ERRATA

PART TWO, CHAPTER XXXIX, SPECIAL SUBJECTS REGIONAL
(Volume 3)

Page XXI-3, Par. 7, Line 5 - change function is now known to functions are not known.

Page XXII-11, Par. 25, Line 8 - change 112 to 12.

Page XXIV-10, Par. 23, Last line - change Troxell to Sohon.

Page XXIV-16 - change Troxell, E. L. to Sohon, J. A.

Page XXV-1, Par. 2, Line 10 - change $Fe_{1-x}S$ to $Fe_{x-1}S_x$.

Page XXVIII-19, Par. 67, Line 2 - change VI to V.

Page XXVIII-20, Par. 70, Line 5 - change VI to V.

Page XXIX-25, Par. 63, Lines 3 and 4 - delete as shown by Plate 1.

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
150 CAUSEWAY STREET
BOSTON 14, MASSACHUSETTS

Final revisions
Special Subjects Regional
Chapter XXXIX Part Two
Volume 3
March 17, 1955

1. Attached are revised pages xvii, xviii, xxxv, xxxvi, xxxvii, xxxviii, XXII-5, XXII-6, XXVI-7, XXVI-8, XXVI-11, XXVI-12, XXVI-13, XXVI-14, XXXIa-5, XXXIa-6, XXXId-25, XXXId-25a, XXXId-25b and XXXId-26, comprising the final revision for Part Two, Chapter XXXIX of the Report of the New England-New York Inter-Agency Committee entitled The Resources of the New England-New York Region, Special Subjects Regional. Note that each revised page is identified by the revision symbol in the lower corner. It is requested that you open the binding of your copy, remove the superseded pages, insert the revised pages, and destroy the replaced pages.

2. Also attached is an errata sheet showing minor corrections for which no revised pages are furnished. It is requested that you make all the changes indicated on the errata sheet.

3. Upon completion of the above, the copy of the Chapter of the Report you have will be in final form.

G. B. Troland

G. B. TROLAND
Coordinator

FOREWORD

This book contains Volume 3 of 4 volumes comprising Chapter XXXIX of Part Two of the Report of the New England-New York Inter-Agency Committee, organized by direction of the President of the United States for the purpose of making a comprehensive survey of the land, water and related resources of the New England-New York Region.

The complete report comprises three parts:

Part One - The General Report.

Part Two - The Technical Report, with detailed studies of the river basins and special subjects.

Part Three - Reference Data.

NOTE

Chapter XXXIX, Special Subjects, Regional, is published in four volumes:

Volume 1. Fisheries, Wetlands.

Volume 2. Mapping, Mineral Commodities.

Volume 3. Mineral Commodities.

Volume 4. Hurricanes.

THE RESOURCES

OF THE

NEW ENGLAND-NEW YORK REGION

CONTENTS

Part Two

Chapter I - The New England-New York Region

Chapter II - Subregion "A"

Chapter III - Saint John River Basin

Chapter IV - St. Croix River Basin

Chapter V - Penobscot River Basin

Chapter VI - Kennebec River Basin

Chapter VII - Androscoggin River Basin

Chapter VIII - Presumpscot River Basin

Chapter IX - Saco River Basin

Chapter X - Maine Coastal Area

Chapter XI - Special Subjects Subregion "A"

Chapter XII - Subregion "B"

Chapter XIII - Piscataqua River Basin

Chapter XIV - New Hampshire Coastal Area

Chapter XV - Merrimack River Basin

Chapter XVI - Massachusetts Coastal Area

Chapter XVII - Narragansett Bay Drainage Basins

Chapter XVIII - Pawcatuck River Basin

Chapter XIX - Rhode Island Coastal Area

Chapter XX - Thames River Basin

Chapter XXI - Connecticut River Basin

Chapter XXII - Housatonic River Basin

Chapter XXIII - Connecticut Coastal Area

Chapter XXIV - Special Subjects Subregion "B"

Chapter XXV - Subregion "C"

Chapter XXVI - Lake Memphremagog Drainage Basin

Chapter XXVII - Lake Champlain Drainage Basin

Chapter XXVIII - St. Lawrence Drainage Basin

Chapter XXIX - Special Subjects Subregion "C"

Chapter XXX - Subregion "D"

Chapter XXXI - Black River Basin

Chapter XXXII - Oswego River Basin

Chapter XXXIII - Genesee River Basin

Chapter XXXIV - Small Streams Tributary to Lake Ontario

Chapter XXXV - Lake Erie - Niagara River Drainage Basin

Chapter XXXVI - Special Subjects Subregion "D"

Chapter XXXVII - Subregion E - Hudson River Basin

Chapter XXXVIII - Special Subjects Subregion "E"

Chapter XXXIX - Special Subjects, Regional

HC107
.A11N3443
1955
pt.2
ch.39
v.3
c.2

THE RESOURCES

OF THE

NEW ENGLAND-NEW YORK REGION

PART TWO

CHAPTER ~~XXXIX~~

SPECIAL SUBJECTS
REGIONAL

VOLUME 3
(of 4 volumes)

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

SPECIAL SUBJECTS, REGIONAL

CONTENTS-VOLUME 1

	Page
SECTION I - COMMERCIAL OFFSHORE FINFISHERIES OF NEW ENGLAND	
INTRODUCTION -	1
HISTORY OF NEW ENGLAND FISHERIES -	3
NEW ENGLAND OFFSHORE FISHING GROUNDS -	4
COMMERCIAL FINFISH SPECIES, HARVEST, AND VALUE -	4
GROUNDFISH - Ocean perch, Haddock, Cod, Flounders, Yellowtail, Blackback, Lemon sole, Grey sole, Sea dab, Halibut, Pollock, Cusk, Whiting, Hake, Tilefish, Wolffish.	7
SHOREFISH - Scup, Butterfish, Summer flounder, shad, Alewives, Tautog, Sea bass, Common eel, ocean pout, Striped bass.	22
PELAGIC FISH - Menhaden, Herring, Mackerel, Thimble-eyed mackerel, Smelt, Bluefish, Swordfish, Tuna.	33
THE INDUSTRY -	44
INTERNATIONAL COOPERATION -	49
DISCUSSION -	53
A PROGRAM FOR NEW ENGLAND FISHERY RESEARCH - Biological-oceanographic research, Statistical program, Exploratory fishing and gear development, Technological studies, Education and market development.	55
SUMMARY - Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut.	65
SECTION II - SHELLFISHERIES OF NEW ENGLAND	
INTRODUCTION -	1
AMERICAN LOBSTER - Maine, Massachusetts, New Hampshire, Rhode Island, Connecticut.	1

SECTION II - SHELLFISHERIES OF NEW ENGLAND (continued)

SOFT CLAM - Maine, Massachusetts, New Hampshire, Connecticut, Rhode Island. 14

HARD CLAM - Maine, Massachusetts, Rhode Island, Connecticut. 30

OYSTERS - Massachusetts, Rhode Island, Connecticut. 38

SCALLOPS - Massachusetts, Rhode Island, Connecticut, Maine. 47

MUSSELS - Surf or Skimmer Clam, Ocean Clam. 53

MISCELLANEOUS - 56

DISCUSSION - 59

SUMMARY - 60

SECTION III - A SURVEY OF THE MARINE SPORT FISHERY OF NEW ENGLAND

GAME FISH HABITAT OF NEW ENGLAND - 2

MARINE GAME FISH OF NEW ENGLAND - 3

PELAGIC SPORT FISH - Swordfish, Tuna, Marlin, Mako shark. 4

INSHORE GAME FISH - Striped bass, Bluefish, Mackerel, Weakfish. 7

GROUNDFISH - Fluke, Winter flounder, Scup, Tautog, Sea Bass, Kingfish, Pollock, Cod, Tomcod, Cunner. 13

ECONOMIC VALUES - 19

DISCUSSION - 28

SUMMARY - 33

SECTION IV - WILDLIFE WETLANDS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

SECTION IV - WILDLIFE WETLANDS IN THE NEW ENGLAND-NEW YORK REGION (continued)

SCOPE OF WETLAND SURVEYS IN NEW YORK AND NEW ENGLAND - 2

METHODS USED IN WETLAND INVENTORY - 2

RESULTS - 3

INLAND FRESH AREAS - Seasonally flooded basins or flats, Fresh meadows, Shallow fresh marshes, Deep fresh marshes, Open fresh water, Shrub swamps, Wooded swamps, Bogs. 3

COASTAL FRESH AREAS - Shallow fresh marshes, Deep fresh marshes, Open fresh water. 5

COASTAL SALINE AREAS - Salt flats, Salt meadows, Regularly flooded salt marshes, Sounds and bays. 6

PRESENT AND FUTURE WETLANDS PROGRAMS - 7

CONTENTS-VOLUME 2

SECTION V - STATUS OF TOPOGRAPHIC AND GEOLOGIC MAPPING IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

STATUS OF TOPOGRAPHIC MAPPING - Standard topographic maps. 3

TOPOGRAPHIC MAP COVERAGE OF THE NEW ENGLAND-NEW YORK REGION - General. 5

MAINE - Existing coverage, Present program. 5

NEW HAMPSHIRE - Existing coverage, Present program. 7

VERMONT - Existing coverage, Present program. 8

MASSACHUSETTS - Existing coverage, Present program. 9

RHODE ISLAND - Existing coverage. 9

CONNECTICUT - Existing coverage, Present program. 9

SECTION V - STATUS OF TOPOGRAPHIC AND GEOLOGIC MAPPING IN THE NEW ENGLAND-NEW YORK REGION (continued)

NEW YORK - Existing coverage, Present program, Summary of topographic mapping authorized or in progress. 10

STATUS OF GEOLOGIC MAPPING - Definition, Bedrock maps, Surficial geologic maps. 11

BASE MAPS FOR GEOLOGIC MAPPING - 15

PRESENT COVERAGE - 15

ESTIMATE OF MAN-YEARS NEEDED TO COMPLETE GEOLOGIC MAPPING OF THE REGION - 18

CONCLUSIONS AND RECOMMENDATIONS - Topographic mapping, Geologic mapping. 22

SECTION VI - AN EARLY HISTORY OF THE MINERAL INDUSTRY IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GRAPHITE - 2

IRON - Iron in New York, Iron in Connecticut, Iron in Rhode Island, Iron in Massachusetts, Chronological history of the iron industry in Massachusetts, Iron in Vermont, Iron in New Hampshire, Iron in Maine. 5

LEAD AND ZINC - Lead and zinc in New York, Lead and zinc in Connecticut, Lead and zinc in Massachusetts, Lead and zinc in New Hampshire, Lead and zinc in Maine. 18

COPPER - Copper in New York, Copper in Connecticut, Copper in Massachusetts, Copper in Vermont, Copper in New Hampshire, Copper in Maine. 29

SALT - 34

BUILDING MATERIALS - 40

MARBLE - 45

GRANITE - 49

SELECTED BIBLIOGRAPHY ON MINERALS - 55

SECTION VII - IRON ORE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

MINERALOGY - Hematite, Magnetite, Limonite, Siderite. 6

GEOLOGY - Magnetite deposits, Ilmenite-magnetite deposits, Hematite deposits, Limonite deposits, Siderite. 7

MINING METHODS AND METALLURGY - 12

OTHER ECONOMIC FACTORS - 12

DESCRIPTIONS OF MINES AND DEPOSITS - 17

MAGNETITE DEPOSITS (NONTITANIFEROUS) OF NEW YORK - Mineville-Port Henry area, Hammondville area, Lyon Mountain area, Ausable Forks area, Saranac Valley area, St. Lawrence County, Fort Ann area, Salisbury district. 17

MAGNETITE DEPOSITS (SOUTHEASTERN NEW YORK) - Sterling Scott group. 26

TITANIFEROUS MAGNETITE DEPOSITS (NEW YORK) - 27

OTHER TITANIFEROUS DEPOSITS (NEW YORK) - 29

HEMATITE ORES (NEW YORK) - 29

LIMONITE AND SIDERITE DEPOSITS (NEW YORK) - 31

MAINE - 32

NEW HAMPSHIRE - 34

VERMONT - 35

MASSACHUSETTS - 35

CONNECTICUT - 38

RHODE ISLAND - 39

RESOURCES AND FUTURE OF THE IRON AND STEEL INDUSTRY - 40

SELECTED BIBLIOGRAPHY ON IRON ORE - 42

SECTION VIII - COPPER IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

HISTORY - 2

GEOLOGY - 4

MINING METHODS - Ore treatment, Smelting, Manufacturing. 5

NEW ENGLAND MINES - Maine, New Hampshire, Vermont, Massachusetts, Connecticut. 7

CONCLUSION - 14

SELECTED BIBLIOGRAPHY ON COPPER - 15

SECTION IX - ANORTHOSITE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

DESCRIPTION AND USE OF THE MATERIAL - 2

HISTORY AND PREVIOUS RESEARCH - 3

GEOLOGY - Adirondack anorthosite massif, Anorthosite mass near Thirteenth Lake, Other anorthosite masses in New York, Anorthosite dikes on Monhegan Island, Maine. 4

MINING AND TECHNOLOGY - 10

FUTURE POSSIBILITIES - 11

SELECTED BIBLIOGRAPHY - 13

SECTION X - BARITE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY AND MINERALOGY - 1

PRODUCTION - 3

RESERVES AND NEARBY SOURCES - 3

SELECTED BIBLIOGRAPHY ON MINERALS - 4

SECTION XI - CARBONATE ROCKS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

AVAILABLE INFORMATION - 3

DESCRIPTION OF DEPOSITS, VERMONT, MASSACHUSETTS, AND CONNECTICUT - The western New England limestone belt, Other carbonate rocks in Vermont, Other carbonate rocks in Massachusetts, Other carbonate rocks in Connecticut. 3

NEW HAMPSHIRE - 6

MAINE - Knox County, Franklin County, Aroostook County, Other deposits. 6

RHODE ISLAND - 9

NEW YORK - Adirondack Mountains and southeastern New York, Eastern New York and around the Adirondack Mountains, Southern, central and western areas. 9

CEMENT - 22

CONSIDERATIONS IN THE DEVELOPMENT OF A CEMENT INDUSTRY - 23

HISTORY - 30

TYPES OF CEMENT - Natural cement, Portland cement, Mining methods, Preparation of the raw material, Cement handling. 32

LIME, LIMESTONE AND DOLOMITE - 36

VARIETIES OF LIME - 36

THE HISTORY OF THE LIME INDUSTRY - 37

RAW MATERIALS USED IN THE MANUFACTURE OF LIME - 38

USES OF LIME - 39

PRODUCTION - The lime industry in New York, The lime industry in New England. 40

	Page
SECTION XII - COAL IN THE NEW ENGLAND-NEW YORK REGION	
INTRODUCTION -	1
HISTORY -	2
GEOLOGY -	2
COAL MINES -	4
PORTSMOUTH AREA - North and South Slopes, Case mine, Mount Hope Bridge.	4
CRANSTON MINE -	7
THE MANSFIELD AREA - Harden mine, The Sawyer or Wading mine, The Tremont Street mine.	8
TAUNTON AREA -	9
NATURE AND COMPOSITION OF THE COAL -	9
UTILIZATION POSSIBILITIES - Fuel, Graphite, Lightweight aggregates, Rock wool.	10
SELECTED BIBLIOGRAPHY ON COAL -	14
SECTION XIII - COKE IN THE NEW ENGLAND-NEW YORK REGION	
INTRODUCTION AND SUMMARY -	1
CONCLUSIONS -	1
THE COKE INDUSTRY - Metallurgical, Coke-oven gas, Coal chemicals.	1
COMPETITIVE FACTORS - Natural gas.	7
SECTION XIV - DIATOMITE IN THE NEW ENGLAND-NEW YORK REGION	
INTRODUCTION -	1
GEOLOGY AND RESOURCES - Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont.	1
SELECTED BIBLIOGRAPHY ON DIATOMITE -	8

SECTION XV - FUEL STATISTICS FOR NEW ENGLAND

INTRODUCTION - 1

CONCLUSIONS - 2

CONSUMPTION - 3

MANUFACTURERS - Residential and Commercial, Electrical Energy. 6

TRENDS IN NEW ENGLAND CONSUMPTION - 10

TRANSPORTATION - Anthracite, Bituminous Coal, Fuel Oil. 11

NEW ENGLAND FUEL COST FACTORS - Bituminous Coal, Anthracite, Oil, Other Fuels, Natural gas, Manufactured gas. 14

FUEL SELECTION - Dependability of supply, Cost, Other factors. 20

BIBLIOGRAPHY ON FUEL STATISTICS - 23

SECTION XVI - GYPSUM IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY - 2

RESERVES AND RESOURCES - 3

HISTORY AND GROWTH OF THE INDUSTRY - 6

GYPSUM PRODUCTS - 9

PRODUCTION AND CONSUMPTION - 13

MINING AND TECHNOLOGY - 14

MILLING - 15

COMPETITIVE POSITION OF NEW YORK STATE GYPSUM DEPOSITS - 15

FUTURE POSSIBILITIES - 17

PRODUCERS - 18

VOLUME 3

SECTION XVII - MINERAL INSULATION IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY - 1

HISTORY AND PRODUCTION - 3

INSULATING MINERALS - 4

PROPERTIES OF MINERAL INSULATION - 5

NATURAL INSULATORS - 5

TREATED INSULATORS - 7

MANUFACTURED INSULATORS - 8

DISCUSSION - 11

CONCLUSION - 12

SELECTED BIBLIOGRAPHY ON MINERAL INSULATION - 14

SECTION XVIII - NATURAL IRON OXIDE PIGMENTS IN THE NEW ENGLAND-NEW YORK REGION

SUMMARY AND CONCLUSIONS - 1

INTRODUCTION - 1

HISTORY - 1

COMPOSITION AND CLASSIFICATION - 2

MANUFACTURED IRON OXIDE PIGMENTS - 3

MINING - 4

TREATMENT OF ORES - 4

GEOLOGY AND RESOURCES - New York, Vermont, Massachusetts, Maine, Connecticut, New Hampshire, Rhode Island. 5

SELECTED BIBLIOGRAPHY ON NATURAL IRON OXIDE PIGMENTS IN NEW ENGLAND AND NEW YORK - 10

SECTION XIX - NICKEL AND COBALT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

DESCRIPTION OF DEPOSITS - Mt. Prospect complex, Connecticut, Hodges prospect, Connecticut, Cleveland deposit, Massachusetts, Dracut deposit, Massachusetts, Eastern Magnesia Co., Johnson, Vermont. 2

POTENTIAL RESOURCES AND FUTURE SUPPLIES - 6

SECTION XX - PEAT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

PREVIOUS WORK - 1

FUTURE POSSIBILITIES - 3

CLASSIFICATION AND TYPES OF PEAT - 4

PROPERTIES OF PEAT - Physical characteristics, Chemical composition. 5

TYPES OF DEPOSITS - Upland or highmoor deposits, Lowland or lowmoor deposits, forest or swamp deposits, Aquatic or sedimentary deposits. 7

PEAT RESOURCES - 8

REGIONAL DISTRIBUTION OF PEAT DEPOSITS - Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont. 9

HISTORICAL USE OF PEAT - 12

PRODUCTION AND CONSUMPTION - Mining practices in New England and New York, Marketing. 14

USES OF PEAT - Fuel, Fertilizers, Mull and litter material, Mattresses and sanitary appliances, Insulation, Cation exchangers, Dry stuffs, Tanning substances, Paper goods, Textiles. 21

SELECTED BIBLIOGRAPHY ON PEAT - 26

SECTION XXI - MINERAL FERTILIZERS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

SUMMARY - 1

GENERAL - 2

SOURCES OF ELEMENTS USED IN FERTILIZERS - Nitrogen, Phosphorus (reported as phosphoric anhydride-P_2O_5), Potassium (reported as potash - K_2O), Calcium and magnesium, Sulphur. 3

LOCATION OF PLANTS AND SUPPLY TO NEW ENGLAND-NEW YORK REGION - 5

FERTILIZER MINERALS FOUND IN NEW ENGLAND-NEW YORK REGION - 7

PRESENT CONSUMPTION AND PRODUCTION IN NEW ENGLAND-NEW YORK REGION - 9

CONCLUSIONS - 12

SECTION XXII - GRAPHITE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

DESCRIPTION AND USES - 2

CONSUMPTION - 3

HISTORY - 5

GEOLOGY - 7

DESCRIPTION OF PRINCIPAL DEPOSITS - Northwestern Adirondacks, Northeastern Adirondacks, Southeastern Adirondacks, Southeastern New York area, Massachusetts, Rhode Island. 11

RESOURCES AND FUTURE POSSIBILITIES - 16

SELECTED BIBLIOGRAPHY ON GRAPHITE - 19

SECTION XXIII - HIGH-GRADE SILICA MATERIALS AND FOUNDRY SANDS

INTRODUCTION - 1

SECTION XXIII - HIGH-GRADE SILICA MATERIALS AND FOUNDRY SANDS (continued)

GEOLOGY AND RESOURCES - 1

HIGH-GRADE SILICA MATERIALS - In New York, Vermont, Massachusetts, and Connecticut, New Hampshire, Maine, Rhode Island. 2

FOUNDRY SANDS - 8

RESOURCE POTENTIAL - 8

SELECTED BIBLIOGRAPHY ON HIGH-GRADE SILICA AND FOUNDRY SANDS - 10

SECTION XXIV - MISCELLANEOUS MINERAL COMMODITIES IN THE NEW ENGLAND-NEW YORK REGION

MOLYBDENUM - 1

TUNGSTEN - 3

TIN - 6

GOLD - 7

SILVER - 9

PLATINUM - 12

URANIUM - 12

SELECTED BIBLIOGRAPHY ON MISCELLANEOUS MINERAL COMMODITIES -13

SECTION XXV-- SULFUR RESOURCES (PYRITE AND PYRRHOTITE) IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

HISTORY - 2

GEOLOGY OF THE DEPOSITS - 3

DESCRIPTION OF DEPOSITS - Deposits in Maine, Deposits in New Hampshire, Deposits in Vermont, Deposits in Massachusetts, Deposits in Connecticut, Deposits in Rhode Island, Deposits in New York. 4

SECTION XXV - SULFUR RESOURCES (PYRITE AND PYRRHOTITE) IN THE NEW ENGLAND-NEW YORK REGION (continued)

POTENTIAL RESOURCES AND FUTURE SUPPLIES - 9

SELECTED BIBLIOGRAPHY ON SULFUR RESOURCES (PYRITE AND PYRRHOTITE) IN NEW ENGLAND AND NEW YORK 10

SECTION XXVI - SALT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY - 1

RESOURCES - 5

TECHNOLOGY - Processing, Economics, Exports and imports. 6

NEW YORK STATE SALT INDUSTRY - History, Current production, Marketing. 10

SELECTED BIBLIOGRAPHY ON SALT - 17

SECTION XXVII - SAND AND GRAVEL IN THE NEW ENGLAND-NEW YORK REGION

Introduction, Future possibilities, Classifications. 1

CONSUMPTION AND DEVELOPMENT - 5

TECHNOLOGY - Prospecting, Exploration, Development, Removal of overburden, Equipment, Methods, Preparation. 11

ECONOMICS OF THE SAND AND GRAVEL INDUSTRY - United States, New York, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont. 14

SELECTED BIBLIOGRAPHY ON SAND AND GRAVEL - 22

SECTION XXVIII - GRAVEL AND SAND RESOURCES OF THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GLACIAL DEPOSITS - General statement, Morainic (till) deposits. 1

OUTWASH SAND AND GRAVEL DEPOSITS - General statement, Classification of outwash deposits. 4

SECTION XXVIII - GRAVEL AND SAND RESOURCES OF THE NEW ENGLAND-NEW YORK REGION (continued)

QUALITY OF GLACIAL DEPOSITS IN RELATION TO BEDROCK SOURCES - 9

ALLUVIAL DEPOSITS - 11

MARINE AND LAKE DEPOSITS - 12

AEOLIAN (WIND-BLOWN) DEPOSITS - 12

GEOGRAPHIC DISTRIBUTION OF PRINCIPAL TYPES OF DEPOSITS - 14
Correlation of subregions with physiographic provinces.

PRINCIPAL TYPES OF DEPOSITS BY AREAS - New England Province Valley and Ridge Province, St. Lawrence Valley Province, Adirondack Province, Central Lowland Province, Appalachian Plateaus Province. 16

MAPPING OF SAND AND GRAVEL DEPOSITS - 19

SELECTED BIBLIOGRAPHY ON GRAVEL AND SAND - 22

SECTION XXIX - TALC IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY - 1

CONCLUSIONS - 2

DESCRIPTION AND UTILIZATION - 3

GEOLOGY - New York, Vermont, Massachusetts. 8

ECONOMICS OF THE INDUSTRY - History and development 12

ECONOMIC TRENDS: UNITED STATES - 14

NEW ENGLAND - Vermont. 15

NEW YORK - The industry in New York. 17

MINING AND TECHNOLOGY - Mining, Milling. 18

RAW MATERIAL CONTROL BY THE INDUSTRY - 20

MARKETING - 21

SECTION XXIX - TALC IN THE NEW ENGLAND-NEW YORK REGION (continued)

PRICE HISTORY - 22

NEW YORK - 23

VERMONT - 23

RECENT QUOTATIONS - 23

BIBLIOGRAPHY ON TALC - 26

SECTION XXX - TITANIUM IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY - 1

USES - Pigments, Electric welding rod coating, Titanium metal. 2

EXTRACTION - 4

ILMENITE DEPOSITS - 4

RHODE ISLAND - Iron Mine Hill, History, Reserves. 4

NEW YORK - History, Geology, Sanford Hill Deposit, Sanford Lake area, Elizabethtown-Westport-Mineville area, Other occurrences. 5

CONCLUSIONS - 8

SELECTED BIBLIOGRAPHY ON TITANIUM - 9

SECTION XXXI - WOLLASTONITE IN THE NEW ENGLAND-NEW YORK REGION-

INTRODUCTION - 1

GEOLOGY AND RESOURCES - 1

USES - 4

HISTORY, MINING, AND BENEFICIATION - 5

APPENDIX - 7

SELECTED BIBLIOGRAPHY ON WOLLASTONITE - 8

SECTION XXXIa - MANGANESE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY AND MINERALOGY - Deposits in Aroostook County, Maine, Other bedrock deposits, Surficial deposits. 1

RESERVES AND RESOURCES - Other deposits. 5

RECOMMENDED FUTURE WORK - Other deposits. 7

SELECTED BIBLIOGRAPHY ON MANGANESE 9

SECTION XXXIb - ASBESTOS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY - 2

OCCURRENCE AND DISTRIBUTION IN THE REGION - 2

RESERVES AND POTENTIAL RESOURCES - 5

SELECTED BIBLIOGRAPHY ON ASBESTOS 6

SECTION XXXIc - ABRASIVES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

ABRASIVES INDUSTRY - General. 2

DESCRIPTION AND USE OF PRINCIPAL ABRASIVES MATERIALS - 2

NATURAL MINERAL ABRASIVES - Industrial diamonds, Corundum, Garnet, Emery, Feldspar, Quartz, Ground sandstones and sands, Diatomite. 3

ARTIFICIAL ABRASIVES - Silicon carbide, Fused aluminum oxide, Boron carbide. 8

METALLIC ABRASIVES - 10

ABRASIVE CHEMICAL PRECIPITATES - 10

MISCELLANEOUS ABRASIVE MATERIALS - 11

STRUCTURE AND PRODUCTS OF THE ABRASIVES INDUSTRY - 11

SECTION XXXIc - ABRASIVES IN THE NEW ENGLAND-NEW YORK REGION (Continued)

HISTORY AND GROWTH OF THE INDUSTRY 14

GEOLOGY - Distribution of Deposits in New England and New York, Garnet, Emery, Feldspar, Quartz, Sand and Sandstone, Sharpening and millstones, Diatomite. 16

ECONOMIC POSITION OF THE ABRASIVES INDUSTRY IN NEW ENGLAND AND NEW YORK - Mineral deposits, Industry. 28

MINING AND TECHNOLOGY - 35

FUTURE POSSIBILITIES - 37

SELECTED BIBLIOGRAPHY ON ABRASIVES - 39

SECTION XXXId - STONE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - Production history and uses of stone, Crushed stone. 1

GEOLOGIC STUDIES - General geology and regional distribution of commercial stone, Competitive stone from outside sources. 4

THE STONE INDUSTRY - Granite, Limestone, Marble, Sandstone, Anorthosite, Salient features of the dimension-stone industries. 7

CRUSHED STONE - Prospecting, exploration, mining and processing. 14

SLATE AND ROOFING GRANULES - Slate, Roofing granules. 25

FUTURE OUTLOOK - 25

SELECTED BIBLIOGRAPHY ON STONE - 26

SECTION XXXIa - MANGANESE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY AND MINERALOGY - Deposits in Aroostook County, Maine, Other bedrock deposits, Surficial deposits. 1

RESERVES AND RESOURCES - Other deposits. 5

RECOMMENDED FUTURE WORK - Other deposits 7

SELECTED BIBLIOGRAPHY ON MANGANESE 9

SECTION XXXIb - ASBESTOS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

GEOLOGY - 2

OCCURRENCE AND DISTRIBUTION IN THE REGION - 2

RESERVES AND POTENTIAL RESOURCES - 5

SELECTED BIBLIOGRAPHY ON ASBESTOS 6

SECTION XXXIc - ABRASIVES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

ABRASIVES INDUSTRY - General. 2

DESCRIPTION AND USE OF PRINCIPAL ABRASIVES MATERIALS - 2

NATURAL MINERAL ABRASIVES - Industrial diamonds, Corundum, Garnet, Emery, Feldspar, Quartz, Ground sandstones and sands, Diatomite. 3

ARTIFICIAL ABRASIVES - Silicon carbide, Fused aluminum oxide, Boron carbide. 8

METALLIC ABRASIVES - 10

ABRASIVE CHEMICAL PRECIPITATES - 10

MISCELLANEOUS ABRASIVE MATERIALS - 11

STRUCTURE AND PRODUCTS OF THE ABRASIVES INDUSTRY - 11

SECTION XXXIc - ABRASIVES IN THE NEW ENGLAND-NEW YORK REGION (Continued)

HISTORY AND GROWTH OF THE INDUSTRY 14

GEOLOGY - Distribution of Deposits in New England and New York, Garnet, Emery, Feldspar, Quartz, Sand and Sandstone, Sharpening and millstones, Diatomite. 16

ECONOMIC POSITION OF THE ABRASIVES INDUSTRY IN NEW ENGLAND AND NEW YORK - Mineral deposits, Industry. 28

MINING AND TECHNOLOGY - 35

FUTURE POSSIBILITIES - 37

SELECTED BIBLIOGRAPHY ON ABRASIVES 39

SECTION XXXId - STONE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - Production history and uses of stone, Crushed stone. 1

GEOLOGIC STUDIES - General geology and regional distribution of commercial stone, Competitive stone from outside sources. 4

THE STONE INDUSTRY - Granite, Limestone, Marble, Sandstone, Anorthosite, Salient features of the dimension-stone industries. 7

CRUSHED STONE - Prospecting, exploration, mining and processing. 14

FUTURE OUTLOOK - 25

SELECTED BIBLIOGRAPHY ON STONE 26

SECTION XXXIe - LIGHTWEIGHT AGGREGATES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION - 1

ECONOMIC FACTORS AFFECTING THE MANUFACTURE OF LIGHTWEIGHT AGGREGATES - History. 2

PHYSICAL PROPERTIES OF A LIGHTWEIGHT AGGREGATE - 4

CLASSIFICATION OF LIGHTWEIGHT AGGREGATES - 5

NATURAL AGGREGATE - Diatomite. 6

BYPRODUCT AGGREGATES - Slags and cinders, Coke-breeze, Sawdust, Peat. 6

SPECIALLY PROCESSED AGGREGATES - Expanded clay, shale, and slate, Diatomite, Silt, Other. 7

SECTION XXXIf - CLAY AND SHALE IN THE NEW ENGLAND-NEW YORK REGION

GENERAL STATEMENT - 1

PRESENT KNOWLEDGE OF THE DEPOSITS - 2

ECONOMICS OF THE CLAY INDUSTRY IN NEW ENGLAND AND NEW YORK - 3

DESCRIPTIONS OF DEPOSITS - New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, Vermont, Maine. 7

TECHNOLOGY - 26

MINING - 28

RESERVES - 29

WORK THAT SHOULD BE DONE - 30

SELECTED BIBLIOGRAPHY ON CLAY AND SHALE 31

SECTION XXXIg - PEGMATITES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY - 1

BRIEF HISTORY OF PEGMATITE MINING IN NEW ENGLAND AND NEW YORK - 3

SECTION XXXIg - PEGMATITES IN THE NEW ENGLAND-NEW YORK REGION (continued)

DESCRIPTION AND USES OF PRINCIPAL MINERALS - Feldspar, Mica, Beryl, Columbium-Tantalum Minerals, Quartz, Lithium Minerals, Pollucite. 5

ECONOMICS - Mineral economics, Economic considerations in in prospecting, Mining, and Marketing, Commodity analysis. 12

COMPETITIVE POSITION AND IMPORTANCE OF PEGMATITE MINERALS IN NEW ENGLAND AND NEW YORK - Feldspar, Mica, Beryl. 18

GEOLOGY - Previous geologic work, Forms of Pegmatites. 21

PROSPECTING AND EXPLORATION - 30

MINING AND MILLING - Mining, Milling. 32

STRUCTURE OF THE INDUSTRY IN THE NEW ENGLAND - NEW YORK REGION - Feldspar, Mica, Beryl, Columbian-Tantalum Minerals, Other minerals. 36

FUTURE OUTLOOK - 38

SELECTED BIBLIOGRAPHY ON PEGMATITES 44

VOLUME 4

CONTENTS

	Page
SECTION XXXII - HURRICANES -	
INTRODUCTION -	1
Purpose. -	1
Scope. -	1
CHARACTERISTICS OF HURRICANES -	2
Definition. -	2
Origin. -	3
Hurricanes of the Western Hemisphere. -	5
Hurricane effects on large bodies of water. -	7
Hurricane effects on land. -	8
HISTORY OF HURRICANES -	9
HURRICANE OF SEPTEMBER 1938 -	17
General. -	17
Antecedent conditions. -	17
The Hurricane. -	18
Damages. -	19
Summary. -	24
HURRICANE OF SEPTEMBER 14-15, 1944 -	23
HURRICANES OF 1954 -	25
Hurricane Carol. -	25
Hurricane Edna. -	31
Hurricane Hazel. -	33
DAMAGES CAUSED BY 1954 HURRICANES -	35
General. -	35
Loss of life. -	36
Public property. -	37
Public buildings. -	38
Highways. -	38
Shore protective structures. -	39
Channel shoaling. -	40
Beach erosion. -	40
Works under construction. -	41
Estimates of damage. -	42
Shipping. -	42
Commercial vessels. -	44

Page

DAMAGES CAUSED BY 1954 HURRICANES (CONT'D)
Small craft. - 45
Utilities. - 46
Water systems. - 46
Sewerage. - 48
Communication utilities. - 51
Power utilities. - 51
Transportation facilities. - 53
Military installations. - 54
Commercial installations. - 54
Industrial property. - 56
Agricultural damages. - 57
Foodstuffs. - 60
Drug establishments. - 63
Fisheries and wildlife. - 63
Damage to private and personal property. - 67
Employment losses. - 72
Interior river flood damages. - 73
Summary. - 83

COMPARISON OF 1938 AND 1954 HURRICANES AND EFFECTS - 84

MENACE TO PUBLIC HEALTH - 89
Contamination of food and drugs. - 89
Contamination of water supplies. - 91
Spoilage of foods. - 94
Disruption of sanitary sewer systems. - 94
Interference with hospitalization. - 95

RELATION TO NATIONAL DEFENSE - 97

CIVIL DEFENSE FUNCTIONS - 100

PROTECTIVE POSSIBILITIES - 102
Warning service. - 102
Protective measures. - 106
Protection from abnormal tide and wave action. - 108
Zoning. - 120
Protection from floods caused by hurricane rains. -120
Drainage improvements. - 121
Protection from abnormal winds. - 123
Hurricane shelters. - 129
Protective measures for specific localities. - 131

CONCLUSIONS - 154

PLAN - 157

BIBLIOGRAPHY ON HURRICANES - 159

SPECIAL SUBJECTS, REGIONAL

LIST OF TABLES - VOLUME 1

Table		Page
	SECTION I - COMMERCIAL OFFSHORE FINFISHERIES OF NEW ENGLAND	
1.	Total New England catch and value of commercial finfisheries - 1952 -	5
2.	Total catch and value of the commercial finfisheries in New England -	6
3.	Summary of fishermen, vessels and boats by States, New England commercial fishery - 1951 -	45
4.	Summary of operating units by States -	46
5.	New England finfish catch in pounds by gear - 1951 -	47
5a.	Glossary of offshore fisheries -	68
	SECTION II - SHELLFISHERIES OF NEW ENGLAND	
6.	Total catch and value of shellfish in New England -	3
7.	Maine lobster landings from 1943-1952 -	6
8.	Lobster landings for Massachusetts -	8
9.	Lobster landings in New Hampshire from 1943-1952 -	10
10.	Lobster landings in Rhode Island 1943-1952 -	12
11.	Lobster landings in Connecticut 1943-1952	13
12.	Maine soft shell clam landings 1942-1953 -	20
13.	Massachusetts soft clam production for 1943-1950 -	24
14.	New Hampshire soft clam production 1943-1952 -	25
15.	Soft clam production in Connecticut 1942-1952 -	27
16.	Soft clam production in Rhode Island 1943-1952 -	29
17.	Hard clam landings in Maine 1943-1953 -	32
18.	Hard clam production of Massachusetts 1943-1952 -	33
19.	Hard clam production of Rhode Island 1943-1952 -	35
20.	Hard clam production for Connecticut 1943-1952 -	37
21.	Oyster production in Massachusetts 1943-1952 -	41
22.	Oyster production in Rhode Island 1943-1952 -	43
23.	Oyster production in Connecticut 1943-1952 -	46
24.	Catch and value of sea scallops in New England 1942-1952 -	49
25.	Miscellaneous shellfish taken in New England 1952 -	58
	SECTION III - A SURVEY OF THE MARINE SPORT FISHERY OF NEW ENGLAND	
26.	Estimated value of marine sport fishing equipment in New England -	21
27.	Estimated annual expenditures for marine sport fishing in New England -	25

LIST OF TABLES - VOLUME 1 (continued)

Table		Page
28.	Commercial catch of sport fish in New England -	32
	SECTION IV - WILDLIFE WETLANDS IN THE NEW ENGLAND-NEW YORK REGION	
29.	State summary wetland classification and evaluation, New York -	9
30.	State summary wetland classification and evaluation, Maine -	10
31.	State summary wetland classification and evaluation, New Hampshire -	11
32.	State summary wetland classification and evaluation, Vermont -	12
33.	State summary wetland classification and evaluation, Massachusetts -	13
34.	State summary wetland classification and evaluation, Connecticut -	14
35.	State summary wetland classification and evaluation, Rhode Island -	15

LIST OF TABLES - VOLUME 2

SECTION V - STATUS OF TOPOGRAPHIC AND GEOLOGIC MAPPING IN THE NEW ENGLAND-NEW YORK REGION

36.	Published bedrock and surficial geologic maps -	16
37.	List of Regional maps as of July 1, 1954 -	24
	SECTION VII - IRON ORE IN THE NEW ENGLAND-NEW YORK REGION	
37a.	Production of iron ore in the New England - New York Region in 1880 -	1
37b.	Iron ore (Direct shipping concentrate and sinter) produced in New York -	2
37c.	Pig Iron produced in New York and Massachusetts as compared to the United States -	2
37d.	Capacity of blast furnaces -	13
37e.	Steel capacity (Ingots and steel for castings) -	14

LIST OF TABLES - VOLUME 2 (continued)

Table		Page
37f.	Iron ore resources of New England - New York Region -	18
37g.	Principal magnetite deposits in New York -	21
	SECTION IX - ANORTHOSITE IN THE NEW ENGLAND-NEW YORK REGION	
38.	Average chemical composition and modes of Marcy and Whiteface facies of the Adirondack anorthosite -	8
	SECTION XI - CARBONATE ROCKS IN THE NEW ENGLAND-NEW YORK REGION	
39.	Selected analysis of carbonate rocks from the New England-New York region -	17
40.	Average composition of dolomite in the vicinity of Lee, Massachusetts -	21
41.	United States production and consumption of cement -	22
42.	Salient statistics of the portland cement industry as they affect New York and New England -	24
43.	Cement freight rates as of August 1952 from potential or actual producing regions to selected markets in New England -	28
44.	Kinds of lime produced in New York and New England -	38
45.	Sales of lime for selected years (in 1000's short tons) -	41
46.	Selected and adjusted lime statistics, 1950 -	46
47.	Selected data for World War II magnesium plants -	51
	SECTION XII - COAL IN THE NEW ENGLAND-NEW YORK REGION	
48.	Selected meta-anthracite analyses -	11
	SECTION XIII - COKE IN THE NEW ENGLAND-NEW YORK REGION	
49.	Gas data for Connecticut, Rhode Island and that part of Massachusetts east of Longitude 72° and south of Latitude 42° 26' for selected years -	5
50.	Gas sales of companies in New York, excepting in the Buffalo area, who used coal or coke in the manufacture of gas in 1938 -	6

LIST OF TABLES - VOLUME 2 (continued)

Table		Page
	SECTION XV - FUEL STATISTICS FOR NEW ENGLAND	
51.	Approximate consumption of fuel in trillion B. T. U., 1949 -	5
52.	Approximate consumption of principal fuels in trillion B. T. U. - 1948-1951	12
53.	Bituminous coal cost factors for large consumers of nut and slack in Boston -	16
54.	Cost of principal fuels in Boston - millions of B.T.U. per dollar -	17
	SECTION XVI - GYPSUM IN THE NEW ENGLAND-NEW YORK REGION	
55.	Chemical analyses of New York gypsum -	4
56.	Growth of the gypsum industry of the United States and New York -	8
57.	Gypsum consumed in the New York market territory in thousands of short tons -	10
58.	Some comparative costs of Nova Scotian and New York State gypsum -	11
59.	Growth of the gypsum industry by states, comparing 1949 production and value with that of 1939 -	12
60.	Crude gypsum mined in the United States, Mexico and Canada -	13

LIST OF TABLES - VOLUME 3

	SECTION XVII - MINERAL INSULATION IN THE NEW ENGLAND-NEW YORK REGION	
61.	Heat conductivities of various insulating materials -	6
	SECTION XIX - NICKEL AND COBALT IN THE NEW ENGLAND-NEW YORK REGION	
62.	Nickel and cobalt occurrences in New England -	7
	SECTION XX - PEAT IN THE NEW ENGLAND-NEW YORK REGION	
63.	Salient peat statistics of the United States for selected years -	15
64.	Peat production in New England, 1947 to 1949 -	16

LIST OF TABLES - VOLUME 3 (continued)

Table		Page
	SECTION XXI - MINERAL FERTILIZERS IN THE NEW ENGLAND-NEW YORK REGION	
65.	Fertilizer plants in New England-New York Region -	6
66.	Total fertilizer consumption in the New England-New York Region	10
	SECTION XXII - GRAPHITE IN THE NEW ENGLAND-NEW YORK REGION	
67.	Consumption of natural graphite in the United States for selected years and uses -	4
68.	Principal graphite localities of New York -	9
69.	Selected graphite localities of New England -	10
	SECTION XXIV - MISCELLANEOUS METALLIC MINERALS IN THE NEW ENGLAND-NEW YORK REGION	
70.	Selected molybdenum occurrences of New England -	2
71.	Selected tungsten occurrences of New England -	4
	SECTION XXVI - SALT IN THE NEW ENGLAND-NEW YORK REGION	
72.	Analyses of salt and bittern in New York -	4
73.	Salt sold or used by producers in the United States, 1939 and 1951, by states -	8
74.	Some selected economic data concerning salt production from artificial and natural brines in 1939 and 1947, for New York as compared with the industry as a whole -	11
75.	Primary shipments of evaporated and rock salt to States within the marketing area of New York State producers, 1939, 1949, by States of destination, in approximate short tons -	15
76.	Salt sold or used by producers in the United States by method of recovery -	16
	SECTION XXVII - SAND AND GRAVEL IN THE NEW ENGLAND-NEW YORK REGION	
77.	Sand and gravel sold or used by producers in the United States, 1939 and 1949, by use -	6
78.	Sand and gravel sold or used by producers in New England and in New York, 1949 -	9
79.	Comparative data of the sand and gravel industry in New York and New England -	10
80.	Sand and gravel preparation facilities in the United States, 1938 and 1949 -	15

LIST OF TABLES - VOLUME 3 (continued)

Table		Page
	SECTION XXIX - TALC IN THE NEW ENGLAND-NEW YORK REGION	
81.	Properties of principal talc minerals -	4
82.	Chemical analysis of industrial talcs -	5
83.	Talc, pyrophyllite and ground soapstone sold be producers in the United States, by uses, in percentages, 1925-1951 -	7
83a.	Deposits of talc in New England-New York Region -	11
84.	Summary table of salient statistics of the talc industry in the United States, 1925-1951 -	16
84a.	Comparison of salient statistics on talc, pyrophyllite and ground soapstone in the United States and the New England-New York Region -	25
	SECTION XXXIc - ABRASIVES	
84b.	Deposits of abrasive materials in New England-New York Region -	26
84c.	Price comparison of garnet, emery, silicon carbide and aluminum oxide, average value per short ton, selected years, 1920-1951 -	31
84d.	Salient statistics of high-grade abrasive materials, average annual United States production and value per ton -	32
	SECTION XXXId - STONE	
84e.	Average annual sales of dimension stone for three 5-year periods, 1908-1913, 1924-1929, 1946-1951 -	15
84f.	Granite industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, 1946-1951 -	16
84g.	Marble industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, 1946-1951 -	17
84h.	Limestone industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, 1946-1951 -	18
84i.	Sandstone industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929 1946-1951 -	19
84j.	Basalt industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, 1946-1951 -	20

Table		Page
	SECTION XXXIf - CLAY AND SHALE	
84k.	Shipments of unglazed common and face brick for selected years -	5
84l.	Composition range of Hudson River clays -	10
84m.	Analyses of Connecticut clays -	14
84n.	Analysis of washed koslin	15
84o.	Representative chemical analysis of Vermont koslin -	22
84p.	Mineralogical analysis of Vermont koslin -	23
84q.	Ceramic characteristics of Vermont koslin -	23
84r.	Chemical analysis of Maine clay -	25
84s.	Miscellaneous clay and shale sold or used in The New England-New York Region -	27
	SECTION XXXIg - PEGMATITES IN THE NEW ENGLAND-NEW YORK REGION	
84t.	Classification of commercial feldspars -	6
84u.	Typical analysis of commercial feldspars in New England and New York -	6
84v.	Classification of commercial Lithium minerals -	11
84w.	Salient statistics of pegmatite minerals industry in the United States, 1935-1951 -	14
84x.	Production of pegmatite minerals in New England and New York, 1925-1951 -	15
84y.	Distribution of pegmatite mines operated during the period, 1951-1954, in New England and New York -	39

VOLUME 4 - LIST OF TABLES

SECTION XXXII - HURRICANES

Tables		Page
85.	Summary of hurricane damages to public properties in New England, 1954 -	43
86.	Shipping losses from Hurricane Carol and Edna, New England, 1954 -	46
87.	Summary of monetary damages to water supply systems by 1954 hurricanes -	48
88.	Summary of monetary damages to sewerage systems by 1954 hurricanes -	50
89.	Direct damage,,customers affected, and load dropped, 1954 hurricanes (New England) -	51b
89a.	Direct damage, customers affected, and load dropped, 1954 Hurricanes (New York) -	51d
89b.	Hurricane damages to utilities in coastal communities of New England, 1954 -	52
90.	Damages to railroad facilities in New England from 1954 hurricanes -	53
91.	Damages to commercial installations in New England from hurricanes, 1954 -	55
92.	Hurricane damages to industrial plants in New England, 1954 -	57
93.	Summary of agricultural damages from 1954 hurricanes -	61
94.	Private property damage from 1954 hurricanes in New England -	71
95.	Summary of reservoir regulation in New England, Hurricane Edna -	81
96.	Summary of damages by state for 1954 hurricanes -	82
97.	Summary of 1954 hurricane damages by type of loss -	83
98.	Damage suffered in seven communities in southern New England from Hurricane Carol and Edna -	84
99.	Forward speeds of 1938 and 1954 hurricanes -	85
100.	Summary of 1954 hurricane experience -	155

SPECIAL SUBJECTS, REGIONAL

LIST OF PLATES - VOLUME 1

Plate		Follows page
	SECTION I - COMMERCIAL OFFSHORE FINFISHERIES OF NEW ENGLAND	
1.	North Atlantic fishing grounds -	I-6
	SECTION III - A SURVEY OF THE MARINE SPORT FISHERY OF NEW ENGLAND	
2.	New England marine sport fishing facilities -	III-28

LIST OF PLATES - VOLUME 2

	SECTION V - STATUS OF TOPOGRAPHIC AND GEOLOGIC MAPPING IN THE NEW ENGLAND-NEW YORK REGION	
3.	Status of topographic mapping in the New England-New York Region -	V-5
4.	Index to topographic mapping in Maine -	6
5.	Index to topographic mapping in New Hampshire and Vermont -	10
6.	Index to topographic mapping in Massachusetts, Connecticut, and Rhode Island -	10
7.	Index to topographic mapping in New York -	10
8.	Topographic mapping authorized or in progress in the New England-New York Region -	12
9.	Subregion "A" - Type of published geologic mapping -	16
10.	Subregion "B" - Type of published geologic mapping -	16
11.	Subregion "C" - Type of published geologic mapping -	16
12.	Subregion "D" - Type of published geologic mapping -	16
13.	Subregion "E" - Type of published geologic mapping -	16
14.	Subregion "A" - Status and type of unpublished geologic mapping -	16
15.	Subregion "B" - Status and type of unpublished geologic mapping -	16
16.	Subregion "C" - Status and type of unpublished geologic mapping -	16
17.	Subregion "D" - Status and type of unpublished geologic mapping -	16
18.	Subregion "E" - Status and type of unpublished geologic mapping -	16

Plate | Follows page

SECTION VIII - COPPER IN THE NEW ENGLAND-NEW YORK REGION

19. Copper location map - VIII-2

SECTION IX - ANORTHOSITE IN THE NEW ENGLAND-NEW YORK REGION

20. Principal occurrences of anorthosite - IX-4
21. Sketch of Adirondack anorthosite massif - 7

SECTION XI - CARBONATE ROCKS IN THE NEW ENGLAND-NEW YORK REGION

22. Active Portland cement mills, by regions in the United States - XI-26
23. Portland cement industry in the United States - 26
24. Manufacture of portland cement - 36
25. The basic pattern of milestone production - 40
26. Functions of lime - 42
27. Uses of limestone (primarily physical) - 42
28. Uses of limestone (primarily chemical) - 44
29. The lime industry in the United States - 44
30. Lime in New York - 48
31. Lime in Connecticut - 50
32. Lime in Maine - 50
33. Lime in Massachusetts - 52
34. Lime in New Hampshire - 52
35. Lime in Rhode Island - 54
36. Lime in Vermont - 54

SECTION XII - COAL IN THE NEW ENGLAND-NEW YORK REGION

37. Coal mines and prospects in Massachusetts and Rhode Island - XII-4
38. Mine workings in Portsmouth, Rhode Island - 4
39. Cranston mine, Cranston, Providence County, Rhode Island - 8
40. Coal mines and prospects in Mansfield, Bristol County, Massachusetts - 8

SECTION XIII - COKE IN THE NEW ENGLAND-NEW YORK REGION

41. Consumption of metallurgical and foundry coke in New England-New York and the United States - XIII-2
42. Water and producer gas coke used in New England-New York - 6
43. Selected fuels used in home heating and in manufacture in New England-New York - 8

Plate		Follows page
	SECTION XIV - GYPSUM IN THE NEW ENGLAND-NEW YORK REGION	
44.	Locations of gypsum deposits in New York -	XVI-2
45.	Sketch showing relations of gypsum, anhydrite, and salt deposits in the Salina group of New York -	2
	LIST OF PLATES - VOLUME 3	
	SECTION XXV - SULFUR RESOURCES (PYRITES AND PYRRHOTITES) IN THE NEW ENGLAND-NEW YORK REGION	
46.	Sulfur resources -	XXV-4
47.	Pyrite and pyrrhotite property location -	4
	SECTION XXVI - SALT IN THE NEW ENGLAND-NEW YORK REGION	
48.	History of salt production in New York -	XXVI-2
49.	Area underlain by salt deposits in the Great Lakes Region and known salt deposits in the maritime provinces -	2
50.	Area underlain by salt deposits in New York and locations of producers -	2
51.	Imports and exports of salt, 1880-1950 -	6
52.	Impurities in dry salts derived from artificial brines from wells in Genesee and Wyoming Counties -	10
	SECTION XXVII - SAND AND GRAVEL IN THE NEW ENGLAND-NEW YORK REGION	
53.	Sand and gravel in the United States -	XXVII-18
54.	Sand and gravel in New York -	18
55.	Sand and gravel in Connecticut -	20
56.	Sand and gravel in Maine -	20
57.	Sand and gravel in Massachusetts -	20
58.	Sand and gravel in New Hampshire -	20
59.	Sand and gravel in Rhode Island -	20
60.	Sand and gravel in Vermont -	22
	SECTION XXVIII - GRAVEL AND SAND IN THE NEW ENGLAND-NEW YORK REGION	
61.	Subregions and physical divisions of the New England-New York Region -	XXVIII-14
	SECTION XXX - TITANIUM IN THE NEW ENGLAND-NEW YORK REGION	
62.	Titanium deposits -	XXX-4

Plate		Follows page
	SECTION XXXIa - MANGANESE	
62a.	Geologic structure section of Mopla Mountain - Hovey Mountain -	XXXIa-6
62b.	Geologic structure section of Mopla Mountain - Hovey Mountain -	6
	SECTION XXXIb - ASBESTOS	
62c.	Asbestos location map -	XXXIb-4
	SECTION XXXId - STONE	
62d.	Sales of dimension stone in the United States, 1916-1951 -	XXXId-8
62e.	Value of rough and dressed building stone as a percent of total value of nonresidential building construction -	12
62f.	The crushed stone industry in the United States -	20
	SECTION XXXIg - PEGMATITES IN THE NEW ENGLAND-NEW YORK REGION	
62g.	Pegmatite districts of New England and New York -	XXXIg-6
62h.	Typical flow sheet of dry ground feldspar mill -	34
62i.	Typical flow sheet in preparation of sheet mica for market -	34
62j.	Typical flow sheet in preparation of ground mica for market -	36
62k.	Flow sheet for production of beryl to beryllium metal -	36
62l.	Typical flow sheet of froth flotation feldspar mill -	38

VOLUME 4 - LIST OF PLATES

SECTION XXXII - HURRICANES

Plate		
63	Hurricane Paths Affecting the New England-New York Region 1845, 1938 - 1954 -	Frontispiece
		Follows page
64	Typical Trough of Hurricanes	8
65	Paths of Tropical Storms of Hurricane Intensity -	16
66	Major Coastal Damage Areas, New England, August 31, 1954 -	34
66A	Major Coastal Damage Areas, New England, September 11, 1954 -	34
67	Major Damage Areas, Hurricane of August 31, 1954, Long Island, New York and vicinity -	34
68	Major Damage Areas, Hurricane of September 11, 1954, Long Island, New York and vicinity -	34
69	Mass Rainfall Curves, Hurricanes of August 31, and September 11, 1954 (Selected Stations) -	74
70	Isohyetal Map of Hurricane Edna, September 11, 1954 -	74
71	Monthly Reservoir Operation-Franklin Falls Reservoir -	78
72	Monthly Reservoir Operation - Blackwater Reservoir -	78
73	Monthly Reservoir Operation - Edward MacDowell Reservoir -	78
74	Monthly Reservoir Operation - Surry Mountain Reservoir -	78
75	Monthly Reservoir Operation - Union Village Reservoir -	78
76	Monthly Reservoir Operation - Knightsville Reservoir -	80
77	Monthly Reservoir Operation - Birch Hill Reservoir -	80
78	Monthly Reservoir Operation - Tully Reservoir -	80
79	Monthly Reservoir Operation - Mansfield Hollow Reservoir -	82
80	Progress of 1938 and 1954 Hurricanes -	84
81	Comparison of Load, Week of Hurricane Carol and Preceding Week, New England Electric System -	126

Plate		Follows page
82	Progress of Restoration, New England Telephone and Telegraph Company -	128
83	Extent of Tidal Flooding, Fairfield, Connecticut August 31, 1954 -	132
84	Extent of Tidal Flooding, New London, Connecticut August 31, 1954 -	134
85	Extent of Tidal Flooding, Newport, Rhode Island, August 31, 1954 -	138
86	Extent of Tidal Flooding, Bristol, Rhode Island, August 31, 1954 -	142
87	Extent of Tidal Flooding, Providence, Rhode Island, August 31, 1954 -	144
88	Extent of Tidal Flooding, Assonet, Massachusetts, August 31, 1954 -	148
89	Extent of Tidal Flooding, New Bedford-Fairhaven Harbor, Massachusetts, August 31, 1954 -	150

LIST OF PHOTOGRAPHS

VOLUME 1

	Follows page
Dragger operations. Typical haul of miscellaneous fish.	I-8
Fishing for menhaden.	I-34
Fishing for tuna.	I-44
Clamming on tidal flats. Plum Island, Massachusetts.	II-4
Sport fishing. Surf caster with striped bass. Cape Cod, Massachusetts.	III-2
Marine sport fishing. Surf casting for striped bass. Cape Cod, Massachusetts.	III-8
Marine sport fishing. Fishermen with striped bass. Cape Cod, Massachusetts.	III-24
Marine sport fishing boat livery. Noank, Connecticut.	III-26
Wetlands. Types 16 and 18, coastal salt marsh. Massachusetts.	IV-2
Wetlands. Types 3 and 4, inland freshwater marsh. New York.	IV-4
Wetlands. Types 5, 6, 7 and 8, inland freshwater swamp and bog. Maine.	IV-8

VOLUME 2

Cranston, Rhode Island, Meta-Anthracite.	XII-2
Cranston, Rhode Island, Meta-Anthracite.	XII-8

VOLUME 3

Peat Bog, Hancock County, Maine.	XX-8
Peat Bog, Hancock County, Maine.	XX-18

VOLUME 4 - LIST OF PHOTOGRAPHS

SECTION XXXII - HURRICANES

	Follows page
Timber damage. Near Keene, New Hampshire. Hurricane September 21, 1938 -	20
Small craft damage. Barrington (above) and Wakefield, Rhode Island. Hurricane September 21, 1938. New England-New York Region. -	22
Wind damage. Utility service and use of street disrupted by fallen trees. Hurricane Carol. Quincy, Massachusetts -	26
Private property damage. East side of Charles Neck, Marion, Massachusetts. Hurricane Carol. Private property damage. Cottages from Charles Neck, Marion, Massachusetts. -	28
Wind damage. Trees and utility poles block street. Hurricane Edna. Castine, Maine -	32
Rescue operation. Tidal flooding. Hurricane Carol, Westport Point, Massachusetts -	36
Beach damage. Breach in barrier beach. Hurricane Carol, Westhampton, L. I., New York -	40
Vessel damage. Fishing vessels aground. Popes Island, Massachusetts. Hurricane Carol. -	42
Before: Assembly for 1954 U. S. Atlantic Tuna Tournament at Narragansett, Rhode Island - During: Boats riding at or above level of pier and autos awash - After: Wrecked Tuna Tournament craft. Hurricane Carol -	44
Damaged recreational craft. Scituate Harbor, Massachusetts. Hurricane Carol -	46
Waterfront property damage. Narragansett Pier, Narragansett, Rhode Island -	54
Industrial property damage. Hurricane Carol. New Bedford, Massachusetts -	56

LIST OF PHOTOGRAPHS

VOLUME 1

	Follows page
Sport fishing. Surf caster with striped bass. Cape Cod, Massachusetts.	III-2
Marine sport fishing. Surf casting for striped bass. Cape Cod, Massachusetts.	III-8
Marine sport fishing. Fishermen with striped bass. Cape Cod, Massachusetts.	III-24
Marine sport fishing boat livery. Noank, Connecticut.	III-26
Wetlands. Types 16 and 18, coastal salt marsh. Massachusetts.	IV-2
Wetlands. Types 3 and 4, inland freshwater marsh. New York.	IV-4
Wetlands. Types 5, 6, 7 and 8, inland freshwater swamp and bog. Maine.	IV-8

VOLUME 2

Cranston, Rhode Island, Meta-Anthracite.	XII-2
Cranston, Rhode Island, Meta-Anthracite.	XII-8

VOLUME 3

Peat Bog, Hancock County, Maine.	XX-8
Peat Bog, Hancock County, Maine.	XX-18

VOLUME 4 - LIST OF PHOTOGRAPHS

SECTION XXXII - HURRICANES

	Follows page
Timber damage. Near Keene, New Hampshire. Hurricane September 21, 1938 -	20
Small craft damage. Barrington (above) and Wakefield, Rhode Island. Hurricane September 21, 1938. New England-New York Region.-	22
Wind damage. Utility service and use of street disrupted by fallen trees. Hurricane Carol. Quincy, Massachusetts	26
Private property damage. East side of Charles Neck, Marion, Massachusetts. Hurricane Carol. Private property damage. Cottages from Charles Neck, Marion, Massachusetts -	28
Wind damage. Trees and utility poles block street. Hurricane Edna. Castine, Maine -	32
Rescue operation. Tidal flooding. Hurricane Carol, Westport Point, Massachusetts -	36
Beach damage. Breach in barrier beach. Hurricane Carol, Westhampton, L. I., New York	40
Vessel damage. Fishing vessels aground. Popes Island, Massachusetts. Hurricane Carol. -	42
Before: Assembly for 1954 U. S. Atlantic Tuna Tournament at Narragansett, Rhode Island - During: Boats riding at or above level of pier and autos awash - After: Wrecked Tuna Tournament craft. Hurricane Carol -	44
Damaged recreational craft. Scituate Harbor, Massachusetts. Hurricane Carol -	46
Waterfront property damage. Narragansett Pier, Narragansett, Rhode Island -	54
Industrial property damage. Hurricane Carol. New Bedford, Massachusetts -	56

Follows page

Agricultural damage. Dairy barn destroyed. Hurricane Carol. Somerset, Massachusetts - 60

Residential property damage. Wareham, Massachusetts. Hurricane Carol - 68

Private property damage. Crescent Beach, Mattapoisett, Massachusetts. Hurricane Carol - 70

Seawall. Winthrop, Massachusetts - 110

Bulkhead. Scarborough Beach, Rhode Island - 112

Impermeable groins. Winthrop, Massachusetts - 114

Breakwaters. Scituate, Massachusetts - 116

Offshore breakwater. Winthrop, Massachusetts - 118

SECTION XVII - MINERAL INSULATION IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY

1. The supply, manufacture, distribution and use of mineral insulation are discussed in this section. The scope of the industry in New England and New York is obscure. Nevertheless it is well known that the manufacture and sale of mineral insulation is an important factor in New England and New York economy. Short descriptions of mineral insulation materials and processes of manufacture are presented. Data on various phases of the industry are available from literature shown in the bibliography.

2. Insulation retards the transfer of electricity, heat or sound. Acoustics, the science of sound, takes in many phases of sound origination, distribution and control. Insulation to retard the flow of heat will dampen sound waves. Some mineral insulators are used in sound control purposes other than to prevent its transfer. Such uses are architectural and do not come within the scope of this section. The insulation of electricity is not treated here as it is a highly specialized field using plastics, fabrics, and other materials as well as some minerals.

3. Mineral insulation is used to contain heat of high temperature surfaces such as boilers, hot pipelines and other heated areas. Refrigerators and low temperature installations are insulated to prevent the inward flow of heat.

4. Insulation in dwellings, business and industrial buildings serves a dual purpose by containing heat in winter and keeping it out in summer.

5. Insulation saves energy and adds to the physical comfort of the occupants of buildings by making possible a more even control of inside temperature.

6. Mineral insulation being fireproof tends to retard the spread of fire.

7. Fuel savings up to 40 percent may be obtained by insulating the walls and roof of an uninsulated house 1/. Complete insulation, including weather stripping, is estimated to save as much as 50 percent in fuel 2/.

8. Raw materials for heat insulation may be animal, vegetable, metal and nonmetallic mineral products. Organic materials are not within the province of this section.

9. The greatest demand for home and building insulation is naturally during periods of heavy building. The long and occasionally severe winters, which average about 6,000 fuel degree-days[1] in New England and New York, and the increasing cost of fuel should cause a steady demand for the insulation of homes and buildings. Installing insulation in them will cause savings in fuel that will repay costs promptly.

10. Several plants in the New England and New York area were producing and/or distributing metallic and nonmetallic mineral insulation as of November 1953.

---

1. A degree day is the departure of one degree per day in the mean daily temperature below 65° F. (U. S. Weather Bureau).

1/ T.I.B.M. 3, Bureau of Standards, March 4, 1936.
2/ Thermal Insulation of Dwelling Houses, Circular Letter L.C. 774: U. S. Department of Commerce, January 3, 1945, 13 pp.

11. Metals are used as insulation chiefly for reflection of heat rays. Polished aluminum and aluminum foil are good examples. Some metal insulation is manufactured in the region, principally in New York.

12. In the nonmetallic field most of the raw materials are vermiculite from the Western states and North and South Carolina, perlite from the Western states, furnace slag from Pennsylvania and Buffalo, and glass marbles from Ohio. There is a possibility of using wollastonite from New York for future mineral wool production. Fuel for use in preparation of insulation is shipped in - coal or coke from the Appalachian coal field, oil from other states or a foreign source.

HISTORY AND PRODUCTION

13. The use of nonmetallic mineral insulation became important with the development of steam as a source of power. Its application to buildings probably started late in the 19th century. Most of the materials and methods now used have been adopted since about 1925.

14. Mineral wool production was started in the United States prior to 1900. Fifty thousand tons are estimated to have been produced in 1928 and 500,000 tons in 1936 3/. The Bureau of the Census reports

3/ Thoenen, J. R., Mineral Wool: Bureau of Mines I.C. 6984R, June

mineral wool production valued at $138,305,000 in 1952 4/. This value probably represents about 2½ million tons.

15. Vermiculite sales, after an erratic start in 1924, were about 7,000 tons in 1935 and increased to 209,000 tons nationally in 1951 5/.

16. Perlite was introduced in 1946. Four thousand tons were produced that year and 135,000 tons nationally in 1951 5/.

17. Diatomaceous earth is used to a limited extent as insulation for pipe wrappings and furnace door linings. The tonnage data are not available.

18. Foamglas and silica aerogel are new products. Their use as insulation is minor compared to their many other uses.

INSULATING MINERALS

19. Many of the metals, especially the white or bright metals, are used as heat insulators. Although they absorb heat they block the passage of air and reflect radiant heat.

20. Nonmetallic mineral insulation may be natural, treated or manufactured. The kind of insulation used generally depends on its abundance, weight and cost, as the poorer insulator only has to be made proportionately thicker to equal the "K" value of the best. (The insulating value "K" is the amount of heat measured in B.t.u.'s which will pass through one square foot of material one inch thick in one hour with a difference of one degree Fahrenheit on opposite sides of the slab.) Special installations may require control of weight, volume and "K" value so that a particular

---

4/ 1952 Annual Survey of Manufacturers: U. S. Department of Commerce Series MAS-52-1, No. 32750, p. 14.

5/ Minerals Yearbooks, Minor Nonmetals Chapter: Bureau of Mines.

material is necessary. Table 61 shows the weight per cubic foot and the "K" value of the most commonly used heat insulators.

21. Insulation is used loose, shredded, in sheets, fabricated in either flexible or rigid shapes, pressed boards, and molded forms.

PROPERTIES OF MINERAL INSULATION

22. Metallic insulation should be polished and have high reflective power.

23. Nonmetallic mineral insulation should have resistance to heat well above the maximum temperature to be encountered. It should be chemically inert, a non-conductor of electricity, and odorless, as well as fire, corrosion, mold and vermin proof.

24. Insulating value in nonmetallics depends chiefly on the porous structure of the material. Dead air is one of the best insulators known. The air pockets in the insulators serve to block the passage of heat and sound.

NATURAL INSULATORS

25. Diatomite and pumice have natural air spaces. Asbestos needs only to be shredded. Loose mica flakes and pumicite may also be considered natural insulators.

26. Diatomite is described in more detail in Section XIV of this chapter. Diatomite of doubtful value is reported in some of the New England and New York river basins.

27. Asbestos occurrences in the vicinity of Spencer Lake, Somerset County, Maine, were investigated in the summer of 1954 by the Bureau of Mines as part of the work of the Committee. Eleven drill holes were put down in an area nine miles in length, beginning at Johnson

Table 61--Heat Conductivities of Various Insulating Material 6/

Material	Reference	Density, Lb per Cu Ft	Mean Temperature Deg F	Conductivity K
Concrete-pumice aggregate	37	65	75	2.42
Concrete-expanded burned clay aggregate	37	59.9	75	2.28
Cellular concrete	37	50	75	1.44
Cellular concrete	37	70	75	2.18
Concrete-expanded vermiculite aggregate	37	50	90	1.1
Concrete-expanded vermiculite aggregate	37	20	90	0.68
Glass-wool fibers 0.0003 to 0.0006 in. in diameter	37	1.5	75	0.27
Fibrous material made from dolomite and silica (mineral wool)	37	1.5	75	0.27
Fibrous material made from slag (mineral wool)	37	9.4	103	0.27
Mineral wool, granulated, machine-blown. Horizontal position, no covering	37	5.74		0.30
Rock wool (loose)	38	6	100	0.27
Rock wool felted between wire mesh	38	16.6	100	0.283
Rock wool, felted blanket	77	8.2	300	0.41
85% magnesia, 15% asbestos slab	37	19.3	86	0.51
Foamglas	69	10.5	50	0.45
Foamglas	69	10.5	300	0.70
Vermiculite, expanded	70	8	100	0.48
Diatomite powder	70	10.6	86	0.31
Still air	77	0.08	32	0.156
Kaolin insulating brick (recalculated)	72	27	932	1.2
Kaolin insulating brick (recalculated)	72	27	2100	3.1
Silica aerogel (Santocel) 7/		3.5 to 6.0	60	0.16

6/ Lamar, J. E., and Machin, J. S., Industrial Minerals and Rocks, (second edition): A.I.M.E. 1949, p. 449.

7/ 17 Profit Building Industrial Applications of Santocel, Monsanto Chemical Company.

Bog and continuing westward to Little Spencer Stream. Eight holes penetrated 3 to 8 percent chrysotile asbestos and all bottomed in asbestos-bearing serpentine. Nickel and chromium were also present. The results are encouraging and further investigation is warranted. All asbestos in the drill cores was short fibre but good quality.

28. The occurrence of pumice and pumicite in New England and New York, sufficient to warrant consideration for production, has not been reported.

TREATED INSULATORS

29. Some minerals must be processed to make them suitable insulators. Vermiculite and perlite expand six to twenty times their volume on heating. Many clays and shales are bloated by heating. Screened and cleaned vermiculite from Western states and North and South Carolina, and perlite from the Western states are shipped to plants near point of consumption. Such plants treat the crude material and distribute the product within the trade area. A portable expanding furnace is available that makes it possible to process vermiculite on the job.

30. Expanded vermiculite and perlite are used as loose insulation, in plaster, concrete aggregates and in gypsum wallboard. The principal use of bloated clays is as aggregate for lightweight concrete which itself is a fair insulator.

31. Air bubbles are sometimes mechanically entrained in ordinary concrete to reduce the weight and increase resistance to the passage of heat.

MANUFACTURED INSULATORS

32. The principal manufactured heat insulators are gypsum products, "85 percent magnesia", mineral wool, foamglas, the silica aerogels and some metals.

33. Aluminum foil or sheet aluminum less than 0.006 inch thick and foils of other metals are used as insulation. The foil is generally mounted on one or both sides of heavy building paper.

34. Gypsum is discussed in Section XVI of this chapter. Gypsum products generally are not considered efficient heat insulation.

35. "Eighty-five percent magnesia" is composed of basic magnesium carbonate and asbestos with 1/2" to 1" fibers in a ratio of 85 to 15 by weight. The material is used chiefly as plaster and over-dried forms for pipe and boiler coverings. It is good insulation for temperatures to 550-600° F. Magnesia is used more often in refractories. Section XVI on carbonate rocks discusses magnesia more fully.

36. Mineral wool is a fibrous wool-like material generally made by a high speed jet of air or steam blown through and normal to a free falling stream of melted natural rock, slag or glass. Some glass fiber is made by drawing in which a fine (1 to 4 microns) continuous strand of glass is wound on a drum. A minor amount of wool is made by a spinning disk which throws the liquid material through the air at high speed. The material is melted in water-cooled cupolas. A few plants use electric furnaces. The technical features and processes of mineral wool manufacture and its application are given in many publications, several of which are listed in the bibliography.

37. Raw materials required for making mineral wool are basically silica, lime, alumina and magnesia with minor amounts of many other minerals. The percentage of the basic minerals used may range widely. Combinations of rocks and clays found in many areas of New England and New York will yield a workable mixture.

38. Wool from any combination of the raw materials listed has about the same properties and insulating value. It ranges in color from white to dark grey.

39. Other factors such as nearby abundant markets, low cost fuel and good transportation facilities must be considered besides the supply of minerals in establishing a mineral wool plant. The fuel used to melt the material is usually coke. Fuel oil, gas and electricity are used in a few plants.

40. Coke required to make wool from natural rocks or mixed minerals ranges from 4/5 to 5/5 the weight of the raw materials 8/; slag requires but 1/6 to 1/4 its weight in coke.

41. Slag has a further advantage over raw rocks in that it has been burned while raw rocks lose considerable weight on ignition and the slag wool contains less shot. In areas where slag is available it is used almost entirely. The saving in fuel permits the profitable shipment of suitable slag from Pennsylvania to eastern Massachusetts instead of using local minerals.

8/ Lamar, J. E., and Machin, J. S., Industrial Minerals and Rocks, (second edition): A.I.M.E. 1949, p. 454.

42. The following example shows the estimated cost of fuel necessary to produce 10 tons of wool a day (an average plant) from slag and from raw rocks:

Slag			Raw Rocks		
3 tons	make	2 tons wool 9/	2 tons	make	1 ton wool 9/
15 "	"	10 " "	20 "	"	10 tons "
1/4 "	coke	for 1 ton slag 9/	4/5 "	coke	for 1 ton rock 10/
4 "	"	" 15 tons "	16 "	"	" 20 tons "
4 "	"	@ $20.00 T 11/ $80.00	16 "	"	@ $20.00 T $320.00

43. The National Mineral Wool Association listed 3 rock wool plants operating in New England and New York on June 1, 1951. All were using slag as a raw material. Two plants in Massachusetts have closed since then.

44. Fiber glass or glass wool is made by practically the same process as rock wool. Glass or glass making minerals are used for the furnace charge. The wool is white to cream color and generally has longer and smaller fibers than rock wool.

45. Fiber glass one inch thick, sandwiched between porcelain-faced metal sheets, provides the insulation for completed panels 1-1/2" thick used in the construction of the new Statler Hotel at Hartford, Connecticut. The panels will replace customary 12" brick curtain walls 12/. The market for fiber glass in such construction is increasing.

9/ 1952 Annual Survey of Manufacturers: U. S. Department of Commerce Series MAS-52-1, No. 32750, p. 14.

10/ Lamar, J. E., and Machin, J. S., Industrial Minerals and Rocks, (second edition): A.I.M.E. 1949, p. 449.

11/ Price per ton computed from E & MJ, vol. 25, March 25, 1954, $16.50-$17.00 ton plus estimated freight and unloading expense.

12/ New Statler Hotel to Gain Extra Space by Porcelain-faced Wall: American Metal Market, July 23, 1953.

46. Cellular glass or foamglas is made by melting glass, or glass producing minerals, mixed with a gassing agent such as calcium carbonate or carbon. The heat freed gas (CO_2) causes the liquid to foam. When the desired cellular condition is reached the glass is cooled 13/. The product may be sawed or cut to any shape for use as heat insulation.

47. Silica aerogel, a comparatively new product, is made by chemical and heat treatment of white purified silica sand. It is a fine white powder, about 94 percent air, with lowest "K" value of any known substance. The infinitely small air spaces in this material in some way reduce the conductivity of still air as much as 10 percent below its theoretical limit 14/. The principal insulating use is for low temperature work such as making and handling liquid oxygen. Silica aerogel has numerous other uses outside the insulation field and is rather expensive for general insulation.

48. The ton/mile transportation cost of mineral wool, foamglas and other insulators is high because the bulk limits the tonnage in carrier space. Plants should be established near centers of heavy consumption.

DISCUSSION

49. Asbestos, gypsum, and magnesia, rock and glass wool, and possibly bloated clays are the only common insulation for which minerals may be obtained in New England and New York. There are many districts within the area in which the required silica, lime, alumina, and magnesia for making rock wool may be assembled. None is being used in insulation now.

13/ Lamar, J. E., and Machin, J. S., Industrial Minerals and Rocks, (second edition): A.I.M.E. 1949, p. 452.

14/ 17 Profit Building Industrial Applications of Santocel, Monsanto Chemical Company.

Wollastonite occurs near Willsboro, New York. It is reported to be excellent material for rock wool. No manufacturing costs are available at this time (May 1954). It may be used in the future.

50. The Bureau of Mines made rock wool from a mixture of 40 percent granite from Dracut, Massachusetts, and 60 percent limestone 15/.

51. The University of Rhode Island in cooperation with the Bureau of Mines ran a series of experiments on making rock wool from the Rhode Island meta-anthracite mixed with local limestone. The tests showed that:

"(1) Satisfactory mineral-wool insulation can be made from Rhode Island meta-anthracite coal and limestone, using a slagging gas producer.

"(2) Gas is obtained in sufficient quantity as a by-product in the process for making mineral wool to more than provide all heat requirements.

"(3) A commercial plant, based on the process and the design data worked out is technically feasible" 16/.

The report presents much data on furnace charges and results obtained. No cost estimates are shown in this section.

CONCLUSION

52. Rock wool manufacture from most New England and New York raw rocks would be uneconomic because of the excessive cost of fuel over that for slag.

15/ Gorski, C. H., White, O. D., and Moreland, M. L., Raw Materials for the Mineral Wool Industry: Rept. of Inv. 4821, Bureau of Mines, October 1951, p. 8.

16/ Crawford, T. S., Corey, R. C., Schwartz, C. H., Sapno, L. A., and Carpenter, E. L., A Slagging Gas Producer for the Production of Mineral Wool from Rhode Island Meta-Anthracite: Bulletin No. 3 of R. I., July 1953, 35 pp.

53. Rhode Island meta-anthracite may become a source of saleable wool. The cost of the prepared cupola charge from mine and quarry, with the amount and possible use of material rejected in the preparation of the charge, should be determined. Excess energy may be generated in the process. Use of the excess gas in a lime kiln is suggested in Rhode Island's Bulletin No. 3 17/.

17/ Crawford, T. S., Corey, R. C., Schwartz, C. H., Sapno, L. A., and Carpenter, E. L., A Slagging Gas Producer for the Production of Mineral Wool from Rhode Island Meta-Anthracite: Bulletin No. 3 of R. I., July 1953, p. 6.

SELECTED BIBLIOGRAPHY ON MINERAL INSULATION

1. _____. Annual Survey of Manufactures 1952. Bureau of Census (No. 32750).

2. BOWLES, OLIVER. Asbestos. Bureau of Mines Inf. Circ. 6817, 1935.

3. BOWLES, OLIVER. Industrial Insulation with Minerals Products. Bureau of Mines Inf. Circ. 7263, December 1943.

4. BOWLES, OLIVER. Home Insulation with Mineral Products--Conserves Fuel - Reduces Cost - Increases Comfort. Bureau of Mines Inf. Circ. 7388, October 1946.

5. CRAWFORD, T. S., AND OTHERS. A Slagging Gas Producer for the Production of Mineral Wool from Rhode Island Meta-Anthracite. University of Rhode Island Bull. No. 3, July 1953.

6. GORSKI, C. H., WHITE, O. D., and MORELAND, M. L. Raw Materials for the Mineral Wool Industry. Bureau of Mines Rept. Inv. 4821, October 1951.

7. KING, E. G., AND OTHERS. Perlite Thermal Data and Energy Required for Expansion. Bureau of Mines Rept. Inv. 4394, November 1948.

8. LAMAR, J. E., and MACHIN, J. S. Industrial Minerals and Rocks (second edition) ch. 24. A. I. M. E. 1949.

9. MOLLOY, S. M., and CALHOUN, W. A. Laboratory Methods for Evaluating Materials for Mineral Wool Production. Bureau of Mines Rept. Inv. 4296, June 1948.

10. MOYER, F. T. Lightweight Aggregate for Concrete. Bureau of Mines Inf. Circ. 7195, 1942.

11. OGDEN, F. F., and WHITE, J. F. Use of Silica Aerogel as Thermal Insulation. Refrigeration Engineer, November 1946.

12. _____, Processing Foamglas at Pittsburgh Corning Corporation. Ceramic Industry, February 1944.

13. _____. Production of Silica Aerogel. Chemical and Metallurgical Engineer, February 1943.

14. _____. T. I. B. M. No. 3. Bureau of Standards, March 4, 1936.

15. SCHAEFFER, J. A. Mineral Wool and Vermiculite as Insulation. Industrial and Engineering Chemistry 1935. (1298-1303)

16. _____. Thermal Insulation of Dwelling Houses. Department of Commerce Circ. Let. L. C. 774, January 3, 1945.

17. THOENEN, J. R. Mineral Wool. Bureau of Mines Inf. Circ. 6984R. June 1939.

18. THORNDYKE, J. T. Mineral Wool from Wollastonite. Mining and Metallurgy, March 1936.

19. WHITE, J. F. Manufacture of Silica Aerogel. Chemical Industry, July 1942.

SECTION XVIII - NATURAL IRON OXIDE PIGMENTS IN THE NEW ENGLAND - NEW YORK REGION

SUMMARY AND CONCLUSIONS

1. The principal resources of natural iron oxide pigment materials are the Clinton iron ores of central and western New York, and the ocher of western New England and southeastern New York. The only producer of natural iron oxide pigment from local material uses the Clinton iron ore. Production probably will not increase in the foreseeable future because of better raw materials produced outside the area and the increasing use of manufactured pigments.

INTRODUCTION

2. Mineral pigments (according to Harness, 1949) "give color, opacity, or body to paint, stucco, plaster, mortar, cement, linoleum, rubber, and similar materials". Only natural mineral pigments whose color is due to iron oxide are discussed in this section.

3. Natural iron oxide pigments are those which are marketed essentially as dug from the earth. They may, however, be washed, ground, blended, or calcined during preparation. Raw material for natural iron oxide pigments should be finely divided (or easily ground), be of uniform particle size, chemically inert, only slightly soluble, should have the proper mass color (appearance of the pigment in linseed oil), tinting strength (appearance when diluted in a zinc oxide and linseed oil paste), and preferably a low oil absorption. The chemical composition may be quite variable.

HISTORY

4. Usage of iron oxides for personal adornment, and to describe events or scenes of significance, is characteristic of the most primitive people.

American Indians used mineral paints before the earliest settlers arrived and it probably was these paints that prompted early exploration for iron deposits.

5. The manufacture of low-priced paint in New England and New York is a small, but very old industry. Red paint made from local raw materials has long been used for painting barns in New England. Mineral pigment has been produced at Clinton, New York, for 143 years (1953).

COMPOSITION AND CLASSIFICATION

6. Natural iron oxide pigments usually derive their essential color from limonite or hematite (rarely from magnetite), with or without mixtures of clay and manganese oxides. They form yellows, reds, yellow-browns, browns, and occasionally greens.

7. Harness, (1949, p. 592) gave the following classification of iron oxide pigments by color and composition:

Color:	Raw: Yellow, yellow-brown* Burnt: Red, red-brown, salmon		Dark brown to black
	Ochers	Siennas	Umbers
Fe_2O_3	17-60 percent**	25-75 percent	37-60 percent
MnO_2	----	small percentage	11-23 percent
SiO_2	35-50 percent	10-35 percent	16-35 percent
N_2O_3	10-40 percent	10-20 percent	3-13 percent
Loss on ignition	10-12 percent	15-20 percent	10-15 percent

* Red-brown, and red should be included in this list.
** Guild (1954) reports that in Brazil a deep red ocher containing 72.7 percent Fe_2O_3 is mined for pigment.

8. Ocher is an earthy, pulverulent form of hematite (iron oxide) and limonite (hydrated iron oxide) more or less admixed with impurities such as clayey material. Hematite usually gives red-colored ochers and limonite gives yellow, yellow-brown, or brown-colored ochers. Various shades of each are due to the degree of hydration and oxidation and to the amount and kind of impurities present.

9. Sienna is a yellow-brown variety of ocher which is usually high in iron and contains a small percentage of manganese oxide. It grades into umber as manganese content increases, and into ordinary yellow and brown ocher as iron and manganese content decreases.

10. Umber is a variety of ocher containing hydrated iron oxide, clay, and manganese oxide. The manganese oxide content gives umber its typical dark brown color.

MANUFACTURED IRON OXIDE PIGMENTS

11. Manufactured iron oxide pigments are usually more uniform in quality and of a higher tinting power than natural pigments. They are characterized by uniformity, fine particle size, friable structure which makes for easy grinding, high covering power, and color permanence. These desirable characteristics have led to a steady increase in the use of manufactured iron oxide pigments and to a higher unit value. In 1950, synthetic pigments were 35 percent of the total tonnage sold but constituted 62 percent of the total value of sales. 3/

12. If some of the large pyrite and pyrrhotite deposits of New England and New York should be actively mined, it is possible that synthetic red iron oxide pigments could be produced as a by-product of roasting of the pyrite in sulphuric acid manufacture.

3/ Minerals Yearbook, 1950: U. S. Bur. of Mines.

MINING

13. Deposits of ocherous materials occurring in weathered rock outcrops, residuum, and associated with limonite ores (including bog iron ore) have been mostly mined by hand or power shovel from shallow pits and open-cuts. In New England and New York such deposits are very small (bog iron deposits) or, as is the case in Vermont, the ocher occurs in pockets or beds in clay or other material. Such conditions necessitate selective mining and in many places a large amount of other material must be removed to recover the ocher.

14. In recent years, however, most of the production of iron oxide pigment materials in this area has come from the Clinton iron ores of New York. This material is mined underground with some adaptation of the room-and-pillar stoping system. This system allows a greater recovery of ore per unit volume of rock moved and does not destroy the surface land as strip mining does.

TREATMENT OF ORES

15. Washing, blending, roasting or other treatment of the raw materials is necessary in most instances. The harder materials must be crushed, but most pigments are treated by comparatively simple washing processes using such equipment as logwashers, rake classifiers, settling tanks, and filters. Settling and filtering become a problem in the case of nearly all the products of this type. Steam-heated drum driers are popular but care must be taken to avoid color change because of contact heating. Burnt ochers and red paint pigments require calcining in kilns or rotary burners.

16. Dale (1953) describes the present operation at Clinton as follows: "The thickness of the ore is two feet. The ore is taken from a 50-foot shaft

at the mine and transported to the paint mills at Franklin Springs where the process comprises the following steps: The ore is crushed after it is conveyed to heaters which dry off all mechanically combined moisture and volatile matter and, in a red hot condition, it is conveyed to the hammers where the material is ground against iron meshes with one-quarter inch holes. The ground material then passes on to the millstone stage where the hematite is completely pulverized, the ground hematite being finally blown into the bagging chute. The powdered hematite, which is used in coloring mortar or bricks and mixed with oil, serves as an excellent red paint. It is also used in coloring cement floors."

GEOLOGY AND RESOURCES

17. Deposits of natural iron oxide pigment materials are widely distributed in New England and New York. The deposits are of two main types: (a) deposits formed by weathering processes or deposition by ground water, and (b) bedded sedimentary hematite deposits in the Clinton formation.

18. The ocherous deposits consist of irregular residual masses, such as gossans on deposits containing iron sulfides, or ancient soils derived from iron-bearing bedrock. The Katahdin iron mine was an outstanding example of the first type. The ocherous and kaolin deposits of the Brandon residual formation in western Vermont are examples of the second type (Burt, 1931). Both kinds of deposits are irregular, variable in quality, and difficult to explore and mine. Deposits may also form in bogs by precipitation from streams.

19. The deposits of the Clinton formation are bedded like coal, are very extensive, and contain millions of tons of minable material.

20. The intimate association of iron oxides with other materials such as manganese and clay, and multiple use of the materials, present major problems in recording and analyzing production statistics. Where tonnages of any one constituent are large, the major use may be recorded and the others overlooked. Many bog deposits opened up for iron ores in colonial days undoubtedly contributed material for bara paint incidental to the main operation. The same iron-stained clay that could be used for ocher might make good brick or tile. Deposits mined on a large scale at one time for iron ore might continue in operation on a small scale for pigment.

21. New York. - The one active company, at Clinton, Oneida County, is mining the Clinton hematite (Silurian). The Clinton beds crop out from Otsego County westward to the Niagara River gorge, and dip southward at about 50 feet per mile. The iron ores are interbedded with conglomerate, shale, limestone, and dolomite. Gillette (1947) has described four beds along the length of the formation, two of which are present at Clinton. The ore is of two types, a lower oolitic ore and an upper "red flux" type. The "red flux" ore contains 40 to 55 percent of calcium and magnesium carbonates and only 10 to 20 percent iron. It ranges in thickness from a few inches to about 6 feet. Although not mined now, it is said to have been ground for mineral pigment in the past (Hartnogel and Broughton, 1951). The oolitic ore is siliceous and ranges in iron content from 35 to

45 percent. The ore ranges in thickness from a few inches to 3 feet, either in a single bed or in two beds separated by a shale parting. Where now being mined the bed averages about 2 feet thick. This bed has been mined for pigment since about 1810 (Dale, 1953). Ore reserves at Clinton were estimated by Dale to total 120-150 million tons of a minimum thickness of 18 inches, presumably of at least 40 percent iron.

22. Deposits of red hematite associated with the Grenville schist, gneiss, and limestone (Pre-Cambrian), in St. Lawrence and Jefferson Counties, yielded about 2,500,000 million tons of iron ore before 1910 and since then have been worked for mineral pigment in small quantities. Occasional production reported from Rossie, St. Lawrence County, is believed to be obtained from picking old mine dumps (Hartnagel and Broughton, 1951).

23. The limonites of southeastern New York and Staten Island are typical of a series of deposits extending from Vermont to Alabama. The deposits range in size from hundreds of thousands of tons to small pockets. Though some of the ocher in the deposits is probably of commercial quality, most of the usable material would be too expensive to mine.

24. Vermont. - A considerable quantity of ocherous clay occurs in a discontinuous belt of deposits extending along the western side of the Green Mountains for almost the entire length of Vermont and across Massachusetts. The individual deposits are usually less than 2 square miles in extent and range in thickness from 10 to 175 feet. The deposits are in remnants

of the Brandon residual formation which consists of kaolin, ocher, quartz sand, iron ore, manganiferous ore, and lignite. The various materials occur as alternating beds, in pockets, and as stringers cutting at all angles. The overburden ranges from 2 to 15 feet thick (Burt, 1933). The deposits have been worked in the past for manganiferous iron ore, iron ore, ocher, and kaolin. Good quality ocher occurs with the kaolin but probably not in sufficient quantities to sustain an operation for it alone. Future ocher production, if any, will probably be as by-product of kaolin mining.

25. Ocher mining began in Vermont as early as 1820. From 1889 to 1913, Vermont ranked third among the States in amount of ocher produced. In 1891, a peak value of ocher production of $11,095 was reached. After 1913, production fell rapidly, and since 1916 little, if any, ocher has been mined (Burt, 1931). Only the kaolin is of possible commercial value by itself and there has been some intermittent production in recent years.

26. Massachusetts. - Ocher and sienna of fair quality occur in Berkshire County with limonite ore in a formation similar to, and which may be correlated with, the Brandon formation of Vermont. Pockets of material suitable for pigments in lower grade ocherous clay were formerly worked at Williamstown.

27. Ocher and sienna were also mined in the 1850's at East Whately, Franklin County, from a small, high-quality deposit of bog iron ore 10 to 30 inches thick. The material was homogeneous, fine-grained, and well suited for pigments. The ocher was a sienna-brown, and when calcined was

a red to burnt sienna color. This deposit probably has been completely worked out. A small deposit of ocher has been reported at Monroe, Franklin County (Emerson, 1895).

28. Bog iron occurs at many widely scattered localities in eastern Massachusetts and also at some localities in western Massachusetts. A "paint mine" was operated at Georgetown, Essex County, in the 1890's for brown ocher. Value of the product in 1890 and 1891 was about $2,700. Some of the deposits of eastern Massachusetts were important sources of iron ore during the colonial period, doubtless with mineral pigment as a by-product.

29. Maine. - Balch (1882) mentioned the buildings were being protected by the decomposed iron ores of Maine. Very likely the ferruginous material came from the gossan on the sulfide body at the Katahdin mine, Piscataquis County. Bog ore has been reported at many localities in Maine.

30. Connecticut. - Ocher occurs with the limonitic iron ores of Litchfield County. Though some of this material and bog ore dug at several places in the State undoubtedly were used as mineral paint, there is no record of the production.

31. New Hampshire. - Numerous small deposits of bog iron ore are found in New Hampshire (Schrader, Stone and Sanford, 1917). There is no record of mineral pigment production from these deposits but some ore may have been utilized for pigment years ago.

32. Rhode Island. - Bog iron ore was mined at several localities in Rhode Island. It is not known if any of the material was used for natural iron oxide pigments.

SELECTED BIBLIOGRAPHY ON NATURAL IRON OXIDE PIGMENTS

BALCH, William R., 1882, Mines, Miners, and Mining Interests of the United States. Mining Industrial Publishing Co., Philadelphia.

BISHOP, J. L., 1864, A History of American Manufactures, vol. I. Edward Young & Co., Philadelphia, pp. 208-407.

BURT, F. A., 1931, Geology of the Vermont Ocher Deposits. Vermont State Geologist 17th Rept., pp. 107-136.

BURT, F. A., 1933, Iron Oxide Mineral Pigments of the United States, Vermont Ocher Deposits. U. S. Bur. of Mines Bull. 370, pp. 179-183.

BURT, F. A., 1929, The Origin of the Bennington Kaolins. Vermont State Geologist 16th Rept., pp. 65-84.

DALE, Nelson C., 1953, Geology and Mineral Resources of the Oriskany Quadrangle. New York State Mining Bull. 345.

ECKEL, Edwin C., 1905, Limonite Deposits of Eastern New York and Western New England. U. S. Geol. Survey Bull. 260, pp. 335-342.

EMERSON, B. K., 1895, A Mineralogical Lexicon of Franklin, Hampshire, and Hampden Counties, Massachusetts. U. S. Geol. Survey Bull. 126, pp. 101-102.

GILLETTE, Tracy, 1947, The Clinton of Western and Central New York. New York State Mus. Bull. 341, pp. 1-91.

GUILD, P. W., 1954, Personal communication.

HARNESS, C. L., 1949, Industrial Minerals and Rocks, Mineral Pigments. Am. Inst. Min. Met. Eng., New York, pp. 591-601.

HARTNAGEL, C. A., and BROUGHTON, J. G., 1951, The Mining and Quarry Industries of New York State, 1937-1948. New York State Mus. Bull. 343, pp. 64-65.

_____. Minerals Yearbook, 1950. U. S. Bur. of Mines.

SCHRADER, F. C., STONE, R. W., and SANFORD, S., 1917, Useful Minerals of the United States. U. S. Geol. Survey Bull. 624.

SEARS, J. H., 1905, The Physical Geography, Geology, Mineralogy, and Paleontology of Essex County. Essex Institute, Salem Massachusetts, p. 234.

WILSON, Hewitt, 1933, Iron Oxide Mineral Pigments of the United States. U. S. Bur. of Mines Bull. 370.

SECTION XIX - NICKEL AND COBALT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Nickel is produced predominantly from sulfide deposits that occur in norite, peridotite, and related igneous intrusive rocks. The sulfide deposits, both massive and disseminated, consist of pyrrhotite ($Fe_{x-1}Sx$), pentlandite ((FeNi)S), and chalocopyrite ($CuFeS_2$). The ore commonly contains 1 to 2 percent nickel, and cobalt is also present in small amounts, usually 0.05 to 0.1 percent. Over 80 percent of the world production of nickel is from sulfide deposits of this type in the Sudbury district, Ontario, Canada (International Nickel Co., Geology Department, 1950).

2. A number of noritic and peridotitic intrusives crop out in New England and opposite the east tip of Maine, in New Brunswick, Canada. Some contain sulfide deposits, but none of the deposits is large enough and rich enough to be profitably mined. Examples of this type of deposit are found at Mt. Prospect, Connecticut (Cameron, 1943), Dracut, Massachusetts (Dennen, 1943), and in New Brunswick near St. Stephen and St. George (Dunham, 1950).

3. In another type of occurrence, nickel and cobalt arsenides in small amounts have been found in quartz veins that cross gneiss and schist at Great Hill, Connecticut (Blake, 1883). A little nickel and cobalt are also present in talc bodies associated with serpentinite in Vermont (Davis, 1945).

4. Cobalt also occurs as a minor constituent in certain massive pyrrhotite ($Fe_{x-1}S_x$) deposits in New England, notably the Elizabeth mine, South Strafford, Vermont (Burbank and others, 1948), and the Katahdin pyrrhotite deposit, Piscataquis County, Maine (Miller, 1945). The later deposit also contains traces of nickel.

5. The nickel and cobalt-bearing deposits of New England were discovered during the eighteenth and nineteenth centuries and were worked for limited periods until almost the end of the nineteenth century. When nickel was discovered in the ores of these deposits and metallurgical processes for the separation of nickel and cobalt were developed, small shipments of nickel-copper and of nickel-cobalt concentrates were made sporadically from a few of the deposits. The small size of the ore bodies explored, the low grade of the ores, and the difficulties encountered in ore reduction forced the owners to suspend operations prior to 1900. These properties have not been worked for many years and the openings are in large part caved and flooded.

DESCRIPTION OF DEPOSITS

6. Great Hill, Connecticut. - This deposit is located 1.5 miles northeast of Cobalt in the town of East Hampton. It was first worked in 1762, and mining continued intermittently until 1855. The ore is believed to have been in small high-grade pockets in several quartz veins in the Bolton schist and gneiss, with a maximum thickness of 1 foot. Assays of the dressed ore reported in 1853 showed 9 percent nickel and 9 percent cobalt. The average content of nickel and cobalt in the

ore as mined was 2.2 percent (Blake, p. 402, 1883). Shipments of as much as 20 tons of ore were made at various times during the nineteenth century. The main shaft was about 120 feet deep, and several other shafts, cross cuts and adits were opened. Mineralogists of the U. S. Geological Survey found pyrite, chalcopyrite, and a mineral intermediate between arsenopyrite and lollingite in one specimen from this locality, and gersodorffite and niccolite in another.

7. Mt. Prospect complex, Connecticut. - A complex composed of norite, pyroxenite, hornblendite, and dioritic gneiss (Cameron, 1951) is located at Mt. Prospect, about 3.5 miles west of Litchfield, Connecticut. Within this complex are six deposits of iron, copper, and nickel sulfides (Cameron, p. 658-660, 1943). The deposits consist of disseminations and small massive bodies of pyrrhotite, chalcopyrite, and pentlandite formed by fracture filling replacement of silicates (Cameron, p. 678, 1943). No systematic arrangement of the ores with respect to the intrusive rocks (norite and hypersthene pyroxenite) is apparent (Cameron, p. 661, 1943). At four of the deposits and sulfides occur chiefly in the older igneous rocks of the complex adjacent to the sulfide-bearing norite and hypersthene pyroxenite (Cameron, p. 661, 1943). Because of limited surface exposures and inaccessibility of the workings, the amount of sulfide-bearing rock cannot be determined. The deposits were worked intermittently from 1832 to 1870, but the most active mining was done between 1850 and 1865. The workings are shallow, with a maximum depth of 40 feet. The Buck deposit, perhaps the best, is estimated to have produced several hundred tons of ore.

8. Hodges prospect, Connecticut. - About 1 mile northwest of the village of West Torrington sulfides occur in a small mass of amphibolite within hornblende dirotie intrusive into the Berkshire schist and gneiss (Agar, p. 186, 1930). The hornblende diorite mass is about half a mile in diameter. A pit at the contact of amphibolite and hornblende diroite shows lean disseminations of pyrrhotite, chalcopyrite, and pentlandite.

9. Cleveland deposit, Massachusetts. - The location of this deposit is not known, but it is reported to lie 4 miles south and west of the village of New Marlboro. It occurs in pyroxenite, which is intrusive into the Washington Gneiss. The pyroxenite contains considerable pyrrhotite and a little chalcopyrite. Assays of the ore (probably selected) showed a nickel content of from 3 to 25 percent (Emerson, p. 64, 1899). The deposit was worked for nickel in 1891. No record of mining of this deposit has been reported since then.

10. Dracut deposit, Massachusetts. - This deposit is located on Nickel Hill, about 4 miles northeast of Lowell. It lies within the Dracut norite stock, which occupies an area of 27 square miles (Fairbanks, p. 379, 1927) directly north of the Merrimack River, between the cities of Lowell and Lawrence. The deposit is about 0.5 mile from the perhiphery of the norite stock, which is intrusive into the Merrimack quartzite. The sulfide deposit appears to be localized in a dark variety of the norite (Dennen, 1927), and the ore consists mostly of pyrrhotite, with minor amounts of pentlandite, chalcopyrite, and magnetite. The ore from the old workings of this deposit averaged about 1 percent

(Dennen, p. 47, 1943). Nickel was first recovered from the ore of the Dracut deposit in 1876. Some exploration was done, but the small size and low grade of the deposit, as well as the difficulties encountered in ore reduction, forced the owners to cease operations in 1900.

11. Eastern Magnesia Co., Johnson, Vermont. - A talc deposit in schist and associated with serpentinite contains small amounts of nickel and cobalt-bearing pyrrhotite. The pyrrhotite occurs as blebs along foliation planes of the talc. The company has produced a sulfide concentrate as a byproduct of its froth flotation of talc (Davis, p. 83, 640, 645, 1945) that is reported to contain over 10 percent nickel and about 1 percent cobalt. The production capacity is small, and the product has not been marketed.

12. Two other deposits that contain minor cobalt or nickel are the Elizabeth and Katahdin sulfide bodies in Vermont and Maine respectively. The former is described in Section XXXII on copper and the latter in Section XXV on sulfur. The cobalt content of the Elizabeth ore body is reputed to be about 0.05 percent and the Katahdin deposit contains about 0.1 percent of cobalt, and the same amount of nickel (Miller, 1945).

13. Copper and nickel sulfide bodies have been found in Charlotte County, New Brunswick just east of Maine. These deposits occur in a norite complex near St. Stephen (Dunham 1950) and near Beaver Harbour, 6 miles southeast of St. George (New Brunswick - Gaspe sheet, Map 259A, 1939).

POTENTIAL RESOURCES AND FUTURE SUPPLIES

14. New England has nickel and cobalt deposits similar to those that have been mined elsewhere, but the grade and size of the New England deposits are not adequate for profitable exploitation. New ore bodies of commercial grade and size may be discovered in the future but the probability of such discoveries is not great. Another, more possible development might be the future recovery of cobalt, or nickel as a byproduct when deposits such as the Katahdin one become profitable to mine for sulfur.

Table 62 - Nickel and cobalt occurrences in New England

Name of deposit or area	Location	Quadrangle	Country rock	Principal ore Minerals	Date last worked	Remarks	References
Great Hill	Near Cobalt, Middlesex County, Connecticut	Middle Haddam	Bolton schist and gneiss	Gersdorffite Niccolite Arsenopyrite Cobaltite Chloanthite Smaltite	1855	Ore minerals occur in quartz veins	Shepard, p. 56-58, 1837 Blake, p. 401-402, 1883 Schairer, p. 107-109, 1931 Harte, p. 137-144, 1945
Hodges	Near West Torrington, Litchfield County, Connecticut	West Torrington	Hornblende diorite in schist and granite	Pyrrhotite Chalcopyrite Pentlandite	1853 (?)	Sulfides disseminated in amphibolite	Agar, p. 189-190, 192-194, 1930
Mt. Prospect area (6 deposits)	Near Bantam, Litchfield County, Connecticut	New Preston	Norite and pyroxenite in dioritic gneisses and Berkshire gneiss	Pyrrhotite Chalcopyrite Pentlandite	1871	Sulfides occur in norite and associated older intrusive rocks	Howe, p. 337-338, 1915 Cameron, p. 658-660, 1943 Harte, p. 144-147, 1945
Cleveland	Near New Marlboro, Berkshire County, Massachusetts	South Sandisfield (?)	Pyroxenite in Washington gneiss	Pyrrhotite Chalcopyrite	1891	No data available	Emerson, p. 63-64, 1899
Dracut (Nickel Mine Hill)	Near Dracut, Middlesex County, Massachusetts	Lawrence	Norite in diorite and gabbro	Pyrrhotite Magnetite Pentlandite	1885 or 1899	Sulfides disseminated along contact of norite and quartzite	Fairbanks, p. 407-411, 1927; Dennen, p. 41-48, 1943
Deposits containing nickel and cobalt as an accessory constituent							
Elizabeth mine	At South Strafford, Orange County, Vermont	Strafford	Schist	Chalcopyrite Pyrrhotite	Operating at present	Cobalt is largely associated with pyrrhotite; ore contains about 0.05 percent cobalt	Burbank and others, p. 89-92, 1948
Eastern Magnesia Company	Near Johnson, Lamoille County, Vermont	Hyde Park	Ultramafic rocks (serpentinite, peridotite, talc)	Pyrrhotite	1944	Sulfides occur in talc, grit, and serpentine. Concentrates contain 10% Ni and 1% Co	Davis, p. 646, 1942 Davis, p. 83, 645, 1943
Katahdin pyrrhotite	Near Katahdin Iron Works, Piscataquis County, Maine	Sebec	Gabbro	Pyrrhotite	1890	Pyrrhotite has not been mined. Contains 0.1% Ni and 0.1% Co	Miller, p. 16-17, 1945

SELECTED BIBLIOGRAPHY ON NICKEL AND COBALT

Agar, W. M., 1930, The Hodges nickel prospect, Torrington, Connecticut: Am. Jour. Sci., v. 19, no. 111, p. 185-194.

Alcock, F. J., 1946, Preliminary map of St. Stephen, New Brunswick: Canada Dept. Mines and Resources Geol. Survey paper 46-2.

Allen, J. W., 1948, Lynn Lake Area, Manitoba: Pre Cambrian, v. 21, no. 3, p. 4-8.

Bastin, E. S., 1908, A pyrrhotitic peridotite from Knox County, Maine -- a sulfide ore of igneous origin: Econ. Geology, v. 16, p. 124-138.

Berg, G., und Friedensburg, F., 1944, Die Metallischen Rohstoffe. 6 heft Nickel und Kobalt, Stuttgart, Germany.

Blake, W. P., 1883, Nickel, in mineral resources of the United States -- 1882: U. S. Geol. Survey, p. 399-420.

Burbank, W. S., and others, 1948, Cobalt and nickel, in mineral resources of the United States, p. 89-92, 152-155, Washington Public Affairs Press.

Cameron, E. N., 1943, Origin of sulfides in the nickel deposits of Mt. Prospect, Connecticut: Geol. Soc. America Bull., v. 54, no. 5, p. 651-686.

----------, 1951, Preliminary report on the geology of the Mt. Prospect complex: Connecticut Geol. and Nat. History Survey Bull. 76, p. 1-44.

Currier, L. W., Cooperative geologic project progress report for the period January 1, 1941 to June 30, 1942: Massachusetts Dept. Public Works.

Davis, H. W., 1944, Cobalt and nickel, in Minerals Yearbook 1942: U. S. Bureau of Mines, p. 651-655, 645-650.

----------, 1945, Cobalt and nickel, in Minerals Yearbook 1943: U. S. Bureau of Mines, p. 638-643, 644-649.

----------, 1951, Cobalt, in Minerals Yearbook 1949: U. S. Bureau of Mines, p. 389-392.

Dennen, W. H., 1943, A nickel deposit near Dracut, Massachusetts: Econ. Geology, v. 38, no. 1, p. 25-55.

Dunham, K. C., 1950, Petrography of the nickeliferous norite of St. Stephen, New Brunswick: Am. Mineralogist v. 35, no. 9-10, p. 711-727.

Emerson, B. K., 1899, The geology of eastern Berkshire County, Massachusetts: U. S. Geol. Survey Bull. 159, 139 p.

Fairbanks, E. E., 1927, A geological reconnaissance of the Dracut norite stock of Massachusetts: Boston Soc. Nat. History Proc., v. 38, no. 8, p. 397-412.

Harte, C. R., 1945, Connecticut minor metals and minerals: Connecticut Soc. Civil Eng. 61st Ann. Rept.

Hickok, W. O., 4th, 1933, The iron deposits of Cornwall, Pennsylvania: Econ. Geology v. 28, no. 3, p. 193-255.

Howe, Ernest, 1915, Sulfide-bearing rocks from Litchfield, Connecticut: Econ. Geology, v. 10, no. 4, p. 330-347.

International Nickel Co. of Canada, 1950, Geological Department, Ontario Nickel Industry: Can. Min. Jour., v. 71, p. 134-143.

Low, B., 1930, A nickel-copper deposit in New Brunswick, Canada: Eng. and Min. Jour., v. 130, no. 3, p. 115-118.

Miller, R. L., 1945, Geology of the Katahdin pyrrhotite deposit and vicinity, Piscataquis County, Maine: Maine Geol. Survey Bull. 2.

Schairer, J. F., 1931, The minerals of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 51, 112 p.

Shepard, C. U., 1837, A report on the geological survey of Connecticut, New Haven.

New Brunswick-Gaspe sheet, 1939: Canada Dept. Mines and Resources map 259A.

SECTION XX - PEAT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Peat is one of the most abundant, undeveloped natural resources of the New England-New York Region. Before railroads were built in New England and New York, small quantities of peat were used locally for fuel in spite of an abundant wood supply. After railroads were built, and coal became readily available, the use of peat as fuel was discontinued. Today the principal use of peat is for agricultural purposes. In 1951, the total sales of domestic peat showed 73 percent for soil improvement, 19 percent for mixed fertilizers, and 8 percent for other purposes 1/. In 1952, although peat was produced in all of the States of the New England-New York Region with the exception of Vermont and Rhode Island, large amounts were imported.

2. During the past 30 or 40 years the commercial production of peat has tripled, and consumption has increased about six times. The demand for peat has been met partly by domestic production, though the greatest rate increase has been in imported peat, which has increased more than forty times. Imported peat is generally a moss peat or peat moss of a higher quality and grade than the average domestic variety, which accounts largely for its widespread acceptance in domestic markets. Deposits along the coast of Washington and Hancock Counties, Maine, which contain the commercially important sphagnum moss peat, are worthy of consideration for immediate use.

PREVIOUS WORK

3. Many studies have been made to determine the utilization possibilities of peat in New England and New York, and a number of deposits that appear suited for more extensive development have been described.

1/ Minerals Yearbook: U. S. Bur. of Mines, 1951, p. 932.

Probably one of the earliest investigations of peat deposits in the New England-New York Region was by Shaler 1/. In 1903, Ries 2/ described the uses and occurrence of peat in New York. In 1909, the U. S. Geological Survey investigated the peat deposits of Maine 3/, and in 1916 Burr 4/ described some of the peat deposits of Maine. A report on the peat and muck deposits of Vermont was published by the Vermont Agricultural Experiment Station 5/. In 1922, the U. S. Geological Survey published in Bulletin 728 the results of a detailed study of most of the peat deposits and large swamplands of the United States 6/. Bulletin 728 has been one of the principal sources of information on the methods of peat formation, and the distribution, quantity and quality of peat deposits in the United States.

4. In 1926, as a result of a Congressional act, the U. S. Bureau of Mines 7/ investigated the possibilities of the use of peat as a fuel and the production of commercial byproducts. In 1940, peat investigations were made in Connecticut 8/ and New Hampshire 9/. Because

---

2/ Shaler, N. S., Fluviatile Swamps of New England: Am. Jour. Sci., 3rd series, vol. 33, 1887, pp. 210-221.

2/ Ries, Heinrich, Uses of Peat and Its Occurrence in New York. (Reprint from 21st Rep. of New York State Geologist, 1901): Univ. of the State of New York, 1903, pp. 35-90.

3/ Bastin, E. S., and Davis, C. A., Peat Deposits of Maine: U. S. Geol. Survey Bull. 376, 1909, pp. 1-127.

4/ Burr, F. F., The Peat Deposits of Maine: Public Utilities Commission of Maine Second Annual Report, 1916.

5/ Hills, J. L., and Hollister, F. M., The Peat and Muck Deposits of Vermont: Vermont Agr. Exper. Station Bull. 165, 1912.

6/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, pp. 1-207.

7/ Odell, W. W., and Hood, O. P., Possibilities for the Commercial Utilization of Peat: U. S. Bur. of Mines Bull. 253, 1926, p. 160.

8/ Morgan, M. F., Peat and Swamp Muck for Soil Improvement in Connecticut: Conn. Agr. Exper. Station Circ. 142, 1940, pp. 85-96.

9/ White, George W., New Hampshire Mineral Resource Survey, Pt. 3, Peat Deposits: New Hampshire State Planning and Devel. Comm., 1941, pp. 1-16.

of a shortage of fuel wood in certain parts of Maine in 1942, the Maine Geological Survey 1/ prepared a report on some of the more promising deposits in the state. In 1941, the New Hampshire State Planning and Development Commission made a preliminary survey of some of the peat deposits in New Hampshire 2/. A review of the peat industry of New York from 1937 to 1942 was published in 1951 3/.

5. Soil maps of the Department of Agriculture show the areal distribution of peat and muck in certain areas. These maps, of course, do not classify the material nor show thickness, but they are of great value as a base for detailed study, sampling, and testing.

FUTURE POSSIBILITIES

6. In 1953, nearly 181,000 tons of peat was imported into the United States. Most of it was used in the north-central and northeastern States in direct competition with the domestic product. With greater interest and under proper management, it might be possible for peat produced from deposits in New England and New York to capture part of this market.

7. Proximity to an assured market and native ingenuity make the development of domestic peat bogs feasible. Farmers, fishermen, cannery workers, and others could mine local bogs on a part-time, off-season basis. In places, peat and muck lands have been drained and cultivated,

---

1/ Trefethen, J. M., and Bradford, R. B., Domestic Fuel Possibilities of Maine Peat: Maine Devel. Comm. Geol. Survey Bull. 1, 1944, pp. 1-47.

2/ White, George W., New Hampshire Mineral Resource Survey, Pt. 3, Peat Deposits: New Hampshire State Planning and Devel. Comm., 1941, pp. 1-16.

3/ Hartnagel, C. A., and Broughton, J. G., The Mining and Quarrying Industries of New York State, 1937-1948: New York State Mus. Bull. 343, 1951, pp. 76-79.

but where drainage costs are high, areas marginal to bogs might be used to grow cranberries and blueberries, which are adapted to high-acid, bog type of soils.

CLASSIFICATION AND TYPES OF PEAT

8. Peat consists of partly decomposed and disintegrated plant material that has accumulated in bogs, marshes or swamps. Peat varies in consistency from a fibrous, matted, turf-like material to a mud-like plastic, slime or ooze.

9. The formation of peat is the first step in the transformation of plant material into coal, and the process involves many complex chemical changes. As the plant materials slowly accumulate and decompose below water level, the soft parts form a colloid-like material and the hard parts form a fibrous material. During decomposition the plant material retains much of its carbon and loses hydrogen and oxygen.

10. Many varieties of peat have been recognized, based on the dominant plant constituent, or on the texture. The most common varieties are peat moss, moss peat, reed or sedge peat, peat humus, and muck. Most of these terms are also trade names.

11. Peat moss, or sphagnum moss, is without fibrous tissues of any sort. This type is rare in the United States.

12. Moss peat is generally a combination of sphagnum moss and one of the cotton grasses, such as Eriophorum. It is therefore a combination of a non-fibrous material with a considerable amount of tough, fibrous matter. As the amount of fibrous matter increases the peat is called sedge peat. Reed peat is formed from grasses, rushes, bulrushes and cattail flags. Deposits in which these grasses form the predominant

vegetal matter are often so thoroughly decomposed as to be almost without fibrous matter.

13. Peat humus is the more thoroughly decomposed reed or sedge peats, often called reed or sedge muck. Peat humus is principally of the reed type and is found as the bottom layers of the bogs. The term "muck" describes surface layers in an advanced stage of decomposition in which plant remains have lost their identity completely.

PROPERTIES OF PEAT

14. Physical characteristics.--In addition to plant material, peat contains inorganic minerals and water. The proportion of each component is extremely variable, as a result of which the apparent specific gravity of peat ranges from 0.1 to 1.01, and its bulk density from 7 to 65 pounds per cubic foot. The lower figures apply only to dried peat. The physical properties vary from place to place, and from one deposit to another, depending upon the type of peat-forming plants present, differences in water levels, ages, the quantity of sediments deposits during accumulation, and differences in climate.

15. The texture of peat depends in part upon the individual plant constituents, and in part on physical conditions during formation; the texture is fine if peat is formed from algae and mosses; fibrous if from grasses or woody plants; and woody if from shrubs and trees. If all vegetation is completely decomposed, the peat is fine-grained.

16. The color of peat, partly a measure of the degree of decomposition, ranges from light yellow through shades of brown to jet black. In general, the darker the color, the greater is the degree of decomposition. Most peat becomes brighter colored when air-dried. Very light varieties of peat usually change to darker colors after drying and maceration.

17. Because of its high porosity and capillarity, peat may contain as much as 90 percent or more water. In general, a short ton of raw peat contains 200 pounds of solid matter and 1,800 pounds of water. Most of the water must be removed before utilization. The most effective and economical process of water removal is by evaporation or air drying.

18. The thermal conductivity of peat is very low. It is suitable for use in ice houses when low-cost sawdust is not available.

19. Chemical composition.--Peat is composed of carbon, hydrogen, oxygen, and small amounts of nitrogen. A typical, but not exact, formula is $C_{62}H_{72}O_{24}$. Ash and moisture are omitted from the following analysis of peat.

Composition of peat 1/

Carbon	59.50
Hydrogen	5.50
Oxygen	33.00
Nitrogen	2.00

> "The quantity of fixed or free carbon generally ranges from 10 to 60 percent, the remainder being combined with other elements. Volatile matter ranges from 25 to 70 percent and moisture from 15 to 30 percent in air-dried peat. As the volume of oxygen is relatively high, good peat ignites readily and burns freely, having little unconsumed residue. Sulphur usually ranges from 0.2 to 0.6 percent and nitrogen from 1 to 4 percent, the average for nitrogen being about 2 percent." 1/

20. The ash content, ranging from 3 to 30 percent of the dry weight of peat, is composed of mineral matter carried in suspension or solution by water. Peat ash is composed chiefly of silica and alumina, with small amounts of iron oxide, magnesia, lime soda, potash, sulphuric acid, chlorine, and phosphoric acid.

1/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, pp. 16-17.

TYPES OF DEPOSITS

21. Undrained land may be classified as bogs, marshes, or swamps. Most of the peat deposits in the New England-New York Region are in bogs. The chief differences between a bog and a marsh are the type of vegetation and the amount of surface water. Both areas are generally without trees, the bog containing abundant sphagnum moss and heath shrubs, or sedges and grasses. The marsh is devoid of sphagnum but contains grasses, sedges, cattails, bulrushes, or reeds. Marshes are more common near lakes and rivers and along the seacoast. A swamp is covered or saturated with water and overgrown with trees, with or without an undergrowth of shrubs or other small plants.

22. In countries where peat deposits have been investigated in detail, four predominant types of deposits have been recognized, based, in general, on the environment of deposition and the principal type of plant material contained in the bogs.

23. Upland or highmoor deposits.--Upland peat is characteristic of raised, built-up, or climbing bogs. Plants accumulate in place and moss peat is generally formed, composed chiefly of various species of sphagnum moss and cotton grass.

24. Lowland or lowmoor deposits.--Lowland peat consists principally of marsh peat (fresh and salt water), reed peat, sedge peat or humus peat. Sphagnum mosses are absent or occur sparingly. The deposits form mainly in filled-in lakes and river valleys and are fed for the most part by ground water which may have a high content of mineral salts.

25. Forest or swamp deposits.--Forest peat commonly accumulates in the upper courses of rivers, but may occur at places at the edge of the upland bogs. These are fed both by ground water and precipitation; these waters

have a lower mineral content than the waters of the lowland deposits.

26. Aquatic or sedimentary deposits.--Aquatic, or sedimentary, peat most commonly occurs in the lowest layers of the peat profile. It results from the accumulation of algae and other aquatic plants and animals and generally contains an admixture of spores, pollen, and clay and sand particles. Transitional and other types of peat deposits are common in places but are of little significance to this discussion.

PEAT RESOURCES

27. The original reserves of air-dried peat in the United States are estimated by the U. S. Geological Survey to total 13,827,000,000 tons 1/, of which 4.4 percent is in the New England-New York region. At the present rate of United States consumption the estimated New England-New York reserves would last approximately 1,600 years.

28. The following is a summary of known peat reserves in New England and New York 1/:

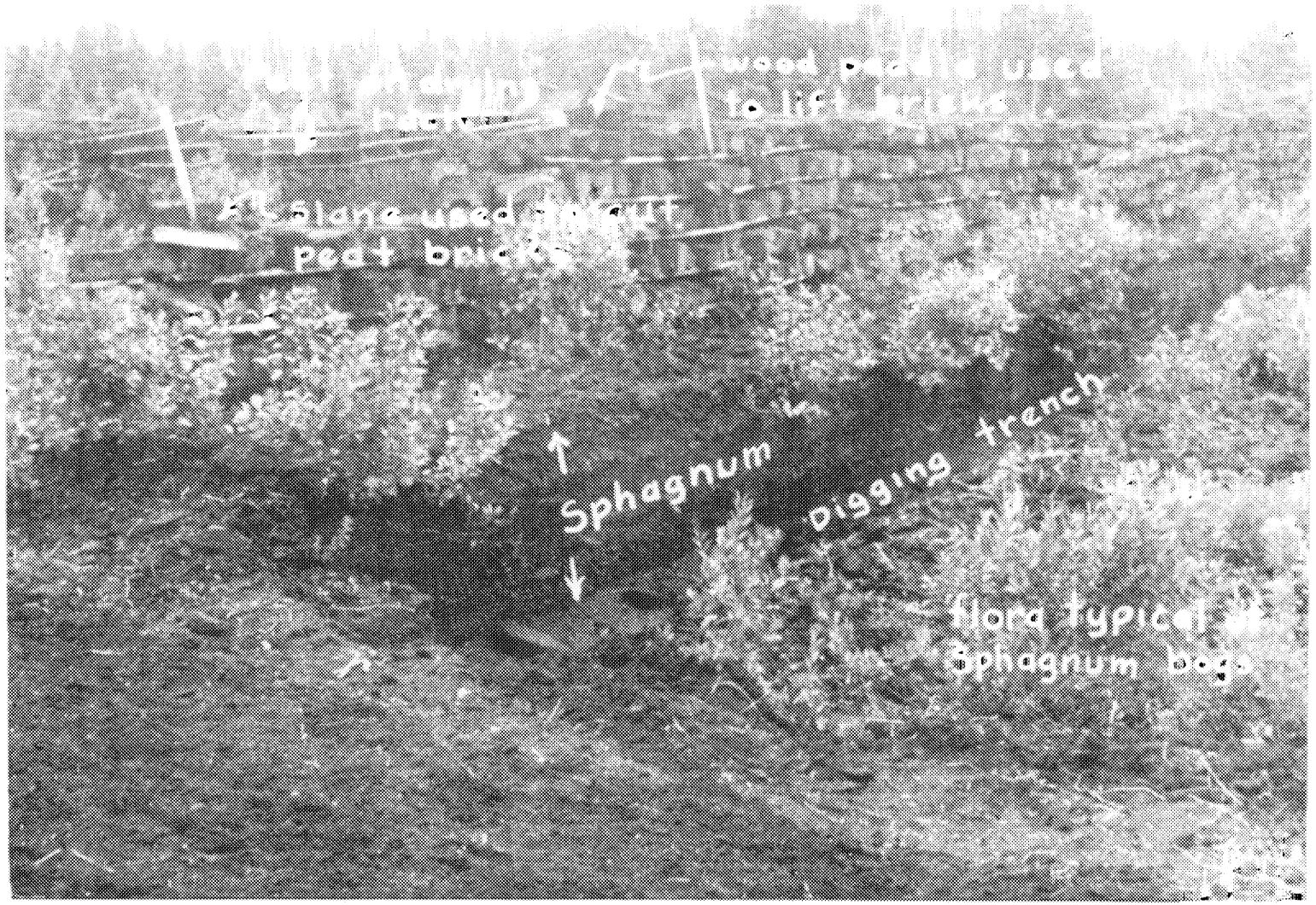
State	Original reserves (air dried, short tons)
Connecticut	2,000,000
Maine	100,000,000
Massachusetts	12,000,000
New Hampshire	1,000,000
Rhode Island	1,000,000
Vermont	8,000,000
New York	480,000,000
Total	604,000,000

Recent surveys by White and Percival 2/ and Trefethen and Bradford 3/ would increase slightly the estimate of reserves in Maine and New Hampshire.

1/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, p. 92.

2/ White, George W., New Hampshire Mineral Resource Survey, Pt. 3, Peat Deposits: New Hampshire State Planning and Devel. Comm., 1941, pp. 1-16.

3/ Trefethen, J. M., and Bradford, R. B., Domestic Fuel Possibilities of Maine Peat: Maine Devel. Comm. Geol. Survey Bull. 1, 1944, pp. 1-47.



Peat Bog, Hancock County, Maine. New England-New York Region.

REGIONAL DISTRIBUTION OF PEAT DEPOSITS

29. Most of the widespread peat deposits in the New England-New York Region are a result of drainage imperfections caused by glacial erosion and the uneven distribution of glacial deposits. The deposits occur for the most part in the lowland and coastal areas of New England and southeastern New York, and in the lowlands area along Lake Ontario, but in addition, deposits also occur in the western Adirondack Mountains and in the Lake Champlain Valley of New York and Vermont.

Connecticut

30. Connecticut ranks first in the production of peat in the New England-New York Region. The deposits occur principally near the coast and in the Connecticut River Valley near potential centers of use. Three producers reported production or sales of peat in 1951; only one reported in 1952. Most of Connecticut's peat reserves are of the less valuable varieties.

Maine

31. Although Maine ranks second to Connecticut in total output of peat in the New England-New York Region, and second to New York in reserves, it ranks first in quality and value. Three producers reported production or sale in 1951; only two in 1952.

32. Of total estimated reserves of 100,000,000 tons, 48,000,000 tons are considered to be readily accessible. Peat deposits probably are more abundant in Maine than records indicate because only those near the lower courses of the major streams and coastal areas have been examined in detail. Inaccessibility rather than the scarcity of deposits of peat has been the chief factor in the lack of knowledge of the exact distribution and quality of the peat deposits of central and northern Maine.

33. Most of the easily accessible deposits that have been examined have a high content of low quality fibrous peat. Those deposits currently in operation are believed to contain a high quality fibrous peat composed largely of sphagnum moss (moss peat). The sphagnum moss content in the unexplored and undeveloped deposits, particularly in the northern part of the State, is unknown. Soper and Osbon 1/ noted sphagnum deposits at the following places:

Aroostook County	- Otter Pond
Penobscot County	- Alton Bogs
Waldo County	- Cross Pond
Washington County	- Lake Hadley - Lake Meddybemps

34. Some of the bogs near large cities and resort areas might be drained and cultivated for market gardens.

Massachusetts

35. In Massachusetts, most of the peat deposits are in the eastern part of the State and in the Connecticut River Valley. During 1951 and 1952 two companies produced peat, both in western Massachusetts, at Hinsdale near Pittsfield and at Westfield. Many of the bogs close to Boston in Middlesex and Norfolk Counties have been drained and developed into large commercial market gardens.

36. Low-grade fibrous peat is, in general, the principal variety in Massachusetts. Soper and Osbon 1/ listed sphagnum deposits at the following places:

Middlesex County	- Littleton Bog, Tophet Swamp and the West Medford marsh
Norfolk County	- Norwood and Walpole Bogs

1/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, p. 81.

New Hampshire

37. Most of the large peat deposits in New Hampshire occur in the southern and southeastern parts of the State. Two deposits were being worked in this area in 1952.

38. Low-grade fibrous peat is the most widespread variety. Soper and Osbon 1/ noted sphagnum moss in the following localities:

Cheshire County	-	bog near East Jaffrey
Hillsboro County	-	bogs near Greenfield, South Milford, and Ponewah
Rockingham County	-	bog near Fremont

New York

39. Deposits in New York are located between Lockport and Rochester in western New York; west, north and east of Syracuse in central New York; and in southeastern New York, south of Poughkeepsie and southwest of Newburg. Additional deposits occur in scattered places in the western Adirondack Mountains and in the Lake Champlain Valley.

40. Most of New York's peat is fibrous and has a relatively low market value. Many of the large peat and muck lands near some of the principal urban centers have been drained and used for agricultural purposes, particularly in southeastern and central New York. Of the known peat reserves estimated by Newland 2/ to total 480,000,000 short tons air-dried, about 75,000,000 tons are readily accessible.

Rhode Island

41. The peat deposits in Rhode Island are in the southwestern part of the State. Most of the deposits examined by Soper and Osbon 1/ contain

1/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, pp. 81, 188-190.

2/ Newland, D. H., The Mining and Quarry Industries of New York State: New York State Mus. Bull. 102, 1906, p. 19.

low-grade fibrous peat or are muck lands. Although no production has been recorded in recent years, it is believed that small amounts of Rhode Island peat have been harvested and used locally as a soil conditioner.

Vermont

42. The peat deposits in Vermont are chiefly in the Lake Champlain Valley. Although peat reserves are large, most of the deposits have a high content of low-grade fibrous peat, and no sales of commercial peat have been reported in recent years. Soper and Osbon 1/ report sphagnum moss deposits at the following places:

Addison County	- Bristol Pond, East Monkton Bog, Monkton Bog
Grand Isle County	- Isle LaMotte Bog
Franklin County	- Cranberry "marsh"

HISTORICAL USE OF PEAT

43. The earliest recorded use of peat was made about 70 A.D. 2/. Pliny, in his accounts, expresses pity for the "miserable people" living in East Friesland (Germany and Bavaria) "who dug out with the hands a moor-earth, which, when dried, they used for preparing their food and warming their bodies". As these peoples were not civilized in a comparative sense, it is more than probable that peat was used very early in man's development.

44. The use of peat has been particularly widespread in those regions where there was an absence of other better fuels. As countries developed

1/ Soper, E. K., and Osbon, C. C., The Occurrence and Uses of Peat in the United States: U. S. Geol. Survey Bull. 728, 1922, p. 81.
2/ Pliny, Natural History: Chap. XVII and XXXIV, trans. Riley, H. T. and Bostock, John, London, 1855 and 1857.

in northern Europe, peat became an important resource. The charters granted by the Church for the first monasteries conveyed to the Abbots the right to dig turf, and Beckmann, in his "History of Inventions", states that Abbot Ludolph, in the year 1113, gave a letter of sanction to a nunnery near Utrecht (Germany) giving the nuns permission to dig cespites (turf) for their own use from his vena (turf-bog). Peat had some commercial importance in Scotland as early as 1140 (the sale of peat is mentioned in the Legus Burgorum), and in Flanders about the year 1223 as mentioned by a historian named Brito.

45. The colonists of America noted the presence of peat both near the shores of New England and in the Great Dismal Swamp of Virginia; however, a plentiful supply of wood, cut as a requisite of clearing the land, appears to have met their fuel needs. Early records of the colonists in New England mention a coal of poor quality as among the minerals available to them. As wood started to become scarce along the coast in 1680, import records from that time until the Revolution show that coal was brought to the colonies from Scotland, Newcastle, and Nova Scotia.

46. In 1744 imported coal cost approximately 8 pounds sterling per chaldron (about 2500 pounds) 1/. The widespread use of imported coals at a very high price might indicate how little the colonist thought of the peat that abounded throughout the region, or it might have been due to economic pressure by the "mother country". The use of peat showed some increase after the Revolution.

47. Dr. Hitchcock 2/ in his "Report on the Geology of Massachusetts" says, "Taking the State as a whole, peat is but little used, either as

1/ Weeden, W. B., Economic and Social History of New England: Vol. 1 and 2, pp. 18, 532, 904, 907.

2/ Hitchcock, Edward, Dr., Report on the Geology of Massachusetts: Amherst, 1833.

a fuel or manure; yet for both purposes its use is rapidly increasing". A record of the use of peat in New York in 1819 may be found in the "Report of the New York Survey" submitted by W. W. Mather in 1839 1/.

48. Isolated records like these and others have shown that peat was a subject of interest to the people. In the years during and just after the Civil War when the price of coal was $16 to $20 a ton in New England, peat processing plants were developed, but as coal prices declined so did the peat fuel business. Historically, peat has had little use as a fuel in New England or New York.

PRODUCTION AND CONSUMPTION

49. The commercial production of peat has tripled over the past thirty odd years, while consumption has increased six times. The demand for peat has been met principally by domestic production, though the greatest rate increase has been in imported peat which has increased over forty times. The growth of peat production, imports and consumption are shown in Tables 63 and 64. There has been no attempt made to break the data down into the various grades of peat, since domestic producers have only recently agreed to fair-trade name practices. Imported peat is generally a moss peat or peat moss of a higher quality and grade than the average domestic variety.

50. In addition to the consumption data shown in Table 63 it has been estimated that noncommercial and unrecorded peat consumption and production in the United States may be equal to or greater than that recorded.

51. Throughout the period shown, 1920 to date, over 90 percent of the peat has been used in one form or another as a soil improvement material

1/ Mather, W. W., Third Annual Report, 1839: State of New York, Legislative Document #275.

Table 63--Salient peat statistics of the United States for selected years 1/

Item	1920	1925	1935	1940	1945	1950	1952
U. S. production in short tons	73,204	72,436	37,060	70,097	107,000	130,723	210,582
Value per ton	$12.59	$ 6.25	$ 5.38	$ 7.37	$ 7.67	$ 8.74	
Imports in short tons	2,762	10,233	54,547	21,689	77,673	124,864	167,298
Value per ton	$13.11	$11.90	$12.42	$20.96	$30.81	$30.96	
Available for domestic consumption	75,966	82,669	91,607	91,786	184,673	255,587	377,880
Number of U. S. plants	18			50	Est. 59	48	
Major producing States	Illinois New Jersey	New York New Jersey	New York New Jersey	New York New Jersey	Florida New Jersey	New Jersey Florida	
Major exporting countries	Germany Sweden	Germany Sweden	Germany Sweden	Canada	Canada	Canada	

1/ Data from: Minerals Yearbooks - Peat: U. S. Bur. of Mines, 1923 to date.

Table 64 - Peat production in New England, 1947 to 1949 1/

	1947		1948		1949		1950	
	Tons	Value; dollars per ton	Tons	Value; dollars per ton	Tons	Value; dollars per ton	Tons	Value; dollars per ton
Connecticut	5,061	5.08	4,332	5.57	5,974	5.53	6,294	5.58
Maine	2,647	27.53	1,100	27.00	3,312	23.96	2,912	21.15
Massachusetts	820	13.42	441	14.03	595	12.46	650	11.65
New Hampshire					15	19.73		
Totals- New England	8,528		5,873		9,896		9,856	

1/ Minerals Yearbook, 1949, Peat. Values calculated.

(direct, mixed, or as a filler for fertilizers). The remainder has been used principally as mull or litter. It may be expected that the domestic industry will continue in its growth, especially when and if it introduces new products made from peat.

Mining practices in New England and New York

52. Peat mining practices are relatively simple. In deposits containing sphagnum it is considered preferable to dig out blocks by hand, In deposits of reed or sedge peat, the bog surface is harrowed and scraped. Though this latter method is less costly, the peat does not lose as much moisture through air-drying.

53. In both cases, the bog is outlined with drainage ditches, which draw off surface waters. When the bog is harrowed and scraped, the peat is placed in a pile where it loses from 30 to 50 percent moisture. It is then ground in a hammer mill and baled or bagged.

54. Where blocks are cut, they are laid out on the side of the ditch, and then put on drying racks. There, they lose about 94 percent of their moisture content . The bricks when cut weigh about 20 pounds, after air-drying they weigh approximately 3 pounds, having a moisture content of 30 percent. Machines have been developed to cut the blocks, but these have not proven to be economical in this region. After air-drying, the peat is brought to a dry storage building, usually a slat-sided frame with a solid roof, ground in a hammer mill, and then baled for market.

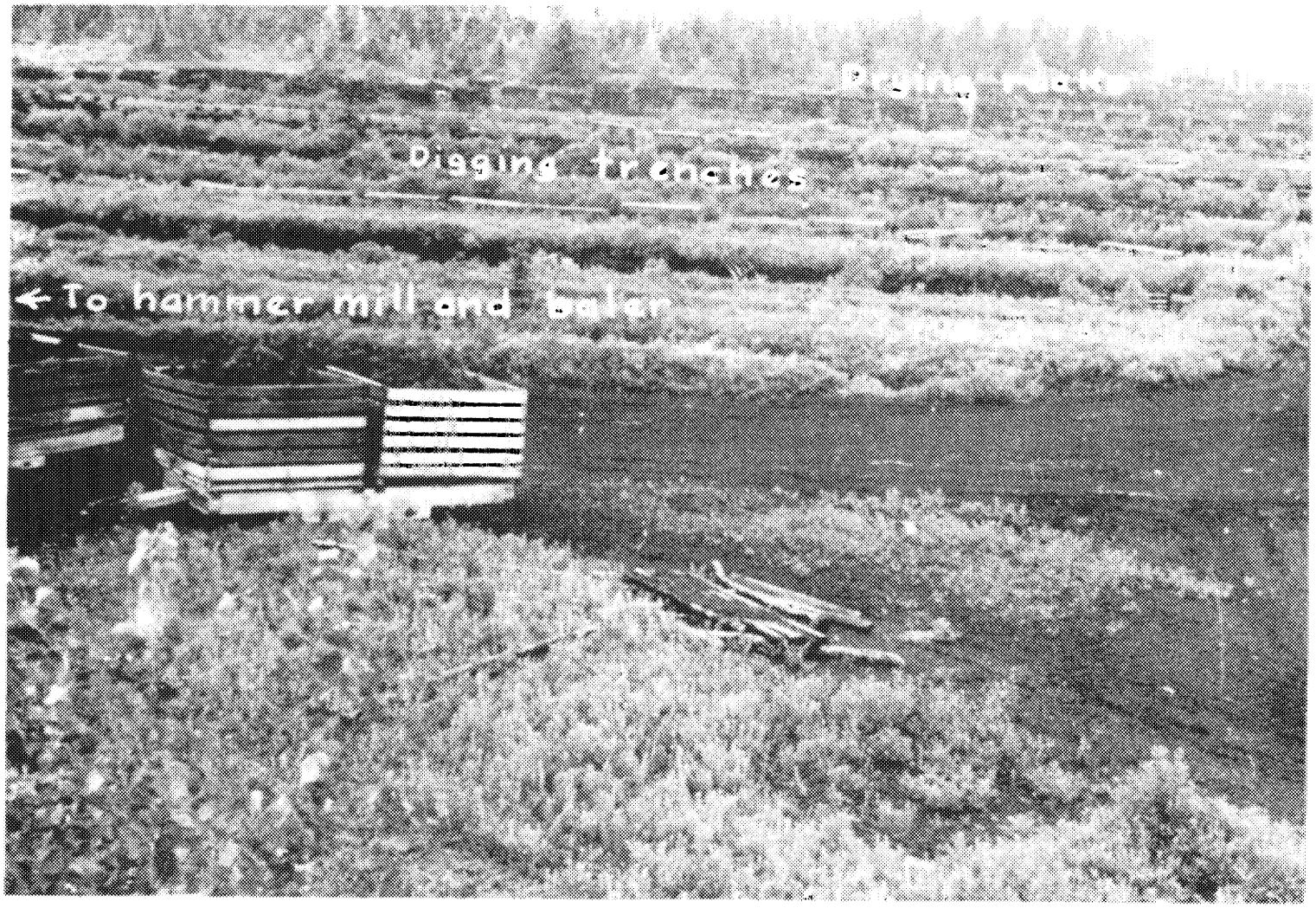
55. About 100 men are required to dig and harvest 1,000 tons of block-cut peat. The harvest season is from June through October. Prior to June the bog is usually too wet, after October the bog freezes, but a late fall may permit digging up to December in some bogs. It is the

combination of time of year and manpower that is a principal deterrent to greater development of the Maine bogs. Most of the available labor consists of farmers, fishermen, berry pickers, and hunters; they are able to earn more money at their regular occupations during those months than they could working in a peat bog.

56. It is important to insure that the drying racks are full at the end of the digging season. The best natural drying months are April, May, and June because winter freezing expands the blocks and makes them amenable to air action. It would be ideal, however, to grind and bale in December and January, as the best market for eastern producers is from February through April since foreign peat is not readily available until May; but to do so, would require capital investments exceeding $300,000. The failure of many heavily financed operations has limited the availability of venture capital for peat.

57. One possible method of overcoming the need for high capitalization and labor might be the mining of peat during the winter. Many contractors in the northern sections of the New England-New York Region have no road or other building work from December through March, depending upon the mildness of the winter. The use of their otherwise idle equipment on a contract or partnership basis to excavate peat bogs could be beneficial. It would enable the contractor to decrease his amortization charges; it would eliminate the need for mining the deposits by hand during periods when labor is scarce and expensive; and it would take advantage of the preferable drying season.

58. Near Chicago, Illinois, heavy-duty equipment is used to excavate a deposit of peat humus. The deposit is a low-lying one, into which a



Peat Bog, Hancock County, Maine. New England-New York Region.

great deal of water seeps from the surrounding terrain. The peat is dug with a crane and a scraper. By tensioning the track cable, the scraper is raised into the air and returns to the digging point by gravity. The inhaul cable then brings the loaded scraper in to a point immediately in front of the crane, where the peat is dumped.

59. When the pile reaches a height of six to seven feet, the scraper is exchanged for dragline bucket and the peat is then cast behind the crane onto solid ground, where it is permitted to dry out enough to be handled by a loader. If the peat is very wet, a tractor-loader spreads it out in long windrows.

Marketing

60. Peat is sold mainly by the bale. Unfortunately, there is no way to describe such a unit. For example, two companies have contracts with the Federal Government. One sells a 40-pound bale, the other, one containing 145 pounds. Another definitive of bale size is to measure it in terms of bushels; however, the average purchaser can go to one store and buy a bale containing 5½ bushels of peat, and then go to another where the bale consists of 7½ bushels. A third description is the measured size of the bale; one dealer sells a bale that measures 36" x 17" x 21", another a bale 38" x 28" x 42". There are almost as many sizes of bales as there are producers and brokers. The majority of bale sizes appear to be based on the theory that it isn't the weight, content, or size that counts, it is the ability to post a sign showing a price lower than a competitor for "a bale" of peat.

61. Peat sold in New England and New York comes from several sources. The major portion comes from Europe as it can be delivered to brokers on

the eastern seaboard docks for $2.35 to $2.50, - $1.00 per bale below the price of comparative domestic peat.

62. Canadian sphagnum peat is sold by a few companies whose customers appreciate the higher quality, the lesser tendency to clump, and the greater ability to maintain a porous soil condition. This sphagnum is quite comparable to some of the peat in Hancock and Washington Counties, Maine.

63. Peat from Michigan and New Jersey is marketed through hardware and flower stores, though it is the lower quality sedge or reed type. Its increasing sales in this region are the result of packaging in 25-to 100-pound bags, distribution, and promotional advertising.

64. Present production from bogs in New England and New York has a limited market. The high-quality Maine peat is sold principally in West Virginia, Pennsylvania, Ohio, and Kentucky, which States do not have native resources of sphagnum, and are sufficiently distant from seaboard to make foreign peat non-competitive. Peat produced in New Hampshire, Connecticut, Massachusetts, and New York is sold in a local area, the buyer usually going to the bog to purchase a reed or sedge peat that has been air-dried, macerated, and baled.

65. Only the lower-quality peats can compete in the very active small-package market. The low price per ton obtained for this peat can be increased by mixing it with other fertilizers or by selling low-weight units for a high-unit price. Peats containing sphagnum are valued at three to four times those containing reed or sedge, and, therefore, if packaged in small lots would be unable to compete in that market.

66. The increased demand for peat is stems from the decrease in manure with the decrease in horses and cows near eastern communities. Some producers distribute peat to poultry farms, collect the peat after a month, and sell it as fertilizer. The two major selling seasons for the peat industry are (a) February and April when the peat is used for mixing with heavy soils; and (b) August and October when it is used for mulching.

67. The cost of shipping Maine peat to market averages 65 cents per bale. The cost of shipping Canadian peat to this same market is equal to or less than that; while peat is brought all the way from Europe to the eastern seaboard for considerably less, but is non-competitive west of New York and Virginia because of added stevedoring and other handling charges.

USES OF PEAT

68. The commercial development of peat deposits in the United States has suffered from speculation and poor business attitudes. Many companies have started to manufacture various peat products without first ascertaining the marketing conditions or, in some cases, have neglected to apply technical knowledge to the development of the peat bog. Whatever the cause, there have been numerous bankruptcies and other forms of business failures among new industries concerned with the utilization of peat; more, according to some observers, than in most other forms of business ventures. With proper methods, the development of some peat bogs in New England and New York could be profitable to the region and to the entrepreneur concerned.

69. Among the many possible uses of peat are the ones discussed below:

Fuel

70. Peat as a fuel has had little acceptances in the United States. In a few

instances where the bog is so close to the point of consumption that a market based on a freight differential has been secured, there is some production. But even then, peat is generally used as a daytime and cooking fuel because, like wood, it is difficult to maintain a fire without a substantial amount of supervision. Glistening white ranges in the kitchen, clean rooms and clothes are impossible when peat is used. Laboratory dried peat has approximately one-half the heating value of a good bituminous coal on a weight basis, but it is more bulky, and has never been produced at a competitive fuel cost.

Fertilizers

71. The principal use of peat is as a soil conditioner. The peat used should be of a type that maintains a porous soil and does not have a tendency to clump; it should be rich in available nitrogen and organic matter. A peat moss or moss peat is preferred. Because fibrous and brown peats do not readily release nitrogen, few are of value for this use. Gray and red peat, and peat with white spots usually contain too much inorganic matter.

Mull and litter material

72. Next to its use in soil improvement, the most substantial consumption of peat is as mull and litter material. Peat finds use as a mull and litter material because: it is capable of absorbing much larger amounts of moisture in proportion to its weight than any other material in general use for stock bedding; its deodorizing capacity lends itself to the barnyard and stable, and it delays the decomposition of the nitrogenous and other organic substances deposited thereon; and it helps to keep the feet of animals in a healthy condition because it is springy and durable.

73. The peat preferred for this use is chiefly composed of poorly decomposed sphagnum moss and other herbaceous plants. When dug it is light brown in color.

Mattresses and sanitary appliances

74. The absorbent, deodorizing, and antiseptic properties of peat may be utilized to make mattresses, medical dressings, deodorizing absorbents, and moulds for antibiotic medicines. Moss peat and peat moss that have been thoroughly cleansed of sticks and other coarse matter are best suited for these types of products.

75. Probably this is one use of peat that could receive more attention, especially with regards to its potential use for hospital and infant mattresses that would be comparatively inexpensive, deodorizing, and easily replaced. Peat was used thus during World War I.

Insulation

76. Dry, fibrous peat is a good insulator and has been successfully used as packing around pipes, in icehouses, and in refrigerators. The upper layers of a moss peat bog would be the most desirable source for this type of material as this portion of the bed has those fibers with the greatest number of air spaces between.

Cation exchangers

77. A class of water softeners, made from such carbonaceous materials as coal, lignite, peat and wood, has emerged from the laboratory and is available commercially. Softeners are especially useful in the treatment of boiler-feed water where dissolved silica from zeolitic softener materials gives trouble. The carbonaceous exchangers are virtually free from silica.

78. These cation exchangers may be operated either as a sodium or hydrogen exchanger. Regeneration with NaCl results in a sodium exchanger, and with dilute HCl or H_2SO_4, a hydrogen exchanger.

Dry stuffs

79. Peat may be used to make a brown dye by dissolving some of the organic acid compounds with suitable alkaline substances.

Tanning substances

80. Those peats derived from woody plants are a source of tannic acid, tannin, and related substances. A bog should be properly tested to determine if it may be a profitable source for these materials which are consumed in large quantities in New England. The process requires that a powdered peat be treated with nitric acid in cemented cisterns, diluted with water, heated in the presence of steam and stannous chloride, and then decanted.

Paper goods

81. The fibrous type of peat may be made into various paper goods by mixing it with wood pulp or other paper stock. The product would be dark brown in color as bleaching has been generally uneconomical. The various types of paper goods that have been made from peat are: boxboard, fiberboard, cardboard, and coarse brown paper.

82. As there is a great deal of waste to be handled per unit of fiber produced, the use of peat would be limited to those periods when other materials are difficult to obtain. The type of peat deposit best suited for this use would be one composed of successive layers of grassy plants to a considerable depth and covering a large area.

Textiles

83. A possible by-product of some peat operations would be the recovery of the stronger fibers from the more fibrous types of peat. These fibers, after separation, cleansing, and treatment to make them pliable, when woven are similar to hemp.

SELECTED BIBLIOGRAPHY ON PEAT

1. ALTON, F. Ammoniated Peat as a Fertilizer Material. Oil, Paint, and Drug Rept., vol. 153, January 16, 1933, p. 53. (Excerpt - Sci. Amer., April 1933, p. 230.)

2. ALTON, F. Peat as a Fuel for Industrial Steam Raising. Eng. Boiler House Rev., 1942, pp. 55, 282.

3. ARNOLD, C. L., LOWY, A., and THIESSEN, R. Isolation and Study of the Humic Acids from Peat. U. S. Bur. of Mines Rept. Inv. 3258, 1934, 9 pp.

4. ATWOOD, A. C. Peat - A Contribution Towards A Bibliography of the American Literature through 1925. U. S. Dept. of Agriculture Library, Washington, D. C.

5. BASTIN, E. S., and DAVIS, C. A. Peat Deposits of Maine. U. S. Geol. Survey Bull. 376, 1909, pp. 1-127.

6. BJERLING, P. R., and GISSING, F. T. Peat, Its Use and Manufacture. Charles Griffin & Co., Ltd., London, 1907, 173 pp.

7. BLIZARD, JOHN. The Value of Peat Fuel for the Generation of Steam. Canada Dept. of Mines and Resources, Mines and Geology Branch, Rept. 447, 1917, 42 pp.

8. _____. Briquette Making from Peat. Fuel Economist, No. 12, 1937, p. 411.

9. BRODERICK, S. J. Softening Water with Nonmetallic Minerals. U. S. Bur. of Mines Rept. Inv. 3578, 1941, 18 pp.

10. BURR, F. F. The Peat Deposits of Maine. Public Utilities Commission of Maine Second Annual Rept., 1916.

11. _____. Canada Peat Moss Industry. Can. Min. Jour., March 1946, p. 169.

12. CAWLEY, C. M., and KING, J. G. The Extraction of Ester Waxes from British Lignite and Peat. Dept. of Sci. and Industrial Research, Fuel Research, Tech. Paper 52, 1946, 29 pp.

13. _____. Commercial Utilization of Peat. Engineering, October 22, 1926, p. 500.

14. DACHNOWSKI, STOKES, A. P. Peat Resources in Alaska. U. S. Dept. of Agriculture, Tech. Bull. 769, 1941, 84 pp.

15. DACHNOWSKI, STOKES, A. P. Quality and Value of Important Types of Peat Material. U. S. Dept. of Agriculture, Bull. 809, 1919, 40 pp.

16. DAVIS, C. A. The Uses of Peat for Fuel and Other Purposes. U. S. Bur. of Mines Bull. 16, 1911, 214 pp.

17. DAVIS, JOHN H. The Peat Deposits of Florida, Their Occurrence, Development, and Uses. Florida Geol. Survey, Geol. Bull. 30.

18. DODSON, W. R. Observations and Studies on the Peat Deposits of Louisiana. Louisiana State University and Agricultural and Mechanical College, Agr. Exper. Station, Louisiana Bull. 343, 1942, 27 pp.

19. _____. Federal Standard Stock Catalogue, Sec. IV, Q-P-L66, General Services Administration, 1947.

20. FERNALD, R. H. Features of Producer Gas Power Plant Development in Europe. U. S. Bur. of Mines Bull. 4, 1911, 27 pp.

21. FOXWELL, G. E. The Use of Peat in Gas Manufacture. Gas World, vol. 105, 1936, p. 176.

22. FRANK, F. Peat Coke. Coke and Smokeless Fuel Age, 1944, pp. 6, 231.

23. FRASER, C. K. Peat Deposits of Scotland, Part I. Geol. Survey, Scotland, Wartime Pamphlet 36, 1943.

24. GILES, A. W. Peat as a Climatic Indicator - General Distribution of Coals. Geol. Soc. Bulletin, September 1930, pp. 405-28, 426.

25. GIRARD, HENRI. Peat Industry in the Province of Quebec. Can. Min. Jour., vol. 65, 1944, pp. 283-293.

26. GIRARD, HENRI. Peat in Quebec. Quebec Dept. of Mines, Geol. Rept. 31, 1947, pp. 1-48.

27. GIRARD, HENRI. Quebec's Peat Moss Industry. Can. Min. Jour., October 1948, p. 197.

28. GISSING, F. T. Peat Industry Reference Book. Charles Griffin & Co., Ltd., London, 1920, 292 pp.

29. _____. Grades of Peat and Muck for Soil Improvement. U. S. Dept. of Agriculture Circ. 290, August 1943. (Available for free distribution at Dept. of Agriculture.)

30. HAANEL, B. F. Facts About Peat. Canada Dept. of Mines and Resources, Mines and Geology Branch, Ottawa, Canada, Rept. 614, 1924, 48 pp.

31. HAANEL, B. F. Final Report of the Peat Committee. Canada Dept. of Mines and Resources, Mines and Geology Branch, Ottawa, Canada, Rept. 641, 1926, 298 pp.

32. HARTNAGEL, C. A., and BROUGHTON, J. G. The Mining and Quarry Industries of New York State, 1937-1948. New York State Mus. Bull. 343, 1951, pp. 76-79.

33. HAUSDING, A. A Handbook on the Mining and Utilization of Peat. Fuel Research Board, H. M. Stationery Office, London, 1921, 506 pp. (Trans. Third German ed. by H. Ryan.)

34. HILLS, J. L., and HOLLISTER, F. M. The Peat and Muck Deposits of Vermont, Vermont Agr. Exper. Station Bull. 165, 1912.

35. HITCHCOCK, EDWARD, DR. Report on the Geology of Massachusetts. Amherst, 1833.

36. HOWELL, G. Economics of Peat Fuel Utilization. Petroleum, vol. 5, 1942, pp. 184, 199; vol. 6, 1943, pp. 13, 26.

37. _____. Hydropeat. Engineering, No. 120, 1925, p. 177.

38. _____. Irish Peat Waxes. Industrial Research Council, Dept. of Industry and Commerce, Eire, Bull. 3, 1943.

39. LEAVITT, T. H. Facts About Peat as an Article of Fuel. Boston, 1865, 165 pp.

40. LEEDS, C. H. Use of Peat Moss to Protect a Stoping. Coal Age, vol. 37, December 1932, p. 444.

41. McNEIL, H., and LULY, E. L. The Harvesting and Briquetting of Peat. British Jour. Inst. Fuel, 1938, pp. 11, 344.

42. MARTIN, J. The Winning and Utilization of Milled Peat for Briquetting and Power Generation. Inst. Civ. Eng., Ireland, 1945-46, pp. 72, 197.

43. MARTIN, ROBERT M. Statistics of the Colonies of the British Empire. London, 1839.

44. MATHER, W. W. Third Annual Report, 1839. State of New York, Legislative Document #275.

45. METCALF, D. M. Mining and Processing Peat in Florida. Min. & Met., vol. 13, July 1932, p. 313.

46. _____. Minerals Yearbook. U. S. Bur. of Mines, 1951, p. 932.

47. _____. Minerals Yearbook - Peat. U. S. Bur. of Mines Annual, 1923 to date.

48. MONKHOUSE, A. Electrical Developments in the U.S.S.R. Colliery Guardian, vol. 150, 1935, p. 67.

49. MORGAN, M. F. Peat and Swamp Muck for Soil Improvement in Connecticut. Conn. Agr. Exper. Station Circ. 142, 1940, pp. 85-96.

50. NEWLAND, D. H. The Mining and Quarry Industries of New York State. New York State Mus. Bull. 102, 1906, p. 19.

51. ODELL, W. W., and HOOD, O. P. Possibilities for the Commercial Utilization of Peat. U. S. Bur. of Mines Bull. 253, 1926, 160 pp.

52. OGG, W. G. Peat, Chemistry and Industry. 1939, pp. 58, 375.

53. PARKER, D. J., BENSON, J. B., CASH, F. E., and BIRD, J. H. Peat-Bog Fires - Their Origin and Control. U. S. Bur. of Mines Inf. Circ. 7411, August 1947, 12 pp.

54. PARSONS, A. L. Peat, Its Formation, Uses, and Occurrence in New York. New York State Mus. 57th Annual Rept., vol. 1, 1905, pp. 15-58.

55. _____. Peat Fuel for Steam Heating. Engineering, March 8, 1946, p. 223.

56. _____. Peat Land on the Pacific Coast States in Relation to Land Use and Water Resources. U. S. Dept. of Agriculture Miscellaneous Publication 248, October 1936. (Out of print.)

57. PLINY. Natural History, Chap. XVII and XXXIV. Trans. Riley, H. T. and Bostock, John, London, 1855 and 1857.

58. PLUMMER, C. E. Report of Progress in Peat Development. Pub. by Iron Range Resources and Rehabilitation Commission, State Office Bldg., St. Paul, Minn., 1949, 142 pp.

59. POWERS, W. E. Recent Advances in the Study of Peat. National Research Council Bulletin, Washington, D. C., 1932, p. 53.

60. PURCELL, P. F. The Peat Resources of Ireland. British Fuel Research Board, Special Rept. 2, 1920, 25 pp.

61. PURCELL, P. F. The Production of Air-Dried Peat. British Fuel Research Board Rept., 1922-23, 146 pp.

62. QUARENDON, R. Bacterial Removal of Hydrogen Sulphide from Water and Gas and Coal Gas by Peat and Peat-Oxide Mixtures. Jour. Soc. Chem. Ind., 1941, pp. 60, 267.

63. REILLY, J., et al. Distillation Under Reduced Pressure of Certain Constituents of Peat, Part II. J. Reilly and J. Sullivan, Sci. Proc. Royal Dublin Soc., 1927, pp. 18, 383.

64. REILLY, J., et al. Low-Temperature Carbonization of Peat, Part III. J. T. Donelly and J. Reilly, Sci. Proc. Royal Dublin Soc., 1930, pp. 19, 365.

65. REILLY, J., et al. Low-Temperature Carbonization Under Various Conditions, Part IV. C. O. Sullivan and J. Reilly, Sci. Proc. Royal Dublin Soc., 1930, pp. 19, 441.

66. REILLY, J., et al. Studies on Peat, Part I. The Thermal Decomposition of Peat Under Reduced Pressure. J. Reilly and G. Pyne, Sci. Proc. Royal Dublin Soc., New Series, 1926, pp. 18, 329.

67. RIES, HEINRICH. Uses of Peat and Its Occurrence in New York. (Reprint from 21st Rept. of New York State Geologist, 1901.) Univ. of the State of New York, 1903, pp. 35-90.

68. RISI, J., BRUNETTE, C. E., SPENCE, D., and GIRARD, H. A Chemical Study of the Peats of Quebec. Dept. of Mines, Province of Quebec, Preliminary Rept. 234, 1950, pp. 1-36.

69. _____. Schade's Process of Preparing and Briquetting Peat. Can. Chem. & Met., February 1927, p. 34.

70. SCHOEDLER, H. T. Swiss Work on Gasification of Peat. Iron Coal Tr. Rev., vol. 155, October 1947, pp. 10, 12.

71. SHALER, N. S. Fluviatile Swamps of New England. Am. Jour. Sci., 3rd Series, vol. 33, 1887, pp. 210-221.

72. SHYBEKAY, DERSO, DR. Utilization of Peat and Byproducts. Washington, D. C., 1951, 4 pp.

73. _____. Some Aspects of the German Peat Industry. British Intelligence Objective Subcommittee Final Rept. 479, Items 22, 30, 31, H. M. Stationery Office, London, England.

74. SOPER, E. K., and OSBON, C. C. The Occurrence and Uses of Peat in the United States. U. S. Geol. Survey Bull. 728, 1922, pp. 1-207.

75. SUSLOV, B. M. Lump Peat as a Fuel for Blast Furnace. Iron Age, November 17, 1933, p. 17.

76. SWINNERTON, A. The Peat Moss Industry of Canada. Canada Dept. of Mines and Resources, Mines and Geology Branch, Memorandum Series No. 9, 1946, 12 pp; and Memorandum Series No. 10, April 1950.

77. TAYLOR, PAUL. Peat Moss in New Brunswick. Can. Min. Jour., vol. 63, 1942, pp. 357-360.

78. _____. Tests on Industrial Heating Appliances Using Turf as a Fuel. Industrial Research Council, Dept. of Industry and Commerce, Eire, Bull. 1, 1937.

79. _____. The Carbonization of Peat. Coke and Smokeless Fuel Age, 1941, pp. 3, 211.

80. _____. The Carbonization of Peat in Vertical Gas Retorts. British Fuel Research Board, Tech. Paper 4, 1921, 16 pp.

81. _____. The Harvesting of Peat. Fuel Economist, No. 12, 1937, pp. 328, 359.

82. _____. The Winning, Harvesting, and Utilization of Peat. Great Britain Dept. of Sci. and Industrial Research, Fuel Research, London, 1948, 24 pp.

83. _____. The Winning, Preparation, and Use of Peat in Ireland. British Fuel Research Board, H. M. Stationery Office, London, 1931, 76 pp.

84. THIESSEN, R. What is Coal? U. S. Bur. of Mines Inf. Circ. 7397, 1947, 53 pp.

85. THIESSEN, R., and JOHNSON, R. C. An Analysis of a Peat Profile. Ind. and Eng. Chem., Anal. ed., vol. 1, 1929, pp. 216-220.

86. _____. Trade Practice Rules. Federal Trade Commission, 1950.

87. TREFETHEN, J. M., and BRADFORD, R. B. Domestic Fuel Possibilities of Maine Peat. Maine Devel. Comm. Geol. Survey Bull. 1, 1944, pp. 1-47.

88. _____. Tubular Peat Preparation in Sweden. International Coal Trade, vol. 15, No. 1, January 31, 1946, pp. 10-11.

89. _____. Turf as a Domestic Fuel. Industrial Research Council, Dept. of Industry and Commerce, Eire, Bull. 2, 1941, 23 pp.

90. WACKSMAN, S. A. The Peats of New Jersey and Their Utilization. State of New Jersey, Dept. of Conservation and Development, Part A, Geologic Series, Bull. 55. The Nature and Origin of Peat, etc., Part B. (By Wacksman and others), The Peat Resources of New Jersey, 1943.

91. WARNER, C. A. Mechanical Methods of Peat Production. Trans. Inst. Civ. Eng., Ireland, 1942-43, pp. 39, 69.

92. WEEDEN, W. B. Economic and Social History of New England. Vol. 1 and 2, pp. 18, 532, 904, 907.

93. WHITE, D., and THIESSEN, R. The Origin of Coal. U. S. Bur. of Mines Bull. 38, 1913, 390 pp.

94. WHITE, GEORGE W. New Hampshire Mineral Resource Survey, Part 3, Peat Deposits. New Hampshire State Planning and Devel. Comm., 1941, pp. 1-16.

95. WOODBURN, ARTHUR. Use of Peat in Gas Turbines. London Times, October 10, 1949.

96. WOODS, A. J. Peat Combustion for Industrial Steam Heating. Engineer, 1946, pp. 181, 228.

SECTION XXI - MINERAL FERTILIZERS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. This section discusses the possibility of replacing or augmenting the importation of raw materials used as fertilizers by the fertilizer industry of New England and New York with materials obtained within that area.

2. At present about 1,000,000 tons of mineral fertilizers are consumed yearly in the New England-New York Region Much of it is imported, either as finished fertilizer or as raw materials to be converted in local plants into a product which can be of service to the agriculture of the area.

SUMMARY

3. Mineral fertilizer raw materials from the New England-New York Regionthat might be used in the fertilizer industry of this region may be summarized as follows:

a. The major mineral fertilizer materials, phosphate rock, potash-bearing minerals and nitrogenous minerals do not occur in this area. Ammonium sulphate is produced as a by-product of the coke industry.

b. Limestone, dolomite, olivine, and serpentine occur in various parts of the area and are available for use by fertilizer plants. Limestone and dolomite from local sources are used in large quantities as soil conditioners in all states in the area. Olivine and serpentine also have a potential value as sources of magnesium, but additional research is necessary before their development for this use is justified.

c. Sulphur is found in Maine, in combination with iron as pyrrhotite and pyrite, but development as a fertilizer raw material is not

warranted. The need for this element is generally supplied by the inclusion of other minerals which are combined with sulphur, with the largest part coming from sulphuric acid (H_2SO_4) in superphosphate.

d. Gypsum occurs in quantity in central and western New York, but market competition from Canadian sources is too keen to warrant development of local deposits for the fertilizer industry at present.

e. The minor fertilizer elements [1] occur at scattered points but the quantities needed are so small as not to warrant the cost of their development and preparation under present conditions.

4. The fertilizer industry will probably increase in size and scope as the demand expands, even though the principal mineral ingredients do not occur in New England-New York. The development of the secondary calcium, magnesium, sulphur, and minor mineral fertilizer raw materials does not appear to offer much inducement. A considerable quantity of limestone is used locally.

GENERAL

5. Fertilizers are classified on the basis of the principal element which they contain. The major elements are nitrogen (N), phosphorus (as P_2O_5), and potassium (as K_2O). It has been found that these three elements are of the most value to plant life and various mixtures of them form the so-called "complete" fertilizers.

6. In addition to these three primary elements there are three others, calcium (Ca), magnesium (Mg), and sulphur (S) which have become known as "secondary" fertilizer elements and are widely used.

1. Carbon, iron, copper, manganese, zinc, boron, molybdenum, cobalt, and iodine.

7. There are several "minor fertilizer elements", carbon (C), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), boron (B), molybdenum (Mo), cobalt (Co), and iodine (I), used in small amounts, a matter of pounds or ounces per acre, and although found to assist normal plant growth their exact functions ~~is now~~ are not known.

8. In addition to these actual "food" elements there are several indirect fertilizers which are added to the soil to modify its physical or chemical condition and thus benefit the plant life. Of these, limestone, dolomite and peat are probably used in greatest quantities. The New England-New York area has abundant deposits of these and production could easily be expanded.

SOURCES OF ELEMENTS USED IN FERTILIZERS

9. Only brief mention of the sources and properties of the elements used in fertilizers is necessary as details are available in many publications.

Nitrogen

10. Nitrogen is an essential plant food, but, unlike other nutrient materials, does not come from rocks and minerals from which soil is formed. Its principal source is the atmosphere from which it is obtained by the action of micro-organisms and electric fixation.

11. Prior to 1920, the Chilean natural sodium nitrate deposits furnished practically all the nitrogenous material used by the fertilizer industry. Since then synthetic ammonia plants and by-products ammonia have supplied the largest proportion of nitrogenous material. About

1-½ million tons of nitrogen compounds for use in fertilizer were imported into the United States in 1951.

Phosphorus (reported as phosphoric anhydride - P_2O_5)

12. The production of this element is dependent on natural phosphate rock found in various parts of the country. Before use it generally is converted to one of the various soluble phosphates and then mixed into a variety of phosphatic or mixed fertilizers. The chief producing areas of the United States in order of importance are Florida, Tennessee, and the Western States (Idaho, Utah, Wyoming and Montana).

Potassium (reported as potash - K_2O)

13. The element potassium is generally applied to the fields as one of the various potash compounds with chlorine, sulphur, nitrogen or carbon. The United States supply now comes largely from deposits in New Mexico, California, Utah, and Michigan. Some potash is recovered from cement-kiln flue dust in Maryland and California. The alunite beds near Marysville, Utah, are large, and two products, potassium sulphate and alumina, which can be obtained from them, are a possible source of future supply for the industry of the country.

Calcium and Magnesium

14. Calcium and magnesium occur together in most soils but possess the distinct difference that magnesium is a necessary plant food whereas calcium is largely a conditioner. Magnesium is largely applied as dolomite in mixed fertilizers. Calcium is largely applied as limestone but also occurs in gypsum and anhydrite which, however, are used in fertilizers mainly for their sulphur content. Calcium also is combined with phosphate rock, but this material is used mainly for its phosphate content.

15. The largest use of limestone and dolomite is in the role of soil conditioners rather than as actual fertilizing materials.

16. Olivine and serpentine have recently been the object of considerable research and experiment in an endeavor to expand their use as a source of magnesium in fertilizers. It has been shown that magnesium probably acts as a carrier of phosphorus and in New Zealand in recent years many thousands of tons of serpentine have been used to increase the availability of the phosphorus in phosphate fertilizers 1/. In Seattle, Washington, an electric furnace process has been developed to make a calcium-magnesium phosphate in a form readily available for plant life.

Sulphur

17. Sulphur, although a plant food and a soil conditioner, is generally supplied in sufficient quantities in gypsum or anhydrite or combined with other elements in the superphosphate fertilizers or with ammonium sulphate obtained as a by-product of the coke industry.

LOCATION OF PLANTS AND SUPPLY TO NEW ENGLAND-NEW YORK AREA

18. There are 81 fertilizer plants in the New England-New York area distributed as shown in Table 65.

19. The location of these plants is not only based on the immediately adjacent market, but also on the close relationship of easy and plentiful transportation as supplied by water routes and major railroad service. Recently truck haulage has become important. As far as is known the occurrence of nearby deposits of fertilizer mineral

1/ Industrial Minerals and Rocks: A.I.M.E., 1950, p. 529.

raw materials has had little or no effect on the location of plants which prepare or market commercial fertilizers.

Table 65 - Fertilizer plants in New England-New York Region 2/
New England-New York Region

State	A	B	C	D	Total
Connecticut			9	1	10
Maine	1		14		15
Massachusetts	1	3	3	1	8
New Hampshire					
Rhode Island			2	3	5
Vermont			1		1
New York	2	3	34	3	42
Total	4	6	63	8	81

A. Complete plant-manufacturing sulphuric acid, superphosphate and mixed fertilizers.
B. Manufactures superphosphate and mixed fertilizers.
C. Manufactures mixed fertilizers only (no superphosphate or sulphuric acid).
D. Sells goods manufactured for them.

20. All the plants are in agricultural areas with the more intensely cultivated regions having the greatest concentration. The western and central parts of New York have plants at Buffalo, Rochester, Syracuse, and Elmira; in the eastern part at Albany and New York City, with some also on Long Island.

2/ Data from Commercial Fertilizer Yearbook, September 1925, pp. 72-109; and National Fertilizer Review, April, May and June 1953.

21. The Maine plants are close to ocean transportation at Portland, Bangor and Calais (in the extreme eastern corner of the State) and along the railroad in the agricultural zone in the eastern part of the State near the Canadian border. The Connecticut and Rhode Island plants are also close to the ocean at New Haven, Hartford, and Providence. The Vermont and New Hampshire plants are at Burlington and Concord in the farming sections of these states. Massachusetts has 18 plants from Springfield and Greenfield east to Boston and Lowell.

FERTILIZER MINERALS FOUND IN NEW ENGLAND-NEW YORK AREA

22. None of the minerals from which the major fertilizer elements are obtained are knwon to occur in New England and New York; that is, no deposits of the nitrogenous minerals, rock phosphate, or potash minerals are known. The coke industry does, however, produce an appreciable quantity of ammonium sulphate as a by-product.

23. Sources of calcium and magnesium which occur in the limestones, dolomites, and gypsum (New York only) are known in many different parts of the area and can supply the local needs for the calcium and magnesium in fertilizers as well as the "soil conditioners" which may be desired.

24. Olivine and serpentine are found in Vermont, Maine, Massachusetts, and Rhode Island and could probably supply the local requirements if the processes by which these minerals become of fertilizer importance are further developed. The availability of large amounts of low cost electric power would be one of the major requirements of the development of processes to utilize these materials.

25. Native sulphur is not known to occur in the New England-New York area, but deposits of pyrrhotite and pyrite, iron sulphides, have been found, in Maine and New York, which are readily accessible and could probably be used, after treatment, as a source of both iron and sulphur if the need becomes of sufficient importance to justify the treatment plants which would be necessary to make these elements available. Pyrrhotite also occurs associated with the copper deposits of the Vermont Copper Company's property in Vermont.

26. The gypsum deposits in north central New York are reported to be the farthest east of any in the United States, and thus are in a favorable position for the markets in the New England-New York area, except for Canadian competition from New Brunswick and Nova Scotia. The individual source of supply for any new fertilizer plants in New England will, of course, depend on the location and type of plant desired.

27. The "minor fertilizer elements" [1] are used in such small amounts that their production in the New England-New York area or their importation from other parts of the country or from abroad is of little importance to the fertilizer industry.

28. Deposits of iron are well known in the area; in fact, a small iron producing industry thrived at scattered points in the early history of the colonies and a substantial amount of iron was produced in New York in 1952. It is probable that the cost of opening any of the old iron deposits and erection of new plants in New England to put the mineral in proper form for use in fertilizers would be far too great.

1. Carbon, iron, copper, manganese, zinc, boron, molybdenum, cobalt, and iodine.

29. Copper is plentiful in Vermont and traces of it have been found in other states of the area, but here again the cost of production and preparation would be too much to permit use of the mineral in the fertilizer industry.

30. Zinc and manganese are known in Vermont, New Hampshire, Maine, Massachusetts, and Connecticut, but probably the production costs of the small quantities needed would be excessive.

31. Molybdenum, cobalt, iodine, and boron, are not found in workable deposits in the area. They can be imported at relatively low cost.

32. The subject of the minor fertilizer elements can be summed up briefly by stating that at present the needs for them in the New England-New York area can best be met by importing the quantities required rather than by local development.

33. Some experimental work has been done over many years to ascertain if ground feldspar-bearing rock, or "granite dust" could be used as a source of potash. Results have been satisfactory under certail controlled conditions and on some crops, as for instance on tobacco in Connecticut. If further research is successful, it may be that some of the occurrences of feldspars in New England might become of added value for fertilizer use. Research is still required, hence the use of this mineral for fertilizer is still questionable.

PRESENT CONSUMPTION AND PRODUCTION IN NEW ENGLAND-NEW YORK AREA

34. Total fertilizer consumption in the New England-New York area in recent years is shown in Table 66 3/.

3/ See work cited in footnote 2.

Table 66 - Total fertilizer consumption in the New England-New York Region, 1/

State	1940	1946	1947	1948	1949	1950	1951	1952
Maine	147,520	294,587	284,716	263,994	228,156	200,069	172,219	216,917
New Hampshire	19,227	27,886	21,976	29,610	26,223	27,879	23,280	16,589
Vermont	28,742	46,369	42,688	54,146	54,146	50,722	66,164	46,186
Massachusetts	69,164	88,714	84,554	85,885	87,483	88,334	86,620	95,448
Rhode Island	11,843	18,346	17,607	19,045	21,126	16,402	17,419	16,309
Connecticut	62,768	83,397	78,419	83,509	92,509	91,080	93,305	83,339
New York	397,718	550,397	574,299	580,000	575,000	609,500	625,000	631,000
TOTAL	736,982	1,109,696	1,104,259	1,116,189	1,087,429	1,083,986	1,084,007	1,105,788
Percent of U.S. Total	8.9%	7.5%	7.2%	7%	6.6%	6%	5.8%	5.5%
U. S. TOTAL	8,249,156	14,892,322	15,039,379	15,979,701	16,449,088	17,983,988	18,826,107	20,119,039

1/ Includes entire state of New York.

35. In 1951 4/ there were 93 plants in the New England-New York area manufacturing or preparing fertilizers as shown in Table 65. An additional 21 companies are listed in the Commercial Fertilizer Yearbook, 1951, whose scope is not noted, but included in this listing are some of the best known firms in the country. They probably are in the fertilizer business in some degree, possibly some are of considerable importance.

36. Capacities of many New England-New York fertilizer plants are given in the September 1951, Commercial Fertilizer Yearbook. Among the plants listed, a total capacity of 1,162,950 tons per year is given. This figure cannot be considered to show accurately the real capacity of the plants in the area because some producers do not give figures and there is a difference in the form in which some of the others report their operations.

37. The figure above is indicative of the fact that apparently the total capacity of fertilizer plants in the New England-New York area is about equal to the consumption of the region. Some of the plants merely import the raw fertilizer materials and mix them for sale as "mixed fertilizers" or else sell products prepared to their specifications by other manufacturers, within or outside the area.

38. During the period 1940 to 1950, the general trend of consumption of all types of fertilizers was up, with the principal increase shown between 1940 and 1946, the war years. Since that time consumption has been about steady with a slight decrease in 1949 and 1950.

4/ See pp. 73-122 of work cited in footnote 2.

39. The consumption in the individual states has been irregular - a sharp increase in all states between 1940 and 1946 with very different trends since that time. Maine consumption has been steadily decreasing while New York has been continually increasing its use of fertilizers. The other five states have had a general rise in consumption, although Vermont and Rhode Island had sharp decreases in 1950

40. It is probably safe to say that the use of mineral fertilizers in the New England-New York area will increase in the future, but the degree and rapidity of this rise cannot be foretold. The general condition of the agricultural market and other conditions will determine this action.

CONCLUSIONS

41. The needs of agriculture in the New England-New York Region are being met by the existing plants. It is quite evident that most raw material needs will be met by the importation of mineral raw materials. Only the secondary and minor fertilizer-minerals exist in the area, and they are used in such limited quantities that their development and beneficiation is not likely. Soil conditioning limestone, dolomite and peat are available in sufficient abundance for all needs.

42. The future of a mineral fertilizer industry in the New England-New York Region is dependent largely on a supply of minerals and chemicals from sources outside the area.

SECTION XXII - GRAPHITE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Graphite has been mined intermittently during the past century at many localities in New England and New York, but during recent decades the industry has declined. Since 1942 the only producer of natural graphite in the area has been the Cranston mine at Providence, Rhode Island. Artificial graphite is produced at Niagara Falls, New York.

2. Graphite is classified as crystalline or amorphous; the amorphous graphite is, in reality, crystalline too, but very fine grained. The crystalline graphite is further classified as flake, lump, chip, or dust. In New England and New York most of the mined graphite has been flake, but the amorphous variety is found at several localities in the highly metamorphosed coal beds in the eastern part of the Narragansett Basin in Rhode Island and, to a minor extent in a metamorphosed coal bed in phyllite near Worcester, Massachusetts 1/.

3. Flake graphite, which is suitable for all graphite uses, has been a noteworthy mineral product of New York and a minor product of Massachusetts, Connecticut, New Hampshire, and Maine. The only production since 1921 has come from a deposit near Pope Mills, St. Lawrence County, New York, which was mined from 1937 to 1942.

1/ Perry, J. H., and Emerson, B. K.,1903, 1949, Geology of Worcester Massachusetts: Worcester Nat. History Soc., Worcester, pp. 16-17.

DESCRIPTION AND USES 2/

4. Graphite is classified as natural, and manufactured or artificial including colloidal. Natural graphite is sold as: (1) flake, which is classified according to the size of the flakes, carbon content, and impurities; (2) needle lump which is a special quality material because of its fibrous structure and contains from 90 to 95 percent carbon; (3) lump with a carbon content of about 90 percent; (4) chip - 80 percent; (5) dust - 55 percent; and (6) amorphous graphite which differs from the other grades because the individual grains cannot be distinguished by the naked eye. The trade name for flake, lump, chip, and dust is "crystalline".

5. Manufactured or artificial graphite is made from anthracite culm or petroleum coke with quartz, sand, and sawdust. Colloidal graphite is a form of manufactured graphite.

6. Commercial graphite contains various impurities. The paint industry uses the lowest grade which has a carbon content ranging from 30 to 35 percent; crucible grade has an 83 to 90 percent graphitic carbon content; pencil and lubricating grades range from 95 to 97 percent; and the carbon content necessary for commutator brushes is often better than 97 percent. Precise specifications are based upon the consumer demands for special blends that have been made and tested in accordance with the secrets of the trade.

7. The use of graphite is based upon the application of one or more of its natural properties. Its unctuousness or plasticity permits

---

2/ Gwinn, G. R., 1903, 1949, Graphite: A.I.M.E. Mudd Series, p. 431.

it to be readily worked; its refractoriness enables it to withstand fairly high temperatures; it is a good conductor of heat and electricity; it is inert to a great number of chemicals; and it is miscible with other materials and liquids.

8. Graphite is principally used in the manufacture of crucibles for melting metals, as a foundry facing to protect metal from marking by the molds, as a lubricant, and in paint, polish, pencils, electrodes, commutator brushes, dry batteries, and fertilizers.

CONSUMPTION

9. Table 67 indicates the trends in consumption by uses. A decline in the consumption of natural graphite is indicated for those uses requiring a high-quality, high-cost graphite, such as for pencils and commutator brushes. Suitable low-cost substitutes have reduced use of graphite considerably in the paint and polish industries.

10. Wide variations in demand and prices have been associated with the graphite industry over the past forty years. These have been caused by political controls exerted primarily by England and France, and by localized and global wars. Under these circumstances, few producers have been able to maintain or resume mining operations in the United States.

Table 67 - Consumption of natural graphite in the United States for selected years and uses 3/

	Percent of total consumption						Value per ton 1949 (dollars)
	1913	1923	1933	1937	1947	1949	
Foundry facings	10	43.5	38.0	38.5	32.5	33.9	72.00
Lubricants	5	3.0	11.0	10.9	14.1	14.0	172.00
Crucibles	55	15.0	17.5	8.3	14.5	12.5	220.00
Pencils and crayons	10	9.0	12.0	10.6	7.8	5.2	692.00
Paints and polish	15	18.5	12.0	4.0	a	1.1	62.00
Commutator brushes		8.5	3.5	.6	1.1	a	429.00 c
Other 1/	5	2.5	6.0	27.1	30.0	33.3	167.00
Total consumption 2/							
Amorphous	6.5	29.5	5.8	21.0	8.2	16.3	33.00
Crystalline	21.5	10.0	5.7	6.7	9.2		124.00
U. S. Production-shipments 2/	4.8	6.0	b	b	5.2	5.2	91.00

1. Other includes batteries, stoppers, packings, retorts, bearings, electrodes and brake linings.
2. In 1,000's of short tons.
a. Included with other
b. Confidential data
c. 1947 data

3/ Minerals Yearbook - Minor Nonmetals: Bur. of Mines, 1949, p. 1352; 1947, p. 1267; 1940, p. 1471.

HISTORY

11. The earliest mining operations in the United States were carried on in the graphite deposits of New York and New England. However, the mode of occurrence of graphite and the associated impurities have prevented the low production costs essential to meet competition. The tendency has been to overestimate recovery and yield, and the history of the industry in the region has been characterized by the number of failures rather than by the few successes 4/. The Rhode Island production is one of the few exceptions.

12. The first graphite mine to be worked in the United States was near Sturbridge, Massachusetts 5/. In 1644, John Winthrop, Jr. was given a grant to mine the "black lead", but there is no evidence available to show whether the production was for lead or to be used as a refractory. The property was later operated during 1828-1829.

13. The Adirondack deposits were initially developed in the 1840's. Numerous companies actively exploited these deposits, and New York soon became prominent in the production of a high-grade crystalline graphite. This position was maintained up to 1915, then started to decline until operations ceased in 1921. Domestic production, outside of Alabama, has been unable to compete with the high-quality, low-cost foreign production.

14. Mining operations in New York were resumed in the fall of 1937 and ceased in 1942 when explorations indicated no extension of

4/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199, 1918.

5/ Nicholson, H. P., and Mitchell, D. W., An Early History of the Mining Industry in New England-New York.

commercial ore 6/. The fact that this operation ended during a period of greatly expanded demand, coupled with the fact that no other operations existed in New York during World War II indicates the non-commercial nature of these natural graphite deposits.

15. New York is predominant in the manufacture of artificial graphite, and has been since 1904. The Acheson Graphite Company, located at Niagara Falls, is one of the principal manufacturers in the world.

16. In the early 1920's Congress imposed a tariff on imported graphite. The principal reason for this was to stimulate the industry in the United States. Despite this tariff, in 1923 the best Ceylonese and Madagascar graphite sold for 4 to 5 cents per pound in New York, duty paid, while domestic graphite cost from 14 to 18 cents per pound to produce.

17. This cost differential is based on the ease of mining by open-pits using low-cost labor at some foreign deposits as compared to higher-cost underground mining operations using expensive labor in the United States. Some Alabama and Texas deposits are competitive because they can be worked by open pit methods, using mechanized equipment; the relative softness and low-silica content of the weathered ore permits low-cost beneficiation; and the deposits are located within a short freight haul of consuming plants.

6/ Hartnagel, C. A., and Broughton, J. G., The Mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 37.

18. Flake graphite occurs (a) disseminated in complexly folded schist, quartzitic schist, and gneiss; (b) concentrated in small, local, and erratically distributed bodies of relatively rich material, either in marble near a large granite intrusive mass, or in schist and gneiss in proximity to pegmatite and granite dikes; and (c) as narrow graphitic veins. Deposits of the first two types are found only in schist, marble, and gneiss that have been derived from sedimentary rocks originally rich in carbonaceous material. The disseminated deposits (type a) are the most important source of graphite in New York and New England.

19. In New York most of the deposits are in folded and faulted metamorphosed sedimentary rocks of the Grenville series and occur chiefly in the eastern Adirondacks in Essex, Warren, Washington, and Saratoga Counties 7/ 8/; several small vein deposits (type c) occur in and adjacent to Grenville rocks in southeastern Essex County. Deposits also occur in the Grenville rocks of St. Lawrence County and in metamorphic rocks of the "Highland" area in Rockland County, New York. The graphitic carbon content of the Adirondack deposits ranges from 0.5 to 15 percent and averages about 6 percent.

20. In New England some small deposits contain enough flake graphite to have been of economic interest in the past. They occur mostly disseminated in schists and are scattered among graphite-bearing members of metamorphic rocks that extend (a) from Fairfield County in western Connecticut northward through the Berkshire Mountains

7/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199. 1918.

8/ Otte, Herman, The Explanding Mineral Industry of the Adirondacks: New York State Dept. of Commerce Pub. No. 10, Albany, 1943, p.43

of Massachusetts and the Green Mountains of Vermont; (b) from Tolland and Windham Counties in northeastern Connecticut northeastward to the town of Sturbridge, Worcester County, Massachusetts; (c) from Cheshire County in southern New Hampshire northward to Sullivan County; and (d) from Oxford County in western Maine northeastward to Franklin County.

21. Amorphous graphite occurs, as stated above, where a coal bed near Worcester, Massachusetts, and several coal beds in Rhode Island, have been highly metamorphosed. The Massachusetts deposit is a 5-foot graphitic coal layer interbedded in phyllite. The Rhode Island coal beds, ranging up to 60 feet in thickness, are also of graphitic anthracite. The grade of metamorphism in these occurrences was such that the coal has been only partly altered to graphite.

DESCRIPTION OF PRINCIPAL DEPOSITS

22. The principal graphite deposits of New York, together with their locations, type of deposit, and references are listed in Table 68; the New England deposits are listed in Table 69. The New York deposits are located in four areas; northwestern Adirondacks, northeastern Adirondacks, southeastern New York. The deposits are chiefly disseminated in schist or mable except in the northeastern Adirondacks and southeastern New York, where the deposits are mostly of the contact metamorphic type and are usually associated with granite or pegmatite. In New England noteworthy graphite deposits are found only near Sturbridge, Massachusetts, where graphite lenses occur in schist;

Table 68- Principal graphite localities of New York

Area	County	Quadrangle	Location	Property or company	Type of deposit	References and remarks
Northwestern Adirondacks	St. Lawrence	Hammond	1 1/2 miles southeast of Pope Mills.	Pope Mills mine	Disseminated in quartz schist.	Alling, 1918, p. 111-112 Mined ore contained 20-25% graphite.
	St. Lawrence	Hammond	3 miles south of Rossie	Rossie prospect	Disseminated in marble and quartzite.	Average grade about 12% graphite.
Northeastern Adirondacks	Essex	Ausable	4 miles south of Clintonville, Chesterfield Tp.	Smith property	Disseminated-contact type in quartz schist altered by granitic solutions.	Alling, 1918, p.112-118. Samples of ore range from 6-14% graphite.
	Essex	Paradox Lake	10 miles northwest of Ticonderoga, Crown Point, Tp.	Crown Point Graphite Co.	Contact deposit between marble and pegmatite.	Alling, 1918, p. 17-21. Last worked about 1910.
	Essex	Paradox Lake	2 3/4 miles northwest of Ironville, Crown Point Tp.	Columbia Graphite Co.	Contact deposit in marble near pegmatite.	Alling, 1918, p. 21-23. Worked 1903-1904.
	Essex	Ticonderoga	3 miles northwest of Ticonderoga, Ticonderoga Tp.	Lead Hill mine	Contact deposit between limestone and pegmatitic granite.	Alling, 1918, p. 23-31. Mineralogic analysis indicated 6% graphite.
Southeastern Adirondacks	Essex	Paradox Lake	4 miles southeast of Hammondsville, Ticonderoga Tp.	Bear Pond Mountain property (Columbia Graphite Co.)	Disseminated in feldspar schist.	Alling, 1918, p. 68-71. 2-3% graphite.
	Warren	Paradox Lake and Bolton	5 miles west of Hague, Hague Tp.	American mine (Dixon-American Graphite Co.)	Disseminated in quartz schist.	Alling, 1918, p. 43-56. Worked 1881 - 1921. Largest production of the N. Y. graphite deposits 5-7% graphite.
	Warren	Paradox Lake	At Hague, Hague Tp.	Lakeside mine	Disseminated in quartz schist, 12-15 feet thick.	Alling, 1918, p. 57-58. Worked 1880-1917. Mineralogic analyses showed over 9% graphite.
	Warren	Schroon Lake	3 1/2 miles northwest of Pottersville, Chester Tp.	International Graphite Co.	Disseminated-contact type in quartz feldspar schist altered by granitic solutions. Ore zone 18-25 feet thick.	Alling, 1918, p. 80-83. Mineralogic analyses showed 4.5 and 7% graphite.
	Warren	North Creek	6 miles southwest of River side Station, Johnsburg Tp.	Rowland Graphite Co.	Disseminated-contact type in schist altered by granitic solutions. Ore zone 25 feet thick.	Alling, 1918, p. 83-92. Mineralogic analyses showed 2-9.4% graphite. Worked 1901-1910.
	Washington	Whitehall	About 2 1/4 miles northwest of Whitehall, Dresden Tp.	Adirondack Mining and Milling Co.	Disseminated in quartz-feldspar schist.	Alling, 1918, p. 78-79. Chemical analysis showed 5.3% graphite. Worked 1904-1907.
	Washington	Whitehall	2 1/2 miles west of Whitehall, Dresden Tp.	Champlain Graphite Co.	Disseminated in quartz-feldspar schist.	Alling, 1918, p. 76-78. Ore runs 4-7% graphite.
	Washington	Bolton	5 miles west of Whitehall, Dresden Tp.	Hooper Brothers mine	Disseminated in quartz-feldspar schist.	Alling, 1918, p. 71-76. 5-6% graphite.
	Saratoga	Luzerne	1 1/4 miles west of Conklinsville, Day Tp.	Sacandaga mine	Disseminated-contact type in feldspar schist; average thickness 5 feet.	Alling, 1918, p. 92-96. Contains up to 10% graphite.
	Saratoga	Saratoga	4 miles north of Saratoga Springs, Wilton Tp.	Graphite Products Corp.	Disseminated in quartz schist with pegmatite stringers.	Alling, 1918, p. 105-110. Mineralogic analyses averaged 7.8% graphite.
	Saratoga	Saratoga	4 miles west of Kings, Greenfield Tp.	Flake Graphite mine	Disseminated in two beds of quartz schist, 10-14' and 4-5' thick.	Alling, 1918, p. 97-105. Mineralogic analyses range from 4.5-10% graphite.
Southeastern New York	Rockland	Ramapo	1/2 mile northwest of Hillburn.	Suffern property	Contact deposits in lenses of metamorphosed sediments in granite gneiss.	Miller and Sanford, 1949.

Table 69. - Selected Graphite Localities of New England

State	County	Quadrangle	Location	Name	Type of Deposit	References and Remarks
Connecticut	Litchfield	Cornwall	Near Cornwall Bridge	Mine Mountain	Disseminated in mica schist.	Schairer, 1931, p.49,110.
	Tolland and Windham	Westford	Northwestern part of town of Ashford and near Union	Lead Mine Hill area	Disseminated in Bolton schist.	Schairer, 1931, p.49,110.
Maine	Sagadahoc	Boothbay	Georgetown			Schrader and others, 1917, p. 148.
	Sagadahoc	Bath	Phippsburg			Schrader and others, 1917, p. 148.
	Franklin	Phillips	New Madrid		Disseminated in schist.	Trefethen, 1945, p. 22.
	Oxford	Rumford	Plumbago Mtn. near Newry		Disseminated in schist.	Trefethen, 1945, p. 22.
Massachusetts	Worcester	Southbridge	4½ and 5½ miles southwest of Sturbridge, town of Holland	Sturbridge mine and Cozzens prospect.	Abundant graphite in lenses and pockets in Brimfield schist.	Apfel, 1944. Sturbridge mine last worked in 1909.
	Worcester	Worcester North	Near Wigwam Hill, Worcester	Old Worcester coal mine	5-6 ft. graphitic coal bed in Worcester phyllite.	Perry and Emerson, 1903, p. 16-17.
New Hampshire	Cheshire	Monadnock	1 mile northwest of Nelson, town of Nelson.	Osgood graphite mine		Hitchcock, 1878, p. 81. 30 tons of graphite mined during 3 month period prior to 1872.
	Sullivan	Sunapee	At Mt. Sunapee, town of Goshan	Goshan graphite mine	Disseminated in a lens, in pyritiferous mica schist; also in veins.	Hitchcock, 1878, p. 81. 20 tons of graphite mined in 1840.
Rhode Island	Providence	Providence	South side of Providence	Cranston mine	Graphitic coal	Toenges, Quinn, and others, 1948, p. 8, 21-24. Producing at present.
	Providence	Providence	Providence	Fenners Ledge	Disseminated in schist and as lenses of graphitic coal.	Brown, 1910. p. 115-116. Schrader and others, 1917, p. 269. Produced several thousand tons of graphite until 1917.
	Providence	Pawtucket	Pawtucket	Valley Falls	Graphitic coal	Shaler and others, 1899, p. 206.
	Washington	Narragansett Pier	Bridgetown		Graphitic coal	Ashley, 1915, p. 57.
	Washington	Wickford	Saunderstown		Graphitic coal	Schrader, and others, 1917, p. 269.
	Newport	Tiverton	4 miles south of Tiverton		Graphitic coal	Schrader, and others, 1917, p. 269. 200 tons of graphite produced until 1917.

and at Providence, Rhode Island, where a graphitic coal bed has been mined.

23. Northwestern Adirondacks. - Disseminated graphite deposits occur near Pope Mills and Rossie, New York. The graphite at these two deposits is a very fine flake, and little of it is of commercial flake size.

24. At Pope Mills the country rocks are arkosite, schist, quartzite, and marble of the Grenville series which are intruded by small masses of igneous rocks. The Grenville rocks lie in oisoclinal folds, the limbs of which are complicated by minor folding. The Pope Mills' deposit occurs in a quartz schist near the axis of a fold. The commercial grade ore, which was mined out in 1942, is reported to have contained 20 to 25 percent graphite. 9/

25. The graphite at the Rossie prospect occurs as a disseminated deposit in a narrow belt of silicified limestone and quartzite in granite gneiss. The deposit consists of two graphitic beds in "limestone" and quartzite in granite gneiss. The deposit consist of two graphitic beds in "limestone", each about 10 to 12 feet thick, separated by 5 feet of quartzite. The total thickness of the ore zone where exposed is about 25 feet and the ore from the graphitic beds is reported to have averaged about 12 percent. A little graphite was produced from this deposit.

26. Northeastern Adirondacks. - Alling 10/ distinguished the

9/ Hartnagel, C. A., and Broughton, J. G., The Mining and Quarrying. Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 37.

10/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199, 1918, pp. 38-39.

northeastern Adirondack deposits from those of the southeastern Adirondacks on the basis of mode of occurrence. The deposits of the northeastern Adirondacks occur mainly in marble of the Grenville series, adjacent to intrusive granite pegmatite or quartz syenite. In several deposits, however, graphite occurs in quartzite or other Grenville rocks; the associated intrusives are granite pegmatite and gabbro.

27. The contact metamorphic deposits are small irregular bodies of graphitic rock, scattered along the contacts of igneous intrusives, and locally cut by graphitic quartz veins. These deposits are characterized by many contact metamorphic minerals and a considerable range in grain size with graphite flakes measuring up to an inch in diameter. According to Alling 11/, the contact memtamorphic deposits are too limited in extent and variable in grade and composition to be of economic value. In 1918 the Smith property appeared to be the most desirable deposit in the area 12/. This property is chiefly a disseminated deposit, but the graphitic quartz schist has been thoroughly altered by granitic emanations which have formed contact-type flake graphite varying in size from fine to coarse.

28. Vein deposits, consisting chiefly tof fine to coarse flake graphite, occur as fracture-fillings in country rocks of several kinds near Ticonderoga.

11/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199, 1918, p. 39, 40.

12/ Otte, Herman, The Expanding Mineral Industry of the Adirondacks: New York State Dept. of Commerce Pub. No. 10, Albany, 1943; p. 43.

29. Southeastern Adirondacks. - The deposits of the southeastern Adirondacks consist of graphitic disseminations in schist and are located south of Paradox Lake and Ticonderoga in Warren, Washington, and Saratoga Counties as well as in southwestern Ticonderoga Township, Essex County. The rocks of the area are folded and faulted schist, marble, quartzite and gneiss of the Grenville series, and granite, quartz syenite gneiss, pegmatite and metagabbro. The igneous rocks do not occur in contact with the graphitic schists, but emanations during their intrusion may have slightly metamorphosed the host rocks of the disseminated deposits. Graphite disseminations occur locally at several horizons in two schists of the Grenville series 11/. The schists range in thickness from 3 to 30 feet and are composed largely of quartz and feldspar with variable amounts of graphite, biotite, pyrite and chlorite. Fine-grained disseminated flake graphite is localized in lenses in the schists. The ore lenses range in graphite content from 5 to 10 percent, and the richest concentrations occur where the schist has been slightly metamorphosed by igneous emanations 13/.

30. Southeastern New York area. - A graphite deposit on the Suffern property near Hillburn, Rockland County, was investigated in 1949 by the U. S. Bureau of Mines, who concluded that no further prospecting of the deposits was warranted. Graphite occurs in numerous

13/ Alling, H. L., Adirondack Graphite Deposits: New York State mus. Bull. 199, 1918, p. 119.

14/ Miller, W. T., and Sanford, R.S., Investigation of Suffern Graphite Deposits, Rockland County, New York: Bur. of Mines Rept. Inv. 4438, 1949.

small pockets or lens-shaped bodies parallel to the foliation of the granite gneiss country rock, but not confined to any definite zone. According to Miller and Sanford 14/, the best concentrations of graphite are in the northeastern part of the property where graphitic pods occur along a series of small pegmatites. The larger graphite flakes, one-half inch in diameter, are associated with quartz, feldspar and biotite. Graphite probably formed where pegmatites in the gneiss contact-metamorphosed lenses of carbonaceous limestone or carbonaceous schist. Only one of five pits excavated by the Bureau of Mines exposed a definite graphitic zone 14/.

31. Graphite also occurs disseminated in a lens of schist in granite gneiss at Tuxedo Park, Orange County. The schist is 20 feet thick and is overlain by pegmatite 15/.

32. Massachusetts. - Two graphite deposits, the Sturbridge and the Cozzens, are located near Sturbridge, Worcester County. The Sturbridge deposit near Quassuck Lake is in a narrow zone of the Brimfield schist that is rich in biotite and pyrite. The Brimfield schist is intruded by dikes of granite and pegmatite. The graphite occurs in a series of pockets and lenses oriented parallel to the foliation of the schist. According to Apfel 16/, the graphite lenses range in thickness from about 3 to 18 inches, and in some places contain

14/ Miller, W. T., and Sanford, R. S., Investigation of Suffern Graphite Deposits, Rockland County, New York: Bur. of Mines Rept. Inv. 4438, 1949.

15/ Stewart, A.C., Note on the Occurrenceoof Graphite Schist in Tuxedo Part, New York: Econ. Geology, vol. 3, 1908, pp. 536-538.

16/ Apfel, E. T., Graphite Deposits near Sturbridge, Massachusetts: Massachusetts Dept. Public Works - U. S. Geol. Survey Cooperative Geol. Project, open file report, Inf. Circ., Boston, May, 1944, pp. 8, 10, 12.

as much as 10 percent graphite. The largest workings consist of a more or less continuous open cut with a maximum depth of 60 feet and a length of 750 feet along the strike. Two shafts were sunk from the bottom of the open cut to depths of about 100 feet and an adit was driven to intersect the graphite zone at depth. The adit crossed the graphite zone, but the ore was too lean to warrant further development.

33. The Cozzens prospect is about 1 mile southwest of the Sturbridge mine and apparently lies in the same graphitic zone in the Brimfield schist. The zone is about 3 feet thick and lies in a feldspathic schist or gneiss cut by a few pegmatites. In this zone two irregular, lenticular masses of graphite are separated by schist containing a lean dissemination of graphite. Apfel 16/ estimated that the average graphite content of the minable width of the graphite zone is 10 to 15 percent.

34. According to Apfel 16/ the lenses and pockets of high-grade graphite at these two deposits are too small and erratic in distribution for economic mining, and if worked, only part of the graphite would be of flake grade suitable for use in crucibles.

35. Rhode Island. - The Cranston or Sockanosset mine, is at the southern limit of the city of Providence. The mine has been worked intermittently for many years. Since World War II about 4,000 tons a year have been mined 17/. The productive rock is a bed of graphitic coal 4 to 60 feet thick, which dips 10 to 25 degrees eastward. The

17/ Toenges, A. L., Quinn, A.W., and others, Investigation of Metaanthracite in Newport and Providence Counties, Rhode Island: Bur. of Mines Rept. Inv. 4276, 1948, p. 8.

average minable thickness is 12 feet and the average grade is 75 percent fixed carbon. The so-called meta-anthracite has been used in the past as a fuel, and graphite has been recovered for use as a refractory. According to Toenges, Quinn, and others 17/, "the high cash content and graphitic character are unfavorable to its use as a fuel without treatment... Prior to the present development for graphite, the material was treated by flotation to remove some of the ash and then made into briquettes." The low-grade amorphous graphite as mined is now ground at the Cranston mill and shipped to plants for processing into refractory products. The unusual thicknesses of the Cranston deposit may have resulted from flowage during deformation of a coal bed into the apex of an overturned close fold in the Rhode Island formation.

RESOURCES AND FUTURE POSSIBILITIES

36. The principal resources of flake graphite in the New England-New York Region are in the southeastern Adirondacks. Alling 18/ estimated the inferred ore reserves of the American mine and Faxon property at 5,000,000 tons and of the Flake Graphite Company's property at 250,000 tons. The graphite content of the ore in these deposits ranges from 4 to 10 percent. Alling 19/ estimated the probable reserves of graphitic schist in the Faxon, Hooper Brothers, Flake Graphite Company, and Graphite Products Corporation's properties

18/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199, 1918, pp. 56, 105

19/ Alling, H. L., Adirondack Graphite Deposits: New York State Mus. Bull. 199, 1918, p. 140.

at about 10 to 13 million tons, half of which is readily available. The deposits in St. Lawrence County contain only small reserves and the graphite is too fine grained for many uses. The contact metamorphic deposits of Essex County also contain only small reserves, and the ores are too complex mineralogically to be beneficiated economically. The promising properties in Warren, Washington, and Saratoga Counties constitute a potential source of fine-grained flake graphite and might become a economic value by the application of modern mining, beneficiating and marketing practices. The complex structure of these deposits and the necessity for underground mining are disadvantages.

37. The Cranston mine probably has sufficient reserves to supply the small demand for amorphous graphite for a few decades at the present rate of production. According to Toenges, Quinn, and others 20/, "the recoverable reserves cannot be estimated, because the structure and thickness of the meta-anthracite bed may change sharply in any direction".

38. Further geologic mapping of schist belts known to contain graphitic members in New England might reveal additional local concentrations, but the probability of discovering any new deposits of commercial grade is not great.

39. The largest amount of natural graphite ever consumed in the United States was 40,000 tons in 1945. Even this unprecedented demand would be sufficient to maintain only a few domestic mines.

20/ Toenges, A. L., Quinn, A.W., and others, Investigation of Meta-anthracite in Newport and Providence Counties, Rhode Island: Bur. of Mines Rept. Inv. 4276, 1948, pt. 2, p. 24.

40. Pockets of high grade natural graphite in New England or New York could be exploited on a small scale, possible on a part-time basis during agricultural and industrial off-seasons. The nature of the deposits in the region is such that it might be more economical to operate them with a minimum of capital investment, preparing the amorphous grade, and taking advantage of freight rates over more distant domestic producers.

41. The production of domestic graphite is limited principally to the manufactured variety. Manufactured graphite competes with natural graphite for numerous uses; and the atomic energy program of the United States may make this product extremely important. Niagara Falls, New York, and Canada have been the centers for the manufactured graphite industry since its early days. Low-cost electric power is a requisite in the manufacture of artificial graphite, which sells for $30 to $300 per ton.

SELECTED BIBLIOGRAPHY ON GRAPHITE

1. ALLING, H. L., 1918, Adirondack Graphite Deposits: New York State Mus. Bull. 199, pp. 38-40, 56, 105, 119, 140.

2. APFEL, E. T., May, 1944, Graphite Deposits near Sturbridge, Massachusetts: Massachusetts Dept. Public Works - U. S. Geol. Survey Cooperative Geol. Project, open file report, Inf. Circ., Boston, pp. 8, 10, 12.

3. ASHLEY, G. H., 1915, Rhode Island Coal: Geol. Survey Bull. 615, pp. 18-20, 30, 57.

4. BASTIN, E.S., 1913, in Mineral Resources of the United States: Geol. Survey, Mineral Resources, pt. 2, pp. 181-251.

5. BROWN, C. W. 1910, Preliminary Report of the Natural Resources Survey of Rhode Island: Rhode Island Bur. Indus. Statistics Ann. Rept., 1909, pt. 3, Nat. Resources Survey Bull. 1. pp. 59-128.

6. GWINN, G. R., 1949, Graphite: Am. Inst. Min. and Met. Eng. Mudd Series,, p. 431.

7. HARTNAGEL, C. A., and BROUGHTON, J. G. 1951, The mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, pp. 36-39.

8. HITCHCOCK, C.H., 1878, The Geology of New Hampshire: vol. 3, pt. 5, Concord, New Hampshire, p. 81.

9. MILLER, W. T., and SANFORD, R. S. 1949, Investigation of Suffern Graphite Deposits, Rockland County, New York: Bur. of Mines Rept. Inv. 4438.

10. Mineral Resources of the United States, 1948, Bur. of Mines and Geol. Survey: Public Affairs Press, Washington, D.C. pp. 110-111.

11. Minerals Yearbook 1940, Minor Nonmetals: Bur of Mines, 1949, p. 1352; 1947, p. 1267; p. 1471.

12. MITCHELL, D. W., and AVERITT, PAUL, October, 1954. Coal in New York: New England-New York Inter-Agency Committee Rept.

13. NICHOLSON, H. P., AND MITCHELL, D. W., 1954, An Early History of the Mineral Industry in New England-New York: New England-New York Inter-Agency Committee Rept., p. 2.

14. OTTE, HERMAN, 1943, The Expanding Mineral Industry of the Adirondacks: New York State Dept. of Commerce Pub. No. 10, Albany, P. 43.

15. PERRY, J. H., and EMERSON, B. K. 1903, Geology of Worcester, Massachusetts: Worcester Nat. History Soc., Worcester, pp. 16-17.

16. PETERSON, R. B. 1950, The Mineral Industries of New York State: New York State Dept. of Commerce, Albany, pp. 73-77.

17. SCHAIRER, J. F. 1931, The Minerals of Connecticut: Conn. Geol. and Nat. History Survey Bull. 51, pp. 49, 110.

18. SCHRADER, F. C., STONE, R. W., and SANFORD, SAMUEL, 1917, Useful Minerals of the United States: Geol. Survey Bull. 624, pp. 148, 269.

19. SHALER, N. W., WOODWORTH, J. B., and FOERSTE, A. F. 1899. Geology of the Narragansett Basin: Geol. Survey Mon. 33, p. 206.

20. SMITH, G. O. 1906, Graphite in Maine: Geol. Survey Bull. 285, pp. 480-483.

21. STEWART, A. C. 1908, Note on the Occurrence of Graphitic Schist in Tuxedo Park, New York: Econ. Geol., vol. 3, pp. 536-538.

22. TOENGES, A. L., QUINN, A. W., and other, 1948, Investigation of Meta-anthracite in Newport and Providence Counties, Rhode Island: Bur. of Mines Rept. Inv. 4276, p. 8, (pt. 2) pp. 21-24).

23. TREFETHEN, J. M., 1945, Report of the State Geologist, 1943-1944: Maine Devel. Comm., pp. 22-23.

24. TREFETHEN, J. M., 1947, Report of the State Geologist, 1945-1946: Maine Devel. Comm., p. 7.

SECTION XXIII - HIGH-GRADE SILICA MATERIALS AND FOUNDRY SANDS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Silica materials are among the most valuable resources of the New England-New York Region and are used for many purposes. The silica-bearing formations and deposits discussed in this section are sandstone, quartzite, quartzose conglomerate, quartz rock, vein quartz, glass and foundry sands. They vary from place to place with respect to composition, lithologic character, thickness, and structure. No attempt is made here to list all occurrences; instead, localities have been selected which, it is believed, represent the best sources of high-grade silica and foundry sand in New England and New York. Other silica resources are described in the sections on Sand and Gravel, Abrasives, and Diatomite.

GEOLOGY AND RESOURCES

2. The principal deposits of silica materials considered are distributed as follows: sandstone in northern and eastern New York; quartzite in west-central Maine, southwestern Vermont, central and western Massachusetts, northern Rhode Island, northwestern Connecticut, and southeastern New York; quartzose conglomerate in western New Hampshire, and southeastern and southwestern New York; rock quartz and vein quartz in southern and western New Hampshire, northeastern Rhode Island, and southeastern Connecticut; glass sand in central New York; and foundry sand in the Hudson River Valley.

In New York

3. The Potsdam sandstone (Upper Cambrian) crops out in an arcuate belt extending from Jefferson County on the west through St. Lawrence, Franklin, and Clinton Counties. In this belt the formation is a white, friable, thin-bedded, pure quartz sandstone. According to Colony (1919, p. 15-16), "the better beds of this formation at various localities in Clinton and Franklin Counties * * * seem to offer possibilities as sources of supply for glass-making rock, so far as indicated by these analyses." The localities mentioned by Colony are: Clinton County, in the town of Mooers; Franklin County, occurrences 4-5 miles southwest of Malone, 3 miles southeast of Bangor, in the towns of Moira and Bangor, and in West Bangor Village.

4. The most extensive exposure of the Oriskany sandstone (Lower Devonian) is at its type locality in Oneida County where it reportedly does not exceed 20 feet in thickness. Here it is a medium to coarse-grained, fossiliferous, thick-bedded, flat-lying sandstone. The rock is buff to bluish-white on fresh exposures. It disintegrates readily and, in places, has weathered to a loose, clayey sand. Factors deterrent to development are: (1) small outcrop area, (2) thinness of unit of high-purity silica rock, and (3) expense of removing overburden of hard, cherty limestone.

5. Numerous outliers of the Olean conglomerate member (of the Pottsville formation) cap the high plateaus along the southern boundary of Cattaraugus County and extend westward into Chautauqua County. In Cattaraugus County the conglomerate is thick-bedded, flat-lying, and averages 20 to 30 feet in

thickness. Clean well-rounded pure quartz pebbles are loosely bonded in a matrix of grit and coarse sand which comprises more than 50 percent of the rock. Most of the pebbles are less than one-quarter inch in diameter. The cementing material is chiefly silica, though small amounts of iron oxides are present. In recent years the conglomerate has been used for ferro-silicon stock, and it probably could be used in low-alumina silica brick. Reserves are believed to be substantial.

6. The Shawangunk conglomerate (Silurian) crops out in a continuous belt extending southwestward from Kingston, Ulster County through Sullivan and Orange Counties into New Jersey. The formation consists of a varicolored series of fine to coarse conglomerates, conglomeratic quartzite, quartzitic sandstone, and shale. The strata are cross-bedded and form the steep northwest slope of Shawangunk Mountain. According to Holzwasser (1926, p. 66-68), the maximum thickness is 500 feet. In Ulster County, quartzite was quarried for crushed stone at Otisville (Newland, 1921, p. 276), near Accord for millstone, and in the vicinity of Ellenville for glass-making (Colony, 1919, p. 11-12). At present (1954) there is only a small production of millstone and fieldstone veneer. Because of the heterogeneous character of the formation, selective mining would be required to obtain high-grade silica raw materials. In this respect Colony (1919, p. 13) says, "There is not, as a rule, a very heavy cover or overburden on the Shawangunk, especially where the dip is steep, as at Ellenville; the rock is variable, however, and considerable care would be necessary in stripping undesirable beds in order to reach and quarry the better layers, an operation which would cause much wastage."

7. The "Poughquag" quartzite (Lower Cambrian) occurs in Dutchess, Orange, Putnam, and Westchester Counties. It is well exposed along the southern and eastern edges of Dutchess County and is the stratigraphic equivalent of the "Cheshire quartzite" in Connecticut, Massachusetts, and the Green Mountain region of Vermont. At the type locality of Poughquag the formation is more than 100 feet thick, elsewhere it ranges from 1 to 30 feet in thickness. The formation is very uniform lithologically, the predominant variety being a gray-white or pink dense medium-grained, thin-bedded, well jointed, pure quartzite. In some localities, particularly in Dutchess County, the Poughquag quartzite is sufficiently pure and dense to meet specifications for metallurgical use, acid refractories, and tube mill liners.

8. Blanket deposits of glass sand occur in a belt about half a mile wide which parallels the northern and eastern shores of Lake Oneida. The deposits range in thickness from 6 inches to 3 feet and are overlain by a thin soil cover. According to Newland (1921, p. 241), at one time large shipments were made to factories in central and western New York, and production declined because of competition with manufacturing centers in Pennsylvania, Ohio, and other states. The product shipped contained "97 to 98.5 percent silica, about .2 pereent ferric oxide and a little alumina, magnesia and lime" (Newland, 1921, p. 241). Sand from these deposits was used at the glass works in Corning, Steuben County in the 1930's.

Vermont, Massachusetts, and Connecticut

9. The Cheshire quartzite (Lower Cambrian) extends most of the length of Vermont and crosses western Massachusetts and the northwest corner of Connecticut.

10. In Vermont, the formation ranges from a quartz pebble conglomerate to a fine-grained quartz-mica schist in Bennington County; is a white to buff, massive, fine-grained quartzite in Rutland County; and a white, massive quartzite with, locally, seams of quartz-mica schist in Addison County. The formation ranges in thickness from 400 to 1200 feet. North of Addison County the Cheshire quartzite is too impure to be considered a source of high-grade silica raw material.

11. Exposures of the Cheshire quartzite in Massachusetts are limited to Berkshire County in the extreme western part of the State. It ranges from 40 to 150 feet in thickness and in most places is a dense, vitreous quartzite. Near Cheshire it includes a white, very pure, friable member which disintegrates into pure silica sand. Currently (1954) two companies quarry the Cheshire quartzite in Berkshire County for foundry sand, sandblast sands, furnace linings, and filler in mechanics' soap.

12. In Connecticut, most of the outcrops of Cheshire quartzite are in Litchfield County, though there are a few small deposits in Fairfield County. The outcrop areas are small and rather widely scattered. Detailed field investigations would be needed to determine which deposits might be suitable for high-grade silica products.

13. The Westboro quartzite (pre-Cambrian) is exposed in the southeast corner of Worcester County, Massachusetts and at a few localities in Providence and Kent Counties, Rhode Island. In some places it is a pure, nearly white, fine-grained sugary quartzite (Emerson, 1917, p. 24-25, 27). There is no record of this quartzite having been used as a high-grade silica raw material, though it might be usable for pebblemill liner material.

14. The Quabin quartzite (Carboniferous) occurs in a northward-trending narrow, discontinuous belt in Hampden, Hampshire, and Franklin Counties, Massachusetts. The formation varies from a sugary, white, friable, thin-bedded quartzite to a white, friable, sericitic schist, and in places is conglomeratic. According to Emerson (1917, p. 75), "It makes a great portion of Quabin and Felton Mountains as a pure, white, sugary quartz rock, in many places flaggy, and was formerly used as hearthstones for iron furnaces."

15. The Lantern Hill silica deposit is 4 miles west of North Stonington, New London County, Connecticut. "Lantern Hill is the highest point of a continuous ridge more than a mile long, which consists almost wholly of quartz. Its width at the base is more than 1,000 feet, but this includes a certain amount of talus. Its upper part, above the talus accumulations, is but a few hundred feet in width." (Loughlin, 1912, p. 135). The deposit consists of massive quartz cut by a network of vein quartz and porous, friable quartz. The Lantern Hill deposit is worked for glass sand, silica flour, lithographic sand, mechanics' soap filler, and several grades of ganister or ladle-mix.

New Hampshire

16. Discontinuous, tabular bodies of quartz are concentrated in Grafton, Sullivan, Hillsboro, and Rockingham Counties. Meyers (1941, p. 5) believes these deposits are silicified zones "along major fractures in the country rock, apparently faults." The masses are of medium to coarsely granular milky quartz, range from several hundred to several thousands of feet in length, and average about 100 feet in width. The chief impurities are iron

oxides and alumina. Some of the deposits contain large tonnages of high-grade silica suitable for ceramic and glass-making purposes.

Maine

17. The Misery quartzite member of the Moose River sandstone (Devonian) in central Somerset County is a gray to tan dense quartzite as much as 500 feet thick. The content of silica is high, of iron and alumina, low. Consequently, it is believed this quartzite is a possible source of raw material for acid refractory brick and silico-alloys. Formerly, the rather isolated location of the deposit prevented development. Now, a new paved Federal highway crosses the southwestern end of the outcrop belt and the northern end of the belt is crossed by the Canadian Pacific Railway.

Rhode Island

18. A deposit of vein quartz more than 1,000 feet wide and a mile long forms Diamond Hill in Providence County. The deposit consists of many intersecting veins of clear to milky quartz. In places much of the quartz is stained red by iron oxides and there are small inclusions of silicified felsite. It has been quarried for road metal and crushed stone, poultry grit, roofing granules, fire sand, and fire brick (Warren and Powers, 1914, p. 473). Because the iron content of the Diamond Hill quartz is higher than that of the nearby Lantern Hill deposit in Connecticut and the reserves at Lantern Hill are large, the outlook for future development of the Diamond Hill quartz is rather dim.

FOUNDRY SANDS

19. Foundry sand is one of the more important mineral commodities produced in the New England-New York region. The resources of molding and foundry sands are very large, especially dune sands that have accumulated at many places in the major river valleys and in the coastal areas. Although many of the deposits are small, others are extensive as, for example, those dug near Camden, Oneida County, New York and on Cape Cod, Barnstable County, Massachusetts. Also, as mentioned previously in this section, foundry sand has been produced from the Cheshire quartzite and similar rocks.

20. The best known and most widely used foundry sands in New England and New York are those known in the trade as "Albany molding sands." These sands occur in the Hudson River Valley from Fort Edward, Washington County to the vicinity of Poughkeepsie, Dutchess County, New York. They have long been recognized as being especially suitable for brass, aluminum, and the smaller types of iron castings. Hartnagel and Broughton (1951, p. 97) report that the deposits average 18 inches in thickness, rest on clay or "sharp" gray sand, and are overlain by soil or by dune sand. For details concerning individual deposits, the bibliography lists some of the literature.

RESOURCE POTENTIAL

21. The regional resource potential of silica raw materials is certainly adequate to meet the present demand within the region for many years to come. Even though the present rate of consumption were to be stepped up appreciably, local materials, with some exceptions, occur in sufficient grade and quantity to avoid the necessity of importation. This is not

so true for resources of high-quality silica sand for glass melting and chemical use; nor for resources of pure quartzose gravel or lightly-indurated conglomerate for metallurgical use.

SELECTED BIBLIOGRAPHY ON HIGH-GRADE SILICA AND FOUNDRY SANDS

Colony, R. J., 1919, High-grade silica materials for glass, refractories and abrasives: New York State Mus. Bull. nos. 203-204.

Emerson, B. K., 1899, The geology of eastern Berkshire County, Massachusetts: U. S. Geol. Survey Bull. 159.

----------, 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597.

Hartnagel, C. A., and Broughton, J. G., 1951, The mining and quarry industries of New York State, 1937 to 1948: New York State Mus. Bull. 343.

Holzwasser, F., 1926, Geology of Newburgh and vicinity: New York State Mus. Bull. 270.

Meyers, T. R., 1941, Some New Hampshire quartz deposits. Preliminary report part 6, Mineral Resource Survey, New Hampshire. New Hampshire State Planning and Development Commission.

----------, 1950, Foundry sands of New Hampshire: New Hampshire State Planning and Development Commission Mineral Resources Survey, pt. 13.

Nevin, C. M., 1925, Albany molding sands of the Hudson Valley: New York State Mus. Bull. 263.

----------, 1929, The sand and gravel resources of New York State: New York State Mus. Bull. 282.

Newland, D. H., 1921, The mineral resources of the State of New York: New York State Mus. Bull. nos. 223-224.

Quinn, Alonzo, and others, 1948, The geology and ground-water resources of the Pawtucket quadrangle, Rhode Island: Rhode Island Indus. Comm. Geol. Bull. 3.

SECTION XXIV - MISCELLANEOUS METALLIC MINERALS
IN THE NEW ENGLAND-NEW YORK REGION

MOLYBDENUM

1. In the United States molybdenum is produced predominantly from sulfide deposits which occur in granite and related intrusive igneous rocks. The deposits are of two main types: disseminations of molybdenite (MoS_2) in granite porphyry and molybdenite-bearing quartz veins associated with large low-grade disseminations of copper minerals in granite porphyry. The ore mined from disseminations in granite ranges from 0.4 to 1.5 percent MoS_2; ore from low-grade copper deposits ranges from about 0.01 to 0.05 percent MoS_2 (U. S. Bureau of Mines, 1954, p. 858). Small quantities of molybdenum have been recovered from powellite, $Ca(Mo,W)O_4$, and wulfenite, $pbMoO_4$.

2. Occurrences of molybdenum-bearing minerals, chiefly molybdenite, have been found at several places in New England but none have been of commercial importance. Molybdenum-bearing minerals also have been reported at several localities in New York (Newland, 1921, p. 163-165).

3. The noteworthy molybdenite occurrences in New England are near Cuttingsville, Vermont; at Holt's Ledge near Lyme, New Hampshire; and near Tunk Lake, Cooper, and Houlton, Maine. The occurrences are of three main types: disseminations in syenite, disseminations in quartz veins in metamorphosed rocks near granite intrusives, and disseminations in pegmatite and granite. Data on the occurrences are summarized in Table 70.

4. The molybdenite occurrences of New England were discovered during the nineteenth century and early part of the present century and were explored

Table 70 - Selected Molybdenum occurrences of New England

State	Locality	Quadrangle	Ore minerals	Remarks	References
Vermont	Granite Hill, 1 mile southwest of Cuttingsville, Rutland County	Wallingford	Molybdenite	Lean disseminations in a mineralized zone 3100 feet long and 125 feet wide. Zone occurs in syenite.	Eggleston, 1918, p. 378, 406. Jacobs, 1937, p. 24.
New Hampshire	Holt's Ledge, Town of Lyme, Grafton County (Holt's Ledge molybdenite prospect)	Mt. Cube	Molybdenite Powellite Bismuthinite	Molybdenite occurs in 2 quartz veins ranging from 1 inch to 4 feet in width. Assays range from .02 to .07% Mo.	
Maine	Catharine Hill, 3/4 mile northwest of north end of Tunk Lake, Hancock County	Tunk Lake	Molybdenite	Molybdenite is irregularly disseminated in pegmatite and granite, and along fractures near the periphery of a granite intrusive. Deposit explored but no mining done	Hess, 1908, p. 234-238. Hills, 1909, p. 323-324. Emmons, 1910, p. 42. Trefethen, 1947, p. 54-56.
	2 miles north of Cathance Lake, Cooper Twp., Washington County (Cooper molybdenite mine)	Gardner Lake	Molybdenite	Molybdenite is disseminated in pegmatite dikes several inches in thickness and in granite adjacent to the dikes. Grade is 0.1-.2% MoS_2; 1 or 2 tons of MoS_2 concentrate produced.	Smith, 1905, p. 197-199. Hess, 1908, p. 231-234. Emmons, 1910, p. 47. Trefethen, 1953, p. 50-51
	About 6 miles north-northeast of Houlton, Littleton Twp., Aroostook County (Henderson farm)	Houlton	Molybdenite	Disseminations of molybdenite in small lenses and veins in quartz and lime silicate rock near granite; aggregate thickness of several zones of mineralized rock is not more than 2 feet. Average grade exposed is 0.1-.2% MoS_2.	Miller, 1947, plate 4.

to a small extent for limited periods until 1934-1935 when some prospecting was done at Granite Hill, near Cuttingsville, Vermont. The only reported production of ore was from the Cooper molybdenite mine near Cooper, Maine. The low grade of the deposits forced abandonment of operations near Cuttingsville, Tunk Lake, and Cooper. Rocks of the copper-molybdenum bearing type of porphyry have not been discovered in the New England-New York Region.

TUNGSTEN

5. The economic tungsten-bearing minerals are scheelite, $CaWO_4$; feberite, $FeWO_4$; wolframite, $(FeMn)WO_4$; and huebnerite, $MnWO_4$. Tungsten is produced in the United States chiefly from scheelite and huebnerite; small quantities are obtained from wolframite and feberite. The principal deposits are in limestone in contact with granitic rocks or in quartz veins cutting schist or granite. The ore mined commonly contains 0.3 to 2.5 percent tungsten oxide (U. S. Bureau of Mines, 1954, p. 1287).

6. Occurrences of tungsten-bearing minerals, chiefly scheelite and wolframite, have been found at several widely scattered localities in New England. The minerals are in contact zones between limestone and granitic rocks, in granite and pegmatite, and in quartz veins near granite intrusives. The most noteworthy occurrence and the only deposit that has been mined for tungsten is near Long Hill, Connecticut. Data on this deposit and other selected tungsten localities in New England are shown on Table 71.

7. As far as known, the only tungsten locality in New England that has been investigated in detail (Fisher, 1942) is near Long Hill, Connecticut.

Table 71 — Selected Tungsten occurrences of New England

State	Locality	Quadrangle	Ore Minerals	Remarks	References
Connecticut	1 mile north of Long Hill village and 1/4 mile east of the Poquonock River, Fairfield County	Long Hill	Scheelite Wolframite Sphalerite	Tungsten mineral disseminated in a contact zone between pegmatite-bearing gneiss and limestone; zone ranges from 1 to 19 inches in thickness. 11 short tons of 60% WO_3 produced (1900-1916).	U.S.Geol.Survey, 1901, p. 258. Hobbs, 1901, p. 7-22. Fisher, 1942, p. 3-5.
	West of Monroe village. Fairfield County (Lane's mine)	Long Hill	Wolframite Scheelite Bismuth(native) Chalcopyrite Sphalerite Galena	Reported occurrence of scheelite and wolframite in quartz.	Dana, 1892, p. 984, 985, 987.
	Near Huntington village, Fairfield County	Long Hill	Wolframite Bismuth(native) Rutile	Reported occurrence of wolframite in quartz.	Dana, 1892, p. 987.
Massachusetts	Near Chelmsford, Middlesex County	Billerica	Scheelite	Scattered scheelite grains in limestone lenses in gneiss.	
New Hampshire	Holt's Ledge, town of Lyme Grafton County (Holt's Ledge molybdenite prospect)	Mt. Cube	Scheelite Powellite Molybdenite	Scheelite occurs in 4 veins ranging from 8 inches to 2 feet in width.	
	Near North Groton, Grafton County	Rumney	Wolframite	Wolframite occurs in pegmatite; a small quantity recovered as a by-product of mica mining.	U.S.Geol. Survey, 1921, p. 944.
Maine	Cornish-Limerick vesuvianite area, York County	Kezar Falls and Newfield	Scheelite	In lime silicate rocks along limestone granite contacts.	
	8 miles from Lewiston, Androscoggin County	Lewiston	Scheelite	Reported occurrence of scheelite.	Wooton, 1925, p. 584.
	Bowdoinham, Sagadahoc County	Gardiner	Wolframite	Reported occurrence of wolframite in granite.	Merrill and Perkins, 1930, p. 37.
	Near Winslow, Kennebec County (Winslow tin mine)	Waterville	Scheelite Cassiterite	Scheelite occurs in quartz veins 4-12 inches in width.	
	Near Blue Hill Falls, Hancock County (Camdage farm)	Blue Hill	Wolframite Molybdenite	Reported occurrence of wolframite and molybdenite in granite.	Emmons, 1910, p. 24. Merrill and Perkins, 1930, p. 36.
	Catharine Hill, 3/4 mile northwest of north end of Tunk Lake, Washington County	Tunk Lake	Scheelite	Reported occurrence of scheelite in pegmatite.	Hess, 1917, p. 38.

The deposit was worked for brief periods during the latter part of the nineteenth century and early part of the present century. It was first worked for copper, lead, and silver and later for tungsten from about 1890 until 1916. According to Fisher (1942), the indicated tonnages of mineralized rock ranging in grade from about 0.17 to 0.21 percent WO_3 for a three-foot mining width appear to be too small to justify further exploration or development.

8. Although no detailed studies have been made to determine the size and grade of other tungsten occurrences in New England, none of them is large or rich enough to have encouraged much prospecting. Tungsten-bearing quartz veins comparable to those in North Carolina have not been found in New England. The possibilities of discovering tungsten-bearing quartz veins of economic value in the region, however, cannot be eliminated until the geology is better known and further investigations are made in favorable localities.

TIN

9. Tin is produced from cassiterite (SnO_2), which occurs in placers or in veins. No important tin deposits have been found in the United States.

10. Noteworthy occurrences of cassiterite in the New England-New York region have been discovered only near Jackson, New Hampshire, and Winslow, Maine. The occurrences are in narrow quartz veins which contain sulfides in addition to disseminated cassiterite. Cassiterite also occurs as an accessory mineral in some pegmatite and small quantities have been recovered near Rumford and Paris, Maine.

11. The only reported production of tin from vein deposits in New England was 11½ ounces recovered in 1843 from ore at Tin Mountain near Jackson, Carroll County, New Hampshire (Hitchcock, 1878, p. 66-67). According to Hitchcock, the occurrence consists of 4 veins, one of which contained 30 percent tin; the rocks adjacent to the veins contained from 2 to 10 percent tin. The occurrence also has been described by Jackson (1843) and (1844, p. 80, 139, 223).

12. The occurrence of cassiterite near Winslow, Kennebec County, Maine, has been described by Jackson (1869, p. 269), Hunt (1873, p. 373-375), and Hitchcock (1880, p. 173). The cassiterite is disseminated in veins one or two inches thick. This occurrence has not been explored and no data are available on the grade of the veins.

13. The cassiterite-bearing veins of New England were discovered during the nineteenth century and those at Tin Mountain were worked for a brief period about the middle of the century. The small size of the veins has discouraged further investigation and exploration. It is unlikely that tin-bearing deposits of economic value will be found in the region.

14. Although gold has been profitably produced as a byproduct of base metal mining in New England, no deposits have been successfully worked solely for gold (see Section XXXII, copper). Noteworthy quantities of gold have been recovered from copper ore near South Strafford, Vermont. Many deposits in Maine, New Hampshire, and Vermont have been mined for gold but all operations failed. Mining costs were much greater than the value of the metal extracted. It is unlikely that deposits in the region will be mined for gold as the principal ore mineral.

15. In Maine, small quantities of gold have been obtained as a byproduct of copper-lead-zinc sulfides mined near Blue Hill and Deer Isle, Hancock County (Emmons, 1910, p. 32, 37) and from placers along the Swift River, Oxford County (Pratt and Condon, 1947, p. 64-65). According to Pratt and Condon, there is not enough gold in the streams of the Swift River Valley to support a mining industry, and no local "mother lode" is likely to be found owing to the glacial origin of the gold-bearing sand. Other gold occurrences in Maine are as follows: in base metal sulfides near Cherryfield, Cutler, and Lubec, Washington County; and in placers at Wyman Dam (Moscow), Somerset County; Milton (Milton plantation), Oxford County, and several places in Hancock and Washington Counties.

16. Most of the gold mining in New Hampshire has been confined to the Ammonoosuc district of northwestern Crafton County (Billings, 1935, p. 45-46). The gold, which is mostly associated with pyrite, occurs in small discontinuous quartz veins and in conglomerate (Ross, 1923). At the Milan mine near Milan, Coos County, small quantities of gold have been obtained as a byproduct of pyrite, and copper and zinc sulfides (U. S. Geol. Survey, 1911, p. 682) and

(Emmons, 1910, p. 48-60). Gold occurs at the following places in New Hampshire in addition to the Milan mine: Pittsburg (Indian Stream), Coos County; Bath, Canaan, Grafton, Hanover, Haverhill, Landaff, Lebanon, Lisbon, Littleton, and Lyman, Grafton County; and Plainfield, Sullivan County.

17. Most of the gold produced in Vermont has been obtained as a byproduct of the copper ores of several mines in Orange County, chiefly from the active Elizabeth mine near South Strafford. Production of byproduct gold from the copper ores of Vermont from 1905 until 1951 inclusive was about 1,000 ounces of which 156 ounces was recovered in 1951 (Minerals Yearbook for 1951, 1954, p. 623). Several narrow gold-bearing quartz veins and several small placers also have been worked in Orange and Windsor Counties. The mineralized area is probably a southwestward extension of the Ammonoosuc district of New Hampshire. Gold occurs at the following localities in Vermont in addition to the Elizabeth mine: Readsboro, Bennington County; Ely, Lake Morey, and Corinth, Orange County; Somerset, Windham County; and Bridgewater Corners, Gaysville, and Plymouth, Windsor County.

18. Many gold deposits have been reported in glacial drift in the Adirondack Mountains of New York and in veins in Massachusetts, Connecticut, and Rhode Island, but few proved to contain more than a trace of the metal and none have been worked profitably. According to Hartnagel and Broughton (1951, p. 99) there is no authentic record of gold having been produced in commercial quantities at any of the reported deposits in New York. In Massachusetts, small quantities of gold occur in tetrahedrite with base metal sulfides in a quartz vein at the Chipman mine near Newburyport, Essex County (Clapp and Ball, 1909, p. 244), and in sulfide-bearing quartz veins near Sheldonville, Norfolk County (Warren and Powers, 1914).

19. Silver has been obtained as a byproduct of base metal mining in all of the states of the New England-New York region except Rhode Island. Noteworthy quantities of silver have been recovered as a byproduct of lead-zinc ore mined near Balmat, St. Lawrence County, New York, and as a byproduct of copper ore mined near South Strafford, Vermont.

20. The principal silver occurrences in Maine are in the lead-zinc mines near Sargentville and West Sullivan, Hancock County. The mines have been described by Emmons (1910, p. 36-37, 39-40). The chief silver-bearing mineral is argentiferous galena, but in a few mines, especially near West Sullivan, native silver and other silver-bearing minerals have been produced in small quantities (Kempton, 1879, p. 349-356). The deposits are quartz fissure veins mined chiefly for zinc and lead; only small quantities of silver were recovered from most of the ore produced. Between 1880 and 1884 inclusive about 10,500 ounces of silver were produced in the State, presumably from these mines (Mineral resources of the United States, 1882-1884). Silver or silver-bearing minerals have been found at the following localities in Maine in addition to the mines noted above: Blue Hill, Deer Isle, Gouldsboro, and Franklin, Hancock County; Cherryfield, Lubec, and West Pembroke, Washington County; Embden Pond near Bingham, Somerset County; and Milton (Milton plantation), Oxford County (Emmons, 1910).

21. In New Hampshire, silver occurs chiefly in galena-bearing quartz veins but the quantity of galena in the veins is small. Hitchcock (1878, p. 32-34) described several vein deposits in the towns of Bath, Monroe, Lyman, and Littleton in northwestern Grafton County. Jackson (1844, p. 216) stated that

galena mined at Shelburne, Coos County and at Eton, Carroll County contained from 24 to 36 ounces of silver per ton of ore. Concentrates from the copper ore at the Milan mine near Milan, Coos County contained about 1 ounce of silver per ton (Emmons, 1910, p. 49). Argentiferous galena occurs at the following places in New Hampshire in addition to the deposits listed above: Madison and Sandwich, Carroll County; Haverhill, Lisbon, and Warren, Grafton County; Lyndeboro and Nashua, Hillsboro County; and Dumbarton and Epsom, Merrimack County.

22. Silver has been produced in Vermont chiefly as a byproduct from copper ore mined at the active Elizabeth mine near South Strafford. Vermont has produced about 247,500 ounces of silver (includes small quantities from New Hampshire) since the earliest available records, of which about 41,000 ounces were recovered in 1951 (Minerals Yearbook for 1951, 1954, p. 624). Silver-bearing minerals, chiefly argentiferous galena, occur at the following places in Vermont in addition to the Elizabeth mine: Morristown, Lamoille County; Corinth, Ely, Lake Morey, and Thetford, Orange County; and Bridgewater Corners and Weathersfield, Windsor County.

23. In Connecticut, small quantities of silver have been recovered from galena mined near Middletown, Middlesex County (Shepard, 1854). Silver-bearing minerals, chiefly argentiferous galena, have been reported at the following places in Connecticut in addition to the deposit near Middletown: Brookfield, Monroe, Sandy Hook, Trumbull, and Wilton, Fairfield County; Berlin, Bristol, and Southington, Hartford County; Bantam, Bethlehem, Litchfield, New Milford, Roxbury, and Woodbury, Litchfield County; East Hampton, Middlesex County; and New Haven, Seymour, Southbury and Wallingford, New Haven County (~~Broxell~~ Sohon, 1951, p. 69).

24. In Massachusetts, silver has been recovered from small quantities of galena mined at the Chipman mine near Newburyport, Essex County; at the Loudville mine near Northampton, Hampshire County; and near Sheldonville, Norfolk County (Warren and Powers, 1914, p. 473-474). The galena occurs in quartz veins and is associated with other base metal sulfides. Galena produced at the Loudville mine contained about 12 ounces of silver per ton (Emerson, 1898, p. 504), and galena produced at the Chipman mine contained about 60 to 70 ounces of silver per ton (Clapp and Ball, 1909, p. 244).

25. In New York, silver has been recovered from galena mined at several deposits in the inactive Shawangunk Mountain district of Ulster, Orange and Sullivan Counties and at the active Balmat mine near Balmat, St. Lawrence County. The only available record of silver produced in the Shawangunk district was 129 ounces recovered in 1918 from a deposit near Summitville, Sullivan County; the ores mined in the district probably contained "some thousands of ounces of silver but how much was recovered is unknown" (Hartnagel and Broughton, 1951, p. 99). Assays of 153 samples of ore taken at the Summitville mine near Summitville show a silver content ranging from a trace to 2.4 ounces per ton (Eilertson, 1950, p. 12-18). The production of silver in New York from earliest available records is about 529,000 ounces, of which about 47,500 ounces was recovered in 1951 (Minerals Yearbook for 1951, 1954, p. 624). Most of the production was probably from the Balmat mine, whose galena contains less than 1 ounce of silver per ton. Argentiferous galena occurs at the following localities in New York in addition to those listed above: Edwards and Hyatt, St. Lawrence County; Ellenville, Ulster County; Guymard and Otisville, Orange County; and Ancram, Columbia County. Many silver and gold deposits have been reported in New York, but

there is no authentic record of silver having been produced at any of these properties (Hartnagel and Broughton, 1951, p. 99).

PLATINUM

26. Platinum-bearing minerals that occur chiefly in ultramafic rocks have been found in the region in very small quantities at a few places in Maine, and in a boulder in glacial drift near Plattsburgh, New York. The chromite-platinum-bearing boulder was probably transported by ice from northern Vermont or Quebec (Peterson, 1950, p. 105). No platinum has been reported in the sulfides that occur at several places in the ultramafic intrusives of Vermont. Platinum occurrences have been reported by Schrader, Stone, and Sanford (1917, p. 149) at the following places in Maine: East Union, Knox County; Hermon, Penobscot County; and in pyrrhotite ores in Piscataquis County.

URANIUM

27. Incomplete reconnaissance surveys of localities containing radioactive minerals in the New England-New York Region have failed to disclose any noteworthy occurrences of uranium-bearing minerals except possibly at the Phillips mine near Peekskill, New York. Further investigations are being made by the U. S. Geological Survey and the Atomic Energy Commission.

28. Uranium minerals have been noted in the apatite-bearing magnetite ores at Mineville, New York and in pegmatites in Maine, New Hampshire and Connecticut.

SELECTED BIBLIOGRAPHY ON MISCELLANEOUS METALLIC MINERALS

Billings, M. P., 1928, The petrology of the North Conway quadrangle in the White Mountains of New Hampshire: Am. Acad. Arts Sci. Proc. v. 63, no. 3, p. 126-127.

----------, 1935, Geology of the Littleton and Moosilauke quadrangles, New Hampshire: New Hampshire State Planning and Devel. Comm., p. 45-46.

Clapp, C. H., and Ball, W. G., 1909, The lead-silver deposits at Newburyport, Massachusetts, and their accompanying contact zones: Econ. Geology, v. 4, no. 3, p. 244-245.

Cutting, H. A., 1872, Mining in Vermont: Vermont State Board of Mining, 1st Ann. Rept., 1870-72, p. 686, 691.

Dana, E. S., 1892, A system of mineralogy, John Wiley & Sons, New York, p. 235, 984-985, 987-988.

Eggleston, J. W., 1918, Eruptive rocks at Cuttingsville, Vermont: Am. Jour. Sci., 4th ser., v. 45, p. 377-410.

Eilertson, N. A., 1950, Investigation of Shawangunk mine zinc-lead deposit, near Summitville, Sullivan County, New York: U. S. Bur. Mines Rept. Inv. 4675, p. 12-18.

Emerson, B. K., 1895, A mineralogical lexicon of Franklin, Hampshire, and Hampden Counties, Massachusetts: U. S. Geol. Survey Bull. 126, p. 87.

----------, 1898, Geology of Old Hampshire County, Massachusetts: U. S. Geol. Survey Mon. 29, p. 504.

Emmons, W. H., 1909, Some regionally metamorphosed ore deposits and the so-called segregated veins: Econ. Geology, v. 4, no. 8, p. 764, 768-769.

----------, 1910, Some ore deposits in Maine and the Milan mine, New Hampshire: U. S. Geol. Survey Bull. 432, p. 24, 31-32, 36-45, 47-60.

Fisher, J. O., 1942, Report on the geology of the old tungsten mine near Trumbull, Connecticut: Connecticut State Geologist open file report, University of Connecticut, Storrs, Connecticut.

Gurlt, Adolph, 1894, On a remarkable deposit of wolfram ore in the United States: Am. Inst. Min. Eng. Trans., v. 22, p. 236-242.

Hartnagel, C. A., and Broughton, J. C., 1951, The mining and quarry industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, p. 61, 98-100.

Hess, F. L., 1908, Some molybdenum deposits of Maine, Utah, and California: U. S. Geol. Survey Bull. 340, p. 231-240.

----------, 1917, Tungsten minerals and deposits: U. S. Geol. Survey Bull. 652, p. 38.

Hills, B. W., 1909, The molybdenite deposits of Tunk Pond, Maine: Mining World, v. 31, no. 5, p. 323-324.

Hitchcock, C. H., 1878, Geology of New Hampshire: pt. 5, Concord, New Hampshire, p. 7-12, 19-27, 32-35, 60-69.

----------, 1880, Reputed tin discovery in Maine: Eng. Min. Jour., v. 30, p. 173.

----------, 1904, New studies in the Ammonoosuc district of New Hampshire: Geol. Soc. Am. Bull. 15, p. 471-472, 474.

Hobbs, W. H., 1901, The old tungsten mine at Trumbull, Connecticut: U. S. Geol. Survey 22nd Ann. Rept., pt. 2, p. 7-22.

Holmes, Ezekiel, and Hitchcock, C. H., 1861, Preliminary report on the natural history and geology of the State of Maine, 1861: Maine Board Agr., 6th Ann. Rept., p. 307-310.

----------, 1862, Second annual report upon the natural history and geology of the State of Maine, 1862: Maine Board Agr., 7th Ann. Rept., p. 422-425.

Hunt, T. S., 1873, Remarks on an occurrence of tin ore at Winslow, Maine: Am. Inst. Min. Eng. Trans., v. 1, p. 373-375.

Jackson, C. T., 1842, Report of the State Geologist, 1842: New Hampshire Legislature Journals, p. 241-242.

----------, 1843, Description of the tin veins of Jackson, New Hampshire: Assoc. American Geographers, Rept., p. 316-321.

----------, 1844, Final report on the geology and mineralogy of the State of New Hampshire: Concord, New Hampshire, p. 80, 139, 216-217, 223, 228.

----------, 1869, Tin ore in Winslow, Maine: Boston Soc. Hist. Proc., v. 12, p. 269.

Jacobs, E. C., 1937, Vermont mineral industries: Vermont State Geologist Rept., 1935-1936, no. 20, p. 24.

Jurgenson, C. M., 1930, Gold in Maine: Rocks and minerals, v. 5, no. 2, p. 53.

Kempton, C. W., 1879, Sketches of the new mining district at Sullivan, Maine: Am. Inst. Min. Eng. Trans., v. 7, p. 349-356.

Kerr, P. F., 1946, Tungsten mineralization in the United States: Geol. Soc. America Mem. 15, p. 30-31, 202-206.

Merrill, L. H., and Perkins, E. H., 1930, First annual report on the geology of the State of Maine: Augusta, Maine, p. 28-46.

Miller, R. L., 1947, Manganese deposits of Aroostook County, Maine: Maine Geol. Survey Bull. 4, pl. 4 (map).

Newland, D. H., 1921, The mineral industries of the State of New York: New York State Mus. Bull. 223-224, p. 24-25, 163-165.

Perkins, G. H., 1902, Report of the State Geologist on the mineral industries and geology of certain areas of Vermont, 1901-1902: v. 3, Albany, New York, p. 32-39, 79.

----------, 1904, Report of the State Geologist on the mineral industries and geology of certain areas of Vermont, 1903-1904: v. 4, Montpelier, Vermont, p. 54-58.

Peterson, R. B., 1950, The mineral industries of New York State: New York State Dept. Commerce, Albany, New York, p. 105-106.

Pratt, Elbert, and Condon, Henry, 1947, Reconnaissance of portions of the Swift River valley, Maine: Maine State Geologist Rept., 1945-1946, p. 60-65.

Ross, C. P., 1923, The geology of a part of the Ammonoosuc mining district, New Hampshire: Am. Jour. Sci., 5th ser., v. 4, no. 28, p. 291-296.

Schairer, J. F., 1931, The minerals of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 51, p. 109.

Schrader, F. C., Stone, R. W., and Sanford, Samuel, 1917, Useful minerals of the United States: U. S. Geol. Survey Bull. 624, p. 149.

Shepard, C. V., 1854, Middletown silver-lead mine: Mining Mag., v. 2, no. 2, p. 205-208.

Smith, G. O., 1904, Quartz veins in Maine and Vermont: U. S. Geol. Survey Bull. 225, p. 81-88.

----------, 1905, A molybdenite deposit in eastern Maine: U. S. Geol. Survey Bull. 260, p. 197-199.

Trefethen, J. M., and Miller, R. N., 1947, Molybdenite occurrence, 10, Hancock County, Maine: Maine State Geologist Rept., 1945-1946, p. 54-56.

Trefethen, J. M., 1953, Cooper molybdenite mine: Maine State Geologist Rept., 1951-1952; p. 50-51.

Sohon, J. A. ~~Troxell, E. L.~~, 1951, Connecticut minerals, their properties and occurrence: Connecticut Geol. and Nat. History Survey Bull. 77, p. 34, 36, 69.

U. S. Bur. Mines and U. S. Geol. Survey, 1948, Mineral resources of the United States: Public Affairs Press, Washington, D.C., P. 143-146, 198-202.

U. S. Bur. Mines, 1954, Minerals Yearbook, 1941: p. 623-624, 858, 1287.

U. S. Geol. Survey, 1901, Mineral resources of the United States, 1900: p. 257-259.

----------,1902, Mineral resources of the United States, 1901; p. 261-265.

----------, 1911, Mineral resources of the United States, 1910; p. 682.

----------,1921, Mineral resources of the United States, 1917: pt. 1, p. 931-954.

Warren, G. H., and Powers, Sidney, 1914, Geology of the Diamond Hill-Cumberland district in Rhode Island-Massachusetts: Geol. Soc. American Bull. 25, no. 4, p. 473-474.

Wooten, Paul, 1925, Tungsten ore discovery in Maine reported: Eng. Min. Jour., v. 120, no. 15, p. 584.

SECTION XXV-- SULFUR RESOURCES (PYRITE AND PYRRHOTITE) IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. The occurrence and possible use of pyrite and pyrrhotite and other metallic sulfide minerals as a source of sulfur or sulfur derivatives in the New England-New York area are described in this section.

2. Pyrite and pyrrhotite, both iron sulfide minerals, are widespread and abundant in many mineral deposits. Pyrite has the composition, FeS_2, equivalent to an iron content of 46.6 percent and sulfur content of 53.4 percent. Other minerals are generally mixed with pyrite as impurities, however, so that the sulfur content of commercial pyrite ores seldom exceeds 50 percent. Pyrite is a hard, heavy, brass-yellow mineral that crystallizes in the isometric system. Marcasite has the same chemical composition as pyrite, but crystallizes in the orthorhombic system and is paler in color on fresh surfaces. Pyrrhotite varies somewhat in its iron-sulfur ratio: its formula may be expressed as $Fe_{x-x}S$ The sulfur content of pyrrhotite from different localities ranges from about 35 to 42 percent; impurities usually reduce the sulfur content of commercial ores to 30 percent or less. Pyrrhotite is heavy, bronzy in color, and may be magnetic.

3. Pyrite, marcasite, and pyrrhotite are all suitable sources of sulfur. They have been termed by the collective name, pyrites, by the trade. The iron sulfides are usually burned to yield sulfur dioxide, which may be used directly in some industrial processes, or may be the first step in the manufacture of sulfuric acid. The iron-rich cinder that is left after calcining pyrites may be used to make iron.

4. Sulfur may be extracted from pyrites by several processes. However, unless the source of the ore is ideally located, no known process will

permit successful competition with natural sulfur produced by the Frasch process on the Gulf Coast.

5. Pyrites concentrates weigh at least twice as much as an equivalent quantity of elemental sulfur, and therefore incur unfavorable freight costs. Furthermore, the installation cost per ton of sulfuric acid capacity for a plant using pyrites is double that for an elemental sulfur burning plant 1/. Only in the most favorable location with respect to freight haul, delivered cost per ton of concentrates, and market can pyrites compete.

HISTORY

6. Until the perfection of the Frasch process of mining natural sulfur from deposits in salt domes, pyrites were the chief source of sulfur. Some sulfur was imported from Italy and considerable pyrites came from Spain prior to World War I. The wartime interruption of sea transportation led to expansion of pyrites mining in the New England-New York area. Production continued until about 1920, when full production of Frasch process sulfur forced the mines to close because of inability to compete.

7. A shortage of sulfur from the Gulf Coast in 1950 caused revival of interest in pyrites as an additional source of sulfur. The base metal smelters stepped up sulfur recovery, as sulfuric acid, from sulfide ores. Other potential producers, such as petroleum, gas, and coal industries, expanded their production. Some of the steel and several of the chemical companies began acquiring or considering acquisition of pyrites deposits in New England and New York.

1/ Jones, W. P., Economic Aspects of Sulfuric Acid Manufacture: Paper delivered at the Annual Meeting of the A.I.M.E., New York, February 8, 1952.

8. Pyrrhotite is recovered as a by-product at the Elizabeth Copper Mine in Vermont; and pyrite, at the Balmat and Edwards zinc-lead mines in New York. No mine in the area was operating for pyrites alone in 1954.

GEOLOGY OF THE DEPOSITS

9. The iron sulfides are the principal minerals in many deposits. They are commonly accompanied in some deposits by variable amounts of other sulfide minerals - chalcopyrite (copper iron sulfide), sphalerite (zinc sulfide), or galena (lead sulfide).

10. The iron sulfide deposits of the region are massive, lenticular or tabular bodies in metamorphic or igneous rocks. Their size ranges from narrow lenses that may contain only a few ten thousands of tons to huge deposits (such as the Katahdin deposit) that may have millions of tons of ore. Very few deposits have been explored sufficiently, however, to outline their shape or size completely.

11. Weathering of the iron sulfide minerals at the ground surface has altered them to limonite, a mixture of iron oxides which commonly has the appearance of rusty cinders or slag. The limonite capping, or gossan (its usual name), is characteristic of weathered iron sulfide deposits, and is the most obvious sign of the presence of such a deposit where it crops out at the surface. In the New England-New York region a mantle of glacial deposits covers the bedrock in many places, however, and there may be large iron sulfides deposits which are completely covered. Discovery of buried deposits will probably require geophysical survey methods that detect magnetic or electrical properties of mineral deposits.

DESCRIPTION OF DEPOSITS

12. The deposits in the New England-New York region that have iron sulfides as the principal minerals of economic, or potential economic, importance are described below. Some of these deposits have been productive in the past, but none is being mined at the present time. The copper and lead-zinc deposits that contain marketable or potentially marketable iron sulfides are described in Section XXXII on Copper in this chapter. The principal deposits in New York and New England are indicated in Plates 46 and 47.

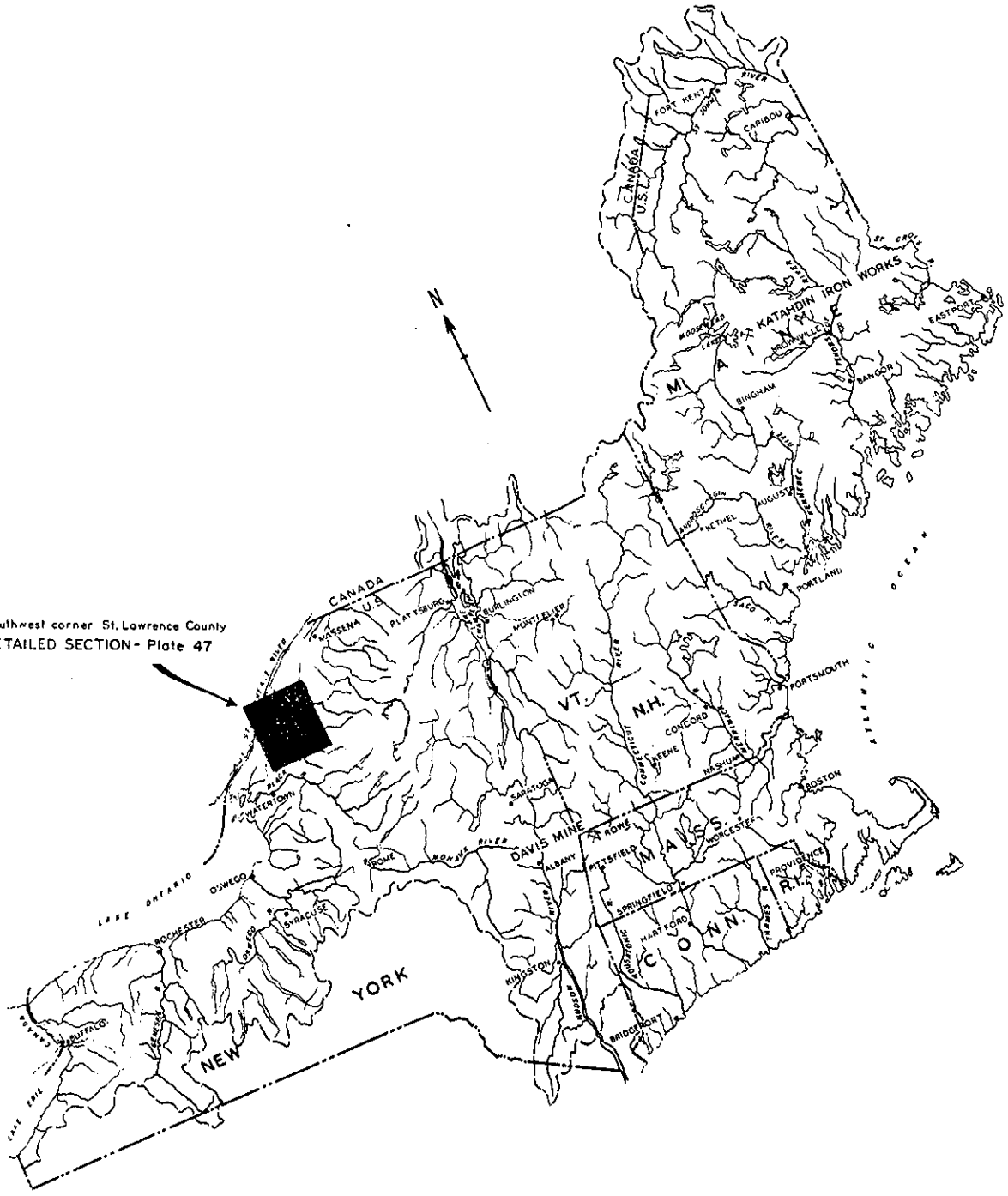
Deposits in Maine

13. The Katahdin deposit.--The Katahdin pyrrhotite deposit is located on Ore Mountain in southeastern Piscataquis County, ten miles northwest of Brownville Junction and one mile west of the village of Katahdin Iron Works.

14. Pyrrhotite and silicate minerals (plagioclase and pyroxene) in the ratio of 2 parts sulfides to 1 part silicates are the principal constituents of the Katahdin ore. Four analyses of the ore given by Miller 2/ show sulfur content ranging from 26.17 to 28.08 percent, and iron content ranging from 43.18 to 47.20 percent; minor amounts of nickel and cobalt are also present. The ore is weakly magnetic. A limonite gossan, which has been removed by iron mining, formerly capped the deposit.

15. The deposit occurs in gabbro, and has surface dimensions of 2050 by 400 feet, according to Miller. The deposit has been explored by drilling,

2/ Miller, R. L., Geology of the Katahdin Pyrrhotite Deposit and Vicinity, Piscataquis County, Maine: Maine Geol. Survey Bull. 2, 1945, pp. 1-21.

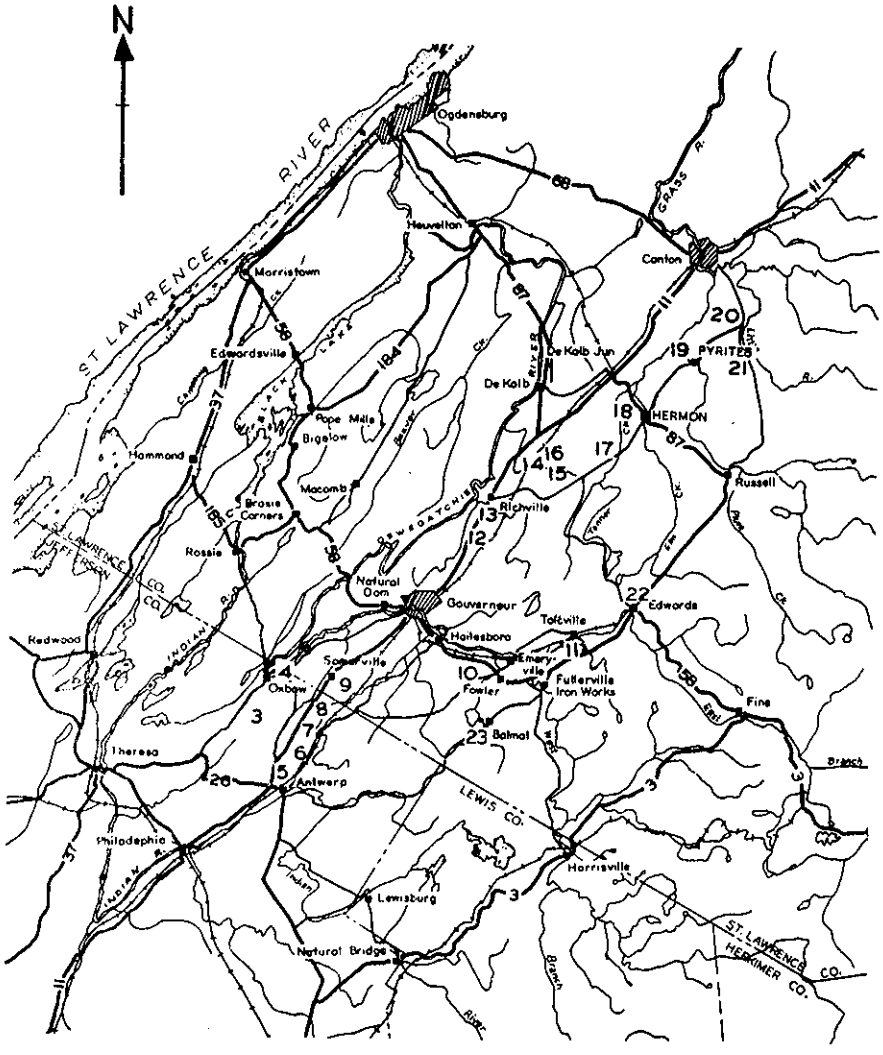


SPECIAL SUBJECTS-REGIONAL
SULFUR RESOURCES
(PYRITE AND PYRRHOTITE)
LOCATION MAP

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
OCTOBER 1954
SCALE IN MILES
0 10 20 30 40

U.S.B.M. Boston, Oct. 1954

PLATE 46
CHAPTER XXXIX



INDEX

SUB-REGION C

MINE OR PROSPECT	
NO.	NAME
3	OXBOW SOUTHWEST
4	GOLD HILL
5	DICKSON
6	WIGHT
7	MORGAN
8	KEENE
9	CALEDONIA
10	KILBURN
11	PLEASANT VALLEY SCHOOL
12	COLE
13	HENDRICKS
14	STILES
15	MITCHELL
16	FARR
17	ORE BED SCHOOL
18	STELLA
19	PYRITES
20	BRICK CHAPEL
21	LITTLE RIVER

MINE OR PROSPECT (LEAD-ZINC)

22	EDWARDS MINE
23	BALMAT MINE

SPECIAL SUBJECTS-REGIONAL

St. Lawrence County

PYRITE AND PYRRHOTITE PROPERTY LOCATION

New England-New York Inter-Agency Committee

April 1954

SCALE OF MILES

4 0 4 8

USBM Boston, April 1954

PLATE 47

CHAPTER XXXIX

but the information on its underground character is not available. The ore reserves have been estimated by Miller 3/ to amount to "9,400,000 long tons of pyrrhotite ore ... for every 100 feet of depth beneath the surface. Of this 4,100,000 tons would be metallic iron and 2,500,000 tons sulfur."

16. The limonite gossan was mined between 1848 and 1890 and smelted to iron in a charcoal blast furnace at Katahdin Iron Works. Operations ceased in 1890 and machinery was removed in 1892; the property has since been idle.

17. General Chemical Division of Allied Chemical and Dye Corporation explored the property by drilling in the early 1930's, purchased all the stock of the Piscataquis Iron Works Corporation in early 1952 and acquired about 31,000 acres in the vicinity 4/. The sales price was reported to be more than $1,000,000.

18. Moosehead Lake.--An Associated Press dispatch in the "Boston Post" of May 26, 1952, stated: "The Freeport Sulphur Co. seeking iron sulfides and other minerals has leased all or parts of 43 Moosehead Lake region towns." Mr. J. M. Trefethen, Geologist for the State of Maine, reported in June 1953 that the company "carried on the explorations last summer and this winter. The results of their work have not been made public."

Deposits in New Hampshire

19. The known pyrite and pyrrhotite deposits in New Hampshire are associated with copper, lead and zinc in three districts: the Milan-Ammonoosuc copper district in Coos County; the Croyden-Unity deposits in Sullivan

3/ Miller, R. L., Geology of the Katahdin Pyrrhotite Deposit and Vicinity, Piscataquis County, Maine: Maine Geol. Survey Bull. 2, 1945, pp. 1-21.

4/ Jones, W. E., Sulphur Shortage May Reopen Old Katahdin Iron Works: Boston Globe, April 13, 1952, p. A-13.

County; and the Ore Hill Zinc-Lead Mine near Warren, Grafton County.

Deposits in Vermont

20. The Elizabeth Mine (see Section XXXII) was opened about 1793 to mine pyrrhotite for the manufacture of copperas but there is no record of the pyrrhotite being used after the production of copper was started about 1829 until recently. Some pyrrhotite is now being saved and used in the manufacture of sulfite cooking liquor by the Brown Paper Company at Berlin, New Hampshire.

21. The Sulphide Ore Process Company reports the development of an electrolytic process for making 99.99 percent pure powdered iron and a sulfur sufficiently pure for use in a sulfur burning plant from the Elizabeth pyrrhotite 5/.

Deposits in Massachusetts

22. The Davis pyrite mine in Rowe, Franklin County, was a successful operation from 1882 to 1910. Production reached 300 to 400 tons a day 6/. The mine is reported to have been worked for about 900 feet along the strike and 1400 feet down the dip. "During the early summer of 1910, the Davis Mines were exhausted and the company started to rob pillars with the result that the mine collapsed, presumably closing it for all time" 7/.

5/ Konrad, Erich, Electrolytic Process with Promise: Chemical Engineering, April 1953, pp. 189-192.

6/ Weed, W. H., Copper Deposits of the Appalachian States. U. S. Geol. Survey Bull. 544, 1911, pp. 33-37.

7/ Phalen, W. O., Mineral Resources of the United States: U. S. Geol. Survey, 1912, part 2.

23. The copper mines in Massachusetts were not successful and it is doubtful if the pyrites would be of sufficient value to justify mining.

Deposits in Connecticut

24. Pyrites deposits of sufficient size and purity to warrant development have not been discovered in Connecticut. Copper sulfide ore bodies have been mined at Granby and at Bristol, Hartford County, in the Triassic rocks and the older crystalline schists adjacent to them. However, pyrite was absent or found only in small amounts in these deposits and no attempt made to recover it.

Deposits in Rhode Island

25. Pyritiferous deposits of possible economic character have not been discovered in Rhode Island.

Deposits in New York

26. The mining of pyrite for sulfuric acid was of considerable importance in New York State during the period 1900 to 1920, when more than 600,000 long tons of pyrite concentrates containing 40 percent sulfur was produced. The industry reached its peak during World War I owing to the curtailment of pyrite imports from Spain because of enemy submarine activity.

27. The mines whose sole product was pyrites were closed in 1921, because they were not able to compete with low cost native sulfur from the Gulf Coast. Pyrite has continued to be recovered as a by-product at the Balmat and Edwards lead-zinc mines.

28. Jefferson and St. Lawrence Counties.--The principal pyrites deposits in New York lie near the St. Lawrence River in Jefferson and St. Lawrence Counties. They were investigated during World War I by Buddington 8/

8/ Buddington, A. F., Report on the Pyrite and Pyrrhotite Veins in Jefferson and St. Lawrence Counties, New York: New York State Defense Council Bulletin No. 1, 1917.

and recently by Prucha 9/ whose report described each deposit and from which the following information is summarized. (See Plate 47).

29. Nineteen deposits of pyrites are known, most of which lie in a northeast-trending belt about 35 miles long and 4 miles wide. Although both pyrite and pyrrhotite occur in all the deposits, usually one or the other of the minerals greatly predominates in a given deposit. In some deposits, veins that are mainly pyrite are adjacent to veins that are composed mostly of pyrrhotite. A small amount of hematite is present, and traces of chalcopyrite and sphalerite are found in places. The deposits are sheetlike veins that are conformable to the foliation of the gneiss country rock.

30. Channel samples taken by Prucha 9/ of 12 of the most promising veins range in sulfur content from 20.2 to 35.6 percent. Thickness of the veins at the sample ranges from 2 to 30 feet. Prucha points out that considerable exploration by diamond drilling would be necessary to obtain adequate information on the sulfur content and size of the deposits. He considers the most promising deposits to be at the Cole and Stella mines (the principal former producers), and at the Dickson, Wight, and Gold Hill prospects.

31. Besides the Jefferson and St. Lawrence Counties occurrences, a deposit of pyrite and pyrrhotite at Anthony's Nose on the Hudson River upstream from Peekskill, Westchester County, was worked for a period of years. The output was used locally for the manufacture of sulfuric acid.

9/ Prucha, J. J., The Pyrite Deposits of Jefferson and St. Lawrence Counties, New York: New York State Science Service, Univ. of New York, R. I. No. 8, Jan. 1953, 66 pp.

POTENTIAL RESOURCES AND FUTURE SUPPLIES

32. Although under current economic conditions (1954) no sulfide deposits in New York or New England can be mined for pyrites alone in competition with native sulfur from the Gulf Coast, the deposits will become economic when the supply of native sulfur decreases, as it inevitably must. By-product sales could also help restore some of the larger properties to producing status. The potential resources are large, although only partly explored, and the regional demand for sulfur is great. In the future, however, pyrite from Maine may face stiff competition from by-product sulfur from large, base metal mines in New Brunswick and Quebec. In the more distant future, the large resources of gypsum and anhydrite of western New York could become important sources of sulfur.

SELECTED BIBLIOGRAPHY ON SULFUR RESOURCES
(PYRITE AND PYRRHOTITE)

1. BASTIN, E. S. Large Pyrrhotite Deposits in Maine. Eng. and Min. Jour., vol. 104, 1917.

2. BARDILL, J. D. War's Impact on the Mineral Industry of New York and New England. U. S. Bur. of Mines Report, Jan. 1945, on open file at College Park, Maryland.

3. BRINSMADE, ROBERT B. Pyrite Mining and Milling in St. Lawrence County, New York. The Mineral Industry, vol. XIV, 1906, pp. 525-527.

4. BUDDINGTON, A. F. Report on the Pyrite and Pyrrhotite Veins in Jefferson and St. Lawrence Counties, New York. New York State Defense Council Bulletin No. 1, 1917.

5. CAMERON, E. N. Origin of Sulphides in the Nickel Deposits of Mount Prospect, Connecticut. Geol. Soc. America Bull., vol. 54, 1943, pp. 651-686.

6. CROSBY, I. B. Report on Mineral Resources of Massachusetts, A Survey of Literature. Massachusetts Ind. and Devel. Comm., Boston, 1932.

7. CUSHING, H. P., and NEWLAND, D. H. Geology of the Gouverneur Quadrangle. New York State Mus. Bull. 185, 1926.

8. EMERSON, B. K. Geology of Massachusetts and Rhode Island. U. S. Geol. Survey Bull. 597, 1917.

9. HARTE, C. R. Connecticut's Iron and Copper. Conn. Soc. Civil Eng., 60th Annual Report, 1944, pp. 131-166.

10. JONES, W. E. Sulphur Shortage May Reopen Old Katahdin Iron Works: Boston Globe, April 13, 1952, p. A-13.

11. JONES, W. P. Economic Aspects of Sulfuric Acid Manufacture: Paper delivered at the Annual Meeting of the A.I.M.E., New York, February 8, 1952.

12. KAISER, E. P. Reconnaissance of Area of Magnetic Anomalies Piscataquis County, Maine. U. S. Geol. Survey unpublished report, 1952.

13. KONRAD, ERICH. Electrolytic Process with Promise: Chemical Engineering, April 1953, pp. 189-192.

14. MARTIN, JAMES C. The Pre-Cambrian Rocks of the Canton Quadrangle. New York State Mus. Bull. 185, 1916.

15. MILLER, R. L. Geology of the Katahdin Pyrrhotite Deposit and Vicinity, Piscataquis County, Maine. Maine Geol. Survey Bull. 2, 1945, pp. 1-21.

16. NEWLAND, D. H. Pyrite in Northern New York. Eng. and Min. Jour., vol. 104, pp. 947-948.

17. _____, Zinc-Pyrite Deposits of the Edwards District, New York. New York State Defense Council Bulletin No. 2, 1917a.

18. O.E.E.C. Sulphur Documentation. Published by the Organization of European Economic Co-operation, Paris, June 1952.

19. PHALEN, W. O. Mineral Resources of the United States - 1911, U. S. Geol. Survey, 1912, part 2.

20. PRUCHA, J. J. The Pyrite Deposits of Jefferson and St. Lawrence Counties, New York. New York State Science Service, Univ. of New York, R. I. No. 8, Jan. 1953, 66 pp.

21. PRUCHA, JOHN J. The Pyrite Deposits of Jefferson and St. Lawrence Counties, New York (Preliminary Report). New York State Science Service, 1945, p. 3.

22. QUINN, A. W. Geology of the Charlemont-Heath Area (with special reference to pyrite and copper deposits). Cooperative Geol. Project, Mass. Dept. Public Works and U. S. Geol. Survey, open file report, U. S. Geol. Survey and Barnum Museum, Tufts College, Medford, Mass., 1943, pp. 1-28.

23. RUTLEDGE, J. J. Davis Pyrite Mine, Massachusetts. Eng. and Min. Jour., vol. 82, 1906, pp. 673-676, 724-728, 772-775.

24. SMITH, P. S. Pyrite Deposits in the United States, in Mineral Resources of the United States - 1917, part 2, U. S. Geol. Survey, 1920, pp. 28-56.

25. SMYTH, C. H., JR. On the Genesis of the Pyrite Deposits of St. Lawrence County, New York. New York State Mus. Bull. 158, 1912, pp. 143-182.

26. VOGEL, FELIX A. Pyrites Mining and Milling in St. Lawrence County, New York. The Mineral Industry, vol. 16, pp. 845-851.

27. WEED, W. H. Copper Deposits of the Appalachian States. U. S. Geol. Survey Bull. 544, 1911, pp. 33-37.

SECTION XXVI-SALT IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Salt is one of the most important mineral resources of the New England and New York Region; the deposits are commercially equal to any known salt deposits in the world and account for one-fifth of the domestic production of the United States.

2. Salt occurs in a series of extensive beds interlayered with shale, limestone, and anhydrite in the Syracuse salt formation of the Salina group in western New York. The beds, which are composed chiefly of salt, occur at variable depths and underlie an area of about 6,000 square miles, more than half of which is included in the region. No salt deposits have been found in eastern New York or New England.

3. The salt reserves of New York are in excess of any foreseeable demand. Continued prosperity for the New York industry is forecast by the rapid growth of chemical manufacturing. The increased demand will result in more extensive production from wells; this in turn will require more intensive technological research so that deposits at greater depths and of inferior grade can be mined economically. Data on salt presented in Table 73 and Plate 48 are indicative of the tremendous potential outlook for the industry in New York.

4. Salt is used chiefly in the manufacture of soda ash, chlorine, bleaches, and chlorates, and for livestock salt. Other major uses are in chemicals, meat packing, and water treatment, for table salt, and dust and ice control on highways and railroads.

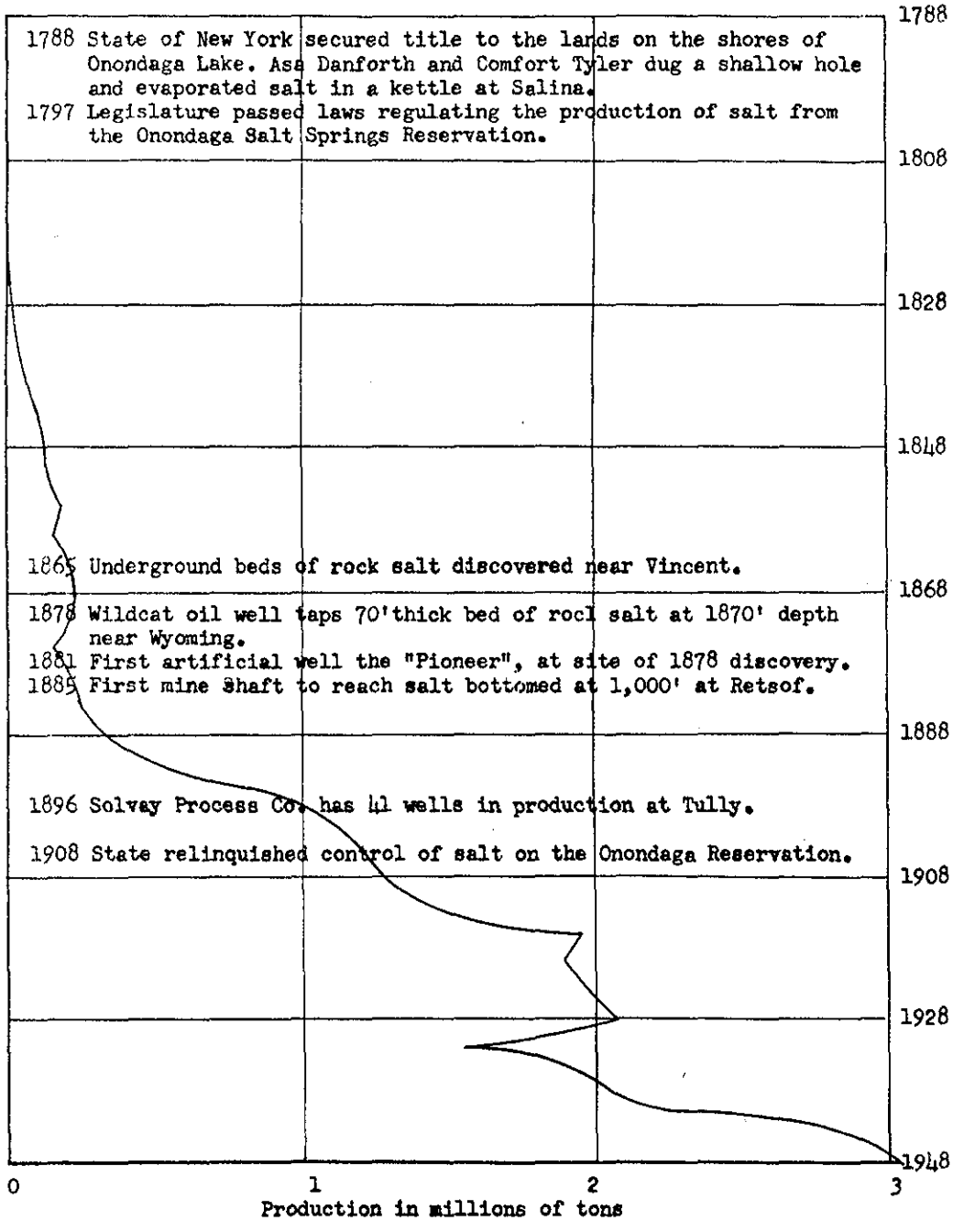
GEOLOGY

5. The salt beds of New York are in the Syracuse salt formation which occurs in a large basin of sediments of the Salina group that underlies

parts of New York, Pennsylvania, West Virginia, Ohio, Michigan, and Ontario. The deposits in New York are in the northeastern part of the basin of sediments as shown in Plate 49. In addition to the productive deposits in New York, other important salt beds occur in the Syracuse salt formation in Ohio, Michigan, and Ontario.

6. An extensive area underlain by salt beds has been fairly well defined in western New York by the logs of many salt, gas and oil wells. The northern limit of salt beds is usually less than 10 miles south of the outcrop of the Syracuse salt formation. The area underlain by salt deposits, referred to as the "salt area" in this discussion, is bounded on the west by Chautauqua, Cattaraugus, Erie, and Genesee Counties; and on the east by Madison, Chenango, and Broome Counties. More than one-half of the area and all of the productive deposits are included in the New England - New York Region, as shown in plate 50, which follows page 2.

7. The salt deposits in the Syracuse salt formation are beds composed chiefly of salt and occur as a series of individual flat-dipping bodies that vary in thickness, areal extent, and grade, but all have lenticular form with lateral dimensions greatly exceeding their thickness. Commonly, several salt beds occur in successive layers interbedded with shale or in echelon pattern in a cross section of the Syracuse salt formation. In general, one to four beds are present, but in some localities as many as 7 individual beds have been encountered. In the vicinity of the western and eastern boundaries of the "salt area" only one salt bed is usually present. The salt deposits are fairly well distributed in the Syracuse formation, although in many places they pinch out and are separated from other deposits by shale that contains relatively small



SPECIAL SUBJECTS—REGIONAL

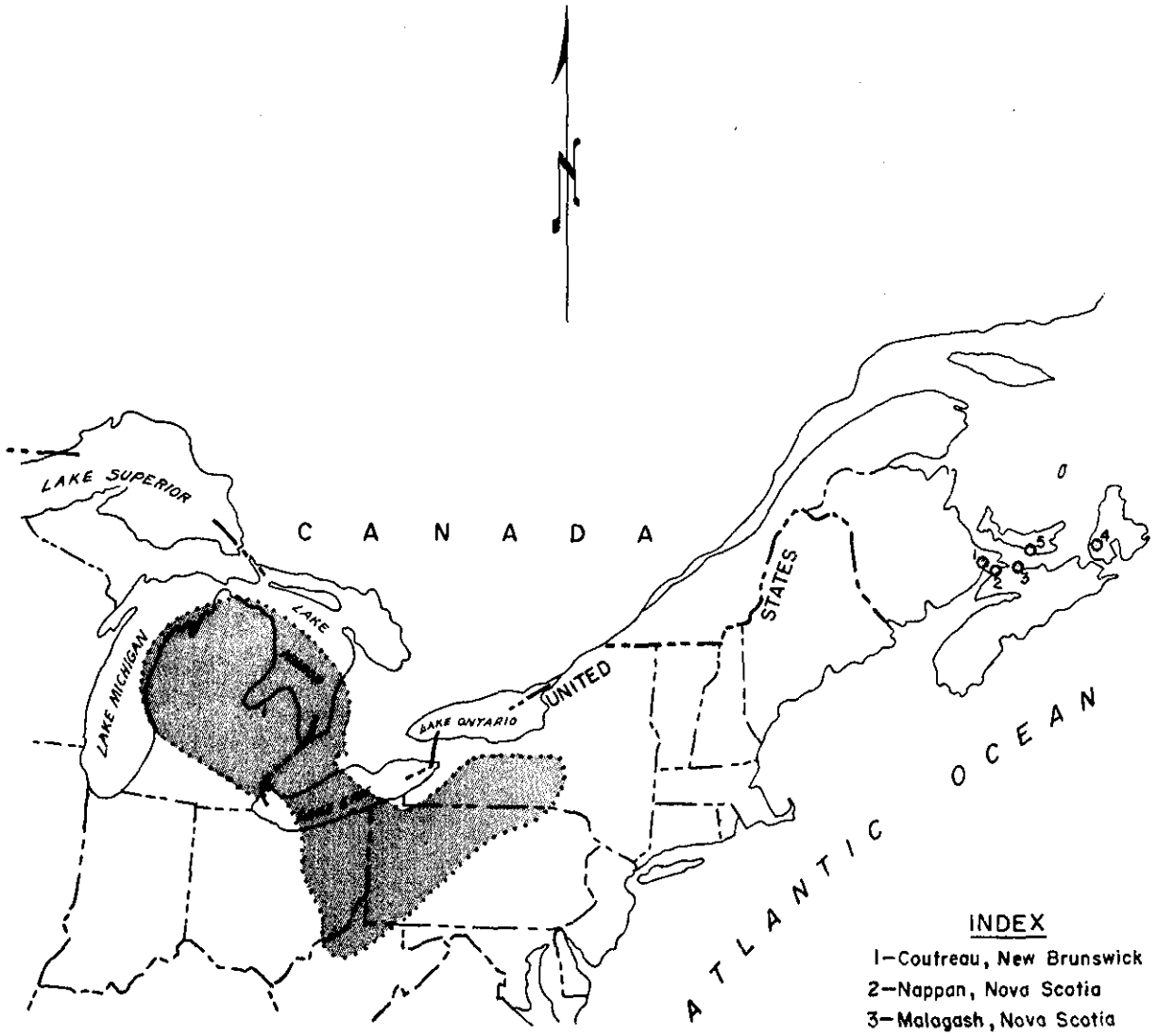
THE HISTORY OF SALT PRODUCTION IN THE STATE OF NEW YORK

New England-New York Inter-Agency Committee

JAN. 1954

USBM Boston Jan. 1954

PLATE 48
CHAPTER XXXIX



INDEX

1—Coutreau, New Brunswick
2—Nappan, Nova Scotia
3—Malagash, Nova Scotia
4—Mabou, Cape Breton Island
5—Hillsborough Bay, Prince Edward Island (salt in deep oil well.

SPECIAL SUBJECTS-REGIONAL

AREA UNDERLAIN BY SALT DEPOSITS
IN THE GREAT LAKES REGION
AND KNOWN SALT DEPOSITS
IN THE MARITIME PROVINCES

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

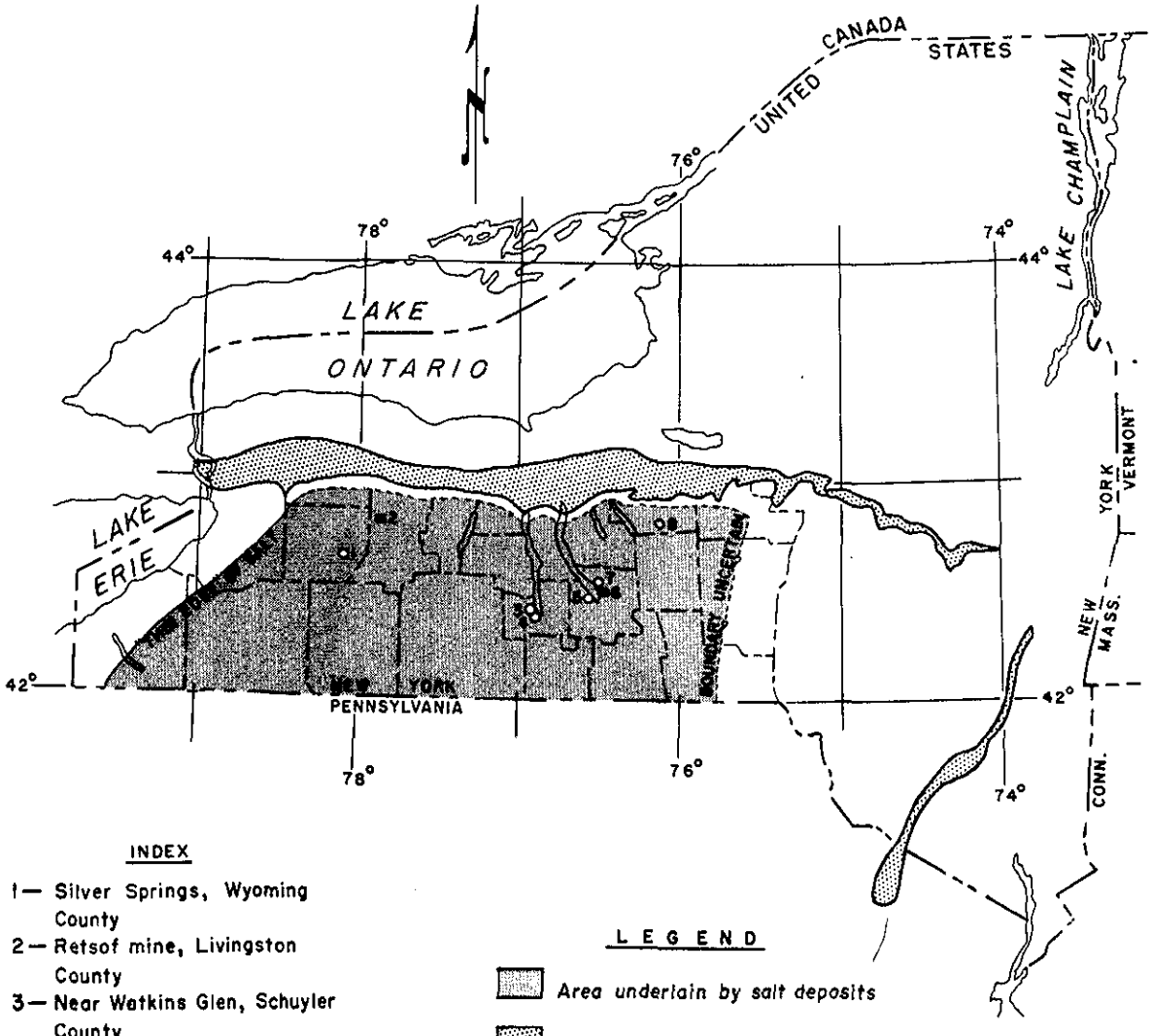
JULY 1954

SCALE IN MILES

0 75 150 225 300

U.S.G.S. BOSTON JULY 1954

PLATE 49
CHAPTER XXXIX



INDEX

1 — Silver Springs, Wyoming County
2 — Retsof mine, Livingston County
3 — Near Watkins Glen, Schuyler County
4 — Watkins Glen, Schuyler County
5 — Near Ithaca, Tompkins County
6 — Mine at Myers, Tompkins County
7 — Myers (Ludlowville), Tompkins County
8 — Near Tully, Onondaga County

LEGEND

Area underlain by salt deposits

Outcrop of Salina formation

Producing salt mines

Producing group of wells

SPECIAL SUBJECTS-REGIONAL

MAP OF AREA UNDERLAIN BY SALT DEPOSITS IN NEW YORK AND LOCATIONS OF PRODUCERS

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JULY 1954

SCALE IN MILES 0 20 40 60

U.S.G.S. BOSTON JULY 1954

PLATE 50
CHAPTER XXXIX

quantities of salt. Their attitude conforms to the regional southward dip of the Syracuse formation in the northern portion of the "salt area". In the southern portion of the area, south of a line extending through Belfast, Dansville, Penn Yan, and Cortland, the country rocks are gently folded and the deposits have been deformed by flowage in many places, particularly on the crests of anticlines.

8. Salt deposits do not crop out because the salt has been leached from the beds for variable distances down dip. The leached zone extends as much as 18 miles south of the outcrop of the Syracuse formation, near Syracuse, and several large salt springs occur above this zone.

9. The salt deposits dip southward about 45 feet to the mile in the northern part of the "salt area". The regional southward dip of the Syracuse salt formation and the higher elevations in the Allegheny Plateau in southern New York place the salt deposits more than 4,000 feet in depth along the southern border of the State 1/. The regional southward dip of this formation is complicated by folding in the southeastern part of the "salt area". In northern Tompkins County, salt deposits occur in the crests of anticlines where salt beds have been contorted by flowage in drag folds more or less parallel to the axes of the anticlines. Near Myers the salt bed ranges in thickness from 2 or 3 feet on the flanks of drag folds to 60 feet in the crests of the folds 2/.

10. The rock salt mined in New York is 96 to 98 percent sodium chloride. The remainder of the rock consists chiefly of calcium sulfate (anhydrite), magnesium sulfate, calcium chloride, magnesium chloride, and shaly, limy,

1/ Hartnagel, C. A., and Broughton, J. G., The Mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 91.

2/ Broughton, J. G., Personal Communication, 1952.

and carbonaceous material, which are commercially considered as impurities. The impurities constitute from 4 to 6 percent of the salt beds in the mines and are chiefly calcium and magnesium sulfates and chlorides. The Syracuse salt formation does not contain appreciable quantities of the other saline minerals that have commercial value, as for example, salts of potassium and iodine.

11. The analyses in Table 72 show the chemical composition of salt and bittern from several localities in New York.

Table 72 --Analyses of salt and bittern in New York

	Rock Salt			Bittern
Sample No.	1 1/	2 2/	3 1/	4 1/
Location	Silver Springs Wyoming County	Livingston County 3/	Myers, Tompkins County	Ithaca, Tompkins County
$NaCl$	98.383	98.35	85.62	67.750
$CaSO_4$	0.571	0.68		0.054
$CaCl_2$	0.465		4.44	22.675
$MgCl_2$	0.068		0.05	4.245
Na_2SO_4		0.48	4.01	
$MgSO_4$	0.085	0.49		0.142
KCl	0.082	trace	0.28	2.130
H_2O				1.906
Insoluble			5.30	
Totals	99.654	100.00	99.70	98.902

1/ Analyses from New York State Science Service, Albany, New York.

2/ Phalen, W. C., Industrial Minerals and Rocks: Am. Inst. Min. Met. Eng., 1949, p. 809

3/ Locality not given.

12. The principal impurities derived from artificial brines in New York are calcium sulfate, calcium chloride, and magnesium chloride as shown in Plate 51.

RESOURCES

13. The thickness of individual salt beds ranges from a few feet to 75 feet 1/. Available data on the aggregate thickness of the beds in that part of the "salt area" included in the region are limited chiefly to well logs in widely scattered places and are summarized as follows:

Counties	Range in aggregate thickness
Southeastern Erie, Wyoming, Livingston, Yates, Seneca, Cayuga, Onondaga, and Madison	6 - 154 feet
Northern Cattaraugus, Allegany, northeastern Steuben, Schuyler, and Tompkins	25 - 1010 feet

14. The extent and continuity of salt beds in the Syracuse formation is not well known in many parts of the "salt area", and published data on the size and grade of the salt deposits in the productive localities are not available. Because of the lack of factual information, estimates of the resources are little more than educated guesses.

15. Estimates of the total salt resources in New York range from hundreds of billions of tons 1/ to 1 to 10 trillion tons 2/. Allowing for the absence of salt beds in some parts of the "salt area", the lower estimate is probably more realistic. The resources in the southern part

1/ Hartnagel, C. A., and Broughton, J. G., The Mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 91.

2/ The Mineral Resources of the United States: U. S. Bureau of Mines and U. S. Geological Survey, Public Affairs Press, 1948, p. 180.

of the "salt area" included in the region are at too great a depth for economic development at present, except in the crests of anticlines where the salt beds are relatively close to the surface.

The annual world production of salt averages more than 40 million tons. Assuming a population of two billion people, world-wide salt per capita consumption would be about 40 pounds. During the past decade, the production of salt in the United States has been more than 17 million tons annually, a per capita consumption of about 200 pounds, five times the estimated world average.

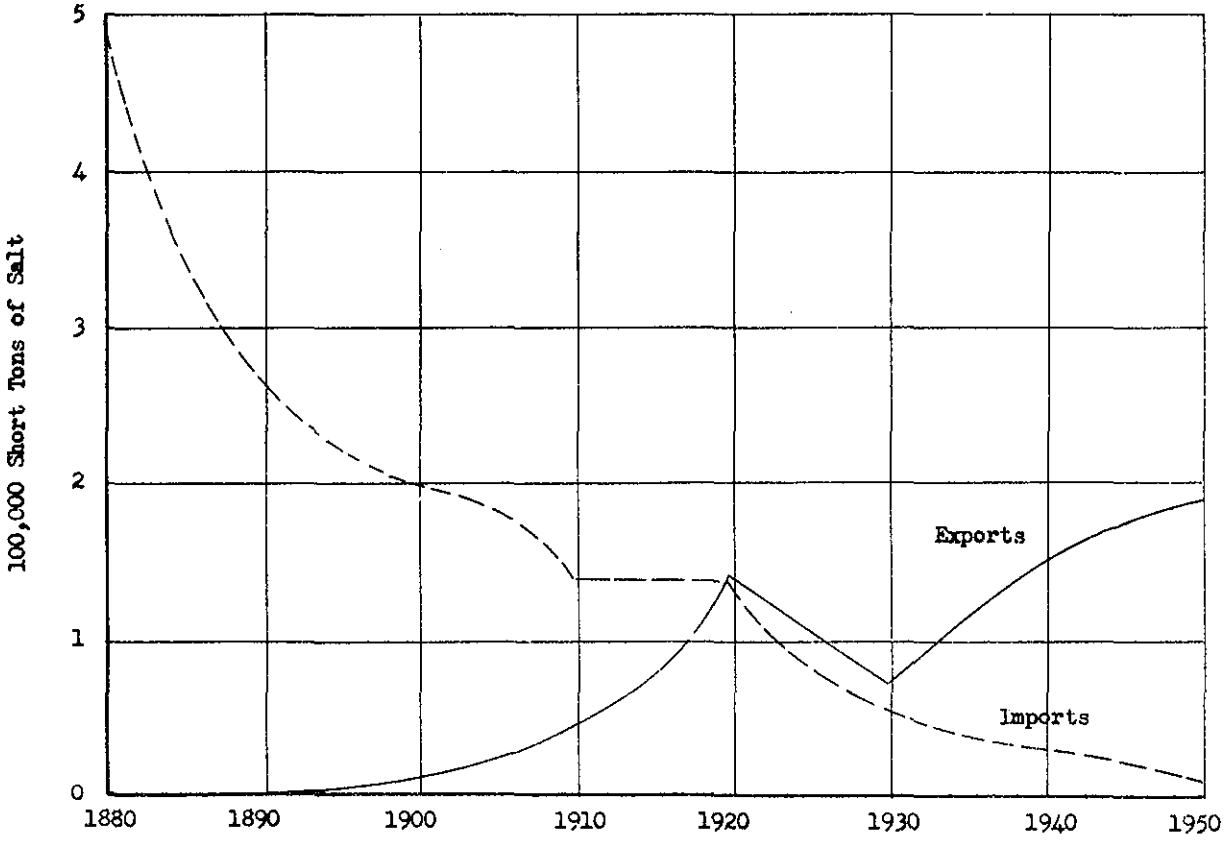
TECHNOLOGY

As a commercial source for salt, bedded sedimentary deposits are by far the most important. Such deposits provide approximately 94 percent of the salt used in the United States, 72 percent from wells drilled to the salt beds and 22 percent from underground mining operations. Salt is obtained from its sources: by wells producing artificial or natural brines; by surface or subsurface mining operations; or by evaporation of surface salt waters.

Wells are used where production is from:

Artificial brines	(1)	Where rock-salt beds are too deep to permit economical mining.
	(2)	Where the beds contain impurities that, if mined, would require removal before the salt is marketed.
Natural brines	(3)	Where the salt is already in solution and is found below the surface brines.

Production of salt from saline waters by solar evaporation was the primary method of recovery when the New York salt industry provided salt for most of the country from the salt springs and wells of the



SPECIAL SUBJECTS-REGIONAL

IMPORTS AND EXPORTS OF SALT, 1880 - 1950

New England-New York Inter-Agency Committee

JAN. 1954

USBM Boston Jan. 1954

PLATE 51
CHAPTER XXXIX

Onondaga Reservation. Today it is of importance only in those parts of the country where the climate is favorable: the western part of the United States, particularly California and Utah.

Processing 1/

20. The salt produced from wells is mainly sold or used as brine, the solution as pumped from the wells. This is the raw material from which chemical plants make soda ash and chlorine products. More than half the total production of salt in the United States is used in this way.

21. Approximately 20 percent of the salt produced from wells along with 10 percent of the mined rock salt and 30 percent of the salt produced by solar evaporation is processed by one of the following methods depending upon its ultimate use:

a. Vacuum pan process
b. Grainers and/or open pans

The product is termed evaporated salt, which is the salt most familiar to the average person, that is, table and other food salts.

22. Rock salt is the term applied to crude salt as mined. It requires only crushing and sizing before being marketed.

Economics

23. Salt is one of the least expensive of the raw materials required by our industrial development 2/.

1/ For detailed information, the reader is referred to the following standard texts: Taggart, A. F., Handbook of Ore Dressing, John Wiley & Sons; Gaudin, A. M., Principles of Mineral Dressing, 1939, McGraw-Hill.

2/ The value of salt f.o.b. mines or producing plants in New York State in 1939 was $2.78 per net ton, while in 1949 it was $4.42, an increase to 159 on a commodity index basis 8/. The commodity index for the entire domestic salt industry as a whole was 129. The commodity index for all raw materials in 1949, as compared with 1939, was 233 9/.

Table 73--Salt sold or used by producers in the United States, 1939 and 1951, by states 1/

State	1939			1951		
	Quantity		Value	Quantity		Value
	Short tons	Percent of total		Short tons	Percent of total	
California	404,689	4	$ 1,980,777	1,275,574	7	$ 5,261,780
Kansas	641,752	7	2,591,934	900,917	5	6,639,343
Louisiana	1,072,540	12	2,830,331	2,737,149	13	7,662,179
Michigan	2,408,872	26	6,726,912	5,137,639	25	21,221,330
NEW YORK	2,041,492	22	5,855,422	3,518,715	17	16,552,890
Ohio	1,794,788	19	2,647,355	3,112,472	15	5,848,478
Puerto Rico	13,325	2/	57,707	10,566	2/	119,338
Texas	352,008	4	604,633	2,401,063	12	4,000,100
Utah	68,100	2/	202,244	131,444	1	570,379
West Virginia	144,727	2	773,988	379,299	2	1,314,818
Other States 3/	335,618	3	238,377	602,293	3	544,365
Total	9,277,911	100	$24,509,680	20,207,131	100	$69,735,000

1/ Mineral Market Report MMS. No. 2098: U. S. Bureau of Mines, 1952, p. 2.
Minerals Yearbook, Salt: U. S. Bureau of Mines Annual, 1939, p. 1423.

2. Less than 1 percent.
3. Includes Nevada, New Mexico, Oklahoma, Virginia and Colorado (1939).

24. Shipping distance and freight costs are the primary factors in the economic development or expansion of a salt producing area. Because of the initial low cost of salt at the point of production in relation to the cost of shipping the product to the consumer, each producing area has what is termed its own natural self-marketing territory 1/. Inter- or intra-territory competition is limited to those grades of salt that are overproduced. Salt producers must have a continually strong market since evaporated salt and salt making equipment have a rapid rate of deterioration. It is often better to sell salt at a loss and to continue production than it is to shut down an operation 2/.

Exports and imports

25. The technological advances in the mining and refining of salt in the United States have resulted in the production of an inexpensive, high-quality product. Efficient and low-cost methods of production, aided by import duties 3/, have enabled the domestic producers to dominate the salt market in this country, and to enable them to export salt to those countries not blessed with climate and natural conditions for low-cost production of salt by solar evaporation methods. Small tonnages are imported from Canada and Jamaica to consumers who are located close to the industrial boundary and the eastern seaboard.

1/ Salt Producers Association, September 1933.

2/ Phalen, W. C., Technology of Salt Making in the United States: U. S. Bureau of Mines Bull. 146, November 1917, p. 118.

3/ The various import duties for salt that is imported under tariff restrictions are:

1 ton	Duty
Salt in containers	11¢ per pound
Salt in bulk	7¢ per pound
Salt in bond*	0

*This represents that salt used to cure: fish on the shore of navigable waters of the U.S., fish taken by vessels licensed to engage in the fisheries; or meat that is to be exported.

26. The graph shown on Plate 52 illustrates the trend in export and import trade in salt since the year 1880.

NEW YORK STATE SALT INDUSTRY

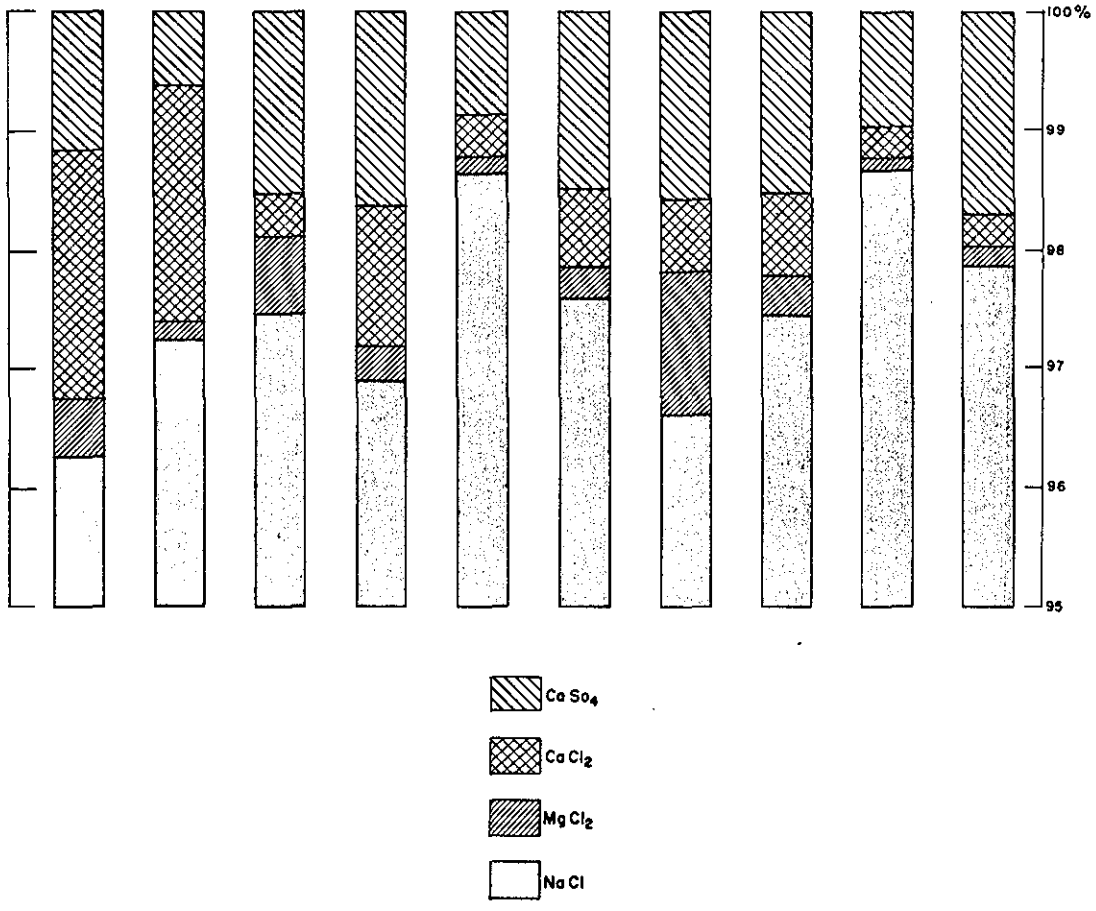
History

27. In the early part of the 17th century, Jesuit missionaries reported Indians making salt from saline springs around Onondaga Lake. In 1788, the State of New York secured title to the lands on the shores of Onondaga Lake "for the common benefit of the people of the State of New York and the Onondagas for the purpose of making salt". In that year salt production was begun at Salina by dipping salt brine out of shallow holes and evaporating the brine in kettles.

28. The State assumed control of the growing salt industry in 1797 when the legislature passed laws regulating the utilization of the brines on the Onondaga Salt Springs Reservation. Control was relinquished in 1908 at which time production in this area was decreasing rapidly.

29. In 1821, solar evaporation of the surface salt brines was begun near Syracuse. Underground beds of rock salt were discovered in 1865, but the exploitation of these beds did not begin until 1888. Production of salt in New York from 1797 through 1949 has amounted to approximately 113,840,000 tons.

30. In the early 1900's there were 30 companies producing salt in New York. Overproduction, poor marketing practices, price cutting, and large foreign imports, resulted in unstable conditions in the evaporated salt industry. The abandonment of the less favorably situated enterprises, plus market development, and economical production has stabilized the industry. This is evidenced by the strength of the New



Modified from figure 5 of "Salt report for the B&O area". Courtesy of the Baltimore and Ohio Railroad Company.

SPECIAL SUBJECTS - REGIONAL

IMPURITES IN DRY SALTS DERIVED FROM ARTIFICIAL BRINES FROM WELLS IN GENESEE AND WYOMING COUNTIES

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JULY 1954

U.S.G.S. BOSTON JULY 1954

PLATE 52

CHAPTER XXXIX

Table 74 -Some selected economic data concerning salt production from artificial and natural brines in 1939 and 1947, for New York as compared with the industry as a whole 1 /

	United States			New York State		
	1939	1947	Percent change	1939	1947	Percent change
Number of establishments	40	38	- 5	4	6	+ 50
Persons employed	4555	4809	+ 6	728	917	+ 26
Salaries and wages	$ 5,928,000	$12,762,000	+115	$ 900,000	$2,279,000	+153
Value of product shipped	$27,530,000	$46,056,000	+ 67	$4,663,000	$7,308,000	+ 56
Value added by manufacture	$17,961,000	$25,197,000	+ 40	$2,957,000	$4,060,000	+ 37

1/ 16th Census of the U. S., Manufacturers 1939: U. S. Bureau of Census, vol. II, Pt. 1, 1940, p. 816.
17th Census of the U. S., Manufacturers 1947: U. S. Bureau of Census, vol. II, Pt. 1, 1949.

York salt industry during the 1930's and its ability to meet present high demands.

31. The salt industry represents a minor segment of the economy of New York in terms of persons employed and value of the product. By accounting for the value of the products made from or dependent upon this salt within New York and the New England States, the production of New York salt becomes a factor of considerable economic importance to this area.

32. An expansion of the salt industry may be expected as the chemical industry continues its remarkable growth and importance in the United States. It may be expected that New York will have an increased percentage of total production because of its large reserves of high-grade salt and their proximity to the eastern industrial region.

Current Production

33. The annual production of salt in New York is approximately 3½ million tons. This entire production came from underground deposits of rock salt. At the present time, there are five companies producing salt from these deposits. These companies, their locations, production methods, and products are: given below.

34. International Salt Company, Inc., has artificial brine wells at Watkins Glen in Schuyler County and at Myers in Tompkins County. In addition, it mines rock salt at Retsof in Livingston County.

35. All production at the Retsof mine is from a 20-foot-thick salt bed over 1,000 feet below the surface. This salt as mined contains 99 percent sodium chloride. Over 200 persons are employed at this mine which produces 4 to 5 thousand tons of rock salt per shift.

36. Allied Chemical & Dye Company is the only producer of salt in brine in New York, and one of the major producers of this salt in the United States. Their wells at Tully, Onondaga County, supply brine through pipelines (17 miles) to the Solvay process plant at Solvay. This plant produces a considerable portion of the Nation's needs for: soda ash (Na_2CO_3) and its derivatives, washing soda $Na_2CO_3 \cdot 10H_2O$, $Na_2CO_3 \cdot 7H_2O$, and $Na2CO_3 \cdot H_2O$); acid sodium carbonate (bicarbonate, $NaHCO_3$) and its derivatives, caustic soda (NaOH) and baking powders of various acidic parts; and chlorine and chlorine products.

37. The Watkins Salt Company has wells for the production of evaporated salt at Watkins Glen, Schuyler County.

38. Worcester Salt Company has wells for the production of evaporated salt at Silver Springs in Wyoming County.

39. Cayuga Rock Salt Company, Inc., mines rock salt at Portland Point along the eastern shore of Cayuga Lake in Tompkins County.

40. The main shaft at the mine is approximately 2,000 feet deep, cutting several beds of salt. Mining operations are in a 58-foot bed that is approximately 1,900 feet below the surface. The arithmetical average composite analysis of this salt indicates that it contains 97.3 percent sodium chloride.

Marketing

41. The market area for New York State salt production is the New England States, New York, New Jersey, Delaware, Maryland, District of Columbia, Pennslyvania (except Star Points), and Accomac and Northampton Counties, Virginia. The market area is solely dependent upon the salt produced in New York, except for a small tonnage produced elsewhere, as shown in table 75.

42. The most outstanding feature of the information shown in the table below is that the increase in consumption within the New York salt marketing territory is due to the increased use of rock salt. In New England, rock salt is used chiefly because of its lower price and for its suitability in the paper, fish-curing, tanning, textile, soap, and dairy cattle industries which are of major importance to the New England economy.

43. The manufacture of chemicals from salt consumes approximately 70 percent of the total salt sold or used by producers in the United States.

Table 75 Primary shipments* of evaporated and rock salt to states within the marketing area of New York State producers, 1939, 1949, by States of destination, in approximate short tons 1/

Destination	1939 Evaporated	1939 Rock	1949 Evaporated	1949 Rock
New England				
Connecticut	13,200	4,900	13,400	14,900
Maine	8,200	20,800	11,700	60,600
Massachusetts	52,400	34,900	54,400	70,200
New Hampshire	5,300	30,400	4,600	58,900
Rhode Island	8,600	7,300	8,800	11,400
Vermont	5,800	5,800	6,400	24,900
New York	183,200	316,300	194,200	511,300
New Jersey	74,800	124,300	101,500	139,200
Delaware	2,600	29,300	5,900	12,600
Maryland	26,500	21,000	36,200	60,300
District of Columbia	4,600	1,200	5,400	2,100
Pennsylvania & Virginia	125,000	82,000	129,000	108,000
Totals	510,200	678,200	571,500	1,069,400
N. Y. State Production 2/	365,900		417,500	
Foreign Imports	7,000		1,500	50
Tonnage from other States 3/	137,300		152,500	
United States	2,658,600	2,035,200	3,284,400	3,468,000

1/ Minerals Yearbook, Salt: U. S. Bureau of Mines Annual, 1948-1949, 1939.

2/ Production data for rock salt is not available.
3/ Estimated.

* Primary shipments of evaporated and rock salt are the only available measure of consumption. Data on salt in brine has been omitted. Salt in brine accounts for more than ½ of the country's salt production but is used principally by the soda ash industry and does not figure in New England's salt consumption.

Table 76 -Salt sold or used by producers in the U. S. by method of recovery

Method or recovery	1939 1/		1949 1/		Percent change in value
	Short tons	Value per ton 2/	Short tons	Value per ton 2/	
		(Dollars)		(Dollars)	
Evaporated:					
Bulk:					
Open pans or grainers	499,331	8.46	504,771	13.78	+ 63
Vacuum pans	1,615,838	5.84	1,744,569	9.72	+ 66
Solar	391,287	3.59	766,183	3.68	+ 3
Pressed blocks	152,121	7.47	268,838	12.02	+ 61
Rock:					
Bulk	1,995,915	3.12	3,404,791	4.64	+ 49
Pressed blocks	39,242	6.71	63,214	9.46	+ 41
Salt in brine:	4,584,177	0.40	8,838,331	0.87	+118
Total	9,277,911	2.64	15,590,697	3.47	+ 31

1/ Minerals Yearbook, Salt: U. S. Bureau of Mines Annual, 1939, p. 1423; 1949, p. 1054.

2/ Estimated average value f.o.b net ton mine or refinery.

SELECTED BIBLIOGRAPHY ON SALT

1. ALLING, H. L. Geology and Origin of the Silurian Salt of New York State. New York State Mus. Bull. 275, 1928, 139 pp.

2. _____. Baltimore & Ohio Railroad, Salt Report for the B. & O. Area; 56 pp.

3. COLE, L. H. The Salt Industry of Canada. Canada Dept. Mines, Mines Branch, No. 716, 1930, 116 pp.

4. GAUDIN, A. M. Principles of Mineral Dressing. McGraw-Hill, 1939.

5. HARRIS, F. E. Marketing of Salt. U. S. Bureau of Mines Inf. Circ. 7062, April 1939.

6. HARTNAGEL, C. A., and BROUGHTON, J. G. The Mining and Quarrying Industries of New York State, 1937 to 1948. New York State Mus. Bull. 343, 1951, pp. 88-94.

7. KINDLE, E. M. Salt and Other Resources of the Watkins Glen District, New York. U. S. Geol. Survey Bull. 260, 1905, pp. 567-572.

8. LADOO, R. B., and MYERS, W. M. Nonmetallic Minerals. McGraw-Hill, 2nd ed., 1951, pp. 436-453.

9. LUTHER, D. D. The Brine Springs and Salt Wells of the State of New York and the Geology of the Salt District. New York State Mus., 50th Ann. Rept., vol. 2, 1899, pp. 171-226.

10. MERRILL, F. J. H. Salt and Gypsum Industries of New York. New York State Mus. Bull., vol. 3, No. 11, 1893, 89 pp.

11. _____. Minerals Yearbooks, 1933-1950. U. S. Bureau of Mines.

12. _____. Monthly Labor Review. U. S. Dept. Labor, Bureau of Statistics, vol. 70, No. 2, February 1950.

13. NEWLAND, D. H. The Mineral Resources of the State of New York. New York State Mus. Bull. 223-224, 1919, 315 pp.

14. PETERSON, R. B. The Mineral Industries of New York State. New York State Dept. Commerce, 1950, pp. 54-60.

15. PHALEN, W. C. Technology of Salt Making in the United States. U. S. Bureau of Mines Bull. 146, November 1917.

16. PHALEN, W. C. Salt Resources of the United States. U. S. Geol. Survey Bull. 669, 1919, 284 pp.

17. PHALEN, W. C. The Marketing of Salt. Eng. and Min. Jour., Jan. 27, 1923, pp. 185-190.

18. PHALEN, W. C. Industrial Minerals and Rocks. Am. Inst. Min. Met. Eng., 1949, pp. 807-843.

19. _____. Salt Producers Association, September 1933.

20. _____. 16th Census of the United States, Manufacturers 1939. U. S. Bureau of Census, vol. II, pt. 1, 1940, p. 816.

21. _____. 17th Census of the United States, Manufacturers 1947. U. S. Bureau of Census, vol. II, pt. 1, 1949.

22. TAGGART, A. F. Handbook of Mineral Dressing. John Wiley & Sons.

23. _____. The Mineral Resources of the United States. U. S. Bureau of Mines and U. S. Geological Survey, Public Affairs Press, 1948, pp. 179-180.

24. TRUMP, E. N. Mining Soluble Salines by Wells. Am. Inst. Min. Met. Eng., Min. Tech., vol. 8, No. 3, 1944.

SECTION XXVII - SAND AND GRAVEL IN THE NEW ENGLAND-NEW YORK REGION

1. Introduction. - Sand and gravel are extremely common, bulky materials of low unit value. However, they are mineral resources of major importance to the economic development of this country and to the New York-New England Region. This section encompasses the industry as a whole, with specific interest directed toward the industry in New York and in the New England states.

2. Future possibilities. - The industry in New England and New York is composed of many small plants producing one or two grades of marketable material. There are few large, heavily equipped plants in the region, possibly because of the enormous reserves of material so readily available and because the capital required for large-scale plant and excavation equipment ranges from $1.50 to $2.70 per ton of annual capacity.

3. There are several metropolitan areas in the region that do not have good deposits nearby. At many of these places, a well-equipped plant producing a marketable product from low quality sand and gravel beds might have been economic in the decade following World War II.

4. Such a plant might find an additional market in Massachusetts, Rhode Island, and Connecticut where there is an increasing demand for molding and glass sands. This demand is presently met by the purchase of sand from New Jersey, West Virginia, Pennsylvania, Illinois, and a small sugary quartz deposit at Stonington, Connecticut. As this sand costs from $8 to $12 a ton delivered, a potential producer in the region has much reason to investigate the possibilities; there is no evidence that this has been done.

5. The preparation of a sand to meet the specifications of the glass container industry could be of great economic value to the New England region. Most of the glass containers used in the region come from Bridgeton, New Jersey, and Clarion, Pennsylvania. The cost of shipping these containers to Boston is 52¢ to 68¢ per hundredweight, which is approximately one-third the cost of the fuel and raw materials consumed in their manufacture.

6. Classifications. - A commercial sand comprises the fine granular material, usually less than ¼ inch in diameter (ASTM Designation C58-28), and gravel consists of the coarse, granular material larger than sand (ASTM Designation C125-46T). Sand is sold or used under a variety of names. A list of some trade classifications 1/ follows:

> Asphalt sand designates a clean silicious sand of medium grade and sharpness used for mixing in the body and making the face of asphalt pavement and paving blocks.
>
> Bedding sand is a fine, clean sand that is scattered over the floor of cattle cars.
>
> Blast sand is a clean, tough, sized silica sand, either with round or angular grains. It is used by means such as compressed air to clean metal castings, to dress stone, etc.
>
> Brass sand is used in making molds for casting aluminum, brass, and bronze on which a very smooth surface is desired. It has a strong bond, but is so fine-grained that its permeability is slight and care has to be taken to avoid "blowing".
>
> Building sand should be silicious, clean, free from salts, as sharp as can be obtained at a reasonable cost, and dry;

1/ Stone, R. W., Sand and Gravel, Mineral Resources of the United States: Geol. Survey Annual 1912, p. 630, with modifications.

it should not contain more than 10 percent by weight of clay or loamy material; should pass a #10 sieve and 80 percent should be retained on a #74 sieve. It is used to make mortar and concrete and sand-lime brick.

Burnishing sand is a fine-grained, tough, clean, silica sand, with the grains as nearly round as possible; the size should be uniform, passing through a 65-mesh screen and retained on a 100-mesh screen. It is used in rolling down and burnishing gold decorations of chinaware and porcelain.

Core sand is a coarse molding sand used to make a solid form, usually porous, to be placed in a mold, about which the metal is poured, so as to be cast hollow. Permeability is the special quality required.

Engine sand is used on locomotives and streetcars to keep the wheels from slipping on wet or slick rails. The principal requirements are that the sand be of hard minerals, preferably quartz-sharp, clean, dry, and fairly fine and even-grained, so that it will be free running.

Facing sand is a molding sand used to make the face of the mold when such is of different sand than the body.

Filler sand is used as an inert filler in certain types of prepared fertilizer and as topping on certain types of roll roofing. Any fine-grained clean sand may be used.

Filter sand is clean silica sand in sorted sizes, used for beds in water-filtration plants and in small mechanical filters. It must be free from lime, clay and organic matter.

Fire sand is a highly refractory silica sand used with a binder for lining furnaces and ladles used to contain molten metal.

French sand is a very fine, open, sharp, yellow sand imported from France for making molds for statuary, brass, and bronze work.

Furnace sand is a highly refractory silica sand used for lining and patching reverberatory and other furnaces, cupolas, and ladles used to contain molten metal. Since pure silica sand is noncohesive, some binder is added to give bond. Furnace sand is also useful for making runners for pig-iron casting.

Glass sand is the major constituent of glass, constituting from 52 to 65 percent of the original mixture. Since the

quality of the glass depends largely on the quality of the sand, high-grade glass sands are over 90 percent SiO_2. High iron content often results in rejection; maximum Fe_2O_3 ranges from 0.02 percent for first quality to 1.0 percent for ninth quality. Glass sand should be nearly white in color, of medium fineness (passing a 20 to 50-mesh horizontal sieve); the grains should be uniform in size, even, and angular; or, less preferably, they may be rounded. There are no known commercial glass sands in New York or New England.

Grinding and polishing sands are sharp, tough, hard sands free from clay or foreign material and sized, for use in sawing, cutting, and polishing stone and for grinding and etching glass. The size of the sand varies with the character of the material to be worked on and the kind of work to be done.

Molding sands are silicious, sandy materials used in foundries for making molds and cores for casting metal. They vary from loamy clay to clean silica sand or gravel, the character of the material used depending on the kind of metal to be poured, the size of the casting, the surface desired, and the place in the mold where the sand is to be used. Molding sands should be high in silica to be sufficiently refractory, should have a strong bond when moist, and should have less than 1 percent of iron oxide. Some molding sands lack bond and are tempered by the addition of a small amount of clay or other binding material.

Mortar sand is building sand used particularly for making mortar.

Parting sand is a noncohesive sand with which the meeting faces of a mold are dusted to prevent their sticking together and with which brick molds are dusted to aid in separating the form from the mold. It is a fine sand free from clay.

Paving sand is a designation applied to sand used in various ways in road and walk making. It is used for the cushion foundation for brick pavement, as the body and facing of asphalt paving, as part of the composition of concrete and cement walks, etc. The requirement for this type of sand is principally convenient location unless otherwise specified.

Railroad-ballast sand and gravel have usually but one requirement, bulk, although coherence is a desirable quality.

210

Silica sand is composed largely of quartz and is obtained from banks of unconsolidated material and by crushing sandstone. Its uses include, among many: making glass, silica brick, molding metal, filters, facing concrete and asphalt, as an abrasive, firebrick, and scouring soap.

Silver sand is an English term for a fairly pure, fine, white sand used mainly for scouring and making soil more light and porous.

Standard sand is a clean, even-grained, uniform, high-grade silica sand used as a laboratory standard in physical tests of other sands for cement. In the United States, sand from Ottawa, Ill., is used for this purpose.

Steel sand is a molding sand used for casting. A high degree of refractoriness is required; and, therefore, a white, clean, quartz sand about 99-1/2 percent silica is used. Silicious clay, molasses, or other material is added as a binder.

Other uses to which sand is put are for chicken grit, pebble dash, sanding woodwork, and sand-lime brick.

7. Gravel is used principally as railroad ballast and as an aggregate in concrete. Local regulations and consumer specifications determine sizes and compositions utilized.

CONSUMPTION AND DEVELOPMENT

8. Consumption and production in 1949 are compared with 1939 in Table 77. There was a major decline by government and contractor operations in the building fields. Privately owned plants produced a much greater proportion for the 1949 total demand than they did for 1939, including production for road building uses. The increase in total consumption of sand and gravel is in line with increases in consumption of all construction materials over that period. Most important, the price increase was not commensurate.

9. It is to be recognized that sand or gravel from a single deposit could be sold for varied uses: for filter beds, building or mortar sand and core sand.

Table 77--Sand and gravel sold or used by producers in the United States, 1939 and 1949, by use 2/

	1939		1949			
	1000 Short Tons	Average Value Per Ton	1000 Short Tons	Average Value Per Ton	Percent of change in Tonnage	Percent of change in Average Value Per Ton
Commercial operations						
Sand:						
Glass	2,468	$1.73	4,339	$2.48	+ 76	+ 43
Molding	3,728	1.08	6,114	1.66	+ 64	+ 54
Building	26,406	.54	59,307	.81	+125	+ 50
Paving	19,468	.52	31,520	.82	+ 62	+ 58
Grinding, polishing, and blast	668	1.34	1,081	1.91	+ 62	+ 43
Fire or furnace	172	1.15	318	1.35	+ 85	+ 17
Engine	1,470	.58	1,884	.97	+ 28	+ 67
Filter	173	1.13	189	1.99	+ 9	+ 76
Railroad ballast	1,259	.26	956	.43	- 24	+ 65
Other	1,780	.79	2,300	.85	+ 29	+ 8
Gravel:						
Building	21,107	.65	49,788	.99	+136	+ 52
Paving	27,387	.61	60,571	.87	+121	+ 43
Railroad ballast	9,972	.31	10,444	.54	+ 5	+ 74
Other [1]	2,314	.40	2,393	.72	+ 3	+ 80

Table 77 (Continued)

	1939		1949			
	1000 Short Tons	Average Value Per Ton	1000 Short Tons	Average Value Per Ton	Percent of change in Tonnage	Percent of change in Average Value Per Ton
Government and contractor operations [2]						
Sand:						
Building	4,184	.37	1,604	.60	- 62	+ 62
Paving	5,282	.27	7,424	.38	+ 41	+ 41
Gravel:						
Building	9,819	.50	3,133	.71	- 68	+ 42
Paving	57,141	.28	75,738	.41	+ 33	+ 46
Total operations						
Sand	67,078	.59	117,036	.90	+ 74	+ 53
Gravel	127,740	.44	202,068	.71	+ 58	+ 61
Grand total	194,819	.49	319,104	.78	+ 64	+ 59
Grand total value	$95,224,047		$248,443,000		+161	

1. Includes sand or gravel used by railroads for fills and similar purposes.
2.. By states, counties, municipalities, and other Government agencies directly or under lease.

2/ Minerals Yearbook: Bureau of Mines, 1940, p. 1206; 1949, p. 1069. "Percent of change in-" by author's estimate.

10. Consumption by uses in New England and New York in 1949 is shown in Table 78. Several interesting facets of the industry are made apparent: the cost per ton is considerably greater in Rhode Island than in any other state shown; despite large consumption and production, commercial sand and gravel in New York is relatively expensive. These will be discussed in greater detail in the discussion of the resources and economics of the industry.

11. Table 79 provides miscellaneous data with respect to the industry in the New England states and in New York. Production, as compared with the rest of the country, is not as great as the population or financial status of the region might indicate. The increased development of highways, dams, and buildings in the western and southeastern sections of the United States has resulted in the comparative production decline for the New England-New York Region.

12. Tons produced per man shift are greater in New England and New York than the average for the country. This is a reflection of the high efficiency and productive capacity of the plants in this region.

13. The high rate of efficiency appears to have had little effect on the cost of sand and gravel in New York. The industry as a whole should be credited for maintaining a low unit price while most other building material prices have soared. The low average value per ton for New England sand and gravel may be attributed to the large noncommercial production in Maine, Vermont, and New Hampshire.

Table 78 - Sand and gravel sold or used by producers, 1949 3/

New England-New York Region

(1000 short tons at $ ----- per ton)

	Conn.	Me.	Mass.	N. H.	R. I.	Vt.	New York
Sand:							
Glass	none	none	none	none	none	none	none
Molding	none	none	A	none	A	none	359@2.04
Building							
Commercial	641@ .75	42@.46	1746@ .78	A	98@ .94	32@ .61	7388@ .76
Govt.-Contract	682@ .07	2@.19	½@ .37	none	none	4@1.36	91@ .97
Paving							
Commercial	330@ .71	69@.50	611@ .73	A	81@ .75	23@ .61	2099@ .86
Govt.-Contract	16@ .18	150@.32	75@ .48	352@ .12	29@ .72	225@ .24	354@ .17
Grinding, polishing, and blast	none	none	A	none	none	A	none
Fire or furnace	none	none	18@ .61	none	A	none	A
Engine	none	none	27@ .67	A	none	2@ .79	A
Filter	A	none	A	none	none	none	54@ .67
Railroad Ballast	none	none	none	none	none	none	38@ .45
Other	28@ .44	A	38@ .65	none	2@ .61	13@ .69	111@ .60
Gravel:							
Building							
Commercial	491@1.02	57@.79	1638@1.01	A	66@1.03	A	3186@1.10
Govt.-Contract	none	none	2@ .20	none	none	25@ .31	326@ .55
Paving							
Commercial	311@ .82	162@.74	758@ .81	66@1.32	34@1.02	87@ .97	2690@ .93
Govt.-Contract	104@ .33	3954@.27	484@ .15	1649@ .12	66@ .97	1108@ .45	1698@ .23
Railroad Ballast	A	A	A	none	none	none	A
Other	28@ .34	4@.38	A	18@1.00	A	A	65@ .72
Sand and gravel:							
Total Commercial	1847@ .81	499@.60	4944@ .86	A	303@ .97	219@ .74	16074@ .90
Total Government-and-Contractor	801@ .11	4106@.27	561@ .20	2001@.12	95@ .89	1362@ .41	2469@ .29

A. Confidential information.

3/ Minerals Yearbook: Bureau of Mines, 1949, p. 1070-1075.

Table 79 -Comparative data of the sand and gravel industry 4/
New England-New York Region

Item	1935	1938	1942	1946	1949
Percent of total production (U. S. = 100%)					
New England	5.6	6.9	4.3	4.8	5.4
New York 2/	8.7	7.5	5.4	4.8	5.8
Percent of average number of employees 1/ (U. S. = 100%)					
New England	2.1	3.2	3.6	3.9	4.0
New York 2/	10.4	8.8	5.9	5.3	5.3
Efficiency Index based on tons produced per man-shift (8.6 hours) 1 (U. S. = 100%)					
New England	94	148	141	122	111
New York 2/	116	113	119	100	111
Index of average value per ton (U. S. = 100%)					
New England	50	62	79	73	68
New York 2/	104	102	118	110	105

1/ Excluding sand and gravel produced by contractors and government agencies.

2/ Includes entire State of New York.

4/ Author's calculations based on data in Minerals Yearbook: Bur. of Mines, 1937, 1939, 1942, 1946, 1949.

TECHNOLOGY

14. Sand and gravel technology is intimately tied to the economics of the industry. Workable deposits may be found in every state. Finding sands of such a quality that they may be utilized for special purposes is most important to the New England-New York states.

15. Prospecting and exploitation should be based solely on the economic aspects involved. An examination of the production tables for the various states shows that the value per ton is extremely low in some as compared with others, and that increased production in certain areas will not be beneficial to the industry. The contrary is equally true.

16. Prospecting. - Prospecting for sand and gravel invloves the systematic examination of favorable areas, known excavations, and drill hole records. Most deposits have been previously noted by Federal and state geologists, contractors, railroad companies, and others, many of whom will gladly furnish advice and direction upon request.

17. Exploration. - After a potentially commercial deposit is located, it should be delineated in order to determine the thickness and lateral extent, the possible tonnage, and depth of overburden, and to obtain representative samples of the entire deposit. If the tonnage is sufficient to warrant erection of a plant, the material should be tested to determine if it will meet specifications with regard to soundness, crushing strength, absence of deleterious matter, alkali reactivity, and proper grading.

18. Development. - The method of operation and the choice of equipment employed are based on information obtained through prospecting and exploration; the capacity desired; the market to be served; capital available; and the availability and cost of labor, power, and water.

19. From the viewpoint of the producer, deposits of sand and gravel fall into three general classes 5/:

a. Bank deposits are level with or above the surrounding terrain.

b. Pit deposits:
   (1) Dry pit deposits are below ground level, but the excavation floor is above the level of the permanent ground water.

   (2) Wet pit deposits are below ground level, and the excavation floor is below the level of the ground water. Therefore, sand and gravel are removed below water.

c. Submerged deposits:
   (1) River deposits are sand and gravel beds, bars, or islands in a river. There are two types: one, where the material was laid down at an early stage in the evolution of the river, and which may be excavated only once because there is no upstream source to replenish the deposit; and two, where the river carries sand and gravel, refilling excavations.

   (2) and (3) Lake and ocean deposits are sand and gravel beds or beaches.

20. Removal of overburden. - In water and wet deposits there is either little overburden to cope with, or a major portion of the overburden can be segregated from the sand and gravel. In dry operations,

5/ Thoenen, J. R., Development of Sand and Gravel Deposits: Bur. of Mines Inf. Circ. 6689, 1933, p. 13, with modifications.

a general rule of thumb is that when the ratio between overburden and sand and gravel is small, it is economical to remove all together and separate at the washing plant. Overburden could be tested to determine if it has any commercial value, loam, and mineral content.

21. Equipment. - The type of excavating equipment used is dependent on whether the operation is wet or dry. All types of earth moving equipment may be used, such as power shovels, drag-line excavators, cableway and drag scrapers, dredges, clamshells, and hydraulic hose, depending on the size of the deposit and extent of the operation.

22. Methods. - The removal of large quantities of unconsolidated material at the lowest possible cost determines the methods used.

23. In many New England ocean-or bay-side pits there is the problem of salt films. The sand must be thoroughly washed with fresh water if it is to be acceptable for most purposes. In other water deposits special precautions must be taken to avoid deposition of silt and debris in the workings by controlling the incoming current above the operation.

24. Preparation. - Market specifications and the number and varieties of sizes demanded influence the selection of a deposit and affect the development of preparation procedures. A preparation plant must be economical and must substantially improve the product so as to meet the competitive demands of the market.

25. Sand and gravel from a small percentage of the deposits may be

sufficiently clean to be marketed without washing or preparation. In most cases, the material must be screened to meet size specifications and washed to remove clay, silt, and soil. Preparation plants producing considerable tonnages require many different types of equipment, such as screens, crushers, classifiers, and dewatering units.

26. The sand and gravel industry is composed of many small plants producing one or two grades from marketable deposits, but the bulk of the yearly production comes from large, heavily equipped plants. (See Table 80).

ECONOMICS OF THE SAND AND GRAVEL INDUSTRY

27. Totally aside from the technological problems besetting the sand and gravel industry, but of even greater importance, are the many economic problems involved. A property may have ideal operating conditions from a technical viewpoint, yet its distance or inaccessibility to a market may disqualify its development. A common sand and gravel deposit may be excellently located with respect to a market area, and yet may not be able to produce the types of sand and gravel that are desired by the specialized trades in that region.

28. The major economic factors governing the sand and gravel industry are pit and market locations. For example, a large bank and plant 50 to 60 miles south of Boston produces paving sand at 32 cents per ton; shipment to a road project in Boston by rail costs approximately $2.20 per ton, and alternate truck transport costs about $1.60 per ton. It is possible for small roadside pits within ten miles of the projects to produce a similar grade of sand for 91 cents per ton with a truck transportation cost of 25 cents per ton. The resultant saving of 74 cents

Table 80 -Sand and gravel preparation facilities in the United States, 1938 and 1949 6/

	1938	1949
Percent of production prepared at:		
Commercial operations	88	91
Government-and-contractor operations	18	28
Percent increase in value added by preparation at:		
Commercial operations	128	104
Government-and-contractor operations	113	296
Percent of total production by size of plants in tons [1]:		
Less than 25,000	10.2	4.1
25,000 to less than 50,000	13.3	6.8
50,000 to less than 100,000	20.6	14.2
100,000 to less than 200,000	22.0	21.0
200,000 to less than 300,000	9.3	15.8
300,000 to less than 400,000	5.7	8.0
400,000 to less than 500,000	4.4	7.5
500,000 to less than 600,000	5.8	3.9
600,000 to less than 700,000	0.6	1.7
700,000 to less than 800,000	2.1	3.7
800,000 to less than 900,000		2.6
900,000 to less than 1,000,000	4.3	1.3
1,000,000 and over	1.7	9.4
Total number of plants [1]	2113	2458

1. Commercial plants only.

6/ Minerals Yearbook: Bureau of Mines, 1939, p. 1174-1175; 1949, p. 1076-1078.

per ton allows the temporary development of small sites at the expense of an established, well-equipped plant. The control of the area in which these are located enables the owner-contractor to successfully underbid any competitors.

29. The next major economic factor affecting the industry is the degree of production in the local area. There might be a condition of market saturation, or there may be a marked deficiency in production as compared with consumption. Overproduction of any commodity causes a lowering of price levels. If these were unwarrantably high, the local population benefits by the addition of new plants. When they have been fair and production has been artificially stimulated, sharp competition results in price cutting, failure of plants, and unstable prices, with both the producers and the public suffering.

30. It is beyond the scope of this section to make a proper evaluation of all market areas in New England and New York, yet a limited study of the states involved shows many interesting facts. For this purpose a brief graphical history accompanied by pertinent statements is presented for the sand and gravel industry in the United States, in New York, and in each of the New England States. Table 78 showed a comparable demand for the various types and grades of sand and gravel in each of the states; minor exceptions have little effect on the overall picture.

31. The data for average value are based on a composite statistical average. They include noncommercial or government-contractor costs, as well as commercial values for the product.

32. The average values since 1930 have been held down by the large consumption of low-cost noncommercial production, ranging from 1/2 to 1/3 of that for commercial sand and gravel. This lower value may be accounted for by reason of no taxes, little or no provision for amortization of property or of equipment, and often lower standards and specifications.

33. Paving and building sand and gravel represent almost 90 percent of consumption. Therefore, average values do not reflect properly the price of sands prepared to rigid specifications.

34. United States.- Plate 53 shows that for the 40-year period indicated, annual production in the United States increased about 5 times, while the average net ton price increased approximately 2-1/2 times.

35. The curve has a cycle typical of most commodities. Production increased during times of prosperity and decreased in periods of depression and war; each succeeding peak has been greater than the previous one, while each succeeding trough did not reach the low of its predecessor.

36. The average value per net ton curve is of interest. An artificial price increase occurred during the first world war, when production was forced to decline and demand, both civil and military, could not be satisfied. America's quick, sharp depressions of 1920-21 and 1937-38 evidence a major decline in price and only minor declines in production. Both value and production declined rapidly during the 1930-34 depression.

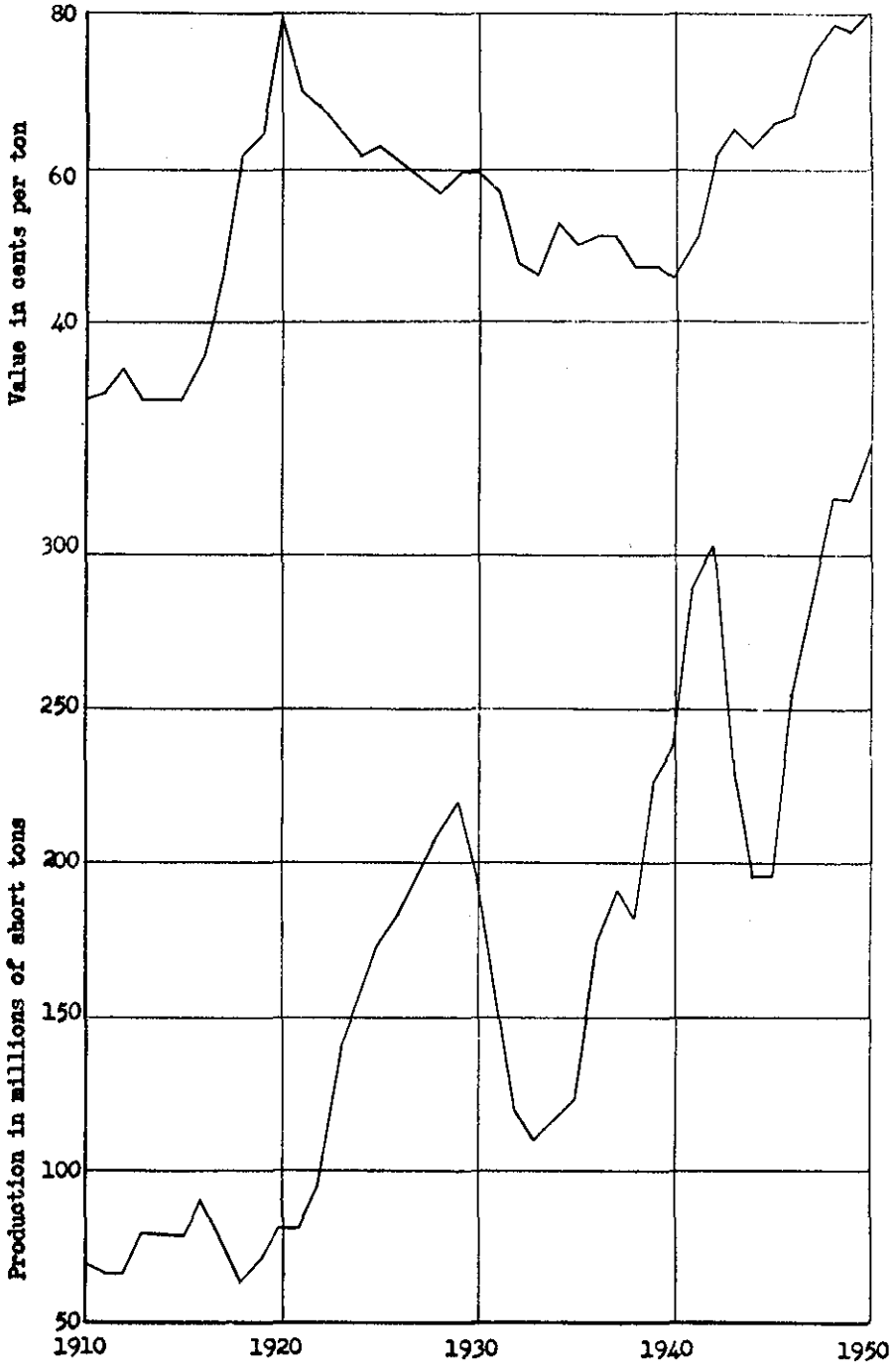
37. After 1921, sand and gravel production was so great throughout the nation that despite a continuing building boom there was some market saturation with concurrent price decreases. After the 1938 decline, both production and price climbed toward new highs, price lagging, but these

were accountable to European developments rather than to abnormal local or national conditions. It is debatable whether the low price for sand and gravel during the 1930's was a direct result of the depression, or was a continuation of the trend created by overdevelopment in the industry during the previous decade. No real price increase was evidenced until 1941, when demand was governed by the war in Europe.

38. With America's entrance into the second world conflict, most sand and gravel operations closed down or curtailed production. Major areas of consumption had already been satisfied, and the price level remained constant; the slight rise that occurred was a result of the continued production and sale of higher-valued sand products for war industries, such as molding sand.

39. After the war, both building and road construction resumed, with a concomitant period of inflation. If it were not for the advances made by the sand and gravel industry in operating efficiency, prices would have been considerably greater during this period. After the volume of construction has reached a more normal condition, it may be expected that the trend in price and production will begin the decline typical of its past experience.

40. New York.- Plate 54, showing average value and annual production in New York, is quite similar to that for the United States with the exception of production during the late 1920's. This period marked unparalleled volume construction in the State. The rate of ascent and decline in sand and gravel tonnage was such as to create considerable chaos in the industry. The present trend, starting with the end of World War II, graphically approximates that of the twenties. Over the 40-year



SPECIAL SUBJECTS-REGIONAL

SAND AND GRAVEL IN THE UNITED STATES

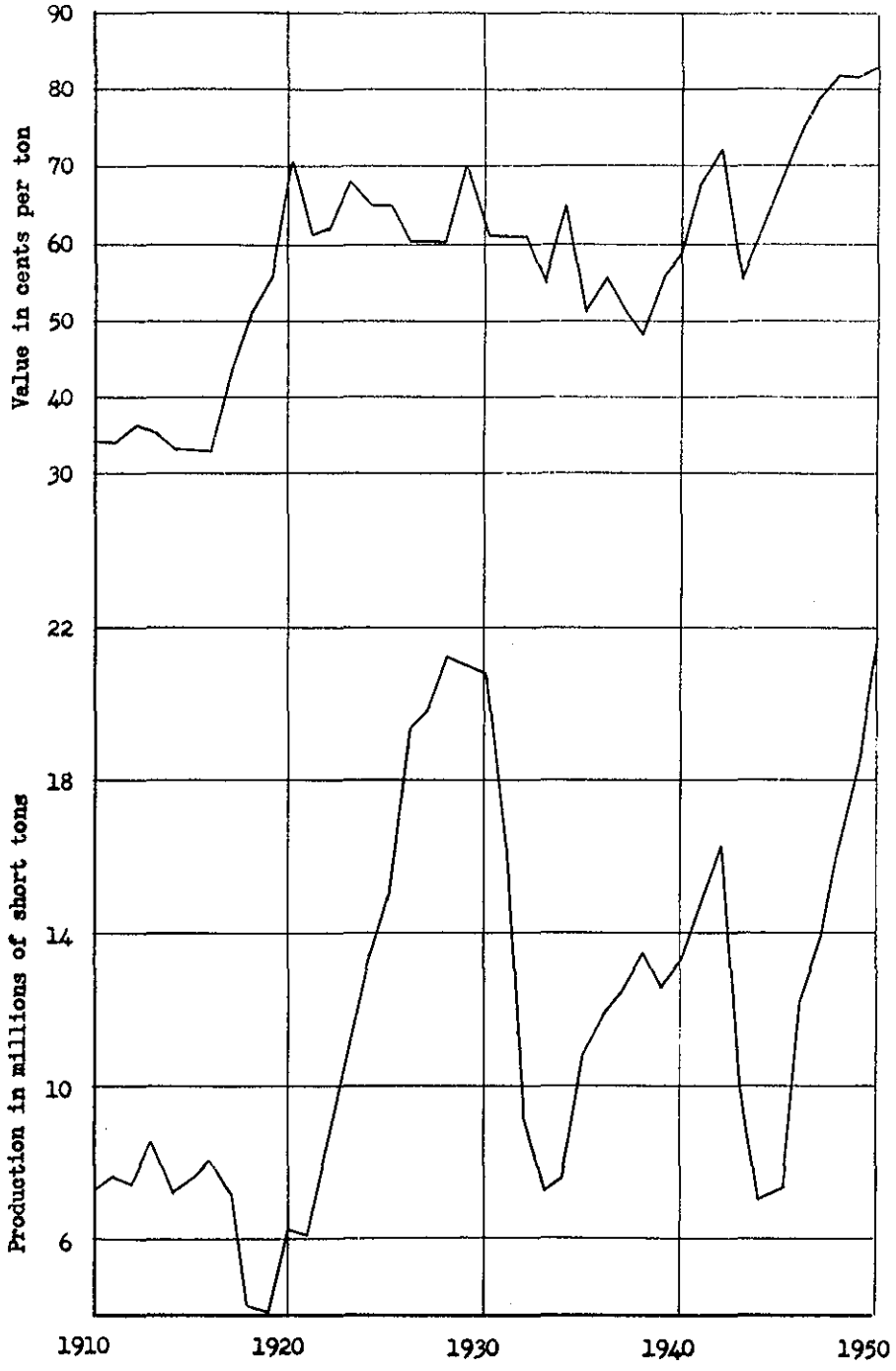
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 53

CHAPTER XXXIX



SPECIAL SUBJECTS - REGIONAL

SAND AND GRAVEL IN NEW YORK

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 54

CHAPTER XXXIX

period shown, the average net ton value of sand and gravel in New York has maintained a remarkably steady level. This is indicative of the balance between production and consumption, and that the sand and gravel industry in this state has fully utilized the technological advances made, thus holding price down during periods of generally spiraling costs.

41. There has been no evidence of market saturation or overproduction in New York.

42. Connecticut. - Production of sand and gravel in Connecticut has followed the cyclical trend of the industry as a whole. (See Plate 55). The low level of production has prevented the peaks and troughs from becoming too apparent. The erratic trend followed by the value curve for the period prior to 1935 has shown no signs of being repeated in the past fifteen years, and it may be assumed that the quarry operators have a better understanding of their market, and that there exists a better opportunity for the expansion of that market.

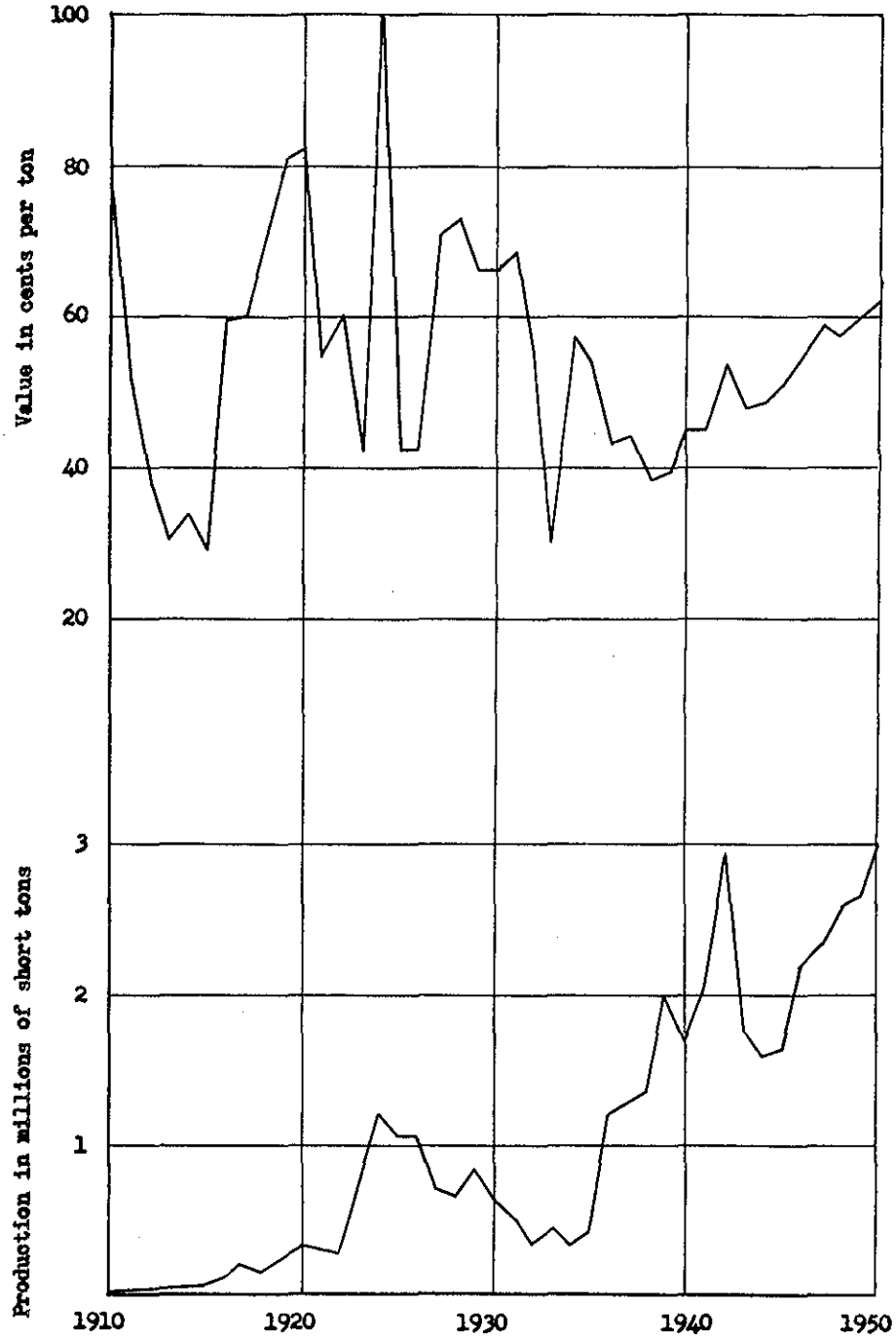
43. During the past fifteen years there has been no evidence of market saturation; the present trend is extremely healthful; and with the proper application of business and engineering know-how the sand and gravel industry in Connecticut may be expected to continue its present course.

44. Maine. - From its onset, the sand and gravel industry in Maine appears to have encountered serious difficulties; production and prices have both been extremely unsteady. The high peaks shown on the production curve were generally created by large paving projects; if these had been spread over a longer period of time there might have been considerably less dislocation in the industry. The present price trend, if it continues, would be most indicative of production approaching market saturation. (See Plate 56).

45. Massachusetts. - The production curve for Massachusetts (See Plate 57) shows signs of carefully guided consumption. During the depression, a comparatively high sales level was maintained, with a concurrent drop in price. This assisted the consumer and supported the industry at a time when consumption was governed solely by direct necessity. Such industry control did not exist prior to 1930. The continued growth of production, in the twenties, despite major price changes may be associated more with an attempt to locate a proper price level than with oversaturation. It is to be doubted if such extreme fluctuations could have been, or are, beneficial to the industry. The present trend indicates spiraling prices because of increased consumption. This trend is not comparable with the trends shown for the other states; and it does not follow the marketing practices of the thirties which maintained the strength of the industry.

46. New Hampshire. - The absence of commercial data for New Hampshire sand and gravel producers since 1935 makes any analysis difficult. Noncommercial production should maintain a constant price level; price variations, prior to 1935, are typical of a normal supply and demand. The State government is to be admired for its ability to supply its needs at prices in keeping with the availability and quality of the sand and gravel deposits. (See Plate 58).

47. Rhode Island. - The industry here has been affected more by supply and demand than any other state in the region because of limited resources. There are extreme variations in price and production, (See Plate 59) which are not conducive to the healthy growth of the industry and are not in the best interests of the residents of the State. As a



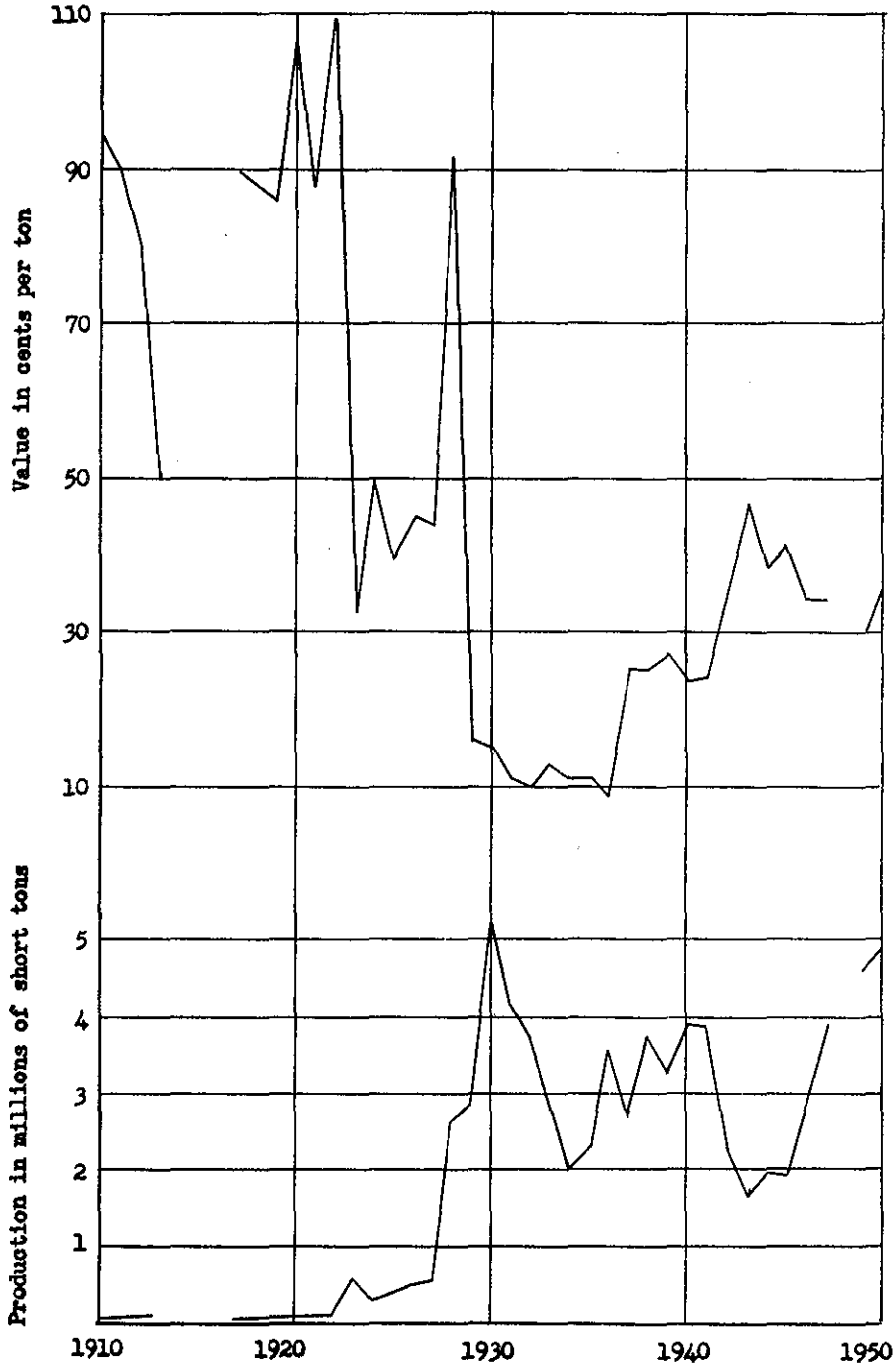
SPECIAL SUBJECTS-REGIONAL

SAND AND GRAVEL IN CONNECTICUT

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 55
CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL

SAND AND GRAVEL IN MAINE

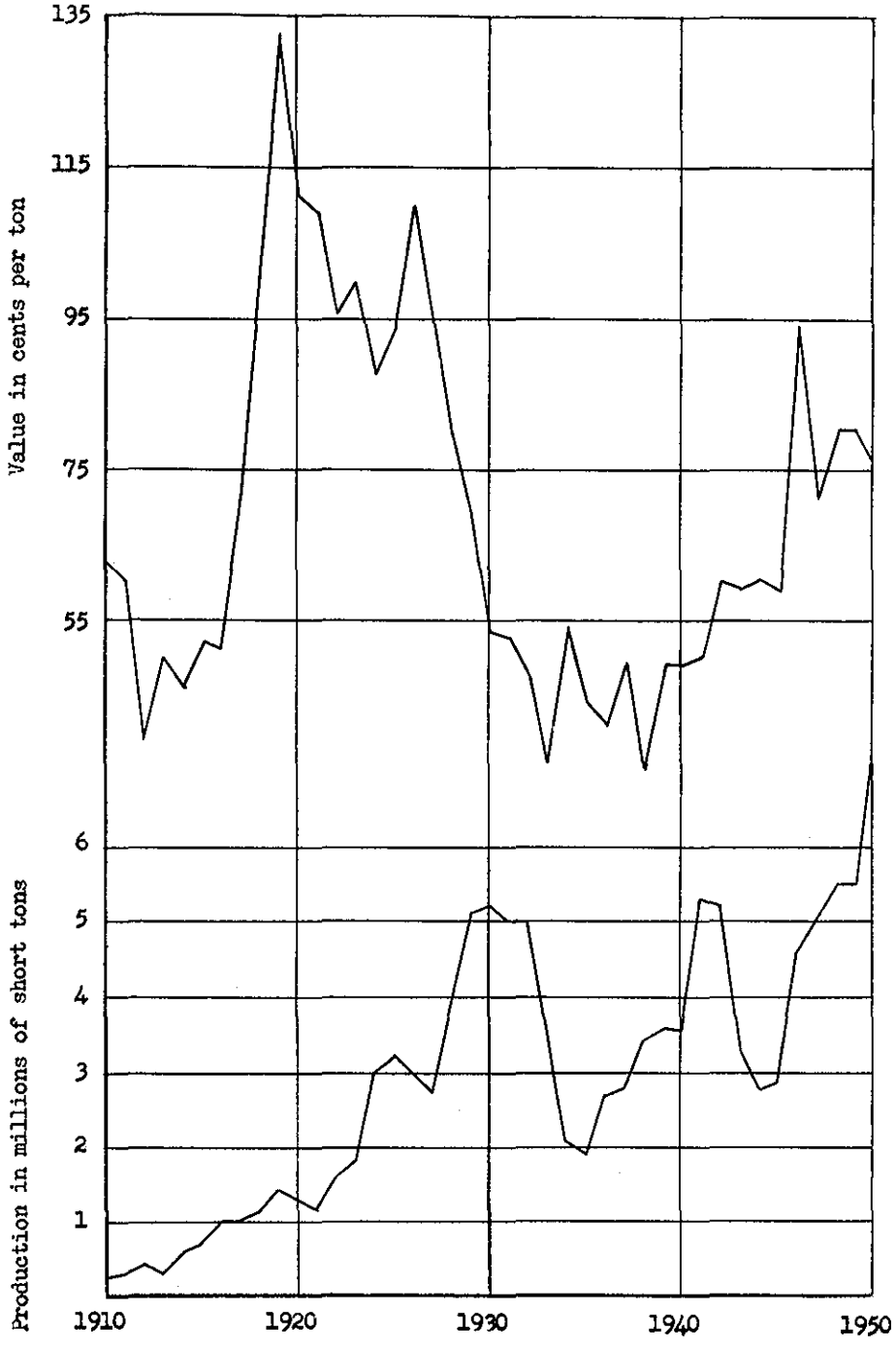
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 56

CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL

SAND AND GRAVEL IN MASSACHUSETTS

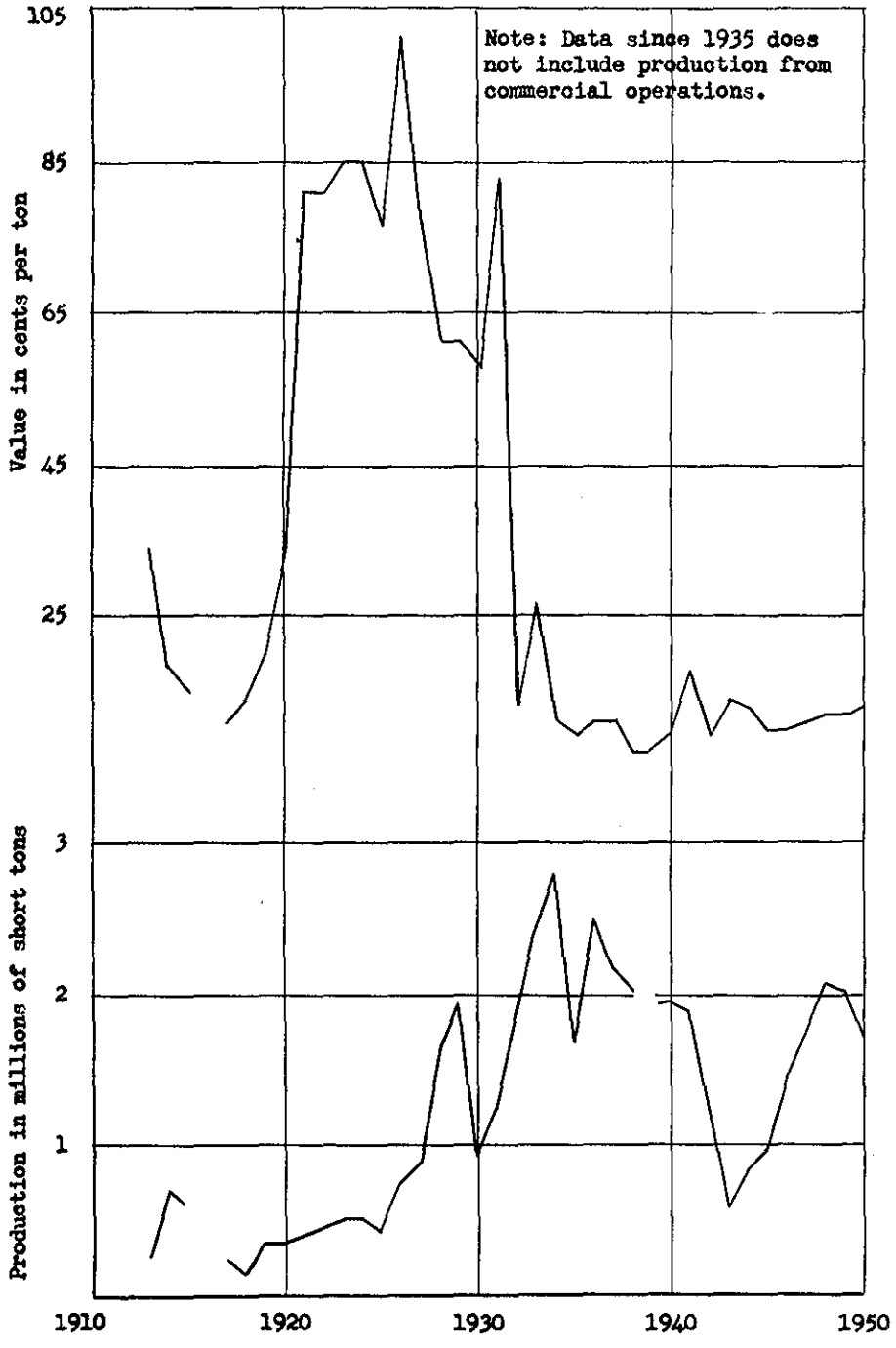
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 57

CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL

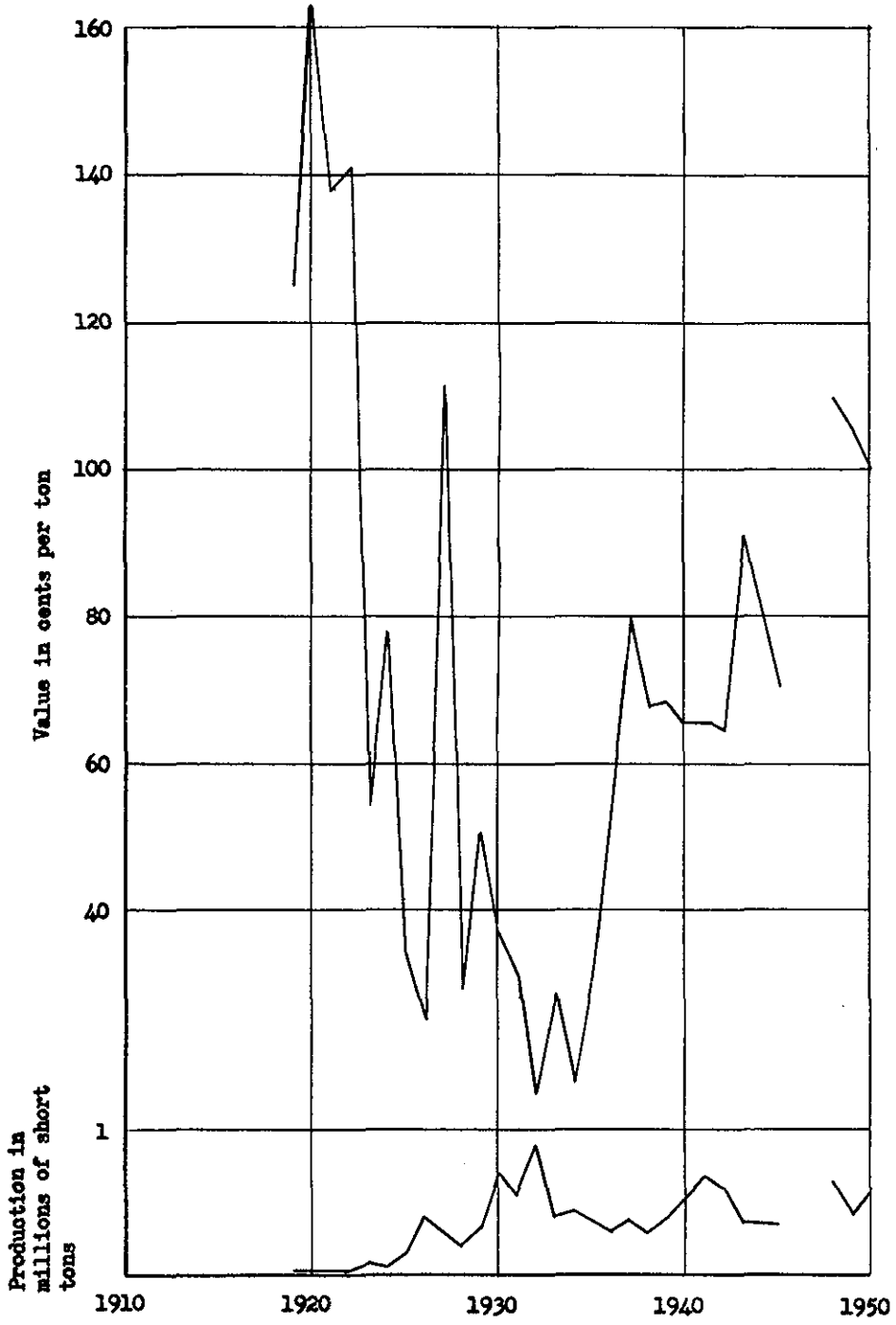
SAND AND GRAVEL IN NEW HAMPSHIRE

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 58
CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL

SAND GRAVEL IN RHODE ISLAND

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

U S B M BOSTON JANUARY 1955

PLATE 59
CHAPTER XXXIX

result, most of the sand and gravel used in Rhode Island is produced in other states.

48. Vermont. - The production of sand and gravel in Vermont has been extremely sporadic; (See Plate 60) the failure to maintain price or volume levels must have deterrent effects on the effectual utilization of the sand and gravel deposits. There are numerous indications of market saturation or other business weaknesses over the forty-year period shown. Producers and consumers alike might concern themselves with this problem in such a way as to benefit all.

SELECTED BIBLIOGRAPHY ON SAND AND GRAVEL

1. _____. Minerals Yearbook. Bureau of Mines, 1937, 1939, 1942, 1946, 1949.

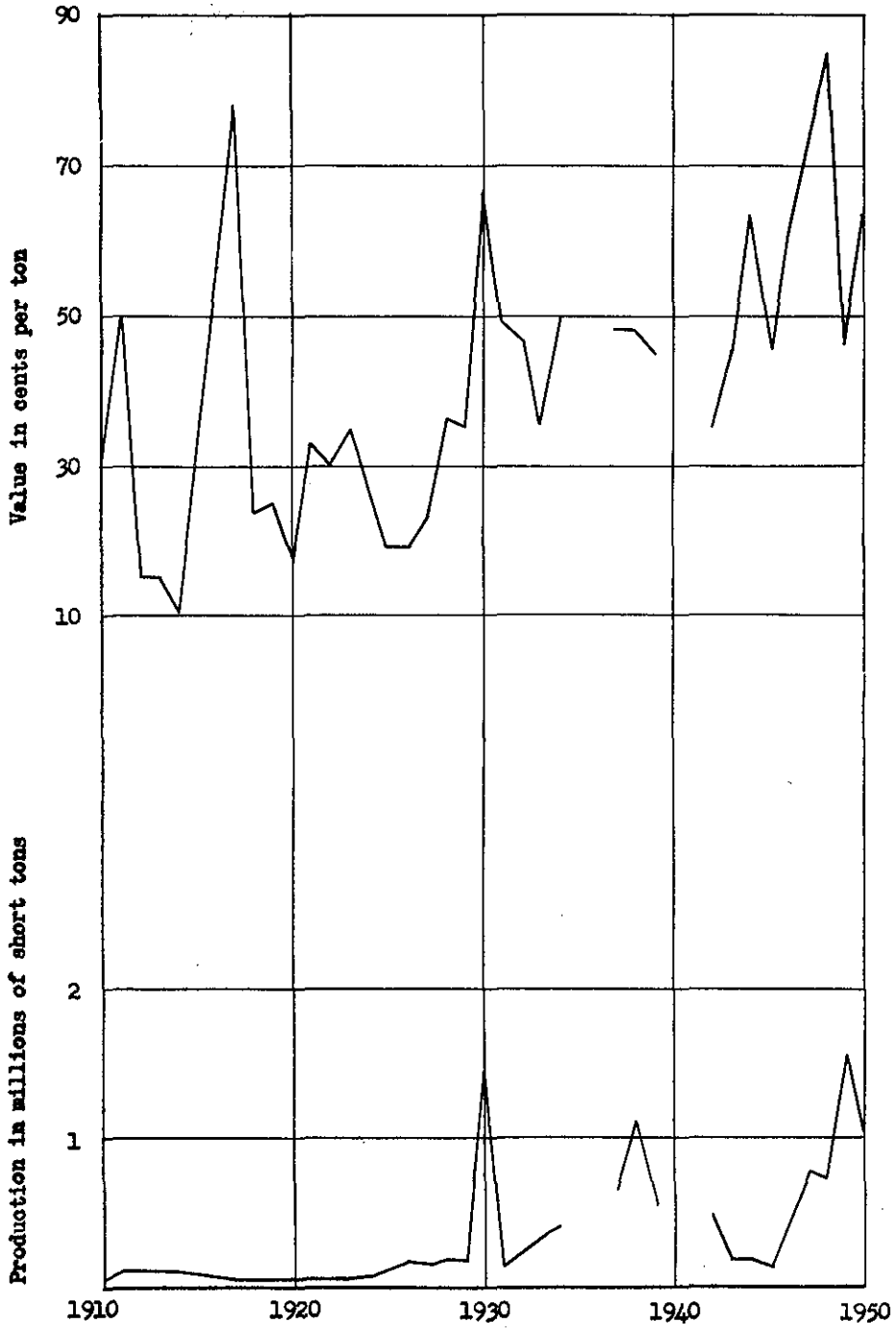
2. _____. Minerals Yearbook. Bureau of Mines, 1939, p. 1174-1175; 1949, p. 1076-1078.

3. _____. Minerals Yearbook. Bureau of Mines, 1940, p. 1206; 1949, p. 1069.

4. _____. Minerals Yearbook. Bureau of Mines, 1949, p. 1070-1075.

5. STONE, R. W. Sand and Gravel, Mineral Resources of the United States. Geol. Survey Annual 1912, p. 630, with modifications.

6. THOENEN, J. R. Development of Sand and Gravel Deposits. Bureau of Mines Inf. Circ. 6689, 1933, p. 13, with modifications.



SPECIAL SUBJECTS- REGIONAL

SAND AND GRAVEL IN VERMONT

NEW ENGLAND-NEW YORK INTER- AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON JANUARY 1955

PLATE 60

CHAPTER XXXIX

SECTION XXVIII - GRAVEL AND SAND RESOURCES OF THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Deposits of sand and gravel are widespread in the New England-New York region and constitute one of its principal mineral resources. Most of the pits are operated intermittently to supply local needs. Because of the great number and variety of known deposits, and because they have been worked at countless points it is impracticable to describe in detail either the deposits or the individual pits. On the other hand, a broad description of the geologic modes of occurrence with relation to the regional geology will serve adequately to indicate the importance of the resource in the regional economy and development. Except for some special sands, such as "glass sand", certain molding and foundry sands, et. al., for which restrictive textural, compositional and physical properties are required, sand and gravel are used chiefly for local construction and are not commonly transported for long distances.

2. Sand and gravel deposits of the region fall into four principal genetic categories - e.g., glacial, alluvial, marine, and aeolian. Of these, deposits of glacial origin are by far the most widespread and important.

GLACIAL DEPOSITS

General statement

3. The entire region was glaciated several times during the Pleistocene epoch ("Ice Age") by continental ice sheets. The last ice left the region

so recently (probably 10,000 to 20,000 years ago) that in general the glacial landforms have been but slightly modified by post-glacial erosion and they stand as sharply defined glacial features, giving a distinctive appearance to the landscape and a complexity of mantle materials that characterize the region everywhere. As a result of glacial deposition the area has countless lakes and swamps, extensive plain-like areas of sand and gravel, and a variety of smaller landforms composed of granular materials with a wide range in texture. Pre-glacial valleys were partly or entirely filled with rock and soil debris, and drainage systems were locally disarranged or diverted. These features present many problems related to engineering projects concerned with foundations and structures; on the other hand, the glacial deposits provide a generally abundant supply of sand and gravel that figure prominently in the resources economy of the region.

4. The glacial deposits may be considered under two broad groups, moraines and outwash deposits.

Morainic (till) deposits

5. As the ice sheet glaciated the area from the north, it scraped up pre-existing soils, abraded bedrock, and plucked blocks of bedrock from projecting exposures. Some of these materials were embodied within the ice and carried long distances. Most of them probably were spread out under the ice as a general layer of unsorted and heterogeneous soil and rock debris that ranges in texture from clay to boulder sizes. Such material is called till. This general layer of till, for the most part covering both hills and valley floors, is called ground moraine, and is so designated on surficial geologic maps. In some places where the ice front remained stationary for an appreciable length of time frontal ridges of till and

associated gravel were built up; these are the end-moraines as commonly designated on surficial geologic maps. In part the end-moraines mark the terminal positions, across valleys, of finger-like valley-lobes of ice; in other places they mark broader fronts of wider lobes, trending in somewhat irregular course but with impressive length and continuity across the country.

6. Lobal valley moraines are common, for example, in the Finger Lakes region of New York, where they formed dams behind which meltwaters were ponded. Long ridges on Cape Cod extending parallel to Buzzards Bay and the south shore of Cape Cod Bay, and others extending along Long Island, and the southwest coast of Rhode Island are examples of the end-moraines extending across both valleys and divides.

7. Moraines of all kinds yield relatively little sand and gravel except for local pockets or small knobs that are, for the most part, poorly sorted. The till, of which moraines are principally composed, is of variable texture and composition, reflecting the nature of the bedrock over which the glacier rode. Much of the till of eastern and central New England, and the Adirondacks region was derived mostly from siliceous crystalline rocks and is gravelly; it is sometimes sold as gravel, for in many places it has as back-fill and even for subgrade material in highway construction. The resources of such gravelly tills are large but only of very local importance and for restricted use. In places where the tills were derived from non-crystalline rocks (non-metamorphosed or slightly metamorphosed rocks) chiefly shales, slates, phyllites, limestones, and fine-grained sandstones, the till materials are finer-grained and more compact, and are rarely

suitable for engineering use where granular materials of high porosity are needed. Such rocks contribute more clay minerals and rock flour to the till matrix than do the coarser crystalline rock, such as granitic rocks, gneisses, and quartzites.

Outwash sand and gravel deposits

General statement

8. As the glacial ice melted, much of the rock and soil debris picked up and embodied within the ice, and some of the morainic materials deposited beneath or in front of the ice, were transported, sorted, and deposited by the meltwaters. Such deposits are included in the general term outwash; they include materials ranging in texture from clay sizes to very coarse gravels, according to the carrying and sorting power of the meltwater streams. Boulders are not uncommon in outwash deposits, where they may either be residual from reworked till deposits, or may have been dropped from ice blocks or bergs onto the outwash deposits. In some outwash deposits, particularly those in which the coarser gravels are prominent constituents, boulders are so concentrated as to make working of the deposit difficult.

9. Outwash deposits have various landforms, according to the loci and modes of deposition. To some degree, also, the probable general texture of the deposit may be predicted from the origin and form of the deposit. For these reasons, a detailed surficial geologic map is of great value in locating probable supplies of gravel and sand and computing the volumes of the deposits.

10. The principal loci of deposition of glacial outwash were the major valleys that were occupied by ice tongues, or by stagnant, residual blocks

of ice during the recession of the continental ice-sheet. Here meltwater streams transported, sorted, and deposited rock debris along the floors and walls of the valleys, around and against ice blocks and tongues of ice, and in grooves, crevices, and holes in or upon the ice. In many places, also, valleys were dammed by morainal deposits, or by the receding ice front in northward draining valleys, so that lakes and ponds were formed. Deltal and lake floor deposits formed in these lakes, most of which were drained by melting of the ice dams or subsequent breaching of morainal dams by erosion.

Classification of outwash deposits

11. For practical purposes outwash deposits are probably most satisfactorily classified by their landforms, for there is commonly a broad correlation between the forms of deposition, and the variability and textural range of component materials. Nevertheless, the textural range is great in many deposits, and can be ascertained only by actual pitting, sampling, and screening. Unlike many alluvial gravels of non-glacial origin even the coarse textured deposits contain a large and greatly variable percentage of sand sizes. Mapping of landforms, therefore, gives a practical key to further exploration for materials of desirable texture, but needs to be supplemented by sampling and sizing tests for engineering uses in which textural control of granular materials is important.

12. The following glacial landforms are ordinarily indicated on detailed surficial maps.

13. Kames; kame fields.— Small irregular hillocks and knobs, (kames), as a class show great variability in texture and poorest degree of sorting. Boulders and large cobbles may be abundant. Kames constitute one of the chief sources of coarse granular materials. Exceptionally, kames may be

composed predominantly of fairly well-graded sand, and even where large cobbles and coarse gravel sizes are prominent the sand matrix in some kames may amount to more than 50 percent.

14. Groups of kames are sometimes mapped as kame fields.

15. Ice-channel deposits (eskers; crevasse fillings).—These are ridges of gravel and sand representing deposits that were formed in tunnels beneath or within the glacial ice, in channels and furrows upon the ice, or in narrow crevasses through the ice. Most of them are characteristically sinuous, narrow, and uneven-crested. Some are several miles long, though most of them are a few hundreds or thousands of feet long. They are greatly variable in texture and commonly contain boulders. Ice-channel deposits constitute one of the chief sources of coarse granular materials. In Maine eskers are particularly important sources. Like kames they have a sand matrix, which may predominate over the coarser sizes.

16. Kame terraces; kame plains; kame deltas.—These are comparatively broad and flat-topped deposits, terrace-like in form. Kame terraces were formed between valley walls and residual ice-blocks or lobes within valleys, so that they rest against the walls, present relatively steep, "ice-contact", slopes toward the valley floor, and are perched at various elevations above the floor. In the larger valleys these terraces may be very extensive, more or less lining the valley for several miles. Isolated, mesa-like deposits of closely similar origin, representing those formed in holes within residual ice-blocks, are indicated on some maps as kame plains; where deposited in ponded waters and consequently possessing a deltal structure they have been mapped as kame deltas.

17. Because all these forms represent deposits by the larger streams of meltwaters that flowed for fairly long distances along valleys in which ice still remained, they are commonly composed of better-sorted granular materials than are kames and ice-channel fillings, and are major sources of medium and fine gravels, and sand; the sand content is characteristically high. The margins, being partly or entirely steep-sided ("ice-contact slopes"), afford easy development. Kame terraces ordinarily rest upon floors and slopes of till, less commonly on bedrock. Boulders and large cobbles are present but less abundant, in general, than in other ice-contact forms (kames and ice-channel fillings).

18. Outwash plains; valley trains.— Meltwaters that issued from the front of the glacier sorted and deposited extensive plains of sand and gravel, usually as coalescent fan-shaped deposits that merge into low, nearly flat, smooth plains farther from the ice-front. Known also, in part, as "sand plains", these are mapped as outwash plains and in some areas are the most abundant sources of fine-granular materials. Long, narrow outwash plains deposited along valley floors are commonly mapped as valley trains.

19. Outwash plains and valley trains are composed, in general, of well-sorted and stratified sand and fine gravel, except in parts formed near the ice-margin. The materials are progressively finer away from the margin. They have particularly broad distribution in the lower and more level parts of the region, such as central New York and southeastern New England.

20. Glacial lake (glacio-lacustrine) deposits.— General withdrawal of the ice-sheet left many lakes in blocked valleys, or depressions in the general morainic deposits. Many of these were drained by melting away of ice-dams, or by breaching of morainal dams; others still exist, though greatly

shrunken so that small lakes and ponds are now common in areas once occupied by larger and higher bodies of water. During recession of the ice, copious outwash was deposited in these lakes, both as deltas and as floor deposits; subsequent draining of the lakes has left these perched along valley walls, as deltas, or spread broadly on valley floors and plain areas, as lake clays, silts, and sands.

21. Of the glacial lake deposits, for most of the area the deltas are of greater importance than the floor, beach, or bar deposits. They constitute valuable sources of sand and gravel in which the sand constituent is generally predominant, but from which large supplies of medium and fine-textured gravels are obtained by screening. Notable areas for such resources are the Finger Lakes region of central New York, the valleys of the Mohawk, Hudson, Housatonic and Connecticut rivers, and the Champlain Valley. By no means, however, are important deposits of such origin restricted to these areas, for countless glacial-lake deltas are distributed broadly through the Adirondacks, the Catskills, and most of New England, especially the central and southern parts. In particular, very large deltas in the Chicopee-Springfield, and Montague-Sunderland areas of Massachusetts yield large quantities of sand and fine to medium textured gravel. It is noteworthy that the essentially horizontal top-set beds of glacial-lake deltas are composed mostly of gravel and coarse sand, whereas the underlying, inclined, fore-set beds are characteristically of finer texture, with sand as the predominant constituent.

22. Lake-floor deposits are composed usually of fine-textured sand, silt, and clay, with thin beds - mostly very local - of the finer gravels. Much of the flat plains area of west-central New York, for example, is underlain

by extensive sand plains, beaches, sand bars, and low, thin deltas, all of which were deposited in the once very extensive glacial Lake Iroquois, now shrunken to the present Lake Ontario; lake beaches and bars mark various elevations of this lake. Many sand and gravel pits have been dug in these deposits, which, though comparatively thin, are widespread and, in unrestricted areas, are potential sources for local use. They furnish chiefly well-sorted and stratified sands and fine to medium gravels.

QUALITY OF GLACIAL DEPOSITS IN RELATION TO BEDROCK SOURCES

23. Because of their derivation from various types of bedrock over which the continental glacier rode, the outwash and till commonly reflect the areal lithology.

24. For a large part of New England and the general Adirondack area - excepting chiefly the Champlain-Hudson, Housatonic, and Connecticut Valleys, and smaller segments of the major valleys in central and eastern Maine - the glacial debris was collected mostly from crystalline rocks and the pre-glacial soils derived therefrom. Consequently, pebbles of hard and durable granitic rock and gneisses, quartzites, and volcanics are prominent and commonly dominant constituents. Platy fragments of less durable, foliated, micaceous schists, phyllites, and other slaty rocks abound in areas underlain by such bedrock formations; these are often found to be in such abundance as to limit the usefulness of the gravel and sand. Both granitic and schistose types of bedrock formations are widespread in New England and northern New York, and the proportions of these constituents in the gravels vary greatly. Consequently, although the gravels are universally suitable for ordinary "fill", they need to be examined closely for use as concrete aggregate or more specialized purposes.

25. It is not practicable to delimit the gravel and sand deposits geographically according to the nature of the constituent pebbles. Nevertheless, there are several general areas that reflect the bedrock lithologies prominently. Thus the glacial deposits in most of the Connecticut Valley of Massachusetts and Connecticut contain an abundance of fragments of the red sandstones, shales, and conglomerates of the Triassic formations. Gravels of eastern Massachusetts, southern Maine and New Hampshire, most of Rhode Island, and the Adirondacks highlands contain an abundance of granitic and other coarsely crystalline rocks. Schist fragments are commonly dominant in the gravels of central and western New Hampshire, eastern and central Vermont, central and western Massachusetts, and much of Connecticut. Pebbles of carbonate rocks - chiefly marbles, both calcitic and dolomitic - appear prominently in the broad valley provinces of western Vermont and Massachusetts, between the Green Mountains-Berkshire uplands on the east, and the Taconic ranges along the western borders of these states.

26. In New York there is great variability. Hard, quartzitic sandstone, and granitic rocks are prominent in the northeastern part of the State. Gravels and tills of the northwestern part of the State contain locally high percentages of the reddish Medina sandstone. In the central-northern part of the State, boulders and pebbles of the hard quartzitic Potsdam sandstone and of granitic and gneissic rocks are commonly abundant. In central New York, west of Schenectady, the underlying shales and argillaceous sandstones - both of which are weak and platy - are present in abundance in the glacial deposits; east of Schenectady, the older and extensive delta deposits of glacial Lake Albany had their source in the soft sedimentary rocks of the Mohawk basin, but later deposits in the same area were coarser-grained and

more quartzose, owing to derivation from the Adirondacks areas as it was uncovered by the retreating ice. Sands and gravels of the Hudson Valley, in general, contain a relatively high percentage of fragments from the soft and platy Hudson River shale, and slate. Shale and limestone beds contributed abundantly to the glacial deposits of central and western New York.

ALLUVIAL DEPOSITS

27. Much of the load picked up, transported, and deposited by present-day rivers is derived from glacial deposits, both outwash and till. Some of this load, which ranges in texture from clay sizes to cobbles, is deposited as flood-plains; the finer materials for the most part find their way to the sea or the larger lakes.

28. Locally, small deltas are being formed in the larger lakes, but, unlike the earlier deltas formed by streams of glacial meltwaters, these are of inconsiderable importance.

29. Because of the partly submerged, or "drowned", nature of the coast, rivers emptying into the sea are not forming significant deltas, though sediments - chiefly of sand, silt, and clay sizes - are contributed as bottom deposits to the embayments and shallow coastal areas, where they are in part reworked by shore and wave currents into beaches, bars, and sand spits together with materials derived from glacial deposits being attacked and redistributed by these currents.

30. Large quantities of gravel and sand were formerly dredged from the Niagara River in the vicinity of Buffalo, but this production is reported to have been stopped by Government restrictions. Recent alluvial deposits are, in general, better sized than those of glacio-fluvial origin and, in

particular, river gravels - though commonly occurring as thin beds - are apt to be of much more uniform texture. In areas underlain chiefly by shale and thinly-bedded sandstone, such as in much of central and western New York, the alluvial sediments are usually of poor quality and have little economic value.

31. Floodplains of the Connecticut River in parts of Massachusetts and Connecticut can yield large supplies of the finer textured sands; these deposits are of considerable thickness in a few places, but are generally thin.

MARINE AND LAKE DEPOSITS

32. Sand and shingle beaches abound along the New England coast south of southwestern Maine. Beach sands have been exploited in a few places, but at present there is little or no production from such sources because of restrictions as residential and recreational areas.

33. In New York bottom and bar sands and gravels of Lake Ontario have been dredged extensively. Such deposits, though relatively thin, yield well-sorted sands and fine gravels. Dredging from Lake Erie, as formerly reported by Nevin (1929), have been prohibited by State law.

34. Beach and bar deposits of the area have been derived almost entirely from materials of glacial origin. Generally, they have been reworked many times by currents and waves and are consequently well-sized and uniform. Pebbles in them are well-rounded.

AEOLIAN (WIND-BLOWN) DEPOSITS

35. Wherever strong winds with a prevailing direction blow across sand plains and beaches that have scant vegetation they pick up and transport the fine

sand, silt and dust. These materials are then deposited in favorable places where obstructions retard the winds. Fine sand and silt sizes commonly blanket large areas. Such aeolian deposits are widespread in the region and furnish an appreciable amount of the thin soil cover in many areas, ranging ordinarily from a few inches to a few feet in thickness. They do not appear, however, to have economic value in the region.

36. On the other hand, along broad beaches and on bare sand plains bordering major rivers, dunes have formed locally and in places have furnished well-graded foundry, filter and asphalt sands. For foundry purposes they generally require additions of some bonding material. High dunes just east of Provincetown, on Cape Cod, have been successfully worked for several years (see Section XXIII, Silica). The resources are very large. Dunes occur at many places elsewhere along the coastal belt of Cape Cod, but have not been exploited. For the most part they lie in restricted areas, a possible exception being parts of Scorton Neck and Sandy Neck, in Sandwich and Barnstable.

37. In the Connecticut Valley many dunes occur on the broad terraces bordering the Connecticut River flood plains of Massachusetts, and to a much less extent in northern Connecticut. They are almost entirely confined to the terraces east of the river. Although most of these dunes are but a few feet high, some dunes have heights up to approximately 50 feet. High dunes appear to be particularly abundant in Massachusetts south of Springfield, and are valuable potential sources of very uniformly graded sand. Indeed, much of this area has a general blanket of aeolian sand, which includes the large, well-formed dunes.

38. In New York, according to Nevin (1929), "On the old sand plains at Albany, Forestport, and Rome ideal conditions must have prevailed for dune formation, since today we find in these districts many ancient sand dunes which have been anchored by vegetation and are no longer active. Their commercial value is limited to the fine grades of core and filter sands and, in some cases asphalt sand." Nevin further reports that "at Selkirk on the eastern shore of Lake Ontario, an excellent sand dune deposit is now being formed. The sand is highly siliceous, white in color, and is blown from the beach by prevailing westerly winds. In many respects this deposit is similar to the famous Michigan City core sands."

GEOGRAPHIC DISTRIBUTION OF PRINCIPAL TYPES OF DEPOSITS

Correlation of subregions with physiographic provinces

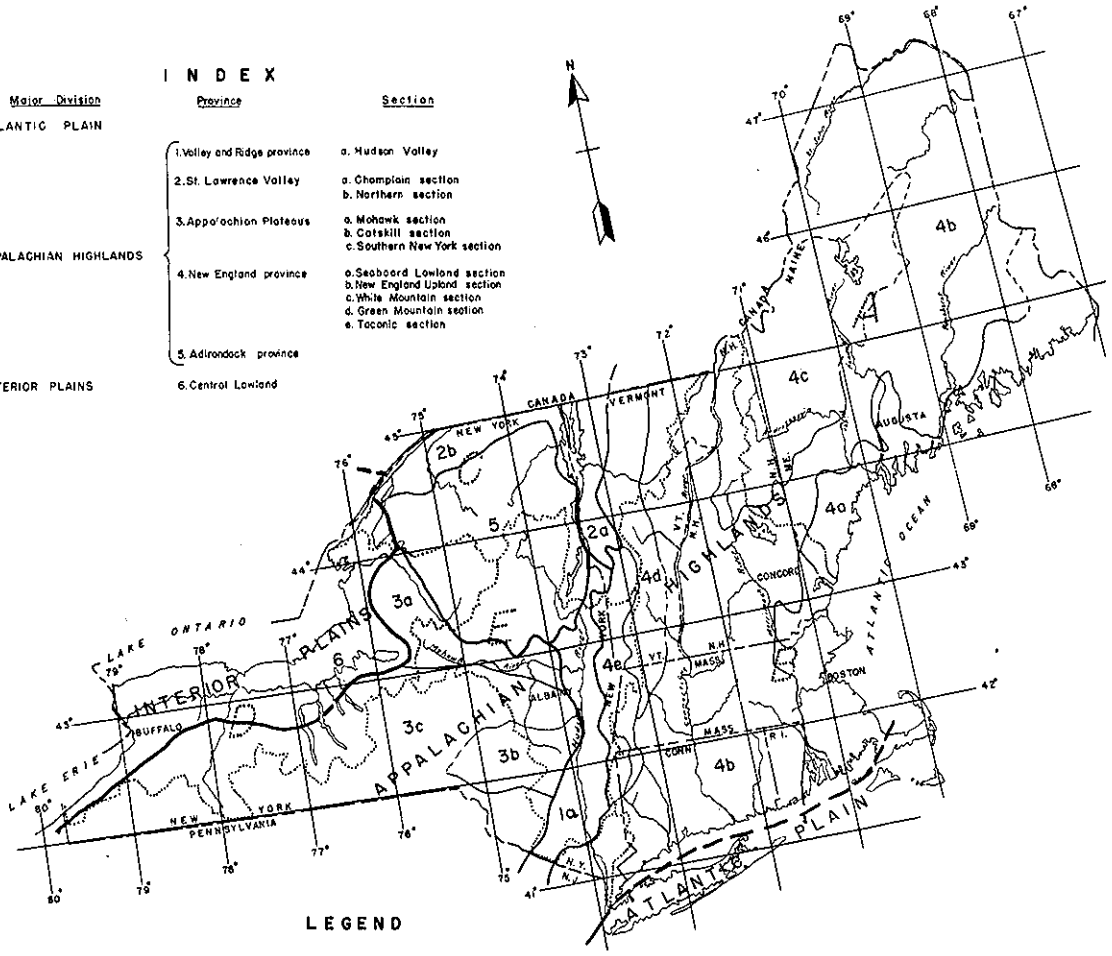
39. The following summary presents the general geographic distribution of the principal types of sand and gravel deposits by physiographic provinces, sections, and subregions. It does not imply, however, exclusion of other types of deposits, as described in this section, from the individual areas.

40. The physiographic provinces are those outlined on the map entitled "Physical Divisions of the United States", as prepared by N. M. Fenneman in cooperation with the Physiographic Committee of the Geological Survey. A correlation of these provinces with subregions is made as follows:

Province	Section	Subregion
New England	Seaboard Lowland	Coastal belts of A and B from easternmost Maine to south-central Rhode Island.
	New England Upland	A and B, except coastal belt from eastern Maine to south-central Rhode Island, White, Green, and Taconic Mts., sections.

INDEX

Major Division	Province	Section
ATLANTIC PLAIN		
APPALACHIAN HIGHLANDS	1. Valley and Ridge province	a. Hudson Valley
	2. St. Lawrence Valley	a. Champlain section b. Northern section
	3. Appalachian Plateaus	a. Mohawk section b. Catskill section c. Southern New York section
	4. New England province	a. Seaboard Lowland section b. New England Upland section c. White Mountain section d. Green Mountain section e. Taconic section
	5. Adirondack province	
INTERIOR PLAINS	6. Central Lowland	



LEGEND

Subregion boundary

Major physical division

3 Physiographic province

3b Physiographic section

Note: Broken line indicates boundaries much generalized or poorly known.

SPECIAL SUBJECTS-REGIONAL
SUBREGIONS
AND
PHYSICAL DIVISIONS
OF THE
NEW ENGLAND-NEW YORK REGION

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
OCTOBER 1954

SCALE IN MILES
25 0 25 50 75 100

PLATE 61
CHAPTER ~~XXXIX~~

U.S. B.M., BOSTON, OCT. 1954

Province	Section	Subregion
New England	White Mountains	Chiefly in A, small part in B; north-central and northern New Hampshire, north-central and western Maine.
	Green Mountains	Chiefly in western part of B; north-south belt through west-central Vermont into northwestern Massachusetts.
	Taconic	Small parts of C and E. A short narrow belt extending south from Rutland into northwestern Connecticut and including parts of the Champlain-Hudson, Otter Creek, Hoosic, and Housatonic Valley.
Valley and Ridge	Hudson Valley	Part of E. Narrow valley area Lake George south to Newburg.
St. Lawrence Valley	Champlain	In eastern part of C. Champlain basin.
	Northern	In northern part of C. Low plains north of Adirondack section and west of Champlain section.
Adirondack		Adjacent parts of C, D, and E. Northern New York highlands.
Central Lowlands	Eastern Lake	Entirely within D. Low lake plains bordering Lake Ontario and Erie.
Appalachian Plateaus	Mohawk	In eastern part of D and western and central parts of E. Chiefly the Mohawk Basins, extending southeast and east from Rome, N. Y. to Schenectady, N. Y., but includes a narrow belt from Rome to a point just east of Watertown.
	Catskill	Eastern part in south-central part of E.
	Southern New York	Southern parts of D and E.

PRINCIPAL TYPES OF DEPOSITS BY AREAS

New England Province

41. Seaboard Lowland section. -In this coastal belt strip of low altitudes and relief, ranging up to 60 miles in width are included the coastal basins of Maine, New Hampshire, Massachusetts, and eastern Rhode Island, and the coastal segments of other major basins within the belt.

42. Principal deposits. - Outwash sands and gravels are abundant, but greatest from southwestern Maine to southern Rhode Island. Marine and glacial clays and silts are prominent in several areas. Beach and dune sands especially abundant along Massachusetts coast south of Scituate and particularly on Cape Cod, but most areas restricted; production current near Provincetown.

43. New England Upland section. - This is a dissected plateau province that includes central, eastern, and northern Maine, central and southern New Hampshire, eastern Vermont, central Massachusetts, and Connecticut.

44. Principal deposits. - Outwash sands and gravels within all major valleys, the amount generally increasing to the south and particularly extensive in the Connecticut, Merrimack, Housatonic, Farmington, and upper Thames valleys and their principal tributaries. Clays chiefly of glacial origin are associated in the Connecticut, Quinnipiac, and Quinebaug valleys. Many beaches with small dunes along Connecticut coastal belt, but mostly restricted.

45. White Mountains section. - A mountainous region in northern, western Maine (includes chiefly the upper parts of Kennebec and Androscoggin basins), northern New Hampshire, and northeastern Vermont; includes headwater sections of Connecticut River basin.

46. Principal deposits. - Data for this area are scant but probably comparatively small deposits of outwash gravel and sand, in part as terraces, considerably dispersed along valley walls.

47. Green Mountains section. A north-south belt through west-central Vermont and a few miles into northwestern Massachusetts; an area of long, north-south trending, mountain ridges and valleys. Includes central and upper parts of Missisquoi, Lamoille, Winooski, White, and Deerfield basins.

48. Principal deposits. - Numerous outwash deposits of sand and gravel chiefly as kame terraces and deltaic deposits along walls of major valleys. Great variability in quality; in many places the gravels are poor where they contain an abundance of leached and oxidized pebbles from the siliceous limestone beds of the Waits River formation, and thin platy fissile fragments of the associated beds of phyllite and slate, and various schists of adjacent formations. Specific data on deposits are very scant for this area, and practically no surficial geologic maps are available.

49. Taconic section. A short, narrow belt extending south from the vicinity of Rutland into northwestern Connecticut, and including parts of the Champlain-Hudson, Otter Creek, Hoosic, and Housatonic basins. It is an area of old, dissected mountains and adjacent broad valleys, underlain chiefly by highly folded beds of schist, slate, and marble.

50. Principal deposits. - Scant data are available, but deposits appear to consist chiefly of many relatively small and dispersed glacial outwash terraces (kame terraces), kames, deltas, and outwash plains.

Valley and Ridge Province

51. Hudson Valley section. A narrow valley area in a glaciated peneplain, extending southward from Lake George area to vicinity of Newburgh.

52. Principal deposits. - Extensive deltal deposits of glacial derivation, composed of beds of clay, silt, and sand, with subordinate gravel; from Schenectady to Albany it is covered by broad outwash sand and gravel deposits. Locally, kame terraces of sand and gravel.

St. Lawrence Valley Province

53. Champlain section. - This is a rolling lowland area lying between the Adirondack section and the Green Mountains, largely occupied by the Lake Champlain basin.

54. Principal deposits. - Numerous scattered, generally small outwash deposits, and some large deltas composed chiefly of sand.

55. Northern section. - This section is a generally low, smooth, glaciated plain with a covering of marine sediments.

56. Principal deposits. - Sand plains; alluvial (dredging) gravels from St. Lawrence River.

Adirondack Province

57. A much dissected, glaciated, mountainous area underlain by crystalline metamorphic and igneous rocks including much marble.

58. Principal deposits. - Local and widely dispersed deposits of outwash gravel and sand, chiefly as small kame terraces, kames, and glacial lake deltas in the lower parts of the valleys.

Central Lowland Province

59. Eastern Lake section. - Predominantly nearly flat lake plains with low beach and morainic ridges. Essentially the shore and shallow water areas of the former glacial Lake Iroquois, antecedent of present Lake Ontario.

60. Principal deposits. - Abundant sand deposits, much of it suitable for concrete and molding; subordinate gravel in numerous relatively small, local, deltal, terrace, and esker deposits in most of which the sand fraction is comparatively high; beach and bar deposits of sand and gravel in Lake Ontario. Dredging of gravels from Lake Erie, formerly an important source, have been prohibited by State law.

Appalachian Plateaus Province

61. Mohawk section. - A maturely dissected plateau area of marked relief. The Mohawk Valley was a major drainage channel for glacial melt-waters and glacial Lake Iroquois.

62. Principal deposits. - Glacial outwash deposits numerous and widespread as kames, kame terraces, and deltas, particularly in upper part of valley. Thick outwash plains are prominent in the central and lower parts of the valley.

63. Catskill section. - Maturely and deeply dissected plateau area of mountainous relief; many glaciated valleys.

64. Principal deposits. - Numerous and widespread glacial outwash deposits in the prominent valleys as kames, kame terraces, deltas, and valley trains.

65. Southern New York section. - A large part of this section within the New England-New York region consists of a broadly bevelled escarpment of the Appalachian Plateau Province that is deeply notched by prominent valleys; some of the larger of these valleys contain the Finger Lakes.

66. Principal deposits. - Numerous glacial outwash deposits, including kames, kame terraces, glacial lake deltas, and outwash plains. Many of the gravel deposits contain a high percentage of shale and limestone fragments.

MAPPING OF SAND AND GRAVEL DEPOSITS

67. Sand and gravel deposits are shown on surficial geologic maps. The region as a whole is very deficient in such maps. (Section ~~VI~~ V gives the status of topographic and geologic mapping). References to the principal literature and maps relating to sand and gravel deposits are given in the appended selected bibliography.

68. For the greater part of the area surficial geologic maps should be made on a scale not smaller than 1:31,680 and contour interval of 10 feet, if maximum value of the mapping is to be realized in the delineation of resources of sand and gravel. The 7½-minute quadrangle surficial geologic maps now being made for Massachusetts and Rhode Island may well be taken as a standard for such mapping. Besides these States, Connecticut, much of New York (chiefly the central and western parts), the southern parts of New Hampshire and Vermont, and elsewhere the major valleys, are appropriate areas for mapping at this scale. Principal exceptions are the Adirondacks, northern and central Maine, and the higher mountainous parts of New Hampshire and Vermont, where a smaller scale, but not smaller than 1:62,500, could be used to practical advantage.

69. It is to be noted that, according to the section on the status of topographic mapping, probably 50 percent of the appropriate area will be provided with suitable topographic base maps for the larger-scale mapping when present projects and plans for topographic mapping are completed, and the rest of the region will be provided with base maps on a scale of 1:62,500.

70. Current and continuing mapping programs are directed to the complete surficial geologic mapping of Massachusetts and Rhode Island by 7½-minute quadrangles, on a scale of 1:31,680 (2 inches to a mile). In addition, an earlier surficial map (Alden, 1924), on a scale of 1:125,000 covers 8 15-minute quadrangles of central Massachusetts. (For indexes see Section ~~VI~~ V on status of geologic mapping).

71. In New York, surficial mapping, completed or in progress, has been reported for 6 15-minute quadrangles in the St. Lawrence Lowland, and 7 quadrangles in the area from Alexandria Bay to Sackett's Harbor.

72. A State map of Connecticut, entitled "Map showing the glacial geology of Connecticut" (Flint, 1947), was published on a scale of 1:125,000, in 1930, by the State Geological and Natural History Survey. This map shows the generalized sand and gravel areas, and locations of many of the pits.

73. A map entitled "Surficial geology of New Hampshire", on a scale of 1:250,000, was published in 1950 by the New Hampshire State Planning and Development Commission (see selected bibliography). This map indicates the generalized distribution of principal glacial deposits. It was based on large part on an earlier file report on sand and gravel deposits made for the State Highway Commission.

74. A map entitled "Glacial deposits, State of Maine", on a scale of 1:250,000, was published in 1934 as a supplement to Volume II of Maine Technology Experiment Station Bulletin 30, "A Survey of Road Materials and Glacial Geology of Maine." (See selected bibliography). The geologic data are very much generalized, and except for the valleys of the St. Johns and Aroostook Rivers, and the lower reaches of the Allagash and Fish Rivers in northern Maine, they are limited to the southern half and eastern part of the State. Particularly noteworthy on this map are the abundant and exceptionally long ice-channel fillings (mapped as eskers). The text of the bulletin describes in considerable detail the known gravel pits of importance.

75. Little data are available concerning sand and gravel deposits in Vermont. Like other parts of New England the larger valleys contain an abundance of glacial outwash deposits and terrace sands, in large part of marine origin, are abundant in the Champlain Valley. Brief descriptions appear in scattered reports and papers (see selected bibliography), but no specific program of surficial geologic mapping has yet been carried on in the State. However, it is reported that it is planned to begin such a program in 1955.

SELECTED BIBLIOGRAPHY ON GRAVEL AND SAND

Alden, W. C., (1924) The physical features of central Massachusetts: U. S. Geological Survey Bulletin 760-B.

Brigham, A. P., (1929) Glacial geology and geographic conditions of the lower Mohawk valley: New York State Museum Bulletin 280.

Fairchild, H. L., (1912) Glacial waters in the Black and Mohawk valleys: New York State Museum Bulletin 160.

Flint, R. F., (1930) Glacial geology of Connecticut: State Geological and Natural History Survey Bulletin No. 47.

Goldthwait, J. W., et. al., (1951) Surficial geology of New Hampshire: New Hampshire Planning and Development Commission Bulletin.

Leavitt, H. W., and Perkins, E. H., (1934), A survey of road materials and glacial geology of Maine: Maine Technology Experiment Station Bulletin No. 30.

Massachusetts--surficial geology of 7½-minute quadrangles, Geologic Quadrangle Map Series; U. S. Geological Survey.

Ayer quadrangle, 1953
Brockton quadrangle, 1950
Colrain quadrangle, (in process of publication)
Mt. Grace quadrangle, 1949
Mt. Toby quadrangle, 1951
Shelbourne Falls quadrangle (in process of publication)
Williamsburg quadrangle (in process of publication)

Massachusetts Cooperative Program, Gravel and sand reports on open file.

Essex County, areas contiguous to route 1
Granville 15-minute quadrangle
Hingham
Gravel and sand resources of Northfield, Millers Falls, and Bernardston quadrangles
Area around Norwood Pond, Beverly
Gravel and sand deposits adjacent to relocation route 2, West Concord to Ayer
Gravel and sand deposits adjacent to relocation route 3, North Lexington to Chelmsford
Gravel and sand deposits of the Springfield-Mt. Toby area
Gravel and sand deposits adjacent to route 122, Sutton to Uxbridge

Miller, W. J., (1914) Geological history of New York State: New York State Museum Bulletin 168.

Nevin, C. M., (1929) The sand and gravel resources of New York State: New York State Museum Bulletin 282.

Rhode Island--surficial geology of 7½-minute quadrangles, Geologic Quadrangle Map Series; U. S. Geological Survey.

Bristol quadrangle, (in process of publication)
Crompton quadrangle, (in process of publication)
East Greenwich quadrangle, (in process of publication)
Georgiaville quadrangle, 1953
Pawtucket quadrangle, 1949
Providence quadrangle, (in process of publication)
Slocum quadrangle, (in process of publication)

Rich, J. L., (1935) Glacial geology of the Catskills: New York State Museum Bulletin 299.

Vermont--Report of the State Geologist, 1905-1906, p. 232, 236; 1907-1908, p. 113; 1909-1910, p. 199.

SECTION XXIX-TALC IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Industrial talc 1/ is widely distributed in the earth's crust. The importance of talc is derived from its many unique and desirable properties. Production of commercial talc has been centered usually in the countries of large industrial development. Since the period 1935-1939, the United States has produced about half of the world's supply. The New England-New York Region contributed more than 50 percent in 1940-1945, and about 40 percent in 1946-1951. (See Table 84, Part 2, p.18).

2. The principal talc deposits of commercial importance in the New England-New York Region are located in New York and Vermont. Talc also occurs in Massachusetts and Rhode Island. New York State has been the leading producer in the United States for many years. Vermont, one of the largest producers during the early 1900's has ranked about fourth. The talc produced in New York has always been higher in value than that produced in Vermont. Since 1880, New York has accounted for about 42 percent of the output and 40 percent of the value of the talc produced in the United States; Vermont has accounted for about 20 percent of the output and 14 percent of the value of the domestic production. No significant production has been reported from Massachusetts and Rhode Island. (See Table 84, Part 2, p. 18).

3. In 1951, production of talc, pyrophyllite, and ground soapstone in the United States was 636,068 tons valued at more than $11,322,830, an average value of $17.80 per ton. This tonnage was contributed by

1/ The term "talc", as used in this report, is to be construed to mean "talc, pyrophyllite, and soapstone" unless otherwise designated.

the following states in percentages: New York, 24.0; North Carolina, 17.9; California, 19.9; Vermont, 12.4; Georgia, 12.3; Maryland and Virginia, 7.1; and Nevada, Montana, Texas and Washington, 6.4.

PROPERTIES AND USES OF TALC

4. The mineral talc is a hydrous magnesium silicate occurring in a variety of rocks marketed as industrial talc. Industrial talc generally contains a number of mineral impurities which vary its properties and value and restrict its end use to industries requiring talc materials of particular specifications. Industrial talc commonly contains, in addition to the mineral talc, widely variable proportions of the following minerals: carbonates (magnesite, dolomite, calcite), chlorite, serpentine, tremolite, anthophyllite, diopside, and quartz. Table 81 lists the chemical and physical properties of the principal industrial talc materials.

Table 81 - Properties of talc, soapstone, and pyrophyllite

Mineral/Rock	Chemical Composition	Hardness	Color	Remarks
Talc (mineral)	$Mg_3Si_4O_{10}(OH)_2$ SiO_2, 63.50 percent MgO, 31.70 percent H_2O, 4.80 percent	1-1.5	silvery white, green	Feels greasy; usually occurs as soft foliated or compact massive aggregate; specific gravity about 2.75
Soapstone (rock)	Higher than 50 percent talc; varying amounts of Al_2O_3, FeO, MgO, Fe_2O_3, CaO, and H_2O		greenish-gray	Usually feels soft and soapy; easily cut into slabs or other structural shapes
Pyrophyllite (mineral)	$Al_2Si_4O_{10}(OH)_2$ Al_2O_3 - 28.3 percent SiO_2 - 66.7 percent H_2O - 5.0 percent	1-2.5	white, yellow	Usually in compact or foliated masses.

5. Talc is an inclusive term generally used to denote all gradations from the pure mineral to impure massive talcose rocks that may contain as little as 10 percent of the mineral talc, particularly in tremolite. Table 82 shows analyses of several varieties of industrial talc from New York and Vermont. Steatite, an alternate mineralogical name for talc or soapstone, has been used in recent years to designate a high-grade talc, in block or ground form, suitable for special ceramic and electronic uses.

Table 82 - Chemical analysis of industrial talcs in the New England-New York Region 1/

Constituent	1	2	3	4	5
SiO_2	59.80	66.23	56.33	51.20	63.5
Al_2O_3	0.57	1.05	3.19	5.22	
Fe_2O_3	0.05	0.13)	5.39	8.45	
FeO	0.15	0.22)			
MnO	0.39	0.16	0.11		
CaO	6.80	2.26	0.41	1.17	
MgO	27.45	25.71	27.89	26.79	31.7
Na_2O+K_2O			0.87		
SO_3	0.07	0.01			
Ign. loss	4.75	3.86)	5.68	6.90	4.8
Water (105°)	0.45	0.25)			
CO_2	1.18	0.56	0.36		
Total	101.66	100.84	100.23	99.73	100.0

1. Analysis of average sample of mined talc zone, Talcville, Gouverneur district, New York.
2. Analysis of average sample of mined talc zone, Fowler, Gouverneur district, New York.
3. Analysis of talc of Vermont, Vermont State Geological Survey.
4. Analysis of soapstone from Grafton, Vermont.
5. Theoretical composition of pure talc.

1/ Engel, A. E. J., Talc and ground soapstone chapter, Industrial Minerals and Rocks: A.I.M.E., 2nd Ed., 1949, p. 1019.

6. The important properties found in industrial talc which are desirable are extreme softness and smoothness, good luster, high slip tendency, low moisture content, good oil and grease absorption, chemical inertness, high fusion point, low electrical and heat conductivity, high dielectric strength, good retention for filler purposes, whiteness, and high specific heat. The fibrous form of talc is capable of retaining heavy paint pigments in suspension longer, preventing caking and settling, and acts as a bonding agent in the paint film. The current industrial demand is for finely ground talc in sizes ranging as small as 0.1 micron.

7. Talc is one of the great multi-purpose materials, being utilized for a variety of applications. Table 83 on page 5 shows that about 86 percent of the total United States production in 1951 was consumed chiefly by six industries: ceramics, paint, rubber, insecticides, roofing, and paper. The balance was accounted for in toilet preparations, pharmaceuticals, foundry facings, refractories, and other uses which include white shoe polishes, white glove cleaners, dusting powder, nail finisher, molds, leather finisher, filler material, grease component, abrasives, and bedding material.

8. Table 83 shows the sales of talc, pyrophyllite, and ground soapstone, by uses, in the United States for the years 1925-1951. The changes in the use pattern for the same period indicate that ceramics used about 20 percent of the annual consumption in 1945-1951, or 107,000 tons, compared to only one percent in 1931 or 1,600 tons.

9. The insecticide industry consumed 14 percent in 1951, or 90,000 tons compared to 2 percent in 1941 or 8,500 tons. The relative percentage of total annual consumption in the paint industry declined markedly from

48 percent in 1931 to 22 percent in 1946-1951 but the tonnage increased from 80,000 tons in 1931 to 115,000 tons in 1946-1951. In the paper industry, the drop in percentage was from 16 percent in 1931 to 5 percent in 1946-1951 while the quantity remained the same, 30,000 tons.

Table 83 - Talc, pyrophyllite, and ground soapstone sold by producers in the United States, by uses, in percentages, 1925-1951 2/

Use	1925-29	1930-34	1935-39	1940-44	1945-59	1950	1951
Paint	50	48	27	29	23	23	19
Ceramics	1	1	13	14	17	24	27
Rubber	10	11	13	12	14	12	11
Insecticides	1	1	(1)	4	13	12	14
Roofing	15	11	12	12	11	9	10
Paper	20	16	14	9	6	5	5
Toilet articles	(2)	3	3	5	3	2	1
Foundry facings	1	1	1	2	1	1	1
Crayons	-	-	(1)	(2)	(2)	(2)	(2)
Other	2	8	17	13	12	12	12
Total	100	100	100	100	100	100	100

1. Included in other uses.
2. Less than 0.5 percent.

10. The demand for talc in the ceramic and insecticide industries has increased sharply since 1940 as a result of intensive research by industry and government, whose findings revealed the superior properties of talc materials in these respective fields.

2/ Bureau of Mines Minerals Yearbook, 1931-1951.
Mineral Resources of the United States: Geological Survey, 1925-1930.

GEOLOGY

11. Previous geologic work and descriptions of the talc deposits in New England and New York have been published in reports listed in the bibliography. Early state geologic reports and maps describe many talc deposits in the region and several reports have been published since 1900 on the talc deposits and the talc industry, particularly of New York and Vermont. The U. S. Geological Survey has made detailed studies of the general geology and talc resources of the Gouverneur district of New York 3/, and similar studies by the Geological Survey are now in progress in Vermont.

12. Nearly all commercial talc deposits are divided into two classes: those derived from or very closely related to ultramafic (igneous) rocks, and those related to sedimentary magnesium-bearing carbonate rocks. Most of the commercially important talc deposits of New England are in ultramafic rocks. The deposits are lenticular, pod-shaped, and tabular bodies, many of which pinch and enlarge irregularly. Some of the more irregular ones are branched, folded, and faulted, particularly those in Vermont. The typical talc-serpentinite bodies in Vermont are concentrically zoned with a common central core of serpentinite which is surrounded by a shell of talc-carbonate rock (grit). In Massachusetts the talc deposits occur largely in a long, narrow, winding belt. The talc deposits in New York State occur in belts generally associated with metamorphosed sedimentary carbonate rocks.

3/ Engel, A. E. J., Talc and ground soapstone, Industrial Minerals and Rocks: Am. Inst. Min. Eng., 1949, pp. 1018-1041.

TALC DEPOSITS IN THE REGION

13. New York. - The commercial talc deposits in New York State are in St. Lawrence and Lewis Counties. Those in the Gouverneur district, in St. Lawrence County, are by far the larger and more important. They occur in a belt that trends northeastward from Sylvia Lake to near Edwards, a distance of about 10 miles. The mines near Talcville, Fowler, Edwards, Emeryville, and Balmat are among the most important talc mines in the United States.

14. The talc deposits in New York are associated chiefly with magnesian marble and were formed by metamorphism of structurally and compositionally favorable zones. The deposits 4/ are in ancient (pre-Cambrian) highly deformed and recrystallized marble of the Grenville series in the Gouverneur district. The talc commonly is intermixed with relatively large proportions of tremolite, anthophyllite, and serpentine, in irregular tabular masses which are interlayered with schistose and silicated marble in a northeast-trending belt. The "talc" beds have a composite length of more than 5 miles and a known continuous dip to the northwest of more than 1,500 feet in depth. Minable zones range in thickness from several feet to about 200 feet. The talc in Lewis County occurs in an irregular plug-like mass of marble that is highly brecciated and partly replaced by veins of serpentine, talc, chlorite, prehnite, quartz, and other silicates. 5/

4/ Engel, A. E. J., Talc and ground soapstone, Industrial Minerals and Rocks: Am. Inst. Min. Eng., 1949, pp. 1024-1026.

5/ Since 1945, the material mined at Natural Bridge, Lewis County, New York has been recorded as limestone production although it is described in the geologic literature as very impure talc.

15. The commercial talc rock in New York varies widely in composition and appearance. The color ranges from gray through pale green, pink, and lavender to white. The texture ranges from massive through fibrous to schistose.

16. Vermont. - The talc deposits of Vermont occur chiefly along the east flank of the Green Mountains in an irregular belt 10 to 20 miles wide that extends through the central part of the state from Canada to western Massachusetts. A few talc deposits are on the west flank of the mountains in the northern part of the state. Chidester, Billings, and Cady 6/ list 145 localities at which ultramafic rocks are known, most of them talc-bearing.

17. At the present time only four deposits are being mined: the Johnson mine, in Johnson; the Waterbury mine, in Moretown; the Hammondsville mine, in Reading; and the Windham mine, in Windham. In the past, principally before 1927, many deposits throughout the state, particularly in the central and southern parts, were mined, both for grinding talc and for soapstone. The principal abandoned mines, rated on the bases of past production, are thw Williams mine, Rochester; the East Granville mine, Granville, and the Carleton quarry, Chester. The other important centers of talc mining, from northern Vermont southward, were: Montgomery, Waterville, Jeffersonville, Johnson, Waitsfield, Bethel, Stockbridge, Ludlow, Grafton, Newfane, Dover, and Marlboro.

6/ Chidester, A. H., Billings, M. P., and Cady, W. M., Talc investigations in Vermont, Preliminary Report. U. S. Geological Survey Circular 95, 1951, pp. 8-14.

18. Numerous known deposits have never been mined, and many of them have not been prospected. The larger of these occur in Troy, Eden, Cambridge 7/, Stowe 8/, Waterbury 9/, Roxbury, Plymouth, Ludlow, Cavendish, and Windham.

19. The talc-bearing ultramafic bodies in Vermont range in width from a few feet to as much as a mile, and in length from less than 100 feet to more than 3 miles. The talc-carbonate rock shell commonly found surrounding a core of serpentine in these bodies ranges from a few to hundreds of feet thick. The talc-carbonate rock occurs at the margins of the deposits and occasionally may form the core of several interconnected ultramafic bodies. Massive talc rock (steatite) occurs at the outer margin of the grit and ranges from a few inches to 4 or 5 feet thick. At the border of the steatite zone, there is commonly a narrow ring (the "blackwall") of dark green to black chlorite-bearing rock, or narrow concentric zones of chlorite and biotite minerals, generally less than 1 foot thick.

20. The average talc-carbonate rock or grit is composed of 50-70 percent talc and 30-50 percent magnesite and ranges in color from greenish to light gray. The carbonate forms anhedral to rhombic grains in a matrix of fine to coarse flaky talc. Massive talc rock (steatite) is composed of 95 percent or more talc with minor amounts of chlorite, sphene, and carbonate. It is dark green to gray and may be massive or schistose.

7/ Chidester, A. H., Stewart, G. W., and Morris, D., Geologic map of the Rousseau Talc Prospect, Cambridge, Vermont, Mineral Investigation, U. S. Geological Survey, Map MF-8, 1952.

8/ Chidester, A. H., Geology of the talc deposits, Sterling Pond Area, Stowe, Vermont, Mineral Investigation, U. S. Geological Survey, Map MF-11, 1953.

9/ Chidester, A. H., Stewart, G. W., and Morris, D., Geologic map of the Barnes Hill Talc Prospect, Waterbury, Vermont. Mineral Investigations, U. S. Geological Survey, Map MF-7, 1952.

21. Massachusetts. - The talc deposits are associated with ultramafic rocks in a belt that extends across western Massachusetts from near Rowe at the north to Westfield at the south. Ultramafic masses are scattered in central Massachusetts 12 to 15 miles from Enfield, but none is reported to contain talc. No talc has been mined in Massachusetts since 1922, although moderate production was obtained at several localities for more than 20 years previously. The principal deposits mined were at Rowe, Zoar, Windsor and Hoosac tunnel, and others are reported at Middlefield, Groton, and West Shrewsbury.

22. The most important deposits were at Zoar where two mines were operated commercially before 1922 by the Massachusetts Talc Company and the International Talc Company (formerly Foliated Talc Company), respectively. The properties of these companies were adjacent and located about 4 miles north of the town. The talc as mined was foliated to massive, greenish to dark gray in color, and occurred in a chlorite and hornblende schist. The talc belt crops out on the surface for about two miles, striking toward the northeast and dipping 65°SE. The ore bodies were reported to be about 55 to 65 feet thick 10/.

23. Maine. - The distribution of ultramafic rocks and associated talc deposits in Maine is not adequately known. Ultramafic rocks are known on Deer Isle and in northwestern Maine south of Moosehead Lake.

10/ Ladoo, R. B., Talc and soapstone: Bur. of Mines Bull. 213, 1923, p.9.
11/ Hurley, P. M., and Thompson, J. B., Airborne magnetometer and geological reconnaissance in northwestern Maine: Geol. Soc. America Bull., v. 61,1950, p. 836.

Hurley and Thompson 11/ report possibly large deposits of talc in the Moosehead Lake area "near the road by Jim Pond . . . (and) on Enchanted Stream". Serpentinite on Little Spencer Stream has been drilled for asbestos. However, data are not sufficient to evaluate the contained talc.

24. New Hampshire..- Ultramafic rocks occur in the vicinity of Hanover, and Hitchcock 12/ shows several "beds of steatite" in central and southern New Hampshire in the towns of Francestown, Canterbury, Warner, Weare, Haverhill, Lancaster, and Orford. Several of these have been mined, but none since about the middle 1800's.

25. Connecticut. - Rice and Gregory 13/ noted the occurrence of talc in Torrington and New Hartford, and of serpentinite at Maltgy Lakes near New Haven.

26. Rhode Island. - Emerson 14/ shows an ultramafic body in northeastern Rhode Island near Woonsocket. In the early 1900's soapstone was quarried near Manville, chiefly for local use.

RESOURCES

27. Reserves of talc cannot be accurately evaluated because few talc mines carry out systematic development programs in advance of mining. Many of the mines in New York State have been worked continuously for more than 70 years and present reserves are estimated to be very large. Untapped and undiscovered resources are believed to be much larger than known reserves.

12/ Hitchcock, C. H., Atlas accompanying the report on the geology of New Hampshire, New York, 1878.

13/ Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: State Geological and Natural History Survey, Bull. No. 6, p.100, 112-113.

14/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U.S. Geol. Survey Bull. 597, 1917, Plate X.

28. Reserves of talc at active mines in Vermont are considered adequate for at least 10 to 20 years at present rate of output. Reserves in several explored prospects and the resources of a large number of unexplored deposits are very large, and should prove adequate to meet any forseeable demand for many years.

29. Little accurate information is available on talc resources of other New England States. Hurley and Thompson 15/ mention two deposits in the Spencer Lake area in Maine "that may be of future economic interest". Although deposits in New Hampshire, Massachusetts, Connecticut, and Rhode Island may be of economic size and quality, none is likely to be exploited in the near future.

ECONOMICS OF THE INDUSTRY

30. History and development. - The earliest known uses of talc (soapstone) were for ornamental and carving material in the days of Pliny. The Cathedral of Trondhjem, Norway, was constructed of soapstone about 1200 A. D.

31. In the United States, the early American Indians first recognized the qualities of soapstone for use in bowls, pots, and cooking utensils. Later the American settlers employed heated soapstone bricks as "warming stones" in carriages, wagons, sleighs, and beds. Tubs, sinks, hearthstones, mantels, griddles, and firebrick were manufactured from soapstone beginning about 1880.

32. Later in the 19th century, talc was recognized for its value as a superior filling, surfacing, and insulating agent. It soon displaced

15/ Hurley, P. M., and Thompson, J. B., Airborne magnetometer and geological reconnaissance in northwestern Maine: Geol. Soc. America Bull, v. 61, p.836. 1950.

Deposits of talc in the New England-New York Region 16/

Vermont

Mineral	County	Deposit	Location
Talc	Windsor	William Talc Mine	Rochester
Talc	Windsor	Greeley Talc Mine	Stockbridge
Talc	Windsor		Plymouth
Talc	Windsor	Hammondville Talc Quarry	Reading
Talc	Windsor	Carlton Talc Quarry	Reading
Talc	Windham	Vermont Talc Company	Windham
Talc	Windsor	Barton Talc Quarry	Chester
Talc	Windsor	Davis-Holden Quarry	Chester
Talc	Windham	"Unnamed Quarries"	Grafton, Marlboro
Talc	Addison		East Granville
Talc	Lamoille	Johnson Talc Mine	Johnson
Talc	Washington		Moretown
Talc	Windham		Hammondville, Windham
Talc	Windsor		Chester, Perkinsville, Rochester, Stockbridge, Weathersfield
Talc	Orleans		Lowell
Talc	Washington		Roxbury
Talc	Windham		Newfane
Talc	Windsor		Bridgewater
Talc	Washington	Waterbury Talc Mine	Moretown

New Hampshire

Soapstone	Hillsboro		Francestown
Soapstone	Merrimack		Canterbury
Soapstone	Merrimack		Warner
Soapstone	Hillsboro		Weare
Soapstone	Grafton	Quarry	Haverhill
Soapstone	Coos		Lancaster
Soapstone	Grafton		Orford

16/Incomplete list.

Mineral	County	Deposit	Location
		Massachusetts	
Talc	Berkshire		Hoosac Tunnel-Dalton
Talc	Franklin		Rowe, Zoar
Talc	Hampshire		Middlefield
Talc	Middlesex		Groton
Talc	Worcester		West Shrewsbury
		Rhode Island	
Talc	Providence		Manville
		New York	
Talc	St. Lawrence	Mines	Talcville, Fowler (2) Edwards, Balmat, Emeryville

other materials for filling in paper, rubber, and paint. New York fibrous talc from the Gouverneur district was discovered to be excellent as a blending agent with organic pulp in the manufacturing of paper products.

33. The discovery of talc at Talcville, near Gouverneur, New York, occurred about 1876. The first talc mines were opened in that section in 1878, but noteworthy production did not begin until 1880 when about 4,000 tons were shipped, valued at about $12.50 per ton. Production increased rapidly to a peak of 100,000 tons valued at about $10.30 per ton in 1916.

34. New York has always been the leading domestic producer in value and usually in tonnage. Other states along the East Coast began to produce by 1892. California reported its initial production in 1896. During 1880-1900, the entire domestic talc industry produced

about 1,000,000 short tons valued at about $12.57 per ton with New York and Vermont ranking first and second, respectively, in total output.

35. The New York State deposits in St. Lawrence County have developed into one of the largest and most productive talc areas in the world, with an annual output since 1930 averaging about 100,000 tons. Five principal mines in St. Lawrence County accounted for nearly one-third of the total domestic talc output in 1951.

36. The talc industry in the United States expanded from a handful of mining and processing operators before 1900 to about 50 companies in 1951, of which eight companies are in the New England-New York region and have provided employment for about 500 production workers.

37. In 1951, production was reported from 49 producers in eleven states - 32 talc, 10 pyrophyllite and 7 soapstone producers. The bulk of the talc was produced in New York, while most of the pyrophyllite came from North Carolina and the balance from California. Soapstone was produced in Vermont, Virginia, Maryland, California, and Texas.

38. Research by industry and government since 1920 has paved the way for the increased demand for talc use in ceramic materials. There are no reserves of block-steatite talc in the United States, and, therefore, it is one of the strategic materials stockpiled by the U. S. Government.

ECONOMIC TRENDS

39. United States. - The United States has been the major talc producing country, contributing about one-third of the annual world output. The supply of talc, pyrophyllite, and soapstone, with the

exception of strategic-grade block steatite talc, is adequate to meet all forseeable increased requirements for many years. Recent research on substitutes for the strategic variety indicates that there might be a decreasing need for block steatite talc.

40. The general industrial expansion pattern during the period, 1925-1951, shows a three-fold increase in apparent consumption from about 200,000 tons in 1925 to a record peak of 636,068 tons in 1951 to meet growing demands as a result of more diversified utilization of talc. (See Table 84, Part 1, p. 17).

41. New sources are being developed and companies are modernizing their plants and improving technology.

NEW ENGLAND

42. Vermont. - Vermont was formerly the leading domestic producer of talc during early 1900's, with a high of 90,612 tons at an average value of $8.59 per ton in 1918. The State has ranked about fourth in recent years, maintaining a steady marketed output of over 70,000 tons per year valued at about $12.65 per ton in 1946-1951 compared to an average annual prewar output of 40,000 tons valued at $8.46 per ton. Wartime production averaged about 60,000 tons per year with a peak of 75,000 tons in 1946.

43. Vermont production has been furnished chiefly by the following companies:

Table 84, Part 1 - Summary table of salient statistics of the talc industry in the United States, 1925-1951 17/

Year	Production		Imports		Exports		Apparent consumption-Short tons 4.
	Short tons	Avg. value per ton	Short tons	Avg. value per ton	Short tons	Avg. value per ton	
1925-1929[1]	187,721	$11.43	25,651	$21.77	1,644[2]	$660.35	212,057
1930-1934[1]	149,341	10.86	22,389	18.95	3,112[3]	304.87	169,862
1935-1939[1]	217,131	10.83	24,718	18.11	7,505	139.84	234,344
1940-1944[1]	379,488	11.84	14,173	15.18	10,188	117,39	383,473
1945-1949	470,437	14.96	16,001	25.29	15,448	205.70	470,990
1950	620,750	17.11	23,387	29.58	20,644	88.19	623,493
1951	636,068	17.80	20,640	33.63	23,009[3]	94.25	634,017

1. Annual average.
2. "Powders, talcum, face, compact, bath, and other toilet powders". Quantity not recorded in 1929.
3. Does not include "Powders - talcum (in package), face and compact". Quantity not recorded in 1931, 1932, 1951.
4. Compiled from incomplete data. Estimated to be 1,500 to 3,000 short tons higher after 1928.

17/ Mineral Resources of the United States: Geological Survey, 1925-1930.
Bureau of Mines Minerals Yearbook, 1931-1951.

Table 84, Part 2. - Summary table of salient statistics of the talc industry in the United States and in New England-New York Region, 1925-1951 18/

Year	United States			New England-New York Region								
				New York					Vermont			Average percent of U. S. production
		Short tons	Avg. value per ton		Short tons	Avg. value per ton		Short tons	Avg. value per ton			
1925-1929[1]		195,880	$11.75		95,951	$12.75		55,135	$ 9.45			77.3
High	1929	219,783	11.96	1929	109,583	13.08	1929	60,469	9.04			
1930-1934[1]		149,341	10.86		76,245	12.20		37,078	8.53			75.7
High	1930	174,028	11.31	1930	93,216	12.79	1930	45,881	8.71			
1935-1939[1]		217,131	10.33		87,399	12.41		40,824	9.24			59.4
High	1939	253,976	10.63	1939	99,880	12.54	1936	45,746	8.96			
1940-1944[1]		379,488	11.84		135,054	13.34		54,322	11.43			50.2
High	1941	416,369	11.29	1941	153,560	12.49	1944	60,692	11.94			
1945-1949[1]		470,437	14.96		117,563	19.67		70,295	12.50			40.2
High	1947	518,746	15.93	1946	124,446	17.73	1947	77,327	12.93			
1950		620,750	17.11		163,974	24.64		72,135	12.57			38.0
1951		636,068	17.80		152,652	27.32		78,694	12.05			36.4

18/ See work cited in footnote 17.

1. Annual average.

Company	Location: Mine	Location: Mill	Location: County
Eastern Magnesia Talc Co. Inc.	Waterbury #4, Johnson	Waterbury #4, Johnson	Washington Lamoille
Vermont Talc Co.	Windham	Chester	Windsor
Vermont Mineral Products, Inc.	Chester	Reading	Windsor

44. New York. - New York has been the leading state in the talc industry in the United States in total tonnage and value since 1880 with the exception of 1918-1922. During the period, 1930-1940, the State produced about one-half of the total domestic output, decreasing to about one-third in 1941-1951. The decline in the ratio is owing to production contributed by other states, although the annual rate of output in New York has actually increased about 30 percent in New York. (See Table 84, Part 1, p. 17).

45. Talc mining in New York, in progress for more than seventy years, has been yielding high quality talc-bearing ore without any apparent significant decrease in rate of production. The rate of output has been maintained at a high level because sufficient mine discovery and development have been replenishing the diminishing reserves.

46. The industry in New York. - There are two companies actively engaged in mining and milling talc in the State.

Company	Location: Mine	Location: Mill	Location: County
International Talc Co.	Talcville, Fowler (2), Edwards	Hailesboro Emeryville	St. Lawrence
Gouverneur Talc Co.	Balmat	Balmat	St. Lawrence

47. The talc mined in New York comes from the area near Gouverneur in St. Lawrence County, where fibrous talc-bearing tremolite, clear white in color, is produced chiefly for use in paints, ceramics, and a variety of other applications. More than half of the annual production is used in the paint industry. The ore near Gouverneur has properties which make it preferred for many growing industrial uses.

MINING AND TECHNOLOGY

48. Mining. - The mining of talc minerals may be underground or open pit, depending upon the size, shape, and attitude of the deposit, the country rock, and the topography of the terrain. However, the bulk of industrial talc and soapstone is mined underground by means of adit, inclined or vertical shaft. Horizontal openings (drifts and crosscuts), some of which are more than 20 ft. wide, driven from the main shafts, and core drilling, are employed to explore for further ore reserves and trace the talc ore in depth for subsequent mining. Raises are cut as large as 20 ft. square and are commonly inter-connected to develop and mine as much ore as possible. Little

timbering is done in the region, but the mine at Waterbury, Vermont, was timbered to prevent caving owing to the very soft, slippery nature of the talc. Wet-drilling is widely used now to reduce the dust hazard.

49. The Gouverneur Talc Company in St. Lawrence County, New York, operates its mines from a 700-ft. shaft which is vertical and largely concrete-lined. There are three working levels (300-foot, 500-foot, and 700-foot) which are mined by modified room and pillar method 19/. The large talc mines in the New England-New York area are introducing modern mining methods involving the employment of much mechanized equipment in their operations.

50. Shafts and other types of permanent mine openings are commonly located in the solid rock adjacent to the ore body for safety reasons. Underhand stoping and sub-level stoping methods are common talc mining practices. Long-hole drilling is used in the Gouverneur district, New York; Johnson, Vermont; and in Inyo County, California.

51. Milling. - The common milling procedure of industrial talcs is usually a dry-grinding operation followed by air separation. Low-grade talc is beneficiated by wet flotation and then dried before being cycled through a standard talc process (Eastern Magnesia Talc Co.).

19/ Gillingham, Walter P., Grinding Talc to Superfine Size: Compressed Air, vol. 55, No. 2, Feb. 1950, pp. 32-34.

52. The ordinary commercial talc-bearing rock mined is passed through primary and then secondary crushers which reduce it to 1/8 - 1/2 inch. Most industrial talc is ground from minus 200 mesh to finer sizes, ranging between 0.1 and 25.0 microns, averaging about 5 microns.

53. At the Gouverneur Talc Company operations, the ore is reduced to 1-inch in size by a gyratory primary crusher and then conveyed to wet-storage bins. The undersize ore is charged into a rotary drier, crushed, and stored in dry bins. Spiral conveyors carry the ore from dry storage to the pebble mill for grinding to 200-325 mesh. However, the bulk of the ore is more finely ground to 0.1 micron in size by pulverizing mills which are powered by compressed air at 150 psi and at a temperature of about 800°F20/.

54. The only commercial talc flotation plant in operation is that of Eastern Magnesia Talc Company at Johnson, Vermont, which was activated in 1937. The mill is divided into two sections, milling and flotation. In the former, the ore is dry-milled and air classified to various final sizes for marketing. Some of the low-grade ore is passed through the flotation process for upgrading into relatively pure talc 21/.

20/ See work cited in footnote 19.

21/ Franz, Hemming, Flotation of talc: Bull. Am. Ceram. Soc., vol. 23, No. 12, 1944, pp. 470-472.

55. Studies by the Bureau of Mines in cooperation with industry disclosed that domestic talc ores, chiefly from the Gouverneur district, may be beneficiated by flotation 22/ 23/.

56. The dust hazards at talc mines and mills of New York were investigated by the New York Division of Industrial Hygiene as a result of the high rate of disabling and fatal respiratory ailments in the industry 24/ 25/.

57. Raw material control by the industry.26/ - The wide variety of markets and end products for talc necessitates tests and specification standards for certain variations of grain size, shape, color, chemical and mineral composition, specific gravity, hardness, and other pertinent physical properties. Effective material control to minimize costs is exercised by efficient coordination of mining, milling and laboratory, and by maintaining close liaison with the manufacturers using the talc.

MARKETING

58. Talc is marketed usually as a finely ground powder, (150-325 mesh and micron sizes) and in coarse sizes ranging from 30 to 80 mesh.

22/ Norman, J. E., O'Meara, R. G., and Baumert, F.X., Froth flotation of talc ores from Gouverneur, New York: Bull. Am. Ceram. Soc., vol. 18, No. 8, August 1939, pp. 292-297.

23/ Gottlieb, Sidney, Beneficiation of domestic talcs: Bull. Am. Ceram. Soc., vol. 22, No. 7, July 1943, pp. 223-225.

24/ Siegal, William, Smith, A. R., and Greenburg, Leonard, Study of Talc Miners and Millers: Industrial Hygiene Div. of Industrial Hygiene, New York State Dept. of Labor, Reprints from Industrial Bulletin, vol. 22, No. 11, Nov. 1943 and No. 12, December 1943.

25/ Review of Literature on Dusts, Bureau of Mines Bull. 478, 1950, p. 38.

26/ Gaskins, W. W., Raw Material Control by the Talc Producer; Ceramic Bulletin, vol. 32, No. 4, 1953, p. 162.

59. The largest markets for talc are in the great industrial districts east of the Mississippi River and in California. Most talc is sold in car lots directly by the producer to the consumer but lesser quantities are generally handled by brokers and dealers.

60. The coarse grades of talc are shipped in bulk form in box cars. The finer grades usually are packed in self-sealing 3 and 4 ply 50 lb. paper bags. Bulk shipments of fine grades are made in paper-lined box cars.

61. Most industrial talcs are ground for market in four general size specifications: 96 percent minus 200-mesh; 98.5 percent minus 325-mesh; 99.5 percent minus 325-mesh; and 99.95 percent in micron sizes.

62. Crayons are made from selected massive compact talc or spapstone by sawing the blocks of crude talc into thin slabs. The slabs are cut to final size, usually 5 by 1/2 by 3/15 inches, and packed in small wooden boxes for shipment. Care is taken that the grain of the talc runs lengthwise in the crayon for greater strength 27/.

PRICE HISTORY

63. Most grades of marketed domestic talc rose in price between 1940 and 1951, with a general overall increase from an average value per ton of $11.31 in 1930 to the highest level on record of

---

27/ Ladoo, Raymond B., and Myers, W. M., Nonmetallic minerals: McGraw-Hill, 1951, p. 540.

$17.80 in 1951. During the period 1930-1941, domestic prices rose steadily to about the present level which was reached in 1942. The trend in prices has paralleled closely the annual rate of output ~~as shown by Plate I~~. Table 84a contains the complete salient annual statistical data on prices and production in the region compared with the total United States during the period, 1925-1951.

64. The all-time relatively low prices were established in 1933, with an average value of $10.35 per ton and in 1939, with a minor depression, of $10.63 per ton.

65. The highest prices industrial talcs in the United States are largely of steatite grade from California which sold for about $45 per ton in recent years.

66. Domestic prices are usually quoted on a short ton basis f.o.b. cars at the grinding mill, and vary according to the type of talc, pyrophyllite, or soapstone, fineness of grind, and purity. In general, prices of soapstone and pyrophyllite are in the same range as talc because of their similarity in occurrence, properties, utilization, and production costs.

67. All grades of foreign imported talc averaged $33.62 per ton in 1951, compared to $17.67 in 1938, and $21.61 in 1946; the higher prices are due to the imported material being chiefly ground steatite.

68. New York talcs increased from an average value per ton of $12.22 in 1930-1942 to $24.20 per ton in 1946-1951, with the World War II peak of about $17 per ton.

295

Table 84a - Comparison of salient statistics on talc, pyrophyllite, and ground soapstone in the United States and New England-New York area, by year, 1925-1951 28/

Year	Production (Short tons)	United States Value	United States Avg. val. per ton	Production (Short tons)	New York Value	New York Avg. val. per ton	Production (Short tons)	Vermont Value	Vermont Avg. val. per ton	Percentage of U. S. Production New York	Percentage of U. S. Production Vermont	Percentage of U. S. Production Total
1925	182256	2011793	$11.04	85109	993913	$11.68	54883	533603	$9.72	46.7	30.1	76.8
1926	181568	2110994	11.63	83231	1030075	12.38	53510	514527	9.62	45.8	29.5	75.3
1927	192316	2234724	11.62	94553	1191453	12.60	54688	503716	9.21	49.2	28.4	77.6
1928	202976	2537994	12.50	107321	1504103	14.01	52125	502501	9.64	53.9	25.7	79.6
1929	219783	2628662	11.96	109543	1439272	13.08	60469	546658	9.04	49.8	27.5	77.3
1930	174028	1969055	11.31	93216	1192604	12.79	45861	399548	8.71	53.6	26.4	80.0
1931	156898	1753350	11.18	84977	1059790	12.47	38424	318322	8.29	54.2	24.5	78.7
1932	117479	1292227	10.99	62833	764692	12.17	30361	250130	8.24	53.5	25.8	79.3
1933	159792	1653643	10.35	82618	969338	11.73	36233	299558	8.27	51.7	22.7	74.4
1934	138505	1448685	10.46	57580	681184	11.83	34243	313346	9.15	41.6	24.7	66.3
1935	172716	1848055	10.70	69125	817092	11.82	42739	381643	8.93	40.0	24.7	64.7
1936	216191	2343171	10.84	85429	1043232	12.21	45746	410045	8.96	39.5	21.2	60.7
1937	229999	2561753	11.14	96140	1215834	12.65	41118	384474	9.35	41.8	17.9	59.7
1938	212775	2302560	10.82	86423	1110024	12.84	35126	329084	9.37	40.6	16.5	57.1
1939	253976	2700834	10.63	99880	1252525	12.54	39393	378492	9.61	39.3	15.5	54.8
1940	281375	3008320	10.69	113611	1402524	12.35	38516	423368	10.99	39.5	13.7	53.2
1941	416369	4701392	11.29	153560	1917732	12.49	57248	663268	11.59	36.9	13.7	50.6
1942	387963	4754076	12.25	136752	1886678	13.80	58695	659314	11.23	35.2	15.1	50.3
1943	412868	5121414	12.40	136291	2003080	14.70	56458	658471	11.66	33.0	13.7	46.7
1944	398863	5017462	12.58	120000[1]	1677600[1]	13.98	60692	724556	11.94	30.0	15.2	45.2
1945	398384	5407235	13.57	108019	1873688	17.35	63574	752583	11.84	27.1	16.0	43.1
1946	457066	6445344	14.10	124446	2206553	17.73	75144	843247	11.22	27.2	16.4	43.6
1947	516094	7682481	14.89	120000[1]	2216400[1]	18.47	77327	999704	12.93	23.2	15.0	38.2
1948	518746	8265363	15.93	119716	2613935	21.83	70922	1014718	14.31	23.1	13.7	36.8
1949	461896	7523478	16.29	115636	2658774	22.99	64508	788341	12.22	25.0	14.0	39.0
1950	620750	10620743	17.11	163974	4039973	24.64	72135	906396	12.57	26.4	11.6	38.0
1951	636068	11322830	17.80	152652	4170987	27.32	78694	998792	12.05	24.0	12.4	36.4

1. Estimated

28/ See work cited in footnote 17.

69. The prices in the State followed a similar pattern to that of the total annual average value in the United States. New York, which controls the market for certain grades of talc, maintains the highest average value per ton compared to both foreign and other domestic industrial talcs.

70. Vermont. - Vermont talcs sold at an average value of $9.30 per ton in 1930-1942 as compared to a higher value of $12.62 per ton in 1946-1951. Wartime peak was at $11.93 per ton in 1943.

71. The talc is mainly of the massive variety which is sold at a lower price than the New York grade because of relatively inferior quality, a highly competitive market, and surplus supply of certain grades.

72. Recent quotations. - Talc prices quoted by the Engineering and Mining Journal, Metal and Mineral Markets, July 1953, were as follows:

New York: Double air-floated, short fiber, 325 mesh, $18.50 at $20.00.

Vermont: 100 percent through 200-mesh, extra white, bulk basis, $12.50; 99 1/2 percent through 200-mesh, medium white, $11.50 at $12.50. Packed in paper bags, $1.75 per ton extra.

73. Talc prices quoted in Oil, Paint, and Drug Report, in September 1952, were as follows:

New York: Fibrous, ground, $25.00-$30.00, 99.5 percent, 325-mesh, $27.00, 99.95 percent, micronized, $36.00.

Vermont: Ground, $14.00 - per ton, carload lots, f.o.b. works, containers included unless otherwise specified.

SELECTED BIBLIOGRAPHY ON TALC

1. AVERY, W. M. Loomis Talc Makes Improvements in Mining and Packing Facilities. Pit and Quarry, vol. 40, No. 4, October 1947, pp. 77-79, 83.

2. BOWLES, OLIVER, and JUSTICE, C. W. Growth and Development of the Nonmetallic Mineral Industries. Bureau of Mines Inf. Circ. 6687, 1933, 50 pp.

3. BOWLES, OLIVER. The Technology of Marble Quarrying (Soapstone). Bureau of Mines Bull. 106, 1916.

4. BROUGHTON, J. G. Geology of Ceramic Materials in New York State. New York Acad. Sci., vol. 7, 1945, pp. 107-108.

5. CHIDESTER, A. H., BILLINGS, M. P., and CADY, W. M. Talc Investigations in Vermont, Preliminary Report. Geological Survey Circular 95, 1951, pp. 1-33.

6. CHIDESTER, A. H., STEWART, G. W., and MORRIS, D. Geologic map of the Barnes Hill talc prospect, Waterbury, Vermont: U. S. Geol. Survey Mineral Investigations, Map MF-7, 1952.

7. CHIDESTER, A. H., STEWART, G. W., and MORRIS, D. Geologic map of the Rousseau Talc Prospect, Cambridge, Vermont. Geological Survey Minerals Investigations MF-8, 1952.

8. CHIDESTER, A. H. Geology of the talc deposits, Sterling Pond area, Stowe, Vermont: U. S. Geol. Survey Mineral Investigations, Map MF-11, 1953.

9. CLEMMER, J. BRUCE, and COOKE, S. R. B. Flotation of Vermont Talc-Magnesite Ores. Bureau of Mines Rept. Inv. 3314, 1934, 12 pp.

10. EMERSON, B. K. Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, 1917.

11. ENGEL, A. E. J. New York Talcs, Their Geological Features, Mining, Milling, and Uses. Mining Engineering, Trans. Am. Inst. Min. and Met. Eng., vol. 184, September 1949, pp. 345-348.

12. ENGEL, A. E. J. Talc and Ground Soapstone Chapter, Industrial Minerals and Rocks. A.I.M.E., 2nd. ed., 1949, pp. 1018-1041.

13. FRANZ, HEMMING. Flotation of Talc. Bull. Am. Ceram. Soc., vol. 23, No. 12, 1944, pp. 470-472.

14. GASKINS, W. W. Raw Material Control by the Talc Producer. Ceramic Bulletin, vol. 32, No. 4, 1953, pp. 162-163.

15. GILLINGHAM, WALTER P. Grinding Talc to Superfine Size. Compressed Air, vol. 55, No. 2, Feb. 1950, pp. 32-37.

16. GOTTLIEB, SIDNEY. Beneficiation of Domestic Talcs. Bull. Am. Ceram. Soc., vol. 22, No. 7, July 15, 1943, pp. 223-225.

17. GREAVES-WALKER, A. F., and OWENS, C. W., JR. The Expansion of Pyrophyllite. Am. Ceram. Soc. Bull., vol. 15, No. 9, September 1936, pp. 303-305.

18. GREENBURG, L. Dust Hazard in Tremolite Talc Mining. Yale Jour. Biology and Medicine, vol. 19, 1947, pp. 481-501.

19. HARTNAGEL, C. A., and BROUGHTON, J. G. The Mining and Quarry Industries of New York State, 1937-1948. New York State Mus. Bull. 343, May 1951, pp. 110-112.

20. HITCHCOCK, C. H. Atlas accompanying the report on the geology of New Hampshire, New York, 1878.

21. HUGHES, H. H. Soapstone. Bureau of Mines Inf. Circ. 6563, Feb. 1932, 18 pp.

22. HURLEY, P. M., and THOMPSON, J. B. Airborne magnetometer and geological reconnaissance in northwestern Maine: Geol. Soc. America Bull., v. 61, 1950, p. 835-842.

23. LADOO, R. B. Talc and Soapstone - Their Mining, Milling, Products, and Uses. Bureau of Mines Bull. 213, 1923, 133 pp.

24. LADOO, R. B. Talc Mining in New York. Bureau of Mines Rept. Inv. 2171, 1920, 15 pp.

25. LADOO, RAYMOND B., and MYERS, W. M. Nonmetallic Minerals. McGraw-Hill, 1951, pp. 531-545, 484-488, 415, 418.

26. _____. Mad River Talc Mines, Washington County, Vermont. War Minerals Rept. 222, 1944, 22 pp.

27. _____. Mineral Resources of the United States. Geological Survey, 1925-30.

28. _____. Minerals Yearbook. Bureau of Mines, 1931-1951.

29. NORMAN, J. E., O'MEARA, R. G., and BAUMERT, F. X. Froth Flotation of Talc Ores from Gouverneur, New York. Am. Ceram. Soc., vol. 18, No. 8, August 1939, pp. 292-297.

30. _____. Review of Literature on Dusts. Bureau of Mines Bull. 478, 1950, p. 38.

31. RICE, W. N., and GREGORY, H. E. Manual of the geology of Connecticut: State Geological and Natural History Survey, Bull. No. 6, 1906.

32. SIEGAL, WILLIAM, SMITH, A. R., and GREENBURG, LEONARD. Study of Talc Miners and Millers. Industrial Hygiene, Division of Industrial Hygiene, New York State Dept. of Labor. Reprints from Industrial Bulletin, vol. 22, No. 11, Nov. 1943 and No. 12, December 1943.

33. SPENCE, H. S. Talc, steatite, and soapstone; pyrophyllite: Canada Bur. of Mines, Mines Branch No. 803, 1940.

34. ZODAC, PETER. A Talc Quarry near Chester, Vermont. Rocks and Minerals, vol. 15, October 1940, pp. 269-370.

SECTION XXX - TITANIUM IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY

1. Titanium the ninth most abundant element in the earth's crust, is a strong, tough, light metal, between silver and stainless steel in color, with a specific gravity of 4.50. It melts at 3,150F, resist. many corrosives, and expands very little on heating. Although the melting point of titanium is extremely high, it absorbs oxygen and nitrogen and becomes brittle upon continued exposure to temperatures above 1,000°F.

2. The titanium bearing minerals ilmenite, $FeO.TiO_2$; arizonite, $Fe_2O_3 \cdot 3TiO_2$ 1/; sphene, $CaTiSiO5$; the dioxides rutile, brookite, and octahedrite with the same chemical composition TiO_2; and leucoxene, a name given altered ilmenite, occur in rock deposits, a few beach sands and stream placers at many locations throughout the world. Ilmenite and rutile are now the most important ores and ilmenite is the only titanium ore of economic importance known to occur in New England and New York.

3. Ilmenite, a heavy, iron-black mineral, occasionally with a reddish to brownish tinge, crystallizes in the hexagonal system, but good crystals are seldom found. It occurs in rock deposits of New England and New York as embedded grains and masses associated with magnetite. The mineral contains 47.3 percent FeO and 52.7 percent TiO_2 or 36.8 percent iron and 31.5 percent titanium.

4. Magnetite, Fe_3O_4 a heavy, black, magnetic iron oxide, while not a titanium mineral in itself, is important in New England and New York titanium ores because it is associated with the known ilmenite deposits

1/ The material classified as arizonite has been shown to be a mixture (presumably of iron-titanium oxides and titanium oxide); this mixture is referred to and sold by the industry as ilmenite.

of the area. Magnetite in lumps or sinter is an excellent source of iron.

5. Titanium oxide is used chiefly in pigments and electric welding rod coatings. Minor amounts are used in ceramics, carbides, and miscellaneous products. The metallic element and its alloys, the manufacture of which was only recently started, have so many favorable properties that the uses as a structural and engineering metal can hardly be surmised without further tests and experiments in its production and adaptation. The promise is great. The problems of production and fabrication are many.

USES

6. Pigments.--Titanium oxide, because of its light weight, whiteness, opacity, spreading qualities, and resistance to chalking and fading, is fast becoming the principal base of white and light tinted paints.

7. The oxide is manufactured chiefly from ilmenite by dissolving the contained metals in sulfuric acid, crystallizing the iron and other minerals out of solution, then precipitating the titanium sulfate by hydrolysis. The sulfate is calcined to oxide. In another process the iron is removed in a blast furnace and the titanium recovered from the slag which runs up to 70 percent TiO_2.

8. Ninety-nine percent of the ilmenite used in the United States, 683,000 short tons in 1952, went into the manufacture of pigments 2/

9. Electric welding rod coating.--The peculiar property of titanium compounds to stabilize an electric arc leads to their use as a coating

2/ Tumin, A. F., Titanium in 1952: Bureau of Mines Mineral Market Reports, MMS. No. 2179, July 1953, p. 5.

for electric welding rods. Manufacturers of welding rods use rutile, ilmenite, and manufactured TiO_2, but rutile is preferred. In 1952, about 11,000 short tons of rutile were so used.

10. Titanium metal. - Pure titanium has a tensile strength of about 35,000 pounds per square inch and is relatively soft, but the addition of small amounts of chromium, iron, nitrogen and carbon gives strength up to 175,000 psi and increases the hardness to about that of stainless steel. The coefficient of expansion is very low. Titanium and its alloys may be forged, worked, rolled and drawn. However, extra precautions are required to avoid contamination. The metal is practically immune to most corrosives, especially sea water. Where it is susceptible to attack by solutions containing hydrofluoric, phosphoric and a few other acids, the rate of corrosion may be severe.

11. The manufacture of ductile titanium is a new industry. Because of the many excellent properties and the interest of the Armed Services, the Bureau of Mines started experiments in 1942 to develop a process for its commercial production. The Bureau had sufficient metal on hand by 1944 to distribute free samples to investigators who would experiment and report their findings. Thus many large and responsible companies became interested.

12. By 1952 two large companies had entered metallic titanium production with a planned output of 10 tons a day each. Several other large metal, chemical, and paint companies have started, or are planning production. The Defense Procurement Administration hopes to have a production of 22,000 short tons a year by the end of 1955 3/.

3/ Tumin, A. F., Titanium in 1952: Bureau of Mines Mineral Market Reports, MMS. No. 2179, July 1953, p. 5.

EXTRACTION

13. The method of extraction used is a modification of a process devised by W. J. Kroll. Titanium tetrachloride, produced by the chlorination of titanium ore, is reduced to metallic sponge with magnesium in an inert atmosphere. The sponge, after cleaning, is melted in an electric furnace and ingots of about 99.3 percent titanium cast. Titanium sponge 99.3 + percent pure is quoted at $5.00 a pound 4/.

14. The present method of extraction is complicated, slow and expensive. With such widespread interest in the metal, industry feels that a new and entirely different metallurgical process may be brought out at any time thus making expensive installation obsolete. Consequently, the Office of Defense Management is granting quick capital write-offs for plant and equipment to encourage immediate production.

15. An electrolytic process for the reduction of TiO_2 to 99.9 percent titanium is reported in the July 1953 issue of "Iron Age". The estimated cost on a 50 ton per day plant would be about $1.50 a pound 5/.

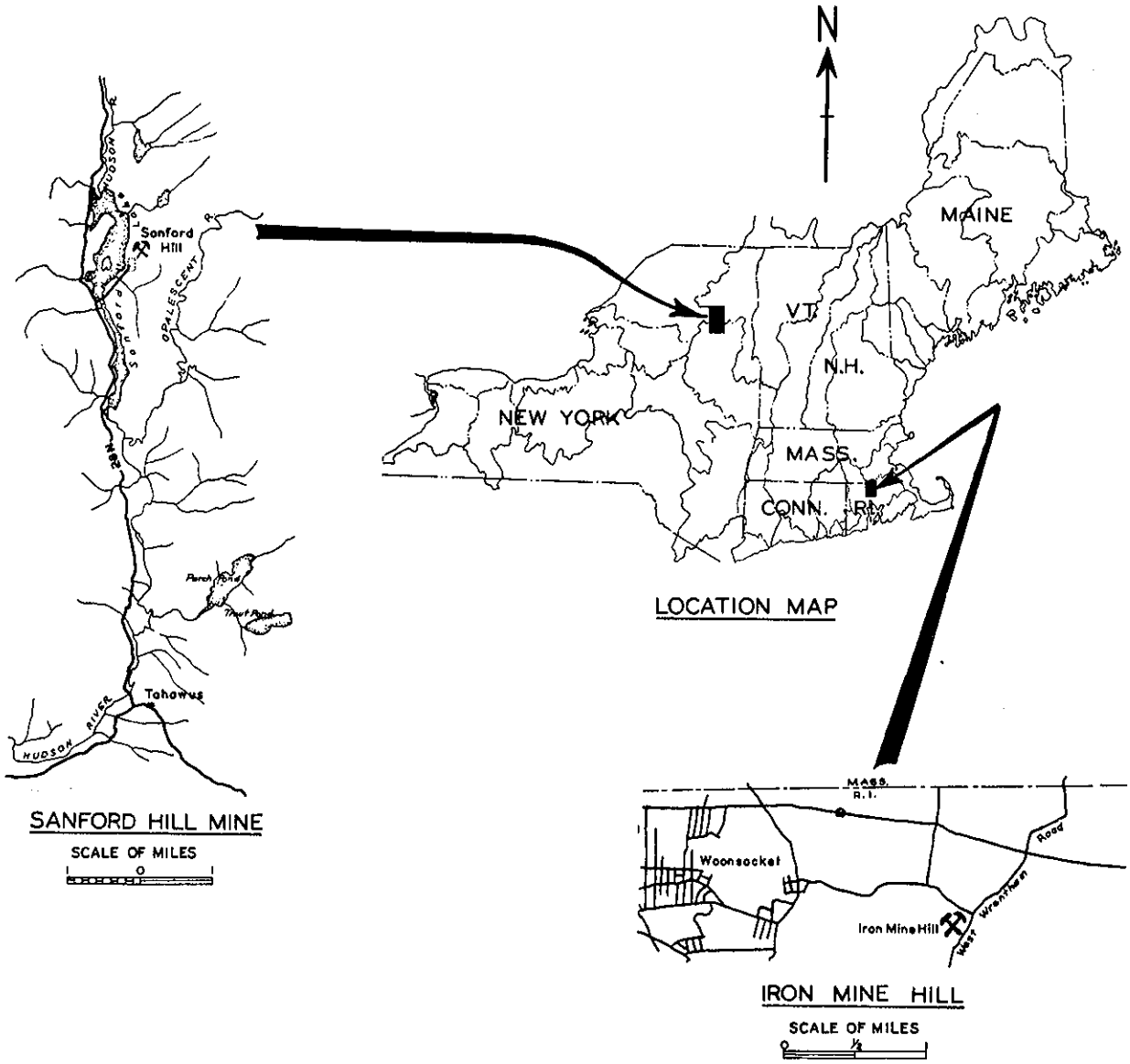
ILMENITE DEPOSITS

16. Deposits of ilmenite, the only ore of titanium known to occur in economic concentration in New England and New York, are located in Rhode Island and in New York (Plate 62). The ore is associated with magnetite, which is generally more plentiful than the ilmenite.

RHODE ISLAND

17. Iron Mine Hill. - Iron Mine Hill, in Cumberland, three miles east of Woonsocket, Providence County, contains fine-grained ilmenite intimately

4/ American Metal Market, August 27, 1953.
5/ Hatsheck, R. L., Titanium: New Process Leaves Lab.; Iron Age, July 9, 1953, p. 73.



SPECIAL SUBJECTS-REGIONAL

GENERAL REFERENCE MAP

TITANIUM DEPOSITS

New England-New York Inter-Agency Committee

March 1954

USBM Boston, March 1954

PLATE 62
CHAPTER XXXIX

intergrown with magnetite and disseminated in a dark green igneous intrusion. This material is called cumberlandite from its location.

18. Cumberlandite contains about 20 percent magnetite and 18 percent ilmenite with labradorite and iron-rich olivine the principal gangue minerals. Bureau of Mines tests show that a clean concentrate of magnetite-ilmenite may be made by magnetic separation after grinding to 100 mesh. Separation of the ilmenite from the magnetite was not accomplished at 200 mesh 6/. Metallic iron and titanium as TiO_2 can be recovered from the first magnetic fraction by the Soda Sinter Process 7/.

19. History.--Cumberlandite was considered a source of iron for many years. In 1703, some of it was mixed with ore from Cranston, Rhode Island to produce iron for cannon. None of the several attempts to produce iron from the material was economically successful. The greatest use of the rock has been for road metal.

20. Reserves.--There is no record of systematic drilling to establish reserves. However, the nature of the deposit indicates considerable depth. The surface area is reported to be about 600,000 square feet so that each 100 feet of depth should contain about 7,000,000 tons of material 8/.

NEW YORK

21. Some of the magnetite ores in the Adirondacks are associated with ilmenite. The largest deposits of magnetite-ilmenite occur in a

---

6/ Novell, E. W., and Lamb, F. D., Results of Tests on Titanium Magnetite Ore from Iron Mine Hill Deposit Located Near Cumberland, Rhode Island: Unpublished Bur. of Mines Report February 11, 1944.

7/ MacMillan, Robert T., Heindl, R. August, and Conley, John E., Soda Sinter Process for Treating Low-Grade Titaniferous Ores: Bureau of Mines R. I. 4912, 1952, pp. 46-61.

8/ Johnson, B. L., and Warren, C. H., Contributions to the Geology of Rhode Island: Am. Jour. Sci., 4th ser., vol. 25, 1908, pp. 6-8.

mineralized area across Essex County in the vicinity of Sanford and Henderson Lakes. There are also several scattered and comparatively small deposits outside of this area 9/.

22. History.--Mining activity started in the Lake Sanford vicinity in 1826, the ore being used to feed a small blast furnace to produce iron. Because of many production and transportation difficulties, severe winters, and the presence of an unknown mineral, identified as titanium in 1848, the endeavor was not permanently successful and closed in 1858 shortly after the death of the manager. Considerable prospecting and testing of the ore was done during the early 1900's but no mining was attempted. In 1941, because of the war threat to ilmenite imports, the National Lead Company purchased 11,000 acres in the vicinity of Sanford Lake and started production in 1942 to obtain ilmenite for use in the manufacture of pigments. The output was soon built up so that almost half of the ilmenite used in the United States now comes from New York.

23. Geology.--The ilmenite-magnetite ores of northern New York are associated with pre-Cambrian anorthositic igneous rocks of the large Mt. Marcy massif in the Adirondack Mountains. Ilmenite occurs as separate grains intergrown with the magnetite. Most of the known economic deposits of the state are all within a two mile radius of the Sanford Hill deposit 10/. The accessible ore reserves of this area are thought to be in excess of 100,000,000 tons 11/

24. Sanford Hill Deposit.--The Sanford Hill deposit is located in Essex County about 7 miles north of Tahawus, near the headwaters of the Hudson

9/ Peterson, R. B., Mineral Industries of New York State: Department of Commerce, State of New York, September 1950, p. 29.

10/ Hagar, I. D., Titanium and the MacIntyre Development: Paint Industry Magazine, December 1941.

11/ Hagar, I. D., Titanium and the MacIntyre Development: Paint Industry Magazine, December 1941, p. 31.

River. It lies on the west slope of Sanford Hill, off the eastern shore of Lake Sanford, and is a massive body of ore consisting of two near parallel veins 250 feet and 400 feet thick, and over 2000 feet long, separated by 200 feet of barren gobbroic anorthosite.

25. The ore contains from 32 percent to 45 percent iron and averages 18 percent titanium dioxide. A small amount of vanadium is present, seldom over 0.50 percent V_2O_5. The gangue within the ore is inclusions of green feldspar with some garnet, hornblende and biotite. Milling is by magnetic separation and flotation. A fairly clean ilmenite is obtained, but the magnetite retains the intergrown ilmenite which amounts to about 10 percent TiO_2 in the magnetite concentrates.

26. The National Lead Company estimated, in 1942, the deposit contained 15,000,000 tons of ore above the lake level 12/. Since that time mining from open cuts has been continuous and at the rate of more than 1,000,000 long tons a year.

27. Sanford Lake area.--The Iron Mountain, Calamity Mill Pond, Cheney Pond and Andrew Mountain deposits, all in the vicinity of Sanford Lake, have not been worked but sufficient investigation has been made to prove considerable reserves of minable ore at each.

28. Elizabethtown-Westport-Mineville area.--There are several magnetite-ilmenite deposits in or in the vicinity of the Elizabethtown, Westport, Mineville triangle. The deposits are reported to be small, rather low grade and of doubtful economic importance.

29. Other occurrences.--Minor occurrences of titanium-bearing magnetite

---

12/ Hagar, I. D., Titanium and the MacIntyre Development: Paint Industry Magazine, December 1941.

are reported at Port Leyden, Lewis County, near Peekskill, Westchester County, and near Saranac Lake, Franklin County.

CONCLUSIONS

30. The established value of ilmenite in the pigment field and its growing importance as a source of metallic titanium demonstrate its usefulness in the national economy. No area which might contain deposits of the mineral should be permanently abandoned until a complete and detailed examination is made. This applies particularly to the magnetite-ilmenite area in the Adirondack Mountains of Essex County, New York.

31. The examination should entail preparation of a surface and subsurface geological map, using whatever methods are necessary to obtain complete and accurate data.

SELECTED BIBLIOGRAPHY ON TITANIUM

1. _____. American Metal Market, August 27, 1953.

2. BALSLEY, R. R. Vanadium-Bearing Magnetite-Ilmenite Deposits Near Lake Sanford, Essex County New York. Geol. Survey Bull. 940-D, 1943, pp. 99-123.

3. HAGAR, I. D. Titanium and the MacIntyre Development. The Paint Industry Magazine, December 1941.

4. _____. Handbook on Titanium Metal. Titanium Metals Corporation of America, 6th ed., October 15, 1952, pp. 1-109.

5. HATSHECK, R. L. Titanium: New Process Leaves Lab.; Iron Age, July 9, 1953, p. 73.

6. JOHNSON, B. L. and WARREN, C. H. Contributions to the Geology of Rhode Island. Am. Jour. Sci., 4th ser., vol. 25, 1908, pp. 6-8.

7. KNOERR, A. W. World's Major Titanium Mine and Smelter Swing into Full-scale Production. Eng. and Min. Jour., vol. 153, No. 3, March 1952, pp. 72-90.

8. KUHN, W. E. Production of Titanium Ingots by Melting Sponge Metal in Small Inert-Atmosphere Arc Furnace. Electro-chemical Society Journal, vol. 99, March 1952, pp. 89-96.

9. MacMILLAN, ROBERT T., HEINDL, R. AUGUST, and CONLEY, JOHN E., Soda Sinter Process for Treating Low-Grade Titaniferous Ores: Bureau of Mines R. I. 4912, 1952, pp. 46-61.

10. MEYER, H. M. Minerals Yearbook, 1949 - Titanium. Bureau of Mines GPO, 1951, pp. 1220-1232.

11. NOVELL, E. W. and LAMB, F. D. Results of Tests on Titanium Magnetite Ore from Iron Mine Hill Deposit Located Near Cumberland, Rhode Island. Unpublished Bureau of Mines Report February 11, 1944.

12. PETERSON, R. B. Mineral Industries of New York State. Department of Commerce, State of New York, September 1950, p. 29.

13. SANFORD, R. S. Truck Haulage at National Lead Company Open-Cut Ilmenite-Magnetite Mine, Tahawus, New York. Bureau of Mines Inf. Circ. 7584.

14. STODDARD, C. K. and PIETZ, EMIL. Pilot Plant Distillation and Purification of Titanium Tetrachloride. Bureau of Mines R. I. 4153.

15. TUMIN, A. F. Titanium in 1952. Bureau of Mines Mineral Market Reports, MMS. No. 2179, July 1953, p. 5.

16. WARTMAN, F. S., and others. Production of Ductile Titanium at Boulder City, Nevada. Bureau of Mines Bull. 4519.

SECTION XXXI - WOLLASTONITE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Wollastonite, $CaSiO_3$, is a white to gray, tabular and generally fibrous mineral which, when pure, contains 48.25 percent CaO and 51.75 percent SiO_2. It is found in metamorphosed limestone at contacts with igneous rocks.

2. Wollastonite occurs at several places near Willsboro, Essex County, New York, and a large deposit is being worked in the vicinity. Occurrences elsewhere in New England and New York are few. Commercial deposits, other than that at Willsboro, have not been found in the region.

3. Small quantities of wollastonite were mined (1938 to 1948) from the Willsboro deposit for experimental purposes. Since 1948 it has been used in ceramics such as low-loss electrical insulation, glazed wall tile and other white wares, and in welding rod coatings. The most promising uses are in the paint and ceramic industries 1/. The entrance of wollastonite into the commercial nonmetallic field is so recent that its future value in industry cannot be appraised with certainty.

GEOLOGY AND RESOURCES

4. Although occurrences of wollastonite have been reported in New York in metamorphosed limestones of the Grenville series in northern Lewis County, northern Essex County, and in eastern Warren County, large deposits of wollastonite have been found only near Willsboro.

5. The deposits near Willsboro occur in a belt of gneisses as skarn

---

1/ Personal communication from R. B. Ladoo, Consulting Geologist, Godfrey L. Cabot, Inc., Boston, Mass.

(lime silicate rock)[2] which extends northwestward about 6 miles from a point about 2 miles southwest of Willsboro. The belt, which has been intruded by anorthosite, strikes N70°W and has an average width of a quarter of a mile. Wollastonite occurs with garnet and diopside as irregular layers at 10 or more places in the southeastern 2½ miles of the belt. In this portion of the belt the rocks consist chiefly of a series of alternating layers of garnet-rich rock, pyroxene granulite, pyroxene-garnet-plagioclase skarn, and local layers of wollastonite.

6. The Willsboro deposit, about 2½ miles southwest of Willsboro, is in a zone of skarn rocks along the southern boundary of the belt of metamorphosed Grenville rocks. "The ore occurs in two, or possibly three, roughly parallel, continuous bands, or beds, which vary widely in thickness, strike and dip. The thickness of minable-quality ore in the south band, on which most of the work has been concentrated, ranges from 4 to 70 feet, averaging 43 feet. Very little work has been done on the more northerly band or bands, and nowhere is the full width exposed on the surface." [3] The "south ore bed," as indicated by 14 drill holes totaling 2,280 feet, has a strike length of about 2,000 feet and an average dip of about 20 degrees to the north. The drilling has proved ore reserves to an average depth of 200 feet along the strike. The "south ore bed" consists of layers of wollastonite intercalated with layers of garnet up to 8 inches thick. In some places irregular masses and stringers of garnet are associated with coarse-grained wollastonite.

[2] The term skarn, as used in this section, is a contact-metamorphosed rock composed chiefly of pyroxene, garnet, or wollastonite, or various proportions of these silicates.

[3] Burnham, K. D., Butterfield, H. M., and Hall, A. L., Geology of the Willsboro, N. Y. Wollastonite Deposits: Godfrey L. Cabot, Inc., Boston, Mass., February 1953, p. 7.

7. The chemical composition of the wollastonite ore mined in 1952 is as follows: SiO_2, 51.76 percent; CaO, 47.56 percent; FeO, 0.46 percent; MnO, 0.04 percent; and H_2O, 0.09 percent. The physical properties are are shown in the appendix. The analysis indicates over 98 percent calcium silicate and analyses of core samples of ore from drill holes through the "south ore bed" showed the same chemical composition 4/. Although the average composition of the ore body is very uniform, the wollastonite-garnet ratio varies considerably in the garnetiferous layers. The garnet and diopside constitute 10 to 20 percent of the "south ore bed". A chemical analysis of the wollastonite product taken from the mill in 1950 is as follows: SiO_2, 50.90 percent; CaO, 46.82 percent; MgO, 0.85 percent; Al_2O_3, 0.78 percent; Fe_2O_3, 0.50 percent; TiO_2, 0.08 percent; and Na_2O, 0.08 percent 5/.

8. In 1953 the reserves of probable ore to a depth of 200 feet and strike length of 2,000 feet in the drilled part of the "south ore bed" were estimated at more than 3,720,000 tons 6/. Additional unexplored ore reserves at greater depth in the "south ore bed" and in the adjoining ore bed to the north were not estimated.

9. The discovery of thick beds of wollastonite near Willsboro indicates that deposits of commercial size and grade are likely to be found elsewhere in the eastern Adirondacks where metamorphosed limestones of the Grenville series are in contact with anorthosite. One of the more prom-

---

4/ Hall, A. L., Ladoo, R. B., Secord, R. N., and Stokes, C. A., Enter Wollastonite--New Commercial Non-metallic Mineral: Mining Eng., vol. 4, No. 10, Oct. 1952, p. 952.

5/ Ladoo, R. B., Wollastonite--A New Industrial Mineral: Eng. Min. Jour., vol. 151, No. 11, Nov. 1950, p. 97.

6/ Burnham, K. D., Butterfield, H. M., and Hall, A. L., Geology of the Willsboro, N. Y. Wollastonite Deposits: Godfrey L. Cabot, Inc.. Boston, Mass., February 1953, p. 6.

ising places to look for deposits of economic value appears to be where the metamorphosed limestones have been intruded by anorthosite in the eastern part of the Adirondack anorthosite massif, particularly between Port Kent and Westport, New York. In the northwestern Adirondacks, pyroxene, garnet, and wollastonite skarn has not been found where metamorphosed limestone is in contact with granitic rocks. It is unlikely, therefore, that this area contains any deposits of commercial wollastonite.

USES

10. In the finer grinds, wollastonite exhibits a constant bright color and has excellent fiber characteristics. These properties indicate its possible use as a filler and extender for products such as paint, paper, rubber, asphalt, and plastics. In paint it maintains clear tints and shows desirable weathering qualities.

11. Prepared wollastonite has uniformity, purity, reflectivity, and a needle-like shape of particle. These properties are desirable for many ceramic applications.

12. A high-grade tile has been produced from bodies containing wollastonite showing good water adsorption characteristics, high compression strength, and good glaze. Production of this type of tile can be made by a one-fire instead of the conventional two-fire process with a consequent fuel saving and improved kiln production rates.

13. Wollastonite acts as a natural "frit" or fusing compound, in the manufacture of glazes and enamels. It shows promise as an ingredient in ceramic low-loss electrical insulators 7/.

7/ Hall, A. L., Ladoo, R. B., Secord, R. N., and Stokes, C. A., Enter Wollastonite--New Commercial Non-metallic Mineral: Mining Eng., vol. 4, No. 10, Oct. 1952, p. 953.

HISTORY, MINING, AND BENEFICIATION

14. The Willsboro deposit was first reported by Dr. William Meade in 1810. There is no record of any attempt to use the wollastonite until about 1938, at which time J. B. Burnham, mining garnet in the vicinity, exposed a face of the mineral and began a search for possible uses.

15. Production from 1943 to 1949 was less than 300 tons annually 8/, principally for experimental purposes. In 1947 a pilot plant was set up under a Federal grant to study milling, beneficiation and utilization of the mineral. About 500 and 2,500 tons were mined in 1949 and 1950 respectively 9/. In 1951 the Cabot Carbon Company, a subsidiary of Godfrey L. Cabot, Inc., of Boston, became interested in the development. The pilot plant was enlarged to a capacity of 65 tons a day. By 1952, with milling practice and some markets established, the company began construction of a mill, with a capacity of 200 tons a day which was completed in September 1953.

16. The ore at the Willsboro deposit is friable, easy to drill, blast, and crush. A major portion of the deposit will be worked as an open pit. Methods of mining will be developed as experience is gained. The ore as mined contains about 75 percent recoverable wollastonite, 15 percent garnet, and 10 percent waste 10/.

17. "The mill flow scheme incorporates primary crushing and screening followed by drying. Drying insures most efficient beneficiation on magnetic separators and air tables. Garnet and wollastonite are sub-

---

8/ Hartnagel, C. H., and Broughton, J. G., The Mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 120.

9/ Minerals Yearbook, Minor Nonmetals: Bureau of Mines, 1949, p. 1343, 1950, p. 1362.

10/ Ladoo, R. B., Wollastonite--A New Industrial Mineral: Eng. Min. Jour., vol. 151, No. 11, Nov. 1950, p. 95.

stantially freed at about 10 mesh, but both magnetic and gravity separation give best results on the coarser particles. This necessitates multiple stage crushing in closed circuit to minimize fines. Accurate screening is a must; high capacity separation depends on closely sized feed. Fine grinding is done with a pebble mill-air separator circuit." 11/

18. Four finished grades have been developed for the market: a C-1 grade for ceramics, P-1 for the paint trade, and two fiber grinds, F-1 and F-2. The physical properties of these grades are shown in the appendix. Additional grades are contemplated and experimental work on their development is in progress. "Among these are a coarser ceramic grade (about 80 percent - 325 mesh), a finer paint in the low micron size range, and a special fiber grind for filter aid." 11/

11/ Hall, A. L., Ladoo, R. B., Secord, R. N., and Stokes, C. A., Enter Wollastonite--New Commercial Non-metallic Mineral: Mining Eng., vol. 4, No. 10, Oct. 1952, p. 953.

Physical properties of commercial grades of wollastonite

General:	
Chemical formula	$CaSiO_3$
Color	Colorless, white or grey
Hardness	5-5½ (Mohs' scale)
Luster	Vitreous
Fusibility	4 to a white, almost glassy, globule
Crystalline structure	Acicular
Refractive index	1.62-1.63
pH (10 percent slurry)	10.1- 10.3
Specific gravity	2.8- 2.9

	Grade			
Specific:	P-1	C-1	F-1	F-2
Oil adsorption lb./100 lb.	26	24	43	55
Brightness (GE)	92-96	92-96	--	--
Bulk density lb./ft.^{3}	57	57	41	35
Particle size				
Percent finer than 44 μ (325-mesh)	99.5	96	55	90
20 μ	93	89		
10 μ	63	54		
5 μ	43	37		

SELECTED BIBLIOGRAPHY ON WOLLASTONITE

1. AMBERG, C. R., and McMAHAN, J. F. Wollastonite, An Industrial Mineral: New York State College of Ceramics, Ceramic Experiment Station, Bull. 4, 1949.

2. BROUGHTON, J. G., and BURNHAM, K. D. Occurrence and Uses of Wollastonite from Willsboro, N. Y.: A.I.M.E. Trans., vol. 173, 1947, pp. 632-639.

3. BUDDINGTON, A. F. Adirondack Igneous Rocks and Their Metamorphism: Geol. Soc. Am. Memoir 7, 1939, pp. 40-41.

4. BUDDINGTON, A. F., and WHITCOMB, LAWRENCE. Geology of the Willsboro Quadrangle, New York: New York State Mus. Bull. 325, 1941.

5. BURNHAM, K. D., BUTTERFIELD, H. M., and HALL, A. L. Geology of the Willsboro, N. Y. Wollastonite Deposits: Godfrey L. Cabot, Inc., Boston, Mass., February 1953.

6. CERAMIC RESEARCH DEPARTMENT. The Use of Fiber-ground Wollastonite as a Thermal Insulation Material: New York State College of Ceramics, Monthly Progress Rept. No. 104, Alfred, N. Y., February 1945.

7. COX, P. E. Wollastonite and Diopside: Ceramic Age, June 1946, p. 260.

8. GILLESPIE, J. E. The Manufacture of Rock Wool: Canadian Inst. Min. Met. Trans., vol. 51, 1948, pp. 33-36.

9. HALL, A. L., LADOO, R. B., SECORD, R. N., and STOKES, C. A. Enter Wollastonite--A New Commercial Non-metallic Mineral: Min. Eng., vol. 4, No. 10, Oct. 1952, pp. 952-953.

10. HARTNAGEL, C. H., and BROUGHTON, J. G. The Mining and Quarrying Industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951.

11. LADOO, R. B. Wollastonite--A New Industrial Mineral: Eng. Min. Jour., vol. 151, No. 11, Nov. 1950, pp. 95-97.

12. LADOO, R. B., and MYERS, W. M. Nonmetallic Minerals: McGraw-Hill, 1951, pp. 583-585.

13. _____. Minerals Yearbooks, Wollastonite: Bureau of Mines, 1948-1950.

14. TROST, A. H, Boom Town in the Adirondacks: Pit and Quarry, vol. 45, No. 5, Nov. 1952, pp. 89-91.

15. VANUXEM, L. Description and Analysis of the Table Spar from the Vicinity of Willsborough, Lake Champlain: Jour. Acad. Nat. Sci. 2, pt. 1, 1820, pp. 182-185.

SECTION XXXIa-MANGANESE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Manganiferous rocks are found at many places in New England and New York. The most promising are the manganese and iron-bearing sedimentary rocks of eastern Aroostook County, Maine where over 40 deposits have been discovered within an area 30 miles wide and 70 miles long. This area may be subdivided into 3 districts - northern, central, and southern. The northern district which includes deposits within the cultivated region west of Caribou and Presque Isle, the central district which is in the heavily wooded area west of Bridgewater, and the southern district which centers on Houlton, the county seat.

2. Several minor manganese deposits occur in a belt near the western border of New England and manganese oxides are found in many bogs in New England and New York.

GEOLOGY AND MINERALOGY

3. Deposits in Aroostook County, Maine. - The manganese and iron-bearing rocks of Aroostook County are bedded deposits and are conformable with the enclosing slates. They are discontinuous, but generally occur as steeply dipping lenses of different thicknesses and lengths. The beds have been intensely and complexly folded and in places are broken by faults.

4. The beds of economic interest are of two types: (1) red hematitic shales, slates, and banded ironstones, and (2) green siliceous carbonate rocks. Generally, only one type is found in a deposit,

although both types may be present. The rocks are extremely fine grained while the mineralogy is complex and not clearly understood, with ore and gangue minerals intimately mixed.

5. In the hematitic rocks, the manganese is found in several oxy-silicate and silicate minerals, and in manganese-iron carbonates of variable composition. Hematite commonly is the most abundant metallic mineral. Iron-manganese carbonate is the principal manganese mineral in the siliceous carbonate rocks, and hematite is absent. Where metamorphosed, both types of rocks contain magnetite. The gangue minerals consist mostly of quartz, feldspar, one or two varieties of mica and chlorite, and lesser amounts of minerals such as apatite, pyrite, and less frequently pyrrhotite. The general grade and chemical composition of some of the "ores" are indicated in the tables on pages XXXIa-5 and XXXIa-6.

6. The manganese and iron-bearing strata range from single beds only a few feet thick to sequences of layers well over 100 feet thick. In the Maple-Hovey deposit of the central district, the sequence of "ore" layers is over 140 feet thick. The deposit has the form of a complex syncline or downwarp 6,300 feet long and 3,100 feet in maximum width. The beds are complexly folded and faulted. The upper and middle manganiferous units are about 57 feet thick each, while the lower manganiferous unit is approximately 33 feet thick. The grade of material that would be mined in the Aroostook deposits varies widely. The "ore" layers themselves are of different grades and they are interbedded with barren shale and slate in many proportions. The barren layers may range from a fraction of an inch to several feet in

thickness. Although selective mining of thick formations is possible, mining of relatively thin, higher grade layers within a lean formation would probably not be economically feasible, especially if open pit mining methods were used. The problem of wall rock caving would be considerable because the enclosing rocks in many deposits have a well developed slaty cleavage.

7. The manganese and iron are believed to have been deposited with the enclosing rocks; no good evidence of later reworking and concentration has been found. Exploration must, therefore, be guided by the principles that govern bedded deposits. The magnetite-bearing metamorphosed beds may be located by magnetic surveys but not all magnetic anomalies are related to the manganese-iron formation.

8. Other bedrock deposits. - The ore at the Taconic mine, a mile northeast of West Cummington, Hampshire County, Massachusetts is similar to that found elsewhere in New England and consists of manganese carbonate, manganese-iron carbonate, manganese silicates associated with secondary iron and manganese oxides, quartz, and some sulfide minerals. The ore bodies occur in feldspathic schist and appear to be concentrated along the axes of steeply plunging folds. The ore attained a maximum thickness of 60 feet at the crest of one fold, and thinned out on both limbs.

9. Physical exploration 1/ and geologic investigations 2/ of this

1/ Mosier, McHenry, and Thomas, M. L., Investigation of Anson Betts manganese mine, Hampshire County, Massachusetts: U. S. Bur. Mines Rept. Inv. 4443, pp. 1-8, 1949.

2/ Quinn, Alonzo, Geology of the Plainfield-Hawley area: Open file Rept. of the U. S. Geol. Survey, Massachusetts Dept. of Public Works Co-op. Program, 1945.

deposit indicate that the manganese is irregularly distributed. Drill hole samples 3/ show the manganese content to be low; analyses range from less than 1 percent to approximately 23 percent manganese. The recorded production 4/ between 1938 and 1942, the principal period of operation, is 10,080 short tons of ore averaging 21.5 percent manganese.

10. Surficial deposits. - Manganese oxides, closely associated with iron oxides are commonly concentrated in soils and similar surficial deposits by weathering processes; they may be precipitated in swamps and lakes by bacterial or other chemical action.

11. Manganiferous brown iron ores are found along or near the major fault which separates the Green Mountains from the carbonate rocks of the Lake Champlain Valley. Here the manganese and iron oxides occur as nodular and irregular masses in kaolinitic clays. The deposits are small, irregular, and difficult to mine. Many of the deposits are found in the Brandon "residual formation" 5/ which is believed to have been formed by weathering of iron and manganese-bearing Cambrian feldspathic quartzite and pre-Cambrian gneisses and by solution and redistribution of the manganese and iron within the clay residuum.

12. Manganese oxides form nodular and irregular masses in bogs also. These deposits are commonly low grade because of an admixture of clay and iron oxides. They are small and at most contain only a few hundred tons each.

3/ Mosier, McHenry, and Thomas, M. L., Investigation of Anson Betts manganese mine, Hampshire County, Massachusetts: U. S. Bur. Mines Rept. Inv. 4443, Figs. 3-6.

4/ Minerals Yearbook, U. S. Bureau of Mines.

5/ Burt, F. A., The geology of the Vermont ocher deposits: Vermont State Geologist 17th Rept., 1929-1930, pp. 107-136, 1931.

RESERVES AND RESOURCES

13. The manganese deposits in Aroostook County, Maine are the only potential sources of manganese in the New England-New York Region and at this time recovery and treatment are too difficult to be economically feasible.

14. Reserves of manganese in Aroostook County are large. Miller 6/ has summarized the reserves. Combining the data for individual deposits contained in his summary 6/, the reserves in long tons of contained manganese for the northern and southern districts are as follows:

	To depth of 100 feet long tons Mn content	Aver. grade percent	To depth of 200 feet long tons Mn content	Aver. grade percent
Measured "ore"	543,000	10.3	970,000	10.2
Measured and indicated "ore"	791,000	9.3	1,340,000	8.4
Measured, indicated, and inferred "ore"	1,100,000	8.8	1,735,000	8.7

15. Recent investigations of the central district deposits have enlarged the estimates of manganese reserves in Aroostook County.

6/ Miller, R. L., Manganese deposits of Aroostook County, Maine: Maine Geological Survey Bull. 4, pp. 36-39, Table 1, p. 38.

Eilertson 7/ gives the following estimate of "crude ore reserves in place" for the central district:

Classification	Long tons	Mn%	Fe%	P%	SiO_2%	S%	Al_2O_3%	CaO%	MgO%
Minimum 10% Mn	121,000,000	11.2	23.9	0.90	25.4	0.05	7.61	3.28	1.39
5 to 10% Mn	135,000,000	6.8	17.9	0.70	36.0	0.12	11.43	2.55	2.01
Total	256,000,000	8.9	20.7	0.80	31.0	0.08	9.62	2.89	1.72

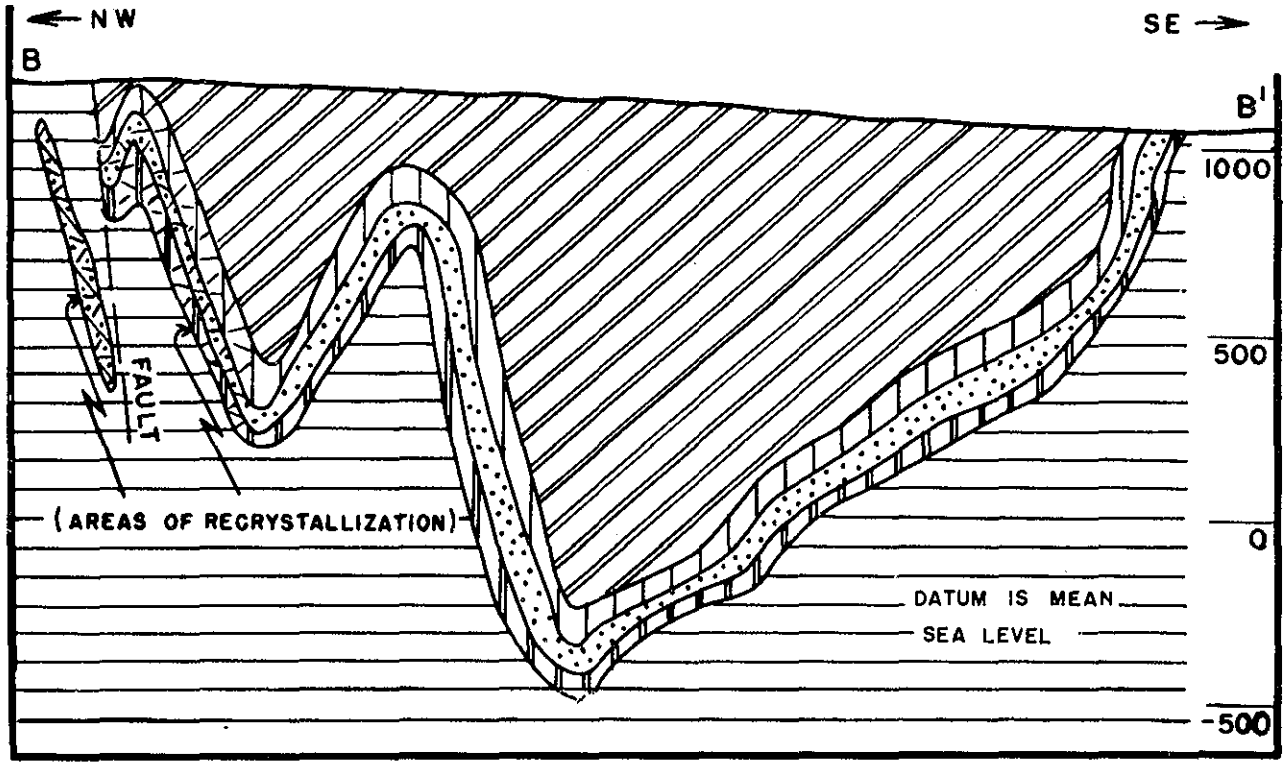
These reserves include measured, indicated and inferred ore 7/.

15. Other deposits. - Manganiferous brown iron ores characteristically form small, spotty, and discontinuous deposits. They have been mined chiefly as iron ores, e.g. the Kinney-Kobble mine in South Wallingford, Vermont produced about 20,000 tons of iron ore containing 20-35 percent manganese. The quality and quantity of manganiferous brown iron ores in New York and New England is not known, but the reserves are believed to be small and low grade.

16. Bog manganese deposits are found at many places in New England and New York, but they are neither large enough nor of high enough grade to be considered as manganese ores. The most promising contain only a few hundred tons of material carrying 10 to 25 percent manganese. Dale 8/ has described the principal bog deposits in Columbia County, New York.

7/ Eilertsen, N.A., Maple Mountain-Hovey Mountain manganese project, central district, Aroostook County, Maine: U. S. Bur. Mines Rept. Inv. 4921, pp. 2, 16, 1952.

8/ Dale, N. C., Post-glacial manganese in Columbia County, New York: New York State Mus. Bull. 207-208, pp. 85-100, 1919.



VERTICAL 500 0 500 HORIZONTAL
FEET

EXPLANATION

MANGANIFEROUS INTERBEDDED HEMATITIC & GREEN SLATE.

MANGANIFEROUS BANDED HEMATITE.

GRAY-GREEN SLATE.

GREEN SLATE (HORIZONTAL LINE PATTERN), ENCLOSING LENTICULAR UNITS (DIAGONAL LINE PATTERN).

MANGANIFEROUS PURPLE & RED SLATE

SPECIAL SUBJECTS-REGIONAL

GEOLOGIC STRUCTURE SECTION

MAPLE MOUNTAIN - HOVEY MOUNTAIN DEPOSIT

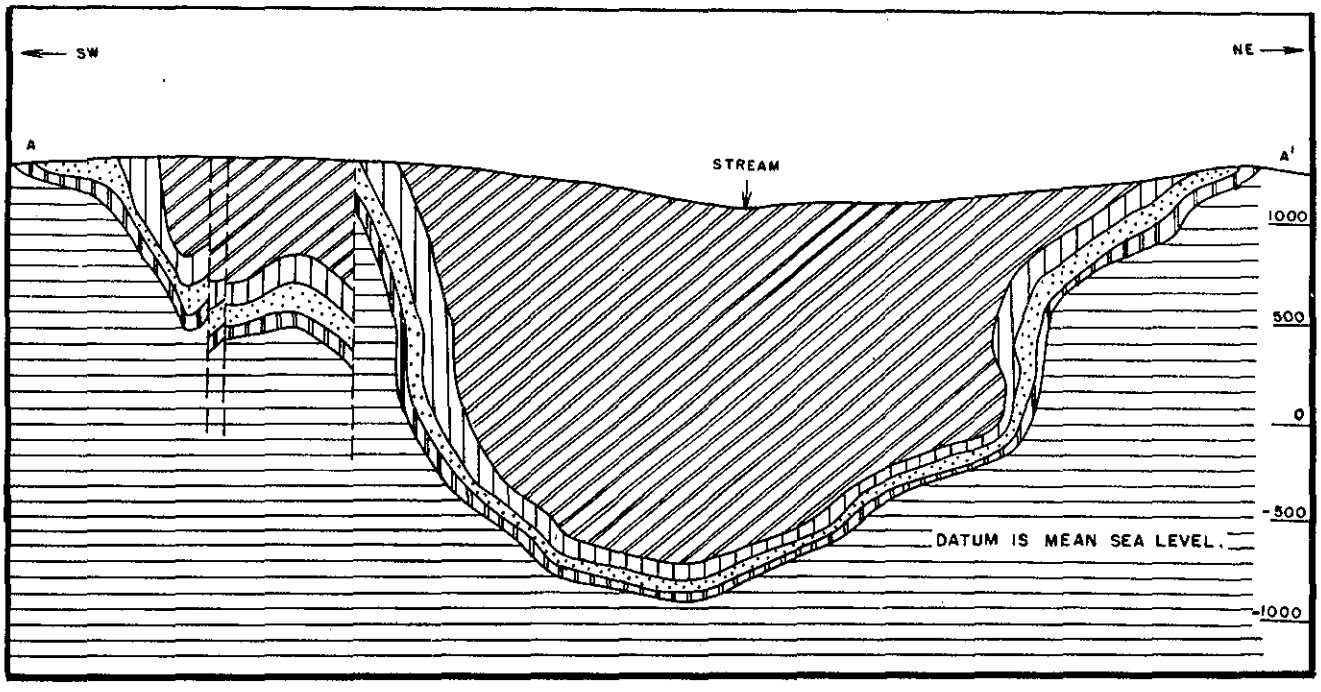
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON, JAN. 1955

PLATE 62A

CHAPTER XXXIX



FEET

VERTICAL 500 0 500 HORIZONTAL

EXPLANATION

- MANGANIFEROUS BANDED HEMATITE.
- GRAY-GREEN SLATE.
- MANGANIFEROUS INTERBEDDED HEMATITIC & GREEN SLATE.
- PROBABLE FAULT.
- MANGANIFEROUS PURPLE & RED SLATE.
- GREEN SLATE.

SPECIAL SUBJECTS-REGIONAL

GEOLOGIC STRUCTURE SECTION

MAPLE MOUNTAIN- HOVEY MOUNTAIN DEPOSIT

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON, JAN. 1955

PLATE 62 B

CHAPTER XXXIX

FUTURE WORK

17. Field investigations of the Aroostook deposits within the last decade have shown the presence of large reserves of low grade manganiferous rocks in Aroostook County, Maine. These deposits can be readily detected and outlined by ground magnetic methods where magnetite is present even in moderate amounts. However, the rocks in areas outlined by magnetic anomalies may not be manganiferous and trenching or drilling must be used to determine the manganese content. As the reserves blocked out in the area are very large, further research should be directed toward the development of a metallurgical process to facilitate an economic recovery of the manganese rather than toward physical exploration.

18. The regional geology of the Aroostook manganese area is not completely understood and detailed geologic mapping is recommended. A more fundamental knowledge of the geologic framework and the stratigraphic sequence of formations in this belt will be valuable in guiding any future prospecting for additional deposits in the area if a successful process for treating them can be developed.

19. Other deposits. - It is unlikely that other types of manganese deposits in New England and New York will produce appreciable quantities of manganese ores. They are small, low grade, and spotty and any beneficiation studies made will probably be restricted to deposits with a potential for large production such as those in Aroostook County, Maine and elsewhere in the country.

20. The same disadvantages apply to the low grade occurrences of wad which are scattered among the bog deposits. Recently concluded investigations by the Southwest Engineering Company for the Defense

Minerals Production Administration on the treatment of such manganiferous material in Virginia have not resulted in developing any economically feasible recovery method for their contained manganese. Field investigations of waddy bog deposits are therefore not warranted.

21. The small amount of manganese present in surficial deposits such as the "Brandon residual formation" in Vermont would probably be costly to find and difficult to recover and treat. Experience with similar deposits of manganese in clay residuum along the Appalachian Mountains in the Southeastern United States and in Arkansas illustrates the problems of finding, mining, and treatment of such ores. Scientific exploration for such deposits is costly and tedious; it often involves the sinking of numerous test shafts to determine the amount of mineralization present. From these shafts samples of sufficient bulk to enable the determination of concentration ratios may be taken. Costly exploration of this nature is probably beyond the potential worth of many of these deposits in New England, but it is desirable for the successful exploitation of deposits of this type.

SELECTED BIBLIOGRAPHY ON MANGANESE

Burt, F. A., 1931, The geology of the Vermont ocher deposits: Vermont State Geologics 17th Rept., 1929-1930, pp. 107-136.

Dale, N. C., 1919, Post-glacial manganese in Columbia County, New York: New York State Mus. Bull. 207-208, pp. 85-100.

Eilertsen, N. A., 1952, Maple Mountain-Hovey Mountain manganese project, central district, Aroostook County, Maine: U. S. Bur. Mines Rept. Inv. 4921, pp. 1-118.

Harder, E. C., 1910, Manganese deposits of the United States: U.S. Geol. Survey Bull 427, pp. 1-298.

Miller, R. L., 1947, Manganese deposits of Aroostook County, Maine: Maine Geol. Survey Bull. 4, pp. 1-77.

Mosier, McHenry, and Thomas, M. L., 1949, Investigation of Anson Betts manganese mine, Hampshire County, Massachusetts: U. S. Bur. Mines Rept. Inv. 4443, pp. 1-8.

Quinn, Alonzo, 1945, Geology of the Plainfield-Hawley area: Open file rept. of the U.S. Geol. Survey, Massachusetts Dept. of Public Works Co-op. Program.

White, W. S., 1943, Occurrences of manganese in eastern Aroostook County, Maine: U. S. Geol. Survey Bull. 940-E, pp. 125-161.

SECTION XXXIb-ASBESTOS IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Most of the asbestos consumed in the United States is chrysotile, the serpentine variety; the country is dependent upon imports, chiefly from Canada, for approximately 90 percent of its supply. Nearly all of the domestic supply comes from one mine in northern Vermont, but Arizona produces small quantities of very high grade, long-fiber chrysotile. Several western and southeastern states sporadically produce a few hundred tons of amphibole asbestos, entirely tremolite and anthophyllite varieties. One deposit in Massachusetts has produced a little anthophyllite.

2. Little information has been published on the occurrence of asbestos in New England and New York. Jenkins 1/ and Bowles 2/ give brief accounts of some occurrences. Several of the reports of the Vermont State Geologist briefly describe some deposits. (See Marsters 3/, Perkins 4/, and Richardson 5/.) Preliminary results of a program of mapping in the belt of ultramafic rocks of Vermont have been published by the U. S. Geological Survey 6/. The State Geological Survey of Maine has studied some of the ultramafic rocks in Maine, and two reports have recently been published 7/ 8/. The U.S. Bureau of Mines recently (1954) core drilled asbestos

---

1/ Jenkins, G. F., Asbestos, Industrial Minerals and Rocks: Am. Inst. Min. Eng., 1949, pp. 55-76.

2/ Bowles, Oliver, Materials Survey, Asbestos, 1950: U. S. Bureau of Mines, 1952, p.II-1.

3/ Marsters, W.F., A Preliminary on a Portion of the Serpentine Belt of Lamoille and Orleans Counties, 1903-1904. Vermont State Geologist 4th Report, 1904, pp. 86-102; 1905, pp. 36-51.

4/ Perkins, G. H., Report on the Mineral Industries of Vermont, 1901-1902: Vermont State Geologist 3rd Rept., 1902, pp. 36-40.

5/ Richardson, C. H. Asbestos in Vermont, 1909-1910: Vermont State Geologist 7th Report, 1910, pp. 315-330.

6/ Chidester, A. H., Billings, M. P., and Cady, W. M., Talc Investigations in Vermont, Preliminary Report: U.S. Geol. Survey Circ. 95, 1951.

7/ Wing, L. A., and Dawson, A. S., Preliminary Report on Asbestos and Associated Rocks of Northwestern Maine, 1947-1948: Report of the State Geologist, Maine Devel. Comm., 1949, pp. 30-62.

8/ Wing, L. A., Asbestos and Serpentine Rocks of Maine, 1949-1950: Report of the State Geologist, Maine Devel. Comm., 1949, pp. 30-62.

deposits in the Spencer Lake area in Maine.

GEOLOGY

3. Asbestos is a general term denoting fibrous varieties of serpentine and amphibole. Serpentine asbestos or chrysotile ($Mg_3Si_2O_5(OH)_4$) is a common mineral in the ultramafic intrusives that crop out in places in all of the New England States. In a few large, relatively fresh peridotites chrysotile is sufficiently abundant and of good enough quality to be mined profitably.

4. Chrysotile asbestos is found in veins as cross-fiber, in which the fibers are approximately at right angles to the vein walls, and as slip-fiber, in which the fibers lie approximately in the same plane as the vein or along shear surfaces. Cross-fiber asbestos ranges in length from a small fraction of an inch to several inches, but seldom exceeds 2 or 3 inches. Slip-fiber is generally less than an inch long, but may be as long as 1 foot. Fiber of good quality separates readily into strong and pliable threads. Freshly broken veins of chrysotile have a pearly luster, and range in color from deep green or brown to pale yellowish green or very light amber.

5. The amphibole asbestos anthophyllite, $(MgFe)_7Si_8O_{22}(OH)_2$, is found at several places in New England where blocks of peridotite enclosed in granite have been hydrothermally altered. The anthophyllite is colorless, fibrous and in bodies up to 12 feet thick.

OCCURRENCE AND DISTRIBUTION IN THE REGION

6. The most important asbestos deposit in New England, and the only one that is now being worked, is on Belvidere Mountain, Lamoille County,

Vermont 9/. The asbestos is both cross-fiber and slip-fiber, but only the cross-fiber is commercially important. The cross-fiber is found in massive dunite (a side variety of peridotite composed entirely of olivine) that is only partly serpentinized, or if completely serpentinized is unsheared. Most of the veins are less than one-half inch wide, but some are more than an inch wide. The slip-fiber is in locally sheared and completely serpentinized rock. The fibers are mostly less than one-half inch long, though some may be very long. The sheared and serpentinized zones with abundant slip-fiber are concentrated near the margins of the ultramafic bodies. Only a small proportion of the Vermont fiber is of spinning grade, and this fiber is of low, non-strategic quality with a fairly high iron content.

7. A large volcanic greenstone belt in Maine, extending from Oxford County to northeast Aroostook County, contains, and, in places is bordered by, extensive bodies of serpentine.

8. Considerable geological work has been done along this belt by the State of Maine 10/ 11/ 12/. An airborne magnetometer and reconnaissance survey was made in northwestern Maine in 1950 13/ and two Canadian

---

9/ Marsers, W. F., Petrography of the Amphibolite, Serpentine, and Associated Asbestos Deposits of Belvidere Mountain, Vermont, 1905-1906 (found in Asbestos, G. H. Perkins). Vermont State Geologist 5th Report, 1905, pp. 36-51.

10/ Keith, Arthur, Preliminary Geological Map of Maine: Published by the Maine Geological Survey, Orono, Maine, 1933.

11/ Wing, Lawrence A., Summary Report on Maine Greenstones: Report of the State Geologist, Published by the Maine Development Comm., Augusta, Maine 1949-1950, p. 47.

12/ Report of the State Geologist 1947-1948.

13/ Hurley, Patrick M., and Thompson, James B., Airborne Magnetometer and Geological Reconnaissance Survey in Northwestern Maine: Geol. Soc. of Am. Bull., vol. 61, Aug. 1950, pp. 835-842, 1 Pl.

asbestos mining companies drilled small areas on both sides of Little Spencer Stream. The results of the drilling are unknown and no mining was attempted.

9. Investigation by the U.S. Bureau of Mines in 1954 indicated the presence of cross-fiber chrysotile, asbestos, nickel, and chromium in the serpentine rocks from Johnson Bog to Little Spencer Stream in Somerset County.

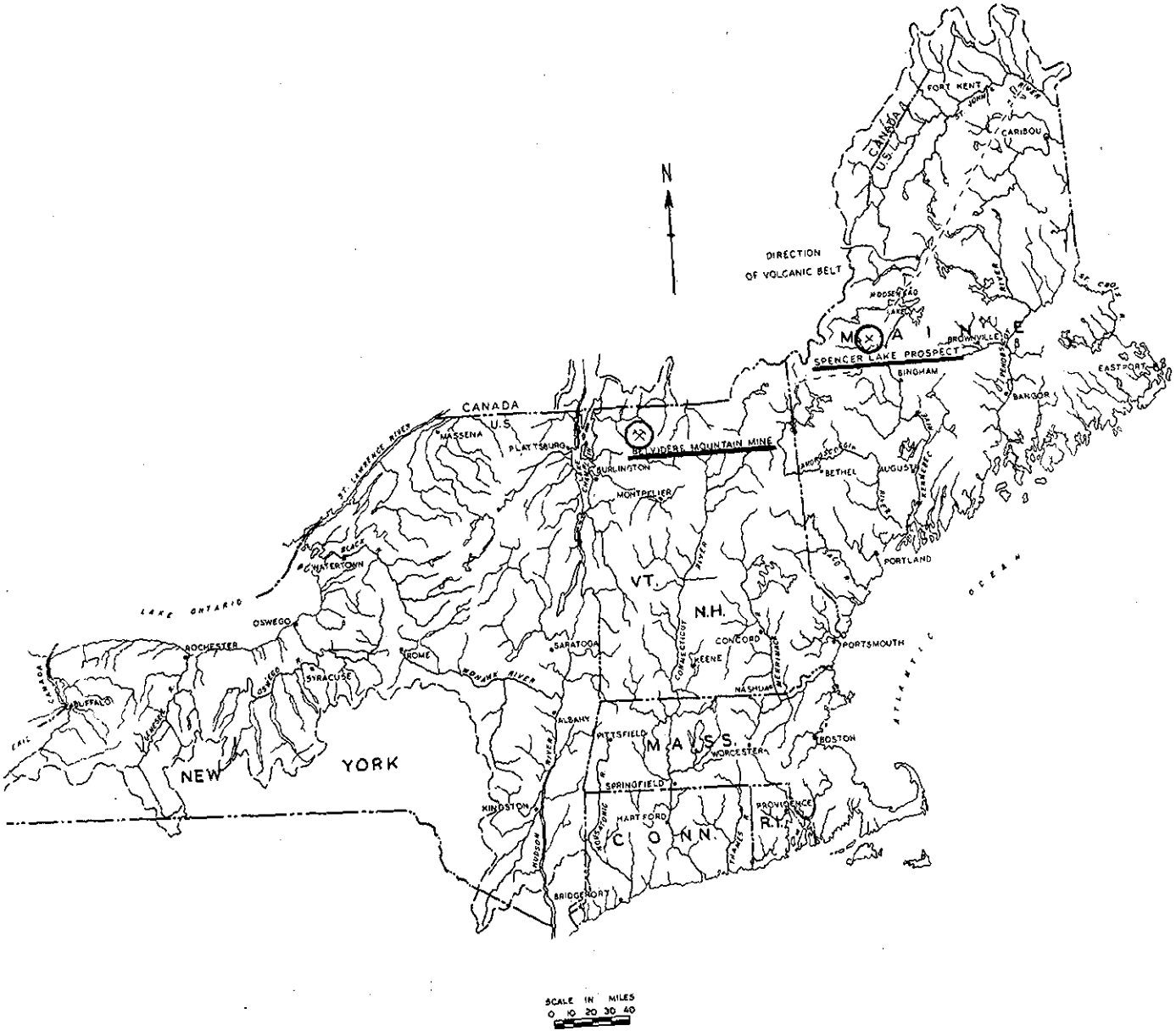
10. Asbestos estimated at 3 to 5 percent was found in the core samples of 9 drill holes and 2 outcrop samples. The holes all stopped in asbestos-bearing serpentine. The arithmetical average of the chemical analyses of the 11 samples shows 0.22 percent nickel and 0.37 percent chromium, which is about the average for most nickel-chromium bearing peridotite.

11. A complete report of the investigation by the U. S. Bureau of Mines of Asbestos and associated metal occurrences in northwestern Maine is in preparation.

12. Chrysotile asbestos has been noted in very small amounts in ultramafic rocks in New England (See Talc Section). The only deposits that at present appear to offer commercial possibilities, besides those at Belvidere Mountain in northern Vermont, are northeast of Belvidere Mountain in Lowell, Troy, and Westfield, Vermont, and in the vicinity of Spencer Lake in northwestern Maine (See Plate 62c).

13. Emerson 14/ noted the occurrence of anthophyllite asbestos at several places in Massachusetts, and some was mined years ago. Emerson described the occurrences as follows:

14/ Emerson, B. K., Geology of Massachusetts and Rhode Island: U. S. Geological Survey Bull. 597, 1917, pp. 215-217.



SPECIAL SUBJECTS-REGIONAL

ASBESTOS
LOCATION MAP

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

PLATE 62 C
CHAPTER XXXIX

USBM BOSTON, JAN. 1955

"A great block of black saxonite is included in . . . granite in Pelham (Mass.), a mile southwest of Mount Lincoln . . . It has been much worked for asbestos and corundum and has been opened for 200 feet along the strike . . . Other similar masses occur at Shutesbury, Pelham, Leverett, New Salem, and Wilbraham . . .

"The saxonite . . . in a layer from 3 to 12 feet thick . . . (is) broken into a mass of blocks and . . . altered into colorless fibrous anthophyllite . . . (some fibers are) more than 2 feet long."

RESERVES AND POTENTIAL RESOURCES

14. Known reserves of chrysotile asbestos in the region are adequate for existing mining operations at the present rate of production for many years, but would supply only a small part of the domestic requirements. Available geologic information is inadequate to appraise the potential reserves of asbestos in New England and New York, and other important deposits may be found. Northern Vermont and northwestern Maine are believed to be the most promising areas in the region to search for asbestos deposits of economic importance.

SELECTED BIBLIOGRAPHY ON ASBESTOS

1. BOWLES, OLIVER. Materials Survey, Asbestos, 1950. U. S. Bureau of Mines, 1952, p. II-1.

2. CHIDESTER, A. H., BILLINGS, M. P., and CADY, W. M. Talc Investigations in Vermont, Preliminary Report. U. S. Geol. Survey Circular 95, 1951.

3. EMERSON, B. K. Geolgy of Massachusetts and Rhode Island. U. S. Geol. Survey Bull. 597, 1917, pp. 215-217.

4. HURLEY, PATRICK M., and THOMPSON, JAMES B. Airborne Magentometer and Geological Reconnaissance Survey in Northwestern Maine. Bull. of Geol. Soc. of Am., vol. 61, Aug. 1950, pp. 835-842, 1 Pl.

5. JENKINS, G. F. Asbestos, Industrial Minerals and Rocks. Am. Inst. Min. Eng., 1949, pp. 55-76.

6. KEITH, ARTHUR. Preliminary Geological Map of Maine. Published by the Maine Geological Survey, Orono, Maine, 1933.

7. MARSTERS, W. F. A Preliminary on a Portion of the Serpentine Belt of Lamoille and Orleans Counties, 1903-04. Vermont State Geologist 4th Report, 1904, pp. 86-102.

8. MARSTERS, W. F. Petrography of the Amphibolite, Serpentine, and Associated Asbestos Deposits of Belvidere Mountain, Vermont, 1905-1906 (found in Asbestos, G. H. Perkins). Vermont State Geologist 5th Report, 1905, pp. 36-51.

9. PERKINS, G. H. Report on the Mineral Industries of Vermont, 1901-1902. Vermont State Geologist 3rd Report, 1902, pp. 36-40.

10. RABBITT, J. C. A New Study of the Anthophyllite Series. Am. Mineralogist, vol. 33, 1948, pp. 263-323.

11. RICHARDSON, C. H. Asbestos in Vermont, 1909-1910. Vermont State Geologist 7th Report, 1910, pp. 315-330.

12. Report of the State Geologist 1947-1948.

13. WING, L. A. Asbestos and Serpentine Rocks of Maine, 1949-1950. Report of the State Geologist, Maine Devel. Comm., 1951, pp. 35-46.

14. WING, LAWRENCE A. Summary Report on Maine Greenstones. Report of the State Geologist. Published by the Maine Development Comm., Augusta, Maine, 1949-1950, p. 47.

15. WING, L. A., and DAWSON, A. S. Preliminary Report on Asbestos and Associated Rocks of Northwestern Maine, 1947-1948. Report of the State Geologist, Maine Devel. Comm., 1949, pp. 30-62.

SECTION XXXIc-ABRASIVES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. This section presents a review of the abrasives industry in the New England-New York Region compared with the general abrasives industry in the United States. The geology of the deposits and economics of the various abrasive mineral industries are emphasized.

2. Abrasives are an essential industrial requirement in a peacetime economy and can become critical in a civil or military emergency. The most important area in the United States with reference to the production and consumption of abrasives is located in New England and New York, extending to the Great Lakes and Philadelphia vicinities.

3. The domestic abrasives industry, measured in terms of dollar value, is operating currently on a level nearly triple that of the period 1937-1940 and double that of peak wartime, 1943. In 1951 production of abrasive mineral raw materials in the United States exceeded a total of 2 million tons, valued at about 75 million dollars. Artificial abrasives accounted for about 85 percent of this tonnage and value, of which the New England-New York Region contributed about one-half.

4. Many deposits of abrasive materials, occurring extensively in the New England-New York Region, remain undeveloped for reasons of market conditions; limited reserves of high-grade materials; lack of adequate geologic information; and lack of incentive for industry to encourage prospecting and development. The deposits in this area could supply

substantial additional tonnages of abrasive material if intensive mineral and market investigation programs were initiated.

5. The problem of available low-cost electric power is a major concern to the artificial abrasives industry, consequently, the bulk of that industry is concentrated in the general vicinity of Niagara Falls. The power problem, more pronounced during periods of national defense, would possibly be relieved by the construction of plants in areas where there are sufficient inexpensive power sources, good transportation facilities, and an adequate labor supply.

ABRASIVES INDUSTRY-GENERAL

6. The abrasives industry is a primary integral part in any industrial economy. Its products are vital to most manufacturing and industrial operations. In the manufacture of aircraft engines, for example, practically every part of the engine is ground or finished by abrasives 1/.

7. Imports of artificial abrasives, chiefly from Canada, have greatly exceeded production in the United States. The Canadian plants are located generally just across the border near Niagara Falls. Most of these plants are owned and managed by American firms whose principal crushing, grinding, finishing facilities and main offices are located in the New England-New York Region.

DESCRIPTION AND USE OF PRINCIPAL ABRASIVE MATERIALS

8. Abrasives are grouped into two primary categories, natural and artificial. However, two important subdivisions are coated abrasives

1/ O'Neill, Leo J., Non-Metallic minerals needed for defense, Part 2, Abrasives: Bureau of Mines Inf. Circ. 7168, May 1941, p. 1.

and grinding wheels which are made from either natural or artificial materials. Abrasives are used chiefly in such forms as grinding wheels, drill bits, grain, powder, sticks, and coated papers, cloths and tapes. Coated abrasives include all abrasive materials that are glued in grain form to papers and cloths for various uses. Grinding wheels include ceramic, shellac, plastic and rubber bonded wheels.

9. Natural abrasives consist of minerals that receive little treatment other than crushing, grinding, and grading; artificial abrasives are produced by physical and chemical changes of the original raw material, usually in electric furnaces at high temperatures. It is estimated that about 85 percent of the abrasive products manufactured by industry are artificial abrasives, namely fused aluminum oxide and silicon carbide 2/.

NATURAL MINERAL ABRASIVES

10. This group includes diamonds, corundum, emery, garnet, pumice and pumicite, flints, sandstone, quartz and quartzite, sands, diatomite, tripoli, feldspar, kaolin, chalk, limestone, talc, and agricultural products. The materials discussed in this section are limited to those of chief importance to the economy of this region.

11. Industrial diamonds. - Industrial diamonds are subdivided into four types, with the percentages of 1953 imports as follows: (1) bort, 64 percent; (2) industrial stones, 30 percent; (3) diamond dust, 6 percent; and (4) carbonado and ballas, less than 1/10 of 1 percent. Bort is an inclusive term which refers to off-color, flawed or broken fragments of diamonds unsuitable for gems. Carbonado, commonly referred to as

2/ O'Neill, Leo J., Non-Metallic minerals needed for defense, Part 2, Abrasives: Bureau of Mines Inf. Circ. 7168, May 1941, P. 1.

black diamond, is an aggregate of very minute diamond crystals. Ballas is a globular mass of diamond crystals radiating from a common center. All diamonds are composed entirely of carbon. The hardness is 10 in Mohs' scale of hardness.

12. The industrial diamond is one of the most useful materials in modern industry. The outstanding value of this material was shown in defense production activities during and after World War II. Industrial diamonds are of prime importance in high-speed mechanical operations of precision grinding and sawing on a relatively simple and reasonable cost basis. Diamond-coated tools are the most efficient type of equipment for rapid and accurate cutting and shaping of high-speed tool steels, cemented carbides, and a variety of other hard, tough alloys and materials. Diamond-tipped tools are essential for shaping, dressing, and correction of abrasive wheels to specification size.

13. More than three-quarters of the annual diamond production by weight and one-fourth by value is consumed in industrial uses, principally in the manufacture of diamond grinding wheels, wire-drawing dies, drill-bit heads, and dressing and truing tools.

14. Corundum. - Corundum, the second hardest mineral known, is found in barrel-shaped hexagonal crystals; also in compactgranular and lamellar masses. The transparent crystalline varieties, sapphire and ruby, are very valuable as gem stones. Corundum is composed of aluminum oxide (Al_2O_3) with 52.9 percent aluminum and 47.1 percent oxygen. It is used as the type mineral for No. 9 in Mohs' scale with the specific gravity ranging from 3.9 to 4.1. Corundum may be found in such colors as red, green, yellow, black, brown, white or colorless. Synthetic corundum is

discussed under artificial abrasives.

15. Corundum has declined in importance but it continues to be superior to other abrasive materials for use in snagging wheels used in finishing heavy iron and steel castings and forgings and for precision grinding optical lenses. This advantage is based upon the manner in which corundum grains gradually break down against sufficient friction to expose new cutting edges in contrast to the rounded wear of the tougher artificial abrasive grains. With virtually no domestic production of corundum, the United States has been dependent upon foreign sources for her ore supply. Imports of ore and semi-process corundum have averaged about 4000 tons annually in recent years.

16. Garnet. - The garnet group includes a series of mineral subspecies that have similar crystal habit and physical properties. Chemically they are similar, although the elements present differ widely. Many of the subspecies grade more or less into each other. Almandite, $Fe_3Al_2(SiO_4)_3$, is the principal abrasive garnet and andradite, $Ca_3Fe_2(SiO_4)_3$, is used to a lesser extent; others have been used in large quantities. The hardness of garnet ranges from 6.5 to 7.5 in Mohs' scale of hardness, but some of the almandite from Warren County, New York, has been reported to have a hardness of 8 3/. Garnet has no cleavage but has sub-conchoidal fracture and it is also brittle. Abrasive-grade almandite from Warren County,

---

3/ Eardley-Wilmot, V. L., Abrasives: Canada Dept. of Mines, Pt. 3, 1927, p. 1.

New York, is characterized by pronounced laminated structures that form planes of weakness along which the mineral separates. The partings, sometimes referred to as "lamellar partings", are not true cleavage. The properties of optical-grade garnet are improved by heating the grain for 12 hours at 800°C and then quenching.

17. Garnet was valued as a semi-precious stone for centuries, but its chief market today is in the abrasive industry where it is used chiefly as a coating on cloths and papers in various types of grinding operations. It is estimated that about 90 percent of the abrasive quality garnet (almandite) currently is used for the manufacture of coated papers and cloths and the remainder as a lower-priced material in the form of loose grain for various purposes such as surfacing and polishing marble, slate, soapstone, and other soft stones; in some sandblast operations; and a very small quantity for the surfacing of plate glass. Small quantities are used in the form of bonded grinding wheels.

18. Garnet-coated abrasives are used chiefly in the domestic wood-working industries, particularly for hardwoods; they are also employed extensively in the leather industry.

19. Emery. - Emery is an impure form of corundum of "an intimate mixture of granular corundum and magnetite with some hematite" 4/ but it may contain other minerals, or one of the

---

4/ Eardley-Wilmot, V. L., Abrasives: Canada Dept. of Mines, Pt. 2, 1927, p. 36.

principal minerals may be lacking. Eardley-Wilmot divides emery into three varieties: (1) true emery, (2) spinel emery, and (3) feldspathic emery. True emery is composed of corundum and magnetite, with or without hematite; spinel emery is composed of spinel, corundum, and magnetite, but corundum may be entirely lacking; feldspathic emery is similar to spinel emery, but it contains in addition 30 to 50 percent plagioclase.

20. Emery, until the commercial development of artificial abrasives, was considered one of the hardest and most efficient abrasives known, being exceeded in hardness only by corundum and diamond.

21. The important uses of emery have been as blocks in rock-grinding mills, as loose grains and dust in special tools, in the form of coated abrasives, in grinding wheels, and in sharpening stones and polishing compositions. A new use for emery, developed in recent years, employs it in the form of grains as a component of non-skid concrete or stone surfacing, especially for heavy-duty floor and stair treads.

22. Feldspar. - The bulk of feldspar production is consumed as a flux, bond, and glaze in the glass, pottery, and enamel industries. Abrasive soaps and scouring compounds consumed less than about one percent in 1951, or about 3,000 tons.

23. Feldspar used in soaps must contain very little quartz (less than 5 percent), be light-colored when ground, and of low iron content. Potash and soda-rich feldspars are generally used.

24. Details on feldspar are included in the section on pegmatites.

25. Quartz (Milling, grinding, polishing) 5/. - Quartz is a very common, hard, brittle mineral composed of silicon dioxide. It has a conchoidal fracture and occurs in a wide variety of colors and forms. Its hardness is 7 in Mohs' scale.

26. Quartz is a very useful natural abrasive material owing to its hardness, extensive distribution, and low cost of production. As an abrasive, quartz is used as a medium-hard material in the form of sandpaper, buffing compounds, and scouring soaps and powders.

27. Ground sandstones and sands. - Sandstone is composed essentially of quartz sand which is cemented by clay, silica, calcium carbonate, or iron oxide. Natural sands for abrasive purposes are also composed largely of quartz.

28. Ground sandstone and sand employed as abrasives are consumed chiefly in cleansing and scouring compounds in glass grinding, stone polishing, sandpaper, and sand blasting.

29. Several types of sandstone are used for the production of millstones, pulpstones, special and natural sharpening stones such as oilstones, whetstones, grindstones, and scythestones.

30. Diatomite.6/ - Diatomite is an earthy material composed principally of silica which is derived from the fossil remains of the microscopic aquatic organism known as the diatom. Diatomite

---

5/ Jensen, Nan C., Marketing silica: Bureau of Mines Inf. Circ. 7202, 1942, 39 pp.

6/ Jensen, Nan C., Marketing silica: Bureau of Mines Inf. Circ. 7202, 1942, 39 pp.

usually contains clay, lime, and other impurities and varies in color from pure white to black. High-grade diatomite is a chalk-like aggregate in appearance, porous, and friable.

31. The principal characteristics that make diatomite valuable as a mild abrasive material are its relatively low hardness (1-1.5) and specific gravity (less than 1, when pure and dry).

32. Diatomite is the gritty ingredient of a large number of metal polishes, powders, and pastes.

ARTIFICIAL ABRASIVES

32. This group includes principally silicon carbide, fused aluminum oxide, and boron carbide.

33. Artificial abrasives dominate the field of high-grade abrasives with a few exceptions. The artificial type of abrasive is more essential to modern industry than the natural variety, except diamond, because it is superior in hardness and performance and more uniform in composition and quality. Modern high-speed streamlined production methods require very accurate and efficient specialized tools whose specifications cannot be met with the common natural abrasives except the diamond 7/ 8/ 9/. (On the revised Moh's scale of hardness, the minerals are listed as quartz - 8, garnet - 10, corundum and tungsten carbide - 12, silicon carbide - 13, boron carbide - 14, and diamond - 15).

7/ Chemical Age, Silicon Carbides: London, vol. 51, No. 1317, 1944, p. 302.

8/ O'Neill, Leo J., Non-Metallic minerals needed for defense, Part 2, abrasives: Bureau of Mines Inf. Circ. 7168, May 1941, p. 7.

9/ Fisher, Henry C., Abrasives in the role of super-refractories: Metal Progress, vol. 40, No. 2, 1941, pp. 177-282.
Ceramic Abstract: Am. Cer. Soc., vol. 21, No. 2, Feb. 1942, p. 42.

34. Silicon carbide. - Silicon carbide is commonly marketed under the trade names Carborundum, Crystolen, Carbolon, and others. It is made by fusing a mixture of high-grade silica sand and carbon in an electric furnace. The preferable form of carbon used currently is petroleum coke, but low-ash anthracite and coke have been used. Several types of silicon carbide products are manufactured in which the hardness, toughness, and mesh size of the grains are varied. Silicon carbide is more efficient in grinding materials of low tensile strength than any other abrasive material 7/8/9/.

35. Fused aluminum oxide. - Fused aluminum oxide is commonly known as artificial bauxite or artificial corundum. Abrasive-grade bauxite, low in silica and iron, is the principal crude raw material of artificial aluminum oxide. This product is made by charging calcined bauxite ore and ground coke into the furnace. The finished product generally consists of about 95 percent Al_2O_3. Pure aluminum oxide is used for certain purposes instead of calcined bauxite, making a product of about 99 percent Al_2O_3. Fused aluminum oxide is made into products of varied hardness, toughness, and grain size. Fused aluminum oxide abrasive products are best suited to the tough, high tensile strength materials.

36. Boron carbide. - Baron carbide was introduced in 1934 under the trade name of Norbide. It is reported to be one of the hardest artificial abrasives. Boron carbide is made from a charge of boric oxide and petroleum coke. The principal products are

molded sandblast nozzle liners and extrusion dies. Boron carbide in the form of grains and powders is used principally in grinding and lapping operations which, for certain materials, previously were possible only with diamond dust.

METALLIC ABRASIVES

37. Metallic abrasives include chiefly steel shot, grit, and various forms of manufactured scouring and cleaning abrasive materials such as crushed steel and steel wool. Steel shot is spherical globules of chilled cast iron manufactured from selected high-grade scrap and charcoal iron and marketed in various mesh sizes. Steel grit is produced in various mesh sizes from granulated coarse material. Steel wool is made from ordinary and stainless steel by machines which shave or scrape continuously moving wire.

ABRASIVE CHEMICAL PRECIPITATES

38. Abrasive chemical precipitates are chiefly oxides of metal which are of very fine grain size and are used as final polishing agents. These precipitates include rouge, paste, and powder products of metal oxides having important although limited abrasive application.

MISCELLANEOUS ABRASIVE MATERIALS

39. Many natural and artificial materials are used in limited quantities for abrasives purposes. A number of metallic oxides, including oxides of tin, magnesium, iron (rough and crocus), cerium, chromium, and manganese are employed as polishing agencts. Certain

carbides, such as boron carbide and the cemented carbides, which include tantalum carbide, titanium carbide, and tungsten carbide, have been used for their abrasive properties or because of their extreme hardness or durability. Other substances with abrasive applications include kaolin, finely ground and calcined clays (ball and fire clays), lime, talc, river silt, slate flour and whiting.

STRUCTURE AND PRODUCTS OF THE ABRASIVES INDUSTRY

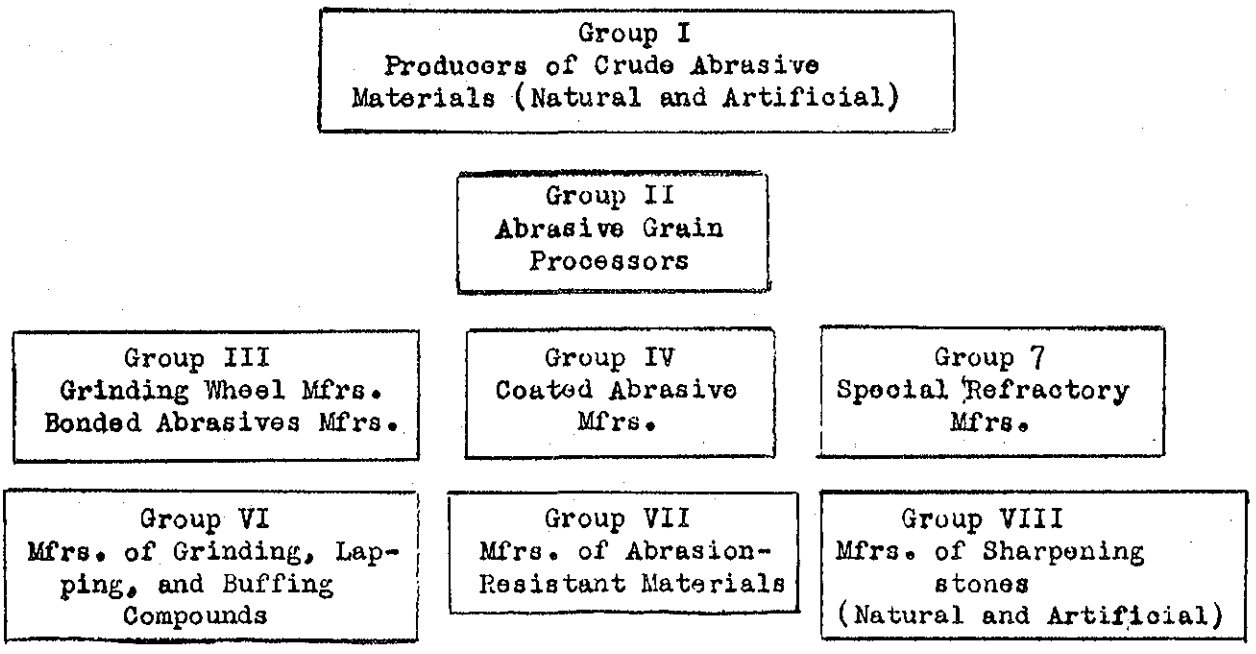
40. The abrasives industry is one of the most important industries in the New England-New York Region. The industry is vital to the whole economy of the United States and many parts of the world.

41. Nearly three-fourths of this 300 million dollar industry, employing about 15,000 workers, is centered in the Niagara Falls-Boston-Philadelphia area. At Niagara Falls, the industry is situated on both sides of the Niagara River and, therefore, it is significant to the United States and Canada. In many instances, the company interests are inter-related.

42. There are eight principal groups of primary and secondary products in the industry. The primary group includes (1) crude abrasives and (2) abrasive grains, while the secondary group includes (3) grinding wheels, (4) abrasive paper and cloth, (5) special refractory byproducts, (6) abrasive compounds, (7) abrasion-resistant

materials, and (8) sharpening stones. For further details on abrasive products, refer to publications by Ladoo 10/ and Bateman 11/.

43. Abrasive grain is the most important form of intermediate industrial abrasive product. It is produced from a wide variety of natural and artificial crude materials. Its importance lies in the fact that it can be used as grain or incorporated as the base for surface-coated abrasives, polishes, cleaners, and grinding pastes. The grain is used more than all other manufactured abrasive forms.



10/ Ladoo, R. B., and Meyers, W. M., Nonmetallic minerals, Abrasives: McGraw-Hill, 1951, p. 5.
Ladoo, R. B., Industrial minerals and rocks, Abrasives: A.I.M.E., 2nd edition, 1949, pp. 1-54.

11/ Bateman, Alan M., Economic mineral deposits, Abrasives: John Wiley & Sons, Inc., New York, 1942, p. 810.

HISTORY AND GROWTH OF THE INDUSTRY

44. The use of natural abrasives dates back to ancient times when the Paleolithic man shaped and polished tools and weapons with many minerals of high hardness.

45. With the advent of the industrial era, many abrasive materials were produced from a variety of minerals and used extensively in all industries. The automobile, airplane, and soap industries developed into the largest consumers of abrasives. Since 1860, there has been a continuing search for materials for many diverse applications which required the use of abrasives of particular hardness and grain size.

46. Artificial abrasives originated in 1891 when Edward Acheson first prepared silicon carbide in an electric furnace from domestic silica sands.

47. Fused aluminum oxide appeared on the market as an abrasive product in 1901. It soon displaced natural materials in many operations, and it has now become the most important abrasive product in terms of quantities consumed.

48. Prior to 1891, the industry was primarily engaged in manufacturing grindstones, millstones, whetstone oilstones, and similar products from natural stone. The most significant change since 1891 has been the development and increased use of artificial abrasives and the development and expansion of the coated abrasive and bonded grinding wheel industries.

49. The relatively rapid speeding-up of unit operations in the metalforming industries spurred on by World Wars I and II, and the Korean emergency, hastened the replacement of softer and slower-cutting types of abrasives by the harder artificial abrasives. However, substantial quantities of the natural materials continue to be preferred for certain operations.

50. This industry is commonly employed as a guide to indicate the general business activity in industry and commerce. A comparison of peak years of industrial activity clearly shows the growth of the abrasive industry in the United States by volume of consumption, product value, and the increased importance of artificial abrasives. The domestic industry underwent a major structural change after 1929 which was indicative of the extent to which mechanical application of abrasive materials replaced the manual art and also the relatively slowly operated semi-mechanical units (see table 84b.)

51. The growth of the natural abrasives industry in the New England-New York Region stemmed from: (1) original location of the metal-working industry in this region; (2) the occurrence of the large emery deposits at Peekskill, New York, and Chester, Massachusetts; and (3) the world's largest garnet deposits at North Creek, New York, and vicinity.

52. The artificial abrasives industry became concentrated in the Niagara Falls area because of the available abundant low cost electrical energy. Production of natural abrasives has survived as a small but useful industry.

53. The industry (natural and artificial abrasives) in the region has grown from 73 establishments and 4614 production workers in 1931 to 102 establishments employing 11,047 production workers in 1947. Current reports indicate further growth in establishments and personnel.

GEOLOGY

54. Distribution of deposits. - Garnet is a common accessory mineral in metamorphic rocks and in some igneous rocks; its most characteristic occurrences are in mica schists, hornblende schists, and gneisses. Although these rocks are abundant in New York and New England, relatively few deposits of garnet have been found suitable as economic sources of abrasive garnet, with the exception of the Adirondack area in New York.

55. New York. - Garnet occurs in deposits scattered throughout the Adirondack Mountains. The deposits in the district near the intersection of Warren, Hamilton, and Essex Counties, New York, are large enough to satisfy the world demand for high-quality garnet.

56. Generally, the garnet occurs in more or less lenticular inclusions of Grenville metasediments in granite gneiss or in gabbro. The garnet is mostly imperfect or crushed laminated crystals of almandite that average less than 3 inches but may be more than 3 feet in diameter. In the more important deposits, the crushed garnet crystals are uniformly distributed in rock that contains more than 6 percent garnet.

57. The Barton deposit north of the summit of Gore Mountain near North Creek in Warren County is the world's principal source of abrasive garnet. The outcrop of garnet-bearing rock is about 4000 feet long, as much as 300 feet wide, and it strikes northeast to east between granite gneiss and gabbro 12/ 13/. The rock is composed of orthoclase, labradorite, hornblende, hypersthene, alamandite, garnet, and minor quantities of biotite and zoisite. Hornblende constitutes about half of the rock, which is believed to be metamorphosed Grenville formation.

58. The garnet occurs as imperfect, laminated crystals that average 3 inches in diameter and constitute 10 to 12 percent of the rock. Many of the crystals are completely enclosed by hornblende rims that are 2 to 3 inches thick 14/. The crystals are badly crushed or coarsely granulated and generally do not show smooth, flat crystal faces 14/.

59. At Willsboro, Essex County, andradite garnet occurs in layers intercalated with wollastonite. The garnet is recovered as a byproduct of wollastonite mining. Reserves of garnet at this mine are reported to be large.

12/ Otte, H. F., The expanding mineral industry of the Adirondacks: New York Exec. Dept., Div. Commerce Pub. 10, 1943, pp. 37-40.

13/ Hartnagel, C. A., and Broughton, J. G., The mining and quarrying industries of New York State, 1937 to 1948: New York State Mus. Bull. 343, 1951, p. 35.

14/ Miller, W. J., The garnet deposits of Warren County, New York: New York State Mus. Bull. 164, 1914a, pp. 95-102.

60. Deposits have been mined on Casey Mountain in Hamilton County, and in Warren County on Oven Mountain and near Thirteenth Lake, Rexford, Wevertown, and Johnsburg. Deposits are known on Ruby Mountain, Peaked Mountain, Panther Mountain, and Twin Lakes Mountain in Hamilton County and near Botheration Pond in Warren County. Garnet was once mined from small scattered deposits about 3 miles north of Gouverneur, St. Lawrence County, but no mills were erected 15/.

61. The rock in these deposits contains no more than 8 percent garnet in crystals that average less than 3 inches in diameter. The geology of these deposits is similar to that of the Barton deposit. Unlike the rock in the Barton deposit, garnet-bearing rock in the Oven Mountain deposit contains little or no hypersthene, oligoclase or labradorite, and the deposits form several small inclusions in quartz syenite 16/. The deposits near Wavertown and Johnsburg are small and scattered. Many of them are small masses of garnet rather than disseminated crystals. Garnet constitutes about 10 percent of the lenses of amphibolite in quartz syenite on the west flank of Panther Mountain and on the south side of Twin Lakes Mountain in Hamilton County 17/.

15/ Myers, W. M., and Anderson, C.D., Garnet - Its mining, milling, and utilization; Bureau of Mines Bull. 256, 1925, 54 pp.
Newland, D. H., Mineral resources of the State of New York: New York State Mus. Bull. 223, 1921, pp. 66-69, 79-85, 154-156.

16/ Miller, W. J., The garnet deposits of Warren County, New York: New York State Mus. Bull. 164, 1914a, pp. 95-102.

17/ Cannon, R. S., Geology of the Piseco Lake quadrangle, New York: New York State Mus. Bull. 312, 1937, p. 101.

62. New Hampshire. - Garnet occurs in small quantities in several districts of New Hampshire, but the only commercially significant production has been in Merrimack County. Two deposits have been worked--one near North Wilmot and one near Danbury--and several unexploited deposits are known 18/. The garnet-bearing rock from which most of the production came crops out near the top of Currier Hill in North Wilmot, Merrimack County. The main deposit is exposed over an area 200 feet by 240 feet 19/, and in 1935 an excavation 100 feet wide, 180 feet long, and 300 feet deep had been made. The deposit was not buttomed. Another outcrop of garnet-bearing rock has been found two-thirds of a mile southeast of the quarry 18/.

63. The garnet-bearing rock in the Currier Hill quarry is a uniform mixture of garnet, biotite, quartz, albite, and accessory minerals 20/. The deposits are elongated parallel to the trend of the enclosing rock, which strikes about N20°E and dips steeply east 21/. The crystals are poorly developed and average about three-eighths of an inch in diameter. Almandite garnet constitutes from 30 to 80 percent of the rock and averages about 50 percent. Abundant

---

18/ Conant, L. C., New Hampshire garnet deposits: Econ. Geology, vol. 30, No. 4, 1935, pp. 387-399.
19/ Katz, J., Mineral resources of the United States, Part II, 1913, Abrasive Materials: Geol. Survey, 1914, pp. 253-272.
20/ Katz, J., Mineral resources of the United States, Part II, 1913, Abrasive Materials: Geol. Survey, 1914, pp. 253-272.
21/ Conant, L. C., New Hampshire garnet deposits: Econ. Geology, Vol. 30, No. 4, 1935, pp. 387-399.

minute inclusions of quartz, biotite, magnetite, and other minerals in the garnet weaken it, also, the garnet is strongly fractured, and the fractures are filled with thin sheets of chlorite 21/. These foreign substances cause a major milling problem, because fine crushing is necessary to remove them 22/. At best, the inclusions cannot be completely removed. The Currier Hill garnet deposit does not have lamellar partings 22/, and this, plus the minute intergrowths make it inferior to Barton garnet.

64. A deposit of garnet similar in almost all characteristics to that on Currier Hill was once worked near Danbury, Merrimack County. The garnet-bearing rock crops out on both sides of Severance Hill in bands between layers of porphyritic granite, porphyritic schist, granite, and mica schists 23/. In the deposits in Merrimack County, wherever the relationship is clear, the garnet is in porphyritic schist in close proximity to its contact with the Meredith granite.

65. Connecticut. - Garnet deposits near Roxbury and Roxbury Falls, Litchfield County, were once worked for abrasive garnet. Well-formed dodecahedral crystals of garnet with a composition close to that of andradite occur in mica schist 24/. The crystals are as large as 2 inches in diameter, but average less than 1 inch.

22/ Ladoo, R. B., and Myers, W. M., Nonmetallic minerals, Abrasives: McGraw-Hill, 1951, pp. 5, 243.
Ladoo, R. B., Industrial minerals and rocks, Abrasives: A.I.M.E., 2nd edition, 1949, pp. 1-54.

23/ Conant, L. C., New Hampshire garnet deposits: Econ. Geology, vol. 30, No. 4, 1935, pp. 387-399.

24/ Ladoo, R. B., and Myers, W. M., Nonmetallic minerals, Abrasives: McGraw-Hill, 1951, p. 5.
Ladoo, R. B., Industrial minerals and rocks, Abrasives: A.I.M.E., 2nd edition, 1949, pp. 1-54.

66. A deposit of grossularite, $Ca_3Al_2(SiO_4)_3$, that occurs southwest of West Redding, Fairfield County has been investigated 25/. Because of its relative softness - about 6½ in Mohs' scale - grossularite has not been used as an abrasive.

67. Vermont. - In 1939, a small quantity of almandite garnet was produced with mica at Gassetts, Windsor County. The garnet occurs in a quartz-mica schist that also contains staurolite, kyanite, and tourmaline.

68. Maine. - Hooper 26/ reported that "Maine supplies a variable amount of second-grade mineral." No significant abrasive-garnet industry has developed in the State of Maine.

EMERY

69. Emery occurs in basic igneous rocks, amphibolites, schists, and crystalline limestones. In New England and New York deposits of workable size and grade have been found only with basic igneous rocks near Peekskill, New York, and with amphibolite near Chester, Massachusetts.

70. New York. - Deposits of emery near Peekskill were first worked for iron ore, but with little success, and mining for abrasives began in 1889 27/. Since 1913, when operations ceased near Chester, Massachusetts, the deposits near Peekskill have been the only source of emery in the New England-New York Region, and the only commercially

---

25/ Mikami, H. M., Horney, W. R. Handel, C. W., III, Garnet deposit at West Reiding, Connecticut: Rept. to the Supt. of the Conn. Geol. and Nat. History Survey, 1945, i pp.

26/ Hooper, F. C., The American garnet industry: Mineral Industry, 1897, vol. 6, 1898, p. 21.

27/ Butler, J. W., Jr., Origin of the emery deposits near Peekskill, New York: Am. Mineralogist, v. 21, No. 9, 1936, p. 54.

important source in the United States since 1928 28/.

71. The emery near Peekskill occurs in an igneous rock mass (the "Courtlandt series") that crops out over an area of 25 to 30 square miles 27/and in schist near the contacts with the igneous rocks. The Cortlandt intrusives include many types of rocks such as granite, syenite, sodalite syenite, diorite, gabbro, pyroxenite, periodotie, and hornblendite. Most of the rock mass is a basic norite or pyroxenite 28/.

72. The following is a summary of the geologic occurrence of the Peekskill deposits as given by Rogers 29/ :

1. The ore usually occurs in a region in which mica schist inclusions are abundant and often within a hundred feet or so of such an inclusion; and the largest mines (McCoy, Dalton, etc.) are within 1,000 feet of the border of the Cortlandt Series.

2. The ore is always in sharply defined veins, pockets or lenses, but its constituents often occur disseminated through the rocks immediately adjacent.

3. The ore is immediately associated with abnormal rocks, containing sillimanite, cordierite, garnet, quartz or allanite, which are found nowhere else in the area, except around certain schist inclusions near Crugers; or more rarely, it adjoins rocks which are normal except for the spinel scattered through them. There is often a great abundance of biotite around the ore, which is also characteristic of these inclusions.

28/ Gillson, J. L., and Kania, J. E. A., Genesis of the Emery deposits near Peekskill, New York: Econ. Geol., v. 25, no. 5, 1930, p. 506-527.
29/ Rogers, G. S., Geology of the Cortlandt Series and its emery deposits: New York Acad. Sci. Annals 21, 1911, p. 76-77.

4. These rocks often exhibit evidence of shearing, faulting and cracking, which is rare in other parts of the district, except around schist inclusions.

73. Most of the emery mined in the Peekskill district is of the spinel variety (averaging spinel, 65 percent; magnetite, 20 percent; and corundum, 15 percent). Feldspathic emery is also found, and some deposits contain large quantities of quartz. Several bodies of emery contain sillimanite--specially those near the Manhattan schist 30/.

74. Despite the comparatively extensive scientific literature on the Peekskill deposits, factual data on the size of ore bodies, the proportions of the different kinds of emery, or the reserves, do not appear to have been published.

75. Massachusetts. - The emery deposits near Chester, Hampden County, Massachusetts, were first worked for iron ore in 1856. In 1864, mining of the deposits for abrasive emery was begun. All operations ceased in 1913 after an estimated 25,000 tons of emery had been produced during several periods of activity 31/.

76. The Chester amphibolite in which the emery deposits occur crops out in a northward trending belt that Emerson 32/traced nearly across the State. Emery has been found only in the area west of the

---

30/ Spinel-emery and feldspathic-emery are lower in quality than the pure corumdum-emery, because spinel and feldspar decrease the hardness.

31/ Apfel, E.T., Emery deposits near Chester, Massachusetts: Dept. of Public Works and Geol. Survey Inf. Circ. No. 5, 1944, 15 pp.

32/ Emerson, B. K., Geology of New Hampshire County, Massachusetts: Geol. Survey Mon. 29, 1898, pp. 117-147, 156.

village of Chester where the amphibolite is thickest, about three-fourths of a mile wide. Because the dip is nearly vertical, the width of outcrop closely approximates the thickness.

77. The emery bodies have been broken into blocks whose margins are altered to chlorite-margarite rock. Only nodules of emery remain in the centers of some blocks, and thin bodies are completely altered; hence, thin sheets of emery are not likely to be found 33/.

78. Though emery marketed from the deposits near Chester was highgrade 34/, Apfel 33/ indicates that the proportion of magnetite to corundum was high in most mines, and in order to market high-grade emery, it was necessary to mine and separate large quantities of low-grade material; this perhaps was one reason that operations ceased.

79. Six mines were worked--the Snow mine, Sackett mine, Macia mine, Old mine, Melvin Mine, and Wright mine. Miners who worked in the Wright mine believed that "ore" was exposed when the mine closed 33/. A prospect pit, 6½ miles north of Chester 33/exposes a vein about 4 feet wide.

FELDSPAR

80. Feldspar, principally mined from pegmatites, occurs extensively in the area, particularly in New Hampshire, Maine and Connecticut, with lesser quantities in New York and Massachusetts. New Hampshire, Maine

---

33/ Apfel, E. T., Emery deposits near Chester, Massachusetts: Dept. of Public Works and Geol. Survey Inf. Circ. No. 5, 1944, 15 pp.
34/ Emerson, B. K., Geology of Old Hampshire County, Massachusetts: Geol. Survey Mon. 29, 1898, pp. 117-147, 156.

and Connecticut have been leading producers of feldspar since 1914. Reserves of abrasive quality feldspar are large enough to meet any increased demand. Pegmatite mining in New Hampshire began in 1803 with the opening of the famous Ruggles mine at Grafton, Grafton County. Since then, over 200 pegmatite localities in New Hampshire have been found and studied.

81. Details on deposits of feldspar and quartz may be found in the section on pegmatites.

QUARTZ

82. Extensive deposits of quartz are widely distributed in New England and New York. Numerous deposits have been worked intermittently. Recent production came principally from Connecticut, Massachusetts, and Maine. Market conditions and cost of transportation to the nearest consuming area determine the scale of operations.

83. Abrasive-grade quartz in the area is derived from numerous veins and pegmatite dikes. Several quartzite and conglomerate deposits have yielded large quantities for abrasive purposes.

SAND AND SANDSTONE

84. Deposits of these raw materials in New England and New York are extensive and widely distributed; enormous quantities of sand occur in beach, river, and glacial deposits.

85. For additional discussion of sand the reader is referred to Sections XXVII and XXVIII.

SHARPENING AND MILLSTONES

86. Sharpening stones--including scythestones, honestones, and whetstones--have been produced in commercially important quantities in New England. For more than 100 years scythestones have been quarried at Pike, Grafton County, New Hampshire, from a fine-grained, dark gray, highly siliceous, laminated quartz-mica schist 35/. The quartz grains occur in layers separated by layers of mica flakes. Near Evansville, Orleans County, Vermont, a "bluish-chocolate-colored" quartz-mica schist was quarried for scythestones 35/; a similar rock was quarried at Lisbon, Grafton County, New Hampshire. Sharpening stones also have been produced in Tolland and Windham Counties, Connecticut; Hampshire and Norfolk Counties, Massachusetts; Providence County, Rhode Island; and Cortland County, New York 36/ 37/. Sharpening stones have been produced at many other places for local use.

87. Ulster County, New York, has been a principal source of millstones. The millstones, known to the trade as Esopus stone, are quarried from the Shawangunk grit, a quartz conglomerate, along the Roundout River between High Falls and Kerhonkson. About 1927, New York was the largest producer of millstones in the United States; almost all of the production was near Alligerville, Ulster County.

35/ Ladoo, R. B., and Myers, W. M., Nonmetallic minerals, Abrasives: McGraw-Hill, 1951.
Ladoo, R. B., Industrial minerals and rocks, Abrasives: A.I.M.E., 2nd edition, 1949, p. 40.

36/ Schrader, F. C., Stone, R.W., and Sanford, Samuel, Useful minerals of the United States: Geol. Sur. Vull. 624, 1917, pp. 101,162,270.

37/ Eardley-Wilmot, V. L., Abrasives: Canada Dept. of Mines, Pt. 3, 1927, p. 62.

Millstones similar in texture to Esopus stones were produced from a quartz conglomerate near Fair Haven, Rutland County, Vermont 38/. Granite millstones were marketed from quarries on Millstone Hill, near Barre, Washington County, Vermont 39/. Production of grindstones or millstones has been reported from Hartford County, Connecticut, and from Berkshire, Norfolk and Middlesex Counties, Massachusetts 40/.

DIATOMITE

88. Deposits of diatomite have been reported in New York and in all of the New England States except Rhode Island. The deposits are in ponds, peat bogs, marshes, and small lakes and commonly are associated with peat. In New Hampshire, many small bog deposits occur northeast and southwest of Lake Winnipesaukee and near Lake Umbagog--in Kelknap, Carroll, Cheshire, Coos, Grafton, Merrimack, and Sullivan Counties. In Maine, intermittent production is obtained from a bog deposit near Phillips, Franklin County. Most of the known deposits in New York are in Herkimer and Hamilton Counties.

89. The largest known deposits are in New York where reserves have been estimated to be 2 or 3 million cubic yards, but many of the larger deposits are on State-owned land where mining operations are

---

38/ Eardley-Wilmot, V. L., Abrasives: Canada Dept. of Mines, Pt. 1, 1927, p. 47.

39/ Jacobs, E. C., Mineral industries of Vermont: Vermont State Geologist Rept., 1939-40, 1941, p. 23.

40/ Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful minerals of the United States: Geol. Sur. Bull. 624, 1917, pp. 99, 160.

are restricted 41/. Beds of diatomite 30 feet thick have been reported, though a more typical deposit would average about 3 feet thick over about 5 acres.

90. Details on diatomite deposits in New England and New York may be found in the section on diatomite.

ECONOMIC POSITION OF THE ABRASIVES INDUSTRY IN THE NEW ENGLAND-NEW YORK REGION

91. Mineral Deposits. - The chief economic natural abrasive materials occurring in New England and New York are garnet, feldspar, quartz, and emery. Several diatomite deposits of possible economic importance are found in New York. Some special sands of abrasive quality occur widespread in the area.

92. The largest commercial garnet deposits in the country are in Warren County, New York, where the Barton Garnet Mining Company, North Creek, New York, is the principal producer. This mine has been in continuous operation since 1880, and the ore reserves are still large. The Barton deposit contributed about half of the world garnet output and three-quarters that of the domestic production. Factors that help to make the Barton deposit the principal source of abrasive garnet are mentioned in paragraphs 55, 56 and 57.

93. Deposits of feldspar and quartz of satisfactory abrasive quality are extensive in Maine, New Hampshire, and Connecticut. Smaller quantities occur in New York and Massachusetts. However, their economic potential development is dependent upon the immediate market conditions.

41/ Hartnagel, C. A., and Broughton, J. G., The mining and quarrying industries of New York State, 1937 to 1948; New York State Mus. Bull. 343, 1951, pp. 31-32.

Table 84b - Deposits of abrasive materials in the New England-New York Region

State	Mineral	Location	Status[1]	Resources	Remarks
New York	Garnet	Gore Mt. at North Creek, Warren County	Active	Very large	Excellent-economic
	Garnet	Willsboro, Essex County	Active	Large	Economic
	Garnet	Wevertown, Warren County	Inactive	Small	Sub-marginal
	Garnet	Johnsburg	Inactive	Small	Sub-marginal
	Garnet	Casey Mt. at North River. Essex County	Inactive	Substantial	Marginal
	Garnet	Ruby Mt. at North River, Essex County	Inactive	Large	Good-economic
	Garnet	Peaked Mt. at North River, Essex County	Inactive	Large	Good-economic
	Garnet	Thirteenth Lake at North River, Warren County	Inactive	Small	Marginal
	Garnet	Oven Mt. at Wevertown, Warren County	Inactive	(1)	(1)
	Garnet	Rexford at North Creek, Warren County	Inactive	(1)	(1)
	Garnet	Panther Mt.	Inactive	(1)	(1)
	Garnet	Twin Lakes Mt.	Inactive	(1)	(1)
	Emery	Peekskill, Cortland County	Active	Large	Excellent-economic
	Diatomite	White Lead Lake, Herkimer County	Inactive	Small	Marginal
	Diatomite	Clear Lake, Big Crooked Lake, Hawk Lake, Chub Lake, Riley Pond, and Poland, Herkimer County	Inactive	Large	Fair-marginal
	Diatomite	Sampson Lake, Sampson Bog, Cat Lake, Mud Lake, and Bennet Lake, Hamilton County.	Inactive	Large	Fair-marginal
	Diatomite	(Cold Spring Harbor, Long Island)	Inactive	(1)	(1)

Table 84b (Continued)

State	Mineral	Location	Status	Reserves	Remarks
New York	Millstone	Ulster County	Active	Very large	Excellent-economic
	Slipclay	Albany	Active	Very large	Good-economic
	Sandstone	Adirondacks, Mohawk Valley	Inactive	Large	Good-economic
	Quartzite-quartz conglomerate	Ulster, Orange, Sullivan Counties	Inactive	Large	(1)
	Sand	Oneida Lake	Inactive	(1)	(1)
New Hampshire	Sandstone	Littleton, Grafton County	Active	Large	Excellent-economic
	Feldspar	Alstead, Cheshire County	Active	Large	Good-economic
	Quartz	Alstead, Cheshire County	Active	Large	Good-economic
	Garnet	North Wilmot, Merrimack County	Inactive	Small	Sub-marginal
	Diatomite	Belknap, Carroll, Coos, Grafton, Merrimack, and Sullivan Counties	Inactive	Large	Marginal
Maine	Quartz-feldspar	Topsham	Active	Large	Good-economic
	Quartz-feldspar	Brunswick	Inactive	(1)	Marginal
	Quartz-feldspar	Albany, Oxford County	Active	Large	Good-economic
	Quartz-feldspar	Plumbego Mts. Bethel, Oxford County	Active	Large	Good-economic
	Quartz	East Stoneham	Inactive	(1)	(1)
	Quartz	Buckfield	Inactive	(1)	(1)
	Diatomite	Phillips, Franklin County	Active	(1)	(1)
Massachusetts	Quartz, Sand, quartzite	Cheshire, Berkshire County	Active	Large	Good-economic
	Emery	Chester, Hampden County	Inactive	(1)	Marginal
Connecticut	Quartz	North Stonington, New London County	Active	Very large	Excellent-economic
Rhode Island	Quartz	Diamond Hill, Cumberland	Inactive	Large	Marginal

1. Data not available.

Feldspar and quartz have low unit values and, generally, cannot be marketed any great distance from their source.

94. There are only three emery deposits in the United States, two of which occur in New England and New York; the first is located at Peekskill, New York, and the second is at Chester, Massachusetts. The only deposit of current commercial importance is at Peekskill, where the principal mine operators are the companies of Joe DeLuca and DiRubbo and Ellis. The mines at Chester, Massachusetts are inactive, but a local company is expected to resume operations in the near future.

95. The impurities, magnesium and iron oxides, and the low variable aluminum oxide content of domestic emery reduce its hardness. Consequently it is less satisfactory for most abrasive purposes than the imported emery from Greece and Turkey.

96. The diatomite from deposits in the region, although of inferior abrasive quality to those of California, can compete sufficiently to be absorbed in the local markets for certain abrasive and filter materials.

97. Beneficiated special sands in the area can be substituted advantageously for imported silica-rich materials and can supply any sharp increase in demand.

98. Information available regarding the economic development of the abrasive deposits in the area is inadequate. Hence, an intensive mineral and market survey should be conducted tin order

to evaluate this situation with greater accuracy.

INDUSTRY

99. Companies in the area have been supplying the world industry with abrasive products which they process and fabricate from minerals imported from other sections of the country and abroad. An example of the economic importance of the abrasive-mineral-processing industry centered in the area is the utilization of the industrial diamond which in crude form amounted to about 40 percent of the value of the total domestic consumption of abrasives in 1951. Other examples are novaculite from Arkansas for the production of natural sharpening stones (oilstones), diatomite chiefly from California for abrasive compounds, and bauxite from Arkansas and abroad for artificial abrasive products 42/.

100. The area includes some of the most important producers of abrasives in the world. These firms account for almost the entire domestic output of garnet, emery, silicon carbide, and fused aluminum oxide, and lesser quantities of the other materials. The industry, particularly in this area, has been increasing in activity with the trend of many abrasives showing a sharp rise in tonnage output and value in recent years. New production records were attained in 1951, and this level is expected to continue during the next few years according to recent market indications.

42/ Domestic reserves of abrasive-grade bauxite, the principal raw material of artificial aluminum abrasives, are becoming depleted. Hence, greater emphasis is being focused on increased imports from South America.

101. Effective competition from diatomite-based cleansing, scouring, and polishing compounds may eventually diminish the need for the harsher type of abrasives, such as feldspar and quartz.

102. New York State continues to remain one of the most important garnet and emery mining areas in the world; however, the rise of artificial abrasive products has seriously handicapped the industry by limiting the consumption of these natural abrasives. The artificial abrasives which, formerly, were much more expensive have been reduced to about the price level of the natural materials. Natural abrasives, particularly industrial diamonds and garnet, are superior to any artificial products for many uses.

103. Output of garnet in the United States declined from an annual average of 6,868 tons valued at $540,996 during the period 1924-1929 to the lowest annual average level of 3,057 tons valued at $218,805 in 1930-34; other natural abrasives followed a similar pattern. Recovery of natural abrasives from a low output during the depression was at a slower rate than artificial abrasives which were aided by a sharp decrease in price from an average value per ton of $185.63 in 1920 to $93.23 per ton in 1929 and $63.97 in 1937 (see table 84c). Sales gains of all abrasives have been substantial and steady since 1934, with production in 1951 exceeding all previous peaks on record (see table 84d).

Table 84c - Price comparison of garnet, emery, silicon carbide, and aluminum oxide, average value per short ton, selected years, 1920-1951 43/

	1920	1929	1931	1937	1943	1948	1951
Garnet	$ 79.33	$73.04	$ 65.52	$78.66	$72.30	$73.12	$ 88.75
Emery	28.35	11.60	10.85	8.69	9.48	12.84	13.77
Silicon Carbide	190.16	97.33	118.13	72.97	84.82	93.20	116.77
Aluminum Oxide	181.10	89.12	93.20	54.97	60.72	66.33	99.13

104. The Niagara Falls area of the United States and Canada furnishes most of the silicon carbide and fused aluminum oxide output in North America, mainly on account of the large available supplies of hydro-electric power. Adequate electric energy available at low cost is the primary factor which will determine the future location of the artificial abrasives industry.

Table 84d - Salient statistics of selected high-grade abrasive materials, average annual United States production and value per ton, 1920-1951 44/

	Garnet		Emery		Silicon carbide		Fused aluminum oxide	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1920-1924	6,575	$ 79.83	1,716	$10.57	12,554	$135.19	31,443	$123.30
1925-1929	6,868	78.73	785	10.93	23,980	101.38	55,982	90.92
1930-1934	3.057	71.58	512	5.55	15,250	98.77	33,525	82.95
1935-1939	3,852	75.85	397	8.90	26,705	75.93	61,981	59.99
1940-1944	5,127	66.32	4,961	9.24	53,136	79.87	166,584	62.58
1945-1949	7,078	72.12	6,031	11.12	62,384	87.40	143,980	64.50
1950	9,304	85.29	5,949	12.66	65,004	112.36	140,352	85.20
1951	14,050	88.75	11,634	13.77	100,498	116.77	216,329	99.13

43/ Mineral Resources of the United States, Part II, Abrasive Materials: Geol. Survey, 1921
Minerals Yearbook, Abrasives: Bureau of Mines, 1932, 1937, 1943, 1948, 1950

44/ Mineral Resources of the United States, Part II, Abrasive Materials: Geol.Survey, 1921.
Minerals Yearbook, Abrasives: Bureau of Mines, 1932, 1937, 1943, 1948, 1950.

105. The bulk of all natural abrasive raw materials is mined by conventional open-pit or quarrying methods. Hand-cobbing and simple crushing, screening, and jigging devices recover most of the abrasive materials for shipment to the industry. The preparation of abrasive material for market requires crushing, grading, and sizing of the lump ore.

106. In the United States, there are several emery crushing and grading mills in which the crude ore, both American and imported, is first reduced by jaw crushers, passed through a series of rolls and then ground to finer sizes in ball mills. The waste material is removed and the emery passed over a series of long troughs and shaking screens and graded into about 30 different sizes.

107. Garnet is mined generally by quarry benching (open cut) methods. At the Barton Mines Corp. operations in New York, there are three adjacent quarries along the strike of the vein being operated. Blast -holes are accomplished with wagon drills and the garnet-bearing rock is loaded onto trucks and rail cars by power shovel. The ore is hauled a few hundred yards to the mill for treatment. Although the Barton mines deposit has been worked for more than 60 years, the garnet was recovered by hand-cobbing until 1923, at which time a mill was built at Gore Mountain, New York. The mill was improved in 1941 with the successful incorporation of the "sink-float" or heavy-media separation process 45/ 46/.

45/ Diesel Power and Diesel Transportation, Mining Garnet with Diesel Power: Vol. 19, No. 12, December 1941, pp. 1027-1029.

46/ Myers, W. M., and Anderson, C.D., Garnet-Its mining, Milling and utilization: Bureau of Mines Bull. 256, 1925, 54 pp.

108. In preparation for market, the garnet is concentrated by gravity methods and graded by alternately crushing and screening to obtain the full range of mesh sizes required by the coated-abrasive manufacturers 47/.

109. Artificial aluminum oxide is produced by mixing calcined bauxite (Al_2O_3, 73.9 percent; H_2O, 26.1 percent) or corundum (Al_2O_3), coke, and iron turnings and fusing the mix at about 4000°F in an electric arc furnace. The furnace is a cylindrical water cooled shell, the heat being supplied by the arc established between electrodes which are lowered into the shell. A ten-ton ingot requires nearly thirty hours of fusing and about ten days to cool. After cooling, the ingot is broken into pieces by drop weights and hand sledges. Jaw crushers reduce these pieces to smaller sizes (3/4") which are then further crushed to grain form and graded. The grain is then treated for removal of iron particles by magnetic separation and roasting at high temperatures to clean and temper the grain.

110. The principal mineral raw material in the manufacture of artificial abrasive silicon carbide is silica sand, which consists chiefly of quartz grains. A mixture of silica sand, petroleum coke, and small amounts of salt and sawdust is fused in an electric furnace

---

47/ Mineral Resources of the United States, PartII, Abrasive Materials: Geol. Survey, 1921.
Minerals Yearbook, Abrasives: Bureau of Mines, 1932, 1937, 1943 1948, 1950.

producing silicon carbide which is then processed similarly to that of artificial aluminum oxide as described in the foregoing paragraph.

111. Other miscellaneous abrasive materials are not discussed because their use as an abrasive is of relatively minor importance compared with their principal application.

FUTURE POSSIBILITIES

112. The New England-New York Region possesses large tonnages of many important raw materials for the manufacture of abrasive products, with the exception of bauxite. The known domestic reserves of abrasive-grade bauxite, located in Arkansas, are reported to be nearly depleted. Greater emphasis is on increased imports of abrasive-grade bauxite from South America. Present sources of bauxite in the United States are yielding low-grade ore and will provide an emergency source of supply in the future if our imports of high-grade ore from abroad are cut off.

113. Bauxite, corundum, silica, lime, magnesia, clay, salt, boron and tungsten minerals, iron and steel, rubber, natural gas and oil are the chief mineral raw materials for the manufacturing and the artificial abrasive products. Many of these raw materials, particularly silica, are found in New England and New York. Some materials of abrasive quality, occurring in this region, could be used in the local market thus reducing transportation charges for imported materials from outside the region, which in certain cases may amount to as much as one-half of the cost of the final abrasive products.

114. Conditions for the survival of a limited natural abrasive industry in this region are considered favorable. The manufacture of natural abrasives is currently a relatively small but important industry owing to certain inherent physical properties which some of these minerals possess that cannot be duplicated readily by artificial methods.

115. Artificial abrasives are universally accepted as being more efficient and better adapted to modern methods of production for most applications than the natural abrasives. Artificial abrasives are constantly being improved, and unless new uses are developed for natural abrasives, it is probable that eventually they will completely replace the natural type.

116. During a national emergency, natural abrasives will have to substitute in certain cases for some of the artificial products; consequently, emphasis should be placed on maintaining the exploitation and development of domestic deposits of the natural abrasives vital to defense-geared industries.

117. The development of new uses for the large reserve of some of the natural abrasives such as garnet, diatomite, feldspar, quartz, and others will increase the demand and prolong the existence of this phase of the industry. Research and development programs are needed to investigate new uses and the interchangeability of all abrasives.

SELECTED BIBLIOGRAPHY ON ABRASIVES

1. APFEL, E. T. Emery Deposits Near Chester, Massachusetts. Dept. of Public Works and Geol. Survey Inf. Circ. No. 5, 1944, 15 pp.

2. BALK, ROBERT. Geology of the Newcomb Quadrangle, N.Y. New York State Mus. Bull. 290, 1931, pp. 84-86.

3. BARDWELL, E. S. Garnet Mining in New Hampshire. E. & M. J., vol. 91, 1911, pp. 1209-10.

4. BATEMAN, ALAN M. Economic Mineral Deposits, Abrasives. John Wiley & Sons, Inc., New York, 2nd ed., 1950, pp. 808-820.

5. BUDDINGTON, A. F., and WHITCOMB, LAWRENCE, Geology of the Willsboro Quadrangle, N.Y. New York State Mus. Bull. 325, 1941, pp.117-118.

6. BUTLER, J. W., JR. Origin of the Emery Deposits Near Peekskill, New York. Am. Mineralogist, vol. 21, No.9, 1936, pp.537-574.

7. CANNON, R. S. Geology of the Piseco Lake Quadrangle, N.Y. New York State Mus. Bull. 312, 1937, p. 101.

8. _____. Chemical Age, Silicon Carbides. London, vol. 51, No. 1317, 1944, p. 302.

9. _____. Ceramic Abstract & Bulletin, Silicon Carbides. Vol. 24, No. 1, Jan 25, 1945, p. 2.

10. COLONY, R. J. High-Grade Silica Materials for Glass Refractories and Abrasives. New York State Mus. Bull. 203, 204, 1917.

11. CONANT, L. C. New Hampshire Garnet Deposits. Econ. Geology, vol. 30, No. 4, 1935, pp. 387-399.

12. _____. Diesel Power and Diesel Transportation, Mining Garnet with Diesel Power. Vol. 19, No. 12, December 1941, pp. 1027-1029.

13. EARDLEY-WILMOT, V. L. Abrasives, Canada Dept. of Mines, Pts. 1-4, Nos. 673, 675, 677, 699, 1927-1929, 383 pp.

14. EMERSON, B. K. Geology of Old Hampshire County, Massachusetts. Geol. Survey Mon. 29, 1898, pp. 117-147, 156.

15. EMERSON, B. K. Geology of Massachusetts and Rhode Island. Geol. Survey Bull. 597, 1917.

16. FISHER, HENRY C. Abrasives in the Role of Super-Refractories. Metal Progress, vol. 40, No. 2, 1941, pp. 177-282.

17. FISHER, HENRY C. Ceramic Abstract. Am Ceramic Soc., vol. 21, No. 2, Feb. 1942, p. 42.

18. GILLSON, J. L., and KANIA, J.E.A. Genesis of the Emery Deposits Near Peekskill, New York. Econ. Geology, vol. 25, No. 5, 1930 pp. 506-527.

19. HARTNAGEL C. A., and BROUGHTON, J. G. The Mining and Quarrying Industries of New York State, 1937 to 1948. New York State Mus. Bull. 343, 1951, pp. 32-33, 35-36, 63-64.

20. HEYWOOD, JOHNSON, Abrasive Grains and Their Use. Published under the auspices of the Abrasive Grain Association, Penton Publishers Co., Cleveland, 1943, 73 pp.

21. HOOPER, F. C. The American Garnet Industry. Mineral Industry 1897, vol. 6, 1898, pp. 18, 21.

22. JACOBS, E. C. Mineral Industries of Vermont. Vt. State Geologist Rept. 1939-40, 1941, p. 23.

23. JENSEN, NAN C. Marketing Silica. Bureau of Mines Inf. Circ. 7202, 1942, 39 pp.

24. KATZ, F. J. Mineral Resources of the United States, Part II, 1913, Abrasive Materials. Geol. Survey, 1914, pp. 253-272.

25. KEMP, J. F., and NEWLAND, D. H. Preliminary Report on the Geology of Washington, Warren, and Parts of Essex and Hamilton Counties. New York State Geologist An. Rept. 17, for the year 1897, 1899, pp. 499-533.

26. KRIEGER, M. H. Geology of the Thirteenth Lake Quadrangle, New York. New York State Mus. Bull. 308, 1937, pp. 100-120.

27. LADOO, R. B. Industrial Minerals and Rock, Abrasives, A.I.M.E., 2nd ed., 1949, pp. 1-53.

28. LADOO, R. B., and MYERS, W. M. Nonmetallic Minerals, Abrasives, Corundum and Emery, Garnet. McGraw-Hill, 1951, pp. 3-15, 166-171, 241-248.

29. LADOO, R. B. Wollastonite - A New Industrial Mineral. E. & M.J., November 1950.

30. MAGNUS, H. C. Abrasives of New York State. New York State Mus. Annual Rept. 57, 1905, pp. 158-179.

31. MERRILL, F. J. H. Mineral Resources of New York. New York State Mus. Bull. 15, 1895, pp. 553-555.

32. MIKAMI, H. M., HORNEY, W. R., HENDEL, C. W., III. Garnet Deposit at West Redding, Connecticut. Rept. to the Supt. of the Conn. Geol. and Nat. History Survey, 1945, 8 pp.

33. MIKAMI, H. M., HORNEY, W. R., HENDEL, C. W., III. The Lantern Hill Quartz Vein, North Stonington, Connecticut. Rept. to the Supt. of the Conn. Geol. and Nat. History Survey, 1945, 1947, p. 4.

34. MILLER, W. J. Garnet Deposits of Warren County. Econ. Geology, vol. 7, 1912, pp. 493-501.

35. MILLER, W. J. The Garnet Deposits of Warren County, New York. New York State Mus. Bull. 164, 1914a, pp. 95-102.

36. MILLER, W. J. Geology of the North Creek Quadrangle, New York. New York State Mus. Bull. 170, 1914b, pp. 78-82.

37. MILLER, W. J. Genesis of Certain Adirondack Garnet Deposits. Am. Mineralogist, vol. 23, 1938, pp. 399-408.

38. Minerals Yearbook, Abrasives, Bureau of Mines, 1932-1951.

39. MYERS, W. M., and ANDERSON, C. D. Garnet - Its Mining, Milling, and Utilization. Bureau of Mines Bull. 256, 1925, 54 pp.

40. NASON, F. L. Economic Geology of Ulster County. New York State Mus. 47th Annual Rept., 1894, pp. 587-588.

41. NEWLAND, D. H. Mineral Resources of the State of New York. New York State Mus. Bull. 223, 1921, pp. 79-85, 66-69, 154-156.

42. O'NEILL, LEO J. Non-Metallic Minerals Needed for National Defense Pt. II, Abrasives. Bur. of Mines Inf. Circ. 7168, May 1941, 17 pp.

43. OTTE, H. F. The Expanding Mineral Industry of the Adirondacks. New York. Exec. Dept., Div. Commerce Pub. 10, 1943, pp. 37-40.

44. PRATT, J. H. The Occurrence and Distribution of Corundum in the United States. Geol. Survey Bull. 180, 1901, pp. 23-26, 70, 82.

45. ROGERS, G. S. Geology of the Cortlandt Series and Its Emery Deposits. New York Aca. Sci. Annals 21, 1911, pp. 66-67.

46. SCHRADER, F. C., STONE, R. W., and SANFORD, SAMUEL, Useful Minerals of the United States. Geol. Survey Bull. 624, 1917.

47. TREFETHEN, J. M. Report of the State Geologist, 1943-1944. Maine Dev. Comm., Maine Geol. Survey, 1945.

48. WILLIAMS, G. H. The Contact Metamorphism Produced in the Adjoining Mica Schist, and Limestones, by Massive Rocks of the Cortlandt Series, Near Peekskill, New York. Am. Jour. Sci., 3rd series, vol. 36, 1888, pp. 254-269.

SECTION XXXId - STONE IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. The stone industry has been an important segment of the economy of the New England-New York Region for many years. In recent years, the annual stone production (omitting stone for cement and lime) has exceeded 40 million dollars, equal in value to more than 10 percent of the total domestic output of stone, and about 3 percent of the total agricultural production of the New England-New York Region. Over 10,000 persons are employed by the stone industry; in and near Barre, Vermont, about 2,000 persons are engaged in the production of dimension granite, almost entirely for monumental uses.

Stone production in 1950
(except limestone used for cement and lime)

	Quantity (short tons)	Value
United States	252,113,050	$390,582,097
New England-New York Region	19,279,000	42,438,000
New York	13,122,000	19,729,000
Massachusetts	3,284,000	8,485,000
Connecticut	1,861,000	2,789,000
Vermont	447,000	8,039,000
Maine	310,000	2,214,000
Rhode Island	239,000	798,000
New Hampshire	16,000	384,000

Source of data: U. S. Bureau of Mines, Minerals Yearbook, 1950.

2. Production history and uses of stone. - The stone industry of the New England-New York region began in colonial times with the use of field stones in walls, foundations, and occasionally for entire buildings. Dimension stone was first produced by splitting granite boulders and cobbles. Between 1749 and 1754, Kings Chapel on the corner of Tremont and School Streets, Boston was built with this type of split stone. In 1825, granite quarrying began at Quincy, Massachusetts, to supply stone for the Bunker Hill Monument, Charlestown, Massachusetts. Until railroads were built most commercial production was from quarries near water transportation. Also, much of the early production was used for coastal protection, such as the construction of sea walls and for wharves and forts. During the second quarter of the nineteenth century architectural stone for buildings was in considerable demand. Inland quarries became important during this period. During the middle of the nineteenth century large quantities of granite were shaped for paving blocks and paving-block production was important until the 1920's, after which it declined greatly. The use of all stone products expanded considerably between 1900 and 1913, declined during World War I, and reached a peak between 1925 and 1930. Between 1930 and 1935 production declined rapidly and has never regained its former levels. In 1950, nearly 50 percent of the nation's monumental granite was produced in the New England-New York Region, of which about 93 percent was produced at Barre, Vermont. Much of the granite building stone and curbing are also produced in this

region, and more than half the total output of domestic paving blocks. The sales of dimension stone from 1917 to 1950 is shown on Plate 62d.

3. Limestone quarrying for the production of lime probably began in the Hudson River Valley. In 1751, limestone was used at the Sterling iron furnace in Orange County, New York. Dimension limestone and sandstone quarrying began in earnest in the second decade of the nineteenth century, about the time the Erie Canal was built. Limestone is also considered in the report on Carbonate Rocks.

4. In 1785, a marble quarry was opened at Dorset, Vermont. The first commercial quarry and mechanized mill in the New England-New York Region was put into operation shortly before 1800 at Marbledale in the town of New Milford, Connecticut. Considerable marble was produced during the nineteenth century in the western New England marble belt, in Connecticut, Massachusetts, and Vermont. Small quantities of marble have been quarried also in the Adirondacks, particularly in the Gouverneur district. The marble industry today is centered at Proctor and West Rutland, Vermont, which together constitute one of the principal marble production centers of the world. Marble imported from Italy and France is milled at Proctor.

5. Sandstone production has come principally from Ulster and Franklin Counties, New York and from the Connecticut River Valley at Middletown, Connecticut and Longmeadow, Massachusetts ("Brownstone").

Today only very small quantities are quarried. A few millstones and buhrstones are produced for grinding and some flagstones are quarried in Ulster, Greene and Albany Counties, New York, and curbing blocks are produced near Malone, Franklin County, New York.

6. Crushed Stone. - The demand for crushed stone began late in the nineteenth century with the introduction of water-bound macadam roads, and, in 1900, for use in concrete for foundations and buildings. The New England-New York Region was the principal source of the early production and has maintained a high rank in the total output of the nation. New York, Connecticut, and Massachusetts are the principal producing states. In 1950, New York was the third ranking state in total output of crushed stone.

7. Some dimension-stone producers utilize their waste materials in part for making crushed-stone products. Agricultural limestone, concrete aggregate, and finely ground carbonate rocks for use as a filler have been produced by some limestone and marble companies. Small quantities of mineral fertilizer are being produced from crushed granite. Most of the crushed stone is used as aggregate material, road metal, and railroad ballast.

GEOLOGIC STUDIES

8. The reports of Dale (1912, 1915, 1923) on the marble deposits of Western New England and the commercial granites of New England (Dale 1923) still are standard references, and Newland's report (1906)

on the quarry material of New York has not been superseded. Since the early reports, the principal published works are those of Bain (1938 and 1941) on the marble deposits of western Vermont.

9. Geologic investigations of the marble resources in the vicinity of Rockland, Rockport, and Union, Maine, have been made, and preliminary reports have been published (Allen, 1951).

10. General geology and regional distribution of commercial stone. - Granite and gneissic granites are the most widespread rocks of igneous or metamorphic origin used for building, monumental, curbing, and paving purposes. The individual bodies range from a few thousand feet to tens of miles long, and from hundreds of feet to several miles wide. Most of the granite quarries are east of the Green Mountains, Berkshire Hills, and the Western Highlands of Connecticut; some are in the Adirondack Mountains of New York.

11. The famous marble deposits of Proctor and West Rutland, Vermont, lie in the Otter Creek valley between the Green and Taconic Mountains. Originally flat-lying limestone beds, similar to those in east-central New York, were tightly folded and recrystallized into marbles. In the past dimension marble was quarried at many places in the Otter Creek valley, and in the southward continuation of the marble belt in western Massachusetts, western Connecticut, and southeastern New York. Marble, also, has been quarried from the tightly folded and metamorphosed limestone of the Adirondack Mountains, principally

in the Gouverneur district. A highly silicious rock called "Champlain marble" is quarried intermittently from slightly folded sedimentary rocks at Swanton and Isle LaMotte, Vermont.

12. The Medina sandstone of Orleans County, New York has been quarried extensively, chiefly for paving stones and curbing. Nearly flat-lying sandstone (bluestone) have been quarried in Wyoming, Albany, Green, and Ulster Counties for building stone and flagging. The Potsdam sandstone of the northern Adirondacks is quarried at times.

13. The serpentine rocks of New England lie in a southward trending belt east of the Green Mountains. Most of the serpentine (verde antique) is quarried intermittently at Roxbury, Vermont, although in the past it has been produced at Moretown, Rochester, and Proctorville, Vermont, and near Westfield, Massachusetts. Serpentinized marble has been quarried from strongly folded and metamorphosed Grenville limestone in the Adirondack Mountains, principally in the Gouverneur district.

14. Crushed stone is quarried chiefly from limestones in central, southern, and western New York; from intrusive sills and dikes, and lava flows associated with the sedimentary sandstones and shales in the Connecticut River Valley of Massachusetts and Connecticut; and from volcanic and metamorphosed igneous rocks of eastern Massachusetts. Considerable quantities of crushed stone are a by-product of granite quarrying in New England and New York. Two of New York's iron mines ship mill waste for aggregate and road metal.

15. Competitive stone from outside sources. - Data are not available showing the relative importance of the types of stone brought into the New England-New York Region. The famous oölitic limestone produced in the Bloomington-Bedford area of Indiana probably is the chief outside competitor chiefly because of low prices made possible by large scale operations and ready workability of the stone. Various stones are obtained from outside sources to satisfy architectural demands for colors and types that are not produced in New York or New England. In general, the quantity of dimension stone brought in is much less than the quantity shipped out of the New-England-New York Region.

THE STONE INDUSTRY

16. In the stone industry the words, "rock" and "stone" are not synonymous; they have distinct meanings. The word "rock" is applied to those geologic materials which form an integral part of the earth's crust. "Stone" is that material which is quarried from natural rock either as crushed stone (shape not specified) or dimension stone (shape specified).

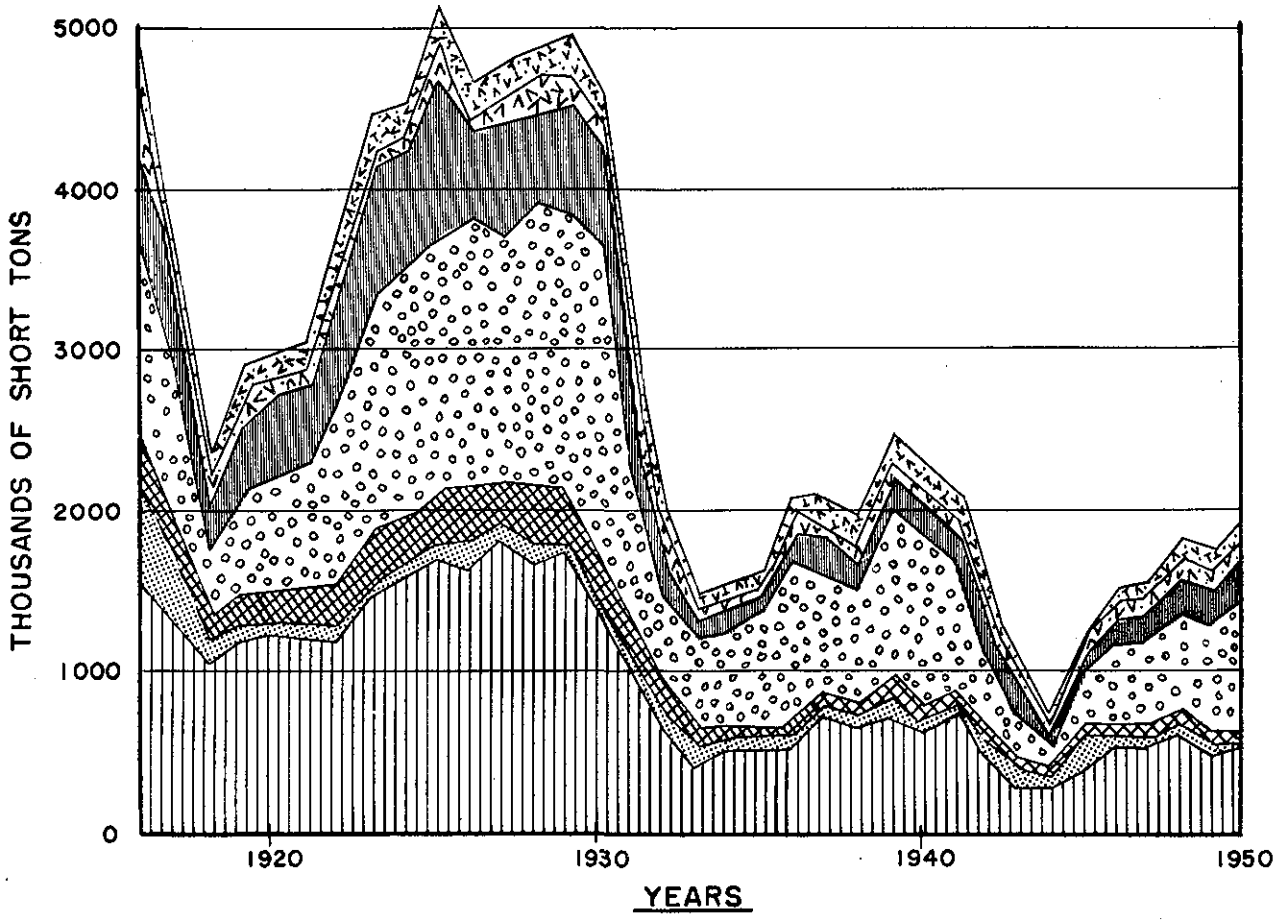
17. On the basis of composition and texture the following general classification is used by the stone industry (1) granite, (2) basalt and related rocks, (3) marble, (4) limestone, (5) sandstone, (6) slate (treated in a separate chapter), and (7) miscellaneous stone (includes volcanic rocks, schists, serpentine, soapstone and boulders).

18. According to use, crushed or broken stone is marketed as: (1) crushed stone (aggregate material), (2) riprap, (3) furnace flux, (4) refractory stone, (5) agricultural stone, and (6) stone used for miscellaneous purposes. Dimension stone, according to use, is subdivided into (1) building stone, (2) monumental stone, (3) paving blocks, (4) curbing, and (5) flagging.

19. Large blocks of quarried stone used to protect fill and in the construction of breakwaters are called riprap. Most crushed stone is used for concrete aggregate and road metal. Only crushed limestone and marble are satisfactory as a fluxing material in the refining of iron. Crushed dolomite and some clayey sandstones are used as refractory stone. Agricultural stone consists largely of limestone but varying quantities of dolomite are commonly present.

20. Marketable products of building stone are (1) rough construction stone, (2) rubble, and (3) cut stone. The rough construction stone has uneven surfaces and irregular shapes. Rubble has only one good face and consists of irregularly shaped fragments. Cut stone includes stone cut into specific sizes and shapes with smooth or polished faces.

21. Although outcrops of most types of dimension stone are widespread in the New England-New York Region, because of unfavorable conditions only a few of them can be quarried economically. Surface examinations alone are not adequate for the selection of a



LEGEND

SLATE		MARBLE	
MISCELLANEOUS		BASALT	
SANDSTONE		GRANITE	
LIMESTONE			

SPECIAL SUBJECTS-REGIONAL

SALES OF DIMENSION STONE
IN THE UNITED STATES, 1916 TO 1951
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62 D
CHAPTER XXXIX

quarry site; they should be supplemented by core drilling. Considerable attention should be given to the occurrence and spacing of joints, dikes, inclusions, and faults, textural variations, color, and mineralogical composition.

22. In some places considerable overburden consisting of soil and weathered rock may have to be removed. Unless a small quantity of a special type of stone is required it is most economical to operate a quarry on a large scale in order to produce large, regularly shaped blocks. From these large blocks smaller ones can be cut and milled according to specifications.

23. In general, most dimension stone is obtained from open pits or surface quarries. Some limestones and marbles are quarried by underground methods, but this is generally done when the stone has a higher than average value and where conditions are unsuited for open-pit operation. In quarrying dimension stone considerable skill is needed to remove the large blocks without developing fractures and without producing an excessive amount of waste rock. In recent years wire saws have been used to some extent for cutting marble and granite. Sand commonly used as abrasive, is fed by water under the moving wire.

24. Preparation for market varies with the different types of stone and its use. In general, the stone is cut into blocks in the mill by circular, gang, or wire saws, and carborundum and diamond

wheels. The softer stones are smoothed by planers; granite is "roughed down" with a cutting head driven by compressed air. The final surfacing and polishing is commonly done by use of rubbing beds, rotating abrasive heads and polishing pads. Carving is done by hand operated air-driven tools. Lettering and most of the design work is done by sandblasting. Details of mining and processing of both dimension and crushed stone are described in several of the publications listed in the bibliography, particularly "Industrial Minerals and Rocks" and "The Stone Industries".

25. Granite. - In the stone industry granite includes nearly all coarse-grained igneous rocks. "Light granites" include syenite, granodiorite and monzonite as well as granite, and "black granite" consists of diorite, gabbro and anorthosite.

26. All commercial granites are strong, hard, and of low porosity. Features that affect their adaptability are color, uniformity of texture and grain size, and absence of knots, hair lines, and other imperfections. Structural features, such as sheeting, jointing, and inclusions must be recognized for effective quarry planning. Granite for exterior use should not contain excessive amounts of pyrite or garnet because these minerals tend to decompose and produce iron stains.

27. Limestone. - Although limestones are composed mainly of calcite (calcium carbonate), they differ widely in texture, color,

and structure. The common impurities are siliceous, argillaceous, and carbonaceous materials. Limestones which have a high magnesian content are termed "dolomitic." In the New England-New York Region small amounts of building limestone have been quarried chiefly near Syracuse, Onondaga County, New York.

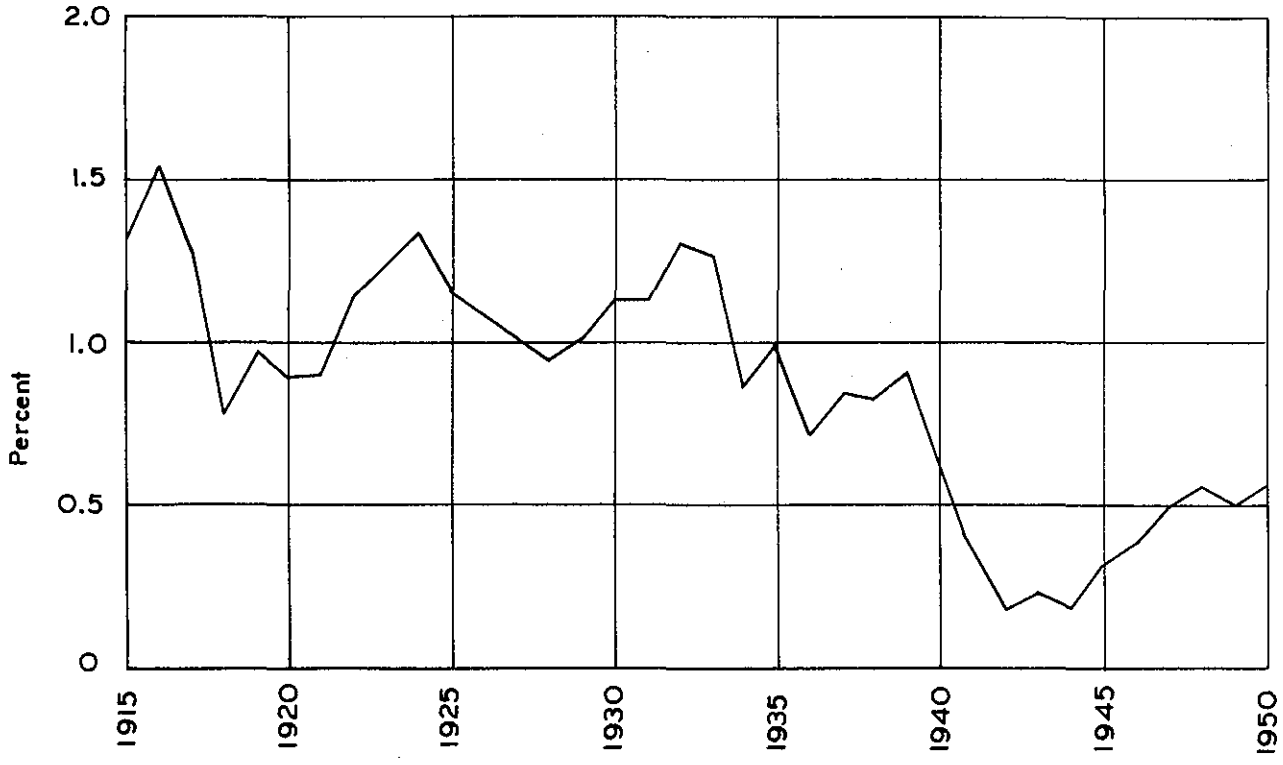
28. Marble. - Geologically, marble is a crystalline carbonate rock derived from calcitic and dolomitic limestones by metamorphism. Commercially, marble is any calcareous rock that will take a polish. Verde antique (serpentine) though not a calcareous rock, is marketed as marble because it is soft and takes a polish.

29. Marble, if pure, is white, but many marbles have been stained by iron oxides which produce tan, red, or brown colors. Organic matter in general imparts a gray or black color. Serpentine marbles range from light to dark green. Staining may be produced by iron sulfide minerals, such as pyrite. Silicate minerals may, or may not, produce attractive qualities in marble. In general they increase the hardness and make mining, cutting, and polishing more difficult and expensive. Also, they may cause uneven weathering if applied to exterior use.

30. Sandstone. - Sandstone is a sedimentary rock composed chiefly of quartz grains which are cemented or compacted together by natural processes. The common natural cementing agents are iron oxide, clay, calcite, and silica. Bluestone and freestone

are special types of sandstones. Bluestones are generally thin-bedded, easily cleavable sandstones, regardless of color. They are commonly compact and hard. Freestone is a special architectural sandstone which is cut or carved easily, yet does not split readily. Fine-grained sandstones are most desirable because they have a more attractive appearance. Permanence of color is necessary, particularly if stone is for exterior use. In general, sandstones are more porous than other building stones and become discolored easily by dust and soot.

31. Anorthosite. - Though anorthosite is used only to a minor extent as a "black granite", it is important as a potential source of alumina, and as a substitute for feldspar in ceramics. Anorthosite is composed chiefly of labradorite, a feldspar rich in calcium and aluminum. Since 1942, industry and government have been investigating methods for extracting alumina from anorthosite. In 1953 the U. S. Bureau of Mines renewed its pilot plant investigations at Laramie, Wyoming on the anorthosite in the vicinity of Laramie. Recent progress reports indicate that alumina can be recovered on a laboratory scale, but further research is needed to make it commercially acceptable as a source material for alumina. Many billions of tons of anorthosite averaging not less than 25 percent Al_2O_3 occur in the eastern Adirondacks.



SPECIAL SUBJECTS - REGIONAL

VALUE OF ROUGH AND DRESSED BUILDING STONE AS A PERCENT OF TOTAL VALUE OF NONRESIDENTIAL BUILDING CONSTRUCTION

1915 TO 1951

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62E
CHAPTER ~~XXXIX~~

32. Salient features of the dimension-stone industries. - The most striking feature about dimension stone production is that successive peaks do not reach the height of the preceding peaks, and each trough is successively lower than the preceding one. The low points reached during periods of business recession, depression, and wartime are characteristic of production trends of other nonmetallic mineral industries during the same periods. The failure to recover from these low points is characteristic of a shrinking industry. If it were possible to segragate and subtract the values for monumental stone, and constant dollars were used, the shrinkage would be even greater. One reason for the decline was the introduction of concrete which took the place of building stone extensively. Another was the use of structural steel and concrete for wall construction. A thin veneer of stone has superseded the massive stone walls, of earlier years.

33. Plate 62e shows the total value of rough and dressed building stone as a percentage of the total money spent for nonresidential building construction. The data have been adjusted to an index of 1939 = 100, in order that the separate values may be more comparative. This graph shows that the dimension stone industries are affected by wars, rumors of wars, and industrial depressions. The increased use shown during the early 1930's was the result of high-valued building programs initiated in 1928-29, and of public works

programs. Another deterrent to the wider use of building stone is the excessive labor cost involved in the many hand processes employed in quarrying and fabrication. For example, the important monumental granite industry of the Barre district, Vermont, had an output of 0.30 cubic feet of rough quarry stock per dollar of payroll in 1939 and 0.15 cubic feet in 1949 (calculated from data in Minerals Yearbooks, 1939, p. 1126; 1949, p. 1138).

34. Tables 84e to 84j, summarize the sales of dimension stone for the United States, New York, and each of the New England states during three five-year periods; 1908 to 1913; 1925 to 1929; and 1946 to 1951. These periods were selected because of their relatively equivalent position with respect to business cycles. Each five-year span followed a war or depression during which stone production was curtailed, and each covered a period of normal growth and industrial expansion.

CRUSHED STONE

35. All of the rock types used as dimension stones are used for making crushed stone with the exception of serpentine. In addition, some metamorphic rocks and gravel are crushed for use as road metal and aggregates. Limestone is used most commonly for crushed stone in New York. Owing to the absence of widespread limestone deposits in New England, basalt (trap rock), and granite are the principal sources of crushed stone.

Table 84e --Average annual sales of dimension stone for three five-year periods, 1908-1913, 1924-1929, and 1946-1951 in thousands of dollars 27/
The New England-New York Region

	U. S.	N. Y.	Conn.	Maine	Mass.	N. H.	R. I.	Vermont
1908-1913								
Granite	13,791	217	419	2,009	1,838	1,090	675	2,738
Marble	7,322	453			215			3,725
Limestone	6,391	228	½	(a)	(a)		(a)	5
Sandstone	5,867	1,450	223		(a)			
Slate	5,953	115		247				1,784
Basalt	288	13	13		18			
Total	39,611	2,476	656	2,256	2,072	1,090	675	8,253
1924-1929								
Granite	22,149	487	468	2,308	3,507	1,548	445	3,971
Marble	14,004	269			182			5,006
Limestone	16,862	114	½	(a)	(a)		(a)	10
Sandstone	6,738	1,131	22		(a)			
Slate	11,911	917		607				4,066
Basalt	251	1	8		5			
Total	71,915	2,919	499	2,915	3,694	1,548	445	13,054
1946-1951								
Granite	20,479	104	157	1,197	2,486	313	276	3,704
Marble	9,197							3,000
Limestone	10,832	6	½					3
Sandstone	4,189	345	13		(a)			
Slate	5,598	32		(a)				1,375
Basalt	85		4					
Total	50,380	487	174	1,197	2,486	313	276	8,081

(a) Value included with sales of another state. Data shown with state producing the greatest proportion of the total, whenever possible.

27/ Calculated from data in: Minerals Yearbook, Stone: Bureau of Mines, 1946, 1947, 1948, 1949, 1950
Mineral Resources of the United States, Stone: Geol. Survey, 1908-13, 1924-29.

Table 84f--Granite industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, and 1946-1951, in thousands of dollars [1]
The New England-New York Region

State	Building $	Monumental $	Paving $	Curbing $	Rubble $	Total $
United States						
1908-1913	5,776	4,236	2,532	914	332	13,791
1924-1929	6,551	9,976	3,132	2,172	209	22,149
1948-1951	3,963	14,958	436	1,267	247	20,479
Maine						
1908-1913	1,280	151	464	96	18	2,009
1924-1929	606	205	1,328	167	0.8	2,308
1946-1951	912	214	(2)	64 (2)	6	1,197
New Hampshire						
1908-1913	578	240	204	59	10	1,090
1924-1929	748	348	223	226	3	1,548
1946-1951	209	97	1	10	2	313
Vermont						
1908-1913	1,022	1,698	14	2	1	2,738
1924-1929	165	3,806	-	-	-	3,971
1946-1951	9	3,697	-	-	-	3,704
Massachusetts						
1908-1913	830	520	313	118	58	1,838
1924-1929	1,379	919	627	514	67	3,507
1946-1951	1,000	70	-	-	20	2,486
Rhode Island						
1908-1913	197	415	55	8	0.7	675
1924-1929	5	437	-	3	-	445
1946-1951	-	273	-	-	-	276
Connecticut						
1908-1913	218	84	38	34	45	419
1924-1929	229	207	-	30	-	468
1946-1951	65	65	-	11	15	157
New York						
1908-1913	82	30	90	4	12	217
1924-1929	392	83	12	-	0.1	487
1946-1951	96	-	?	4	8	104

1. 1946-1951 data other than for U. S. is estimated.
2. included elsewhere

Table 84g --Marble industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929 and 1946-1951, in thousands of dollars [1]
The New England-New York Region

State	Total	Monument
United States		
1908-1913	7,322	1,279
1924-1929	14,004	3,257
1946-1951	9,197	3,916
New York		
1908-1913	453	
1924-1929	269	
1946-1951		
Vermont		
1908-1913	3,725	
1924-1929	5,006	
1946-1951	3,000	
Massachusetts		
1908-1913	215	
1924-1929	102	
1946-1951		

1. 1946-1951 data other than for U. S. estimated.

Table 84h--Limestone industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, and 1946-1951 in thousands of dollars 1

The New England-New York Region

State	Rough Building	Dressed Building	Paving	Curb-stone	Flag-ging	Rubble	Total Dimen-sion Stone
United States							
1908-1913	2,266	2,616	338	185	40	946	6,391
1924-1929	1,942	14,376	-	-	-	544	16,862
1946-1951	2,564	7,958	-	-	83	224	10,832
New York							
1908-1913	122	52	11	4	0.9	38	228
1924-1929	(2)	(2) 68	-	-	-	-	114
1946-1951	-	-	-	-	-	-	6
Vermont							
1908-1913	4	-	-	-	-	1	5
1924-1929	-	-	-	-	-	-	10
1946-1951	-	-	-	-	-	-	3
Connecticut							
Maine							
Massachusetts							
Rhode Island							
1908-1913	0.5						0.5
1924-1929							0.5
1946-1951	0.4						0.4

1. 1946-1951 data other than for U. S. is estimated.
2. Combined with dress building stone.

Table 84i —Sandstone industry growth, average annual value of sales for three 5-year periods, 1908-1913, 1924-1929, and 1946-1951 in thousands of dollars 1
The New England-New York Region

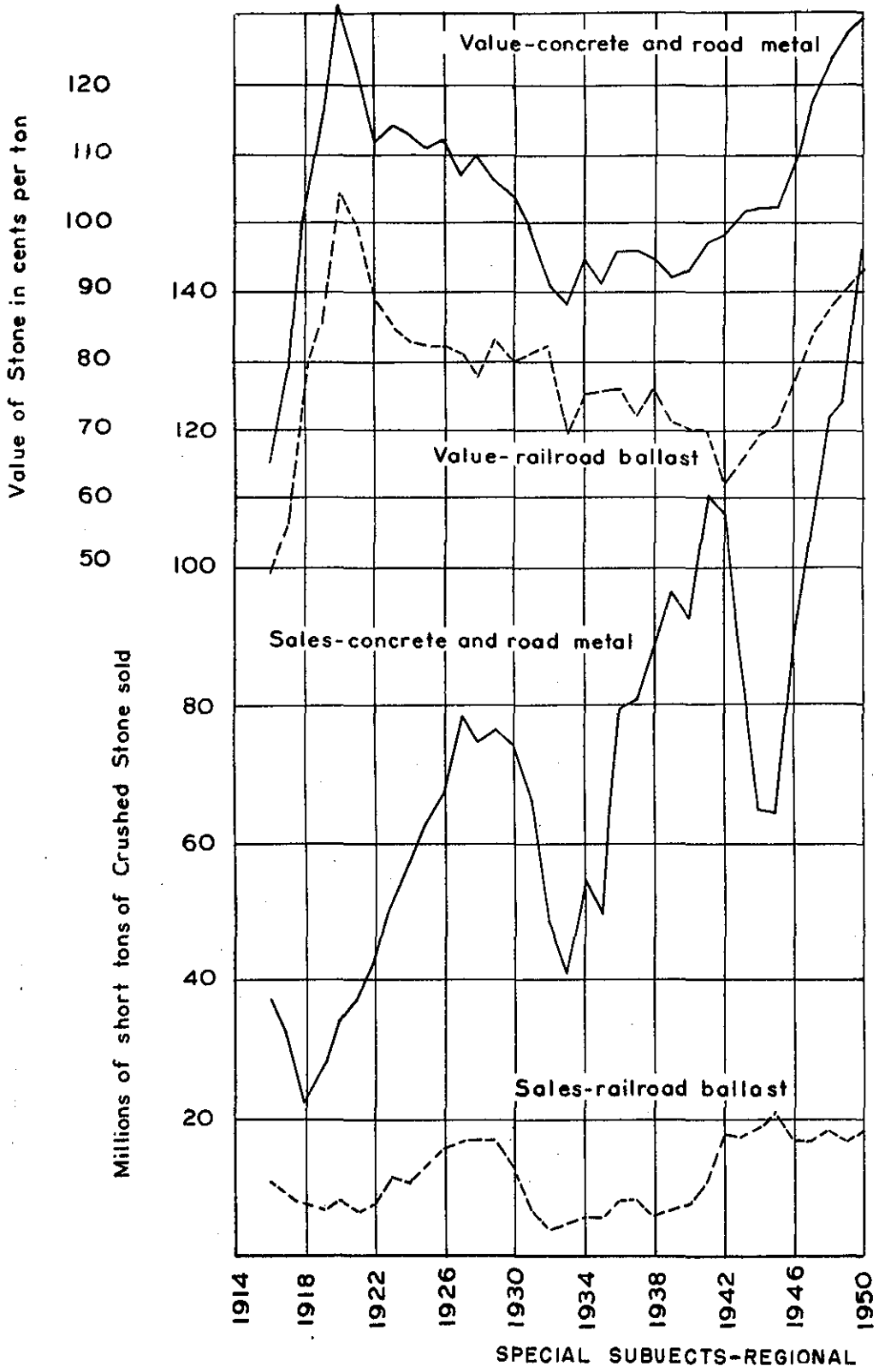
State	Building	Paving	Curbstone	Flagstone	Rubble	Total Dimension
United States						
1908-1913	2,663	686	1,016	828	403	5,867
1924-1929	2,556	210	2,034	600	220	6,738
1946-1951	3,361	(2)	165(2)	541	123	4,189
Massachusetts-Conn.						
1908-1913	208	-	0.8	-	14	223
1924-1929	15	-	-	-	-	22
1946-1951	13	-	-	-	-	13
New York						
1908-1913	435	268	419	304	23	1,450
1924-1929	315	53	664	96	3	1,131
1946-1951	146	-	17	171	11	345

1. All data other than for U. S. is estimated.
2. Combined with curbstone.

Table 84j--Basalt industry growth, average annual value of sales for three 5-year periods, 1908-1913 1924-1929, and 1946-1951 [1]
The New England-New York Region

State	Building	Rubble and Paving	Total
United States			
1908-1913	67,682	219,849	287,531
1924-1929	52,559	198,095	250,654
1946-1951			84,660
Connecticut			
1908-1913	9,365	3,391	12,756
1924-1929	7,000+	1,000+	8,000
1946-1951			4,000
Massachusetts			
1908-1913	17,911	-	17,911
1924-1929	5,497	-	5,497
1946-1951			-
New York			
1910-1912	12,525	-	12,525
1924-1929	1,355	-	1,355
1946-1951	-	-	-

1. 1946-1951 data other than for U. S. is estimated.



SPECIAL SUBJECTS-REGIONAL

THE CRUSHED STONE INDUSTRY
IN THE UNITED STATES
NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62 F
CHAPTER XXXIX

36. Limestone has been described. Basalt ("trap rock") is a fine-grained dense rock equivalent to the coarse-grained "black granites". It occurs mainly in sills, dikes, and lava flows of the bank of the Hudson River south of Haverstraw. Most of the crushed stone quarries of the Boston area are in more siliceous metamorphosed volcanic rocks, chiefly felsite rather than basalt.

37. Physical properties such as hardness, toughness, and abrasiveness, are not only significant in the uses of crushed stone but also in its production. Some rocks are so abrasive that production machinery deteriorates rapidly. In general, the serviceability of crushed stone depends upon toughness, hardness, and resistance to abrasion. The soundness of rock refers to its weathering properties, chiefly its resistance to freezing and thawing action. Determinations of these properties, and others, together with mineralogical analyses are generally made to ascertain whether a rock is acceptable for specific uses.

38. The rapid and enormous growth of the crushed stone industry in the United States from 1916 to 1951 is illustrated in Plate 62f showing sales of stone for concrete, road metal, and railroad ballast.

39. In the past thirty years production of crushed stone in the United States has increased threefold, yet the price level has remained relatively constant, due to the remarkable technological advances that have been made.

40. Statistics for New York and each of the New England states show little similarity to the strong growth trend for the total sales in the United States (Plate 62f), except for New York and Connecticut, where the trend has been toward a levelling off without creating a condition of overproduction. The graphs for the other states indicate erratic production which are evidently due to wide variations from year to year in market demands.

41. Very little limestone is used as crushed stone in New England. Most production comes from basaltic or granitic deposits which are more expensive to operate.

42. Railroads serving Connecticut and New York principally use limestone for ballast. Railroads serving northern New England obtain nearly all of their ballast in Massachusetts where it is produced from "trap rock". It is reported that limestone produced in Maine and Vermont is so expensive that ballast is transported by rail from Massachusetts.

43. Because of the restrictions placed on the industry by transportation, it may be expedient to operate small pits for the temporary production of stone near the point of consumption. The maximum economical truck haul is about 30 miles; the maximum rail haul seldom exceeds 100 miles. Since World War II, over 50 percent of transportation of crushed stone in the United States has been by truck, 30 percent by rail, and the remainder by water or unspecified methods.

44. The present trend is toward the construction of large capacity, well-equipped plants in areas of high consumption, because of high costs entailed in the preparation of stone in small plants for a market that is continually demanding a higher-quality product.

45. Prospecting, exploration, mining, and processing. - The technology of crushed stone differs in many ways from that of dimension stone, principally because the end-products are entirely different. However, prospecting and exploration methods are similar. In recent years the trend has been toward the construction of large plants capable of operating at a low cost. Frequently it is necessary to select a site near a special job and install a plant which will produce small or large tonnages for relatively short periods.

46. The type and program of drilling and choice of equipment is determined by preliminary examination and testing. An important factor in the effective operation of a quarry is to correlate drilling and blasting with the size and type of loading equipment. The power shovel is the most common type of loading machine. Also, it can be used to strip the overburden.

47. Crushed stone is obtained most commonly from either a pit or bank quarry. Stone from a bank quarry is taken chiefly from above the level of the adjacent country; stone from a pit quarry is raised to the crushing and treatment plants at the surface. The bank type quarry usually is without pumping problems. Quarry methods are de-

pendent upon the characteristics of the deposit. In recent years underground mining has increased, particularly where the overburden is too heavy for economic removal and where a strong roof may be maintained without timbering. Underground mining, in general, produces a cleaner stone, and permits more continuous production than is possible in open pits.

48. Preparation of materials for commercial use is confronted with the problem of constantly increasing rigidity of specifications. Both stationary and portable treatment plants are common. The latter type has been used recently to meet the needs of temporary projects at sties too remote from the large, stationary commercial plants. The portable plant consists primarily of a small crusher, elevator, sectional revolving screen, and one or two stacker conveyors.

49. Crushing is the first step in the treatment. Both jaw and gyratory crushers are widely used.

50. For sizing, small plants generally use trommel screens because of their low initial cost, and because they aid in simplifying mill design. Large plants commonly use revolving screens for scalping prior to crushing. For openings of one inch or less, vibrating screens are preferred.

51. Washing has become increasingly important. Log washers are used to break up tough clay, and fishtail sprays over screens are generally adequate to remove small amounts of dust. The amount

of washing and the equipment needed is dependent upon the nature of the material and the market demands.

52. Large storage areas are often required at the plant in order to balance variations in demand for different sizes. In general, the demand is seasonal. For example, in New England and New York spring highway construction first requires small sizes for patching winter damage and later for the surface-chipping and oiling programs that must be completed prior to the renewal of heavy, warm weather traffic. Large sizes of stone are needed during the summer and fall for new highway construction and new road surfacing projects.

SLATE AND ROOFING GRANULES

53. Slate. - Slate was first quarried about 1750 in Massachusetts, and since then has been quarried in all the states of the region except Rhode Island. The industry expanded rapidly and reached its peak in the period 1900-1925. The major use, as roofing in residential construction, dropped from about 2.08 squares per dwelling in the decade 1900-1910 to only 0.28 squares per dwelling in the period 1946-1950. The main reason for the decline was competition from asphalt composition and asbestos-cement roofing shingles. The value of slate production in the New York-New England Region from 1949 to 1952 was as follows:

	1949	1950	1951	1952
New York	$1,617,097	$2,054,725	$1,464,669	$1,810,865
Vermont & Maine	$3,925,221	$4,870,811	$4,586,491	$4,451,705

54. Slate is formed from shale by metamorphism of sufficient intensity to recrystallize the original clay minerals into platy minerals, principally mica and chlorite, and orient them to produce a planar cleavage. The value of a deposit depends largely on the perfection of the cleavage, and in most districts only a small proportion of slate will yield a satisfactory product. Color and color fastness are important and, depending on the mineral composition, slate may be black or of various shades of gray, red and green. Some ferruginous minerals, such as sulfides and carbonates, weather readily and therefore are undesirable. Some slates are good insulators and are used extensively for switchboards.

55. Slate quarrying in the region centers in a belt that extends southward from western Vermont into New York State east of the Hudson River, and in the vicinity of Monson, Maine. The New York-New England industry faces severe competition from eastern Pennsylvania, where the largest slate quarries in the country are, yet it now produces about four-tenths of the national supply.

56. Maine. - The Monson district in Piscataquis County is the principal source of electrical slate in the country. The slate is dense, blue black, easily drilled and cut, and has exceptionally high dielectric strength. The main slate bed is about 10 feet thick, and other beds range from 2 to about 18 feet thick. The beds dip steeply, and are mined underground by overhead stoping. In 1939 one shaft was about 1,000 feet deep. The Brownville district, near Monson, has yielded good roofing slate.

57. Vermont and New York. - The Vermont-New York slate belt extends from Rutland County, Vermont into Washington County, New York. The belt is second only to Pennsylvania in production of structural and roofing slate, and produces the only colored slates in the United States. The Cambrian Mettawee formation yields green, purple, and variegated slates, and the Ordovician Normanskill formation yields red, bright green, and black slates.

58. The slate belt may be divided into three main districts. The northern district, in Vermont, includes quarries near Poultney, Fair Haven, and Hydeville that produce roofing and mill stock slate. The southern Vermont district, from Wells to West Paulet, produces mostly roofing slate. The third district includes quarries at Granville and Hampton, New York, which produce red and green slates for roofing, floors, walks, and walls, and for granules and flour.

59. Roofing granules. - Roofing granules are crushed rock particles used to protect and decorate asphalt composition roofing and siding. Granules are also used to surface tennis courts, patios, and the like. The mineral surfacing lengthens the life of roofs by protecting the asphalt from the sun, and greatly increases the fire resistance of the surface. Slate granules were first shipped for roofing in 1906, and figures on use have been available only since 1942. The granule industry has grown rapidly in recent years.

60. Several materials are used for granules. Slate was widely accepted very early, because of pleasing colors, flat grain shape, and good adhesion. Diabase and altered volcanic rocks, brick and artificial ceramic materials are used. Most granules are colored artificially in order to provide choice and stability of color.

61. Production of slate granules in the New York-New England Region in 1951 was 232,860 tons valued at $3,321,409.

FUTURE OUTLOOK

62. During the next 10 to 15 years the crushed stone industry may be expected to show an increase in production. Such a forecast is based on the growing need for more and larger airports, and on an increase in public works projects; also on the prospect of extensive construction of arterial highways. The amount of building stone used will depend not only on economic factors, but upon architectural demands. A moderate increase in dimension-stone production is probable, particularly if wire saws and other types of labor-saving equipment attain wider use.

SELECTED BIBLIOGRAPHY ON STONE

Allen, H. W., 1951, Preliminary report of limestone survey of a portion of Knox County, Maine: Maine State Geol. Rept. 1949-1950, p. 78-90.

----------, 1953 Progress report on limestone survey, Knox county, Maine State Geol. Rept. 1951-1952. Maine Development Commission pp. 11-29.

Bain, G. W., 1933, The Vermont marble belt; 16th International Geol. Cong., Guidebook 1, Eastern New York and Western New England, p. 75-87.

----------, 1938, Mining marble: Am. Inst. Min. Met. Eng. Trans. v. 129, p. 99-114.

----------, 1941, Geological, chemical, and physical problems in the marble industry: Am. Inst. Min. Met. Eng. Trans. v. 144, p. 324-339.

Bastin, E. S., 1908, Description of the Rockland quadrangle, Maine: U. S. Geol. Survey, folio no. 158.

Bowles, Oliver, 1916, Technology of marble quarrying: U. S. Bur. Mines Bull. 106, 174 pages.

----------, 1917, Sandstone quarrying in the United States: U. S. Bur. Mines Bull. 124, 143 p.

----------, 1931, Economics of crushed stone production: U. S. Bur. Mines Econ. Paper 12, p. 54-62.

----------, 1932, The wire saw as a tool for cutting slate and building stone: Am. Inst. Min. Mat. Eng. Trans., v. 102, p. 117-121.

----------, 1939, The stone industries: 2nd ed., McGraw-Hill Book Co., New York, 519 p.

----------, 1949, Dimension stone: Industrial Minerals and Rocks, Chap. 14, p. 313-344, Am. Inst. Min. Met. Eng., New York.

----------, 1949, Challenge of the stone industry: Stone, July.

Bowles, Oliver, and deVitry, P., 1942, The single-strand wire saw. Am. Inst. Min. Met. Eng. Trans., v. 148, p. 231-235.

Bowles, Oliver, and Hatmaker, P., 1931, Trends in production and uses of granite as a dimension stone: U. S. Bur. Mines Rept. Inv. 3065, p. 21.

Bowles, Oliver, and Banks, D., 1933, Limestone: U. S. Bur. Mines Inf. Circ. 6723, 21 p.

Cady, W. M., 1945, Stratigraphy and structure of west-central Vermont: Geol. Soc. Amer. Bull., v. 56, p. 515-558.

Colby, S., 1941, Occurrances and uses of dolomite in the United States: U. S. Bur. Mines Inf. Circ. 7192, 21 p.

Dale, T. N., 1912, The commercial marbles of western Vermont: U. S. Geol. Survey Bull. 521, p. 1-170.

----------, 1915, The calcite marble and dolomite of eastern Vermont: U. S. Geol. Survey Bull. 597, p. 1-289.

----------, 1923, The lime belt of Massachusetts and parts of eastern New York and western Connecticut; U. S. Geol. Survey Bull. 744, p. 1-71.

----------, 1923, The commercial granites of New England: U. S. Geol. Survey Bull. 738, p. 1-488.

Deiss, C. F., 1953, Dimension stone in the United States in 1952 - a summary: abstract Econ. Geology, v. 48, p. 324.

Eckel, E. C., 1912, Building stones and clays: John Wiley & Sons, New York, 264 p.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geol. Survey Bull. 597, p. 1-289.

Fletcher, R. A., and Mould, W., 1953, A half century of dimension granite quarrying in Massachusetts: abstract, Econ. Geology, v. 48, p. 325.

Fowler, P., 1950, Stratigraphy and structure of the Castleton area, Vermont: Vermont Geol. Survey Bull. 2, p. 1-83.

Gildersleeve, B., 1950, Building stone of the Crabtree Orchard district, Tennessee: Am. Inst. Min. Met. Eng. Trans., v. 187, p. 883-885.

Goldbeck, A. T., 1949, Crushed stone: Industrial minerals and rocks, Chap. 12, p. 245-293, Am. Inst. Min. Met. Eng., New York.

Hatmaker, P., 1931, Utilization of dolomite and high magnesium limestone: U. S. Bur. Mines Inf. Circ. 6524, 17 p.

Keith, Arthur, 1933, Outline of the structure and stratigraphy of northwestern Vermont: 16th International Geol. Congr. Guidebook 1, Western New York and Western New England, p. 48-61.

----------, 1933, Preliminary geologic map of Maine: Maine Geol. Survey Orono, Maine.

Kessler, D. W., 1919, Physical and chemical tests of commercial marbles of the United States: Nat. Bur. Standards Tech. Paper 350, 91 p.

----------, 1931, Weathering test procedures for stone: Amer. Soc. Test. Mat. Proc. v. 31, pt. II, p. 799-803.

Kessler, D. W. and Sligh, W. H., 1927, Physical properties of the principal commercial limestones used for building construction in the United States: Nat. Bur. Standards Tech. Paper 349, 94 p.

Kessler, D. W., Insley, H., and Sligh, W. H., 1940, Physical mineralogical and durability studies on the building and monumental granites of the United States: Nat. Bur. Standards Jour. Research, v. 25, p. 161-206.

Longwell, C. R., 1933, Geology of western Vermont and northwestern Massachusetts: 16th International Geol. Congr. Guidebook 1, Eastern New York and western New England, p. 61-68.

Merrill, G. P., 1910, Stones for building and decoration: John Wiley & Sons, New York, 551 p.

Moore, F. H., 1935, Marbles and limestone of Connecticut: State Geol. and Nat. History Survey Bull. 56, p. 1-56.

Newland, D. H., 1916, The quarry materials of New York - granite, gneiss, marble, and trap: New York State Mus. Bull. 181, 212 p.

Newsom, J. B., 1932, Results of wire saw tests: Am. Inst. Min. Met. Eng. Trans. v. 102, p. 117-121.

O'Neill, L., 1941, Nonmetallic minerals needed for national defense: U. S. Bur. Mines Inf. Circ. 7179, 14 p.

Perkins, G. H., 1933, Marble industry of Vermont: Vermont State Geologist Rept. 1931-1932, p. 1-315.

Prindle, L. M., and Knopf, E. B., 1932, Geology of the Taconic quadrangle: Am. Jour. Sci., 5th ser., v. 24, p. 257-302.

Richardson, C. H., 1917, Building stones and clays: Syracuse Univ. Bookstore, Syracuse, New York, 437 p.

Thoenen, J. R., 1929, Study of quarry costs: U. S. Bur. Mines Rept. Inv. 2911, 105 p.

----------, 1930, Study of quarry costs, trap rock, sandstone, and granite: U. S. Bur, Mines Inf. Circ. 6291, 24 p.

Trefethen, J. M., 1947, Limestone: Maine State Geologist Rept. 1945-1946, p. 66-93.

Tyler, P. M., and Bowles, O., 1934, Economic notes on the nonmetallic mineral industries: Am. Inst. Min. Met. Eng. Trans. v. 109, p. 318.

U. S. Bur. Mines, Minerals Yearbook, 1932-1950.

U. S. Geol. Survey, Mineral Resources of the United States, 1890-1931.

Vermont Marble Corp., 1949, Miracles in marble: Vermont Marble Corp., Proctor, Vermont.

Warnes, A., 1926, Building stones, their properties, decay, and preservation: Ernest Benn, Ltd., London, 269 p.

Weigel, W., 1931, Application of the wire saw in marble quarrying: Am. Inst. Min. Met. Eng. Trans., v. 96, p. 163-164.

Weitz, J., 1942, High grade dolomite deposits in the United States: U. S. Bur. Mines Inf. Circ. 7226, 86 p.

SECTION XXXIe - LIGHTWEIGHT AGGREGATES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION

1. Several plants in the region import and expand perlite and vermiculite from African and western United States sources. The resulting aggregate has been used principally in the building trades, but this consumption is small compared with the demand for similar products in other sections of the country.

2. The Buffalo Slag Co., Inc., Buffalo, New York, is the largest producer of lightweight aggregates made from "native" resources in the region. The company employs over 100 people at two plants producing an air-cooled blast furnace slag aggregate.

3. John H. Black Company produces an expanded clay or shale aggregate under the "Haydite" patent at their plant in Jewittville, New York, employing about 40 persons. This production is in conjunction with their manufacture of face brick.

4. In New England, one company is considering large scale production of lightweight aggregate. If the results come up to expectations they may provide the long delayed impetus toward the development of an industry utilizing local materials. See Page 10, Silt.

5. There has never been a lightweight aggregate market survey in New England or New York. A number of estimates have been made 1/, and there is no question that a large market does exist, at least for cinder block aggregate.

6. There is minor production of cinder or slag in New England and New York, but it is inadequate to meet the demand. Cinders are brought into the region from Pennsylvania, - both supply and price fluctuate widely. In the metropolitan New York area, cinders sell for $2.25 to $3.50 a ton. In the New Haven area the cost is from $3.75 to $4.20, and in Boston $3.00 to $3.25 a ton.

7. Approximately 70,000,000 lightweight aggregate concrete blocks are made annually in New England and New York, which alone represents a market for almost 3,000,000 tons of lightweight aggregate.

ECONOMIC FACTORS AFFECTING THE MANUFACTURE OF LIGHTWEIGHT AGGREGATES

8. One of the major problems affecting the manufacture of lightweight aggregates is the limited market for the product within a given shipping area as compared with the capital investment for a plant. High freight rates invariably prohibit the shipment of lightweight aggregates or finished products for any great distances.

1/ Based on discussions with officials of Structural Clay Products Association, Portland Cement Association, and five of the largest clay products producers in New England and New York.

424

9. The marketing problem has been studied by the Armour Research Foundation which has been working on the design of a kiln that would be low in cost, have a relatively low capacity, and which could be economically operated. The results of some of these studies were described in their reports to The Portland Cement Association, October, 1949, Project No. 1-678 G.

10. History. - Romans used fragments of pumice as aggregate to reduce the dead weight in the construction of their great domes, such as that of the Pantheon.

11. The middle of the nineteenth century brought a radical change in building design, involving the transfer of the structural dead load from thick, heavy, load-bearing walls to thin walls and beams and columns. The evolution of the new designs followed the development and widespread availability of structural steel and concrete as the members of the load-carrying framework. Engineers and architects envisioned the possible development of skyscraper-like structures and long-spanned bridges, but as the building of these monoliths progressed it became evident that it would be necessary to obtain lighter weight materials to enlarge these structures and to decrease their costs.

12. Common rock-sand concrete weighs between 145 and 155 pounds per cubic feet. The only practical means of decreasing the weight of concrete is to decrease the weight of the aggregate used. 1/

13. Since 1910, great strides have been made in the development of lightweight aggregates that are suitable substitutes for sand, gravel, and crushed stone in the mixing of structural concrete. Their growing importance may be illustrated by the following examples:

> A cured Gravelite-sand concrete, weighing 95 to 97 pounds per cubic foot, was used in the upper-deck floor of the San Francisco-Oakland Bay Bridge. Its use in place of crushed rock or gravel concrete is said to have effected a savings of approximately 15,000 net tons in the weight of concrete alone.
>
> Savings on the General Petroleum Building in Los Angeles were estimated to have been $180,000 for structural steel by using $61,000 worth of lightweight concrete.
>
> It has been conservatively estimated that at least 40 to 50 thousand dollars were saved in the construction of the John Hancock Building in Boston by the use of vermiculite in the concrete.

PHYSICAL PROPERTIES OF A LIGHTWEIGHT AGGREGATE

14. The specifications for the physical properties of a manufactured lightweight aggregate used in construction are determined by the use. The uses are divided roughly into two groups. The first

---

1/ Aggregates is a general term used to designate those chemically inactive and inert materials which, when bound together by a cement, form concrete. Approximately 90 percent of a concrete consists of aggregates, and it is a paramount necessity that the properties of the aggregates correspond to and equal the properties desired in the concrete.

comprises those aggregates used in the manufacture of low-cost, low-strength concrete products, such as cinder blocks, for which a compressive strength of 1,000 pounds per square inch or less is adequate.

15. The second group consists of those high-quality, high-strength aggregates that produce a concrete able to sustain a minimum load of 2,000 pounds per square inch. There is a large potential market for aggregates of both groups.

16. The qualities that should be sought in a good aggregate includes: 1) light weight, 2) strength, 3) particle shape to promote good workability, 4) low water absorption, 5) uniform particle-size gradation, 6) chemical inertness, 7) low production cost. 2/

CLASSIFICATION OF LIGHTWEIGHT AGGREGATES

17. Lightweight aggregates are classified according to their source. A natural aggregate, such as pumice, is used as mined with minor preparation. Byproduct aggregates are manufactured, such as cinders. Specially processed aggregates are those that are manufactured by a particular process with the aggregate being the primary end product, such as expanding clay by a heat process. 3/

2/ Conley, J. E., Wilson, H., Klinefelter, T. A., et al., Production of Lightweight Concrete Aggregates from Clays, Shales, Slates, and other Materials: Bur. Mines Rep. Inv. 4401, 1948, p. 8.

3/ Moyer, Forrest T., Lightweight Aggregates for Concrete: Bur. of Mines, Inf. Circ. 7195, Jan. 1942, p. 3-22.

NATURAL AGGREGATE

18. Natural aggregates are made principally from vesicular volcanic materials. Anthracite and diatomite are other natural materials that have had use as lightweight aggregates. Of these materials only diatomite and meta-anthracite occur in the New York-New England region.

19. Diatomite. - Pure diatomite has an average weight of about 28 pounds per cubic foot. Diatomite has been used as an aggregate in concrete for special high-temperature insulation on furnaces. A 1:5 mix by weight of this concrete will average approximately 60 pounds per cubic foot. Impure diatomite and diatomaceous shales have been made into lightweight aggregates by patented processes which are described under the subject, "Specially Processed Aggregates".

BYPRODUCT AGGREGATES

20. Slags and cinders. - Air-cooled slags and coal cinders have been the most important of the various byproducts used for aggregates.

21. The dearth in the supply of cinders has come about only recently since railroads have adopted the use of diesel equipment and many large users of lump coal have converted to powdered coal or oil. There are few iron smelters in the region, and slag production is inadequate and not properly located with respect to markets.

22. The supply problem has caused users to investigate other materials, primarily those listed under "Specially Processed Aggregates".

23. Coke-breeze. - Coke breeze is another byproduct aggregate in short supply in New York and New England because of the decreasing

production of coke and manufactured gas. Also, coke breeze is more valuable for other uses.

24. Sawdust. - Sawdust has been used in many European countries as a lightweight aggregate. With the proper treatment and marketing programs, sawdust from the lumber operations in New England and New York may prove to be an acceptable substitute for cinders in the manufacture of some precast concrete units.

25. Peat. - Peat has been used in Scotland as a lightweight aggregate in cement blocks. See Peat section.

SPECIALLY PROCESSED AGGREGATES

26. Specially processed aggregates are those manufactured by treating raw materials to develop certain desired properties. Two of the most important are vermiculite and perlite. Neither is native to the New York-New England region.

27. Expanded clay, shale, and slate. - These three materials are grouped because of their similarities, though shale and slate are more adaptable to the manufacture of lightweight aggregates.

28. The type of clay and shale generally employed in the manufacture of lightweight aggregates is the same used to make brick, tile, sewer pipe, and similar wares. Several plants produce both ceramic and bloated products from the same clay or shale 5/.

29. The constituents responsible for the bloating of a clayey material are the minor minerals or impurities associated with the

---

5/ See p. 9, 10, 13, 14, 98 of work cited in footnote 2.

basic clay mineral. They include carbonaceous material, various iron compounds, limestone, dolomite, and gypsum, which are potential sources of gases for bloating; and feldspar, mica, and free quartz sand, which have uncertain roles in the bloating phenomenon. Tests have shown that these materials are necessary to effect extensive bloating, and their addition to a deficient clay aids bloating 6/.

30. Only a few tests have been made to determine the bloating characteristics of the clay, shale, or slate of New England and New York. The samples tested by the Bureau of Mines for their Report of Investigations 4401 are shown below:

> A kaolinitic type clay from Orleans County, Vermont, bloated at a temperature of 1205°C., and the resulting aggregate weighed 23 pounds per cubic foot. An illitic type clay from Cumberland County, Maine, bloated at a temperature of 1260°C., the resulting aggregate weighed 37 pounds per cubic foot.

31. There are numerous patented processes to make expanded clay or shale aggregates. Among these are:

Trade name	U. S. Patent	Patent date	Material	Weight in lbs. per cu. ft.
Cel-Seal	2,015,381	Oct. 1, 1935	Clay	6-3/4 to 30
Gravelite	2,035,845	Mar. 31, 1936	Clay, shale	40 to 55
Haydite	11,255,878	Feb. 1918	Clay	40 to 60
Haydite	1,707,395	Apr. 1929	Shale	40 to 60

32. Diatomite. - Low-grade diatomite and diatomaceous shales have been prepared for use as lightweight aggregate in ordinary concrete by burning the organic impurities out in a kiln. If any

6/ See work cited in footnote 2.

bloatable clay is present in the raw material it may expand so that the product weighs approximately 40 to 50 pounds per cubic foot. The resulting aggregate has been sold in California under the trade names "Diacrete" and "Raylite". "Airrox", a lightweight aggregate made by oil-impregnation of diatomaceous shale, has been produced under U. S. Patent 2,112,380, March 29, 1938; the product weighs about 35 to 40 pounds per cubic foot in a saturated, surface-dry, loose condition.

33. Silt. - A brick company at North Haven, Connecticut has tested 22 clay deposits in Massachusetts and Connecticut to find a suitable material for lightweight aggregate. Their tests conclude that a "black silt", occurring as a 10 to 20 foot overburden on their brick clay at North Haven, would be suitable. Their tests further indicate that the clay tested at Taunton, Massachusetts would be satisfactory, but not as good.

34. Production was scheduled to start in 1954. STILITE is the name the company proposed to use for the finished product. Plans called for sintering the silt on a Dwight-Lloyd sintering machine and the production of 500 cubic yards per day.

35. Other. - Vermiculite, perlite and expanded slags have had what is perhaps the greatest market acceptance of all the types of specially processed aggregates, but since the raw materials must be imported into the New York-New England region they are not described in detail in this report.

SECTION XXXIb-CLAY AND SHALE IN THE NEW ENGLAND-NEW YORK REGION

GENERAL STATEMENT

1. Large clay deposits occur at many places in New England and New York. Clay was deposited in the late glacial and early post-glacial estuaries and lakes which occupied many of the river valleys. Clay of marine origin underlies much of the lowland close to the New England coast. Cretaceous and Tertiary marine and fresh water clays occur on Staten, Long, Nantucket, and Block Islands and Martha's Vineyard. Kaolin occurs at scattered localities in the western part of New England. Other clays in New England and New York, such as boulder and flood plain clay, either occur in small quantities or are of very low quality and have little value.

2. Shale (a fine-grained, laminated, earthy material that is commonly more indurated than clay) is very abundant in New England and New York. Shale deposits are particularly widespread in New York where they can be found near all large centers of population. In New England shale crops out at many places, but is much more restricted in its distribution than in New York. The shale deposits of the region range in age from Cambrian through Triassic and are much older than the clays.

3. In New England and New York, clay and shale are used very extensively in making brick, tile, and other structural clay products. Large amounts of these raw materials are used in the manufacture of pottery and as an ingredient in portland cement. Some of the deposits are suitable for slip clay required in making glazed products. Deposits of kaolin in Vermont contain material that is suitable for refractory clay products and light colored brick, and some of this clay may be used for

paper filler, rubber filler, sanitary ware, and other purposes. Many of the clay and shale deposits of the region are suitable for use in making lightweight aggregates.

PRESENT KNOWLEDGE OF THE DEPOSITS

4. Results of a comprehensive survey of New York clay and shale resources and their ceramic properties have been published by the New York Department of Commerce (Brownell, Broughton, and Peterson, 1951). This state-wide study of clay and shale resources was conducted as a joint project by the New York State College of Ceramics, the New York State Science Service, and the New York State Department of Commerce. The report contains much information concerning the geology and ceramic properties of clay and shale deposits in New York.

5. The Maine Geological Survey has investigated clay resources in the State for several years and published the results of the work in the Maine State Geologist Reports (Perkins, 1930, p. 75-81, Trefethen, 1945, p. 23-26, Trefethen, Allen, Leavett, Miller, and Savage, 1947, p. 10-46, Goldthwait, 1949, p. 63-69, 1951, p. 24-34). A preliminary report on the clays of New Hampshire (Chapman, 1950, p. 1-27) and a report on the clays in the southeastern part of the State (Goldthwait, 1953, p. 1-15) have been published by the New Hampshire State Planning and Development Commission. A small amount of information concerning the Vermont kaolin deposits is available in the Vermont State Geologist's Reports (Jacobs, 1941, p. 9-17, Burt, 1929, p. 65-84). Available reports on clay deposits in other parts of New England are older and less reliable or provide incomplete information concerning the economic geology of clay deposits.

Information of this type includes the reports of Shaler, Woodworth, and Marbut (1896, p 957-1004), Loughlin (1905, p. 1-121), and Bastin (1906, p. 428-431).

6. Very little information is available concerning the mineralogy of clay and shale deposits of New England and New York, even though the mineral composition controls the physical properties. For example, kaolinite and illite clay minerals have low swelling and shrinkage properties, and these minerals make up the bulk of raw materials used in structural clay products. Montmorillonite, on the other hand, swells very much in the presence of water and only small percentages of this mineral can be tolerated in ceramic materials.

ECONOMICS OF THE CLAY INDUSTRY IN NEW ENGLAND AND NEW YORK

7. The commercial clays and shales in the New England-New York Region have been used in the manufacture of common or building brick 1/, some types of floor and wall tiles, pottery, and cement 2/. Such products have a low value as far as clay products are concerned, and have difficulty competing with products from other areas. Production and marketing of tile and brick are generally limited to an economical truck haul from the processing plant.

1/ The principal exception is the unique water-struck brick made by three companies, with plants located in Maine, New Hampshire, and Connecticut.

2/ The use of clay and shale in the manufacture of cement is an inherent part of that industry and is discussed in Section on Carbonate Rocks.

8. Brickyards in the region sell firebrick, sewer tile, and face brick produced elsewhere. These and other clay products were manufactured in the region at various times, using clay obtained from outside the region, but, invariably, the high cost of transportation and handling resulted in eventual failure of the enterprises. A large national producer of tile has a plant in the region, for, in this case, it is more economical to transport the necessary raw materials long distances and the fragile product a short distance. Face brick production in New York and New England is minor as compared with the production of common brick. Flower pots and pottery are made in the region and marketed throughout the United States.

9. The region does not contain substantial deposits of clay or shale suitable for products that can enter into interstate commerce; i.e., face brick, tile and terra cotta. The principal producing states for such wares are Ohio, Pennsylvania, Virginia, Illinois, and North Carolina. The cost of production in those states is such that a higher quality and better color face brick may be shipped into the New England-New York Region at a price competitive with that of locally produced common brick. This factor, combined with a low consumption of brick, and with the substitution of less costly cinder block and sand-lime brick for back-up work, has resulted in a gradual decline in the clay products industry of New England and New York, see Table 84k.

10. There is a $20 a thousand-brick-delivered price differential between the New England-New York region and the higher quality brick produced elsewhere. The use of brick produced in New England is limited to back-up work, yardstock for small-lot dealers, and sewer construction.

Table 84k - Shipments of unglazed common and face brick for selected years 1/
New England-New York Region

	U. S.	New York	N.Y. as a percent of U.S.	New England	N.E. as a percent of U.S.
1951					
Number of plants	612	23	3.8	33	5.4
Shipments 2/	6,307	477	7.5	170	2.7
Value 3/	27.07	24.77		32.02	
1950					
Number of plants	633	23	3.6	35	5.5
Shipments 2/	6,486	490	7.6	183	2.8
Value 3/	25.36	24.12		30.24	
1949					
Number of plants	639	24	3.8	36	5.6
Shipments 2/	5,252	439	8.4	151	2.9
Value 3/	24.60	23.44		29.87	
1926					
Number of plants	1,857	96	5.2	87	4.7
Shipments 2/	9,517	1,323	13.9	418	4.4
Value 3/	13.68	13.31		15.14	
1925					
Number of plants	1,939	105	5.4	85	4.4
Shipments 2/	9,572	1,072	11.2	363	3.8
Value 3/	13.45	12.28		15.26	
1923					
Number of plants	1,983	109	5.5	92	4.6
Shipments 2/	9,213	989	10.7	392	4.3
Value 3/	14.47	15.19		17.64	

1/ Calculated from data made available by the U. S. Department of Commerce, Bureau of the Census.
2/ Quantities in millions of standard brick.
3/ Value in dollars per thousand standard bricks. Values cannot be equitably compared because of the large percentage of face brick that comprises the figures for the United States, and the large percentage of low-valued common brick of New England and New York.

The quantity of brick shipped into New England is not known but reliable sources estimate that it is at least twice that produced within New England.

11. Brick produced in New York are sold almost entirely on the low-cost construction market in metropolitan New York; e.g. apartment houses and homes, and shopping centers.

12. The manufacture of clay products during the past twenty years in New England has been a marginal industry, primarily because of high fuel and high labor cost.

DESCRIPTIONS OF DEPOSITS-NEW YORK

13. Shale. - Shale suitable for use in making brick and other structural clay products can be found over most of the State. The only large areas that do not contain shale are the Adirondack Mountains, the southeastern highlands, and Long Island. The shale deposits that are consistently best suited and most widely used for ceramic raw material occur in rocks of Devonian age. Except for the southeastern highlands area, Devonian rocks cover approximately the half of the State that is south of a line between Albany and Buffalo. In the southern and southwestern part of the State shale suitable for structural clay products can be found within a few miles of most cities. Because of metamorphism accompanying folding, shales east of the Hudson River commonly are somewhat slatey, a condition which reduces their suitability for ceramic raw materials. At a few localities however, these shales are mixed with clay and used for making brick. Only a few of the shale deposits in the northern half of the State contain high quality raw materials for structural clay products. Probably the most promising shale deposits of this area are in a belt 7 to 9 miles wide along the southern shore of Lake Ontario.

14. Clay. - Clay deposits are widely distributed throughout the State of New York. The deposits range in age from Cretaceous to Recent, but most of them were deposited in lakes and estuaries during the retreat of the great ice sheets in the Pleistocene. Clay deposits in the Hudson River valley have been the source of raw material for most of the vast quantities of structural clay products used in the metropolitan area of New York City. Strata of Cretaceous age, including clays interbedded with sand, gravel and silt, occur on Staten Island and Long Island. Most of the clay and enclosing beds were deposited in estuaries and lagoons cut off from the sea. These deposits are exposed along the north shore of Long Island and on Staten Island. They contain material that is suitable for tile, face brick and pottery and some of the clay is semi-refractory.

15. The two principal areas of valuable clays in New York are the Hudson-Champlain valley and the lowlands around Lake Erie and Lake Ontario. Other smaller occurrences are found throughout the State. The clay deposits extend almost continuously along the Hudson River from the Canadian border to the vicinity of Haverstraw, 30 miles above the mouth of the river. Most of the deposits that are usable in ceramic products are located south of Glens Falls. Average thickness of the deposits is about 50 feet, but locally as much as 100 feet of clay is present. In most places the clay is covered by sand and gravel and lies on sand, glacial till, or bedrock. The top of the clay deposits gradually increases in altitude northward from 60 to 100 feet above sea level in Putnam and Westchester Counties to about 300 feet above sea level in Saratoga County.

16. The Hudson River valley clay is typically blue gray in the lower part and brown and yellow above. The brown and yellow colors originate in the oxidation and weathering of the blue-gray clay. The oxidized zone is commonly as much as 25 feet thick. The blue and the oxidized clay differ slightly in physical properties, but both types are used in making portland cement, brick, pottery, and other ceramic products. A soft, greasy type of clay that occurs in the vicinity of Albany is used as a slip clay for glazing electrical insulators and for bonding abrasive wheels. The alumina content of this clay is lower than in most of the other clays in the Hudson River valley.

17. Hudson River valley deposits are characterized by fine-grained, plastic, red-firing clays. Details of their unfired and fired properties are given by Brownell, Broughton, and Peterson (1951, p. 147-154, 237-349). Illite is the dominant clay mineral and some montmorillonite is present in most of the deposits. Common non-clay minerals are calcite, quartz, dolomite, feldspar, garnet, hornblende, and mica minerals. The range of chemical composition of Hudson River valley clay deposits is given in Table 841.

Table 841 - Composition range of Hudson River clays (Brownell, Broughton, and Peterson, 1951, p. 150)
New England-New York Region

SiO_2	50 - 60%
Al_2O_3	10 - 20%
Fe_2O_3	5 - 9%
CaO	4 - 8%
MgO	2 - 4%
Na_2O	1 - 2%
K_2O	1 - 3%
TiO_2	0.5 - 1.0%
Ign. loss	7 - 12%

18. Clay deposits, essentially continuous with those in the Hudson River valley, occur as far up the Mohawk Valley as Rome. This material is very similar in occurrence, properties, and composition to that of the Hudson Valley clay. Though some of the Mohawk Valley deposits are rich in calcium, most of them are good for making brick and tile and other structural clay products.

19. Many thin, glacial clay deposits occur in the lowland areas bordering Lake Erie and Lake Ontario and in the Saint Lawrence River valley as far north as Ogdensburg, Saint Lawrence County. The clay is similar to the Hudson Valley deposits and some of it is used in the same products. Glacial clay deposits have provided much of the raw material for brick, tile, and pottery at Buffalo, Rochester, and Syracuse, and have been worked in many other places.

20. Clay accumulated in small glacial lakes is scattered all over New York. The deposits are not uniform and most of them are very impure, but at a few localities they have been worked for pottery clay. Boulder clays of glacial origin are also widespread, but most of them are too rich in calcium carbonate to be useful for ceramic materials.

21. Kaolin. - High-alumina, kaolinitic clays occur in small quantities at Homer and Kreisherville. The deposits are too small, however, to be of much interest.

22. Fuller's earth. - A small amount of fuller's earth (a fine-grained earthy material now used for clarifying fats and oils) was produced near McConnellsville, Oneida County, from 1870 to 1905 (Newland and Hartnagel, 1939, p. 38-40). The gray to brown clay occurs in a

ridge extending from the Oneida Lake neighborhood eastward to the vicinity of Vienna, Oneida County. The clay occurs in layers 2 to 8 inches thick interbedded with sand layers of similar thickness. The thickness of the clay-sand sequence ranges from 15 to 20 feet (Ries, p. 849). Where this clay was mined it was necessary to remove the individual layers of clay one by one. The product was used for cleansing and fulling woolen goods in New York and neighboring states. The amount of such absorbent clay available in this area appears to be large (Peterson, 1950, p. 100); however, the exact quality of these deposits is not known and the fuller's earth in them is probably not suitable for clarifying oils (Ries, 1900, p. 850).

DESCRIPTIONS OF DEPOSITS-CONNECTICUT

23. Shale. - The shale deposits of Connecticut are limited to the Triassic rocks of the Connecticut and Pomeraug valleys in the central part of the State. The shale, which is banded and fissile, occurs in strata and lenses enclosed in coarser sedimentary rocks. The shale deposits of Connecticut are of two types: (1) red shale composed chiefly of grains of quartz and feldspar in an iron-rich clay matrix that is probably chiefly composed of illite, and (2) dark-gray, black, green, and blue shale made up of organic material mixed with illite and kaolinite type clays. Some of the shale is mixed with clay for making brick.

24. Clay. - The geology of the clay deposits of Connecticut has been discussed at some length by Loughlin (1905, p. 1-121) and more recently by Flint (1933, p. 968-976) and Lougee (1938, p. 24). The important

clay deposits in Connecticut are in the central part of the State, and may be divided into four geographical units. (1) The Hartford clay extends along both sides of the Connecticut River from Windsor Locks south to Weathersfield. It is overlain by a layer of aqueo-glacial sand in most places. The clay is commonly a dull blue-gray in color, displaying distinct clay-silt banding or varves. At places the deposit exceeds 100 feet in thickness, the upper 40 feet of which is often free of the silt-clay-calcium carbonate concretions which are found throughout the other Connecticut clays. (2) The Clayton clay is found near Clayton between the Hartford clay to the north and the Berlin clay to the south. It is red-brown, and its upper surface lies at a distinctly higher elevation than the clay beds to the north and south. (3) The Berlin clay extends from Middletown on the Connecticut River, west along the valley of the Mattabesset River to Berlin. It consists of red-brown clay that is as much as 80 feet thick in some places. (4) The Quinnipiac clay extends northward from New Haven along the valley of the Quinnipiac River at least as far north as Wallingford. It is a red-brown, varved clay that contains much silt. In places the deposits are as much as 150 feet thick. Except in the vicinity of New Haven, the clay is deeply covered by overburden. Near New Haven only the margin of the clay deposit can be worked because of marshy terrain.

25. According to Loughlin (1905, p. 62-66) most Connecticut clays are characterized by high iron content and extremely low fusing points. These characteristics limit the use of the clays to products in which a red color is desired, or at least, tolerated and refractory properties

are not necessary. Chemical analyses of samples of several Connecticut clay deposits are given in Table 84m.

Table 84m - Analyses of Connecticut clays (Loughlin 1905, p. 59)

	1	2	3	4	5
SiO_2	52.73	50.33	55.27	58.02	56.75
Al_2O_3*	22.25	27.06	20.52	17.93	17.54
Fe_2O_3	3.14	2.29	5.34	4.89	4.92
FeO	4.55	2.62	1.55	1.24	0.93
CaO	1.48	1.22	2.21	3.42	4.18
MgO	3.20	3.34	2.80	1.92	2.34
Na_2O	2.22	1.78	2.82	3.33	3.40
K_2O	4.28	4.40	3.43	3.06	3.16
Water loss at 107°C	1.12	1.42	1.37	0.99	1.24
Water loss on ignition ‡	4.91	5.24	5.06	5.36	6.28

* Includes possibly titanium dioxide and phosphorus pentoxide.
‡ Includes CO_2 and possibly chlorine and sulfur dioxide.
No. 1 from East Windsor Hill Brick Co., South Windsor, Connecticut.
No. 2 from Park Hill Co., West Hartford (Elmwood), Connecticut.
No. 3 from Tuttle Bros., Newfield, Connecticut.
No. 4 from Berlin Brick Co., Berlin, Connecticut.
No. 5 from I. L. Stiles and Son, North Haven, Connecticut.

26. Kaolin. - Kaolin has been noted at several localities in Connecticut, but the largest deposit is at West Cornwall in Litchfield County. This kaolin contains quartz sand and mica and is probably a residual product of weathering of a metamorphosed feldspathic quartzite. The deposit is at least 1,000 feet long, 400 feet wide, and 35 feet thick. The overburden consists of more than 80 feet of unconsolidated glacial and post-glacial material. In describing the clay Loughlin (1905, p. 58) stated:

> "The washed clay is very white, is rather granular to the feel, and apparently lacks plasticity; but several experi-

ments and practical tests have shown that, when mixed in a body, the mixture is equal in plasticity to that of bodies made from other kaolins. The material is also highly refractory, as its analysis indicates. Its fusing point is somewhat higher than 3,000 degrees F."

Table 84n - Analysis of washed kaolin (Loughlin, 1905, p. 57)

SiO_2	47.50
Al_2O_3	37.40
Fe_2O_3 and FeO	0.80
Cao	Trace
MgO	0.00
Na_2O and K_2O	1.10
H_2O	12.48

27. The clay at West Cornwall is probably the equal of other high-grade domestic and foreign clays as a filler in paper. It is also suitable for sanitary ware, wall tile, and semi-porcelain china. The quartz sand and the mica might be recovered as by-products during washing. The deposit was worked intermittently by borehole hydraulic methods for over 20 years prior to 1922. Other smaller deposits of kaolin at New Milford, Cornwall, and Kent were worked more than 100 years ago.

DESCRIPTIONS OF DEPOSITS-RHODE ISLAND

28. Shale. - Large quantities of shale occur in the Carboniferous rocks that underlie most of eastern Rhode Island. The Carboniferous rocks consist of conglomerates overlain by shaly and slatey beds intercalated with sandstones and conglomerates. Some of the shale might be usable for brick and lightweight aggregate, but high quality shale for structural clay products is not known in the State.

29. Clay. - Clay deposits in Rhode Island range in age from

Cretaceous to late Pleistocene. They have been described by Shaler, Woodworth, and Marbut (1896, p. 983, 986-988), and most of the following information is from their report. Cretaceous, Tertiary, and Pleistocene clays of commercial grade occur in small quantities on Block Island. The ceramic clays are on the south side of the island in steeply inclined beds, and much of the clay is under thick overburden.

30. Most of the mainland in the vicinity of Narragansett Bay is covered by thick sand deposits, but varved clay is exposed in a few places. Although the clay beds are as much as 60 feet thick only the uppermost few feet above high tide can be mined profitably. Most of the available clay was removed before 1896, and little clay seems to be left.

DESCRIPTIONS OF DEPOSITS-MASSACHUSETTS

31. Shale. - Shale deposits of possible ceramic value in Massachusetts occur in (1) the Connecticut River valley, (2) the vicinity of Boston, and (3) in the Narragansett structural basin along the Rhode Island boundary. The shale beds in the Connecticut River valley are in Triassic rocks. Most of these shale deposits are dark gray or red and many of them contain thin beds of limestone and carbonaceous material. The shale deposits near Boston are in a sequence of rocks about 3,500 feet thick. The rocks consist of gray, green, and red-banded shale interbedded with slate, argillite, and some sandstone. The shales in the Narragansett basin are interbedded with sandstone in rocks of Carboniferous age, and are somewhat slatey.

32. Very little is known about the usability of Massachusetts shales in ceramics, but it seems likely that much of the shale could be used in making brick and other structural clay products.

33. Clay. - The clay of eastern Massachusetts has been described in detail by Shaler, Woodworth, and Marbut (1896, p. 951-1004), and much of the following information is from their report. Horizontal or gently dipping beds of clay are best developed in the major stream valleys and topographic basins below an elevation of 100 feet, and the most important deposits are within 25 miles of Boston. The unoxidized clay is blue and finely laminated, and the thickness varies. At North Cambridge a well has penetrated 85 feet of clay above a bed of glacial till (Shaler and others, 1896, p. 990). These clays have been worked at many localities near Boston for brick and pottery.

34. Deposits of varved clays near Bridgewater and Taunton are used in making brick. Similar clays have been noted at several other localities in southeastern Massachusetts.

35. Thick deposits of Cretaceous and Tertiary clays underlie parts of Martha's Vineyard and Nantucket. The clays are interbedded with sand and lignite. The clay varies greatly in chemical composition and physical character, and beds of economic value are restricted to the western part of Martha's Vineyard. Some of this clay was mined and shipped to Boston for use in making brick, but operations were abandoned because of thick overburden and distance to markets. Lignitic clay from Gay Head, Martha's Vineyard has been used in making alum (Crosby, 1932, p. 4).

36. Pleistocene glacial lake clays occur in many of the river valleys of interior Massachusetts. Clay beds have been worked at Turner's Falls, Montague City, Springfield, West Brimfield, Williamansette, Amherst, Easthampton, Northampton, East Brookfield, Still River, South Fitchburg, and many other places. The principal clay deposits of

central and western Massachusetts are in the Connecticut River valley, and are very similar to the clays down stream in central Connecticut. In Massachusetts the deposits are as much as 180 feet thick (Emerson, 1917, p. 142). Smaller glacial clay deposits of the same general type as the Connecticut River valley clays have been worked in the valleys of the Nashua and Otter Rivers and at other localities in central and western Massachusetts. The clay deposits of this State are best suited for structural clay products and pottery, and reserves are believed to be adequate for local needs.

37. Kaolin. - Kaolin was reported by Ries (1903, p. 149-150) at two localities in Massachusetts. Material from a deposit of white clay at Blanford, Hampden County, formerly was mixed with New Jersey clay and used in white brick and terra cotta. At one place the deposit was nearly 1,000 feet wide. Apparently the deposit is residual clay formed by the weathering of a pegmatite in a mica schist. A large deposit of high-alumina clay 4 miles south of Clayton was formerly used for terra cotta; it probably was formed by pre-glacial weathering of feldspathic quartzite or gneiss.

38. Small kaolin deposits, apparently of doubtful value, have been reported at Kent's Island and elsewhere in Massachusetts.

39. Fuller's earth. - A deposit of glacial silt 1 mile northeast of Lancaster, Massachusetts (Alden, 1910, p. 402-404) was used as fuller's earth in fulling cloth and as a ceramic binder in grinding wheels from some time before 1910 until at least 1928 (Crosby, 1932, p. 6). Pleistocene varved clay from Northampton, Massachusetts was used early in the

19th century for decolorizing dyed cloth, and a similar deposit near Stoughton, Massachusetts was once worked (Ladoo and Myers, 1951, p. 235). The fuller's earth deposits in Massachusetts probably do not contain material suitable for clarifying oils.

DESCRIPTIONS OF DEPOSITS-NEW HAMPSHIRE

40. Clay. - After the retreat of the last ice sheet, southeastern New Hampshire was covered by the sea as far inland as Epping, Lee, Barrington, and Rochester. In this area a fairly uniform layer of marine clay essentially continuous with that in Maine and eastern Massachusetts was deposited upon glacial sands and gravels. The clay has been used for brickmaking at Dover Point, Rochester, Exeter, Epping, Gonic, and other localities. As the ice sheet slowly receded, varved clays were deposited in long, narrow lakes that occupied the valleys of the Connecticut and Merrimac Rivers and their tributaries. In most places these clays are covered by sand and gravel deposits that range from a few inches to more than 10 feet in thickness. The clay has fair to good strength in its unfired condition, and when fired shows greater strength than required for most structural clay products. The color of the fired products from New Hampshire clays varies from light red to medium-dark red. Reserves of clay in the State are more than adequate to meet local needs for structural clay products, and bloating characteristics of many of the clays suggest that they would be good for making lightweight aggregate.

DESCRIPTIONS OF DEPOSITS-VERMONT

41. Clay. - Clay deposits in Vermont are located in the lowlands around Lake Champlain and along the valleys of the Missisquoi, Lamoille,

Winooski, Otter, and Connecticut Rivers. Most of the clay is suitable for brick and other structural clay products, and deposits have been worked at many localities. Most of the products made from the clay range from light red to medium-dark red and have adequate strength for use in buildings.

42. Kaolin. - The most extensive kaolin deposits in the New England-New York Region are in Vermont. These deposits extend in a discontinuous belt along the west side of the Green Mountains. Iron and manganese minerals are associated with the clay. Production of kaolin has been intermittent, and some of the deposits have been worked for iron and manganese ores as well as for clay. Some of the kaolin deposits cover more than 20 acres and exceed 150 feet in thickness. Jacobs (1941, p. 14) stated:

> "In 1936 * * kaolin producers * * jointly undertook a study of the deposits and, by core drilling, proved the existence of some three million tons of crude clay, in addition to the three million tons already revealed by former drilling. These six million tons constitute the largest deposit of kaolin north of the Carolinas."

The geology and origin of the kaolin deposits have been well described by Burt (1929, p. 65-84), who concluded: (1) The kaolin deposits were formed at or near their present location by weathering of pre-Cambrian gneissic rocks and to a lesser extent the feldspathic and argillaceous phases of quartzitic rocks. (2) The sand and the iron-manganese ores in the kaolinite represent different members of the parent rock. (3) The kaolin was formed in the Tertiary period and was protected from later glacial erosion by its topographic position. (4) Known deposits of kaolin do not form a continuous belt, but their continuity is more nearly complete than surface

conditions indicate. Burt (1931, p. 14), in a report on ocher deposits in Vermont, recognized that, "Where ocher and kaolin beds are extensive, and near the surface, swampy conditions exist. In consequence of this fact swamps, especially if close to the base of the Green Mountains, usually indicate kaolin and ocher beds."

43. The kaolin has been used for paper filler, pottery, sagger clay, building brick, and refractory brick. The clay fuses between pyrometric cones 30 and 33, which indicates suitability for high heat duty. Because of its color variability, much of the kaolin must be bleached before it can be used as a paper filler. Very fine-grained graphite is present in many of the deposits, and in the absence of an economic method to remove it, the value of the deposits is seriously reduced. Some chemical and physical properties of some of the kaolins are indicated in Tables 84o, 84p, and 84q.

Table 84o - Representative chemical analyses of Vermont kaolin

	1 Crude white	2 Washed kaolin	3 Same before washing	4 Crude white	5 Crude buff	6 Crude red	7 Crude mixed
SiO_2	58.00	48.90	58.00	56.98	57.10	53.96	58.96
Al_2O_3	29.60	34.88	26.87	29.52	28.17	27.16	26.03
Fe_2O_3	0.81	1.18	1.46	0.76	1.19	4.93	1.72
TiO_2	0.03	1.15	1.40	1.67	1.35	1.23	1.39
CaO	0.35	0.30	.42	0.10	0.09	0.09	1.12
MgO	0.97	0.86	.94	0.77	0.67	0.96	0.86
K_2O	1.05*	1.29	2.16	1.41	1.10	2.63	1.64
Loss on ignition	9.20	11.47	8.89	9.25	9.43	8.26	8.46

* Includes Na_2O.
1. Burt, 1929, p. 77.
2-3 Jacobs, 1935, p. 35.
4-7 Jacobs, 1941, p. 15.

Table 84p - Mineralogical analyses of Vermont kaolin
(Burt 1929, p. 79)

	1	2
Quartz	10.3%	7.0%
Clay minerals (kaolinite, etc.)	65.6	88.0
Feldspar	21.3	1.5
Accessories	3.2	3.5

1. Vermont Kaolin Co., northeast of Bennington.
2. Green Mountain Kaolin Corp., southeast of Bennington.

Table 84q - Ceramic characteristics of Vermont kaolin
Data by American Refractories Institute (Jacobs, 1941, p. 15)

	Washed kaolin	Crude kaolin
Pyrometric cone equivalent	32-33	30-31
Water of plasticity	40.5%	30.2%
Drying shrinkage	20.2%	15.8%
Bulk specific gravity	1.47	1.64
Linear drying shrinkage	7.3%	5.6%

DESCRIPTIONS OF DEPOSITS-MAINE

44. Clay. - Clay deposits cover most of the Maine coastal area and extend up the major stream valleys as much as 80 miles. The elevation of the top of the clay deposits ranges from sea level to about 400 feet. Most of the clay was deposited in salt water, but the portions of the deposits that are farthest inland probably contain clay of glacial and fresh water origin. The clays average about 15 feet thick, but in places deposits are as much as 50 feet thick. Where the entire thickness of the clay is exposed, the upper part which has been oxidized is brown; the lower unoxidized part of the clay is blue-gray. The deposits most favorably situated for mining are in the southwestern part of the State, where there is very little overburden; they have been worked extensively for brick and tile. Much of the clay in the

south-central part of the State is covered by considerable thickness of sand and gravel which increase mining costs. In Knox County clay material was formerly used with limestone in the manufacture of cement. Table 84r gives analyses of a few typical Maine clays.

Table 84r - Chemical analyses of Maine clay

	1	2	3	4
SiO_2	62.80	62.33	61.59	60.62
TiO_2	0.87	0.79	-	0.96
Al_2O_3	17.36	17.70	19.10	17.91
Fe_2O_3	4.40	5.19	) 7.53	6.25
FeO	2.00	1.72	)	-
CaO	0.88	1.00	1.68	0.93
MgO	1.58	1.53	1.87	2.53
Na_2O	1.48	2.38	-	) 5.07
K_2O	3.05	2.41	-	)
H_2O (at 107 degrees C)	1.31	1.11	)	-
H_2O (on ignition)	4.39	3.81	) 5.51	4.77
CO_2	None	None	)	-

No. 1. Thomaston, Maine (Bastin, 1908, p. 13).
No. 2. Hayden Point, South Thomaston, Maine (Bastin, 1908, p. 13).
No. 3. Rockland-Rockport Lime Co., (Bastin, 1908, p. 13).
No. 4. Illite clay from Cumberland County (Conley, 1948, p. 14).

45. The possibility of leaching iron oxide and bleaching of organic matter cheaply so that the clay could be used as a paper filler has been considered (Fuller, 1949, p. 70-89). Though small-scale experiments have been conducted in the laboratory, commercial-scale trials of a process have not been attempted.

TECHNOLOGY 3/

46. The clays common to the New England-New York Region are principally used for heavy-clay products. Since the end product has a low

3/ Ries, H., Clay: Industrial Minerals and Rocks, Seely Mudd Series, A.I.M.E., 1949, pp. 231-233.

value, most of the clays could not stand the cost of beneficiation beyond thorough mixing, perhaps some blending, and crushing and screening. Table 84s shows the quantity of clay used in the region.

MINING

47. Most clay deposits are worked as open pits or banks. It is seldom necessary in the New England-New York Region to practice selective mining; e.g., mining a two-foot seam from a 20-foot thick bed of clay. Economical mining requires that the cost of removing the overburden be kept at a minimum.

48. Direct bank loading is the most common method of mining. Power shovels, draglines, scrapers, and planers are the principal means of loading into trucks, conveyors, or rail cars. Some operators have successfully combined transportation and beneficiation by setting a blunger at the pit and pumping the clay to the plant where it receives final treatment.

49. The brick making season in most of New England is limited by the weather, to the months from May through September or October, because the raw brick must air-dry before the temperature goes below 28°.

50. In New England the soft mud process of making brick is the dominant method used even though much hand labor is required. Some of the more modern plants in the area have costs just as great, despite the advantage of quicker drying, year-round operations, and permanent kilns, because of increased fuel demand.

51. One company in New England has gone into the manufacture of brick made from shale. The final product is competitive in quality

Table 84s - Miscellaneous clay and shale sold or used in New York and New England, in 1947, 1949, and 1951, in short tons 1

	1947	1949	1951
New York	1,174,134	1,285,027	1,559,472
Connecticut	184,751	289,090	275,900
Maine	20,865	27,918	21,885
Massachusetts	124,717	150,530	143,023
New Hampshire	28,605	26,392	28,501
Totals	1,533,072 2/	1,778,957 2/	2,028,781 2/

1/ Minerals Yearbook - Clay: Bureau of Mines Annual, 1947, p. 253; 1949, p. 256.

2/ Includes use in manufacture of portland cement.

with brick produced outside the region, and in price with the lower quality brick produced in New York and New England.

52. Two companies, out of the 23 in the Hudson Valley district of New York, produce brick made from a shale-clay mixture. At the present time, the shale content is approximately 30 percent. The shale is hard, almost slatey, and requires considerable fine grinding and pugging to make it sufficiently plastic. The shale along the Hudson River has a high carbon content which poses a problem of oxidation. Along the Hudson River Valley, it has not been practical to produce brick other than by the soft-mud process.

RESERVES

53. The cost of appraising deposits of clay and shale is relatively high. In addition to measuring the size of deposits and blocking out the tonnages that can be mined, expensive ceramic tests must be made in order to evaluate the material for use in one or more ceramic products. These costs are the chief reason why very little information is available about the size and quality of reserves of possible high-grade clay material. In New England and New York reserves of clay and shale suitable for use in structural clay products, pottery, and cement are essentially inexhaustible. Rhode Island is the only state in the region that does not have adequate supplies of these resources. Very large reserves of clay and shale are conveniently situated to provide the raw material necessary to supply Metropolitan New York City and other centers of population with structural clay products and cement. Clay material suitable for making light colored face brick is not abundant in New England and New York.

54. The reserves of clay within the region that can be considered for use as paper filler, rubber filler, and high heat duty refractory products are chiefly in Vermont kaolin deposits. According to Jacobs (1941, p. 14) six million tons of kaolin have been proved in Vermont. The total tonnage of kaolinite in Vermont may be more than twice the figure stated by Jacobs.

WORK THAT SHOULD BE DONE

55. Complete investigation and evaluation of all the clay and shale deposits in New England and New York are not feasible because of the large and scattered areas covered by the deposits, the relatively low value of the commodity, and the high costs of ceramic and other types of laboratory tests required to appraise a deposit.

56. Important contributions to our knowledge of clay and shale deposits of the region can be made by detailed investigations in selected areas. Studies of this type should include geologic mapping, mineralogic investigations, and laboratory tests to determine the value of the clays for ceramic and other uses. Geologic maps of areas containing significant clay deposits are particularly important because they provide information about the location and extent of deposits as well as some indication of the amount of material that can be mined. Mineralogical data are important when considering the potential uses of clays.

SELECTED BIBLIOGRAPHY ON CLAY AND SHALE

Alden, W. C., 1910, Fuller's earth and brick clays near Clinton, Massachusetts: U. S. Geological Survey Bull., 430, p. 402-404.

Bastin, E. S., 1906, Clays of the Penobscot Bay region, Maine: U. S. Geological Survey Bull. 285, p. 428-431.

_ _ _ _ _ _ _, 1908, Description of the Rockland quadrangle, Maine: U. S. Geological Atlas, folio 158, p. 1-15.

Brownell, W. E., Broughton, J. G., and Peterson, R. B., 1951, The clays and shales of New York State: New York State Department of Commerce, p. 1-349.

Burt, F. A., 1929, Origin of the Bennington kaolins: Vermont State Geologist Report, 1927-1928, p. 65-84.

_ _ _ _ _ _ _, 1931, The geology of Vermont ocher deposits: Vermont State Geologist Report, 1929-1930, p. 107-136.

Chapman, D. H., 1950, Clays of New Hampshire: Min. Res. Survey, pt. 12, New Hampshire State Planning and Devel. Comm. p. 1-27.

Conley, J. E., Wilson, H., Klinefelter, T. A., and others, 1948, Production of lightweight concrete aggregates from clays, shales, slates, and other materials: U. S. Bur. Mines Rept. Inv. 4401, p. 1-121.

Crosby, I. B., 1932, Report on the mineral resources of Massachusetts, a survey of the literature: Massachusetts Development and Industrial Commission, p. 35.

Emerson, B. K., 1917, Geology of Massachusetts and Rhode Island: U. S. Geological Survey Bull. 597, p. 1-289.

Flint, R. F., 1933, Late Pleistocene sequence in the Connecticut valley: Geol. Soc. America Bull., v. 44, p. 965-988.

Fuller, Earl, 1949, Improving the quality of Maine clays: Maine State Geologist Report, 1947-1948, p. 70-89.

Goldthwait, Lawrence, 1949, Clay survey, 1948: Maine State Geologist Rept. 1947-1948, p. 63-69.

_ _ _ _ _ _ _, 1951, The glacial-marine clays of the Portland-Sebago Lake region, Maine: Maine State Geologist Rept. 1949-1950, p. 24-34.

_ _ _ _ _ _ _, 1953, Clays of southeastern New Hampshire: New Hampshire State Planning and Development Commission. Mineral Resources Survey, pt. 15.

Grim, R. E., 1953, Clay minerals: McGraw-Hill Book Co., Inc., New York, p. 1-384.

Jacobs, E. C., 1935, Report of the State Geologist on the mineral industries of Vermont, 1933-1934, p. 1-36.

_ _ _ _ _ _ _, 1941, Report of the State Geologist on the mineral industries of Vermont, 1939-1940, p. 1-67.

Ladoo, Raymond, and Myers, W. M., 1951, Clays and clay products, in nonmetallic minerals: McGraw-Hill, 1951, 2d ed., p. 1-605.

Lougee, R. J., 1938, Physiography of the Quinnipiac-Farmington lowland in Connecticut: Colby Coll. Monograph 7, p. 1-64.

Loughlin, G. F., 1905, The clay and clay industries of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 4, p. 1-121.

Newland, D. H., and Hartnagel, C. A., 1939, Mining and quarry industry of New York, 1934-1936: New York State Museum Bull. 319, p. 38-40.

Perkins, E. H., 1930, The post-Pleistocene clays of Maine: Maine State Geologist 1st Ann. Rept., p. 75-81.

Peterson, R. B., 1950, Clay products, in the mineral industries of New York State: New York Dept. of Commerce, 96 pages.

Ries, Heinrich, 1900, Clays of New York, their properties and uses: New York State Museum Bull. 35.

_ _ _ _ _ _ _, 1903, The clays of the United States east of the Mississippi River: U. S. Geol. Survey Prof. Paper 11.

_ _ _ _ _ _ _, 1949, Clay: Industrial Minerals and Rocks, Am. Inst. Min. Met. Eng., pp. 231-233.

Shaler, N. S., Woodworth, J. B., and Marbut, C. F., 1896, The glacial brick clays of Rhode Island and southeastern Massachusetts: U. S. Geol. Survey, Ann. Rept. 17, pt. 1, p. 951-1004.

Trefethen, J. M., Allen, H., Leavitt, L., Miller, R. N., and Savage, C., 1947, Preliminary report on Maine clays: Maine State Geologist Rept. 1945-1946, p. 10-46.

U. S. Bureau of Mines, Minerals Yearbooks.

SECTION XXXIg - PEGMATITES IN THE NEW ENGLAND-NEW YORK REGION

INTRODUCTION AND SUMMARY

1. This section presents the principal features of the geology, mining, technology, and economics of the pegmatite industry and an evaluation of its future possibilities in the region.

2. Pegmatite (acidic) is a type of mineral deposit similar to granite, composed principally of feldspar, quartz, and mica and lesser quantities of numerous rarer minerals. The major distinction between pegmatite and granite is the larger size of the component minerals in pegmatites.

3. In general, it is the large, coarse-grained deposits which yield minable concentrations of marketable minerals including feldspar, quartz, beryl, mica, columbium-tantalum minerals, lithium minerals, and others. Pegmatites are the chief commercial source of most of these minerals.

4. Many pegmatites occur in the New England-New York Region, being reported in all of the states in New England and New York, except Rhode Island. The deposits of economic importance are in Connecticut, Maine, and New Hampshire.

5. The pegmatite minerals industry is expanding, particularly those companies consuming beryllium, lithium, mica, and ceramic-grade feldspar. Consequently, the pegmatite reserves of New England and New York are of commercial significance.

6. Known reserves of the marketable minerals are gradually being diminished. The lack of adequate exploration and development of pegmatites

in the region has seriously handicapped the mineral industry. Geologic information on individual deposits is generally inadequate. Most of the operated deposits have been mined intermittently, usually for only one mineral at a time, unless concentrations of other marketable minerals were encountered in the course of mining. In addition, the remote location of large high-grade deposits and the low unit value of the chief mineral products are among the important factors retarding the rapid growth of the various pegmatite mineral industries.

7. As many mineral products of pegmatites are being required in increasing quantities, it is evident that a new approach to the industry is necessary in order to solve its numerous complex economic problems. Since pegmatites are composed chiefly of low unit valued minerals, it is necessary to develop economic methods for beneficiating pegmatitic material for the recovery of the rare minerals of high unit value. Research on beneficiation methods is being conducted at several U. S. Bureau of Mines Experiment Stations. When a process is developed for treating the pegmatite minerals on a commercial basis, a concentrating plant in a pegmatite district would effectively stimulate the industry in that particular area and the region.

8. Commercial methods of beneficiating low grade ore are needed to sustain a profitable mining industry rather than a series of risky mining ventures.

9. During 1935-1951, the United States imported more than 90 percent of its total annual requirements. The strategic value of beryllium points up the need for detailed studies of domestic pegmatites and exploration for

additional domestic beryllium ore reserves. Such studies would also provide valuable data on the distribution and reserves of all important pegmatite minerals in the area. Intensive research and development investigations on improving the technology of beneficiating low-grade ore could be initiated and continued advantageously with the active participation of industry in cooperation with government, both in field and laboratory studies.

BRIEF HISTORY OF PEGMATITE MINING IN THE NEW ENGLAND-NEW YORK REGION

10. Pegmatite mining began in New England in 1803 when production of mica was recorded from the Rugglos mine, Grafton County, New Hampshire. Commercial production of feldspar was reported in Connecticut in 1825, Maine in 1852, New York in 1910, and New Hampshire in 1914.

11. New Hampshire ranked first in sheet mica output in the United States until shortly after the Civil War when production in North Carolina furnished large supplies of high-grade mica at much lower prices. In 1880-1890, production declined again as a result of foreign competition when the federal government permitted duty-free imports of sheet mica.

12. New York was a leading feldspar producer in 1910-1924, furnishing about 15 percent of the domestic production for that period. However, the state has declined to a position of minor importance in the production of pegmatite minerals.

13. During World War II, the supply of sheet mica was one of the chief mineral procurement problems of the United States. Despite high subsidy prices for mica of strategic quality, a comparatively small part of the

requirements were obtained from domestic sources.

14. Beryllium, due to its increased use as an alloying element and in the field of atomic energy has assumed strategic importance. In 1942-1944, a shortage of beryllium ore in the United States created a critical supply problem similar to that of mica. Special measures were undertaken including importing the ores (sheet mica, beryl, columbite-tantalite and others) into this country from foreign sources by military air transports. Pegmatite mining in the United States expanded rapidly in 1944 with the reopening of old mines and the discovery of new deposits by intensive prospecting for beryl and mica.

15. During the World War II years, the Colonial Mica Corporation (Branch office - Newport, N. H.) was designated the official agent of the United States Government-sponsored Metals Reserve Company for the purchase of domestic mica. The Colonial Mica Corporation stimulated mica production by purchasing mica at subsidy prices, by providing mining equipment at nominal rental fees, and by loans and technical advice regarding the mining and preparation of mica.

16. Strategic mica was recovered from most of the 125 pegmatite deposits in New Hampshire, Maine, and Connecticut which were mined during 1942-1944 1/. In addition to mica, many of these pegmatites yielded feldspar as the chief product with a little beryl, columbite, tantalite, lithium minerals, and quartz as byproducts. Pegmatite mining declined rapidly in New England in 1945 when demand and prices decreased, causing unstable market conditions in contrast to rising domestic wages and foreign competi-

---

1/ Olson, J. C., Feldspar and Associated Pegmatite Minerals in New Hampshire: State Planning and Development Commission, 1950, p. 9.

tion. During 1942-1944 and 1946-1951, New Hampshire was one of the important producers of mica, beryl, and feldspar in the United States. Maine also supplied significant quantities of these minerals during these periods.

DESCRIPTION AND USES OF PRINCIPAL MINERALS 2/

17. More than 50 minerals have been identified in pegmatites and as many as 30 varieties from a single deposit. Most of these have no commercial use at present. Some pegmatites contain minerals of gem quality and many contain interesting mineralogical specimens.

18. Granitic pegmatites are the chief source of feldspar, mica (sheet and scrap), beryl, and columbium-tantalum and lithium minerals. In addition, the deposits yield a significant tonnage of quartz.

19. Feldspar. - Feldspar is a group name for two series of anhydrous aluminum silicate minerals - potassium feldspars and the sodium-calcium feldspars.

2/ Tyler, Paul M., Economic Importance of Pegmatites: Bureau of Mines Inf. Circ. 7550, 1950, pp. 1-57.

Table 84t. - Classification of commercial feldspar 3/

Feldspar	Formula	Theoretical composition, percent						
		K_2O	Na_2O	CaO	Al_2O_3	SiO_2	Specific gravity	Hardness
Orthoclase	$K_2O:Al_2O_3:6SiO_2$	16.9	-	-	18.4	64.7	2.44-2.62	6
Microcline	$K_2O:Al_2O_3:6SiO_2$	16.9	-	-	18.4	64.7	2.54-2.57	6-6.5
Albite	$Na_2O:Al_2O_3:6SiO_2$	-	11.8	-	19.4	68.8	2.5-2.7	6-6.5
Anorthite	$CaO:Al_2O_3:2SiO$	-	-	20.1	36.62	43.28	2.6-2.8	6-6.5

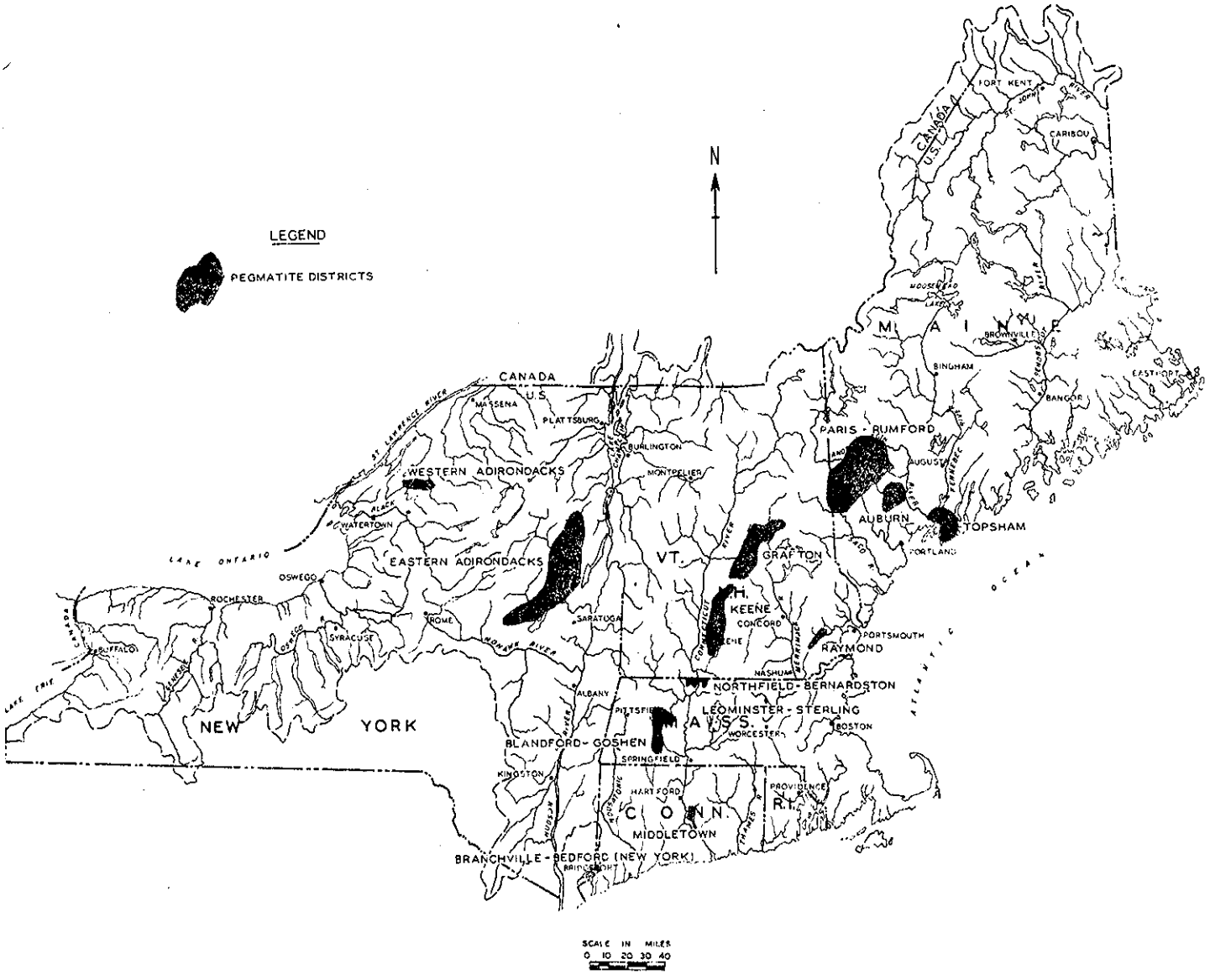
Table 84u. - Typical analyses of commercial feldspars in New England and New York 4/

No.	Ignition loss	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Total
1	-	64.67	19.18	0.20	-	0.99	Trace	12.76	2.54	100.34
2	-	74.34	14.45	0.14	-	Trace	Trace	8.63	2.00	99.56
3	-	67.81	18.55	0.08	-	0.21	0.07	9.32	4.27	100.31
4	0.25	65.24	19.74	0.12	-	0.00	0.00	11.84	3.04	100.23
5	0.40	73.88	15.73	0.36	0.01	0.86	0.36	0.48	7.97	100.05
6	(0.51	70.00	16.33	0.09	-	0.30	-	7.78	4.77	99.78)
7	(0.50	68.10	18.70	0.05	-	0.20	-	7.30	5.40	100.25)

1. Potash feldspar, New Castle, Lincoln County, Maine
2. Feldspar, Cathance, Sagadahoc County, Maine
3. Feldspar, Auburn, Androscoggin County, Maine
4. Feldspar, Portland, Middlesex County, Connecticut
5. Feldspar, Bedford, Westchester County, New York
6. Feldspar, Colony Mine, Alstead, Cheshire County, New Hampshire
7. Feldspar, Yuhas Mine, Alstead, Cheshire County, New Hampshire

3/ Ladoo, Raymond B., and Myers, W. M., Nonmetallic Minerals, Feldspar: McGraw-Hill, 1951, p. 205.

4/ Ladoo, Raymond B., and Myers, W. M., Nonmetallic Minerals, Feldspar: McGraw-Hill, 1951, p. 206.



SPECIAL SUBJECTS - REGIONAL

PEGMATITE DISTRICTS OF NEW ENGLAND AND NEW YORK

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

USBM BOSTON, JAN. 1955

PLATE 62 G
CHAPTER XXXIX

20. The bulk of feldspar production is consumed as a flux, bond, and glaze in the glass, whiteware pottery, and enamel industries. It is also used in roofing and concrete facing granules, poultry grit, and as a bonding material in abrasives.

21. Mica 5/. - Mica is the group name for nine minerals composed principally of the silicates of potassium, aluminum, and magnesium. Less common mica species contain lithium, vanadium, and chromium as essential chemical constituents. The hardness of mica ranges from 2 to 4.

22. The commercially important pegmatite minerals of the mica group are muscovite and lepidolite. Muscovite (white, ruby, rum, green, and potash) may be white, red, brown or green. Lepidolite (lithium or pink mica) may be yellow to deep purple.

23. Several of the mica minerals are of commercial significance. Muscovite mica is characterized by a well-developed basal cleavage, sometimes appearing as layered flat six-sided crystals, commonly occurring in "books" which can be split easily into tough, elastic, transparent thin sheets of films 0.001 inches thick. These sheets are highly resistant to heat, water, acid, and electricity and their properties remain virtually constant at extreme temperatures.

24. Sheet muscovite is of strategic importance in the electronic and electrical industries. The higher qualities of mica are essential for capacitors in radar, radio, telephone, miscellaneous communications, and depth sounding and submarine detection equipment. High quality muscovite is required in magnetos for airplanes and it is also employed in radio

---

5/ Ladoo, Raymond B., and Myers, W. M., Nonmetallic Minerals, Mica: McGraw-Hill, 1951, pp. 314-333.

tubes, television equipment, and a number of miscellaneous items. Large quantities of lower quality sheet muscovite or "electric mica", in the form of sheet or plate, are used as insulation material in electric appliances such as flat irons and toasters.

25. Muscovite and phlogopite (a magnesium-bearing mica not found in pegmatites) are used in splittings for making built-up mica insulation products such as mica cloth, tape, and plate.

26. Scrap muscovite mica is the principal source of ground mica. Although it is of relatively low unit value compared with strategic quality sheet muscovite, scrap mica comprises the major percentage of the domestic mica production both in tonnage and value. Scrap mica is a term employed for mica material obtained as a byproduct from the preparation of sheet mica, clay milling, factory trimmings and scalings from sheeting, the remains after punching, the waste from splittings, rejects of subspecification products, and from other mining and milling operations.

27. Wet-ground mica is used as an ingredient in paint, coating wallpaper, and as a filler in rubber goods. Dry-ground mica is consumed in large quantities for coating roofing materials to prevent shingles and rolls from sticking together and to render some fabrics waterproof. Both forms of ground mica are employed in a wide variety of other uses such as a surfacing material, decoration, lubricant, and in oil-well drilling mud.

28. Beryl. - Beryl is beryllium-aluminum silicate with a hardness of 7.5-8.0 and specific gravity of 2.63-2.80. Beryl is the chief commercial ore of berylium. The mineral beryl contains only 5 percent beryllium metal, depending upon the extent of partial replacement and impurities.

29. Beryllium is consumed in the production of beryllium-copper alloy for use in the electrical and electronic industries. It is also alloyed with aluminum, magnesium, nickel, and iron. The metal is an important element in atomic energy applications. Beryllium oxide is used in the manufacture of specialized ceramic and refractory materials. Beryllium nitrate, beryllium chloride, and sodium beryllium fluoride are also used in limited quantity.

30. Columbium-Tantalum Minerals. - Columbite and tantalite, the principal columbium and tantalum minerals of commercial interest, are minerals in an isomorphous series; all gradations between pure columbite, $(Fe,Mn)Cb_2O_5$, and pure tantalite, $(Fe,Mn)Ta_2O_5$, occur in nature. Microlite, $Ca_2Ta_2O_7$, and simpsonite, $Al_2Ta_2O_8$, are rare minerals of other tantalum ores, whereas samarskite, koppite, and pyrochlore are rare minerals of other columbium ores.

31. The principal ore mineral of tantalum is designated tantalite if the percentage of tantalum pentoxide exceeds that of columbium pentoxide; if the converse is true, the ore is designated as columbite.

32. Columbite is usually black, has a hardness of 6 and a specific gravity of 5-6. Tantalite is generally dark brown to black, has a hardness of 6, and a specific gravity of 7-8.

33. Columbium and tantalum metals, in pure form, are similar in physical properties and often interchangeable in certain applications. They are malleable, ductile, and resistant to corrosion.

34. Columbium is used primarily as an alloying agent in high temperature ferroalloys for use in jet propulsion engines and gas turbines.

35. Tantalum is used chiefly in the form of the pure metal in the construction of corrosion-resistant chemical equipment, and in radio and electronic parts. It is also employed in surgery for skull plates, wires, and sutures, spinal photographic equipment; tantalum compounds are used as catalysts in the manufacture of synthetic rubber and tantalum carbide is used in cutting tools.

36. Quartz. - Quartz, a common pegmatite mineral, is composed of silicon dioxide and few impurities. It has a hardness of 7 and a specific gravity of 2.65.

37. Pegmatitic quartz is used in crushed form for metallurgical flux, silica flour (ceramics, paints, filler materials), coated abrasive materials, abrasive sand, and as a filling and surfacing material. Limited quantities of pure quartz are used in the manufacture of high grade glass and in refractory materials.

38. Lithium Minerals. - The principal commercial lithium minerals are spodumeme, lepidolite, and amblygonite. Table 84v shows the properties of all the commercial lithium minerals.

Table 84v. - Classification of Commercial Lithium Minerals

Mineral	Chemical Composition	Lithium Oxide (Li_2O), percent: Theoretical Content	Lithium Oxide (Li_2O), percent: Range in marketed ore	Hardness	Specific Gravity	Color
Spodumeme	$LiAlSi_2O_6$	8.03	4-8	6.5-7	3.17	White, pale green, yellow and pinl
Lepidolite	$LiKAl_2F_2Si_3O_9$	6.43	3-5	2-4	2.8-2.9	Pink, lilac, purple, yellow, and re
Amblygonite	$LiAlFPO_4$	10.1	8-9	6	2.8-3.1	White
Petalite	$LiAlSi_4O_{10}$	4.89	2-4	6	2.4	White, gray

39. Lithium is a multi-purpose raw material which is used either in its mineral form, as a metal, or in the form of various chemical compounds. The long list of applications for lithium include lubricants, ceramics, glass, metallurgy, air conditioning, welding or brazing, medicinals, dry-cells, and alkaline storage batteries.

40. Pollucite. - Pollucite is the chief ore mineral of cesium metal. Pollucite is a hydrous silicate of aluminum and cesium. The theoretical cesium oxide content in the mineral is 42.5 percent, but it averages only 25 percent. Pollucite is clear and colorless, resembling quartz in appearance but has traces of cleavage. It has a hardness of 6.5 and specific gravity of 2.90.

41. The major industrial use of the metal is in the field of electronics and in radio tubes. Cesium compounds are also employed as catalytic agents.

Table 84w - Salient statistics of pegmatite minerals industry in the United States, 1935-1951 6/

Mineral	Production, Mine Shipments								Imports for Consumption	
	1935-1939		1940-1944		1945-1949		1951		1951	
	Short tons	Average value per ton	Short tons	Average value per ton	Short tons	Average value per ton	Short tons	Average value per ton	Short tons	Average value per ton
Feldspar	253,527	$ 4.50	354,228	$ 4.40	487,401	$ 4.87	448,492	$ 6.28	19,183	$ 7.64
Mica 1/	14,148	166.48	22,014	89.86	35,701	26.98	72,168	28.33	12,438	1,709.89
Lithium Minerals	1,327	36.38	6,544	36.91	3,334	77.82	12,897	69.47	6,500	62.32
Beryl	50	30.00	258	105.23	146	255.90	484	333.36	4,316	316.70
Columbium-Tantalum Minerals	6	1,740.00	3	3,581.00	2	3,112.50	2/	3,300.00	888	1,748.62
Tin	2	1,336.30	28	1,005.70	17	1,938.70	-	-	64,822	2,422.31
Total	269,060	13.23	383,075	10.04	526,601	6.98	534,041	10.54	108,147	177.94

1/ Sold or used.
2/ Less than one ton.
6/ Minerals Yearbook: Bureau of Mines, 1930-1951.

ECONOMICS

42. Mineral economics. - Complete production data of pegmatite minerals in the New England States and New York are not available for this report because the statistics are not published separately by the Bureau of Mines or various state agencies, in order to avoid disclosure of individual company operations. Table 84x, Production of Pegmatite Minerals in New England and New York, 1925-1951, is based upon existing published data and estimates.

43. Table 84x shows that the New England-New York Region produced about 14 percent of the domestic output of feldspar, 7 percent of the mica (sheet and scrap), and 26 percent of the beryl, in 1925-1951. Limited quantities of lithium and columbium-tantalum minerals, and cesium-bearing pollucite were recovered as byproducts of pegmatite mining operations during the period.

44. The bulk of the tonnage output of all pegmatite minerals was feldspar, mica ranked second, and beryl third. Production of feldspar in the region has been continuous since 1914 with the exception of New York which has declined to a negligible producer of all these minerals.

45. Economic considerations in prospecting, mining, and marketing 6/. - Most pegmatite mines are usually small and mining is frequently begun with a small capital investment. Exploration and development work are generally insufficient, and consequently, the opportunity for efficient operation at minimum cost on a long-term

6/ Gwinn, G. Richard, Domestic Mica: Bureau of Mines Inf. Circ. 7617, November, 1951, p. 23.

Table 84x - Production of pegmatite minerals in The New England-New York Region, 1925-1951 7/

	1925-1938		1939-1950		1951		Total	
	Short tons	Percent of U. S.	Short tons	Percent of U. S.	Short tons	Percent of U. S.	Short tons	Percent of U. S.
New England								
Connecticut								
Feldspar	10,000	3.9	15,000	3.6	15,000	3.3	335,000	2.9
Mica	400	2.8	400	1.4	200*	.29	10,600	1.7
Beryl	2	5.7	5	2.5	-	2.0	88	3.0
Maine								
Feldspar	15,000	5.9	16,000	3.8	21,000	4.7	423,000	3.5
Mica	300	2.1	300	1.0	200*	.29	7,800	1.2
Beryl	5	14.3	15	7.4	15	3.1	195	6.0
New Hampshire								
Feldspar	25,000	9.8	40,000	9.5	40,000	8.9	870,000	7.2
Mica	1,000	7.0	800	2.8	800*	1.1	24,000	4.0
Beryl	10	28.6	30	14.8	50	10.3	550	17.0
New York								
Feldspar	9,000	3.5	6,000	1.4	-	-	198,000	1.7
Total								
Feldspar	59,000	23.1	77,000	18.3	76,000	16.9	1,826,000	13.6
Mica	1,700	11.9	1,500	5.2	1,200	1.7	42,800	6.9
Beryl	17	48.6	50	24.7	65	15.4	833	26.0

7/ Minerals Yearbook: Bureau of Mines, 1930-1951; includes published statistics and estimates.
* Estimated.

basis is limited. The record shows that the largest pegmatite mines which have operated most steadily are those mined primarily for feldspar. Assured sales of all marketable coproduct minerals would exert a stabilizing influence on this small-scale industry. Unfortunately, pegmatite mining has hitherto suffered from numerous disadvantages with the result that most operations ended as marginal ventures or failures.

46. The history of most of the pegmatite mines shows that they have been worked intermittently by a succession of different operators because of insufficient capital, fluctuating market demand, and numerous other causes.

47. Mining and prospecting often proceed blindly and the operator concentrates his activities in the richest parts of the deposit either to take advantage of high prices or to recover as much of his expense as possible through sales before his lease expires. In general the small operator of a mine is handicapped by increasing costs and variable demand for the product. Producing for an anticipated market is traditionally hazardous. Competition from imports, substitutions for some pegmatitic minerals, and unstable market conditions created by emergency requirements are some of the factors which discourage sufficient capital investment for relatively long-range mining projects.

COMMODITY ANALYSIS

48. Feldspar. - United States production of crude feldspar in 1952 increased 5 percent in tonnage and 31 percent in value over

1951. There were eleven producing states, of which New Hampshire ranked second, Maine - fifth, Connecticut - sixth, and New York - eleventh.

49. Mica. - In 1951, United States production of all types of mica, largely scrap, increased 100 percent in tonnage and remained at about the same level in value per ton, as held during the period, 1945-1949.

50. Twelve states reported production of mica in 1950-1951. New Hampshire ranked about third, and Maine and Connecticut, fifth and seventh, respectively. A small production of mica from New York was reported in 1950.

51. Beryl. - United States production of beryl in 1952 increased 6 percent in tonnage and 13 percent in value over 1951. Of the eight producing states, New Hampshire ranked fourth, Maine - sixth, and Connecticut - eighth.

52. Other minerals. - Limited quantities of quartz, lithium, and columbium-tantalum minerals, cesium-bearing pollucite, and others were recovered as byproducts of some of the pegmatite operations in the region.

TYPES OF PEGMATITE DEPOSITS AND RESERVES OF PEGMATITE MINERALS

53. Pegmatites are the only source of commercial feldspar, beryl, sheet and scrap mica, spodumene, lepidolite, and pollucite in the New England-New York Region. All of these minerals rarely occur in a single pegmatite. In general, only one mineral is concentrated

sufficiently in a particular zone of a pegmatite to permit commercial operations. However, a few pegmatites have produced large tonnages of feldspar and mica, and small quantities of beryl. In each of these pegmatites the economic minerals were concentrated in separate zones. In at least two pegmatites, the mica deposits were mined prior to the discovery of the feldspar deposits.

54. Reserves of mica and beryl have been estimated, but feldspar reserves in the New England-New York Region have not been determined. Although tentative estimates for feldspar are lacking, recent improvements in milling techniques have automatically increased the recoverable amount of feldspar from pegmatites. In addition, some of the old dumps may contain sufficient amounts of potash feldspar to be milled. Since 1925, the New England-New York Region has produced nearly 2,000,000 tons of crude feldspar. In the next 30 years it is estimated that considerably more than 2,000,000 tons will be produced.

55. The amount of mica available in the deposits of the New England-New York Region "can be estimated only in terms of the amount of mica that might be mined under a given set of economic conditions * * * a conservative estimate indicates that with ratios of cost to sales prices comparable to those of 1943-44, minable reserves in known deposits would sustain operations for 4 years at the 1943-44 rate of about 2,550 tons of crude mica per year. Total reserves available under such conditions may be much greater." 8/

8/ Cameron, E. N., Larrabee, D. M., McNair, A. H., Page, J. J., Shainin, V. E., and Stewart, G. W., Pegmatite Investigations in Maine, New Hampshire and Connecticut, 1942-1945: Geol. Survey Bull. 255, 1954, pp. 47, 56.

56. In 1944, reserves of beryl in known deposits of Connecticut contained 835 tons of indicated and 106 tons inferred; in Maine about 250 tons indicated and 575 tons inferred, and in New Hampshire about 55 tons indicated and 550 tons inferred. The total known reserves in New England are about 1,140 tons indicated and 1,231 tons inferred. At least 50 percent of the beryl in Connecticut will have to be recovered by milling 7/. Some of these estimated reserves have been mined and at least one new beryl deposit has been discovered in Maine. The tonnage of beryl recovered from this recently discovered deposit in Maine is unusually large.

COMPETITIVE POSITION AND IMPORTANCE OF PEGMATITE MINERALS IN THE NEW ENGLAND-NEW YORK REGION

57. Production data in Table 84x indicates the relative position of pegmatite industry in the region compared with the other pegmatite districts in the United States. The New England-New York Region has maintained a fair, although steadily declining, position in comparison with the other districts. Producers in this region are concerned about the use of substitute materials particularly for feldspar and the lack of large economic pegmatite deposits.

58. Feldspar. - Sufficient data are not available concerning the quality of the feldspar produced in the region. However, it is known that there has been a deficiency of high quality potash feldspar reserves in New England and New York. Those mines which have produced glass-grade feldspar have been unable to compete favorably with

producers of substitute materials such as aplite and nepheline syenite, or with the large-scale feldspar producers in the other districts. Some of the marginal mines in the region have been closed but others operate intermittently.

59. Many ceramic products are produced in New England and New York, but more than half of the total glass production of the United States is manufactured in eastern Ohio, western Pennsylvania, and West Virginia. The bulk of the feldspar is shipped to those producing regions. Most of the potash feldspar, an important constituent in the manufacture of high-grade pottery, is consumed in plants at Trenton, New Jersey, and East Liverpool, Ohio, the centers of this industry. Large tonnages of feldspar produced in Colorado and South Dakota are shipped to the glass factories in Illinois, Indiana, and Wisconsin. Small tonnages of New England feldspar (potash) are shipped to Ohio, Illinois, Indiana, and Wisconsin.

60. Mica. - Mining and processing sheet mica and splittings require much hand labor. The differential between domestic and foreign wages has not permitted the producers in the United States to compete successfully with imports from other countries. The domestic market for certain qualities of iron-free sheet and scrap mica is very favorable at present. However, for mica mining to be profitable, scrap mica must be recovered as a byproduct.

61. Beryl. - Since 1940 beryl production in the United States has not only been small but has been insufficient to meet the demand. When demand and prices rose during World War II, production increased.

Much hand labor is required to recover beryl and few deposits contain sufficient beryl to warrant its recovery as the principal product of a pegmatite operation. Most beryl will continue to be produced as a byproduct of feldspar and/or mica mining under the existent conditions.

62. Sheet mica, columbium-tantalum minerals, and beryl have always been in short supply, and the entire domestic industry has been dependent upon imports. When the demand for these minerals increased sharply, both during World War II and the recent Korean emergency, the United States Government, under Defense Acts of 1939 and 1950, provided assistance for domestic producers of strategic and critical materials. These programs included subsidy prices, participation in exploration, and loans for development and production. As a result, Connecticut, Maine, and New Hampshire have been contributing substantial quantities of these minerals to the total United States supply.

63. The mineral industry located in The New England-New York Region has sufficient capacity to process larger quantities of nearly all of the pegmatite minerals that are currently produced in the region.

64. Production in the region has increased slightly since the defense programs for sheet mica, beryl, and columbite-tantalite have been in effect. A number of pegmatite mines are active in Maine, New Hampshire, and Connecticut. Future developments in improved technology, exploration, and mining methods could result in considerable expansion of production of marketable pegmatite minerals in the region.

GEOLOGY

65. Previous geologic work. - The literature on pegmatites and pegmatite minerals of the New England-New York Region is extensive. Most of the articles deal strictly with the mineralogy and genesis of pegmatites; a few describe the economic geology of pegmatite deposits. Selected publications of the latter type are reviewed briefly in the following summary.

66. In 1907, 1910, and 1911, the U. S. Geological Survey published a series of articles by Bastin that probably represents the first systematic study of pegmatites in the New England-New York Region, particularly the feldspar deposits of Maine. In 1916, Newland, the State geologist, described many of the pegmatite mines in New York and reviewed the economic geology of feldspar deposits. Also in 1916, the U. S. Bureau of Mines published an investigation of the feldspar resources in New England and northern Appalachian states, including a brief description of some deposits and laboratory tests on properties of the feldspars of Maine, Massachusetts, and New York. The detailed works of Sterrett were published by the U. S. Geological Survey in 1914 and 1923; about 100 pegmatite mines and prospects were described in Maine, New Hampshire, Connecticut, and New York. In 1942, as a part of its Strategic Mineral Investigations, the U. S. Geological Survey published a detailed study of the mica deposits in New Hampshire by Olson. During 1941-42 Bannerman began field studies on some pegmatites in the Grafton district, New Hampshire in which he combined for

the first time detailed plane table mapping techniques with studies of structure and mineral occurrences in individual pegmatites. As an outgrowth of these investigations by Bannerman, together with an increased demand for strategic mica and beryl, the U. S. Geological Survey expanded its pegmatite investigations throughout the United States during 1943-1945. The results of the New England investigations were published in 1954 8/. During this same period the U. S. Bureau of Mines was active in investigations and diamond drilling some of the pegmatites in Maine, New Hampshire, and Connecticut 9/ 10/ 11/ and 12/. Following World War II

9/ Hess, F. L., et al, The Rare Alkalis in New England: Bur. Mines Inf. Circ. 7232, 1943, pp. 1-51.

10/ Boos, M. F., et al, Investigation of Portland Beryl-Mica District, Middlesex County, Connecticut: Bur. Mines Rept. Inv. 4425, 1949, pp. 1-26.

11/ Levin, S. B., Beryl Mountain, Sullivan County, New Hampshire: Bur. Mines Rept. Inv. 4216, 1948, pp. 1-3.

12/ Levin, S. B., and Mosier, M., Investigation of Big Mica Mines, Cheshire County, New Hampshire: Bur. Mines Rept. Inv. 4410, 1949, pp. 1-16; Investigation of Blister Mica Mine, Cheshire County, New Hampshire: Bur. Mines Rept. Inv. 4409, 1949, pp. 1-12.

pegmatite investigations were continued by the Maine Geological Survey 13/, by the U. S. Geological Survey in New Hampshire 14/, and by the U. S. Bureau of Mines in Maine 15/.

67. Since 1950, detailed field examinations of mica and beryl deposits have been made by representatives of the U. S. Bureau of Mines and U. S. Geological Survey for the Defense Minerals Exploration Administration (unpublished reports).

REGIONAL DISTRIBUTION AND GENERAL GEOLOGY OF PEGMATITES

68. Most of the pegmatite mines and prospects in the New England-New York Region occur in districts that lie east of the Connecticut River in Connecticut, Massachusetts, New Hampshire, and Maine, or in the eastern foothills of the Adirondack Mountains of New York (see Plate 62g). The districts in Maine are: Topsham, Auburn, and Paris-Rumford; in New Hampshire, Grafton, Keene, and Raymond; in Massachusetts, Northfield-Bernardston, Blandford-Goshen, and Leominster-Sterling; and in Connecticut, the Middletown district. The Branchville-Bedford district is in the highlands of southwestern Connecticut and southeastern New York. In the Adirondacks most of

---

13/ Shainin, V. E., Economic Geology of Some Pegmatites in Topsham, Maine: Maine Geol. Survey Bull. 5, Maine Development Commission, Augusta, Maine, 1948, pp. 1-32; Preliminary Report of the Pegmatites on Red Hill, Rumford, Maine: Ann. Rept. State Geologist 1947-1948, Maine Development Commission, Augusta, Maine, 1949, pp. 90-102.

14/ Olson, J. C., Feldspar and Associated Pegmatite Minerals in New Hampshire: Geol. Survey in cooperation with New Hampshire State Planning and Development Commission, Concord, N. H., 1950, pp. 1-50.

15/ Neuman, G. L., Bumpus Pegmatite Deposit, Oxford County, Maine: Bur. Mines Rept. Inv. 4862, 1952, pp. 1-15.

the productive pegmatites have been in the vicinity of Lake George between Crown Point and Fort Ann, and in the western Adirondacks, east of Gouverneur.

69. Pegmatite districts in the region, except in the Topsham district in Maine, are located in maturely dissected, and well drained glaciated uplands. The Topsham district lies in a hilly section of the coastal lowland of southwestern Maine.

70. The bedrock that underlies all the districts consists chiefly of schists, and gneisses and granitic rocks. Quartz-mica schist is the most abundant type of the metamorphic rocks. The most widespread igneous rock types are granodiorite, quartz monzonite, and granite which form large elongate bodies, small stocks, domes, sheets, and dikes that are intrusive into older metamorphic rocks.

71. Some of the principal feldspar mines of the region, at Acworth in the Keene district, are located in the metamorphosed Ammonoosuc volcanic rocks along the flanks of a dome of Oliverian granodiorite gneiss. Most of the large, commercial mica deposits are in the Littleton formation, a quartz-mica schist.

FORMS OF PEGMATITES

72. Pegmatites range in size from inches to more than one-half mile long and hundreds of feet wide. Most of the pegmatites to which special reference will be made are relatively large bodies, usually less than 1000 feet long and 100 feet thick. Erosion has

dissected the pegmatites to varying degrees. The lowermost terminations of only a few pegmatites have been reached by mining or exploration. Many pegmatites in the New England-New York region probably do not extend downward for more than 1000 to 2000 feet.

73. Shape. - The shape of pegmatites is variable, but most are lenticular or tabular bodies. Some occur in sheet-like bodies and a few are pipe-like. A very few are extremely irregular and have large offshoots.

74. Attitude. - The attitude of pegmatites changes only slightly from district to district or from one type of wall rock to another. Most dip at angles greater than 45 degrees, but some are gently dipping.

75. Relation between shape of pegmatite and type of wall rock. - Simple discordant pegmatite lenses are common in massive granites and poorly foliated granite gneisses. Concordant pegmatites are more common in the strongly foliated schists and gneisses. In New Hampshire approximately 60 percent of the pegmatites in the Littleton formation are concordant and 40 percent discordant to the foliation.

76. Texture. - Pegmatites may differ greatly in texture and the component parts, or zones, of an individual pegmatite may also have a wide range in texture. All parts are generally coarser than coarse-grained granites. In order that a uniform terminology of mineral

grain-size be adopted for pegmatites the following size classification has been suggested 16/:

Term	General mineral grain size
Fine	Less than 1 inch
Medium	1 to 4 inches
Coarse	4 to 12 inches
Very coarse	Greater than 12 inches

In general, the grain size increases from the walls inward toward the center of the pegmatite. Most of the pegmatites that have yielded commercially valuable minerals have a coarse or very coarse-grained texture.

77. Zonal structures. - It is estimated that about 80 percent of the pegmatites in the New England-New York region have a textural uniformity from wall to wall and resemble granite except for their coarser texture. Minable concentrations of valuable minerals are seldom found in these pegmatites. There are, however, many pegmatites in which the minable minerals are unevenly distributed or segregated into structural and lithologic units of contrasting mineral composition and texture.

78. Three general types of structural and lithologic units have been recognized in the New England pegmatites: zones, replacement bodies, and fracture fillings. Although replacement bodies and fracture fillings have been found, zones are the most common and are the most important economically.

16/ Cameron, E. N., Jahns, R. H., McNair, A. H., Page, L. R., The Internal Structure of Granitic Pegmatites: Econ. Geol., Monograph 2, 1949, p. 16.

79. Zones are systematically arranged units, complete or incomplete, that reflect the general shape or structure of the pegmatite body. If their development were perfect, the zones would occur as successive shells concentric about an innermost zone or core. In most zones there are specific mineral assemblages, but variations in mineral proportions within zones are common.

80. The number of zones in pegmatites is variable, but four general types have been recognized.

Border zone. A fine-grained pegmatite, commonly not more than a few inches thick, in contact with the wall rock.

Wall zone. Usually a medium to coarse-grained pegmatite next inside the border zone.

Intermediate zone. Any zone between the innermost zone (core) and the wall zone. Texture ranges from medium to very coarse. The innermost part of the intermediate zone may be called the core-margin zone. More than one intermediate zone may be present.

Innermost zone, or core. Texture is medium to very coarse and commonly contains large crystals of feldspar and quartz.

81. Zones are poorly developed in many pegmatites. In some pegmatites the core is represented by small disconnected lenses, sometimes called "pods".

82. Geologic mapping, sampling, and diamond drilling have aided in locating and determining the size of minable concentrations of

valuable minerals in certain zoned pegmatites. The continuity of valuable mineral deposits in depth may be inferred from the size, shape, and behavior of the zone containing the deposit.

83. Compositional, textural, and structural features. - The great variety of mineralogical, textural, and structural features of zoned pegmatites is frequently emphasized. However, some common characteristics may be noted.

84. In all zoned pegmatites the arrangement of zones follows a systematic scheme by a characteristic succession of zones from the walls of the pegmatite inward to the core. In places, a particular zone may differ slightly in composition and in texture, or in both. Contacts, or boundaries, between zones are commonly gradational; textural and mineralogical changes occur over a space of several inches or feet. A definite sequence of mineral assemblages from the walls inward to the core is characteristic of zoned pegmatites. Nine zones based on different mineral assemblages have been recognized in the New England pegmatites. No individual pegmatite contains all of these assemblages. Most zoned pegmatites have two zones; many contain three, and four or more have been recognized in a few pegmatites.

85. In general, minable concentrations of minerals can be assigned to a particular zone or zones. In most pegmatites sheet mica is mined from the wall or core-margin zones. In both of these zones the content of plagioclase feldspar (soda-lime feldspar) and quartz

is more abundant than in the other zones. Minable quantities of high-grade potash feldspar occur most commonly in a continuous or discontinuous perthite, or perthite-quartz core. Wall zone beryl deposits occur in some pegmatites, but the core margin zones have been the only ones that have been mined economically. This core-margin zone is the only zone in a pegmatite that contains large crystals that are amenable to hand-sorting.

86. Economic significance of zoning. - Variations in grain size and the abundance of economic minerals usually determine the fate of a mining operation. Many pegmatite mines have been abandoned because the economic minerals were not in minable concentrations. A pegmatite may have a high content of potash feldspar (perthite), but if it occurs as small grains and is uniformly distributed and intimately intergrown with quartz and plagioclase, the deposit will be uneconomical to operate by ordinary mining and milling methods. In a similar way the content of mica and beryl may be high, but the crystal may be too small for hand-sorting. In some pegmatites the crystals may be large, but they are not sufficiently concentrated or segregated to permit economical mining.

87. In pegmatites where economic minerals are concentrated and are in zones, they may be mined by selective mining methods. All of the mine workings may be confined to a particular zone, or zones. In some pegmatites a particular mineral may be more concentrated in certain places within the zone than in others, similar to an ore shoot in an ore body.

PROSPECTING AND EXPLORATION

88. In most parts of New England, in places in the foothills of the Adirondack Mountains, and in southeastern New York the prominence of many small hills and some high hills and ridges appear to be partly controlled by the underlying and more resistant pegmatites. Lumbermen, hunters, farmers, and prospectors have long been attracted by the light-colored exposures of feldspar and quartz, the reflecting surfaces of mica books, and the blue-green and golden beryl crystals.

89. Prospecting in the past has been limited to the discovery of a mineral deposit at the surface and then exploring and mining it downward as far as possible. The most favorable exposures of feldspar, mica, and beryl are believed to have been examined or prospected. Future discoveries will depend more and more upon the recognition of pegmatite zones. Nearly all the economic minerals of pegmatites have been mined from deposits contained in zoned pegmatites. Investigations by the U. S. Geological Survey since 1939 have contributed much valuable information for recognizing definite zones in pegmatites, for predicting and locating mineral deposits within zones and for evaluating zoned pegmatites.

90. After its discovery a pegmatite should be mapped on a large scale and all mineralogical and structural data collected and plotted in order to establish the number of zones and to evaluate deposits that might be contained in them. Prospecting in a region where there are old mines would be advantageous because certain zones and mineral

deposits may be characteristic of the district. A few specific minerals and some structural features may occur that could be used effectively as a guide in prospecting.

91. Mineralogical guides may be helpful in determining the zones which containsa feldspar, mica, or beryl deposit. A rich plagioclase zone along the wall is not proof of a wall-zone mica deposit, but it is suggestive. The presence of abundant perthite and biotite near the wall is not favorable for a wall-zone mica deposit, but the intermediate zone, if present, should be checked for mica deposits. A perthite-quartz, or quartz core, may not be visible, but a marked bulge in the walls suggests that more pegmatite is present and another zone, or the core, may have developed in this place. Core-margin zones might contain muscovite mica or beryl, or both. Usually a perthite core is not bordered by a core-margin zone of muscovite, but some beryl crystals might be present.

92. The amount and distribution of mica in a pegmatite were determined by certain physical and chemical conditions at the time of the formation of the pegmatite and not by topography. The quality and quantity of mica has increased in depth in some pegmatites; in others, they have decreased. In general, mineral stains in mica are persistent but the distribution may vary. Clay and vegetable stains may decrease in depth. Similar relations apply to the quality and quantity of feldspar.

93. The application of geophysical and geochemical methods of prospecting for locating hidden pegmatites may become useful if

methods of differentiating certain physical and chemical properties can be developed. In places where the overburden is not too thick a pegmatite containing radioactive minerals might be located with a geiger counter or scintillometer. Tracing boulders containing high-grade feldspar, mica, or beryl back to the original source might lead to the discovery of an economic mineral deposit. Panning sands and gravels in a known pegmatite region might be worthwhile in a search for columbite-tantalite, and other heavy minerals.

94. During and subsequent to World War II the Federal Bureau of Mines and a few private companies have demonstrated that the diamond drill is an effective tool for the exploration of pegmatites and pegmatite zones. Random diamond drill holes may locate the pegmatite underground; however, diamond drilling is most effective when the location of holes is planned in accordance with structural and mineralogical data gathered by geologic mapping of a pegmatite. Examination of the drill core will reveal whether a particular zone continues in depth and whether there is a certain mineral shoot within the zone, or may expose a new zone or zones which contain valuable mineral deposits. In pegmatites which show a mineral deposit, but few exposures, exploration by trenching, test pits, or bulldozing might precede diamond drilling to provide additional data before an expensive and detailed exploratory drilling program is planned. It should be emphasized that diamond drilling does not determine the size, quantity, or quality of mica books in a particular zone, or the sizes and quantity of beryl crystals in a deposit. However,

the recognition of a particular mineral assemblage might suggest whether a zone would contain muscovite or beryl. Large crystals of perthite near the center of a pegmatite would be indicative of a perthite, or perthite-quartz core.

MINING AND MILLING

95. Mining. - The minable ore concentrations of most pegmatites are relatively small. The occurrence of marketable minerals in pegmatites is irregular and often unpredictable except by adequate mapping, exploration, and sampling. The characteristics of most pegmatite deposits are such that the costs of the exploratory and development work required to maintain ore reserves often exceed the economic limits of mining. Consequently, pegmatite mining is maintained by small individual operations.

96. Mining methods vary in accordance with the size, shape, and attitude of the deposit. The ore is mined by both open-cut and underground methods. When the cost of moving the overburden, composed of either the overlying mantle material or rock in the barren-zones becomes excessive, underground mining methods are adopted. A bench system is used commonly in open pit mining when the pegmatite outcrops in areas of high relief. Many open-cuts are usually begun at the top of the outcrop and followed downward, sometimes bounded by almost vertical walls for more than 100 feet. In some open-cut operations, a derrick and pan are used for hoisting; others may have been opened on a slope and worked downward by a ramp, thus

permitting the removal of ore and waste by truck. Some deposits are opened at the bottom of a slope and mined up the slope by combined open-pit and underground methods.

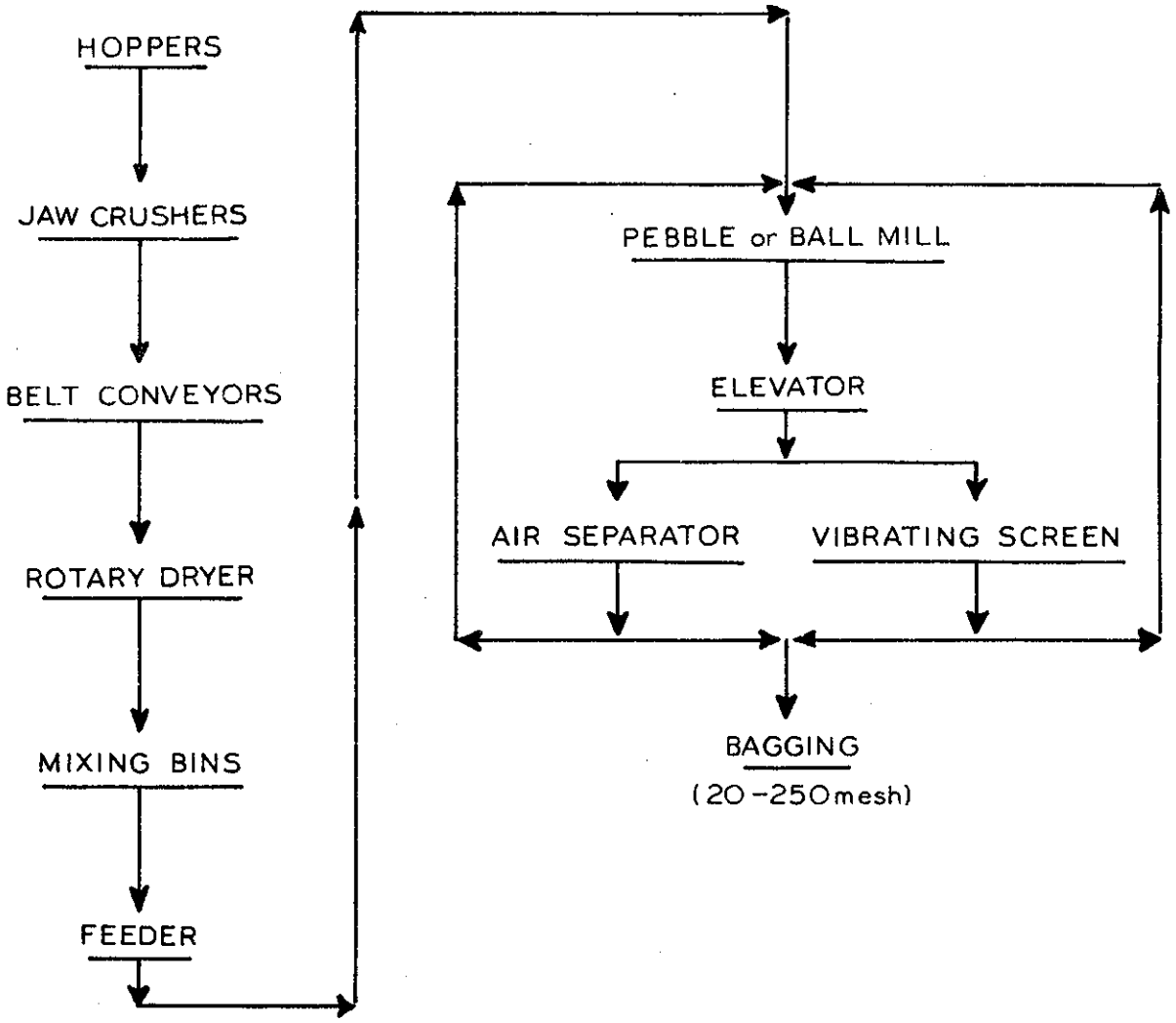
97. All pegmatites vary in size, shape, and geologic structure relative to the enclosing rock, requiring different or a combination of methods of mining that are economically adaptable to the existing conditions. Pegmatite mining is necessarily selective by the nature of the occurrence of the marketable minerals. Much hand labor is required in most mines.

98. Jackhammers are generally employed for drilling, but wagon drills are used in some large open-outs. In most operations, the ore is hand-sorted at the working face and then the ore and waste are removed separately. In a few mines, the ore is loaded into trucks by mechical loaders and hauled to the crushing plant. At one operation, the ore-bearing rock is crushed, put through a grizzly (parallel spaced bars) and passed over a series of picking belts from which the valuable minerals are recovered by hand sorting. Most of the books of mica, large pieces of beryl, and other mineral such as lithium minerals, columbite, tantalite, and gem stones may be recovered at the working face. Hand-sorting methods in the mine pit or on a picking belt at the mill are very effective in recovering coarse mineral fragments or rejecting waste rock. Hand-sorting operations at several feldspar mines have been partly mechanized by employing belt conveyors, crushers, and screening equipment on the quarry floor.

99. Few pegmatite operations in the region have sufficient known ore reserves blocked out and developed for low-cost mining methods. It is possible that after improved methods of concentrating pegmatite minerals are adopted, pegmatite mining may be conducted on a larger and more systematic scale by the mass mining of entire deposit. Mining costs would ultimately be reduced with the greater efficiencies resulting from the increased use of mechanized equipment.

100. Milling. - Until recent years, the milling of pegmatite minerals was limited chiefly to the crushing, grinding, and screening of feldspar and mica after hand-separation of the larger crystals and other marketable minerals. Advanced methods of mineral treatment for the concentration and separation of all of the marketable minerals have not become commercially practicable. Several new methods of improved technology have been proved on a laboratory scale by the U. S. Bureau of Mines and industry and they have been adopted with some modifications by some companies in the feldspar industry in the region.

101. Most of the crude feldspar is reduced in a jaw-crusher and dry-ground in pebble mills to meet the specifications of the consumers. The glass manufacturers commonly used 20 to 40-mesh size, and the pottery, enamel, and other ceramic companies require the 200-mesh size. Iron-bearing minerals and other impurities, including biotite mica, garnet, tourmaline, and iron-stained muscovite mica are removed by high-intensity magnetic separation within certain



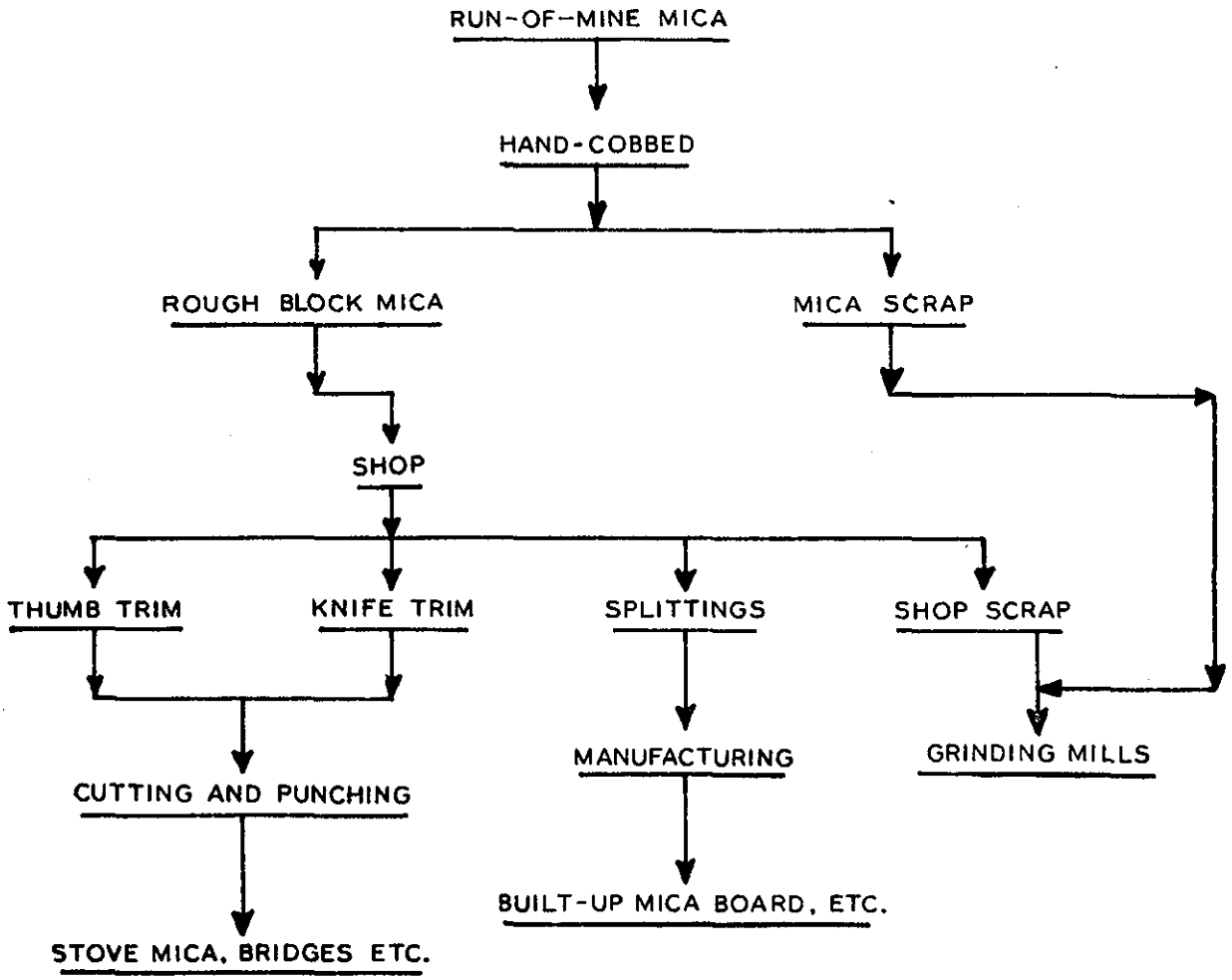
SPECIAL SUBJECTS-REGIONAL

TYPICAL FLOW SHEET OF
DRY GROUND FELDSPAR MILL

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE
JANUARY 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62 H
CHAPTER XXXIX



SPECIAL SUBJECTS-REGIONAL

TYPICAL FLOW SHEET IN PREPARATION OF SHEET MICA FOR MARKET

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62 I

CHAPTER XXXIX

specification limits required by the consumer. Electromagnetic separation of feldspar is used effectively by one company. After removal of the iron-bearing minerals, the ground material is conveyed to storage bins for shipment. A typical flow sheet is shown in Plate 62h.

102. In processing, mica is classified into two groups, sheet and scrap. The steps of the preparation of sheet mica include (1) cobbing or sorting, (2) rifting or sheeting, (3) trimming, (4) grading (sizing), (5) and classification. Sheet mica is hand-cobbed into books at the mine and then shipped to the trimming plant. The books are then split with a special sharp bevel-edged knife to facilitate splitting into thinner sheets and films, which are trimmed by knife to remove edge imperfections. The mica is then graded and classified according to size and clearness. Scrap mica (recovered from rejected sheet quality material, factory scrap, mica-bearing schist, and as a by-product of other minerals recovery) is converted into ground mica by three grinding methods, (1) wet-ground, (2) dry-ground, and (3) micronized. The degree of fineness in grinding varies from 20 to 250-mesh size, according to the requirement of the consumer. The specifications commonly require grinding to a gravity of 14-20 pounds per cubic foot. A typical plant flow sheet for the processing of sheet mica is shown in figure 62i and scrap (ground-mica) on Plate 62j.

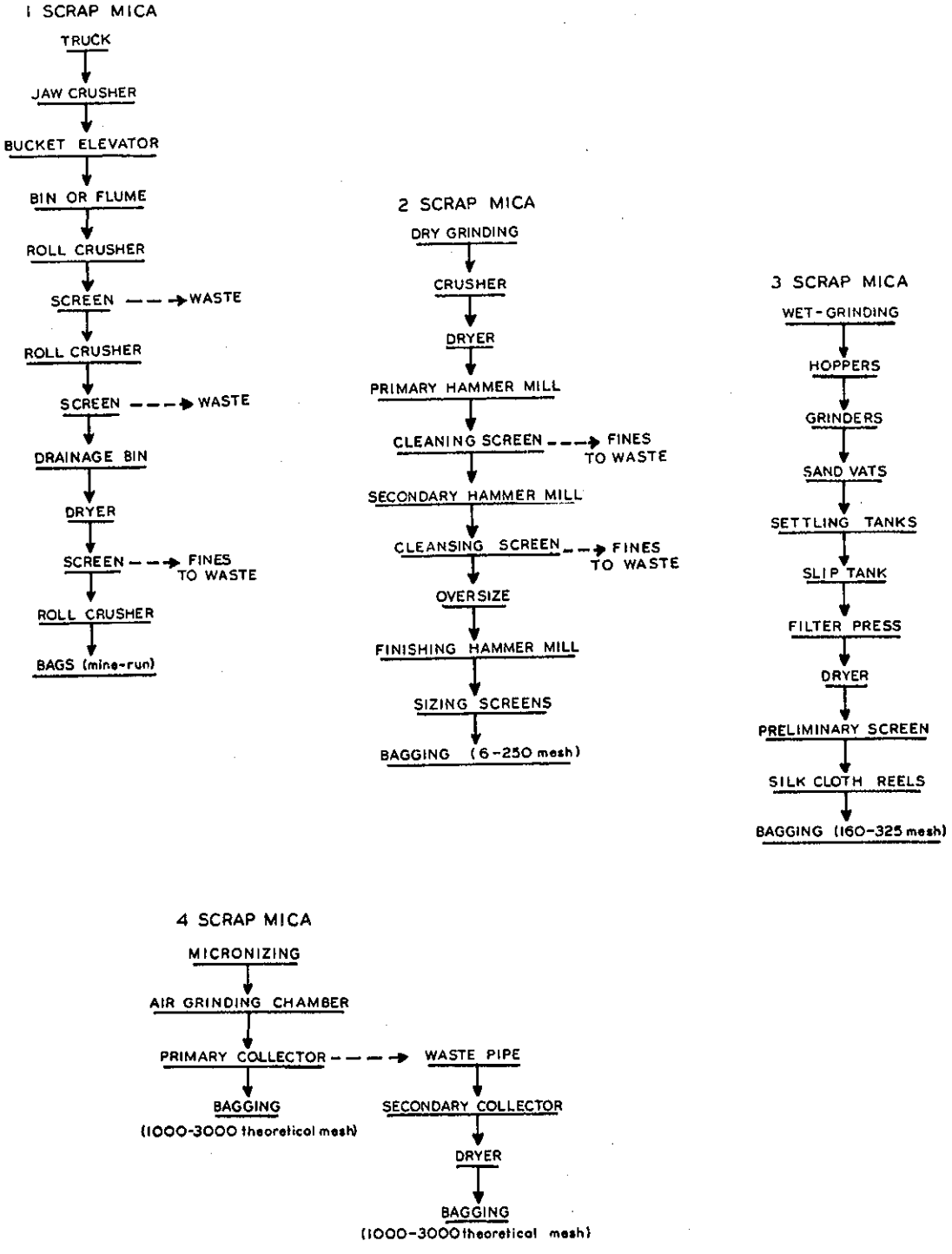
103. Wet-ground mica is produced in chaser mills where the mica is reduced and delaminated. Hammer mills are commonly used for dry-

grinding followed by screening. Micronized mica is produced in jet impact machines.

104. Other pegmatite minerals are recovered by hand picking, but mechanical concentration is necessary for greater efficiency. The high specific gravity of columbium-tantalum minerals enables them to be concentrated by gravity methods along with other possibly occurring relatively heavy constitutents such as garnet. However, the quantities of the marketable minerals present should justify the additional equipment costs before installation. Comparative cost analyses should be calculated against the increased profits of the operation.

105. Beryl, columbium and tantalum minerals, and lithium minerals are shipped to the metallurgical plants for treatment to recover the metal and manufacture alloys and chemicals. These ores are generally reduced in jaw crushers and then ground in ball mills to about 200 mesh. (See Plate 62k.) Flow sheets of certain operating plants for pegmatite minerals outside of the New England-New York Region may be found in several Bureau of Mines publications referenced in the bibliography.

106. Research has been conducted by industry and government on the beneficiation of pegmatite minerals. The separation and concentration of the minerals present many complex problems as most of the minerals occurring in pegmatites are silicates. However, mica, beryl, feldspar, and quartz can be concentrated by selective flotation methods.



SPECIAL SUBJECTS-REGIONAL

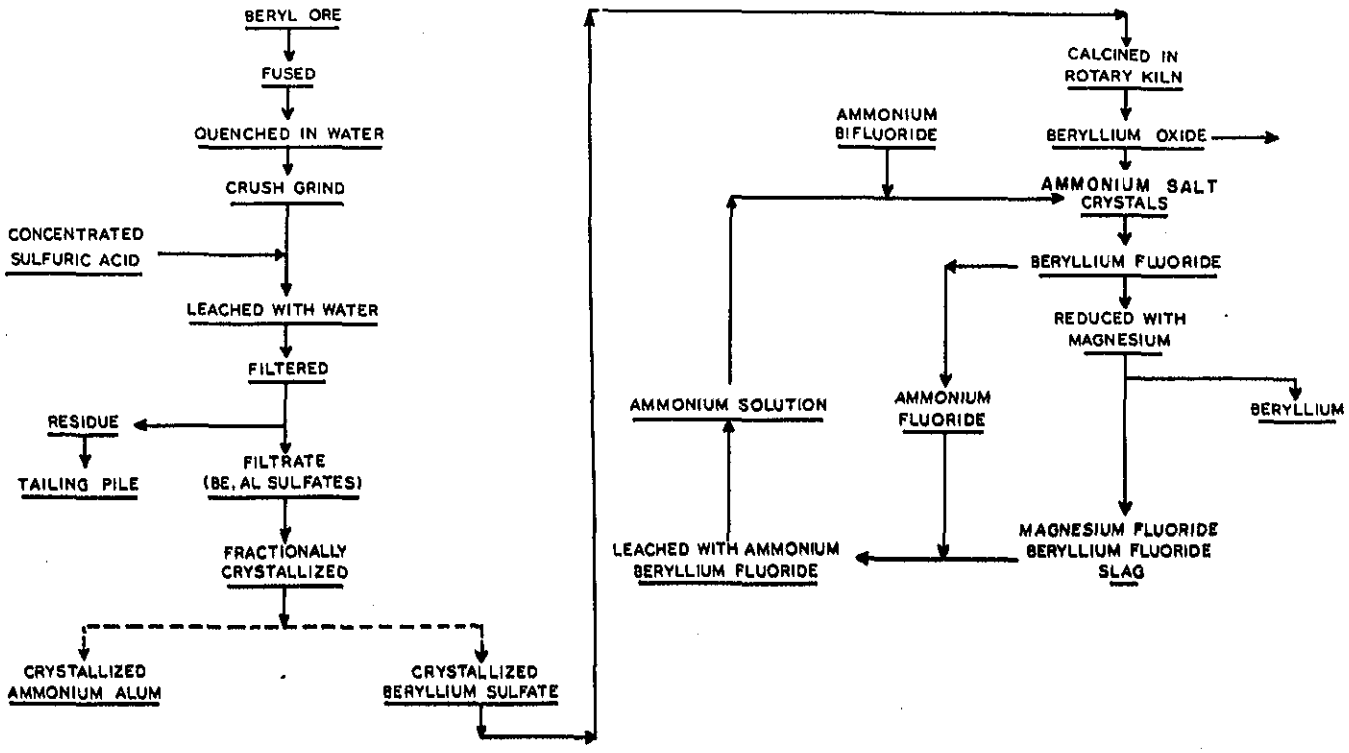
TYPICAL FLOW SHEET IN PREPARATION OF GROUND MICA FOR MARKET

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON, JAN. 1955

PLATE 62 J
CHAPTER XXXIX



SPECIAL SUBJECTS- REGIONAL

FLOWSHEET FOR PRODUCTION OF

BERYL TO BERYLLIUM METAL

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JANUARY 1955

USBM BOSTON, JAN. 1955

PLATE 62 K

CHAPTER ~~XXXIX~~

107. Several pegmatite mineral flotation plants have been constructed in the United States, but the only one in the New England-New York Region is located at Gilsum, New Hampshire. At this plant, feldspar is prepared for market by two methods, dry-grinding and flotation. Scrap mica and quartz are recovered as by-products from both methods. (See Plate 62L.)

108. One of the major obstacles in a pegmatite flotation operation is the lack of separation of soda-lime feldspar from potash feldspar to meet the present market specifications. Except for glass-making, the ceramic industry requires a high-potash feldspar content; the glass industry can use either high-potash feldspar or soda feldspar, depending upon the quality of the product.

STRUCTURE OF THE INDUSTRY IN THE NEW ENGLAND-NEW YORK REGION

109. Feldspar. - Except for a small quantity of crude feldspar shipped to consumers outside of the region, virtually all of the feldspar mined in Connecticut, New Hampshire, and Maine is ground locally. Most merchant grinders mine part of the crude ore that they process. They also purchase large tonnages of crude feldspar from other producers. Most ground feldspar is sold on the basis of consumer specifications.

110. Mica. - Mica produced in New England and New York that meets specifications for strategic quality is sold to the federal purchasing depot at Franklin, New Hampshire. Sub-grade material and scrap mica is sold to merchant grinders, dealers, and industrial consumers located in Maine, New Hampshire, and Massachusetts.

111. An establishment in Vermont purchases domestic and foreign scrap mica and splittings for the manufacture of bonded mica products such as a compressed mica paper.

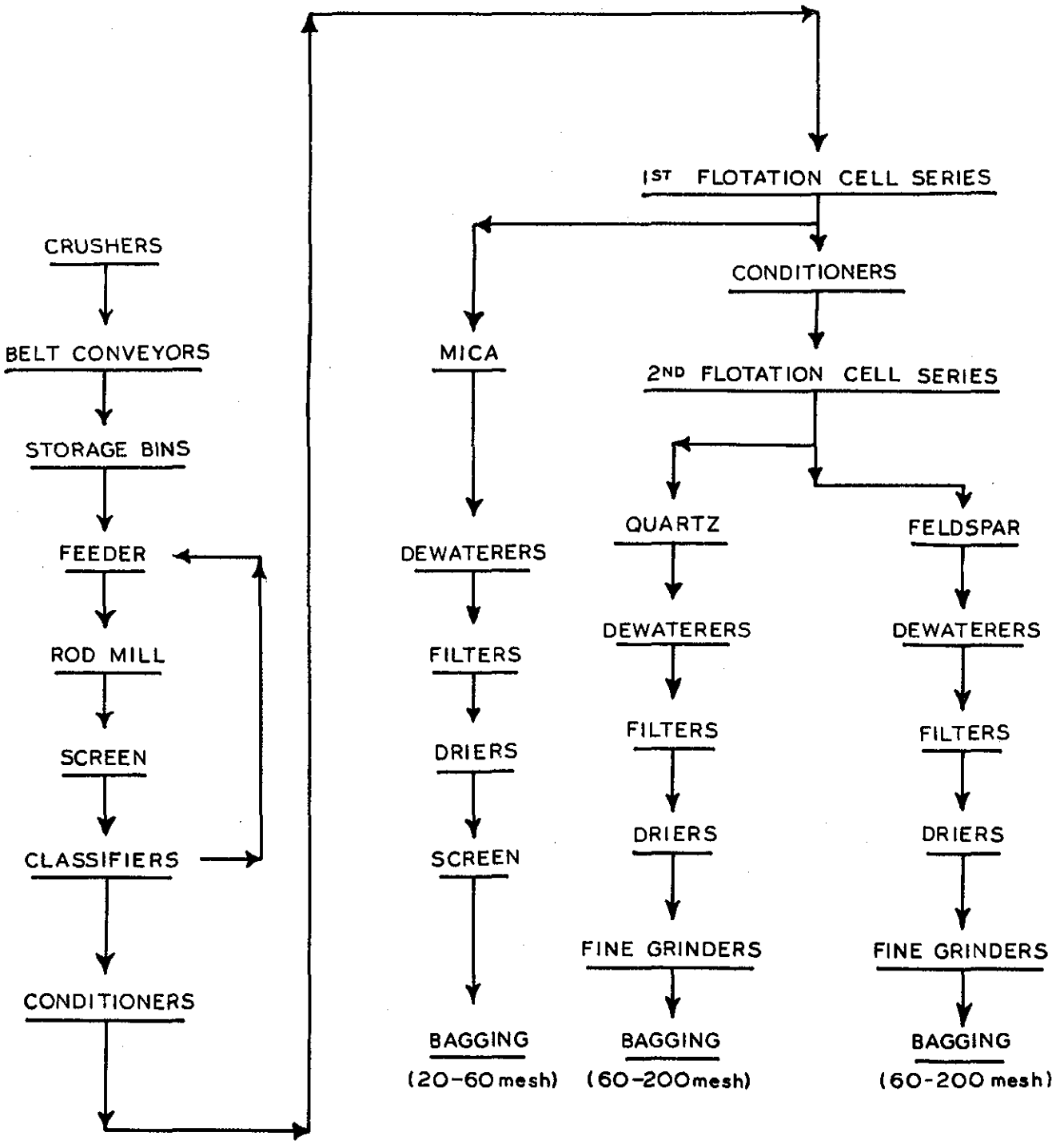
112. Large quantities of natural and reclaimed scrap mica are shipped to fine-grinding plants in Massachusetts and New Hampshire for production of an intermediate raw material which is sold to a variety of other industries.

113. Beryl. - Beryl of specification grade, mined generally as a byproduct of other pegmatite minerals, is sold to the federal purchasing depot at Franklin, New Hampshire. Some lots are shipped out of the region to the industry in Pennsylvania and Ohio.

114. One of the largest beryllium companies with mining operations in Oxford County, Maine, processes the ore in their plant located at Reading, Pennsylvania.

115. Columbium-tantalum minerals. - The incidental quantities of these minerals are recovered and sold in small lots to the local federal purchasing depot servicing the region.

116. Other minerals. - Other minerals, recovered as byproducts, are sold as the market permits.



SPECIAL SUBJECTS-REGIONAL

TYPICAL FLOW SHEET OF FROTH FLOTATION FELDSPAR MILL

NEW ENGLAND-NEW YORK INTER-AGENCY COMMITTEE

JAN. 1955

U.S.B.M. BOSTON, JAN. 1955

PLATE 62 L

CHAPTER XXXIX

Table 84y - Distribution of pegmatite mines operated during the period, 1951-1954, in New England

State	Location	Mine	Mineral Products	Operator
Conn.	Portland district	Hale	Feldspar	Eureka Mica Mining & Milling Co., Portland, Conn.
Conn.	Middle-Haddam	Worth Spar	Feldspar, mica (sheet and scrap)	Worth Spar Co., Cobalt, Conn.
Conn.	Portland district	Strickland	Sheet mica	Homer L. Hise, E. Norwalk, Conn.
Conn.	Portland district	Tollgate	Sheet mica	Harry E. Leach, Winstead, Conn.
Conn.	Branchville	Branchville	Sheet mica, beryl	Homer L. Hise, E. Norwalk, Conn.
Maine	Newry	Scotty	Beryl, scrap mica	The Beryllium Corp., Bethel, Me.
Maine	Norway	BB-1, 7	Sheet mica, scrap mica	Stanley I. Perham, S. Paris, Me.
Maine	Gilead	Wheeler	Sheet mica	Roger W. Wheeler, Bethel, Me.
Maine	(Paris (Newry	(Mt. Mica (Durgin	(Sheet mica (Sheet mica	Lawrence Anderson, E. Stoneham, Maine
Maine	Rumford Pt.	Geo. Elliot	Sheet mica	" " " "
Maine	Albany	Guy Johnson	Sheet mica	" " " "
Maine	Canton	Peabody	Feldspar, sheet mica, and beryl	Sabon P. Milligan, Rumford Pt., Maine
Maine	Rumford	Black Mt.	Beryl, lepidolite, spodumene, scrap mica	Dana C. Douglass, Bethel, Me.
Maine	N. Norway	Dunn	Sheet mica	Lawrence Anderson, E. Stoneham, Me.

Table 84y (Continued)

State	Location	Mine	Mineral Products	Operator
Maine	Albany	Bumpus	Beryl, (sheet and scrap mica), rose quartz, feldspar	Bell Minerals, Inc., West Paris, Maine
Maine	Greenwood	Perham	Feldspar, beryl, scrap mica	The Beryllium Corp., Bethel, Me.
Maine	Norway	Nubble	Sheet mica, scrap mica	Dana C. Douglass, Bethel, Me.
Maine	Topsham	Rumrill	Sheet mica	Topsham Feldspar Co., Topsham, Me.
Maine	Albany	Wardwell	Sheet mica, beryl	Wm. C. Pechnik, Albany, Me.
Maine	Rumford	Bean	Sheet mica	John L. Maderic, Rumney, N. H.
Maine	Topsham	(Purington (Mt. Ararat (McIber	Feldspar	Consolidated Feldspar Corp., Topsham, Maine
Maine	Minot	Laflamme	Feldspar	Bell Minerals, Inc., W. Paris, Me.
N. H.	Grafton	Ruggles	Feldspar, beryl, sheet mica	Whitehall Feldspar Co., Keene, N. H.
N. H.	Groton	Palermo	(Sheet and scrap) mica, beryl	Ashley Mining Corp., Rumney, N. H.
N. H.	Unity	Sargeant	Sheet mica	L. E. Sargeant, Newport, N. H.
N. H.	Newport	Smith	Sheet mica	Fred L. Smith, Claremont, N. H.
N. H.	Sunapee	Kent	Sheet mica	H. L. Robinson, Newport, N. H.
N. H.	Groton	Draper	Sheet mica	W. D. Wood, Inc., Warren, N. H.
N. H.	Groton	Nancy #2	Sheet mica	Strafford Mines, Inc., Bristol, N.H.
N. H.	Wentworth	McGinnis	Sheet mica	E. R. Lupien, Jr., Warren, N. H.
N. H.	(Wentworth (Groton	(Harriman (Tarr	Sheet mica	Virginia D. Harriman, W. Rumney, N. H.

Table 84y (Continued)

State	Location	Mine	Mineral Products	Operator
N. H.	Groton	Fletcher	Sheet mica	Donald Esty, Hebron, N. H.
N. H.	Wentworth	Dufour	Sheet mica	Charles E. Dufour, W. Rumney, N. H.
N. H.	Orange	Hoyt Hill	Sheet mica	John L. Maderic, Rumney, N. H.
N. H.	Wakefield	Weeks	Feldspar, beryl, scrap mica	Raymond B. Weeks, Burleysville, N. H.
N. H.	Alstead	Allen	Feldspar	Golding-Keene Co., Keene, N. H.
N. H.	Alstead	Colony	Feldspar, quartz	Golding-Keene Co., Keene, N. H.
N. H.	Alstead	Yuhas #2	Feldspar	J. F. Morton, Inc., Cold River, N. H.
N. H.	Rumney	Rumney	Feldspar	Golding-Keene Co., Keene, N. H.
N. H.	Gilsum	Big	Feldspar, sheet mica	Golding-Keene Co., Keene, N. H.
N. H.	Alstead	Britton	Beryl	The Beryllium Corp., Bethel, Me.
N. H.	Alstead	French	Beryl, sheet mica	- Lassman, Alstead, N. H.
N. H.	Alstead	Osborne	Beryl	Linwood Congdon, Keene, N. H.
N. H.	Grafton	Saunders	Sheet mica	John L. Maderic, Rumney, N. H.
N. H.	Groton	Valencia	Sheet mica and scrap mica	W. D. Woods, Warren, N. H.
N. H.	Gilsum	Nichols	Sheet mica	N. H. Mining Co., Keene, N. H.
N. H.	Acworth	Beryl Mt.	Beryl	Ashley Mining Corp., W. Rumney, N.H.
N. H.	W. Rumney	Atwood	Sheet mica	Richard N. Berry, W. Rumney, N. H.
N. H.	Groton	Brown Lot	Feldspar	Golding-Keene Co., Keene, N. H.
N. H.	Groton	Diamond	Sheet mica	John L. Maderic, Rumney, N. H.

FUTURE OUTLOOK

117. Prospecting and exploration for pegmatite minerals by the Federal and state agencies, private companies, and individuals, demonstrated very clearly that the chances of discovering new large high-grade deposits at existing surface exposures are limited without the aid of additional geologic data. Some new deposits will be found by intensive prospecting and general geologic mapping. More advanced methods of exploration, such as diamond drilling or systematic trenching, will be necessary to indicate concentrations of minerals in pegmatites.

118. The application of geophysical and geochemical prospecting methods to pegmatites has not been effectively explored. In 1942, the Bureau of Mines conducted experimental geophysical surveys on pegmatites in Alabama, but detailed results of these surveys have not been published. However, it is possible to locate buried pegmatites by electrical resistivity surveys if large quartz bodies are present. No differentiation can be made between large, massive bodies and the smaller, but more numerous ones. If extensions of existing pegmatites could be outlined by geophysical methods, trenching and diamond drill holes could be located with greater accuracy and economy.

119. More systematic and economical methods of mining can be adopted after a deposit has been mapped and studied geologically. The average operator usually is not adequately informed about his

deposit and, therefore, large quantities of pegmatite rock are mined which contain insufficient concentrations of marketable minerals for a profitable operation. Only certain zones of a deposit should be selectively mined to permit the recovery of the marketable minerals. Many deposits should be developed further in depth in search for other mineral-rich zones not exposed in the upper parts of the pegmatite 17/.

120. The most successful operations will be those from which all marketable minerals are recovered. Many of the large dumps of active or abandoned mines might be reworked for all the commercially valuable minerals when new milling methods become economic.

121. Efficient management and improvements in mining and milling methods, advanced beneficiation techniques, and conservation practices, will lead to greater recovery of material. Further successful research on these methods may eventually permit the mass mining by conventional methods of all the rock in a pegmatite. This is the only way that the pegmatite industry can become equal to the position of some of the other prosperous non-metallic industries in the region 18/.

17/ Tyler, Paul M., Economic Importance of Pegmatites: Bureau of Mines Inf. Circ. 7550, 1950, p. 3.

18/ Tyler, Paul M., Economics of Pegmatites: Mining Engineering, vol. 5, No. 9, September 1953, P. 898.

SELECTED BIBLIOGRAPHY ON PEGMATITES

BANNERMAN, H. M. New Hampshire Mineral Resource Survey, General Summary, Part I. N. H. State Planning and Development Commission, Concord, N. H. 1940, pp. 1-9.

BANNERMAN, H. M. Structural and Economic Features of Some New Hampshire Pegmatites, Part 7. N. H. State Planning and Development Commission, Concord, N. H., 1943, pp. 1-22

BANNERMAN, H. M., and CAMERON, E. N. The New England Mica Industry. Trans. Am. Inst. Min. Met. Eng., Min. Technology T. P. 2024, 1946, pp. 1-8.

BASTIN, E. S. Feldspar and Quartz Deposits of Southeastern New York. Geol. Survey Bull 315, 1907, pp. 394-399.

BASTIN, E. S. Economic Geology of the Feldspar Deposits of the United States. Geol. Survey Bull, 420, 1910, pp. 1-85.

BASTIN, E. S. Geology of the Pegmatites and Associated Rocks of Maine. Geol. Survey Bull. 445, 1911, pp. 1-152.

BILLINGS, M. P. Pegmatites of Massachusetts. Mass. Dept. Public Works and Geol. Survey, Cooperative Geologic Report, Bull. 5, 1941, pp. 1-19.

BILLINGS, M. P. Mica Deposits in the Chester-Blanford State Forest. Mass. Dept. Public Works and Geol. Survey, Inf. Circ. II, 1944, pp. 1-16.

BILLINGS, M. P., and WOLFE, C. W. Spodumene Deposits in the Leominster-Sterling Areas, Massachusetts. Mass. Dept. Public Works and Geol. Survey, Inf. Circ. III, 1944, pp. 1-9.

BILLINGS, M. P. Pegmatites of Massachusetts. Progress Report, Mass. Dept. Public Works and Geological Survey; open file Washington, D. C., and 270 Dartmouth Street, Boston, Mass., 1945.

BOOS, M. F., MAILOTT, E. E., MOSIER, M. Investigation of Portland Beryl-Mica District, Middlesex County, Connecticut. Rept. Inv. 4425, 1949, pp. 1-26.

BURGESS, B. C. Industrial Minerals and Rocks, Feldspar. Am. Inst. Min. Met. Eng., 1949, pp. 345-373.

CAMERON, E. N., LARRABEE, D. M., McNAIR, A. H., PAGE, J. J., SHAININ, V. E., and STEWART, G. W. Structural and Economic Characteristics of New England Mica Deposits. Geol. Survey Press Bull, Sept. 1944, Econ. Geol., vol. 40, 1945, pp. 369-393.

CAMERON, E. N., and SHAININ, V. E. The Beryl Resources of Connecticut. Econ. Geol, vol. 42, 1947, pp. 353-367.

CAMERON, E. N., JAHNS, R. H., McNAIR, A. H., PAGE, L. R. The Internal Structure of Granitic Pegmatites. Econ. Geol., Monograph 2, 1949.

CARLSON, E. J., KAUFFMAN, A. J., JR., KEISER, H. D., NEEDLEMAN, STANLEY. Minerals Yearbook, Minor Metals (preprint chapter). Bureau of Mines, 1951.

DAWSON, E. H. Industrial Minerals and Rocks, Mica. Am. Inst. Min. Met. Eng., 1949, pp. 551-566.

GRIFFETH, R. L. and YOUNGLOVE, E R. Improved Electrical insulation from Mica Paper. Product Engineering, May 1953, pp. 210-213.

GWINN, G. R. Domestic Mica. Bureau of Mines Inf. Circ. 7617, Nov. 1951, pp. 1-37.

HANLEY, J. B., HEINRICH, E. WM., and PAGE, L. R. Pegmatite Investigations in Colorado, Wyoming, and Utah. Geol. Survey Prof. Paper 227, 1950, pp. 1-125.

HESS, F. L., WHITNEY, R. J., TREFETHEN, J. M., and SLAVIN, M. The Rare Alkalis in New England. Bur. Mines Inf. Circ. 7232, 1943, pp. 1-51.

JAHNS, R. H. Mica Deposits of the Petacca District, Rio Arriba County, New Mexico. New Mexico School of Mines, State Bureau of Mines and Mineral Resources, Bull. 25, 1946, pp. 1-289.

JAHNS, R. H. Milling Improves Northern New Mexico Scrap Outlook. Eng. Min. Jour., vol. 149, No. 5, 1948, pp. 96-100.

JAHNS, R. H. The Genesis of Pegmatites. Am. Miner., vol. 38, Nos. 7-8, July-August 1953, pp. 563-598.

JAHNS, R. H., and LANCASTER, F. W. Physical Characteristics of Commercial Sheet Muscovite in the Southeastern United States. Geol. Survey Prof. Paper 225, 1950, pp. 1-110.

JAHNS, R. H. Geology, Mining, and Uses of Strategic Pegmatites. Trans. Am. Inst. Min. Met. Eng., vol. 190, 1951, pp. 45-60.

JAHNS, R. H. Pegmatite Deposits of the White Picacho District, Maricopa and Yavapac Counties, Arizona. Arizona Bur. Mines Bull. 612, 1952, pp. 1-105.

KELLER, W. D. Industrial Minerals and Rocks as Plant Nutrient Sources. Ann. Rept. of State Geologist, 1949-1950, Maine Development Commission, Augusta, Maine, 1951, pp. 8-23.

LADOO, R. B., and MYERS, W. M. Nonmetallic Minerals, Feldspar. McGraw-Hill, 1951, pp. 102, 205,220, 288-294, 314-333.

LAMB, F. D. Beneficiation of New England Beryllium Ores. Bureau of Mines Rept. Inv. 4040, 1947, pp. 1-9.

LEVIN, S. B. Beryl Mountain, Sullivan County, New Hampshire. Bureau of Mines Rept. Inv. 4216, 1948, pp. 1-3.

LEVIN, S. B., and MOSIER, M. Investigation of Big Mica Mines, Cheshire County, New Hampshire. Bureau of Mines Rept. Inv. 4410, 1949, pp. 1-16.

LEVIN, S. B. and MOSIER, M. Investigation of Blister Mica Mine, Cheshire County, New Hampshire. Bureau of Mines Rept. Inv. 4409, 1949, pp. 1-12.

LODDING, W. New Jersey's Potential Feldspar Resources. Rutgers Univ. Bur. Mineral Research Bull. 5, Part II, Mineral Technology and Economic Evaluation, 1951, pp. 1-70.

MAILOTT, E. E., BOOS, M. F., AND MOSIER, M. Investigation of Black Mountain Beryl Deposit, Oxford County, Maine. Bureau of Mines Rept. Inv. 4412, 1949, pp. 1-10.

MILLER, R. N. and WING, L. Reports on Prospects and Mines. Rept. State Geologist 1943-1944, Maine Development Commission, Augusta, Maine, 1944, pp. 29-58.

. Mineral Resources of the United States. Geological Survey, 1882-1923.

. Minerals Yearbook. Bureau of Mines, 1931-1950.

. Mineral Position of the United States and Hearings before a Subcommittee of the Committee on Public Lands. U. S. Senate, Eightieth Congress, 1947.

NEEDLEMAN, STANLEY. Minerals Yearbook, Beryllium (preprint chapter), Bureau of Mines, 1951.

NEUMAN, G. L. Bumpus Pegmatite Deposit, Oxford County, Maine. Bureau of Mines Rept. Inv. 4862, 1952, pp. 1-15.

NEWLAND, D. H. The Quarry Materials of New York - Granite, Gneiss, Trap, and Marble. New York State Mus. Bull. 181, 1916. pp. 154-175.

OLSON, J. C. Mica-Bearing Pegmatites of New Hampshire. Geol. Survey Bull. 931-P, 1942, pp. 363-403.

OLSON, J. C. Feldspar and Associated Pegmatite Minerals in New Hampshire. Geological Survey in cooperation with New Hampshire State Planning and Development Commission, Concord, N. H., 1950, pp. 1-50.

ORDWAY, R. J. Radioactivity of Some Maine Pegmatites. Ann. Rept. State Geologist 1949-1950, Maine Development Commission, Augusta, Maine, 1951, pp. 91-106.

SHAININ, V. E. Economic Geology of Some Pegmatites in Topsham, Maine. Maine Geol. Survey Bull. 5, Maine Development Commission, Augusta, Maine, 1948, pp. 1-32.

SHAININ, V. E. Preliminary Report of the Pegmatites on Red Hill, Rumford, Maine. Ann. Rept. State Geologist 1947-1948, Maine Development Commission, Augusta, Maine, 1949, pp. 90-102.

STERRETT, D. B. Mica Deposits of the United States. Geol. Survey Bull. 740, 1923, pp. 1-342.

STOLL, W. C. Mica and Beryl Pegmatites in Montana and Idaho. Geol. Survey Prof. Paper 229, 1950, pp. 1-64.

STAFF, TUSCALOOSA DIVISION, MINING BRANCH, BUR. MINES. Mica and Beryl Examination and Exploration in Cleburne, Randolph, Clay, Coosa, Chilton, Tallapoosa and Lee Counties, Alabama. Bureau of Mines Rept. Inv. 3905, 1946, pp. 1-119.

TREFETHEN, J. M. The Harden, Keith, Small Spodument Prospect, Township E, Maine. Ann. Rept. State Geologist 1943-1944, Maine Development Comm., Augusta, Maine, 1945, pp. 20-21.

TYLER, P. M. Economic Importance of Pegmatites. Bureau of Mines Inf. Circ. 7550, 1950, pp. 1-57.

TYLER, P. M. Economics of Pegmatites. Mining Engineering, vol. 5, No. 9, Sept. 1953, pp. 894-898.

. Materials Survey on Beryllium. Office of Defense Mobilization, Sept. 1953, 150 pp.

U. S. TARIFF COMMISSION. Earths, Earthenware, and Glassware. Trade Agreement Digests, vol. 11, 1946.

. War Changes in Industry Series, Mica, Rept. 21. U. S. Tariff Commission, 1946.

WATTS, A. S. Feldspars of New England and Northern Appalachian States. Bur. Mines Bull. 92, 1916, pp. 1-181.