DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS

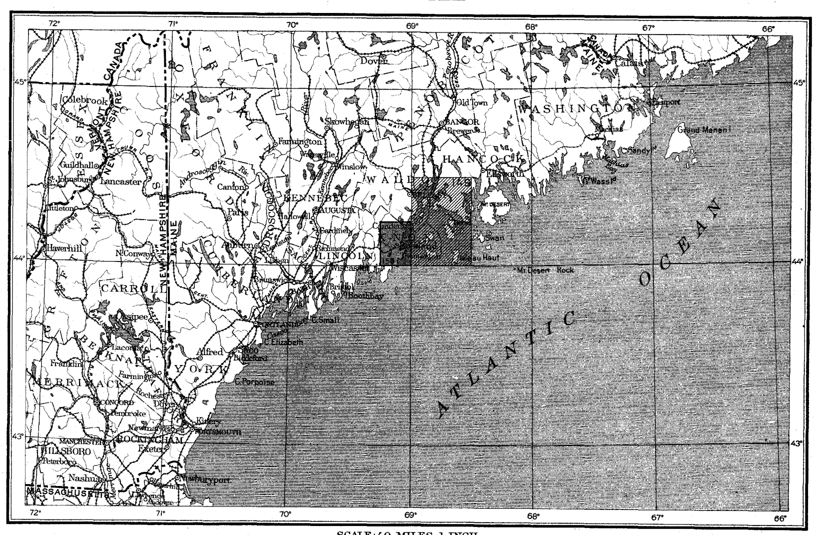
OF THE

UNITED STATES

ROCKLAND FOLIO

MAINE

INDEX MAP



SCALE: 40 MILES-1 INCH

ROCKLAND FOLIO

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GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

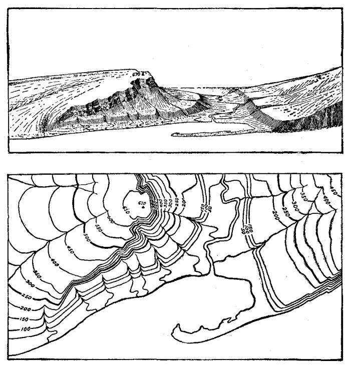

FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say, every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out thru them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent; Pleistocene	Q	Brownish-yellow.
	Tertiary	Pliocene; Miocene; Oligocene; Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian; Pennsylvanian; Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian	Saratogan; Acadian; Georgian	Є	Brick-red.
	Algonkian		A	Brownish-red.
	Archean		ᴀʀ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow thru them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

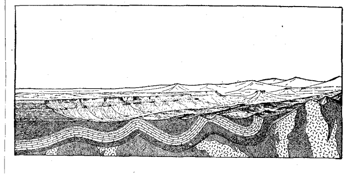

Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

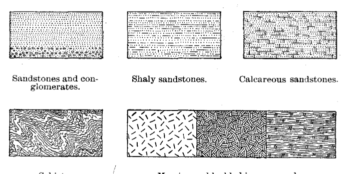

Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

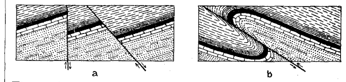

Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,

Director.

May, 1908.

DESCRIPTION OF THE ROCKLAND QUADRANGLE.

By Edson S. Bastin.

INTRODUCTION.

LOCATION, AREA, AND PRINCIPAL TOWNS.

The Rockland quadrangle is situated on the western side of Penobscot Bay, about midway between the eastern and western borders of Maine. The area included within it extends from latitude 44° to 44° 15′ and from longitude 69° to 69° 15′, and embraces about 215 square miles, of which only about two-thirds is land. The quadrangle lies almost wholly within Knox County. Rockland, the principal town, with a population of a little over 8000, has an excellent harbor and is an important distributing point for the islands to the east. It is the terminus of the Rockland branch of the Maine Central Railroad and in the summer season is readily reached by steamer from Boston. Camden and Thomaston are the towns next in importance.

GENERAL GEOGRAPHY AND GEOLOGY OF THE PROVINCE.

The Rockland quadrangle and the State of Maine, in which it lies, belong to a geographic and geologic province which includes nearly all of New England, together with Nova Scotia, most of New Brunswick, and the eastern townships of Quebec. This region is perhaps less clearly defined as a geologic province than are many other portions of the North American continent, but it nevertheless presents certain unifying features, giving it a character distinct from that of bordering regions.

Topographically the province has considerable diversity of form, but for the most part is an upland region. It is bordered on the southeast by the great Atlantic Ocean depression and on the northwest by the St. Lawrence Valley and the great Canadian highland beyond; on the west it includes the Green and Taconic mountains of Vermont and Massachusetts. The higher portions of this upland region are deeply incised by rivers and streams. In their lower courses some of the rivers flow in broad, mature valleys. The drainage in the southeastern and western parts of the province flows southward into the Atlantic Ocean, the principal rivers being the Connecticut, Kennebec, Penobscot, St. Croix, and St. John. The northern portion of the region drains northward and northeastward into St. Lawrence River and the Gulf of St. Lawrence, the principal drainage channels in this direction being Richelieu, Chaudiere, and Restigouche rivers. The headwaters of the St. John also flow toward the north, but in northeastern Maine the river makes a sharp turn and flows southward, a diversion probably the result of glacial action. Above the higher parts of the New England plateau rise the White Mountains of New Hampshire, the Green Mountains of Vermont, a range of lower hills in western Maine, and Mount Katahdin.

As a geologic province the region is characterized by the presence of metamorphic Paleozoic sediments and by an abundance of surface volcanic rocks and of intrusive granitic and basic rocks, of early and late Paleozoic age. The most distinctive feature is the abundance of late granitic intrusives, which in the main show a tendency to be elongate in a general northeast-southwest direction, parallel to the trend of the major structural features of the region. The sedimentary rocks are for the most part quartzites, marbles, schists, and slates, of early Paleozoic age, that have been altered by dynamic and contact metamorphism. These characters in its rocks differentiate the New England province from the Canadian highlands to the northwest, where the igneous and sedimentary rocks are largely of pre-Cambrian age, and from the Appalachian region of western New England and eastern New York, where late granitic intrusives are largely absent.

Within the New England province itself there is some diversity even in regard to the major geologic features. An important variation consists in differences in the period and the severity of regional metamorphism. Throughout Maine the Silurian rocks show little or no evidence of dynamic metamorphism and present a sharp contrast to the intensely altered beds of the Ordovician and Cambro-Ordovician. In southern New England, on the contrary, rocks as late as Carboniferous show the effects of severe dynamic metamorphism. Important variations are also observed in the relation of the Ordovician to older rocks. In the extreme western and southeastern parts of the province the Ordovician beds lie upon Cambrian rocks which in turn rest upon the pre-Cambrian. Throughout central Connecticut and Massachusetts and a part of northern New England, however, the Ordovician rocks directly overlie the pre-Cambrian.

The general northeast-southwest trend of the folds in the metamorphic sediments of the province indicates lateral pressure coming either from the southeast or from the northwest. It is probable that the thrust was initiated in the Atlantic Ocean basin and came therefore from the southeast.

It was formerly supposed that the highly metamorphic and nonfossiliferous rocks of the southern and western parts of Maine and of many other parts of the New England province were of pre-Cambrian age, but in recent years geologic work in Maine, in the Green Mountain region, in the Hudson Valley region, and in other parts of New England has tended to remove these rocks from the pre-Cambrian category and place them in the Paleozoic. In Maine this conclusion was reached as a result of detailed work in the Penobscot Bay and Rockland quadrangles, and reconnaissance work seems to extend this age determination over large areas in the southern and western parts of the State. The assignment by the Canadian geologists of a Cambrian and Cambro-Ordovician age to metamorphosed sedimentary rocks near the Maine boundary still further confirms this correlation.

The igneous activity which especially characterizes this province began in Cambrian time, volcanic rocks probably of this age being known on the Maine coast and in eastern Massachusetts. In the Silurian period volcanic activity again prevailed and was followed, probably in Devonian and Carboniferous time, by the intrusion of granitic rocks already referred to. It is noteworthy that these granites do not form a part of any Archean protaxis, as formerly held, but represent relatively late intrusions.

TOPOGRAPHY OF THE QUADRANGLE.

Relief.—The northern part of the Rockland quadrangle is a region of remarkable beauty, and in the summer attracts large numbers of visitors, many of whom have summer homes in the vicinity of Camden or Rockport. The principal charm of the region lies in the unusual combination of hills, lakes, and irregular rocky seacoast. None of the hills are of great height, Mount Megunticook, the highest, being 1380 feet and Ragged Mountain 1300 feet, but the appellation of "mountain" is to some extent justified by the abruptness of many of their slopes and by a certain magnification due to the prevailing haziness of the atmosphere in the coastal region. The group of hills represented by Meadow, Pleasant, Spruce, Ragged, Bald, and Megunticook mountains continues with decreasing prominence for a short distance north of the quadrangle. Its highest peaks, Megunticook and Ragged mountains, are, with the exception of Green Mountain, on the island of Mount Desert, the highest points in this part of the State, and on a clear day the view from the summit of Ragged Mountain is one of great extent and beauty. Fresh-water lakes are very numerous among the hills; their borders are ragged and rocky, and their surfaces are dotted with small islands.

Shore lines.—The most striking feature of the shore line is its extreme irregularity, which manifests itself especially in long, narrow tidal estuaries such as St. George and Weskeag rivers and in the multitude of little islands in the southeastern part of the quadrangle. The irregularity is characteristic to a greater or less degree of the whole of the Maine coast. It can not be accounted for by the eroding action of the ocean waves, for it is as marked in the protected coves and estuaries as in parts which are exposed to the full violence of the storms.

A glance at the topographic map of the Penobscot Bay quadrangle shows the presence of certain long, narrow channels which are largely free from islands. The Coast Survey chart of the same region shows that these are deep-water channels with depths averaging 25 to 35 fathoms, and are therefore the principal paths of navigation. The largest of these channels, which is followed by the eastern boundary line of Waldo County, is a direct southward continuation of the present Penobscot River valley. This relation suggests an explanation for the irregular coast line, namely, that a subsidence of the coast has transformed the lower portions of the old river valleys into deep marine channels and the smaller valleys into tidal estuaries, thus changing a hilly land surface into an archipelago of small islands. A shore line exhibiting these characteristics is termed a "drowned coast."

It is evident, however, that to produce the degree of coastal irregularity here observed, the contour of the land before submergence must also have been irregular to a degree somewhat commensurate with much of the present land surface. The region is characterized by a great variety of rocks distributed in a very uneven manner. Even within a single formation there are in many localities great variations in the texture and composition of the rocks, differences some of which are original while others are produced in the processes of metamorphism. Weathering and stream erosion, acting on these rocks before the advent of the glaciers, sculptured them into a succession of hills of greatly varying size and slope and irregular form. There is a complete absence of plateaus, monadnocks, or any other features indicative of cycles of erosion. Later the eroding and depositing action of the glaciers reduced to some extent the irregularities of the hills by planing off the more jagged prominences and filling up some of the depressions, but the resulting contours were still very irregular. The present topography is mainly the result of these processes, postglacial erosion having had but slight effect on the landscape.

Drainage.—The present drainage is most unsystematic, partly as a result of the preglacial irregularities in the form and distribution of the hills and partly as an effect of the blocking of the preglacial stream courses by deposits of glacial drift. Most of the streams are brooks only a few miles in length and their courses are in many places devious and obstructed by ponds or marshes. Water power is obtained along a number of them and utilized for mill purposes, notably along St. George River at Warren and along Megunticook River in the western part of Camden. On both of these streams woolen mills of considerable size are operated. The largest "river" in the quadrangle, the St. George, is in reality a tidal estuary as far inland as Warren village. Weskeag "River" is wholly a tidal estuary which receives and discharges its waters through narrows at South Thomaston. The tide runs through this gap for a considerable part of each day with a force capable of generating a large amount of power if means can be devised for its conversion.

DESCRIPTIVE GEOLOGY.

CHARACTER OF ROCKS.

INTRODUCTORY STATEMENT.

The geologic description of the Rockland quadrangle is based on a study of igneous rocks and of sediments that have suffered regional and contact metamorphism. The igneous rocks include the Devonian granites and their associated diorites, diabases, pegmatites, and flow gneisses. These rocks are intrusive in all the other rocks of the region and thus present no difficult stratigraphic problems, though they furnish interesting studies in the processes of magmatic differentiation. The main geologic problems center about the intensely folded and regionally metamorphosed sedimentary rocks, and their solution involves detailed stratigraphic work. None of the sedimentary rocks of the region are fossiliferous, but related formations in the adjacent Penobscot Bay quadrangle are associated with small amounts of fossiliferous rocks so that their age can be approximately determined. The sedimentary rocks of the quadrangle constitute a single conformable succession made up of four formations, ranging from the Islesboro slate at the base to the Rockport limestone at the top. The age of these rocks is somewhat uncertain, but is believed to be Cambrian and Cambro-Ordovician. Over two-thirds of the area of the quadrangle is occupied by the Penobscot formation and its injected and contact-metamorphosed phases. Next in areal importance are the granites and the Rockport limestone. The other rocks occupy only relatively small areas.

In the adjacent Penobscot Bay quadrangle surface volcanic rocks, of both basic and acidic types, are abundantly present and range in age from probable Cambrian or Cambro-Ordovician to Silurian. In the Rockland quadrangle, however, surface volcanic rocks are entirely absent.

SEDIMENTARY ROCKS.

ISLESBORO FORMATION.

Definition.—The name Islesboro is applied to a series of folded and metamorphosed sedimentary rocks which occupy the larger part of the island of Islesboro, in the Penobscot Bay quadrangle, but within the Rockland quadrangle are confined mainly to the point east of Rockport Harbor. The formation includes two members—the lower, composed of slate, and the upper, the overlying Coombs limestone, named from Coombs Point, on the eastern shore of Islesboro.

Areal distribution.—Within the Rockland quadrangle the lower or slate member of this formation is known to occur only in a single area extending for a few hundred feet along the eastern shore of Rockport Harbor, about midway between the head of the harbor and Beauchamp Point.

The upper or Coombs limestone member is also confined mainly to the point east of Rockport Harbor, though small areas occur one-half mile west of Simonton Corners and about 2 miles due west of Camden, near the road to Hosmer Pond. On the point east of Rockport Harbor the limestone outcrops on the northwest shore of Hog Cove and appears again in the cove west of Deadman Point, where it is exposed only at low tide. Between these two shore outcrops there are no exposures, but the strike of the beds is such as to indicate that they form a continuous strip across the intervening neck of land. Along the eastern shore of Rockport Harbor the limestone outcrops interruptedly for nearly a mile, its continuity being broken at several points by areas of the overlying quartzite folded down in small synclines, and by a single area of the underlying slates upfolded as a small anticline.

Structure and stratigraphy.—The rocks of the Islesboro formation are much folded and metamorphosed, the general form and trend of some of the larger folds being indicated by the outlines assumed by the areas of the Coombs limestone member in the vicinity of Rockport. The main area of this limestone outcropping along the east side of Rockport Harbor has a general northwesterly strike and dips to the northeast, but this simple relation is disturbed by the presence of a number of cross folds whose axes trend northeast and southwest. These cross folds find expression in the wavy outline of the eastern border of the limestone.

Superimposed upon the major folds are a great number of minor folds, many of them closely compressed and of nearly parallel trend, the resulting structure being too complicated to express on a map of the scale here used. The minor folding is well shown along the eastern shore of Rockport Harbor.

Upon Islesboro the formation occurs in a parallel succession of long, narrow folds. Locally these also are closely compressed and complicated by a great number of minor folds, with a well-developed slaty cleavage in many places. These structural features are similar to those observed in the Penobscot slate, the two formations having been folded in the same manner and to about the same degree in the same period of regional metamorphism.

The small area of argillite belonging to the Islesboro formation which occurs on the eastern shore of Rockport Harbor is brought to the surface as the crest of a small anticlinal fold which strikes a little north of east and pitches steeply to the northeast. The argillite plainly dips beneath the Coombs limestone, whose outcrops immediately succeed it along the shore both to the north and to the south. This rock is the lowest and oldest exposed within the quadrangle. The base of the formation is not exposed in the adjacent Penobscot Bay quadrangle.

The Coombs limestone member, exposed on the east side of Rockport Harbor, lies conformably above the argillite just described and is conformably overlain by the Battie quartzite, which in general dips gently to the east, although affected by a number of minor folds that produce local variations in the dip. There is no reason to think that the beds here have been overturned. On the contrary, all the folds observed within the Battie quartzite are gentle and nowhere approach overturns. On the point north of Parker Cove, Islesboro, in the Penobscot Bay quadrangle, very similar relations are observed, the Coombs limestone lying below a thick mass of Battie quartzite which dips about 50° SE. Here, as at Rockport Harbor, there is no evidence of overturning of the beds.

The exact contact between the Coombs limestone and the Battie quartzite is well exposed at both of the small limestone areas on the western shore of Rockport Harbor. The change from one to the other is abrupt, but there is perfect conformity. These two patches, as well as the small areas near Simonton Corners and 2 miles west of Camden, are brought to the surface in anticlinal folds, as are the quartzite masses with which they are associated.

The thickness of the Coombs limestone in the Rockland quadrangle varies somewhat, but seems not to exceed 75 feet nor to fall below 30 feet. On Islesboro, in the Penobscot Bay quadrangle, it ranges from 8 feet to nearly 100 feet, these variations being as a rule, accompanied by important lithologic changes. The thickness of the slate member is unknown, the base being nowhere exposed.

Lithology.—The rocks of the small area of Islesboro argillite outcropping on the eastern shore of Rockport Harbor can not be distinguished lithologically from the commoner phases of the Penobscot slate. They are dark-gray to purplish argillites and reveal their bedded character in an alternation of compact, fine-grained layers of somewhat micaceous quartzite with beds originally of more shaly composition. The latter have a more abundant and coarser development of mica than the quartzitic beds, and show numerous "knoten." Only in a few places do they exhibit well-developed slaty cleavage.

The Coombs limestone is nearly everywhere exceedingly impure. As a rule the impurity consists in a great abundance of shaly layers, but on Islesboro, in the Penobscot Bay quadrangle, arenaceous phases are also found. In a few places, as along the road which parallels the eastern shore of Rockport Harbor, a few rather massive and pure beds occur, but their thickness is not great enough to make them of economic importance. Along the shore of Rockport Harbor the limestone is very thin bedded and shows much minor folding. A peculiar feature exhibited by some of the minor folds is the presence of thin siliceous layers which cut across the bedding planes at varying angles but maintain a subparallelism among themselves. They are confined largely to the more calcareous layers, which are presumably the layers that were least resistant in the folding. The siliceous layers probably represent secondary fillings by solution and deposition along planes of cross fissility on the crests of the folds and of parallel fissility on the limbs. Such fissility would be most perfectly developed in the less resistant layers.

On the western shore of Rockport Harbor few of the purer beds in the limestone exceed 5 inches in thickness. On Islesboro the limestone was present at two localities in sufficient quantities to be quarried and burned for lime, but it was too siliceous and its quantity too small to make the venture profitable.

Age.—The age of the Islesboro formation can not be determined from relations shown within the Rockland quadrangle, but in the Penobscot Bay quadrangle these rocks on southern Islesboro and the neighboring islands are interbedded with fragmental volcanics belonging to the North Haven greenstone. It is also probable that the prevailing greenish tone of much of the slate on this island is due to admixture of volcanic mud and dust from the volcanoes which erupted the greenstones. The Islesboro argillites and the North Haven greenstone are therefore about contemporaneous, and on the island of North Haven this greenstone underlies fossiliferous sediments of Silurian age. The greenstone is shown to be considerably older than these fossiliferous rocks by the presence of a pronounced unconformity between them and by the fact that the greenstone has been much affected by regional metamorphism, whereas the sediments are relatively little disturbed.

If the relations outlined above are correct, the Islesboro argillite is considerably older than Silurian. It is provisionally classed as Cambrian, for reasons discussed in the section entitled "Historical geology."

BATTIE QUARTZITE.

Name.—The Battie formation is named from the locality of its best and most extensive exposures—Mount Battie, near Camden. This mountain is composed almost entirely of a conspicuous quartzite which outcrops in large, clean-surfaced ledges. Excellent exposures occur along the footpath leading up the southeastern slope of the mountain from the village to the summit, and especially fine exposures are found on the summit just northeast of the clubhouse.

Distribution and stratigraphy. — The Battie quartzite is confined to the northeastern part of the quadrangle, and outcrops most abundantly near Rockport and Camden. The largest area is that of Mount Battie, extending southwestward from the col between Mounts Battie and Megunticook to the road between Camden and Hosmer Pond. Beyond this road no exposures of the quartzite occur, but the presence of a single outcrop of the Coombs limestone member of the Islesboro formation south of the road indicates that the overlying quartzite also continues somewhat farther to the south. The bands of pebbles in the quartzite indicate the true bedding planes. Dip measurements on these bands show that on the southeastern slopes of Mount Battie the prevailing dips are southeasterly, on the southwestern slopes they are southwesterly, and on the northern slopes they are northerly. Near the summit the dips are rather low; thus just north of the Mount Battie clubhouse bands of pebbles strike N. 75° W. and dip 30° N. These observations indicate that the mountain is a dome of quartzite. Structurally, the rocks of this whole area lie in a northeast-southwest anticline which is domed up and broadened in the vicinity of Mount Battie. There is a small area of quartzite conglomerate three-fourths mile southeast of the summit of the mountain, separated from the Mount Battie area by Penobscot slate.

The second largest area lies between Rockport and Simonton Corners and seems also to have a domelike structure.

The relations between the Battie quartzite and the adjacent formations are best exhibited in the area along the east side of Rockport Harbor, where the quartzite outcrops as a narrow band about one-eighth mile in width dipping eastward under the Penobscot slate at angles of about 40° to 50°. This dip and width of outcrop indicate a thickness of 400 to 500 feet.

A small quartzite area lies a short distance south of Ogier Point. Here the quartzite seems very plainly to come up from below the Penobscot slate; its continuity along the shore is interrupted in one place by a small mass of Penobscot slate plainly overlying the quartzite in a small synclinal fold. As its form suggests, the quartzite area of Ogier Point occupies the crests of two parallel and closely adjacent anticlinal folds trending slightly west of north.

The southern of the two quartzite areas along the western shore of Rockport Harbor also exhibits an anticlinal structure. At both its northern and southern borders along the shore the quartzite plainly comes up from beneath the Penobscot slate, and near the middle of the quartzite on the shore a narrow area of the underlying Coombs limestone member marks the crest of the southwestward-pitching anticlinal fold. Similar relations are observed in the quartzite which extends as a narrowing belt from the northern part of Rockport Harbor toward Simonton Corners, but the relation to the Penobscot slate is not so well shown as it is farther south. Here also the crest of the anticlinal fold is marked by a small shore outcrop of the Coombs limestone.

On the east side of the point east of Rockport Harbor quartzite occurs west of the limestone in the cove west of Deadman Point and is also present west of the limestone along the shore opposite Goose Rock. Between these shore exposures there are no outcrops, but the strike of the beds is such as to indicate that the quartzite is continuous across the intervening belt. Quartzite is exposed at low tide east of the limestone in the cove west of Deadman Point, but no exposures occur east of the limestone on the shore of Hog Cove or on the intervening neck. The presence of a considerable amount of quartzite on Hog Cove ledge indicates, however, that the quartzite does cross the neck. Structurally, therefore, the central belt of Coombs limestone bordered on the east and west by quartzite represents an anticlinal fold.

About one-half mile southwest of Simonton Corners occurs a single ledge of typical quartzite conglomerate bordered on the north by an outcrop of limestone not more than 30 feet in width. Presumably these rocks are brought up as an anticlinal fold, the limestone being the underlying Coombs limestone. Another small anticline brings the quartzite conglomerate to the surface just beyond the northern extremity of Rockland Harbor, and a small patch of massive quartzite also appears on the shore about one-half mile north of Jameson Point.

Pine Hill, north of Clam Cove, consists of buff-colored, somewhat feldspathic quartzite.

On the western part of the summit of Mount Megunticook there are two small masses of quartzite, each of which is about 100 feet wide and 300 to 400 feet long. The rock here is buff to reddish in color and shows much recrystallization. In places it is cut by a complex network of minute quartz veins, mostly 1 inch or less in thickness; in other places a distinct schistosity has been developed. This is the most highly altered phase of the quartzite observed in the region. The bordering rocks are andalusite schists, with andalusite crystals averaging one-fourth inch in thickness, and are intensely metamorphosed phases of the Penobscot slate.

A small patch of quartzite conglomerate of the Mount Battie type outcrops on the peninsula at the south end of Megunticook Lake.

Lithology.—In the Rockland quadrangle the most widespread phase of the Battie quartzite is a conglomerate. This rock is light gray in color when freshly fractured but becomes buff or pinkish on weathered surfaces. It contains quartzite pebbles in a matrix of almost identical composition, though in places slightly darker in color from a greater number of shaly constituents. Some of the pebbles are 6 inches in diameter, but in the main they are under 2 inches. Most of them are somewhat rounded and show little evidence of elongation or slicing, and they are usually arranged in bands from a few inches to several feet thick and separated from each other by beds of massive quartzite or by finer conglomeratic beds. These beds serve as indices of the true strike and dip of the formation. Massive quartzites, besides being interbedded with the conglomerates, make up the bulk of certain areas of Battie quartzite, notably the Pine Hill area near Clam Cove and the southern area along the western shore of Rockport Harbor. Most of the quartzite of the Pine Hill area is distinctly though not very highly schistose.

Microscopic examination shows a filling of finely divided muscovite between the quartz grains in most of the specimens. This represents an original clayey component and shows that most of the quartzite was somewhat argillaceous. Where the micaceous matrix is present, the original outlines of the quartz grains have usually been well preserved, most of them not being well rounded. In specimens where there is little or no micaceous matrix the quartz grains interlock in the irregular manner characteristic of recrystallized quartz rocks. Dynamic action is indicated in many of the thin sections by parallel elongation of the quartz grains, by undulatory extinction, and by granulation. The well-defined schistosity observed in some localities is due largely to a subparallel arrangement of the mica plates. In many places hematite, magnetite, and pyrite are abundant constituents and upon weathering give the rock a rusty appearance. In a few specimens chlorite is also abundant.

Age.—The age of the Battie quartzite is tentatively placed as Cambrian, for reasons which are set forth in the section on historical geology.

PENOBSCOT FORMATION.

The Penobscot formation is composed of metamorphosed shaly sediments which are typically developed along nearly all of the western shore of Penobscot Bay and occupy considerable areas between the bay and Kennebec River. Two phases are recognized—(1) the sediments affected simply by dynamic or regional metamorphism and (2) those which besides suffering dynamic metamorphism have been further altered at a later period by contact with intrusive granite and diorite.

DYNAMIC METAMORPHIC PHASE.

Areal distribution. — If the small associated masses of other sedimentary rocks are disregarded, the dynamic metamorphic phase of this formation may be described as forming a single belt extending from the north border of the quadrangle near Mount Megunticook southward and southwestward to Rockland and Thomaston and thence to Cushing. The greatest width of this belt, about 5 miles, is in the latitude of Thomaston; between Thomaston and Cushing it narrows to only a mile and from a point a mile or more south of Thomaston it lies wholly west of St. George River. Good exposures occur along the shores of Camden and Rockland harbors and on Ingraham and Beach hills. North of the Rockland quadrangle the same belt continues as far as Lincolnville Beach, where the contact-metamorphosed phase begins to appear. The latter extends northeastward to Little River, in the Penobscot Bay quadrangle, beyond which the dynamically metamorphosed phase again becomes dominant and continues northeastward beyond Searsport and Bucksport. Southwest of the Rockland quadrangle the belt of Penobscot slate extends as far as South Cushing and Pleasant Point.

Lithology.—The rocks of the Penobscot formation which were unaffected by contact metamorphism are phyllites, pelite schists, argillaceous quartzites, and small amounts of true slate. The fresh surfaces range in color from light gray through steel gray and purplish gray to black, the darker grays predominating. Many of the weathered surfaces are rusty. Most of these rocks cleave rather readily along planes of schistosity which are developed to varying degrees of perfection at different localities and in different beds at the same locality. The most quartzose layers exhibit little or no schistose structure; less quartzose beds show widely spaced, highly micaceous surfaces of easy parting. The original argillaceous varieties are extremely micaceous throughout, but the secondary mica is usually present in very minute flakes.

Certain bands, in places only 6 inches or so in width, may be "knoten" schist, while the adjoining layers are ordinary phyllite or are quartzitic. In such cases the "knoten" seem to have developed only in the more argillaceous strata, thus preserving or even accentuating the original bedding. Good examples of this are found on the point east of Sherman Cove, near Camden.

A noteworthy andalusite schist occupies considerable areas on the summit and slopes of Mount Megunticook. The groundmass of this rock is nearly black in color and is crowded with square prismatic crystals of andalusite variously oriented. Most of these crystals are from one-eighth to one-fourth inch in diameter and from one-half to 1 inch in length. On the summit of Ingraham Hill, 1 mile south of Rockland, the rock is an exceedingly fine grained phyllite, much contorted and nearly black.

On the 140-foot hill due north of South Thomaston the rock plainly represents an arkose and shows numerous angular and rounded fragments up to one-eighth inch in size and brown, bluish, and buff in color. A somewhat similar rock occurs on the hill about one-fourth mile north of the head of Rockport Harbor. At several points near the contact between the Penobscot formation and the Rockport limestone, north and northeast of the head of Rockport Harbor, the Penobscot is conglomeratic, bowlders of buff to light-gray quartzite up to 1 by 2 feet in size, but usually much smaller, being embedded in a schistose matrix that is mainly argillaceous but in a few spots becomes quartzitic. Conglomerate resembling this to some extent occurs on the shore about one-half mile south of Brewster Point. Some of the smaller pebbles at this locality are quartzitic, but the larger pebbles, some of them 6 to 7 inches long, are shaly. These conglomerates are wholly different in appearance from the quartzite conglomerate of Mount Battie. Quartzitic phases occur on the west side of Ingraham Hill and near the Maine Central wharf on Atlantic Point, in Rockland.

Calcareous beds in the Penobscot formation outcrop along the shore at the head of Clam Cove and along the south side of Jameson Point. At the latter place the shaly limestone is seen to be only 8 to 10 feet thick and is succeeded above and below by phyllites. Limestone outcropping in a small cave on the southwestern slope of Bear Hill, near Chickawaukie Pond, is probably of similar character.

Microscopic examination of typical specimens of the rocks of this formation which have not been affected by contact metamorphism shows that quartz and muscovite are the most abundant constituents, their relative abundance varying greatly in the different varieties. The quartz shows undulatory extinction and gives evidence of extensive recrystallization in the irregular manner in which the grains interlock. The muscovite is usually accompanied by chlorite and locally by hornblende, these minerals having a subparallel arrangement, thus giving the rock a more or less perfect schistosity. Magnetite is generally present in small, irregular grains and in places is very abundant.

The andalusite schist of Mount Megunticook shows under the microscope a groundmass consisting of an irregular aggregate of quartz and some feldspar through which finely divided magnetite is scattered in such abundance as to render the rock almost black in the hand specimen. The muscovite occurs in large plates and also in aggregates of very minute shreds. Scattered abundantly through the groundmass are andalusite crystals, whose outlines are rendered more or less irregular by inclusions and embayments of the groundmass.

Structure and stratigraphy.—The sedimentary character of this formation is shown at many points by the presence of distinct bedding planes. Considered in its larger relations the formation is rather flat lying, its thickness being slight as compared with its large areal extent. The beds have, however, been thrown into a large number of folds in which most of the dips are steeper than 45°. In some areas the folding is nearly isoclinal, the beds over several miles dipping at slightly varying angles in the same general direction; this is the case in the region east of Lilly Pond, near Rockport, where the dips are nearly all to the northeast. The prevailing strike of the beds is about N. 20°–30° E., or about parallel to the general trend of the major folding of the region. There are notable variations from this usual direction, but they are local and are apparently the result of cross folding. Superimposed upon the major folds are a great number of minor folds of nearly parallel trend, many of them closely compressed. These are well shown on the north side of Atlantic Point, in the southern part of Rockland, and just north of the northernmost pier along the Rockland water front.

In the folding of these sediments a well-defined schistosity has usually been developed. The strike of the planes of schistosity is nearly parallel to the general trend of the folds; the dip of the planes is generally about vertical, so that they may intersect the bedding planes at any angle, though in most cases this angle is small. True slaty cleavage is present here and there. As may be inferred from the foregoing description, it is as a rule impossible to work out the details of structure in the formation, because of the complex folding and because the bedding is more or less obscured by a schistose structure. In the few localities where structural details can be worked out it is not possible to represent them on a map of the scale used in this folio. In the structure sections it has been necessary to generalize on the basis of the known character of the folding revealed at a few places.

The stratigraphic relations between the Penobscot and the other sedimentary formations of the quadrangle are best shown on the point lying to the east of Rockport Harbor. Here the Penobscot phyllites and schists may be traced downward without break into the Battie quartzite, and they are conformably overlain by the Rockport limestone. The upward gradation from typical Penobscot argillite through calcareous argillite into limestone is well shown in the small cove just northwest of Beauchamp Point.

The thickness of the formation can not be directly measured but can be inferred from its width of outcrop in localities where the underlying and overlying formations are also exposed. On the western part of the point east of Rockport Harbor the minimum width of the Penobscot formation exposed between the Battie quartzite and the Rockport limestone is about one-eighth mile. About one-half mile due west of the head of Rockport Harbor approximately an equal width of the Penobscot formation is exposed between a small infolded mass of Rockport limestone and two adjacent areas of Battie quartzite. These observations show that in the vicinity of Rockport the Penobscot formation has a thickness of not more than 700 feet. In other areas, especially in the western part of the Penobscot Bay region, its thickness is probably greater. This may be inferred from the absence, over large areas where the rocks are closely folded, of any exposures of the rocks immediately below or above this formation.

Age.—The Penobscot formation, like the underlying Battie quartzite and Islesboro formation, is thought to be of late Cambrian age. The reasons for this correlation are set forth under the heading "Historical geology."

CONTACT-METAMORPHOSED AND INJECTED PHASES.

Areal distribution. — Rocks belonging to the Penobscot formation which have suffered contact metamorphism by injected granitic and basic rocks as well as dynamic metamorphism occur in the region between Owlshead and South Thomaston and along both sides of St. George River from a point about $1\frac{1}{2}$ miles below Thomaston to the southwest corner of the quadrangle. They are also the most abundant rocks throughout the western and northwestern portions of the quadrangle. The latter body has been traced northeastward to a connection with the area of contact-metamorphic Penobscot slate and schist between Ducktrap Harbor and Little River, in the Penobscot Bay quadrangle. It has also been traced westward nearly to the western border of Knox County and may extend much farther. In the region between Weskeag and St. George rivers small amounts of rocks belonging to the Rockland formation are included within the area mapped as metamorphosed and injected Penobscot formation.

Structure.—Where the Penobscot sediments have been affected by contact metamorphism, the bedding has for the most part been completely obscured and no structural details can be worked out. In many places a rock of gneissic texture is produced by the intimate intrusion of granite between the schist foliæ, and in most localities the schist is so intermixed with gneiss of this type, with igneous or flow gneiss, and with pegmatitic and normal granite that the separation of these rocks on the map is wholly impracticable. The phenomena of contact metamorphism are more fully discussed in the section on granite (pp. 6–7).

Lithology.—The contact-metamorphic rocks of the Penobscot formation are mostly mica schists which are notably coarser than those produced by regional metamorphism only. The mica plates are in the main of megascopic proportions, though few of them exceed one-eighth inch in length. In one locality, however, $1\frac{1}{2}$ miles southwest of West Rockport, the mica plates are one-eighth to one-fourth inch in diameter. The recrystallization of the rocks has been so complete and the schist foliæ are so contorted that usually these schists split less readily than most of the normal schists of the formation, some phases being almost massive. The secondary minerals, garnet, andalusite, and staurolite, are developed in greater abundance and in greater size than in the dynamic metamorphic phase. A specimen of schist obtained 1 mile northeast of Beach Hill contains much brown tourmaline and numerous small garnets.

Microscopic examination of a rock from the summit of Spruce Mountain, representing a contact-metamorphic phase of the formation, shows that quartz and muscovite are the most abundant constituents and that both are much coarser than in the dynamic metamorphic phase. The muscovite, though mostly in large plates, also occurs in aggregates of minute subparallel shreds. The quartz shows undulatory extinction and its irregular borders indicate complete recrystallization. Chlorite, mainly of the pennine variety, and brown, highly pleochroic biotite are also very abundant, but occur in somewhat smaller plates than the muscovite. Nearly colorless garnets are abundant in certain layers in the schist. Magnetite occurs plentifully in small irregular masses, usually inclosed by or closely associated with the chlorite. A single crystal of microcline was observed and several crystals of plagioclase feldspar.

A schist from the eastern shore of St. George River one-half mile south of Hospital Point, near a mass of intrusive granite, is not highly foliated and differs megascopically from many common varieties of the dynamic metamorphic sediments only in being flecked with larger mica plates. Under the microscope its difference from the dynamic metamorphic schists is more apparent. The rock is a hornblendic quartzite in which the hornblende crystals show a subparallel arrangement that produces the imperfect schistosity. The hornblende is somewhat altered to chlorite. Magnetite is scattered abundantly through the rock in grains, most of which show crystalline outlines. There are a few grains of plagioclase feldspar. The muscovite plates which gave a "flecked" appearance to the hand specimen are seen to reach diameters of one-sixteenth inch and to possess diverse orientations with respect to the schistosity. Some of them trend directly across the schistosity and they inclose grains of quartz, magnetite, and hornblende similar in every way to those in the main mass of the rock. Plainly, these large muscovite crystals formed subsequent to the development of the schistose structure in the rock. Probably this structure was brought about during the regional metamorphism, and the large muscovite plates resulted much later from contact metamorphism.

ROCKLAND FORMATION.

Definition.—The Rockland formation is made up of folded and metamorphosed sedimentary rocks and is best developed just west and southwest of Rockland. The formation includes three members—the Weskeag quartzite, a siliceous limestone member, and the Rockport limestone. The last named constitutes the greater part of the formation even where the other members are present.

Areal distribution.—The Weskeag quartzite member is confined wholly to the vicinity of Rockland and Weskeag River. Its easternmost exposures are in the southwestern part of the city of Rockland, just west of Broadway; its northernmost exposures about midway between Limerock and Middle streets, about one-fourth mile west of Broadway; its westernmost exposure along the shore of St. George River just west of Hospital Point; and its southeasternmost exposures between the 100-foot and 140-foot hills situated $1\frac{1}{2}$ miles northwest of South Thomaston. The quartzite is present only locally between the Penobscot formation and the limestone members of the Rockland formation, its principal development being in the region southeast of the main Rockland-Thomaston limestone belt. The best and most extensive outcrops occur on the 140-foot hill southeast of Marsh Brook and on the 120-foot hill northwest of this brook. On the east side of the main limestone belt the quartzite dies out toward the north and at Blackinton Corners is entirely absent, the limestone here being directly succeeded to the east by the argillites of the Penobscot formation. The western border of the main belt of Rockport limestone is concealed for its whole length by surficial deposits, but presumably the quartzite is not present along this margin because it is wholly absent about the small outlying limestone area situated on the south slope of Mount Battux.

The siliceous limestone member, like the Weskeag quartzite, is confined to the region southwest of Rockland, the two members usually occurring together. Its outcrops are most numerous about the borders of the narrow limestone belts lying southeast of the main Rockland-Thomaston belt. It is well exposed on the north side of Limerock street a short distance west of Broadway, where it has been quarried to some extent for road material. Excellent exposures also occur on the 120-foot hill northwest of Marsh Brook, and west of the limestone on the 140-foot hill $1\frac{1}{2}$ miles northwest of South Thomaston.

The largest area of the Rockport limestone member extends from Chickawaukie Pond to Thomaston, where its southernmost exposures are seen in the yard of the State prison. The length of this belt is 5 miles and its average width about a mile. The second largest area extends from the eastern shore of Rockport Harbor northward to Lilly Pond, and thence assumes a more westerly trend, including the Jacobs quarry on the electric railroad between Rockport and Camden and extending west of this road for a little over a mile. After a short interruption, the limestone reappears just west of Simonton Corners, where it is present in the Eells quarry. Next in commercial importance is the deposit 2 miles northwest of the village of Warren and just outside of this quadrangle. This deposit is relatively small and its trend is similar to that of most of the other areas. Several narrow belts occur between the Warren deposits and Alford Lake and southeast of the main belt in the vicinity of Rockland.

Structure and stratigraphy.—The rocks of the Rockland formation have been folded and largely recrystallized in the dynamic metamorphism which has affected this region. Only in a few localities is it possible to determine the true sequence of the several members and the stratigraphic position of the formation as a whole with respect to the other sedimentary formations of the quadrangle.

Along the old country road about one-half mile north of Blackinton Corners and at a large number of localities in the Camden-Rockport area the Rockport limestone may be observed to pass directly and conformably into the rocks of the Penobscot formation, but only on the point east of Rockport Harbor is it clearly shown which formation lies above the other. Here beds of Battie quartzite showing a general dip to the northeast of about 50° are succeeded conformably by Penobscot slate, which in turn passes conformably into Rockport limestone. In view of the open, gentle folding which characterizes the Battie quartzite in other parts of the quadrangle, it is extremely improbable that its beds at this point have been overturned. The succession from Battie quartzite below through Penobscot schist into Rockport limestone seems therefore to represent the order in which the beds were originally deposited. The Weskeag quartzite and siliceous limestone members are absent at this locality.

The structural relations between the three members of the Rockland formation are best exhibited on the eastern slopes of the 140-foot hill situated $1\frac{1}{2}$ miles northwest of South Thomaston. Here is exposed the south end of one of the small outlying folds of the Rockport limestone member, the beds of the siliceous limestone member are plainly seen to dip northward beneath the purer limestone, and the quartzite beds in turn dip in the same direction beneath the siliceous limestone. In such a situation as this there is no opportunity for overturning of the beds and the sequence observed must be that in which the beds were originally laid down. The Weskeag quartzite is therefore older than the siliceous limestone member, which in turn is older than the Rockport limestone. The transition from the quartzite to the siliceous limestone is rather abrupt, but there is perfect conformity. The contact between the Weskeag quartzite and the Penobscot formation is best exhibited in Rockland just north of Limerock street about one-fourth mile west of Broadway; the two are conformable but pass into each other rather abruptly.

The distribution of the various members of the Rockland formation southeast of the main limestone belt near Rockland may be taken as an index of the character of the folding in the larger belts of Rockport limestone and also in the Penobscot formation. However, the presence there of the resistant bed of Weskeag quartzite has tended to make the folding slightly more open than in certain other parts of the region. The long, narrow limestone belts of this area represent downfolds or synclines and involve only the lower beds of the limestone member.

The Rockland-Thomaston belt of limestone constitutes a synclinorium—that is, a broad downfold of limestone complicated by a large number of smaller folds having the same general trend. The main fold is not perfectly symmetrical, its northwest side being relatively steep; as a result the limestone terminates abruptly on the northwest, whereas to the southeast the gentler average dip manifests itself in the small outlying limestone troughs already mentioned. In the earth movements which have affected this region the Rockport limestone has yielded much more readily than the Battie or Weskeag quartzite or even the Penobscot formation, so that the folds of the limestone are very sharp or entirely closed.

The limestone has also been so completely recrystallized that the original bedding has been modified or obscured. In many of the quarries of the Rockland-Thomaston belt the rock is so homogeneous in color and texture that no traces of bedding can be recognized, but in others the rock shows very conspicuous banding of blue-gray to purple layers between bands of light gray or white. On the wall of the Gay quarry, about 2 miles southwest of Rockland, the banding exhibits a small anticlinal arch about 20 feet across. Most of the bands are very narrow, but some are as much as 10 inches wide. There can be no doubt that the broader color bands represent planes of original sedimentation. It is probable that the finer bandings, however, if present at all in the rock before metamorphism, have been much modified and accentuated during the recrystallization of the limestone. Prominent banding of this sort is not generally present in unmetamorphosed limestones, and it seems probable that the recrystallization has resulted in a purification of certain bands and a concentration of the impurities in others.

Another evidence of the close compression which the limestone has suffered is found in the form of a number of intrusive diabase dikes which have been folded with the limestone. One of these dikes, 2 to 3 feet in width, well exposed on the southern wall of the Blackinton quarry just south of the corner of Limerock street and the old county road, has apparently been pinched apart in the close folding in much the same way that a piece of putty may be pinched in two between the thumb and forefinger. The limestone face forming the east wall of a small abandoned pit just south of this quarry shows a peculiar waviness, and on closer inspection the limestone is seen to constitute only a thin layer conforming to the surface of the same diabase dike which is exposed in the Blackinton quarry. Here the dike has been "pinched" in a large number of places and in a most irregular manner. What is probably the same dike appears farther south on the west wall of the Nellie Ulmer quarry, near the Park street iron bridge. Here the maximum width is only 15 inches and the diabase has been fractured so irregularly as to show a very jagged outline. It presents an instructive example of the contrasting ways in which rocks differing in composition and rigidity are affected by the same deforming forces. The brittle diabase has yielded by fracture, while the limestone has yielded by flowage, its banding conforming in gentle curves to the broken surface of the diabase. In the abandoned Levensaler quarry three-fourths mile north of Thomaston several hard quartzitic beds from 1 inch to 3 inches thick in the limestone have been fractured in the folding in much the same manner as the diabase dike referred to above.

Differential movement between the beds after the period of intense folding and metamorphism is indicated in a number of the limestone quarries by the presence of slickensided surfaces. On the east wall of the Blackinton quarry these scratches occur over a space 50 feet high by 200 feet long. In the Nellie Ulmer quarry they cover almost the whole of the vertical east wall and are nearly horizontal in position, thus indicating movement between the beds in a direction parallel to the general trend of the folds.

The major part of the folds within the main Rockland-Thomaston belt of limestone are nearly upright in position, but a few are notably inclined. In the Creighton quarry, 2 miles southwest of Rockland, near the new county road, the axial planes of the folds dip to the northwest at about 60°, so that the western wall of the quarry is overhanging. In the Gay quarry, on the east side of the old county road, the west wall is curved, the curvature amounting to more than 10 feet. Almost the whole of this face, 250 feet long by 100 feet high, is covered with steeply dipping slickensides.

Cross folds with axes highly inclined to the axes of the main folds are recognized within the Rockland formation at many points. Southeast of the main limestone belt near Rockland they manifest themselves in the discontinuous character of many of the narrow limestone belts. On the north slope of the hill south of the clubhouse of the golf club in Rockport a cross anticline causes considerable eastward deviation of the west border of the Rockport limestone. Within the main limestone belt near Rockland the cross folds are the cause of the variations in trend observed in some of the limestone "veins," notably in the abandoned quarries which form the southeastward continuation of the O'Neil "hard-rock" quarry.

Thickness.—The thickness of the Weskeag quartzite at the point where it outcrops in Rockland about one-fourth mile west of the corner of Limerock street and Broadway must closely approximate its width of outcrop—250 to 300 feet—for the beds there are highly inclined. At the 140-foot hill 1½ miles northwest of South Thomaston the thickness may somewhat exceed this amount, although the large area of surface exposures here is mainly the result of a doming up of the quartzite by a cross anticlinal fold. The width of outcrop of the siliceous limestone member at the first of the above-mentioned localities is 100 to 150 feet, and this is probably not far in excess of its thickness. An exposure in a drainage ditch about one-half mile due south of the Park street iron bridge over the limestone quarries shows a thickness of only 75 feet for this member. The thickness of the Rockport limestone can not be estimated with even the approximate degree of accuracy attained in the case of the other two members. In the Rockland region it is known to be at least 400 or 500 feet and may reach two or three times this figure.

Lithology.—The Weskeag quartzite member differs from the Battie quartzite in the total absence of conglomeratic forms and in being, for the most part, thin bedded. As a rule outcrops of the Battie quartzite still preserve the smooth, rounded surface given to them by the overriding glaciers, whereas ledges of the Weskeag quartzite usually show a hackly surface over which small angular quartzite fragments are scattered more or less abundantly. The prevailing color is yellowish gray on freshly fractured surfaces and buff-brown on weathered surfaces. In many places the upper surfaces and joint planes are coated with a thin layer of iron rust. Locally somewhat shaly beds are present, but sheared phases were not observed.

Quartzite collected just north of Limerock street, in the western part of the city of Rockland, shows under the microscope a considerable amount of microcline associated with the quartz and also a small amount of finely divided muscovite between the quartz and feldspar grains. The quartz grains interlock in the irregular manner characteristic of recrystallized quartz rocks, and show high undulatory extinction, indicative of dynamic action.

The siliceous limestone member is made up for the most part of hard, tough rocks of prevailingly greenish-gray color, some of which are mottled or banded purplish brown and greenish gray. They are usually fine grained, though in some places the constituent grains reach a length of one-eighth inch. In the coarser phases the abundance of fibrous minerals gives a somewhat satiny luster to the freshly fractured surfaces. Many varieties are calcareous and effervesce somewhat with acid; in the more calcareous portion considerable amounts of greenish talc are usually present. The greenish color and satiny luster of these rocks distinguish them readily from all other sedimentary rocks of the quadrangle. Their presence is a valuable indication of proximity to the purer limestone.

Under the microscope the most common phases of this member are seen to be highly siliceous. A specimen from the north side of Limerock street, about one-fourth mile west of Broadway, shows quartz and tremolite as its principal minerals, with considerable amounts of zoisite and calcite and a few grains of microcline. Tremolite forms much the largest crystals in the rock and usually incloses numerous quartz grains and some of feldspar. A specimen from the east side of "The Marsh," a short distance south of Dunton's quarry, consists largely of tremolite in prisms and needles which reach a length of one-eighth of an inch. With this mineral are associated zoisite, calcite, and titanite. The rock probably represents a slightly calcareous, fine-grained quartzitic shale, which has been wholly recrystallized in the metamorphism so that it now consists mainly of secondary minerals.

The Rockport limestone is virtually a marble, although it is either too coarse, too dark colored, or too much fractured to be used for ornamental or building purposes. In color the rock ranges from dark purplish gray to pure white, the commonest colors being light gray and dark blue-gray; banded varieties showing alternate grayish-white and dark blue-gray layers are also very common. The constituent grains are usually under one-sixteenth inch in diameter, and in some occurrences are too small to be recognized with the unaided eye, but here and there they may reach a diameter of one-fourth inch.

One of the commonest varieties of the limestone in the main Rockland belt, a variety extensively quarried for lime making, shows conspicuous banding of white or gray layers with layers that are blue or purplish. This rock is well exhibited in the easternmost range of quarries of the Rockland-Rockport Lime Company. The "soft rock" of the quarrymen is mainly of this type, and is so called because it is more easily quarried and broken up than most of the unbanded, darker-colored varieties. A finely banded specimen from the Gay quarry shows gray bands with grains of an average size of about one-sixteenth inch alternating with finer-grained bands of dark purplish-gray tint. The bands show some contortion. Under the microscope the light bands are seen to be made up of practically pure calcite in interlocking grains. Calcite in smaller grains also forms the main part of the darker bands, their gray color being due to the presence in the calcite of a large amount of very finely divided, more or less opaque material, whose exact character is indeterminate. It probably represents an original clayey or carbonaceous constituent. Small grains of pyrite occur here and there in the darker layers but are almost never seen in the lighter ones.

Other types also classed by the quarrymen as "soft rock" are light gray in color and are only very indefinitely if at all banded. Rock of this type occurs associated with the banded phases in the Blackinton farm quarry and in the Eells quarry near Simonton Corners.

Much of the limestone in the large belt near Rockland is rather uniformly dark blue-gray to purplish blue in color, though showing some irregular mottling. This rock effervesces freely with acid, but is not pure enough to be used in lime manufacture. It is the so-called "bastard" rock of the quarrymen.

Other varieties of the limestone which are as dark in color as that above referred to and are only with difficulty distinguished from it are relatively free from siliceous or aluminous material and are successfully used in the manufacture of lime. They are somewhat lighter in weight than the worthless varieties. This material is more difficult to quarry than the soft rock, and is termed "hard rock" by the quarrymen. It is well exposed in the Fred Ulmer hard-rock quarry and in the O'Neil quarry belonging to the western range of quarries of the Rockland-Rockport Lime Company.

In nearly all portions of the Rockport limestone scattered small veins of calcite are present, and some of the calcite is of the fibrous variety. In some of the quarries veins of buff to greenish talc also occur, but these as a rule are not numerous enough to render much of the rock unfit for burning.

A rock outcropping between the Nellie Ulmer quarry and the "hard rock" quarries next to the west and appearing less extensively at a few other points in the main Rockland belt is rendered valueless for lime-making purposes by the abundant development within it of silicate minerals. By the quarrymen it is called "grasshopper rock," from the fancied resemblance of some of the long prismatic or brushlike crystals to the legs of grasshoppers. The most abundant of these minerals is tremolite, occurring in brushlike aggregates of fibers averaging about one-half inch in length. Blue-gray diopside is present in square prisms one-half to three-fourths inch long and one-sixteenth to one-eighth inch in diameter. Wollastonite occurs locally in prisms some of which have a diameter of one-fourth to one-half inch. These prisms inclose much unreplaced calcite and are therefore softer than pure wollastonite and effervesce somewhat with acid. All these minerals are silicates of calcium or of calcium and magnesium.

Intraformational limestone conglomerates occur at several localities, especially in the Lilly Pond limestone area near Rockport. One of the best exposures is at the south end of this pond, where the conglomerate is made up of limestone pebbles mostly under 1½ inches in diameter but in places as much as 4 inches, lying in a matrix so similar to the pebbles that it is only where they stand out in relief on the weathered surfaces that they can be differentiated at all. Most of the pebbles are well rounded, but some are angular. They are largely concentrated along certain layers which represent original bedding planes. The pebbles have been fractured somewhat and for the most part are elongate parallel to the bedding. This direction, however, is also the trend of the schistosity in the neighboring schists, so that the elongation may have been produced in regional metamorphism.

West of Lilly Pond one fragment in the conglomerate was 4 inches wide by 8 inches long. Good exposures also occur about due south of Lilly Pond along the north side of the road which skirts its southern and eastern sides. About one-half mile west of the north end of the pond some of the pebbles lying in the limestone matrix are quartzitic, but may have been produced from limestone pebbles by replacement. Conglomeratic phases of the limestone are also abundant about the old quarries near the west end of this limestone belt.

Dolomitic varieties of the Rockport limestone are confined largely to the small outlying limestone belt southeast of the main Rockland-Thomaston belt and to the area near Warren. In these localities they constitute most of the material. In the small belts southwest of the city of Rockland the rock is so highly magnesian that it does not effervesce with acid. The grain is exceedingly fine and the color blue-white to cream. Talc is locally abundant, especially along slickensided fracture planes.

The rock quarried in both the upper and lower quarries at West Warren is also highly magnesian and is much coarser than the dolomite of the Rockland region. The deposit is distinctive in exhibiting not only the effects of regional metamorphism but also to a marked degree the effects of contact metamorphism by granite masses. The average size of grain at the lower quarry is slightly less than one-eighth inch, and in the upper quarry many of the grains average one-fourth inch. The color ranges from pure white to bluish. The unusual coarseness of grain is plainly the result of contact metamorphism caused by the granite which intrudes the limestone and the surrounding gneisses as numerous dikes and irregular apophyses. The contact effect also manifests itself in the presence of wollastonite, talc, and small amounts of garnet, pyrite, bornite, sphalerite, and brown biotite in certain portions of the limestone. Wollastonite is the most abundant of these minerals and in places occurs in crystals 1½ inches in length. The talc is abundant in small irregular veins.

Age.—As explained in the section on historical geology, the Rockland formation is considered to be of Cambro-Ordovician age. It seems to be the representative in Maine of the general period of limestone deposition represented elsewhere in the eastern United States by the Stockbridge and Shenandoah limestones.

SURFICIAL DEPOSITS.

Almost all the surficial deposits of the Rockland quadrangle are Pleistocene or later in age and owe their origin to glacial or marine agencies operating either separately, together, or in succession. Fluviatile, lacustrine, and organic deposits are present over small areas. The materials most abundant are glacial till, sand and gravel, and marine clay.

GLACIAL TILL.

The till deposits of the quadrangle are, for the most part, thin and of very irregular distribution. They are thickest in the valleys and depressions between the hills, but even here their depth, so far as observed, in few places exceeds 40 or 50 feet and is usually much less. Most of the larger hills and many of the smaller ones are practically bare of drift. The topography is in general controlled not by the drift but by the rock surface, most of the characteristic features of drift topography, such as eskers and drumlins, being wholly wanting. No continuous belts of drift showing a distinctly morainic topography are present and it is therefore not possible to trace successive positions of the ice border, but there are two small areas of drift which show the succession of low knobs and shallow kettles characteristic of a weak type of terminal moraine. One of these morainic patches lies just opposite the south end of Fish Pond, in the northwestern part of the quadrangle. This area is three-fourths mile long by one-half mile wide and shows a number of characteristic morainal knolls rising not more than 20 or 30 feet above the intervening hollows, some of which are without outlet. Over the surface granite bowlders, many of them 3 or 4 feet in diameter, are scattered in unusual abundance. The other morainic area is about three times as large as the one just described and is situated about one-half mile farther south. Its features are similar to those of the northern area except that the knolls are somewhat higher. It is bordered on the north and on the south by an outwash plain of glacial gravel.

No differentiation of the drift of this quadrangle into sheets can be made either on the ground of structural relationships or on lithologic differences. The till shows some variations, however, and sandy, clayey, and intermediate varieties are represented. The till was found at a number of places to underlie the marine clays, and presumably also some of the till deposits overlie these clays, as some deposits of stratified glacial drift occupy this position. No exposures were discovered, however, which proved this relation.

OUTWASH SAND AND GRAVEL.

Deposits of sand and gravel are very abundant in the northern and eastern parts of the quadrangle, but are rare in the southern and southwestern parts. Nearly all are of glaciofluviatile origin, though in many deposits there are suggestions of reassortment of the materials by wave action.

Two of the larger gravel deposits are clearly defined glacial valley trains marking important channels of drainage from the melting ice. One of these occupies the valley of Megunticook River for nearly 2 miles, extending from a point near the outlet of Megunticook Lake to the western part of Camden village. For three-fourths mile below the lake the gravels are somewhat interrupted, but below this stretch they cover practically the whole of the valley floor, with an average width of about one-half mile. Originally this deposit must have had a nearly plane surface sloping gently down the valley, but only slight remnants of this surface now remain and they are deeply dissected. In the western part of the village of Camden, just north of the Hope road, a gravel pit shows clearly the relation of this gravel to the marine clays. At the top of the continuous section here exposed are 2 feet of moderately fine gravel. This grades below into 5 feet of horizontally stratified sand, which becomes finer below and passes gradually into typical marine clay that is at least 15 feet thick, its base not being exposed. A less dissected valley train forms a belt one-fourth to one-half mile wide extending from Alford Lake to Crawford Lake, a distance of nearly $2\frac{1}{2}$ miles. North of the road from East Union to Guerney Hill most of the original plane surface is still preserved, but south of this road it has been largely destroyed by erosion.

Gravelly areas associated with the southern of the morainic deposits near South Hope seem to represent small glacial outwash plains. Their nearly smooth surfaces slope gently to the southwest and their materials become finer in this direction, the glacial stream which deposited them apparently flowing in about the direction now taken by Quiggle Brook. The large gravel deposit near West Rockport is shown by its form and structure to be a delta deposited by glacial drainage from the Oyster River Pond valley. The delta structure is well shown in a gravel pit about half a mile northwest of the corners at West Rockport, on the west side of the road to Oyster River Pond, where the lower layers exposed dip at about 20° S., while the upper layers are almost horizontal. The original plane surface of this deposit is well preserved over much of the area and is especially well shown at the trotting park. Less than one-half mile to the south the gravel is wholly replaced by sand, which in turn gives way to sandy clay extending for some distance down the valley of Oyster River. This rapid change in coarseness can be explained only on the hypothesis that the deposits are water-laid. The mean altitude of the surface of this delta deposit is about 240 feet and a study of the contours shows that a body of water standing at this elevation must have opened out to the ocean in the direction of "The Bog" and Oyster River valley, unless this valley was then obstructed by a tongue of the ice sheet or a mass of stagnant ice. These deposits may therefore have been formed at the head of a marine estuary at a time when the land stood about 240 feet lower than at present, or they may be lacustrine beds formed in a lake dammed back by ice which obstructed Oyster River valley. If such an ice dam existed, it left no record of its presence. It seems more probable, therefore, that the delta deposits are marine and record the highest altitude reached by the sea in this region.

Another important gravel deposit occupies the eastern part of the peninsula between Clam Cove and Rockland Harbor. At a pit just east of the cemetery most of the material is under an inch in size, though there are a few cobbles whose diameter reaches 6 or 8 inches. This deposit seems to be thickest and coarsest to the west and to become thinner and finer to the east, where some of the shore exposures show only 2 feet or so of "pin gravels." In the northern part of the cemetery it is so thick that the graves do not penetrate it, but farther northeast the gravel is mixed with the underlying marine clay when the land is plowed. These gravels were probably laid down either as an outwash apron or as a delta deposit when the ice stood close to their present western border, but there has probably been some subsequent reworking of the material by wave action.

Along the eastern slopes of Dodge and Battux mountains gravel is present up to an elevation of about 200 feet and is traceable for nearly a mile southwest of Chickawaukie Pond. The northern part of this strip of gravel has the form of a bench or terrace, only 50 to 75 feet wide at the top and sloping steeply down to the pond. A pit near its north end reveals considerable variety in the materials. At the top is about 12 feet of stratified gravel of moderate coarseness; this grades down into about 10 feet of somewhat sandy clay, followed by 3 feet of coarse gravel and at the base of the section 3 feet or more of sand and fine gravel. This section is indicative of rapidly shifting conditions. The whole deposit was probably formed by glacial drainage flowing between Dodge Mountain and a mass of glacial ice, possibly stagnant, occupying the Chickawaukie Pond depression. The steep eastern slope of the gravels was probably produced by their slumping when the retaining wall of ice melted away. No corresponding well-developed terrace was observed on the east side of Chickawaukie Pond, but certain gravels found there suggest that there was some glacial drainage on that side also. On the northwestern slope of the 260-foot hill southeast of Chickawaukie Pond a large gravel pit covering about an acre exposes 10 feet of rather fine grained, horizontally stratified gravel. The surface of the deposit in which this pit is located is nearly level over several acres and then falls off with a steep slope to the northwest. This steeper slope probably marks the position of the ice front, outside of which the gravel was deposited as an outwash apron. Presumably the deposit is about contemporaneous with the gravels on the east and west sides of the pond.

There is a large gravelly area near Ash Point, but the gravel here seems to be thin and for the most part is rather fine. It shows indications in many places of having been worked over by wave action. Sand and gravel deposits scattered abundantly over the peninsula south of Rockland Harbor and occurring at a number of other places in the quadrangle are too small and unimportant to merit separate description.

UNDIFFERENTIATED STRATIFIED DRIFT AND TILL.

A few areas in the vicinity of Rockland and Rockport are mapped as undifferentiated stratified drift and till. In most of these areas the gravels are so thin or so irregularly distributed with respect to the till deposits that the separation of the two on a map of this scale is impracticable. The area just west of Rockport Harbor is largely covered by a thin deposit of gravel which is well exposed at a number of places along the electric railroad. In the northeastern part of this area, just west of the railroad, an old gravel pit shows the gravel conformably overlying the marine clay. The gravels of the eastern part of this area are mainly well stratified, but in the western part the assortment is less complete. In places there are suggestions of the reworking of the materials by wave action.

LACUSTRINE DEPOSITS.

A deposit of sand and fine gravel bordering Grassy Pond, in the northwestern part of the quadrangle, and extending 15 to 20 feet above the present level of the pond was evidently formed at a time when the surface of the water stood at least that amount above its present level. Presumably the conditions of high water and rapid deposition immediately followed the retreat of the glaciers and the pond has since then slowly lowered its outlet.

Small deposits of sand and fine gravel just southwest of Meadow Mountain are also mapped as lacustrine. Their fineness and the general level character of their surfaces indicate deposition in standing water, while their high average altitude of about 330 feet above sea level discredits the idea of marine deposition. It seems probable that they were formed in a temporary lake resulting from the damming of the Quiggle Brook valley by glacial ice. The thinness of the till sands here and the heavy timbering of much of this vicinity renders it difficult to make a more exact determination of the history.

MARINE CLAY.

The lowlands which border this part of the coast are covered by a nearly horizontal mantle of clay, of varying thickness but of such uniformity of grain and color that only here and there can a division into distinct beds be recognized. The clay ranges in color from yellowish gray to blue-gray, the former being by far the more common. For the most part it is exceedingly fine grained and, except in a few localities, very free from sand and pebbles. Its thickness is, in general, greatest on the lowlands and least on the adjacent hill slopes. Depths of 15 to 35 feet are very common, and some well records seem to show a depth of 50 to 75 feet. A well drilled at the Thomaston brick yards went through 45 or 46 feet of this clay to limestone.

Areally, the clay is most broadly distributed and penetrates farthest inland along the rivers and tidal estuaries; along steeper parts of the coast it may be entirely absent. Along Penobscot River it is well developed as far inland as Bangor, and along St. George River in this quadrangle it reaches inland for a distance of over 20 miles, to and beyond the villages of Thomaston and Warren.

Vertically, most of the clay deposits are confined to the interval between sea level and the 125-foot level, and though not all the land within this interval is occupied by these deposits, it is probably safe to say that, on the mainland at least, they occupy fully one-half of it. A very few deposits, as that near West Rockport, occur at elevations as great as 230 feet.

The clay is readily recognized where it has been exposed by the waves or streams and where it has been uncovered in excavations. Excellent natural exposures occur at Sherman Cove, near Camden, along the north side of Rockland Harbor, along St. George River near Thomaston, and at many other localities on the shore, where they have been cut into by the waves and now stand up as benches or terraces rising 10 to 25 feet above the beach. Artificial exposures are common in the railroad cuts and in the cuts and ditches of many of the wagon roads. One of the best exposures is at the brickyard at Thomaston, and other good exposures occur at the quarries west of Rockland, where the clay must be stripped off before the limestone can be reached. Even where sections can not be found, the presence or absence of the clay can usually be recognized from the general appearance of the land surface. Extensive flats or gently sloping plains occupying the lowlands and free from surface bowlders are nearly always found to be built up of this clay. Where roads traversing these flats have not been surfaced with materials brought in from other localities, the clayey character is revealed by the fine light-gray dust which develops in dry weather, the sticky gray mud which forms after a heavy rain, and the absence of pebbles or cobbles.

The distribution of the clay with respect to the present coast line at once suggests its marine origin, a conclusion which is sustained by the presence here and there in the clay of the shells of marine animals. The clay represents, in truth, old clam flats formed at a time when the sea level was considerably higher, relative to the land, than it is at present. Their age is fixed by their relation to the deposits made by the glaciers which covered the region in the Pleistocene period. At several localities they were seen to overlie deposits of glacial bowlder clay, and they were overlain in turn by gravel deposited by streams flowing from the melting ice. The gravel pit in the western part of Camden showing 15 feet of clay of the marine type grading upward into stratified sand and gravel has already been described. The Camden trotting track is built on a thin, nearly level bed of gravel overlying the marine clay. These relations fix the age of the clay as glacial. The streams flowing from the melting glaciers were heavily laden with sediment; the coarser portions, the gravel and sand, were deposited on the land surface, or in the ocean close to the shore, but the finer portions were carried farther out and deposited as these beds of marine clay. They differed from the clam flats of to-day only in the greater rapidity with which the muds were deposited.

The chemical and physical characters of the clay and its commercial utilization are considered in the section on economic geology (pp. 13–14).

BEACH SAND AND GRAVEL.

Along most of the shore line of the quadrangle is exposed either the bed rock or deposits of till or marine clay into which the ocean waves are actively cutting. A part of the material thus eroded is redeposited in the form of sand and gravel beaches and in places as spits and bars. The position of the principal deposits of this kind is shown on the surficial geology sheet. Most of them occupy shallow indentations in the coast and many inclose behind them small swamps. Some of them represent simply a reworking of older gravels of glacial or glaciomarine origin. The largest of the sand beaches are Crescent Beach, 3 miles southeast of Rockland, and the beach three-fourths of a mile southwest of Owlshead light-house.

SWAMP MUCK AND PEAT.

Peat may be defined as a soil made up largely or entirely of the partly decomposed remains of plants. It is frequently called muck, although this name is more properly applied only to the more impure clayey varieties. The color ranges from light brown to nearly black and the texture from fibrous to structureless and homogeneous. Deposits of this nature accumulate in poorly drained depressions and may attain a thickness of 10, 20, or even 30 feet. In the Rockland quadrangle they are confined largely to the vicinity of Rockland and West Rockport and have accumulated since the withdrawal of the glaciers. They are characterized by a nearly level surface and most of them possess a typical heath flora consisting principally of mosses of the genus *Sphagnum*, plants of the heath family, sedges, and a few small larches and spruces.

Some of these bogs, as the one at the south end of Fish Pond, represent a gradual encroachment of vegetation from the banks into the waters of a lake. In such bogs the typical heath plants, though at present occupying most of the surface, have not been the only ones concerned in the peat development. In some bogs their rôle seems to have been very subordinate. Elsewhere, as in "The Bog" 2 miles northwest of Rockland, the character of the peat indicates that the *Sphagnum*, *Rhododendron*, *Cassandra*, *Ledum*, and sedges which now inhabit the area have been the principal peat producers during all stages of its growth. In these places a lake of the size of the bog probably never existed but the peat has accumulated from the bottom upward, layer upon layer, by the gradual growth and decay of the heath plants. In some bogs the borders or even the whole area may, in the late stages of its development, become tenanted by a hard-wood forest growth. The northern part of "The Bog" furnishes an example of this condition. In all the bogs the peat below the surface layers is completely saturated with water.

The economic value of the peat is discussed under "Economic geology."

RECENT ALLUVIUM.

Along most of the streams in this quadrangle postglacial fluviatile deposits are so small that they can not be outlined on the map. This is a result of the extreme youthfulness of the streams. In a few places, however, as along Quiggle Brook in the northwestern part of the quadrangle, parts of the stream are reduced to low grade and flow in a meandering course through sand and sandy clay deposited by the stream itself. In many deposits the alluvium is mixed to some extent with the products of vegetable decay.

IGNEOUS ROCKS.

GRANITE.

AREAL DISTRIBUTION.

Granite occupies large areas in the southeastern part of the Rockland quadrangle and occurs in small, scattered patches in the northern and northwestern parts. Many occurrences within the areas of contact-metamorphic Penobscot formation are too small to be indicated on the map. The easternmost granite occurrence is on Monroe Island. To the southwest it reappears at Ash Point and extends westward to Dyers Point. Thence its boundary swings northward, paralleling the shore of Weskeag River but keeping a little to the west of it. The granite boundary extends a short distance north of the road between South Thomaston and Thomaston, and then trends southwestward toward Long Cove. Ash Island is partly granite, and Dix, High, Andrews, and the neighboring islands are wholly granite. South of the Rockland quadrangle this granite area includes Whitehead, Rackliff, and Clark islands and extends to Tenants Harbor.

In the north-central part of the quadrangle granite occupies a small area about 1 mile southwest of West Rockport. In the extreme northern part of the quadrangle granite occurs on the shores and islands of the eastern part of Megunticook Lake. In the northwestern part of the quadrangle granite covers about 1 square mile at the south end of Fish Pond, and there are two smaller areas at East Union and 1½ miles to the south.

The boundaries of these granite areas are not sharply defined in the field, for there is a gradual transition from the areas of pure granite to the areas mapped as injected and contact-metamorphosed Penobscot formation. The areas indicated on the map, however, are areas of practically pure granite, though they include a variety of textures. Within these mapped areas diorite, diabase, and igneous or flow gneiss are present only locally and in small amounts.

A small isolated mass of granite porphyry is present south of Camden, about one-half mile northwest of Ogier Point, and scattered granite dikes are found cutting the typical Penobscot slate. One such dike is seen along the road west of Chickawaukie Pond.

GENERAL DESCRIPTION.

Granite of the main area.—The granite of the large area in the southeastern part of the quadrangle shows some variation in composition and in texture, the distribution of the granites of different coarseness being indicated in a general way on the economic geology sheet. Most of this area, however, is occupied by granite of medium grain and of fairly constant character throughout. This granite is dark gray on fresh surfaces, but some of it shows a faint pink tint on weathering. Its texture is granular and the minerals visible to the naked eye are white or gray feldspar, gray quartz, muscovite, biotite, and a few small garnets. The feldspar grains are mostly of irregular form and from one-eighth to one-fourth inch in size, though at nearly all localities a few of the crystals are tabular and may reach a length of one-half inch. The quartz usually occurs in much smaller grains than the feldspar, their size in general ranging from one-sixteenth to one-eighth of an inch. As a rule the quartz is about equal to the feldspar in abundance, though here and there it is subordinate, as at the quarries 1½ miles west of Hayden Point. Mica is usually about equal to quartz in abundance and the two varieties, muscovite and biotite, are normally present in nearly equal amounts. In the few places where muscovite largely dominates over biotite, as at a small quarry three-fourths mile north of Sprucehead village, this rock blackens rapidly on exposure and is of poor quality for building or ornamental purposes.

The granite from the Weskeag quarry, about 1 mile west of Pleasant Beach, may be taken as typical of most of the granite of the northern part of the main belt. The following description of its characters is given by T. Nelson Dale (Bull. U. S. Geol. Survey No. 313, 1907, p. 127):

> The granite is a biotite-muscovite granite of slightly bluish medium-gray color and of medium to coarse, even-grained texture, with feldspars up to one-half inch and mica 0.15 inch. It consists, in descending order of abundance, of light-bluish potash feldspar (orthoclase and microcline), smoky quartz, bluish or white soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with accessory garnet, magnetite, and apatite. The oligoclase is partly altered to kaolin and a white mica.

The rock quarried at the High Isle quarries, which are the most important granite quarries of the quadrangle, is described by Dale (op. cit., p. 122) as a biotite granite of slightly pinkish medium-gray color with conspicuous black mica. Its texture is medium to coarse, even grained, the feldspars measuring up to one-half inch and the biotite scales mostly up to one-tenth but in part two-tenths inch. Delicate pink feldspar is the most abundant constituent, smoky quartz next, and then white feldspar and black mica. Magnetite, apatite, and secondary chlorite are present in small amounts. Microscopic examination shows that the feldspars have the same composition as those of the Dix Island granite.

Granite similar to that of High Isle occurs on Birch, Little Green, Little Pond, and Great Pond islands, on "The Neck," and in the northern part of Andrews Island. The granite of Otter Island is slightly coarser than that of High Isle.

Typical porphyritic phases occur on the 120-foot hill 1½ miles north of Harrington Cove, where the feldspar phenocrysts average one-half to three-fourths inch in length and in places show parallel orientation.

Areas of fine-grained granite.—Certain areas of granite are characterized by a texture much finer than the normal. One such area forms the eastern half of Monroe Island and the average size of the feldspars in the granite here is somewhat less than one-eighth inch. The biotite in this granite is very subordinate. Fine-grained granite also outcrops in an area along the shore north of Ash Point. The rock here is a gray biotite granite showing in places a slight tendency toward the development of porphyritic feldspars. It grades rather abruptly toward the south into the medium-grained granite of Ash Point; its westward extent is masked by surface deposits. A third area lies just southwest of South Thomaston, the granite being well exposed at many points on the shore. It is similar to the granite north of Ash Point and grades into the medium-grained type. The fourth area of fine-grained granite lies between Harrington and Long coves. The rock of this area differs from the fine-grained granite of the other areas in being, in part at least, intrusive into the granite of normal texture, an exposure in one of the old quarries showing a few angular blocks of typical medium-grained granite caught up in the fine granite. The average size of the feldspars in the rock here does not exceed one-eighth inch, but their development here and there to a diameter of one-fourth inch gives the rock a somewhat mottled appearance. Quartz, biotite, and muscovite are its other constituents, the biotite greatly predominating over the muscovite. The color is dark gray. The feldspar is mainly orthoclase and microcline, though there are a few crystals of plagioclase. The various constituents occur in grains that are mostly irregular in outline and vary considerably in size. Some of the feldspars are much decomposed and a few of the biotite plates are altered to chlorite. Black, highly biotitic "knots" from one-fourth inch to an inch in diameter are abundant in this granite and render it unfit for ornamental purposes.

Coarse-grained granite.—Phases of the granite which are slightly coarser than the normal occur on Otter Point and the small point just to the east, on Eben Island, and along the shore north and west of Thorndike Point. On Otter Point the rock in most places is porphyritic and many of the feldspars are one-half inch in length; they show considerable parallelism of orientation. On the point next to the east many of the feldspars reach three-fourths inch in length, and on Eben Island feldspars 1 inch long are common. The granite near Thorndike Point is similar to that on Eben Island. At all these occurrences the coarser granite grades into that of medium grain.

Granite of the minor areas.—The granite of the small areas in the northwestern part of the quadrangle, in the region of metamorphosed and injected Penobscot formation, is usually of medium grain and of uniform character throughout the areas mapped. In the Megunticook Lake area the rock is a gray medium-grained muscovite-biotite granite. In the small area 1¼ miles south of East Union the rock is medium grained and somewhat porphyritic and shows a few elongate basic segregations most of which trend about N. 5° E. The rock of the East Union area and the area between Fish and Lermond ponds is medium grained. The granite of the small area 1½ miles northeast of South Hope is a gray fine-grained rock in which muscovite is the dominant mica. It is easy to work and has been quarried to a slight extent for local use.

Outside of these larger areas granite occurs throughout the area of metamorphosed and injected Penobscot formation in a large number of minor intrusions that are too small to be indicated on the map. Many of these form dikes which are here medium grained and there fine grained, though the major part are pegmatitic and exceedingly irregular in form. These irregular injections are especially well shown on the summit and slopes of Ragged Mountain, and over much of the northwestern part of the quadrangle it is impossible to go 100 yards without encountering some of this pegmatitic material.

Rhyolitic phases of the granite.—A dike exposed for a short distance on the west shore of Broad Cove, near Owlshead, is of peculiar interest because parts of it were originally glassy and of rhyolitic composition. The central portion possesses a gray aphanitic groundmass through which are scattered slightly decomposed phenocrysts of feldspar averaging about one-eighth inch in diameter. The groundmass also contains small, rather numerous partially decomposed crystals and irregular masses of pyrite. Those portions of the dike, however, which lie next the walls of Penobscot schist show a subconchoidal fracture and a groundmass of purplish-brown color and glassy appearance. Scattered through this groundmass are feldspar phenocrysts similar to those of the central portion of the dike, though standing out in greater contrast. The marginal portion of the dike exhibits on its weathered surface a well-defined flow structure paralleling the walls of Penobscot schist. The central portion of the dike was not examined microscopically but it is clear from the megascopic appearance that it was originally less glassy than the border portion.

> The more glassy peripheral portions of this dike show under the microscope a groundmass which is gray between crossed nicols and very finely holocrystalline, though probably glassy at the time of original crystallization. Slight differences in double refraction in the gray portion of the groundmass indicate that this is not one mineral but is probably made up of both quartz and feldspar. Throughout the groundmass are abundant shreds of pale-brown hornblende lying with their longer axes subparallel so as to clearly define the original flow lines. These lines bend around the feldspar phenocrysts, most of which still retain their characteristic crystal outlines, though they show considerable decomposition. Most of them are filled with a granular aggregate of epidote and zoisite and with minute shreds of white mica and scattered calcite grains. A single small phenocryst of pale-brown hornblende partly decomposed to chlorite was observed and several phenocrysts of brown biotite more or less elongate parallel to the flow structure. Most of the biotite is decomposed to pennine, epidote, and small grains of magnetite, and certain bands composed wholly of chlorite, epidote, and magnetite are probably the result of biotite decomposition. This microscopic study shows, therefore, that the rock is a devitrified and somewhat decomposed porphyritic rhyolite.

No other rocks of rhyolitic texture and composition are known within the Rockland quadrangle, though the granite on the shore south of Crescent Beach is in places so fine as to be almost rhyolitic. Rhyolites are known, however, on the island of Vinalhaven, 6 miles east of this locality, within the Penobscot Bay quadrangle. It is possible that the rhyolite here described belongs to these Vinalhaven rhyolites, but its close proximity to the main mass of granite and to dikes of very fine grained granite intruding the Penobscot schist and slate strongly suggests that it is an offshoot from the granitic magma. If the latter view is correct, the presence of this glassy rock so near the main granite mass is significant of the conditions under which the granite magma solidified. These conditions are discussed on page 9, under "Historical geology."

Dikes of aplitic and fine-grained granite.—Numerous dikes of fine-grained granite, usually aplitic, intrude all other phases of the granite, though more abundant in certain localities than in others. Most of these dikes are under 6 inches in width, but some are much wider, as on the northeast side of Eben Island, where a dike of pink fine-grained granite is 4½ feet wide. Aplite dikes are particularly abundant and well exposed on the northeast shore of Sprucehead Island, about one-fourth mile east of the bridge to Elwell Point. Somewhat farther east along the north shore of Sprucehead Island, an intrusion of aplite has followed the same path as a dike of fine-grained diorite which cuts the normal granite, the aplite being intruded on each side of the diorite, between it and the walls of normal granite. A few of the aplite dikes are coarser in their central portions than along their borders. Some aplitic phases of the granite, notably on High Isle, inclose spheroidal knots of pegmatite 2 to 8 inches across. The texture of these knots is irregular and the minerals are quartz, orthoclase, and black tourmaline, the tourmaline usually in the center. The aplitic dikes do not appear to represent a distinct period of granitic intrusion but belong rather to the later stages in the intrusion of the main masses of granite with which they are invariably closely associated.

Pegmatite dikes in the main granite areas.—Pegmatite dikes intruding the granite occur at several points within the main area, but are not very abundant. One at the south end of Elwell Point is about 1 foot in width and intrudes gray biotite granite of medium coarseness. The dike shows quartz and feldspar in graphic intergrowth, some of the feldspars being 3 to 4 inches across. Dark-green, somewhat irregular tourmalines form radiating branches a few of which are 5 inches in length. Muscovite is also abundant. On one wall of the dike the coarse pegmatite is in direct contact with medium-grained granite, but on the other wall a zone of fine-grained granite intervenes.

Pegmatite dikes associated with areas of metamorphosed and injected Penobscot formation.—Throughout much of the area mapped as metamorphosed and injected Penobscot formation pegmatite is of common occurrence and is as a rule closely associated with fine-grained granite or with granitic flow gneiss. A good exposure one-half mile west of South Hope shows pegmatite of exceedingly irregular texture, some parts being rather fine grained while others are very coarse. In the coarser portions there are many feldspars 2 to 3 inches in diameter which show a well-defined crystal form, the cross sections being nearly square. Larger feldspar masses, one of which measured 1 foot by 4 inches, also reflect the light as single crystals. These are more or less elongate, do not in general show definite crystal outlines, and usually inclose quartz, probably in graphic intergrowth. Quartz also occurs in the pegmatite as lenses and in masses of irregular form.

Pegmatite of the same general appearance and composition, occurring southwest of South Hope, consists mainly of white feldspar and gray quartz, with which are associated mica and garnet. The mica is largely muscovite, although there are scattered plates of black biotite. The garnets are mainly small and are most abundant in certain irregular bands. Microscopic examination shows the feldspar to be oligoclase. Near the corners 1 mile north of Melvin Heights pegmatitic muscovite granite of very irregular grain is garnetiferous and also contains locally large hornblende crystals, some of which are 1 inch in diameter. A few of these inclose quartz. One-fourth mile west of East Union pegmatite dikes contain black tourmaline prisms half an inch across and 3 inches long.

Quartz veins.—Dikes or true veins of quartz are not abundant either within the granite areas or within the areas of contact-metamorphosed and injected Penobscot formation. Those which are present are mostly dikelike in form and appear to be intrusive offshoots from the granitic magmas. A quartz dike 4 to 5 feet wide on the east side of Monroe Island strikes N. 35° W. Another, 4 feet wide, on the south side of this island also strikes N. 35° W. and incloses angular fragments of schist variously oriented. Both have parallel walls and are dikelike in form and nearly vertical. A third occurs on the shore just southeast of Owlshead light-house. It is nearly vertical, with a maximum width of 5 feet, though it tapers to a width of 1 foot only 30 feet away. In one place its border shows alternate bands of fine granite and of quartz, so that the quartz must be regarded as an injection from the granite stock.

Basic knots and lenses in the granite.—Basic differentiations from the granite magma, showing great variety in form and magnitude, form one of the most interesting features connected with the granite intrusions. Small segregations or "knots," as they are called by the quarrymen, occur locally in nearly all parts of the granite areas and in granite of all textures, though most abundant in the small areas of coarse-grained rock on Otter Point, Eben Island, and near Thorndike Point. The form of most of these basic bodies is spheroidal and their diameter under 4 or 5 inches. They are fine grained and show rather uniform basicity from center to circumference. The inclosing granite has about a normal composition, even near the contact between the two rocks, where there is complete interlocking of the grains. On Garden Island one rounded segregation is 4 feet across; another is 2 feet across and of kidney-shaped outline. These bodies are somewhat more feldspathic toward the center than on their borders, and are inclosed by medium-grained biotite granite which shows no decrease in its basic constituents next the segregations.

Under the microscope the basic rock is found to possess a rather fine grained granitic texture and to consist of biotite, green hornblende, andesine feldspar, quartz, and magnetite, with small amounts of titanite and epidote and numerous small prisms of apatite as inclusions in the feldspar. This rock is a quartz diorite and grades with perfect interlocking of the grains into the surrounding medium-grained granite. The latter shows the same minerals as the segregation, but the proportion of quartz is larger and that of hornblende considerably smaller. In addition, the granite contains orthoclase and microcline.

On the shore north of Thorndike Point the basic segregations are lens or disk shaped, the planes of greatest dimension in the various segregations being nearly parallel. In places the feldspar phenocrysts of the inclosing coarsely porphyritic granite are oriented parallel to the long axis of the basic masses, a relation which indicates that these masses owe their orientation and probably their elongate form to flowing movements within the granite before complete solidification took place. On the north shore of Eben Island segregations of similar character are much more elongate and some are much larger. They range from 1 inch to 10 feet in length and from one-fourth inch to 1 foot in width, and many of them show a somewhat curved cross section. Joint planes and aplite dikes cut directly across the basic lenses and the coarse-grained granite in which they lie. The rock forming the segregations here is dark gray in color, very fine grained, and in places is full of somewhat irregular feldspar phenocrysts from one-sixteenth to nearly one-fourth inch in diameter.

Under the microscope the basic rock is seen to be a fine-grained aggregate of biotite, green hornblende, and feldspar showing a granitic texture. The feldspar grains are usually somewhat larger than the hornblende and biotite, which many of them inclose. Their index of refraction and extinction show them to be andesine. Titanite occurs in large irregular masses and apatite is abundant as minute inclusions in the feldspar.

Elongated basic masses similar to those on Eben Island occur at several points in the granite of the area mapped as contact-metamorphosed and injected Penobscot formation. The most instructive of these localities is on the east shore of St. George River near the extreme southern edge of the quadrangle. Here porphyritic granite of normal composition, with feldspar phenocrysts from one-half to three-fourths inch in length, contains a number of elongated parallel lenses of much finer grained dioritic rock, the largest being about 6 feet long and 1 foot wide.

The inclosing granite shows a decided "grain" parallel to the direction of the elongation of the basic lenses. Within a few rods of this exposure occurs a ledge of exceedingly coarse banded gneiss whose more acidic bands have about the composition of the normal granite, the basic bands, some of them 6 inches in width, having the composition of the basic lenses described above. It is evident that this gneiss represents only a more advanced stage in the process of combined differentiation and flowage that gave rise to the basic lenses in the granite.

Under the microscope the basic lenses and granitic matrix are both seen to be feldspathic and granitic in texture, but the basic bands, besides being finer grained than the others, contain a much larger percentage of green hornblende and a somewhat smaller percentage of quartz. Both phases contain abundant titanite in grains many of which show a well-defined crystal form. The feldspar in both has the composition of oligoclase andesine.

Granite gneiss.—Igneous or flow gneiss similar in origin to the banded rocks described above is present in small amounts at many points within the area mapped as granite. It is especially abundant within the area mapped as metamorphosed and injected Penobscot formation, particularly in those parts which are nearest to the granite areas. Nowhere else, however, was its banding so coarse as at the locality on the east shore of St. George River, just described. A common type of the gneiss is silver gray in color, shows bands which are less than one-eighth inch wide, and is fine grained except for the development of muscovite in plates some of which are one-fourth inch in width. It is indistinguishable megascopically from certain of the coarser phases of the metamorphosed formation, but under the microscope its igneous character is clearly shown by its large percentage of feldspar, usually microcline and orthoclase with some plagioclase.

Hornblende gneiss.—On the west shore of St. George River, about one-half mile north of the south edge of the quadrangle, several small masses of a dark-green hornblende rock of gneissic structure are inclosed by lighter-colored gneiss. The light-gray gneiss is highly feldspathic, with the composition of a granite, and is probably of igneous origin. The dark layers of the basic gneiss are seen under the microscope to be composed largely of fresh green hornblende with which are associated quartz and magnetite; the lighter-colored layers are composed largely of quartz and feldspar with some hornblende. The form of the lighter layers suggests that they may represent portions of the surrounding more acidic gneiss which have been injected into the basic rock. The origin of these basic masses is uncertain. They are perhaps most plausibly explained as basic border differentiations from the granite magma, which after partial solidification have been caught up by still fluid masses of more acidic composition, partly remelted, injected by the more acidic material, and molded to some extent in the flowing movement which produced the gneissic structure of the surrounding rock. Hornblende gneiss of similar character also occurs in association with granite gneiss 1 mile northwest of South Warren.

Basic granite.—On the west shore of Harrington Cove, near the south edge of the quadrangle, normal medium-grained granite is found to grade into a somewhat finer grained rock of darker color in which the ferromagnesian minerals are much more abundant. In the normal granite biotite is the dominant femic mineral and hornblende is present only in very small amounts. In the more basic granite the hornblende dominates over the biotite. This basic granite, in turn, grades with decrease in quartz and increase in the percentage of hornblende into a typical quartz diorite of extremely fine grain. All these varieties are intruded by aplite dikes. Diorite of this kind, evidently formed by magmatic differentiation from the granite magma, is abundant in the vicinity of Harrington Cove and occurs within the main area mapped as granite at a number of other places, most of which are near the borders of the area. It is also very abundant within the area mapped as metamorphosed and injected Penobscot formation. Its characters and relations are fully described in the section on basic intrusive rocks.

"Finger" injections of granite in diorite.—On the shore of Harrington Cove, also, a dark-gray quartz-hornblende diorite is intruded by a number of cylindrical or "finger-shaped" masses of medium-grained biotite granite. The diameter of these masses ranges from 1 inch to 5 inches, their cross sections usually being circular, but in some being oval, pear shaped, or dumb-bell shaped. The only longitudinal section of these granite "fingers" is exposed along a steeply inclined joint plane, where the finger shows a width of 1 inch to 1½ inches and a length of 2 feet and appears to connect at its lower end with a dike of granite. The granite of all these "fingers" is of medium grain and normal composition, its principal constituents being quartz, brown biotite, orthoclase, and oligoclase. The basic rock is a quartz-biotite diorite in which the feldspar is oligoclase and the biotite is in excess of the hornblende. Both rocks are very fresh. At their junction there is complete interlocking of the crystals, though the transition from one to the other is in general very abrupt. It is difficult to understand how granite fingers of this kind could be intruded into diorite unless the latter was in a somewhat plastic condition.

Relations of granites and associated basic rocks to the surrounding sediments.—In order to understand fully the relations between the granite and the sediments of the Penobscot formation as exhibited within this quadrangle, it is necessary to contrast the relations here observed with those found in certain parts of the adjacent Penobscot Bay quadrangle. In many parts of the latter area, notably along the granite-schist contact from Bluehill village northward and from Bluehill Falls southwestward to Sedgwick, the granite preserves its normal medium grain up to the exact contact. In most places this contact is so sharp that it is possible to stand with one foot resting upon typical Ellsworth schist and the other foot resting upon normal granite. Dikes and irregular intrusions of granite are not very abundant in the schists near the main granite masses, and flow gneiss, pegmatite, and basic differentiations from the granite magma are almost entirely absent. In the Rockland quadrangle and in certain parts of the Penobscot Bay quadrangle the contact relations are wholly different, the change from pure granite to pure sediments taking place gradually through a transition zone of contact-metamorphosed and injected sediments 2 to 3 miles in width. The areas mapped as granite are occupied by nearly pure granite, and the rocks of the areas mapped as Penobscot formation are almost wholly sedimentary. The areas mapped as contact-metamorphosed and injected Penobscot formation comprise sedimentary schist and slate, injection gneiss, diorite, diabase, flow gneiss, pegmatite, and granite of various textures associated in the most irregular manner, so that it is impossible to delineate them separately on a map of the scale used in this folio. The sedimentary schists are most abundant in those portions of these belts which lie nearest to the purely sedimentary areas, and the flow gneisses, diorites, pegmatites, granites, etc., are most abundant near the granitic areas.

The indefinite character of certain portions of the granite border is well shown along the shore for half a mile or so north of Ash Point, where there are alternate stretches of schist and fine-grained granite. In some of these border areas the granite in its intrusion has produced an intense shattering of the intruded rocks. This phenomenon is well shown at Ash Point, where the gray hornblende-biotite granite contains many fragments, both large and small, of diorite and of schist belonging to the Penobscot formation. The fragments are usually angular and sharply differentiated from the granite, though in a very few places the boundary is not sharp and there has apparently been a slight amount of absorption. A still finer example of a breccia of this type is found on the west shore of Monroe Island. Here the fragments, ranging up to 1 foot in length, are all schist of the Penobscot formation and are all exceedingly angular, with sharp borders, which show no evidence of absorption. Similar phenomena are shown on the point at the western entrance to Deep Cove near Owlshead.

The contrast between the sharp contacts observed in the Bluehill region and the very gradual transitions observed in the Rockland quadrangle seems to be best explained on the hypothesis that the broad contact-metamorphosed and injected zones represent portions of the "roof" of granite batholiths (see structure section B–B), whereas the sharp contacts in the Penobscot Bay quadrangle represent the sides of similar batholiths (see structure section A–A, Penobscot Bay folio). The character of the rocks which are found in the two types of contacts lends support to this view. The abundance of fine-grained granites, some so fine as to be rhyolitic, in the broad transition zones and the persistence of a normal medium grain up to the exact contact in the Bluehill region are readily explained by the more rapid rate of cooling in the roof portion of a granite batholith than deeper down along its flanks. The more ready escape of gases and water vapor upward than laterally may explain the great abundance of pegmatitic granite in the transition zones, inasmuch as the presence of gases and vapors is believed to be an important factor in the development of pegmatitic textures. It is a reasonable supposition also that basic differentiation from the granitic magma would be more rapid upward than laterally, and the abundance of diabase and diorite in the broad transition zones may thus be accounted for.

Contact phenomena of the transition zone are also discussed somewhat in the section on the metamorphosed and injected phases of the Penobscot formation (p. 3).

AGE.

Contact relations show that the granite and its associated basic rocks and flow gneisses are younger than any of the other rocks of this quadrangle with the single exception of some dikes of diabase and analcite basalt. In the adjacent Penobscot Bay quadrangle the granite intrudes sedimentary rocks of Niagara age. The granite is therefore at least as young as late Silurian.

In the Silurian rocks of the Perry region, in the extreme eastern part of Maine, no granite pebbles are found, but granite pebbles plainly derived from the main granite masses of this region occur abundantly in the conglomerate at the base of the Perry formation, which is probably of Devonian age. The granite of the Perry region is therefore late Silurian or Devonian. There is every reason to believe that all the granites of the coast of Maine, which form a nearly continuous belt from the Rockland quadrangle to the Perry region, belong to the same period of igneous intrusion. Those of the Rockland area may therefore be assigned with considerable certainty to late Silurian or to Devonian time.

BASIC INTRUSIVE ROCKS.

GENERAL DESCRIPTION.

Basic intrusive rocks, principally diorite and diabase, are present in nearly all portions of the quadrangle. The most widespread are the dikes, chiefly diabasic in composition, which cut all the sedimentary formations and in some places cut the granite. A second abundant type is represented by the areas of diorite and diabase, usually irregular rather than dikelike in form, which are associated principally with the granite and are probably differentiations from the same parent magma. A third type of intrusive, much more basic in composition, is represented by the rock to which the name lermondose has been applied and by associated rocks in the vicinity of East Union.

BASIC DIKES.

Distribution and character.—The basic dikes are usually fine grained to aphanitic and range in color from dark green or purple to nearly black. No system could be recognized in their arrangement, but their strike is commonly between northeast and northwest. They are most numerously exposed along the shores and average only about 2 to 3 feet in width, though some of them reach 10 feet. Diabase is the rock type generally represented, but in spite of the prevailing lithologic similarity of the dikes their relations to the other rocks of the region show that they are not all of the same age. On the north shore of Clam Cove a basic dike in the Penobscot formation is intensely fractured, many, but not all, of the fractures being continuous from the dike rock into the schists. In place also this dike is slightly schistose. The basic dikes intruding the Rockport limestone and well exposed in the limestone quarries near Rockland have already been described in the section devoted to the Rockland formation. As there stated, many of them show evidence of having been pinched apart in the deforming movements to which the limestone has been subjected, and others have been fractured in a most irregular manner and show jagged borders. The banding in crystalline limestone bordering these dikes conforms in gentle curves to the angular irregularities of the dikes, the limestone having yielded by flowage to the movements which produced fracturing in the more brittle dike rocks. These relations show clearly that the dikes antedate at least the later periods of regional metamorphism.

Other dikes which are wholly similar in general appearance to those just described cut the sediments in such a way as to indicate clearly that they were intruded subsequent to the period of dynamic metamorphism. Such are most of the basic dikes exposed along the shore between Camden and Rockland. On the north shore of Sprucehead Island and at a few other localities basic dikes cut the granite. At the former locality an aplite dike, following nearly the same path as the basic dike, has forced its way in on each side of the basic mass and in a few places has cut across it. As some of the aplitic dikes of this region constitute a late phase of the granite intrusion, it would seem that here at least the basic dike was also nearly contemporaneous with the main body of granite.

Still other basic dikes, as for instance a dike of analcite basalt on the shore near Jameson Point, appear because of their extreme freshness to be much younger than any of the other dikes in the region.

Lithology.—Megascopically the oldest basic dikes of the region, those which have been deformed in the regional metamorphism, range from greenish or purplish aphanitic rocks to dark gray-green phanerocrystalline rocks in which typical ophitic texture can be recognized with the unaided eye. The dike so well exposed on the south wall of the Blackinton quarry is of this kind.

Under the microscope the ophitic texture of this rock is still more clearly defined. Idiomorphic laths of labradorite up to 2 millimeters in length but averaging about one-half millimeter lie in a matrix occupied by irregular grains of pale-green hornblende, some pale-green chlorite, brown biotite in small scattered plates, small irregular grains of magnetite, and some calcite, probably a secondary infiltration from the surrounding limestone. Here and there the labradorite shows some micatization. No pyroxene remains, though it was probably present. The rock may be classed as a typical diabase.

The dikes cutting the metamorphosed sedimentary formations but distinctly younger than the period of deformation range from purplish aphanitic rocks to dark-green phanerocrystalline rocks with an average size of grain of about one-sixteenth inch, and are indistinguishable megascopically from the dikes which have been deformed in the metamorphism. A single exception is the porphyritic dike near Owlshead to be described later.

Under the microscope the purplish finer-grained dikes of this series are seen to possess the texture and composition of typical diabases and to differ in no essential way from the older dikes. Certain coarser dikes of dark-greenish tint, one of which is exposed on Hog Cove ledge and another on Jameson Point a short distance southwest of the Samoset Hotel, differ from most of the other dikes in containing a much smaller amount of feldspar and a much larger percentage of hornblende. The dike rock from Hog Cove ledge is practically a fine-grained hornblendite; that from Jameson Point is made up of pale-green hornblende and labradorite with magnetite in irregular aggregates of minute grains. Brown biotite occurs abundantly. It is usually inclosed by hornblende, from which it is probably derived.

Two basic dikes about 5 feet wide on the point just south of the pier in Owlshead village are remarkable in showing abundant phenocrysts of somewhat altered feldspar scattered through a fine groundmass of dark-purplish color. Some of the phenocrysts are three-fourths inch in diameter, but most are under one-half inch. In the central portion of the dikes the orientation of the phenocrysts is wholly irregular, but at the borders of the dikes they lie subparallel and their long axes are parallel to the dike walls.

Under the microscope the feldspar of the phenocrysts is seen to be plagioclase with high index of refraction, but considerably decomposed so that its exact composition can not be determined. The fine-grained groundmass of the rock is an irregular aggregate of brown biotite, feldspar, pale-green amphibole, chlorite, and small groups of magnetite and pyrite grains. The original rock appears to have been a porphyritic diabase.

A basic dike cutting the granite on the north shore of Sprucehead Island is a very fine grained rock, mostly dark blue-gray in color but with irregular mottlings of dark green.

Under the microscope the texture is found to be typically diabasic. The narrow, lath-shaped, idiomorphic feldspars are shown by their maximum extinction angles to be labradorite. All but the larger ones are perfectly fresh. The remainder of the rock consists of an irregular assemblage of deep-green hornblende and brown biotite in nearly equal amounts and scattered grains or small aggregates of magnetite and titanite. The rock is a typical diabase. The dark-green spots which are visible in the hand specimen represent irregular areas that consist almost wholly of hornblende and biotite.

The freshest and probably the most recent type of basic dikes in the Penobscot Bay region is represented in the Rockland quadrangle by only one observed occurrence. Others doubtless are present, but the dikes of this type are not nearly so numerous as the diabases already described. The single dike referred to is 2 feet in width and cuts the metamorphosed Penobscot schists on Jameson Point. It is dark purple in color and is somewhat amygdaloidal throughout, though the largest amygdules are in the central portion. In megascopic appearance it is wholly similar to many of the diabase dikes, but microscopic examination shows it to be an analcite basalt.

Under the microscope the rock appears perfectly fresh. Its most abundant mineral is basaltic augite in crystals averaging one-fourth millimeter, but reaching 1 millimeter in length. Many of these show distinct crystal outlines. Some show concentric and hourglass structures. Among the augite crystals are scattered crystals of perfectly fresh olivine up to 3 millimeters in diameter. Small grains of magnetite distributed abundantly through the rock in part show crystal faces but are mostly irregular grains. Between these minerals is a colorless, isotropic substance which can hardly be regarded as a glass in view of the rather coarse crystallization of the other components and which is most probably the isometric mineral analcite. The amygdules are mainly filled with calcite.

A rock of similar character but without olivine and containing more of the isotropic groundmass (analcite?) was found in the Penobscot Bay quadrangle on Flye Point, where it cuts an earlier basic dike and the granite.

Age.—The pinched and fractured dikes typified by those in the limestone quarries near Rockland are at least as old as the latter part of the period of dynamic metamorphism which affected the rocks of this region. This deformation, as discussed in the section on geologic history, is believed to have taken place at the close of Ordovician time. There can be little doubt that certain other basic dikes are practically contemporaneous with the granite and represent basic differentiations from the granitic magma. This conclusion is borne out by observations in the Penobscot Bay quadrangle and by the presence of massive stocks of diabase in the Rockland quadrangle between the granite border and St. George River. The dikes of this set, like the granite, are probably of Silurian or Devonian age.

The freshness of the analcite rocks suggests that they may be Mesozoic, and, together with some of the diabase, they may with considerable probability be correlated with the Triassic eruptions of Nova Scotia and southwestern New England.

STOCKS AND IRREGULAR MASSES OF DIORITE, DIABASE, AND GABBRO.

Most of the larger diabase, diorite, and gabbro masses in the quadrangle are not distinctly dikelike in form and are closely associated with granitic rocks, so that they seem to be more closely related to the latter in origin than to the smaller basic dikes. A gradation of the diorite into the granite, such as has been described in the section on granite, is, however, only rarely observed. In by far the greater number of occurrences the diorites, though probably derived from the same magma which produced the granite, crystallized somewhat earlier, intrusions of the granite into the diorite being very common but the reverse relation being rarely seen.

The intimate relationship in age and origin between the granite and these more basic rocks is shown in part by the unusual manner in which the granite intrudes the diorite in many places. Granite dikes of normal appearance cutting the more basic rocks are common, but the granite also forms dike networks of the most intricate character in the diorite. One of the best examples of such a network is on the east shore of Harrington Cove, where the irregularity of the granite dike is so great as to suggest that the diorite was in a somewhat plastic condition at the time of the granite intrusion. Similar phenomena are exhibited on the east shore of St. George River due east of Bradford Point. Here both the diorite and the intruding granite are cut by dikes of alaskite.

Diabase is an abundant intrusive rock in certain parts of the area mapped as metamorphosed and injected Penobscot formation, especially in the region northeast and southeast of the village of St. George. It is closely associated with diorite, flow gneiss, and granite, and like the diorite seems to be a product of differentiation from the granite magma. Most of the so-called "black granite" quarried in the vicinity of Long Cove is diabase. In the largest of the "black granite" quarries the rock is very dark gray in color and has an average size of grain between one-sixteenth and one-eighth inch.

Under the microscope the rock shows in places an ophitic texture, though in other places its texture is granular. The femic minerals are brown biotite, augite, hypersthene, and green hornblende, the hornblende being in part original and in part an alteration product from pyroxene. The prismatic feldspars are labradorite. Some magnetite is present in small irregular masses and many of the feldspars are crowded with small reddish-brown needle-like inclusions which may be rutile. The longer among these inclusions occur in several sets developed along the cleavage planes; many of the shorter ones lie in every conceivable direction. The rock is almost perfectly fresh.

Diabase from a small quarry in the same vicinity is brownish black in color and much coarser grained, most of the pyroxene and hornblende crystals ranging from one-eighth to one-fourth inch in diameter.

Under the microscope this rock shows an ophitic texture throughout. The mineral components are the same as in the diabase just described, but there has been much more extensive replacement of pyroxene by hornblende, which in this rock is mainly of the brown rather than the green variety.

Rocks that have the texture and general appearance of gabbros occur on Thorndike Point, along the southern shore of Rockland Harbor north of Post Hill, on "The Graves," a ledge 1½ miles off the coast between Camden and Rockport harbors, and at a few other localities. On Thorndike Point the basic rock is intruded by granite. On the south shore of Rockland Harbor it is intrusive into the Penobscot schists.

On microscopic examination these rocks are found to consist mainly of plagioclase, biotite, magnetite, epidote, and green hornblende, much of the hornblende being more or less fibrous. Pyroxene if originally present has been wholly replaced by hornblende, which in some places has itself been altered somewhat to chlorite.

LERMONDOSE AND RELATED ROCKS.

A rock of very unusual character intrudes the Penobscot formation on the farm of Mr. Charles P. Miller in East Union, where some of the decomposed rock has been taken out for road material. At this exposure numerous rounded bowlders of disintegration, 3 to 4 feet through, lie partially embedded in a gravelly mass of disintegrated peridotite. All the surfaces are extremely rusty. The rock is extremely tough and resistant under the hammer but when freshly fractured is seen to be a granular aggregate of pyrrhotite and some chalcopyrite with dull greenish-black minerals and some areas of gray feldspar.

Under the microscope the most abundant constituent of the rock is seen to be olivine in grains varying from 0.2 millimeter to 2 millimeters in diameter and possessing the rounded outlines and irregular cracks characteristic of that mineral. Magnetite inclusions are scattered through the olivine, mainly as curved bands of minute particles. Some of the grains show slight serpentinization, but the major part are almost wholly undecomposed. Between the olivine grains and conforming in the most perfect manner to their rounded outlines are pyrrhotite, chalcopyrite, hornblende, plagioclase, and pale reddish-brown biotite. The pyrrhotite and chalcopyrite plainly crystallized together and are associated in a most intimate manner. The former greatly predominates and contains some nickel and cobalt. Minute particles of pyrite are also associated with the pyrrhotite. The feldspar is andesine-labradorite and is very fresh; it is completely allotriomorphic with respect to the olivine. Fine reaction rims of amphibole occur between the feldspar and olivine and pyrrhotite.

The rock is of unusual interest as the first described representative of subclass 2 of Class V of the quantitative system of classification, and has been named lermondose from Lermond Pond, which lies near its typical occurrence. It is also of interest as a representative of the little-known type of sulphide ores formed as original crystallizations from a molten magma, although the analyses show that the percentages of copper, nickel, and cobalt in the rock are too small to give it any present economic value. (For a more detailed description of this rock see Jour. Geol., vol. 16, 1908, pp. 124–138.)

A few rods northeast of the exposure described above there is another outcrop of peridotite but the rock is much less basic. It contains some pyrrhotite, but most of the rock is made up of light-colored secondary hornblende with epidote and chlorite. The contact between these basic rocks and the surrounding sediments and granitic rocks is nowhere exposed, but the basic masses are more or less elongate parallel to the general trend of the metamorphic sediments and probably were intruded in them in the form of broad, irregular dikes. They may represent either a distinct period of basic intrusion unrecorded at any other place in the Rockland quadrangle, or an extreme phase in the basic differentiation from the granite magma usually represented in this vicinity and elsewhere in the quadrangle by numerous occurrences of diorite and diabase.

STRUCTURE.

General outline.—The present structural features of the sedimentary rocks of the Rockland quadrangle originated mainly during a period of dynamic metamorphism which affected this region, probably in late Ordovician time. The movements of this period produced a series of major and minor rock folds. At the same time they produced in the limestones a recrystallization and in the shaly sediments a schistosity which render the detailed interpretation of the minor folding difficult and in many cases impossible. In the regions shown on the map as metamorphosed and injected sedimentary rocks, principally Penobscot formation, the structural features have been further obscured by the intrusion, in a most intimate manner at many places, of masses of granite and associated igneous rocks. (See structure sections.) The granite presents no serious structural problems, for the reason that it is intrusive into all the other rocks of the region (with the exception of certain basic dikes).

Folds.—The great structural features of the region are outlined in part by the areal distribution of the various rock formations. They consist of broad anticlinoria and synclinoria whose general trend is about parallel to the coast line but whose regularity and continuity is interrupted by cross folds. One of the principal synclinoria is represented by the broad belt of Rockport limestone extending from Chickawaukie Pond to Thomaston (see structure section B–B), and one of the principal anticlinal belts exposes the Mount Battie area of quartzite. The presence of cross folds is indicated by the tapering out of the small limestone belts southwest of Rockland and by the broadening of the belt of Weskeag quartzite near the head of Weskeag River. In the Rockport region the broader structures, as outlined by the distribution of the formations, are less regular than in most other parts of the quadrangle. The synclinorium of Rockport limestone which on Beauchamp Point has a nearly north-south trend turns nearly at right angles beyond Lilly Pond and trends toward the limestone of the Simonton Corners area. The latter area quite plainly was originally continuous with the Rockport area, but has been separated from it by a broad anticline northeast of Simonton Corners, whose axis trends nearly north and south across the limestone belt. Subsequent erosion has exposed the underlying Penobscot formation along the axis of this fold. The Mount Battie quartzite mass and the one east of Simonton Corners are domelike in structure, as shown by strike and dip observations on the quartzite beds as well as by the general form of the areas.

In those areas which are characterized by little or no diversity in the kinds of rocks present the recognition of structural features is much more difficult. This is notably the case in the large tracts occupied by the Penobscot formation, whose rocks throughout are gray to black schists and phyllites. It is almost certain that they are folded in a manner somewhat similar to the folding indicated by the distribution of the limestones and the thinner quartzite beds, but the details of the folding can only here and there be worked out and their indication on the map is wholly impracticable.

Superimposed upon the major folds of the region are a large number of minor folds whose trend is in general parallel to that of the larger structural features. (See structure sections.) Most of the minor folds dip at high angles and they are very closely compressed so that the rocks over considerable areas dip steeply in the same direction. This is notably true in the Penobscot formation between Lilly Pond and Ogier Point, where the prevailing dips are to the northeast at steep angles. Minor folding is well shown in some of the quarries of the Rockland-Thomaston limestone belt, and a few instances have already been described in the section on the Rockland formation. The banding exhibited in the limestone brace between the Perry and the Blackinton farm "soft rock" quarries indicates the presence within the width of the quarry (about 150 feet) of an anticline and a syncline which are so much compressed that the beds of the opposite limbs of the folds are nearly parallel. The height of these folds is two or more times their width. A well-defined anticlinal fold is shown in the small quarry just west of the Nellie Ulmer quarry at Rockland and can be seen from the Park street iron bridge. This fold has an exposed width of about 15 feet and nearly an equal height. At the base the arch of the beds is rather broad, but the apex is so closely compressed that the two limbs of the fold are practically parallel. It is only such closely compressed portions of the folds that are usually exposed in the limestone quarries. The "fingering out" of the Lilly Pond limestone area at its west end indicates the presence of a number of folds with axes parallel to the general trend of the belt. Minor folding is indicated on the hill south of the golf club grounds near Rockport by the zigzag course assumed by an outcropping band of shaly limestone 20 to 30 feet in width. Only at a few places is open folding observed in the limestone.

In the Penobscot formation the same kind of close folding prevails, though less easily recognized. The rather narrow width of outcrop of this formation as exposed between the Rockport limestone and the Battie quartzite in the vicinity of Rockport (see structure section A–A) presents a striking contrast to its broad distribution elsewhere in the quadrangle. This difference may be explained on the assumption that the formation is thinner in the Rockport region than elsewhere. It seems probable, however, that the thickness everywhere is not greatly in excess of that in the Rockport region, but that throughout most of the quadrangle the formation is as a whole flat lying, though at all points characterized by minor folding. (See structure section B–B.)

The Battie quartzite, being more massive, offered much more resistance to the forces of deformation, and its beds, except in a few somewhat shaly portions, show evidence of only rather open folding. (See structure section A–A.)

Faults.—Indications of faulting were observed at many localities in the quadrangle, and faults doubtless occur at numerous other places where their presence is obscured by the drift covering or because of the similarity in the character of the beds on both sides of the fault plane.

The movement along most of the individual fault planes seems to have been very slight, although the aggregate displacement along the whole series was doubtless of considerable magnitude. In general the faulting has been insufficient in amount to affect materially the surface distribution of the rocks in the quadrangle or to modify in any important degree the main structural characters which are the result of folding. At one locality in the quadrangle, on the west shore of Beauchamp Point, it was necessary to assume faulting in order to explain the surface distribution of the rocks, although the actual fault plane could not be recognized. The Rockport limestone here at its western shore exposure abuts against the Battie quartzite, whereas a short distance to the north the normal succession is found from the Rockport limestone through the Penobscot formation to the Battie. A fault dying out to the north is necessary to explain this distribution.

By far the greater number of the recognizable fault planes are parallel or nearly parallel to the trend of the major or minor foldings, and in general the fault planes dip at high angles. Evidence derived from the trend of slickenside striæ on fault-plane surfaces indicates that in a large number of faults the principal component of movement has been horizontal rather than vertical. Fault planes illustrative of this type of movement are best exposed in the quarries in the Rockport limestone west of Rockland and have already been described in the section on the Rockland formation. Many of the fault planes are curved, but it is difficult to state whether such fault planes were originally curved or whether the curving is a result of later warping. On many of the fault planes exposed in these quarries the slickensides are perfectly horizontal.

The movements which produced this faulting are undoubtedly later than the movements which produced the folding and recrystallization of the sediments in the quadrangle. The exact period at which they originated is unknown, though the presence of fault planes cutting the granite suggests that at least some of the faults in the sedimentary series may be later than the period of granitic intrusion.

The movements which resulted in the folding of the sediments and in the recrystallization of the limestones also produced in the argillaceous rocks of the Penobscot formation and to a slight degree in the quartzites a certain amount of recrystallization and developed more or less perfectly a parallel structure in the mineral constituents. These changes manifested themselves in the development of schists and phyllites of various types and in the production here and there of a true slaty cleavage. Because of the close character of the folding and the general steepness in the dips of the folds, most of these secondary structural features are parallel to the bedding planes in the sediments, though locally, as at the crests and troughs of the folds, they cut across the original bedding at considerable angles.

HISTORICAL GEOLOGY.

The geologic history of this area is recorded in the rocks and surficial deposits and is interpreted through the study of their characters. In the preceding portions of this text the various types of rocks, as well as the structure developed in them, have been described. So far as the rocks are concerned, the geologic record is one of sedimentation and igneous intrusion, and of dynamic activity which affected the rocks both by metamorphism of their physical characters and by changes in their attitude. The later chapters of the history are more easily read and the record can be more faithfully interpreted, as the glacial and alluvial deposits with their characteristic topography remain relatively unmodified.

The geologic history as recorded by the rocks of this quadrangle began, probably in early Paleozoic time, with the deposition on the ocean bottom of muds and impure sands which are now represented by the Islesboro slate. This deposition presumably took place in moderately shallow water and not far from shore, but the position of the land masses which furnished the sediments is wholly conjectural. The period of mud deposition gave way to one in which conditions were favorable for the accumulation of the sediments now represented by the Coombs limestone member. Such deposits are indicative of clearer waters in which lime-secreting animals could exist in abundance, and may have resulted in several ways—through a slight deepening of the water by subsidence of the sea bottom, through a decrease in the amount of erosion on the neighboring land areas, through drainage changes on the land which carried the bulk of the argillaceous sediments to some other part of the coast, or through a combination of two or more of these processes. The considerable amount of argillaceous material associated with the limestone and the variations in the purity of the limestone from place to place may be taken as indicating shallow water and somewhat shifting currents.

The changes which closed the period of limestone deposition were more rapid and of greater magnitude than those at its beginning, and resulted in the deposition above the limestone of sands and gravels of considerable purity, which are now consolidated to form the Battie quartzite. The conglomeratic phases of this quartzite show a somewhat impure quartzitic matrix in which are embedded pebbles of very pure quartzite. The fact that most of these pebbles are well rounded indicates that the rock from which they were derived was itself a well-indurated sandstone or possibly a quartzite. The massive quartzite has a composition about like that of the matrix in the conglomerates. Presumably these rocks represent shallow-water or beach deposits that were subject to the sorting action of waves and currents. No quartzite beds which could have served as the source for such deposits are known in this part of the State, though they may occur buried beneath later formations. The parent formation need not have been wholly or even largely of quartzite, for the assorting and disintegrating action of waves and currents would suffice to separate more resistant quartzitic portions from less resistant shaly or calcareous materials. Certain beds, however, must have been made up of very pure sandstone or quartzite in order to furnish the clean, pure pebbles so characteristic of the conglomerate.

After the deposition of the Battie sands and gravels conditions for the accumulation of muds were again restored and very extensive deposits were laid down which are now represented by the Penobscot formation, the most widely outcropping formation of the region. The change is probably indicative of slight but long-continued subsidence.

In the region just west and southwest of Rockland some local change of conditions led to a cessation of mud deposition and the development, instead, of the sand deposits now represented by the Weskeag quartzite, while in the Rockport region the conditions continued favorable for mud deposition.

A gradual decrease in the amount of sand and mud carried into the sea resulted in clearer waters in which lime-secreting organisms could flourish, the initial stages of limestone deposition being recorded in the Weskeag quartzite area by the beds of the siliceous limestone member and in the Rockport area by shaly limestone. The great purity and thickness of the Rockport limestone succeeding these transition beds, when compared with the character of the Coombs limestone, indicate that the waters were clearer and the period of deposition of longer duration. That some of the purest phases of this limestone were deposited well within the zone of action of waves and currents is shown by the presence of beds of pure limestone conglomerate at several horizons within the formation.

During a part at least of this period of sedimentation, volcanic activity was in progress only a few miles toward the east, in the Penobscot Bay quadrangle. This resulted in the Castine formation and the North Haven greenstone, but no volcanic rocks are present in the Rockland quadrangle. Erosion early destroyed all trace of the volcanic craters from which issued the flows, tuffs, and dust composing these deposits. They may have formed small islands lying some distance off the coast or may have been features of a larger land area lying to the east of a bay or sound in which the above-described sedimentary deposits were laid down.

After the volcanic eruptions and after the deposition of the Rockland formation the whole Penobscot Bay region was affected by severe dynamic metamorphism which threw the rocks into a series of closely compressed folds and caused the recrystallization of their constituents on an extensive scale. How long an interval elapsed between the close of the sedimentary deposition recorded in the Rockland quadrangle and the beginning of this period of metamorphism is unknown, but it was probably sufficiently long to allow the sediments to become well consolidated, for it seems probable from the relatively small amount of deformation which the rocks of the Battie formation suffered that they were already well-indurated quartzites before the folding began. The pelites seem to have been shales rather than clays at the time of the folding, and the limestones behaved as moderately rigid bodies. The duration of the period of dynamic metamorphism is equally a matter of uncertainty. It may have been a single, continuous period of crustal movement or a succession of shorter periods separated by longer or shorter intervals of quiescence. The trend of the folds indicates that the thrust producing them was directed nearly at right angles to the trend of the present coast line; presumably it came from the southeast.

The period of dynamic metamorphism is the last event recorded in the hard rocks of the Rockland quadrangle prior to the intrusion of the granite, but in the Penobscot Bay area there is a record on the Fox Islands of an extensive erosion interval following the metamorphism and succeeded by the deposition of fossiliferous Niagara sediments and the eruption of andesitic and rhyolitic lavas. These fossiliferous beds furnish almost the only basis for estimating the age of the metamorphosed sedimentary series of the Rockland quadrangle. Being separated from the Niagara rocks by an erosion interval and by a period of dynamic metamorphism representing an unknown but probably very considerable period of time, the sediments of the Rockland quadrangle can hardly be supposed to be younger than Ordovician in age, and may, on the other hand, be considerably older. Geologic studies in the southern Appalachian region and northward into Maryland, Pennsylvania, and New Jersey show that the transition period from Cambrian to Ordovician in these regions was uniformly one of limestone deposition. In the absence of a more definite basis of correlation it seems not unreasonable, therefore, to regard the pure limestones of the Rockland formation as of Cambro-Ordovician age. The underlying Penobscot formation, Battie quartzite, and Islesboro formation would on this assumption be placed in the Cambrian. This view receives support from the fact that in other parts of northern New England the close of the Ordovician is known to have been a time of regional metamorphism capable of producing metamorphic effects such as are found in the Rockland region. It is fully recognized, however, that such a basis of correlation is at best very uncertain, and that the rocks in question may all be Cambrian or even pre-Cambrian.

It is believed that the volcanic activity in the Fox Islands region ceased before the close of the Silurian, and possibly it did not outlast Niagara time. After its close there ensued gentle folding and some faulting, which brought the Niagara sediments and volcanic rocks into their present attitude; then followed the great intrusions of granite and diorite. The transfer of these masses of molten rock from deeper portions of the earth's crust into these essentially surface formations was an event of great geologic importance. Not only were the intruded rocks metamorphosed somewhat by the hot vapors given off by the intrusive magma, but the adjacent portions of the sedimentary strata became widely separated or replaced by the masses of igneous rock thus injected.

The age of this intrusion is not shown by relations developed within the Rockland quadrangle, but granites that are in all probability contemporaneous, in the Perry Basin of eastern Maine and in New Brunswick, have been proved to be of late Silurian or early Devonian age.

The few dikes of analcite basalt and some of the diabase dikes are later than the granite, and locally some minor faulting has occurred since the granite intrusion; with these exceptions, the geologic record furnishes no clue to the events which took place in this region during the whole of Mesozoic and Tertiary time. By the beginning of the Pleistocene period, however, the familiar processes of subaerial erosion had reduced the land surface to about its present topographic form.

The record begins again with the advent in Pleistocene time of the great ice sheet which radiated from the region east of Hudson Bay. The most apparent evidences of glaciation are the polished and striated surfaces which are abundant even on the outermost islands of this part of the coast. The general trend of the striæ is about S. 20° E., though their direction may vary as much as 20° on either side of this average. The deposits of glacial till are in general thin and furnish almost no record, in morainic ridges or other features, of the successive positions occupied by the ice margin. It can not be positively asserted that there was only one invasion of this region by the glaciers, but there is no evidence, either from divergent sets of striæ or from dissimilar drift sheets, to lead to the opposite conclusion.

The height of the land at the time when the region was completely covered with ice is not certainly known, but during the early stages in the retreat of the ice the land seems to have stood, for a brief period, about 240 to 250 feet below its present level, though the evidence on this point can not be regarded as conclusive. Along neighboring parts of the coast, especially on the outer islands, rolled gravels have been traced up to elevations of 225 to 230 feet above sea and there found to terminate abruptly. (See Stone, G. H., Mon. U. S. Geol. Survey, vol. 34, 1890, pp. 52–53.) On Mount Desert Island, according to William C. Alden, gravels of delta structure and probably of glaciomarine origin have been found at an average elevation of about 210 feet. The only evidence in the Rockland quadrangle that the sea stood at this high level is found in delta gravels and sands near West Rockport whose mean elevation is about 240 feet. These have been described in the section on surficial deposits. The absence of cliffs of erosion in the solid rock or even in the drift materials at this elevation is evidence that the land remained at this level only for a short period and then rose rapidly nearly to its present level. The final stages in this uplift are recorded by the marine terraces which are well developed along nearly all the rivers and tidal estuaries of this part of the coast. The most widely developed terrace stands about 15 to 25 feet above mean tide and is characteristically shown at many points along St. George River and at numerous other localities within the quadrangle. For the most part it is a built terrace of marine clays, but locally in the more wave-exposed positions it is a cut terrace in till deposits. The sea seems to have remained at this elevation for a relatively long period of time. Terraces at altitudes between this and the 250-foot level are nowhere clearly developed in the Rockland quadrangle. In the adjacent Penobscot Bay quadrangle suggestions of such terraces may be seen at the south end of Sears Island at elevations of about 30, 60, and 80 feet. The well-developed terraces have plainly never been overridden by glacial ice. The almost total absence of wave-cut cliffs in the solid rock and of barrier beaches, spits, bars, and hooks at elevations above the present shore line indicate that the sea stood at these higher levels only for rather short periods of time.

The changes produced upon the land surface since the land and sea attained their present relation have been of relatively small magnitude. Ocean waves and currents have been active in the development of shore features of the types enumerated above. The net result of the development of such features is to simplify and straighten the coast line, but as yet this process has only begun.

Inland stream erosion has been at work smoothing the inequalities of the drift surface and dissecting the terrace flats of marine clay, though as yet their original contours have been but little altered. The drainage lines in the clay flats are all of the youthful, V-shaped type. The finer materials thus washed from the higher portions of the region have found their way in part into the large stream valleys, where they contribute to the stream flats or alluvial plains, and in part into the ocean, where they contribute to the tidal flats or are carried out into deeper water.

In a few basin-like depressions which have received little wash of clay or sand from the neighboring highlands the growth of swamp vegetation has resulted in the slow accumulation of peat in considerable amounts, "The Bog," 2 miles northwest of Rockland, showing in places 20 feet of this material.

ECONOMIC GEOLOGY.

LIMESTONE.

Preliminary statement.—The limestone of Maine which is commercially important in the production of lime is wholly within Knox County and, with the exception of the West Warren deposits, lies in the Rockland quadrangle. The deposits at West Warren are just west of the quadrangle, but are similar in character and in structural relationship to the other deposits and will be described with them. The lime industry in this region dates back to the year 1733, when Samuel Waldo experimented on the limestone and, finding it of satisfactory quality, erected a kiln and prepared lime for the Boston market. In 1823 lime was first shipped to New York and sold at $2 per cask. In 1905 limestone was quarried at nineteen quarries in this district operated by ten different companies and employing an average of 250 quarrymen. The great bulk of the rock is burned for lime, being unsuited for use as a building stone. All of the rock used belongs to the Rockland formation, the Coombs limestone being too shaly to be commercially valuable.

Character of the rock used.—The characters of the various types of the Rockport limestone have already been described in some detail in the section on the Rockland formation. Commercially, three types are most important—the "soft rock," the "hard rock," and the magnesian limestone or dolomite. The so-called "soft rock" is more readily quarried and broken up than the other types and includes the conspicuously banded varieties and the light-gray mottled or obscurely banded varieties typically developed in the easternmost line of quarries of the Rockland-Rockport Lime Company near Rockland. These rocks are the purest limestones in this region, as is shown by analyses Nos. 5 and 7 of the table on page 15.

The "hard rock" varieties are somewhat less easily quarried than the "soft rock." They contain a slightly larger percentage of magnesia and are usually somewhat higher in silica and insoluble matter.

The magnesian limestone or dolomite used commercially is as a rule nearly white and is almost a pure dolomite, as is shown by analyses Nos. 2 and 4 of the table.

The percentage of magnesium carbonate usually exceeds 40, though at a few localities, as at the abandoned Levensaler quarry 1 mile north of Thomaston, the percentage is somewhat lower, as shown by analysis No. 3.

The Rockland-Thomaston belt.—The eastern boundary of the main Rockland-Thomaston belt is clearly defined except between the electric railroad and St. George River, where exposures are lacking. It is known, however, that the limestone belt extends as far as this river because about 340 feet of limestone was penetrated in drilling a well at the Thomaston brickyards. The narrow tongue of limestone extending southward from the main belt into the western part of the city of Rockland is mapped on the basis of limestone outcrops occurring a short distance west of Broadway, about midway between Limerock and Middle streets, and a broad ledge of banded limestone farther north on the north side of Rankin street. Between the latter point and the abandoned quarries near Blackinton Corners there are no outcrops, but the trend of the beds makes it highly probable that the limestone extends between these places and toward the north into the main belt. The western limit of the large limestone belt is wholly obscured by deposits of clay and glacial drift. It is probable that in the northern half of the belt the boundary follows rather closely the base of the ridge of which Dodge Mountain and Mount Battux form a part. Farther southwest limestone is found in the bed of Mill River, 1 mile north of the old mill in Thomaston, and this is probably close to the western border of the belt. Southwest of the old quarries north of Thomaston the only limestone exposed is in the abandoned quarries in the yard of the State prison. The limestone probably extends only a short distance southwest of this point, the south side of St. George River near this locality being occupied, so far as known, by the Penobscot formation. Near its south end the troughlike limestone belt becomes divided into two troughs, as indicated on the map. This is shown by outcroppings of the underlying Penobscot formation in the bed of Mill River near the electric railroad and one-half mile farther northeast in the bed of a small creek between the old and new county roads. Most of the southern part of the city of Thomaston is probably underlain by Penobscot slate.

At the north end of the belt limestone outcrops at several places within one-fourth mile of the south end of Chickawaukie Pond. Along the west and east sides of this pond the rocks are Penobscot slate, with the exception of a small infolded mass of limestone on the hillslope west of the pond, opposite its widest portion, and a small mass of limestone exposed in a cave on the southwest slope of Bear Hill. The last-mentioned mass of limestone is anticlinal in structure and therefore represents a lower limestone horizon than the main belt. Its amount seems to be exceedingly small, and it probably represents a small lens within the Penobscot formation. The small area west of the pond may be of similar character or may be a small infolded synclinal outlier of the main belt, its structural relations not being clear from field observations. The deposit here is only 15 feet wide by 50 feet long and has been completely exhausted. North of Chickawaukie Pond, almost a mile intervenes before the appearance of the first outcrops, which are of slate. It is possible that limestone as a narrow band underlies a part of this area, but the surface deposits here are thick and it is doubtful whether the limestone even if present could be profitably quarried.

Within the Rockland-Thomaston limestone area outlined above only a part of the rock is of commercial value, and of this valuable rock several varieties are recognized. The quarries have the form of long, narrow troughs, many of them very deep, whose general northeast-southwest trend is parallel to that of the belt as a whole. They are flanked by belts of poor or "bastard" rock. This distribution is the result of structural relations already described, the broad limestone belt being a great downfold of limestone within which are a large number of smaller upfolds and downfolds of nearly parallel trend. The folding of the limestone has been so close and so irregular and the recrystallization of the limestone so extensive that it is impracticable to work out the details of structure even in areas of almost continuous exposure. A number of highly inclined faults trending about parallel to the strike of the folds also complicate the relations. It is impossible, therefore, to predict in more than a general way the distribution of valuable and worthless rock in the areas of few or no outcrops. Nor is it possible either to determine whether the "soft rock" overlies or underlies the "hard rock" or to determine the original position of the beds of poor rock with respect to the valuable rock. It is known, however, that the magnesian limestone constitutes the lowermost part of the limestone member. In spite of this uncertainty as to exact relations, it is possible to set forth some principles, based on a knowledge of the general structure of the region, which should be of practical value.

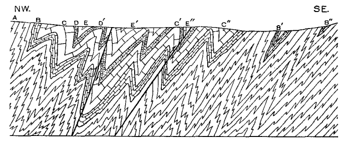

FIG. 1.—Ideal geologic section across the principal belt of Rockport limestone southwest of Rockland, Me.

A, Sedimentary rocks underlying Rockport limestone; B, B′, B″, magnesian limestone or dolomite; C, C′, C″, "hard rock;" D, D′, impure limestone; E, E′, E″, "soft rock."

Fig. 1 is a diagrammatic cross section from northwest to southeast across the limestone belts southwest of Rockland and is intended to illustrate the general relations outlined above; it is not drawn to scale and is purely diagrammatic, the folding being in places even closer than shown. The sedimentary rocks underlying the limestone are represented by A in the figure, the locally developed quartzite and talcose limestone beds not being separately shown. Among the limestones several varieties are indicated.

The position of the magnesian limestone at the base of the limestone series is definitely determined by field studies, but the relative position and thickness of the "hard rock," the impure limestone, and the "soft rock" are not known, the relations having been obscured by the folding and its attendant alteration of the rocks. The reader is therefore especially cautioned against drawing any inferences from the diagram in regard to the sequence or relative thickness of these three types of rock.

The principles brought out by the diagram may be enumerated as follows:

(1) Repetition of beds: The character of the folding is such that the same bed is likely to be repeated several times in the width of the belt. Thus the bed E appears again at E′ and E″, and the bed C is repeated at C′ and C″. As a result we may have within the broad limestone area several nearly parallel belts of almost identical rocks, separated by belts of poor rock or of good rock of a different kind. This principle finds an immediate application in the prospecting for new deposits. This search should be conducted by test troughs or ditches dug through the surface clays and gravels at a right angle to the general trend of the limestone belts. Such prospect ditches are likely to disclose, beyond the walls of poor rock which bound the pits now worked, a repetition of the same profitable bed or the presence of a bed of good rock of a different kind—that is, "hard" instead of "soft" rock, or vice versa.

(2) Width of surface outcrops: The surface width of the bands of "hard rock," "soft rock," and impure limestone depends not only on the original thickness of these various beds, but also on the character of the folding and the position of the present surface with respect to these folds. Thus the "hard rock" as it outcrops at C is a broad band, but at C′ its outcrop is narrow. The same is true of the impure limestone, which, as represented at D′, has a broad outcrop, but at D a very narrow one.

(3) Depth of the folds: As already stated, the folds which are developed in these rocks are more compressed even than is shown in the diagram. Their depth is greater than their width; in many places it is probably two or three times as great. As a consequence it may be expected that as a rule a "vein" of a valuable rock can be worked to a depth which is at least equal to its width and which may be twice its width. In only a few places, as at locality D′, is the depth likely to be less than the surface width. At such a locality the banding if present should dip at low angles; wherever the dip of the banding is high the depth of the deposit may be expected to be considerable.

Within the broad Rockland-Thomaston belt magnesian limestone was found only at one locality—this is the Levensaler quarry about 1 mile north of Thomaston. The analysis of this rock is No. 3 of the table (p. 15), and its probable position with respect to the rest of the limestone belt is indicated by the letter B in fig. 1. Besides carrying a lower percentage of magnesia, this rock is coarser and of a bluer color than the dolomite of the outlying areas east of the main belt. The absence of magnesian rock throughout most of the belt is readily understood from the diagram (fig. 1); it is buried beneath the other members of the limestone series. Theoretically, as shown in the diagram, it should come to the surface on the eastern border of the belt, but this border is covered up by clays throughout its length. The steeply inclined faults within the main Rockland belt further complicate the distribution of the different types of rock, though they do not vitiate the principles laid down above.

Outlying belts east of the Rockland-Thomaston belt.—The presence of a small outlying mass of limestone in the extreme western part of Rockland about a mile due west of Crockett Point is indicated by the occurrence of a banded limestone in a well on the north side of Limerock street. The limestone does not outcrop, but the underlying siliceous limestone and Weskeag quartzite outcrop just to the northwest. This mass is separated from the main limestone belt and from the belt lying to the northeast by outcrops of the Penobscot slates. Presumably it is an isolated limestone body of only slight extent, although it is possible that it connects to the north with the main belt, outcrops being wholly lacking in that direction. The southeasternmost of the outlying limestone belts includes the quarry 1 mile southwest of Rockland, operated by S. P. Dunton. The rock at this quarry is a white, fine-grained dolomite and is exposed for a width of about 100 feet. Between the quarry and the edge of the marsh an outcrop of slate occurs, but there are no outcrops to indicate the eastern boundary of the limestone. From analogy with the other similar limestone belts its width is believed to be not more than 150 to 200 feet. An analysis of the rock from this quarry is No. 2 of the table. A considerable amount of the rock is rendered worthless because of the abundant development of talc (a silicate of magnesium), but it remains to be seen whether the quantity of this mineral is sufficient to prohibit profitable development. Toward the north the limestone is exposed in a test pit about midway between the quarry and Thomaston street, and the presence of outcrops of Weskeag quartzite and of siliceous limestone just west of the west end of Holmes street indicates that this limestone may extend almost equally far to the north, at least north of Thomaston street. South of Dunton's quarry there are no limestone outcrops until the quarry on the Butler farm formerly operated by George W. Barry is reached, but between these two quarries, near the edge of the marsh, there are several exposures of the siliceous limestone that immediately underlies the dolomite. It is highly probable that limestone will be found just to the east of these siliceous-limestone outcrops and that both of these quarries are located on the same limestone belt. The limestone exposed for a width of 100 feet at the Butler farm quarry trends in the direction of the Dunton quarry, and is exactly similar in appearance and chemical composition. This belt ends less than one-half mile south of the Butler farm quarry.

The easternmost of the limestone belts south of Weskeag River is about in line with the belt just described. Its rock has been quarried in a small way at several points a short distance north of the road from South Thomaston to Thomaston. As exposed for a width of 80 feet in the largest of these pits the rock is fine grained, almost white, and highly dolomitic, resembling very closely the rock from Dunton's quarry. Farther north along this belt much of the rock is blue-gray and more highly calcareous, and some of it is shaly. The amount of rock is too small and the quality too poor to warrant further development. The small limestone area next to the west, at the head of Weskeag River, is represented by a single limestone outcrop on the north side of the river near the level of the marsh.

The small limestone area extending northward from the 120-foot hill west of Marsh Brook is represented by several outcrops on the northern slope of this hill and by a small abandoned quarry whose rock is in part white dolomite and in part a blue calcareous limestone. Much of it is very impure. North of this quarry limestone outcrops at one place in the road, but beyond this place there are no exposures and the extent of the limestone is wholly conjectural.

In the limestone belt just south of the 120-foot hill mentioned above and just north of the head of Weskeag River all the exposures are northeast of the South Thomaston road, the extent of the belt southwest of this road being wholly conjectural. In the exposures nearest the road much of the rock is a blue-gray calcareous limestone, but in other places, especially in the northernmost exposure, which is a test pit one-half mile northeast of the road, at the very edge of the marsh, the rock is a white dolomite similar to that at Dunton's quarry.

About in line with the last-mentioned deposits, but one 1 mile farther southwest, limestone outcrops in a pasture. In part this is white dolomite and in part a talcose and micaceous limestone. The width seems to be only 50 to 75 feet, so that it has no commercial value.

The limestone belt lying just southeast of the Maine Central Railroad and trending nearly parallel to it includes the abandoned Gay farm quarry. Much of the rock at this quarry is a white dolomite similar to that at the Dunton quarry, but associated with the dolomite is a rock of bluer color which effervesces with dilute acid and whose composition is represented by analysis No. 1 of the table. A conspicuous exposure of dolomite where some quarrying has been done occurs on the slope of the hill not far north of the Gay farm quarry; the extent of the limestone north of this point is unknown. Southwest of the Gay farm quarry no exposures occur.

About 1 mile southeast of the mouth of Mill River, in Thomaston, the presence of another belt of limestone is indicated by an exposure of limestone in a small pit and by limestone found in digging a well. The belt seems to be narrow and is separated into two parts by a "horse" of gray quartzitic limestone. This occurrence may or may not connect to the northeast with the Gay farm area. What may be a southward continuation of this same belt is represented by a single small limestone outcrop about 1 mile southeast of Hospital Point. A small and unimportant body of impure limestone outcrops on the shore of St. George River due east of Hospital Point.

The relation of these outlying limestone belts to the large belt is indicated in fig. 1, in which two outlying troughs are shown at B′ and B″. The relations shown at B″ may be taken to represent the conditions observed at the Dunton quarry, only the lowermost portion of the limestone series, the dolomitic beds, being present. The relations represented at B′ exemplify the conditions in some of the other outlying areas, where some of the higher, more calcareous beds are present with the dolomite. In general, the exploitation of these isolated belts of limestone should proceed in a most cautious manner and the following facts should be kept constantly in mind: First, most of the rock is a magnesian limestone which at present finds a market only with the pulp mills; second, a certain proportion of the rock is likely to be talcose, and therefore commercially valueless; third, the amount of rock is relatively small, the belts in few places exceeding 200 feet in width and commonly being less. They may be expected to narrow rather than to widen with depth. The installation of expensive machinery is therefore not warranted.

The Rockport area.—Except in the region north of Lilly Pond the exposures in the limestone area around Rockport are sufficiently abundant so that the limits of the limestone can be accurately traced. Indications of structure within this area are even fewer than in the Rockland-Thomaston belt, the banded phases being absent and the rock very uniform in appearance over considerable areas. Certain conglomeratic and shaly layers, however, furnish by their distribution some index to structural relations. The most instructive locality for studying these relations is the 200-foot hill south of the golf club house in Rockport, where a band of shaly limestone 20 to 30 feet wide has an outcrop which is zigzag across the general trend of the belt, thus indicating that the limestone within the belt is thrown into a number of folds parallel to the general trend of the whole. The folded beds of shaly limestone here pitch to the north and are underlain by limestone which is highly conglomeratic and full of irregular quartz nodules and veins. Above the shaly limestone lies massive pure limestone, only rarely conglomeratic. South of this hill limestone pure enough and in sufficient amounts to be commercially valuable occurs only near the Henry cottage. The rock here will probably never be utilized on account of the value of the land for summer residence purposes. Between the golf links and the road skirting Lilly Pond there is some rock of good quality, but its amount is not large, and shaly and conglomeratic varieties reappear on the north side of this road. Conglomeratic phases occur near the eastern border of the area at the south end of Lilly Pond and are also very abundant near the west end of the belt. The productive quarries are located in the central and wider portion of the limestone area, near the point where it is crossed by the electric railroad. The distribution of the valuable and worthless rock indicates that the shaly and conglomeratic beds occur in the lower part of the limestone series, their outcrops being confined mainly to the narrow southern part of the belt and to the borders of the wider portion. In this wider portion the higher and most valuable beds occur, and it is here that prospecting is likely to be productive of good results. The country for over one-half mile west of the Jacobs quarry is without outcrops, but prospecting here by means of test ditches or lines of drill holes extending from northeast to southwest across the trend of the belt is likely to disclose much valuable rock.

The Simonton Corners area.—The details of structure in the Simonton Corners limestone area can not be worked out, but the general form of the tract shows that it constitutes a basin and that the thickest and presumably the purest deposits will be found in its central portion, which seems to lie somewhat north of the present quarries. The rock in and near the Eells quarries is mainly rather dark gray in color and only very locally shows any banding; it is nearly all of good commercial quality. About the northern and eastern borders of the area most of the rock is shaly. Prospecting for one-fourth mile north and northeast of the present quarries is likely to reveal valuable rock under a not very thick cover of surface deposits.

Small areas west and northwest of the Rockland-Thomaston belt.—A small lens of limestone occurs a short distance west of the main Rockland-Thomaston belt, on the southern slopes of Mount Battux. The rock here is a rather coarse banded blue and white limestone, with a nearly vertical dip and a strike of about N. 25° E. Practically all of the available material has been worked out, the remaining pit being 150 feet wide at the north end and narrowing toward the south. The structural relations here are not clearly shown, but presumably this is a small downfolded mass representing the lower horizons of the Rockport limestone. If this interpretation is correct, it shows that the highly dolomitic layers characteristic of the basal part of the Rockport limestone in the region southwest of Rockland die out to the northwest, as is true of the Weskeag quartzite and the siliceous limestone member.

About $1\frac{1}{2}$ miles due west of Rockport is an old limestone pit about 300 feet long and 150 feet in greatest width. The limestone here has a gray color and an average grain of about one-sixteenth inch, and effervesces freely with dilute acid. It was formerly quarried and was burned and barreled on the grounds, but practically all of the available rock has been worked out. The structural relations between the limestone and the surrounding schists are obscured by surface deposits, but it is quite certain from relations observed elsewhere that this is a small downfolded mass representing the lowermost horizons of the Rockport limestone. A deposit of limestone a little over a mile northeast of Warren, on the road to Camden, is very small and has been practically exhausted.

Several bands of limestone of nearly parallel trend occur in the region between Alford and Crawford lakes, as is shown on the map. Almost all these bands are extremely narrow, the width being usually less than 100 feet and in many places under 50 feet. Much of the limestone is shaly; the purer varieties are in places white dolomite and elsewhere a blue-gray, more or less banded rock which is less highly magnesian. The limestone is cut by many granite dikes and the continuity of the belts is in places interrupted by larger and less regular granite intrusions. The limestone of these belts has in the past been quarried in a small way at a number of points, but is not worked at present. In general, the quantity of good rock available is too small to warrant exploitation. A possible exception to this rule is the easternmost of the three limestone belts which are crossed by the road from East Union to Guerney Hill. The rock is well exposed on both sides of the creek south of the road bridge. This belt is somewhat wider than any of the others and a considerable amount of good rock is exposed. The north and south ends of the belt are obscured by gravel deposits, and its extension in these directions may be somewhat greater than shown on the map. No quarrying has been done in this belt, but it is possible that it could be profitably worked, even though the amount of rock available is not sufficient to warrant the introduction of expensive equipment.

The West Warren area.—The extent of the limestone near West Warren was not observed in detail, but the deposit seems to form a single belt trending about N. 20° E. and traceable for three-fourths mile north of the present quarries. The rock is now excavated at two closely adjoining quarries operated by the same company. In both of these quarries the stone is a white to light-gray dolomite which effervesces only feebly with dilute acid. It differs from the dolomites of the region southwest of Rockland in being much coarser grained, the crystals in some localities averaging one-fourth inch in diameter though usually between one-sixteenth and one-eighth inch. This greater coarseness is due to the contact-metamorphic effect of the granite which injects the surrounding schists and gneisses and cuts the dolomite itself as a number of dikes of various sizes. Part of the eastern wall of the upper or eastern quarry is formed by a dike of granite at least 5 feet in thickness, striking N. 30° E. and dipping 45° NW. The contact effect of this granite dike is apparent from the development in the adjoining dolomite of wollastonite in crystals up to $1\frac{1}{2}$ inches in length and small amounts of garnet, pyrite, bornite, sphalerite, and brown biotite. The beds dip to the southeast at an angle of about 55°, so that the eastern wall is overhanging, and deep excavation for this reason becomes dangerous. The distribution of the good rock is rather irregular because of the interruptions caused by the granite intrusions and because of the local development of silicates in the limestone.

The lower or western quarry shows a single "vein" of good rock about 90 feet in width with very little development of silicate minerals and a somewhat finer grain than the rock of the upper quarry. The valuable rock seems to continue along the trend of this vein both to the north and to the south and as yet there is no sign of its dying out with depth.

Methods of quarrying.—In the smaller quarries the methods of operation are very simple, a line of drill holes being sunk by hand drills and the rock blasted out by the simultaneous explosion of charges of powder in each of these holes. The rock is then broken up by sledges to lumps about the size of a man's head and loaded into wagons to be hauled to the kilns. In the shallower quarries the wagons descend on an incline to the floor of the quarry. The deeper quarries are equipped with bull-wheel derricks operated by small hoisting engines, and the broken rock is hoisted in steel "drags" and dumped into the wagons or cars which convey it to the kilns. The larger quarries near Rockland are 100 to 150 feet in width and descend with nearly vertical walls to depths of 200 to 250 feet. In these larger quarries the drilling is done by steam power and the rock is blasted from a face extending across the whole width of the quarry by the simultaneous explosion of dynamite in a dozen or more holes arranged in a row parallel to the old face. The Rockland-Rockport Lime Company owns and operates its own standard-gage railroad, with $12\frac{1}{2}$ miles of track for conveying the rock from the quarries to the kilns. The equipment includes four locomotives of 14,000 to 15,700 pounds tractive power and 413 dump cars, the rock being dumped directly from elevated trestlework into the kilns. At this company's quarries between Rockport and Camden the rock is hoisted by means of a cable tram operated by electric hoist and the laden dump cars are transferred over the tracks of the Rockland, Thomaston and Camden Street Railway Company to the kilns at Rockport. From the Eells quarry near Simonton Corners and from many of the quarries in the large Rockland-Thomaston belt the limestone is hauled to the kilns by teams, the distance being in some cases as much as 2 miles.

Methods and products of manufacture.—Nearly all the kilns now operated are located on the water front at Thomaston, Rockland, or Rockport, Rockland possessing by far the largest number. The rock at West Warren is burned at kilns close to the quarries situated on the Georges Valley Railroad, a short line running from Union to Warren station, on the Maine Central Railroad. Nearly all the kilns now in use are of the vertical, separate-feed type, the limestone and fuel not being in contact. The older kilns of this type are square in cross section, are built of granite, and when full hold about 200 casks of rock. In another type which is rather common the kiln has a stone base but a steel stack. In kilns of these kinds the lime is usually raked from the draw pit onto a hearth, where it is allowed to cool before barreling. At Rockport, Rockland, and West Warren a number of more modern kilns whose framework is steel throughout are in use. Their capacity is considerably greater than that of the kilns of older types, ranging from 500 to 700 casks of limestone per charge. The base of the kiln chamber is hopper shaped and is provided with steel "shears" so that the lime can be drawn into small steel cars and transferred for cooling to any desired place.

The fuel used is principally coal, though a few of the newer kilns burn producer gas and a few still burn wood. The use of wood is not continued, in most cases, for reasons of economy, coal being considerably cheaper, but because there is still a demand from certain consumers for wood-burned lime, which they believe to be of better quality than that burned with coal. In general, the common lime marketed is of two qualities. That of the first quality, constituting from one-fourth to one-third of the whole product, includes only large, well-burned clean lumps adapted for finishing purposes; the lime of the second quality is not "selected" and includes more fine material. These grades are sold under a great number of brands, depending on the market they are intended for and the size of the barrel used. Most of the lime is shipped in casks of 200 pounds, but certain markets demand a larger cask. Some for New York shipment hold 350 pounds.

About two-thirds of the lime produced goes to the New York market, where for many years it has had the highest reputation. Nearly all of this is shipped by water, the largest of the companies maintaining a fleet of six barges, each capable of carrying 15,000 casks (200 pounds each) of lime and of bringing on the return voyage 1500 tons of coal. The remainder of the product goes to Boston and other New England markets.

One of the firms engaged in the lime industry in this district has in the past produced considerable quantities of "lime pencils" for use in stereopticons, though at present none of these are being made. In their manufacture it is essential that the lumps of lime be broken up as little as possible, a result best attained by burning the limestone in an old-fashioned intermittent kiln in which the rock and wood are piled in alternating layers.

Of recent years a process has been taken up by the Rockland-Rockport Lime Company which has not only proved a great success here and elsewhere, but which seems to point out an important line of future development in the lime industry. This process consists in a complete hydration of the lime before it is placed on the market. It has been carried on successfully in other parts of the country under a variety of patents, the product being variously known as "new-process lime," "hydrated lime," "limoid," etc. The Rockland product goes under the name of "prepared pure white lime." Although differing in details, the various processes are identical in principal. The lime after being burned is crushed or ground until no lumps larger than 1 inch in size remain. It is then transferred to a mixer, where it is thoroughly mixed with about 25 per cent of its weight of water, the chemical change produced being represented by the equation—

$$CaO+H_2O=Ca(OH)_2$$
Lime+water=lime hydrate.

A description of the effects produced by this hydration and of the subsequent steps in the process of manufacture may be quoted from a prospectus of the Rockland-Rockport Lime Company. The lime "undergoes a radical change, its heating and expanding qualities being entirely removed; it is then conveyed to bins where it is allowed to age, the same result being obtained as when slaking lime several months before it is used; it is then bolted to the varying degrees of fineness according to the different purposes for which it is used, and drawn into bags or barrels for the market." This process of manufacture has several decided advantages over the ordinary process. (1) Crushed and crumbled lime can be used in this way which can not be barreled for shipment as "lump" lime, although its quality may be equally good. (2) Coarse-grained limestone which does not retain the lump well on burning can be utilized in this process. (3) The hydrated lime "will not absorb moisture—in other words, it will not air slake—hence it will keep in good condition until used." This fact much decreases the risk in shipment by water and leads to a proportional reduction in insurance rates. Lime thus prepared may be shipped in bulk and for long distances, the Rockland-Rockport Lime Company having recently made shipments to Panama for disinfecting purposes. (4) "As the lime has been reduced to a powder, there is absolutely no liability of its pitting on the walls." Finally, it is believed that this process of manufacture is not greatly more expensive than the manufacture of common lime; the machinery needed is not complex; savings in the matter of materials utilized and of insurance have already been mentioned; and there is an additional saving when shipments are made in cloth bags. These are much cheaper than casks, which cost 16 to 17 cents each, and being light can be shipped back after emptying and used again and again.

The magnesian limestones of this district are used almost exclusively in the maceration of wood pulp in paper mills, and for this purpose the rock is shipped both in a burned and in an unburned condition. During recent years, however, the company operating the dolomite quarries at West Warren has placed on the market considerable amounts of this lime for building purposes. On the relative merits of calcium and magnesian limes for building purposes, the following may be quoted from E. C. Eckel (Cements, Limes, and Plasters, 1905, p. 115):

The relative merits of these two classes have been frequently discussed in the text-books and technical journals and are still subjects of controversy. The facts of the case, however, seem to be simple enough and may be summarized as follows:

High-calcium limes slake rapidly on the addition of water and evolve much heat during slaking. They also expand greatly, giving a large bulk of slaked lime. Magnesian limes slake very slowly and evolve very little heat during the process. Their expansion is also less, so that, taking equal weights they give less bulk of slaked lime.

Owing to the slowness and coolness with which the magnesian limes slake, there is some danger that the average mortar mixer will not give them sufficient time to slake thoroughly. Owing to the fact that they make less bulk of slaked product than do high-calcium limes, the average contractor or builder thinks they are too expensive; but, on the other hand, they are very much stronger in long-time tests than the high-calcium limes, and will therefore carry much more sand.

On the whole, the shipment of magnesian limes for building purposes is to be encouraged, but it is a question whether a product of more merit can not be secured by the hydration of this lime before it is placed upon the market. The process of hydration would not be much slower than in the case of calcium limes and the danger from imperfect slaking at the hands of the mortar mixer would be completely avoided. The result should be a lime which is superior in strength to the calcium limes.

Recently there has been considerable complaint from pulp-mill operators because there has often been much dirt mixed with the raw magnesia rock and with the magnesian lime which was shipped to them, and some custom has been lost for this reason. Owing to the clay covering which usually overlies the limestone here, it is difficult to keep the rock perfectly clean. Probably this trouble could be remedied in part by keeping the stripping of the clays further in advance of the quarrying, but it is worth considering whether the rock could not be washed before shipment or burning, at little or no extra expense, by utilizing the water which is pumped from the quarry but which usually serves no useful purpose.

Utilization of the limestone for Portland cement.—The possibility of utilizing in the manufacture of Portland cement the clays which are abundantly developed in the Rockland region and which in some places directly overlie the limestone has already received some attention from quarry operators in this region and is treated rather fully in another part of this folio under the discussion of clay. These clays have a composition which adapts them perfectly for this purpose, and if the clays obtained from stripping could be utilized in this way, limestone beds could be profitably worked which otherwise it would not pay to uncover. For cement-making purposes the magnesian limestones are not serviceable, for when mixed with clay they do not form so strong a cement as the calcium limes.

Production.—The following table shows the amount of lime and limestone produced in Knox County for a number of years:

Production of lime and limestone in Knox County, Me., 1898–1904.[a]

Year.	Common lime.	Hydrated lime.	Lime for pulp-making purposes (mainly magnesian).[b]	Limestone for flux and pulp-making purposes.
	Casks.[c]	*Tons.*	*Casks.*[c]	*Casks.*[d]
1898	1,610,178	----------	([e])	([e])
1899	1,939,427	----------	([e])	([e])
1900	1,728,134	----------	([e])	([e])
1901	1,962,717	----------	94,133	([e])
1902	1,589,982	----------	78,157	([e])
1903	1,817,787	10,000	72,001	([e])
1904	1,792,559	12,500	52,909	21,000

[a] Compiled from records of lime inspectors at the various ports and from the records of private companies.
[b] All from quarries at West Warren.
[c] Of 200 pounds.
[d] Of 400 pounds.
[e] Statistics not available.

The lime and limestone production of this region in the years 1904 to 1906, as given in the Mineral Resources of the United States, was as follows:

Production of lime and limestone in Knox County, Me., 1904–1906.

Year.	Lime.		Limestone.	Total value.
	Short tons.	Value.	Value.	
1904	186,881	$799,517	$2,955	$802,272
1905	220,927	971,305	7,428	978,733
1906	228,208	1,066,275	2,000	1,068,275

GRANITE.

According to the statistics for 1906 compiled by the United States Geological Survey, Maine ranks third in the list of granite-producing States, Massachusetts being first, with a production valued at $3,790,211, and Vermont second. The Maine production in 1906 was valued at $2,560,021. In 1905 Maine ranked first in the list of producing States, with an output valued at $2,713,795.

A number of the most important granite quarries in the State are in the Rockland quadrangle, the largest being on High Isle and Sprucehead Island. Another large quarry is located on Clark Island, just beyond the southern border of the quadrangle.

The distribution of the granite has been discussed in the section on the general geology of the granites. The most important area economically is the large one in the southeastern part of the quadrangle. Deep-water channels suitable for large coasting vessels extend to the very edge of the quarries, so that the largest blocks of granite can be loaded directly upon the vessels which are to carry them to the cities of the Atlantic coast. Thus the cost of transportation is reduced to a minimum.

The character of the granite in different parts of the region has already been described. The grain ranges from fine to coarse, although most of the rock quarried might be termed medium grained; in this kind the feldspars average from one-eighth to one-fourth inch in diameter. The areas occupied by granite of different grains are shown approximately on the economic geology sheet. The dark segregations or "knots" and the aplite dikes which are found in the granite at some localities are usually not common enough to affect the amount of clear stone available in the quarries. The basic "knots" seem, moreover, to be most abundant in those phases of the granite which are somewhat too coarse grained for commercial use. Most of the granite is remarkably free from pyrite and other mineral constituents which can produce stains on exposure, as is shown by the slight amount of discoloration in the weathered surfaces. The amount of weathered rock on the surface is very slight, so that very little work is necessary to open a quarry, even the surface blocks often being used.

A most important feature affecting the granite industry is the distribution of joints in the rock mass and the direction of the rift or plane along which the granite splits most readily. The spacing of these parting planes in the rock determines the kind of work for which each quarry is especially adapted. In a few quarries in the Rockland quadrangle the joints are so close together that only material for curbing and paving blocks can be quarried, but in many others exceptionally large blocks suitable for monoliths can be easily taken out.

Observations on the strike and dip of joint planes were taken at many localities in the main granite area and are plotted on the economic geology map. By reference to this sheet it will be seen that in the region from Harrington Cove eastward to Sprucehead Island and thence northward to Sprucehead village the dominant joint planes trend 60° to 80° east of north. To the northeast along the coast to Thorndike Point and Otter Point, a set of joints trending 50° to 70° west of north becomes more prominent. On Dix Island, High Isle, and the neighboring islands both sets are well developed, as are also several subsidiary sets. The dips of the joint planes almost nowhere depart more than 30°, and in but few places more than 15°, from the vertical, except those of flat-lying joints, which are in general not recognizable outside of the quarries. There is apparently little concordance in dip among the steeply inclined joint planes. The dominant joints seem to be wholly unrelated to the present topography and appear to have little relation to the main structural features of the quadrangle.

The following detailed quarry descriptions are taken mainly from a report, by T. Nelson Dale, on the granites of Maine (Bull. U. S. Geol. Survey No. 313, 1907), supplemented by the writer's own observations:

High Isle quarry.—This quarry is in Muscle Ridge Plantation, 9½ miles southeast of Rockland. Operator, William Gray & Son; office, Thirtieth street, below Walnut, Philadelphia, Pa.

The granite is a biotite granite of slightly pinkish medium-gray color, with conspicuous black mica, and of medium to coarse, even-grained texture, the feldspars measuring up to one-half inch and most of the biotite scales up to one-tenth inch, but some one-fifth inch across. It consists, in descending order of abundance, of a delicate pink potash feldspar (orthoclase and microcline), smoky quartz, milk-white (very slightly bluish) soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite, apatite, and secondary chlorite. The oligoclase is in some places partially altered to a white mica. The contrasts between the minerals are rather marked, but the polish is not very satisfactory, owing to the large size of the biotite scales.

The following chemical analysis and determination of specific gravity were made for the firm by Prof. James F. Kemp, E. M., of Columbia University:

Analysis of granite from quarry at High Isle.

SiO_2 (silica)	74.54
Al_2O_3 (alumina)	13.30
Fe_2O (ferrous oxide)	.79
Fe_2O_3 (ferric oxide)	.92
CaO (lime)	1.26
MgO (magnesia)	.009
Mn (manganese)	.51
S (sulphur)	.038
Na_2O (soda)	3.69
K_2O (potash)	5.01
	100.067

Loss on ignition, 0.55.
Specific gravity, 2.641, equal to 165.06 pounds per cubic foot.

The results of four crushing tests on cubes (2-inch) bedded with plaster of Paris, made at the engineering laboratory of Columbia University, are as follows: First crack at 100,000 to 126,300 pounds; ultimate strength, in pounds per square inch, 25,880, 32,360, 32,490, 33,085.

The grain and general character are fairly uniform over the whole of the island, though here and there a few bands or lenses show considerable variation from the normal grain.

The quarry, opened about 1894, consists of five openings, each about 100 feet square, with a maximum depth of 50 feet and an average depth of about 17 feet. The drainage requires pumping. The stripping is usually insignificant, but in places is from 5 to 10 feet thick.

The sheets, which are from 2 to 14 feet thick, are lenticular, tapering, and curve over to the northwest and southeast at low angles. A prominent joint course trends N. 80° W. and forms a heading on the south side of the island. Another set trending N. 45° E. is prominent and also forms a heading. A third prominent set trends N. 35° W. and dips 65° SW. The rift is vertical, with east-west course. Irregular horizontal dikes of pegmatite, up to 2 inches thick, consist of the same minerals as the granite—a pink orthoclase and microcline, smoky quartz, cream-colored oligoclase, and biotite. A rock stained by partial decomposition and known to the quarrymen as "sap" rock occurs along some of the more closely spaced joint planes. Along some of the headings the granite is weathered to a sand at a depth of 20 feet.

The plant consists of 9 derricks, worked by 8 engines; 2 locomotive cranes, 2 compressors (with a capacity of 862 cubic feet per minute), 15 large pneumatic drills, 28 pneumatic plug drills, 13 surfacers, and 20 pneumatic hand tools. Transportation is effected by gravity and track 650 feet to the wharf.

The product is used for buildings, chiefly in Philadelphia. Sundry small buildings and bridge seats for the Pennsylvania Railroad have been made of this stone. Contract in 1905: The new Wanamaker store in Philadelphia.

Dix Island quarries.—These quarries lie in Muscle Ridge Plantation, one-half mile southwest of High Isle. Owner, Thomas Dwyer, 1613 Amsterdam avenue, New York.

Six openings were operated extensively in 1880 by the Dix Island Granite Company, which employed 1400 men when filling large contracts. These quarries furnished material for the United States Treasury Department extension at Washington, the basement of the Charleston custom-house, the New York and Philadelphia post-offices, and the trimmings for the New York Metropolitan Museum of Art. Only an occasional block is now quarried. There is a wharf with 12 feet of water at low tide. These quarries are referred to by J. E. Wolff in Tenth Census, vol. 10, 1888, pp. 119, 120, and by G. P. Merrill in Ann. Rept. Smithsonian Inst., pt. 2, 1889, p. 416.

The granite is a biotite granite of somewhat dark gray shade and of medium to coarse, even-grained texture, with feldspars up to one-half inch and numerous fine biotite scales rarely exceeding one-tenth inch. It consists, in descending order of abundance, of delicate pink potash feldspar (orthoclase and microcline), smoky quartz, a very slightly bluish white soda-lime feldspar (oligoclase), and black mica (biotite), together with accessory magnetite and apatite. The oligoclase is partly altered to a white mica and rarely contains a little calcite. The biotite is here and there interleaved with muscovite. The chief difference between this and the High Isle granite is that in this the biotite scales are generally smaller and much more abundant, which darkens the shade of the rock and diminishes the contrast between the minerals.

The sheets are from 2 to 10 feet thick and dip 20° to 40° S. in places. Headings strike N. 80° E. and N. 35° W. In the northwestern part of the island the principal joints strike N. 80° E. and dip 45° to 55° N. In the southern part of the island joints were observed striking N. 5° E. with dip of 45° E., and N. 65° E. with dip of 70° NW.

"The Neck," Andrews, and Little Green islands.—The granite of the northern and central parts of "The Neck" is of medium grain and is similar to that on High Isle.

The joints are widely spaced and much of the rock should be commercially valuable. At the south end of the island the quality of the granite is injured by the presence of numerous spheroidal and lens-shaped basic segregations 1½ to 2 inches in diameter.

Most of the granite of Andrews Island is extremely close-jointed and much of it is of finer grain than the normal granite. It is doubtful if any is of commercial value.

Granite has been quarried to a slight extent on Little Green Island. The granite here is practically identical with that on High Isle, but its area is too small to make it of commercial importance.

Sprucehead quarry.—This quarry is on Sprucehead Island, in the town of St. George, about 10 miles south of Rockland and just south of the border of the Rockland quadrangle. Operator, Bodwell Granite Company, Rockland, Me.

The rock is a quartz monzonite, with conspicuous black and white particles and medium to coarse, even-grained texture, consisting, in descending order of abundance, of translucent white soda-lime feldspar (oligoclase), milk-white potash feldspar (microcline), smoky quartz, black mica (biotite), and black hornblende, together with accessory titanite, magnetite, pyrite, zircon, apatite, and secondary epidote. Zonal structure is common in the oligoclase. The contrasts between the black minerals, the smoky quartz, and the feldspars are very marked.

The quarry is about 275 by 250 feet, with a maximum depth of 55 feet and an average depth of about 27 feet. Those parts of the quarry which lie below sea level require pumping. No stripping is necessary.

The sheets, which range in thickness from less than a foot to 13 feet, lie horizontal or dip from 10° to 15° northwest and southwest, intersecting the surface, which dips gently to the southeast. The sheets are irregular in thickness, owing to the tapering out of the lenses, but in general become thicker downward. Prominent joints trend N. 57° E. Another set strikes N. 70° W. and dips 70° NE. The rift is vertical, with a N. 60° E. course. Some basic knots and dikes of aplite and pegmatite occur.

The plant consists of 4 derricks, operated by 4 engines, 1 compressor with a capacity of 527 cubic feet of air per minute, 2 steam drills, and 3 surfacers. Pneumatic drills and tools were about to be added in 1905. Transportation is effected by cartage 300 feet to the wharf. The quarry was idle in July, 1905, but preparations were being made for resuming work.

The product, consisting chiefly of building stone and some random and paving blocks, finds a market mostly in the West and South. Specimen buildings, etc.: Carnegie Library at Allegheny, Pa.; the new post-office and custom-house at Atlanta, Ga.; the columns of the Auditorium Building, Chicago, Ill.; the Mutual Life Insurance Company's building, New York.

Clark Island quarry.—The quarry on Clark Island, in the town of St. George, is about 12 miles south-southwest of Rockland and just beyond the border of the Rockland quadrangle. Operator, John C. Rodgers; office, 1909 Amsterdam avenue, New York.

The granite is a biotite-muscovite granite of bluish medium-gray color and of fine to medium, even-grained texture, with feldspar up to one-fourth inch and mica under one-tenth inch. It consists, in descending order of abundance, of light-bluish potash feldspar (microcline and orthoclase), clear or very slightly smoky quartz, light-bluish soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite), together with accessory garnet, zircon, apatite, and secondary chlorite. The oligoclase is partly altered to a white mica and includes a little carbonate. The quartz contains hairlike crystals of rutile (?). In general, as the quartz is so nearly clear, the bluish tint of the feldspar dominates and the contrast is mostly between it and the thickly disseminated black mica. It takes a very fine polish.

E. C. Sullivan, of the United States Geological Survey, finds that this granite contains 0.218 per cent of CO_2 (carbon dioxide), and that warm dilute acetic acid extracts 0.24 per cent of CaO (lime) and much MgO (magnesia). Figuring the CO_2 to both CaO and MgO, this would give 0.43 per cent of $CaCO_3$ (lime carbonate) and 0.06 per cent of $MgCO_3$ (magnesium carbonate). As stated above the thin section also shows carbonate.

Two tests of the crushing strength of this stone, made by the Pittsburg Testing Laboratory in March, 1899, showed 13,000 and 15,175 pounds per square inch.

The quarry, opened about 1870, is 500 by 300 feet and has a maximum depth of 50 feet and an average depth of 25 feet. A very little pumping suffices for drainage. There is no stripping.

The sheets, from 2 to 10 feet thick, strike N. 30° W. and dip 20° E. and on the east side of the quarry 20° to 30° W. They do not conform to the topography of the surface. Vertical joints strike N. 65° to 70° W., recurring at intervals of 10 to 20 feet. The rift is vertical, with a N. 85° W. course. There are two dikes of coarse pegmatite, up to 6 inches thick, one striking N. 15° W., the other N. 40° E. They consist of feldspar, quartz, muscovite, biotite, black tourmaline, and red garnet. The usual sap occurs along the sheets.

The plant consists of 8 derricks and 8 hoisting engines, 1 overhead traveling electric crane of 16 tons capacity and 1 hand crane of 2 tons capacity, 2 compressors (capacity 850 and 300 cubic feet of air per minute), 4 steam drills, 7 pneumatic plug drills, 8 surfacers, 2 polishers (Jenny Lind), 2 small polishing lathes, 22 pneumatic hand tools, and 2 steam pumps throwing 6-inch and 4-inch streams. Transportation is effected by horse power on a track 900 to 1200 feet long, extending to the wharf.

The product is used for building and ornamental work. Specimen buildings: The Hartford, Conn., and Buffalo, N. Y., post-offices; the Standard Oil building in New York. In 1905 the cutting plant was working on Stonington granite for the United States dry dock at Norfolk, Va.

Flat Ledge quarry.—This quarry, in the town of St. George, north of Clark Island and just south of the Rockland quadrangle, consists of several small openings ("motions") operated by Edwin Edwards. Address, Clark Island.

The granite is a biotite-muscovite granite of dark-gray color and fine, even-grained texture with flow structure, consisting, in descending order of abundance, of white potash feldspar (microcline and orthoclase), clear or barely smoky quartz, white soda-lime feldspar (oligoclase), black mica (biotite), and white mica (muscovite).

The quarry is operated for paving blocks, which are carried 1½ miles to the wharf.

Weskeag quarry.—This quarry is in the town of South Thomaston, 1 mile west of Pleasant Beach, which is 7 miles south of Rockland. Operator, C. E. Hudson, South Thomaston.

The granite from the Weskeag or Hudson's quarry has already been described in the general discussion of the granite. The stone takes a fine polish, but the abundance and size of the mica plates are not favorable to the durability of the polish under outdoor exposure.

The quarry, reopened in 1905 and still in process of development, covers about an acre of ground and has an average depth of 20 feet. The sheets are horizontal and tapering (lenticular). Joints strike N. 80° E. and dip 80° S. The rift is vertical and strikes N. 80° E. The grain is horizontal.

Smaller quarries.—A small quarry a few rods south of the Weskeag quarry, on the opposite side of the Pleasant Beach road, is worked for local use by N. C. Bassick & Son, of South Thomaston. The rock is the same as that at Hudson's quarry.

About 1½ miles southwest of the village of South Thomaston are several small quarry pits, one of which is operated by James Anderson, of South Thomaston, mainly for local building and monument work and for material for lining limekilns, though a few paving blocks are also quarried. The granite here is gray and of medium grain and contains both muscovite and biotite. It differs from the rock in the Weskeag quarry in having a larger number of tabular feldspars and in being slightly finer grained. The rock has a semiporphyritic appearance. The principal joints at the openings now operated strike N. 40° E. and dip 60° NW. A subsidiary set strikes N. 52° W. and dips 65° SW. The rift is about vertical and strikes nearly east and west.

A small quarry from which some stone is taken for local use for sills and monument work is located about a mile west of the village of South Thomaston, on the south side of the Thomaston road. The gray, medium-grained muscovite-biotite granite from this quarry is similar in a general way to that from Hudson's quarry. It shows excellent contrast between the polished and the hammered surfaces.

Five small quarries in medium-grained granite, not now worked, are located about 1 mile west of South Thomaston village, a short distance south of the Thomaston road, near the road corners close to the mouth of Sharkeyville Creek, in the southern part of Sprucehead village, and 1 mile southwest of Sprucehead village Their exact positions are indicated on the economic geology sheet.

In general, the medium-grained granite of the mainland differs from that of High Isle and Dix Island in carrying considerable amounts of muscovite. The presence of this mineral renders the stone less capable of retaining a high polish, but its quality for ordinary building purposes, for paving, etc., is excellent.

Harrington Cove quarries.—Several quarries, now abandoned, located near the northwest shore of Harrington Cove, have in the past furnished considerable amounts of fine-grained gray granite. These quarries form part of a considerable area of fine-grained granite whose extent is shown on the economic geology sheet. It seems to be intrusive in the normal medium-grained granite, for in one place in the quarry a few angular blocks of the latter are inclosed in the fine-grained granite. It is probable, however, that both granites belong to the same general period of intrusion. The average size of the feldspar grains in the stone from these quarries does not exceed one-eighth inch, though reaching one-fourth inch in places. The grains of gray quartz will not average more than one sixteenth inch. The rock is crowded with plates of muscovite and biotite up to one-eighth inch in diameter. The fracture of the rock under the hammer is easy and true, and it can be worked with great ease, especially for paving blocks. The abundance of mica renders it unfit to retain a polish, hence it is unsuited for monumental work. It also carries a large number of biotitic "knots" from one-fourth to 1 inch in diameter, some of which are slightly elongate parallel to each other.

"BLACK GRANITE."

Under the commercial term "black granite" are included a variety of rocks of different character, origin, and appearance—gabbros, diorites, diabase, etc. They have, however, three mineralogical characters in common; they contain comparatively little or no quartz, their feldspar belongs entirely or almost entirely to the series which contains both soda and lime, and they contain a considerable amount of one of the pyroxenes, or hornblende, or biotite and magnetite. The presence of these dark, iron-bearing minerals accounts for their dark color.

The area within which "black granite" of various kinds occurs in commercial quantities is indicated approximately on the economic geology map. Not all the rocks of this area are "black granites" nor is all the "black granite" there found of commercial quality.

"Black granite" is at present quarried only at one locality within the Rockland quadrangle; this is near the west shore of Long Cove, just north of the southern border. A small quarry here is worked intermittently by N. C. Bassick & Son, of South Thomaston. On the freshly fractured surfaces the principal constituent of this stone is seen to be dark-brown pyroxene in fresh crystals mostly one-eighth to one-fourth inch in diameter. Between the pyroxene crystals gray feldspar occurs, much of it showing distinct lath-shaped forms. Under the microscope this rock is seen to have the texture and composition of a typical diabase, though there has been a partial alteration of the pyroxene to brown and green hornblende. It polishes to a brilliant surface which is almost black, and the contrast between the hammered and the polished surfaces is moderately good.

"Black granite" from an abandoned quarry about 2 miles northeast of St. George village is much lighter in color and contains black mica (biotite) as its principal dark mineral. White feldspar is the other principal constituent and makes up fully half of the rock. Some dark-red garnet is also present. The abundance of mica in this rock would prevent it from taking a high polish and its quality is injured by the presence here and there of "knots" of coarser texture. Under the microscope this rock is seen to contain some quartz and some potash feldspar. It is therefore a true granite, though richer in dark-colored minerals than is usual. The rock for one-half mile north of this quarry is of similar character.

Just south of the quadrangle, near the west shore of Long Cove, a "black granite" quarry is operated by George McConchie, of South Thomaston (Crown Granite Works). The following description is quoted from Dale's report already cited:

> The rock is a norite of very dark gray shade and fine to medium texture, consisting, in descending order of abundance, of an unaltered colorless to smoky feldspar containing both soda and lime (andesine to labradorite), hypersthene partly altered to brown hornblende, black mica (biotite) in scales up to 0.2 inch, and magnetite, together with accessory pyrite.
>
> The quarry, opened in 1888, is about 50 feet square and from 10 to 15 feet deep and is provided with one derrick.
>
> The stone has to be carried 10 miles to the cutting works at South Thomaston, although the quarry itself is within one-fourth mile of seaboard.
>
> The product is used entirely for monuments. Specimen structures: The soldiers' monuments at Warren and Union, Me.

CLAY.

The general character and the distribution of the clays in this quadrangle are discussed in the section on surficial deposits (p. 5). In common with the limestone and much of the granite of Maine, the clays possess the commercial advantage of proximity to the coast, where the manufactured product can be easily and cheaply shipped by water.

Present utilization in brickmaking.—Plants for the manufacture of common brick are numerous along the lower portion of Penobscot River, near Damariscotta on Damariscotta River, and at other localities along this part of the coast. Within the Rockland quadrangle the only company engaged in brick manufacture is the Thomaston Face and Ornamental Brick Company, with a plant in the eastern part of the village of Thomaston. The clay at this brickyard is buff gray in color and free from pebbles or concretions. As it occurs in the banks it is moderately dry. It is dug by steam shovel and transferred in small cars to the disintegrator, where it is dry crushed. The clay is worked by the stiff-mud process, the dry material being carried by a belt from the disintegrator to a Raymond pug mill, where it is mixed with about 20 per cent of water and fed into a Raymond "999" brick machine provided with an automatic down-cut cutting table. This machine has a capacity of 8000 to 12,500 standard side-cut bricks per hour. The bricks are dried in a 10-tunnel drier having a capacity of 75,000 bricks. The burning is done in an ordinary scove kiln. The bricks show an air shrinkage of one thirty-second of their length and a fire shrinkage of one sixty-fourth, and incipient fusion takes place at about 3000° F. The product goes principally to Massachusetts and is shipped by rail, although water shipment is equally feasible. At present the whole output is common brick; but the clay is considered to be of too high grade for use solely for this purpose, and the company is now installing machinery for the production of pressed brick.

Chemical composition.—In the table below are given analyses of clays from three localities in the Rockland quadrangle:

Analyses of clays from Knox County, Me.

	1.	2.	3.
Silica (SiO_2)	62.80	62.33	61.59
Titanium oxide (TiO_2)	.87	.79	----------
Alumina (Al_2O_3)	17.36	17.70	19.10
Ferric oxide (Fe_2O_3)	4.40	5.19	} 7.53
Ferrous oxide (FeO)	[a] 2.00	[a] 1.72	
Lime (CaO)	.88	1.00	1.68
Magnesia (MgO)	1.58	1.53	1.87
Soda (Na_2O)	1.48	2.38	----------
Potash (K_2O)	3.05	2.41	----------
Water (at 107° C.)	1.31	1.11	} 5.51
Water (on ignition)	4.39	3.81	
Carbon dioxide (CO_2)	None.	None.	
	100.12	99.97	97.28

[a] The values reported for ferrous iron are questionable on account of the presence of a small amount of organic matter.

1. Clay from brickyards at Thomaston, Me. W. T. Schaller, analyst, U. S. Geological Survey laboratory.
2. Clay from Hayden Point, near South Thomaston, Me. W. T. Schaller, analyst, U. S. Geological Survey laboratory.
3. Clay on the property of the Rockland-Rockport Lime Company, near Rockland, Me.

Although these three samples were taken at localities several miles distant from each other their analyses are closely similar, a fact which suggests that throughout this region the clays possess a rather uniform composition. From the chemical analyses and also from a microscopic examination it is seen that these are not what could be called "sandy" clays, though the amount of sand is sufficient so that none need be added in mixing for brickmaking. Ries (The clays and clay industry of New Jersey: Final Rept. State Geologist New Jersey, vol. 6, p. 55), from a consideration of several hundred analyses of brick clays, finds that the silica percentages range from 34 to nearly 91, with an average of about 59 per cent. The Penobscot Bay specimens are only slightly above this average. The percentage of iron is fairly constant and is sufficient to give the burned bricks a bright-red color. The average for brick clays is about 5 per cent. The absence of calcium carbonate, shown by the absence of CO_2 in analyses 1 and 2, is a desirable feature, as is also the rather high percentage of alkalies. The latter are the most important fluxing constituents of the clay, and on burning serve to bind the grains together. If, as in this case, their quantity is large, the brick may be burned at a lower temperature than otherwise.

Possible utilization in the manufacture of Portland cement.—The lime industry of the Rockland region is discussed in another part of this folio, and it is worth considering whether the marine clays may not be utilized with this limestone in the manufacture of Portland cements. These cements are artificial mixtures whose essential constituents are lime, silica, and alumina. The first is generally supplied by limestone or marl, the other two by clay. In burning, the three constituents unite to form complex silicates, and it is essential that they be combined in the proper proportions in order to give the best results.

In clays utilized in the manufacture of Portland cement the silica percentage should lie between 60 and 70. These clays show 62 to 63 per cent silica. According to E. C. Eckel (Cements, Limes, and Plasters, 1905, p. 354), "the alumina and iron oxide together should not amount to more than one-half the percentage of silica, and the composition will usually be better the nearer the ratio $Al_2O_3+Fe_2O_3=\frac{SiO_2}{3}$." In the clay from Hayden Point (No. 2 in the table) this ratio is $\frac{SiO_2}{2.7}$. In reference to the quantity of clay needed Eckel (op. cit., p. 305) estimates that there should be in sight at least 1,600,000 cubic feet of clays, a twenty years' supply. This would mean only 3.67 acres excavated to the moderate depth of 10 feet. In view of what has been said of the extent and depth of the clays there should be no doubt as to the adequacy of the supply.

The limestone used should be relatively free from magnesia. Lime made from a highly magnesian limestone has the property of setting under water to a very hard mass. When mixed with clay, however, and burned at high temperatures in a Portland cement, it gives cements of doubtful character. The reason for this is that the carbonate of magnesia, unlike the carbonate of lime, does not ordinarily combine with silica or alumina at the clinkering heat employed in the manufacture of Portland cement. In amounts of less than 4 or 5 per cent, however, magnesia is certainly not injurious. The so-called "soft rock" of this region, being poorest in magnesia, would be the most available for cement purposes. As regards quantity needed, Eckel (op. cit., p. 305) estimates that at least 3,800,000 cubic feet should be in sight for each kiln established, a twenty years' supply. This would correspond to a body of rock 100 feet wide, 100 feet deep, and 380 feet long. The amount of limestone in the region is probably adequate to meet the demands.

At present the nearest Portland cement works are located in the eastern part of New York State, and the opportunities for building up a good local cement market seem to be good. With the same advantages of easy and cheap shipment by water, there seems to be no reason why Rockland cement, like Rockland lime, should not be able to hold its own in the New York market, as well as at other points on the Atlantic coast. In this connection it may be borne in mind that nowhere on this coast south of Rockland do pure low-magnesia limestones occur near the seaboard.

Future utilization in brickmaking.—The high quality of these clays, their abundance, and their favorable situation on the seaboard appear to warrant a much more extensive commercial development. A factor worthy of consideration in this connection is the possibility of utilizing in brick or Portland cement manufacture some of the water power of the coastal region. At a number of places along this part of the coast long tidal estuaries penetrate inland for considerable distances and are usually much contracted in width at one or more places. Through these narrow portions the tide, both at ebb and at flow, surges with great power, which, if harnessed, could be made to serve a variety of useful purposes. It is along such estuaries that the marine clays are best developed, and the possibility of the application of this power in the manufacture of brick, especially pressed brick, and of cement naturally suggests itself. A good example is Weskeag River, with narrows at the village of South Thomaston, 4 miles south of Rockland. There has recently been some talk of utilizing the power at this point. Marine clays of fine and uniform texture occur abundantly in this vicinity, the clay of analysis No. 2 being taken from Hayden Point, only 1 mile distant.

SAND AND GRAVEL.

Gravel and sand for road improvement and for building purposes occur abundantly in all except the southwestern part of the quadrangle. The location and approximate area of the deposits and the location of the pits from which sand or gravel has been dug are shown on the surficial geology sheet. The bulk of these materials is of glaciofluviatile origin, but modern beach gravel and sand are utilized to a slight extent. The deposits of glacial gravel which occupy the valley of Megunticook River are the principal source of supply for Camden and vicinity. Rockland is supplied largely from deposits of gravel south of Chickawaukie Pond. A large pit one-half mile northeast of Blackinton Corners shows a maximum exposure of 10 feet of horizontally stratified gravel, and the bottom has not yet been reached.

ROAD MATERIALS.

The Rockland quadrangle is fairly well supplied with materials suitable for the construction of good roads. Trap rock, which experience has shown to be the best all-around hard-rock road material, occurs abundantly within the quadrangle in a belt extending in a northerly direction from Long and Cutlers coves to a point somewhat beyond the St. George–South Thomaston line, as shown on the economic geology sheet. The trap rock in this area ranges from fine-grained diorite to typical diabase and fine-grained gabbro, and has been quarried in a small way at a number of places for building and ornamental purposes. A test of a rather fine grained gabbro from the McConchie quarry, already described in the section on "black granite," shows the rock to be hard though not very tough, and to possess fairly high resistance to wear and good cementing value. This would make an excellent road material, and much other trap of this area would probably be of equally good quality. These rocks could be readily quarried and shipped by water to Thomaston or Rockland. Trap rock of excellent quality also occurs abundantly on the islands of North Haven and Vinalhaven, in the adjacent Penobscot Bay quadrangle, and could be cheaply shipped to the city of Rockland.

No samples of granite from this quadrangle have been tested to determine their road-making value. In common with similar granites occurring elsewhere they possess a high degree of hardness, but are deficient in toughness and in cementing value, and show only moderately good resistance to wear. The finer-grained varieties are in general more suitable for road construction than the coarse varieties, but their use alone on the roads can not be recommended. Good roads may, however, be constructed with a foundation of granite and a top dressing of trap or of limestone.

The rocks of the Penobscot formation and of the areas occupied by Penobscot slate injected by granitic material all possess a foliated structure which causes them to break up rapidly under traffic. They are uniformly of poor quality for road construction.

Tests made by the Office of Public Roads on Battie quartzite occurring on Pine Hill, north of Clam Cove, and of Weskeag quartzite occurring 2 miles southwest of Rockland show that both of these rocks are hard but of rather low toughness. They possess fairly high resistance to wear and moderate cementing value. Their use alone on the roads, because of their low toughness and somewhat deficient cementing properties, can not be recommended, but the rock might be successfully used for road foundations if covered with a top dressing of trap or of limestone.

A test made on a typical sample of the limestone quarried near Rockland shows that like most limestones it is rather soft. It has low toughness and low resistance to wear, but possesses very good cementing value. As already suggested it could be utilized as a top dressing for roads constructed of quartzite or other rock deficient in cementing quality.

In the western part of the city of Rockland siliceous limestone of the Rockland formation has been quarried to a slight degree for road use. As it combines in a measure the hardness of quartzite with the good cementing value of limestone, it should make a very satisfactory road material, but it occurs in too small quantity to be available for anything more than very local purposes.

The gravels are the materials most extensively used on the roads of the quadrangle. They are particularly abundant in the eastern and northern parts of the area and are for the most part of good road-making quality. Their distribution and the location of all important gravel pits are shown on the surficial geology sheet.

Over considerable areas in the southern part of the quadrangle marine clays are very abundant. Many of the roads in these areas could be notably improved by mixing with the clay a proper amount of sand to form a sand-clay road. Experience has shown that a mixture of these materials in the proper proportion compacts into a hard and lasting road bed. No definite rules can be given here for determining the correct proportions of these constituents, for they depend on the local composition of the materials. In general, however, the clay should be present in sufficient amount to occupy completely all the interspaces between the sand grains, and experience has shown that the mixing can not be successfully accomplished in the dry state, but that the materials must be "puddled" in water.

PEAT.

When thoroughly dried peat has the property of igniting more or less readily and burning with a clear flame and very little smoke. When of good quality and well dried its fuel value equals about three-fifths that of a good bituminous coal. In preparing it for use as fuel it is essential to reduce its water content from the 80 to 90 per cent present when it is freshly dug to 15 or 20 per cent. Experience has shown that mere squeezing of the material, even under high pressure, will not expel enough of the water. To effect this result the peat must be thoroughly torn to pieces and dried either in the open air or by artificial heat. Subsequent compression into briquets makes the material easier to handle and transport and also causes it to hold its form better in burning. Both crude and compressed peat have been extensively used as a fuel in Europe for many years and will doubtless come into wide use in America as well.

The Rockland quadrangle possesses an abundant supply of peat of a quality suitable for fuel. The largest peat bog lies 2 to $2\frac{1}{2}$ miles northwest of Rockland and is drained by Keene Brook, East Branch of Oyster River, and Branch Brook, a fork of Mill River. Much of this bog is an open heath whose plants are sphagnum mosses, small shrubs belonging to the heath family, and scattered small spruces and larches. Considerable areas in the northern part of the bog are covered with a heavy growth of hardwood timber. Tests holes put down in the southern part of the bog showed the peat to be brown, compact, fairly well decayed, and apparently of excellent quality for commercial use. Analyses of two samples of peat from this bog gave the following results:

Tests on oven-dried peat samples from bog near Rockland, Me.

		1.	2.
Volatile combustible		66.12	
Fixed carbon		29.74	
Ash		4.14	19.70
Sulphur		.22	.50
Nitrogen		.87	3.10
Calorific value	Calories	4956	4374
	British thermal units	8921	7873

1. Dark-brown fibrous peat from depth of 3 to 4 feet in southeastern part of "The Bog." Consists of partially decayed sphagnum moss with some remnants of sedges and stems and leaves of plants of the heath family.

2. Peat from depths of 10 to 12 feet at another hole in southeastern part of "The Bog." Appears more thoroughly decayed than No. 1. Clay bottom is encountered at depth of 13 feet.

In percentage of ash sample No. 1 is considerably below the average for most Maine peats, 37 samples from bogs in different parts of the State showing 8.46 per cent of ash. Sample No. 2, on the other hand, is much above the average in ash content, probably because it came from within a foot or so of the clay bottom of the bog. The heating values (calorific values) given above may be compared with the figure 8875, which is the average value in British thermal units for 37 samples of Maine peats. The thermal value (dry) for bituminous coals of good grade usually ranges from 12,000 to 15,000 B. t. u.

The average ash content and calorific value for the peat of the bog would probably be nearer the values for sample No. 1 than those for No. 2.

In places in the southern part of this bog 20 feet of peat were found, and its average depth is probably not less than 10 feet. Its area, which is at least 1 square mile, insures a quantity of peat sufficient to supply all possible local demands for many years to come. The number of tons of air-dried machine peat which a bog will yield may be estimated roughly by dividing the volume of peat in cubic feet by 200. On this basis the Rockland bog should yield at least 1,300,000 tons.

Tests made at the United States Geological Survey fuel-testing plant at St. Louis show that peat may be most economically used by converting it first into gas in a producer-gas plant, 2.39 pounds of peat from Florida used in this way to drive a gas engine furnishing as much power as 5.78 pounds of the same peat used under a steam boiler. In both quantity and quality the gas obtained from a ton of the peat tested was superior to that usually obtained from the better grades of bituminous or anthracite coal.

In this connection the possibilities of the use of producer gas obtained from peat in the burning of lime are worthy of consideration. Producer gas obtained from coal has been used in lime burning in a number of places and though in general somewhat more expensive than the ordinary fuel has the advantage of being cleaner. With the use of peat gas instead of coal gas the cost would probably be materially lessened and might fall below that of the coal or wood now used in lime burning.

Besides its use as a fuel, peat has been successfully employed in the manufacture of certain kinds of paper and paper board, as packing, as bedding for stock, and as an absorbent in the manufacture of fertilizers.

SOIL.

The soils of the Rockland quadrangle are mainly of glacial origin, modified to some extent by post-glacial accumulations of humus. The most fertile areas are undoubtedly those covered by glacial till, but the abundance of bowlders in many places makes the original clearing of these areas a difficult task. Their extent is shown on the surficial geology sheet. In the more hilly northern and northwestern parts of the quadrangle the till covering is very thin or wholly lacking over considerable areas, which, as a consequence, are suitable only for pasturage. The lowlands covered by marine clays are usually much less fertile, although they are extensively cultivated. Their surfaces are free from bowlders and the labor of clearing the land is much less than in the till-covered areas. The lesser fertility seems to be not so much a matter of chemical composition as of texture, for in wet seasons the crops on the clay areas are frequently much delayed because of the slowness with which the ground absorbs the excess of moisture.

WATER.

The present water supply of the Rockland region is derived in part from lakes and in part from underground sources, the waters from streams being little used except for watering stock. The larger part of the supply for domestic use on the farms is obtained from dug wells 5 to 30 feet deep, tapping the ground water in the surficial deposits. Wells of this kind are commonly very shallow and many of them are located on low ground. The quality of the water obtained ranges from excellent to very poor, such wells being liable to contamination from barnyard and other sources. Those located wholly within deposits of glacial till usually yield a moderate supply but are in danger of failing during a dry summer. The same danger from drought exists in the wells located wholly in deposits of marine clay. As a rule the best supply from surficial deposits is obtained from the gravels or sands which may overlie the marine clays, the till, or solid rock, the principal flow usually being found near the bottom of the deposit. In a few localities gravel underlies marine clay, and a good water supply is obtained by penetrating through the clay to the gravel. Some wells of this kind are free flowing when first dug.

Springs are rather abundant in this quadrangle, being most commonly located on hill slopes, especially at the contact between gravel or sandy till, and underlying clay or solid rock. Most of them are subject to much seasonal variation, and only a few survive a severe drought. There are several excellent springs about one-fourth to one-half mile west of Rockport village, along the north side of the road to West Rockport; and in Nabby Cove, near Pleasant Beach, a bubbling spring of fresh water of considerable volume issues on the clam flats well below the high-tide mark.

There is a growing disposition in this region to utilize the ground water stored in the solid rock, and a large number of wells have been drilled to various depths up to 640 feet. These wells are mostly located at elevations of less than 100 feet and their yield varies greatly, some being very successful while a few are failures. From most of them the supply can be obtained only by pumping, though the water usually rises in the well above the level at which it is first struck. The village of Warren derives its water supply from a well 196 feet deep with 6-inch bore, located in the schists and gneisses of the hill east of the village at an elevation of about 200 feet above tide. This well when drilled was free flowing and yielded 12 to 15 gallons per minute, but a much larger supply ranging from 100 to 125 gallons per minute is obtained by pumping, effected by windmill and by a gasoline engine. A test in which pumping was continued for five days and five nights gave an average flow of 100 gallons per minute. The water is soft and of excellent purity. It is pumped to a reservoir about 800 feet distant and furnishes an abundant supply to the village. A well drilled at Crescent Beach in 1906, also within the area of injected Penobscot formation, attained a depth of 75 feet and furnished 5 to 6 gallons of water per minute. It is reported that in the wet season the water rises within 2 or 3 feet of the surface. The well supplies the summer cottages at this place. By pumping, the water level can be lowered to 30 or 40 feet, but the well can not be pumped dry. A well with 8-inch bore sunk to a depth of 640 feet in Penobscot slate on the grounds of the Samoset Hotel near Rockland failed to obtain any considerable supply, though a slight amount was obtained at a depth of 185 feet.

The water obtained from wells drilled in limestone and from dug wells within or near limestone areas is uniformly very hard. The only known drilled well in the limestones is at the plant of the Thomaston Brick Company. It was drilled for 46 feet through marine clay, then in limestone for 340 feet, making a total depth of 386 feet. The water is hard, and the supply is only about 3 to 5 gallons per minute.

Many parts of the shore occupied by summer residents are remote from any lakes or streams and are nearly free from surficial deposits, and in such localities the ground water in the rocks is practically the only source available. It becomes of vital importance, therefore, to know something of the conditions controlling this supply.

The prevailing rocks over much of the quadrangle are massive granites, and the rest of the land area is occupied by much folded and metamorphosed sediments which are compact and well cemented. The physical character and the structure of these rocks are plainly quite different from those observed in typical artesian basins; in no strict sense can it be said that a porous stratum between impervious strata is present, neither is there any approach to basin structure. However, that artesian water exists in this area is proved by the flowing well at Warren and by other deep wells which do not flow but in which the water encountered is under static pressure, as shown by the rise within the well. Essentially, then, the water supply of these deep wells is of the artesian type—that is, the water rises within the drill hole for a score or more of feet above the level at which the drill tapped it.

In rocks so massive as the granites and diorites of this quadrangle and so thoroughly cemented as the sedimentary rocks, the circulation of the ground water must take place largely along fracture planes rather than through pore spaces. The fractures may follow joint planes and planes of bedding and of schistosity in sedimentary rocks, but in the granitic rocks the joints are practically the only openings. The development of artesian pressures in such rocks must be dependent on the distribution of the fracture planes and on differences in the readiness of water circulation along different sets of fractures. It involves (1) greater ease of circulation at considerable depths than near the surface and (2) the existence of certain channels for the transfer of water from higher zones to the zones of deeper circulation, thus producing a "head."

One of the simplest ways in which the above-named conditions may be fulfilled is afforded in places where an inclined fracture zone in the rock serves both as the deep-seated zone of easier circulation and as the channel for the transfer of water from higher to lower horizons. In such places a well penetrating a considerable thickness of relatively impervious rock, taps the fracture zone, which has become filled with ground water, and the water rises in the well nearly to the level at which it stands in the fracture zone.

A relatively impervious cover may result in at least two other ways—(1) by more complete cementing of the fracture planes in the upper horizons than in the lower, or (2) by greater ease of circulation along nearly horizontal fractures than along those which are highly inclined. Either of these conditions, if supplemented by the presence of a few inclined channels for the passage of water from higher to lower levels, may result in artesian conditions of water confined under "head." The study of ore deposits has shown that the filling of fractures by cementation or the deposition of minerals from water solutions goes on more rapidly in the upper part of the ground-water zone than in the lower part. Cementation of this kind is known to have taken place in the sedimentary rocks of this quadrangle and may be an important factor in the production of artesian pressures. Greater ease of circulation along nearly horizontal fractures than along those which are highly inclined has not been proved for any of the rocks of this region, but may be an important factor in the granite, where flat-lying joints are very numerous. The weight of the rocks themselves would tend to close the flat-lying openings, but this effect may be offset by lateral pressure, as will be brought out later.

Few drilled wells have been sunk within the granite areas of this quadrangle, but the water conditions throughout these areas are probably similar to those encountered in the vicinity of Stonington, in the adjacent Penobscot Bay quadrangle, where in drilled wells 5 to 6 inches in diameter sunk to depths of 50 to 150 feet the water rises within 20 or 10 feet or even less of the surface, and a steady supply of 1 to 3 gallons per minute can be procured by pumping. In the well of the Pine Rock Water Company, sunk to a depth of 183 feet, a flow of 28 gallons per minute is reported. The depth at which the principal flow is obtained varies in different wells, ranging from 12 to 180 feet. The fact that in almost all wells drilled in granite the water is under a pressure which causes it to rise in the well hole when struck proves that there are masses of the granite which are practically impervious to the flow. They are surrounded by fissures, more or less inclined, which are full of water; and when the drill, having passed through the impervious block, strikes a fissure, the water rises to its own level in the drill hole. If the level is above the top of the drill hole, the well becomes free flowing; if below, the water must be pumped. The fact that the drill sometimes drops several inches on reaching the water-bearing level shows that some of these channels are of considerable width. In many of the granite quarries the rock is found to be under very considerable lateral pressure, as indicated by the fact that a block once removed from between two granite walls can not, after the lapse of a short time, be replaced, the walls of the opening having in the meantime drawn closer together. Such lateral pressure would tend to close highly inclined joints and thus restrict the flow of water along them, while at the same time relieving to some extent the pressure due to the weight of the rock and making circulation easier along flat-lying fractures. How great an influence this condition has on the underground circulation is unknown, but it is probably not very great. It is to be expected that, except at very high points in the granite areas, a sufficient water supply for domestic purposes may be obtained at depths of 100 to 150 feet. The water is usually soft, and that obtained from the granite is freer from mineral matter than that from any other rocks of the quadrangle. The poorest water seems to be obtained from the areas of metamorphosed and injected Penobscot formation. The water in these areas is likely to be high in iron and sulphates, probably as a result of the greater development of sulphides, especially pyrite, in these rocks by contact metamorphism.

In many other parts of the quadrangle inclined fracture zones seem to be of considerable importance, many successful wells being located on nearly vertical fracture zones or tapping at some depth a fracture zone which descends at a rather steep angle from the surface. Some unsuccessful attempts to find water appear to have resulted from failure to strike such an inclined fracture zone, as in the case of well B in the diagram (fig. 2). Many failures like this could have been avoided by a preliminary study of the position of the fracture planes at the surface and the inclination at which they descend into the earth. The position of a successful well is shown at A in the diagram. In the case of small cracks, however, it is not safe to place much dependence on their persistence in depth. Broad zones of fracturing, which are in many places indicated by low belts between higher ledges, are more reliable. The depth of most of the drilled wells ranges from 100 to 300 feet, the principal flow being obtained at depths of 60 to 140

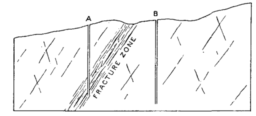

FIG. 2.—Diagrammatic section showing a well at A obtaining water from a fracture zone and a dry well at B.

feet. The water rises within 10 to 35 feet of the surface, and supplies of 4 to 20 gallons per minute are obtained by pumping. Because of the presence of limestone the water from many of the wells in the Rockland-Camden region is hard.

In general, the distribution of fractures in the rocks in this quadrangle is such that a few failures among deep wells may be expected, for the water circulation is confined mainly to certain trunk channels rather than distributed equally throughout the water-bearing zone, but the percentage of failures should be very small if judgment is used in the selection of the location for drilling. In most localities an abundant flow may be expected at a depth of less than 100 feet, but in some the drill may reach a depth of 300 or 400 feet before water is encountered in good quantity. In general, the flow of ground water is from the land toward the sea, but wells located close to the seashore, especially in a highly fractured region, are liable to some inflow of salt water in case the volume of fresh water flowing out from the rocks under head is not sufficient to fill the fissures and keep the salt water out. In such wells active pumping is likely to increase the brackishness, as the fresh-water artesian pressure is thereby reduced, while the back pressure from the ocean waters remains practically unaffected.

The city water supply of Camden, Rockport, Rockland, and Thomaston is derived largely from Oyster River Pond (Mirror Lake), situated near West Rockport at an elevation of 373 feet. This is a deep lake which is fed largely by springs and the water is of excellent purity. Several analyses show this water to be practically free from nitrates and nitrites and to contain only a normal percentage of chlorine. The total solids range from 20 to 50 parts per million. The increasing number of summer cottages around the lake introduces a source of contamination of the waters which should be carefully watched. Rockland derives an auxiliary water supply from Chickawaukie Pond at an elevation of 123 feet. This pond is shallower and is situated in a more settled region and is therefore still more liable to contamination, though the water is of fairly good quality.

December, 1907.

Analyses of limestone and limes from Knox County, Me.

	1.	2.	3.	4.	5.	6.	7.
Lime carbonate	----------	53.13	74.36	53.52	----------	----------	98.17
Magnesium carbonate	----------	42.94	21.62	45.13	----------	----------	.09
Calcium oxide	55.10	----------	----------	----------	96.31	85.51	----------
Magnesium oxide	38.70	----------	----------	----------	1.13	9.25	----------
Silica and insoluble matter	4.59	2.87	1.85	} .90	1.42	2.74	1.08
Iron and alumina	1.61	1.06	1.04		1.08	1.61	.15
	100.00	100.00	98.87	[a]100.00	99.94	[b]100.00	[c]99.77

[a] Total includes moisture, etc., 0.45 per cent.
[b] Total includes 0.89 per cent loss on ignition.
[c] Total includes 0.28 per cent of organic matter.

1. Magnesian lime from Gay farm quarry, 2 miles southwest of Rockland along the railroad. R. S. Edwards, analyst.
2. Magnesian limestone from quarry operated by S. P. Dunton, 1 mile southwest of Rockland. Specimen taken at depth of 18 feet. F. C. Robinson, analyst, Brunswick, Me.
3. Magnesian limestone from Levensaler quarry, 1 mile north of Thomaston. Deficiency in total may indicate error in figures.
4. Magnesian limestone from quarries at West Warren. S. P. Sharpless, analyst, Boston, Mass.
5. "Soft rock" lime from eastern pit of Rockland-Rockport Lime Company, near Rockland. R. S. Edwards, analyst.
6. "Hard rock" lime from Fred Ulmer "hard rock" quarry, west of Rockland. R. S. Edwards, analyst.
7. "Soft rock" from McNamara quarry, Rockland. F. C. Robinson, analyst, Brunswick, Me.

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MAINE
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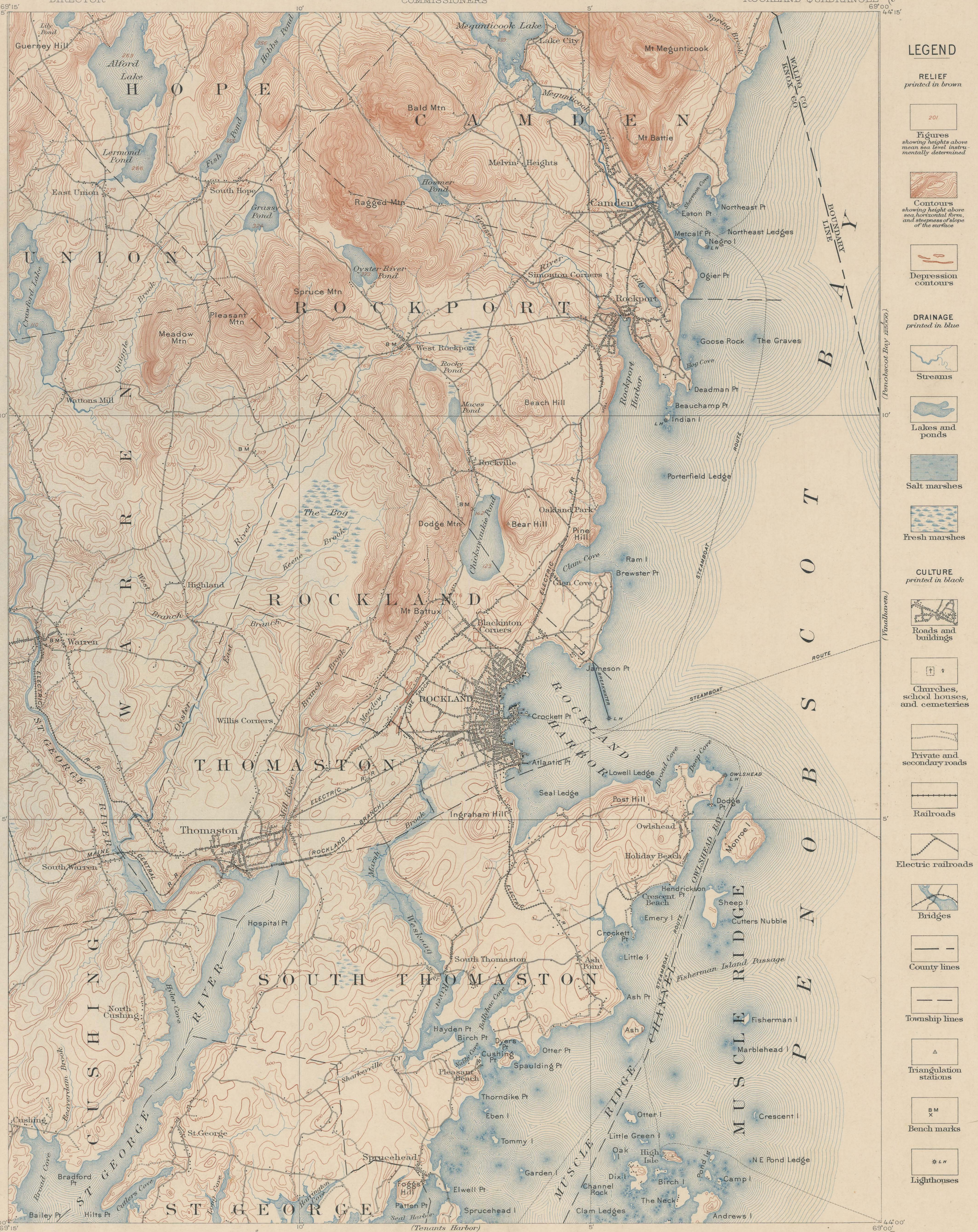
ROCKLAND QUADRANGLE



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Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.

Datum is mean sea level.

Edition of Mar. 1906, reprinted Feb. 1908.

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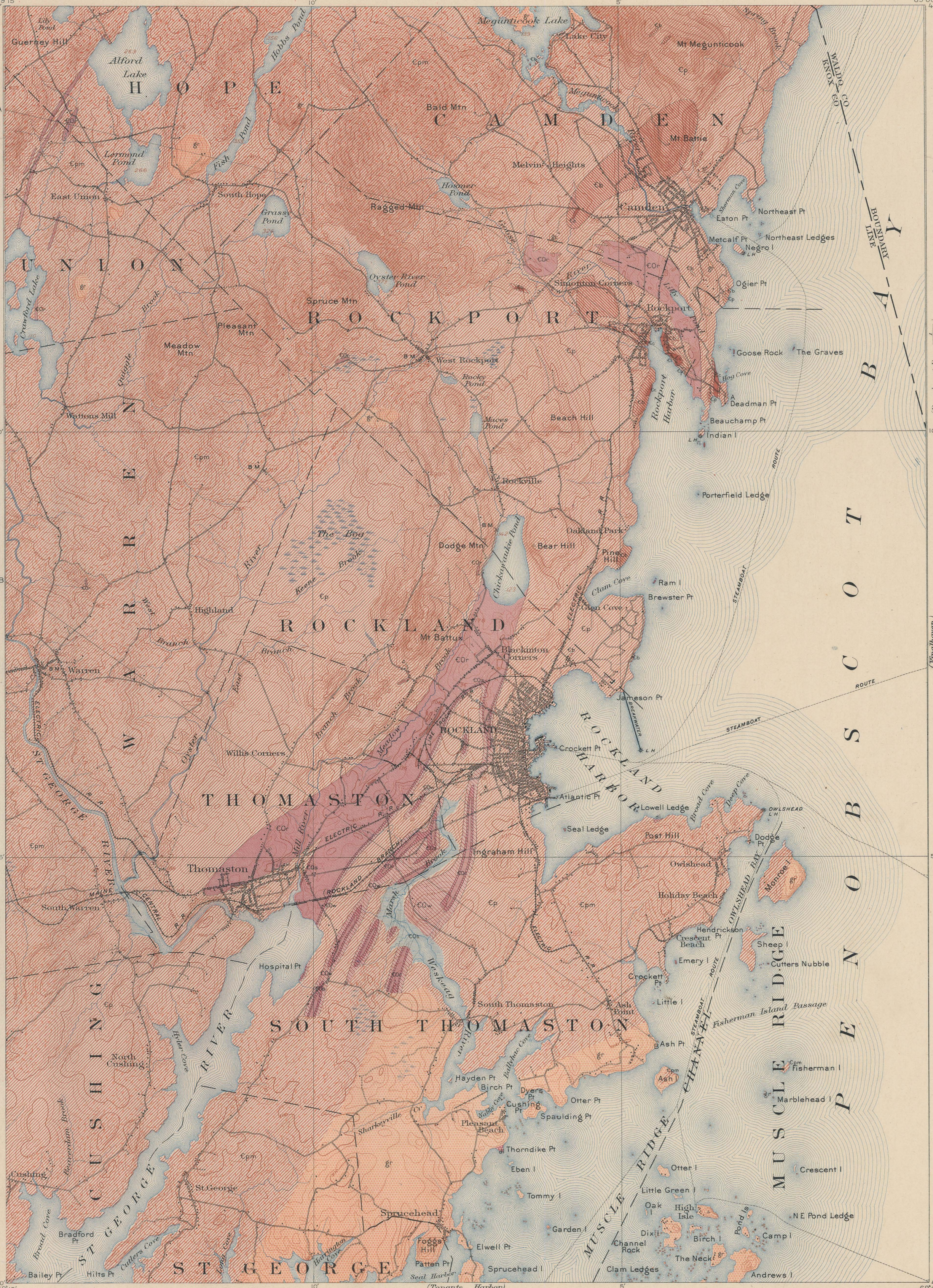

LEGEND

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; metamorphism is indicated by hachures combined with the line patterns)

CAMBRO-ORDOVICIAN ?

€Or, €Os, €Ow — **Rockland formation** *(white to purple crystalline limestone, limestone conglomerate, and shaly limestone, comprising Rockport limestone member, €Or, with greenish siliceous limestone member, €Os, and Weskeag quartzite member, €Ow, locally at the base)*

CAMBRIAN ?

€p — **Penobscot formation** *(regionally metamorphosed rocks, chiefly slate and schist)*

€pm — **Metamorphosed sedimentary rocks** *(principally Penobscot formation, injected and further metamorphosed by granite, diorite, and diabase)*

€b — **Battie quartzite** *(quartzite and quartzite conglomerate)*

€c, €i — **Islesboro formation and Coombs limestone member €c** *(slate and schist with shaly, and occasionally pure limestones, €c)*

IGNEOUS ROCKS

(Areas of igneous rocks are shown by patterns of triangles and rhombs;)

SILURIAN OR DEVONIAN

gr — **Biotite-granite** *(fine, medium, and coarse-grained granite)*

di — **Diorite, diabase, and gabbro**

Faults

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Scale 1/62500

Miles — Kilometers

Contour interval 20 feet.
Datum is mean sea level.

Edition of Mar 1908

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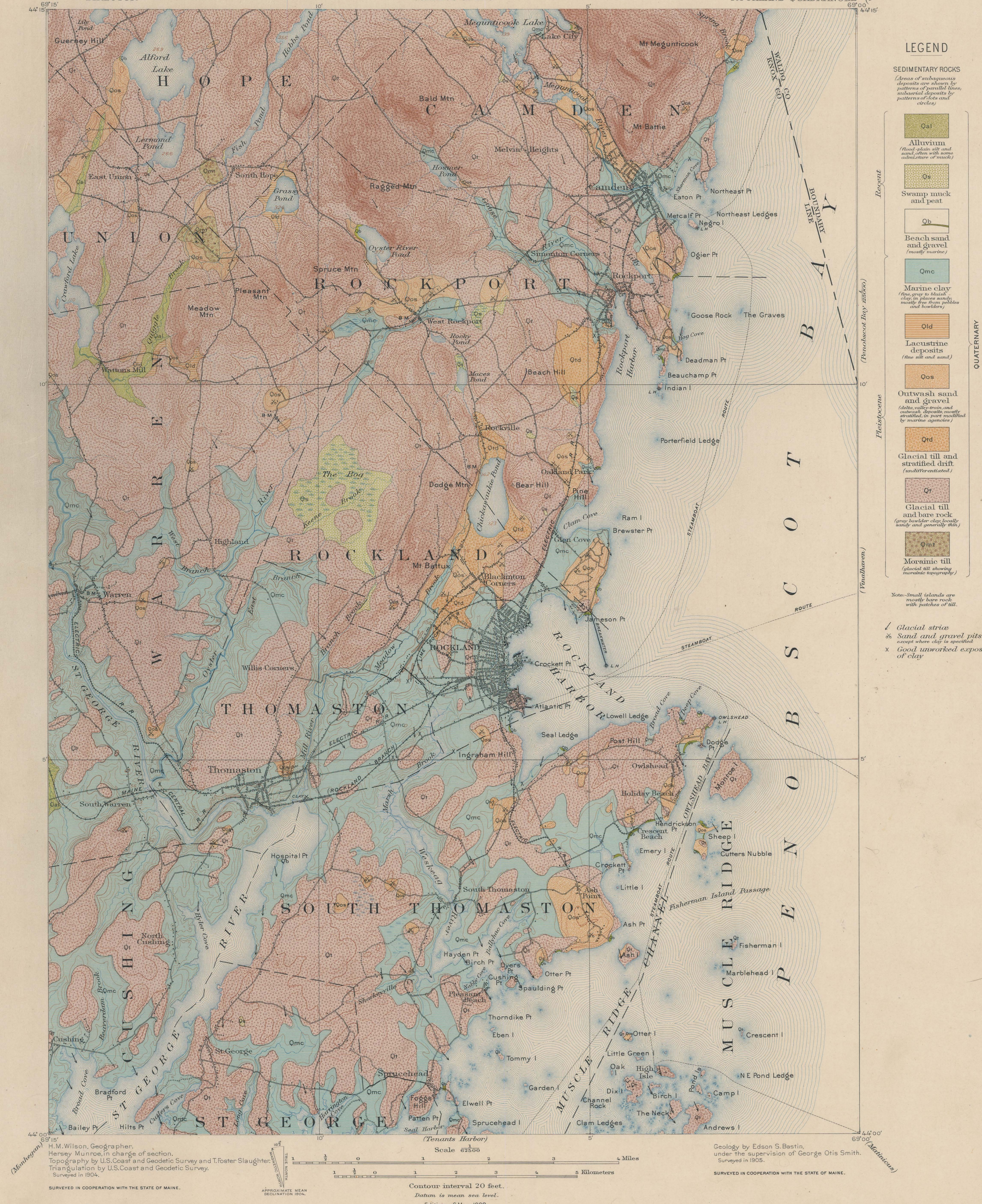

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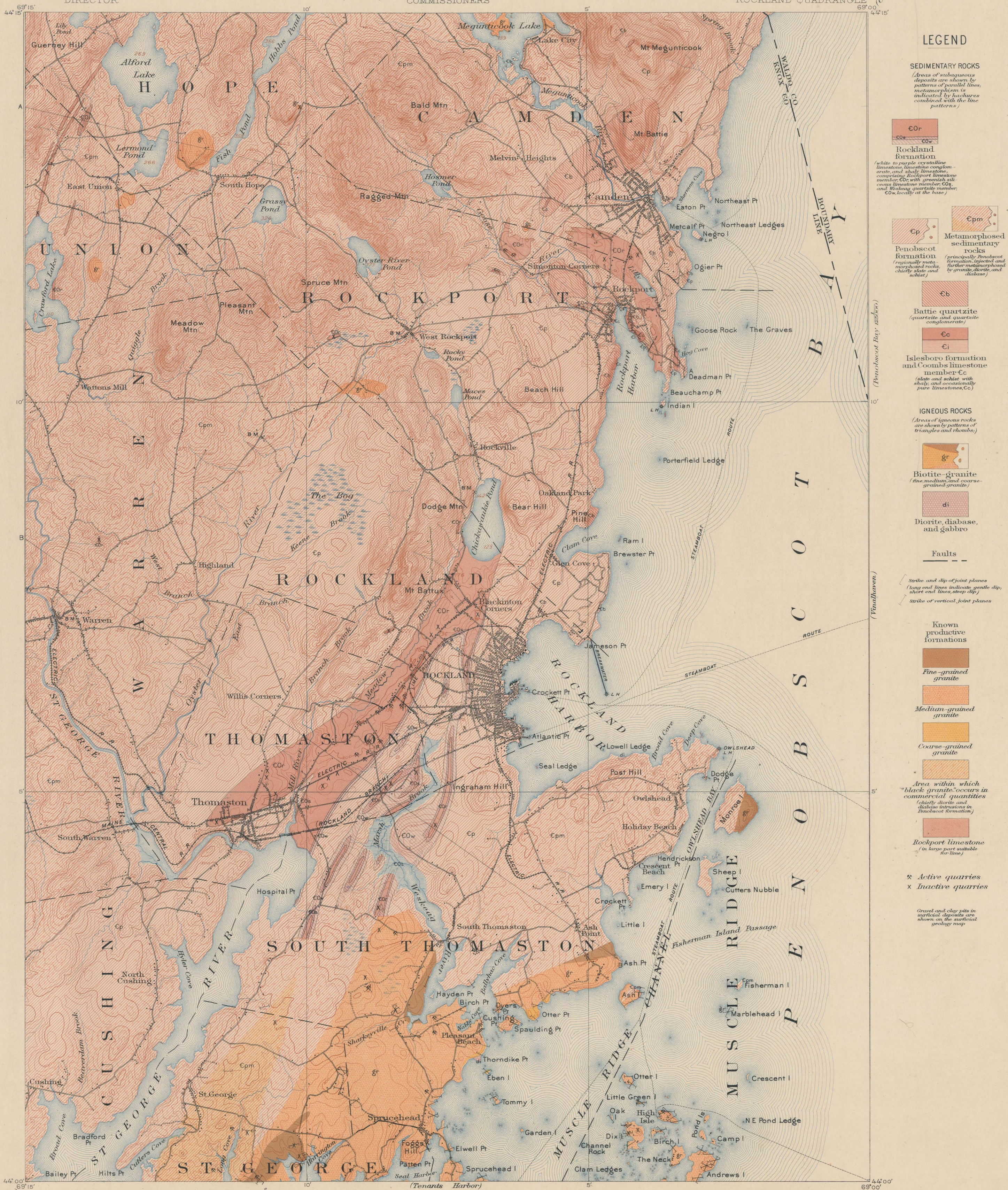
ROCKLAND QUADRANGLE



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MAGNETIC NORTH
16½°
APPROXIMATE MEAN DECLINATION 1904.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

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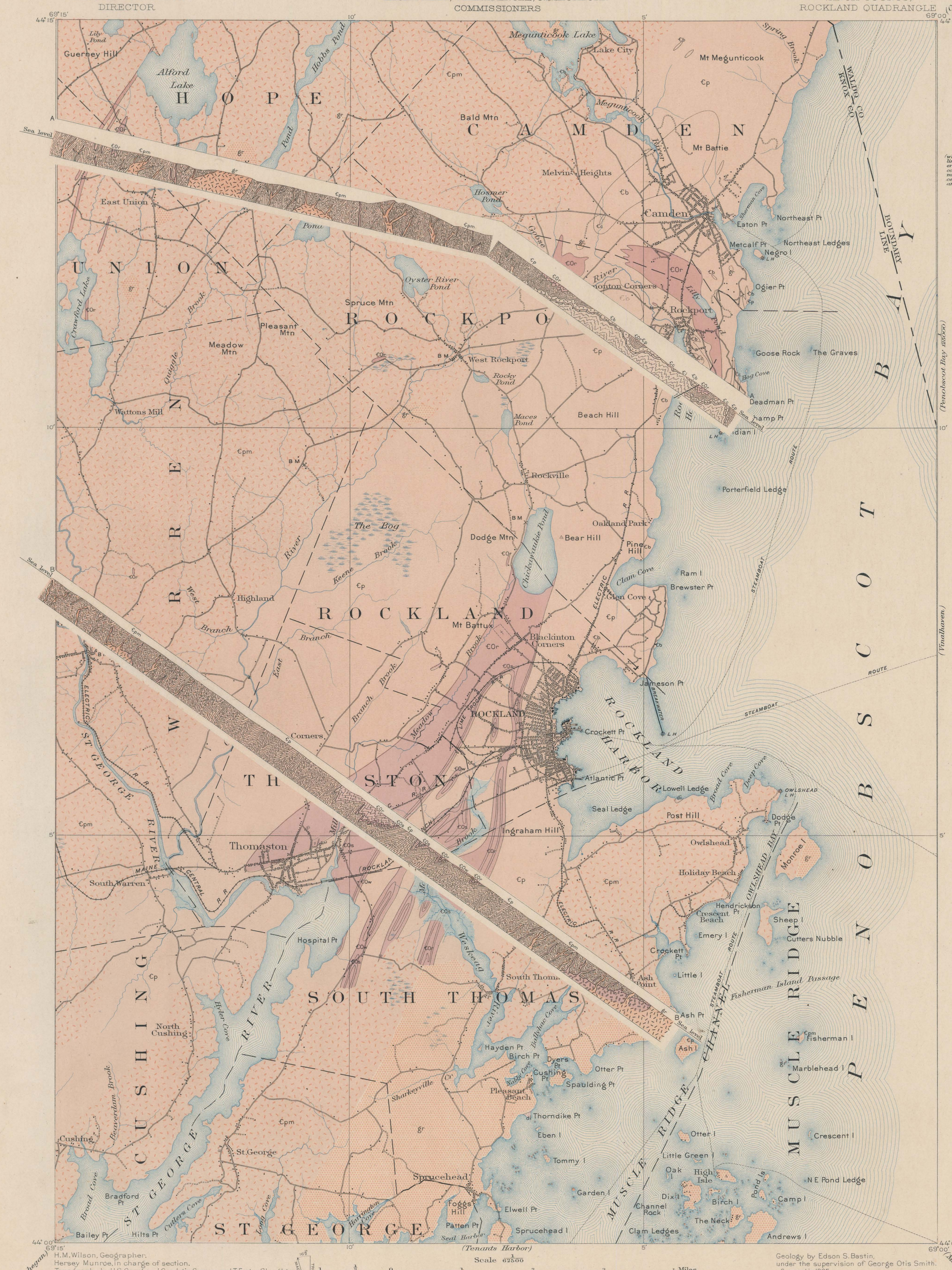

LEGEND

SEDIMENTARY ROCKS

SHEET SYMBOL — SECTION SYMBOL

Rockland formation (white to purple crystalline limestone, limestone conglomerate and shaly limestone, comprising Rockport limestone member, €Or, with greenish siliceous limestone member, €Os, and Weskeag quartzite member, €Ow, locally at the base) — €Or, €Os, €Ow

Penobscot formation (regionally metamorphosed rocks, chiefly slate and schist) — €p

Metamorphosed sedimentary rocks (principally Penobscot formation, injected and further metamorphosed by granite, diorite, and diabase) — €pm

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Battie quartzite (quartzite and quartzite conglomerate) — €b

Islesboro formation and Coombs limestone member €c (slate and schist, with shaly and occasionally pure limestones, €c) — €c, €i

CAMBRIAN?

IGNEOUS ROCKS

Biotite-granite (fine, medium, and coarse-grained granite) — gr

Diorite, diabase, and gabbro, — di

SILURIAN OR DEVONIAN

Faults

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† Payment must be made by money order or in cash.
‡ These folios are out of stock.

Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.