DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

EASTPORT FOLIO
MAINE

BY

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

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 of the most important ones 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 vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

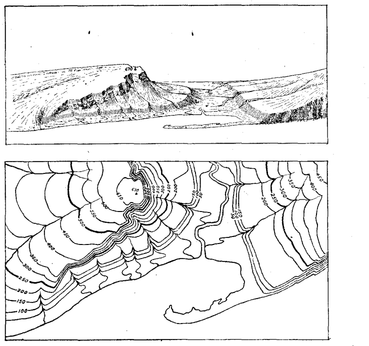


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines 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 the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and 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 the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain 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.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. 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 the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, 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, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States 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 $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. 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 are printed the names of adjacent quadrangles, if the maps are published.

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, by means of structure sections, their underground relations, so 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.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the 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. Some of the materials are carried in solution, and deposits of these are 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 kinds of deposit named 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*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *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 various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

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, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be 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 contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

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

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*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, 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. Where 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 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 many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general 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 may be 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 that of their metamorphism.

Symbols, 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.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. 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 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 of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

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		TR	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
	Algonkian		A	Brownish red.
	Archean		AR	Gray-brown.

SURFACE FORMS.

Hills, 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 through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 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. 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 afterward 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. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or 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 particular formation, its name should be sought in the legend and its color and pattern noted; then 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 names of 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.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that 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 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 to a considerable depth. Such a section is illustrated in figure 2.

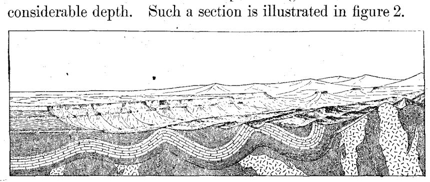


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

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 patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

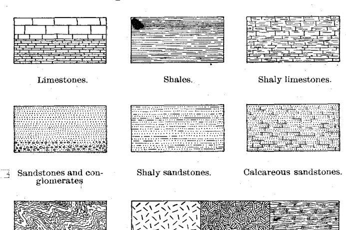


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. 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 of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact 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 figure 4.

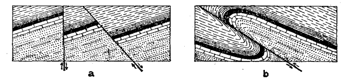


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. 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 by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but 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 uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. 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 shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the 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 folded or 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 were metamorphosed, they were disturbed by 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 figure 2 are ideal, but they illustrate actual relations. 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 that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that 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 that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that 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, 1909.

DESCRIPTION OF THE EASTPORT QUADRANGLE.

By Edson S. Bastin and Henry S. Williams.[a]

INTRODUCTION.

POSITION AND AREA.

The Eastport quadrangle is bounded by parallels 44° 45′ and 45°, and its mapped portion extends eastward from meridian 67° 15′ to the boundary between the United States and Canada. The area of this portion is approximately 250 square

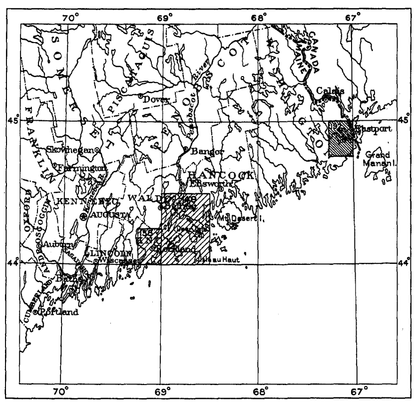


FIGURE 1.—Index map of eastern Maine.

The location of the Eastport quadrangle (No. 192) is shown by the darker ruling. Published folios describing other quadrangles, indicated by lighter ruling, are the following: Nos. 149, Penobscot Bay; 158, Rockland.

miles, of which nearly one-half is water. It occupies the eastern extremity of Maine and lies wholly in Washington County. (See fig. 1.) The principal town, from which the quadrangle takes its name, is Eastport, situated on Eastport or Moose Island, in its east-central part.

OUTLINE OF GEOGRAPHY AND GEOLOGY OF REGION.

GEOLOGIC FEATURES OF THE APPALACHIAN PROVINCE.

GENERAL FEATURES.

In its general geographic and geologic relations the Eastport quadrangle forms a part of the Appalachian province, which comprises a belt of country, 70 to 350 miles wide, lying nearly parallel to the Atlantic coast line and extending from Alabama to Newfoundland, that was a zone of sedimentation with intermittent uplift throughout the Paleozoic era which culminated in mountain-building at its close.

The Appalachian province as thus defined is now only in part mountainous. Many portions that were once mountainous have been planed down by erosion; other portions, though characterized by highly folded rocks, may never have been mountainous; they may be called potentially mountainous, erosion having kept pace with uplift and prevented the growth of mountains, though the conditions were otherwise favorable for mountain building. The crustal movements varied in kind and in intensity in different parts of the province and were not everywhere synchronous. In general the main structural features trend northeast and southwest, following the trend of the province as a whole, particularly in the southern Appalachian region, where the rocks of the Appalachian Valley are compressed into long, symmetrical, parallel folds. In northern New England only the older Paleozoic rocks conform closely to this trend.

The Appalachian province was not only subject to great crustal movements, but along its eastern border its strata were intruded by great masses of igneous rocks, the best examples being the large areas of granite, which form an important economic resource. In a few places the igneous rocks issued on the surface from volcanic vents and formed extensive flows and deposits of tuff, especially in New England.

NORTHERN APPALACHIAN REGION.

Although certain features are common to the entire Appalachian province others serve to differentiate the part of the province in New England and New Brunswick from that lying farther south. In the southern Appalachians the province comprises two great belts composed of rocks of different types, a southeastern belt composed chiefly of metamorphic and igneous rocks and a northwestern belt composed of sedimentary rocks. The crystalline belt is the older and includes the higher parts of the Appalachian Mountains and the Piedmont Plateau, east of the mountains. The sedimentary belt includes the Appalachian Plateau and the group of alternating ridges and valleys known as the Appalachian Valley. The metamorphic rocks are largely Cambrian and pre-Cambrian; the sedimentary rocks range from the Cambrian through the Carboniferous.

In southern New England practically all the rocks have been rendered schistose, even some of the Carboniferous rocks being dynamometamorphosed. As a result the division of the rocks of the province into a crystalline and a sedimentary belt, applicable farther south, is here not applicable, the line of division not being well defined.

A second distinction between the northern and the southern parts of the Appalachian province lies in the character of the boundary of the province. South of Cape Cod and Long Island the province is bounded on the southeast by the unconsolidated sediments of the Coastal Plain; north of Cape Cod the Coastal Plain is submerged, the ocean forming the eastern boundary of the province.

Volcanic eruptions occurred in eastern Massachusetts, in Maine, and in New Brunswick during Paleozoic time but were not so numerous farther south.

NORTHERN NEW ENGLAND AND NEW BRUNSWICK.

Even in New England, however, there were considerable local differences in geologic history. In southern New England rocks as late as Carboniferous have been recrystallized by mountain-building forces. In northern New England, on the other hand, including the Eastport quadrangle, all rocks of Silurian or later age are unmetamorphosed. Not only are the younger Paleozoic rocks unmetamorphosed but they lie in broad and rather irregular folds, wholly different from those in the southern Appalachians. Too little is known of the geology of northern New England and New Brunswick to warrant a description of the broad structural features, but from southern to northern and eastern Maine metamorphosed rocks, Ordovician or older, give place to unmetamorphosed Silurian and Devonian rocks and in New Brunswick Carboniferous rocks cover large areas.

PHYSIOGRAPHIC FEATURES OF THE APPALACHIAN PROVINCE.

GENERAL FEATURES.

The physiographic development of the Appalachian province has been complicated by great differences in structure, in character of rocks, in altitude, and in distance from the sea. For most of the time since the close of the Carboniferous period the province has been a land area and has been subjected to erosion. The physiographic records of this erosion date back to Cretaceous time, when, during a long period of uninterrupted erosion, much of the surface was reduced to a plain sloping gently seaward. Remnants of this peneplain form the tops of mountains and ridges throughout large areas in the southern Appalachians and are obscurely recognizable as far north as Connecticut and Massachusetts. The Cretaceous peneplanation probably extended over northern New England and New Brunswick, but all evidence of it has been destroyed by subsequent erosion. Since Cretaceous time the region has been several times uplifted, extensively dissected, and, in its northern part, glaciated.

NEW ENGLAND.

Over most of New England the erosion that destroyed nearly all vestiges of Cretaceous peneplanation reduced the surface to a somewhat uniform upland or plateau, whose surface ranges in altitude from several hundred to two thousand feet above sea level. Above the western part of this upland rise irregular mountain groups—the White Mountains in New Hampshire, the Green Mountains in Vermont, and other lesser groups. Above it also rise isolated mountain peaks, among them Mount Katahdin, in central Maine, and Mount Monadnock, in southern New Hampshire. The last important physiographic event was the glaciation of New England in Pleistocene time. The ice sheet scoured the surface free of soil and subsoil in places and redeposited the eroded material elsewhere as till, making important changes in the form of the land surface and shifting and modifying the lines of drainage. Most of the lakes that form characteristic features of New England are due to the obstruction of preglacial drainage lines by glacial deposits. In Maine such lakes cover 5 to 10 per cent of the larger drainage basins. Streams flowing from the melting glaciers produced further modifications of the topography by forming eskers, delta plains, and sand plains and furnishing the material for extensive deposits of marine clay near the coast.

During at least the later part of Pleistocene time the coast of Maine was depressed several hundred feet below its preglacial position, the movement being possibly a direct effect of the weight of the ice sheet. Coincident with the withdrawal of the ice sheet the movement was reversed. The uplift, though amounting along most of the Maine coast to over 200 feet, did not, however, restore the land to its preglacial position, and the coast still presents in its profusion of islands and estuaries the features of drowned stream valleys.

Since glacial time New England has been subjected to slight uplift and to renewed erosion. The larger streams have cut terraces in the glacial gravels bordering them, the marine clays of the coastal tract have been subjected to both stream and marine erosion, and marine erosion has produced minor modifications of the coast line.

TOPOGRAPHY OF THE QUADRANGLE.

RELIEF.

The Eastport quadrangle is characterized by numerous rocky hills and ridges that rise above more extensive flat lowlands. The irregular form and the steep slopes of many of these hills are important elements in the scenic beauty of the region. Most of the hills are less than 300 feet high. The highest point in the quadrangle, Mount Tom, in the northwest corner, reaches an elevation of only about 400 feet. Many of the hills in the northern half of the quadrangle are elongate in a northwest-southeast direction, whereas those in the southern half of the quadrangle show a less pronounced tendency toward elongation in a southwest-northeast direction.

COAST LINE AND DRAINAGE.

The district has an exceedingly irregular coast line, characterized by long, narrow bays and estuaries and many islands. The degree of irregularity of the coast may be more fully appreciated when it is stated that the distance from Eastport to Lubec around the shore is 100 miles, whereas the distance "as the crow flies" is but 3 miles. Many of the estuaries in the northern half of the quadrangle trend northwest-southeast, but those in the southern half of the quadrangle generally trend southwest-northeast. These directions are parallel to the directions of elongation of the hills and ridges, and the geologic map shows that the trend of both ridges and estuaries is parallel to the trend of the hard rock formations. Much of the shore is rocky, but considerable stretches bordering the lowlands are formed of low bluffs cut in clay or gravel.

The tides are rather high, the average distance between high and low water at Eastport being about 18 feet. The high tides increase the difficulty of navigating the shallower estuaries, many of which are large and discharge their water through relatively narrow mouths that become turbulent races or falls at half tide. One of the most picturesque narrows is Cobscook Falls, in the channel between Falls Island and Falls Point; another is the narrows between Lubec and the Canadian shore.

All the streams of the quadrangle are small, none being navigable above the head of tidewater. The largest streams are Pennamaquan, Dennys, and Orange rivers. Many of the streams have been dammed for lumbering, for power, or for creating reservoirs, and the local enlargements of some of the streams, as along Little River above Perry and along Pennamaquan River above Pembroke, are partly or wholly of such artificial origin. A number of small fresh-water lakes lie in the quadrangle, which includes also portions of Rocky, Pennamaquan, and Boyden lakes. Some of the streams are sluggish throughout long stretches and are bordered by fresh-water marshes. Isolated fresh-water marshes and bogs are also common features of the topography. In general the courses of the streams and the form and distribution of the lakes and bogs are very irregular, and the irregularity is traceable largely to the influence of glaciation.

[a] The geologic field work for this folio was done chiefly during the summers of 1907 and 1908 by Edson S. Bastin, assisted by Carpel L. Breger. In the summer of 1910 Mr. Bastin revisited the field for a few weeks to obtain additional data. The paleontologic work was done by Henry S. Williams, assisted by Mr. Breger. Prof. Williams made a number of short trips to the field and members of the party made short trips to St. John and to points along the Canadian shores of Passamaquoddy Bay to compare the geology on the two sides of the international boundary. The thanks of the authors are due to Dr. G. F. Matthew, of St. John, and to Dr. G. A. Young and the late Dr. R. W. Ells, of the Geological Survey of Canada, for courtesies extended during the trip to St. John.

The work was done under a cooperative agreement between the United States Geological Survey and the State Survey Commission of Maine. The writers wish to express their appreciation of the aid rendered by the late Dr. Franklin C. Robinson, professor at Bowdoin College and State geologist, in furthering the work.

CLIMATE AND VEGETATION.

The climate is temperate and moderately humid, the mean annual temperature at Eastport being 41.6° F. and the mean annual rainfall 42.4 inches. In summer few days are very hot and the nights are invariably cool. Much of the region near the shores has been cleared for agriculture, but large areas west of Cobscook River and between Orange Lake and West Quoddy Head are covered with a dense growth of conifers and deciduous trees. Among the conifers spruces and firs predominate. Pines, once abundant, are now subordinate, because of the encroachments of lumbering. No large tracts of virgin forest remain within the quadrangle, but in its western part the spruce and hardwood timber that was passed over in the early days of lumbering now supports small lumbering industries.

CULTURE.

Eastport, the principal town, with a population, according to the census of 1910, of 4961, is the terminus of the Washington County branch of the Maine Central Railroad. It may also be reached by steamship from Boston or Portland and has one of the best harbors on the Atlantic coast. The southern gateway to the harbor, Lubec Narrows, is navigable only at certain tides, and the principal approach to the harbor is the channel between Campobello and Deer islands. Cobscook Bay and its many branches can in general be safely navigated only at favorable tides and under the pilotage of one who is thoroughly familiar with the region. Only vessels of light draft can pass beyond Cobscook Falls.

Among the industries of the region agriculture divides honors with fishing, and many of the inhabitants living near the shores pursue both callings. About one-half of the land area of the quadrangle has been cleared for agriculture. Eastport and its neighbor Lubec are sardine-packing centers, and at both places large quantities of cod, herring, and other fish are salted or smoked and packed for shipment. Shipbuilding, which was a thriving industry in this region a generation ago, has passed away with the decadence of the coastwise trade.

In the past the region supported several manufacturing industries. A small brickyard was worked at one time below West Pembroke. Small amounts of limerock were burned at North Lubec. At the time when shipbuilding was active at Pembroke a furnace there smelted iron ore, brought presumably from Canada. A small mill run by tide power at the canal crossing the southern part of Seward Neck at one time manufactured plaster from gypsum imported from New Brunswick and Nova Scotia. Like many small industries elsewhere in rural New England, these passed away with the development of transportation facilities and the growing concentration of industries near the large cities.

The Eastport region, though somewhat handicapped by high tides, is one of the most beautiful portions of the Maine coast, and Campobello and St. Andrews, on the adjacent Canadian shore, have a well-established patronage of summer visitors. The American side has been less frequented as a summer resort, but as desirable locations on the coast farther south are taken up there is every reason to believe that the Eastport region will also become a popular recreation ground.

DESCRIPTIVE GEOLOGY.

PREVIOUS STUDY OF THE REGION.

Among those portions of the eastern United States whose geology has been carefully studied, the Eastport quadrangle is exceptional because of the complicated manner in which sedimentary rocks are interbedded with a great variety of volcanic rocks and because the fossils show much closer affinities with those of western Europe than with those of equivalent formations in other parts of the United States. The geology is further complicated by the presence of abundant intrusive masses and by extensive faulting.

Owing to the situation of the region—on an extremely irregular coast line where marine erosion is active—the bedrocks are exposed at many places along the shore and can be accurately mapped in great detail except where they are covered by Pleistocene deposits. Much of the sparsely settled part of the quadrangle that lies back from the shore is covered with a heavy growth of timber and contains few outcrops of the bedrock, so that in those areas it is at present impracticable to map the complex details of the geology. As a result the geologic mapping of the shore and the inland exhibits considerable unevenness in detail. Faults are seen here and there along the shore, but in general their presence inland can only be inferred from the distribution of the rocks.

Much of the area is covered by till, by marine deposits of late Pleistocene age, and by recent alluvium, all of which add to the difficulty of mapping the hard rock formations.

The Eastport region and adjacent portions of New Brunswick have been occasionally studied by American and Canadian geologists since 1836, with the results summarized below.

The earliest published reports on geologic work done in the region are those of Charles T. Jackson,[a] the first State geologist of Maine. In a short trip which he made in 1836 Jackson noted the occurrence of "greenstone trap" on Moose Island and the presence of lingulas and other fossils in the slates of Broad Cove. Northwest of Eastport he observed the Perry formation, which he termed "New Red Sandstone," and traced it northward along the shore to a point opposite St. Andrews. He made a circuit of South Bay, visiting the Lubec lead mines, which were then in operation, and finally made excursions to West Quoddy Head and to Pembroke and Dennysville.

[a] Jackson, C. T., First report on the geology of the State of Maine, 1837.

The next important field observations were those of Charles H. Hitchcock,[a] made in 1861, during the progress of the second geologic survey of Maine. He called attention to the abundance of "trap rock" on Moose Island and along the road from Perry to the south end of Boyden Lake and defined its stratigraphic position, noting that it lies between the highest Silurian sediments and the Perry formation, but he recognized the fact that not all the trap rock of the region is of the same age, noting that some trap cuts the Perry formation as dikes and that pebbles of other trap are contained in the Perry. Descriptions, by J. W. Dawson, of species of plants from the Perry formation were given in this report and the age of the formation was fixed as Devonian. The futility of prospecting for coal in these Devonian and Silurian rocks was pointed out.

In the second report on the geology of Maine, published in 1862,[b] several new species of plants from the Perry formation were described by Dawson; the progress of work at the Lubec lead mines was recorded, and mention was made of the opening of a new mine on Denbow Point.

For over 20 years after Hitchcock's surveys no work was done in the Eastport region by American geologists, but important work was carried on by the Canadian geologists L. W. Bailey and G. F. Matthew. A report[c] by these geologists, published in 1871, summarized the earlier work in this region and gave the results of field studies made in 1868–1870. The rocks of Deer and Campobello islands were described and in the absence of fossils were assigned mainly to the Kingston group, then regarded as of Huronian age. Certain rocks of the north and east shores of Passamaquoddy Bay and the east shore of St. Croix River opposite Chamcook Lake were described under the name of "Mascarene series." From observations and collections made on an excursion to Eastport and Pembroke these geologists referred most of the rocks of Moose Island and those extending from that island nearly to Pembroke to the "Mascarene series." Fossils collected along the west shore of Pennamaquan (Pembroke) River were assigned by Billings to the "Upper Silurian," and fossils from Denbow Point, though not well preserved, were also classed by him as of "Upper Silurian" age.

The volcanic flows of the region were not recognized as such by Bailey and Matthew in this report but were regarded as "reconstructed sediments." Later, however, in the report cited below, published in 1875, these geologists correctly interpreted the volcanic rocks.

Bailey and Matthew were the first to point out that no fragments of granite occur in any sediments below the Perry formation, which was regarded by them as Upper Devonian or "Lower Carboniferous."

In a later report by these authors,[d] published in 1875, a detailed section of the rocks on the Mascarene shore was given and the conclusion was reached that "the Mascarene series is nothing more than the Upper Silurian strata under a peculiar aspect, resulting from the beds being deposited in shallow water and from the mingling of lava and volcanic ashes with the higher beds."

In a report published in 1877 G. F. Matthew[e] recognized the presence of a master fault zone extending from the center of the parish of St. David, N. B., to the vicinity of Quoddy Head and bringing the older rocks of Campobello and Deer islands against the "Upper Silurian" rocks of Moose Island. He described the granite of adjacent parts of New Brunswick as distinctly intrusive in the "Upper Silurian" sediments with notable contact-metamorphic effects.

In the summer of 1884 N. S. Shaler[f] spent two months in the Cobscook Bay region studying the rocks and making collections of fossils at many localities. He recognized the presence of volcanic flows and tuffs and also of diabase intrusions, and called attention to the fact that faulting rather than complex folding is the dominant structural feature of the region and that the prevailing trend of the faults is northeast and southwest. By means of the fossils collected the rocks near Edmunds village were referred provisionally to the "Lower Helderberg;" those of Leighton or Schooner Cove to the "Clinton and Niagara;" and those of the northern part of Moose Island to the Devonian, all these rocks being included under the name "Cobscook series." Shaler recognized the rocks of West Quoddy Head and their continuation on Campobello Island as older than his Cobscook series and, failing to find any fossils in them, classed them provisionally as Cambrian. His collections of fossils have been reexamined by Prof. Williams in the preparation of the present folio.

[a] Hitchcock, C. H., Preliminary report upon the natural history and geology of the State of Maine, 1861.

[b] Hitchcock, C. H., Second annual report on the natural history and geology of the State of Maine, 1862.

[c] Bailey, L. W., and Matthew, G. F., Preliminary report on geology of southern New Brunswick: Canada Geol. Survey Rept. Progress for 1870–71.

[d] Bailey, L. W., and Matthew, G. F., Summary report of geological observations in New Brunswick: Canada Geol. Survey Rept. Progress for 1874–75, pp. 85–89.

[e] Matthew, G. F., Slate formations of the northern part of Charlotte County, N. B., with a summary of geologic observations in the southeast part of the same county: Canada Geol. Survey Rept. Progress for 1876–77, pp. 321–350.

[f] Shaler, N. S., Preliminary report on the geology of the Cobscook Bay district, Maine: Am. Jour. Sci., 3d ser., vol. 32, pp. 35–60, 1886.

L. W. Bailey[a] in an article published in 1889 referred the rocks of Campobello and Deer islands to the pre-Cambrian system and used the names "Cobscook" and "Mascarene" as practically synonymous.

For about 20 years after Shaler's observations no important geologic field work appears to have been done in this region. In the summer of 1903 George Otis Smith and David White, of the United States Geological Survey, made a short reconnaissance of the region about Perry. This exploration was undertaken primarily to determine whether minable coal occurred in this region, but it yielded important scientific results. It showed that the Perry formation near Perry possessed in general a synclinal structure and was separated into two sedimentary and two volcanic members. Numerous fossil plants were obtained from the formation and its Upper Devonian (probably Chemung) age was reaffirmed. The report on this exploration[b] also contained a review by H. S. Williams and E. M. Kindle of the Silurian fossils collected by Shaler in the Cobscook Bay region and notes by Charles Schuchert on the fossils collected by Smith and White from Carlow Island, the identifications showing that the rocks containing the fossils are older than the Helderbergian, and therefore assigning Shaler's Moose Island series to the Silurian rather than to the Devonian system.

About 1904 field work was resumed on the Canadian side by R. W. Ells, whose results were published in 1907.[c] The report contains a complete summary of all previous geologic work on the Canadian side. Ells reviewed the data on the "Mascarene series" and concluded that the determination that they were "Upper Silurian" was not wholly satisfactory because of the reported presence in the rocks at Beaver Harbor of certain plant remains of Devonian aspect. Following David White and others he regarded the Perry as of Upper Devonian age. Certain ancient-looking rocks of Charlotte and St. John counties which were formerly variously regarded as Cambrian or pre-Cambrian (in part Kingston group) he showed to be much younger rocks altered by contact metamorphism. He says:[d]

> Recent investigations in this area (1903) have shown that the rocks of the islands in Passamaquoddy Bay and in parts of the mainland adjacent to the north, as at Letite, Frye Island, and elsewhere, consist largely of altered Silurian sediments, closely associated with dikes and masses of later intrusives, mostly diabasic in character, which have locally altered the Silurian slates and limestones, though the contained fossils can be seen at several points but are generally much distorted.

From this summary of geologic studies previous to the surveys made by the present writers it is apparent that many of the salient features of the geology had already been correctly interpreted, although their details had not been worked out. Most of the rocks of the region had been recognized as of Silurian age, and among these the rocks now classed as the Quoddy shale were regarded as the oldest. The sparsely fossiliferous rocks of the "Mascarene series," corresponding to a part of the Eastport formation as defined in this folio, were recognized as a part of the Silurian system and believed to constitute its youngest member. The abundance of volcanic rocks of both felsic[e] (acidic) and mafic (basic) varieties had been noted and the granite and much of the diabase was recognized as intrusive in the Silurian rocks. The position of the Perry formation unconformably above the Silurian rocks was established and its age definitely determined as Upper Devonian. Faults with northeast trend were described as one of the major structural features.

STRATIGRAPHY.

GENERAL FEATURES.

The rocks of the Eastport quadrangle include sediments and igneous rocks of Silurian and Devonian age and unconsolidated surficial deposits of Quaternary age. Granite of late Silurian or early Devonian age outcrops a short distance north of the quadrangle.

The strata of the Silurian system consist chiefly of shale and argillite, which grade in places into well-stratified tuff. They include very little limestone. The strata of the Devonian system are chiefly red conglomerate and sandstone. Volcanic rocks are interbedded with the strata of every formation of

[a] Bailey, L. W., On some relations between the geology of eastern Maine and New Brunswick: Roy. Soc. Canada Trans., vol. 7, sec. 4, pp. 57 et seq., 1889.

[b] Smith, G. O., and White, David, The geology of the Perry Basin, in southeastern Maine: U. S. Geol. Survey Prof. Paper 35, 1905.

[c] Ells, R. W., Geology and mineral resources of New Brunswick: Canada Dept. Mines, 1907.

[d] Op. cit., p. 51.

[e] Jour. Geology, vol. 20, p. 561, 1912.

both systems and constitute a greater part of the volume of several formations than do the detrital sediments. They include flows and associated tuffs of many varieties, and their association with each other and with the sedimentary rocks is extremely irregular. The rocks comprise also igneous intrusives of several sorts, chiefly diabase.

The Quaternary deposits include till, marine glacial gravel, and marine clay of Pleistocene age as well as alluvial deposits of Recent age.

As the volcanic rocks are so intimately interbedded with the sedimentary rocks that they are essentially part of the formations the two will be described together. The intrusive rocks that have been separated in the mapping will be described separately.

SILURIAN SYSTEM.

QUODDY SHALE.

Definition.—The Quoddy shale, the oldest formation of the Eastport quadrangle, is composed chiefly of shale, some portions of which are slaty or even schistose, but contains minor amounts of volcanic rocks. It is named from West Quoddy Head, the easternmost point of land in the United States, where the rocks are well exposed. It crosses into Canada and is well exposed on the island of Campobello.

The thickness of the formation is not known, but its uniform character throughout considerable areas indicates that it may be several thousand feet thick.

Distribution.—The formation outcrops not in large, continuous areas but in small, disconnected patches separated by bodies of intrusive rock. Its distribution inland can not be determined accurately because of the scarcity of exposures in the lowlands. It occurs principally in a belt several miles wide lying southeast of a line drawn from Lubec to Whiting, where the country is a succession of low hills, chiefly of diabase, separated by lowlands that are generally covered by swamp deposits or by marine clay and are nearly everywhere heavily forested. Some bodies of Quoddy shale may underlie the lowlands, but they do not outcrop and hence can not be mapped. The relations are probably somewhat more intricate than those shown on the map, the rocks comprising more sedimentary deposits and less diabase. Along the shore, however, exposures are nearly continuous from Woodward Point to the southern border of the quadrangle, and the map of this region shows the diabase and the sedimentary rocks in true proportion.

The formation occurs also in the extreme northwest corner of the quadrangle, near Ayers Junction, and is excellently exposed on the eastern slope of Mount Tom, especially in the railroad cuts near Pennamaquan Lake.

Not much is known regarding the distribution of the Quoddy shale outside the Eastport quadrangle. The main belt of the formation has not been definitely traced south of Moose Cove, but to judge from the early descriptions by Jackson[a] its altered sediments and the accompanying diabase extend southwestward to Cutler and possibly to Cross Island. On the Canadian side its sediments and the associated diabases have been traced by the writer's reconnaissance over much of the island of Campobello, only small areas being occupied by possibly younger rhyolite. The shale is well exposed along the shore of that island from the mouth of Harbor de Lute to East Quoddy Light and shows the same northeasterly strike and steep dip that prevails on the Maine side. The formation probably also occupies part of Deer Island.

Character.—The shale of the Quoddy formation is, as a rule, readily distinguished from the other sedimentary rocks of the region by its hardness and by its nearly total lack of fossils. It is prevailingly thick and even bedded, fine grained, and highly quartzose. Where the quartz is very abundant the rock in some places becomes an argillaceous quartzite; and on the other hand where its clayey constituent largely predominates it is softer and more like the later black shales of the area. Some of its beds are slightly calcareous, but it includes no true limestone. It contains at some places abundant rounded segregations or nodules, slightly more calcareous than their matrix, the largest of which, found at Woodward Point, have a diameter of 18 inches. Considerable portions of the shaly phases of the formation are probably composed of the fine detritus of volcanic rocks, but the material is not recognized as such because of its fine comminution and subsequent alteration.

The prevailing colors on fresh surfaces are blue-gray and purplish gray. The more calcareous beds are lighter gray and the highly argillaceous beds are generally dark gray or black. Greenish tints appear here and there. Bedding, though ordinarily recognizable, is not as a rule very prominent because of the induration of the beds and their evenness in grain and color. Only where quartzose layers alternate with calcareous or highly argillaceous lenses or layers is the bedding conspicuous.

In many places the rock shows no cleavage; it breaks with a conchoidal fracture as readily in one direction as in another. In other places it has even and regular joint planes, which, where closely spaced, simulate cleavage or even schistosity. Close jointing is generally found only where shearing has been most severe; as a rule it is best developed in the argillaceous beds. In a very few places, as along the shore south of the inlet at South Lubec, a schistlike structure appears, but microscopic study shows that it is mainly the result of very closely spaced fracturing and is due only in slight degree to recrystallization.

The volcanic rocks include both flows and tuffs, chiefly of rhyolite, with a little diabase. In color the fresh rhyolite ranges from light gray to purplish gray; the weathered rock from nearly white to buff. Some phases show flow structure, and the massive types are in places porphyritic. Three specimens of the rhyolite of the Quoddy formation when examined microscopically showed no features that especially differentiate them from some of the later rhyolites. They are commonly much recrystallized, the recrystallization having been accompanied by the development of secondary quartz, calcite, and some chlorite.

A small patch of much-altered diabase, in places highly amygdaloidal, is associated with the rhyolite about half a mile northwest of Ayers Junction. Another mass, also amygdaloidal and evidently a flow, occurs at the southern edge of the quadrangle, about half a mile east of East Stream and is bordered by intrusive diabase.

The volcanic rocks are so closely associated with the shale as to leave little or no doubt of their contemporaneous origin. On the eastern slope of Mount Tom rhyolite showing flow structure is conformable in trend with the Quoddy shale near by, and some of the finer phases of the tuff have the same purplish tint that characterizes the shale. A few beds of the shale contain numerous fragments of rhyolite. On the other hand, many of the fresher phases of the rhyolite are indistinguishable from the rhyolites of some of the later formations and possibly some of them are intrusive or are small remnants of later volcanic rocks.

Fossils.—At only a few localities has the formation yielded fossils, and even at those places they are not abundant and are poorly preserved. Most of them have been somewhat distorted by the shearing of the rocks. The localities at which fossils have been found are indicated on the areal-geology map.

The species named below (illustrated in Pl. XVI, figs. 1–12) were collected at the localities indicated:

On the north shore of West Quoddy Head, east of the life-saving station, from quartzose shale underlying an 8-inch calcareous layer:

- Crinoid stems, small.
- Plectambonites transversalis (Wahlenberg).
- Leptæna rhomboidalis (Wilckens).
- Schuchertella subplana (Conrad).
- Cf. Dalmanella elegantula (Dalman).
- Pentamerus cf. oblongus Sowerby, with size and proportions of P. pesovis (Whitfield).
- Atrypa reticularis (Linné) cf. A. nodostriata Hall.
- Anoplotheca cf. barrandei (Davidson).
- Spirifer crispus Linné cf. S. staminea Hall.
- Spirifer radiatus Sowerby cf. S. nympha Billings.
- Orthoceras sp. indet.

In a shaly parting that lies a few inches below the stratum mentioned above:

- Monograptus sp. indet. cf. M. clintonensis Hall.

Along the South Lubec shore at Woodward Point:

- Favosites sp. indet.

At Woodward Point and farther north, at some places, traces of—

- Monograptus sp. indet.
- Orthoceras sp. indet.

In the northwestern part of the quadrangle, in railroad cuts on the southeast flank of Mount Tom:

- Monograptus sp. indet.
- Orthoceras sp. indet.

Correlation and age.—All the species from the Quoddy shale which have been identified are recorded from the Woolhope and Wenlock limestones of England and Wales, which are of middle Silurian age. All but one are found in the Ordovician as well as in the Silurian, and two range upward into the Devonian. The evidence as it stands indicates that the fauna is not later than that of the Wenlock shale, the highest zone at which *Plectambonites transversalis* is recorded in the Shropshire section by Davidson.[a] The fossils are few and imperfect but suggest that the Quoddy shale is of Silurian age and is to be correlated with the lower part of the Wenlock of Great Britain.

Were the graptolites of the formation well preserved they would aid greatly in determining the stratigraphic position of the formation. Recent studies have shown that species of Monograptus are precise horizon markers in Silurian faunas throughout large areas abroad, but unfortunately the Monograptus found in the Quoddy shale is too poorly preserved for specific identification.

Relations.—The formation has been invaded by masses of igneous rock of several sorts which are described under the heading "Igneous rocks." The strata have been greatly disturbed and in places altered by the intrusive masses. At several places near contacts the shale is altered to hornstone and its bedding is much obscured, but it nowhere contains conspicuous typical contact-metamorphic minerals. The shale occurs in relatively small masses bordered by the igneous rocks, and because of the disturbance and distortion of the strata, the rarity of fossils, and the absence of regular lithologic variations, it was not possible to correlate the beds of neighboring areas. Even in a single mass of shale the beds are commonly so much folded and faulted, or so much cleaved, that their sequence is very obscure.

The main area of the Quoddy shale is separated from the later Silurian formations by the Lubec fault zone. (See areal-geology map.) The same stresses that produced the faulting probably also produced much of the close jointing and schistose-like structure in the shale. The Mount Tom area also is separated from the later formations by a fault, the position of which can not be accurately determined because of the lack of outcrops.

DENNYS FORMATION.

Definition.—The Dennys formation comprises a succession of volcanic rocks of several sorts and a few small interbedded masses of fossiliferous strata. The name is taken from Dennysville, near which rocks of the formation are well exposed. The thickness of the formation is unknown.

Distribution.—The formation occupies an area extending nearly the whole length of the west side of the quadrangle, from Ayers Junction to Orange Lake, and having a maximum width east and west of about 4½ miles in the latitude of Edmunds village. Its extent west of the quadrangle is wholly unknown.

Except in small areas near Dennysville and Edmunds the territory underlain by the formation is densely wooded and the rock exposures are rather scattered. Detailed relations that can be worked out along the shore and in cleared areas are lost when the attempt is made to trace them into the wooded areas. The best exposures are along the road from Dennysville to Burnt Cove School, about the shore of Duck Harbor, and in Dennysville.

Character.—The principal rock of the formation is rhyolite, of several types, occurring as flows and tuffs. Interbedded with and otherwise closely associated with the rhyolite are several varieties of andesite, also in flows and tuffs. Diabase flows and tuffs also occur but are of relatively minor importance. The effusive rocks have been disturbed by the intrusion of masses of diabase and of andesite and possibly also of rhyolite.

Gray rhyolite.—The commonest rock of the formation is gray rhyolite. The flows are not prominent, but the associated tuffs form a large part of the formation and are particularly well exposed along the railroad from Dennysville station to Wilson Stream, about Dennysville village, and especially along the shores of Duck Harbor. Flows were observed at a number of localities near Dennysville and in the woods between Dennysville and Roaring Lake. In color the rock of the flows ranges from light gray to dark greenish gray. Some phases are aphanitic and horny-appearing throughout, and others have abundant phenocrysts of white feldspar, the largest an eighth of an inch in diameter, in an aphanitic groundmass. A specimen which was obtained from a point about a mile west of Crane Mountain and which appears fairly representative of the porphyritic type showed under the microscope a microgranular groundmass composed mainly of feldspar and quartz, through which are scattered phenocrysts of orthoclase. Epidote, zoisite, and chlorite are common decomposition products.

The gray rhyolitic tuff is made up largely of fragments of greenish-gray to blue-gray aphanitic rhyolite, in many places associated with fragments of purplish andesite and of pink rhyolite. The matrix may be composed in the main of material similar to the larger fragments, but it generally contains broken phenocrysts of quartz and feldspar, most of which range in diameter from one-sixth to one-eighth inch. The local abundance of these phenocryst fragments is a noteworthy feature of this tuff. A typical specimen of the tuff, collected along the railroad about 1¼ miles north of Dennysville station, when examined under the microscope, showed numerous fragments of finely microgranular rhyolite and a few that are probably andesite. In the matrix fragments of phenocrysts of quartz and orthoclase are numerous. The rock is much altered, chlorite in particular being abundant.

The most abundant phases of the tuff are fine grained and include few fragments that are more than an inch in diameter, but coarse phases whose larger fragments are 3 feet in diameter occur along the south shore of Duck Harbor and at the north entrance to the next inlet south of Duck Harbor. At the former locality the tuff, made up of fragments of gray rhyolite, greenish-gray augite andesite, and pink rhyolite porphyry characteristic of the Dennys formation, includes a thin shale lenticle containing abundant fossils.

Pink and brown rhyolite.—Another type of rock that is very abundant in this formation is a rhyolite porphyry which on fresh surfaces ranges in color from dark salmon to purplish brown and which commonly weathers salmon-pink. Most of the phenocrysts are of pink orthoclase, though rarely some of quartz are present. Under the microscope representative

[a] Jackson, C. T., First report on the geology of the State of Maine, pp. 86-87, 1837.

[a] Davidson, Thomas, A monograph of the British fossil Brachiopoda, vol. 5, Silurian and Devonian supplements, p. 74, 1882.

specimens of these rocks show no unusual features. They are typical rhyolite with phenocrysts of orthoclase and much quartz in the groundmass. Even in those specimens that appear freshest much secondary chlorite and calcite have developed. In certain flow-breccia phases the fragments are of the usual pink type, but the matrix is dark greenish.

This rhyolite occurs as flows, with associated tuffs, and probably also as intrusive masses. It is particularly abundant in the wooded country near the east shore of Rocky Lake and between Orange Lake and Western Pond and occupies a large continuous area from 1 to 1½ miles south of Duck Harbor. The area last mentioned is the most accessible for study, but good exposures occur also along the shores of the inlet next south of Duck Harbor and along the wagon road near the inlet. On the 140-foot hill about three-quarters of a mile south of Duck Harbor there is an exposure of the contact between the massive pink rhyolite and a series of well-bedded gray rhyolite and diabase tuffs, which strike N. 40°–45° W. and dip about 30° NE. The contact cuts across the tuff beds at various angles, in places as much as 60°, though its general trend is N. 10° W. The rocks are completely welded along the contact. The pink rhyolite becomes greenish next the contact, shows flow brecciation, and has picked up small fragments of the tuffs. The inclosed tuff fragments are so ragged and irregular as to suggest that the tuff was unconsolidated when picked up. The crosscutting, the welded contact, and the uniformity of the rhyolite composing this mass suggest that it is of intrusive origin. If so, its intrusion must have taken place in Dennys time, for at the north entrance of the inlet next south of Duck Harbor the main mass of the rhyolite is overlain by coarse agglomerate containing numerous fragments of the rhyolite. This agglomerate is a part of the gray rhyolite tuff series already described and is plainly of Dennys age. Though some parts of the pink rhyolite may be intrusive other parts of it probably formed flows, for they bear delicate flow lines.

Mottled pink and gray rhyolite.—Some of the rhyolite of the Dennys formation is more or less intermediate in character between the pink and the gray types already described. It is exposed at many localities near Dennysville and is found here and there throughout the formation. It is commonly though not invariably porphyritic, with a groundmass ordinarily mottled pinkish brown and greenish gray. Flow-breccia phases show salmon-red or brownish-red fragments in a greenish-gray matrix and in the tuff there is a similar contrast between pink fragments and green matrix. In mineral character the rock is typical rhyolite and is probably closely related in origin to the pink rhyolite of this formation.

Purple rhyolite.—Certain rhyolite porphyries occurring especially in the region between Orange Lake and Western Pond are dark bluish purple in color because of an abundance of iron oxide finely disseminated through the matrix. They are very similar in appearance to some of the purple andesite of this formation but are probably related genetically to the pink rhyolite.

Pyroxene andesite.—The pyroxene andesite ranges from light greenish gray to dark grayish or purplish green, the darker tones predominating. It is generally porphyritic, its common phenocrysts being feldspar, though at some places it contains phenocrysts of pyroxene and biotite. Its chief exposures are 1 to 2 miles west and southwest of Edmunds, numerous excellent exposures lying along the Dennysville-Burnt Cove road for 2 miles north from Burnt Cove School. Especially good exposures occur just west of the road on the 140-foot hill west of Littles Mountain.

The phenocrysts are considerably more abundant in some localities than in others. In some specimens the feldspar phenocrysts are less than a sixteenth of an inch across, though in others they reach a diameter of an eighth of an inch. They range in color from white or pinkish when fresh to gray or greenish when altered, and have the composition of andesine, ranging from $Ab_{50}An_{50}$ to $Ab_{70}An_{30}$, most of them being nearer the latter. The more mafic (basic) varieties of the rock are marked also by an abundance of augite phenocrysts, the largest 1 millimeter in length, though most of them measure less than 0.5 millimeter. Augitic phases were noted and collected near Burnt Cove schoolhouse and on the 140-foot hill west of Littles Mountain. Porphyry collected at a number of other localities was probably augitic when fresh, but the augite is now wholly replaced by secondary minerals. As the matrix is dark the augite phenocrysts are not ordinarily conspicuous. The groundmass is aphanitic and greenish gray to dark grayish or purplish green and is composed of laths of feldspar, generally without regular arrangement but having in places a subparallel orientation indicating flow movement during crystallization. Some of the lines of feldspar laths curve around the phenocrysts. The space between the laths is generally occupied by chlorite, grains or dendritic crystals of magnetite, and either epidote or leucoxene. In the most mafic types the groundmass contains small grains of augite.

The pyroxene andesite shows, on weathering, dark-brown surfaces very similar to the weathered diabases. All the specimens when examined microscopically show notable alteration of both groundmass and phenocrysts. The principal secondary minerals are chlorite, epidote, and a carbonate, probably calcite. In a few specimens replacement, starting with phenocrysts as nuclei, was carried outward into parts of the surrounding groundmass, forming rounded masses of chlorite or chlorite and epidote which give the hand specimen a pseudo-amygdaloidal appearance.

In the field some representatives of the augite andesite series are with difficulty distinguished from certain diabases, and others resemble certain phases of the gray rhyolite.

The pyroxene andesite occurs in the upper part of the Dennys formation, mainly as flows, tuffs being rare. In many exposures the rocks appear to be massive, in others they show distinct flow lines trending a little west of north. The excellent exposures on the 140-foot hill west of Littles Mountain are in some places amygdaloidal and in others show beautiful flow-breccia structure, the dark grayish-green porphyritic fragments lying in a light-gray felsitic matrix. Other phases of this flow breccia contain purplish-gray porphyritic fragments in an Indian-red and aphanitic matrix. The matrix weathers in relief and shows flow lines.

Purple andesite.—Dark-brown to purplish andesite porphyries form a considerable part of the Dennys formation in the region between Edmunds and Dennysville. The best exposures may be seen in the fields a quarter of a mile south of Edmunds village, on the 100-foot hill just south of the entrance to Duck Harbor, and in the eastern part of Dennysville village.

In general the rock is porphyritic, containing feldspar phenocrysts less than an eighth of an inch across, though a few have a diameter of a quarter of an inch. They may be numerous or scattered and in some specimens, because of alteration, they are inconspicuous. The groundmass is aphanitic and ranges in color from greenish gray and purplish gray to Indian red and nearly black.

When studied under the microscope these rocks are found to be much altered. The groundmass shows abundant feldspar laths, whose subparallel arrangement indicates flowage. The other components of the groundmass are secondary chlorite, calcite, and leucoxene (?). Some phenocrysts are well enough preserved to be identified as andesine, but most of them are extensively replaced by epidote, calcite, and chlorite.

Flow-breccia structure is well developed in this andesite on the 100-foot hill south of the entrance to Duck Harbor. Most of the fragments in this breccia show well-developed flow lines and some contain spherulites. Andesite that exhibits very perfect flow lines also occurs in the woods about a mile southwest of Edmunds village, and there can be no reasonable doubt as to the effusive character of the types of andesitic rock described above.

In the woods south of Dennysville village and in the eastern part of the village there is purplish andesite which appears to be entirely massive, showing little or no trace of flow lines, flow brecciation, or other like features. It is possible that some of these masses may be of intrusive origin, but in the absence of exposed contacts such an origin can not be definitively affirmed.

Diabase.—The most mafic rock of the Dennys formation is typical diabase, which occurs in isolated areas in that part of the formation which lies south and east of Dennysville. The flows and tuffs are commonly closely associated and are not separated on the map.

The flows are best exposed in the open fields half a mile southwest of Edmunds village. The flow here is the largest observed and has a thickness of 400 to 500 feet. It ranges in color from dark green to nearly black and contains scattered phenocrysts of labradorite, the largest a quarter of an inch across. Most of the rock is highly amygdaloidal, and that near the base of the flow shows flow-breccia structure. The fine flinty matrix in the flow breccia is commonly light greenish gray, but in places it is terra-cotta colored.

Diabase tuff, well exposed, underlies and overlies the flow just described. That beneath has been disturbed by the flow. Diabase tuff is also well exposed on the 140-foot hill 1 mile south of Duck Harbor, where it is distinctly bedded.

Both tuffs and flows are much altered, the alteration having formed the usual secondary minerals. Finer phases of the diabase tuff weather like trap.

Sedimentary rocks.—Detrital sediments are extremely rare in the Dennys formation. At Duck Harbor thin-bedded light greenish-brown fossiliferous shale forms a small lens in volcanic tuff. The fossiliferous rock outcropping at the lower end of Rocky Lake, at Hall's Mill, just outside the quadrangle, is a greenish-gray fine-grained massive tuff containing only a few fossils. Near it, though not actually in place, is a light-gray calcareous conglomerate containing the same species of fossils that are found in the tuff, with numerous fragments of coral and other fossils. The corals are apparently worn and rolled and are slightly distorted by crushing.

Fossils, age, and correlation.—Fossils have been found in the Dennys formation at two localities described in the preceding paragraph and indicated on the areal-geology map.

The following forms have been identified and are figured in Plate XVI, figures 13–31:

Beyrichia maccoyiana Jones var.	Cf. Leptæna minima var. grayii Davidson.
Beyrichia spinulosa Boll var.	Lingula cf. oblata Hall.
Bilobites bilobus (Linné).	Cf. Orthis equivalvis Davidson.
Bollia bicollina Jones.	Plectambonites transversalis (Wahlenberg).
Cytherella concinna Jones.	Pterinea sp. indet.
Cytherella concinna var. ovalis Jones.	Skenidium lewisi Davidson.
Dalmanites longicaudatus Murchison.	Spirifer crispus (Hisinger).
Cf. Leptæna lævigata (Sowerby).	Cf. Streptelasma calicula Hall.

The only division of the Silurian system of England and Wales in which all the species listed above are reported to occur is the Wenlock, of middle Silurian age. The data available show that the Dennys formation is of Silurian age and that its fauna should be correlated with that of the lower Wenlock of Great Britain.

Relations.—The lower limit of the formation is not known. Its contact with the Quoddy shale in the northwest corner of the quadrangle is not exposed but is almost certainly a fault. Its upper limit has been fixed only approximately by means of structure and lithology rather than by means of fossils, which are found in the formation only at two widely separated localities. In the southern part of the quadrangle the rocks of the formation are fairly concordant in strike with those of the overlying Edmunds formation and no marked break in stratigraphic succession is apparent between the rocks at Hall's Mill, just outside the quadrangle, which contain fossils probably of Dennys age, and those at the east end of Orange Lake, which contain typical Edmunds fossils. Even in that part of the quadrangle, however, the boundary may be an unconformity or a fault, as it is in the region between Burnt Cove School and Ayers Junction. The irregularity of the upper boundary is increased by a number of later faults which cut across and displace it.

Most of the Dennys formation was probably formed on a land surface, a probability indicated by the scarcity of its detrital sediments in comparison with those of the later formations and by the unassorted character of most of its tuffs.

EDMUNDS FORMATION.

Definition.—The Edmunds formation comprises a series of alternating beds of shale and deposits of volcanic rocks of several sorts. It is named from the village of Edmunds, near which the rocks are well exposed. The thickness of the formation can not be accurately measured but is estimated to be 2500 to 3000 feet.

Distribution.—The formation occupies a continuous belt extending from a point about 4 miles north of Dennysville southeastward to Edmunds, thence southward to the mouth of Orange River, and southwestward along the valley of that stream, leaving the quadrangle at its southwest corner. At its north end and in the southwest corner of the quadrangle the belt is rather less than a mile wide, but near its middle, in the general latitude of Straight Bay, it is about 4 miles wide.

The rocks of the formation are exposed almost continuously about the shore of Straight Bay and along the lower courses of Dennys and Orange rivers. Scattered exposures occur north, west, and southwest of Whiting, where the country is densely wooded and where the details of the structure can be only in part worked out.

Character.—The most abundant rock of the Edmunds formation is rhyolite, both gray and red, which forms flows and associated tuffs. The next most abundant rock, found in an area extending from Field Point northward, is purplish-red andesite, also occurring as flows and tuffs. Southwest of Field Point andesite is rare, its place being taken by diabase flows and tuff. Tuff of intermediate character contains fragments derived from two or all of these kinds of rock. Most of the detrital sedimentary rock of the formation is shale.

The frequent alternation of rocks of different kinds that characterizes much of the Edmunds formation is shown in figures 2 and 3. It is manifestly impracticable to show all such variations on a map of the scale used in this folio.

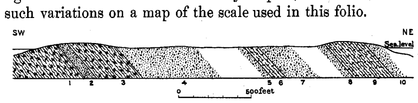


FIGURE 2.—Geologic section of a part of the Edmunds formation on Hallowell Island.

1. Amygdaloidal andesite flow, purplish red to green.
2. Dark purplish-red andesite tuffs.
3. Purplish-red andesite flow showing flow-breccia structure; fragments show flow lines and are inclosed in a dark terra-cotta jaspery matrix; some fragments are 2⅛ feet across.
4. Tuff made up of fragments of dark-red and gray rhyolites.
5. Dark-red rhyolite tuff.
6. Mottled yellowish-green and purplish-red rhyolite porphyry flow; shows flow lines and is locally a flow breccia.
7. Fine-grained tuff of purplish-red and yellowish-green rhyolite fragments.
8. Purplish-red rhyolite tuff.
9. Rhyolite porphyry flow showing phenocrysts of both feldspar and quartz, color variable, ranging from greenish gray to purplish red.
10. Tuff of dark-red rhyolite; some fragments are a foot in diameter.

Gray rhyolite.—The gray rhyolite of the Edmunds formation is not greatly different either in general appearance or in microscopic character from the rhyolites of the older or the younger formations. It occurs as flows and tuff, and in some places as small dikes, but so far as known it does not assume stocklike forms. The rock of the flows ranges in color from very light gray to nearly black but is commonly a somewhat greenish or brownish dark gray. Texturally it ranges from aphanitic rocks to porphyries containing phenocrysts of feldspar, and in places also of quartz, in an aphanitic groundmass. When seen under the microscope most of the aphanitic phases appear to be rather coarsely microcrystalline, though some are so finely microgranitic as to suggest a devitrified glass.

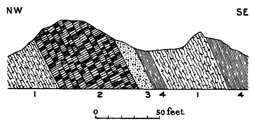


FIGURE 8.—Sketch section showing the succession of beds of the Edmunds formation near the south end of Roaring Lake.
1, Rhyolite flow; 2, diabase flow; 3, diabase tuff; 4, shales

A flow 200 to 300 feet thick on the north side of Timber Cove, Cobscook River, affords one of the best exposures of the very light gray nonporphyritic rhyolite.

The nearly black nonporphyritic variety was found at only one locality, on the east side of the long arm of Straight Bay near Crowe Neck School. The more common dark-gray phase of the rhyolite is well exposed on Hallowell Island. In the cove on the east side of the island a mass of gray porphyritic rhyolite grades into a purplish-red but otherwise similar phase, both being parts of the same flow. The red phase is similar in every way to the abundant flows, all red, described below, and this gradation shows that at least some of the red and the gray rhyolite came from the same source. The gray rhyolite from Hallowell Island contains phenocrysts of feldspar and less abundant rounded phenocrysts of quartz, the latter showing embayments. These phenocrysts average 2 to 3 millimeters in diameter and lie in a greenish-gray aphanitic groundmass. The groundmass is subgranular and consists of quartz, feldspar (probably mainly orthoclase), epidote (probably a product of pyroxene alteration), and hematite (evidently derived from magnetite).

The tuff shows considerable variety, due mainly to the various proportions in which pink and red rhyolite fragments are mixed with the gray. Some flinty-looking fragments are plainly devitrified volcanic glass. In places there is some admixture of fragments of purplish-red andesite. Coarse phases are rare, few fragments exceeding half an inch in diameter. Stratification is common and its regularity indicates that much of the tuff was water-laid; in many places the bedded tuff grades into fossiliferous shale composed largely of fine volcanic débris.

One type of tuff not observed in older formations is conspicuous on the south side of Falls Point and on the west side of the small island off the mouth of Talbot Cove (in Straight Bay). The two localities are at about the same horizon in the formation. This tuff is composed chiefly of small crystals of orthoclase, generally 2 to 3 millimeters in length, most of which are not rounded but have perfect crystal faces. Although more or less mixed with cherty rhyolite fragments, most of the feldspar crystals are neither inclosed by nor attached to any rhyolitic material but lie free in a dark clastic matrix. Quartz crystals are rare. This feldspathic tuff forms beds several feet across, which are so uniform and massive in appearance as to be easily mistaken for granite. Both at Falls Point and at Talbot Cove the tuff grades by increase in the proportion of matrix into black shale. The shale is rather irregularly associated with the more feldspathic part of the rock, as if both had been somewhat disturbed while still unconsolidated. At the locality near Talbot Cove the feldspathic tuff grades into coarser tuff containing some fragments of rhyolite an inch in diameter.

The origin of this peculiar variety of tuff is difficult of explanation. The feldspar crystals were doubtless originally the phenocrysts of a porphyritic rhyolite, but it is not easy to see how the phenocrysts were freed from their matrix and aggregated into thick beds. Possibly these beds may have been built up through weathering on a land surface, the soil formed being washed into the sea and the phenocrysts separated from the decomposed matrix by the action of currents and waves. This explanation, however, is rendered improbable by the fact that the feldspar crystals and the associated fragments of volcanic tuff are fresh and angular. A more plausible explanation may be that actual showers of phenocrysts occurred during the volcanic eruptions. The porphyritic character of many of the flows shows that the lava in the throat of the volcano from which they flowed was also porphyritic. In an explosive eruption of a molten mass crowded with phenocrysts the feldspar crystals will probably be more or less completely separated from their matrix, and if winnowed by the wind during their course through the air or if sorted by waves they may form thick beds, composed almost wholly of phenocrysts.

Red rhyolite.—Reddish-gray to purplish-red rhyolite, commonly porphyritic, is one of the most abundant rocks of the Edmunds formation. Some phases are so dark that they closely resemble the purplish andesite and unless they contain quartz phenocrysts they can not readily be distinguished from that rock in the field. As a rule, however, they are somewhat lighter colored and more lustrous along fresh fractures than the andesite.

The best exposures are along the shore near Edmunds, along the shore north of Mount Dorcas, and near the north shore of the inlet of Wilson Stream. Others occur along the wagon road about a quarter of a mile south of Edmunds and along the Pembroke-Dennysville road nearly due south of Eastman Hill.

Typical specimens of the rock of the flows have a cherty-looking purplish-gray to reddish-brown groundmass, through which are scattered abundant white or pink phenocrysts of orthoclase, which stand out in sharp contrast with their matrix. Some specimens contain rounded phenocrysts of quartz, which are in all specimens much less abundant than phenocrysts of feldspar. The diameter of most of the phenocrysts ranges from 2 to 3 millimeters. Under the microscope the feldspar phenocrysts are seen to be orthoclase. The groundmass is microgranular and consists mainly of orthoclase and quartz but includes fine grains of hematite, which form the coloring pigment. The groundmass shows no trachytic texture, such as was observed in some of the purplish andesite. The rock everywhere contains secondary minerals, the commonest being calcite, epidote, hematite, leucoxene, and sericite.

Certain small masses of pink rhyolite appear to be intrusive. On the shore north of the entrance to Ox Cove, for example, pink rhyolite, massive and so coarse that it is virtually a microgranite, contains fragments like those of the purplish tuff with which it is in contact. Rhyolite in similar relations was observed on the north shore of Youngs Cove. The inclusions are usually single fragments of andesite, not aggregates of fragments, suggesting that the tuff was not consolidated at the time the rhyolite was intruded. The rhyolite of Bar Island, in Cobscook River, is a massive microgranite and is possibly intrusive.

In general the tuffs of the series, though more variable than the flows, are characterized by an abundance of feldspar crystals, which are attached to or associated with reddish cherty-looking fragments. At a few localities fragments of light salmon-colored rhyolite occur.

Andesite.—Purplish andesite like that in the Dennys formation is interbedded with other rocks throughout the Edmunds formation, but as it can not be easily distinguished in the field from some of the dark-reddish rhyolite with which it is interbedded it has not been separately mapped. Flows of this andesite are finely exposed near Edmunds, on the point of land just west of Hallowell Island, and in the small cove three-quarters of a mile east-southeast of Mount Dorcas. Still finer exposures of the flows occur just south of the point where the Pembroke-Dennysville road joins the road that parallels the north shore of Wilson Stream and Cobscook River. Nearly all the flows observed are less than 100 feet thick. Good exposures of the tuff are more numerous, occurring at many points along the shore between Field Point on Cobscook River and Edmunds. The tuff is exceptionally coarse and well exposed at the eastern extremity of the Mount Dorcas peninsula and is also well exposed at many points along the north shore of Cobscook River from Ox Cove to Falls Island, especially on Wilbur Neck.

The flows of this andesite are prevailingly dark reddish or purplish brown, though in places they are greenish, resembling diabase. In places they exhibit to perfection the structures characteristic of surface flows. In a few localities, as on the point west of Hallowell Island, the rock is highly amygdaloidal. Similar outcrops on the shore three-quarters of a mile east-southeast of Mount Dorcas occupy nearly the same stratigraphic position in the formation. Many of the flows show finely preserved flow-breccia structures. The best exposures of such flow breccias occur just south of the point where the road to Ox Cove leaves the main Pembroke-Dennysville pike, where a flow about 30 feet thick strikes northwest and southeast. Plate VI is a reproduction of a photograph of the rock at this point, which shows irregular fragments of purplish-gray andesite crowded with feldspar phenocrysts inclosed in a dark terra-cotta colored and very fine grained matrix. The fragments of the rock at this place are generally amygdaloidal and show no flow lines. At other places, as on the small island just northwest of Hallowell Island, the fragments in the flow breccia are not amygdaloidal but bear well-developed flow lines. Varieties showing well-developed flow lines but no brecciation are exposed on the shore southeast of Mount Dorcas, where there is an alternation of gray, purplish-red, and greenish phases, all apparently parts of a single flow.

The type exposure of the andesite tuff is on the shore at the extreme east end of the Mount Dorcas peninsula. The general tint of this tuff is dark purplish red, but the fragments are lighter than the matrix and show well-developed flow structure. Where exposed beneath the andesite flow on the point west of Hallowell Island the andesitic tuff ranges in color from purplish red to dark green and mottled red and green. It contains few fragments more than half an inch across and is distinctly bedded. Bedding is usually recognizable in all the finer phases of the tuff, and its uniformity indicates that most of them were water-laid. The tuff is not as a rule purely andesitic but contains some fragments of rhyolite or diabase and in places grades into tuff composed largely of those rocks.

The coarser phases of the andesite contain feldspar laths, the largest 3 millimeters in length, lying in a fine-grained groundmass. The same textures are recognizable under the microscope in the finer-grained phases. The feldspar laths are crowded together in profusion, the groundmass forming a relatively subordinate part of the rock. Though generally arranged very irregularly they show in places a subparallel orientation produced by flowage while the rock was becoming consolidated. The texture of specimens of this kind of rock resembles more closely that of diabase than that of rhyolite and some specimens are typically trachytic. The feldspars that were sufficiently fresh for determination show albite twinning, with extinction angles ranging up to 20°, thus placing the composition of the feldspar at approximately $Ab_{65}An_{35}$ (andesine or oligoclase andesine). The groundmass in the fresher specimens contains augite crystals whose outlines are limited by the feldspars, showing that they crystallized later. The grains of magnetite bear a similar relation to the feldspar but in all specimens show much alteration to hematite, which is distributed in grains or in thin films along cracks in other minerals and colors the groundmass red. In some phases the groundmass is peppered with a great profusion of very minute grains of magnetite or hematite.

Other phases of the andesite exhibit textures very similar to certain associated rhyolites, phenocrysts of feldspar being scattered rather sparsely through a relatively fine grained groundmass having a felted texture. In these types the dark minerals are not visible to the naked eye but occur as minute grains scattered through the groundmass.

Most of the andesites contain the secondary minerals found in similar rocks, including calcite, chlorite, epidote, some zoisite, sericite, hematite, and rarely a little serpentine formed from augite. These secondary minerals show no unusual features requiring special description.

Diabase.—Effusive diabasic rocks, though rare in the northern exposures of the formation, are very abundant from Edmunds southwestward to Orange Lake. The flows and the tuffs are mapped separately. The northernmost occurrence of these rocks is between Dennysville and Mount Dorcas and their maximum development is in the hilly country west of Whiting. Some of the best exposures of the flows are near the south end of Roaring Lake, along the shore east of Little Mountain, and near the west shore of Burnt Cove. The tuffs are best exposed on the largest of the Bitch Islands, near Edmunds.

The flows display the usual features of diabase, being in places highly amygdaloidal and exhibiting flow-breccia bolster structure and other diabasic peculiarities. The flow west of Burnt Cove forms a low but continuous ridge for most of its length. Much of it shows flow brecciation, dark-green, relatively coarse grained amygdaloidal fragments being cut by stringers of blue-gray cherty-looking matrix, probably devitrified glass. The contact of the flow with overlying fossiliferous shale is well exposed, the diabase not being different in texture next the shale and the shale filling all the irregularities in the lava surface, which here has a bolster structure. These relations signify that the contact is a normal sedimentary one and suggest that the flow was submarine. Similar relations between a diabase flow and overlying rhyolite tuff were observed on the shore east of Littles Mountain. The upper surface of the flow forms irregular bulbous protrusions.

The diabase tuff exposed on the northernmost of the Bitch Islands weathers to form exceedingly ragged surfaces. Most of the fragments are less than an inch in diameter, but some are as much as a foot across. The occurrence here and there of typical cross-bedding indicates that they were water-laid.

Shale.—The detrital sedimentary rocks of the Edmunds formation are almost entirely shale and mudstone, which, having been easily eroded, now form or underlie lowlands. As the rocks of the lowlands are more obscured by glacial drift and marine clay than are those of the hills, exposures of the shale are relatively rare except along the shore, and the formation therefore probably includes other masses of shale besides those mapped, especially the part of it that lies east of Orange Lake.

Greenish-gray mudstone having little or no shaly parting is especially abundant in the lower part of the formation. Much of it has a flinty appearance and breaks with a conchoidal fracture almost as readily in one direction as in another. Microscopic examination shows that it is made up largely of volcanic dust, though it contains a few fragments of phenocrysts of feldspar. The stratification of such masses is defined chiefly by differences in the color and grain of the separate beds, each of which may be wholly massive throughout a considerable thickness. Fossils are abundant in the mudstone only in some of the less massive layers.

In the sediments of the upper part of the formation shaly parting is better developed and the stratification is more conspicuous. Some layers are calcareous, but the formation includes no true limestone. Tuffaceous layers are common in many places and grade into thick beds of stratified tuff.

Fossils, age, and correlation.—Fossils are abundant in the shale of the Edmunds formation and many of them are well preserved. Seven of the best localities for collecting fossils are shown on the areal-geology map, and all the species figured in Plates XVII, XVIII, and XIX came from one or another of these localities. The following list includes the more characteristic identified species:

Brachyprion shaleri Williams.	Palæopecten transversalis Williams.
Chonetes cobscooki Williams.	Pentamerus galeatus (Dalman).
Chonetes edmundsi Williams.	Pterinea (Tolmaia ?) trescotti Williams.
Chonetes striatella (Dalman).	Tolmaia campestris Williams.
Chonetes cf. striatella (Dalman).	Whitfieldella edmundsi Williams.
Leptostrophia filosa (Sowerby).	Wilsonia saffordi Hall.
Meristina tumida (Dalman).	Wilsonia wilsoni (Sowerby).
Monomerella woodwardi (Salter).	
Palæopecten cobscooki Williams.	
Palæopecten danbyi (McCoy).	

All the species here specifically identified with described British species are found in the Wenlock limestone of Great Britain; only one occurs below the Silurian. Several appear in the Lower Ludlow and Aymestry limestones. The paleontologic and structural evidence indicates that the Edmunds formation is later than the Dennys formation.

The following species, not yet figured, also come from the Edmunds formation and throw further light on the correlation:

Rhipidomella hybrida (Sowerby).	Turbinolopsis bina Lonsdale.
Strophonella funiculata (McCoy).	Rhynchonella borealis (Schlotheim).
Rhynchotreta cuneata (Dalman).	

All these species are recorded from the Wenlock limestone in Etheridge's list.[a] Three of the species listed (*Monomerella woodwardi*, *Rhynchotreta cuneata*, and *Rhynchonella borealis*) are not recorded above the Wenlock limestone in Etheridge's list. Thus the full evidence correlates the Edmunds fauna with the British Silurian faunas of the Wenlock limestone, Lower Ludlow, and Aymestry.

The presence of peculiar species and the particular association of species of wide range and distribution indicate that the above faunas may be correlated with the British Silurian and that they do not show close relationship to Silurian faunas found in the interior of North America. The British faunas of the Wenlock and Ludlow in general are represented in the Niagara and later formations of North America. The fauna of the Edmunds, however, shows some affinity with that of the Cobleskill "Coralline" dolomite of New York and the Decker limestone of New Jersey, as well as with that of the Niagaran strata to which the New York State Survey has given the name Shelby dolomite.[b]

Relations. — The nature of the boundary between the Edmunds and Dennys formations has already been discussed in the description of the Dennys formation. At its upper limit the Edmunds formation passes conformably into the overlying Pembroke formation. The upper boundary of the Edmunds can not at all places be positively fixed but is determined largely by paleontologic evidence. In the region west of Youngs Cove it is placed between the dark-gray shale that contains Pembroke fossils and the underlying purplish-red andesite and rhyolite. In the Long Cove region purplish tuff appears to persist upward for a short distance into the Pembroke formation. In the region southwest of Nutter Cove the boundary is uncertain on account of the scarcity of fossils, the beds being more or less sheared. In a part of this region the boundary is provisionally drawn at a large mass of diabase that seems to have been intruded, in some places at least, along a fault.

PEMBROKE FORMATION.

Definition.—The Pembroke formation is a conformable alternation of rhyolitic and diabasic volcanic rocks with gray and dark-red shales. It is named from the village of Pembroke, near which its rocks are well exposed. The sedimentary rocks in the formation southeast of Leighton Point show no marked lithologic differences from those of the earlier Edmunds formation and are subordinate in amount to the volcanic rocks. Northwest of Leighton Point, however, the formation consists chiefly of two shale members, the lower of which is here named the Leighton gray shale, from Leighton Neck, and the upper the Hersey red shale, from Hersey Neck. The total thickness of the formation is about 6000 feet and that of the Hersey member is 2700 feet.

Distribution.—The formation occupies a belt, 1 to 3½ miles wide, lying just east of and roughly parallel to the belt formed by the Edmunds formation. It enters the north side of the quadrangle near Pennamaquan Lake and extends southeastward to the neighborhood of Federal Harbor, where it turns southward and southwestward and extends to the south side of the quadrangle near Crosby School.

[a] Etheridge, Robert, Fossils of the British Islands, vol. 1, 1888.

[b] Williams, H. S., Correlation of the Paleozoic faunas of the Eastport quadrangle, Maine: Geol. Soc. America Bull., vol. 23, p. 354, 1912.

In the southern part of the quadrangle the shales of the formation are commonly somewhat sheared and slaty and have yielded no fossils. The formation in that area has therefore been mapped solely by noting lithologic features, and as even those have been somewhat modified by shearing the mapping is somewhat uncertain. Some rocks in the region southwest of South Bay that have been mapped as Pembroke may belong to the Eastport formation, and future studies may require some slight shifting of the boundary between the Pembroke and the Edmunds formations.

Character of the rocks.—The Pembroke formation differs from the underlying Edmunds formation in containing no andesite and in including much thicker and more uniform masses of shale. The dark-red shale of the Hersey member is particularly characteristic. Sedimentary rocks are in general more abundant in the part of the formation in Pembroke Township than in the part south of Cobscook Bay. The rhyolite of the Pembroke is not very different from that of the adjacent formations. Flows of diabase and associated tuffs occur throughout the formation but do not cover areas as large as those they occupy in the overlying Eastport formation. As the tuffs and flows are nearly everywhere intimately and irregularly associated they are not differentiated on the map. In places the flows are difficult to distinguish from fine-grained, locally amygdaloidal phases of the intrusive diabase, some of which probably solidified close to the surface.

Rhyolite.—The flows of rhyolite of the Pembroke formation include gray, pink, and dark-red to nearly black varieties. They are abundant southeast of Leighton Point but are not found northwest of it.

The gray rhyolite ranges when fresh from light yellowish gray to dark greenish gray and, exceptionally, nearly to black. Some varieties, as, for example, most of the types that show well-developed flow lines, are nonporphyritic; others are crowded with phenocrysts. The gray rhyolite is particularly well exposed on Denbow Neck west and southwest of Edgecome Point, where, near the north shore, flow lines, flow-breccia structures, and spherulites are well developed. The spherulitic structure is well shown on many weathered surfaces, as illustrated in Plate I, but microscopic examination shows that the original material of the spherulites has been entirely replaced by quartz and calcite without destroying their outlines. The gray rhyolite is abundant in the vicinity of Bassett Creek and Federal Harbor and occurs in less abundance as far south as Yellowbirch Mountain.

An unusually fresh specimen found near Yellowbirch Mountain contains pale-pinkish phenocrysts of feldspar, the largest three-sixteenths of an inch in length, embedded in a blue-gray aphanitic groundmass. Microscopic examination shows that most of the phenocrysts are orthoclase, only a few being oligoclase. They lie in a microgranular groundmass of the quartz and feldspar. Some epidote, chlorite, and calcite have been produced by alteration. A nearly black phase of this rhyolite from a point near the head of Federal Harbor contains scattered phenocrysts of orthoclase and some of sodic plagioclase embedded in a groundmass formed of a felt of quartz grains and orthoclase laths. The dark color results from an unusual abundance of minute grains of magnetite. Secondary chlorite and calcite are abundant and have completely replaced some of the phenocrysts.

Most of the dikes of gray rhyolite are darker within a few feet of their borders and black next to the contact. The microscope shows that this difference in color is due to an increase in the amount of magnetite and pyrrhotite.

Other rhyolites of the formation range in color from bright salmon-pink to brownish red, and are indistinguishable in general appearance from many of the rhyolites of the other formations. Flows of pinkish rhyolite containing well-developed spherulites are well exposed in the small cove a quarter of a mile west of Horan Head, some of the spherulites here being a quarter of an inch in diameter.

One of the most abundant types of rhyolite tuff contains angular fragments of aphanitic salmon-pink rhyolite and scattered fragments of dark-red and gray rhyolite in a dark greenish-gray groundmass. Small outcrops of this tuff occur in Leighton Cove, but the main mass is on Denbow Neck, where it is conspicuously exposed on the ridge between the head of Bassett Creek and the head of Federal Harbor. Scattered exposures occur on the east shore of South Bay and extend southwestward nearly to Whiting. At several localities this rhyolite tuff passes gradually into tuff composed mainly of diabase fragments, and in some of the coarser phases fragments of amygdaloidal or massive diabase are conspicuous among the more abundant fragments of rhyolite. Most of the tuff of this type probably contains some fragments and dust of diabase, to which, in part, doubtless, is due the abundant development of green chlorite in the fine matrix. The groundmass in the specimens examined microscopically consists almost wholly of secondary quartz, chlorite, and calcite, only a few fragments of feldspar crystals being still preserved.

Gray rhyolite tuff is found in nearly every part of the formation, especially on Denbow Neck, but it is commonly subordinate to other types. In general the rhyolite tuff presents no features requiring special description. Some of the finer phases, though extensively altered, still show under the microscope the characteristic structure of volcanic dust, being made up of fragments showing the concave outlines produced by conchoidal fracturing of glassy material.

Reddish and brownish rhyolite tuff occurs in all parts of the formation. Dark-red tuff outcrops in small areas on Denbow Point and about Leighton Cove. Much of the reddish tuff east and northeast of Whiting is of lighter color.

Tuff containing abundant feldspar phenocrysts derived from the porphyritic rhyolite, although occurring in the overlying and underlying formations, is particularly abundant in the Pembroke. Tuff of this character forms nearly all the rhyolite in that part of the formation lying northwest of Leighton Point and also outcrops in scattered places farther south, the exposures extending southward as far as Whiting. Excellent exposures occur between Pembroke and West Pembroke, especially along the river, and in this area one of the tuff beds forms the boundary between the Leighton gray shale member and the first red shale of the Hersey member. A number of excellent exposures occur on both shores of Pennamaquan River below West Pembroke. Tuff of this type is characteristically greenish gray and contains abundant phenocrysts or fragments of phenocrysts of white or pink feldspar, the largest an eighth of an inch across, embedded in a fine greenish groundmass.

The rock in places contains fragments of gray or reddish rhyolite, and in certain small blotchlike areas the phenocrysts lie in a nearly black matrix of secondary chlorite, which has completely replaced the original matrix. Phenocrysts of quartz, most of them having a rounded outline, are less abundant than those of feldspar. In a few localities, as near Pembroke, below the Hersey red shale, the tuff has a dark-red color. On the shore about 1½ miles west of Kelly Point, on Pennamaquan River, the feldspathic tuff contains irregular masses and lenses of dark-gray shale at its base and grades downward into beds of dark-gray shale. At one of these exposures on the north side of the river, about 1½ miles below West Pembroke, tuff in which feldspar phenocrysts are abundantly and rather evenly distributed grades upward into phases in which phenocrysts and fragments of phenocrysts are scattered in irregular aggregates through a fine-grained greenish-gray groundmass, which under the microscope shows the typical structure of volcanic dust. Microscopic examination shows that the phenocrysts and fragments of phenocrysts in this tuff are mostly orthoclase but include a few crystals of sodic plagioclase. Fragments of quartz phenocrysts also occur and show the embayments characteristic of quartz phenocrysts in rhyolite porphyry. The groundmass in ordinary light appears crowded with fragments having the typical concave outlines resulting from the conchoidal fracturing of a volcanic glass. Under polarized light these fragments, being singly refracting, are not conspicuous.

A more typical specimen from the south shore of Pennamaquan River about 3 miles below West Pembroke contains fragments of feldspar and quartz and a few of aphanitic rhyolite, thickly and evenly distributed through a greenish-gray matrix.

Under the microscope the fragments of crystals appear to be unusually fresh. Orthoclase and quartz with embayments predominate, but there is here and there a crystal of sodic plagioclase. Small fragments showing the typical form of particles of volcanic dust are abundant in the groundmass, but under polarized light it is seen that their original glassy substance has been replaced by quartz. In some places the matrix is wholly replaced by chlorite. Here and there is a fragment of diabase carrying much secondary chlorite and calcite.

The color of certain dark-red phases of this tuff that lie just below the Hersey red shale member of the formation from Pembroke northwestward appears on microscopic examination to be due to the secondary development of minute grains of hematite in the groundmass, the iron being derived probably from the overlying red shale. Near Pennamaquan Lake the red feldspathic tuff contains lenses of red shale and passes upward conformably into the main body of Hersey red shale.

Diabase.—Diabase flows and tuff are confined principally to that part of the Pembroke formation which lies northwest of the head of South Bay. Exposures are particularly abundant and instructive on Long Island and along the shore near Edgecome Point. The rocks are generally aphanitic and dark green to reddish brown and have all the structures that are com-

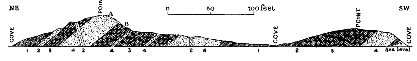


FIGURE 4.—Geologic section of Pembroke formation across the two small points west of Edgecome Point, South Bay.
1, Shales; 2, intrusive diabase; 3, diabase flows; 4, diabase tuffs.

monly found in diabasic flows. Descriptions of some of the structures observed near Edgecome Point in rocks that form part of the sequence shown in figure 4 will serve as illustrations. Most of the diabase flows there exposed have more or less pillow or bolster shaped portions, which are highly amygdaloidal at the center but become less so outward and are surrounded by fine diabase without amygdules but with faintly defined flow lines curving somewhat about the amygdaloidal bolsters, though parallel in general to the trend of the flow as a whole. The common mineral of the amygdules is calcite, but they may contain also some quartz and chlorite. Flow-breccia structures in which angular fragments of normal coarseness and color lie in a matrix of lighter-colored cherty-looking diabase occur in places. Where the lower contact of one of these flows that lies on diabase tuff is exposed the flow is less amygdaloidal within 2 or 3 feet of the contact and then becomes blacker and highly amygdaloidal within 2 inches of the tuff, many of the amygdules being arranged in bands parallel to the contact. The upper surface of a similar diabase flow near by shows conclusively that the tuff was deposited after the flow solidified. As shown diagrammatically in figure 5, the

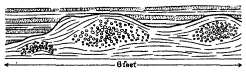


FIGURE 5.—Sketch section showing well-bedded horizontal diabase tuffs deposited on the irregular surface of an amygdaloidal diabase, all in the Pembroke formation. Edgecome Point, South Bay.

amygdules of the flow bear no regular relations to the tuff contact, whereas the bedding planes show that the tuff when deposited filled all the minor irregularities in the surface of the flow. This contact is between the beds marked A and B in figure 4. These details of the structure show conclusively that the amygdaloidal diabases are flows and not intrusive masses. Nearly all the flows are most highly amygdaloidal in their upper portions, where the imprisoned gases could expand most freely.

The tuff interbedded with the diabase flows of the Edgecome Point region ranges in color from dark green to reddish brown and contains few fragments that are more than an inch in diameter. (See Pl. II.) The ripple marks on the surface of some of the tuff and its interstratification with shale shows that some if not all of it was water-laid. At the end of Leighton Point brachiopods are embedded in a few narrow layers, 1 to 2 inches thick, of tuff composed mainly of fragments of diabase, some of them 3 inches in diameter.

Most of the diabase tuff is rather fine grained, but coarse phases are well exposed at several points. At the north end of Long Island most of the fragments are less than 4 or 5 inches in diameter, though some are 2 to 3 feet across. Some of the amygdules there are 1½ inches in diameter. Tuff in the cove just southwest of Black Head, Federal Harbor, contains fragments both of rhyolite and of diabase, the largest a foot across. Similar coarse tuff is exposed along Finnegan Brook a short distance east of the Lubec-Whiting road. Finer tuff that underlies a large diabase flow near this point has been baked for 2 to 3 feet from the contact, and the flow has picked up fragments of the tuff.

An unusually fresh specimen of amygdaloidal diabase from the shore southeast of Edgecome Point shows under the microscope a typical ophitic texture, the laths of feldspar being embedded in considerably larger crystals of augite of more or less rounded outline. The abundant amygdules are composed predominantly of calcite but include some chlorite. The few determinable feldspars show an index of refraction not far from that of balsam. They are probably in part at least albite or oligoclase, formed secondarily at the expense of original feldspar of more calcic composition, an alteration common in the diabases of this region. (See description of intrusive diabases.)

The diabase tuff of this formation is commonly completely altered to an association of secondary minerals, although vesicular and diabasic textures are still recognizable in the fragments. The feldspars are rarely determinable.

Leighton gray shale member.—The Leighton gray shale member consists principally of bluish-gray shale distinctly stratified. It is thin bedded, in many places forming flagstones, and only here and there does it contain calcareous layers. Although there is no unconformity between the Edmunds formation and the Leighton member of the Pembroke formation, the character of the rocks as a whole indicates more continuous and more uniform sedimentation than that in Edmunds time. In many places the gray shale splits not only along bedding planes but also along a plane of incipient cleavage extending northeast-southwest, breaking into splinter-like fragments. Some of the beds are composed largely of fine volcanic débris, as is shown by their gradual passage into distinctly tuffaceous beds. In Leighton Cove layers of tuff containing fragments measuring half an inch in diameter are fossiliferous.

Hersey red shale member.—The Hersey red shale member, though including some gray shale like that of the Leighton member, consists chiefly of purplish-red shale of very uniform character for considerable thicknesses. This shale contains some of the fossils that are characteristic of the Leighton member, but the fauna is ordinarily restricted to species of the genera Leperditia, Platyschisma, and Grammysia, and a few species of ostracodes. Like the shale of the Leighton member it has in places a secondary cleavage with a northeast-southwest trend and a steep dip. The line between the two members is drawn at a layer of rhyolite tuff below which there is practically no red shale.

Fossils, age, and correlation.—The shales of the Pembroke formation are abundantly fossiliferous at many localities. Seven of these that are particularly favorable for study are indicated on the areal-geology map and all the fossils figured in Plates XX, XXI, and XXII came from one or another of those localities.

The following is a list of the more characteristic species which have been specifically identified:

Acaste downingiæ (Murchison).
Actinopteria bella Williams.
Actinopteria dispar Williams.
Actinopteria fornicata Williams.
Bellerophon (Patellostium) expansus Sowerby.
Bellerophon (Plectonotus) trilobatus Sowerby.
Bellerophon (Tropidodiscus) carinatus Sowerby.
Calymene blumenbachi (Brongniart).
Camarotœchia leightoni Williams.
Chonetes bastini Williams.
Cornulites serpularius var. bellistriatus Hall.
Dalmanella lunata (Sowerby).
Eurymyella shaleri var. minor Williams.
Grammysia pembrokensis Williams.
Grammysia cf. pembrokensis Williams.
Grammysia triangulata (Salter).
Leiopteria sp. indet.
Lingula minima var. americana Williams.
Lingula scobina Williams.
Modiolopsis leightoni Williams.
Modiolopsis leightoni var. quadrata Williams.
Nuculites corrugata Williams.
Orbiculoidea cf. morrisi (Davidson).
Orbiculoidea rugata (Sowerby).
Orthoceras cf. imbricatum Sowerby.
Palæopecten danbyi (McCoy).
Pholidops implicata (Sowerby).
Platyschisma helicites (Sowerby).

The faunal differences between the Hersey and Leighton members have already been mentioned. All the species here identified with British species (except *Orbiculoidea morrisi*) are recorded in the Upper Ludlow of Great Britain. The Orbiculoidea is of a type that ranges still higher and its identification is not certain. Only two of the species go higher. The evidence therefore points to correlation with the fauna of the Upper Ludlow of the Silurian of Great Britain.

Relations.—The relations between the Pembroke and the underlying and overlying formations in the northwest part of the quadrangle are those of complete conformity. The boundary between the Edmunds and Pembroke formations from Eastman Hill to Youngs Cove is drawn at the contact between dark-purplish andesite tuff characteristic of the Edmunds formation and gray shale bearing Pembroke fossils. Farther southeast, to Morong Cove, the boundary is drawn on paleontologic evidence.

The upper boundary of the formation in the region between Pennamaquan Lake and Sipp Bay is placed at the contact between dark-red shale containing Pembroke fossils and the overlying diabase tuffs and flows. A little higher stratigraphically the diabase is interbedded with shale containing Eastport fossils. On the north shore of Sipp Bay the red shale of the Hersey member passes upward with perfect conformity into diabasic tuff which is mapped as part of the Eastport formation. The transition takes place within a space of 3 feet, in which there is a series of alternate layers of tuff and red shale. Small lenses of purple shale lie a little above the base of the diabase series and one of them, 2 to 3 feet thick, was deposited upon the pillow-like surface of a diabase flow.

On the west shore of Seward Neck the upper boundary of the formation is drawn between small patches of shale containing Pembroke fossils and an overlying rhyolite that is closely associated with the limestone of Cooper Island which contains Eastport fossils. Rhyolite of that type is nowhere, so far as known, interbedded with sediments of the Pembroke formation.

EASTPORT FORMATION.

Definition.—The Eastport formation comprises the latest Silurian rocks of the quadrangle and like the older formations includes several kinds of sedimentary and volcanic rocks. It is named from the city of Eastport, on Moose Island, where it is well exposed. Its thickness can not be exactly determined but is probably about 8000 feet.

Distribution.—The formation occupies a belt, from 2 to 4 miles wide, that extends from the north side of the quadrangle between Pennamaquan and Boyden lakes southeastward to Carlow, Moose, and Treat islands and Seward Neck. Some small masses of the formation, inclosed by diabase, lie along the west shore of Johnson Bay and others probably extend southward along the east side of South Bay nearly to West Lubec.

The sedimentary rocks are particularly well displayed on the north shore of Moose Island and on Carlow Island.

General character.—The volcanic rocks of the formation comprise both rhyolitic and diabasic varieties, occurring as flows and associated tuffs. Some rhyolite that is probably intrusive is mapped as a part of the formation because it can not everywhere be distinguished from extrusive rhyolite. In bulk the volcanic rocks greatly exceed the detrital sediments, among which are limestone, shales of several sorts, and very small amounts of conglomerate. With few exceptions the masses of sediments are small and represent thin beds intercalated between the volcanic rocks that make up the bulk of the formation.

Red rhyolite.—The red and brown rhyolites of the Eastport formation include flows, tuffs, and numerous sills and dikes. The flows, which locally show well-developed flow lines, are well exposed on Moose Island on the hill back of the pumping station, on Pleasant Point, along the southwest shore of Seward Neck, and at many other places. On the point at the north entrance of Sipp Bay rhyolite showing well-developed flow lines contains in its basal portion numerous fragments of amygdaloidal diabase picked up from the surface of the diabase over which it flowed. Flow lines are particularly well developed in some of the red rhyolite at places half a mile to a mile southwest of Perry, and the upper parts of these flows show in places very perfect flow-breccia structure.

Red flow rhyolite occupies most of Seward Neck and the east shore of South Bay as far south as Red Point. Though showing great range in color, in places being very dark, even black, this rhyolite is characteristically dark red. At many places these lavas show well the typical structural features of volcanic flows. Flow structure is exhibited at many points on the east shore of South Bay, and on slightly weathered surfaces it is in places brought out in minute perfection of detail. Even in the microscopic sections flow structure is strikingly preserved, although the spherulites may have been entirely replaced by quartz and other secondary minerals, which are abundantly developed. Plates IV and V show the microscopic appearance of this rhyolite; Plate IV shows flow lines and spherulites, and Plate V shows flow-breccia structure.

Light-red phases of the rhyolite occur mainly on Moose Island and the adjacent mainland. They are commonly porphyritic, but in some specimens the phenocrysts are inconspicuous because they are partly decomposed or because their dark color resembles that of the groundmass; though in others they are lighter colored and stand out in sharp contrast to the groundmass. When examined under the microscope the commoner types show phenocrysts of orthoclase, the largest an eighth of an inch in length, embedded in a microgranular groundmass of quartz and feldspar. The red color is caused by finely disseminated hematite.

The red rhyolite and its related types commonly show considerable alteration when studied under the microscope. In many of the specimens the feldspars are considerably altered and secondary chlorite, epidote, and calcite are abundant. Groundmass quartz has in some specimens recrystallized, so that it shows the same optical orientation in considerable patches, though inclosing remnants of feldspar and other minerals. Secondary pyrite is abundant in some specimens.

One of the most striking exposures of tuff occurs along the shore of the mainland about a mile north of the Moose Island toll bridge. The finer-grained phases are greenish gray to purplish red and are not stratified. They grade into tuff composed of angular fragments of many kinds and sizes, the largest a foot in diameter. To the west the tuff passes conformably upward into shale and is therefore probably water-laid. The fragments of the tuff were derived from both the red and gray rhyolites and are in general highly altered.

Near the road corner half a mile northeast of the head of Lincoln Cove is some chocolate-brown tuff, which when studied under the microscope is seen to consist mainly of fragments of rhyolite, though it contains also fragments of diabase, some of them vesicular. Rhyolite tuff is especially well exposed at the head of Deep Cove, west of Shackford Head, where the most abundant fragments are chocolate-brown rhyolite porphyry containing conspicuous light-colored phenocrysts of feldspar. Some of the fragments are 4 feet across.

Tuff containing abundant fragments of reddish-brown rhyolite and phenocrysts of feldspar is interbedded with the red shale of the Eastport formation southwest of Perry. Other tuff crowded with fragments of feldspar phenocrysts occurs on Redington Island, at Birch Point, and near the head of Broad Cove. At Birch Point it forms a sharply defined bed about 5 feet thick. On the shore of Seward Neck, south of Cooper Island, feldspathic tuff, which at first sight resembles granite, is interbedded with and grades into limestone. At Broad Cove it forms a bed 2½ feet thick, bounded on one side by a sill of red rhyolite and on the other side grading conformably into shale.

Gray rhyolite.—Massive gray rhyolite is not abundant in the Eastport formation. On the southeast shore of the cove between Moose and Carlow islands, there is a small mass, which is probably part of a flow. It lies close to tuff containing fragments similar to it in composition. In texture it ranges from microgranular to subtrachytic, and in places its texture appears to be almost spherulitic. Quartz and orthoclase are its dominant constituents, and it contains abundant secondary chlorite and grains of pyrite. Gray massive rhyolite is also exposed on the east shore of Seward Neck at several points near North Lubec Landing. Under the microscope the rock is found to be much altered but apparently rhyolitic in original composition. It shows traces of flow lines.

Gray rhyolite tuff is not abundant in the formation, though several good exposures occur on the west end of Moose Island (See Pl. VII.) One of the best exposures is on the southeast shore of the large cove between Moose and Carlow islands, where the rock is well exposed for 200 feet. The tuff is composed of angular fragments, the largest 2 feet in diameter, which for the most part are unassorted. It grades upward, however, into shale similar to that of Carlow Island and the neighboring parts of Moose Island. Most of the fragments in the tuff are gray rhyolite, which shows a microgranular texture when examined microscopically, but the rock contains also a few fragments of pink rhyolite.

The tuff on Kendall Head is more heterogeneous than most of the tuff of the formation and in general is finer grained and more altered. The coarser phases exposed near the summit of the hill contain gray to purplish fragments, which are mostly altered rhyolite, though a few may be much-altered diabase. With these are associated some fragments of pink rhyolite, aphanitic rhyolite of a bright salmon-pink color being especially conspicuous. The finer phases of the tuff at Kendall Head are commonly so much weathered that the original character of the fragments can not be determined. In the rock at many localities veins of secondary pink or white calcite and epidote between the fragments form a characteristic network. The finest phases show bedding planes and grade into the typical gray shale of the formation.

Diabase.—Effusive diabase forms an important part of the Eastport formation. It occupies most of the south half of Moose Island and on the mainland forms two nearly parallel belts, of northwest-southeast trend, extending from the coast past Boyden Lake and Ironworks Mountain to and beyond the north border of the quadrangle. On the mainland these diabasic flows and tuffs alternate irregularly, the flows generally predominating, although between Birch Point and East Bay the tuff predominates. On the south half of Moose Island practically no tuff is associated with the flows. The diabase is particularly well exposed on Moose Island along the east side of Broad Cove and at Estes and Buckman heads.

As the rock is typical diabase it requires no special description beyond the statement that it is in most places so much decomposed that the ferromagnesian silicates have been entirely replaced by chlorite. Secondary calcite appears in all the sections studied and in some is so abundant that the rock is light gray. Some phases, such as that at Estes Head, are massive and locally porphyritic and display imperfect columnar jointing. They presumably represent the central part of the flow and appear to grade into rocks that are amygdaloidal or that display flow-breccia structure in remarkable perfection. In the exposure at Buckman Head, which is exceptionally fine, the massive portions of the diabase form nearly oval masses, the largest 6 or 7 feet long. Between these are portions that are highly amygdaloidal or that show flow brecciation and that disintegrate more rapidly in weathering. The flow breccia contains angular fragments of diabase, all of similar character, embedded in a flinty matrix that is probably devitrified glass.

The diabase is also well exposed on Ironworks Mountain between Boyden Lake and Pennamaquan River, where, on the summit of the hill, there are massive, amygdaloidal, and flow-breccia types. The matrix of the breccia is Indian red. The more massive parts, when examined microscopically, are found to be unusually fresh. The rock shows ophitic texture and contains much unaltered augite and some olivine.

Certain rocks of the formation which in the field appear to be true diabase were found when examined microscopically to contain orthoclase and oligoclase as dominant feldspars. These rocks are dark purplish to black and commonly have amygdaloidal and flow-breccia structures. They are closely associated with the undoubted diabase and are well exposed on the southeast shore of Carryingplace Cove and in the extreme western part of Moose Island, especially along the shore opposite Nipps Island. At Carryingplace Cove the rock ranges in color from dark purplish red to dark green. Much of it is a flow breccia in which the spaces between the fragments range from mere cracks to bands several inches wide, filled with purplish amygdaloidal material or with still finer flow breccia. Under the microscope the texture of the rock is seen to be subophitic, and most of the feldspar laths are orthoclase, though a few that are striated and below balsam in refractive index are probably oligoclase. In the greener phases the spaces between the laths are filled with chlorite and many scattered grains of magnetite. The alteration of the magnetite to hematite imparts to some specimens a purplish tint.

Dark-purplish lava from a point about half a mile west of Porcupine Mountain is in places porphyritic and amygdaloidal. Under the microscope it is seen to contain phenocrysts of orthoclase and a few of oligoclase, lying in a groundmass of trachytic texture composed of laths of orthoclase with abundant iron oxides, secondary chlorite, and epidote.

Flow structures are well developed in lava of this type on the southwest shore of Moose Island. In the vesicular phases, which are of terra-cotta color, the vesicles are filled with dark-green chlorite. The rock is of finely trachytic texture and is made up of a felt of orthoclase laths between which lie grains of chlorite, epidote, and hematite. The more massive portions of this flow, which contain some amygdules, are black. Under the microscope they show a felt of orthoclase laths in typical trachytic texture, chlorite, calcite, and iron oxides appearing in the interspaces.

The only ferruginous minerals now found in this rock, except some magnetite, are of secondary origin, but it undoubtedly once contained abundant iron-bearing minerals, as is indicated by its coarsely amygdaloidal and generally diabasic habit. It is believed that the rock was originally a true diabase but that the feldspars have been altered to the alkalic varieties through the action of circulating solutions, the process having been similar to that described for the intrusive diabases.

An amygdaloidal diabasic flow near Leach Point showed in one place a vesicle 5 inches long and from three-quarters of an inch to an inch wide.

Diabasic tuff of the Eastport formation is well exposed at several places. Perhaps the best exposure is along the shore about half a mile west of Birch Point. The rock there is an assemblage of irregular fragments, the largest 18 inches across. Some are massive, but many are highly amygdaloidal. The finer phases are bedded, but the coarser ones are unassorted. At the mouth of the small arm of Sipp Bay that lies nearly north of Rodgers Point the basic tuff is also well exposed, conformably overlying the red shale of the Pembroke formation. The appearance of the tuff is similar to that near Birch Point, and some of the fragments are 18 inches across.

The finer-grained phases of the diabase tuff when examined under the microscope are usually found to be so highly altered that the original character of the feldspar can not be determined. In places they are gray from extensive development of secondary calcite. Some of the large, massive fragments in the tuff are fresher than any specimens collected from the flows. Two such fragments, one from Sipp Bay and one from Birch Point, showed under the microscope a typical ophitic or diabasic texture. Original augite is abundant in one specimen. Magnetite grains are abundant and show some alteration to hematite. The feldspar is orthoclase and oligoclase, possibly secondary after calcic plagioclase.

Limestone.—The oldest fossiliferous rock of the Eastport formation is a dark-gray, thin-bedded, and somewhat siliceous limestone, which outcrops a short distance northwest of North Lubec Landing and on Cooper Island. There is also a small area on the west side of Johnson Bay near its head. The rock was formerly burned for lime at both localities. Except where it is in contact with intrusive diabase the limestone rests on the red rhyolite that occupies the larger part of Seward Neck.

Some of the beds bear what appear to be casts of mud cracks and of rain prints. Others are oolitic and cross-bedded. At one place an arkosic bed full of feldspar phenocrysts is interbedded with the limestone. Fossils are fairly abundant but include only algæ and ostracodes. The physical character of the limestone, the small size of the areas in which it occurs, and the character of its fossils indicate that it was formed in lagoons.

Shale.—Another detrital rock of the Eastport formation consists predominatingly of dark blue-gray shale, which appears nearly black when wet. It is well exposed near the small limestone mass on the shore of Johnson Bay and outcrops at several places on the east side of Seward Neck, as well as about Shackford Head, Broad Cove, and Prince Cove, and it fringes parts of Rodgers, Dudley, and Treat islands. It includes thin calcareous layers from half an inch to 8 inches thick, especially in the passage beds above the limestone. At most of the localities mentioned the shale is abundantly fossiliferous. These beds are believed to have been formed in shallow water, under conditions that were much more favorable to the growth of marine organisms than those under which the sediments next to be described were deposited.

After an interval, during which the volcanic rocks that make up nearly all the formation were erupted, rapid sedimentation was resumed under notably different conditions and a thick series of red and green shales, flags, and like rocks was deposited. (See Pl. III.) These rocks are exposed at the north end of Moose Island, on Carlow Island, on Pleasant Point, and southwest of Perry. The best section, showing the characteristic appearance of these sediments, is on the extreme north shore of Moose Island just west of the rhyolite prominence known as Kendall Head. The section there exposed was measured in detail and is given below.

Detailed section of rocks of the Eastport formation measured from east to west along north shore of Moose Island.

[The typographic arrangement represents the natural order of the beds, 1 being at the top, 2 next below, and so on downward.]

	Ft.	in.
1. Shale and flag, greenish gray; some massive beds, the thickest measuring 10 inches; ripple marks; lower part includes a bed, 18 inches thick, of calcareous conglomerate composed of fragments of gray and pink rhyolite embedded in a calcareous matrix	35	
2. Tuff, greenish gray, containing gray rhyolite fragments, the largest 2 inches across	3	
3. Shale, greenish gray, and thin flag; ripple marks; fish spine found in calcareous nodule; fossils abundant	25	
4. Shale and flag, red and green, alternated; a few layers, 2 to 4 inches thick, of calcareous conglomerate, made up of small rhyolite pebbles in a calcareous matrix; ripple marks; fossils	10	
5. Shale, dark red, obscurely laminated; calcareous nodules in upper part and bed, 2 to 3 inches thick, of pebbles in calcareous matrix; some lamellibranchs	4	
Fault; displacement about 6 feet.		
6. Shale, greenish gray	8	
7. Shale, dark gray, and thin flag; some calcareous nodules	18	
8. Shale, greenish gray, with some massive beds, the thickest measuring 6 inches; ripple marks; lingulas and modiolopsoid lamellibranchs	23	
9. Shale, dark gray, fissile	70	
10. Conglomerate of gray rhyolite pebbles, slightly rounded, mostly under 1½ inches	2	
11. Shale, dark gray, fissile, with a few more massive beds, the thickest measuring 8 inches; calcareous layers and lenticles, the largest 3 inches thick in places; lingulas and fucoids; sun cracks and ripple marks	75	
12. Flagstone, thick with scattered fragments of gray rhyolite, the largest 2 inches across	1	6
13. Tuff, fine, greenish gray, containing concretionary masses and pebbles, the largest 2 inches in diameter; some of amygdaloidal diabase	4	
14. Flags, thick bedded, and shales, in alternation; ripple marks; the thickest bed measures 8 inches	18	
15. Flags, greenish gray, reddish in places, alternating with greenish-gray to reddish-brown shale in thin layers; ripple marks common; the shale contains three layers of rhyolite tuff, the thickest measuring 8 inches	16	
16. Thin flags and shales, greenish gray	3	
Fault, probably of small displacement.		
17. Flags, gray, alternating with reddish shaly layers	7	
18. Flags, the thickest beds measuring 5 inches, lingulas and impressions of sea weed	7	
19. Volcanic ash, greenish gray, with fragments of gray rhyolite, the largest 2 inches across; no fossils	6	6
Zone of minor faulting, 6 to 7 feet wide.		
20. Shale, greenish gray, and thin flag with some massive beds, the thickest measuring 1 foot	25	
21. Shale, reddish, and thin flags	3	
22. Flag and shale, greenish gray. Exposures covered by till for a few feet but sequence probably continuous	45	
Dike of red rhyolite, 30 feet wide, intruding the shales.		
23. Shale, dark reddish brown; rapid alternation of fissile shaly beds half an inch to a foot thick with more quartzose and resistant layers from 1 to 6 inches thick; ripple marks common; rare lingulas in more quartzose layers	40	
24. Shale, greenish gray, mostly thin bedded but not very fissile	16	
25. Volcanic ash, green to purplish, with fragments of gray rhyolite, the largest 2 inches across	3	
Interval of 10 feet in which there has been some minor folding and possibly some faulting.		
26. Shale, mostly thick bedded and dark greenish gray, but containing some reddish-brown fissile layers; a few more quartzose beds are a foot thick, but most are under 4 inches; fossils	70	
Covered interval of a few feet, beyond which is similar shale with same strike and dip and probably in continuous sequence.		
27. Shale, dark gray, some beds containing gray calcareous nodules; alternation of thin-bedded shale layers and more massive quartzose layers, 6 to 8 feet thick; ripple marks common; lingulas	63	
Fault.		
28. Shale, light greenish gray, thick bedded, with rare lingulas	6	
29. Shale, reddish brown, slightly sandy, with a few hard layers of fine micaceous sandstone the thickest measuring 3 feet; no fossils	7	
30. Shale, thin bedded, greenish	4	6
31. Shale, thick bedded, mostly greenish gray but grading into reddish parts parallel to the bedding, and containing Buthotrephis and rare Planolites trails and a very few lamellibranchs	23	
32. Shale, chocolate-red, thin bedded, sparsely fossiliferous	6	
33. Shale, greenish gray, with a few more quartzose beds 3 to 5 feet thick; fossils mostly lingulas	13	
34. Shale, reddish brown, with alternate fissile layers, the thickest measuring 3 or 4 inches, and more massive layers, the largest measuring 6 inches; sparsely fossiliferous, mostly lingulas, a few lamellibranchs	17	6
Fault.		
35. Shale, red, apparently barren of fossils	15	
Fault.		
36. Shale, greenish gray, mostly fissile; a few beds slightly sandy; some lingulas throughout	24	
Fault.		
37. Conglomerate, the basal portion containing bowlders, some as much as 18 inches across and only slightly rounded; some are of pink rhyolite, but most are gray rhyolite; the upper layers finer	5	
38. Agglomerate, greenish gray, containing nodular pebbles, the largest 5 or 6 inches across	6	
39. Shale, purplish red, not laminated, but bearing a few lingula impressions	3	
40. Shale, greenish gray, not laminated, but containing a few concretion-like nodules	1	6
41. Shale, greenish, imperfectly bedded, containing a layer of fine tuff 1 foot thick; fossils	11	
Fault.		

The shale of Carlow Island, of Pleasant Point, and of the shore north of Pigeon Hill is in general similar in lithologic character as well as in fossils to that of the type section on Moose Island above described. Ripple marks are very common on the shale of Carlow Island and irregular patches on some of the ripple-marked surfaces are calcareous, indicating the deposition of lime in very shallow water. The shale contains many lingulas. On the shore north of Pigeon Hill the shale alternates in its upper part with dark-colored flows of rhyolite porphyry.

At most places the sediments of the upper part of the Eastport formation are gray or greenish gray, but at some localities their predominant color is red. Red shale of slight thickness has already been described in the section on Moose

Island given above, but the strip of shale about a mile southwest of Perry is predominantly red. This shale lies conformably upon the surface of a diabase flow and is undoubtedly made up largely of the fine detritus of the red rhyolite porphyry. Certain layers, especially those near the base of the shale, are crowded with fragments of feldspar phenocrysts similar to those in the associated red rhyolite. In many places the shale is remarkably even textured, free from traces of lamination, and fractures as readily in one direction as in another. In these respects it is similar to certain shales of the Perry formation. In other places, however, lamination is well developed, though the shales are nowhere fissile. In bedded phases well exposed at the reservoir dam above Perry about 15 feet of hard dark-red shale containing some greenish-gray beds is overlain by a few feet of obscurely bedded red shale which weathers to angular gravel. The bedded portions are sparsely fossiliferous.

Red shale that is probably nearly contemporaneous with that described above outcrops on the north shore of the small inlet about a mile south-southeast of Perry. It is dark red, shows no very pronounced lamination, and is overlain by coarse beds made up largely of fragments of the red rhyolite.

Conglomerate.—At a few places the Eastport formation contains beds of conglomerate. On Moose Island, on the west shore of the small cove three-quarters of a mile west of Dog Island, there is a dark reddish-brown conglomerate containing fragments, some of them 18 inches long, of many varieties of the red rhyolite. Some are angular and others are rounded, and the rounding did not occur in place, for the deposit as a whole is unassorted. Some of the well-rounded pebbles when broken show a pink center inside a leached gray crust half an inch or so thick. The leaching is probably due to weathering that occurred before the conglomerate was formed, for most of the fragments have no such leached crust. The matrix of this conglomerate is similar in composition to the fragments. No fossils were found in either the matrix or the pebbles of the conglomerate, but it is probably contemporaneous with the similar appearing fossiliferous conglomerate that is well exposed at several places near the head of the cove west of Shackford Head. At one place where this fossiliferous conglomerate lies on an amygdaloidal diabase its commonest fragments are purplish-red rhyolite porphyry containing conspicuous phenocrysts of gray orthoclase, some of them arranged in flow structure. A few of the fragments are 4 feet in diameter. In places the conglomerate contains pebbles of greenish-gray and dark-red shale, the largest seen being a foot long and 4 inches thick. The matrix is dark purplish red and is apparently composed largely of detritus of the red rhyolite. At one place the conglomerate is cut by a dike of red rhyolite. Shale pebbles in this conglomerate contain fossils that are characteristic of the lower part of the formation. Conglomerate also occurs on the west slope of Kendall Head, the pebbles being mainly highly altered diabase (commonly amygdaloidal) and gray rhyolite, some of which is much silicified.

The conglomerates appear to form an intimate part of the Eastport formation and do not at all resemble the conglomerates of the Perry formation.

Fossils.—Fossils are abundant in the Eastport formation and are found at so many places that only the localities that are of special significance in determining the boundaries of the formation are indicated on the map. Four of the localities most favorable for collecting fossils are so indicated and all the species figured in Plate XXIII came from one or another of those localities. Most of the fossils are well preserved. The following list includes the more characteristic species identified:

Eurymyella angularis Williams.	Lingula cornea Sowerby.
Eurymyella plana Williams.	Streptotrochus carinatus Williams.
Eurymyella recta Williams.	Streptotrochus ione Williams.
Eurymyella shaleri Williams.	Streptotrochus regularis Williams.
Eurymyella shaleri var. brevis Williams.	Streptotrochus sulcatus Williams.
Eurymyella shaleri var. longa Williams.	

Correlation and age.—The only species from the Eastport formation positively identified with a reported British species is *Lingula cornea*, which, according to Etheridge, ranges from the Aymestry limestone upward into the Devonian. It is listed by Elles and Slater in the Ludlow district as beginning in the Temeside (which is above the Upper Ludlow) in beds above those containing *Lingula minima*. The same sequence is shown in the lingulas of the Eastport section, *Lingula minima* being found in the Pembroke formation and *Lingula cornea* in the Eastport formation.

The most characteristic fossils of the formation are the species of Eurymyella which Williams has described as both generically and specifically new,[a] although he regards them as representing and probably including some of the forms called *Anodontopsis angustifrons* McCoy,[b] characteristic of the uppermost Silurian formation of Great Britain, namely, the Downtonian or Temeside formation. The Eastport formation is therefore regarded as of late Silurian age and as equivalent in general to the Ledbury, Downton, and Tilestone formations of the Silurian system in England.

[a] Williams, H. S., U. S. Nat. Mus. Proc., vol. 42, p. 385, Pl. 49, 1912.

[b] McCoy, Frederick, British Paleozoic fossils, p. 271, Pl. I k, fig. 15, 1855.

Relations.—The formation is conformable at its base with the underlying Pembroke formation, the exact contact being well exposed on the north shore of Sipp Bay near its confluence with East Bay. The transition from the Hersey red shale member of the Pembroke formation to the tuff of the Eastport formation extends at one place through a distance of 3 feet, characterized by an alternation of beds of red shale and of greenish tuff. Some irregular beds and lenses of red shale, too small to be mapped, occurring in the volcanic rocks in this vicinity, also express this conformable transition.

Conformable relations also exist between the shale patches on the west shore of Seward Neck, which contain Pembroke fossils, and the overlying rhyolitic lavas, which are mapped as part of the Eastport formation. In both places the boundary between the two formations is rather arbitrarily drawn at the first important lithologic change above the highest recognized Pembroke fossils. The rocks next above the Eastport formation are Devonian. The contact is everywhere an unconformity and is described under the heading "Devonian system."

CORRELATION OF THE SILURIAN FAUNAS WITH THOSE OF GREAT BRITAIN.

A preliminary announcement of the correlation of the Silurian faunas of the Eastport quadrangle was made in December, 1911,[a] and the studies that followed have not materially altered the correlations then announced. The fossils have been minutely examined and it has seemed desirable to subdivide some of the species named in British literature to which the American forms show a general likeness and to assign new specific names to some of the forms in order to indicate local or temporary phases in the evolution of the species or genus represented in the Eastport quadrangle. Precise correlation of faunas requires actual specific identification, hence the presence of a large number of species identical with species of the Silurian formations of Great Britain establishes close relationship between these transatlantic formations. The table below lists the species thus identified specifically with British described species, figures of which are given in the accompanying plates. The formations in which they are reported by Etheridge[b] are indicated. An arrow at the left shows that they occur also above the Silurian of the British section and an arrow at the right that they occur below that system.

Distribution of species in the Silurian formations in the Eastport quadrangle and in those of Great Britain.

		Tilestone, etc.	Upper Ludlow.	Aymestry.	Lower Ludlow.	Wenlock limestone.	Wenlock shale.	Woolhope	Upper Llandovery.	
PEMBROKE FORMATION.										
Acaste downingiæ (Murchison)			*	?	*	*	*	*	*	
Bellerophon expansus Sowerby			*		*				*	→
Bellerophon trilobatus Sowerby		*	*				*	*	*	?
Bellerophon carinatus Sowerby			*						*	→
Calymene blumenbachi (Brongniart)			*		*	*	*	*	*	→
Cornulites serpularius Schlotheim			*	*		*	*	*	*	→
Cornulites serpularius var. bellistriatus Hall										
Dalmanella lunata (Sowerby)			*							
Grammysia triangulata (Salter)			*							
Orbiculoidea morrisi (Davidson)				*	*	*	*			
Orbiculoidea rugata (Sowerby)			*	*	*	*	*	*		
Orthoceras imbricatum Sowerby			*							
Palæopecten danbyi (McCoy)			*		*	*				
Pholidops implicata (Sowerby)			*	*	*	*	*	*	*	→
Platyschisma helicites (Sowerby)	←	*	*						*	→
EDMUNDS FORMATION.										
Chonetes striatella (Dalman)				*	*	*	*	*	*	
Leptostrophia filosa (Sowerby)				*		*	*	*	*	
Meristina tumida (Dalman)				*	*	*	*			→
Monomerella woodwardi (Salter)						*	*	*		
Palæopecten danbyi (McCoy)			*		*	*				
Pentamerus galeatus (Dalman)				*	*	*	*	*	*	
Wilsonia saffordi Hall										
Wilsonia wilsoni (Sowerby)				*	*	*	*	*	*	
DENNYS FORMATION.										
Beyrichia cf. maccoyiana Jones										
Beyrichia spinulosa Boll var.										
Bilobites bilobus (Linné)					*	*	*	*	*	→
Bollia cf. bicollina Jones										
Cytherella concinna Jones										
Cytherella concinna var. ovalis Jones										
Dalmanites longicaudatus Murchison						*	*	*		
Leptæna lævigata (Sowerby)						*	*		*	→
Leptæna minima var. grayii Davidson					*	*	*		*	
Lingula oblata Hall										
Orthis equivalvis Davidson						*	*			→
Plectambonites transversalis (Wahlenberg)				*		*	*	*	*	→
Skenidium lewisi Davidson						*		?		
Spirifer crispus (Hisinger)				*	*	*	*	*	*	
Streptelasma calicula Hall										
QUODDY SHALE.										
Anoplotheca barrandei (Davidson)						*	*	*		
Atrypa reticularis Linné	←		*	*	*	*	*	*	*	→
Dalmanella elegantula (Dalman)			*		*	*	*	*	*	→
Leptæna rhomboidalis (Wilckens)	←			?	*	*	*	*	*	→
Schuchertella subplana (Conrad)										
Pentamerus cf. oblongus Sowerby									*	→
Plectambonites transversalis (Wahlenberg)				*		*	*	*	*	→
Spirifer radiatus Sowerby					*	*		*	*	→
Spirifer crispus (Hisinger)				*	*	*	*	*	*	

The fauna of the Quoddy formation is entirely different from the fauna of the Oswego sandstone and is not Ordovician; hence it is placed at the bottom of the Silurian. It is evidently lower Wenlockian and bears affinities with the New York Niagaran. The Edmunds fauna represents the faunas of Great Britain from the Wenlock shale to the Aymestry inclusive but shows closest affinities with that of the Wenlock limestone and shale. It is apparently not represented in the New York section, but its affinities there are almost as close with the Cobleskill dolomite as with the Rochester. The Pembroke formation is probably not older than the Rondout limestone of New York, but the fauna is not represented definitely in the New York section. The Eastport fauna is certainly distinct from anything reported in either the Silurian or the Devonian of New York. (See correlation table on p. 10.)

[a] Williams, H. S., Correlation of the Paleozoic faunas of the Eastport quadrangle. Maine: Geol. Soc. Am. Bull., vol. 23, pp. 349–356, 1912.

[b] Etheridge, Robert, Fossils of the British Islands, vol. 1, Paleozoic, 1888.

The more common and characteristic species of fossils found in the several formations, including 19 species lately described,[a] have been figured in Plates XVI to XXIII.

DEVONIAN SYSTEM.

PERRY FORMATION.

General character and thickness.—The Perry formation is composed chiefly of red sandstone and conglomerate but includes some red shale and interbedded flows of diabase. It was named by Hitchcock[b] from the town of Perry, in which it is well exposed. Its thickness can not be definitively given.

Distribution.—The largest area occupied by the formation in the quadrangle lies north and northwest of Perry. Smaller areas lie along the shore of the mainland west of Moose Island, on the west shore of East Bay nearly opposite Leach Point, on Hersey Neck, and near the head of South Bay.

In areas north of the quadrangle the formation occurs along the American shore of the St. Croix to Mill Cove, and an outlier is found farther north, near Hilchins Point. On the coast southwest of the quadrangle, at Point of Maine and on Lakeman and Great islands, Hitchcock found conglomerate and sandstone that may belong to the Perry formation.

General lithologic features.—The smaller bodies of the Perry formation are composed entirely of sedimentary rocks, but in the type area northeast of Perry diabase flows are interbedded with the sediments. On the shore near Perry two series of flows, separated by conglomerate and also inclosing thin beds of conglomerate, are recognizable.

The sedimentary rocks of the formation in this region are characterized by their red color, which ranges from bright brick-red to chocolate-brown. Their red color is due primarily to the fact that they are composed largely of fragments of reddish Silurian rhyolites and of red granite, but it has been intensified somewhat by secondary deposition of iron oxide on and between the fragments. Although the red color is characteristic of the Perry formation in the Eastport region it can not be regarded as a safe criterion for the recognition of the formation elsewhere. In certain localities near St. John strata equivalent in age to the Perry are buff.

Breccia.—A characteristic feature of the base of the formation where it rests upon red rhyolite is a breccia composed mainly of angular fragments of the rhyolite of all sizes. The breccia is well exposed on the shore at the south end of Gleason Cove, in the small cove north of Garnet Point, on the west shore of East Bay, and on the south side of Hersey Neck. The fact that the rock is water-laid is shown near the south end of Gleason Cove by the occurrence in it of a few thin beds of red or greenish shale, and in most of the other localities by its gradation upward into typical conglomerate.

The fragments in the breccia are at most places less than a foot in diameter, but at a few places, as on the shore of Hersey Neck near the narrows of Sipp Bay, they are larger. The rock at that locality is composed of angular or only slightly rounded fragments of dark-red rhyolite, many of them 2 to 3 feet across and a few having a diameter of 5 feet. The fragments of rhyolite differ in character and color, some being porphyritic and others not and some being light red and others dark red. The matrix, which forms a very small part of the rock, is made up of small fragments of the same rhyolites and a few fragments of greenish shale. The whole deposit is unassorted.

Conglomerate.—At other places even the basal layers of the formation are composed of well-rounded pebbles. Such deposits were probably formed along portions of the Devonian shore that were exposed to more severe wave action. The matrix of much of the basal conglomerate and basal breccia is pink cherty silica.

A particularly instructive exposure occurs on the south shore of the inlet next south of Little River, where a series of beds about 100 feet thick, composed mainly of very coarse conglomerate with bowlders as large as $2\frac{1}{2}$ feet across, is interstratified with a few thin beds of sandstone and fine conglomerate. The pebbles and bowlders of the conglomerate are well rounded but are not well assorted, many pebbles 3 to 4 inches across and even large bowlders being embedded in a matrix of coarse sand. Most of the bowlders are of granite, and that rock forms much of the finer material, which, however, includes also some fragments of dark-red rhyolite, diabase, quartz, and shale. A remarkable feature is the slicing and recementation of many of the granite bowlders, shown in Plate VIII. Such slicing,

[a] Williams, H. S., U. S. Nat. Mus. Proc., vol. 42, p. 381, 1912, and vol. 45, p. 319, 1913.

[b] Hitchcock, C. H., Preliminary report upon the natural history and geology of the State of Maine, pp. 251–256, 1861.

the result of warping and minor faulting of the beds, was observed on a smaller scale in many parts of the formation. The beds show every characteristic of a beach deposit, closely resembling some of the present beach deposits along the shore farther southwest in Maine at places where granite ledges are exposed to the full sweep of the waves from the open ocean.

The conglomerate just described is faulted against a rhyolite flow, and the bedrock on which it was deposited is concealed, but the fact that it is dominantly granitic and the unusual size of the bowlders render it almost certain that the shore upon which it was laid down was granite, or at least that granite formed the shore near by. The nearest present exposures of granite are at South Robbinston, about 7 miles distant, and the amount of granite in the Perry formation between the two localities is relatively small. It therefore seems probable that granite underlies the exposures just described at no great depth or else occurs near by beneath the water.

In general the conglomerate and sandstone of the Perry formation, though consisting chiefly of fragments of red rhyolite and granite, contain also fragments of gray and nearly black rhyolite. Fragments of diabase and shale are notably scarce, probably because those rocks are more rapidly worn to fine detritus. A few fragments of shale and some of argillaceous limestone containing microscopic remains of organisms were recognized. Another characteristic of the conglomerate is the presence in it of well-rounded pebbles of white quartz, apparently vein quartz. Quartz veins are very rare in any of the older rocks exposed in the quadrangle, and this constituent of the conglomerate was therefore probably derived from some other area. Quartz veins are abundant in some of the rocks of Campobello that are believed to belong to the Quoddy shale.

Shale.—The red shale of the Perry formation is particularly well exposed along South Bay, where it forms part of the promontory known as Red Point, and on Hersey Neck, where it constitutes the dominant material of the formation. Most of this rock has no shaly parting and may be more correctly termed an argillite or mudstone. For considerable distances along the shore of Hersey Neck it is so uniform in character that its strike and dip can not be determined, but here and there the uniformity is broken by a thin bed of sandstone or conglomerate. Its fracture is commonly hackly and irregular and it breaks up on the shore into irregular angular fragments. The rock is more arenaceous and its color is generally a brighter red than that of the Silurian red shales. Evidence of erosion that was contemporaneous with the deposition of the shale was noted in the small cove north of Garnet Point, where, at one place, conglomerate that generally lies in conformity with the beds of red shale cuts sharply across those beds. Some of the red argillite shows indications of worm burrows, but a careful search failed to discover any fossils.

Diabase.—The flows of diabase are amygdaloidal in their lower and especially in their upper part, but their central part is massive and has imperfect columnar structure. Flow structure is common and is especially well shown on weathered surfaces. When examined microscopically the coarser phases of the diabase are found to consist of calcic plagioclase in fine laths and augite in large ophitic plates. The rock contains abundant yellowish serpentine, mainly a replacement of augite. In the finer-grained rock the feldspar laths are crowded more closely and the augite occurs in small grains between them instead of in large ophitic crystals embedding them. The amygdules are mostly less than a quarter of an inch in greatest dimension, but a few are 1 to 1½ inches across. The filling is mainly white calcite (Pl. IX), but in a few places fractures and vesicles are coated with a brick-red mixture of iron and copper oxides.

The contact between the sedimentary rocks of the Perry formation and the diabase members is not well exposed in the Eastport quadrangle, but along the shore north of the quadrangle, a mile south of Lewis Cove, the bottom of the lower diabase member is well shown. Sandstone and shale of the Perry formation dip at a gentle angle beneath the diabase, which within 12 to 18 inches of the contact is highly amygdaloidal but farther up is massive. At a number of places the amygdules are smaller near the contact and are elongate parallel to it. Elsewhere only a chilled zone of fine massive diabase one-sixteenth to one-fourth inch thick lies next to the shale, which is commonly baked for 1 to 3 inches from the diabase.

The contact between the diabase and an interbedded mass of red shale, in places 4 feet in maximum thickness, is well exposed in a small cove a mile southeast of Lewis Cove. The diabase under the shale is highly amygdaloidal for the whole 5 feet exposed, and its upper surface is crumpled or pillow-like. The lamination of the shale is everywhere nearly horizontal and bears no relation to the irregular lava surface. Tongues and irregular masses of shale project into the diabase or cut under its upper portion for several feet. The diabase above the shale, unlike that beneath, is amygdaloidal only within 12 to 18 inches of the contact and has a chilled zone a fraction of an inch thick next the shale, and bands of amygdules just above this are elongated parallel to the contact. In general the evidence is fairly clear that the diabases are flows contemporaneous with the sedimentary rocks and probably submarine.

Fossils.—The Perry formation has yielded fossils at a few localities in the quadrangle. The locality first discovered is on the south bank of Little River about half a mile below the bridge at Perry, where the fossils occur in a thin bed of shale. Collections were made there by J. W. Dawson in 1862 and later by David White. Another locality, recorded by White, is on the Robbinston road about half a mile north of Perry, where fossils occur in sandy shale and sandstone just below the contact with the lower diabase. In a shale lens, about 15 inches thick, on the south bank of Little River just below the sawmill dam at Perry a few poorly preserved plant remains were found by Mr. Breger. A few fragmentary plant remains were seen by Mr. Bastin in shale on the north bank of Little River about half a mile above the reservoir dam at Perry.

Age and correlation.—The Upper Devonian age of the formation is well established, and as the evidence of this correlation has been fully presented in the paper by Smith and White[a] on the Perry Basin it need not be repeated here.

The age of the formation was determined solely by means of its plant remains. Most of the fossils are broken and waterworn stems, so fragmentary that they can not be identified specifically, but at a few localities better preserved and identifiable material was found. Some of the species are—

Platyphyllum brownianum Dn.	Dimeripteris recurva (Dn.) D. W.
Archæopteris jacksoni Dn.	Sphenopteris filicula (Dn.) D. W.
Archæopteris rogersi Dn.	? Psilophyton cf. princeps Dn.
Archæopteris hitchcocki (Dn.) D. W.	Psilophyton ? alcicorne D. W.
Otidophyton hymenophylloides D. W.	Barinophyton richardsoni (Dn.) D. W.
Barrandeina perriana (Dn.) D. W.	Leptophlœum rhombicum Dn.
	Lepidocystis siliqua (Dn.) D. W.

Relations.—The Perry formation rests unconformably upon the underlying rocks, which in the Eastport quadrangle are of Silurian age. At the immediate contact the conglomerate and breccia of the Perry ordinarily consist almost exclusively of fragments of the rocks beneath. An instructive exposure on the shore a short distance east of the mouth of Lincoln Cove shows the contact of the Perry on red Silurian rhyolite. The strata dip 75° E. and the detailed section is as follows:

1. On the west, red rhyolite forming a flow.
2. Breccia, 7 feet, made up of angular fragments of rhyolite, some 2 feet in diameter and many 8 inches to 1 foot, embedded in a brick-red, fine-grained, fragmental matrix.
3. Conglomerate, 12 feet, similar in general to the breccia but showing some rounding of the fragments of rhyolite, a larger proportion of smaller particles, and in the upper part some admixture of foreign material, mainly rhyolite tuff.
4. Typical conglomerate with well-rounded pebbles and a large admixture of material derived from a distance.

The section demonstrates that the conglomerate overlies unconformably the red Silurian rhyolite, the breccia representing the beginning of sedimentation on the lava surface.

In the Eastport quadrangle the Perry formation is nowhere in contact with later formations, except the Quaternary deposits.

The strata of the Perry formation are at several places cut by diabase dikes, which may be of Devonian age and approximately contemporaneous with the interbedded flows or may be of later age. On the west shore of South Bay a diabase dike 10 feet thick cuts red shale, and another dike 2½ to 3 feet thick was intruded along a fault between shale of the Perry formation and older shale. A vertical diabase dike cuts conglomerate of the Perry formation on the St. Andrews shore and a number of others have been noted by Canadian geologists.

The Paleozoic formations of the Eastport quadrangle are correlated with those of New York and Great Britain below:

Correlation of Silurian and Devonian formations of the Eastport quadrangle with those of New York and Great Britain.

	New York. (Hartnagel, 1912.)		Eastport quadrangle. (H. S. Williams, 1914.)	Great Britain. (Geikie, 1903.)	
Devonian.	Chemung and Catskill.		Perry.	Devonian or Old Red Sandstone.	
	* * * * * *		(Absent.)		
Silurian.	Cayugan	Manlius.	Eastport.	Tilestone Downton Ledbury	Ludlow.
		Rondout.	Pembroke.	Upper Ludlow	
		Cobleskill. Salina.	Edmunds.	Aymestry Lower Ludlow	
	Niagaran	Guelph. Lockport.		Wenlock limestone	Wenlock.
		Clinton.	Dennys. Quoddy.	Wenlock shale Woolhope	
	Oswegan	Medina.		Tarannon Upper Llandovery	Llandovery.
		Oswego.		Lower Llandovery	
Ordovician.	Cincinnatian. Mohawkian. Canadian.				Caradoc or Bala. Llandeilo. Arenig.

[a] Smith, G. O., and White, David, Geology of the Perry Basin: U. S. Geol. Survey Prof. Paper 35, 1905.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

WISCONSIN STAGE.

General conditions.—During at least a part of the Pleistocene epoch, the last or Wisconsin stage of glaciation, the Eastport region was covered by a continental ice sheet, which traversed the region from northwest to southeast. This ice sheet and the waters flowing from it deposited large quantities of till, gravel, and sand. At the time the ice covered the region and soon after its retreat the land stood at a much lower level than at present, and by the extended sea of that period widespread deposits of clay were laid down, glacial gravel and sand were more or less rearranged, and in places the shore was eroded. The thickness of the Pleistocene deposits in few places exceeds 100 feet and is generally much less.

Glacial till.—The till is an unassorted mixture of bowlders and cobbles of various sizes and kinds in a sandy or clayey matrix. Most of the pebbles and bowlders are of the same kinds as the bedrocks of the quadrangle and have probably not been transported far. Some of them, notably the large erratic or isolated bowlders, which lie free on the surface, are granite or diorite and may have been transported many miles, for rocks resembling them have not been found in the quadrangle. The erratic bowlders, it is believed, were either carried on the surface of the ice sheet or within its upper part and dropped on the ground when the ice melted. Typical erratic bowlders, some of them 5 feet in diameter, are found on the summit of Kendall Head, on Moose Island. Bowlders of gray granite and diorite, commonly well rounded, are particularly abundant on the southeast flank of Pigeon Hill, 2 miles southeast of Perry, where the largest are 8 feet in diameter.

Deposits of till are in general not so conspicuous and good exposures of till are not so abundant in the Eastport quadrangle as in parts of Maine farther inland. Their absence is due partly to the severity of the glacial erosion, which exposed bedrock at many places, but principally to the fact that much of the till is buried beneath deposits of sand, gravel, and clay. Nowhere in the quadrangle are deposits of glacial till thick enough to produce any of the characteristic forms of morainal topography that are so common in the northern interior of the United States, and it is therefore not possible to trace the successive positions of the ice border in this region. Most of the larger and many of the smaller hills are practically bare of drift and the topography is in general controlled not by the drift but by the rock surface, though modified somewhat by deposits of till and gravel.

Marine-glacial sand and gravel.—Deposits of sand and gravel, though abundant in the Eastport region, are generally small and of irregular form, as shown on the surficial-geology map. They lie at altitudes ranging from sea level to 180 feet above sea level. The higher deposits generally begin near the upper limit of the marine clay (commonly 80 to 100 feet), but the lower deposits are essentially contemporaneous with some of the clay, for sand and gravel were deposited at the more exposed parts of the shore while clay was being deposited in more protected situations.

The constituents of the gravel deposits are commonly well rounded and, although including some rock of local origin, consist predominantly of material derived from places outside the region. A description of a few good exposures will illustrate their character.

The surface of the gravel near West Lubec forms a series of small knolls, few of them more than 10 feet high, the tops of which stand at altitudes of 80 to 100 feet. As exposed in a pit the material ranges from coarse sand to bowlders 18 inches in diameter, though most of it is composed of pebbles less than 3 inches across. Stratification is poorly developed even in the sandy parts of these deposits. Many of the pebbles are rather well rounded and most of the larger ones are granite, diorite, or diabase.

Gravel exposed in a large cut at Dennysville station is composed of fairly well rounded fragments from one-sixteenth to 10 inches across, the average diameter being one-half inch. The relative abundance of the several kinds of pebbles was estimated as follows: Granite and diorite, 25 per cent; rhyolite, 25 per cent; diabase, 25 per cent; shale and other rocks, 25 per cent. The exposed thickness of the deposit is 40 feet. Cross-bedding is recognizable in places, but in general the deposit shows little evidence of stratification. It contains a few pockets of sand and some bowlders, 2 to 6 feet in diameter.

A pit on Lubec Neck exposes 4 feet of gravel, which consists chiefly of rounded pebbles less than 1½ inches in diameter, though it contains a few cobbles measuring 6 to 7 inches across. The assortment is imperfect, and the recognizable stratification planes are slightly inclined. The pebbles are mostly granite and diabase but include a few fragments of rhyolite and shale.

In a gravel pit at the crossroads a mile north of Burnt Cove School the different types of pebbles occur in the following proportions: Diorite, 40 per cent; diabase, 25 per cent; rhyolite, 25 per cent; granite and other rocks, 10 per cent. Fully half the material has been derived from points outside the quadrangle.

Unusually good exposures of gravel occur along the coast in the southeastern part of the quadrangle. At the head of Julia's Cove several feet of gravel overlies somewhat pebbly marine clay. The deposit includes many angular pebbles and some bowlders a foot across and might be mistaken for till were it not for the presence of a few distinct beds composed wholly of pebbles less than 2 inches in diameter and the fact that most of the elongate pebbles lie with their greater dimensions nearly horizontal. The principal varieties of rock are granite, diorite, and rhyolite, the diabase and Quoddy shale that form the bedrock along that part of the coast being only sparsely represented. Just north of Boot Cove gravel of the same kind lies directly upon a striated surface of diabase. Similar gravel at the head of Boot Cove contains granite and diorite as the most abundant material, fragments of the bedrock of the vicinity being practically absent. Some of the granite and diorite cobbles are very rotten and readily crumble to sand. In general the small proportion of fine matrix in the gravel and the fact that the elongate pebbles are not heterogeneously oriented but lie with their greatest dimensions nearly horizontal strongly suggest the reworking of the deposit by waves. Such reworking would seem inevitable on account of its exposed situation.

A gravel deposit of particular interest forms an almost continuous belt from Hersey Neck to Pennamaquan Lake, in many places making a conspicuous though irregular ridge. The gravel of this deposit, though in some places showing no stratification, is in others well stratified, the beds being here and there horizontal but elsewhere differing in the angle and direction of dip, even in a single gravel pit. Some beds at Pembroke dip 40° E. The elongate form of this deposit and the fact that the region south of Pennamaquan Lake is more heavily drift covered than any other part of the quadrangle, the bedrock being entirely concealed, indicate that it marks one of the main paths of glacial retreat and of drainage from the receding ice.

Other gravel deposits are described under the next heading in a discussion of their significance as indicating submergence of the coast.

Raised beach deposits.—A number of deposits of sand and gravel show by their structure or topographic form that they were laid down on an old coast line, which stood much above the present sea level. One of the best examples is a gravel deposit on Moose Island, on the south side of Johnson Cove, on the farm of John McCoy. This deposit, which is shown in Plates X and XI, abuts on the south against a hill of red rhyolite and slopes gently and evenly to the north from a maximum altitude of about 120 feet next to the hill down toward the water. The flats that are shown in the foreground of Plate X are composed of marine clay, which is also exposed in the railroad cut, where it rises in places to a height of about 80 feet above sea level. This clay shows horizontal blue-gray, dark-red, and buff bands and grades upward into sand and gravel, which in a cut a short distance back from the railroad have the structure shown in Plate XI. The inclined or "foreset" beds here exposed are 25 to 30 feet thick, dip 30° to 35° toward the open bay, and are overlain by nearly horizontal beds of gravel, and their dip and even succession are believed to indicate their deposition in a body of standing water, which, as the location of the deposit shows, must manifestly have been the ocean. The smaller and less worn pebbles in this gravel are red rhyolite, shale, and other rock common in the region, but the larger cobbles are mostly granite and diorite derived from some other locality. The deposit is believed to represent material discharged into the ocean from a lobe of glacial ice standing probably in Carryingplace Cove.

The hill on Moose Island northwest of Johnson Cove is flanked on the southeast by another gravel deposit, whose form is spitlike. The deposit extends to an altitude of 110 or 120 feet above sea level and is backed by a rock slope whose profile suggests wave cutting. The locality is shown in Plate XII. A shallow pit just below the base of this "cliff" exposes a deposit of pebbles which, though angular or only slightly rounded, are evidently water deposited and washed free of fine material. About two-thirds of this material is derived from the rocky hill back of the deposit, but the deposit includes also some foreign material. Another pit in the lower part of the same gravel deposit, about 300 feet north of the railroad, shows "foreset" beds of gravel dipping about 35° SE. Here the proportion of material derived from the rock slopes at the north is about one-third and the foreign material constitutes about two-thirds.

Gravel deposits showing "foreset" beds, commonly dipping southeastward, were noted in other parts of the quadrangle and are listed below.

In a gravel pit three-quarters of a mile northeast of Crosby School, in the town of Whiting, the beds dip about 25° SE. Elevation, 110 feet.

About a mile south of No. 9 Hill, in the town of Trescott, stratified gravels dip about 35° SE. Elevation, 140 feet.

Near the road corners a mile southeast of Weir Cove, in the town of Trescott, gravel beds dip 15°–40° SE. Elevation, 100 feet.

Wave action is indicated not only by deposits showing beach structure but also in a few places by forms attributable to wave erosion. A low cliff near Eastport, possibly formed by wave erosion, is shown in Plate XIII. Another example was observed along the east side of Lubec Neck about half a mile southwest of the town of Lubec. The phenomena there shown can be understood by comparing Plate XIV and Plate XV. The seaward side of the ridge here is strewn with more or less rounded bowlders, mostly of granite and diorite, the largest 5 feet in diameter. Toward the sea the bowlders become smaller and less abundant. Near the ridge they lie on or are somewhat embedded in a gravel matrix, which passes seaward into sand and along the shore into clay that has been dug for brick making. Plates XIV and XV show the similarity in appearance between this surface and the adjoining tide flat. As erratic bowlders are rare in this region their extreme abundance in this place is the more remarkable. This bowlder-strewn plain is believed to be the result of marine erosion on a drift-covered shore, the finer constituents having been washed out and redeposited seaward and the coarse bowlders left nearly in place. Floe ice was probably instrumental in transporting some of these bowlders.

A similar bowlder deposit lies at an altitude of about 160 feet above sea level on the southeast slope of the hill three-fourths of a mile southwest of the head of Bassett Creek. If the sea stood at this elevation this hillside would be open to the full sweep of the waves. The bowlders form a belt 25 to 30 feet wide at the foot of a rock slope and cover fully half the surface. They are mostly of diorite and granite of foreign origin, are well rounded, and the largest are 3 feet in diameter.

Evidences of beach action at higher altitudes are less numerous and less clearly defined. On the south side of the 220-foot hill three-quarters of a mile northwest of Lincoln Cove a deposit of gravel that shows little evidence of assortment extends to an altitude of about 200 feet. Some of the pebbles are well rounded, but most of them are angular. The deposit, which has a narrow, sloping crest, has the form of an elevated bar connecting the main hill with a smaller knob farther south, across the road. The stratification planes recognized slope gently away from the crest of the gravel ridge. On the southwest side of No. 9 Hill in Trescott, at an altitude of 200 feet, a pit has been opened in gravel which consists mostly of pebbles over an inch in diameter but includes a few cobbles measuring 6 inches. This material is mainly red rhyolite of local derivation, but some of the more rounded pebbles are of foreign origin. The significant feature is that the gravel is clean and free from finer material and has the general appearance of beach-washed material. Both these deposits would have been exposed to severe wave action had the sea stood at their level. Although these occurrences do not afford conclusive evidence that the land stood 200 feet lower than at present, they are suggestive, especially in view of the corroborative evidence of comparable submergence farther south on the coast.

Marine clay.—Nearly half the quadrangle is occupied by marine clay, which in most places lies less than 100 feet above sea level but in a few localities, as near Eastman Hill, in Pembroke, extends up to an altitude of 130 feet. Although most of the surface below the 80-foot contour is covered with a mantle of clay, this deposit is not found everywhere, for along the coast line of late Pleistocene time, as along the present coast, the clay was deposited in greatest thickness in the more protected places, whereas in the more exposed positions gravel was deposited or wave and current action swept the rock surfaces bare.

The clay ranges in color from buff to blue-gray, but in a few places there are alternate gray and red layers. At an exposure on the west end of Moose Island the clay occurs in alternate thin blue-gray, dark-red, and yellowish layers.

The only place where the contact between marine clay and till was observed is on the south shore of Pennamaquan River about a mile below West Pembroke, where, in a bank 10 feet high, the clay distinctly overlies stony till. This exposure no doubt displays the general relation of the clay and the till, the clay having been deposited after the retreat of the glacial ice. At many localities the clay grades upward into gravel, and at a few localities gravel underlies the clay. An exposure showing the latter relation occurs on the shore of Lubec Neck at the head of the cove between Woodward and Leadurny points, where a mound-shaped mass of gravel 60 feet across is overlain by clay showing an alternation of clayey layers an inch or less thick with others that are slightly more sandy. The banded clay grades upward in turn into sandy clay containing pockets and lenses of well-rounded gravel. Clay overlying well-rounded gravel is also exposed on the north shore of Sipp Bay near the narrows.

Marine shells have been found in the clay at several places. Jackson[a] as early as 1835 reported their occurrence at the old canal crossing Seward Neck and noted the barnacles attached to rocks in that place that stand 26 feet above high-water mark. The fossils reported from this locality by Hitchcock[a] are *Pecten islandicus*, *Saxicava distorta*, *Mya arenaria*, *Mytilus edulis*, *Modiolaria nigra*, and Balanus sp. These fossils in general indicate colder water and lower temperatures than those of the present coast. A large collection of fossils was made by Mr. Bastin at a point on the north shore of Gleason Cove and sent to Prof. Leslie A. Lee for identification, but after his death they were lost and no opportunity was afforded for duplicating the collection.

[a]Jackson, C. T., First report on the geology of the State of Maine, pp. 18 and 19, 1837.

Glacial striæ.—The rocks along the shore at many places have been conspicuously striated and polished by glacial action, and if larger areas of hard rock were uncovered roches moutonnées would probably be found in abundance, but only one good example of this form of glacial rounding and polishing was noted—a small diabase point on the west shore of Straight Bay nearly opposite Gooseberry Island. The prevailing trend of the glacial striæ in the quadrangle is southeast, the direction at many localities being shown by arrows on the surficial-geology map. Diverse sets of striæ were found at only two localities. One of these is just west of the border of the quadrangle, along the railroad, about 2 miles north of Dennysville station, where a flat ledge shows an earlier set of striæ trending S. 53° E. and a later set trending S. 26° E. The second locality is a flat ledge on the east shore of Rocky Lake, near its north end. The earlier set here trends north and south and the later set, trending S. 25° E., truncates and partly erases them.

RECENT SERIES.

Deposits now being formed in the Eastport region include alluvium along certain streams, sand and gravel along beaches, clay on tidal flats, accumulations of peat in bogs, and accumulations of remains of plants in salt marshes.

Deposits of alluvium are so small and so closely confined to the stream channels that it has been impossible to show them on the map. Most of the streams are small, and as a result of glacial or artificial damming of their valleys many of them meander between boggy banks without either eroding or depositing actively.

The larger deposits of beach sand and gravel are marine, for the lakes are small and generally have rocky or marshy shores. Sand and gravel beaches have been formed principally in places subject to moderate wave and current action. In extremely protected inlets well-defined beaches are rare, because there is no strong wave action; on the other hand, along shores fully exposed to the Atlantic wave action is so severe that erosion rather than deposition is dominant. It is along shores subject to wave action between these two extremes that well-defined beaches have been formed, as in Baileys Mistake and Carryingplace Cove (near South Lubec). Current action has been an important auxiliary to wave action in forming some beach deposits, such as the beaches and spits that lie between Lubec and South Lubec. Beaches are in process of destruction or of formation even at the present time. On the shore of Moose Island due south of Carlow Island a peat bog whose plant remains are of fresh-water origin is now flooded by the sea at high tide and is thus being converted into a salt marsh, a condition due either to slight subsidence or to the removal of a protecting barrier beach. A similar condition exists near South Lubec at Carryingplace Cove, where a neck occupied by a peat bog is protected on the south by a barrier beach but entirely unprotected on the north, so that some of it is cut away during every storm from the north. During the last 25 years 200 feet of this bog has been eroded away, according to one of the residents, who reports that the older residents say that fully one-fourth of the bog has been removed. Probably the bog was once protected on the north, as it is now protected on the south, by a barrier beach, but the shifting of marine currents has doubtless caused the removal of this protecting barrier. Other evidence that such changes are in progress was found on the north shore of West Quoddy Head, about three-quarters of a mile east of this bog, where a small lake has been formed by the building of a barrier beach across a recess in the shore. After this beach was formed the currents shifted and produced a spit that projects westward from a point near the center of the barrier beach.

Bars that connect small islands with the mainland or with other islands have been formed at several places, the best example being on the north shore of Moose Island a mile west of Dog Island. An example of the reverse process may be seen in Cobscook River, between Dram Island and Falls Point, where a small island not shown on the map is connected with the mainland by a belt of coarse bowlders, some of them 4 to 5 feet across, which is exposed only at low water. These bowlders are far too large to be moved by any waves that can be formed in this protected place. The tidal currents there being very strong the bowlder "bar" may represent the heavier remnants of a mass of till that originally connected the island with the mainland.

Clays, most of them blue-gray, are now being deposited along the shore, most abundantly in the shallow tidal inlets,

[a]Hitchcock, C. H., Preliminary report upon the natural history and geology of the State of Maine, p. 282, 1861.

especially those into which the larger streams empty. These beds undoubtedly consist in large part of reworked material of the Pleistocene clay, which they resemble closely in appearance.

Peat is forming in many of the undrained basins, and the principal deposits are shown on the surficial-geology map. Its formation records the growth, death, and partial decay of generation after generation of bog plants, principally several species of moss (Sphagnum and Hypnum), of members of the heath family, and of fragments of small black spruce and tamarack. The remains of mosses make up the largest part of the deposit. Peat formation probably began early in postglacial time and has continued to the present day, some of the beds being 20 feet thick. The bogs are described in greater detail in the section on economic geology.

Salt-marsh deposits, consisting of the remains of salt-marsh plants mixed with marine clay and sand, are found at many places along tidal inlets.

INTRUSIVE IGNEOUS ROCKS.

ANDESITE.

Character and relations.—Andesite that is intrusive in the Quoddy shale forms Mount Tom, in the northwest corner of the quadrangle. It is a massive porphyry of very uniform character throughout, consisting of a purplish-black groundmass in which are embedded abundant gray or greenish feldspar phenocrysts, averaging about 2 millimeters in length, and a few smaller black phenocrysts. The rock is traversed by small veinlets of secondary quartz and epidote.

The microscope shows that the rock is much altered. The feldspar phenocrysts, which are plagioclase above balsam in index, are extensively replaced by sericite and epidote and in some places by quartz. Extinction angles up to 16° are preserved in a few crystals and some show zonal structure. Other phenocrysts whose outline shows that they were originally pyroxene are entirely replaced by epidote. The fine trachytic groundmass now consists largely of secondary sericite, epidote, chlorite, and iron oxides, with remnants of minute laths of feldspar.

Age.—The age of this andesite can not be exactly determined. It is younger than the Quoddy shale, which it intrudes, and is very similar lithologically to some of the effusive andesite of the Edmunds formation. Possibly it represents one of the volcanic vents through which these andesites were erupted.

As already pointed out, certain andesitic rocks associated with the Dennys formation may be intrusions rather than flows, but such masses of uncertain origin form only a small part of the andesite as compared with those that are clearly effusive.

DIABASE.

Distribution.—Dark-green to black intrusive diabase is one of the most conspicuous rocks of the Eastport quadrangle. It occurs in a great variety of forms and sizes, comprising stocklike masses, some a mile or more in diameter, as at Pughole Mountain, sill-like masses, some more than 4 miles long, like the diabase ridge east of Pennamaquan River, and small dikes, which are extremely abundant in nearly all parts of the quadrangle. The largest mass lies in the southeast part of the quadrangle, east of a line connecting Johnson Bay with East Stream. The map probably exaggerates the abundance and continuity of the diabase in the inland portions of this mass. The knobs and ridges are almost all diabase, but in the lowlands there are few or no outcrops, and possibly some of the lowland tracts mapped as diabase are occupied by Quoddy shale. The true proportion of diabase and shale is indicated along the shore, where the exposures are nearly continuous.

Character.—The diabase is commonly massive and of uniform character and is distinctly intrusive into the bordering rocks. Although the form and large areal extent of some bodies indicate that they are stocklike, most of the larger masses are more or less elongate parallel to the strike of the inclosing rocks and were probably intruded in general parallel to the bedding, though breaking across it in places. At a few localities, as at Shackford Head and Clement Point, where the contacts are exposed, such intrusion parallel to the bedding may be observed. Most of the smaller intrusions are dikelike.

Although generally finer grained and in places amygdaloidal next their walls, the intrusive masses do not display flow lines, bolster structure, a profusion of amygdules through considerable thicknesses, or other structural features characteristic of the diabase flows.

The diabase is commonly dark green to nearly black, but some of it is reddish or purplish because of abundant pink feldspar. It shows great differences from place to place in fineness of grain, ranging from varieties that are extremely fine grained or aphanitic to rare varieties crowded with feldspar laths one-fourth to one-half inch in length. In the commoner varieties feldspar crystals average 1 to 2 millimeters in length. The texture is commonly ophitic, rarely porphyritic. Microscopic studies show that the commoner varieties are true diabase in both texture and composition.

An unusually fresh specimen from the north side of Federal Harbor shows feldspar laths, the largest of which are 2 millimeters in length. A spotted appearance is produced by the development of coarser pyroxene in areas as much as 3 millimeters across. The microscope shows a typical intersertal texture, the feldspar laths being oriented in all directions with grains of pyroxene, altered in part to brown hornblende, and small grains of magnetite in the interspaces. The rock is typical of much of the rather feldspathic diabase. Other phases, as, for example, the diabase of the northeast shore of Hog Island, in South Bay, have a typical poikilitic texture, a number of feldspar laths being inclosed in much larger single crystals of augite which serve as their matrix. The rock of poikilitic texture is more typical of the coarser than of the finer types, and on weathering its surfaces assume a characteristic knobby appearance.

A fine-grained diabase from the summit of the mountain northwest of Roaring Lake shows under the microscope a finely porphyritic structure, due to the development of crystals or crystal aggregates of augite in a groundmass of very finely diabasic texture. A dike of altered diabase half a mile northwest of the west end of the Moose Island toll bridge is conspicuously porphyritic, containing scattered phenocrysts of feldspar measuring an inch by half an inch.

Some of the diabase is of special interest because of its content of sodic feldspar, generally albite, which has been extensively formed in it, apparently by secondary processes. Some rocks that to the unaided eye appear to be typical diabase and that grade into undoubted diabase are found, when viewed under the microscope, to contain albite instead of the labradorite that characterizes the normal phase. These rocks have, however, the ophitic or poikilitic texture characteristic of true diabase. In some specimens the augite associated with the albite is so fresh that the latter was at first supposed to be an original constituent in spite of the apparent incongruity of the association of pure albite in ophitic or poikilitic development with a calcic pyroxene (augite, extinction angles up to 45°), but there are several reasons for believing that the albite is secondary. One reason is the close similarity in appearance and field occurrence of these albitic rocks to true diabase and the apparent gradation from one to the other at some places, as on Edgecome Point. Another reason is the fact that certain thin sections that have uniform diabasic texture contain, in addition to albite, some plagioclase which shows a refractive index higher than that of balsam. A third reason is the presence of albite and other feldspars in amygdules in both effusive and intrusive diabase, and a fourth is the occurrence in one place of secondary plagioclase with calcite as the filling of a small fracture.

The occurrence of secondary feldspar as amygdule and fracture fillings shows that the rocks have been penetrated by solutions carrying the constituents of feldspars. It appears probable that the albite in the body of these rocks is the product of similar solutions acting upon original calcic feldspar. A prerequisite for such complete replacement of calcic by sodic feldspar without change in volume or the formation of abundant inclusions of alteration minerals would be an abundant supply of sodium in the solution effecting the change. This phenomenon has been noted in eruptive rocks in Scotland and has been described by E. B. Bailey and G. W. Grabliam,[a] who cite earlier observations by others. These writers attribute the alteration to juvenile sodium-rich waters—an effect of volcanic eruption. In the Eastport region there is no strong evidence that the change was brought about by juvenile rather than surface waters. Most of the specimens in which albitization was observed were collected on the shore, where the fractures in the rocks would almost inevitably be penetrated by saline solutions. Most of the diabase, moreover, is in contact with sediments that were laid down in ocean water that was presumably more or less saline. Oceanic salts would seem to be an adequate source of the sodium required for this replacement.

A number of thin diabase dikes that cut the Quoddy shale appear to be older than the main masses of intrusive diabase because they are more highly altered and in places sheared. A diabase dike outcropping on the shore just north of West Quoddy Light is highly schistose, whereas an adjacent mass of the typical diabase of the region is entirely massive. A schistose diabase dike, 4 to 8 inches thick, exposed on the shore in front of West Quoddy Light, is faulted in several places parallel to the cleavage of the Quoddy shale and also at a high angle to the cleavage.

The schistose diabase dikes are fine grained and are greenish gray in fresh specimens. Microscopic examination showed that the rock is sheared and altered diabase. The laths of plagioclase, which is the only original constituent present in large amount, are commonly arranged in the textural pattern characteristic of diabase and have here and there been fractured by the shearing. The matrix consists of secondary calcite, chlorite, and a little quartz. Abundant grains of magnetite have been partly altered to hematite.

Age.—There is abundant evidence of diversity, possibly of wide diversity, in the age of the different masses of diabase that are indicated on the map by the same symbol. Diabase flows are associated with all the formations, from the Quoddy shale to the Perry formation, and the production of intrusive masses of diabase in connection with the diabase flows of each formation may be regarded as a geologic necessity. More concrete evidence of diversity in age is afforded by numerous diabase dikes that cut other masses of intrusive diabase. The general lithologic similarity of all the diabase makes the differentiation in age of isolated masses impracticable.

Notwithstanding the differences in the age of the several masses the great bulk of the diabase probably belongs to a single period of intrusion, a fact indicated by the very evident relation of the form and distribution of the larger masses to the major structural features of the region. Except the great mass intruded into the Quoddy shale in the southeast part of the quadrangle the intrusive masses are largest and most numerous in the area between South Bay and Orange Lake, along or near the axis marking the shift in strike of the Silurian formations from northwest to southwest. That axis, like those of most folds, formed a zone of weakness that was easily penetrated by intrusions. Hence the principal intrusion of diabase is believed to have taken place either synchronously with or shortly after the major deformation of the Silurian formations. This conclusion is further supported by the form of some of the masses, such as that surrounding Lily Lake near the head of Straight Bay, which, in the absence of any trace of deformation in the diabase itself, is most readily explained by assuming its intrusion during or after the major folding. Further substantiation of this conclusion is found in the comparative scarcity of intrusive diabase in the Perry formation, indicating that the principal intrusion occurred before Perry time.

Many of the diabase masses are therefore of uncertain age; they may have been intruded at any time from middle Silurian to Upper Devonian or later. A few may be even as late as Triassic, as diabase of that age is known in Nova Scotia and probably on Grand Manan. The great bulk of the diabase, however, is believed to be of late Silurian or, more probably, of early Devonian age, and to have been intruded before the deposition of the Perry formation.

RHYOLITE.

Character and relations.—Scattered dikes and sills of rhyolite of several varieties cut all the Silurian formations but are not separately mapped. Some of them have already been described in the discussion of the closely associated effusive rhyolites of several of the Silurian formations and mention has also been made of the possible intrusive origin of large areas of pink rhyolite that are associated with the Dennys formation. A number of other rhyolite dikes are described below.

On the shore half a mile south of Woodward Point the Quoddy shale is cut by two vertical dikes of rhyolite porphyry, 2 and 12 feet thick, respectively. Parts of these dikes appear very fresh. Flow structure parallel to the walls occurs throughout the thinner dike but only next to the walls in the thicker one. The parts showing flow structure are banded greenish gray and pinkish, and the aphanitic body of the rock is crowded with rounded phenocrysts of transparent quartz, the largest an eighth of an inch across and with feldspar phenocrysts, some of them as much as a quarter of an inch across. Where the rhyolite is decomposed the phenocrysts of feldspar weather out and exhibit very perfect crystal faces.

The microscope shows that the rock is a typical rhyolite porphyry. The quartz phenocrysts are generally rounded and embayed. Original feldspar phenocrysts of perfect crystal outline are entirely replaced by calcite and chlorite. The groundmass still shows the outlines of minute feldspar laths but has been entirely altered to an aggregate of quartz, calcite, and chlorite. The rock is not nearly so fresh as it appears in the hand specimen.

The rocks of the Pembroke formation are intruded at a few places by dikes of red and of gray rhyolite. On the north shore of Bassett Creek a 2-foot dike of dark-red rhyolite porphyry intrudes fine-grained amygdaloidal diabase that is also believed to be intrusive. On Edgecome Point a dike of gray rhyolite intrudes a flow of diabase. The rhyolite becomes gradually darker colored within 5 feet of the contact and at its border is nearly black. The lighter phases contain irregular darker segregations, the largest 5 inches long, mostly elongate parallel to the trend of the dike.

The rocks of the Eastport formation are intruded by many masses of red rhyolite. At the west end of Carlow Island red rhyolite cuts across the bedding of the shale, as shown in Plate III. The contact is welded and the color of the rhyolite near it is changed from red to nearly black. Dikes of red rhyolite that cut shale are well exposed on Birch Point. A red rhyolite dike on the shore northwest of Kendall Head, on Moose Island, showed very perfectly developed flow lines parallel to its walls. At Buckman Head, on Moose Island, and on the shore half a mile southeast of Clement Point rhyolite dikes intrude diabase flows of the Eastport formation. The rhyolite that intrudes this formation, though not uncommonly indistinguishable from the flows in lithologic character, is in general coarser grained.

[a] Bailey, E. B., and Grabliam, G. W., Albitization of basic plagioclase feldspars: Geol. Mag., decade 5, vol. 6, pp. 250-256, 1909.

Its texture in some places is trachytic and in other places is granular, the granular phases being virtually fine-grained granite and bearing a rather striking resemblance to fine-grained phases of the large granite masses north of the quadrangle. At their borders many of the masses of intrusive rhyolite are markedly more mafic (basic) and in some places, as on the shore of Treat Island and at the west end of Carlow Island, are as dark colored as the diabase. The rock of these border phases, although consisting mainly of orthoclase and carrying some quartz, contains also some plagioclase (oligoclase to andesine), as well as abundant chlorite and epidote, probably decomposition products of hornblende, besides numerous crystals and small disseminated flakes of hematite, an alteration product of magnetite. Many of the smaller rhyolite dikes that cut the sediments or effusive rocks contain abundant oligoclase and approach in composition the contact phases of the larger masses. Some of these dikes are gray rather than reddish, an example being a dike that cuts the diabase flows of Buckman Head.

A 30-foot dike of red rhyolite cutting the sediments on the shore west of Kendall Head contains numerous cubes of pyrite, the largest half an inch in diameter, developed by metasomatic replacement near fracture planes.

Age.—All the intrusive rhyolite is believed to be Silurian or early Devonian in age because no rhyolite was found cutting the Devonian Perry formation. Some of the intrusive red rhyolite may have come from the same magmatic source as the red granite of Robbinston and vicinity but may have crystallized at less depth and therefore assumed finer textures. Such a relation between these two rock types is suggested by the close resemblance of some of the rhyolite dikes to some border phases of the granite.

GRANITE.

Character and relations.—Although not found in place in the quadrangle, granite outcrops a short distance to the north and, as pointed out in the description of the Perry formation, probably underlies certain parts of the quadrangle at no great depth. It forms one of the most abundant constituents of the Perry conglomerates. It is possible, as already suggested, that certain rhyolitic intrusions in the quadrangle are genetically connected with the granites.

The nearest outcrops of granite are on the shore of St. Croix River just west of Mill Cove, from which place granite outcrops almost continuously northward along the west shore of the river to Devils Head. Farther inland the southernmost outcrops of granite are 1½ to 2 miles north of Boyden Lake and on the hills north of Pennamaquan Lake. In that vicinity the Silurian rocks continue with prevailingly northwest strikes until they are cut off abruptly by the granite.

The granite is intrusive in the Silurian series, a relation shown by a local increase in fineness of the granite toward the contact and by the occurrence of granite dikes in diabase that itself in places intrudes the Silurian rocks. The Silurian sediments near the granite contact show great silicification but contain no large amount of distinctive contact minerals.

Though intrusive in certain masses of diabase the granite is itself cut by a 50-foot dike of fresh diabase at Brooks Cove, on the Robbinston shore. This dike is probably Devonian or Triassic in age.

The granite is generally red and its principal dark-colored constituent is green hornblende. The microscopic appearance of a specimen collected at Robbinston may be taken as typical. Its texture is hypidiomorphic granular, the mineral grains ranging in size from 0.5 to 2 millimeters. The minerals, stated in order of abundance, are (1) quartz; (2) orthoclase, usually perthitically intergrown with albite; (3) green chlorite, secondary after hornblende or biotite; (4) albite in lath-shaped crystals; (5) magnetite. The rock contains micrographic intergrowths of orthoclase and quartz and secondary calcite and sericite.

Specimens of granite from the hills north of Pennamaquan Lake are mostly very light pink in color and here and there contain crystals of feldspar 1 centimeter in diameter. Biotite is the dark-colored constituent. This type of granite grades into finer-grained, much pinker phases.

The commercially important granites of this region have been described by Dale.[a]

Age and correlation.—The granite of Robbinston and vicinity should undoubtedly be correlated with the granite masses of the adjacent parts of New Brunswick, which intrude the Silurian beds with notable contact-metamorphic effects. In both Maine and New Brunswick the Perry beds lie unconformably on the granite, this relation fixing its age as younger than the youngest Silurian beds of the region and older than the Upper Devonian Perry formation. It is reasonable to suppose that, like the bulk of the intrusive diabase of the region, the granite was intruded during the period of great structural deformation in late Silurian or early Devonian time.

[a] Dale, T. N., The granites of Maine: U. S. Geol. Survey Bull. 313, p. 164, 1907.

STRUCTURE.

MAJOR FEATURES.

The great structural units of the Eastport quadrangle comprise a central fault block of Silurian and Devonian rocks and two areas of earlier Silurian sediments and associated intrusive rocks, which bound the central area on the northwest and on the southeast. The master faults that outline the central fault block strike northeast-southwest, as shown on the geologic maps, and may be called the Ayers Junction fault and the Lubec fault zone. The first passes near Ayers Junction, in the northwest corner of the quadrangle. The second passes near Lubec through Split Hill and No. 9 Hill, and along East Stream. The position of each zone of faulting can be only approximately determined. The displacement in the Lubec fault zone was not confined to a single fracture but was distributed along several nearly parallel fractures, so as to produce a sheared zone that is in places several hundred feet wide. Although the movement along the east side of the central fault block may have reached a maximum along the Lubec fault zone as defined above, it was by no means confined to it but was more or less distributed over a belt, from 1 to 2 miles wide, immediately west of the Lubec fault zone. The rocks within this belt are cleaved in many places and are cut by minor faults having northeast trends. Close cleavage simulating schistosity is especially noticeable in shale and diabase near the head of South Bay.

The fact that the rocks of the central fault block are younger than the sediments of the bordering areas indicates that the relative movement of this block has been downward. The manner in which the rocks of this block are folded indicates that the downward movement was conjoined with a horizontal movement along the Lubec fault zone, the central fault block moving northeast with respect to the block lying southeast of it. The extent of the displacement is unknown but was certainly great. Movement probably took place at several periods and in different directions at different times.

The central fault block of Silurian and Devonian rocks has several important structural characteristics. Its Silurian rocks, with the exception of the Dennys formation, have been folded into a broad anticline that pitches gently to the northeast. Their strike shifts from northwest in the northern and central parts of the quadrangle to northeast in the southwestern part. The dip in the northern part of the block, as shown in structure section A–A, is prevailingly eastward at angles of 30° to 40°. Near the southeast border of the fault block, however, the dip is in places vertical and even reversed, as shown in structure section C–C. The anticline in the vicinity of Moose Island is modified by a syncline whose axis trends from Pleasant Point southward toward Nipps Island. As a result the rocks of Moose Island are nearly flat or dip gently northwestward, as is shown in structure section B–B. An important structural feature is the thrust fault separating the Edmunds and Dennys formations throughout most of their extent in the quadrangle. In the region north of Western Pond, and especially that west of Cunningham Mountain and west of Eastman Hill, the beds of the Edmunds formation, if followed along their strike, are found to abut abruptly, without change in character, against the rocks of the Dennys formation. This relation is explicable only upon the assumption of faulting. Between Western Pond and Orange Lake no structural break is apparent from one formation to the other, but the exposures are not sufficiently continuous to demonstrate conformity. In the region north and northwest of Burnt Cove School the fault is an overthrust dipping eastward at an indeterminate but low angle. This fact is shown by such relations as those illustrated

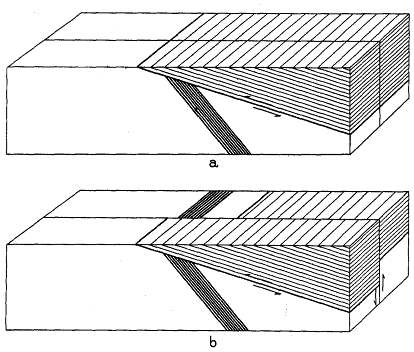


FIGURE 6.—Diagrams explaining structural relations at contact between the Dennys and Edmunds formations near Edmunds village.

In diagram a the Edmunds formation (light ruling) is shown thrust over on the Dennys formation (white). In diagram b the beds have been displaced by a cross fault which has exposed at the surface in the rear block a bed (indicated by the dark band) in the Dennys formation, which has been relatively raised and more extensively eroded.

in figure 6, which shows that in different portions displaced by cross faults erosion has produced unequal eastward recession of the outcrop of the thrust fault. In the densely timbered region farther south, between Crane Mountain and Rocky Lake, the exact geologic relations are very obscure, but a considerable thickness of the Edmunds formation seems to be replaced toward the northwest, in the direction of its strike, by rocks of the Dennys formation. This condition appears to indicate a sharp shift from a south to a southwest direction in the fault between the two formations, so that instead of crossing the Edmunds formation at a small angle the fault crosses it nearly at a right angle. The mechanics of this fault are illustrated by two folded pads of paper shown in figure 7, in which the plane

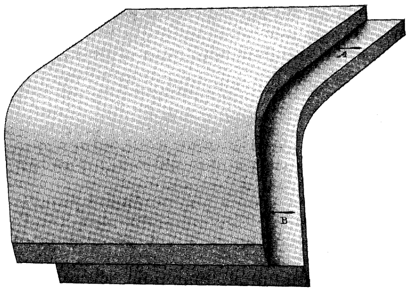


FIGURE 7.—Diagram illustrating the general character of the fault between the Dennys and Edmunds formations.

Drawn from two pads of paper bent as shown and the upper pad moved to the left. The contact between the two pads represents the fault plane and the arrows indicate the direction of fault movement The movement at A simulates a typical flat thrust fault; that at B simulates a steeply dipping fault along which lateral movement has taken place.

between the two pads represents the fault plane. In the foreground of the illustration, where the paper is sharply flexed (at B), the movement between the pads is largely lateral, but in the flatter part of the pads (at A) the movement simulates true thrust faulting.

The rocks of the Perry formation have suffered much less deformation than those of the Silurian formations, from which they are separated by a pronounced erosion unconformity. In nearly all the exposures of the formation the dip is gentle, from 15° to 30°. In some places, however, generally as a result of faulting, the dip is vertical. The type area of the formation between Perry and South Robbinston has been shown by Smith and White to be a syncline, with its axis trending N. 25° W. and with its eastern portion concealed beneath Passamaquoddy Bay. The small area of the formation just northwest of Pigeon Hill and the area on Hersey Neck have been preserved from erosion by downfaulting, and the same is probably true of the South Bay area, though the details of structure there are not so clear. The small area just west of Moose Island is a syncline with very steep dips along its western border and gentle dips along its eastern border. Faulting has not only served to protect some of the Perry rocks from erosion but has elsewhere produced small offsets, which are well shown in the region northeast of Perry. The prevailing trend of the faults is northeast.

MINOR FEATURES.

The most important of the lesser structural features of the quadrangle are the numerous minor faults. That many of these are later than the major folds and faults already described is proved by the fact that they produce offsets in the great thrust fault between the Dennys and Edmunds formations and that some of them fault the beds of the Perry formation. Their prevailing trend is northeasterly, parallel in a general way to the Lubec master fault, and their formation was probably accompanied by renewed movement along that zone. Although it is evident that the minor faults are of more than one age, sufficient evidence was not obtained to permit the assignment of each fault to its proper age. The form of the diabase masses northwest of Whiting suggests that some of the minor faults represent adjustments of the beds at the time of the intrusion of the diabase masses. Most of them, however, appear to be independent of the phenomena of intrusion and to represent adjustment to broad crustal movement. None show the characteristics of thrust faults. An attempt to explain them as a result of nearly horizontal dragging movement encounters difficulty in the fact that not all the blocks southeast of the faults have been shifted in the same direction with respect to the blocks farther northwest. The minor faults, those produced by the intrusion of diabase and possibly some others near the Lubec fault zone, are probably the result of tension. The post-Perry faulting, by which blocks of the Perry were dropped with respect to those on either side and thus protected from erosion, was certainly due to tension.

Schistosity and slaty cleavage are not developed in any of the rocks of the quadrangle, but cleavage—in places wide spaced and in others so close spaced as to simulate slaty cleavage or schistosity—was observed at many localities. In general the cleavage planes are nearly vertical and strike northeast, about parallel to the prevailing directions of the faulting. They are particularly well displayed near the Lubec fault zone. Movement along cleavage planes is shown at several places, notably on the shore in front of West Quoddy Light, where a small diabase dike has been slightly faulted at several places parallel to the slaty cleavage of the inclosing shale. In the shale and rhyolite of the Edmunds formation close-spaced cleavage is conspicuous near Whiting.

In general the absence of true slaty cleavage and schistosity shows that the rocks of the region were deformed at relatively slight depths and thus contrast strongly with those of certain parts of western New England, where Devonian and even Carboniferous rocks have become highly schistose as a result of deformation at great depth and under high pressure.

GEOLOGIC HISTORY.

PRE-SILURIAN TIME.

Schists that are probably at least as old as Ordovician are found farther west in Maine, in the Penobscot Bay quadrangle, and also farther east, in New Brunswick, talc or chlorite schists having been observed near the village of North Head, Grand Manan, but the oldest formation exposed in the Eastport quadrangle is the Quoddy shale, of early Silurian age, the relation of which to the older schists is unknown. Although some such old rocks undoubtedly underlie the rocks exposed in this quadrangle, their history can not be unraveled, and the known geologic history of the quadrangle therefore begins in early Silurian time, the first clearly recognized event being the deposition of the Quoddy shale.

SILURIAN PERIOD.

QUODDY DEPOSITION.

The prevailingly thick and even bedding of the Quoddy shale and its great though unknown thickness indicate that its formation continued through a long time. Its fossils are marine and it was probably deposited along the shore of the sea or in a large estuary. The small masses of interbedded rhyolite, doubtless erupted on the sea bottom, record brief interruptions in an otherwise uneventful period of continuous sedimentation. The quartzitic character of some of the shale and the extreme scarcity of limestone, in addition to the presence of volcanic rocks, indicate deposition near the land, but the formation was evidently not deposited in water so shallow as were some of the later formations, a fact shown by the entire absence of conglomerates, ripple marks, and similar features of deposits laid down in very shallow water.

DENNYS TIME.

The time between the deposition of the Quoddy shale and the eruption of the rocks of the Dennys formation is not recorded in this region, but the fossils of the two formations indicate that the interval, geologically considered, was not long. The dominantly sedimentary rocks of the Quoddy formation present a sharp contrast to the rocks of the Dennys formation, which are almost exclusively volcanic and most of which were apparently erupted upon a land surface. Only here and there, probably in estuaries at the border of the sea, were small masses of marine sediments deposited. Therefore the interval between the deposition of the Quoddy shale and that of the Dennys formation, though perhaps not long, was long enough to convert an area of sea bottom into land. Whether this change was accomplished by uplift or by extensive deposition of volcanic material, or both, and to what extent erosion was in progress, are points not yet determined.

During the deposition of the Dennys formation volcanism was predominant. Rhyolitic and andesitic lavas and smaller amounts of diabase were erupted, in part contemporaneously. They came from many centers whose position can not be determined. The proportion of flows to tuff beds appears to be greater in this formation than in the later formations, and only a little of the tuff shows well-defined bedding. These facts and the almost complete absence of sediments indicate that the rocks of the Dennys formation were largely deposited upon a land surface.

The period marked by the Dennys volcanism was probably closed by subsidence that brought part of the area below sea level, for the small masses of detrital marine sediments in the formation are mainly in its upper part and the rocks of the overlying Edmunds formation include abundant shale and water-laid tuff. In the southern part of the quadrangle no unconformity or other sharp break is recognizable between the Dennys and Edmunds formations, and probably the close of Dennys time was unmarked by other notable changes than the assumed subsidence.

LATER SILURIAN DEPOSITION.

The deposition of the earliest beds of the Edmunds formation marked the beginning of a continuous period of sedimentation and volcanism which continued until the latest Silurian beds of the region had been deposited. During this period slow subsidence of the land was probably in progress, nearly keeping pace with the deposition of sediments and volcanic rocks, so that the area occupied by the sediments remained a shallow part of the sea, possibly bordered by a few areas of low land. That the water in which the beds were deposited was more or less quiet and protected is shown by the general absence of conglomerate and of other evidences of extensive erosive action by waves or currents. During Edmunds time the volcanism was characterized by eruptions of diabase and of several varieties of rhyolite and andesite. The andesitic eruptions ceased near the end of Edmunds time, but rhyolitic and diabasic eruptions persisted until the close of the Silurian period. The location of the vents from which the flows and tuffs were ejected is not clearly known, but some of them were probably within the Eastport quadrangle, for the flows are abundant and thick and some of the tuffs are coarse. Certain masses of andesite and rhyolite that are mapped as part of the Dennys formation but are possibly intrusive may be the eroded necks of some of the volcanoes.

Toward the end of Pembroke time the sea in parts of the region evidently became shallow, either as a result of deposition or of slight uplift. In such shallow waters, probably in bays or estuaries, the sparsely fossiliferous red shale of the Hersey member was deposited. A few miles southeast of the area covered by these shales the deposition of sediments containing a profuse fauna continued in deeper water until late in Eastport time, when the shallow-water, sparsely fossiliferous beds of the upper part of the Eastport formation were laid down. The deposition of these beds and the eruption of the accompanying volcanic rocks forms the closing chapter in the history of the region during Silurian time, a period characterized for the most part by continual and varied volcanic activity along a protected seacoast.

DEVONIAN PERIOD.

POST-SILURIAN DEFORMATION.

Before sedimentation was again resumed in the Eastport region, in late Devonian time, the structure and geography of the region had been greatly changed. In late Silurian or early Devonian time the region was uplifted and its rocks tilted, folded, and faulted into nearly the positions which they now occupy. After these movements, or possibly while they were still in progress, the rocks throughout the quadrangle were intruded by great masses of diabase and those in the area just north of the quadrangle were intruded by great masses of granite. Much of the minor folding and faulting in the area accompanied the intrusion of the larger bodies of these igneous rocks, but the major deformations, such as the Lubec and Ayers Junction faults and the notable shift in the strike of the later Silurian beds from northwest to southwest near the Lubec fault plane, are the expression of much larger mountain-building movements.

As a result of these forces the region was lifted above sea level and immediately became subject to land erosion. The extent of this erosion is unknown, but it was sufficient to expose large masses of coarse-grained granite, which probably solidified at a depth of several thousand feet.

PERRY DEPOSITION.

Late in the Devonian period warping or general subsidence of the land again brought about sedimentation but of a type entirely different from that characteristic of the Silurian. The Devonian sediments comprised in the Perry formation are in the main shore deposits, whose character indicates that they were in some places open to the full sweep of the waves of the sea. With the conglomerate are intermingled sandstone and shale, whose physical character and scanty plant remains indicate an estuarine origin. In fact, the considerable difference in the character of the Perry formation at different places in the quadrangle indicates that the Devonian shore was irregular and that some parts of it were as sheltered and other parts as exposed as the present shore in the southeastern part of the quadrangle. The Upper Devonian was a period not only of sedimentation but also of volcanism, which is recorded by flows of diabase that are interstratified with the conglomerate and sandstone. If later sediments were deposited upon the Perry formation in this region, as they were in parts of New Brunswick, erosion has removed all trace of them, the Perry formation being the latest consolidated formation in the Eastport quadrangle.

POST-DEVONIAN DEFORMATION.

Since the deposition of the Perry formation tectonic movements that were less pronounced than those which occurred at the close of the Silurian have tilted and folded the Perry and older formations and have displaced their beds by numerous northeast-southwest trending faults. At the same time movement was probably renewed along the Lubec and Ayers Junction faults. This movement was accompanied or followed by further uplift of the land, by which the Perry formation was exposed to erosion that removed it entirely from many parts of the region, leaving it only where it had been downfaulted or had been folded into synclines.

LATER HISTORY.

The history of the region in later Paleozoic time and through Mesozoic and most of Cenozoic time can not be interpreted by any geologic record that is preserved in the Eastport quadrangle. Only a short distance to the east, however, in New Brunswick, sediments of Mississippian and Pennsylvanian age occur, and rocks of these ages possibly may once have covered the Eastport quadrangle.

Throughout most of their extent in New Brunswick the Mississippian rocks lie unconformably on the Perry formation. They comprise basal conglomerates, marine limestones, gypsum, and reddish calcareous shales and sandstones—deposits indicating extremely varied conditions of deposition. Evidence of volcanic activity during Mississippian time is afforded by thick beds of tuff and volcanic breccia that are intercalated in the sediments. The deposition of these beds was followed without serious disturbance by more uniform sedimentation in Pennsylvanian time. Thin but extensive beds of coal were deposited. Volcanism, though less active than in Mississippian time, persisted and left its record in beds of tuff. Earth movements subsequent to the deposition of the Mississippian and Pennsylvanian beds have in places folded them gently, but they are much less disturbed than the Devonian or older beds upon which they rest.

The history of Permian time is very imperfectly known. Sediments of that age have been recognized in New Brunswick, but their character has been little studied.

The events of Triassic time are recorded in the deposition of red sandstones and conglomerates at several points along the Bay of Fundy but particularly in Nova Scotia. Igneous activity on a large scale resulted in the formation of dikes and sills of diabase, of which the cliffs of Grand Manan afford a striking example. A few of the diabase dikes of the Eastport quadrangle, such as those that cut the Perry formation, may have been formed during this period.

Of the geologic events through most of Mesozoic and Cenozoic time the rocks of this region furnish no adequate record. The physiographic features of neighboring areas, described in the section on the general features of the province, indicate, however, that the region was probably a land area during much of this time and was repeatedly subjected to partial planation by stream erosion. The record does not become clear again until Pleistocene time.

QUATERNARY PERIOD.

PLEISTOCENE EPOCH.

WISCONSIN STAGE.

Glaciation.—During at least a part of the Pleistocene epoch, the last or Wisconsin stage, the Eastport region, in common with all New England and eastern Canada, was covered by a continental glacier, which spread from a center east of Hudson Bay and left its record not only in deposits of till and gravel but in glacial striæ and polished surfaces. The glacial striæ show that the general direction of movement was southeastward but that the valleys oblique to that direction deflected the ice somewhat, at least in the basal portion of the glacier. That the influence of the topography upon the movement of the ice was so slight in a region containing so many long, narrow valleys is explained by the general shallowness of the valleys and the strength of the ice movement. This strength is demonstrated by the abundance of glaciated rock surfaces and the general thinness of the deposits of till. The larger topographic features, as has already been shown, are closely related to the structure of the bedrock, and the fact that these features had relatively slight influence on the direction of ice movement indicates that, far from being accentuated, they were probably somewhat subdued by the glaciation. Erosion and not deposition was dominant while the ice occupied the region. No conclusive evidence of more than one period of glaciation was obtained. Two divergent sets of glacial striæ were observed at two localities, but in the absence of other evidence of more than one period of glaciation they may be accounted for by supposing a slight shift in the direction of ice movement during the minor retreats and advances of the ice within a single glacial period.

Glaciation had a notable effect in blocking with drift the preglacial drainage ways, in creating numerous bogs and some lakes, and in diverting many streams from their former channels or reversing the direction of their flow.

POST-GLACIAL SUBMERGENCE.

At the time of the retreat of the ice the Eastport region was at least 100 feet lower with reference to sea level than at present, as is demonstrated by numerous marine deposits and eroded surfaces between the present sea level and that elevation.

The numerous small deposits of glacio-marine gravel, sand, and clay laid down during the retreat of the ice have had much greater influence on the topography than the purely glacial deposits. The gravel, except that in a few places, was probably deposited while the ice border stood in its immediate vicinity, but the deposition of marine clay continued as the land gradually rose to its present height. Marine erosion, of course, continued during all this period of uplift, but its records, though of unusual interest, are faint and obscure as compared with the records of marine erosion and deposition along the present shore line, the contrast indicating that the period of uplift was short. The evidence of the submergence of the coast in this region after the retreat of the ice is in harmony with evidence found farther south, about Penobscot Bay[a] and Rockland.[b] In the Penobscot Bay region G. H. Stone[c] found water-worn pebbles as high as 225 feet above sea level, and on the island of Mount Desert C. W. Brown and W. C. Alden[d] have found clays bearing marine fossils at elevations as high as 100 feet, as well as gravel beds with delta structure fronting the open ocean and a probable sea cave at an altitude of 200 feet. Similar phenomena have been observed in neighboring portions of Canada, at Arisaig, Nova Scotia, where Twenhofel[e] found three raised beaches at altitudes of approximately 25, 75, and 125 feet above sea level, the lowest two still preserving steep cliffs.

In the Eastport region a submergence as great as 200 feet probably occurred, though it has not been clearly demonstrated. Evidence of submergence to depths of at least 100 feet is even clearer than that found farther south on the coast.

The explanation of this notable submergence and the subsequent uplift of course belongs to the realm of speculation. The fact that the uplift was in progress while the ice was retreating and that it took place so rapidly that shore features were only imperfectly developed, taken in conjunction with the extensive warping in the region of the Great Lakes at the close of the Pleistocene epoch, suggests a genetic connection between the glaciation and the coastal movement. Possibly the submergence was a result of the weighting of the land by the advancing ice sheet and the subsequent uplift a readjustment due to the decrease in load as the ice melted away. Evidence has been found that other parts of the coast of Maine are now subsiding, but evidence of such movement has not been found in the Eastport region.

RECENT EPOCH.

The processes now in operation on the land in this region are stream and marine erosion and deposition, whose general tendency is to reduce the irregularity of the land surface and the coast line by eroding the more prominent and exposed parts and depositing the waste in the more sheltered valleys and inlets. The interval since glacial time, however, has been short, geologically speaking, so the topography is very irregular, though it exhibits no great relief, and the irregular shore line is typical of a "drowned" coast.

ECONOMIC GEOLOGY.

Mineral resources of economic interest include road materials, peat, scattered deposits of metalliferous minerals, clay, and water.

ROAD MATERIAL.

Road material[f] of excellent quality is abundant in the Eastport quadrangle, though in many places poor material has been used where the best was equally available. The most widely distributed and most cheaply utilized road material is gravel. The locations of the larger deposits of gravel and of the pits from which it has been excavated are shown on the surficial-geology sheet.

Among the hard rocks the most serviceable for road construction is the trap or diabase, whether extrusive or intrusive. Such rock is abundant in the quadrangle and its distribution is shown on the areal-geology map. Trap has been quarried for use on the streets of Eastport from the hill a short distance northwest of the railroad station. Such localities as Estes Head and Shackford Head are particularly favorable for cheap quarrying and for shipment by water to other cities along the coast. At both these points the quantity available is practically limitless and the material, if quarried at the water side, could be loaded directly into vessels. The harbor protection at these points is excellent and the water deepens abruptly, so that vessels may approach close to the beach even at low tide. These two localities are among the most favorable in the whole State for cheaply quarrying and loading on vessels the best quality of road-building rock. Physical tests of trap from Estes Head, made by the United States Department of Agriculture, show that the rock is hard and tough and has good cementing qualities. It should make excellent road material, even for heavy traffic. From Lubec southwestward toward Cutler the trap is generally associated with quartzose shale. This shale is very massive and tests show that it would be good road material, especially if mixed with some trap.

The more massive rhyolites have been utilized on the roads at several localities. They do not pack down or cement as well as the trap and their use can not be recommended in view of the abundance of the superior material.

[a] U. S. Geol. Survey Geol. Atlas, Penobscot Bay folio (No. 149), 1907.
[b] Idem, Rockland folio (No. 158), 1908.
[c] U. S. Geol. Survey Mon. 34, p. 48, 1899.
[d] Personal communication.
[e] Twenhofel, W. H., Am. Jour. Sci., 4th ser., vol. 28, p. 147, 1909.
[f] Leighton, Henry, and Bastin, E. S., Road materials of southern and eastern Maine: U. S. Dept. Agr. Office Pub. Roads Bull. 33, 1908. This report contains more detailed descriptions than are given in this folio.

Shale has been used on some roads near Pembroke and Perry because it could be excavated easily. It wears poorly, soon grinding down to a sticky mud, and its use should be avoided.

PEAT.

Deposits of peat of excellent quality for fuel and other uses to which this material has been applied are abundant in the quadrangle. The location and size of these deposits are shown on the surficial-geology map and the more important ones are briefly described below. Fuller descriptions, accompanied by detailed records of test borings, analyses, and a description of the origin and uses of peat have been published in a bulletin of the United States Geological Survey.[a]

Lubec.—A peat bog occupies nearly all the neck of land, three-quarters of a mile southeast of South Lubec, connecting West Quoddy Head with the mainland. This bog covers 20 to 25 acres. On the assumption that its average depth is 5 feet it should yield at least 26,000 short tons of air-dried machine peat. The facilities for water shipment are poor, the coast to the south being unprotected and the bay to the north being very shoal for a long distance from the shore. The deposit would therefore be available chiefly for local use.

Pembroke.—A large bog of peat of excellent quality lies about $1\frac{1}{2}$ miles southwest of Ayers Junction. This bog covers about 160 acres, and its average depth is probably about 15 feet. The bog will therefore yield at least 500,000 short tons of machine peat. The peat is firmer and more coherent than that found in most other deposits and contains less water.

Another bog lies half a mile east of Ayers Junction, along the Eastport branch of the Maine Central Railroad. The peat of this bog, like that of the bog southwest of the junction, is much drier than that of most of the other bogs tested. This bog covers at least 50 acres, but the average depth of the peat will probably not exceed 5 feet, and some of it is slightly clayey. The bog should yield at least 60,000 tons of air-dried machine peat.

A peat bog lies about a mile northwest of Falls Point, due east of Wilbur Neck. Its total area is about 35 acres. On the assumption of an average depth of 10 feet it should yield at least 78,000 short tons of air-dried machine peat. Although the bog is only a quarter of a mile from salt water, shipment of the peat, except in small vessels, would be difficult, because of numerous shoals and rapid tidal currents. The bog would, however, furnish a large supply of excellent peat for local use.

Perry.—A small bog lies 3 miles south of Perry and half a mile east of Leach Point. Tests show that the quantity of peat in the bog is not large, though probably sufficient for local use as fertilizer or fuel.

Trescott.—A peat bog lies about a mile south of South Trescott, near Haycock Harbor. Its area is probably at least 160 acres. If its average depth is 8 feet (a moderate estimate), the bog should yield at least 280,000 short tons of air-dried machine peat. Its location is unusually favorable for cheap handling of the material, which could be carried by gravity from a factory located on the border of the bog to the shore of Haycock Harbor, and thence shipped in small vessels, for which the harbor affords good protection.

Whiting.—An open bog a mile northeast of Yellowbirch Mountain may contain considerable peat but was not tested.

METALLIFEROUS DEPOSITS.

Metalliferous deposits occur at several localities and have been the object of considerable investments of capital with very little return. The first of these deposits to be discovered (in 1828) is on the west shore of South Bay and is known as the Lubec lead mine. The deposit consists of several small veins carrying galena, zinc blende, and chalcopyrite in a gangue of quartz and calcite, intersecting trap. The property was worked intermittently through several short periods, and the mill is still standing. The veins carry only small amounts of the precious metals and are too small to be worked profitably for the baser metals.

A vein on Denbow Point was observed by Jackson in 1836[b] and described as follows: "The vein is 14 inches wide, and the lead ore is 9 inches in thickness; the remainder of the vein consists of black blende, or sulphuret of zinc, and calcareous spar." The vein trends north-northeast. In 1862 an attempt was made to develop this vein, but work was soon abandoned and the shaft is now filled with slide rock. The shaft is in diabase tuff and the rock on the dump shows ore stringers composed of quartz, zinc blende, galena, and pyrite.

Near the road from West Pembroke to Ayers Junction, on the Sinclair farm, about 2 miles from West Pembroke, several prospects in diabase flows were opened a few years ago but are now idle. Some test drilling for ore has also been done at this locality. The ore occurs as veinlets filling fractures, as disseminations, and as amygdaloidal fillings. The ore minerals are galena, zinc blende, and chalcopyrite. Calcite, dolomite, and quartz are the gangue minerals.

[a] Bastin, E. S., and Davis, C. A., Peat deposits of Maine: U. S. Geol. Survey Bull. 376, 1909.
[b] Jackson, C. T., First report on the geology of the State of Maine, p. 25, 1837.

Both the Lubec and the Pembroke deposits occur in regions of extensive fracturing. The origin of the ore-bearing solutions is not certainly known. The deposits are described in greater detail by W. H. Emmons,[a] in an earlier report of the United States Geological Survey.

A vein of white quartz, 1 to 3 feet thick, occurs in East Bay, on the point north of Rodgers Point. It is banded parallel to the walls and includes numerous horses and small angular fragments of wall rock but no metallic minerals.

An iron furnace and foundry which was operated at Pembroke in the "thirties" derived its ore supply from Nova Scotia. A few small iron-bearing veins were observed within the quadrangle. On the southwest shore of Seward Neck several nearly vertical veins traverse the rhyolitic flows, occupying sharp fracture planes and breccias in the rhyolite. They consist of quartz and specular hematite. The walls and breccia fragments are sharp and there is no mineralization of the rhyolite at the border of the vein. According to an analysis made by C. T. Jackson in 1836 the specularite contains 89 per cent of Fe_2O_3 and 11 per cent of TiO_2.

A small abandoned prospect pit lies near the Lubec road, about 2 miles northeast of West Lubec. It shows lenses of white quartz in sheared trap. The quartz is mostly barren but in places carries a little chalcopyrite.

CLAY.

Marine clay is widely distributed over the lowlands of the quadrangle, as shown on the surficial-geology map. At many places the deposits are thick and are of a quality suited to the manufacture of common brick. They are not now utilized in the quadrangle, but until 1900 a brickyard was worked about a mile southeast of West Pembroke on the road to Leighton Point. The plant is said to have produced 500,000 to 800,000 brick a year. The clay here is buff-gray and burns to terra-cotta color. It is very plastic and nearly free from pebbles.

SUPPOSED COAL DEPOSITS.

Some prospecting has been done for coal in the quadrangle, especially in the Perry formation, and some residents still hold firmly to a belief in its existence. It can be stated with certainty, however, that not only has no trace of coal ever been found in the quadrangle but that all the rocks are older than those in which coal occurs elsewhere. The reputed coal was the subject of a special investigation of part of the district by the United States Geological Survey in 1903.[b] Small patches of supposed coal on the west shore of Broad Cove are merely black shale, which has been polished somewhat along slip planes.

WATER POWER.

In the heavily forested parts of the quadrangle west of Cobscook River many small streams have been dammed in the spring for the purpose of floating down logs and others have been dammed near their mouth to furnish power for sawmills. Tide power was used many years ago for running a plaster mill at what is known as the canal, about a mile south of the village of North Lubec. Tide power is not now utilized in the quadrangle, although there are many narrows through which the tidewater flows with considerable force, both on the ebb and flood. Jackson in his first geologic report (1837) called attention to possible tide power at Haycock Harbor. Another promising locality is at the iron bridge, a little over 3 miles north of Whiting, where an estuary discharges through a passage only about 40 feet wide between rock walls 10 to 12 feet high.

WATER.

The water supplies in the country districts and smaller towns of the quadrangle are derived from springs and shallow dug wells and in general are abundant, soft, low in mineral content, and otherwise excellent in quality. Some wells very near tidewater, however, yield brackish water that is unsuitable for use. Eastport is supplied from Boyden Stream, the outlet of Boyden Lake. The reservoir, built in 1901, and the pumping station are in Perry and the water is pumped to a 60-foot standpipe on Battery Hill, in Eastport. The supply of Lubec is obtained from springs about $1\frac{1}{4}$ miles east of West Lubec whence the water is pumped to a standpipe at the south end of Lubec Neck. The water contains about 100 parts per million of mineral matter and is moderately soft.

Several springs are noteworthy. One near the west shore of Johnson Bay, mentioned by Jackson in his first report on the geology of Maine, yields a steady flow of pure cold water. A salt spring on the farm of Daniel McKinley, at Timber Cove, Cobscook River, about 4 feet above high tide on the edge of a salt marsh, flows all the year. Lubec Saline Spring, at the head of Johnson Bay, yields very salty water.

November, 1913.

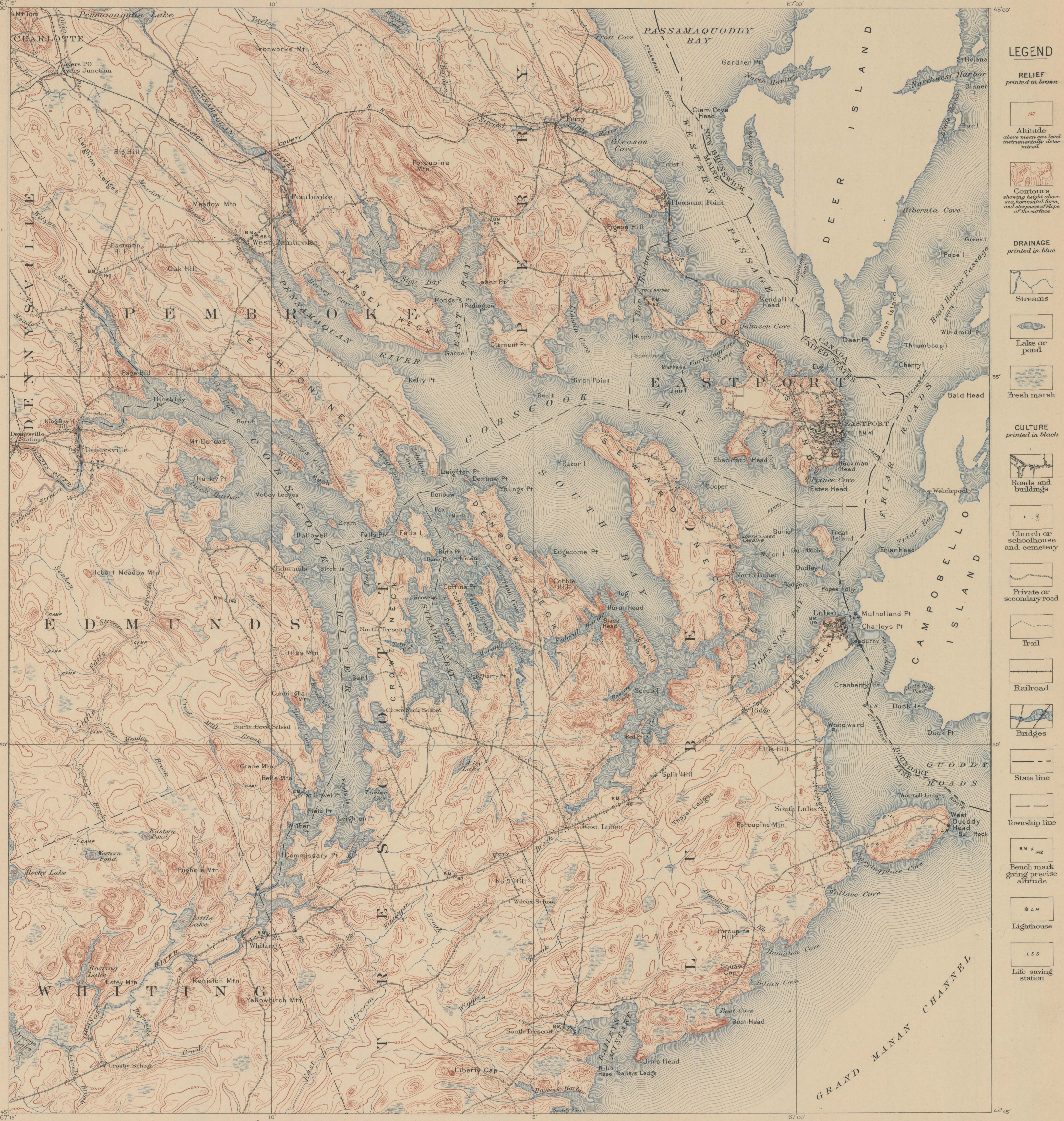
[a] Some ore deposits of Maine: U. S. Geol. Survey Bull. 432, p. 46, 1910.
[b] Smith, G. O., and White, David, The geology of the Perry Basin in southeastern Maine: U. S. Geol. Survey Prof. Paper 35, 1905.

TOPOGRAPHY

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR

STATE OF MAINE
F. C. ROBINSON, C. S. HICHBORN, NATHANIEL M. JONES
COMMISSIONERS

MAINE
(WASHINGTON COUNTY)
EASTPORT QUADRANGLE



Frank Sutton, Geographer in charge.
Topography by Hersey Munroe.
Control and shoreline by Coast and Geodetic Survey.
Surveyed in 1907.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1907.

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 Dec. 1908, reprinted Feb. 1913.

AREAL GEOLOGY

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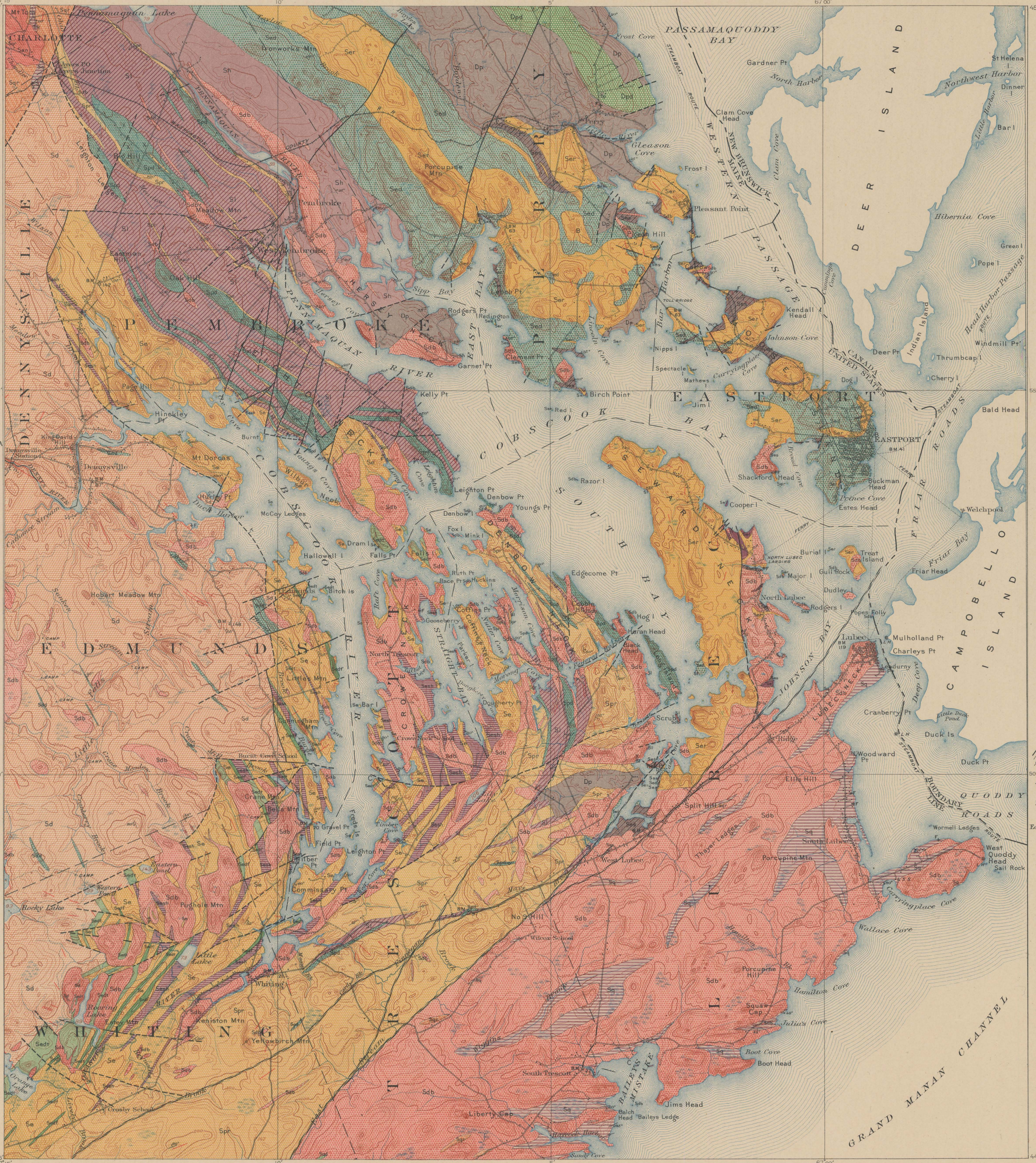
EASTPORT QUADRANGLE



LEGEND

SEDIMENTARY AND EFFUSIVE IGNEOUS ROCKS

Dpd / Dp — Perry formation (conglomerate, sandstone, and some shale, Dp, with interbedded diabase flows, Dpd) — DEVONIAN

UNCONFORMITY

Ses / Ser / Sed / Sel — Eastport formation (diabase flows and tuffs, Sed, rhyolite flows and tuffs, Ser, and subordinate amounts of shale, Ses, and limestone, Sel) — SILURIAN

Sh / Spr / Sl / Spd — Pembroke formation (rhyolite tuffs and flows, Spr, diabase tuffs and flows, Spd, Hersey red shale member, Sh, and Leighton gray shale member, Sl)

Sesh / Se / Sedt / Sedf — Edmunds formation (rhyolite and andesite tuffs and flows, Se, diabase tuffs, Sedt, diabase flows, Sedf, and shales, Sesh)

UNCONFORMITY ?

Sd / Sdd — Dennys formation (rhyolite and andesite flows and tuffs and thin shale lenses, Sd, with some diabase flows and tuffs, Sdd)

SEQUENCE BROKEN

Sqr / Sq / Sqd — Quoddy shale (shales and slates, Sq, some rhyolite flows and tuffs, Sqr, and diabase flows and tuffs, Sqd)

INTRUSIVE IGNEOUS ROCKS

Sdb — Diabase (massive, fine to coarse) — SILURIAN AND LATER

San — Andesite — PROBABLY SILURIAN

Faults

Probable faults

Shear zones

Overthrust side of thrust faults
Strike and dip of stratified rocks
Strike of vertical strata

+F Fossil localities shown only in regions where fossils are scarce
X Prospects (copper or lead)

Economic data: Diabase of various formations is generally suitable for road making; limestone in Eastport formation near North Lubec has been burned for lime; copper and lead have been mined near Big Hill and South Bay.

Frank Sutton, Geographer in charge.
Topography by Hersey Munroe.
Control and shoreline by Coast and Geodetic Survey.
Surveyed in 1907.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

TRUE NORTH
MAGNETIC NORTH
19°
APPROXIMATE MEAN DECLINATION 1907.

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 April 1913.

Geology by Edson S. Bastin,
assisted by C.L. Breger.
Surveyed in 1907, 1908, and 1910.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

U.S. GEOLOGICAL SURVEY
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SURFICIAL GEOLOGY

STATE OF MAINE
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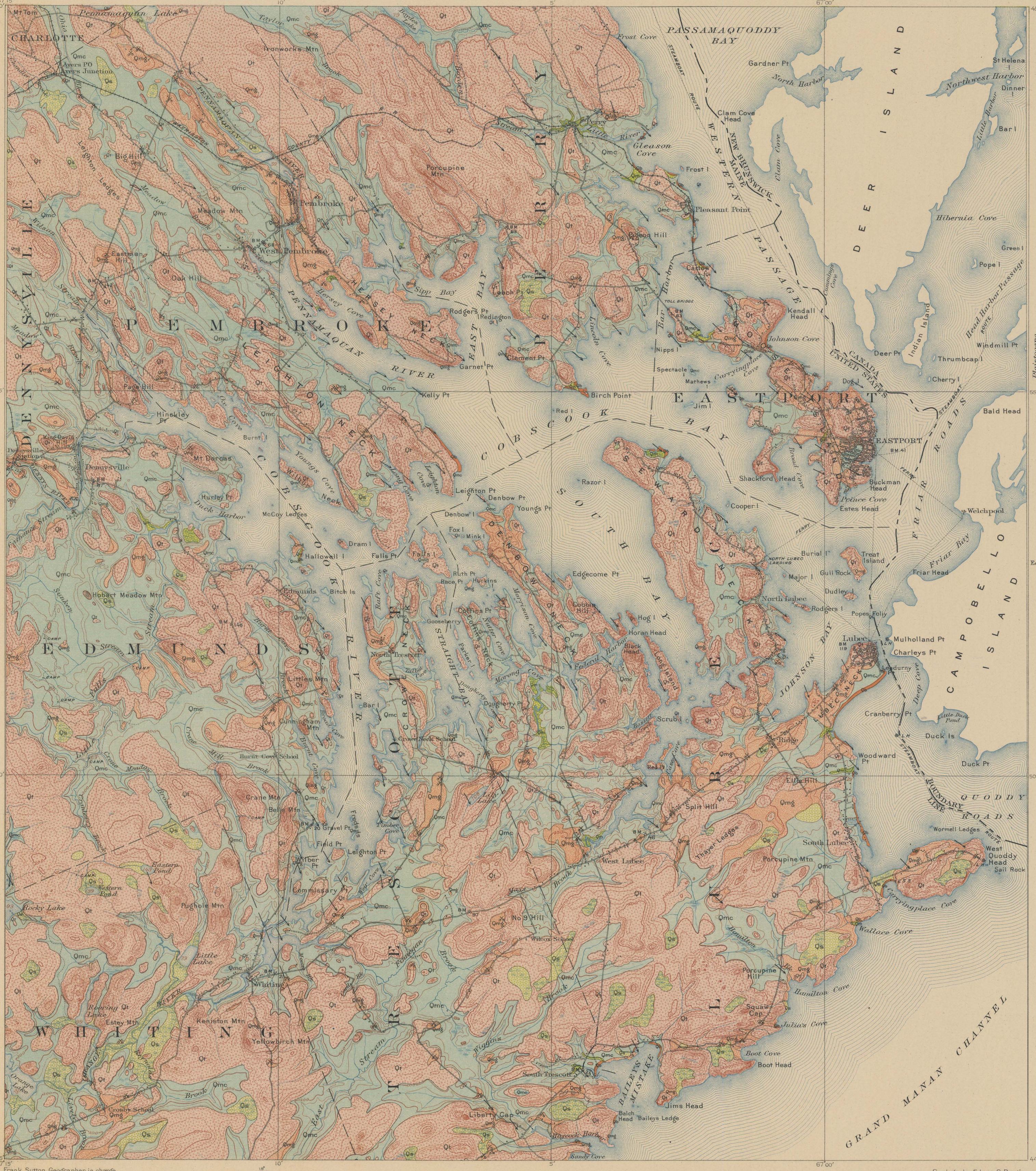
COMMISSIONERS

MAINE
(WASHINGTON COUNTY)
EASTPORT QUADRANGLE



LEGEND

SEDIMENTARY ROCKS
(Areas of subaerial deposits are shown by patterns of dots and circles; subaqueous deposits by patterns of parallel lines)

QUATERNARY

Recent

Qs — Swamp muck and peat

Qm — Salt marsh deposits *(clay enclosing vegetable material)*

Qb — Marine beach sand and gravel

Pleistocene *(Wisconsin stage)*

Qmc — Marine clay *(fine gray to bluish clay with some red bands, sandy in places)*

Qmg — Marine-glacial sand and gravel *(glacial outwash deposited in ocean waters, or otherwise modified by marine agencies)*

Qt — Glacial till and bare rock *(gray bowlder clay locally sandy and generally thin, with numerous outcrops of bedrock)*

Glacial striæ

Sand and gravel pits

Note: *Rock exposures, too small to be mapped, are numerous along the coast and less common in the interior.*

Economic data: *Marine clay is locally suitable for manufacture of common brick; marine-glacial gravel is extensively used in road making; peat, where sufficiently thick and pure, makes excellent fuel.*

Frank Sutton, Geographer in charge.
Topography by Hersey Munroe.
Control and shoreline by Coast and Geodetic Survey.
Surveyed in 1907.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

APPROXIMATE MEAN DECLINATION 1907.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of April, 1913.

Geology by Edson S. Bastin,
assisted by C.L. Breger.
Surveyed in 1907, 1908, and 1910.

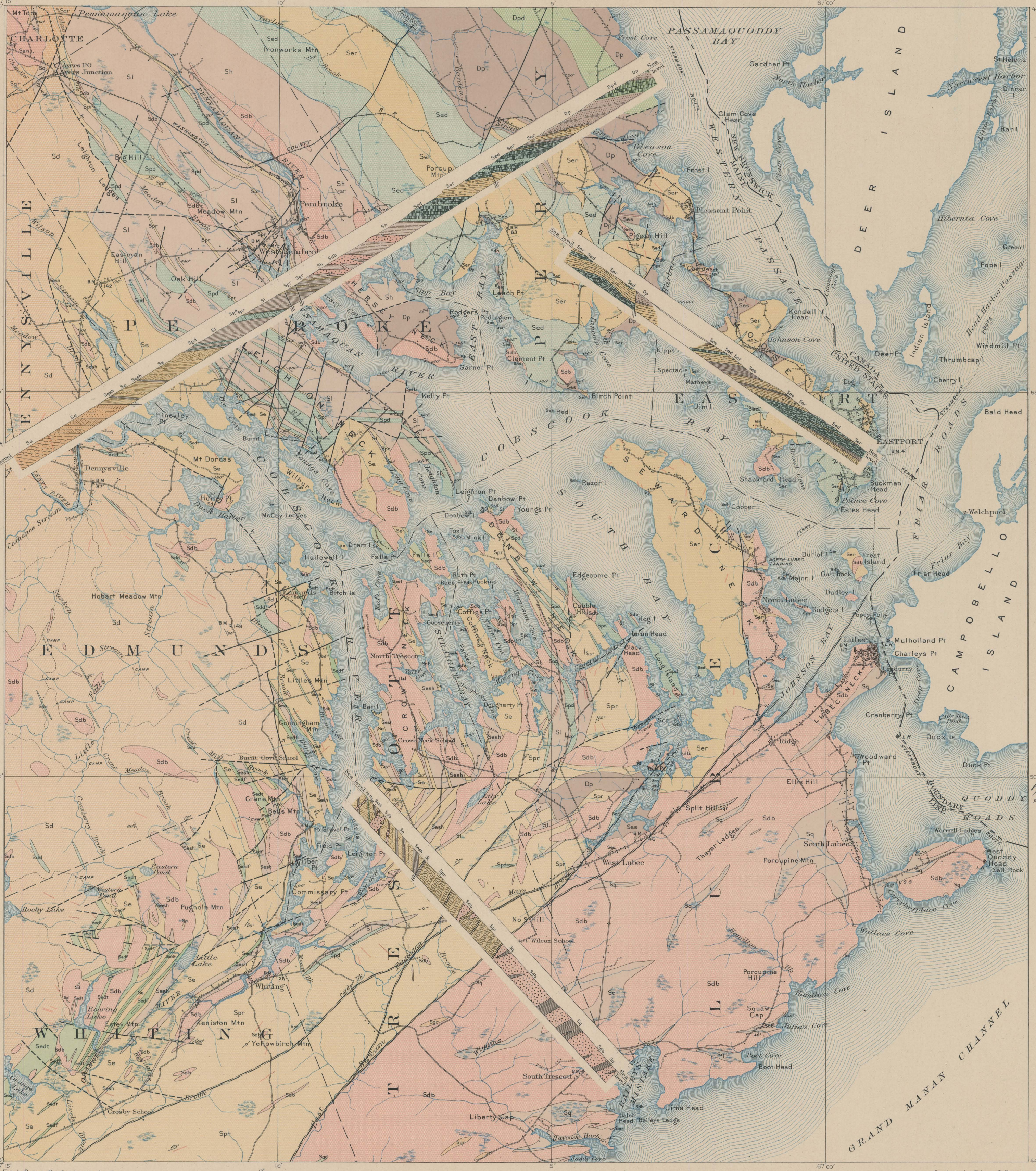
SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

STRUCTURE SECTIONS

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH
DIRECTOR

STATE OF MAINE
F. C. ROBINSON, NATHANIEL M. JONES, C. S. HICHBORN
COMMISSIONERS

MAINE
(WASHINGTON COUNTY)
EASTPORT QUADRANGLE



LEGEND

SEDIMENTARY AND EFFUSIVE IGNEOUS ROCKS

SHEET SYMBOL | SECTION SYMBOL

DEVONIAN

Dpd, Dp — **Perry formation** (conglomerate, sandstone, and some shale, Dp, with interbedded diabase flows, Dpd)

UNCONFORMITY

SILURIAN

Ses, Ser, Sed, Sel — **Eastport formation** (diabase flows and tuffs, Sed, rhyolite flows and tuffs, Ser, and subordinate amounts of shale, Ses, and limestone, Sel)

Sh, Spr, Sl, Spd — **Pembroke formation** (rhyolite tuffs and flows, Spr, diabase tuffs and flows, Spd, Hersey red shale member, Sh, and Leighton gray shale member, Sl)

Sesh, Se, Sedt, Sedf — **Edmunds formation** (rhyolite and andesite tuffs and flows, Se, diabase tuffs, Sedt, diabase flows, Sedf, and shales, Sesh)

UNCONFORMITY?

Sd, Sdd — **Dennys formation** (rhyolite and andesite flows and tuffs and thin shale lenses, Sd, with some diabase flows and tuffs, Sdd)

SEQUENCE BROKEN

Sqr, Sq, Sqd — **Quoddy shale** (shales and slates, Sq, some rhyolite flows and tuffs, Sqr, and diabase flows and tuffs, Sqd)

INTRUSIVE IGNEOUS ROCKS

SILURIAN AND LATER

Sdb — **Diabase** (massive, fine to coarse)

PROBABLY SILURIAN

San — **Andesite**

Faults

Probable faults

Shear zones

Overthrust side of thrust faults
Strike and dip of stratified rocks
Strike of vertical strata

Frank Sutton, Geographer in charge.
Topography by Hersey Munroe.
Control and shoreline by Coast and Geodetic Survey.
Surveyed in 1907.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

TRUE NORTH
MAGNETIC NORTH
19°
APPROXIMATE MEAN DECLINATION 1907.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of April 1913.

Geology by Edson S. Bastin, assisted by C. L. Breger.
Surveyed in 1907, 1908, and 1910.

SURVEYED IN COOPERATION WITH THE STATE OF MAINE.

ILLUSTRATIONS I

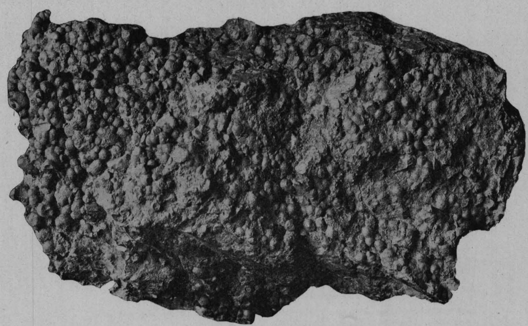


PLATE I.—SPHERULITIC STRUCTURE IN GRAY FLOW RHYOLITE OF PEMBROKE FORMATION.
Northeast shore of Denbow Neck. Natural size.

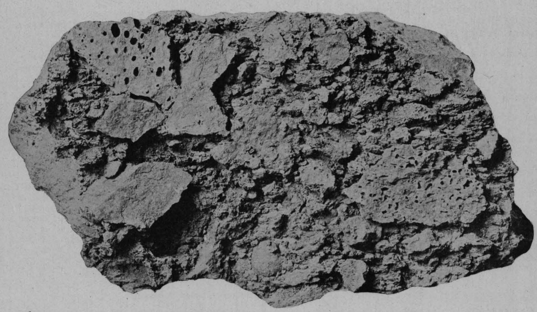


PLATE II.—WEATHERED SURFACE OF DIABASE TUFF OF PEMBROKE FORMATION.
Shore of Federal Harbor. Natural size.

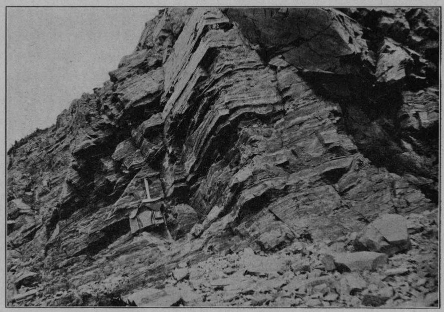


PLATE III.—TYPICAL SHALES OF THE UPPER PART OF THE EASTPORT FORMATION CUT AT THE RIGHT BY A DIKE OF RED RHYOLITE.
Northwest end of Carlow Island.

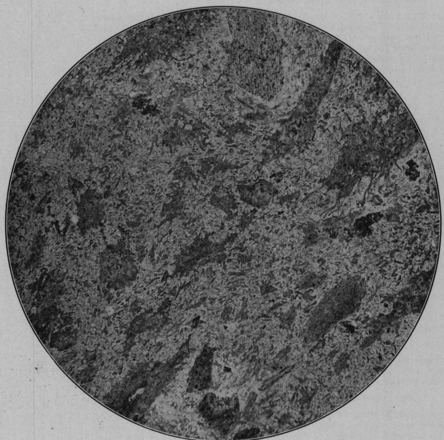


PLATE IV.—MICROPHOTOGRAPH OF DARK-RED RHYOLITE OF EASTPORT FORMATION, SHOWING FLOW-BRECCIA STRUCTURE.
Magnified 30 diameters. East shore of South Bay opposite Long Island.

PLATE V.—MICROPHOTOGRAPH OF NEARLY BLACK RHYOLITE IN EASTPORT FORMATION, SHOWING FLOW-BRECCIA STRUCTURE.
Magnified 30 diameters. East shore of South Bay opposite Long Island.

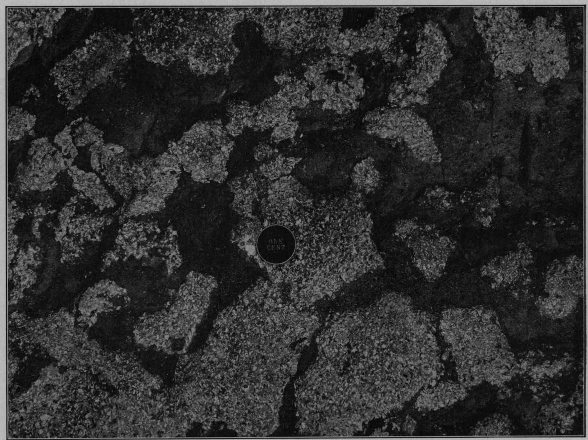


PLATE VI.—FLOW-BRECCIA STRUCTURE IN ANDESITE OF THE EDMUNDS FORMATION.
Near the point where Pembroke-Dennysville road crosses Wilson Stream. Fragments of highly porphyritic andesite are inclosed in a dark-red aphanitic matrix.

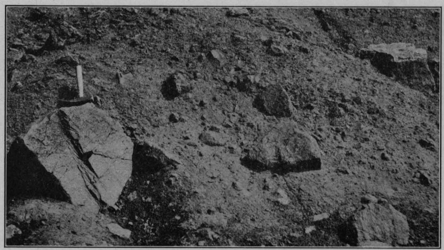


PLATE VII.—COARSE VOLCANIC TUFF OF GRAY RHYOLITE OF EASTPORT FORMATION.
Shore of Moose Island, due south of Carlow Island.

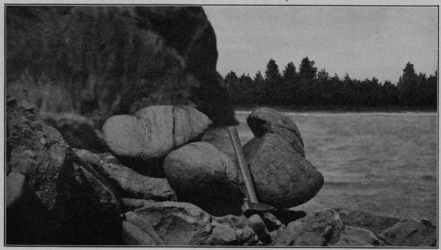


PLATE VIII.—GRANITE BOWLDERS FROM PERRY CONGLOMERATE SLICED DURING THE FOLDING AND MINOR FAULTING OF THE FORMATION AND THE FRAGMENTS RECEMENTED.
Shore northwest of Pigeon Hill, Perry.

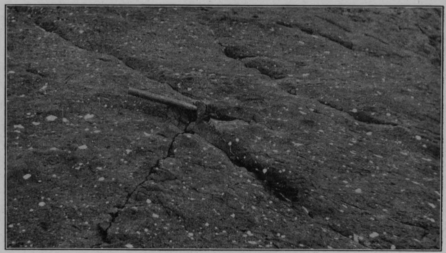


PLATE IX.—SURFACE OF LOWER DIABASE FLOW OF PERRY FORMATION.
On shore 1 mile north of Perry. Shows abundance of calcite amygdules.

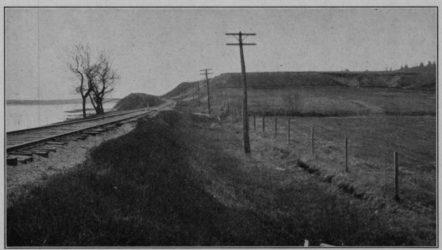


PLATE X.—VIEW LOOKING EAST FROM THE NECK BETWEEN JOHNSON AND CARRYINGPLACE COVES.
Showing the topographic position of the gravel pit shown in Plate XI. The situation and structure of these gravels show that they were deposited in the ocean when the land stood at least 100 feet lower than at present. The flats in the right foreground are marine clay.

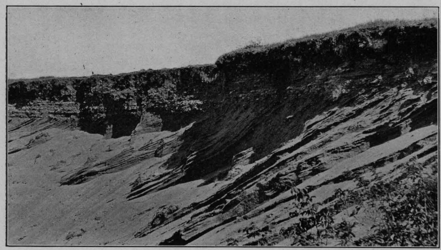


PLATE XI.—GRAVEL PIT AT McCOY FARM, NEAR CARRYINGPLACE COVE, MOOSE ISLAND, LOOKING EAST.
The gravels are about 30 feet thick and overlie marine clays. They show inclined structure typical of deposition in standing water. The inclined beds dip 30°–35° N.

PLATE XII.—HILL NORTHWEST OF JOHNSON COVE.
View looking east, showing the cliff-like profile of the south end of the hill, due possibly to marine erosion. The cliff is fronted on the south by gravels with "foreset" beds.

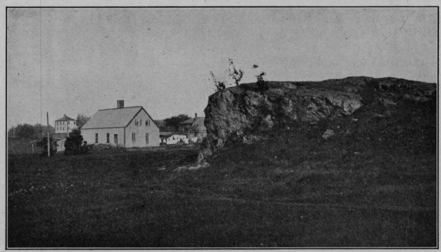


PLATE XIII.—ROCK OUTCROPS FLANKED BY FLATS OF GLACIO-MARINE GRAVELS.
Northern part of the city of Eastport. The form of the outcrops is suggestive of wave erosion.

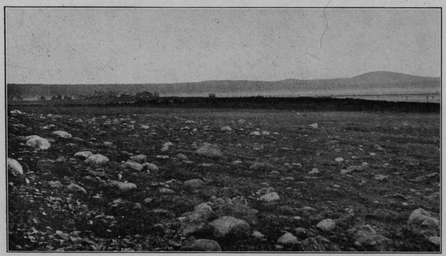


PLATE XIV.—BOWLDER-STREWN TERRACE OF SAND AND CLAY BORDERING THE TIDAL FLAT SHOWN IN PLATE XV.
Probably formed on a tidal flat when the land stood at a lower level.

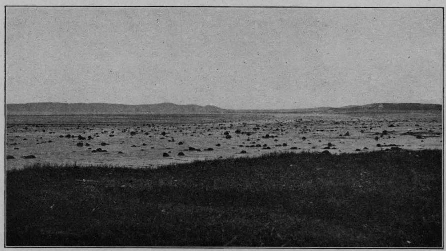


PLATE XV.—BOWLDER-STREWN TIDAL FLAT, EAST SHORE OF LUBEC NECK.

PLATE XVI.

FAUNA OF THE QUODDY FORMATION.

1. Crinoid stem. Exterior mold of joint face of an isolated segment of the stem. Enlarged 2 diameters.
2. *Plectambonites transversalis* (Wahlenberg). Pedicle valve, exterior of a worn shell. Enlarged 1½ diameters.
3. *Leptæna rhomboidalis* (Wilckens). Brachial valve in exterior mold, distorted by lateral extension. Enlarged 1½ diameters.
4. *Dalmanella elegantula* (Dalman). Brachial valve in external mold, distorted by lateral extension. Enlarged 3 diameters.
5. *Schuchertella subplana* (Conrad). Exterior mold and interior of a distorted pedicle valve. Enlarged 2 diameters.
6. *Pentamerus* cf. *oblongus* Sowerby (cf. *pesovis* Whitfield). Pedicle valve, interior mold, showing only umbonal part of shell. Enlarged 3 diameters.
7. *Atrypa reticularis* (Linné), cf. *A. nodostriata* Hall. Small brachial (?) valve, exterior mold of a crushed fragment. Enlarged 3 diameters.
8. *Anoplotheca* cf. *barrandei* (Davidson). Pedicle valve, interior mold. Enlarged 3 diameters.
9. *Spirifer radiatus* Sowerby (cf. *S. nympha* Billings). Mold of exterior of brachial valve, showing characteristic striations. Enlarged 2 diameters.
10. *Spirifer crispus* (Hisinger) (cf. *S. staminea* Hall). Fragment of a brachial valve, showing exterior surface. Enlarged 3 diameters.
11. Monograptus sp. indet. Part of single rhachia with row of cellules. Natural size.
12. Orthoceras sp. indet. A crushed sculpture cast. Natural size.

Specimens shown in figs. 1–10 from locality on north shore of West Quoddy Head, east of life-saving station. Specimens shown in figs. 11 and 12 from locality on east shore of South Lubec, about a mile south of Woodward Point.

FAUNA OF THE DENNYS FORMATION.

13. Cf. *Streptelasma calicula* Hall. Side view of mold of interior. Enlarged 2 diameters.
14. *Lingula* cf. *oblata* Hall. Fragment, showing interior. Natural size.
15. *Plectambonites transversalis* (Wahlenberg). Mold of an interior of a minute pedicle valve.
16. Cf. *Leptæna lævigata* (Sowerby). Mold of interior of pedicle valve. Enlarged 6 diameters.
17. Cf. *Leptæna minima* (Sowerby) var. *grayii* Davidson. Mold of interior of brachial valve. Enlarged 6 diameters.
18. *Skenidium lewisi* Davidson. Internal mold of brachial valve. Enlarged 6 diameters.
19. *Bilobites bilobus* (Linné). Mold of interior of pedicle valve. Enlarged 3 diameters.
20. Cf. *Orthis equivalvis* Davidson. Internal mold of pedicle valve. Enlarged 1½ diameters.
21. Cf. *Orthis equivalvis* Davidson. Internal mold of brachial valve. Enlarged 1½ diameters.
22. *Beyrichia maccoyiana* Jones var. External mold of right valve. Enlarged 10 diameters.
23. Pterinea (?) sp. Fragment of left valve. Enlarged 3 diameters.
24. *Spirifer crispus* (Hisinger). Mold of interior of brachial valve. Enlarged 2 diameters.
25. *Spirifer crispus* (Hisinger). A pedicle valve on a fragment of Strophonella (?). Natural size.
26. *Beyrichia maccoyiana* Jones var. Both valves in conjunction, distorted. Enlarged 10 diameters.
27. *Beyrichia spinulosa* Boll var. Enlarged 10 diameters.
28. *Bollia bicollina* Jones. Enlarged 10 diameters.
29. *Dalmanites longicaudatus* Murchison. A specimen showing pygidium and elongate spine. Enlarged 4 diameters.
30. *Cytherella concinna* Jones. Enlarged 10 diameters.
31. *Cytherella concinna* var. *ovalis* Jones.

About 2 miles east of Dennysville, on south side of Duck Harbor, one-fourth mile east of iron bridge.

PLATE XVII.

FAUNA OF THE EDMUNDS FORMATION.

Whitfieldella edmundsi Williams.

1. Brachial valve, showing muscular impressions.
2. Front view of same specimen.
3. A small specimen, showing spiral arms in the interior. Enlarged 2½ diameters.
4. Pedicle valve of same specimen as that shown in fig 2.

East shore of Burnt Cove, south of Cunningham Mountain, Edmunds Township.

Chonetes edmundsi Williams.

5. Pedicle valve, showing interior surface. Natural size.
6. Mold of exterior of pedicle valve, showing spines. Enlarged 2 diameters.
15. Brachial valve, interior. Natural size.
16. Pedicle valve, showing spines. Enlarged 2 diameters.

Specimens shown in figs. 5, 15, and 16 from locality one-half mile south of Field Point. Specimen shown in fig. 6 from west side of Burnt Cove, Edmunds Township.

Wilsonia saffordi Hall.

7. Front view of specimen, showing both valves. Enlarged 1½ diameters.
8. View of same specimen, showing interior of brachial valve.
11. Cardinal view of another specimen. Enlarged 1½ diameters.
12. View of pedicle valve, interior, same specimen as fig. 11.

East shore of Burnt Cove, south of Cunningham Mountain, Edmunds Township.

Wilsonia wilsoni (Sowerby).

13. View of exterior of pedicle valve, taken from wax mold. Natural size.
14. Cardinal view of specimen, showing both valves, somewhat crushed endwise. Natural size.

West shore of Falls Point, near the southern extremity of Leighton Neck, Pembroke Township.

Chonetes striatella (Dalman).

17. Mold of the interior of a pedicle valve, showing the typical characters of the species. In the original the bases of four spines are seen each side of the middle of hinge but are not shown in the figure. Natural size. West side of cove, about a mile southwest of Race Point, northeast part of Crowe Neck, Trescott Township.

Chonetes cf. *striatella* (Dalman).

9. A small pedicle valve, showing the general character expressed by the younger part of a typical *C. striatella* but not so wide as normal. It comes from the beds that furnished the specimen shown in fig. 17 and is interpreted to be a young of the same species. Enlarged 1½ diameters. Crowe Neck, Trescott Township.

Chonetes cobscooki Williams.

10. Mold of the interior of a pedicle valve, showing a form that is less transverse than some of the specimens of the species, and that bears finer and more numerous lineations than *C. striatella*. Natural size. Calcareous shales south of Field Point, Edmunds Township.

Monomerella woodwardi (Salter).

18. Mold of the exterior of a pedicle valve. Seven-eighths natural size.
19. Exterior of a brachial valve, showing the sculpture of external surface. Seven-eighths natural size.

Gray tuffs at Field Point, west side of Cobscook River, Edmunds Township.

Pentamerus galeatus (Dalman).

20. A somewhat crushed pedicle valve, showing the sulcus and radial plications. Natural size.
21, 22. An exfoliated pedicle valve, showing the general form, the interior surface markings, and the median septum.
23. A somewhat distorted shell, showing exterior of a pedicle valve, with smooth sides and plications in the sulcus.

Calcareous shales on west side of Burnt Cove, Edmunds Township.

Meristina tumida (Dalman).

24. Exterior of pedicle valve, showing smooth surface, the radial striations on the inner layers where exfoliated at right lower corner of figure, and the median furrow reaching to the beak. Natural size.
25. A fragment showing the median furrow and depressed beak.
26. A mold of interior of pedicle valve, showing mold of the muscular scar and the longitudinal striations on the interior surface.

Burnt Cove, Edmunds Township.

PLATE XVIII.

FAUNA OF EDMUNDS FORMATION.

Leptostrophia filosa (Sowerby).

1. Two molds of the interior of a pedicle valve, showing the hinge crenulations not extending to the extremities of the hinge, the muscular impressions, and the minute papillose vascular markings on each side of the muscular impressions. Natural size. West shore of Cobscook River, opposite Wilber Point, Edmunds Township.
4. Another mold of a slightly larger specimen. Natural size. Locality same as fig. 1.
5. Mold of cardinal portion of a brachial valve, showing the hinge crenulations, the crural process somewhat distorted, and the muscular impressions. Enlarged 2 diameters. Locality same as fig. 1.
6. Exterior of a pedicle valve, showing the surface sculpture; taken from wax impression of original. Natural size. Locality same as fig. 1.

PLATE XVIII—Continued.

8. Mold of interior of a brachial valve, showing the impression of the upper part of the muscular scars and the crural and cardinal processes. Natural size. Locality same as fig. 1.

9a, 9b. Molds of the interior (9a) and exterior (9b) of two pedicle valves, showing the surface sculpture, the muscular scars, the vascular papillæ, and the crenulations limited to the central portion of the hinge area. Enlarged 2 diameters. Locality same as fig. 1.

Brachyprion shaleri Williams.

2. Mold of interior of a brachial valve, showing the hinge crenulations, cardinal process, crural process, dental sockets, and the strong ridges bounding the muscular impression. Enlarged 2 diameters. East shore of Burnt Cove, south of Cunningham Mountain, Edmunds Township.
3. Exterior of a small (?) pedicle valve, showing the surface sculpture. Enlarged 2 diameters. Shore of small bay west of Field Point, southeast of Bells Mountain, Edmunds Township.
7. Mold of interior of a pedicle valve, showing the short crenulated area and smooth terminal portion of the hinge and the subquadrate form of the muscular area bounded by strong subparallel ridges. Enlarged 2 diameters. West shore of Cobscook River, opposite Wilber Point, Edmunds Township.

PLATE XIX.

FAUNA OF EDMUNDS FORMATION.

Palæopecten transversalis Williams.

1. An imperfect mold of the interior of a left valve, showing the transversely elongate form, the rays, and the absence of a differentiated anterior ear. Natural size. East shore of Cobscook River, opposite Burnt Cove, Trescott Township.
2. Mold of exterior of the same specimen. Locality same as fig. 1.

Palæopecten cobscooki Williams.

3. A nearly complete mold of the interior of left valve, showing the erect form, the characteristic radii, the pectinoid form, and the crural ridges. This species is the type of the genus. Natural size. Locality same as fig. 1.

Tolmaia campestris Williams.

4. A left valve, from a wax mold, showing the rectangular surface sculpture over body, ear, and wing. Natural size. Field Point on west shore of Cobscook River, Edmunds Township.
5. Natural mold of interior of a right valve, showing through the thin and partly eroded shell the exterior surface sculpture over all parts of the right valve. Locality same as fig. 4.

Palæopecten danbyi (McCoy) sens. strict. Williams.

6. A small specimen, showing the mold of the exterior of a left valve, representing also the form of McCoy's pl. 11, fig. 11, British Paleozoic Fossils, taken as the typical form of his species. Under highway bridge crossing Wilson Stream at head of the tidal inlet, 2 miles north of village of Dennysville.
7. A large specimen of the left valve, drawn from an exterior mold. Locality same as fig. 6.

Pterinea (Tolmaia ?) trescotti Williams.

8. A left valve, showing natural mold of the interior surface, the strong radii, trace of the cardinal teeth under the beak, the lateral tooth, and the well defined and developed anterior ear. Natural size. Cove on east side of Crowe Neck near north end, Trescott Township.
9. Another specimen, showing interior of a right valve. Locality same as fig. 8.

PLATE XX.

FAUNA OF PEMBROKE FORMATION.

Dalmanella lunata (Sowerby).

1. A pedicle valve, drawn from a rubber mold of the exterior. Enlarged 1½ diameters. Head of Leighton Cove, Pembroke Township.
2. A small (young) specimen of the pedicle valve, showing natural mold of the interior. Enlarged 1½ diameters. Locality same as fig. 1 but higher up stratigraphically.
3. A pedicle valve of the broader type, taken from a wax mold of the exterior. Enlarged 1½ diameters. Locality same as fig. 1.
4. A small (young) brachial valve, from a stone mold of the interior. Enlarged 1½ diameters. Locality same as fig. 2.
5. A brachial valve showing the exterior, drawn from a wax mold of the exterior. Enlarged 1½ diameters. Locality same as fig. 1.
8. A pedicle valve of the wide variety, taken from a mold of the exterior. Enlarged 1½ diameters. Leighton Cove, Pembroke Township.

Figs. 1 and 5 show the form of the greater number of specimens. Figs. 3 and 8 show the wide form.

Chonetes bastini Williams.

6. Exterior of a pedicle valve, drawn from a partly exfoliated mold, the drawing being made to represent the exterior. Enlarged 1½ diameters.
7. Exterior of a pedicle valve, drawn from a rubber mold of the exterior, showing the spines and a median furrow. Enlarged 1½ diameters.
10. A slab showing several specimens. The specimen at the upper left-hand corner of the slab is over 20 millimeters wide and barely 10 millimeters long. The specimen on lower right-hand corner has proportions near to those of *C. novascoticus* Hall. On the middle of the sloping side to the left is the mold of an exterior on which the median line is larger than ordinary. Natural size.

Leighton Cove, Pembroke Township.

Camarotœchia leightoni Williams.

9. A brachial valve, mold of the interior, showing the median septum, the plications smooth for the early part of growth, the concentric imbrications not appearing till late stage in growth.
11. A pedicle valve, mold of interior, showing the sinus with three well-defined plications and the imbrications beginning at midgrowth.
12. A pedicle valve, drawn from a rubber mold of the exterior, showing the characteristic smoothness of plications in upper part and concentric imbrications in lower half of shell.
13. Front view of interior, showing both valves. The specimen is compressed from front to beak, making it appear more gibbous than normal.

Leighton Cove, Pembroke Township.

Actinopteria fornicata Williams.

14, 15, 16. Three views of the same specimen, showing internal form and the surface sculpture on fig. 14. Natural size. Northwest shore of Youngs Cove, Pembroke Township.

Actinopteria bella Williams.

17. A natural mold of the exterior of a left valve, slightly enlarged, showing the concentric lines over the whole surface, the radiating lines confined to the body of the shell. Leighton Cove, Pembroke Township.
19. Mold of interior of a right valve, showing concentric lines over the whole surface but no radii. Locality same as fig. 17.

Actinopteria dispar Williams.

20. Mold of interior of a left valve. Natural size. Leighton Cove, Pembroke Township.
21. A small left valve. Enlarged 2 diameters. Locality same as fig. 20.

Lingula scobina Williams.

18. A specimen showing the original shell over part of the surface and its peculiar surface sculpture. Enlarged 3 diameters. Leighton Cove, Pembroke Township.

PLATE XXI.

FAUNA OF PEMBROKE FORMATION.

Orthoceras cf. *imbricatum* Sowerby.

1. Partial cast of a fragment with thirty abandoned chambers and most of the body or living chamber.

1a. View of a septum, showing position of siphon.

11. Partial cast of a fragment, showing ventral bend of the sutures.

Leighton Cove, Pembroke Township.

Calymene blumenbachi (Brongniart).

2. Wax impression of exterior mold of cranidium.

2a. Profile of same.

5. Wax impression of exterior mold of tail or pygidium.

Head of Long Cove, Leighton Neck, Pembroke Township.

Acaste downingiæ (Murchison).

3. Specimen incomplete on left side, showing upper view of whole shell, drawn from impression of exterior mold. Leighton Cove, Pembroke Township.

Platyschisma helicites (Sowerby).

4. Dorsal view of spire of a specimen, showing the outer surface. Enlarged 1½ diameters.
6. Umbilical view of same specimen.
8. Apertural view of same specimen.

Leighton Cove, Pembroke Township.

Orbiculoidea cf. *morrisi* (Davidson).

7. Brachial valve of partly decorticated shell. Enlarged 2 diameters.

7a. Profile of both valves; restoration.

Leighton Cove, Pembroke Township.

PLATE XXI—Continued.

Orbiculoidea rugata (Sowerby).

9. Brachial valve of partly decorticated shell. Enlarged 2 diameters.

9b. Pedicle or flat valve in external mold. Enlarged 2 diameters.

10. Profile of both valves.

Horan Head, west side of South Bay, Lubec Township.

Pholidops implicata (Sowerby).

12, 13. Impressions from exterior molds of two isolated valves. Enlarged 6 diameters.

12a. Profiles of both valves; restoration.

East side of Leighton Point, Pembroke Township.

Palæopecten danbyi (McCoy).

14. Left or rayed valve, sculpture cast. Enlarged 1½ diameters. Horan Head, west side of South Bay, Lubec Township.

Cornulites serpularius var. *bellistriatus* Hall.

15. Wax impression from crushed and flattened exterior mold, showing the form and the exterior sculpturing. Natural size. Leighton Cove, Pembroke Township.

Bellerophon (Tropidodiscus) carinatus Sowerby.

16, 17. Interior molds, umbilical and dorsal views. Enlarged 2 diameters. Leighton Cove, Pembroke Township.

Orthoceras (Dawsonoceras) perelegans Salter.

18. A fragment showing the central portion of the cone with the surface sculpture. Leighton Cove, Pembroke Township.

Bellerophon globatus Sowerby (? = *expansus* Sowerby).

19. Sculpture cast, dorsal view. Enlarged 2 diameters. Horan Head, west side of South Bay, Lubec Township.

Bellerophon (Plectonotus) trilobatus Sowerby.

20. Partial interior and exterior mold, apertural view, of the largest specimen observed. The specimen shows the adult form with expanded lip, deep furrows proceeding to extreme front, separating the shell into three lobes; a marginal sinus (not shown in this figure) which is continued backward along the keel as a distinct slit band. Natural size. Leighton Cove, Pembroke Township.

PLATE XXII.

FAUNA OF PEMBROKE FORMATION.

Grammysia pembrokensis Williams.

2. A right valve. The specimen is believed to be slightly elongated transversely from its natural form. The anterior front of the shell is more sharply angular than associated specimens. Enlarged 1½ diameters. Purple shales of upper part of Pembroke formation in several localities in Pembroke Township.

Grammysia cf. *pembrokensis* Williams.

1, 3. Specimens showing great differences from the typical characters of the species, probably due almost entirely to distortion of the shell after fossilization. Enlarged 1½ diameters. Purple shales of Pembroke formation, exposed on west shore of northernmost cove of Sipp Bay, south of highway bridge, 1½ miles east of Pembroke village.

Grammysia triangulata (Salter).

18. A specimen of the left valve, closely representing the form of one of Salter's figures of the species. Natural size. Tough gray sandstone beds of Pembroke formation at head of Long Cove, near the base of the formation, Leighton Neck, Pembroke Township.

Leiopteria sp. indet.

4, 4a. A small left valve. Enlarged 1½ diameters. Purple shales at head of Sipp Bay, 100 yards south of highway bridge, about 1½ miles east of Pembroke village.

Eurymyella shaleri var. *minor* Williams.

5. A small specimen showing left valve, having the general form and size of the species as it occurs in the Carlow member of the Eastport formation. Enlarged 3 diameters. Purple shales in upper part of the Pembroke formation, on west shore of Sipp Bay, south of highway bridge, about 1½ miles east of Pembroke village.

Lingula minima var. *americana* Williams.

6. A specimen a little larger than medium size, showing the general form of the species. Enlarged 2 diameters. Locality same as fig. 5.

Modiolopsis leightoni Williams.

7, 8, 9, 10. A set of two right and two left valves, showing the fluctuating characters presented by the species. Enlarged 1½ diameters. Argillaceous shales at head of Leighton Cove, Pembroke Township.

Modiolopsis leightoni var. *quadrata* Williams.

12, 13. Two left valves. Fig. 13 shows the ordinary form. Enlarged 1½ diameters. Locality same as figs. 7–10.

Nuculites corrugata Williams.

11. A right valve, the shape a little shorter and the ventral margin a little more arched than average form. Enlarged 1½ diameters. Gray argillaceous shales at head of Leighton Cove, Pembroke Township.
14. A right valve of about normal form, except that by crushing the ventral border is rolled under the edge; if flattened out it would add about a millimeter to the height. Locality same as fig. 11.

Platyschisma helicites (Sowerby).

15, 16. Two views of a medium-sized specimen that by pressure has been elongated in the direction of the mouth, giving a lower spire than is common. Enlarged 2 diameters. Upper purple shales of the Pembroke formation on eastern shore of Hersey Cove, Pembroke Township.
17. A slab showing the molds of exterior of minute specimens, probably young. Enlarged 3 diameters. Upper purple shales of the Pembroke formation on eastern shore of Hersey Cove, Pembroke Township.

PLATE XXIII.

FAUNA OF EASTPORT FORMATION.

Eurymyella shaleri Williams.

1. A right valve. Natural size. Shackford Head, Moose Island.
2. A left valve, crushed. Natural size. Salt works, city of Eastport.
3. A left valve, normal size and shape. Natural size. Salt works, city of Eastport.

Shackford member of the Eastport formation.

Eurymyella shaleri var. *brevis* Williams.

4, 5. A right and left valve. Natural size. Locality same as figs. 2 and 3.

Eurymyella shaleri var. *longa* Williams.

6. A left valve. Natural size. East side Seward Neck, near North Lubec landing.

Eurymyella angularis Williams.

7, 8. Right and left valves of normal size. Natural size. From the upper part of a thick series of gray shales on south side of river below North Lubec Landing, Lubec Township.

Eurymyella recta Williams.

9. A left valve, normal size, made from wax impression. Natural size. Locality same as fig. 7.

Eurymyella plana Williams.

12. A left valve. Natural size. Locality same as fig. 7.

Lingula cornea Sowerby.

10. A valve with the outer layers of the shell removed from lower part, showing the fine radiating lines. Enlarged 1½ diameters. Shackford member of the Eastport formation on the north shore of Moose Island, west of Kendall Head.
11. A specimen somewhat shorter than specimen shown in fig. 10, the two showing the variation assumed by the species in the Eastport formation. Enlarged 1½ diameters. Carlow member of the Eastport formation, Carlow Island.

Streptotrochus carinatus Williams.

13. A specimen showing the carinated whorls. Enlarged 2 diameters. Shales of the Shackford member of the Eastport formation on south side of Shackford Head, Moose Island.

Streptotrochus sulcatus Williams.

14. A specimen from same slab as fig. 13. Enlarged 2 diameters.

Streptotrochus regularis Williams.

15. A specimen showing no revolving carina. From the same slab as fig. 13. Enlarged 2 diameters.

Streptotrochus ione Williams.

16. A nearly perfect shell showing carina on next to last whorl and sulcus on outer whorl, from same slab as fig. 13. Enlarged 2 diameters.

NOTE.—The four specimens shown in figs. 13–16, which lie on a single slab, exhibit the great variability generally expressed by this shell wherever collected in the Eastport shale. Those specific names are given to designate different forms, although their specific rank may be questioned.

ILLUSTRATIONS II

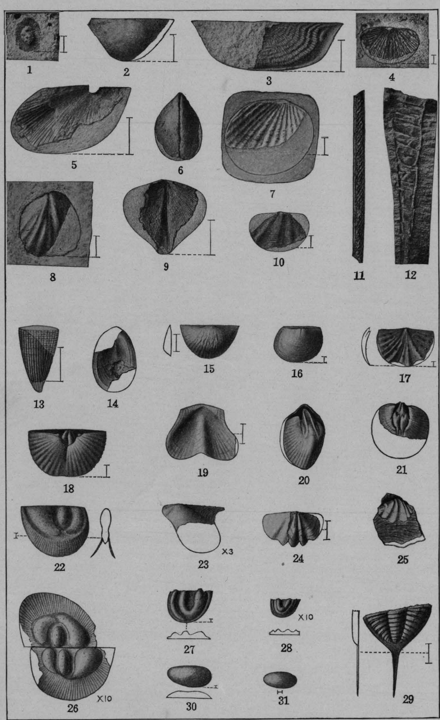


PLATE XVI.—FAUNAS OF QUODDY AND DENNYS FORMATIONS.
Figures 1–12, Quoddy formation; figures 13–31, Dennys formation.

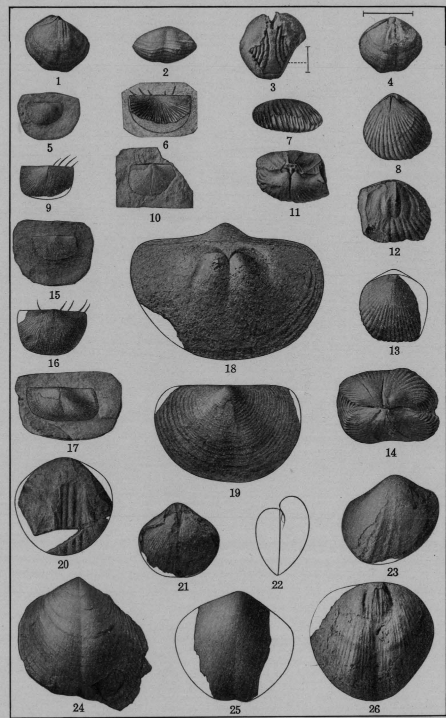


PLATE XVII.—FAUNA OF EDMUNDS FORMATION.

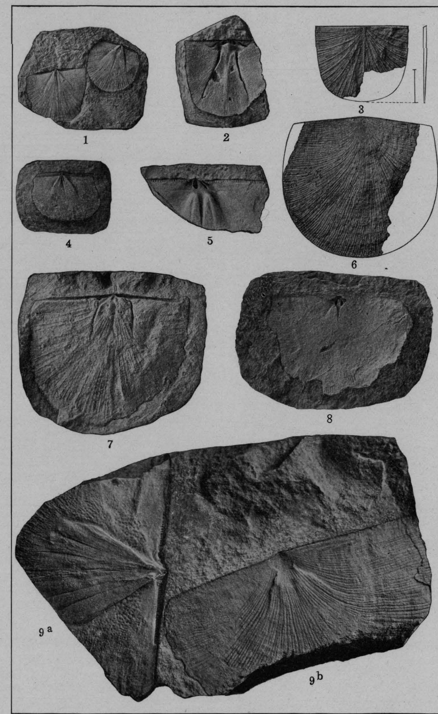


PLATE XVIII.—FAUNA OF EDMUNDS FORMATION.

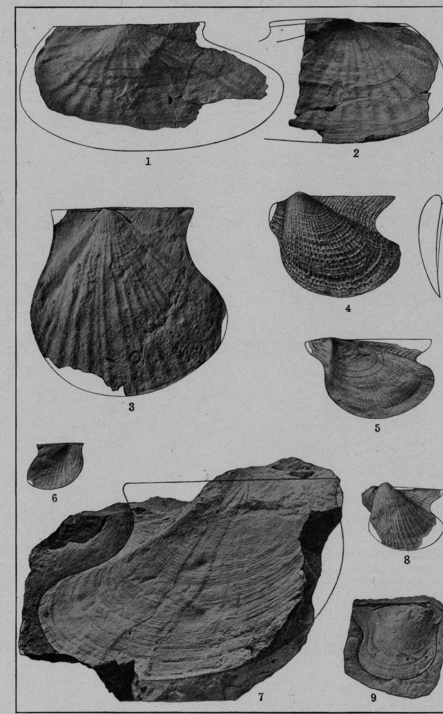


PLATE XIX.—FAUNA OF EDMUNDS FORMATION.

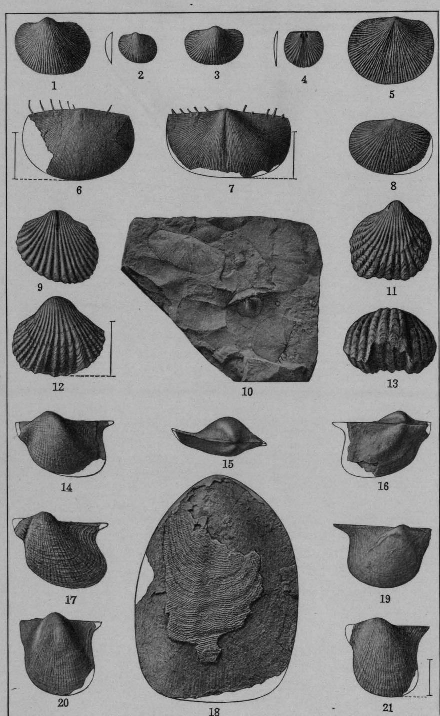


PLATE XX.—FAUNA OF PEMBROKE FORMATION.

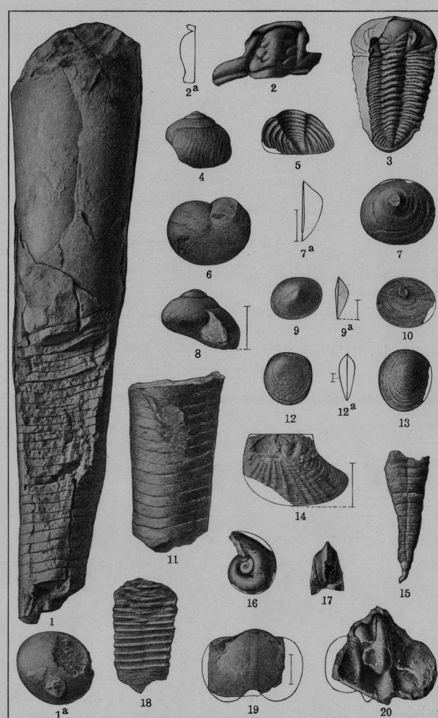


PLATE XXI.—FAUNA OF PEMBROKE FORMATION.

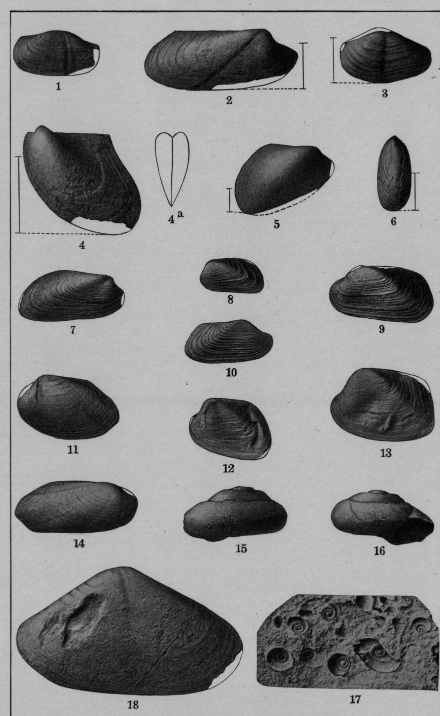


PLATE XXII.—FAUNA OF PEMBROKE FORMATION.

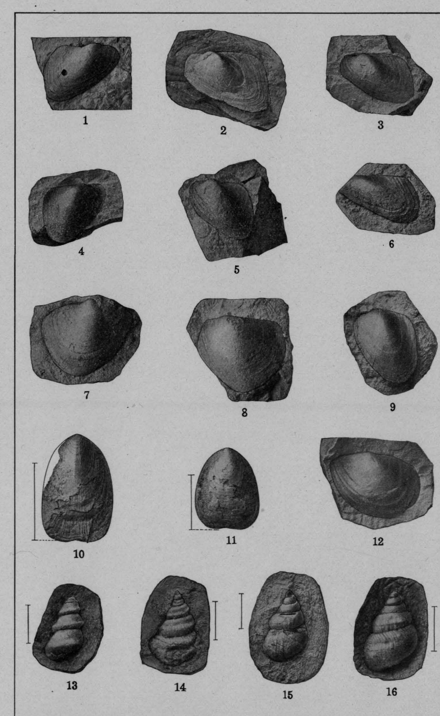


PLATE XXIII.—FAUNA OF EASTPORT FORMATION.

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‡7	Pikes Peak	Colorado	
‡8	Sewanee	Tennessee	
‡9	Anthracite-Crested Butte	Colorado	
‡10	Harpers Ferry	Va.-Md.-W.Va.	
‡11	Jackson	California	
‡12	Estillville	Ky.-Va.-Tenn.	
13	Fredericksburg	Virginia-Maryland	5
‡14	Staunton	Virginia-West Virginia	
‡15	Lassen Peak	California	
‡16	Knoxville	Tennessee-North Carolina	
‡17	Marysville	California	
‡18	Smartsville	California	
‡19	Stevenson	Ala.-Ga.-Tenn.	
20	Cleveland	Tennessee	5
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‡25	Loudon	Tennessee	
‡26	Pocahontas	Virginia-West Virginia	
27	Morristown	Tennessee	5
‡28	Piedmont	West Virginia-Maryland	
‡29	Nevada City Special	California	
‡30	Yellowstone National Park	Wyoming	
‡31	Pyramid Peak	California	
‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
‡34	Buckhannon	West Virginia	
‡35	Gadsden	Alabama	
36	Pueblo	Colorado	5
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
40	Wartburg	Tennessee	5
‡41	Sonora	California	
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‡43	Bidwell Bar	California	
‡44	Tazewell	Virginia-West Virginia	
‡45	Boise	Idaho	
46	Richmond	Kentucky	5
47	London	Kentucky	5
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
50	Holyoke	Massachusetts-Connecticut	5
‡51	Big Trees	California	
52	Absaroka	Wyoming	5
53	Standingstone	Tennessee	5
‡54	Tacoma	Washington	
55	Fort Benton	Montana	5
56	Little Belt Mountains	Montana	5
‡57	Telluride	Colorado	
58	Elmoro	Colorado	5
59	Bristol	Virginia-Tennessee	5
60	La Plata	Colorado	5
61	Monterey	Virginia-West Virginia	5
62	Menominee Special	Michigan	5
‡63	Mother Lode District	California	
64	Uvalde	Texas	5
65	Tintic Special	Utah	5
‡66	Colfax	California	
67	Danville	Illinois-Indiana	5
68	Walsenburg	Colorado	5
69	Huntington	West Virginia-Ohio	5
‡70	Washington	D. C.-Va.-Md.	
‡71	Spanish Peaks	Colorado	
‡72	Charleston	West Virginia	
‡73	Coos Bay	Oregon	
74	Coalgate	Oklahoma (Ind. Ter.)	5
75	Maynardville	Tennessee	5
76	Austin	Texas	5
77	Raleigh	West Virginia	5
78	Rome	Georgia-Alabama	5
79	Atoka	Oklahoma (Ind. Ter.)	5
80	Norfolk	Virginia-North Carolina	5
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	5
90	Cranberry	North Carolina-Tennessee	5
91	Hartville	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
94	Brownsville-Connellsville	Pennsylvania	5
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5

No.*	Name of folio.	State.	Price.†
			Cents.
97	Parker	South Dakota	5
98	Tishomingo	Oklahoma (Ind. Ter.)	5
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
101	San Luis	California	5
102	Indiana	Pennsylvania	5
103	Nampa	Idaho-Oregon	5
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	5
107	Newcastle	Wyoming-South-Dakota	5
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
110	Latrobe	Pennsylvania	5
‡111	Globe	Arizona	
‡112	Bisbee	Arizona	
113	Huron	South Dakota	5
114	De Smet	South Dakota	5
115	Kittanning	Pennsylvania	5
116	Asheville	North Carolina-Tennessee	5
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	5
120	Silverton	Colorado	5
121	Waynesburg	Pennsylvania	5
122	Tahlequah	Oklahoma (Ind. Ter.)	5
123	Elders Ridge	Pennsylvania	5
124	Mount Mitchell	North Carolina-Tennessee	5
125	Rural Valley	Pennsylvania	5
126	Bradshaw Mountains	Arizona	5
127	Sundance	Wyoming-South Dakota	5
128	Aladdin	Wyo.-S. Dak.-Mont.	5
‡129	Clifton	Arizona	
130	Rico	Colorado	5
131	Needle Mountains	Colorado	5
132	Muscogee	Oklahoma (Ind. Ter.)	5
133	Ebensburg	Pennsylvania	5
134	Beaver	Pennsylvania	5
135	Nepesta	Colorado	5
136	St. Marys	Maryland-Virginia	5
137	Dover	Del.-Md.-N. J.	5
‡138	Redding	California	
139	Snoqualmie	Washington	5
140	Milwaukee Special	Wisconsin	5
141	Bald Mountain-Dayton	Wyoming	5
142	Cloud Peak-Fort McKinney	Wyoming	5
143	Nantahala	North Carolina-Tennessee	5
144	Amity	Pennsylvania	5
‡145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	
146	Rogersville	Pennsylvania	5
147	Pisgah	N. Carolina-S. Carolina	5
‡148	Joplin District	Missouri-Kansas	
149	Penobscot Bay	Maine	5
‡150	Devils Tower	Wyoming	
151	Roan Mountain	Tennessee-North Carolina	5
152	Patuxent	Md.-D. C.	5
153	Ouray	Colorado	5
‡154	Winslow	Ark.-Okla. (Ind. Ter.)	
‡155	Ann Arbor	Michigan	
156	Elk Point	S. Dak.-Nebr.-Iowa	5
‡157	Passaic	New Jersey-New York	
158	Rockland	Maine	5
159	Independence	Kansas	5
160	Accident-Grantsville	Md.-Pa.-W. Va.	5
161	Franklin Furnace	New Jersey	5
‡162	Philadelphia	Pa.-N. J.-Del.	
‡163	Santa Cruz	California	
164	Belle Fourche	South Dakota	5
165	Aberdeen-Redfield	South Dakota	5
166	El Paso	Texas	5
167	Trenton	New Jersey-Pennsylvania	5
168	Jamestown-Tower	North Dakota	5
169	Watkins Glen-Catatonk	New York	5
170	Mercersburg-Chambersburg	Pennsylvania	5
171	Engineer Mountain	Colorado	5
172	Warren	Pennsylvania-New York	5
173	Laramie-Sherman	Wyoming	5
174	Johnstown	Pennsylvania	5
175	Birmingham	Alabama	5
176	Sewickley	Pennsylvania	5
177	Burgettstown-Carnegie	Pennsylvania	5
178	Foxburg-Clarion	Pennsylvania	5
179	Pawpaw-Hancock	Md.-W. Va.-Pa.	5
180	Claysville	Pennsylvania	5
181	Bismarck	North Dakota	5
182	Choptank	Maryland	5
183	Llano-Burnet	Texas	5
184	Kenova	Ky.-W. Va.-Ohio	5
§185	Murphysboro-Herrin	Illinois	25
§186	Apishapa	Colorado	5
§187	Ellijay	Ga.-N. C.-Tenn.	25
§188	Tallula-Springfield	Illinois	25
§189	Barnesboro-Patton	Pennsylvania	25
§190	Niagara	New York	50
§191	Raritan	New Jersey	25
192	Eastport	Maine	25

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

§ These folios are also published in octavo form at 50 cents each.

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