Stratigraphy of the Moose River Synclinorium, Maine

GEOLOGICAL SURVEY BULLETIN 1111-E

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By ARTHUR J. BOUCOT

CONTRIBUTIONS TO GENERAL GEOLOGY

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Description of the early Paleozoic rocks in west-central Maine, with emphasis on those of Silurian and Devonian age

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By Arthur J. Boucot

ABSTRACT

The Moose River synclinorium of west-central Maine contains the greatest thickness of relatively unmetamorphosed upper Lower Devonian strata known in the Appalachian belt. These strata, which have a total average thickness of about 10,000 feet, are chiefly dark sandstone and slate, with subordinate amounts of rhyolite. Strata of Oriskany and early Onondaga age form the trough of the synclinorium. On the flanks of the synclinorium they are unconformably underlain by erosional remnants of Helderberg, Late Silurian, possible Silurian(?), Middle Ordovician, Cambrian or Ordovician, and possible Precambrian age. The strata of Silurian through Helderberg age consist chiefly of calcareous sandstone, calcareous siltstone, conglomerate and arkose containing granitic and volcanic debris, limestone conglomerate, and limestone, with a maximum thickness of about 4,000 feet. The pre-Silurian strata consist of light and dark volcanic rocks, slate, phyllite, dark sandstone, graywacke, gneiss, and granitic rocks, with unknown stratigraphic thicknesses. Intrusive rhyolitic rocks of Early Devonian age and intrusive granitic rocks of post-Early Devonian age are present. The granitic intrusive rocks are bordered by contact metamorphic aureoles.

INTRODUCTION

From June 1948 to June 1956 the writer was engaged in a geologic and paleontologic study of the Moose River synclinorium, which covers parts of Franklin, Somerset, and Piscataquis Counties in northwestern Maine (pl. 34). The synclinorium is about 60 miles long and about 15 to 25 miles wide. The writer has completed not only the geologic study but also a paleontologic study of the brachiopods and gastropods. Nine other paleontologists are studying the remainder of the invertebrate fossils, and geologists are now studying the geology of nearby quadrangles in northern Maine.

This paper summarizes the stratigraphy of the Silurian and Devonian rocks of the synclinorium and includes some notes on rocks that underlie them.

PREVIOUS WORK

The Moose River synclinorium has previously been surveyed in reconnaissance only. C. T. Jackson (1837) first recognized Devonian rocks at Parlin Pond (Long Pond quadrangle).[1] C. H. Hitchcock (1861, 1862) also recognized Devonian rocks and mapped their distribution. Silurian fossils were first noted by C. H. Hitchcock and J. H. Huntington (1874), in the Spencer quadrangle. J. M. Clarke (1909) confirmed the presence of Lower Devonian strata in the synclinorium and described a large part of their fauna. H. S. Williams and C. L. Breger (1916) added to the knowledge of the Lower Devonian fauna of the synclinorium. E. H. Perkins (1925) made a reconnaissance of the central part of the synclinorium. E. S. C. Smith (1925, 1930, 1933) observed the rhyolitic rocks in the prominent hills in the southeastern part of the synclinorium. Arthur Keith (1933) prepared a geologic map of the State. P. M. Hurley and J. B. Thompson, Jr. (1950) made the first relatively large-scale map outlining the boundaries of the Moose River synclinorium and indicated its general stratigraphy and structure. H. H. Woodard (1950) mapped part of the Spencer quadrangle and differentiated stratigraphic units of Silurian and Early Devonian age.

GENERAL GEOLOGY

The Moose River synclinorium encloses a great thickness of Devonian rocks equivalent to the Oriskany sandstone and the lower part of the Onondaga limestone of New York. These are underlain unconformably by older Devonian and Silurian rocks, which in turn rest unconformably on rocks that in one place contain Middle Ordovician fossils and elsewhere form a basement complex of uncertain age.

All the lower Paleozoic rocks are in the chlorite zone of regional metamorphism. Where they adjoin younger intrusive rocks, they have in addition been altered or affected by contact metamorphism. The Taconian orogeny of Late Ordovician or Early Silurian age strongly affected the region, and in Middle Devonian time the synclinorium was deformed by the Acadian orogeny (Boucot, 1954, p. 148). Younger intrusive rocks are sporadic in the region.

The rocks of the synclinorium are folded tightly into a multitude of doubly plunging anticlines and synclines (pl. 34). The anticlines on the south side of the synclinorium possess steeply dipping north limbs and gently dipping south limbs; those on the north side of the synclinorium possess steeply dipping south limbs and gently dipping north limbs. Cleavage on the south side of the synclinorium dips steeply south and on the north side dips steeply north. Cleavage planes cutting fine-grained stratified rocks have steep dips (70°–90°); those cutting medium-grained stratified rocks have lower dips. The stratified rocks are cut by widely spaced

[1] Quadrangles and counties (shown in pl. 34) are referred to throughout this paper as an aid to the reader.

nearly vertical and vertical joints normal to the strike of the cleavage.

Along the southeast boundary of the synclinorium the Silurian and Devonian rocks lie with major unconformity on Ordovician and older rocks; in the extreme southwest, however, this contact is thrust faulted. At the southwest end of the trough the Silurian and Devonian rocks lie uncomformably on the basement complex to the west and northwest. An outlier of Silurian rocks, downfaulted on the southeast, lies in the basement complex northwest of the southeast prong of the trough.

The light igneous rocks in the region all weather with a soft chalky rind an 1/8 to 1/2 inch thick. The dark igneous rocks weather with a soft rusty outer rind half an inch thick. All the siliceous stratified rocks except the quartzite weather with a gray-to-brown rind and weather rusty where they contain pyrite. The calcareous stratified rocks weather with a soft punky rind as much as half an inch thick. The limestone units weather to rounded surfaces without a weathered rind.

The prominent northeast trend of both topography and drainage in the region is controlled by the trends of fold axes, cleavage, and bedding planes. The less prominent northwest trend of the topography and drainage is largely controlled by joints. The isolated mountains formed by volcanic and intrusive rocks are unrelated to these drainage trends. The fine-grained stratified rocks form areas of low relief, and the medium-grained stratified rocks areas of moderate relief. The numerous lakes and swamps are of glacial origin.

STRATIGRAPHY

GENERAL STRATIGRAPHIC RELATIONS

The trough of the synclinorium contains the Moose River group of early Onondaga and Oriskany age and the Seboomook formation of Early Devonian age—chiefly dark sandstone, siltstone, and slate. Strata of early Onondaga age form the Tomhegan formation, strata of Oriskany age the Tarratine formation and strata of Oriskany and New Scotland age the Seboomook formation.

The youngest unit is the Tomhegan formation, which includes an upper main part of dark sandstone and rusty-weathering dark sandstone, and a basal Kineo volcanic member. The main part of the Tomhegan formation contains fossils of early Onondaga age, but the age of the Kineo volcanic member is uncertain. The strata of early Onondaga age in the Tomhegan formation are separated from

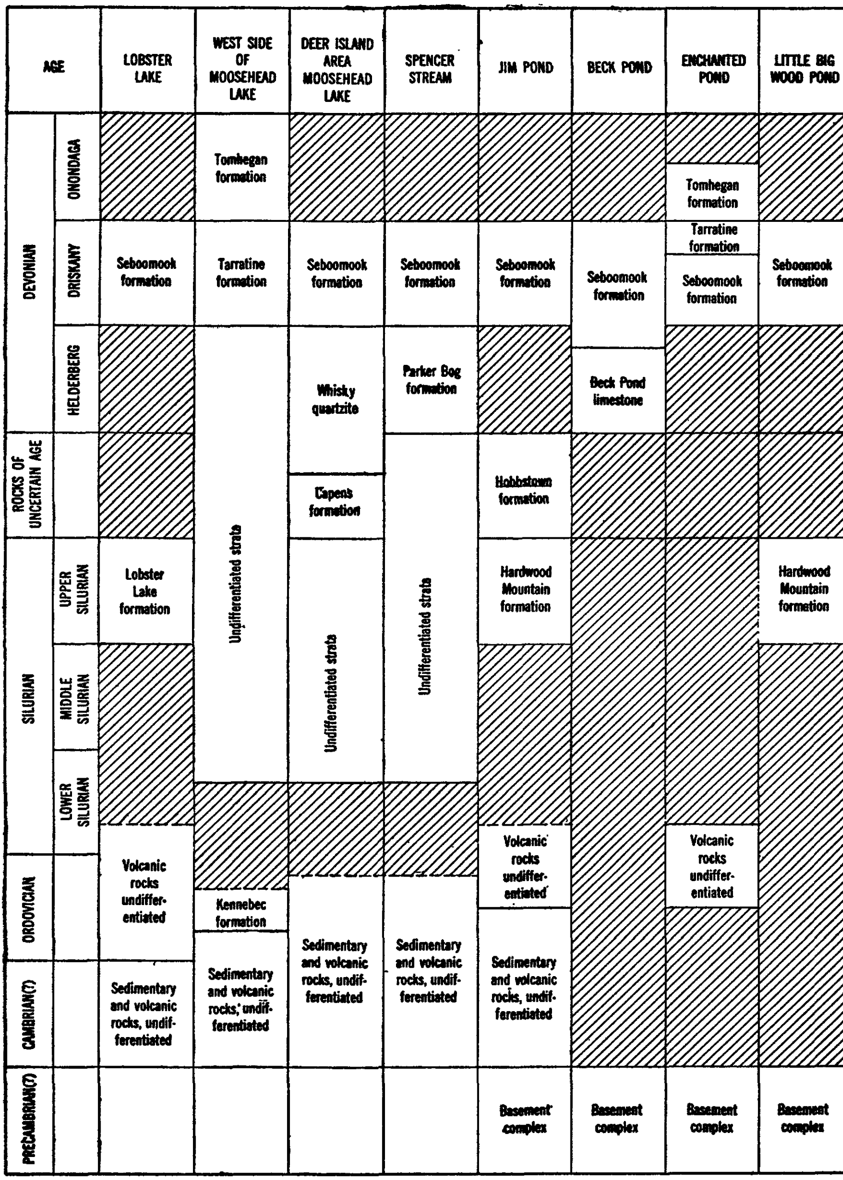

FIGURE 16.—Correlation table of Paleozoic strata in the Moose River synclinorium.

those of Oriskany age below either by the intervening Kineo volcanic member or by unfossiliferous clastic rocks at the base of the Tomhegan.

Beneath the Tomhegan formation is the Tarratine formation, an intergrading sedimentary complex (figs. 17 and 18) containing fossils of Oriskany age. This includes a main part of medium-grained dark sandstone, siltstone, and slate; the Misery quartzite

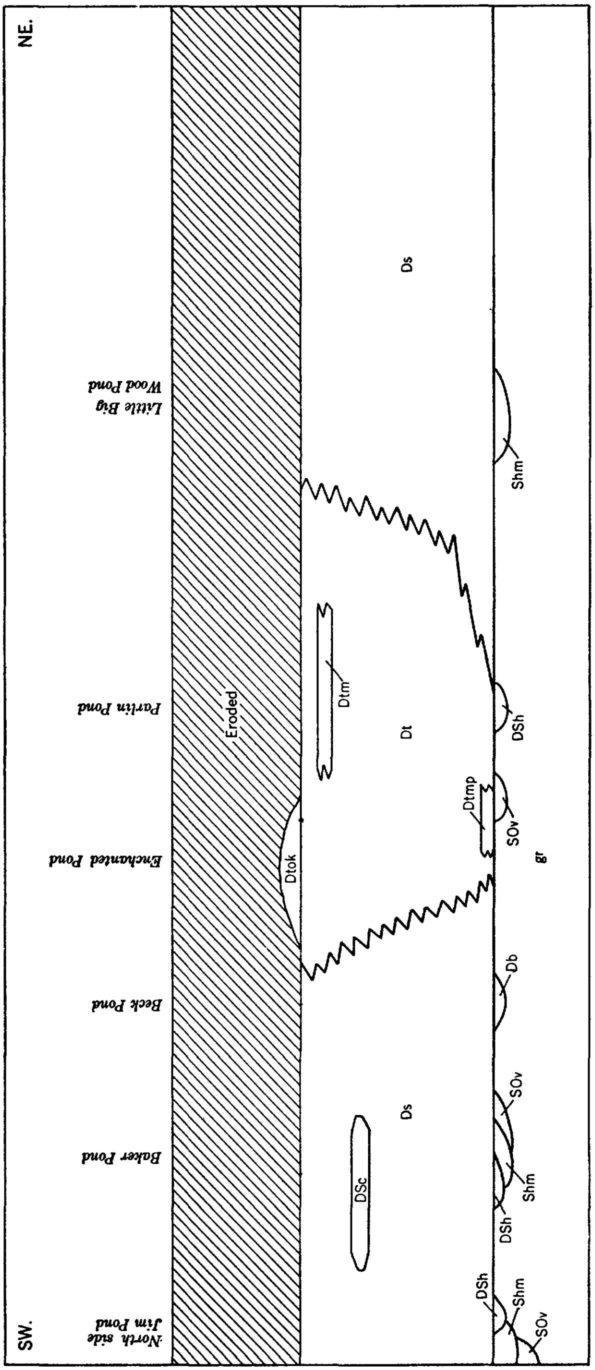

FIGURE 17.—Inferred stratigraphic relations of the Silurian and Devonian strata on the northwest flank of the Moose River synclinorium. (Jim Pond to Little Big Wood Pond.)

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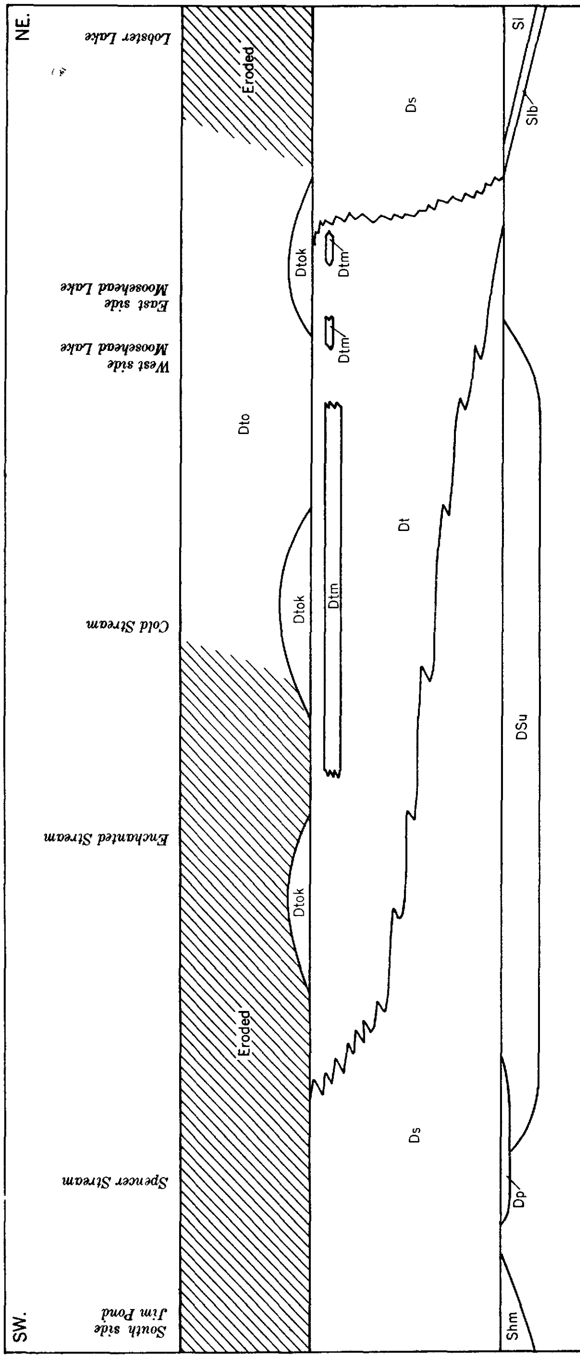

FIGURE 18.—Inferred stratigraphic relations of the Silurian and Devonian strata on the southeast flank of the Moose River synclinorium. (Jim Pond to Lobster Lake.)

members in the upper third; and the very restricted McKenney Ponds limestone member at the base.

The Tarratine formation grades laterally into the Seboomook formation, a distinctive cyclicly layered slate and dark sandstone containing fossils of Oriskany and New Scotland age. The Seboomook includes the Camera Hill greenstone member.

Formations underlying the Moose River group and Seboomook formation are discontinuous, with unconformities between nearly all formational units. They occur in scattered areas around the edges of the synclinorium. Some are well dated by fossils; others are dated only by stratigraphic position relative to well-dated units or by lithologic similarities to well-dated units. Most of them are of Silurian age, but at least one is of earliest Devonian age.

In the area southwest of Spencer Lake is the very restricted Beck Pond limestone of Early Devonian (Helderberg) age, which rests unconformably on the basement complex and is overlain by basal Seboomook beds that also contain fossils of Early Devonian (Helderberg) age.

In the area south and southeast of Spencer Lake is the Parker Bog formation of interbedded felsite and limestone, which contains fossils of Silurian or more probably Early Devonian age. No rocks like it are known elsewhere in northern Maine.

Also of Silurian or Early Devonian age are the unfossiliferous Whisky quartzite and underlying Capens formation, exposed on islands in southeastern Moosehead Lake and on the nearby shore. The Capens formation is a thin unit of red and green slate. The Whisky quartzite appears to be conformable with both the underlying and overlying strata.

Along the southeast margin of the Moose River synclinorium from southeastern Moosehead Lake to Spencer Stream are calcareous slates and argillaceous limestones termed undifferentiated strata of Silurian or Devonian age. They may be partly or wholly equivalent to the Lower Devonian units or to the Silurian units, but geologic and paleontologic evidence is lacking.

Rocks of proved Late Silurian age occur at the northeast and southwest end of the Moose River synlinorium. Those at the southwest end are in the Hobbstown and Hardwood Mountain formations. Those at the northeast end are in the Lobster Lake formation. The Lobster Lake formation includes the basal Big Claw red-bed member and a main body that is largely siltstone, calcareous sandstone, calcareous slate, and limestone conglomerate. The Hardwood Mountain formation contains rocks similar to those in the main body of the Lobster Lake formation. The Hobbstown formation, above the Hardwood formation, consists of arkose and conglomerate which rests unconformably on the basement complex and the Hardwood Mountain formation. The base of the Hobbstown formation contains fossils of early Late Silurian age at two localities, but elsewhere the unit could be of latest Late Silurian or even Early Devonian age.

Fossiliferous rocks of Early Silurian age have not been recognized in the Moose River synclinorium, but Early Silurian fossils occur at two isolated localities in lime-silicate hornfels to the southeast, outside the synclinorium. Stratigraphic relations of these Lower Silurian rocks to the Upper Silurian rocks in the synclinorium are unknown.

The oldest Silurian rocks probably occur among the volcanic rocks of Silurian or Ordovician age that crop out in both the southwest and northeast parts of the synclinorium. These are inferred to be at least partly of Silurian age, but paleontologic evidence is meager and they may be older. A profound unconformity separates Silurian from Ordovician and older rocks.

The oldest rocks of proved Paleozoic age are volcanic rocks of the Kennebec formation of Middle Ordovician age on the southeast border of the synclinorium. This formation may be related to the sedimentary and volcanic rocks designated as Cambrian or Ordovician.

A granitic and gneissic basement complex appears to be the oldest rock unit in the region and is possibly of Precambrian age.

On the northwest border of the synclinorium, near Seboomook Dam and northeastward, the Frontenac formation of Early Devonian age—chiefly dark sandstone, siltstone, and shale—crops out.

MOOSE RIVER GROUP

The term Moose River group of the present report replaces the term Moose River sandstone of Williams (1900, p. 88). It consists of two formations: the Tomhegan formation of early Onondaga age above, and the Tarratine formation of Oriskany age below. Williams' term included the dark sandstone units of Early Devonian age in Somerset County and excluded the cyclicly layered slate and sandstone of the Seboomook formation, which are lithologically distinct. The term Moose River group as here used also excludes Lower Devonian sandstone units elsewhere in northern Maine which are of the same age, such as those near Matagamon Dam (Traveller Mountain quadrangle, Penobscot County), Telos and Webster Lakes (Telos Lake quadrangle, Piscataquis County), and Harrington Lake (Harrington Lake quadrangle, Piscataquis County). These are not now, and probably never were, part of the same stratigraphic unit as the Moose River group. The type area of the Moose River group was loosely defined by Williams, and exposures along the Moose River are not adequate for use as type sections. Type sections of the formations into which Williams' unit has been subdivided are located away from the Moose River.

The Tomhegan and Tarratine formations are both chiefly sandstone and can be recognized as formations only after detailed study.

TOMHEGAN FORMATION

The sandstone, slate, rhyolitic, and volcanic rocks of early Onondaga age in Somerset County and adjacent parts of Piscataquis County form the Tomhegan formation, which is here named from Tomhegan Cove on Moosehead Lake in the northeast quarter of the Brassua Lake quadrangle. It has two subdivisions: an upper unit, the main part of the formation, with type section on the west shore of Moosehead Lake between Blue Ridge on the south and Tomhegan Cove; and a lower unit, the Kineo volcanic member, with its type section on the northeast side of Mount Kineo in the NW¼ of the Moosehead Lake quadrangle.

MAIN PART OF THE TOMHEGAN FORMATION

Lithology.—Dark sandstone, dark tuffaceous sandstone, rusty-weathering argillaceous sandstone, slate, and quartzite form the main part of the Tomhegan.

The dark sandstone units form massive layers a few feet to 10 feet thick, are blue gray on fresh surfaces and gray on weathered surfaces, and contain scattered shell lenses. They consist of fine- to medium-sand-size quartz, feldspar, and felsite grains embedded in a fine-grained dark matrix. The tuffaceous sandstone contains as much as 70 percent felsite and no quartz. The nontuffaceous sandstone is quartzitic, thicker bedded, and more massive than the tuffaceous sandstone.

The slate of the main part is dark blue gray where fresh and is gray where weathered.

The argillaceous sandstone weathers dark gray with rusty streaks and is blue gray where fresh. It contains about 20 to 50 percent angular fine- to medium-sand-size quartz grains, possibly 5 percent feldspar grains, and a remainder of fine-grained silt and clay. Pyrite forms small anhedral scattered grains, but in some places nodules up to several inches in diameter are visible. The rusty-weathering sandstone is cut up into flattish ellipsoids by cleavage planes that obscure the bedding. It forms beds fractions of an inch to several feet thick which are interbedded with gray slate and white-weathering quartzite.

The quartzite forms less than 5 percent of the total volume of the member and consists of fine- to medium-sand-size angular quartz grains. Most of the quartzite beds are less than 10 feet thick.

Thickness.—The main part still preserved in the trough of the Moose River synclinorium is estimated from cross sections to be about 6,000 feet thick. Its original thickness before erosion is unknown.

Age.—The fauna of the dark sandstone is characterized by *Amphigenia*, *Eodevonaria*, and *Rhipidomelloides*, that of the rusty-weathering sandstone by *Globithyris*. The presence of *Amphigenia* and *Eodevonaria* in the sandstone indicates an early Onondaga age, but *Globithyris* in the rusty-weathering sandstone has a known range of Oriskany to early Onondaga. The local stratigraphic position of some of the beds containing *Globithyris* indicates that they are of early Onondaga age, but some of the lowest ones may be intermediate between Oriskany and early Onondaga ages.

Facies relations.—Subdivision of the main part is not practicable, but rusty-weathering sandstone is uncommon on the northwest side of the synclinorium, and dark sandstone is uncommon on the southeast side of the synclinorium where the rusty-weathering sandstone is abundant. Field relations indicate that the dark sandstone and rusty-weathering sandstone are facies of the same unit, but it has not been possible to draw boundaries between the two units because of their gradational and interbedded relation, inadequate exposure, and structural complexity in the trough of the synclinorium.

Lower contact.—The main part rests on volcanic rocks of the Kineo volcanic member or, where they are absent, on the uppermost beds of the Tarratine formation.

The contact with the Kineo volcanic member is not well exposed. The top of the massive felsite bodies in the Kineo has been observed only on Eagle Mountain (North East Carry quadrangle), where it is overlain by conglomerate of poorly rounded cobbles and boulders of massive felsite in a matrix of gray siltstone. The cobbles and boulders were derived from the underlying felsite of Eagle Mountain, and the siltstone resembles that in the overlying main body.

A small flow of massive felsite on the southwest shore of Brassua Lake (Brassua Lake quadrangle) is overlain by cobbles of spherulitic felsite, derived from the underlying flow, in a matrix of gray siltstone. Material eroded from the top of the flow grades upward into the siltstone, with fewer cobbles higher in the section.

Elsewhere in the synclinorium the contact with the Kineo volcanic member has not been observed. Many of the volcanic conglomerate and tuff beds are overlain by sedimentary rocks that may belong to the main part of the Tomhegan formation, but the precise location of the highest beds containing abundant coarse volcanic material is not known. In any event, the field relation between the tuff beds and conglomerate beds and the overlying main part suggest a gradation.

Where the Tomhegan formation is in contact with the underlying Tarratine formation, bedding attitudes on both sides of the contact indicate conformity. A faunal break below the occurrence of *Amphigenia*, *Eodevonaria* and *Rhipidomelloides* suggests that the Tarratine and Tomhegan formations are separated by a disconformity. On the northwest side of the synclinorium, where the Kineo volcanic member is nearly absent, the abundant tuffaceous sandstone beds of the Tomhegan are easily distinguished from the thin-bedded interlayered slate and sandstone of the underlying Tarratine formation, and this lithologic distinction is supported by a number of fossil occurrences. On the southeast side of the synclinorium, where the volcanic rocks of the Kineo volcanic member are absent, it is not possible to distinguish the rusty-weathering *Globithyris*-bearing sandstone of the Tomhegan from similar sandstone that occurs in a few places in the top of the Tarratine, but the distinction is easily made where dark sandstone of the Tarratine formation is present.

KINEO VOLCANIC MEMBER

Lithology.—The Kineo volcanic member consists of a variety of volcanic rocks: massive conchoidally fractured felsite, massive irregularly fracturing felsite containing abundant garnet phenocrysts, dark tuff, light tuff, conglomerate consisting chiefly of volcanic materials, and flow breccia.

The massive conchoidally fracturing felsite weathers bone white and is blue gray where fresh. Small glassy phenocrysts of quartz form about 5 percent of the rock, and gray phenocrysts of feldspar about 2 percent, but garnet phenocrysts are rare. The quartz phenocrysts are usually less than 1 mm (millimeter) in diameter, those of feldspar about 1 to 2 mm in diameter. The feldspar phenocrysts weather out to leave rectangular voids. The gray groundmass is very fine grained. Chaotic flow banding is conspicuous in places, and amygdules filled with calcite are conspicuous in others. Some specimens show vague outlines of spherulites.

The irregularly fracturing felsite contains abundant garnet phenocrysts; the rock on fresh surfaces is blue gray and weathers greenish white. Garnet phenocrysts about 2 mm in diameter form about 5 percent of the rock, and white feldspar phenocrysts about 2 to 3 mm long form 10 to 15 percent; quartz phenocrysts are uncommon. Columnar jointing occurs in places. Vague outlines of spherulites can be distinguished in some places and flow banding in others.

Most of the dark tuff is cut by closely spaced cleavage planes, unlike the more massive felsite. Weathered surfaces are greenish white to light gray, resembling those of the garnetiferous felsite, and the fresh rock is a much darker blue gray than the blue gray of the felsite. Angular felsite fragments make up 20 to 70 percent of the rock and are lighter than the dark groundmass. Some of the felsite fragments are shown by thin-section study to consist of pumice. Devitrified shards of glass are conspicuous in some specimens, and perlite in others. At many localities the dark tuff contains both garnet and feldspar phenocrysts. The dark tuff grades into dark-blue-gray mudstone that is probably very feldspathic, although the "feldspar" grains may be felsite in large part.

The light-colored tuff weathers chalky white and is blue gray where fresh. Felsite and pumice fragments, as large as a quarter of an inch, make up about 50 percent of the rock, and fine-grained volcanic debris containing abundant devitrified shards make up the remainder.

Conglomerate consisting almost entirely of rhyolitic felsite pebbles is abundant in the Kineo. Some of its beds are interlayered with fine- and medium-grained sandstone which probably contains a large amount of sand-size felsitic material. The pebbles in some beds are well rounded and sorted; in others, angular and poorly sorted. Cobbles occur in places. The pebbles and cobbles are embedded in a fine-grained matrix of light sandstone or dark siltstone.

Flow breccia resembles the felsite except that it consists of numerous irregular felsite fragments in a matrix of the same material. Its conglomeratic or brecciated texture can best be observed on glacially polished or artificially polished surfaces; elsewhere the rock resembles massive felsite.

Thickness.—The thickness of the Kineo volcanic member ranges from 0 to 4,000 feet. The thickness changes very rapidly, in some places by several thousand feet in less than a mile. These variations result from its volcanic origin.

Age.—The Kineo volcanic member is of uncertain age. Fossils occur only in the conglomerate, and those obtained thus far either are not diagnostic or are in pebbles that could have been derived from the Tarratine formation. The Kineo may be at least partly contemporaneous with the basal part of the main part of the Tomhegan formation.

The member is probably of early Onondaga age, as indicated by its relations with the associated main body of the Tomhegan, but it may be intermediate in age between the Tarratine formation and the main part of the Tomhegan formation.

Lower contact.—As exposures are few in the critical places, the actual contact of the Kineo with the Tarratine formation has been identified at only one locality, where flow breccia of the Kineo rests with apparent conformity on siltstone of the Tarratine formation. The volcanic rocks of the Kineo lie 500 feet above the top of the Misery quartzite member of the Tarratine formation.

Some of the conglomerate beds of the Kineo contain dark sandstone pebbles like those of the Tarratine and many other older Paleozoic formations of New England. One pebble has yielded fossils of Tarratine type.

The felsite beds on Heald Mountain (Spencer quadrangle) probably belong to the Kineo; their basal rhyolitic flow breccia lies directly on dark sandstone of the underlying Tarratine formation. The contact is sharp but is not intrusive. In the neighborhood numerous dikes of felsite cut the underlying Tarratine formation and may represent feeder dikes.

TARRATINE FORMATION

The Tarratine formation consists chiefly of interbedded dark sandstone, siltstone, and slate, but it contains the Misery quartzite member near the top of the formation in part of the mapped area and a sandy limestone unit, the McKenney Ponds limestone member, locally at the base of the formation. The type section of the Tarratine formation is along the right-of-way of the Canadian Pacific Railroad between Tarratine on the west side of Misery Ridge and Somerset Junction on the east side of the ridge (Brassua Lake quadrangle). The Tarratine formation is named here for the Tarratine railroad stop.

MAIN PART OF THE TARRATINE FORMATION

Lithology.—The main part of the Tarratine formation is almost entirely interbedded dark sandstone, slate, and siltstone. Sandstone makes up over 90 percent of the main body of the formation; it is well indurated, quartzite, and blue gray where fresh and dark brown to gray where weathered. Individual beds are fractions of an inch to 50 feet thick but do not have great lateral extent—none of them occur in more than a single outcrop, and some lense out within a single exposure. The sandstone consists of 50 to 80 percent fine- to medium-sand-size angular quartz grains, with a minor amount of feldspar, and the remainder are fine-grained silt and clay. Cross-bedding, ripple marks, pseudonodules, and shell lenses occur in a few places. Thin layers of slate are interbedded throughout.

The slate of the main part is gray to dark brown on weathered surfaces and dark gray where fresh. It is less resistant to weathering than the associated sandstone. Shell beds, which rarely extend more than a few tens of feet laterally, are more common in the slate than in the sandstone. Some of the shell beds in both the slate and sandstone are more than 6 inches thick, but most of them are thinner.

The siltstone of the main part is black on fresh surfaces and weathers rusty or gray to dark gray. It consists of about 20 to 30 percent angular quartz grains, with a small amount of feldspar. The rest of the rock is fine-grained dark silt and clay.

The lower part of the Tarratine formation, near the contact with the Seboomook formation, is thinner bedded and includes more slate interbeds than the upper part. The middle and upper parts of the main body between Enchanted Pond (Pierce Pond quadrangle) and Spencer Lake (Spencer quadrangle) are decidedly more massive, with some individual beds as much as 50 feet thick and many beds 10 to 20 feet thick. These thick beds form cliffs bordering Enchanted Pond and the slopes of Hedgehog Mountain (Spencer quadrangle). Rusty-weathering siltstone is most abundant in the upper part of the formation, particularly between the Misery quartzite member and the Tomhegan formation.

Thickness.—The Tarratine formation is as much as 10,000 feet thick. Two maximums occur, one near Enchanted Pond and the other near Big Duck Cove (North East Carry quadrangle), the first being about 10,000 feet and the second about 8,000 feet. Southeast and northwest of the trough of the Moose River synclinorium the Tarratine thins rapidly and intergrades with the Seboomook formation. Southwest of Spencer Lake and northeast from Big Duck Cove the formation also rapidly diminishes. These rapid changes in thickness are most striking at the northeast end of the synclinorium, where the 8,000-foot sequence near Big Duck Cove diminishes northeastward to 1,000 or 2,000 feet in about 3 miles, and northwestward to about 1,500 feet in about 3 miles as a result of lateral gradation into the Seboomook formation.

Age.—The Tarratine formation is characterized throughout by the brachiopod *Leptocoelia flabellites*, which in northern Maine is restricted to strata of Tarratine age, although elsewhere in North America it occurs in strata as young as the lower part of the Hamilton group.

The Tarratine contains three distinct faunal facies. Two are known to be of Oriskany age; the third is certainly late Early Devonian and is probably of Oriskany age also, because of its stratigraphic position. The three faunas, in any one section, are usually in a definite sequence, but boundaries between the faunas do not correspond to lithologic boundaries used in mapping. The fauna which normally occurs lowest is characterized by "*Chonetes*" *canadensis* and is proved to be of Oriskany age by the presence of *Beachia*. The middle fauna is characterized by the terebratuloid *Mutationella*, and the upper fauna by *Globithyris*. The two lower faunas contain many species in common, although the diagnostic species are generally not found together except near the boundary between them. At a few places near the boundary between the middle and upper faunas, species common to both are mixed.

Facies relations.—The rapid changes in thickness of the main body of the Tarratine formation cannot be explained by structure. They are closely related instead to a rapid lateral change in facies from dark sandstone of Tarratine lithology to cyclicly layered slate and sandstone of Seboomook lithology. Relations of the McKenney Ponds limestone member to the main body are described below. The Misery quartzite member grades laterally into dark sandstone of the main part.

Lower contact.—At one place the Tarratine grades into the locally underlying limestone of the McKenney Ponds limestone member, but at another the two units are sharply disconformable. The contact with the underlying Seboomook formation (fig. 17, northeast side) is completely gradational, and is placed where cyclicly layered slate and sandstone form more than 50 percent of the exposure.

MISERY QUARTZITE MEMBER

The Misery quartzite member is named here for Misery Ridge (Brassua Lake quadrangle), but the type section is at the northwest end of the railroad cut through Misery Ridge east of Tarratine, in the same quadrangle. The Misery quartzite member is a relatively thin unit of interbedded quartzite, dark sandstone, and slate which occurs near the top of the formation in about half of the area mapped. Where the member is present, it divides the Tarratine formation into an upper and lower part.

Lithology.—Quartzite probably makes up 30 to 50 percent of the total thickness, but its resistance creates the impression that its volume is much greater. The quartzite is light gray on both weathered and fresh surfaces and is cut by numerous small, randomly-directed veinlets of milky quartz. It consists of about 90 percent angular, fine- to medium-sand-size quartz grains with about 10 percent feldspar and slate grains. Most of the beds are about 2 to 5 feet thick, but laminae within the beds are very obscure. Cross-bedding occurs but is not prominent. Individual quartzite beds are lenslike; they thicken and thin very rapidly and cannot be traced more than short distances along the strike. The quartzite is stained red by hematite at a few localities. Some conglomerate is present which contains moderately well rounded pebbles about a quarter of an inch in diameter composed chiefly of quartzite, but partly of felsite and slate.

The dark sandstone, siltstone, and slate interbedded in the Misery quartzite member are like those of the main part of the Tarratine formation.

Thickness.—The Misery quartzite member ranges from 4 to about 500 feet in thickness, the maximum occurring in the southwest half of the synclinorium, particularly southwest of Parlin Stream (Long Pond quadrangle).

Age.—Fossils have not been found in the member, but it lies within the main part of the Tarratine formation, which is of Oriskany age.

Facies relations.—The Misery quartzite member is a facies of the upper half of the main part of the Tarratine formation. At Big Duck Cove (North East Carry quadrangle) one 4-foot bed of quartzite is present, and on the southeast shore of North Bay, east of Mount Kineo (Moosehead Lake quadrangle), there are two 4-foot beds of quartzite. Southwestward the quartzite thickens but is not continuous along the strike. Northeast of Parlin Stream the member has not been observed and is presumably absent. The quartzite is also absent southwest of Enchanted Pond, either because of nondeposition or because of removal before the extrusion of the rhyolite of Heald Mountain, which belongs to the Kineo volcanic member of the Tomhegan formation. Individual beds cannot be traced from one exposure to the next, but it appears that the quartzite of the member is a series of discontinuous lenses at about the same horizon.

Lower and upper contacts.—The Misery quartzite member grades into the main part of the Tarratine formation below and above.

McKENNEY PONDS LIMESTONE MEMBER

The McKenney Ponds limestone member is named here for McKenney Ponds, Upper Enchanted Township (Pierce Pond quadrangle). The type section is at the northeast end of the ponds.

Lithology.—The most abundant rock in this member is limestone, but calcareous arkose, conglomerate, slate, and dark sandstone also occur. The limestone weathers white, and rounded solution surfaces are formed. It is cut by steeply inclined joints filled with coarsely crystalline calcite and is massively and indistinctly bedded. It consists largely of pelmatozoan debris, but also contains a variable amount of noncalcareous clastic material that is chiefly poorly rounded quartz grains with a variable amount of feldspar grains. The limestone is relatively coarse grained, the grains being several millimeters in diameter.

The base of the member is arkosic. Northeast of McKenney Ponds the arkose contains 30 percent angular unweathered cream-colored feldspar fragments, with well-rounded frosted quartz grains about a millimeter in diameter and much calcareous cement. Similar arkose on the northwest side of McKenney Ponds contains about 20 percent shell debris, as well as quartz, feldspar, and a few pebbles of granitic and felsitic rocks.

The unit contains subordinate amounts of slate and dark sandstone. The slate and sandstone near the contacts with the main body of the Tarratine formation resemble those of the main body. Some of the slate farther away from the contacts weathers rusty; it contains nodules of marcasite, which weather to irregular voids, and rounded quartz and feldspar grains up to a quarter of an inch in diameter.

Thickness.—The member is as much as 200 feet thick in the McKenney Ponds area, but is thinner elsewhere.

Age.—The McKenney Ponds limestone member contains the brachiopods *Beachia* and *Hipparionyx*, both of which genera are known elsewhere only in strata of Oriskany age.

Facies relations.—Northeast and southwest of McKenney Ponds the limestone grades laterally into interbedded slate and arkosic dark sandstone belonging to the main part of the Tarratine formation.

Lower contact.—The arkose and slate at the base of the member rest in places on granitic rocks of the basement complex and in others on undifferentiated volcanic rocks of Silurian or Ordovician age. The contact of the granitic basement with the arkose was not accurately located because of the difficulty in distinguishing between indurated arkose and granite. Immediately above the contact with the underlying volcanic rocks the slate contains abundant pebbles of coarse felsitic and granitic debris derived from the underlying units.

SEBOOMOOK FORMATION

The name Seboomook slate was given by Perkins (1925, p. 374–375) to interbedded dark sandstone and slate exposed northwest of the Moose River group, with the name derived from Seboomook Dam (North East Carry quadrangle). It is now termed Seboomook formation because dark sandstone makes up a large part of it at many places, including the Seboomook Dam locality. A type section is now designated on the road and shore at the east end of Seboomook Lake (North East Carry and Seboomook Lake quadrangles) and on the Penobscot River (North East Carry quadrangle) for about a mile downstream from Seboomook Dam. Although incomplete, this is the thickest and best exposed structurally uncomplicated section of the formation known in this region.

The Seboomook formation also includes the cyclicly layered slate, dark sandstone, and dark volcanic rocks exposed southeast and southwest of the Tarratine formation in the trough of the Moose River synclinorium. The volcanic unit within the formation is the Camera Hill greenstone member, the type section for which is on Camera Hill (southwest quarter of the Spencer quadrangle).

Lithology.—The Seboomook formation consists almost entirely of cyclicly layered dark sandstone and slate. The cyclic layering resembles varves, and the sandstone layers grade upward into the slate layers. Weathered surfaces are gray, fresh surfaces are blue gray. The sandstone is lighter than the slate. The layers are fractions of an inch to several feet thick. Where the sandstone layers are thickest, the slate layers are thinner. The sandstone resembles that of the Tarratine formation.

At the base in the Little Big Wood Pond area (Attean quadrangle) is arkose with pebbles of granitic rocks and felsite, as well as cyclicly layered slate and dark sandstone. On the northwest arm of Moosehead Lake, beds about 10 feet thick contain scattered rounded pebbles of felsite and greenstone, as much as several inches in diameter, in a matrix of slate.

Thickness.—The formation is as much as 20,000 feet thick. About 10,000 feet is present in the type section; the remainder is in scattered exposures nearby. The original thickness before erosion of the upper beds is unknown.

Age.—Nearly all the fossils in the Seboomook formation occur within a mile of the Tarratine formation. The presence of *Beachia* indicates that the bulk of the Seboomook formation is of Oriskany age, but the uppermost part could be either Oriskany or early Onondaga. Many of the species in this formation are the same as in the Tarratine formation. The lower part contains fossils of New Scotland age at Beck Pond in slate and in a limestone lentil.

Perkins (1925, p. 375) cited the Silurian fossil *Monograptus* from the Seboomook formation, but the specimens have been mislaid and the present writer did not obtain additional material. The presence of the Hardwood Mountain formation of Late Silurian age beneath seemingly restricts the downward range of the formation into the Silurian, although a small part of it may possibly be Silurian.

Facies relations.—The Seboomook grades laterally into the Tarratine formation, the boundary between the two being where the cyclicly layered rock of Seboomook lithology exceeds the dark sandstone of Tarratine lithology.

Lower contact.—The formation rests unconformably on the basement complex, the Beck Pond limestone, the Hobbstown formation, and the Hardwood Mountain formation, but only the contact with the Beck Pond has been observed.

CAMERA HILL GREENSTONE MEMBER

Lithology.—The Camera Hill greenstone member is named here for Camera Hill in the central part of the southwest quarter of the Spencer quadrangle in Somerset County, Maine. It is felsite with scattered feldspar phenocrysts and some vesicles near the base. The rock is dark green where fresh, but weathers gray to rusty brown.

Thickness.—The member ranges from 0 to 400 feet thick.

Age.—The Camera Hill is of Oriskany age, as it lies above a faunule of that age within the Seboomook formation.

Facies relations.—The member consists of discrete bodies of dark volcanic material in the upper part of the Seboomook formation.

Lower and upper contacts.—The Camera Hill is probably conformable with the remainder of the formation, although the contacts were not observed.

FRONTENAC FORMATION

The term Frontenac formation was first employed by McGerrigle (1935, p. 74–77) for volcanic and sedimentary rocks of pre-Compton (=pre-Seboomook) formation age in Frontenac County, Quebec. Hurley and Thompson (1950, p. 838) suggested that the rocks exposed northwest of the outcrop belt of the Seboomook formation in Somerset County are probably a part of the Frontenac formation as used on the Canadian side of the international boundary. Albee (oral communication, 1959) also assigns these same rocks in Somerset County to the Frontenac formation.

The Frontenac includes more massive sandstone beds than the Seboomook and cyclic bedding is much rarer.

Lithology.—A great variety of rock types occur in the Frontenac formation of Somerset and Piscataquis Counties, Maine. The most frequent are gray to dark-green phyllite or slate and dark subgraywacke, which together constitute about 80 to 90 percent of the exposures studied. The remainder is largely made up of arkose and graywacke plus a minor amount of basalt and felsite.

The slate and phyllite are dark- to light-gray-weathering rocks. Medium- to fine-grained subgraywacke is commonly interbedded with the slate and phyllite. The subgraywacke interbeds are usually from a few inches to a few feet in thickness. Many exposures of slate and phyllite show no variation in grain size or composition which can be used to determine the attitude of bedding, indicating that the beds may be 10 feet or more in thickness.

The cleavage planes glitter due to the development of micaceous minerals parallel to the cleavage surfaces.

The bedding in the subgraywacke may be distinct, usually with thin-bedded layers of subgraywacke separated by layers of finer grained material, or indistinct, usually in the more massive exposures lacking fine-grained material. Crossbedding is rarely observed, graded bedding is seldom a feature, and ripple marks are unusual by contrast with the Seboomook and Tarratine. The grain size varies from fine to medium and individual grains are angular; the bulk of the rock, from 50 to 80 percent, is made up of quartz grains. The remainder of the rock is composed of 5 to 10 percent detrital feldspar grains; the whole is surrounded by a groundmass of fine-grained dark material.

The graywacke is composed of a great variety of materials, including fragments of basalt, felsite, slate, quartzite, and granitic rock. The composition and grain size of the graywacke is very variable; some is made up largely of sand-size material, whereas some includes many pebbles. The grains, whether large or small, are usually angular to slightly rounded. The material between the fragments of rock is made up of angular quartz and feldspar fragments with quartz usually forming 40 to 90 percent of the total, plus a variable quantity of fine-grained dark material whose nature cannot be determined in the field. Some of the graywacke includes up to 20 percent of calcareous materials. The color of the graywacke is usually light gray or white on the weathered surface, probably due to alteration of the feldspar which is commonly abundant. Fresh surfaces of the graywackes are usually dark gray.

The basalt of the Frontenac formation is dark green on the weathered surface. The rocks are a darker green in the fresh specimen than in the weathered specimen. Limonitic stains are found in the joints which cut the basalt. Pillow structure is present in some exposures of the basalt near Canada Falls Deadwater west of Seboomook Lake. Veinlets containing epidote and calcite commonly occur distributed throughout the basalt.

The felsite is white-weathering flinty rock. The color of the fresh felsite may be light or dark gray to black. Phenocrysts of quartz and feldspar are common in some of the felsite but absent in other parts.

Thickness.—The thickness of the Frontenac formation in northern Maine is not known. However, the breadth of outcrop and the variety of rock types exposed suggest that the Frontenac may be thousands of feet thick, and thus comparable to the other Silurian and Devonian rocks of Somerset County.

Age and correlation.—No fossils have been found in the Frontenac formation of Quebec and northern Maine. McGerrigle (1935) and Faessler (1939) both consider that the Frontenac formation is older than the Seboomook formation (=their Compton formation). However, Marleau (1958, p. 86–90) and Albee (oral communication, 1957) have shown that the Frontenac formation actually overlies the Seboomook formation. Its stratigraphic position above the Seboomook formation suggests at least partial equivalence with the Tarratine formation and therefore an early Devonian age.

Lower contact.—The contact between the Frontenac formation and the underlying Seboomook formation in the Seboomook and North East Carry quadrangles is probably gradational.

PARKER BOG FORMATION

The Parker Bog formation consists of interbedded gray felsite and gray limestone exposed at Parker Bog Ponds (northwest part of the southwest quarter of the Pierce Pond quadrangle) and extending southwestward as a narrow belt about 8 miles long. Its type section is at Parker Bog Ponds where the strata are vertical.

Lithology.—At Parker Bog Ponds, whence the formation is here named, it consists of interbedded light-gray limestone and white-weathering flinty felsite in beds a few inches to a few feet thick. The felsite is much jointed and fractured, but the limestone is not so jointed. It forms rounded solution surfaces and contains abundant pelmatozoan columnals in a very fine grained calcareous matrix. The felsite is gray, contains marine fossils, and is a water-laid tuff.

Thickness.—At the type section and below Gore Rapids (Spencer quadrangle) the formation is about 200 feet thick.

Age.—The Parker Bog formation underlies the Seboomook formation, of New Scotland to Oriskany age, and contains a leptostrophid brachiopod with socket plates and another brachiopod possibly belonging to *Eatonia.* The first indicates a pre-Onondaga age, but the second is suggestive of an Early Devonian rather than a Silurian age. Therefore, the formation is classified as of probable Early Devonian age.

Lower contact.—The formation lies conformably on undifferentiated strata of Silurian or Devonian age, as suggested by parallel bedding attitudes, but the actual contact has not been observed.

BECK POND LIMESTONE

The Beck Pond limestone is a heterogeneous assemblage of calcareous rocks exposed to the west and north of Beck Pond (east of the center of the Spencer quadrangle). The type locality is immediately west of the southern tip of Beck Pond, from which the limestone is named (Boucot, Harper, Rhea, 1959).

Lithology.—The Beck Pond limestone includes limestone, arkosic limestone, and limestone conglomerate. The limestones are light gray on fresh surfaces and weather to white solution-rounded surfaces. They consist largely of stromatoporoidal debris and form massive outcrops with very obscure bedding. The arkosic limestone is gray on fresh and weathered surfaces and contains many irregular quartz and feldspar grains, as well as granitic boulders up to 18 feet in diameter and resembling the basement complex. These stand out in high relief on weathered surfaces. Noncalcareous material makes up about 40 percent of the rock, and pelmatozoan debris about 60 percent.

The limestone conglomerate contains well-rounded cobbles of fine-grained gray limestone as much as a foot in diameter, as well as sand-size quartz grains and calcareous material, which fill the interstices.

Thickness.—The Beck Pond limestone is probably 100 to 200 feet thick.

Age.—The Beck Pond lies unconformably beneath the Seboomook formation, of New Scotland to Oriskany age, and above the basement complex, of pre-Upper Silurian age. The pure limestone contains *Nanothyris* cf. *N. subglobosa*, of New Scotland to Oriskany age. The arkosic limestone contains *Orthostrophia strophomenoides*, *Eatonia* cf. *E. medialis*, and *Eospirifer macropleura*, all of which suggests a New Scotland age. Thus part, and possibly all, of the Beck Pond limestone is of New Scotland age.

Lower contact.—The Beck Pond limestone probably rests unconformably on the basement complex.

HOBBSTOWN FORMATION

The Hobbstown formation, of conglomerate and arkose, overlies Upper Silurian strata of the Hardwood Mountain formation and underlies Lower Devonian strata of the Seboomook and Tarratine formations. It is here named from Hobbstown Township (northeast quarter of Spencer quadrangle) between Hardwood and Spencer Mountains. In the type area it includes a lower conglomerate member not present elsewhere.

Age.—The Hobbstown formation is of Late Silurian to Early Devonian age.

MAIN PART OF THE HOBBSTOWN FORMATION

Lithology.—The main part of the Hobbstown formation is mostly interbedded coarse-grained arkose and conglomerate with poorly rounded pebbles and cobbles. Both conglomerate and arkose are blue gray, gray, and dark green and weather white.

The clastic grains in the arkose and in the interstitial sand-size material of the conglomerate are fine to coarse quartz grains with 10 to 30 percent feldspar. They are mostly embedded in a dark fine-grained groundmass. Most of the pebbles and cobbles are granitic rocks from the basement complex. Most of the conglomerate contains some felsite, platy calcareous siltstone, and rounded limestone cobbles. The calcareous fragments resemble those in the Hardwood Mountain formation.

Thickness.—The Hobbstown formation is as much as 1,500 feet thick.

Age.—The only fossils that have been found in the main part of the Hobbstown formation are in pebbles of calcareous rocks derived from the underlying Hardwood Mountain formation. The formation underlies both the Seboomook and Tarratine formations, and it overlies the Hardwood Mountain formation. Its relation to the Beck Pond limestone is unknown. The Hobbstown formation is of Tonoloway (Late Silurian) to Oriskany (Early Devonian) age, and different areas of outcrop may be of widely different age within these limits.

Lower contact.—Generally, the main part of the Hobbstown formation rests unconformably on the basement complex. At one locality dark granitic rocks of the basement complex are overlain by arkose and conglomerate. The granitic rocks near the contact are massive; a few yards closer to the contact their joints are filled with silty debris; next there is a gradation into conglomerate consisting almost entirely of cobbles and boulders of dark granite similar to those below the contact, but including a few limestone cobbles. Within a few more yards, the strata consist entirely of coarse arkose.

The Hobbstown rests on the Hardwood Mountain formation at some localities and on the basement complex at others, and it is younger than a high-angle fault between the Hardwood Mountain and the basement complex.

LOWER CONGLOMERATE MEMBER

Lithology.—Fragments in the lower conglomerate member are a fraction of an inch to several feet in diameter, and most are well rounded. The felsite pebbles weather bone white; the granitic pebbles weather differentially, with the quartz grains standing out in relief from the chalky white feldspar. Fifty to seventy percent of the pebbles and cobbles are granitic, and most of the remainder are felsitic, except for a few of calcareous rocks similar to those of the Hardwood Mountain formation. Interstitial material is fine- to medium-grained quartzitic dark sandstone. Clastic grains in the sandstone are mostly angular, and include quartz and 10 to 15 percent feldspar. Between the sand grains is 10 to 30 percent of fine-grained dark silt.

Thickness.—The lower conglomerate member is as much as 200 feet thick, but it is absent outside the type area of the Hobbstown formation.

Age.—Fossils occur in a 4-inch bed immediately above the base. They are of Late Silurian age but may have been reworked from the Hardwood Mountain formation. The lower conglomerate member is thus at least of Tonoloway (Late Silurian) age but may be as young as the lower part of the Seboomook formation, of New Scotland to Oriskany (Early Devonian) age.

J. M. Berdan (written communication, 1956) reports the ostracodes *Mesomphalus* n. sp. and *Limbinaria?* cf. *L.? muricata* in the lower conglomerate member, these being closely allied to the ostracodes of the underlying Hardwood Mountain formation. The brachiopods *Schizoramma* aff. *S. hami*, *Atrypa* cf. *A. tennesseensis*, *Atrypa* cf. *A. arctostriata*, *Nanospira?* sp., *Delthyris* cf. *D. kozlowski*, and *Nucleospira* sp. are all similar to those in the Brownsport and Henryhouse formations of Tennessee and Oklahoma (Amsden and Boucot, 1958).

Lower contact.—The lower conglomerate member lies unconformably on the Hardwood Mountain formation. The actual contact is clearly exposed at one locality, where conglomerate overlies gray slate of the Hardwood Mountain formation with knife-edge sharpness and no evidence of gradation or structural disturbance; nevertheless, beds on both sides of the contact are parallel. The lower 4 inches of the Hobbstown formation at this locality is coarse granitic debris, shell debris, and fine-grained dark silt. An abrupt change must have occurred from the deposition of fine-grained material to coarse granitic and rhyolitic debris.

WHISKY QUARTZITE

The Whisky quartzite is coarse-grained and conglomeratic quartzite exposed in an eastward-plunging anticline on Deer and Sugar Islands in Moosehead Lake (Moosehead Lake quadrangle). It is named here for Whisky Island in an eastern embayment of Deer Island, and the type section is on the east side of Deer Island near Lambert Island, on the south limb of the anticline.

Lithology.—The Whisky quartzite is light brown where fresh and weathers white. Its surface is rough because of solution of the nonquartzose constituents. The quartz grains are moderately well rounded granules and pebbles, some as much as 1 inch in diameter, but most are about 2 mm. Much of the quartz is blue, like that in some of the Cambrian or Ordovician graywacke. Quartz grains comprise about 80 percent of the rock, the remainder being feldspar, felsite, slate, and fine-grained matrix. Sparse pelmatozoan columnals are scattered throughout the rock. The beds are a few to 20 feet or more thick and are well indurated.

Thickness.—The Whisky quartzite is about 200 feet thick.

Age.—No diagnostic fossils were found in the Whisky quartzite, but it is of Silurian or Early Devonian age. It lies below the Seboomook formation, of Devonian age, and above the unfossiliferous Capens formation and the undifferentiated strata of Silurian or Devonian age.

Lower contact.—On the east side of Deer Island the formation lies with sharp contact on the Capens formation. This contact may be a disconformity, or it may be due merely to the change in lithology from quartzite to slate.

CAPENS FORMATION

The Capens formation is interbedded red slate, green slate, and conglomerate exposed on Sugar Island, Deer Island, and the adjacent mainland in the Moosehead Lake area (Moosehead Lake quadrangle). The type section is between Capens and Lambert Island in the northeastern part of Deer Island, on the north limb of an anticline. The formation is here named for Capens.

Lithology.—Fine-grained and well-indurated red and green slates make up 90 percent of the outcrops and are either interbedded in layers a few inches to several feet thick or as units 10 to 20 feet thick.

Interbedded with the red or green slate is conglomerate, which consists of moderately well rounded pebbles in a matrix of angular to moderately well rounded quartz sand and fine-grained dark silt. The pebbles are of light-colored felsite, greenish felsite, quartz, limestone, and slate. The felsite pebbles resemble the undifferentiated volcanic rocks of Silurian or Ordovician age, the Kennebec formation, and the undifferentiated Cambrian or Ordovician.

Thickness.—The Capens formation is 200 to 400 feet thick on the east side of Deer Island.

Age.—The formation is of Silurian or Early Devonian age as it lies between the undifferentiated strata of Silurian or Devonian age and the Whisky quartzite, which is of Early Devonian or Silurian age.

Lower contact.—The Capens formation appears to be conformable on the undifferentiated strata of Silurian or Devonian age, with a transition zone a few feet thick between them.

UNDIFFERENTIATED STRATA OF SILURIAN OR DEVONIAN AGE

Beneath the Parker Bog, Capens, Seboomook, and Tarratine formations are unnamed calcareous slate, phyllite, sandstone, and limestone conglomerate whose precise ages and relations are unknown.

Lithology.—The most abundant rocks are calcareous phyllite and slate which weather brown and with a punky rind but are blue gray to dark gray where fresh. The calcareous material is almost entirely pelmatozoan columnals and other shell debris, segregated into lenses that grade laterally into slate or phyllite.

Calcareous sandstone and limestone conglomerate make up about 15 to 20 percent of the exposures. The sandstone contains much fine-grained poorly sorted angular to poorly rounded quartz grains and some shell debris and has a punky rind.

The limestone pebbles of the limestone conglomerate weather more readily than the slate or phyllite matrix, producing a pitted appearance.

Thickness.—The breadth of outcrop and attitude of the rocks of the unit indicate that its thickness is as much as 2,000 feet.

Age.—No diagnostic fossils have been found in the unit, but *Atrypa "reticularis"* shows that the beds are late Early Silurian or younger; they can be as young as the overlying Tarratine formation of Oriskany age.

Lower contact.—The unit probably lies unconformably on the Kennebec formation and rocks of Cambrian or Ordovician age.

LOBSTER LAKE FORMATION

Calcareous sedimentary rocks on the shore of Lobster Lake (southeast quarter of North East Carry quadrangle) were termed the Lobster Lake series by Toppan [2] but are here called the Lobster Lake formation. The type section is on the north side of Lobster Lake, from the north end of the arm of the lake known as Big Claw to the unnamed point just north of Sunset Point. The lower part of the formation consists of red sandstone, red slate, and red conglomerate and is here termed the Big Claw red-bed member. Its type section is on the east shore of the lake at the northeast end of Big Claw.

Age.—The Lobster Lake formation is of Silurian(?) and Silurian age.

MAIN PART OF THE LOBSTER LAKE FORMATION

Lithology.—The main part of the Lobster Lake formation is calcareous siltstone, calcareous sandstone, calcareous slate, limestone conglomerate, and limestone. The calcareous siltstone and sandstone weather buff with an outer tan punky rind, but are blue gray when fresh. Beds are a few inches to a few feet thick. The sandstone contains 10 to about 50 percent coarse to fine angular quartz grains and abundant fossil fragments (chiefly pelmatozoan columnals). The siltstone contains less than 20 percent angular quartz grains and consists mainly of fine-grained dark silt. The calcareous slate weathers buff, with a punky rind resembling that of the siltstone and sandstone, and consists of fine-grained blue-gray clay.

[2] Toppan, F. W., 1932, The geology of Maine: Union College master's thesis.

The limestone conglomerate consists of irregular limestone pebbles in a groundmass of siltstone. The limestone fragments are blue gray where fresh and are darker than the gray weathered surfaces of the enclosing siltstone. Weathering produces a pitted surface. The limestone, gray on weathered surfaces and blue gray on fresh surfaces, is relatively massive and obscurely bedded. It consists largely of stromatoporoidal debris, with some fine- and medium-grained clastic debris.

Thickness.—The Lobster Lake formation is as much as 4,000 feet thick, but it is completely beveled by erosion that preceded deposition of the overlying Seboomook formation.

Age.—The main body of the formation contains the tetracoral *Tryplasma* (J. M. Berdan, 1956, written communication) and *Halysites*, which indicates that it is of Silurian age. Elsewhere in the northern Appalachians *Tryplasma* and *Halysites* occur together only in beds of Late Silurian age.

Lower contact.—The contact of the main part with the Big Claw red-bed member has not been observed. Beds on either side of the contact zone are parallel.

BIG CLAW RED-BED MEMBER

Lithology.—The Big Claw red-bed member is named here for Big Claw arm of Lobster Lake, southwest quarter of Ragged Lake quadrangle and southeast quarter of North East Carry quadrangle, Maine. The type locality is on the east side of Big Claw arm west of the northern part of Big Island. The member consists of red quartzite, red sandstone, red slate, and red conglomerate, with a small amount of gray sandstone. The basal bed of the member, 3 to 4 inches thick, consists of about 50 percent milky quartz, 20 percent red phyllite derived from the adjacent underlying Cambrian or Ordovician rocks, and 30 percent gray and greenish felsite, which may have been derived from rocks of Silurian or Ordovician age. The fragments are $1/8$ to $1/4$ of an inch in diameter, with a few larger phyllite fragments. The fresh rock is light tan, poorly indurated, and includes 10 to 20 percent fine-grained matrix.

Overlying the basal bed are red quartzite and red sandstone in massive beds a few feet to 5 feet thick. The red color is due to finely dispersed hematite, but medium-size particles of specular hematite are also scattered throughout the rock. The quartzite contains 70 percent angular quartz grains.

The conglomerate contains poorly rounded to angular pebbles of quartz and felsite and a few pebbles of phyllite.

Thickness.—The Big Claw red-bed member is 200 feet thick.

Age.—The member is unfossiliferous. It rests with angular unconformity on phyllite of Cambrian or Ordovician age and is below the main body of the Lobster Lake formation, which contains Silurian fossils in its middle part. Thus the Big Claw is of Silurian age.

Lower contact.—On the east-central shore of Lobster Lake the Big Claw member rests with angular unconformity on reddish phyllite of Cambrian or Ordovician age. The contact has a relief of several inches in one outcrop; a 4-inch bed of the conglomerate lies immediately above, followed by red sandstone and quartzite. The steeply dipping cleavage of the underlying phyllite is truncated by the Big Claw red-bed member. No contact with the undifferentiated volcanic rocks of Silurian or Ordovician age on the southwest shore of Lobster Lake was observed.

HARDWOOD MOUNTAIN FORMATION

The Hardwood Mountain formation is Upper Silurian calcareous siltstone, limestone conglomerate, and slate that occurs in Somerset County; the type area is a mile southwest of Hardwood Mountain, Hobbstown Township (Spencer quadrangle). No complete, well-exposed, uninterrupted section is known. The formation is here named.

Lithology.—The Hardwood Mountain formation is a heterogeneous assemblage of fine- to medium-grained quartz- and feldspar-rich calcareous clastic rocks, with some impure limestone. The most abundant rocks are calcareous mudstone and siltstone; coarser rocks are less common but include a striking limestone conglomerate made up of pebbles of limestone in a matrix of calcareous siltstone or mudstone. In the type area calcareous siltstone and mudstone form 60 percent of the unit, limestone conglomerate 10 percent, calcareous slate 20 percent, limestone 5 percent, and medium-grained sandstone 5 percent.

The calcareous siltstone and mudstone is blue gray but weathers dark brown; it forms massive 2- to 5-foot beds with little cleavage. Successive layers contain variable amounts of calcareous material which weathers to different depths, giving some exposures a ribbed appearance. The siltstone and mudstone are fine to medium grained and contain 10 to 50 percent poorly rounded or angular grains of quartz with a little feldspar and 10 to 20 percent pelmatozoan fragments in a matrix of fine-grained dark silt. They contain lenses of quartz, feldspar, and limestone pebbles.

The limestone conglomerate is prominently exposed but constitutes only about 10 percent of the unit. It forms massive outcrops in which bedding is very obscure. On weathering, the limestone pebbles dissolve and leave pits as much as an inch deep and an inch to several inches across. The matrix is fine- to medium-grained calcareous siltstone and weathers buff. Proportions of pebbles and matrix are highly variable. In places the pebble beds grade laterally into limestone from which they were derived.

The limestone beds of the Hardwood Mountain formation are massive and irregular and are largely stromatoporoidal debris interspersed with tetracorals. Irregular layers and stringers of noncalcareous debris and slate occur throughout.

The sandstone of the formation consists largely of angular quartz grains, with 5 to 15 percent feldspar and small pebbles of granitic rocks from the basement complex. Variable amounts of calcareous matrix are present. Weathered surfaces are light brown and porous.

Thickness.—The formation is now as much as 3,000 feet thick, but its top has been deeply eroded.

Age.—The Hardwood Mountain formation contains the ostracodes *Dibolbina*, *Limbinaria*, and *Dizygopleura* cf. *D. costata*, characteristic of the Tonoloway limestone, and *Mirochilina*, which indicate a Late Silurian age (Berdan, written communication, 1956). The formation also contains the trilobite *Encrinurus* and the chain coral *Halysites*, which preclude a Devonian age.

Facies relations.—From southwest of Baker Pond to Jim Pond the lower part of the Hardwood Mountain formation consists of about 50 feet of very punky weathering light-colored calcareous siltstone overlain by limestone conglomerate and limestone. Southwest of Hardwood Mountain, the lower part of the formation consists of coarse-grained clastic calcareous arkosic sandstone. The remainder of the formation is a mass of calcareous siltstone, mudstone, limestone, limestone conglomerate, and slate.

Lower contact.—Relations of the Hardwood Mountain formation to the basement complex have not been directly observed, but rocks near the contact were observed at four localities. At one the basement is adjoined by impure limestone of the Hardwood Mountain. At another the base of the Hardwood Mountain is arkose containing granitic debris similar to that of basement-complex exposures nearby. At still others a basal yellow-weathering siltstone occurs about 50 feet above the gneissic basement complex. There is no indication that rocks of the basement complex intrude the Hardwood Mountain.

At one locality the Hardwood Mountain formation overlies volcanic rocks of Silurian or Ordovician age, but with undetermined relations.

Rocks assigned to the Hardwood Mountain formation in the Little Big Wood Pond area (Attean quadrangle) are more calcareous than those to the south. The Silurian rocks in the Attean quadrangle contain an average of about 30-percent impure limestone, far more than those to the south.

VOLCANIC ROCKS OF SILURIAN OR ORDOVICIAN AGE

Volcanic rocks occur beneath strata of Silurian and Devonian age at 3 localities on the northwest side of the synclinorium and at 1 locality on the southeast side, but they are too poorly known to be given formal names.

Lithology.—They include both light and dark volcanic rocks. Massive volcanic rocks in the Pierce Pond quadrangle are green where fresh, light green where weathered, and contain feldspar phenocrysts (about 60 percent), rounded quartz phenocrysts (about 10 percent), and dark minerals (about 5 percent), in a fine-grained groundmass.

North of Baker Pond (Spencer quadrangle) are light-violet volcanic rocks which weather rusty and with a thin rind of white material. They are relatively massive and include beds of medium-grained tuff with a fine-grained groundmass and about 5 percent each of feldspar and quartz phenocrysts.

In Jim Pond Township (Chain Lakes quadrangle) the volcanic rocks include light-yellowish felsite and dark greenstone. The felsite weathers chalky white and contains variable percentages of quartz and feldspar phenocrysts in a fine-grained greenish groundmass. Veinlets of epidote and calcite are common in the greenstone.

The volcanic rocks in the wide band southeast of the Silurian and Devonian rocks in the trough of the synclinorium in Piscataquis County are light to dark felsite, tuff, agglomerate, and dark greenstone. The felsite is flinty to granular, with abundant quartz and feldspar phenocrysts, and weathers chalky.

The dark greenstone is light to dark green but weathers rusty to dark brown. Some contains phenocrysts of white feldspar and greenish ferromagnesian minerals, and some is aphanitic. Bedding is poorly developed in the agglomerate, but the tuff is evenly bedded in layers a few inches to a few feet thick. A few marine fossils occur at one locality.

Thickness.—The thickness of these volcanic rocks in Piscataquis County is unknown. If the scattered exposures of tuff and agglomerate on Moosehead Lake constitute a continuous sequence, they are about 10,000 feet thick, but this cannot be proved.

The thickness of these volcanic rocks in Somerset County is likewise unknown, but their width of outcrop suggests that they may be a few thousand feet thick.

Age.—The age of the volcanic rocks in Piscataquis County is uncertain. The oldest well dated beds above them are in the Lobster Lake formation, which contains Silurian fossils near the middle. A few pelmatozoan columnals and a single pedicle valve of a dalmanellid brachiopod occur in agglomerate of the volcanic rocks on the southeast side of Jackson Cove on Lobster Lake. The brachiopod suggests an age within Middle Ordovician and Late Silurian limits. The volcanic rocks are relatively unsheared in contrast to the badly sheared rhyolitic tuffs of the Middle Ordovician Kennebec formation on the southwest side of Moosehead Lake. They may therefore be younger, although they might include some rocks of the same age.

In Somerset County the volcanic rocks underlie strata of Silurian and Devonian age. No fossils have been found nor has it been proved that all of them are contemporaneous. Their unmetamorphosed condition suggests that they are much younger than the basement complex.

Lower contact.—The base of the volcanic rocks in Piscataquis County is unknown, but in Somerset County they lie with marked difference in degree of metamorphism on the basement complex.

KENNEBEC FORMATION

The Kennebec formation is massive felsite and rhyolite tuff of Middle Ordovician age near Somerset Junction (Brassua Lake quadrangle). The type locality is a quarter of a mile northeast of Somerset Junction on the northwest side of an abandoned railroad right-of-way on the northwest side of the west branch of the Kennebec River. The formation is here named for that river.

Lithology.—Fresh surfaces of the rhyolite tuff and felsite are olive drab, and weathered surfaces and rind are white. The felsite is flinty, with a conchoidal fracture, and the more massive parts contain pyrite. Both the tuff and massive felsite contain abundant quartz phenocrysts. The tuff is poorly sorted and consists of irregular fragments of felsite, quartz phenocrysts, and much silt. The fine-grained layers are metamorphosed to phyllite whose cleavage planes are coated with platy minerals.

Thickness.—The thickness of the Kennebec formation is unknown but is probably a few hundred to a thousand feet.

Age.—The formation contains the brachiopod *Valcourea*, of Middle Ordovician age.

Lower contact.—Basal relations and relations to the Cambrian or Ordovician rocks are unknown.

CAMBRIAN OR ORDOVICIAN ROCKS

An assemblage of slate, phyllite, graywacke, dark sandstone, light and dark volcanic rocks, and carbonate rocks southeast of the Silurian and Devonian strata in the synclinorium is here assigned to the Cambrian or Ordovician.

Lithology.—Slate and phyllite make up 50 to 70 percent of the rocks in this unit, dark sandstone and graywacke 20 to 30 percent, and light and dark volcanic rocks the remainder. Some carbonate rocks are also present.

The slate and phyllite are fine grained, with glittering micaceous minerals parallel to the cleavage. Most of the slate is dark gray and dark green, but some is black and some is interbedded red and green.

The dark sandstone and graywacke are fine to medium grained, massive, and poorly bedded. Beds are 6 inches to several feet thick. The rocks are blue gray where fresh and weather either lighter or darker. The graywacke contains 5 to 10 percent pebbles of slate, quartzite, and dark sandstone, and 50 to 80 percent angular to poorly rounded sand-size feldspar grains, the remainder being fine-grained dark silt. The sandstone contains no pebbles, and the quartz grains are better sorted. Both sandstone and graywacke are well indurated, and most sedimentary structures have been obliterated.

The light and dark volcanic rocks are associated in many places. These are flinty, with a rind of white chalky material, and contain feldspar and quartz phenocrysts. The dark-green volcanic rocks consist of chalky feldspar crystals interlocked with ferromagnesian minerals. Weathered parts are crumbled and iron stained.

Some light-gray argillaceous limestone beds occur in the unit.

Thickness.—The thickness of these rocks is unknown, but they may be tens of thousands of feet thick.

Age.—No fossils have been found in these rocks. On the east shore of Lobster Lake their reddish phyllite beds are overlain unconformably by the Lobster Lake formation, which contains fossils of Silurian age. Near Somerset Junction the phyllites lie near the Kennebec formation of Middle Ordovician age, but the relations are unknown. These rocks are probably of pre-Silurian age, as is indicated by the unconformity at Lobster Lake and their association with strata that are known to be Middle Ordovician, but they are probably not as old as Precambrian. They are here considered to be Cambrian or Ordovician.

BASEMENT COMPLEX

In western Somerset and northern Franklin Counties the oldest rocks are a basement complex consisting predominantly of regionally metamorphosed granite and gneiss, which were not studied in detail. There are also many bodies of amphibolite in the area. Woodard (1951, p. 76) termed the amphibolite on Spencer Mountain (Spencer quadrangle) the Spencer Mountain basics, but in this report the amphibolite is included in the basement complex, to which no formational name is given.

Lithology.—The basement complex contains both granite and gneiss. The granitic rocks weather to dark-gray rough surfaces, with jagged quartz grains projecting above the depressions caused by weathering of feldspar or dark minerals. The fresh granite is pink, gray, or dark green. Some fine-grained granite and aplite occurs, but about three-quarters is medium to coarse grained and contains 30 to 40 percent quartz, 50 to 60 percent feldspar, and lesser amounts of dark accessory minerals.

Associated with the gneiss are muscovite schist, metaquartzite, calc-silicate rock, metaconglomerate, and amphibole. The gneissic rocks are dark, medium grained, and strongly foliated by growth of parallel micaceous minerals. The gneiss contains 30 to 40 percent quartz and 50 to 60 percent feldspar, the remainder being dark minerals.

Age.—The basement complex is overlain unconformably by fossiliferous Silurian and Devonian strata. On the east side of Jim Pond (Spencer quadrangle) the highly metamorphosed basement complex is separated from slightly metamorphosed Cambrian or Ordovician rocks by a narrow strip of Silurian rocks about 600 feet wide. The differences in degree of metamorphism occurring within this small area suggest that the basement complex is older than the Cambrian or Ordovician rocks and may be Precambrian.

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