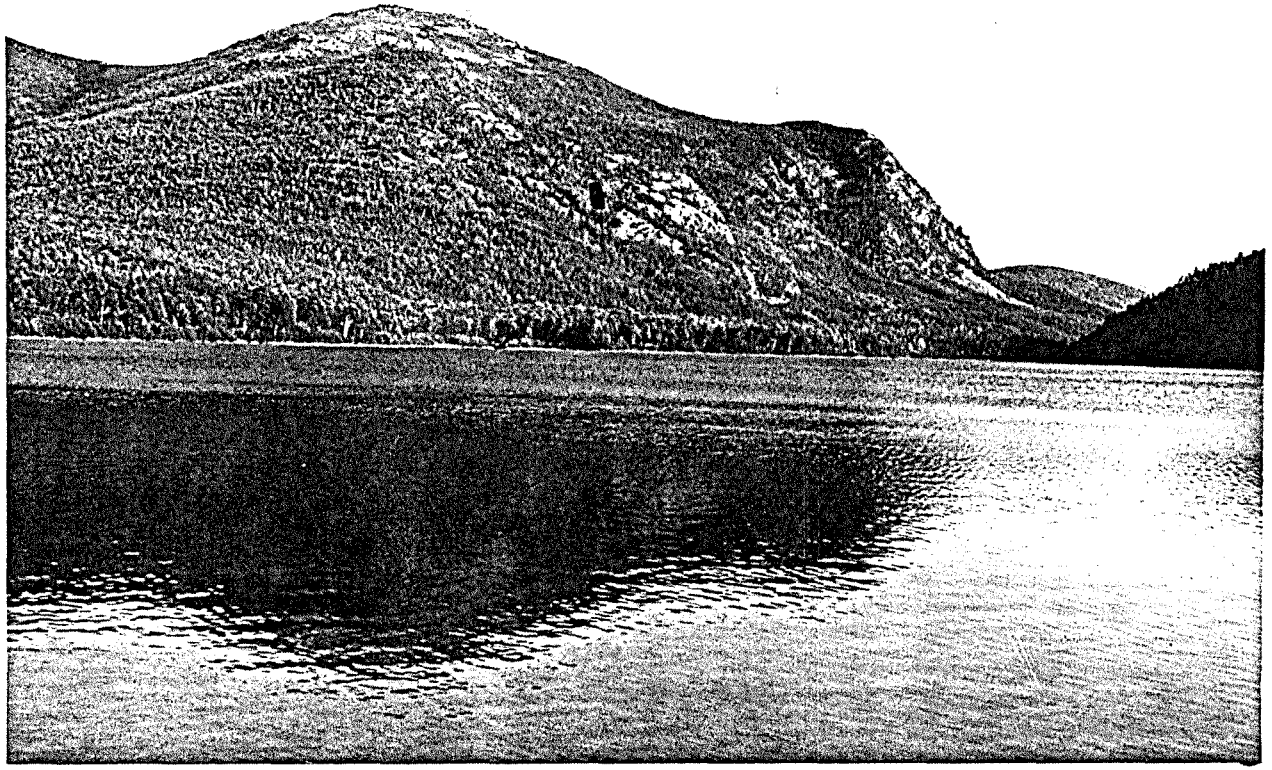
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Geology of the Katahdin - Traveler area, Maine

Rankin, Douglas W.

1961
Harvard University PhD. dissertation



Pinnacle Ridge of Traveler Mountain from South Branch Ponds campsite.

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BEDROCK GEOLOGY OF THE KATAHDIN-TRAVELER AREA, MAINE

A thesis presented

by

Douglas Whiting Rankin

to

The Division of Geological Sciences

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Geology

Harvard University

Cambridge, Massachusetts

May, 1961

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ABSTRACT

Cambrian or Ordovician, Ordovician, Silurian, and Devonian volcanic and clastic sedimentary rocks, with an aggregate thickness of more than 23,000 feet, underlie about 65 percent of the Katahdin-Traveler area, Maine. The stratified rocks are in the chlorite zone of regional metamorphism and were deformed during the Middle or Late Devonian Acadian orogeny into a major southwest plunging synclinorium, the Matagamon synclinorium. The deformed stratified rocks have been intruded by the post-tectonic Katahdin granite, probably of Late Devonian age.

The oldest rocks in the area are tightly folded varicolored slates, quartzites, and grits of Cambrian or Ordovician age. These are overlain with probable unconformity by Middle Ordovician olivine basalt and the basalt is, in turn, unconformably overlain by coarse clastic rocks of Early Silurian age. Practically the only carbonate rocks in the area are thin (300±feet) carbonate-rich siltstones of Middle Silurian age.

This study is focused upon the Lower Devonian rocks, particularly upon the Traveler felsite. The oldest Devonian rocks are a monotonous series of graded beds of dark-colored slate and minor sandstone of the Seboomook formation. These are overlain by about 4500 feet of rusty weathering, cross-laminated sandstone and minor slate of the Matagamon formation.

The Traveler felsite covers about 70 square miles and has an estimated volume of about 70 cubic miles. It is the largest of a chain of Lower Devonian felsite bodies in central Maine, and one of the largest bodies of extrusive felsites in the world. The felsite has been divided into a lower Pogy member, consisting largely of welded tuff, an upper Black Cat member, consisting largely of lava. Typically the Pogy member contains quartz, calcic andesine, and altered mafic silicate phenocrysts; the andesine has structure characteristics of the low thermal modification. Typically the Black Cat member contains calcic andesine, ferraugite, and biotite phenocrysts; the andesine has structure characteristics of an intermediate thermal modification. To a first approximation, the Traveler felsite is isochemical and is believed to have been erupted in a short interval of time. These relationships could be explained by a decrease in the volatile content of the magma during the course of the eruptions. Because of the presence of welded tuff, it is believed that the bulk of the felsite was erupted subaerially. It is also believed that a large caldera was formed during and after the eruption of the felsite.

Clastic rocks of the Trout Valley formation, the youngest stratified unit in the area, unconformably overlie the Traveler felsite. This formation includes at its base, a coarse felsite conglomerate lentil, the Gifford

conglomerate lentil. Early terrestrial plant fossils occur abundantly in the formation. These, other fossils in the Trout Valley formation, and character of the rocks suggest that much of the formation was deposited in shallow brachish water, perhaps adjacent to an eroding volcanic island.

The Katahdin granite, a perthite, plagioclase, biotite granite, covers the entire southern third of the area of study. The granite exposed here is part of a large batholith, which extends to the southwest nearly 30 miles beyond the area of study. On the upper part of Mount Katahdin, the granite becomes pink, vuggy, and has a granophyric texture. This probably indicates proximity to the roof of the magma chamber. If so, the roof of the magma chamber appears to have been nearly flat in the vicinity of Mount Katahdin.

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CHAPTER I

INTRODUCTION

LOCATION

The Katahdin-Traveler area covers about 300 square miles in Penobscot and Piscataquis Counties, north-central Maine, (fig. 1). It includes most of the Traveler Mountain quadrangle (latitude 46°00' to 46°15' N, longitude 68°45' to 69°00' W) and portions of the Katahdin, Shin Pond and Telos Lake quadrangles. The area extends from Baxter Peak of Mt. Katahdin on the south to the northern border of the Traveler Mountain quadrangle on the north and from Nesowadnehunk Lake on the west to Bowlin Pond and the Bowlin Pond Road on the east, (fig. 2). The region between Matagamon Lake and the northern border of the Traveler Mountain quadrangle is included on the geologic map (plate 1), but has been covered by reconnaissance only. Most of the area included from the Katahdin quadrangle also has not been mapped in detail.

TOPOGRAPHY AND DRAINAGE

Figure 2 is a simplified map of the topography and drainage of the Katahdin-Traveler area. The major part of this area consists of a rugged, isolated mountain mass containing three of the six highest mountains in Maine.

The maximum relief in the area studied is 4,860 feet. The mountains lie entirely between the East and West Branches of the Penobscot River.

The western and southern slopes of the mountains are drained by tributaries of the West Branch of the Penobscot River. The most important of these are Sandy Stream and Nesowadnehunk Stream, which rises from Nesowadnehunk Lake (1,372 ft.). The West Branch flows past the mountains in a southeasterly direction outside the area of investigation. The northwestern, northern and eastern slopes of the mountains are drained by the East Branch of the Penobscot and its tributaries, a major one of which is Trout Brook. Trout Brook flows east-northeast along the northwestern end of the mountains into Matagamon Lake (654 ft.), the largest lake in the area. The East Branch flows into the northwest end of the lake and continues south-southeast parallel to the eastern flank of the mountains (figs. 3 and 10). A few miles north of the mountains, Webster Brook flows eastward into the East Branch at the head of Matagamon Lake. The brook is a tributary of the East Branch, but because of the "Telos Cut," carries far more water. (See p. 8). Most of the central portion of the mountains is drained by a large tributary of the East Branch, Wassataquoik Stream, which rises in The Klondike, a high isolated basin west of Mt. Katahdin.

The mountain mass is surrounded on all sides by much lower rolling land, Perkin's (1925) dissected Moosehead Plateau (figs. 3 and 4). The dissected plateau has an average elevation which slopes from 1200 feet on the northwest to 700 feet on the southeast. The average relief of the dissected plateau is 200 feet. The low, rolling land of the plateau is almost entirely underlain by sedimentary rocks, except for a large area south of Mt. Katahdin which is underlain by granite. Igneous rocks, where present, usually form hills such as Wadleigh Mountain north of Trout Brook. North and east of the mountains, low ridges are typically parallel to the strike of the stratified rocks. Because of this, the structure is well displayed on some of the aerial photographs, noteably of Hay Mountain along the western borders of the Shin Pond quadrangle (fig. 5) and of T.6N.,R.9W. north of Wadleigh Mountain.

The mountains form a great kidney-shaped mass around the broad upper Wassataquoik Valley (fig. 9). This crescent is almost cut in two by the 1000-foot deep gap that contains Wassataquoik Lake (1,377 feet) (fig. 6). The higher mountains of the southern half are underlain by granite; the lower ones to the north by felsite.

The southern group culminates in Baxter Peak of Mt. Katahdin (5,267 feet), the highest mountain in Maine,

and the dominating topographic feature in the region (fig. 7). Katahdin is an elongate north-south mass with steep sides which on the south rise 4700 feet above the West Branch of the Penobscot River five miles away. The broad, gently rolling top known as the Table Land slopes from Baxter Peak to Russell Mountain (2801 feet), almost five miles to the north.[1] Hamlin Peak (4751 feet), the crest of a 500-foot hill on the Table Land north-northwest of Baxter Peak, is the second highest mountain in the state. Former mountain glaciers have cut numerous spectacular cirques into the steep slopes leading up to the Table Land. The deepest of these cirques, South Basin, has walls 2,000 feet high (fig. 8).

Turner Mountain (3323 feet) lies east of Katahdin across a deep north-south valley. On the west, the Katahdinauguoh Mountains, also known as the Nesowadnehunk Mountains, form a curving mountain wall that almost encloses the Klondike and continues north to Wassataquoik Lake. North Brother (4,143 feet), the highest peak in this group, is the sixth highest peak in Maine.

The northern group of mountains, known as the Deadwater Mountains,[2] is dominated by Traveler Mountain,

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[1]Regretably the term Table Land is usually applied only to that portion of the rolling plateau which is above timerline.

[2]There appears to be no precise delineation of

a large sprawling mass with generally northwest trending ridges extending five miles from South Traveler Mountain (2677 feet) north-northwest to Little Peaked Mountain (1940 feet).

The highest point in the mass is The Traveler (3541 feet), which rises 3000 feet above the East Branch of the Penobscot River 3.7 miles away. Other prominent peaks along the eastern front of the Deadwater Mountains are Horse Mountain (1589 feet), with its 600 foot cliff of felsite facing Matagamon Lake, and Bald Mountain (2333 feet), a conical peak with a precipitous 1000 foot escarpment facing the East Branch (figs. 10 and 12).

West of Traveler Mountain is a deep north-south valley containing South Branch Ponds (frontispiece) and Pogy Notch (1200 feet). This valley, together with the valley separating Mt. Katahdin from Turner Mountain forms a prominent lineament. The mountains west of Pogy Notch

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the Katahdinauguoh, Nesowadnehunk, and Deadwater Mountains. The name Katahdinauguoh has been applied to the entire mountain mass between the East and West Branches of the Penobscot River, as well as to the range west of Katahdin. The name Nesowadnehunk seems best interpreted as applying to those mountains visible from Nesowadnehunk Lake or Stream. The name, therefore, may have originally included Katahdin. The writer, however, is not using it in this sense. The name Deadwater Mountains seems best interpreted as applying to these peripheral mountains visible from Matagamon Lake. (See Thoreau, The Maine Woods, arranged with Notes by D. C. Lunt, 1950, p. 197). This would exclude Pogy Mountain and the Katahdin group.

present no obvious pattern. The highest of this group is North Pogy Mountain, (2830 feet). In the extreme western portion of the area studied, two relatively isolated peaks, Strickland Mountain (2390 feet) and Center Mountain (2902 feet) rise above Nesowadnehunk Lake.

The forest cover of the region is varied. Average timberline on Katahdin is 4000 feet. No other mountain in the area except Fort Mountain extends above timberline although many have bare, rocky summits. There are densely wooded areas of both hard and soft woods, including several stands of virgin black spruce in ravines on Traveler Mountain. Most of the area, however, has been lumbered or devastated by at least one of three great forest fires which burned several hundred square miles in 1884, 1903, and 1916. Failure of the forest cover to return accounts for the large number of bare summits and the unusual bareness of the southern slopes of many of the Deadwater Mountains, (fig. 13).

In general, outcrops are fairly abundant. Bed rock is well exposed along the walls of the cirques of Katahdin, along many streams, around the shore of Matagamon Lake, and throughout most of the burned land in the Traveler Mountain quadrangle. Outcrops are particularly poor on the Tableland, on the wooded slopes of mountains underlain by granite, in the upper Wassataquoik Valley,

in the vicinity of Nesowadnehunk Lake, and low on the east flank of Traveler Mountain. Unfortunately, many of the important formation contacts are located in these areas.

CULTURE

The Katahdin-Traveler area lies within the eastern portion of the Maine Woods. There are no towns, settlements, active farms or paved roads within the area. The only through road is the dirt road from Patten to Greenville. Because there is a total of only 65 miles of driveable road, access to much of the area is difficult. The nearest towns are Patten which is 20 miles by road from Hay Lake and Millinocket which is 24 miles from Avalanche Brook in the southeast corner of the area.

The only economic activities are recreation, lumbering, and water storage. Most of the area studied lies within Baxter State Park, Maine's largest park, which included 193,000 acres in 1959. Within the area studied the state maintains four patrolled camp sites open to the public from May 15 to October 15. Outside the park, where hunting as well as fishing is permitted, there are four privately operated sporting camps.

Lumbering within the immediate area studied has largely ceased, as more and more land has been purchased for the park by former Governor Percival P. Baxter.

Periodic cutting, mostly of saw logs, continues north and east of the Park, but the last major "cut" was in 1955-56 on land formerly belonging to the Eastern Corporation in T.5N., R.10W. There are, however, many old tote roads, decaying dams, and stumps throughout the area. The open fields of Trout Brook Farm, first cleared in 1837, Black Brook Farm and McCarty Field are the remains of old hay farms. The East Branch Drive, last held in 1946, was one of the most famous in Maine lumbering history. In 1841 a canal, the Telos Cut, was dug from the head of the Telos Lake to an old river channel which drains into Webster Lake (Barrows and Babb, 1912; Avery, 1937). A dam at the foot of Chamberlain Lake brought the large Allegash Lakes into the East Branch drainage system. Lumbering in the upper Wassataquoik Valley dates back to 1841 (Avery, 1929). Reportedly, 30 dams were required to bring saw logs down from Wassataquoik Lake to the East Branch.

The East Branch is currently part of the water storage system of the Bangor Hydroelectric Company. The company maintains a steel and concrete dam, built in 1941, at the foot of Matagamon Lake.[3]

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[3]Water backed up from the dam has flooded the low-lying, 2-mile long area, known as the Thoroughfare, which formerly separated Matagamon Lake from Matagamonsis or Second Lake. At low water, it is again only a channel between two lakes.

The State Forest Service maintains two seasonal lookout towers, Horse Mountain, built in 1913, and Burnt Mountain, built in 1924. The District Headquarters is at Hay Lake.

PREVIOUS WORK

Because of the relative inaccessibility of all of the area prior to 1920 and much of the area at present, and because of the absence of adequate base maps until 1955, all previous geologic work was of a reconnaissance nature. Many of the early published accounts of the Katahdin-Traveler area are by geologists or naturalists. These early accounts centered primarily upon Mt. Katahdin, the outstanding feature of the region, and the rivers, the only plausible routes of travel.

The earliest account of the geology of Mt. Katahdin is by J. W. Bailey (1837), whose party in 1836 ascended the mountain from the West Branch of the Penobscot. Bailey reported granite ledges in the West Branch, diluvial fossiliferous limestone fragments on the slopes of the mountain, and reddish granite on the summit.

The following year, 1837, C. T. Jackson (1838) ascended the mountain via Bailey's route and also noted that Mt. Katahdin was composed entirely of granite.[4]

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[4]Jackson's ascent was made on September 23 in

Subsequently, Jackson continued up the East Branch and the Seboois River, recording that the principal rocks were argillaceous blue-green slate, siliceous clay slates and interbedded "grau-wacke." It is interesting to note that the relationship between cleavage and bedding was unknown to Jackson. At Grindstone Falls on the East Branch, Jackson observed, "It is remarkable that "grau-wacke" beds do not coincide with the fissile layers of slate but dip in an opposite direction." (ibid., p. 22)

In 1857, H. D. Thoreau (The Maine Woods, arranged with Notes by D. C. Lunt, 1950) reported low parallel asymmetrical rock ridges in the vicinity of Grand Pitch along Webster Brook. He was also impressed by the similarity in appearance between Horse Mountain and Mt. Kineo, thus unwittingly making the first recorded correlation.

In 1861 a scientific party headed by C. H. Hitchcock, geologist, and E. Holmes, naturalist, made the first extensive reconnaissance of northern Maine. The results of the survey were published the same year along with the first geologic map of northern Maine (Holmes and Hitchcock,

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a snow storm. He measured the barometric pressure on the summit with a mercury barometer and later calculated the elevation to be 5300 feet. This was the first attempt to measure the elevation of Mt. Katahdin and for many years, the most accurate.

1861). Hitchcock obtained a commendable grasp upon the stratigraphy along the East Branch and Matagamon Lake. He reported trap rock at Pond Pitch and correlated it with the trap rock on Lunksoos Mountain. He correctly dated the fossiliferous sandstone at Stair Falls as Oriskany age and also dated the fossiliferous limestone at Marble Pond (Horse Shoe Pond) as belonging to the "Lower Helderberg group of Upper Silurian rocks" (ibid., p. 403). He correlated the latter with the fossiliferous limestone at Ripogenus Lake. Following contemporary concepts (Williams, 1894), Hitchcock classed the felsite of the Deadwater Mountains, as well as that of Mt. Kineo, as hornstone, or siliceous slate. Concerning their origin he states, "These slates would seem to be the alteration of the sandstone, unless there has been a great dislocation of the strata, for the sandstone layers do not seem to have been disturbed at all by them." By 1874, however, he recognized the igneous nature of the felsite on Mt. Kineo, and presumably also of the Traveler felsite, although he did not specifically refer to the latter (Hitchcock and Huntington, 1874).

C. E. Hamlin (1881) recognized, as had Hitchcock before him that the upper portion of Mt. Katahdin is composed of reddish granite, while the bulk of the mountain is composed of gray granite. Hamlin also noted the high

percentage of xenoliths in certain unspecified portions of the granite. M. E. Wadsworth (in Hamlin, 1881) described 5 thin sections of the Katahdin granite.

The discovery by W. W. Dodge (1881 and 1890) of a Norman's Kill (sic) assemblege of graptolites in black shales near the mouth of the Wassataquoik Stream was one of the major contributions to the geology of the area. In 1933, a further collection was made from the Wassataquoik locality by E. S. C. Smith. Smith's collection and the earlier ones by Dodge were studied by R. Ruedemann (1935) who also concluded a Normanskill age.

In 1905, O. O. Nylander made a number of fossil collections from sandstones along the East Branch above Haskell Deadwater and along Matagamon, Webster, and Telos Lakes. These collections were studied by J. M. Clarke (1909) who concluded that the entire sequence was of Oriskany age and correlated it with the Moose River sandstone of the Moosehead Lake region. On a geologic map, included in Clarke's Memoir, the Deadwater Mountains are indicated as being composed of "igneous rocks."

E. S. C. Smith published a series of short papers from 1928 to 1932 concerning the Traveler region. In 1928 he suggested that the conglomerate at Haskell Rock Pitch on the East Branch was a tillite. In subsequent papers (1928b and 1932), Smith dated the Grand Falls formation

(Ruedemann and Smith, 1935) as Lower Cambrian on the basis of impressions of Oldhamia, a presumed calcareous alga. He also recognized the presence of an unconformity between the Grand Falls formation and Clarke's Moose River sandstone at Stair Falls. In 1930 Smith published the first paper specifically recognizing that the Deadwater Mountains are composed of felsite. In this and other papers, he noted the existence of a discontinuous belt of rhyolitic rocks in central Maine.

In a Master's Thesis at Union College, Toppan (1932) reported further on the felsites of The Traveler, estimating their areal extent to be 100 square miles. Although he did not actually visit the locality, he proposed a correlation between Hitchcock's vertical slates along Webster Stream and Perkins' (1925) Seboomook slate. He also reported a Niagaran age for the Chesuncook limestone of Ripogenus Gorge on the basis of contained fossils dated by W. Goldring. B. Willard (1945) further amplified upon the palentology of the Chesuncook limestone.

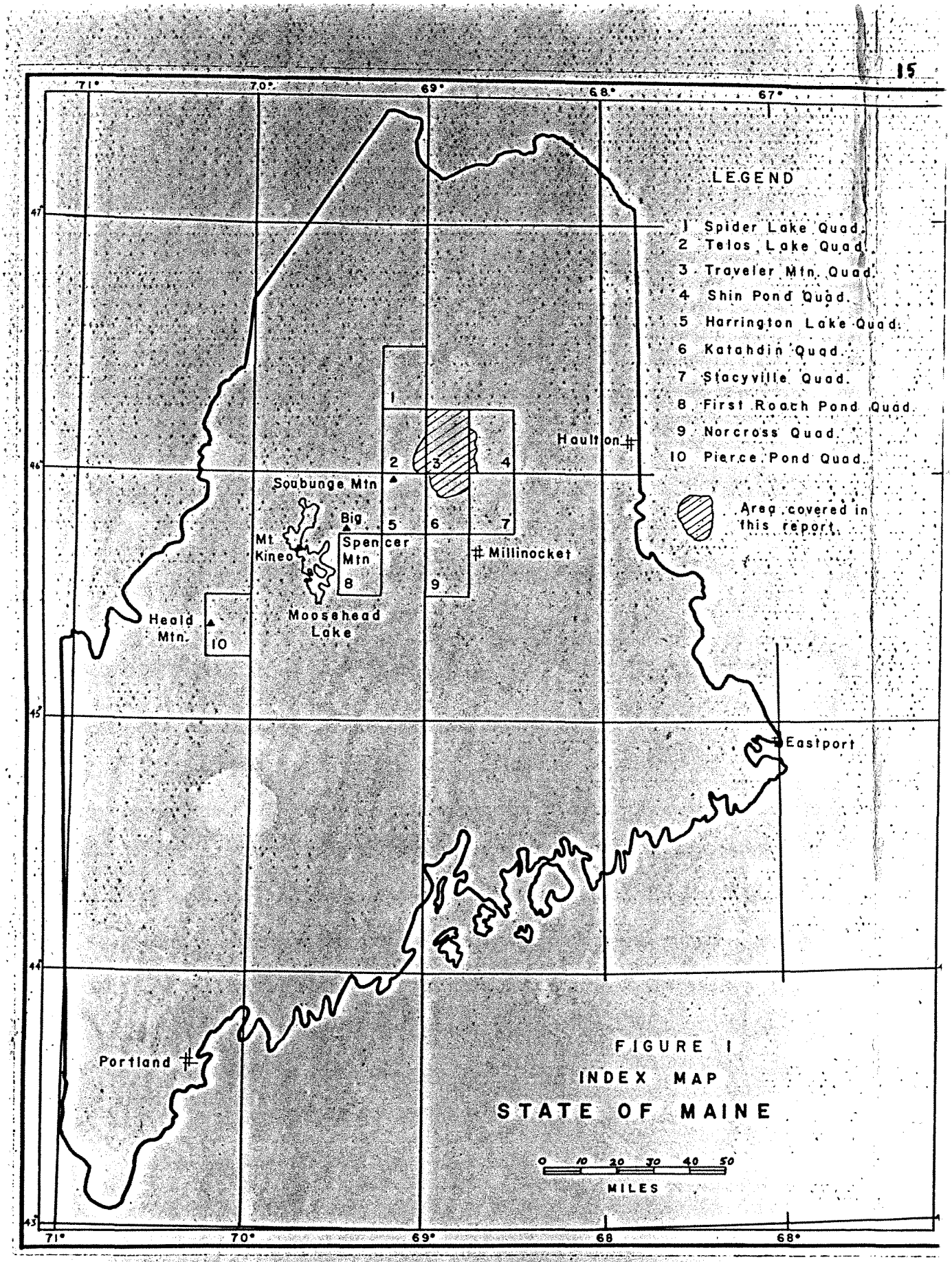
Boucot (1953 and 1961) unraveled the structural and stratigraphic details of the Moosehead Lake region. This comprehensive work has been most helpful in the present study. The following year, Boucot (1954) demonstrated on the basis of regional structure and paleontology that the Katahdin granite must be of post-Early Devonian

age. Subsequently, Lyons et al (1957) published lead-alpha age determinations of zircon from the Katahdin granite at Ripogenus Gorge. They obtained ages of 316 and 320 million years.

Field mapping is currently in progress or has just been completed in the following three adjoining Quadrangles: Harrington Lake, Andrew Griscon, U. S. Geol. Surv.; Shin Pond, Robert Neuman, U. S. Geol. Surv.; and Spider Lake, Bradford Hall, Yale University. Neuman (1960) has published a brief summary of the pre-Silurian stratigraphy of the Shin Pond and Stacyville quadrangles.

REGIONAL GEOLOGIC SETTING

The Katahdin-Traveler area, north-central Maine, is part of the northern Appalachian Mountain system (north of New York City) in which the stratified rocks are folded and are predominately of Paleozoic age. In northwest and north-central Maine, the stratified rocks are a heterogeneous sequence of clastic sedimentary rocks and volcanic rocks, interbedded with minor carbonate rocks. There is some evidence that the older rocks were affected by the Taconic Orogeny. (See Boucot, 1961). Most of the conspicuous structural features, however, are the result of the Acadian orogeny, which is thought to have occurred in this region in the Middle Devonian (Boucot, 1954). In a very general way, the structural features produced by the


71°
70°
69°
68°
67°
47°
46°
45°
44°
43°
LEGEND
1 Spider Lake Quad.
2 Telos Lake Quad.
3 Traveler Mtn. Quad.
4 Shin Pond Quad.
5 Harrington Lake Quad.
6 Katahdin Quad.
7 Stacyville Quad.
8 First Roach Pond Quad.
9 Norcross Quad.
10 Pierce Pond Quad.
Area covered in this report.
Houlton
Soubunge Mtn
Big
Mt Kineo
Spencer Mtn
Millinocket
Moosehead Lake
Heald Mtn.
Eastport
Portland
FIGURE 1
INDEX MAP
STATE OF MAINE
0 10 20 30 40 50
MILES

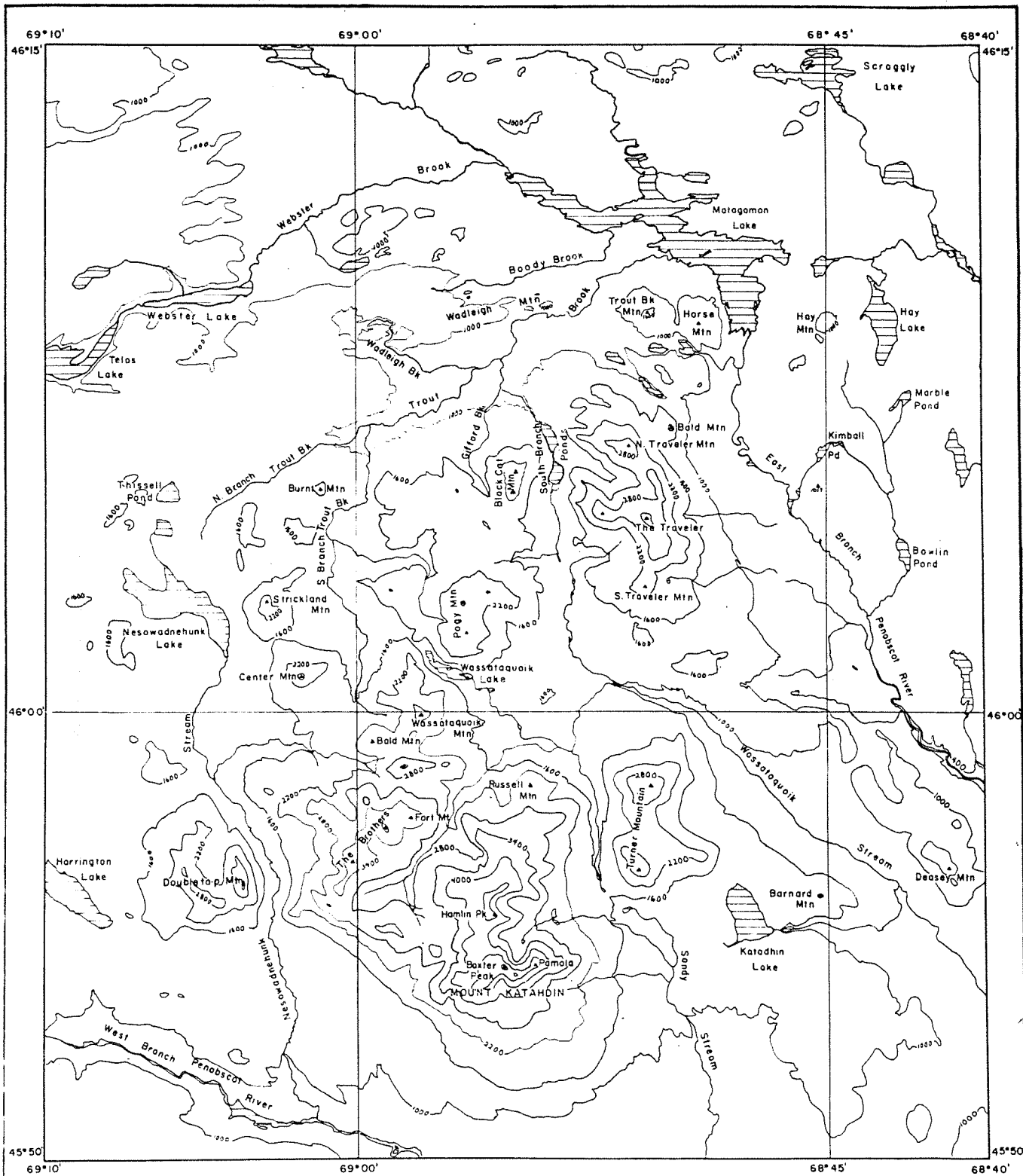


FIGURE 2

TOPOGRAPHIC FEATURES OF THE KATAHDIN—TRAVELER AREA, MAINE

0 1 2 3 MILES

CONTOUR INTERVAL 600 FEET (LOWEST CONTOUR LINE AT 400 FEET)

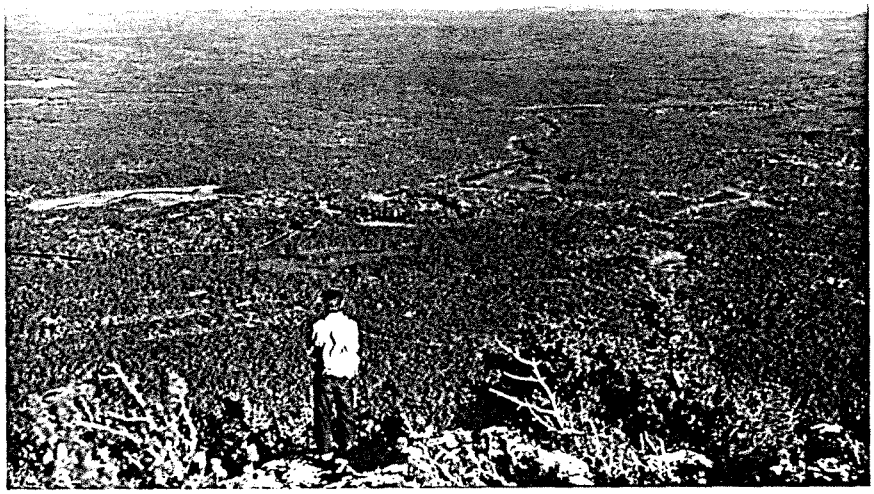


Figure 3. The dissected Moose River Plateau and the valley of the East Branch Penobscot River seen from Bald Mountain, looking east. The Oxbow on the East Branch is visible in the middleground.



Figure 4. The dissected Moose River Plateau and Nesowadnehunk Lake seen from Strickland Mountain, looking southwest. Much of the lower elevations are underlain by sedimentary rock. The major mountains are, left to right, Big Spencer, Little Spencer, and Soubunge. Big Spencer and Soubunge are held up by felsite of the same age as the Traveler felsite.

Figure 5. Aerial photograph showing low ridges parallel to the strike of rocks of the Matagamon formation on Hay Mountain. North is to the top of the page. The bodies of water near the top are, left to right, Matagamon Lake (Deep Cove), Hay Pond and Hay Lake. Grand Lake Road crosses the bottom of the picture. Strata of the Matagamon formation may be seen to wrap around the northeast end of Hay Mountain basin in the upper left. Approximate scale, 1:31,680.

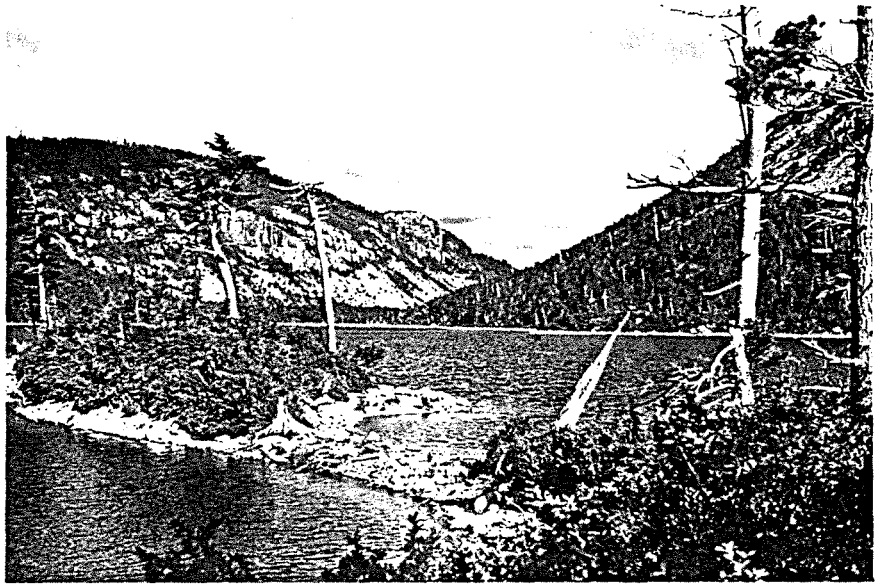


Figure 6. Wassataquoik Lake, looking west. The whiter outcrops in the far left distance are Katahdin granite. The large cliffs in the left center are the Pogy member, Traveler felsite.



Figure 7. Mount Katahdin from South Turner Mountain. Pamola and Baxter Peak are on the left, Hamlin Peak is on the right. The cirques visible in the picture from left to right are South Basin, Great Basin, and North Basin.

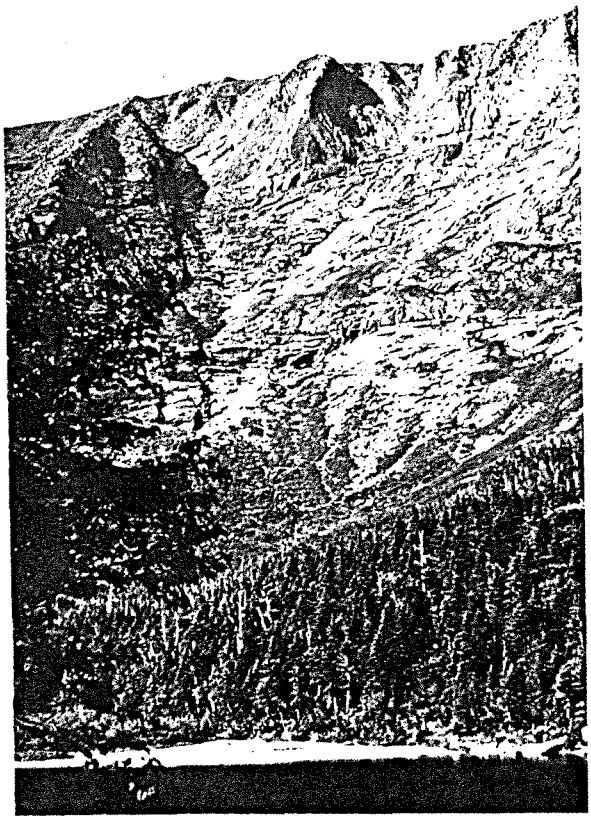


Figure 8. Headwall of South Basin, Mt. Katahdin from Chimney Pond (2900'). Baxter Peak (5267') at right edge of photograph. The zone in which xenoliths are abundant is near the bottom of the outcrops. Above this zone, the granite is the Pamola facies.

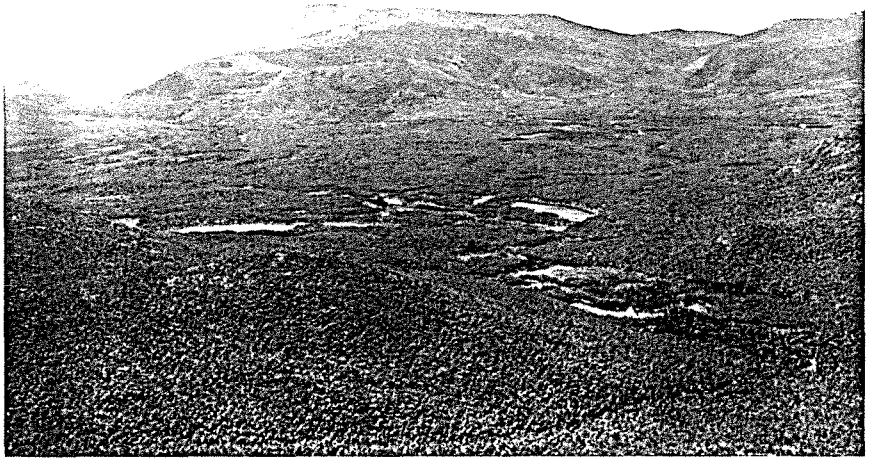


Figure 9. Mt. Katahdin from Pinnacle Ridge, Traveler Mountain. In the middleground is the broad upper valley of the Wassataquoik Stream.

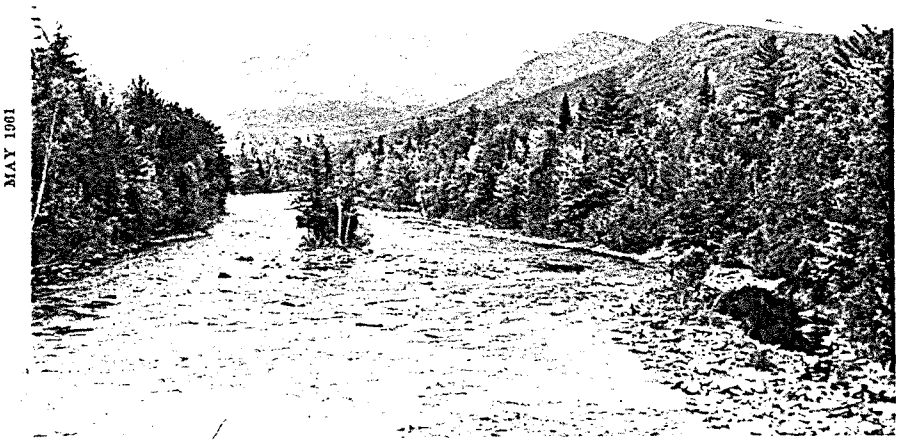


Figure 10. The Deadwater Mountains: The Traveler, Bald Mountain and Billfish Mountain from Grand Lake Dam at the foot of Matagamon Lake. The East Branch of the Penobscot River is in the foreground. North Traveler Mountain shows over the right shoulder of Billfish Mountain.



Figure 11. The Deadwater Mountains: Billfish Mountain, Bald Mountain and North Traveler Mountain seen from Wadleigh Mountain.

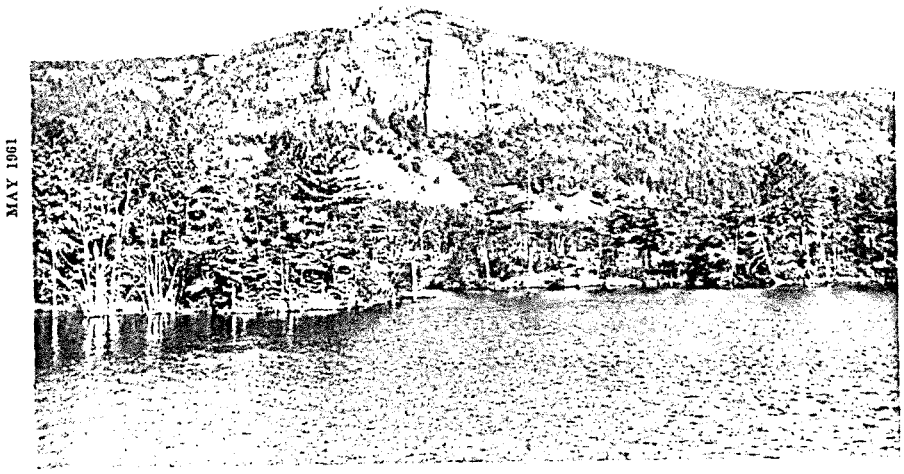


Figure 12. Horse Mountain from the cabin near Grand Lake Dam, showing 600 foot cliff of felsite. The Matagamon formation is exposed at the base of the cliff. Matagamon Lake in the foreground.

Acadian orogeny in northwestern and north-central Maine, may be described as northeast trending synclinoria and anticlinoria. Stratified rocks younger than Oriskany age are preserved only in the troughs of a few of the synclinoria. The present study has demonstrated the existence of one such synclinorium in the Katahdin-Traveler area. The axis of the synclinorium strikes east-northeast, paralleling the valley of Trout Brook, and plunges slightly southwest. This synclinorium, called the Matagamon synclinorium is on strike with the better known Moose River synclinorium situated some 40 to 50 miles to the southwest.

Felsic volcanic rocks in the Moose River synclinorium rest upon marine sediments of Oriskany age (Boucot, 1961). These felsite bodies are relatively small and have never been studied in detail. Marine sediments of Schoharie age overlie the felsite (Boucot, oral communication, March 1961). In the Matagamon synclinorium, a similar stratigraphic sequence has been found except that the felsite forms a much larger and thicker unit and that the Lower Devonian sediments which overlie the felsite apparently were deposited in a brackish-water, near-shore environment. Along strike to the northeast of Traveler Mountain the nearest sediments of Schoharie age occur in the Matapedia Valley, Quebec, about 170 miles distant, and contain marine fossils (Boucot, oral communication). There are no Lower

Devonian felsites in this area of the Matapedia Valley.

PURPOSE AND SCOPE OF STUDY

The primary purpose of this study is to determine the stratigraphy and structure of the Katahdin-Traveler area and to prepare a geologic map. At the outset of the study, no detailed mapping had been done in northern Maine between Moosehead Lake and the manganese deposits of Aroostook County near Houlton. In the last few years there has been considerable interest in northern Maine. The present study plus those in progress or recently completed by other workers will result in the mapping, on a scale of an inch to a mile, of a nearly continuous belt from New Hampshire to the New Brunswick border.

Included in the Katahdin-Traveler area is probably the largest and thickest felsite in the eastern United States and one of the larger in the world. (See Smith, 1961, fig. 3). An estimated 70 cubic miles of felsite were erupted during a short time interval in the Early Devonian. Much of the present study is centered upon these felsites which include both lava flows and welded ash flows. To the writer's knowledge, this is the first field study of welded ash flows in the eastern United States.

A portion of a granite batholith occupies a considerable part of the southern portion of the Katahdin-Traveler area. Because this granite in an adjacent area

is being described in detail by Andrew Griscom, only the major features of the granite are covered in this report.

METHOD OF STUDY

Field work in the Katahdin-Traveler area occupied about three weeks during the summer of 1958 and eight months during the summers of 1955, 1956, and 1957. Topographic quadrangle maps of the United States Geological Survey (scale 1:62,500 enlarged to a scale of approximately 1:31,680) and aerial photographs (approximate scale 1:31,680 and 1:15,840) served as field maps. Unfortunately, during the first two summers of mapping, only preliminary editions of the Telos Lake and Traveler Mountain quadrangles were available. The provisional edition, with 50 foot contour intervals, of the Telos Lake quadrangle became available in the summer of 1957. It was less than satisfactory for mapping in that wooded terrain of low relief. The final edition, with 20 foot contour intervals, was not available until the fall of 1960. Various combinations of topographic maps, aerial photographs, and an aneroid barometer were used to plot field data. Formation boundaries and other pertinent data were ultimately placed in true horizontal position on the appropriate quadrangle maps. Very high altitude, small scale aerial photographs (approximately 1:71,730) were found extremely useful in suggesting structure when used in conjunction with field observation.

Laboratory investigations were carried out during portions of the winters of 1955-60. Three hundred and fifty thin sections were examined, optical determinations were made, especially upon the plagioclase phenocrysts of the felsite, and a considerable amount of X-ray diffraction study of both minerals and rocks undertaken. Three chemical analyses were made by J. Ito of Harvard University.

LOCATION OF POINTS

When desirable to refer to sample or outcrop locations and topographic names are inadequate, the system of locating points is modified from that of J. C. Green (1960). Each five minute ninth of a quadrangle is given a letter symbol as indicated in the diagram below.

NW	NC	NE
WC	C	EC
SW	SC	SE

If this letter symbol is without prefix, the point in question is in the Traveler Mountain quadrangle. If the letter symbol is prefixed by other letters, the point in question is in one of the other quadrangles. The prefixes used are as follows: TL for Telos Lake, SP for Shin Pond, and K for Katahdin. Numbers following the letter symbol give the location of the point in tenths of inches east

from the west edge of the ninth, and, after a hyphen, tenths of inches north from the south edge of the ninth. For example, the location of the Forest Service Camp at Hay Lake, west-central ninth of the Shin Pond quadrangle, is SPWC 14-31. Where more precise locations are desired, a third digit representing hundreths of an inch is used. The sample numbers, prefixed by either KT or KR, should not be confused with the location symbol.

ACKNOWLEDGEMENTS

The writer wishes particularly to thank Professors Marland P. Billings and James B. Thompson of Harvard University under whose guidance this work was carried out. They both freely contributed advice and criticism, and their aid is reflected in all aspects of this study.

Dr. Robert Neuman and Andrew Griscom of the U. S. Geological Survey, mapping in adjacent areas, contributed many valuable ideas in discussions of mutual problems. Professor Arthur J. Boucot of the Massachusetts Institute of Technology furnished insights into questions of the regional geology of Maine. Neuman, Boucot, Professor Erling Dorf of Princeton University, Dr. Jean Berdan of the U. S. Geological Survey and Professor Elso Barghorn of Harvard University very kindly examined fossils from the Katahdin-Traveler area and contributed much needed paleontological knowledge. Dr. Robert L. Smith and Roy

Bailey of the U. S. Geological Survey gave helpful suggestions on the identification and origin of welded tuffs.

Summers of field work were made easier and more enjoyable by the assistance of William Powers, William Sabin, and my father, Carl S. Rankin. Numerous fellow graduate students, by their criticisms both acid and base, provided much stimulation and many helpful ideas.

The Department of Mineralogy and Petrography at Harvard University supplied the thin sections studied and chemical analyses by Dr. Jun Ito. Field expenses incurred during the summers of 1955, 1956 and part of that of 1957 were defrayed by grants from the Robert W. Sayles Fund for Field Geology at Harvard University. Thanks are also due the Maine Geological Survey for assistance received while the author was in its employ during the summer of 1957 and part of 1958. Frequent use was made of various equipment, particularly aerial photographs, kindly provided by American Smelting and Refining Company. Helpful assistance was also received from the Appalachian Mountain Club. The supervisor of Baxter State Park, Helon Taylor, and the park rangers frequently gave much appreciated personal aid. Great Northern Paper Company and Bangor Hydroelectric Company generously permitted the use of their private roads and camps in the area. Laboratory research after the

completion of field work was most materially aided by a grant from the Committee on Natural Sciences at Vanderbilt University for the purchase of a research model petrographic microscope and an Abbe refractometer.

The hospitality of the local people was ever appreciated. In particular, warm thanks are extended to Pat and Mildred Steen of Grand Lake Dam and Robert and Dorothy Laverty of Millinocket whose friendship and interest did so much to make the summers pleasant.

Finally, the author wishes to express his deep gratitude to his wife, Mary Louise, who served ably as his field assistant for one full summer and parts of two others, did much of the drafting, helped to improve the literary style of the manuscript, and gave encouragement throughout the course of the study.

CHAPTER II

STRATIFIED ROCKS

GENERAL STATEMENT

With the possible exception of some mafic dikes, all of the rocks in the Katahdin-Traveler area are of Lower and Middle Paleozoic age. The rocks include a thick sequence of volcanic and clastic sedimentary rocks that has been intruded by the post-Acadian Katahdin granite, forming a large batholith, only a small portion of which is within the area studied.

The stratified rocks, which have a total thickness of about 23,000 feet, belong to the Cambro-Ordovician, Ordovician, Silurian, and Devonian systems. Fossils have been found within the area studied in the Silurian and Devonian sedimentary rocks. Fossils of questionable status have been found in the Cambro-Ordovician rocks, and the Ordovician rocks are dated by correlation with fossiliferous Ordovician rocks in adjacent areas. Included among the stratified rocks are clastic sedimentary rocks (pelites, sandstones, and conglomerates), very minor calcareous sedimentary rocks, basalts, and felsites. These rocks have been assigned to seven mappable units of formation rank. The sedimentary rocks are within the chlorite zone of regional metamorphism.

A generalized stratigraphic section is presented in table 1. The type localities of all but the Seboomook formation are found within the Katahdin-Traveler area. The Traveler felsite, which is the thickest and most extensive stratified unit in the area, will be described in much greater detail than the rest of the rocks.

CAMBRIAN OR ORDOVICIAN

"GRAND FALLS" FORMATION

NAME: Ruedemann and Smith (1935, p. 354) proposed the name Grand Falls formation for the thick series of slates and sandstones "exposed for several miles along the Grand Falls of the [East Branch of the] Penobscot River in Penobscot County." The usage of "Grand Falls" to refer to the combined series of five major falls of the East Branch in T. 5 N., R. 8 W. is confusing because one of the five falls is named Grand Pitch (fig. 19). The naming of the formation the Grand Falls formation is unfortunate because younger rocks crop out at the upper two falls (Haskell Rock Pitch and Pond Pitch) and because, as Neuman (1960) has pointed out, the name was preoccupied.

DISTRIBUTION: The "Grand Falls" formation crops out over several square miles in the southeast portion of the area studied. Excellent exposures are to be found

Table 1. Stratigraphic Sequence in the Katahdin-Traveler Area, Maine

Age	Name		Description	Thickness (in feet)
	North of Trout Brook	Southeast of Trout Brook		
Early Devonian	Trout Valley formation		Dtv: light-blue-gray to black shale, siltstone, and lithic graywacke; granule and pebble felsite conglomerate; some sideritic ironstone. Dtvg: Gifford conglomerate lentil; cobble and boulder felsite conglomerate with very minor lithic graywacke and black shale.	1500+
	UNCONFORMITY			
Early Devonian	Traveler felsite		Dense, flinty, dark-bluish-gray, dark-greenish-gray or black felsite containing a few percent small phenocrysts. Dtfb: Black Cat member; plagioclase, biotite, and clinopyroxene phenocrysts; mostly lava; minor welded tuff and laminated tuff. Dtfp: Pogy member; quartz, plagioclase, and altered mafic silicate phenocrysts; mostly welded tuff, minor lava and tuff.	0-9000±
	Matagamon formation		Dm: Medium-bluish-gray or medium-greenish-gray, rusty weathering, very fine- to medium-grained sandstone, commonly cross-laminated interbedded with minor darker slate.	0-4500±

Table 1 (Continued)

Age	Name		Description	Thickness (in feet)
	North of Trout Brook	Southeast of Trout Brook		
Early Devonian	Seboomook formation		Ds: Graded beds of medium- to dark-bluish-gray slate and very-fine-grained, light-gray lithic graywacke; slate predominates.	4000±
Silurian (some late Silurian	Silurian, undifferentiated		Su: Greenish-gray siltstone, greenstone and fossiliferous red and green tuff.	?
Middle (?) Silurian		Limestone	Clean, light-gray, coarsely crystalline limestone. Not found in outcrop.	?
		Carbonate-rich siltstone	Scs: Thin bedded, light-blue-gray calcareous and/or dolomitic siltstone; some rocks contain calcareous nodules.	300±
Early Silurian		Kimball Brook formation	Skbh: Haskell Rock conglomerate; massive pebble and boulder conglomerate. Skb: gray and greenish-gray slate, siltstone, and lithic graywacke intercalated with thin beds of conglomerate and slate-chip breccia; some calcareous double conglomerate	2500±
UNCONFORMITY				

Table 1 (Continued)

Age	Name		Description	Thickness (in feet)
	North of Trout Brook	Southeast of Trout Brook		
Middle Ordovician		Pond Pitch basalt	Opp: Dark-greenish-gray olivine basalt; rare pillow structure	2000±
UNCONFORMITY				
Cambrian or Ordovician		"Grand Falls" formation	Cgf: Interbedded slates and quartzites of maroon, greenish-gray, and black colors; minor dark-colored grits.	?

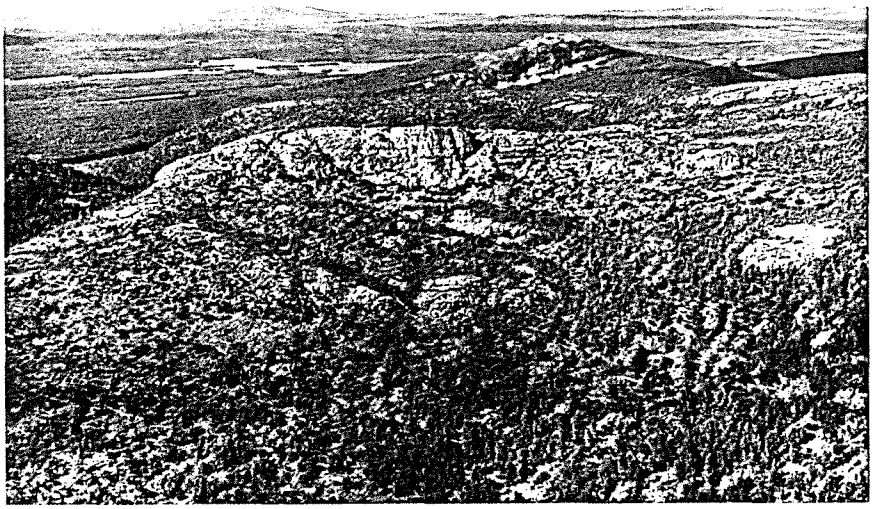


Figure 13. Bare summits and south slopes of the Deadwater Mountains are the result of forest fires which occurred in 1884, 1903 and 1906. Big Peaked Mountain is in the foreground, Trout Brook Mountain and Matagamon Lake are in the middleground. Flow units are visible within the felsite on the mountains.

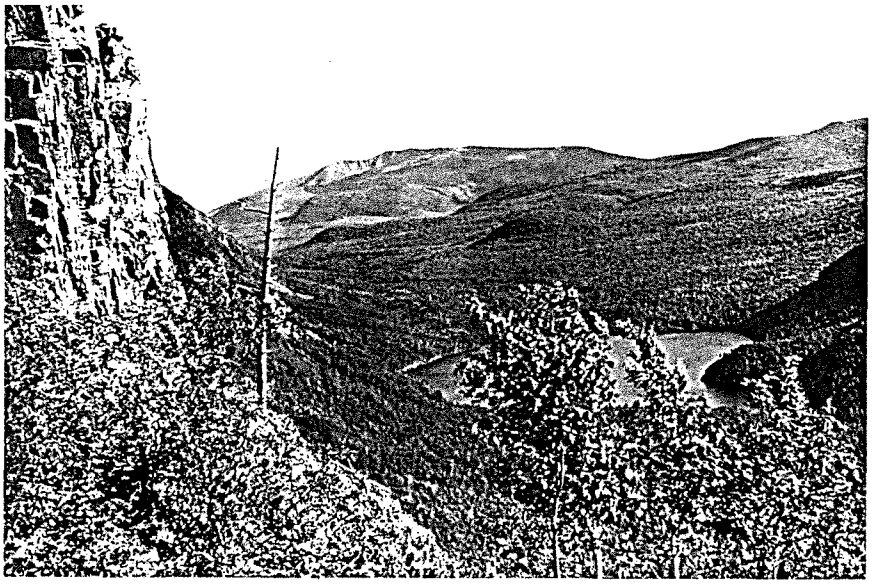


Figure 14. Upper South Branch Pond from the ridge of North Traveler Mountain. Mt. Katahdin is in the background. An outcrop of the Black Cat member, Traveler felsite is at the left.

along the East Branch from just below Pond Pitch[1] to the southeast corner of the area studied, in the gorges of Bowlin Brook below Bowlin Pond, and along the lower portion of Big Spring Brook.

DESCRIPTION: The "Grand Falls" formation consists of interbedded maroon, greenish-gray, gray, and black slates and quartzites that are tightly folded and steeply dipping. There are also minor dark-colored grits. Most of the rocks are thin-bedded (fig. 15). Both cross-bedding and graded bedding are present on a small scale. Graded bedding is the more common. Cleavage is well developed in the slates and thin quartzite beds are typically boudinaged (fig. 16).

Greenish-gray slates and quartzites are probably the most abundant rocks. The green slate contains quartz, plagioclase, muscovite, biotite, chlorite, and opaques. The quartzites typically contain quartz veinlets. Some of them contain slate chips or partings. Maroon slates and quartzites are interbedded with greenish-gray rocks along the East Branch between Grand Pitch and Big Spring

---

[1]The locations of most of the falls or pitches of the East Branch shown on the topographic maps of the Traveler Mountain and Shin Pond quadrangles are incorrect. The correct locations are listed below.

"Upper" Stair Falls ---correctly shown
"Lower" Stair Falls ---EC 28-02
Haskell Rock Pitch ---SE 33-505 (below Haskell Deadwater)
Pond Pitch ---SE 38-45
Grand Pitch ---SPSE 02-405

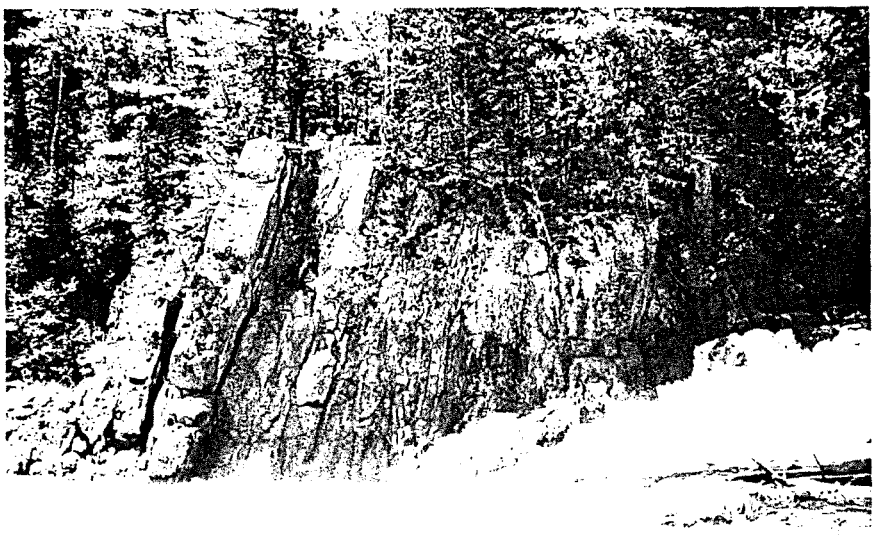


Figure 15. Steeply dipping beds of the "Grand Falls" formation at Grand Pitch on the East Branch Penobscot River.



Figure 16. "Grand Falls" formation showing boudinaged quartzite beds and well-developed cleavage in the slates parallel to the bedding. Above Grand Pitch, East Branch of the Penobscot River.

Brook, along the lower part of Big Spring Brook, and on the sharp hill on the southwest shore of Bowlin Pond. The maroon slate contains quartz, plagioclase, muscovite, chlorite, hematite, and opaques. Dark-gray and black slates, quartzites and grits are exposed just below Pond Pitch on the East Branch, along Bowlin Brook below Bowlin Pond, and on the East Branch below Spencer Rips. An X-ray diffraction pattern of black slate from Bowlin Brook shows the presence of only quartz and muscovite. Minerals constituting less than 5 percent of the slate probably cannot be identified by X-ray diffraction. Amorphous carbon would also probably not be detectable by X-ray diffraction. Some of the grit is feldspathic and rusty weathering.

THICKNESS: The base of the "Grand Falls" formation is not exposed within the Katahdin-Traveler area. Because of the tight folding in the rocks and the lack of stratigraphic detail, it is not possible to give a meaningful estimate of the minimum thickness of the formation.

CORRELATION AND UPPER CONTACT: In the Traveler Mountain quadrangle, the "Grand Falls" formation is overlain by basalts. The contact is exposed at the base of Pond Pitch on the East Branch, and is apparently an unconformable one. Neuman (1960) has suggested that the unconformable nature of the contact may be partly due to

the difference in response of the massive basalt and the underlying thinly bedded quartzites and slates to the Taconic and Acadian orogenies.

Neuman (1960) has found that the "Grand Falls" formation covers a considerable area in the Shin Pond quadrangle. On Sugarloaf Mountain and in Shin Brook (center ninth of the Shin Pond quadrangle), volcanic conglomerate, graywacke and fossiliferous tuffaceous sandstone intervene between the basalts and the "Grand Falls" formation. Neuman interprets the volcanic conglomerate which contains quartzite pebbles as further evidence for an angular unconformity between the "Grand Falls" formation and the overlying basalt.

AGE: Smith (1928) reported finding the fossil Oldhamia, a presumed calcareous alga, in red slates of the "Grand Falls" formation. Toppan (1932, p. 72) refers to the locality as "immediately below the Grand Falls in T.5R.8." B. F. Howell examined Smith's specimens and suggested that they might be Oldhamia (Murchisonites), cf. occidens, indicative of the Lower Cambrian. A. J. Boucot (oral communication) states that the status of Oldhamia as a true fossil is questionable. Such precise dating based only upon Oldhamia seems dubious.

The "Grand Falls" formation underlies with probable angular unconformity the fossiliferous tuffaceous sandstone

from Sugarloaf Mountain and Shin Brook. Neuman (1960) reports that the tuffaceous sandstone contains an assemblage of fossils that suggests early Middle Ordovician age. The "Grand Falls" formation is thus pre-Middle Ordovician and could be Cambrian. It is tentatively assigned a Cambrian or Ordovician age.

ORDOVICIAN

POND PITCH BASALT

NAME: The name Pond Pitch basalt is proposed for the basalt that forms Pond Pitch on the East Branch of the Penobscot River.

DISTRIBUTION: The Pond Pitch basalt is believed to form a belt about one half to three quarters mile wide in the southeast corner of the area. The belt is roughly parallel to the East Branch and, except where it extends a short distance across the river at Pond Pitch, lies entirely to the west of the East Branch. The basalt has been found in outcrop only on the East Branch between Pond Pitch and Haskell Rock Pitch and on the sharp hill between the river and Little Messer Pond. The section on the river has been repeated by faulting.

Heavy basalt float occurs on the northern end of the steep ridge west of Spencer Rips, southwest ninth,

Shin Pond quadrangle. The Pond Pitch basalt is believed to be continuous with basalt to west of the East Branch in the Stacyville quadrangle. In that area basalt was found on Lunksoos Mountain by Hitchcock (1861) and on Deasey Mountain by Neuman and the author.

DESCRIPTION: The basalt is dark greenish gray and most of it is without discernable structure. In a few places, however, structures resembling pillows have been observed. This pillow structure is not clear enough to indicate the direction of the tops. Much of the basalt is very fine grained, but in some, plagioclase laths, dark pyroxene, greenish olivine, and pyrite are visible. Most of the rock fizzes slightly under dilute HCl.

A partial analysis of specimen KT-189, basalt from the sharp ridge northwest of Pond Pitch (SE 35-57) is as follows:

MgO	---	6.0%
CaO	---	8.8
Na_2O	---	2.7
K_2O	---	0.13

The analysis was made through the courtesy of Andrew Griscom by Paul L. D. Elmore and Samuel D. Botts, U. S. Geol. Surv., and appears in Report No. IRC-172 under Lab specimen No. 149749. The rock is a typical basalt except that it is very low in K_2O.

UPPER AND LOWER CONTACTS: As stated in the previous section, the Pond Pitch basalt probably overlies the "Grand Falls" formation with an angular unconformity. It is also believed to be separated from the overlying rocks of Silurian age by an angular unconformity. Cobbles and boulders of basalt are found in the Silurian conglomerates. Further, the basalt has not been found northeast of the East Branch. Along Bowlin Brook east of Kimball Pond, Silurian conglomerates rest directly upon red slates of the "Grand Falls" formation (R. B. Neuman, oral communication).

THICKNESS: The inferred breadth of outcrop of the Pond Pitch basalt is between one half and three quarters of a mile. The greatest possible thickness of the formation (if it were vertical) would, therefore, be about 4000 feet. It is probably considerably less than this.

CORRELATION: The Pond Pitch basalt is believed to be part of a continuous belt of basalt roughly parallel with the East Branch extending as far south as Hunt Mountain. (See Neuman 1960). It is also probably equivalent to the basalt (greenstone) on Sugarloaf Mountain.

AGE: In the Stacyville quadrangle greenstone that is probably continuous with the Pond Pitch basalt has been dated by Neuman (1960) as Middle Ordovician. The black cherts near

the mouth of the Wassataquoik stream which contain graptolites of Normanskill age (Ruedemann and Smith, 1935, and Neuman, 1960) are believed to overlie the greenstone. On Sugarloaf Mountain tuffaceous sandstones, which contain fossils of probable early Middle Ordovician age, underlie the greenstones.

SILURIAN

KIMBALL BROOK FORMATION

NAME: The interbedded slate, siltstone, lithic graywacke and conglomerate exposed along Kimball Brook and along the steep bluff southwest of the brook is called the Kimball Brook formation. Lithic graywacke is used as defined by Pettijohn (1957, p. 291) for a sandstone with greater than 15 percent clay or silt matrix and containing rock fragments in excess of feldspar. The massive pebble and cobble Haskell Rock conglomerate (a name used by Smith, 1928a, p. 65) occurs in the upper portion of the formation. Haskell Rock is the name of a large pillar-like erosional remnant of conglomerate in the river bed of the East Branch at the falls to which it gives its name (fig. 17).

DISTRIBUTION: The Kimball Brook formation forms the major part of the belt of Silurian rocks that crops out from the East Branch northeast to the Bowlin Pond Road. The lower, more heterogeneous, portion of the formation is

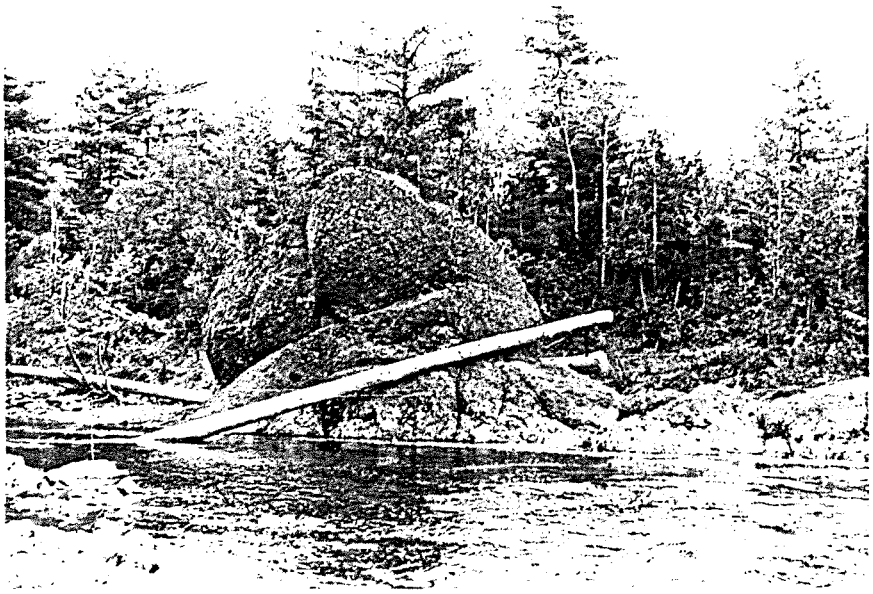


Figure 17. Haskell Rock at Haskell Rock Pitch, East Branch of the Penobscot River. Type locality of the Haskell Rock conglomerate.

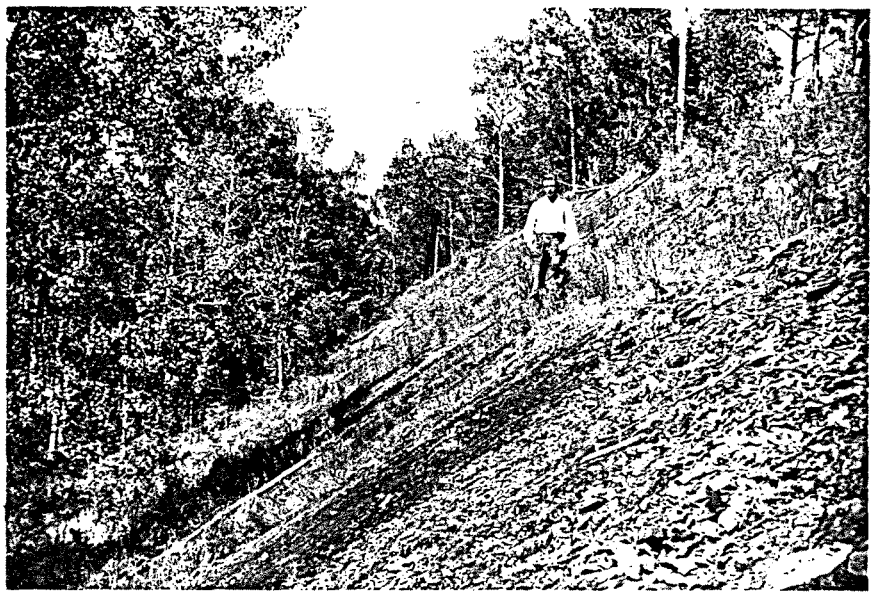


Figure 18. Dip surface of the Seboomook formation, first large hogback ridge north of Boody Brook (NO 20-025). The surface in the picture has a vertical relief of about 50 feet.

exposed along Kimball Brook and the high bluff southwest of the brook, and in scattered outcrops interrupted by faulting along the East Branch between Pond Pitch and Haskell Rock Pitch.

Excellent exposures of the Haskell Rock conglomerate are found at the type locality, Haskell Rock Pitch on the East Branch, on the 1017 foot hill northeast of Haskell Deadwater, and in the wooded hummocky terrain just east of the Bowlin Pond Road. A hornfelsed conglomerate, believed to be the Haskell Rock conglomerate, crops out close to the Katahdin granite about three-quarters of a mile northeast of Hathorn Pond in the southeast corner of the Traveler Mountain quadrangle. No outcrops of any kind have been found between this locality and the immediate vicinity of Haskell Rock Pitch.

DESCRIPTION: The lower more heterogeneous portion of the Kimball Brook formation consists of medium to dark-gray and greenish-gray slate, siltstone and lithic graywacke intercalated with thin beds of conglomerate. Some conglomerate beds consist primarily of milky quartz pebbles or cobbles set in an argillaceous matrix. Others more properly called slate-chip breccia consist primarily of angular fragments of gray, greenish-gray and black slate set in an argillaceous or silty matrix. Many of these

slate-chip breccias could be intraformational breccias. At a number of localities fossil fragments have been found in the matrix of the slate-chip breccia. Other conglomerates consist of a mixture of milky quartz pebbles and slate fragments. Graded bedding is commonly observed in the siltstone and lithic graywacke.

Typically, these rocks of the lower portion of the Kimball Brook formation are non-calcareous or slightly calcareous. Along the East Branch just above the Pond Pitch basalt, however, a fossiliferous calcareous "double conglomerate" occurs with slate-chip breccia, slate, siltstone and lithic graywacke. This "double conglomerate" consists of calcareous conglomerate lenses or cobbles set in a matrix of slate which may also be calcareous. The calcareous lenses or cobbles contain slate fragments and are thus, themselves, conglomerates.

The lower portion of the Kimball Brook formation is believed to grade up into the Haskell Rock conglomerate as the percentage of conglomerate increases.

The Haskell Rock conglomerate is unsorted, containing fragments of all sizes up to boulder size set in an argillaceous matrix. Along the East Branch, no bedding is visible in the conglomerate. On the 1017 foot hill northeast of Haskell Deadwater both bedding and cross-bedding are visible. Rock fragments observed in the conglomerate include quartzite, black chert, red, greenish-gray, and

black slate, milky quartz, greenstone, quartz diorite, and rare fragments of carbonate rocks. The quartz diorite fragments may have come from a porphyritic quartz diorite, possibly of Ordovician age, near Shin Pond (Neuman, 1960). Brachiopod fragments have been found by Neuman (oral communication) in the matrix of the conglomerate along the Bowlin Pond Road.

E. S. C. Smith (1928a) suggested that the Haskell Rock conglomerate might be a tillite. The fact that the conglomerate is cross-bedded, that fossil brachiopods have been found in its matrix, and that it is interbedded with other sediments of the Kimball Brook formation makes it necessary to reject this interpretation.

In the vicinity of the Katahdin granite near Hathorn Pond, cordierite is present in the matrix of the conglomerate.

THICKNESS: Along Kimball Brook, the Kimball Brook formation has a total thickness of the order of 2500 feet. The Haskell Rock conglomerate probably constitutes about 1200 feet of this thickness.

AGE: Fossils were discovered in the slate-chip breccia along Kimball Brook (SPWC 09-075) by R. B. Neuman. These have been studied by A. J. Boucot (oral communication, March, 1961) who concluded that they were of Early Silurian

(Uppermost Llandovery) age. A fossil coral from the southernmost exposure of "double conglomerate" along the East Branch (SE 375-45) has been identified by W. A. Oliver, U. S. Geological Survey, as a heliolitid, a group that ranges through the Silurian into the Lower Devonian (R. B. Neuman, written communication, March, 1961).[2] The Kimball Brook formation is, therefore, believed to be of Early Silurian (Uppermost Llandovery) age.

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[2]Twenty-five feet downstream from (stratigraphically beneath) the southernmost exposure of the "double conglomerate" is a slate-chip breccia. One hundred and ten feet northeast from and on strike with this slate-chip breccia is another outcrop of slate chip breccia, presumably the same bed as the first. Fossils were collected from this second slate-chip breccia locality in September 1959 and sent to A. J. Boucot for study. Boucot (oral communication) has identified the following fossils:

Sowerbyella sp.	Fardenia? sp.
Leptaema "rhomboidalis"	Catazyga sp.
dalmanellida	Clams
Hesperorthis? sp.	Strophomena? sp.

He states that this assemblage indicates an uppermost Upper Ordovician (Asgillian) age.

The slate-chip breccia is identical with others associated with "double conglomerate" further upstream and also with the slate-chip breccia of Early Silurian age from Kimball Brook. Before any revision of the present stratigraphy is undertaken, the author would like to revisit the field.

CARBONATE-RICH SILTSTONE

NAME: Carbonate-rich siltstones overlie the Haskell Rock conglomerate at a few localities in the eastern portion of the Katahdin-Traveler area. These siltstones differ from each other in mineralogy and appearance. Because they have not been studied in detail, are poorly exposed, and are being more thoroughly studied by R. B. Neuman in the Shin Pond quadrangle, they have not been given a stratigraphic name.

DISTRIBUTION AND DESCRIPTION: Carbonate-rich siltstone is exposed at the upper end of Haskell Rock Pitch, on both shores of Kimball Pond, and on a small hill just west of the Bowlin Pond Road (SPWC 115-155).

The fresh rock is light blue-gray. A punky, tan weathering rind is present on most exposures. The rocks are typically thinly bedded (1 cm to 10 cm) and may also be laminated (less than 1 cm). The classification of bedding used in this report is that of McKee and Weir as modified by Ingram (1954). Thin sandy seams may be present. At Haskell Rock Pitch the carbonate mineral is calcite; at Kimball Pond, the carbonate mineral is dolomite, and at the Bowlin Pond Road, both calcite and dolomite are present. The carbonates have been identified from X-ray diffraction patterns.

At the Bowlin Pond Road and at Haskell Rock Pitch, some of the carbonate-rich siltstone contain calcareous lenses and nodules as much as a foot across. These nodules are typically concentrated along certain bedding planes. They weather more easily than the matrix. Thus an exposure is characteristically dotted with large pits in a roughly planar arrangement. Small pyrite nodules occur in the carbonate-rich siltstone at Kimball Pond.

At Haskell Rock Pitch the carbonate-rich siltstone is interbedded with minor pebble and cobble conglomerate similar to that found in the Haskell Rock conglomerate. There are also thin irregular laminae of granule-size or sand-size calcareous slate-chip "breccia" in the carbonate-rich siltstone.

THICKNESS: The carbonate-rich siltstone at Kimball Pond is 200 to 300 feet thick.

AGE: The carbonate-rich siltstone overlies the Haskell Rock conglomerate believed to be of Early Silurian age. Similar rocks at Marble Pond underlie fossiliferous limestones. (R. B. Neuman, oral communication). According to A. J. Boucot (oral communication), the age of the fossils from the limestone at Marble Pond is probably Wenlock. Moore (1958, p. 171) equates, in part, the Niagaran (Middle Silurian) to the Wenlockian. No fossils have been

found in the carbonate-rich siltstone.

Carbonate-rich siltstones containing calcareous nodules are typical of the Silurian or Middle Silurian of much of New England (J. B. Thompson, oral communication).

LIMESTONE

Abundant boulders (up to 20 feet across) of a coarsely crystalline, light gray, highly fossiliferous, clean limestone occur scattered along and above the steep northeast bank of the East Branch just below the main falls of Haskell Rock Pitch (roughly at the "RI" in "River" on the Traveler Mountain quadrangle topographic map). The limestone boulders also occur resting on probable outcrop of conglomerate in the small valley extending north from the river just west of "R" in the word "River." This limestone has not been found in outcrop. The author can only reiterate the words of Hitchcock of 100 years ago: the "--source must be quite near." These boulders may have come from an equivalent of the limestone at Marble Pond, which is Middle Silurian and stratigraphically above the carbonate-rich siltstone (see above). Limestone of Niagaran age also occurs in Ripogenous Gorge on the West Branch of the Penobscot River, Harrington Lake quadrangle (Willard, 1945).

SILURIAN UNDIFFERENTIATED

Reconnaissance, in the company of R. B. Neuman,

along the logging road northwest of Morrell Pond has revealed greenish-gray siltstone, greenstone, and red and green fossiliferous tuff at the northern border of the Traveler Mountain quadrangle. A second and final reconnaissance trip to the north by the author has revealed similar rocks further to the west on the town line between T. 7 N., R. 10 W. and T. 7 N., R. 9 W. (NW 23-03). These rocks, perhaps because of the greenstones, show up as a magnetic high on the aeromagnetic map of northern Maine compiled by Boucot, et al (1960). The contact of these rocks with the overlying Seboomook formation has been inferred from topography and from the aeromagnetic map. Fossils were found in the tuff on a low sharp hill south of the road about one half mile west of the Piscataquis County line (NE 01-445). These have been dated by Boucot (oral communication, March, 1961) as Late Silurian (Lower Ludlow).

DEVONIAN

SEBOOMOOK FORMATION

NAME: Perkins (1925) proposed the name Seboomook slate for the interbedded dark-colored sandstone and pyritic slate that crop out at Seboomook Dam on the West Branch of the Penobscot River (fig. 1). Boucot (1961) revised the name to Seboomook formation because dark-colored sandstone makes up a large part of the formation at many places,

including the type locality at Seboomook Dam.

DISTRIBUTION: The Seboomook formation occurs in the eastern, northern and western regions of the Katahdin-Traveler area. To the east, the Seboomook formation crops out in a homoclinal belt between one half and one mile wide trending northeast. Dips are moderate to steep, northwest. To the north, the formation is much folded and crops out in a broad east-west belt occupying the relatively low area between the felsite hills on the south and the range of hills held up by Silurian volcanic rocks at the northern border of the Traveler Mountain quadrangle. Exposure is excellent along the shore of Matagamon Lake, along Webster Brook (fig. 20) and in the rough terrain of low relief between Frost Pond and Boody Brook (fig. 18).

In the Telos Lake quadrangle the Seboomook formation occurs west of the felsite mountains at the edge of the area studied. Outcrop in this area is extremely poor; the only known outcrops are along the North Branch of Trout Brook. Reconnaissance along a road recently constructed by the Great Northern Paper Company suggests that the outcrop area of the Seboomook formation extends as far northwest as Telos Lake (fig. 2). It is believed that the western area of the Seboomook formation is continuous with the area in the northern third of the Traveler Mountain quadrangle, although faulting of unknown magnitude and extension occurs at the borders of the Traveler felsite.

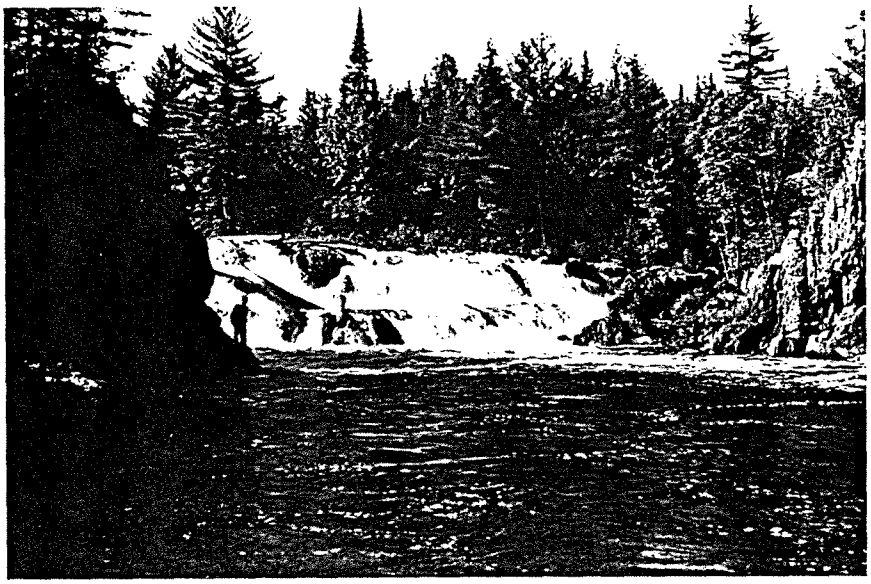


Figure 19. Grand Pitch on the East Branch of the Penobscot River, below Matagamon Lake. The rocks are steeply dipping slates and quartzites of the "Grand Falls" formation.



Figure 20. Gorge cut in the Seboomook formation below Grand Pitch, Webster Brook, above Matagamon Lake. Bedding dips about 30° to the left (south).

On the border of the Traveler Mountain and Telos Lake quadrangles, the Seboomook formation may underlie the topographic low that is rimmed by Center, Strickland, McCarty, Lord, and Wassataquoik Mountains. These mountains are composed of felsite. No outcrops have been found within the basin. However, because no other comparable basins occur within the outcrop area of the felsite, and because there is an outcrop of blue-gray, slightly calcareous slate at an elevation of 1700 feet on the northwest side of Wassataquoik Mountain (SW 10-14), it is believed that this basin is underlain by sedimentary rocks. The slate does not closely resemble any other formation in the Katahdin-Traveler area, but is most similar to the slate of the Seboomook formation.

DESCRIPTION: The Seboomook formation consists predominantly of medium- to dark-bluish-gray slate interbedded with minor lighter bluish-gray, very-fine grained lithic graywacke. Typically, the slate and lithic graywacke form a monotonous sequence of graded beds. The graded bedding is best displayed on water- or ice-polished surfaces as a color gradation from the basal whitish- to light-gray weathering lithic graywacke to the upper darker bluish-gray slate. The graded beds are less than an inch to more than a foot in thickness and average one to four inches. Within

a graded bed the ratio of the basal sand to the upper silt and clay varies considerably, but typically ranges between 1 to 3 and 1 to 5. Many of the beds are internally laminated.

Other primary sedimentary features may also be observed in the Seboomook formation, particularly on water- or ice-polished surfaces. Many of the basal lithic graywackes show current bedding and, in some, ripple marks are visible. Both symmetrical and asymmetrical ripple marks have been observed, and internal cross laminations are visible within the ripples. Ripple marks in the basal lithic graywacke are faintly visible in figure 22. Typically the ripple marks have wave lengths of one to four inches and amplitudes of from one half to one inch. The troughs of the ripple marks are usually filled with darker silt.

A common feature of layers of lithic graywacke that are an inch or more thick is the presence of clay chips roughly parallel to the bedding. These were probably torn from the underlying mud by more competent currents carrying and depositing the sand-size particles.

At a few localities, notably on Webster Brook in the vicinity of Grand Pitch, penecontemporaneous deformation, probably caused by slumping, is visible (fig. 22). This phenomenon is believed to be more common than the present

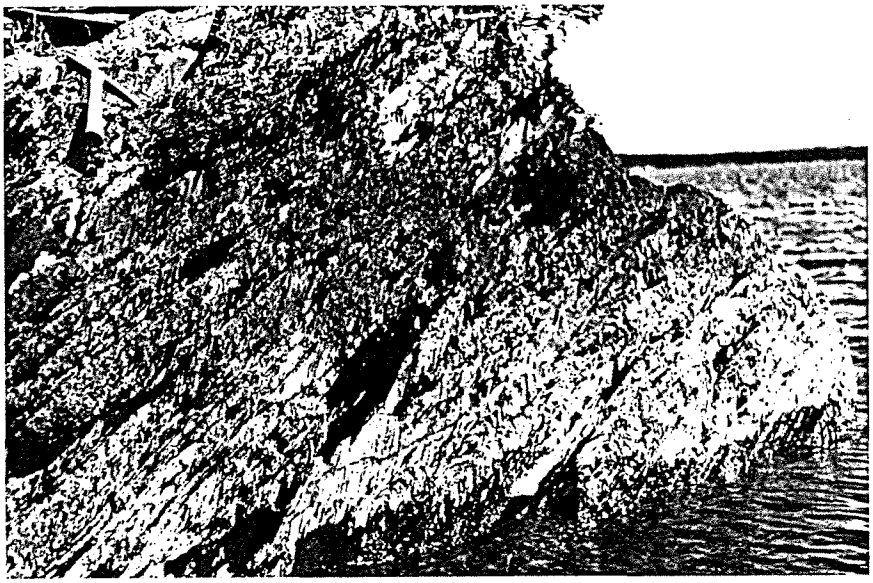


Figure 21. Outcrop of the Seboomook formation at the northeast end of Louse Island, Matagamon Lake, looking northeast. Bedding dips about 35 degrees to the left; axial plane cleavage dips about 70 degrees, also to the left.



Figure 22. Water-polished surface of the Seboomook formation just below Grand Pitch, Webster Brook (north side of the Brook). Asymmetric ripple marks in the light-weathering lithic graywacke, and the effects of penecontemporaneous deformation (slumping?) are visible. The hammer handle points in the direction of the top of the beds.

number of observations indicate. Penecontemporaneous deformation may have been confused with drag folding in poor exposures in the early stages of mapping.

Thicker beds of lithic graywacke that are also present in the Seboomook formation usually contain shaley partings. Large exposures indicate that these thicker beds of lithic graywacke are not continuous, but pinch and swell over relatively short distances. A typical example is found on the north shore of First Lake (NE 12-07). Here a bed of lithic graywacke swells from a thickness of one inch at either end to a maximum thickness of about one foot within a distance of 25 feet along strike. Typically, lithic graywacke forms a higher percentage of the formation close to the outcrop area of the Matagamon formation. For example, just upstream from the sharp right angle bend in Trout Brook (C 22-54) a massive bed of lithic graywacke six feet thick has been observed.

The dominant minerals in the slate are quartz and muscovite. The quartz occurs as subangular to subrounded grains averaging 0.02 to 0.03 mm across; thus the slate is silty. The muscovite flakes have recrystallized sufficiently so that some of them are visible in the hand specimen (0.1 to 0.03 mm across). Most of them, however, are the size of the average quartz grains. X-ray diffraction patterns show the muscovite to be the 2M polymorph of Yoder and

Eugster (1955). The muscovite flakes are poorly oriented with respect to the cleavage of the rock, and some of them are bent between quartz grains.

Other phases present in lesser amounts include chlorite, biotite (pleochroic in yellows and browns), carbonate, opaques, carbonaceous material (amorphous carbon ?), and tiny dark neeldes of high relief which are probably rutile. Plagioclase has been identified by X-ray diffraction. Zircon is present in some rocks. Opaque dust and carbonaceous material are concentrated along incipient cleavage planes. Pyrite is usually not visible in the hand specimen.

Laminations are visible in some thin sections. Typically, the laminations are graded, both in the size of the detrital quartz grains, and with respect to the ratio of quartz to muscovite.

A mode of the lithic graywacke, averaged from three thin sections, is presented below.

quartz	60 percent
plagioclase	7 "
muscovite	8 "
chlorite	8 "
biotite	3 "
carbonate	8 "
opaques plus limonite	6 "
zircon	tr
rutile	tr
tourmaline	tr
apatite	tr

The average size of the detailed grains is 0.05 to 0.10.

Thus the detrital grains are of the very fine sand size of Wentworth (1922). The quartz grains are angular to sub-angular and show undulatory extinction. The only feldspar recognized is plagioclase.

Generally, the lithic graywacke is slightly calcareous, whereas the slate is not. This is reflected by the carbonate reported in the mode and by the fact that the lithic graywacke fizzes slightly under HCl. The calcite in the lithic graywacke might account for the scattered calcite veins and the calcareous quartz veins in the formation. Some reddish brown carbonate, ankerite, is also visible in thin sections. The identification of ankerite has been confirmed by X-ray diffraction.

Finally, it should be stated that some extremely fine-grained aggregates of chlorite and/or muscovite are included in the mode under "muscovite" and "chlorite." Many of these are probably fragments of pelitic sediments.

LOWER CONTACT AND THICKNESS: The lower contact of the Seboomook formation with the underlying rocks of Silurian age has not been observed. North of the narrow neck of water in Kimball Pond, however, the Seboomook formation crops out within 50 yards of calcareous Silurian siltstone. On the basis of gross structural features, the Seboomook formation is believed to be conformable with the

underlying Silurian rocks.

As determined from the probable width of the outcrop belt (6000 feet) and the average dip (45°), the formation is about 4000 feet thick in the vicinity of the Bowlin Pond Road, Shin Pond quadrangle. If the structural interpretations are correct, the formation thins to about 1500 feet southwest of Haskell Deadwater.

The thickness of the Seboomook formation in the northern part of the Traveler Mountain quadrangle is difficult to estimate because of extensive folding and the lack of a marker bed. On the east shore of Hay Brook Logan, however, there is a fairly continuous section with a steep, consistent south dip. The outcrop width of this section is about 4500 feet and the estimated thickness is 4000 feet. Because the area along Hay Brook north of Norway Dam has not been visited, the bottom of this section has not been located.

CORRELATION AND AGE: The cyclically layered slate and lithic graywacke of the Katahdin-Traveler area is lithologically similar to and stratigraphically the equivalent of the Seboomook formation of Boucot's (1961) Moose River Synclinrium. Although it cannot be demonstrated at present by continuous mapping, reconnaissance by the present author and others suggests that the cyclically layered slate and lithic graywacke of the Katahdin-Traveler area is

continuous with the Seboomook formation of the Moose River Synclinorium (Boucot, et al, 1960). The correlation of these rocks was first suggested by Toppan (1932, p. 32) on the grounds that the "vertical slates" reported by Hitchcock along Webster Brook were "directly on the strike of the Seboomook slates."

Fossil fragments have been found in the Seboomook formation at a number of localities in the Katahdin-Traveler area. A collection was made from the only substantial find within the area studied, on the north shore of Deep Cove, Matagamon Lake about 25 yards west of BM 659 feet (NE 23-075). The collection was made when the lake level was low and the locality would probably be flooded at the normal lake level. The rocks in which the fossils occur are unusually massive silty and sandy beds. Professor A. J. Boucot has studied these fossils and concluded that the formation is of Becraft-Oriskany age. The following forms were identified (A. J. Boucot, written communication, April, 1961):

Loxonema sp.	Leptocoelia cf. flabellites
orthoceroid	trilobite
pelecypod	coral
Leptostrophia sp.	

A second fossil locality, possibly in the Seboomook formation, was found outside the area studied in the floor and walls of a gravel pit between Thissell Pond and Little Nesowadnehunk Lake (fig. 2) just south of the new road to

Telos Lake (TLSC 305-54). The outcrops in this gravel pit have steep dips, slickensided bedding surfaces, and consist of rocks unlike those of the Seboomook or any other formation in the area. They consist of thin-bedded, dirty carbonaceous feldspathic sandstones interbedded with black shale and sandy shale. The sandstone weathers a light olive-brown and is a fairly dark gray when fresh. The sandstone contains abundant woody material. The shale is finely laminated with light and dark layers. Graded bedding is conspicuously absent and the bedding planes between the sandstone and shale are well defined. The only similar rocks found, occur in a single outcrop in the gap between Strickland and Center Mountains.

The simplest interpretation is that the Thissell Pond rocks belong to the Seboomook formation. The nearest known outcrops are more than a mile away (TLSC 24-42) and, although they are not typical of the Seboomook formation, they are more like it than those at Thissell Pond. Typical Seboomook rocks do crop out close to the TLSC 24-42 locality (TLSC 20-40) and to the northwest of Thissell Pond (TLC 18-23).

An alternate interpretation is that the Thissell Pond rocks belong to the Trout Valley formation. Because this would provide valuable paleogeographic information, and perhaps a more precise age for the plant fossils and

the Traveler felsite, the area should be studied in more detail.

A. J. Boucot (written communication, April 1961) has identified the following forms in the collection of fossils from the Thissell Pond locality made by the author in 1958:

Schuchertella sp.	Leptostrophia sp.
Metaplasia cf. minuta	platyceratid
Leptocoelia cf. flabellites	Meristella cf. doris
Plicoplasia? sp.	dalmanellid
Corals	dalmanitid
Edriocrinus?	acrospiriferid
starfish	

He states that these forms indicate a Devonian age and that they may be younger than Becraft-Oriskany but that additional forms are needed for confirmation.

In the Moose River synclinorium the bulk of the Seboomook formation is of Oriskany age. The uppermost part of the formation could be either Oriskany or Onondaga, and the lower part is of New Scotland age (Boucot, 1961).

MATAGAMON FORMATION

NAME: The rusty weathering sandstone with interbedded slate in the vicinity of Hay Mountain is here called the Matagamon formation from the exposures at the south end of Matagamon Lake. The exposures on the southeast slopes of Hay Mountain between the Grand Lake Road and the southern summit (EC 33-34) are designated as an alternate type section.

These rocks were formerly included in the Moose River sandstone by Clarke (1909, pp. 64-65). Boucot (1961) has given these Early Devonian sandstones in the Moose River synclinorium group status, and has subdivided the group into formations. The lower sandstones of the Moose River group in the Moose River synclinorium grade laterally into the Seboomook formation, and were thus never continuous with the sandstone of comparable age on Hay Mountain and Matagamon Lake. A local name is desirable, therefore, for the sandstone on Hay Mountain and Matagamon Lake.

DISTRIBUTION: The Matagamon formation crops out in two areas. The larger of the two is a more or less oval shaped area occupying a structural basin, the Hay Mountain basin, in the east-central ninth of the Traveler Mountain quadrangle and the west -central ninth of the Shin Pond quadrangle. Throughout much of this area, the formation, particularly the sandstone, is moderately well exposed. Excellent exposures are found at the north end of Hay Lake, on the southern part of Hay Mountain, in the vicinity of Grand Lake Dam, around the shore of Atwood Pond, and at Stair Falls on the East Branch (the first outcrop downstream from Grand Lake Dam).

The Matagamon formation also crops out over a relatively small area on the north limb of the Matagamon synclinorium between Wadleigh Mountain and Boody Brook. The

extent of the formation in this area is not well known.

DESCRIPTION: The Matagamon formation consists predominantly of rusty weathering lithic sandstone or lithic graywacke with minor interbedded slate and siltstone. A few feet below the Traveler felsite, the sandstone is tuffaceous. The base of the Traveler felsite is mapped as the lowest felsite. The sandstone appears to form a higher percentage of the formation than it actually does because of its superior resistance to erosion and hence greater tendency to form outcrops. Sandstone, nevertheless, probably comprises about 75 percent of the formation. Typically, the sandstone crops out in low hogback ridges. The valleys between the ridges probably contain a higher percentage of slate. Figure 5 shows the appearance on an aerial photograph of these ridges on Hay Mountain.

Cleavage is moderately well developed in the slate (as in the slate of the Seboomook formation), but only crudely developed in the sandstone. The more massive sandstone beds typically break into curving slabs along non-planar and non-parallel joints at a high angle to the bedding. Quartz veinlets are common in some exposures and joints may be lined with quartz and/or calcite.

The sandstone, as well as the formation as a whole, is unevenly bedded. The individual sandy beds range in

thickness from about an inch to several feet and are typically cross-laminated. Ripple marks have been observed in some of the finer grained sandstone. These are particularly well displayed at the north end of Hay Lake. "Clay" pellets are found throughout the sandstones of the formation. Typically, the pellets are concentrated in certain bedding planes suggesting the break up of an unconsolidated silt or clay during or just prior to the deposition of the over lying sand. Sideritic concretions are also found.

At a few localities load-casts have been observed. One load-cast is shown in figure 23. These load-casts consist of rounded or more or less spherical bodies of sandstone surrounded on the bottom and sides by shale. They usually occur in groups restricted to a given stratigraphic horizon. They probably originated by the settling of less fluid sand into highly fluid underlying mud and are hence properly called load-casts (Kelling and Walton, 1957).

Fossil fragments are relatively common in the Matagamon formation. These include both invertibrates and plant material. Typically, the invertibrates are concentrated in "shell beds." The origin of similar shell beds in the Moose River Synclinorium has been discussed by Boucot (in preparation).

The sandstone of the Matagamon formation is typically

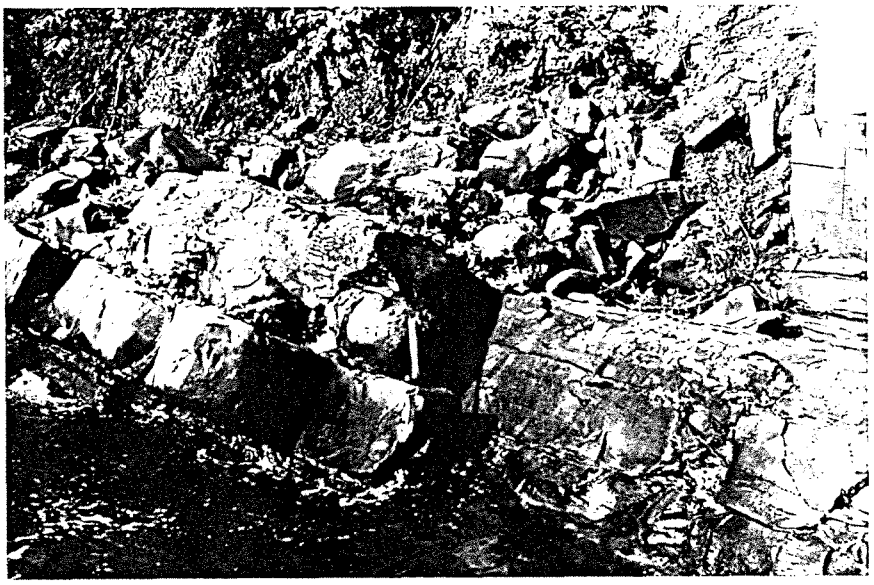


Figure 25. Outcrop of the Matagamon Formation at Grand Lake Dam showing the rusty-weathering sandstone and, at the waterline at the left, slate. The hammer rests against a large load-cast. Cross-laminations can be seen in the lower right. In the upper right is the west abutment of the dam.

rusty weathering and slightly calcareous. On the fresh surface it is a medium bluish gray or greenish gray. The detrital grains are angular to subangular and the average grain size ranges from rock to rock from very fine to medium. Typically, the sandstones contain 10 percent or less feldspar fragments and about one third of the detrital grains are rock fragments. Thus, depending upon the amount of "clay" matrix present they fall into lithic graywacke or the lithic sandstone (more specifically, subgraywacke) classification of Pettijohn (1957, p. 291). The subgraywacke is, in general, better sorted than the lithic graywacke.

Rock fragments include quartzite, chert, pelitic sediments, felsite, basalt, and granophyre (small grains composed of a graphic intergrowth of quartz and alkali feldspar). The felsite fragments are the most abundant perhaps indicating contemporary volcanism in the source area. Granophyre fragments have been found in all thin sections of the sandstone.

Much of the quartz shows undulatory extinction and most of the feldspar is plagioclase possessing polysynthetic albite twinning. Perthite and microcline are also fairly common. The heavy mineral suite typically includes zircon, apatite, magnetite, pyrite, and minor tourmaline. The rusty weathering is due to a limonitic alteration of

disseminated pyrite grains. At a few localities pyrite is visible in the hand specimen.

The relatively large muscovite flakes, common in the slate, are scarce in the sandstone. Much of the former "clay" matrix is now chlorite (very slightly pleochroic in light greens and showing abnormal interference colors) and sericite. A second bright bluish-green chlorite with moderate birefringence is sparsely present in some specimens. Biotite is rare.

A few feet below the Traveler felsite, sparse felsite pebbles appear in the sandstone. Closer to the felsite, beds of tuffaceous sandstone are interbedded with the pebble-bearing sandstone and slate. The tuffaceous sandstone is typically dark gray or black, feldspathic, contains felsite pebbles as well as sand-size fragments, and has a semi-flinty appearance. The detrital fragments, particularly quartz, are very angular and the rock contains about 20 percent matrix, presumably tuffaceous material of silt size or smaller. Local facies changes are rapid in this zone.

THICKNESS: As determined from the width of the outcrop belt between the Seboomook formation on Hay Lake and the axis of the Hay Mountain Basin, the Matagamon formation must be at least between 4000 and 5000 feet thick. The top formation is not exposed here. The

formation probably thins to a feather edge to the southwest. (See below).

CORRELATION AND AGE: The Matagamon formation is lithologically similar to and the stratigraphic equivalent of the Tarratine formation of the Moose River synclinorium. It is not believed, however, to have ever been continuous with the Tarratine formation.

The Oriskany age of these rocks was first established by Hitchcock (1861). This age has been subsequently confirmed and the faunal assemblege amplified upon by Clarke (1909) and Boucot (in preparation). A small collection of fossils by the author from "Lower" Stair Falls on the East Branch, contains the following forms (Boucot, written communication, April 1961):

Meristella sp.
Leptostrophia? sp.
Leptocoelia cf. flabellites

These suggest a Becraft-Oriskany age. Boucot has found that the faunal assemblege of the Matagamon formation is unlike that of the Tarratine, Seboomook, or Cold Stream formations. However, it is most similar to the fauna of the Tarratine formation and Boucot has suggested it may have lived in a similar environment, i.e., in a relatively shallow-water and near-shore environment in contrast to the deeper-water environment of the fauna of the Seboomook formation.

STRATIGRAPHIC RELATIONSHIPS: The Matagamon formation presents a number of interesting and unsolved problems. One such problem is its relationship to the Seboomook formation. Boucot (1961) has observed that Lower Devonian sandstones in northern Maine tend to occur as isolated patches in a terrane of finer grained clastic sediments. They may thus represent local basins of sand deposition. Boucot's interpretation is that these sandstones grade laterally into pelitic sediments such as those of the Seboomook formation.

In the Traveler Mountain area, however, the Matagamon formation appears to overlie the Seboomook formation. The contact with the underlying Seboomook formation is transitional over a hundred feet or a few hundred feet as displayed south of Atwood Pond and on the west shore of Hay Lake. The contact is drawn where sandstone forms greater than 50 percent of the rocks.

In the Telos Lake quadrangle, the Traveler felsite may rest directly upon the Seboomook formation (plate 1). Thus the sandstones of the Matagamon formation may grade into the slates of the Seboomook formation to the southwest. Whether there was a similar facies change to the north, east, and south cannot be determined from available evidence.

A final problem involving the Matagamon formation

is its relationship to the overlying Traveler felsite. This problem has direct bearing on the age of the Traveler felsite, and perhaps upon the dating of the Acadian orogeny.

There is a possibility, although the author considers it unlikely, that Traveler felsite overlies the Matagamon formation with pronounced unconformity. Along the eastern front of the mountains from Bald Mountain to Horse Mountain, the felsite appears to be conformable with the Matagamon formation, both with regards to the map pattern and individual outcrops, although not many of the latter have been observed. Figure 24 shows the locally conformable contact between the Matagamon formation and the Traveler felsite on the east side of Bald Mountain.

The critical area for determining structural and stratigraphic relationships between the felsite and the underlying Paleozoic sediments is along the eastern side of Traveler Mountain. Unfortunately, this area is practically devoid of outcrops at lower elevations, where sedimentary rocks are expected to occur. In the area from Bald Mountain south almost to Hathorn Pond the only outcrops known below an elevation of 1200 feet are in the bed of the stream that flows east from the gap between Bald and Traveler Mountains and in the bed of the stream that flows into Haskell Deadwater. In the former stream west of the park boundary and in the latter stream (for



Figure 24. Conformable contact between breccia of the Traveler felsite and tuffaceous sandstone of the Matagamon formation on the east side of Bald Mountain. The felsite forms the overhang.



Figure 25. Close-up of the contact between breccia of the Traveler felsite and tuffaceous sandstone of the Matagamon formation. Channeling in the sandstone by the breccia is visible at the hammer head.

convenience called Haskell Brook and so labelled on plate 1) below the felsite, rocks atypical of the Matagamon formation crop out. They consist of light gray or maroon quartzites and hard maroon or blue-gray non-fissle shales. Current bedding and ripple marks are visible in the quartzites. The strata typically have moderate dips and are right side up. The maroon color is due to very fine grained disseminated biotite.

It is possible that these rocks belong to the "Grand Falls" formation of pre-Silurian age. If they do, the Traveler felsite overlies the Matagamon formation with pronounced unconformity. However, for a number of reasons it is felt that these rocks are the hornfels of the Matagamon formation adjacent to an unexposed cupola of the Katahdin granite, or to an unexposed volcanic neck or necks. The reasons for believing this are: 1) "normal" Matagamon rocks occur east of the park boundary on the stream between Bald and Traveler Mountains. If the gray and maroon quartzites and shales are of pre-Silurian age, the Silurian section and the Seboomook formation is missing or very thin at this locality. 2) The maroon color of the rocks of the "Grand Falls" formation is due to disseminated hematite, not biotite. 3) Shreddy biotite occurs as a contact metamorphic mineral in pelitic sediments or portions of sediments at two other localities demonstrably close to

the granite, namely near Hathorn Pond and on the north ridge of Wassataquoik Mountain. 4) The lowest felsite on Haskell Brook is recrystallized (fig. 39) and contains abundant tourmaline as tiny prisms either in clusters or disseminated in the groundmass.

TRAVELER FELSITE

NAME: The volcanic rocks of which the Deadwater Mountains are composed were first described petrographically by Smith (1930), who estimated their areal extent to be 50 square miles. They were subsequently briefly described and named the Traveller (sic) rhyolite by Toppan (1932, p. 69). It is now proposed to substitute a more general name because: 1) there is a variation in the types of phenocrysts present which may or may not reflect the chemistry of the groundmass, 2) the groundmass cannot be resolved sufficiently to estimate modes, 3) available chemical analyses indicate that at least some of the rocks are rhyodacitas (aphanitic equivalent of a granodiorite). Hence the name Traveler felsite is proposed for the felsitic volcanic rocks of Traveler Mountain. The spelling of "Traveler" is that which appears on the U. S. Geological Survey Traveler Mountain quadrange map.

DISTRIBUTION: The Traveler felsite forms the mountainous region that covers about 70 square miles in the central and southwestern portions of the Traveler Mountain quadrangle and the southeastern ninth of the Telos Lake quadrangle. A narrow belt (one half mile by seven miles) of felsite is found on Wadleigh Mountain. This body is separated from the main portion of the felsite by

a fault. Its western limit is not precisely known because of glacial cover. The formational contacts shown on the geologic map (plate 1) for this area are based upon the sparse outcrops, major structural interpretation, and lineaments shown on high altitude aerial photographs (approximate scale 1:71,730).

The felsite on Center Mountain, Telos Lake quadrangle, is believed to be an isolated body although it was presumably once continuous with the main area. The felsite on Center Mountain is separated from that on Strickland Mountain by a narrow strip of sedimentary rock. A relatively broad open basin lies to the east of Center Mountain, separating this mountain from the main mountain mass. No other comparable basin occurs within the outcrop area of the Traveler felsite. Hence the physiography suggests that this basin is not underlain by felsite. (See p. 55)

NOMENCLATURE: There is much confusion in the terms in current usage describing volcanic rocks, particularly those commonly known as welded tuffs. In addition to the confusion in the meaning of terms, there are also problems in applying terms, originally defined with reference to Cenozoic rocks to older less well-preserved rocks such as the Traveler felsite. An obvious example is the term shard, which, strictly speaking, refers to a fragment of

volcanic glass. Objects in some thin sections of the Traveler felsite have the outlines of shards, but are no longer composed of glass. They almost certainly were fragments of glass which have devitrified. Because the term devitrified shard is cumbersome, the term shard, as used in this report, is extended to include devitrified shards.

The nomenclature used by R. L. Smith (1960a) for pyroclastic flows will, for the most part, be used here. The terms found in this paper include:

Ash flow - the basic depositional unit of a pyroclastic flow. Smith (1960a, p. 800) defines an ash flow as consisting of fifty or more weight percent ash exclusive of foreign inclusions, and as being "analagous to, or perhaps the same as, the deposit resulting from the passage of one nuée ardente." Ash is a size term for pyroclastic particles less than four mm (Wentworth and Williams, 1932). "Ash flow" is used in preference to the more cumbersome term "deposit of hot ash flow" proposed by the author in an earlier paper (See appendix A). "Ash flow" may also be used for the depositing medium in the same sense that "lava flow" may refer to either

the resulting rock unit or the moving stream of lava.

Welded ash flow - an ash flow in which welding has been an important phenomenon.

Ash-flow sheet - a deposit which has not been subdivided into well-defined units, but which is a mappable, sheet-like stratigraphic unit and is of inferrable ash flow origin.

Welded tuff sheet - an ash-flow sheet containing conspicuous welded tuff.

The author disagrees slightly with Smith in the definition of "welded tuff." Smith (1960a, p. 800) states "A welded tuff is a rock or rock body in which vitric particules have some degree of cohesion by reason of having been hot and viscous at the time of their emplacement." The intent of such a definition is, of course, to exclude all rocks not part of a welded tuff sheet. For example, pyroclastic material welded or fused at an igneous contact (fused tuff) would be excluded (Smith, 1960a, p. 800). On the other hand, some air fall ejecta might have to be included under Smith's definition. This writer believes that the term welded tuff should be applicable to an isolated hand specimen without reference to the outcrop from which it came. There should, thus, be no requirement in the definition as to the time or cause of

welding. Welded tuff, as used here, simply means a tuff in which the shards have been fused or welded together. Whether or not a welded tuff is part of an ash flow must be determined on other than internal evidence.

The application of this definition to older rocks presents certain problems. The obvious result of welding is an indurated, coherent rock. Several authors have pointed out that a similar rock could result from devitrification following the eruption (Fenner, 1925, p. 198, and 1948; Jenks and Goldich, 1956). Fenner (1948) proposed the term "sillar" for tuffs indurated by pneumatolytic crystallization phenomena and not, primarily, welding. Smith (1960a, p. 828) has discussed this problem briefly and pointed out that under optimum conditions there is a valid distinction between the two processes, but such pneumatolitic crystallization was probably initiated above the minimum welding temperature of the tuff (550°C). Hence even here welding probably played a significant role. The rocks over which this controversy has arisen cover large areas in the western Andes from northern Peru to central Chile. These are mostly Early Pleistocene in age.

With the passage of sufficient time, all glassy pyroclastic deposits, even those of air-fall origin, become indurated through devitrification and cementation. Hence, the writer has found this distinction between the causes of cohesion to be untenable in the older volcanic

rocks with which he has been working. In fact, the use of the adjective "welded" with reference to older volcanic rocks is unfortunate because welding is an inferred process rather than an observed result.

Many relatively young rocks are also characterized by the plastic deformation of constituent shards or pumice fragments. The deformed shards are crudely aligned and impart a foliation to the rock. Whatever the cause of the deformation, the resulting deposit is thinner than a comparable deposit containing undeformed shards. In this sense the deformation is a compression. To the extent that the shards are still visible in devitrified tuffs, the deformation or compression of the shards will also be visible. All rocks that are called welded tuff in the following discussion contain features interpreted as deformed shards. This criterion may exclude tuffs in which the cohesion of undeformed shards originated through welding. However, unless the shards are deformed, the evidence is equivocal.

GENERAL STATEMENT: The Traveler felsite includes a variety of rock types, but most of the formation is a dense, dark-bluish-gray or greenish-gray, dark-gray or black felsite that breaks with a conchoidal fracture. The least weathered samples are the darkest. The rock weathers to light rusty tan or bone white. The whitish weathering rind is usually 2 to 5 mm thick, but may be 10 or more cm

thick. Commonly an entire outcrop is so weathered (light greenish or bluish gray) that it is virtually impossible to obtain fresh samples. Nearly all of the felsite is porphyritic and contains a few percent small (1 to 3 mm) phenocrysts. Banding is visible in most hand specimens or thin sections and crude columnar jointing is common in outcrops.

Two members have been defined within the Traveler felsite: the basal Pogy member and the immediately overlying Black Cat member. The felsite of the Pogy member is characterized by the presence of both quartz and plagioclase phenocrysts and a slightly greater total percentage of phenocrysts than the felsite of the Black Cat member. The plagioclase phenocrysts from the Pogy member have structural characteristics of the low temperature modification. Welded tuff is the dominant rock. Plagioclase and pyroxene phenocrysts are present in the felsite of the Black Cat member, but quartz is absent or rare. Plagioclase phenocrysts from this member have structural characteristics intermediate between the high and low temperature modifications. The dominant rock is lava.

This variation in the percentage of quartz phenocrysts is the only consistent difference observable in the field between the two members. The significance of the quartz was recognized after completion of field

work, and the decision to establish the two members was made on the basis of hand specimen and thin section study. The contact between the two members is, therefore, only approximate. Felsite which cannot be assigned to either member because of lack of information is discussed under "Traveler felsite, undifferentiated."

POGY MEMBER: The Pogy member is defined by its position at the base of the Traveler felsite and by the presence of quartz phenocrysts (usually greater than 10 percent of the total phenocrysts content). It is named from exposures on Pogy Mountain. It crops out in two large areas. One is at the northeast end of the felsite including Trout Brook, Horse, Billfish and Bald Mountains, with an arm extending south along the eastern slopes of Traveler Mountain. The other is in the south-central portion of the felsite area including Wassataquoik, Pogy and South Traveler Mountains.

The Pogy member consists of a variety of felsitic rocks, most of which are pyroclastic. Lava seems to be restricted to Trout Brook Mountain. Volcanic breccia of uncertain origin has been found on Wassataquoik and Bald Mountains. Tuffaceous sediments have been found on Bald Mountain. The pyroclastic rocks include welded tuff, porphyritic tuff, nonporphyritic tuff, crystal tuff, and lapilli tuff. Welded tuff is by far the major rock type

and has been found throughout the Pogy member except on Wassataquoik Mountain.

As determined from the attitude of primary planar features within the felsite, the Pogy member is between 2500 and 3500 feet thick on the eastern slopes of Traveler Mountain. The Pogy member may be thicker near Billfish and Pogy Mountains, but without a marker unit and more structural data no meaningful estimate can be made. The Pogy member, as well as the entire Traveler felsite, is believed to have rapidly thinned to a feather edge beyond the present limit of the Traveler felsite to the west, north, and east.

WELDED TUFF: Deformed and devitrified shards are visible in many thin sections of the Pogy member. The term welded tuff is used in this paper as a descriptive rock name for tuffs containing such deformed or flattened shards. The deformed shards[3] in the welded tuff are subparallel and, depending upon the amount of flattening, impart a degree of foliation to the thin section and hand specimen. Lenticules, some of which probably originated as flattened pumice fragments, may augment the foliation. As the amount of flattening increases, it becomes

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[3]No glass has been identified in the Traveler felsite. For ease of expression, however, the adjective devitrified will be omitted with reference to shards throughout this section.

increasingly difficult to distinguish between welded tuff and lava. As the amount of flattening decreases, it becomes difficult to distinguish between welded tuff and non-welded tuff.

Outcrops of welded tuff may show crude prismatic jointing. Columns may be as thick as 4 feet and as long as 45 feet, but most are smaller. In general, columnar jointing is better developed in the Black Cat member.

Welded tuff is well exposed on the cliffs of Horse Mountain, the western summit of South Traveler Mountain, the eastern slopes of South Pogy Mountain, in the broad valley west of Mahar Pond, and in the stream valley between Dry Gorge and Black Cat Mountain (SC 5-49).

Attempts to recognize welded tuff in the field have been only partially successful. Some of the criteria used in the field are now believed invalid. Hence much of the felsite, mapped as welded tuff in the early stages of this investigation, is now thought to be lava. The following discussion of compressed tuff is based upon megascopic and microscopic data from about 50 specimens collected from widely scattered localities within the Pogy member. Features interpreted as deformed shards are visible in all of the thin sections of these specimens.

The welded tuff is very dark gray or black where completely fresh. Relatively fresh specimens are various

shades of gray, greenish gray or bluish gray. The rock is hard, dense, and breaks with a conchoidal fracture. Small phenocrysts, all less than three mm in length, characteristically make up about 15 percent of the rock; many of them are fragmented. Approximately one-third of the phenocrysts are quartz and two-thirds are plagioclase.[4] Sanidine phenocrysts occur in a few specimens and garnet has been observed in two. Completely altered mafic silicates constitute a few percent of the phenocrysts in some welded tuffs. Data on the phenocryst content of representative welded tuffs are presented in table 2. Growth aggregates of two or more phenocrysts, so typical of the lava in the Black Cat member, are scarce. Lithic fragments are present in all samples.

Euhedral, subhedral or fractured quartz phenocrysts, present in all thin sections, constitute from 2 to about 60 percent of the phenocrysts.[5] But in the typical welded

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[4]The compositions of the phenocrysts and methods by which they were determined are discussed in Chapter IV.

[5]In only one specimen does quartz constitute as much as 60% of the "phenocrysts." This specimen is from the base of the Traveler felsite. Hence much of the quartz may be picked-up detrital grains. These detrital quartz grains should not be called phenocrysts, but there is no practical means of distinguishing them from phenocrysts. In several thin sections, however, nearly half of the phenocrysts are quartz.

TABLE 2

Estimated Modes of Phenocrysts in the Pogy Member, Traveler Felsite

Sample No.	1.*	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Total percent Phenocrysts in rock	13	20	7	10	12	17	20	10	35	7	10	5
Mineral constitution of Phenocrysts												
Quartz	4	9	47	15	38	50	15	39	40	20	40	5
Plagioclase	86	73**	47	75	60**	49	64	59	40	64	40	87
Sanidine		x			x		10					
Mafic silicates	8	14		8	tr		8		5	13	19	5
Clinopyroxene										x		
Biotite		x								x		
Hornblende										x		
Garnet					tr							x
Accessories	2											
Opaques***	x	3	5	2	2	1	3	1	15	2	1	2
Zircon	x	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
Apatite	x	1	1	tr	tr	tr	tr	1	tr	1	tr	1

*point count. Phenocrysts represent 134 points out of 1000.
**Total feldspar. Sanidine is thought to be very minor.
***Includes both magnetite and ilmenite.

TABLE 2 (Continued)

1. KR 49 (EC 15-49) Perlitic welded tuff from penninsula north of Forest Service Camp on shore of Matagamon Lake.

2. KT 207 (SE 1-515) Welded tuff from 2100 feet on the east side of The Traveler.

3. KT 210 (SE 4-47) Welded tuff from 1850 feet on the east side of The Traveler.

4. KT 225 (SW 35-20) Welded tuff from 2200 feet on the eastern ridge of the South Pogy Mountain, plagioclase is andesine.

5. KT 228 (SC 25-32) Welded tuff from the western summit of South Traveler Mountain, plagioclase is andesine.

6. KT 274 (SW 32-47) Welded tuff from about 1/2 mile northwest of Mahar Pond.

7. KT 355 (C 36-24) Welded tuff from Bald Mountain Falls (stream northwest of Bald Mountain).

8. KT 531 (EC 13-45) Welded tuff from base of cliffs on Horse Mountain (3-5 feet above Matagamon formation).

9. KT 256 (SC 6-31) Felsite of uncertain origin from 1620 feet on the southwest side of Pogy Notch.

10. KT 372 (SW 28-15) Felsite of uncertain origin from 2180 feet on the south side of South Pogy Mountain, plagioclase is andesine.

11. KT 374 (SW 26-14) Felsite of uncertain origin from 2200 feet on the south side of South Pogy Mountain, plagioclase is andesine.

12. KR 139 (C 36-46) Lava from the lower prominent flow on the south side of Trout Brook Mountain, elevation 1450 feet.

tuff between 15 and 35 percent of the phenocrysts are quartz. Quartz ranges in size from tiny fragments to grains 1.5 mm across; most of it is between 0.1 and 0.4 mm across. Much of the quartz is corroded (fig. 27), and most of it is slightly biaxial with a maximum 2V of about 5° (the isogyres almost separate). Fluid inclusions are invariably present and range in size from vanishingly small to 0.04 mm in diameter. They usually have negative crystal outlines and may contain two phases. Most crystals have one or more inclusions in the size range 0.01 to 0.02 mm and innumerable inclusions of the size range 0.001 to 0.003. The smaller ones may have a linear arrangement. Some inclusions contain only one phase, are isotropic, have an index of refraction less than quartz and have negative crystal outlines; these may be glass. Quartz also contains inclusions of apatite, opaque minerals, calcite, chlorite, and groundmass. Many of the inclusions of groundmass could be embayments in three dimensions. Some, however, have hexagonal outlines and are probably true inclusions.

Feldspar phenocrysts constitute an average of 67 percent of the phenocrysts of the welded tuff. They range in size from tiny fragments up to euhedral or subhedral crystals four mm long. The average length is about one mm. Plagioclase and sanidine have been identified. Both feldspars may be corroded and both contain numerous

inclusions of prismatic apatite and to a lesser extent zircon and opaque minerals.

Plagioclase is ubiquitous; sanidine has been identified in only six thin sections. It is extremely difficult to estimate the relative abundances of coexisting plagioclase and sanidine as most of the feldspar is partly or completely clouded with alteration products (sericite,[6] kaolinite, calcite, clinozoisite and chlorite). It is possible, therefore, that sanidine may have been overlooked in many of the thin sections. Present data, however, indicates that sanidine is very minor. Staining techniques have not been tried.

Fresh plagioclase is strongly zoned and resembles that in the lava of the Black Cat member in details of zoning and twinning. Few samples of welded tuff contain plagioclase fresh enough for optical study. Compositional and optical data for plagioclase phenocrysts from two specimens of welded tuff from the Pogy member are presented in table 7. The average composition of the plagioclase from these two samples is An_{49}.

Much of the sanidine is perthitic with the ratio of the potassic phase to the sodic phase about 4:1. The sanidine has the optic properties of low sanidine (optic

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[6]Sericite is used in this study for any fine-grained white mica.

plane $\perp$(010), distinct dispersion, r>v). The composition of sanidine from two specimens has been determined by measuring 2V. Both specimens contain sanidine with a composition of Or_{67}.[7]

Mafic silicate phenocrysts are notably less abundant than in the lava of the Black Cat member. They may be absent or may constitute as much as 10 percent of the phenocrysts. Almost without exception they are altered so completely that the original mafic mineral is unidentifiable. The alteration products include chlorite, calcite, clinozoisite or epidote, sericite, magnetite, limonite, very fine grained amphibole, and celadonite. Remnants of biotite phenocrysts were observed in a few thin sections; garnet occurs in two specimens.

A greenish mineral, probably celadonite, occurs in some thin sections as an alteration product of mafic silicates or is a lenticule filling. It is characterized by moderate to strong pleochroism (light yellow to bright green), moderate birefringence and parallel extinction. The birefringence and pleochroism are too great for chlorite and the pleochroism is unlike that of biotite elsewhere in the felsite. Biotite is usually pleochroic in yellows, browns and dark brown greens. This greenish mineral also

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[7] The sanidine phenocrysts from one of these specimens (KT 228) coexist with plagioclase phenocrysts of composition An_{48}.

lacks the shagreen texture of biotite. Ross (1958, p. 543) has reported that celadonite occurs as a secondary mineral in welded tuff from Clynch County, Georgia. W. S. Wise of Johns Hopkins University (oral communication) reports that he has identified celadonite in Early Tertiary ash flows of the Pacific Northwest, U. S. A. He states that all celadonite he has seen is moderately to strongly pleochroic with a bright green or bluish green color in transmitted light. Celadonite is a dioctahedral phyllosilicate with an ideal formula, according to Wise, of $K\ Mg\ Fe'''(Si_4O_{10})(OH)_2$. This greenish mineral in the welded tuff of the Pogy member has properties consistent with those of celadonite and probably is celadonite.

Estimation of the percentage of mafic phenocrysts is complicated by the presence of clots of chlorite and, occasionally, amphibole which are not thought to be alteration products of mafic phenocrysts. Some of these clots are in the cores of lenticules and are obviously related to the formation of the lenticules. Others are of irregular shape and uncertain origin.

Deformed shards in the welded tuff range greatly in their size, appearance and mineralogy. In general, shards are not visible in hand specimens, but in a very few specimens they may be seen on the weathered surface. Figure 26 shows white-weathering shards in a very dark-gray

matrix. All shards fall into the ash size category (less than 4mm) of the Wentworth and Williams (1932) classification, and nearly all are less than 2 mm. These figures are, of course, meaningful only for the relatively undeformed shards. They appear to be unsorted, although sorting characteristics cannot be determined accurately in a two dimensional thin section.

Examples of deformed shards are shown in figures 28 through 34. In other thin sections the identification of shards is less certain because of extreme deformation or alteration. Figures 35 through 40 show various features believed to have originated as shards, but about which there may be some doubt. Perlitic fracturing is found in some welded tuffs, such as KR-49 (fig. 36). Angular chloritic bodies in these tuffs are probably shards, but some of them may be chloritic alteration along perlitic fractures. Other specimens contain angular bodies rich in magnetite (figs. 38 and 40). These rocks have a very definite fragmental appearance in thin section and enough of the magnetite-rich bodies resemble shards so that the rock is probably a welded tuff. As the deformation or flattening of the shards become greater, the microscopic foliation looks more and more like flow banding (figs. 37 and 39). It is not always possible to decide whether a given rock is a welded tuff or a lava. In the three

examples given above, however, it is believed that the discontinuities, lensings out (fig. 37), or breaks (fig. 39) in the banding of the groundmass result from the original fragmental nature, rather than flowage.

The amount of deformation of the shards is not constant within one thin section, or from specimen to specimen. The deformation is greatest in the vicinity of phenocrysts or lithic inclusions. Figure 29 shows shards squeezed between two phenocrysts to the extent that the foliation resembles flow banding. Elsewhere in the thin section, the fragmental nature of the rock is evident (fig. 28).

The mineralogy of the shards ranges within wide limits. The following minerals have been identified: quartz, potassic feldspar (probably orthoclase), a non-fibrous zeolite (?), sericite, chlorite, celadonite, saponite, calcite, siderite, epidote, amphibole, and magnetite. The zeolite (?) (distinct lavender color, strong negative relief, very low birefringence) occurs as small scattered grains associated with quartz and potassic feldspar. It has been observed in only three thin sections. The mineral believed to be saponite is platy or fibrous, has a very light olive-tan color, faint pleochroism, moderate birefringence, parallel extinction, refractive indices between those of quartz and chlorite, and is

optically negative with a positive sign of flattening (X perpendicular to plane of flattening). These properties are consistent with saponite (according to Ross, 1960, a trioctahedral magnesian montmorillonite) which seems a reasonable identification of this phase. Ross (1958, p. 543) has also reported saponite as an alteration product of dacitic and rhyolitic shards.

The most common assemblage of minerals in the shards is quartz, potassic feldspar, and saponite, with or without chlorite. Typically the shards have axiolitic borders (elongate crystals growing perpendicular to a surface) of fibrous saponite and prismatic potassic feldspar and cores of a mosaic of quartz, ±chlorite (fig. 33). In some specimens the shards contain only quartz and potassic feldspar. Here again, feldspar forms the borders of the shards and quartz fills the centers. Other samples contain shards apparently composed entirely of saponite or chlorite. It is not always possible to determine whether saponite or chlorite is the mineral present. In a few specimens, bodies interpreted as much flattened shards are composed of optically continuous quartz. Finally, some shards contain such a high percentage of opaque dust, probably magnetite or limonite, that they are nearly opaque (figs. 38 and 40).

Inter-shard areas contain the same minerals as the

shards, although there is commonly a difference between the two areas in the percentage of a given mineral present and in grain size. Most commonly, minerals in the inter-shard area are much finer grained (fig. 28). In such samples, the inter-shard areas look essentially the same as the groundmass of the lava of the Black Cat member. In some thin sections, the shards have been compressed so closely together that there is virtually no area left between them.

Lithic inclusions are present in nearly all samples of welded tuff and constitute from 2 to 20 percent of the rock. Several rock types are represented in the inclusions, but the most common is felsite. The felsite inclusions are themselves varied, but most of them resemble some type of the Traveler felsite and are presumably cognate inclusions picked up from the surface of the underlying unit or from the walls of the vent. Many of the felsite fragments are banded, but whether this is a flow or a compression structure is not known. In some thin sections, the banded felsite fragments are randomly oriented. In others, the banding of the fragments is roughly parallel to foliation of the shards.

Tuff, welded tuff, crystal tuff, pumice, and collapsed pumice have also been identified among the felsite inclusions. The felsite fragments may be visible on the weathered surface of welded tuff (fig. 41).

Typically, they weather to a drak greenish gray or dark gray while the matrix weathers to a light greenish gray or bone white.

Other types of lithic inclusions include subgraywacke siltstone, shale, and diabase. The included sedimentary rocks are identical in appearance and mineralogy with the rock types of the underlying Matagamon and Seboomook formations and are presumably derived from them. Because the sedimentary rock fragments are not restricted to the basal unit of the felsite, some must have been plucked from the walls of the vent.

The diabase inclusions (consisting of plagioclase laths and chlorite) are rare. It is possible that these could have come from the Pond Pitch basalt which crops out along the East Branch of the Penobscot a few miles to the east. More likely they are closely related to similar inclusions in the Black Cat member and to the growth aggregates of phenocrysts (See p.147). Perhaps they come from the crystallized margins of the magma chamber.

Long, thin lenticules, so characteristic of the lava in the Black Cat member, are uncommon in thin sections of welded tuff. They are generally absent from those specimens in which shards are clearly recognizable or only mildly deformed. It is uncertain whether they originated as collapsed pumice fragments, as favored by some authors,



Figure 26. (KT 228, SC 25-32). Welded tuff from the western summit of South Traveler showing light-gray-weathering shards and white-weathering feldspar phenocrysts. Pogy member, Traveler felsite. 10 cm scale.



Figure 27. (KT 463, C 395-20). Corroded quartz phenocryst from a welded tuff, Pogy member, Traveler felsite. The specimen is from Bald Mountain. X 38.

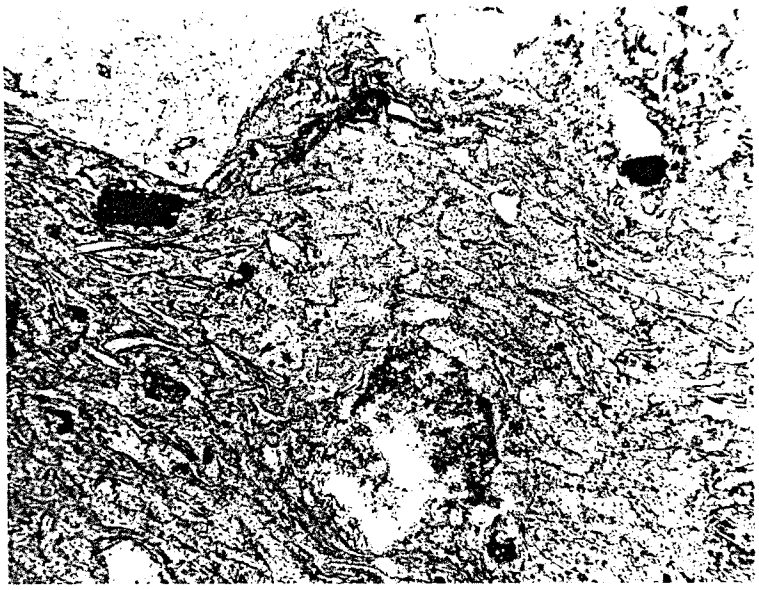


Figure 28a. (KR 77, EC 13-45). Welded tuff of the Pogy member, Traveler felsite from the base of the cliffs on Horse Mountain. This specimen was collected from about 30 feet above the Matagamon formation. The large phenocryst in the upper left is plagioclase. X 38.

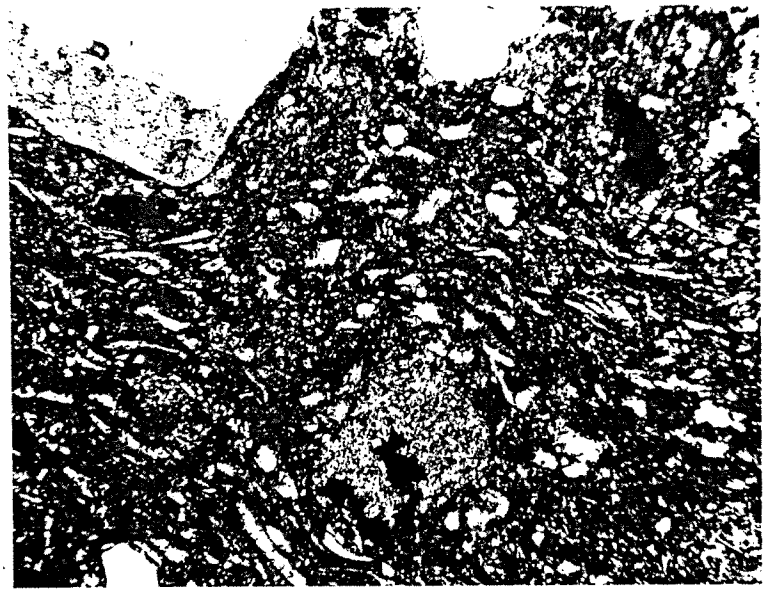


Figure 28b. (KR 77, EC 13-45). Same view as figure 28a; crossed nicols. X 38.

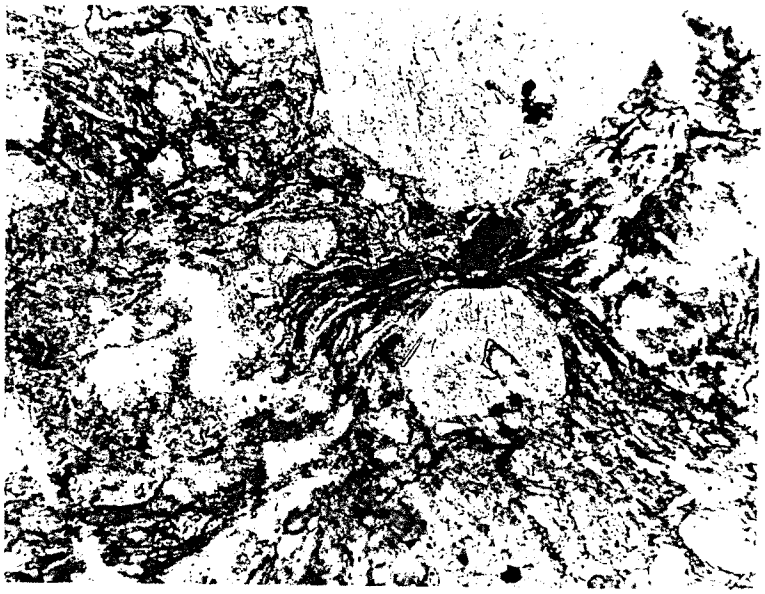


Figure 29. (KT 77, EC 13-45). Shards compressed between two plagioclase phenocrysts in welded tuff of the Pogy member, Traveler felsite. Apatite prisms are visible in the plagioclase phenocrysts. Same thin section as figure 28a. X 38.



Figure 30. (KR 73, EC 13-45). Welded tuff of the Pogy member, Traveler felsite from the base of the cliffs on Horse Mountain, no more than 5 feet above the Katagamon formation. Devitrified shards, quartz and plagioclase phenocrysts and an inclusion of siltstone are visible. X 32.



Figure 31. (KT 225, SW 35-20). Welded tuff from South Pogy Mountain, Pogy member, Traveler felsite. Shards are compressed against an inclusion of spherulitic felsite (upper left). The phenocrysts are quartz and plagioclase. X 32.

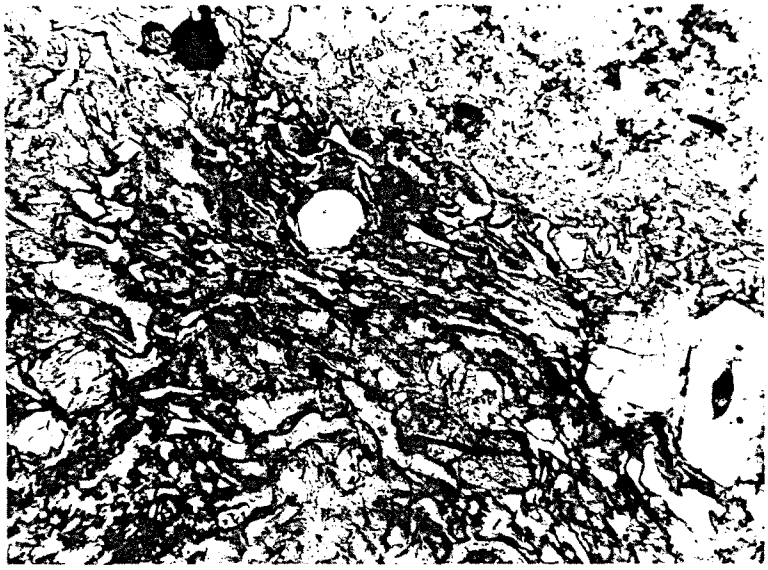


Figure 32a. (KT 355, C 36-24). Welded tuff of the Pogy member, Traveler felsite from Bald Mountain Falls. Quartz and sanidine crystals are visible. X 38.

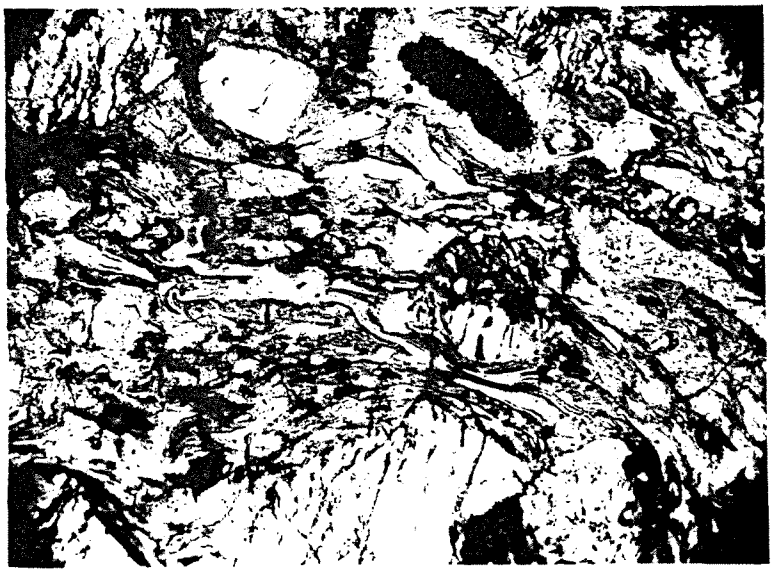


Figure 32b. (KT 355, C 36-24). Welded tuff of the Pogy member, Traveler felsite from Bald Mountain Falls. Same thin section as figure 32a. The phenocrysts are quartz and sericitized plagioclase. X 58.

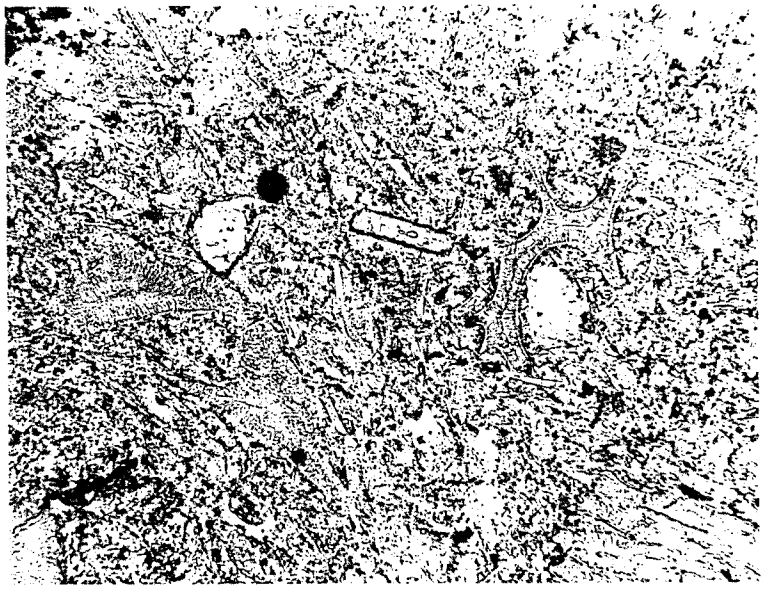


Figure 33. (KT 274, SW 32-47). Shards showing axiolitic borders of saponite in welded tuff from the valley south of Sable Mountain. Apatite prisms are visible. Pogy member, Traveler felsite. X 122.



Figure 34. (KT 274, SW 32-47). Welded tuff of the Pogy member, Traveler felsite. Same thin section as figure 33. X 38.



Figure 35. (KT 49, MC 15-49). Perlitic welded tuff of the Pogy member, Traveler felsite from the shore of Matagamon Lake. Chloritic alteration of shards and a pumice(?) fragment are shown. Much of the groundmass is saponite. X 32.



Figure 36. (KT 207, SE 01-515). Devitrified shards(?) in welded tuff of the Pogy member, Traveler felsite from the east side of The Traveler. X 38.

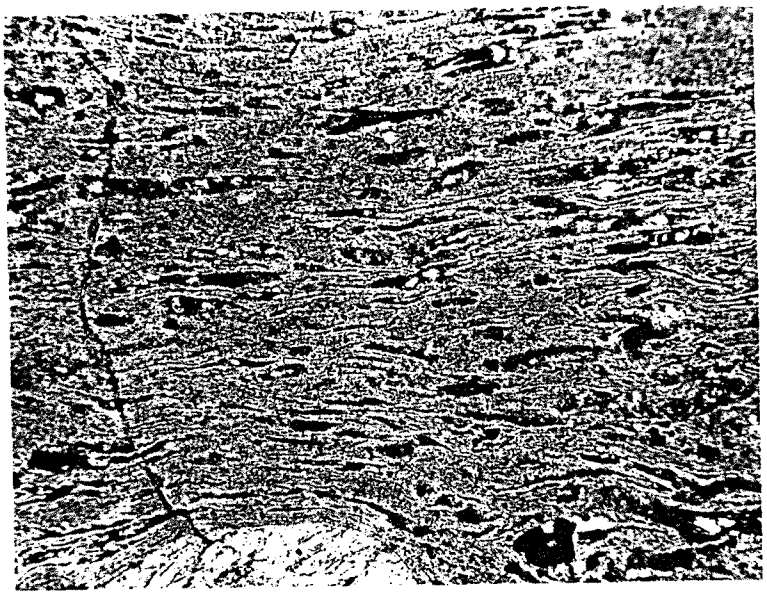


Figure 37a. (KR 65, EC 14-42). Much flattened shards in welded tuff of the Pogy member, Traveler felsite from the top of the cliff on Horse Mountain. The dark mineral in the shards is probably celadonite. X 32.



Figure 37b. (KR 65, EC 14-42). Devitrified shards in welded tuff; same thin section as figure 37a. The phenocrysts are sericitized plagioclase and carbonate pseudomorphous after pyroxene(?). X 38.

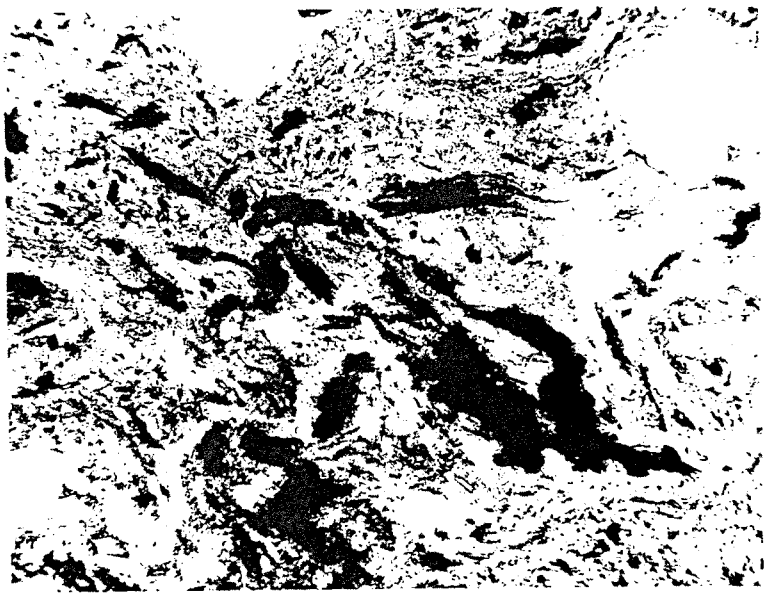


Figure 38a. (KT 257, SC 065-315). Magnetite-rich shards (?) in a welded tuff of the Pogy member, Traveler felsite from North Pogy Mountain. The large white phenocryst in the upper right is quartz. X 32.

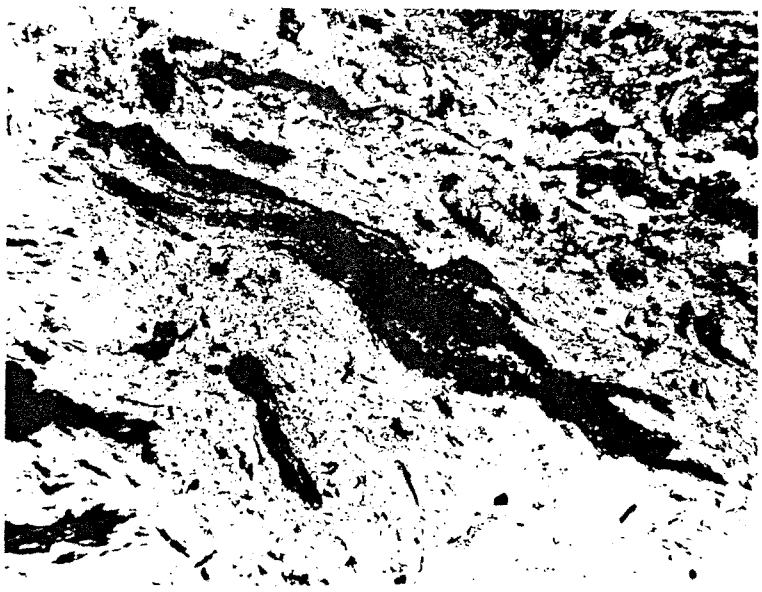


Figure 38b. (KT 257, SC 065-315). Magnetite-rich lenticule in a welded tuff; same thin section as figure 32a. X 32.

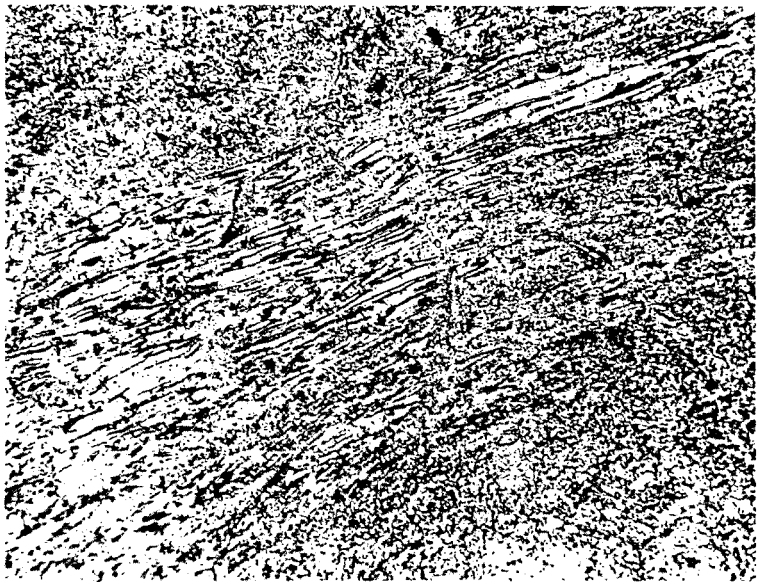


Figure 39a. (KT 206, SE 03-52). Highly compressed welded tuff of the Pogy member, Traveler felsite from the eastern slopes of The Traveler. The shards are outlined by opaque dust. X 122.



Figure 39 b. (KT 206, SE 03-52). Same view as figure 39a, but with crossed nicols. The shards have recrystallized to relatively coarse, equidimensional grains of quartz. The rock contains abundant tiny tourmaline prisms. Near-by sediments are hornfelsed, indicating the proximity of the Katahdin Granite (?) (unexposed). X 122.

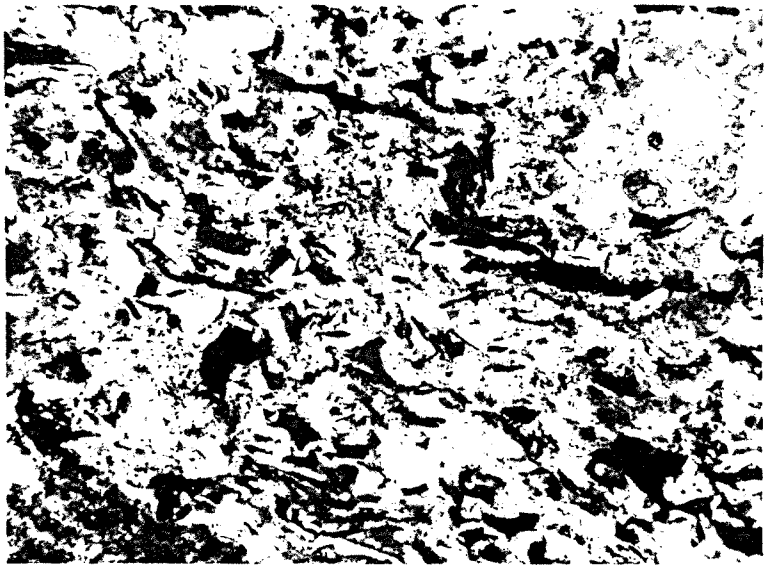


Figure 40. (KT 264, SW 31-32). Limonitic shards(?) in welded tuff of the Pogy member, Traveler felsite from North Pogy Mountain. X 122.

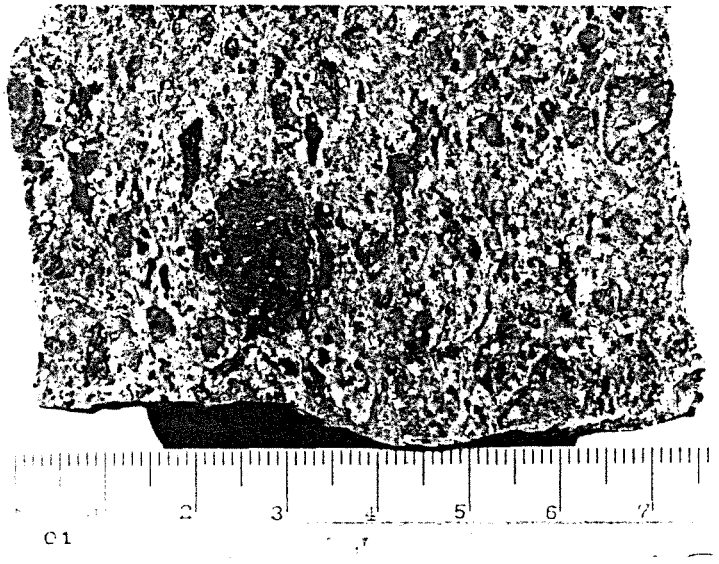


Figure 41a. (KT 282, SW 30-135). Sawed surface of weathered welded tuff showing lithic inclusions and flattened pumice fragments. Pogy member, Traveler felsite from the valley south of Sable Mountain. 10 cm scale.

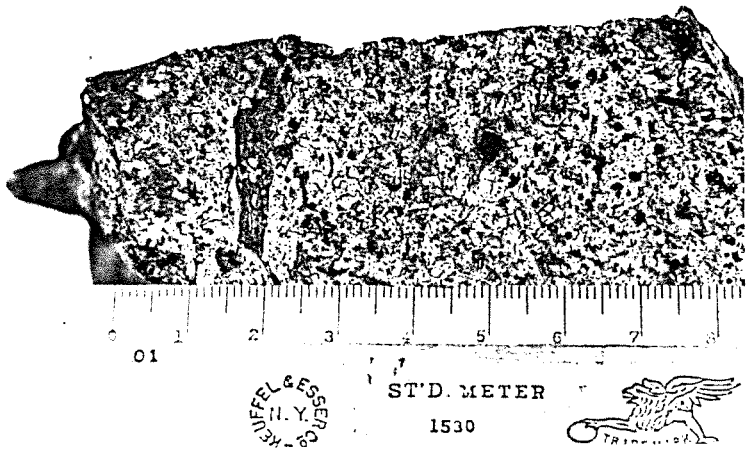


Figure 41b. (KT 534). Weathered surface of welded tuff of the Pogy member, Traveler felsite showing an inclusion of felsite. The specimen is from 9 feet above the Matagamon formation at the base of the cliffs on Horse Mountain.

or as a vapor phase crystallization phenomenon, as favored by Mackin (1960). Angular lithic inclusions and the larger lenticules are usually not found in the same thin section. This observation is consistent with either theory. Welded tuffs do, however, contain darker bodies, usually rich in chlorite and roughly lenticular in shape, which have ragged borders and terminations (fig. 35). Some of these are almost certainly collapsed pumice.

PORPHYRITIC TUFF: Porphyritic tuff occurs at very few localities within the Pogy member: at the base of the Pogy member, at "Bald Mountain Falls," and on the northeastern summit of Billfish Mountain. The porphyritic tuff is characterized by the presence of undeformed shards in thin section and the absence of flattened inclusions in hand specimen. It is thus believed to have once been vitric tuff.

At the base of the Horse Mountain cliffs the non-compressed tuff is no more than two to four feet thick and grades up into welded tuff. It is underlain by tuffaceous sediments of the Matagamon formation. In hand specimen it is a medium to light bluish-gray to greenish-gray porphyritic felsite with phenocrysts of quartz and feldspar and numerous lithic inclusions. The percentage of phenocrysts varies considerably and may be as high as 40 percent. In one thin section the shards, although devitrified, are as well

preserved as any the author has seen from any rock of any age (fig. 43). The shards average 0.1 to 0.2 mm in length; the largest observed was about one mm long. Numerous shards enclose unruptured bubbles which are mostly 0.1 to 0.2 mm in diameter (fig. 42). These bubbles are now filled with quartz (one crystal or several) and the former cavity wall is usually lined with chlorite, worm-like aggregates of clinozoisite, or plates of potassic feldspar. Typically, the shards have an axiolitic texture and the dominant mineral in the shards is saponite. Chlorite and/or calcite may be present in the center of shards. The darker greenish-brown shards are set in a lighter matrix composed largely of quartz grains about 0.01 mm across and disseminated flakes of saponite, chlorite and magnetite.

At the base of the cliffs on the East side of Bald Mountain, porphyritic tuff is interbedded with tuffaceous sediments. Together they form a sequence a few feet thick between the underlying sandstone of the Matagamon formation and the overlying massive lapilli tuff which makes up much of Bald Mountain. The porphyritic tuff contains about 20 percent angular crystal fragments of quartz, sanidine ($2V = 25^{\circ}$) and plagioclase. The ratio of quartz to feldspar is about 2:1. Another 20 percent consists of angular lithic fragments. Most of the lithic fragments are felsite, but some beds contain shale or siltstone fragments and clay pellets. The matrix consists of devitrified shards

and volcanic dust.

The porphyritic tuff that crops out on the northeastern summit of Billfish Mountain is unlike any other observed within the area studied. Unoriented and unflattened shard-like greenish-brown fragments are set in a bone white matrix of weathered rock (fig. 45). The outcrop also contains numerous scattered and unoriented fragments of light gray-green banded felsite, which are as much as 18 inches across. Other rock types present among the fragments include a subgraywacke, which is probably from the Matagamon formation, and quartzite. The larger fragments of all types are usually rounded, but the smaller ones are angular. This tuff is overlain by a welded tuff. The nature of the contact between them is unknown.

The stream flowing north into Middle Fowler Pond on the west side of Bald Mountain flows over a striking 70 foot cataract at an elevation of about 1100 feet (C 36-24). The cataract, which for convenience is herein called Bald Mountain Falls and is so labelled on Plate 1, is formed by interbedded porphyritic tuff (fig. 44) and soft dark-gray fissile shale. These beds have a total thickness of 80 to 100 feet and dip steeply west (50 to 60°). They are overlain by welded tuff and the base of the succession is cut out, in the stream bed, by a major fault. These rocks probably represent subaqueous pyroclastic deposition in a local basin. The interbedded porphyritic tuff and shale

have not been found elsewhere.

The individual porphyritic tuff beds at Bald Mountain Falls are crudely sorted as to the size of the shards present, the percentage of phenocrysts (up to 35 percent) and the size of the phenocrysts. The sorting was not observed in the field and the area has not been revisited. This porphyritic tuff is characterized by the anomalously high content of secondary carbonate (both calcite and siderite), perhaps related to the fault, and by highly carbonaceous inclusions.

NON-PORPHYRITIC TUFF: Very dark-gray massive felsite containing no phenocrysts forms two small outcrops 100 yards apart in a small stream at the southwest end of Pogy Notch (SC 08-30, elevation 1440 feet). In thin section the tuff is similar in appearance and mineralogy to the groundmass of the normal porphyritic felsite. The felsic minerals (0.005 to 0.010 mm) display very indistinct grain boundaries. Although they appear to be equidimensional, they have a noticeable preferred orientation as determined by the gypsum plate. The relationship of this preferred orientation to the outcrop is not known. The other minerals consist of subhedral grains of magnetite (0.002 to 0.005 mm) and flecks of biotite (pleochroic, light tan to greenish brown). The magnetite grains are typically in open clusters. It is notable that the mafic mineral in this rock is

biotite rather than the usual chlorite. Very fine-grained non-porphyritic laminated tuff of the Black Cat member from South Traveler Mountain also contains biotite. The presence of biotite in these two non-porphyritic tuffs may be either a primary mineralogical feature, or, because both occurrences are near the Katahdin granite, a contact effect. Specimens of other rock types of the Traveler felsite from as near the granite contact as the non-porphyritic tuffs do not contain biotite in the groundmass. Because the non-porphyritic tuff has not been found elsewhere, however, the origin of the biotite cannot at present be ascertained.

In thin section the rock is seen to be much fractured. The fractures have been filled with felsitic material leaner in biotite and magnetite than the rest of the rock.

Because no banding is present in either the hand specimen or thin section, this rock is believed to be a tuff rather than a lava or a welded tuff. The pyroclastic material was probably very fine ash or dust. Perhaps further examination of the outcrop would show a coarse stratification.

LAVA: The only unambiguous lava within the Pogy member is on Trout Brook Mountain. Here the lava forms at least three major flows with an aggregate thickness of 400 feet. The lower two flows form prominent cliffs along the

south side of Trout Brook Mountain (fig. 46). Both possess coarse columnar jointing. The columns average a few feet in diameter, are perpendicular to the planar dimensions of the flows and are up to 70 feet long. Well developed wavy and/or contorted flow banding is visible in the weathered outcrops of all the lava (fig. 47). Scattered unoriented inclusions of banded felsite may also be visible and these disrupt the flow banding (fig. 48). Even in the hand specimen, the banding appears to be very delicate and stands out on the weathered surface as very elongate, slightly darker weathering, typically pinkish lenticules set in a bone white matrix. The lenticules range in thickness from vanishingly thin up to several millimeters and are extremely long relative to their width. They may pinch and swell along their length. Oliver (1954) suggested that one way to distinguish welded tuff from lava is that the former should have platy lenticules, whereas the latter have pencil-shaped lenticules. The lenticules in the lava on Trout Brook Mountain, however, are planar features. In thin section, the lenticules look much like those from the Black Cat member and their origin is probably the same. (See p.157). They have axiolitic borders, quartz and chlorite cores, and the thicker ones show the remnants of spherulites in their centers. Crystallization of the axiolitic borders and spherulites

must have occurred after the lava had come to rest, because the axiolitic fibers and spherulites can be seen cutting across flow banding (fig. 49).

The lava contains 5 percent phenocrysts of which 90 percent are feldspar (only plagioclase identified), 5 percent quartz and 5 percent altered mafic phenocrysts. (See table 2). Garnet is present in one of the two thin sections made from the lava. It is pale pink, completely isotropic and is a rounded remnant (0.5 mm across) in the middle of an alteration zone with a total diameter of 1.5 mm. The alteration products include chlorite (washed out appearance, very low birefringence), some shreddy biotite, (strongly pleochroic, X = light brown, Y and Z = brown) calcite, opaques, and sericite. The alteration zone is hexagonal in shape and the flow banding wraps around the entire area. (fig. 49). There is no reason to doubt that garnet is a true phenocryst in the lava.

The felsite at an elevation of 1100 feet on the northern slopes of Trout Brook Mountain (C 33-52) is pinkish red. This felsite may be the oxidized top of one of the flows and indicate its subaerial origin.

VOLCANIC BRECCIA: Volcanic breccia containing randomly oriented banded felsite fragments crops out at a number of places on the northwestern slopes of Wassataquoik Mountain. This rock is unusual in that it contains visible

pyrite and an unusually large amount of garnet (several crystals visible in one hand specimen). This breccia has not been studied in detail because of its poor exposure and the inaccessibility of the area. Its origin is unknown, but in view of its proximity to the body of granophyre on the west ridge of Wassataquoik Mountain, it may be related to a vent.

Another volcanic breccia and lapilli tuff have been observed at a number of localities on Bald Mountain (T.5N., R.9W). The origin of these rocks in not known.

FELSITE OF UNCERTAIN ORIGIN: Except for rocks such as laminated tuffs which are clearly recognizable in the field, the felsite is subdivided into texture types almost entirely upon thin section criteria. The major shortcoming of this procedure, of course, is that the resulting geologic map is a sample map rather than a field map. During most of the mapping, however, the author was unable to subdivide the felsite in the field.

Usually the original texture is well enough preserved in thin section to allow at least a tentative conclusion as to its origin. Nevertheless, it has not been possible to determine whether some banded felsite is lava or welded tuff. There are two reasons for this ambiguity: 1) some specimens are so greatly altered that the only clear textural feature is a crude banding; 2) in

others the texture is well preserved, but has characteristics of both flow banding and the banding of welded tuff.

Little need be said of the specimens in the first group. The type and relative percentages of phenocrysts they contain fall within the limits of those found in other samples of the Pogy member. One of the two analyses of the Traveler felsite presented by Smith (1930) was of a sample of the Pogy member with ambiguous texture.

Samples Nos. KT 372 (SW 28-15) and KT 374 (SW 26-14) from the cliffs of South Pogy Mountain overlooking Wassataquoik Lake, are excellent examples of felsite with well preserved but ambiguous texture. The compositions and structural states of plagioclase from both these samples have been determined. (See p.267). Both samples display excellent banding. They contain lenticules very rich in magnetite, some of which are nearly opaque. Phenocrysts, typically in aggregates, are found in the thicker of the dark lenticules. They may possess very irregular, ragged borders and internal banding, some of which is convolute (fig. 50a). These features would appear to have been caused by flowage. On the other hand, the banding in the groundmass is not smooth and continuous (See fig. 60), and small magnetite rich lenticules resemble flattened shards (fig. 50b).

Spherulites are present in certain banded portions of the groundmass. Thus, whatever the origin of the banding,

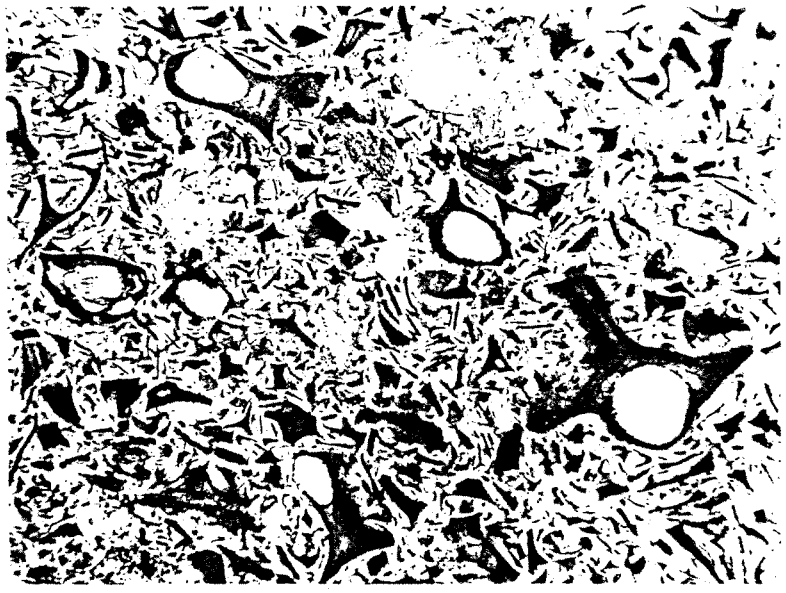


Figure 42a. (KT 153, EC 13-45). Porphyritic tuff from the base of the Traveler felsite (Pogy member) at Horse Mountain. Some shards contain unruptured bubbles now filled with quartz. The former cavity wall is lined with chlorite and potassic feldspar. X 32.

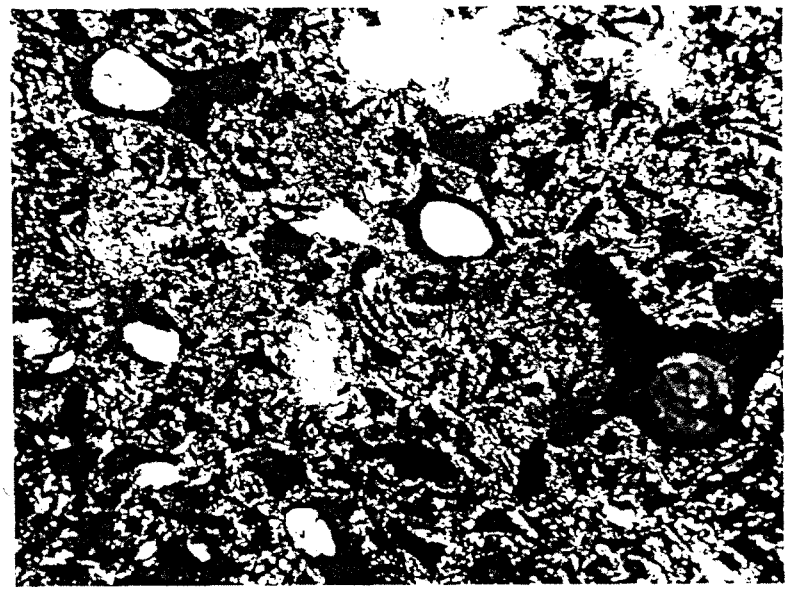


Figure 42b. (KT 153, EC 13-45). The same view as figure 42a, but with crossed nicols. X 32.

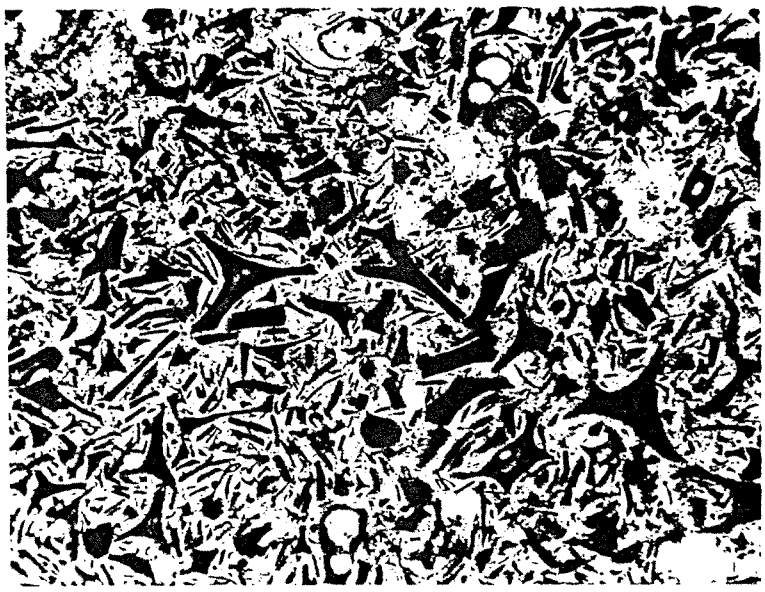


Figure 43. (KT 153, EC 13-45). Porphyritic tuff from the base of the Traveler felsite (Pogy member) at Horse Mountain. The same thin section as figures 42a and 42b. The principle mineral in the shards is saponite. X 38.

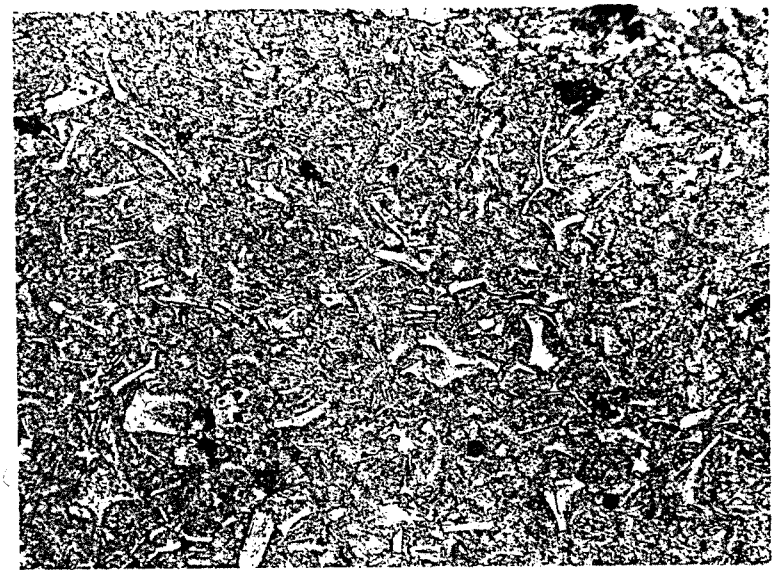


Figure 44. (KT 354, C 36-24) Porphyritic tuff of the Pogy member, Traveler felsite from Bald Mountain Falls. The dark patches are carbonate. X 38.

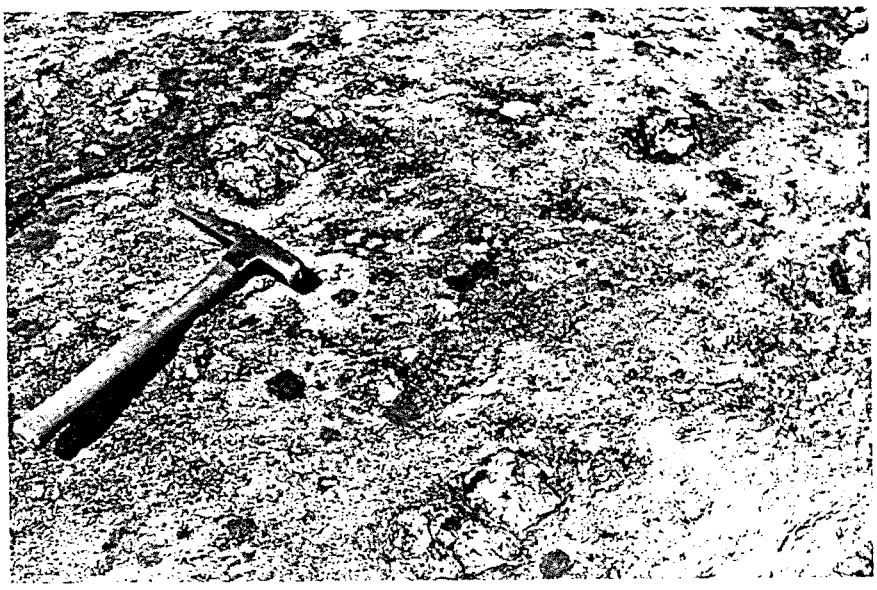


Figure 45. Porphyritic tuff of the Pogy member, Traveler felsite from the northeastern summit of Billfish Mountain (EC 8-31). Most of the inclusions are felsite.



Figure 46. Prominent lava flows of the Pogy member, Traveler felsite on the south side of Trout Brook Mountain. Columnar jointing is evident. The picture was taken from the 1416 foot knob west of Littlefield Pond.

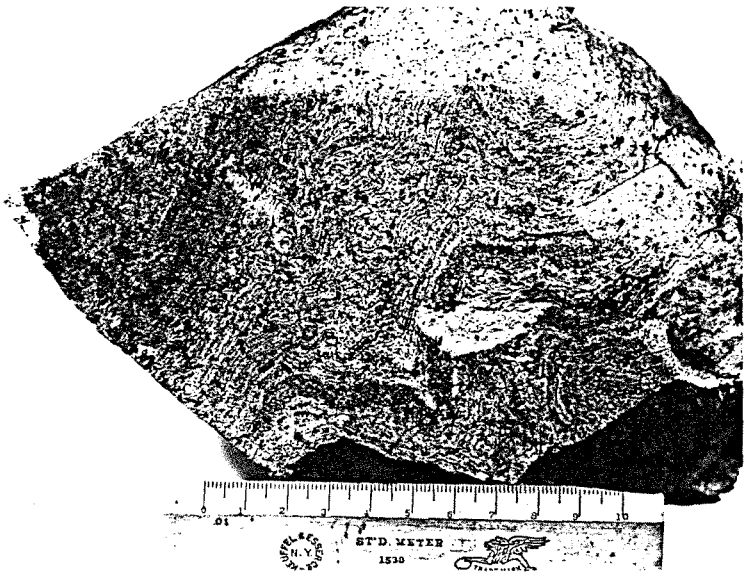


Figure 47. (KT 507). Chaotic flow banding in lava of the Pogy member, Traveler felsite from the summit of Trout Brook Mountain. 10 cm scale.

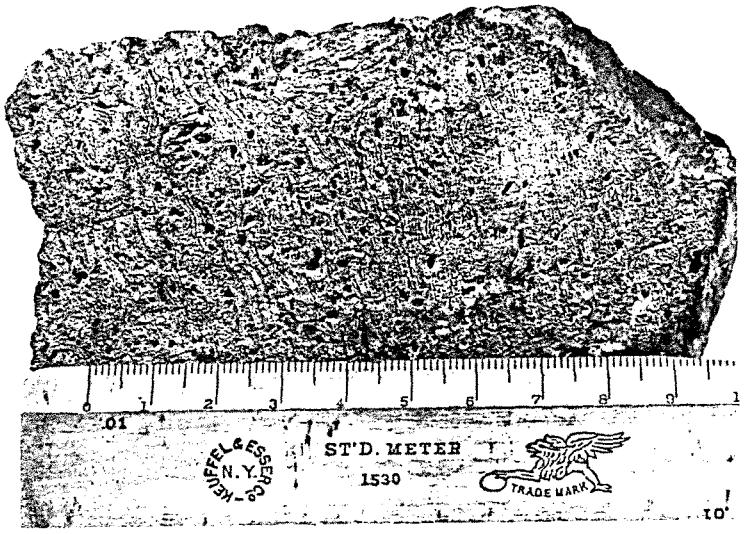


Figure 48. (KR 139, C 36-46). Flow banding in lava of the Pogy member, Traveler felsite from Trout Brook Mountain.

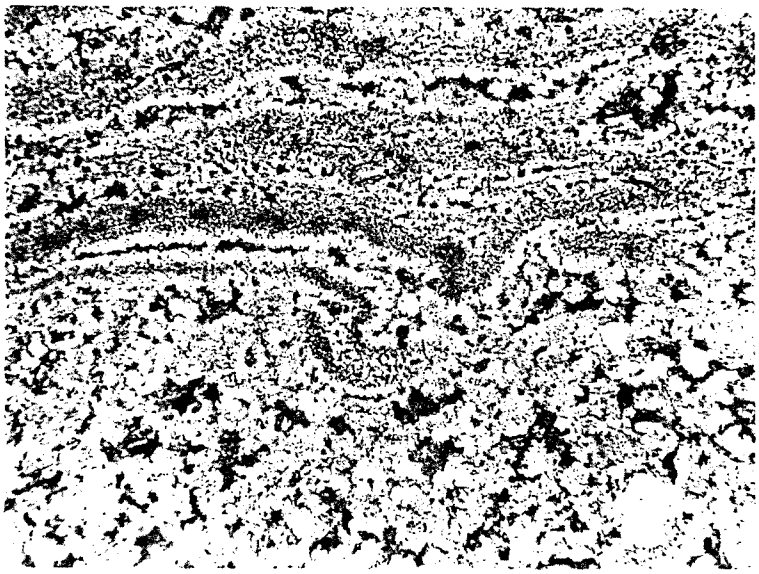


Figure 49a. (KT 139, C 36-46). Flow banding and spherulitic lenticule in lava of the Pogy member, Traveler felsite from Trout Brook Mountain. X 32.

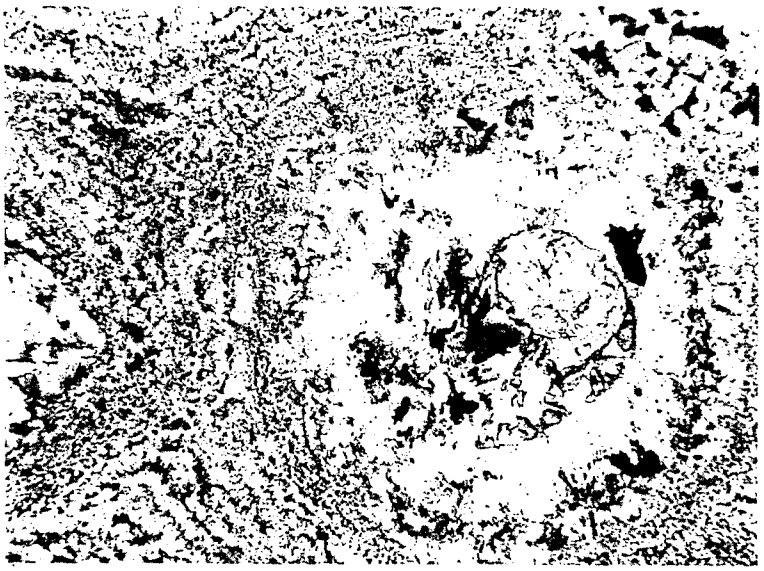


Figure 49b. (KT 139, C 36-46). Garnet phenocryst in lava of the Pogy member, Traveler felsite from Trout Brook Mountain. Note that the flow banding wraps around the phenocryst. The same thin section as figure 49a. X 32.



Figure 50a. (KT 374, SW 26-14). Banded lenticule rich in magnetite in felsite of uncertain origin from South Pogy Mountain; Pogy member, Traveler felsite. The phenocrysts are plagioclase. X 32.



Figure 50b. (KT 374, SW 26-14). Magnetite-rich bodies resembling shards in felsite of uncertain origin from South Pogy Mountain; Pogy member, Traveler Felsite. Same thin section as figure 50a. The phenocrysts are quartz and plagioclase. X 32.

the spherulites must have crystallized after cessation of all movement.

WELDED TUFF SHEETS OF THE POGY MEMBER AND THEIR ORIGIN: On the basis of samples collected, it is believed that the bulk of the Pogy member is welded tuff. Although the welded tuff has not been mapped in detail in the field, it appears to occur in sheet-like bodies characterized by the presence of crude columnar jointing. No internal stratification other than foliation caused by lenticules and the deformation of shards has been observed within the sheets of welded tuff. The predominance of discrete shards in most of the welded tuff indicates that the depositing medium was neither a lava flow nor a foam. The presence of deformed (welded) shards and columnar jointing, and the absence of well-defined internal stratification indicates that the welded tuff was emplaced more rapidly and at a higher temperature than an air-fall pyroclastic rock. The welded tuff, therefore, was almost certainly emplaced by particulate flows or pyroclastic avalanches, i.e. by ash flows.

Individual ash flows have not been mapped within the Pogy member. Roughly tabular bodies of welded tuff, however, have been observed on Billfish Mountain, Horse Mountain, and in the valley south of Sable Mountain (T.5 N., R.9 W.). It is not known whether these tabular

bodies are the result of a single ash flow or whether they are more complex cooling units of several ash flows. Unless further investigation makes subdivision possible, the tabular bodies of welded tuff in the Pogy member should be called welded tuff sheets.

Vertical zoning within welded ash flows in other localities has been described by many authors, eg. Marshall (1935), Gilbert (1938), Enlows (1955), and Boyd (1957). R. L. Smith (1960b) has presented an excellent summary of this zoning and some of the possible complexities of variations in the zoning. The zoning is caused by variations in the compaction (compression) of the constituents and in the devitrification phenomenon. The absolute as well as the relative thickness of each zone may vary almost without limit. One or more of the zones may not be present in any one ash flow. Presumably there are all gradations between densely welded ash flows and those in which no welding has occurred. Horizontal variations in ash flows, though reported by some workers (eg. Enlows, 1955, p. 1240), have been less studied than the vertical variations.

There is some evidence that zoning is present in the welded tuff sheets of the Pogy member. The zoning has not been specifically studied and such a study would be difficult. Many of the indications of the zoning have been obscured by lithification and complete devitrification.

Most of the evidence that remains is visible only in thin section. However, there are pronounced differences in the flattening of shards in thin sections from the same locality and presumably from the same welded tuff sheet.

At the base of the Pogy member on Horse Mountain (EC 13-45) porphyritic tuff forms a thin zone that grades up into welded tuff. This zone is analogous to the incoherent layer of ash at the base of some younger ash flows, such as those of Yellowstone Park, Wyoming (Boyd, 1961). Boyd has suggested, and the writer agrees, that such ash or tuff represents an air-fall deposit prior to the passage of the ash flow. In the valley south of Sable Mountain (T. 5 N., R. 9W.) some specimens contain virtually undeformed shards (fig. 33), while other specimens contain shards which are considerably deformed.

At two localities, the northeastern summit of Billfish Mountain and the southeastern peak of the Black Brook Mountains (SW 26-55), outcrops of welded tuff containing slightly deformed shards are overlain by welded tuff, containing more highly deformed shards. The welded tuff containing the less deformed shards probably represents the upper part of one welded ash flow and the other welded tuff probably represents the lower part of an overlying welded ash flow.

As a suggestion for future work, it would be

interesting to know if evidence of zoning by deuteric crystallization is preserved. Perhaps spherulites are restricted to certain portions of the welded tuff sheets. It may also be possible to observe in the outcrop a vertical change in the amount of flattening of pumice fragments. The author's experience to date is that pumice fragments cannot be recognized with certainty in the field. There is no question that younger volcanic rocks offer more fruitful grounds for studying the zoning in welded ash flows.

The mode of eruption that produces an ash flow is usually thought to be one of the various types of nuée ardente, a term first used by Lacroix in 1904 to describe the eruptions observed on Mt. Pelée in 1902 and 1903. The essential features of a nuée ardente eruption, as deduced by several first hand observers (Lacroix, Anderson, Flett, and Perret), are the frothing of the magma due to the exsolution of volatiles and the bursting of the resulting gas bubbles at some point in the eruptive process. The physical state of the ash flow during emplacement is a highly mobile suspension of viscous liquid or solid in a gas.

The suspension is certainly heavier than air and moves down-slope by gravity. Mackin (1960) has referred to the nuée ardente as a density current. Some authorities

(Fenner, 1923 and Perret, 1935) believe that continued exsolution of gas during flowage adds greatly to the mobility of a nuée ardente. McTaggart (1960) suggested that the entrapment of cold air may be a major factor in the extreme mobility.

The density current or ash flow is accompanied by a large black gas and dust cloud, the lower part of which is usually red and glowing. It is this incandescence which attracted the attention of most early workers and from the impressions caused by this cloud, the names "nuée ardente" and "ignimbrite" are derived. It is now generally recognized that the bulk of the depositional material is carried not by the cloud, but by the density current, ash flow, or glowing avalanche beneath the cloud (Smith, 1960a, p. 803). The ash flow grades up into the cloud. Anderson and Flett (1903, pp. 494-495) compare the relationship between the ash flow and its accompanying cloud with an Alpine snow avalanche and its accompanying cloud of snow and air. Several objections have been raised to the use of observed West Indian nuées ardentes as a model for the mode of eruption of pre-historic ash flows. First, most of the ash flow sheets in the geologic column cover much larger areas than any deposits produced by the observed nuées ardentes. As an extreme example, Mackin (1960) has reported ash flow sheets in southwestern Utah with an areal extent of 10,000 square miles. It is not known

whether such a sheet represents one or many ash flows.

Another difference between the deposits of the West Indian nuées ardentes and other ash flows is the average slope of the base of the flow. This may in part be a consequence of the relatively short distance traveled by the West Indian nuées ardentes. The volcanoes from which they came are close to the shore line.

A third difference is that no observed nuée ardente has resulted in a welded ash flow. Smith (1960a, p. 810) has suggested that this may be a direct consequence of the small size of the deposits formed by the observed nuées ardentes, relative to the welded ash flows in the geologic column. Boyd (1961) has demonstrated that it is thermodynamically reasonable in a subaerial nuée ardente for the ejecta to retain sufficient heat to deform and weld together after emplacement.

The details of the welded tuff sheets of the Traveler felsite have not been sufficiently studied and may not be sufficiently well preserved to contribute much to the concepts of the mode of eruption of ash flows in general, or of those particular ash flows specifically. However, because the known features of the welded tuff sheets of the Fogy member are similar to the characteristics of younger, better preserved welded ash flows, it is believed that the nuées ardentes observed in the West Indies

and the eruption which produced the "sand flow" of the Valley of 10,000 Smokes offer the closest approach in modern times to the eruptive mechanism that produced the welded tuff sheets of the Pogy member.

Because of the geosynclinal environment of the Traveler felsite, the problem as to whether the felsite was of subaerial or subaqueous origin is particularly pertinent. This, in turn, raises the question as to whether welded ash flows can ever form subaqueously, and finally whether any ash flow can be subaqueous. The author believes that an ash flow can neither form from a subaqueous eruption nor maintain its character in a subaqueous environment. The reasoning leading to this conclusion and supporting data on the known environments of deposition of other ash flows are presented in Appendix A.

BLACK CAT MEMBER: The Black Cat member is defined by its stratigraphic position above the Pogy member and by the absence or scarcity of quartz phenocrysts. It is named from exposures on Black Cat Mountain. It crops out in a broad belt from Squirt Dam Mountain eastward to Traveler Mountain and occupies a structural depression between the two large outcrop areas of the Pogy member. The flow breccia on Lord Mountain and the felsite on Sable Mountain (T. 5 N., R. 9W.) are interpreted as outliers on the Pogy member.

The outcrop of the Black Cat member on Trout Brook (WC 27-24) is interpreted as an inlier, probably a buried hill.

The contact between the Pogy and Black Cat members has not been observed, but it is believed to be conformable along both sides of the southeastern prong of the Black Cat member and it is probably unconformable to the west in the vicinity of Sable Mountain.

The Black Cat member is probably more uniform than the Pogy member. Nearly all specimens studied are flow rocks. The other rocks present are mostly restricted to the lower portion of the member and include flow breccia, welded tuff, laminated tuff and laminated crystal tuff.

Because the stratigraphy and structure within the Black Cat member are not known in detail, the thickness of this member can be only approximated. In the region extending from the South Traveler Mountain to North Traveler Mountain the planar features in the felsite have a persistent northwest strike and a northeast dip (average value, 25°). If one assumes that there has been no repetition of units by faulting, the Black Cat member is probably at least 6,000 feet thick.

LAVA: Lava occurs throughout the outcrop area of the Black Cat member. Excellent exposures are found on the eastern slopes of Black Cat Mountain and on North, Center and Pinnacle Ridges of Traveler Mountain.

Individual flows have not been mapped in the field. The flows are not easily distinguishable from one another and separating them would require long and detailed work. Examination of the exposures on Center and North Ridges of Traveler Mountain, however, suggests that with time and care, individual flows might be mapped. Among the criteria which might be used are the presence or absence of quartz, the size and shape (ratio of thickness to length) of lenticules, columnar jointing, and physiography. In some areas, the major flows form a series of prominent outcrops. Their continuity is more apparent when viewed from a neighboring mountain or ridge than from the actual outcrop (fig. 51). The units on Center and North Ridges range in thickness from about 50 feet to at least 300 feet.

Columnar jointing is characteristic of the lava and is usually better developed than in the compressed tuff of the Lower member. Figure 52 shows some typical columns about one foot in diameter on the knobs east of Gifford Brook. Figure 53 shows some larger less perfect columns above upper South Branch Pond. Columns as thin as one inch have been observed. At an elevation of 1700 feet on North Ridge of Traveler Mountain these thin columns are bent in different directions. This phenomenon is probably caused by continued motion of a very viscous lava after partial solidification.

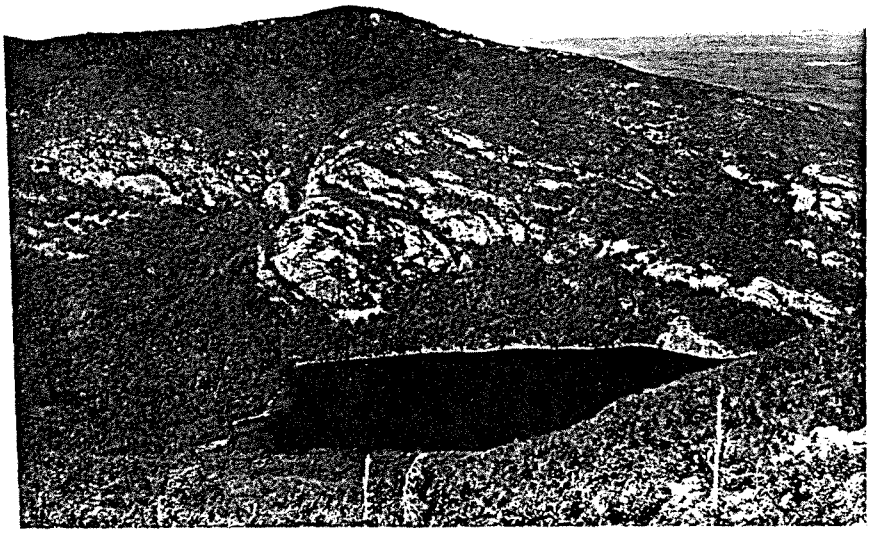


Figure 51a. Lava flows of the Black Cat member, Traveler felsite on Black Cat Mountain as seen from the Center Ridge of the Traveler. The lake is Upper South Branch Pond.



Figure 51b. Homoclinal sequence, dipping to the left and away from the observer, of lava flows on Center(left) and Pinnacle (right) ridges of The Traveler as seen from the northern summit of Black Cat Mountain. The summit of The Traveler is visible in the center background, and Upper South Branch Pond appears at the bottom of the picture. All rocks in the picture belong to the Black Cat member, Traveler felsite.

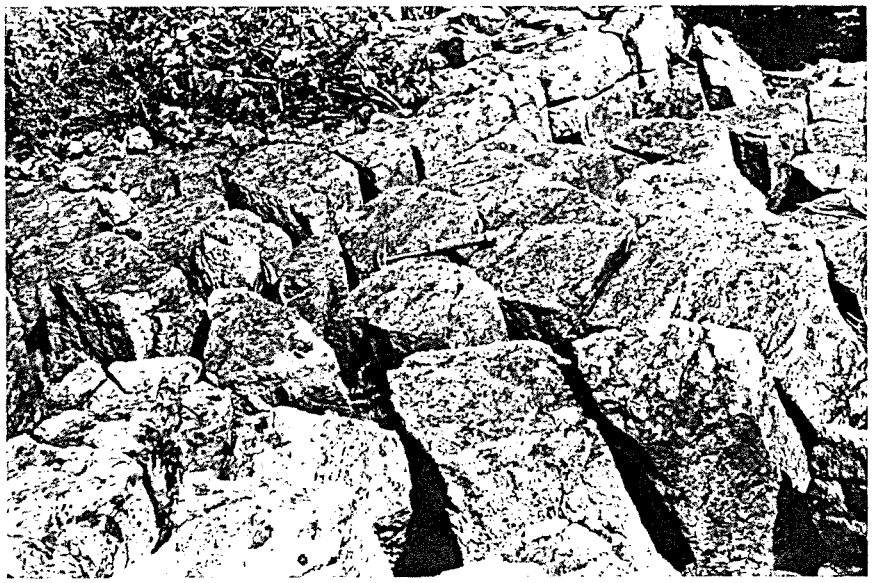


Figure 52. Columnar jointing in lava of the Black Cat member, Traveler Felsite. Knobs east of Clifford Brook.

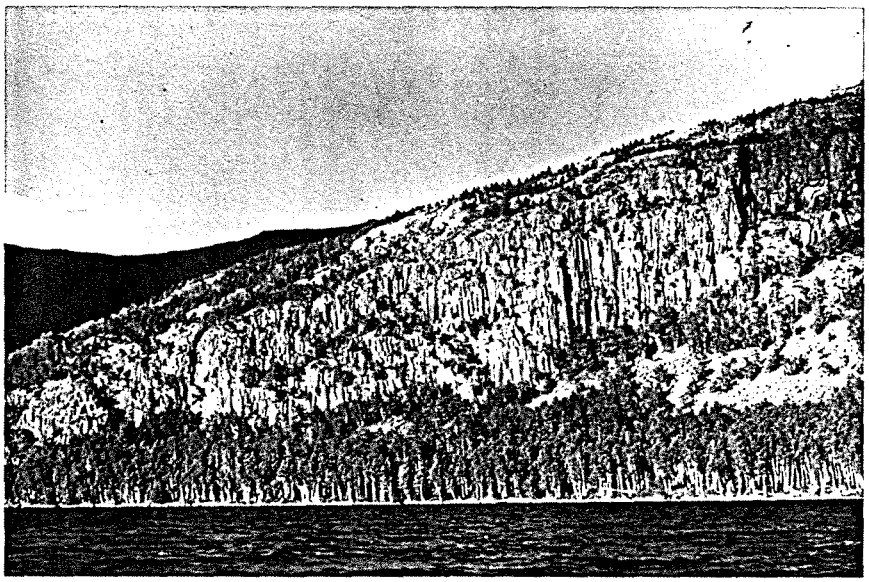


Figure 53. Columnar jointing in a thick (about 300 feet) lava flow of the Black Cat member, Traveler felsite. The picture was taken from Upper South Branch Pond looking at Center Ridge. North Ridge of North Traveler Mountain appears in the background.

Megascopic Description: The rock is dense, hard, and flint-like, breaking with a conchoidal fracture. On the fresh surface, the color ranges from dark bluish or greenish gray to dark gray and black.

The rock contains about 10 percent phenocrysts, all less than 3 mm in diameter. Small euhedral feldspar phenocrysts, 1 to 3 mm in length are the most abundant. They are characteristically milky white or greenish white, but in the darkest felsite may be glassy. Much of the feldspar may be identified in the hand specimen as plagioclase by the presence of albite twinning striations or by the greenish saussuritized cores of the weathered ones. The feldspar phenocrysts commonly weather out leaving rectangular pits. Next in abundance, although not always obvious, are mafic silicate phenocysts. These have usually altered to soft, dark, equidimensional knots, 1 mm or less across, which effervesce in dilute HCl. Occasionally, black pyroxene or biotite is observed in the freshest rocks. Equidimensional quartz phenocrysts, 1 to 2 mm in diameter, constitute a few percent of the phenocrysts in some specimens, while in others they are completely lacking.

The lava typically contains lenticules[8] somewhat lighter in color than the rest of the groundmass (figs. 54

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[8] A lenticule is a small lens-shaped body in a rock mass (Am. Geol. Inst., Glossary, 1957).

and 55). These lenticules may make up as much as 20 percent of the felsite and range in size from thin wisps, barely visible, to sizeable ones 3 feet in length and 2 inches wide. The ratio of length to width ranges from 2:1 to 30:1. Small lenticules, in differing quantities, are ubiquitous, while large ones may or may not be present in a given unit. The larger lenticules contain phenocrysts in about the same proportion as the groundmass. In cross section the lenticules have wavy outlines and may be warped around phenocrysts in the groundmass. The lenticules may bifurcate and usually terminate by wedging out or fingering out into the groundmass. In plan they are irregular in outline, but are planar, rather than linear features, and their gross parallelism imparts a foliation to the felsite. This foliation is usually best observed on the weathered outcrop, where the lenticules stand out in bold relief or have weathered to a darker color than the inclosing groundmass. Oliver (1954, p. 480) and Mackin (1960, p. 91) have suggested such a foliation is a compaction structure, rather than a flow structure in the conventional sense. More will be said of this later.

Inclusions of lithic fragments other than the lenticules are extremely rare in either the hand specimen or thin section. However, small angular inclusions, up to a few mm in diameter, of felsite and graywacke have been observed.

Microscopic Description: 35 thin sections of lava from the Black Cat member were examined. The thin sections reveal small phenocrysts of plagioclase and pyroxene. Biotite phenocrysts are commonly present and quartz is occasionally found. All are set in a holocrystalline micro-felsitic groundmass, which displays well developed flow-banding. The phenocrysts comprise 3 to 17 percent (average 10 percent) of the rock, and tend to occur in clusters or aggregates. Representative modes are presented in table 3.

Plagioclase crystals ranging in length from less than 1 mm to about 3 mm (average length 1 mm) make up 65 to 95 percent (average 77 percent) of the phenocrysts. They are characteristically euhedral to subhedral in outline, but many are fragmented and some are embayed by the groundmass. Although other twins are found, the common type of twinning is a combination of the Carlsbad twin and the polysynthetic albite twin. Small prismatic crystals of apatite are found in nearly every plagioclase phenocryst, and may occupy several percent of the area of a phenocryst area. Inclusions of zircon are common, and opaques, mostly ilmenite, occur to a lesser extent.

The plagioclase phenocrysts are typically zoned, although unzoned ones are fairly common. All zoned phenocrysts tested show an overall increase in Na-content from

TABLE 3

Estimated Modes of Phenocrysts
in the Black Cat Member, Traveler Felsite

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Total percent Phenocrysts in Rock	15	10	10[a]	14[b]	10	12	10	10	18[c]	30	12	15	71[d]	7
Mineral constitution of Phenocrysts														
Quartz	tr		tr					tr		2	2	9		
Plagioclase	90	85	73	66	75	74	75	75	82	85	68	80	76	76
Mafic Silicates	8*	13	18	23		20	20	19	4*	10*	25	9		
Clinopyroxene		x	x	x	10	x	x	x	6					7
Biotite		x		x	10				5		x	x		7
Hornblende													10	
Garnet												x(tr)		
Fayalite				tr										
Opaque Minerals**	1	2	8	11	5	5	5	6	3	3	5	2	13	10
Accessory Minerals			1			1							1***	
Apatite	1	tr	x	tr	tr	x	tr	tr	tr	tr	tr	tr	x	x
Zircon	tr	tr	x	tr	tr	x	tr	tr	tr	tr	tr	tr	x	x

a. Point count. Phenocrysts represent 206 points out of 2000.
b. Point count. Phenocrysts represent 282 points out of 2000.
c. Point count. Phenocrysts represent 178 points out of 1000.
d. Point count. Phenocrysts represent 356 points out of 500.

* Completely altered.
** Includes both magnetite and ilmenite. Some may be secondary.
*** Accessory minerals as inclusions in megacrysts not counted.

TABLE 3 (Continued)

1. (KR 56, C 01-25) Lava from an elevation of 900 feet on South Branch Ponds Brook.

2. (KR 115, WC 36-17) Lava from the low knobs on the north side of Black Cat Mountain.

3. (KR 116, WC 38-16) Lava from the low knobs on the north side of Black Cat Mountain.

4. (KT 208, SE 05-515) Lava from 2230 feet on Haskell Brook on the east side of The Traveler.

5. (KT 236, SC 14-57) Lava from 1520 feet on the west end of Pinnacle Ridge.

6. (KT 242, C 06-05) Lava from 1870 feet on the east slopes of Black Cat Mountain.

7. (KT 297, WC 20-12) Lava from 1160 feet on the north slopes of Black Brook Mountain.

8. (KT 445, C 16-18) Lava from 1620 feet on the east ridge of Big Peaked Mountain.

9. (KT 470, C 37-06) Lava from 2450 feet on the northeast slopes of "Middle" Traveler Mountain.

10. (Average of three thin sections) Felsite from Sable Mountain, T.5N., R.9W.

11. (KT 414, SC 35-38) Compressed tuff from 2380 feet on the north side of Traveler Gap.

12. (KT 424, SE 04-42) Compressed tuff from 2200 feet on the east side of The Traveler.

13. (KT 418, SC 345-32) Laminated crystal tuff from 2530 feet on the south side of South Traveler Mountain.

14. (KT ECS-1, SC 37-415) Lava from the 3060+ foot knob north of Traveler Gap.

core to rim, and are in this sense "normal." The composition change may be continuous or may be combined with abrupt reversals. As many as four major and numerous minor reversals have been observed in a single phenocryst. A given shell between two reversals, shows a continuous increase in Na-content outward and is usually bounded by euhedral surfaces. The compositions of the zones and the correlations of zones from one phenocryst or one sample to another have not been studied.

Plagioclase phenocrysts from 9 samples were separated out of the felsite and their compositions determined optically. The technique is discussed in Chapter IV and the results of the study are presented in table 8. The greatest compositional range observed in one hand specimen observed is 19 percent An, the average range is 14 percent An, and the average composition is An_{48}.

From this study, there is no evidence that the An content of the plagioclase phenocysts changes systematically stratigraphically upward within the Black Cat member.

As stated previously, there is a correlation between the darkness of the felsite and the freshness of the plagioclase phenocrysts. In some samples, particularly the lighter colored ones, the feldspar phenocrysts are so completely altered that it is not possible to identify them positively as plagioclase. Fine grained white mica

("sericite"), kaolinite, calcite, clinozoisite, and chlorite (commonly veining the plagioclase along cleavages) have been observed as alteration products. The following assembleges of alteration products are common:

sericite + calcite + chlorite

sericite + calcite

sericite + clinozoisite

sericite + kaolinite + calcite

sericite + chlorite

The chlorite (prochlorite?) is characterized by its moderate birefringence and its distinct pleochroism, X and Y = fairly bright grass green, Z = light yellow green.

No sanidine phenocrysts were observed in thin section. However, in looking for the lowest α' of the plagioclase from sample KT 208, several fragments of feldspar with all indices less than 1.53 were found. Sanidine phenocrysts in the flows of the Black Cat member are extremely rare, however.

Quartz phenocysts are sparingly present in about half of the thin sections of the Black Cat member. If present, they may make up as much as 10 percent of the pehnocrysts, but usually less than 5 percent. They are subhedral to euhedral in shape or fragmented; many are corroded. In general they are smaller than the plagioclase phenocrysts (average size 0.1 to 0.2 mm). At least some

of the quartz is slightly biaxial. Invariably the quartz phenocrysts contain numerous fluid inclusions. These inclusions typically have "negative crystal" outlines and contain two phases. Both liquid-gas and liquid-solid inclusions have been observed. The solid phase in some of the inclusions is probably chlorite. Inclusions of groundmass have also been observed within the quartz phenocrysts. In three dimensions, however, these may well be embayments rather than inclusions.

Typically 20 percent of the phenocrysts of the flows of the Black Cat member are mafic silicates. In those thin sections in which the mafic silicates are unaltered enough to be identifiable, pyroxene is both ubiquitous and typically the most abundant. Biotite constitutes a significant percentage of the mafic phenocrysts in some thin sections. Rare grains of olivine, presumably fayalite, have been identified in a very few thin sections. The mafic silicates are partly or wholly altered in all but the freshest rocks and in several thin sections it has not been possible to identify with confidence the original mafic silicate. The altered mafic phenocrysts in some thin sections are surrounded by a zone rich in a very fine grained chlorite. This zone grades out into the groundmass and typically extends farthest parallel to the banding.

Clinopyroxene phenocrysts are present in all thin sections which contain mafic silicates fresh enough to be

identified. In most thin sections it is the only primary mafic silicate identified. Pyroxene is usually the dominant mafic silicate and comprises 5 to 35 percent of all phenocrysts (most commonly 20 percent). The pyroxene occurs as light greenish gray, very slightly pleochroic, stuby prismatic crystals up to 2.0 mm long but averaging 0.2 to 0.3 mm. Many of them are fragmented. Twinning on (100), either simple or polysynthetic, is fairly common, and zoning is observed in some. Small prismatic crystals of apatite and zircon and grains of opaque minerals occur within the pyroxene phenocrysts. Pleochroic halos surround some of the zircon. Because the opaque inclusions are found in unaltered pyroxene as well as altered, at least some of them are thought to be primary.

The compositions of pyroxenes from 3 samples[9] were determined optically. (See Chapter IV.) These data are presented in table 9. The average composition in mol percent is $Wo_{30}En_{28}Fs_{42}$ (ferroaugite).

Much of the pyroxene is partly or completely altered. The alteration products are varied and include chlorite, calcite, magnetite, epidote, clinozoisite, sericite, limonite, and very fine grained amphibole. The chlorite is probably

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[9] Plagioclase phenocrysts from these same samples are among the ones whose compositions were determined.

prochlorite and is characterized by moderate birefringence and distinct pleochroism, X and Y = fairly bright gray green, Z = light yellow green. In some specimens, the pleochroic halos surrounding zircon are also found in the chlorite. Felted masses of chlorite speckled with grains of magnetite are common as pseudomorphs after pyroxene. Pyroxene may also be replaced by slightly pleochroic (very pale greenish yellow to colorless) clinozoisite.

In several thin sections the pyroxene is partly or completely altered to a mixture of chlorite, magnetite, ±calcite, and contains rounded, monomineralic colorless to light-tan bodies of clinozoisite (fig. 56). The clinozoisite appears isotropic or nearly so and has distinctly higher relief than chlorite. The average index of refraction is greater than apatite or calcite and very close to that of pyroxene. The bodies may make up most of the pseudomorph. The author at first thought some of these bodies were garnet or the remnants of garnets. Under high magnification, however, they give the suggestion of being made up of very fine grains of extremely low birefringence which may have abnormal blue-gray interference color. Some of the bodies grade imperceptibly into coarser grained clinozoisite which appears more highly birefringent, has abnormal blue and yellow interference colors, and is slightly pleochroic (colorless to light yellow green). The author now believes that all of the rounded bodies are clinozoisite.

Subhedral biotite phenocrysts, 0.1 mm to 1.0 mm in diameter, have been identified in 10 thin sections. In several thin sections biotite is as abundant as pyroxene and may make up as much as 15 percent of the total phenocrysts. Some of the biotite is corroded. Inclusions of apatite and zircon (surrounded by pleochroic halos) are common. The biotite is strongly pleochroic, X = yellowish tan, Y and Z = dark brown or brown green. The γ index of biotite hand picked from the heavy mineral concentrate of KT 236 is 1.661 $\pm$0.003.

In one thin section biotite is apparently replacing pyroxene. A subhedral biotite phenocryst has a mutual boundary with plagioclase on one side and one portion of the biotite crystal contains many inclusions of optically continuous pyroxene (island-and-sea texture). The principal alteraltion product of biotite is chlorite with minor iron ore. Antigorite (?) characterized by relief less than biotite, moderate birefringence, parallel extinction and very weak pleochroism (colorless to very pale green), is present in one biotite phenocryst.

Apatite, zircon and opaque minerals are present as accessory minerals in the lava. Apatite occurs as tiny needles or as prisms 0.5 by 0.05 mm. These crystals are sparse in the groundmass, most abundant as inclusions in the plagioclase phenocrysts and to a lesser extent in the

mafic silicate phenocrysts. Commonly they make up 1 to 3 percent of the area of the plagioclase phenocrysts. Zircon may be either in the groundmass of phenocrysts. Opaque minerals are invariably present and may make up as much as 10 percent of the total phenocrysts. It seems likely that such a high percentage includes many opaques of secondary origin which are alterations of mafic silicate phenocrysts. The grains are characteristically 0.1 mm or less across, but may be as large as 0.4 mm. Both magnetite grains and ilmenite plates are present in most thin sections. The identity of magnetite is confirmed by the magnetic susceptibility of the crushed rock, and theidentity of ilmenite by the shape of the crystal plates in the heavy mineral fraction of the crushed felsite.

Many, but by no means all, of the phenocrysts in the lava of the Black Cat member occur in growth aggregates. The aggregates may be monomineralic or composite (fig. 57). Plagioclase, pyroxene, biotite and opaques occur in the aggregates either singly or in any combination, although biotite alone and biotite with pyroxene are rare. The absence of quartz in the aggregates may be due to the general rarity of quartz phenocrysts. A few aggregates resemble inclusions of pyroxene gabbro and consist of many equidimensional or slightly elongate grains (0.05 to 0.10 mm) of plagioclase and pyroxene (fig 68b). Aggregates of this

sort up to several mm across have been observed. In general, however, the aggregates consist of a few larger phenocrysts.

The constituent phenocrysts usually have euhedral boundaries against the groundmass, but mutual boundaries against each other (fig. 58). This suggests that small phenocrysts, relatively close to one another in the magma prior to eruption, were drawn together, perhaps by surface tension. They then continued to grow while in contact with one another. The author believes that such aggregates are more likely to occur in a lava flow than in an ash flow. It would seem that most aggregates of the irregular shapes observed (fig. 58) would have been broken apart during the vesiculation and rupturing of the bubbles required for the formation of an ash flow. Emeleus and Smith (1959) have described similar aggregates from granophyre ring dikes of Slieve Gullion, N. Ireland.

The groundmass of the lava is characteristically grayish tan and consists of a holocrystalline but very fine-grained mossaic of felsic and mafic minerals. The color becomes darker as the amount of opaque minerals in the groundmass increases relative to the amount of chlorite. Because the plagioclase phenocrysts are least altered, and the primary texture is best preserved in the felsite with the darkest groundmass, it is believed that chlorite has developed at least partly at the expense of opaque minerals.

Grain boundaries between the felsic minerals are indistinct, and may best be observed under crossed nicols with the gypsum plate inserted. The average grain size of the felsic minerals ranges from 0.005 to 0.01 mm, and the opaque dust may be considerably finer than 0.005 mm. The felsic minerals are much too fine grained and much too obscured by the mafic minerals to be identifiable microscopically. X-ray diffraction patterns of the chemically analyzed groundmass of KT 208 indicate the presence of quartz and plagioclase. The groundmass must also contain potassic feldspar because the analysis shows 5.09 weight percent K_2O (table 11 in Chapter IV). Because the most distinctive potassic feldspar peak, the $(20\bar{1})$, is not apparent in the diffraction pattern, it must be masked by the $(10\bar{1}0)$ peak of quartz. The position of the $(20\bar{1})$ peak of potassic feldspar is a function of the K_2O content of the feldspar. A location of the $(20\bar{1})$ peak such that it is masked by the $(10\bar{1}0)$ peak of quartz ($20.9°2\theta$) would require that the potassic feldspar, probably orthoclase in sample KT 208, be very nearly pure $KAlSi_3O_8$ (D. B. Stewart, oral communication). The dominant mafic mineral is pale green chlorite of low birefringence. This microscopic identification was confirmed by x-ray diffraction. Both magnetite and ilmenite are probably present and in the lighter-colored groundmass, carbonate and greenish amphibole

may also be present.

Banding in the groundmass is brought out by linear (or planar?) concentrations of chlorite and/or opaques (figs. 60 and 68b). These strings of dark minerals commonly pass through the coarser grained felsic minerals indicating a recrystallization of the groundmass. That some of the groundmass of the flows was glassy is suggested by the remnants of spherulites in a few thin sections (fig. 59). Although the felsic grains are roughly equidimensional, in several thin sections they appear to have a preferred orientation with the fast rays parallel to the banding.

The lenticules which impart a foliation to the hand specimen are prominent in every thin section. They are conformable with the banding in the groundmass and hence accentuate it. They do, in fact, grade into the banding at their lower size limit.

The lenticules themselves may actually contain linear (or planar?) concentrations of opaques conformable with the banding in the groundmass. Usually, the banding in the lenticules is restricted to the axiolitic margins (see below). In some, however, banding persists to the spherulitic centers (fig. 62). Hence some of the lenticules must be crystallization features rather than original inclusions. More will be said of this later.

The lenticules may be short and stubby or elongate,

pinching and swelling along their length. The larger, thicker ones were selectively avoided in the cutting of thin sections. The lenticules usually terminate either by lensing out in a single unit or by feathering out into the groundmass (fig 63). Wispy off shoots are common (fig. 68a). Some lenticules bifurcate around phenocrysts (figs 61b and 67a). These phenocrysts are separated from the lenticule by an envelope of groundmass, and are thus distinct from phenocrysts occurring within the lenticules.

Axiolitic borders are a typical, but by no means ubiquitous feature of the lenticules. They consist of elongate felsic minerals either fibrous or prismatic and usually clouded with chlorite and/or opaque dust. When identifiable, the principal mineral is alkali feldspar with or without quartz. Typically the fibers or prisms have a length-fast orientation. Note that this orientation is at right angles to that in the groundmass. The thinner lenticules, in addition to having axiolitic borders, characteristically have centers filled with chlorite, sometimes quartz, less commonly amphibole (with a moderate extinction angle and strong pleochroism, light brown to bright grass green), and rarely epidote (fig. 60). Many of the thinner lenticules are thus very similar in appearance to the "drusy cavities" in the Porphyritic Felsite, Slieve Gullion area, Northern Ireland (Emeleus and

Smith, 1959, figs. 2a and 2b). The thicker ones, in addition to the above characteristics, may contain phenocrysts in about the same proportion as the groundmass and spherulites or the remnants thereof. The spherulites (0.1 to 0.4 mm in diameter) are composed of radiating groups of length fast rods of felsic minerals of all degrees of coarseness from vanishingly thin fibers to stumpy crystals. In the coarser spherulites, potassic feldspar and a lesser amount of quartz have been identified, and a crude micrographic intergrowth is typical. Several authors (eg., Harker, 1895 and Iddings, 1899) have described similar variations in the coarseness of the components of spherulites and the correlation of this with the presence of micrographic texture. Apparently there are all textural gradations from coarse, crude graphic intergrowths of optically continuous quartz in optically and physically continuous feldspar, to "centric" graphic intergrowths in which there is a radial growth of large sectors of optically continuous feldspar (e.g., the quadrant feldspars of Iddings, 1899). The "centric" graphic intergrowths, in turn, grade to very delicate radial intergrowths in which the sectors of optical continuity become increasingly small and finally to spherulites composed of unidentifiable radiating fibers with no visible intergrowths. These textural variations, in the opinion of the author, are variations in original

crystallization textures and are not genetic sequences.

Tiny chlorite specks are usually present in the spherulites, particularly at the centers, but chlorite is typically concentrated in between the spherulites.

In light of the above discussion, other interesting textures have been observed. In several thin sections, lenticules with or without axiolitic borders, contain rounded felsic bodies which are stippled with chlorite and/or opaques, and set in a felsic matrix rich in chlorite. These felsic bodies resemble spherulites in occurrence, size, and shape. Some of them contain trains of opaque dust or chlorite parallel to the banding in the groundmass. The felsic mineral or minerals in these bodies are too clouded with chlorite to identify, but each body appears to consist, exclusive of chlorite and magnetite, of a single crystal of a felsic mineral. It is believed that they are recrystallized spherulites and that most of them are composed of feldspar. Similar remnants of spherulites also occur in the groundmass (fig. 59). In at least one thin section (KT 244) the rounded bodies consist of a very fine vermicular intergrowth of quartz and feldspar. The vermicular intergrowth shows no radial growth and is thus distinct from a graphic spherulite. These vermicular bodies are presumably also recrystallized spherulites. If so, one disequilibrium texture has recrystallized to another disequilibrium texture.

Less regular radiolites have also been observed in lenticules. Some of the longer fibers have extinction angles of 5° to 8°, and as in the spherulites, the fibers are length fast. Quartz and potassic feldspar have been identified in the radiolites by x-ray diffraction.

Origin: The rocks discussed above form the bulk of the Black Cat member and are believed to be lava flows. However, because these rocks have some characteristics attributed by other authors to welded ash flows, it is appropriate to present the evidence for both a lava flow and an ash flow origin and to indicate why the former is preferred. The discoidal lenticules visible in outcrop are highly characteristic of welded ash flows (R. L. Smith, oral communication). (Cf. fig. 54 and 55 with Pl. 21K of Smith, 1960b.) The banding, though locally convolute, is commonly regular over the area of a large outcrop or several outcrops. Chaotic flow banding is a characteristic feature of many viscous felsitic lava flows. Finally, at least some of the units appear to have a considerable areal extent, are relatively thin, and have parallel or sub-parallel surfaces. These last features are, again, unusual for viscous felsitic lava flows, but typical of ash flows.

There are several lines of evidence suggesting that these rocks are lava flows rather than ash flows. The

first is the microscopic banding brought out by strings of opaque dust and chlorite grains and the microscopic features of the lenticules. In several thin sections details of this banding are so well preserved that they cannot be ignored. The author cannot conceive how banding such as that in figures 61, 64, 66, 67, and 68a could result from welding and flattening of shards. The regularity and continuity of this banding are striking in comparison with that in the welded tuff. (See figs. 28 through 36). Yet there are also microscopic contortions and dragfolds, particularly in the vicinity of phenocrysts. The sense of these small dragfolds is usually the same in a given thin section (figs. 61 and 67). Certainly there has been some flowage.

There is the possibility that these rocks originated as densely welded tuffs that flowed after welding and compaction. Some of the smaller lenticules look much like the larger flattened shards, with axiolitic borders and quartz and feldspar recrystallization, from the welded tuffs of the Pogy member. (Cf. fig 29 with figs. 58, 63 and 69a).

Before contemporary theories had developed, Iddings (1899, p. 404 to 406 and 1909, p. 331) believed that secondary flowage was a necessary step in the formation of all welded tuffs. In a review article on ash flows R. L. Smith (1960a, p. 807) reports that flowage during and after

compaction is of minor importance. He concludes that the amount of secondary flowage is a matter of only a few inches or a few feet.

It seems unlikely that in the Black Cat member secondary flowage should be so extreme and so wide spread that it has obscured all clear-cut evidence of pyroclastic origin from so many samples collected from such a large area. Further, the type of banding in question (figs. 61, 64, 66, 67 and 68) is almost nonexistent in rocks of essentially the same composition from the underlying formation.

The growth aggregates of phenocrysts provide further evidence that these rocks are lava flows. As mentioned earlier, these aggregates should be more likely to occur in lava flows than in ash flows. The aggregates, though very common in the rocks in question, are notably rare in the welded tuffs of the Pogy member.

Whatever the origin of these rocks of the Black Cat member, it is obvious from megascopic and microscopic textures that the flowage was primarily laminar rather than turbulent. This observation is consistent with the high viscosity of the felsite and the fact that fluids of high viscosity usually have laminar flow. Perhaps convolute banding is neither a necessary nor an expected feature of all felsite lava flows, despite the numerous reported

occurrences of chaotic flow banding.

The formation of the lenticules may be related to the concentration of volatile components in the shear planes of the laminar motion. Boyd (1957) has suggested that shear planes would provide low pressure areas into which volatiles might diffuse. The accumulation of volatiles in certain layers would favor in those layers deuteric crystallization features such as axiolitic borders and spherulites. Some lenticules are restricted to the area between two phenocrysts. These probably are formed by the concentration of volatiles in the pressure "shadow" between the phenocrysts.

The problem of thinness and areal extent of individual flows remains. Perhaps more detailed field work will show that these observations are in error. Perhaps the flows are not simple but are complex, composed of several "flow units" (Nichols, 1936).

Finally, it must be admitted that evidence for origin as lava flows is better for some of the 35 specimens than for others. There is no a priori reason why all or nearly all volcanic rocks in a sequence probably 6,000 feet thick should be of the same origin. Some flowage has unquestionably occurred in about half of the specimens included in this discussion. For the other half, evidence is less satisfying. The small elongated irregular felsic bodies, such as those in figure 69a, could be compressed

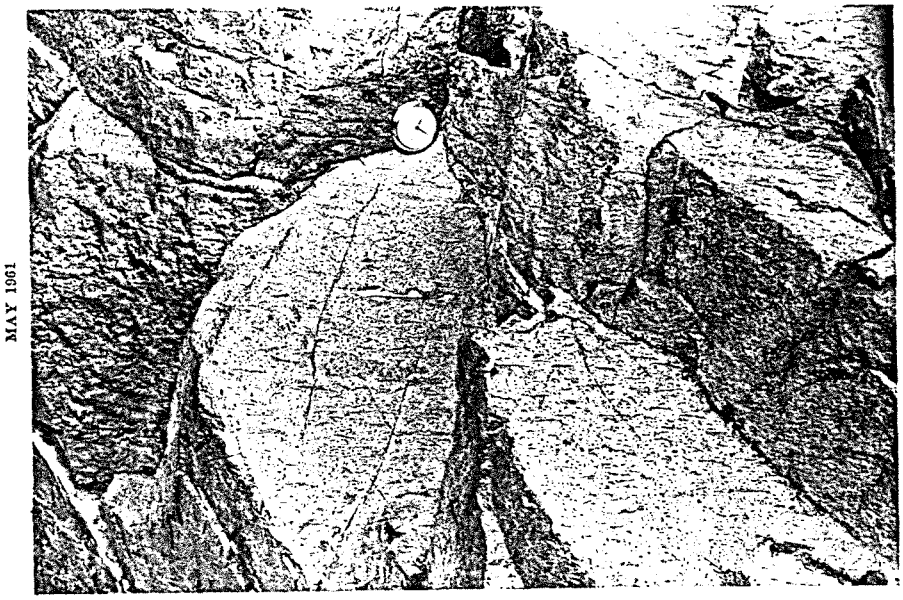


Figure 54. (C 01-25). Outcrop of lava(?) of the Black Cat member, Traveler felsite from along South Branch Ponds Brook showing the typical appearance of the lenticules. Figure 64 shows the thin section texture of a specimen collected from a neighboring outcrop believed to belong to the same rock unit as the outcrop pictured above.



Figure 55. (KT 445, C 16-18). Sawed surface of lava of the Black Cat member, Traveler felsite showing plagioclase and mafic phenocrysts and lenticules. Figures 67a and 67b are of a thin section cut from this specimen. 10 cm scale.

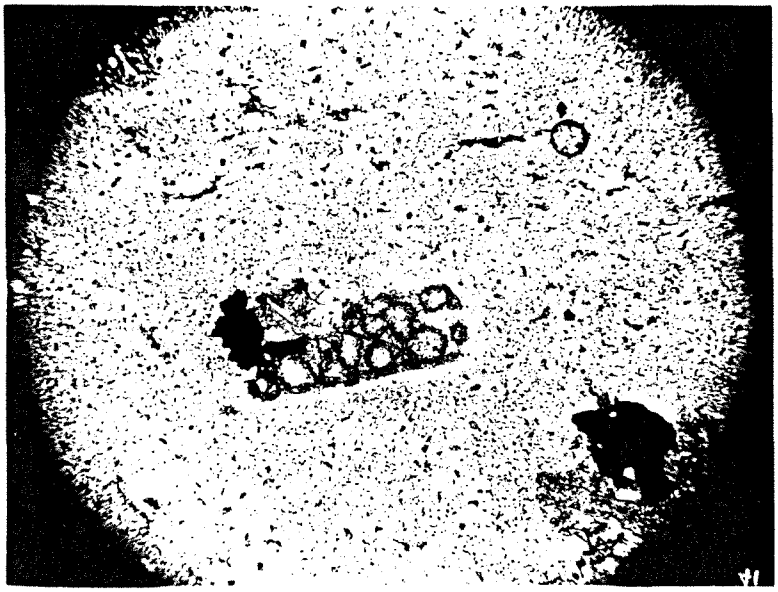


Figure 56. (KT 242, C 06-045). Very fine-grained mono-mineralic bodies of clinozoisite replacing pyroxene in lava of the Black Cat member, Traveler felsite from Black Cat Mountain. X 38.



Figure 57. (KT 297, WC 20-12). Growth aggregates of phenocrysts in lava of the Black Cat member, Traveler felsite from the northern slopes of Black Brook Mountain. Aggregates of pyroxene alone and pyroxene plus plagioclase are present in this picture. Flow banding is also visible. X 38.



Figure 58a. (KT 116, WC 38-16). Aggregate of plagioclase and magnetite phenocrysts in lava of the Black Cat member, Traveler Rhyolite. It is believed that this type of aggregate should be uncommon in welded tuff. X 38.



Figure 58b. (KT 116, WC 38-16). Same view as figure 58a, but with crossed nicols. X 38.

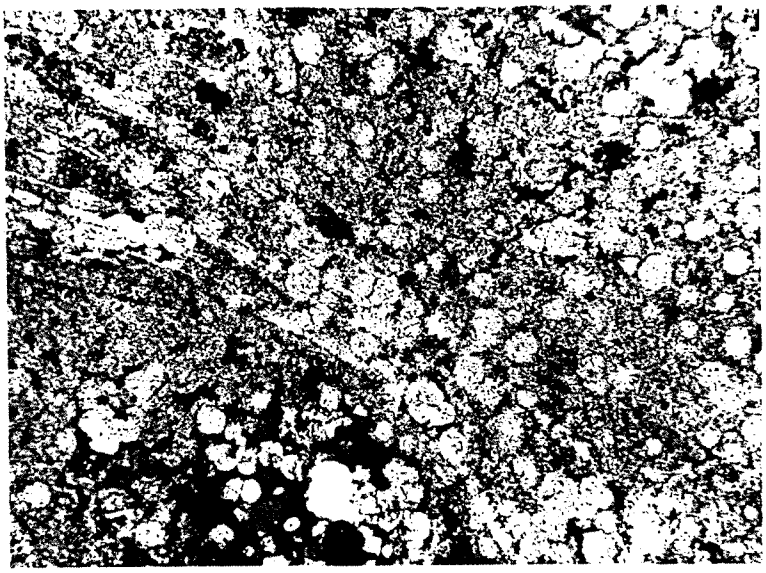


Figure 59. (KT 299, WC 08-04). Groundmass of once glassy lava of the Black Cat member, Traveler felsite from Squirt Dam Mountain. The rounded bodies are believed to be remnants of spherulites. X 38.

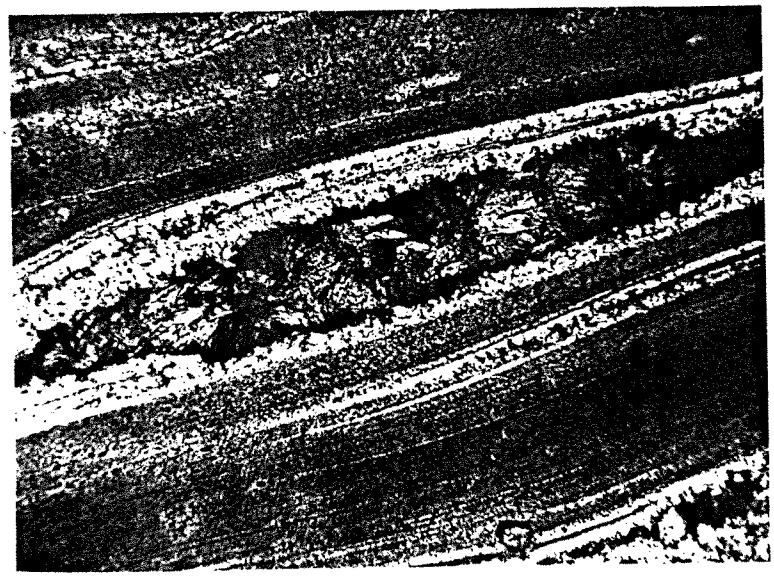


Figure 60. (KT 208, SE 05-515). Lava of the Black Cat member, Traveler felsite from the Eastern slopes of The Traveler. Banding is broubht out by lenticules and by linear (in thin section) concentrations of opaque dust and chlorite. Fibrous amphibole occurs in the core of the large lenticule. X 90.

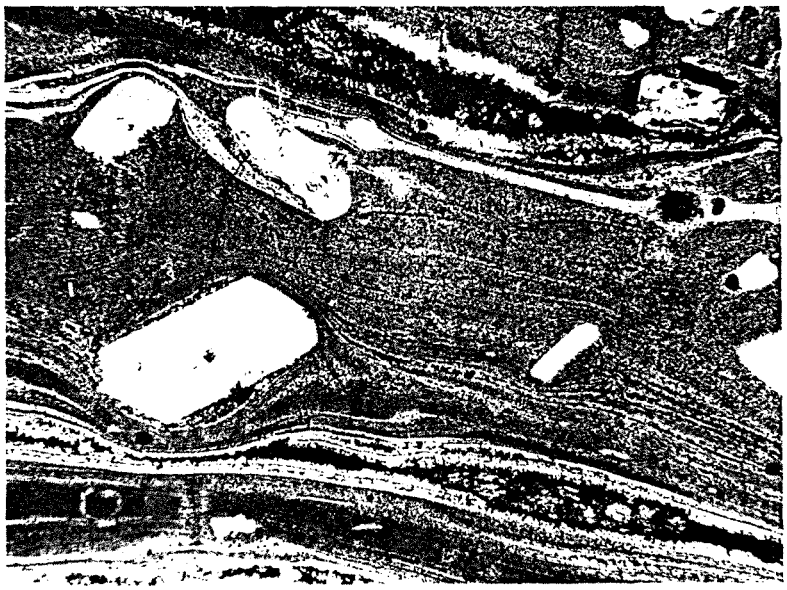


Figure 61a. (KT 208, SE 05-515). Flow banding in lava of the Black Cat member, Traveler felsite. Figure 60 is an enlargement of the lower right corner. The white phenocrysts are plagioclase. Note the consistant left lateral shear along the flow banding in this figure and figure 61b. X 32.



Figure 61b. (KT 208, SE 05-515). Flow banding and lenticules in lava of the Black Cat member, Traveler felsite. Same thin section as figure 61a. Note the lenticule bifurcating around a plagioclase phenocryst. X 38.

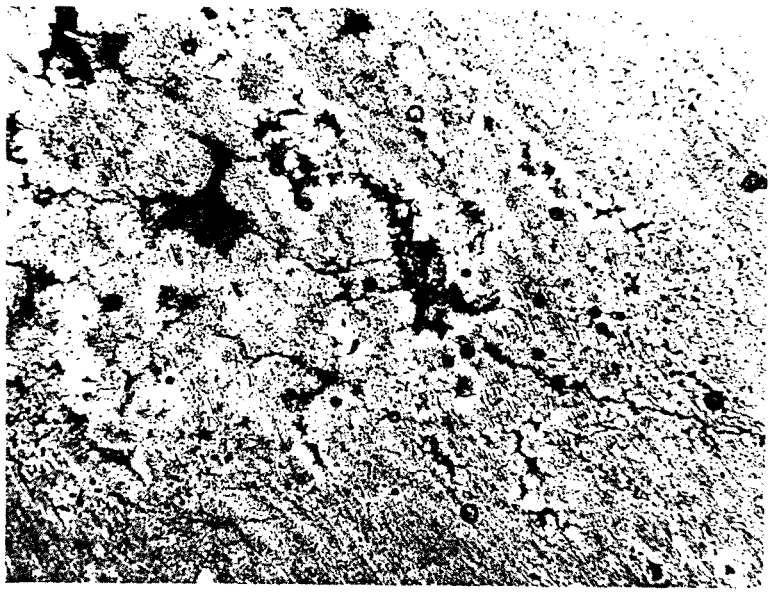


Figure 62a. (KT 116, WC 38-16). Termination of a spherulitic lenticule in lava of the Black Cat member, Traveler felsite from the knobs north of Black Cat Mountain. Note the banding in the groundmass persists through the lenticule. The dark circles are bubbles in the mounting medium. Same thin section as figure 58a. X 38.

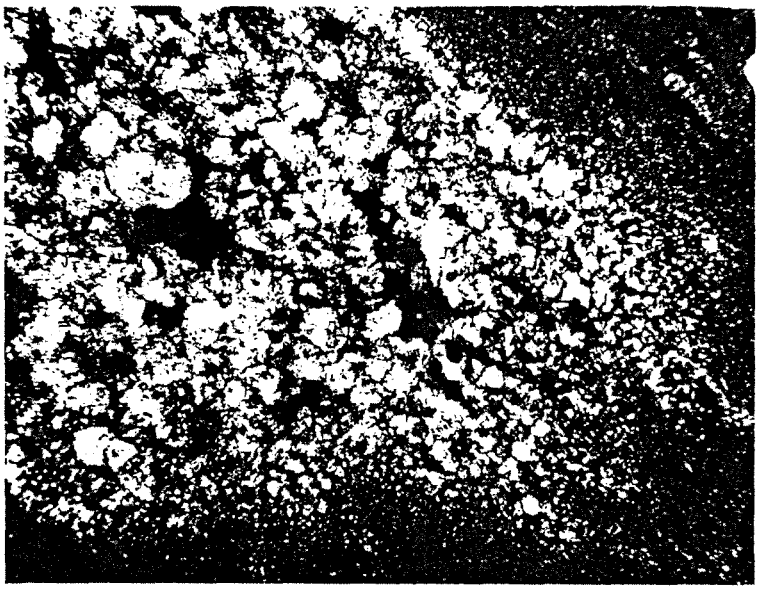


Figure 62b. (KT 116, WC 38-16). Same view as figure 62a, but with crossed nicols. X 38.



Figure 63. (KT 459, C 35-04). Lenticule termination in lava of the Black Cat member of the Traveler felsite from "Middle" Traveler Mountain. Phenocrysts are completely altered mafic silicate and plagioclase, with apatite and magnetite inclusions. In the lower right center below the lenticule is an aggregate of small pyroxene and plagioclase crystals. X 32.



Figure 64. (KR 56, C 01-25). Flow banding in lava from the Black Cat member, Traveler felsite. The phenocrysts are altered plagioclase and mafic silicates. The dark circles are bubbles in the mounting medium. This specimen came from an outcrop close to the one shown in figure 54, and the two outcrops are believed to belong to the same unit. X 38.



Figure 65. (KT 169, SW 095-56). Flow banding in lava of the Black Cat member, Traveler felsite from Squirt Dam Mountain; altered plagioclase and mafic silicate phenocrysts. X 32.

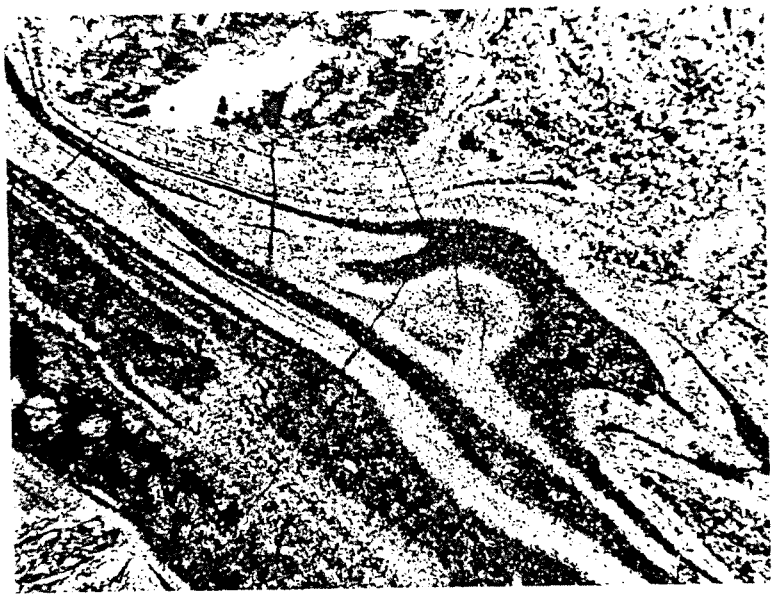


Figure 66. (KT 300, WC 18-01). Flow banding in lava of the Black Cat member, Traveler felsite from Black Brook Mountain. The large phenocryst in the upper left is saussurtized plagioclase. X 32

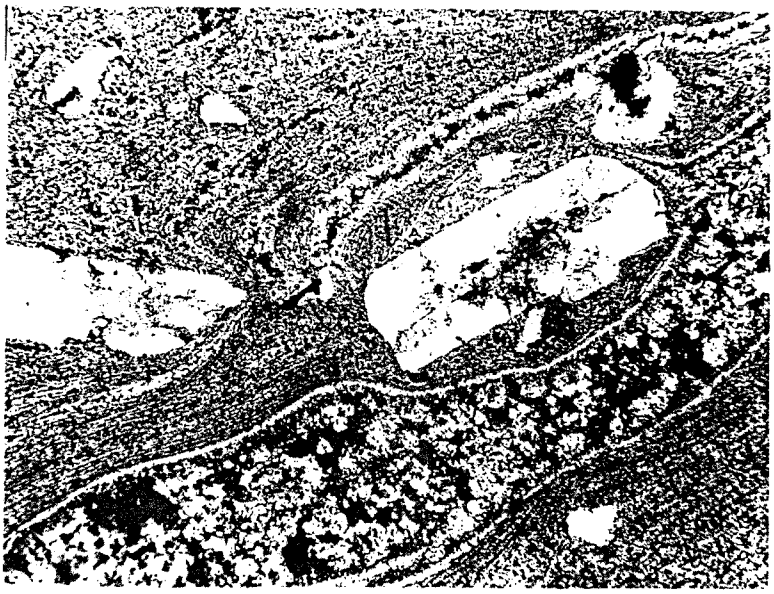


Figure 67a. (KT 445, C 16-18). Sperulitic lenticule with axiolitic borders bifurcating around a plagioclase phenocryst. Flow banding is obvious. Figure 55 shows the hand specimen from which this thin section was cut. Black Cat member, Traveler felsite. X 32.



Figure 67b. (KT 445, C 16-18). Flow banding in lava of the Black Cat member, Traveler felsite from Big Peaked Mountain. Note the consistent left lateral shear in the banding in this figure and figure 67a from the same thin section. X 32.



Figure 68a (KT 470, C 37-06). Lava of the Black Cat member, Traveler felsite from the eastern slopes of "Middle" Traveler Mountain. Phenocrysts are plagioclase, pyroxene and biotite (dark area at bottom of phenocryst aggregate at lower left). Note the wispy offshoots of one lenticule, and that another lenticule appears to be related to a cluster of phenocrysts. X 32.



Figure 68b. (KT 470, C 37-06). Aggregate of small plagioclase and pyroxene crystals resembling an inclusion of pyroxene gabbro. Same specimen as figure 68a. X 122.

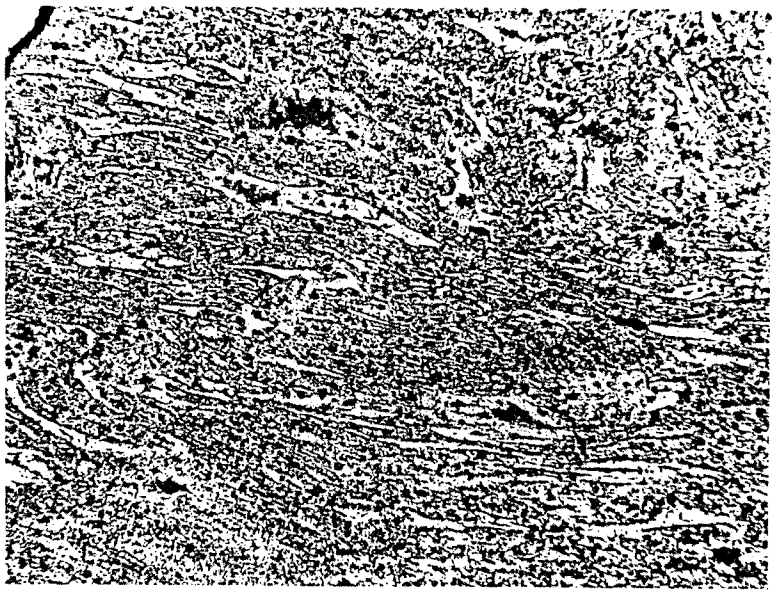


Figure 69a. (KT 289, WC 26-005). Small "pseudo-shards" in the groundmass of lava from the Black Cat member, Traveler felsite. The specimen came from the eastern summit of Black Brook Mountain. X 122.



Figure 69b. (KT 289, WC 26-005). Flow banding in lava of the Black Cat member, Traveler felsite. Same specimen as figure 69a. X 32.

shards. Several of the specimens which contain these bodies are also characterized by relatively short stubby lenticules. These rocks could conceivably be compressed tuff. However, because of their dissimilarity to other welded tuff in the Traveler felsite and the presence of aggregates of phenocrysts, they are believed to be lava.

FLOW BRECCIA: Flow breccia crops out on the Summit of Lord Mountain. The upper slopes of Lord Mountain, particularly the southern slopes, are heavily covered with float of this rock. Therefore, it is believed that it underlies at least the upper one hundred feet of the mountain. Flow breccia, identical with that found on Lord Mountain, also occurs in the beach cobbles on the shore of Wassataquoik Lake. These cobbles may well be part of a glacial drift derived from Lord Mountain.

On a fresh surface the rock is a black flinty felsite. The only indication of its brecciated nature is the absence of phenocrysts in the breccia fragments. The breccia fragments do, however, show up strikingly on the whitish weathered surface. The fragments constitute about 30 percent of the rock and consist of felsite. Most of them are angular, banded, and randomly oriented. They are unsorted and are as much as a foot in diameter.

Flow banding is evident only in thin sections

(fig. 70). Phenocrysts make up from 10 to 20 percent of the matrix and are predominately plagioclase, some pyroxene and magnetite, and minor biotite. Growth aggregates are common.

The felsite breccia fragments are of several types. Banded felsite fragments similar to those found in the welded tuff are fairly common. The most common and also the most striking type of inclusion, however, is a banded, very dark felsite some of which is almost opaque (fig. 70). The darkness and near opacity are caused by a high content of magnetite dust, average grain size 0.002 mm. Because the diameter of the magnetite dust is much less than the thickness of the thin section, it is difficult to estimate the percentage of magnetite present. But the darkest portions are probably more than 50 percent magnetite. Fragments of the inclusions can be readily picked up with a hand magnet. Banding is caused by variations in the percentage of magnetite dust. The dust is set in a matrix of coarser felsic minerals which have a preferred orientation with their fast rays parallel to the banding. An X-ray diffraction pattern of one of these dark breccia fragments shows the presence of quartz, plagioclase, and magnetite. Chlorite is visible in thin section. The magnetite-rich breccia fragments have few phenocrysts (including plagioclase and an olivine, presumably fayalite)

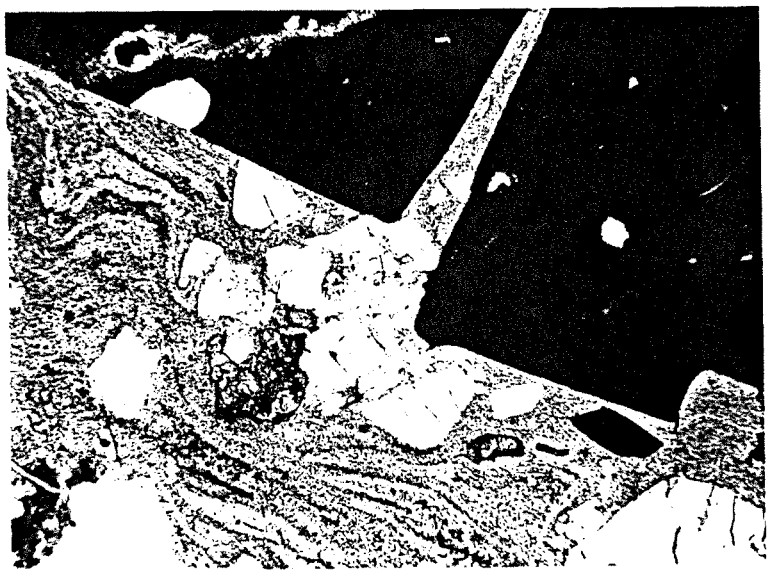


Figure 70. (WT 127, SW 24-09). Flow breccia of the Black Cat member, Traveler felsite from drift along the south shore of Wassataquoik Lake. Similar rocks occur on Lord Mountain. Aggregates of plagioclase and pyroxene phenocrysts, flow banding and dark, magnetite-rich inclusions are visible in this photomicrograph. X 38.



Figure 71. Concentric jointing, similar to that shown in this photograph, has been observed at a number of localities in both members of the Traveler felsite. This particular locality is within the Black Cat member on South Branch Ponds Brook. More than one center for the concentric jointing may be present, giving rise to two or more sets of intersecting curving joints.

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and those phenocrysts present are small. None of the fragments contain more than 5 percent phenocrysts and most have about 1 percent.

WELDED TUFF: Welded tuff has been found at only four localities within the Black Cat member. Three of these localities are at or near the base of the member and the fourth is near the top of the exposed section. On The Traveler it has been found at an elevation of 2,200 feet on the eastern slopes (SE 4-42) and at an elevation of 2,380 feet on the north side of Traveler Gap (SC 35-38). At the latter locality, the welded tuff forms a prominent bench of black felsite showing faint foliation. The mode of this rock is presented in table 3. Aggregates of phenocrysts are rare. Although the shards have been greatly deformed and flattened, they are sharply outlined by magnetite dust (fig. 72). There can be little doubt as to their existence. Some of the larger shards have devitrified or recrystallized to relatively coarse-grained (0.01 to 0.03 mm) quartz, potassic feldspar, chlorite, and magnetite. These larger shards look much like the smaller lenticules in the flows. More typically, however, the grain size of these devitrification products is much smaller (0.005 mm or less). The larger lenticules of the type characteristic of the lava flow are not present.

The felsite on Sable Mountain (T.5N., R. 9W.) which forms the outlier of the Black Cat member unconformably above the Pogy member is probably welded tuff. This felsite is characterized by an unusually high content of phenocrysts (30 percent) and textural features of both lava flows and compressed tuff. A mode of this rock is presented in table 3. The banding (fig. 73a) looks much like flow banding and aggregates of phenocrysts are common. There are also mafic lenticules containing smaller crudely alined plagioclase crystals (0.1 to 0.2 mm long) set in a matrix of chlorite, magnetite, and minor calcite (fig. 74). On the other hand, the groundmass appears to have been fragmented although, if so, the shards are much flattened. One might be tempted to consider this rock intermediate between a welded tuff and a lava. However, accepting for the moment that the welded tuff originated as ash flows, the author can conceive of no other intermediate mechanism between a lava flow and ash flow than a froth flow. The rock resulting from a froth flow would probably not have the fragmental appearance of the groundmass shown in figure 73b. The fragmental appearance seems convincing enough to call the rocks welded tuffs.

The fourth known occurrence of welded tuff in the Black Cat member is on Dry Brook at an elevation of 980 feet (C 08-32). The most spectacular display of columnar



Figure 72a. (KT 414, SC 35-38). Welded tuff of the Black Cat member, Traveler felsite from Traveler Gap. Phenocrysts are of plagioclase. X 58.



Figure 72b. (KT 414, SC 35-38). Welded tuff of the Black Cat member, Traveler felsite from Traveler Gap. The shards are distinctly outlined by opaque dust. This view overlaps that of figure 72a, but with higher magnification. X 122.



Figure 73a. (KT 271a, SW 31-32). Welded tuff(?) of the Black Cat member, Traveler felsite from an outlier on Sable Mountain. The phenocrysts are plagioclase. Banding strongly resembles that of the lavas. X 32.

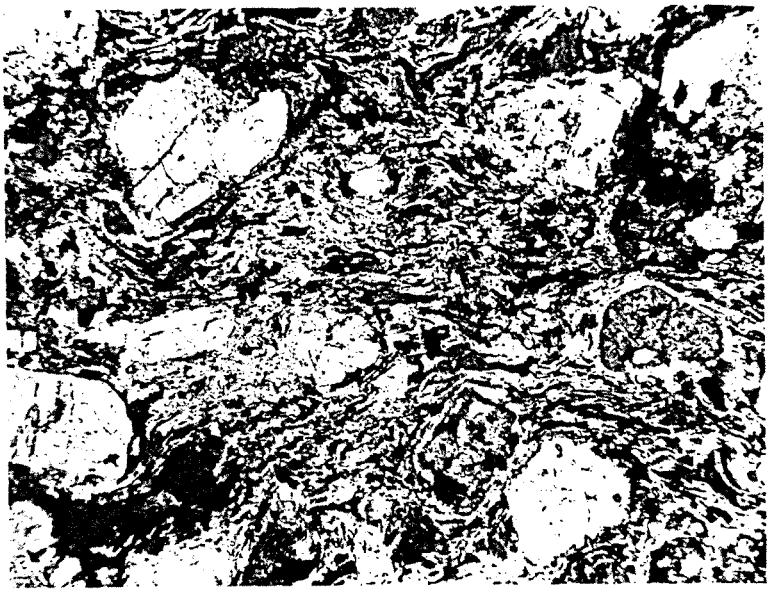


Figure 73b. (KT 273, SW 35-48). Welded tuff(?) of the Black Cat member, Traveler felsite from an outlier on the hill north of Mahar Pond. The phenocrysts are plagioclase and altered mafic silicates (chlorite and celadonite). The "shards" are composed largely of chlorite. X 32.

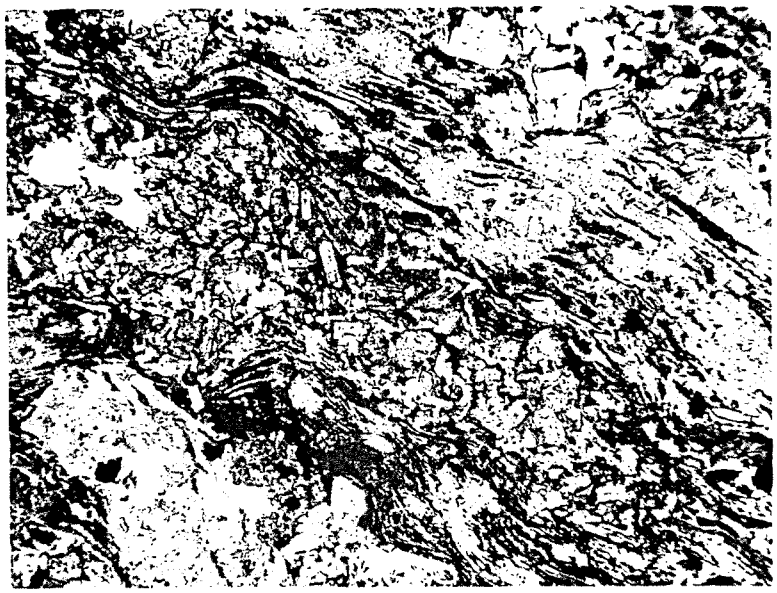
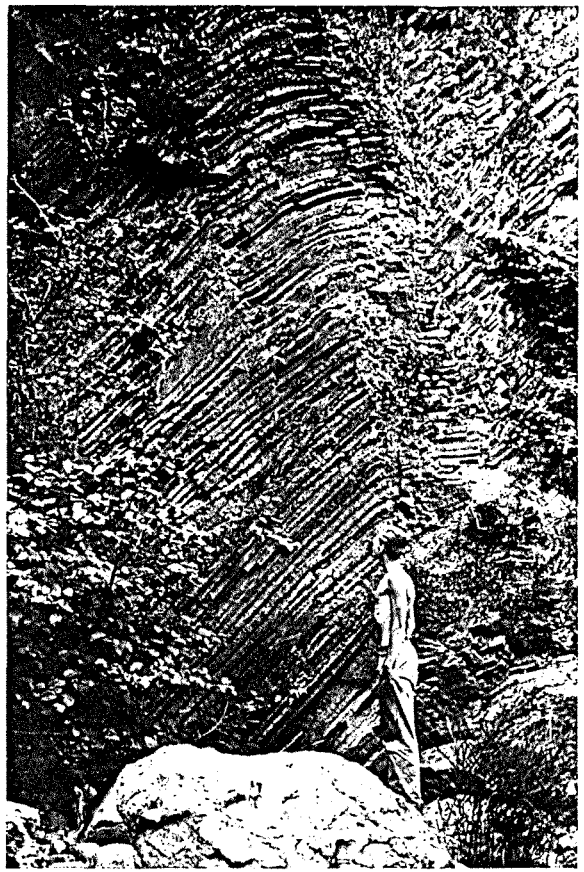


Figure 74. (KT 271a, SW 31-32). Mafic lenticule of plagioclase and altered pyroxene(?) in welded tuff(?) from the outlier of the Black Cat member, Traveler felsite on Sable Mountain. X 32.



Figure 75. (KT 145, C 08-32). Welded tuff of the Black Cat member, Traveler felsite from 980 feet on Dry Brook. X 32.





Figures 76a & b. Columnar jointing in welded tuff of the Black Cat member, Traveler felsite from an elevation of 980 feet on Dry Brook.

jointing observed in the Traveler felsite is found at this locality. The columns average three inches in diameter and are at least several tens of feet long (fig. 76). Figure 75 is a photomicrograph showing the texture of this compressed tuff.

The welded tuff of the Black Cat member is, like the welded tuff of the Pogy member, believed to have been deposited by ash flows.

LAMINATED TUFF AND CRYSTAL TUFF: Laminated tuff and crystal tuff occur intimately associated with each other on the south side of South Traveler Mountain about 100 feet below the highest (eastern) summit. Here the laminated tuff and crystal tuff form a distinctive unit 10 to 15 feet thick, some distance above the probable base of the Black Cat member. The two rock types intertongue and are interbedded. The laminated crystal tuff is minor, however, and occurs as long thin lenses within the laminated tuff. Contorted lamination, presumably a slump structure, is typical of the laminated tuff (fig. 77b). Although cross-lamination has also been observed in the laminated tuff, it is much more common in the laminated crystal tuff. Another unit of laminated tuff possessing contorted lamination crops out 40 feet lower on the south side of South Traveler. No crystal tuff has been observed at this locality.

Although the laminated tuff and crystal tuff have not been found at any other locality, they form a potentially useful marker bed and will be described in detail unwarranted by their known areal distribution.

In a fresh hand specimen the laminated tuff consists of alternating laminae of light-gray and dark-gray dense aphanitic felsite (fig 77a). No phenocrysts are visible. The laminations are brought out by weathering which lightens the dark gray bands to light gray and the light gray bands to very light gray. Typically, the darker bands show a color gradation into the lighter bands in one consistent direction, and a sharp contact with the light bands in the other direction. For the purpose of this discussion, one lamina is defined as the graded color set between two sharp contacts. The laminae range in thickness from less than 0.1 mm to about 10 mm and average 2 to 3 mm. The laminated tuff has a relatively gentle dip and the darker portion of each lamina is on the bottom. Except for the direction of color grading and darkness of color the laminated tuff looks very much like a varved glacial sediment.

In thin section the laminated tuff very closely resembles the groundmass of the lava of the Black Cat member except that the mafic mineral is biotite (greenish brown and distinctly pleochroic) rather than chlorite and there is a bimodal distribution of grain size. The average

grain size of the coarser fraction is 0.02 to 0.04 mm. This fraction consists of scattered angular grains of quartz and feldspar which are probably fragments of phenocrysts.

The finer grained fraction is by far the dominant of the two. Its average grain size is 0.002 to 0.005 mm. The presence of biotite (greenish brown and distinctly pleochroic) rather than the usual chlorite may be a contact metamorphic effect of the Katahdin granite. The granite contact is at an elevation of 2150 feet on the south side of South Traveler, 400 feet below the upper outcrop of laminated tuff.

The felsic minerals in this fraction are too fine grained and too intimately associated with biotite to be identifiable in thin section. Quartz, plagioclase (about An_{30}) have been identified by X-ray diffraction. The grain boundaries of the felsic minerals are indistinct, but the grains appear to be roughly equidimensional. They also have a preferred orientation with the slow rays parallel to the laminations. Carbonate, clusters of magnetite, and an occasional zircon are also present in thin section.

The lamination, clearly visible in thin section, is caused by a higher concentration of biotite in the darker bands. A light band may grade into the dark band on each side, or, as is more common, there may be a

relatively sharp contact on one side and a gradational contact on the other. The direction of the sharpest contact is consistent when observable. Texturally, nothing remains of the original pyroclastic material. Because of the thinness of the laminae, however, this material must have been extremely fine grained, i.e., fine ash (less than 1/4 mm, Wentworth and Williams, 1932, p. 45).

The laminated crystal tuff is dark gray on the fresh surface and weathers to a light or very light gray. Closer inspection of the weathered rock reveals that it contains about 50 percent milky-white prismatic feldspar crystals set in a dark greenish-black matrix. The laminations, which are best observed on the weathered surface, are coarser and less well developed than in the laminated tuff. Fairly broad feldspar-rich layers (about 1 cm thick) are separated by thin feldspar-poor layers (0.1 to 0.3 cm thick).

In thin section the laminated crystal tuff consists of crystals or fragments of crystals of plagioclase, amphibole, and magnetite set in a groundmass of the same material that composes the laminated tuff. A mode of the laminated crystal tuff is presented in table 3.

Plagioclase, either subhedral fractured crystals or angular fragments of crystals, is by far the dominant constituent of the rock (fig 78). Except for the presence

of platy hematite inclusions, the plagioclase xenocrysts are similar to those of the flows of the Black Cat member in details of twinning, zoning, inclusions and alteration. Most of the plagioclase xenocysts are between 0.5 and 1.0 mm in diameter, but they range from tiny fragments to prismatic crystals 1.5 mm long. The average composition in mol percent is An_{45}, and the xenocrysts may be zoned from An_{38} to An_{54}. There is a partial alinment of the plagioclase crystals such that the long dimension and fast ray are parallel to the lamination.

The mafic silicate in the laminated crystal tuff is amphibole, presumably hornblende, and has the following optical properties:

strong pleochroism, X = pale yellow
Y = yellowish green
Z = bright bluish green

distinct dispersion, r>v
$2V_x \cong 55^\circ$, optically negative
$Z \wedge C = 20^\circ$, lamellar twinning on (100)
n > apatite.

Much of the hornblende is clouded with magnetite inclusions. Although subhedral or rounded hornblende crystals up to 0.5 mm long are relatively common, most of the hornblende is interestitial to the plagioclase xenocrysts. Polycrystalline aggregates of relatively fine grained hornblende may completely occupy irregularly shaped areas between several plagioclase xenocrysts. Commonly, however,

a single optically and physically continuous hornblende grain completely occupies such irregularly shaped areas. The pyroclastic origin of the plagioclase crystals is clear by their fragmented nature and by the rarity of growth aggregates of two or more crystals. The hornblende, on the other hand, could have been of pyroclastic origin only if the present texture resulted from subsequent overgrowths of hornblende around the former pyroclastic grain. Overgrowths have been observed, but are uncommon. Moreover, hornblende is extremely rare as phenocrysts in the rest of the Traveler felsite. It may be that hornblende developed at the expense of some pre-existing mafic mineral, probably pyroxene, in the contact aureole of the Katahdin granite.

Magnetite is usually abundant in the laminated crystal tuff. It is also coarser grained than in the rest of the Traveler felsite; much of it is between 0.05 and 0.1 mm across, and some euhedral crystals up to 0.3 mm across have been observed. The high concentration of magnetite is probably primary in the crystal tuff. Certainly a concentration of heavy minerals in a crystal tuff is not unreasonable.

The lamination is the result of compositional banding and the crude alinment of plagioclase crystals. The plagioclase content of the laminae ranges from 80 to 35 percent. Those layers in which the plagioclase content

is relatively low show a corresponding increase in either hornblende and magnetite or in groundmass. In thin section there is a suggestion of a sequence of layers as follows:

minimum plagioclase content, maximum percentage groundmass, scattered hornblende and magnetite

high concentration of plagioclase crystals, relatively minor amount of hornblende and magnetite

high concentration of hornblende and opaques, relatively low plagioclase content.

This observation has not been confirmed in the field, and the specimen was not oriented. The most reasonable stratigraphic orientation for the sequence, of course, is that given above.

It seems clear that laminated tuff and crystal tuff formed by the accumulation of pyroclastic material settling through a fluid medium. Whether the fluid medium was air or water is more problematical. Oliver (1954b, p. 410) has described similar stratified tuff possessing contorted bedding and current bedding. This tuff crops out on the Glaramara Ridge in the Lake District, England, and is in a welded tuff sequence. Oliver believed that the contorted bedding indicated subaqueous slumping, hence the tuffs were water laid. The author visited the Glaramara Ridge locality briefly during the summer of 1960. It seems just as likely that the slumping and current bedding

could be subaerial as subaqueous. Indeed, in view of the association of the stratified tuff with welded tuff at both localities, a subaerial environment of deposition seems more reasonable. In either environment crystals could be effectively separated from finer-grained ash by gravity settling.

It is believed that the color gradation in the laminae of the laminated tuff represents an original compositional variation of particles rather than a size variation. In particular, the darker portions of the laminae represent the accumulation of ash particles richer in magnetite dust than the constituents of the lighter portions of the laminae. As is noted elsewhere, magnetite dust is disseminated throughout the groundmass of the lava flows, but is particularly concentrated in bands which impart a foliation to the groundmass. If this groundmass were broken up into sufficiently small fragments, some would be richer in magnetite dust and correspondingly heavier than others. In addition, magnetite-rich inclusions have been observed in several thin sections of the Pogy member and in the flow breccia on Lord Mountain. These heavier fragments would settle faster than the light ones, even though they were the same size, and could thus produce the color gradation in the laminae. The rhythmic lamination

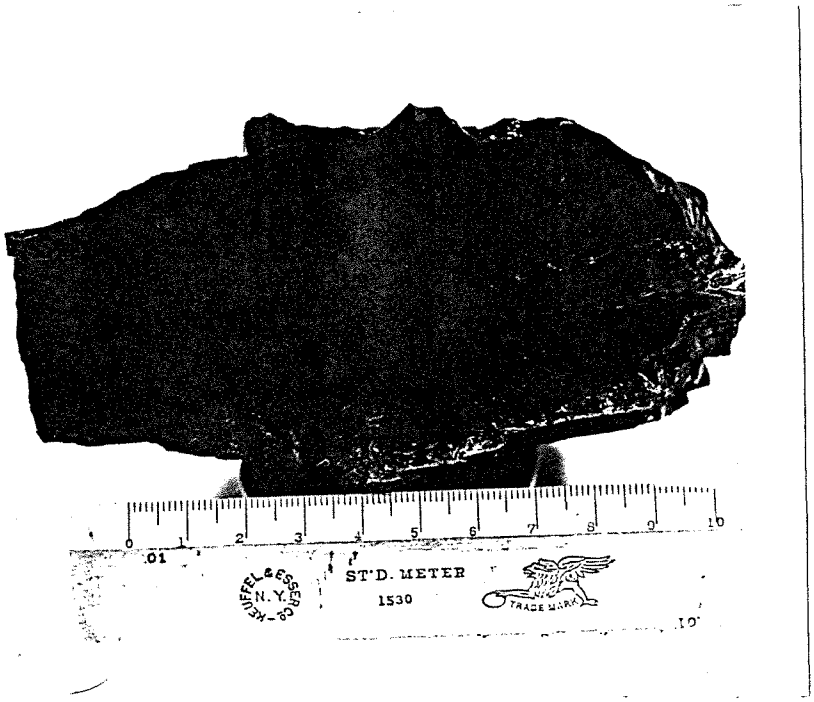


Figure 77a.(KT 417, SC 34-32). Hand specimen of laminated tuff of the Black Cat member, Traveler felsite from South Traveler Mountain. The top of the specimen is to the left. 10 cm scale.

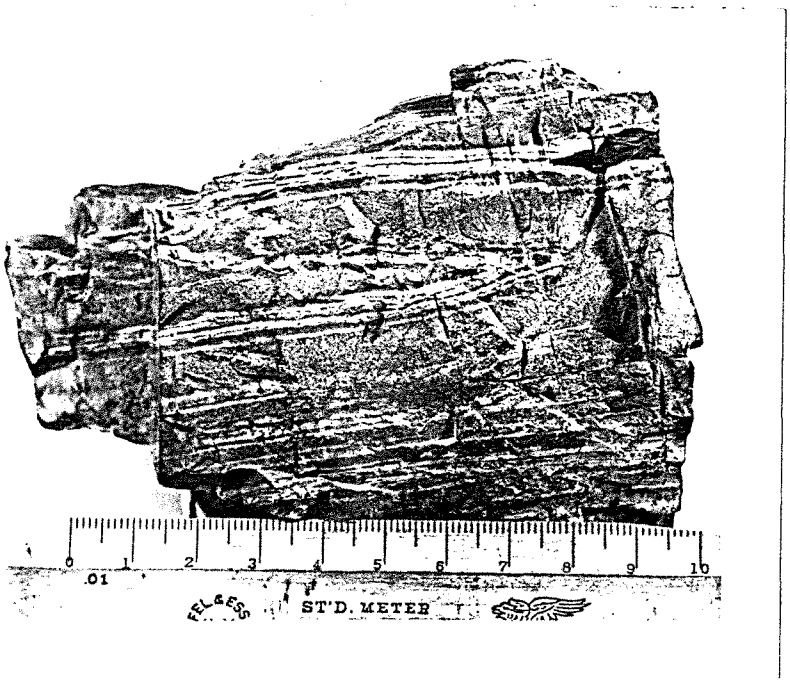


Figure 77b. (KT 417a, SC 34-32). Hand specimen of laminated tuff of the Black Cat member, Traveler felsite from South Traveler Mountain showing slump structures.

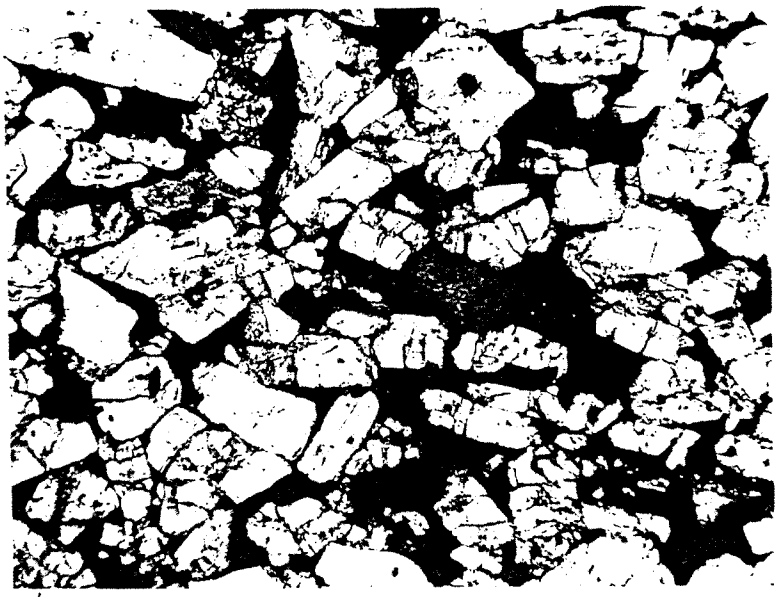


Figure 78a. (KT 418, SC 34-32). Laminated crystal tuff of the Black Cat member, Traveler felsite from South Traveler Mountain. Crystals of plagioclase, opaques, and hornblende (center) are visible. X 32.

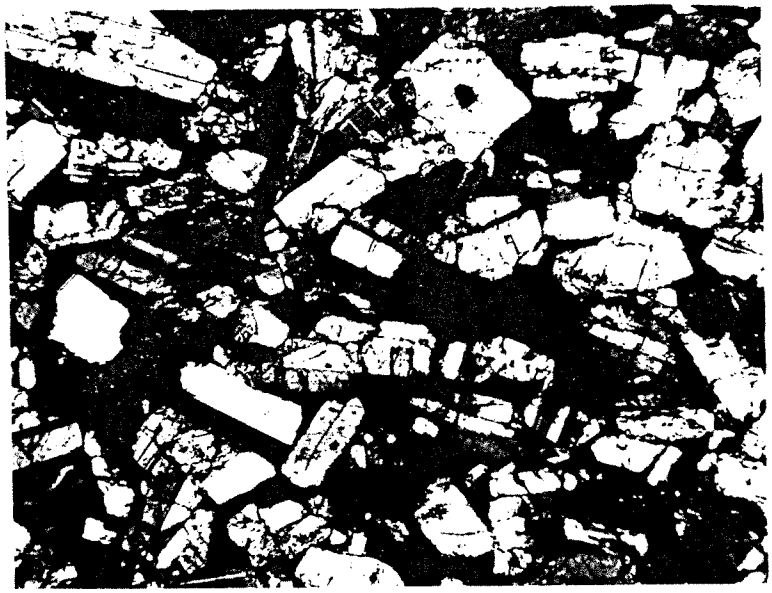


Figure 78b. (KT 418, SC 34-32). Laminated crystal tuff. Same view as figure 78a, but with crossed nicols. X 32.

might be caused by a temporary interruption of the settling process, e.g., by a shift in the wind direction or an increase in the wind velocity.

TRAVELER FELSITE, UNDIFFERENTIATED: Two relatively large areas of felsite, adjacent to the main body of the Traveler felsite, are included under the heading of Traveler felsite, undifferentiated. One of these areas lies on Wadleigh Mountain on the north limb of Matagamon synclinorium. The second, larger area lies to the west of the South Branch of Trout Brook in the Telos Lake quadrangle. The isolated patch of felsite which forms Center Mountain is included in the latter area. Because of lack of outcrop (particularly in the western area), lack of structural data, or lack of distinctive rock types, the stratigraphic relationship of these felsites to either the Pogy or Black Cat member or to each other is unknown.

Specimens of these felsites are characteristically porphyritic, 10 to 50 percent of the phenocrysts being quartz. Hence the phenocryst constitution is most like that of the Pogy member. Representative modes of phenocrysts are presented in table 4. The structural states of the plagioclase phenocrysts from the Lower and Black Cat members are different. (See Chapter IV). Thus it would be useful to know the structural state of the plagioclase

TABLE 4

Estimated Modes of Phenocrysts
in the Traveler Felsite, Undifferentiated

	1.	2.	3.	4.	5.	6.
Total percent Phenocrysts in Rock	7*	10*	15*	12*	15	15*
Mineral constitution of Phenocrysts						
Quartz		40	24	12	41	35
Plagioclase	79	45	60	74	41	50
Mafic silicates		13**	10**	12**	15**	15**
Biotite	20					
Garnet				tr***		
Opaque Minerals+	tr	2	6	2	3	tr
Apatite	tr	tr	tr	tr	tr	tr
Zircon	1	tr	tr	tr	tr	tr

* Aggregates of phenocrysts common.
** Completely altered.
*** Observed in hand specimen, but not in thin section.
\+ Includes both magnetite and ilmenite.

1. (KT 158, TLSE 12-58) Felsite from the North Branch of Trout Brook.
2. (KT 162, TLSE 16-22) Lava from 2300 feet on the west side of Strickland Mountain.
3. (KT 163, TLSE 30-49) Felsite from 1530 feet on the east side of McCarty Mountain.
4. (KT 328, TLSE 10-435) Lava from the 1580+ foot saddle on the south ridge of Morse Mountain.
5. (KT 340, C 06-51) Brecciated felsite from the 1020+ foot summit at the northeast end of Wadleigh Mountain.
6. (KT 350, C 395-50) Brecciated felsite from the 1078 foot summit of Wadleigh Mountain.

phenocrysts from the areas of undifferentiated felsite. The plagioclase phenocrysts of all specimens available, however, are considerably altered; neither their composition nor their structural states have been determined.

The felsite on Wadleigh Mountain has not been studied in detail. It is cut off from the main body of the felsite by a fault. The three thin sections of the felsite which have been studied are so fragmented that their original texture cannot be determined.

Lava is the only type of felsite definitely recognized in the Telos Lake quadrangle. Typically the lava contains 5 to 10 percent phenocrysts. Aggregates are common. Quartz and plagioclase in about equal amounts are the dominant minerals and about 10 to 15 percent of the phenocrysts are completely altered mafic silicates. Garnet (index of refraction = 1.808) was observed in the hand specimen of felsite from the south ridge of Morse Mountain (KT 328, TLSE 10-435).

Flow banding resembles that in the Black Cat member. The specimens showing the most convincing flow banding come from the westernmost summit of Strickland Mountain (TLSE 16-22). Figure 80 is a photograph of a hand specimen from this flow and figure 79 is a photomicrograph of the thin section made from the hand specimen. Lava has also been

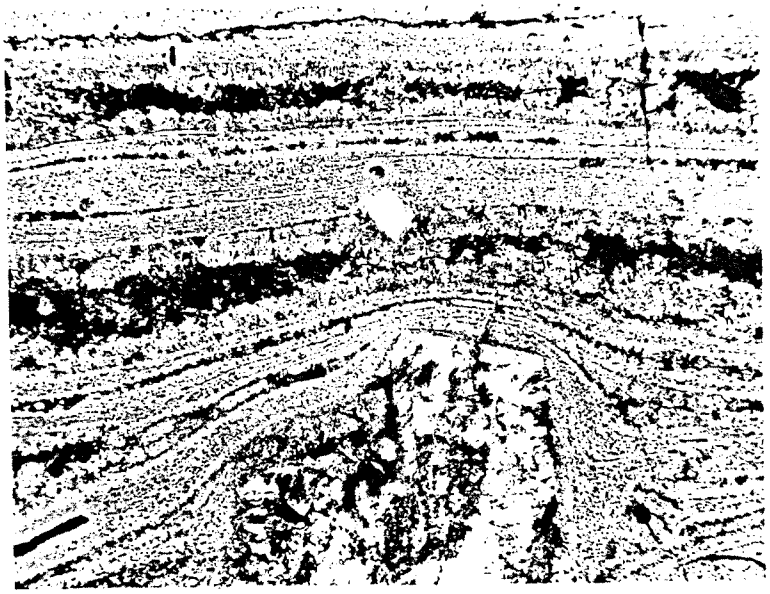


Figure 79a. (KT 162, PLSE 16-22). Lava from the summit of Strickland Mountain. Traveler felsite undifferentiated. X 32.



Figure 79b. (KT 162, PLSE 16-22). Lava from the summit of Strickland Mountain. Same view as figure 79a, but with crossed nicols. Note axiolitic borders to the lenticules. X 32.

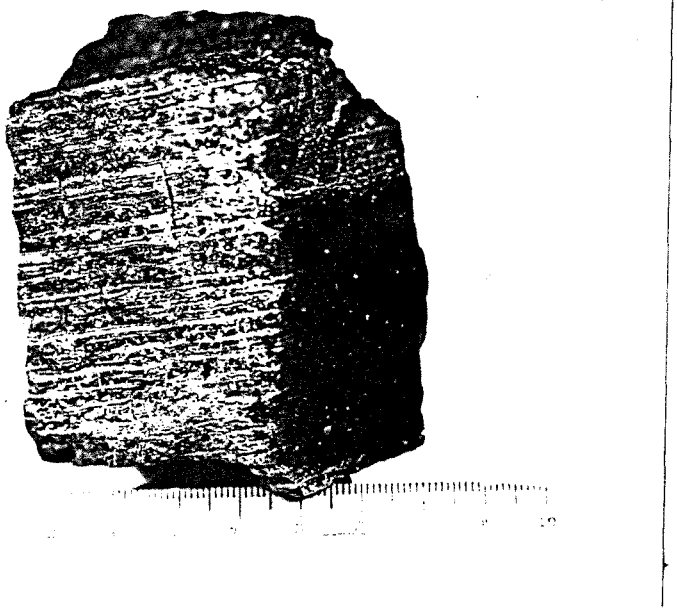


Figure 80. (KT 162, TLSE 16-22). Hand specimen of lava from the summit of Strickland Mountain. Figures 79a & b are photomicrographs of a thin section cut from this specimen. Note that the flow banding appears to be planar rather than linear. 10 cm scale.

found on the southern ridge of Morse Mountain and near the summit of Burnt Mountain. Columnar jointing is prominent at the last named locality.

THICKNESS, VOLUME, AND SOURCE: The combined thickness of the Pogy and Black Cat members is at least 9000 feet. It is believed that during the early stages of the rather violent eruption of the welded tuff of the Pogy member, a caldera developed from the partial collapse of the roof of the magma chamber. At or near the end of the eruption of the lavas of the Black Cat member, there was a further subsidence of the caldera floor. The limit of the caldera was probably not far from the present border of the Traveler felsite on the west, north, and east. The former extent of the caldera is discussed in Chapter V, Structural Geology. Because interbedded sediments are rare, and because no soil zones have been observed between any units, the Traveler felsite is believed to have been erupted in a relatively short time. It is difficult to estimate what this interval of time might have been, but it is believed, by analogy with Quarternary calderas, that several centuries represent a maximum and that the interval of time was probably considerably less. The bulk of the felsite was probably erupted within the caldera, and is thus represented by the present outcrop area of

the Traveler felsite. Assuming an average thickness of the felsite within the caldera of one mile, the volume of felsite erupted is about 70 cubic miles.

The vents from which the felsite was erupted have not been located. Volcanic rocks of the volume of the Traveler felsite, however, are usually erupted from fissures (R. L. Smith, 1960). It is reasonable that some of the fissures were near the margin of the caldera. Perhaps the breccia on Bald Mountain and on Wassataquoik Mountain are related to fissures which served as vents for the felsite.

AGE AND CORRELATION: The age and correlation of the Traveler felsite will be discussed in a later section.

TROUT VALLEY FORMATION

NAME: The heterogeneous assemblage of clastic rocks interbedded with minor sideritic ironstone that occupies the valley of Trout Brook between the west shoulder of Trout Brook Mountain and the north shoulder of Burnt Mountain is here called the Trout Valley formation. A massive felsite conglomerate, the Gifford conglomerate lentil, occurs at the base of the Trout Valley formation along South Branch Ponds Brook.

DISTRIBUTION: The major outcrop area of the Trout

Valley formation is in the broad, relatively flat-bottomed valley of Trout Brook between the felsite of Wadleigh Mountain to the north and the main mass of the Traveler felsite to the south. The formation thus occupies an area that is roughly 1.5 miles wide and 8 miles long and trends ENE. Excellent exposures are found along Trout Brook between The Crossing and the fork of the North and South Branches, along South Branch Ponds Brook and Wadleigh Brook, and in the relatively level "burned land" between the junction of Wadleigh and Trout Brooks and Wadleigh Mountain. In the last named area much of the soil cover has been stripped off and bed rock surfaces, roughly parallel to bedding planes, are exposed over areas of several acres.

The westward extent of the Trout Valley formation is poorly known. The possibility has already been mentioned that the rocks that crop out outside the area of study in the gravel pit between Thissell Pond and Little Nesowadnehunk Lake, Telos Lake quadrangle (fig. 2), may belong to the Trout Valley formation. Until further evidence can be obtained, however, the rocks in this gravel pit are included in the Seboomook formation. Rocks typical of the Seboomook formation crop out beside Black Brook in the Telos Lake quadrangle (TLEC 34-19) and on the North Branch of Trout Brook at BM 1071, Telos Lake quadrangle. At the latter locality the rocks are much deformed and slickensided.

The present interpretation is that the Trout Valley formation does not crop out west of the north shoulder of Burnt Mountain.

The 2580+ foot north shoulder of Wassataquoik Mountain (SE 16-10) is capped by at least 100 feet of baked clastic sedimentary rocks. Cross-bedding preserved in sandstones shows that these sediments are right side up. Thus, unless there is undetected faulting involved, these rocks are younger than much of the Pogy member of the Traveler felsite. There is no direct evidence for the age or correlation of these baked sedimentary rocks. They may be interbedded in the Traveler felsite, they may represent a later period of sedimentation unpreserved elsewhere, or they may belong to the Trout Valley formation. Sandstones comprise a fair percentage of the sedimentary rocks on Wassataquoik Mountain in contrast to the shale and interbedded tuff sequence in the Traveler felsite at Bald Mountain Falls. The author favors the interpretation that the baked sedimentary rocks on Wassataquoik Mountain belong to the Trout Valley formation.

DESCRIPTION

GIFFORD CONGLOMERATE LENTIL: The massive felsite conglomerate exposed at the base of the Trout Valley formation in the gorge of South Branch Ponds Brook and

along Gifford Brook is named the Gifford conglomerate lentil. Very minor sandstone and sandy black shale are interbedded with the felsite conglomerate about 100 feet above its base. The amount of the interbedded sandstone and shale increases stratigraphically upward from this level, and there is a corresponding decrease in the average size of the felsite detritus. The top of the lentil is placed where it looses its distinctive massive character; arbitrarily, the level above which pebble and cobble conglomerate form less than 75 percent of the rocks.

Massive felsite conglomerate comprises more than 95 percent of the Gifford conglomerate lentil except near its top. The felsite conglomerate consists of rounded to subrounded fragments of felsite as much as two feet in diameter set in a greenish-gray matrix which is probably ground-up felsite. Pebble-size and cobble-size fragments are the most abundant (fig. 81b). Repeated examination has failed to reveal any other rock fragments than felsite.

The felsite conglomerate is deeply weathered, and only weathered outcrops have been observed. The felsite fragments are easily broken out of the matrix and the fragments themselves are deeply weathered. This raises the question as to whether there may have been an earlier cycle of weathering.

Because the felsite fragments are so easily separated from the matrix, the massive felsite conglomerate



Figure 81a. Gorge cut in Gifford conglomerate lentil by South Branch Ponds Brook. The location is just upstream from the junction with Gifford Brook. A bed of sandstone is visible in the upper part of the picture, and a joint surface cutting through felsite cobbles is visible in the right center.



Figure 81b. Close-up of Gifford conglomerate lentil in the bed of South Branch Ponds Brook, showing rounded to subrounded fragments of felsite.

looks much like a poorly consolidated Pleistocene tillite. Actually, it is difficult to determine the contact between the felsite conglomerate and the overlying unconsolidated Pleistocene deposits. When, on a traverse down South Branch Ponds Stream, the author first observed the felsite conglomerate about 500 feet downstream from the last outcrop of felsite, he assumed that it was a young tillite. The true nature of the rock was realized only after observing the interbedded sandstone and black shale and discovering joints cutting through cobbles in the felsite conglomerate further downstream (fig. 81a).

As determined from the average dip of the Trout Valley formation, and the width of outcrop of the massive felsite conglomerate, the lentil is about 300 feet thick along South Branch Ponds Brook.

The lentil is not present at the base of the Trout Valley formation along Fowler Brook, and does not crop out along Dry Brook. If the lentil is present, but unexposed, in the vicinity of Dry Brook, it must be considerably thinner than 300 feet because the main body of the Trout Valley formation crops out within 900 feet horizontally of the Traveler felsite. To the west of Gifford Brook, the lentil does not crop out along the South Branch of Trout Brook or along the brook flowing north from the Black Brook Mountains (plate 1).

The Gifford conglomerate lentil, therefore, is interpreted as a local lens of felsite conglomerate, probably a deltaic deposit at the base of the Trout Valley formation. A few observations of imbricate structure of pebbles and cobbles of felsite shows that the currents were from the south from the direction of the main mass of the felsite.

MAIN BODY OF THE TROUT VALLEY FORMATION: The main body of the formation is a heterogeneous assemblege of light-blue-gray to black shale, siltstone, sandstone, and conglomerate. Black sideritic ironstone and sideritic sandstone comprise a small proportion of the formation. Many of the rocks are carbonaceous, and all of the rocks except shales are typically calcareous and cross-laminated or cross-bedded. Channelling in finer grained sediments by coarser-grained material also present. Most of the sandstones contain considerable "clay" matrix and many of the shales are sandy. Lithologic changes are rapid vertically and, to a lesser extent, horizontally. The formation is unevenly bedded. The 25 foot measured section, presented below, is typical of the formation. The outcrop from which this section was measured is on the north bank of Trout Brook where the brook crosses the town line between T.5 N., R.10 W. and T.5 N.,R.9 W. The section from top to bottom is as follows:

5 feet exposed	Sandy black shale containing plant impressions and two thin (2 to 3 inches thick) medium-coarse sandstone beds.
9 feet	Felsite pebble conglomerate with black shale chips and partings. The conglomerate is slightly calcareous.
6 inches	Black carbonaceous shale containing abundant plant impressions.
2 feet	Interbedded coarse sandstone and hard dark-gray slightly calcareous siltstone.
5 feet	Felsite pebble and granule conglomerate. The pebbles are as much as 1 inch in diameter but the average size of the felsite fragments is 1/8 inch.
3 feet exposed	Dark-gray sandy shale.

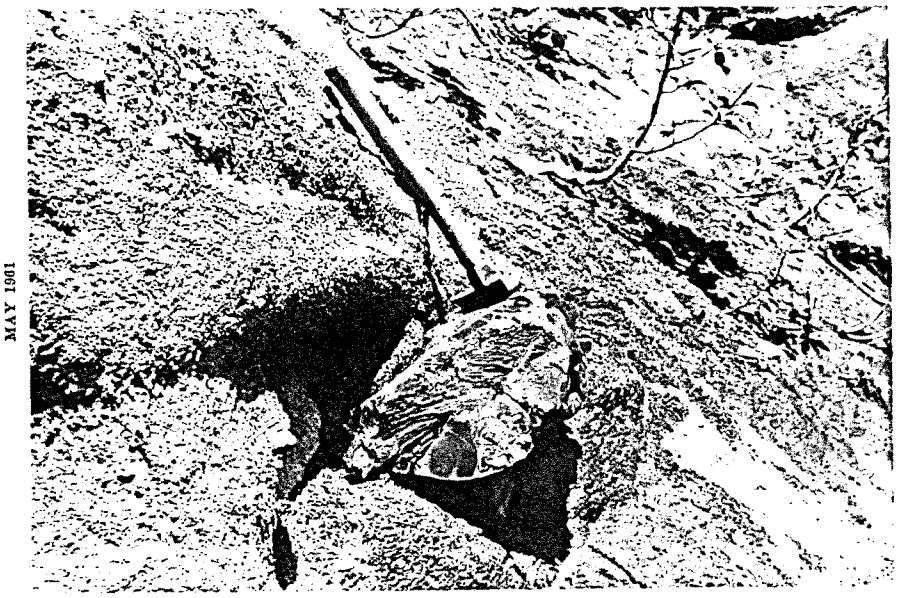
The formation is remarkably undeformed, except close to the high angle fault at the base of Wadleigh Mountain. The average dip of the beds is 15°. Jointing is well developed in the sandstone, but cleavage is not present in the shale.

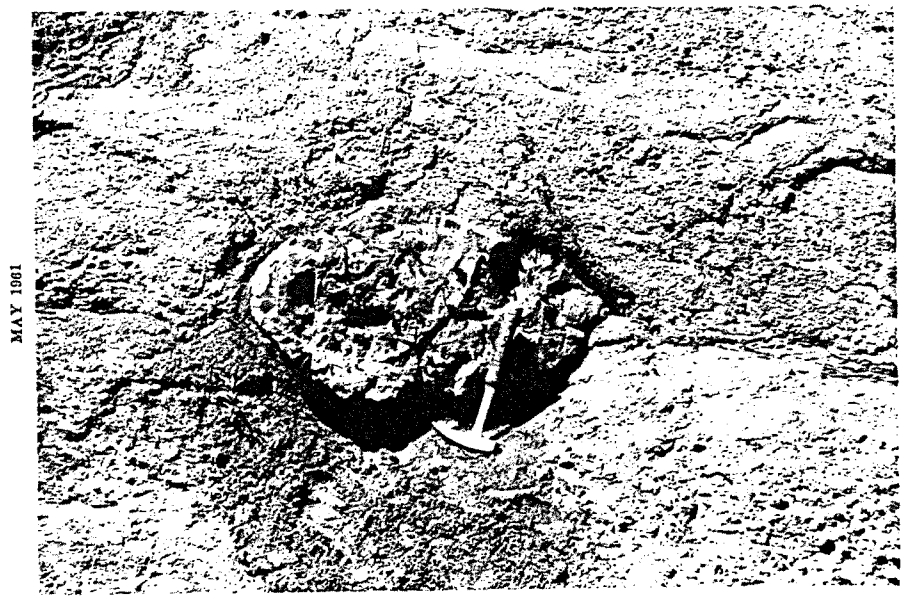
Although boulder and cobble conglomerates are restricted to the base of the formation (largely in the Gifford conglomerate lentil), pebble and granule conglomerate lenses are scattered throughout the exposed thickness of the formation. Conglomerate lenses are, however, less common in the upper part. No rock fragments other than felsite have been observed in the conglomerate. The felsite conglomerate may contain sideritic nodules, and pyrite is visible in some hand specimens.

Along Trout Brook at the base of Wadleigh Mountain and along South Branch Ponds Brook just above (downstream from) the Gifford conglomerate lentil, argillaceous granule conglomerate contains numerous black chert lenses. Some of the black chert lenses are many feet long and have the appearance of sedimentary lenses. Others are not much longer than they are thick and appear to have internal structure (fig. 82). Mineralogically they consist of quartz and fine carbonaceous material. Professor Elso Barghorn (oral communication) has identified one of these as Prototaxites, a plant of uncertain affinities.

The sandstone ranges in grain size from very fine to very coarse. Much of the sandstone breaks across the bedding with a chunky fracture and the finer grained beds are typically dense and hard. In some rocks, borings (?) normal to the bedding contribute to the chunky fracturing.

Most of the sandstone is lithic graywacke, but some is subgraywacke (as defined by Pettijohn, 1957). In some of the sandstone, the sand-size fraction is largely quartz. In others, particularly the coarser grained ones, felsite fragments comprise as much as 90 percent of the sand-size fraction. Considering that the nearby Traveler felsite was probably the source of much of the detrital material, plagioclase is surprisingly sparse in the sandstone. In none of the thin sections of sandstone which were examined





Figures 82a & b. Black chert lenses in the Trout Valley formation, similar to the one identified by Professor Barghorn as Prototaxites. South Branch Ponds Brook below the junction with Gifford Brook.

does plagioclase make up more than 10 to 15 percent of the sand-size fraction. Calcite cement is present in some sandstones and clusters of small siderite grains may also be present.

The shale typically lacks cleavage and is carbonaceous. Much of it is crumbly and sandy. Some black shale is so rich in carbonaceous material that it resembles a low-grade coal.

Sideritic ironstone occurs in the Trout Valley formation either as concretions or as thin beds less than a foot thick. Typically it is a dense, heavy, hard rock composed of fine silt- or clay-size particles. It breaks with a conchoidal fracture. Where fresh, the ironstone is black, but weathers a yellowish brown. The major iron-bearing mineral is siderite, but in some rocks an iron-rich chlorite is also present. A few percent subangular detrital quartz grains are typically present. The identification of siderite and a high-iron chlorite has been confirmed by X-ray diffraction. Estimated modes of two sideritic iron stones are presented in table 5. Spherulites of siderite, grown around detrital quartz grains, have been observed in some siltstones.

The most distinctive rock on the north shoulder of Wassataquoik Mountain is a dark maroon hornfels. An estimated mode of this hornfels is presented in table 5.

Table 5

Estimated Modes of Sideritic Ironstone and Hornfels from the Trout Valley Formation

	1.	2.	3.
Quartz	15	15	33
Sericite*			32
Biotite			33
Fe-chlorite	tr	30	
Calcite		tr	
Siderite	85	54	
Opaques		1	1
Zircon		tr	tr

*Fine grained white mica.

1. (KT 335, WC 30-30) Sideritic ironstone concretion from siltstone, west side of Trout Brook.
2. (KT 338, WC 27-27) Siderite-chlorite ironstone from outcrop on the west bank of Trout Brook.
3. (KT 369a, SW 17-105) Maroon hornfelsed siltstone from 2450 feet on Wassataquoik Mountain.

The quartz grains are up to 0.08 mm in diameter. Biotite flakes (0.01 to 0.02 mm across) are distinctly pleochroic, from colorless to a medium reddish brown. The rock is probably a baked argillaceous siltstone.

THICKNESS AND LOWER CONTACT: The Trout Valley formation overlies the Traveler felsite with considerable unconformity (it truncates the presumed contact between the Pogy and Black Cat members). The time-lapse involved in this unconformity is unknown, but need not be significant, because of the supposed subsidence associated with the volcanism.

The top of the Trout Valley formation has been eroded. The thickness of the formation, including the Gifford conglomerate lentil, is estimated to be about 1500 feet.

PALEONTOLOGY: The fossil assemblege of the Trout Valley formation is interesting and unusual for New England. The age of the formation is discussed in the next section. The occurrence of Prototaxites has already been mentioned. Impressions of plant stems were first discovered in this formation by the author in 1955. Subsequent field work has shown that plant fossils are abundant. They can be found in nearly every outcrop of the formation above the massive conglomerate of the Gifford conglomerate lentil.

The plants occur in greatest concentrations, but are the most poorly preserved, in black sandy shale lenses in granule or pebble conglomerate. The resemblance of some of this black sandy shale to low-grade coal has already been mentioned. The best preserved plant material occurs in hard, but fissile siltstone.

Professor Erling Dorf of Princeton University has studied the material collected from the Trout Valley formation and has identified the following four types of plants (written communication, April, 1961):

Psilophyton princeps var. ornatum Dawson

Taeniocrada cf. T. decheniana Goeppert

Aphyllopteris sp.

Hostimella sp.

According to Dorf (oral communication) this is the second verified occurrence of Psilophyton princeps in the United States. The other occurrence is in the Lower Devonian rocks of Beartooth Butte, Wyoming (Dorf, 1934). The initial specimen of the Psilophyton came from float in the bed of Dry Brook. In August 1959, Professor Dorf visited the author in the field and at this time specimens of Psilophyton were found in outcrop. The Psilophyton impressions occur in relatively hard black shale that is in soft crumbly sandy shale on the east bank of South Branch Ponds Brook about 30 feet above the stream. The

outcrop occurs approximately on the town line between T.6N., R.9W. and T.5N., R.9W.

Ostracodes have been found in fissile black shales stratigraphically above the major plant-bearing beds. The shales are interbedded with siltstone and sandstone and crop out on the north side of Wadleigh Brook a short distance above its junction with Trout Brook (WC 280-315, and 100 yards upstream from this location). The ostracodes have been examined by Jean M. Berdan, U. S. Geological Survey. The following is quoted with her permission from her report dated March 9, 1959.

> These collections contain Kloedenia? sp. and a smooth subrectangular species, (previously reported, 2/10/58). There is also a rather large straight-backed form with a finely reticulated surface, which apparently has two sulci and a dorsally directed spine on the posterior lobe. This form may belong to a new genus, but the preservation is such that it is impossible to determine many of the important characters. In addition to the ostracodes mentioned above, the collections also contain plant fragments, fish scales, and fragments of something that is either a pelecypod or an estherid, probably the latter.

Eurypterid scales or plates were discovered in the Trout Valley by W. H. Forbes of Washburn, Maine in August 1959 during a field trip led by the author through the Traveler Mountain quadrangle. The scales were found in gray, rusty-weathering shale that makes up part of a large outcrop on the southeast bank of Trout Brook about 200 yards upstream from The Crossing (WC 400-400). At the

time of discovery, the fossils were thought to be fish scales. A further, much larger collection was made in the summer of 1960 by Nelda Wright and Arnold Lewis of the Museum of Comparative Zoology, Harvard University. Because no bony material was found with the scales Miss Wright does not believe they are fish scales (oral communication). Dr. Ian Rolfe, post-doctoral fellow, Museum of Comparative Zoology, Harvard University has identified the scales as plates of eurypterids (oral communication).

AGE: The Trout Valley formation overlies with probable unconformity the Matagamon formation of Becraft-Oriskany age and is separated from the Matagamon formation by several thousand feet of the Traveler felsite. The plant fossils provide the best paleontologic basis for dating the formation. Dorf (written communication, April 1961) states, "Each of these forms [of plants] compares closely with a form previously recorded from the Lower Devonian of North America or Europe. The association of these four different forms is a rather typical Early Devonian one. To the best of our knowledge these plants grew in lowland, stream- or lake-border environments." A more precise age is not possible at present.

According to Arnold (1952) Prototaxites has a geologic range from Late Silurian to Late Devonian. The eurypterids plates have not been studied but will probably

be of little help in dating the formation (Ian Rolfe, oral communication). The presence of the ostracode Kloedenia? sp. suggest that a minimum age for the Trout Valley formation is Onondaga. The following is quoted from a report by Jean M. Berdan dated February 10, 1958.

> ... The collection was submitted [by A. J. Boucot] as being either Hamilton or Onondaga in age. If it were not for this reported stratigraphic position, I would have suspected the age of this collection to be Upper Silurian or Lower Devonian, because of the known abundance of kloedenid ostracodes in rocks of these ages in Maine. However, a species of Kloedenia has been described by Swartz and Swain (1941, p. 248) from the Onondaga equivalents in Pennsylvania, and the related kloedenid Welleria occurs in the Hamilton of New York (M. L. Smith, 1956, p. 5) and the Traverse of Michigan (Warthin, 1934, pp. 208-209). Ordinarily these ostracodes are rare in the Onondaga and Hamilton, and are associated with diversified and characteristic faunas of other ostracode genera. Local concentrations of one species may occur, however, as described for Welleria aftonensis by Kesling and Soronen (1957) in the Gravel Point formation of Michigan. It is conceivable that the same type of concentration might have occurred in the Devonian of Maine. As is indicated by the tentative identification of these ostracodes as Kloedenia?, it seems more likely to me that the age of this collection is Onondaga or older rather than Hamilton. However, the material is too poor to justify anything more than a guess. Additional collections should be made in order to settle the point.

A larger collection, which formed the basis for the report quoted earlier in this section, did not contain any evidence permitting a more precise dating of the ostrocodes.

ENVIRONMENT OF DEPOSITION: The Trout Valley formation immediately overlies the Traveler felsite. It

is believed that much of the felsite was erupted subaerially. Therefore, land of considerable elevation must have existed at some point during the eruptive cycle. It is also believed that during the final stages of the eruption, or shortly thereafter, there was a foundering of the roof of the magma chamber. This foundering may help to explain the occurrence of subaqueous deposits on top of a subaerial volcanic sequence several thousand feet thick.

The Trout Valley formation is believed to have accumulated relatively rapidly in a shallow water, nearshore, brackish environment involving rapidly shifting currents. The presence of the Gifford Conglomerate lentil suggests very strongly that at least some of the Traveler felsite was above water level at the time of deposition of the Trout Valley formation. The abundant remains of terrestrial plants further attest to the existence of nearby land.

The association of sideritic ironstone with coal or carbonaceous sediments has long been recognized; for example, the occurrence of black band iron ore (sideritic ironstone) in the Coal Measures of Great Britain. This association is found on a much smaller scale in the Trout Valley formation. These sideritic ironstones are usually thought to have been precipitated from solution in brackish marshes or in shallow seas where organic matter

was abundant (Lindgren, 1933, p. 265-266).

The faunal assemblage is also suggestive of brackish or near shore environment, or, at least, something other than the normal marine environment. J. N. Berdan (written communication, March 9, 1959) reports,

> --On the basis of the ostracodes alone, a marine environment seems more probable, but as essentially nothing is known of Middle and Lower Devonian fresh water ostracodes, it is not possible to state that the types in these collections could not occur in fresh water. The possibility that some of the fragments present represent estherids suggests the possibility of at least a brackish water environment. Chadwick (N. Y. State Mus. Bull. 336, p. 120-121, 1944) reports the association of Estheria and "Beyrichia" in the Kiskaton formation, which he considered non-marine. Goldring (N. Y. State Mus. Bull. 332, p. 268-269, 1943) states that there are six zones in the Ashokan formation with this ostracode-estherid association, and concludes that these are evidence of a brackish water invasion.

At the time of Miss Berdan's report, it was not known that eurypterid plates or scales also occur in the Trout Valley formation. Moore, Lalicker, and Fisher (1952, p. 557-560) state that Silurian and Devonian eurypterids most commonly occur in rocks which do not represent normal marine deposits. They suggest the eurypterids may have lived in water of either very high salinity or very low salinity. Finally, although a search was made, other invertebrate fossils typical of marine environments, such as brachiopods, have not been found.

CORRELATION: The correlation of the Trout Valley

formation is discussed in the next section.

AGE AND CORRELATION OF THE TRAVELER FELSITE AND THE TROUT VALLEY FORMATION

The Traveler felsite overlies the Matagamon formation of Becraft-Oriskany age and underlies the Trout Valley formation which has a probable minimum age of Onondaga. More precise dating of the felsite depends upon a better understanding of its relationships to the Matagamon and Trout Valley formations and a better knowledge of the age of the Trout Valley formation. The uncertainty in dating is small, but may be significant in terms of regional geology.

The Traveler felsite is the northeastern end of a discontinuous belt of felsite extending southwest about 80 miles to Heald Mountain, Pierce Pond quadrangle (fig. 1). These felsites include the extrusive rocks of the Kineo volcanic member of the Tomhegan formation (Boucot, 1961), the Big Spencer volcanics (Heath, 1959), and the unnamed felsite on Soubunge Mountain (E. S. C. Smith, 1933). There are also several small bodies of intrusive felsite, such as the felsite on Coburn Mountain (Boucot, in preparation). Of all the felsites, the Traveler felsite covers by far the largest area. These felsites are grossly similar lithologically, and the extrusive ones rest on marine sandstones of Oriskany age (the Tarratine formation in the Moose Rivers

synclinorium and the Matagamon formation in the Katahdin-Traveler area). (See Boucot, et al., 1960). The felsites are probably roughly equivalent in age.

At Moosehead Lake the felsites of the Kineo volcanic member of the Tomhegan formation grade upward through a felsite conglomerate into marine sandstones of the main body of the Tomhegan formation. The sandstones contain an assemblage of fossils that Boucot (1961) originally dated as Onondaga age, but now believes to be of Schoharie age (oral communication, March 1961). Boucot favors the interpretation that the Kineo volcanic member is at least partially contemporaneous with the basal portion of the main body of the Tomhegan formation. He does not, however, exclude the possibility that the felsite may be intermediate in age between the Tarratine formation and the main body of the Tomhegan formation.

Because of the over-all similarity of the stratigraphy of the Katahdin-Traveler area and the Moosehead Lake area it seems reasonable that the Trout Valley formation is the correlative of the main body of the Tomhegan formation. Paleontological evidence cannot confirm this correlation at present, but does not exclude it. If such a correlation is valid, the Trout Valley formation is of Schoharie age.

The author favors the view that the Traveler felsite is intermediate in age between the Matagamon and

Trout Valley formations. He also believes that the time interval between the deposition of the top of the Matagamon formation and the bottom of the Trout Valley formation was not very long. In fact it may have been so short that both the Traveler felsite and the Trout Valley formation are of Oriskany age. For this reason, a Schoharie age for the Trout Valley formation fits the geologic interpretation better than does an Onondaga age.

There are two major reasons for believing that no long time gap occurred between the deposition of the Matagamon formation and the eruption of theTraveler felsite. First, the Traveler felsite does not represent a sudden initiation of volcanism, but is rather a climax of an increasing tempo of volcanism. Felsite fragments are the most abundant rock fragments found in the lithic graywacke and subgraywacke of the Matagamon formation. Tuffaceous sediments are found in the Matagamon formation immediately beneath the felsite.

Secondly, the sediments at the top of the Matagamon formation were unconsolidated or poorly consolidated at the time of the eruption of the Traveler felsite. There are numerous arenite dikes in the base of the felsite. The large ones are as much as 20 feet thick and several tens of feet long. Small anastomosing dikes, the segments of which may be less than an inch thick, have also been

observed. These sandstone dikes may be seen at the base of the cliffs on Horse Mountain and in the road-cut just north of Eastern Landing, Matagamon Lake. Shallow channels filled by felsite have been observed in the underlying sandstone (fig. 25).

The unconformity between the Traveler felsite and the Trout Valley formation has already been mentioned. It has also been suggested that this unconformity may have been caused, in part, by the formation of a caldera. The time lapse between the final eruption and the first deposition of the basal Gifford conglomerate lentil might, therefore, have been insignificant -- as short as a few weeks or even a few days. Two factors, however, suggest a somewhat longer time interval. One is the presence of the northward plunging anticlinal axis in the felsite at South Branch Ponds. It is possible that this doming was caused by the rise of a post-subsidence stock or lacolith (See Chapter V). Because the Trout Valley formation is not deformed appreciably by the doming, it must have been deposited after the formation of the dome. A second factor that suggests a longer time interval is the presence of terrestrial plant fossils in the Trout Valley formation. Sufficient time, perhaps a few centuries or even several thousand years, may have elapsed to allow the development of such a flora, perhaps as old as any in eastern North

America, on newly created volcanic land. These plants are found in the Trout Valley formation as low as the upper part of the Gifford conglomerate. If the Gifford conglomerate lentil accumulated rapidly, as seems reasonable, its base probably does not represent the earliest deposition after the cessation of volcanism.

CHAPTER III

INTRUSIVE ROCKS

GENERAL STATEMENT

Except for the Katahdin granite, intrusive rocks are of minor importance in the Katahdin-Traveler area. Two small stocks or pipes of granophyre intrude rocks older than the Trout Valley formation. These are probably the intrusive equivalent of the Traveler felsite. Small sills and related dikes of quartz andesite intrude the Trout Valley formation. These are believed to be older than the faulting associated with the Acadian orogeny.

The northern end of the batholith of the Katahdin granite, including the type locality on Mount Katahdin, occupies the southern portion of the area of investigation. Although the granite covers more of the area of study than does any other rock unit, it is even more extensively exposed in quadrangles to the south and southwest. Andrew Griscom is making an extensive study of the granite in the western portion of the Katahdin quadrangle and in the Harrington Lake quadrangle. Therefore, only the major features of the granite are covered in this report.

Mafic dikes, not described here, cut the Katahdin granite at a few localities. They have been observed at Ledge Falls on the Wassataquoik Stream, on Harvey Ridge

and the south wall of Northwest Basin, and in the Chimney (a steep gully extending into South Basin from the col between Pamola and Chimney Peak).

GRANOPHYRE

DISTRIBUTION

Two small intrusive bodies of granophyre have been located within the Katahdin-Traveler area. The smaller of the two is situated on the peninsula south of Norway Dam, Hay Brook Logan (north-central ninth). It is believed to cover an elliptical area roughly 1500 feet by 800 feet.

A second, larger body of granophyre is located on the south side of the western ridge of Wassataquoik Mountain in the southwest corner of the Traveler Mountain quadrangle. Griscom has also found granophyre on Bald Mountain in the northwest corner of the Katahdin quadrangle. The granophyre on Bald Mountain is probably continuous with that on Wassataquoik Mountain. If so, there is a granophyre body roughly a mile and a quarter long in a north-south direction, and, in the Traveler Mountain quadrangle, a half mile wide.

DESCRIPTION

The granophyre, which is very fine-grained or fine-grained, weathers bone white or rusty white. On the fresh surface it is light to medium gray and is

typically spotted with brown or dark green clusters of shreddy biotite. The rock contains a few percent, generally about 5 percent, phenocrysts of quartz, plagioclase and biotite. The plagioclase is slightly zoned and is badly altered; the quartz is corroded. The phenocrysts may be as much as 3 mm across. Accessory minerals include opaques, zircon, apatite, rare tourmaline (from the granophyre on Wassataquoik Mountain only), and sheaves of tiny epidote crystals.

The groundmass typically contains some sort of distinctive intergrowth between potassic feldspar and quartz. In the finer grained granophyre, these intergrowths are spherulites that are set in a microcrystalline mosaic of quartz, feldspar and chlorite. Phenocrysts invariably have spherulitic growths around them. In the coarser grained granophyre, the intergrowths are granophyric (micrographic) with a tendency toward "centric" graphic.

The chilled contact of the granophyre against the inclosing rocks of the Seboomook formation is exposed on the northern side of the peninsula south of Norway Dam. The rock is light greenish-gray aphanitic felsite containing spherulites. Minutely banded chalcedonic quartz is present between some spherulites. Thirty feet into the granophyre from the contact, the rock is as coarse grained as any seen in the granophyre from Wassataquoik Mountain.

A chemical analysis and norm of this coarser grained granophyre from near Norway Dam are presented in table 11 along with analyses of Lower Devonian Maine felsites.

AGE

The granophyre near Norway Dam is intrusive into the Seboomook formation of Becraft-Oriskany age. The granophyre on Wassataquoik Mountain is probably intrusive into the Traveler felsite, although no contact has been observed. Griscom (oral communication) states that the Katahdin granite intrudes the granophyre on Bald Mountain. Thus the age of the granophyre is bracketed between that of the Traveler felsite and that of the Katahdin granite.

It is suggested that the granophyre is the intrusive equivalent of the Traveler felsite. A second interpretation, although not favored, is that the granophyre is an early phase of the intrusion of the Katahdin granite. A third possibility is that, if the time gap between the eruption of the felsite and the intrusion of the granite proves to be less than is now believed, the granophyre could be both the intrusive equivalent of the felsite and an early phase of the granite. Evaluation of the last hypothesis must await more precise dating of the rock units involved. The best evidence available at present, however, indicates that the felsite is Early Devonian and the granite is Late Devonian.

The first interpretation seems reasonable because the phenocryst content of the granophyre is similar to that of the felsite and because the chemical analysis of the granophyre is within the range of variations in chemical analyses of the Traveler felsite. Finally, the texture of the granophyre indicates a near-surface intrusion, while the granite adjacent to the granophyre on Wassataquoik Mountain is much more coarsely crystalline, probably indicating a greater depth of intrusion. If the interpretation that the granophyre is the intrusive equivalent of the Traveler felsite is correct, the granophyre is probably intermediate in age between the Oriskany and the Schoharie.

QUARTZ ANDESITE

DISTRIBUTION

Quartz andesite sills have been observed in the Trout Valley formation at a number of localities. Most of the sills are only a few inches thick. However, at three localities sills between 7 and 30 feet thick have been observed. These are on Dry Brook (C 04-37), on South Branch Ponds Brook just north of the town line between T.5N., R.9W. and T.6N., R.9W., and at the right-angle corner on Trout Brook (WC 16-19). A few much-weathered andesite(?) dikes also occur in the Trout Valley formation and a similar dike cuts the Seboomook formation just upstream from Grand Pitch on Webster Brook. The dikes are too small

to be shown on the geologic map.

DESCRIPTION

Most of the quartz andesite is badly weathered. It is gray or light gray and, if fine grained, is easily mistaken for the lithic graywacke of the Trout Valley formation. Closer inspection, however, reveals small feldspar laths, and a higher percentage of pyrite than is typical of the lithic graywacke. The quartz andesite sills may be seen to terminate sharply or to transgress the bedding locally. The sills typically form resistant units which stand out in contrast to the sedimentary rocks.

The freshest quartz andesite is found in the series of relatively thick bifurcating sills at the aforementioned locality on Trout Brook (WC 16-19). The largest of the sills at this locality is at least 30 feet thick. The relatively coarse grained andesite from this sill is light gray and contains brownish-green euhedral amphibole prisms, up to 10 mm long and 1.5 mm across, set in a matrix of interstitial plagioclase. It probably consisted originally of about 5 percent pyrite, 7 percent quartz and roughly equal amounts of plagioclase and amphibole. The plagioclase is extensively altered to clinozoisite (abnormal blue interference color) and sericite. A rough determination of the index of refraction of the plagioclase indicates that its present composition is albite-oligoclase. The

amphibole, probably hornblende, is weakly pleochroic (X= light tan, Z= greenish-tan), and optically negative with a 2V of 80, $Z \wedge C = 20$. It is partly altered to chlorite. In most outcrops, the original mafic silicate has completely altered to a mixture of chlorite, calcite, epidote or clinozoisite and magnetite.

AGE

The quartz andesite sills and dikes are intrusive into the Trout Valley formation, the youngest stratified unit in the area. Therefore, they are probably younger than Schoharie age. There is no positive evidence as to their minimum age or their relationship to the Katahdin granite. However, because a large sill may be offset by faulting which may be related to the Acadian orogeny, the quartz andesite is tentatively assigned to the Lower Devonian.

KATAHDIN GRANITE

NAME

The name Katahdin granite was first used by Toppan (1932, p. 69), although it has been known since Bailey's visit to the mountain in 1836 that Mt. Katahdin is composed of granite.

DISTRIBUTION

The Katahdin granite is exposed over a larger area within the region of study than any other rock unit. It is believed to underlie all the portion of the Katahdin quadrangle included in this report. The northeast corner of the quadrangle has not been visited in the field because of its inaccessibility. Granite does crop out, however, at Twin Ponds on the east side of Turner Mountain, on Barnard Mountain, and near Hathorn Pond in the southeast corner of the Traveler Mountain quadrangle. Granite also occurs in the southern portion of the Traveler Mountain quadrangle on much of Wassataquoik Mountain, in the broad open Wassataquoik Valley (fig. 9), on Sable Mountain and on the southeast shoulder of South Traveler Mountain. The northeast limit of the granite is poorly known because of lack of exposure. Large blocks (20 x 20 x 30 feet) of granite occur beside the trail to Traveler Pond west of Messer Pond (SE 22-35). These probably have not moved far.

The Katahdin granite probably underlies about 1/10 square mile in the extreme southwest corner of the Shin Pond quadrangle. The Katahdin granite does not extend into the Telos Lake Quadrangle.

DESCRIPTION

The Katahdin granite is a medium-grained,

light-colored biotite, two feldspar granite which has considerable variation in texture and color. Most of the variations appear to be related to the proximity to the unpreserved roof of the batholith. At lower elevations the fresh granite is typically equigranular and grayish-white. This facies is called the Wassataquoik facies because it is the major type of granite found in the valley of the Wassataquoik stream and on the hills and mountains in the southern part of the Traveler Mountain quadrangle. At higher elevations on the Katahdin massif, the granite is typically pinkish, granophyric, and contains phenocrysts of biotite. This facies is called the Pamola facies from the exposures on Pamola.

The two facies grade into oneanother and there are minor variations within each facies. The gradational contact between the two facies has been observed at only a few localities, but appears to slope gently north from about 3800 feet in the Great Basin to about 2000 feet on Russell Mountain.

WASSATAQUOIK FACIES: The granite of the Wassataquoik facies is medium-grained (average grain size 3 mm) and equigranular. On the fresh surface it is grayish white. Along joints it is commonly pink. Aplite dikes are scattered throughout the outcrop area of the facies , but

pegmatites are uncommon. Figure 85a is a photograph of a hand specimen of the Wassataquoik facies.

The essential constituents of the granite are quartz, perthite, plagioclase and biotite. Two modes of the Wassataquoik facies are presented in table 6. The perthite consists of about 70 percent potassic feldspar and 30 percent sodic feldspar. In some specimens the potassic phase possesses faint microcline twinning. In others, none is visible. The plagioclase typically shows strong continuous zoning from cores of andesine to rims of sodic oligoclase. The biotite is strongly pleochroic (light golden brown to dark greenish brown). Biotite from each of the two specimens in the mode had an index of 1.678. Using the same excess Al which was used for the biotite from the Traveler felsite, (0.2 out of 1.0 formula unit Al based upon 24 oxygens) the $\frac{FeO}{FeO+MgO}$ ratio is 88 percent. A few olivine crystals, presumably fayalite, were observed in one thin section.

Some of the Katahdin granite is slightly, but noticeably porphyritic (fig. 85b). Pink-weathering perthite phenocrysts, typically 5 mm long, are set in a groundmass slightly finer grained than the normal granite of the Wassataquoik facies. The porphyritic granite has been observed at a number of localities within the Wassataquoik facies. It is found on several of the summits of the

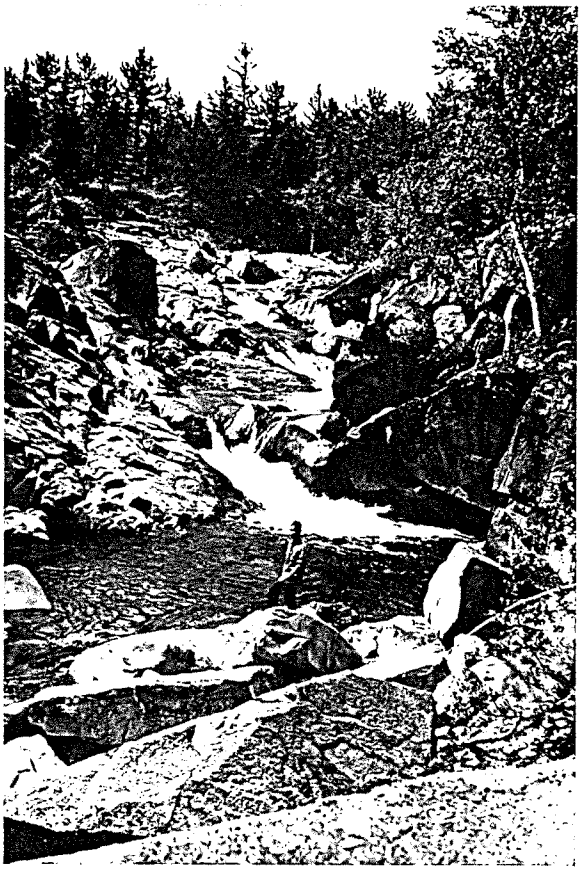


Figure 83. Porphyritic granite of the Wassataquoik facies at Grand Falls, Wassataquoik Stream.

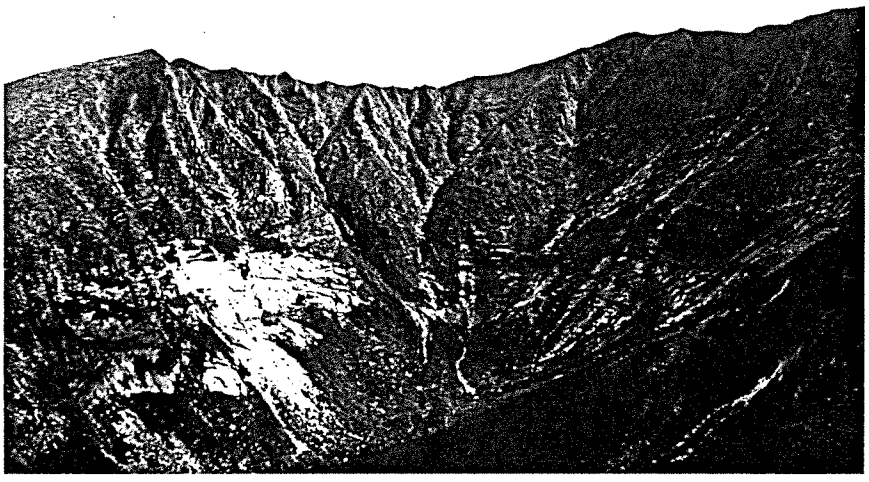


Figure 84. South Basin of Mt. Katahdin from Hamlin Ridge. Pamola (4902 feet) is on the left, Baxter Peak (5267 feet) is on the right. The Knife Edge connects them. Except outcrops at the extreme lower left, all rocks belong to the Pamola facies, Katahdin granite. The zone of xenoliths circles the basin at the bottom of the outcrops. Lighter colored rocks in lower left center have been freshly exposed by slides.

Table 6

Representative Modes of Plutonic Rocks

	1.	2.	3.
Quartz	29.3	25.5	30
Orthoclase			18
Perthite	33.0	41.6	
Plagioclase	27.8	25.5	30
Biotite	7.5	6.8	12
Hornblende			8
Epidote			1
Opaques	2.0	0.4	tr
Apatite	0.2	0.2	1
Zircon	0.2		tr

1. (KT 213) Wassataquoik facies, Katahdin granite from the south side of the 1730 foot hill between Deep Pond and Bell Pond near the southern border of the Traveler Mountain quadrangle. Point count, 2000 points. The plagioclase is strongly zoned, but the average composition is oligoclase.

2. (KT 444) Wassataquoik facies, Katahdin granite from 1880 feet on nose of ridge west of Roaring Brook Campground, north-central ninth, Katahdin quadrangle. Point count, 1500 points. The plagioclase is strongly zoned, but the average composition is oligoclase.

3. (KT 428) Porphyritic granodiorite xenolith in Katahdin granite. 3350 feet on east wall of south Basin at base of cliffs on Pamola. Estimated mode.

Katahdinauguoh Range (on North Brother, Fort Mountain and Mullen Mountain, but not on Wassataquoik Mountain), at Ledge Falls and Grand Falls on the Wassataquoik Stream (fig. 82), on Barnard Mountain, and on the summit and one locality on the southwest side of South Turner Mountain. The relationship between the porphyritic granite and the more "normal" granite is not known, and the porphyritic granite is not shown separately on the geologic map.

PAMOLA FACIES: The granite of the Pamola facies is similar in gross mineralogy to the Wassataquoik facies and grades into it. Figure 86 is a photograph of a typical hand specimen of the Pamola facies. The essential constituents are quartz, perthite, plagioclase and biotite. Typically the biotite is coarser (phenocrysts up to 8 mm) than the felsic minerals and there is a graphic intergrowth between the quartz and feldspar. Either perthite or plagioclase may be involved in the graphic intergrowth, but most of the perthite is involved. In the finer-grained portions of the graphic intergrowths involving alkali feldspar, the perthitic texture is not visible. The plagioclase is strongly zoned.

The lower portion of the Pamola facies adjacent to the Wassataquoik facies is typically a grayish white. With increasing elevation, the granite becomes a mottled pink and white speckled with phenocrysts of biotite. The

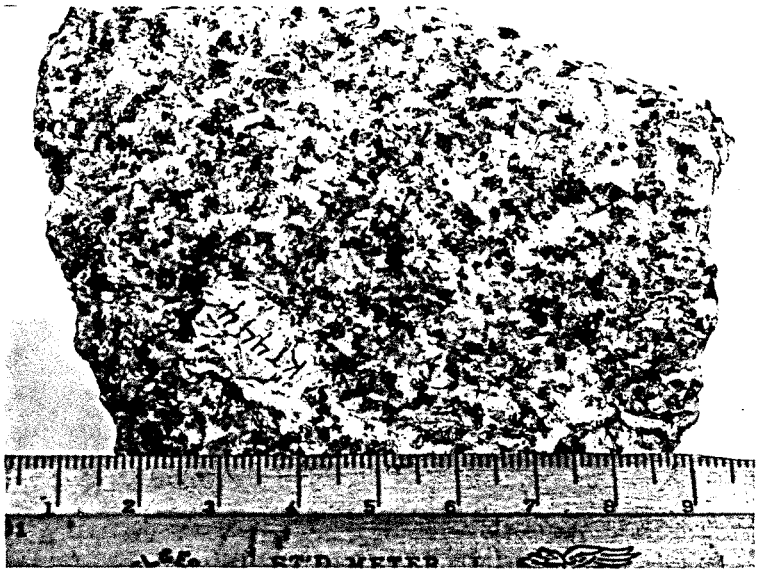


Figure 85a. (KT 444). Wassataquoik facies of the Katahdin granite from 1880 feet on the nose of the ridge west of Roaring Brook Campground, north-central ninth, Katahdin quadrangle. 10 cm scale.

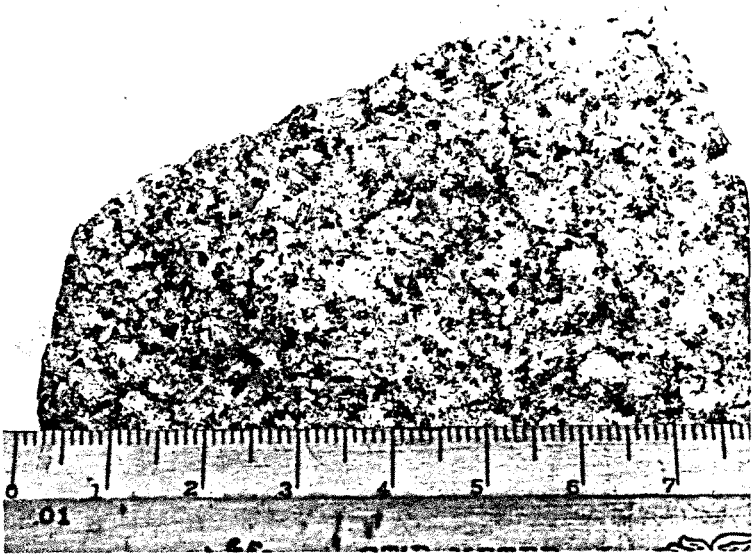


Figure 85b. (KT 217). Porphyritic granite of the Wassataquoik facies, Katahdin granite from Grand Falls, Wassataquoik Stream. The phenocrysts are perthite. 10 cm scale.

proportion of pink gradually increases until, over much of the Table Land, on the walls of North, Great and South Basins and on North Turner Mountain, the granite is salmon pink. The change in color is accompanied by an increase in the percentage of quartz and feldspar involved in graphic intergrowths and the appearance of vugs filled with epidote, tourmaline, quartz and potassic feldspar. In the salmon-pink granite, biotite constitutes only about 3 percent of the rock and is pleochroic in yellows and greens. These changes would seem to imply an approach to the eroded roof of the magma chamber, with an accompanying increase in volatiles and in the activity of oxygen. Similar changes in the granite have been observed close to the contact with the Traveler felsite within a zone a few hundred yards wide.

Aplite dikes are scattered throughout the Pamola facies and at a number of places concentrations of sulfides and tourmaline in joints and fracture zones have been observed. The sulfides include loellengite and bornite.

XENOLITHS: Xenoliths are rare in the Katahdin granite except on the upper part of the Katahdin massif. The greatest concentration of observed xenoliths occurs in a belt between 50 and 150 feet thick extending around the wall of South Basin from beneath Pamola at least as far

as beneath Baxter Peak. The average elevation of the belt is about 3450 feet and it is roughly at the contact between the two facies of granite. The xenoliths range in size from vanishingly small up to 4 feet in diameter and constitute from 20 to 70 percent of the rock (average 40 to 50 percent). They are in general, rounded, corroded and veined with granite. Figures 88a and 88b show two examples of this zone of xenoliths from beneath Pamola. Similar xenoliths have also been observed on the north wall of North Basin and at an elevation of 4000 feet on the south side of South Peak.

The xenoliths are light gray and appear porphyritic with a fine-grained groundmass. The obvious phenocrysts (3 to 5 mm across) are smoky quartz, orthoclase, plagioclase, or biotite. Closer inspection reveals that the seemingly fine-grained groundmass consists of poikilitic quartz and feldspar, at least as coarse-grained as the "phenocrysts." The impression of small grain size is conveyed by inclusions of fine-grained (about 0.1 mm) mafic silicate within the poikilitic quartz and feldspar.

In thin section, the xenoliths typically have an ophitic-like texture. Euhedral or subhedral grains of plagioclase, biotite, and hornblende are set in poikilitic quartz and orthoclase. This texture is illustrated in figures 88c and 88d. An estimated mode of a typical

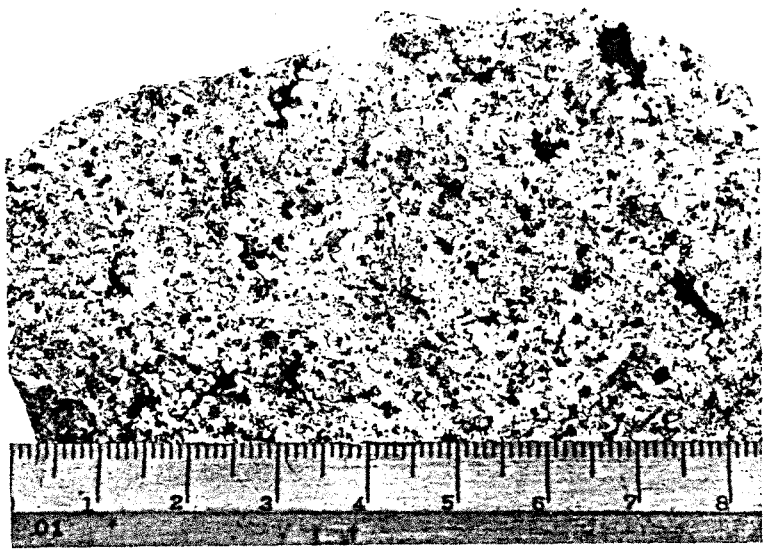


Figure 86. (KT 441). Mottled pink and white granophyric granite of the Pamola facies, Katahdin granite showing biotite phenocrysts. The specimen is from 4260 feet in the Chimney, Mt. Katahdin. 10 cm scale.



Figure 87. (KT 252, C 21-30). Sharp contact between the Pamola facies, Katahdin granite (light) and the recrystallized felsite of the Pogy member (dark). The specimen is from 1500 feet on the western summit of South Traveler. 10 cm scale.

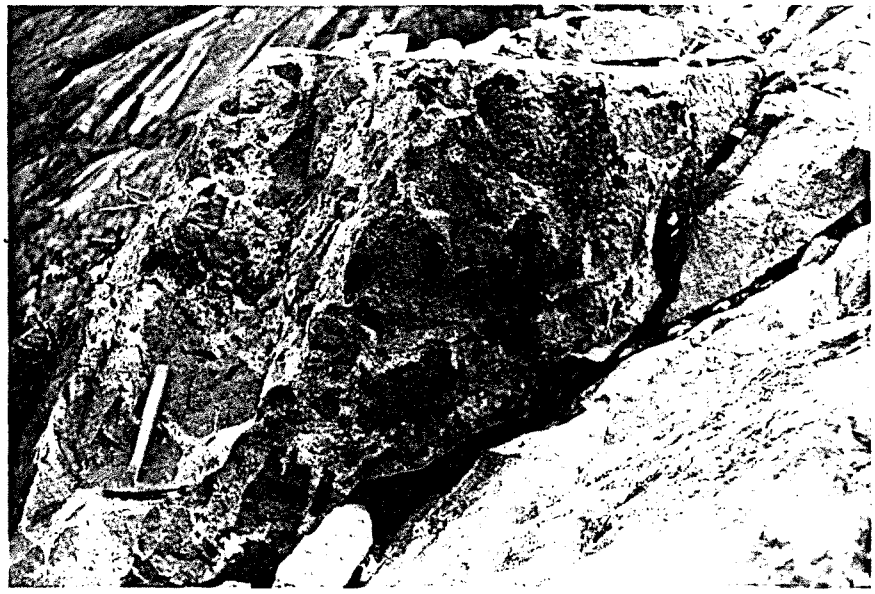
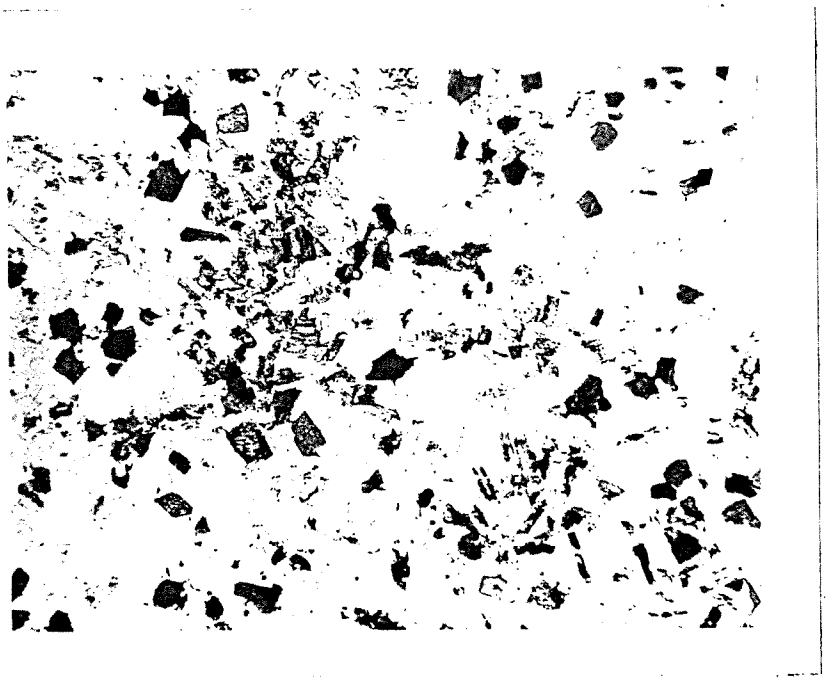


Figure 88a. Xenoliths of granodiorite in the Katahdin granite. Part of a belt between 50 and 150 feet thick extending around the wall of South Basin at an average elevation of 3450 feet.



Figure 88b. Xenoliths of granodiorite in the Katahdin granite, South Basin, Mt. Katahdin.





Figures 88c & d. (KT 100). Ophitic-like texture in granodiorite xenolith. Crystals of zoned plagioclase, biotite and hornblende set in poikilitic quartz and orthoclase. The specimen is from float at an elevation of about 4100 feet on Avalanche Brook, Mt. Katahdin. Figure 88a plane-polarized light. Figure 88b crossed nicols. X 32.

xenolith is given in table 6. The xenoliths are granodiorite.

The plagioclase crystals average 0.5 mm in length, are twinned and strongly zoned. The cores are badly saussuritized and the rims are albite. The biotite is partly strongly pleochroic (light tan to dark brown) and is altered to a chlorite with distinct abnormal blue interference color. The hornblende is also strongly pleochroic (X = light tan green, Z = dark green), has an extinction angle of 15° (Z∧C) and is partly altered to chlorite.

Porphyritic grandiorite, lithologically similar to the xenoliths, has been found near the top of the Saddle Slide (an avalanche scar that is the route of the Saddle Trail on the headwall of the Great Basin) and between elevations 4400 feet and 4800 feet on the Cathedral Trail. These two areas of porphyritic granodiorite do not seem to be connected in outcrop. They are interpreted as roof pendants or very large xenoliths, but have not been studied in detail. On the Cathedral Trail, the porphyritic granodiorite becomes granophyric in its upper part.

AGE

The Katahdin granite exposed in the area of study is the northern end of a large body of granite that extends about 27 miles southwest of Baxter Peak to the vicinity of

Shaw Mountain, First Roach Pond quadrangle. According to the geologic map of northern Maine, compiled by Boucot, et al (1960), the batholith is exposed over about 450 square miles.

Boucot (1954) has shown that the Katahdin granite intrudes fossiliferous Middle Silurian strata in Ripogenus Gorge on the West Branch of the Penobscot River. In the Traveler Mountain quadrangle, the granite intrudes the Traveler felsite, which rests upon the Matagamon formation of Oriskany age.

The intrusive contact of the Katahdin granite is well displayed on the north ridge of Wassataquoik Mountain above Wassataquoik Lake and on the southwest slopes of the western peak of South Traveler Mountain. At the latter locality, the contact is sharp (fig. 87). Within one or two hundred yards of the felsite, the granite resembles the Pamola facies with granophyric texture. Sprays of tourmaline occur on joints both in the granite and in the felsite. In contrast with this, granite from the nearest outcrop to the Kimball Brook formation near Hathorn Pond (SE ninth) shows no observable change from the typical granite of the Wassataquoik facies.

Strata on Wassataquoik Mountain, which have been tentatively assigned to the Trout Valley formation of Schoharie (?) age, have been hornfelsed, presumably by

the granite.

Boucot (1954) suggested that, because of its unaltered condition, the Katahdin granite probably postdates the major deformation affecting Lower Devonian strata in north-central Maine. The present author supports this conclusion, although a pre-orogenic age for the granite cannot be precluded. The age of the major deformation is discussed under the section on structure, but it is believed to be Middle or early Late Devonian (the Acadian orogeny). Hence on the basis of stratigraphic and structural evidence, the maximum age for the Katahdin granite is Middle or Late Devonian.

Lyons, et al (1957, table 5) published a series of age determinations on zircon (lead-alpha method) from some Maine and New Brunswick granites. Two of the determinations were made on zircons from the Katahdin granite at Ripogenus Gorge, Harrington Lake quadrangle. They obtained ages of 320 and 316 m.y. (million years) for the Katahdin granite, 330, 302 and 322 m.y. for a quartz monzonite near Jackman, Maine, and 315 $\pm$11 m.y. for the series of six determinations of Maine and New Brunswick granites (including the determinations mentioned above). It is probable that all these ages are too low because of a systematic error that is now known to be present in the lead-alpha method.

Hurley, et al (1959) obtained a K-A minimum age

of 364 ±10 m.y. for a small quartz monzonite stock which intrudes the Seboomook formation near Jackman. Field work by A. Albee, one of the authors of this paper, demonstrated that the specimens of quartz monzonite given to Lyons et al for study did not come from this post-Oriskany stock, but from an area of pre-Upper Silurian quartz monzonite. Apparently the pre-Upper Silurian quartz monzonite had been sufficiently affected by a post-Oriskany metamorphism so that it did not yield its true age, but rather the age of the metamorphism. Hurley et al also made an age determination on this pre-Upper Silurian quartz monzonite and obtained an age of metamorphism of 356 ±15 m.y. This is in good agreement with the ages of metamorphism obtained from near-by specimens of the Seboomook formation, and with the age of the post-Oriskany quartz monzonite stock.

Two conclusions may be drawn from this evidence. First, the lead-alpha method used by Lyons et al yielded ages that, in the Middle Paleozoic, are about 40 m.y. too low. Second, a quartz monzonite stock near Jackman was intruded at approximately the same time as, or slightly later than a period of metamorphism.

Lyons et al obtained about the same age for the metamorphism of the pre-Upper Silurian quartz monzonite stock near Jackman and for the crystallization of the Katahdin granite. Applying the same 40 m.y. correction

factor to the Lyons et al age of the Katahdin granite would yield 360 and 356 m.y. as the ages of the Katahdin granite. Presumably, therefore, the Katahdin granite was intruded about the same time as the post-Oriskany quartz monzonite stock near Jackman. With reference to the time scale published by Kulp (1961), the Katahdin granite would be of Late Devonian age.

RELATIONSHIP TO THE TRAVELER FELSITE

At a number of localities in the world, plutonic rocks intrude volcanic rocks with which they are believed to be comagmatic. For example, plutonic rocks of the White Mountain plutonic-volcanic series intrude the Moat volcanics (Billings, 1956) and the Tertiary plutonic rocks on the island of Mull, Scotland intrude basaltic lavas of Tertiary age (Richey, 1948). The Katahdin granite intrudes the Traveler felsite, both are probably Devonian in age, and so the question of whether they are comagmatic arises.

No chemical analyses of the granite were made as a part of this study. A possibly significant mineralogical difference is that the felsite contains garnet and the granite does not. Garnet is rare in the felsite, however, and can probably be ignored in a mineralogical comparison. There are no other mineralogical features of either rock which would exclude their being chemically related.

A major factor to be considered is that the felsite

is pre-Acadian (Early Devonian) while the granite appears to be post-Acadian (Late Devonian?). One wonders whether it is meaningful to apply the term comagmatic in the conventional sense to these rocks. Further, there are bodies of felsite, such as that of Mt. Kineo, which are thought to be related to the Traveler felsite, but which are in areas devoid of any equivalent of the Katahdin granite. It seems probable, therefore, that the relationship between the Traveler felsite and the Katahdin granite is not as straightforward as that between the plutonic rocks and the Moat volcanics of the White Mountain series.

CHAPTER IV

CHEMISTRY AND VOLCANIC HISTORY OF THE TRAVELER FELSITE

OPTICAL STUDIES OF THE PHENOCRYSTS

SANIDINE

The composition of sanidine from two welded tuffs (specimens KT 206, SE 03-52 and KT 228, SC 25-32) of the Pogy member has been determined. In thin sections cut from each of the two welded tuffs, at least one sanidine crystal was favorably oriented so as to give a centered acute bisectrix interference figure. The distances between the isogyres of these centered figures was measured in terms of numerical aperture (N.A.) using an objective with an adjustable diaphragm. 2V was then calculated using the relationship $2V = 2 \sin^{-1}(\frac{N.A.}{\beta})$.

β of sanidine ranges only from 1.525 to 1.531 (Wahlstrom, 1955) and any value within this range will not significantly affect the derived value fo 2V in the above relationship. An intermediate value of 1.527, therefore, is arbitrarily assumed for β. Within the limits of the method used, the two sanidine crystals from the Pogy member had identical optical properties. These are as follows:

N.A. = 0.4

2V (calculated assuming β = 1.527) = 30°

Optic plane perpendicular to (010)

According to the data of MacKenzie and Smith (1956, fig. 1), these properties would correspond to a sanidine with a composition of Or_{67}. Estimated 2V's of sanidine from other specimens agree within $\pm 5^{\circ}$ to 30° suggesting that they have compositions in the range Or_{55} to Or_{80}.

The sanidine from specimen KT 228 coexists with plagioclase of composition An_{48}. A chemical analysis of this rock is presented in table 11.

PLAGIOCLASE

The composition of plagioclase from 17 specimens of the Traveler felsite was determined optically. Four of these specimens were from the Pogy member and 13 were from the Black Cat member. These data are presented in tables 7 and 8 respectively. All of the plagioclases studied have about the same composition, are strongly zoned and have an average bulk composition of An_{47}.

Samples which contained the freshest plagioclase were selected by thin section study. Fairly clean separation of the feldspar phenocrysts was obtained by using a Franz Isodynamic Magnetic Separator, the feldspar being in the non-magnetic fraction. The α' on cleavage surfaces (assumed) of the separated plagioclase was determined by using the immersion method and a sodium-vapor lamp. The composition was then read from Tsuboi's curves (Winchell and Winchell,

1951, p. 281). In order to obtain some measure of the compositional zoning of the phenocrysts, the highest and lowest α' observed in a succession of immersion mounts were taken to represent the maximum and minimum An content of the plagioclase from a particular sample. The tabulated average composition of the plagioclase phenocrysts from a given sample is the estimated weighted average of values of α' obtained by a grain count. Estimation of the bulk or average composition of zoned plagioclase has long constituted a problem for petrographers. (See Bowen, 1928, p. 143 and Griscom, 1960). It is probably inherent in the technique used here that the bulk compositions are too high in the anorthite component, because some of the outer portions of the crystals which would be highest in the albite component would probably be lost during the grinding and separation process. However, this source of error is difficult to evaluate, and, rather than assign an arbitrary correction factor, the estimated weighted averages are presented as they were determined.

The compositions of a few plagioclase phenocrysts was also determined in thin section by the extinction angle method (table 8). Measurements of extinction angles in sections cut at right angles to (010), angles measured from trace of (010), give bulk compositions within ± 3 percent An of the bulk composition obtained for that sample

TABLE 7

Optical Determinations of the Composition of Zoned Plagioclase Phenocrysts from the Pogy Member, Traveler Felsite

Specimen Number	Location	Elevation	Rock Type	α' on Cleavage Surface			Mol % An				Remarks
				Lowest	Highest	Estimated Weighted Average	Lowest	Highest	Range	Estimated Weighted Average	
KT 225	SW 35-20 South Pogy Mountain	2200 ft.	Welded tuff	1.548	1.561	1.554	40%	61%	21%	49%	
KT 228	SC 25-32 South Traveler Mountain		Welded tuff	1.547	1.557	1.553	38	54	16	48	Coexists with sanidine, Or_{67}
KT 372	SW 28-15 South Pogy Mountain	2180	Felsite	1.552	1.558	1.553	46	56	10	48	
KT 374	SW 26-14 South Pogy Mountain	2200	Felsite	1.545	1.556	1.551	35	52	17	45	
Averages of the 4 samples							40	56	16	48	
Standard deviation							4.0	3.4	3.9	1.6	

TABLE 8

Opitcal Determination of the Compositions of Zoned Plagioclase Phenocrysts from the Black Cat Member, Traveler Felsite

Specimen Number	Location	Elevation	Rock Type	α' on Cleavage Surface			Mol % An					Remarks
				Lowest	Highest	Estimated Weighted Average	Lowest	Highest	Range	Estimated Weighted Average	From Extinction Angle	
KR 116	WC 38-16 Black Cat Mountain	1500 ft.	Lava	1.547	1.558	1.553	38%	56%	18%	48%	45%	
KT 208	SE 05-515 The Traveler	2230	Lava	1.545	1.557	1.553	35	54	19	48		Some potassic feldspar in sample
KT 236	SC 14-57 Pinnacle Ridge	1520	Lava	1.552	1.560	1.553	46	59	13	48	49	Rim An_{46} by extinction angle
KT 237	SC 16-555 Pinnacle Ridge	2140	Lava	1.547	1.557	1.552	38	54	16	46	48	Poor sample; plagioclase partly altered
KT 241	CO 8-05 Black Cat Mountain	1460	Lava	1.545	1.555	1.552	35	51	16	46		Poor sample; cores completely altered
KT 242	CO 6-05 Black Cat Mountain	1870	Lava	1.545	1.554	1.552	35	49	14	46	48	
KT 289	WC 26-005 Black Brook Mountain	2223	Lava									Core An_{50} by extinction angle
KT 297	WC 20-12 Black Brook Mountain	1160	Lava	1.551	1.555	1.552	45	51	6	46		
KT 469	C 35-04 "Middle Traveler" Mountain	2860	Lava	1.553	1.561	1.556	48	61	13	52		
KT 470	C 37-06 "Middle Traveler" Mountain	2450	Lava	1.548	1.558	1.555	40	56	16	49		
KT 418	SC 345-32 South Traveler Mountain	2530	Laminated Crystal Tuff	1.547	1.557	1.551	38	54	16	45		Some plagioclase phenocrysts badly altered
KT 424	SE 04-42 The Traveler	2200	Welded Tuff	1.544	1.555	1.550	33	51	18	44		Optically (+), 2V ≅ 80 to 85°
KT 425	SC 285-475 The Traveler	1920	Felsite	1.548	1.556	1.551	40	52	12	45		Poor sample; plagioclase partly altered
KT 245	C 17-09 Howe Brook	1160	Felsite	1.552	1.557	1.553	46	54	8	48		Poor sample; plagioclase partly altered
Average of 9 samples Standard deviation			Lava				40 4.8	55 3.6	15 3.6	48 1.9		
Average of last 4 samples Standard deviation			Misc.				39 4.7	53 1.3	14 3.9	46 1.6		
Average of 13 samples Standard deviation			Felsite				40 4.8	54 3.3	14 3.7	47 2.0		

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by indices of refraction (standard deviation = 2.1). Thus the two techniques yield comparable results.

The potassium content of the phenocrysts is unknown. A plagioclase in equilibrium with alkali feldspar and with an anhydrous melt of trachytic or andestic composition would have the maximum possible Or content for a plagioclase of a given An content (Tuttle and Bowen, 1958, p. 131-137). This Or content has not been determined experimentally to the writer's knowledge. Tuttle and Bowen (1958, fig. 64) present an emperical curve (LK_s) representing the maximum solubility of Or in plagioclase. For plagioclase of composition An_{50}, the maximum solubility is 12 percent. Curve LK_s is based upon published analyses of feldspars. It is probable that many analyses which show a high Or component (near curve LK_s in figure 64) are of feldspar grains containing two phases rather than one (J. B. Thompson and D. B. Stewart, oral communication). Hence the maximum Or content of plagioclase is probably considerably less than that indicated by Tuttle and Bowen's curve LK_s in figure 64. Furthermore, in the Traveler felsite, most of the plagioclase is not in equilibrium with potassic feldspar. Sanidine is known to be present in only one out of 17 feldspar samples investigated. The melt was neither anhydrous nor trachytic nor andesitic. All of these factors would lower the permissible Or content. It seems probable that the Or

content of the plagioclase phenocrysts in the Traveler felsite is in the range of 0 to 3 percent. The plagioclase phenocrysts which coexist with sanidine in the Pogy member may have a slightly higher Or content.

The major observation drawn from this study is the similarity of the bulk compositions of the plagioclase phenocrysts from all portions of the Traveler felsite. The average of the bulk compositions of the 13 samples from the Black Cat member is An_{47} with a standard deviation of 2.0 percent An. Four samples from the Pogy member have an average bulk composition of An_{48} with a standard deviation of 1.6 percent An. Admittedly, the sampling is poor, particularly from the Pogy member, but the present data is remarkably consistent. Some support for this conclusion may be obtained from the standard deviations from the average maximum and minimum compositions. Although there are two to three times the standard deviations from the bulk composition, the averages and standard deviations for the two members are in good agreement (tables 7 and 8).

CLINOPYROXENE

The compositions of clinopyroxenes from 4 samples have been determined from their 2V's and β indices using Tröger's (1956, p. 62) clinopyroxene composition diagram. These data are presented in table 9. Three of the samples

TABLE 9

Optical Determinations of the Composition of Clinopyroxene from the Traveler Felsite

Specimen Number	Location	Elevation	Rock Type	Stratigraphic Position	2V (Estimated ±5°)	$\rho \pm 0.003$	Mol %			Orientation of optic plane	N.A.
							Wo	En	Fs		
KT 236	SC 14-57 Pinnacle Ridge	1520 ft.	Lava	Black Cat Member	35°	1.719	26	29	45	11(010), $Z \wedge c = 47°$	
KT 245	C 17-09 Howe Brook	1160	Felsite	Black Cat Member	40°	1.717	30	29	41		
KT 297	WC 20-12 Black Brook Mountain	1160	Lava	Black Cat Member	44° (calculated)	1.720	33	25	42	11(010)	0.65
Averages of the three samples					40	1.719	30	28	42		
KT 372	SW 28-15 South Pogy Mountain		Felsite	Pogy Member	40	1.720	29	27	44		

are from the Black Cat member and one is from the Pogy member. The pyroxenes were separated from the same samples from which plagioclase phenocrysts were obtained for study. Fewer determinations were made, however, because fresh pyroxene is much less abundant than fresh plagioclase and much more difficult to separate (final separation by hand picking). 2V was either estimated ($\pm 5^{\circ}$) from the curvature of the isogyre in an optic axis figure, or, in one favorably oriented crystal, calculated from the measured distance between the isogyres of a centered acute bisectrix figure. For this particular crystal, the distance between the isogyres was measured in terms of numerical aperture (N.A.) using an objective with an adjustable numerical aperture and V calculated using the relationship $V = \sin^{-1}\left(\frac{N.A.}{\beta}\right)$.

All of the clinopyroxenes studied are ferroaugites in the nomenclature of Poldervaart and Hess (1951). The available data suggest that the pyroxenes like the plagioclases are of essentially the same composition throughout the Traveler felsite. All of the compositional variations in table 9 are within the limits of accuracy of the determinations.

BIOTITE

Biotite flakes have been hand picked from the heavy mineral concentration of KT 372 from the Pogy member and of KT 236 from the Black Cat member. If the Al content of

the biotite were known, the Fe:M_g ratio would follow directly from the γ index (Tröger, 1956, p. 84). Thompson (1953 lecture notes) has stated that the local valences in trioctahedral micas are better saturated if the mineral contains Al in excess of the standard formula (coupled substitution octahedral Al^{+3}-tetrahedral Al^{+3} for octahedral Fe^{+2}-tetrahedral Si^{+4}). Analyses presented by Nockholds (1947), however, show that the amount of excess Al is closely related to the aluminum saturation of the rock containing the biotite; the excess is greatest in peraluminous rocks and least in peralkaline rocks. Of the biotite analyses presented by Nockholds, those which come from rocks with the greatest similarity to the Traveler felsite are from the volcanic rocks of the San Juan region Colorado. These biotites have an excess of 0.20 out of 1.0 formula unit Al based on 24 oxygens. An aluminum excess of 0.20 for the biotite from the Traveler felsite is arbitrarily assumed. The available data presented in table 10 suggest that biotite has a slightly higher Fe:M_g ratio than the coexisting clinopyroxene.

GARNET

Garnet has been observed in eight specimens of the Traveler felsite. In most of these only one garnet per specimen was observed. Because of the rarity of garnet in

TABLE 10

Optical Determinations of the Compositions of Biotite from the Traveler Felsite

Specimen Number	Location	Elevation	Stratigraphic Position	Rock Type	$\gamma \pm 0.003$	FeO:FeO+MgO assuming no excess Al	FeO:FeO+MgO assuming Al excess of 0.20 out of 1.0 formula unit Al (24 oxygens)	FeO:FeO+MgO in co-existing clino-pyroxene
KT 236	SC 14-57 Pinnacle Ridge	1520 ft.	Black Cat Member	Lava	1.661	63%	65%	61%
KT 372	SW 28-15 South Pogy Mountain		Pogy Member	Felsite	1.663	66	68	62

the felsite as a whole and also in each specimen, it has not been practicable to attempt to separate the garnet for a cell edge determination. The refractive indices, however, have been determined for the garnet from three specimens. These are given below.

Specimen Number	Location	Elevation	Stratigraphic Position	Rock Type	Index of Refraction ±0.003
KT 302A	SC 03-56 South Br. Trout Brook		Black Cat Member	Flow?	1.813
KT 328	TLSE 10-435 Morse Mountain	1590 ft.	Traveler felsite, undifferentiated	Flow	1. 808
KT 424	SE 04-42 The Traveler	2200	Black Cat member	Welded Tuff	1.811

Because of the many compositional variables in garnet, the composition cannot be determined from the index of refraction alone.

CHEMICAL ANALYSES

There are four available chemical analyses of the Traveler felsite. Two of these were published by E. S. C. Smith in 1930, and two are in a new analysis made by Dr. Jun Ito of Harvard University for the present study. These

four analyses are presented in table 11 along with four analyses published by Smith (1925, 1933) of other Early Devonian felsites of northern Maine. These felsites are roughly equivalent in age. A new analysis by Dr. Ito of the granophyre near Norway Dam is also included for comparison in table 11.

One of Smith's analyses is of a specimen from Snub Pitch, South Pogy Mountain (approximate location SW 34-18) and the other is of a specimen probably from the 3060 foot knob on the south ridge of The Traveler (SC 37-41) (E. S. C. Smith, written communication). Professor Smith very kindly gave the author a small piece of each of these two specimens. The Traveler specimen, here called ECS-1, is a dark-gray to black lava from the Black Cat member. It contains about 7 percent phenocrysts including plagioclase, pyroxene, and biotite. Aggregates of phenocrysts are common. An estimate mode of the phenocrysts in this specimen is included in table 3. Because of the small area of the thin section, little confidence should be placed in this mode.

The Snub Pitch specimen, here called ECS-2, is a dark-gray, fresh-looking banded felsite of the Pogy member. It contains about 7 percent phenocrysts, mostly badly sericitized plagioclase, very minor quartz, and some completely altered mafic silicates. Whether the rock is a lava or a welded tuff cannot be determined from the

TABLE 11

Chemical Analyses and Norms of Early Devonian Felsites and Granophyre from Northern Maine

	Chemical Analyses																				
	1.	*	2.	*	2a.	3.**	*	4.	*	5.	*	6.	*	7.	*	8.	*	9.	*	
SiO_2	73.72		74.39			71.82		71.42		71.74		69.46		73.01		75.41		69.50		SiO_2
TiO_2	0.12		0.33			0.28		0.23		0.23		0.15		0.13		0.10		0.15		TiO_2
Al_2O_3	12.96		12.40			12.79		13.22		13.26		13.04		12.62		12.89		15.12		Al_2O_3
Fe_2O_3	0.23	1.15	1.91	1.23		1.76	2.16	3.21	2.44	3.09	2.35	2.00	2.78	1.55	2.00	0.08	0.96	2.00	2.78	Fe_2O_3
FeO	2.02	1.18	0.66	1.26		2.57	2.21	1.82	2.51	1.74	2.41	3.55	2.85	2.45	2.05	1.79	0.99	3.55	2.85	FeO
MnO	0.04		0.05			0.06		tr		tr		0.07		0.07		0.06		0.05		MnO
MgO	0.11		0.19			0.15		0.51		0.61		0.44		0.44		0.01		0.76		MgO
CaO	0.83		1.32			1.70		2.00		1.92		1.96		1.22		1.09		1.28		CaO
Na_2O	3.44		2.64			3.32		4.40		4.49		4.19		3.80		2.87		2.33		Na_2O
K_2O	4.97		5.09			4.61		3.51		3.34		3.87		3.69		4.63		3.76		K_2O
H_2O^+	0.46		0.63			0.35		tr		nil		1.01		0.64		0.56		1.33		H_2O^+
H_2O^-	0.88		0.31			0.38						n.d.		n.d.		0.06		....		H_2O^-
P_2O_5	0.08		0.32			0.12		0.05		0.06		n.d.		n.d.		0.12		....		P_2O_5
Total	99.86		100.24			99.91		100.37		100.48		99.74		99.62		99.67		99.83		Total

	Weight Percent Norms																				
	1.	*	2.	*	2a.	3.**	*	4.	*	5.	*	6.	*	7.	*	8.	*	9.	*	
Qz	32.49		36.97		30.3	30.74		27.24		29.01		25.08		32.60		38.55		36.43		Qz
Or	29.37		30.06		26.7	27.25		20.76		19.76		22.88		21.79		27.39		22.21		Or
Ab	29.11		22.34		23.7	28.06		37.24		37.97		35.45		32.15		24.28		19.72		Ab
An	3.56		4.45		10.1	6.40		5.95		6.15		5.34		6.07		4.56		6.34		An
Cor	1.24		0.92		0.2									0.16		1.48		4.89		Cor
Mn-Pyx	0.08		0.08		0.1	0.10						0.13		0.12		0.12		0.08		Mn-Pyx
Wo						0.50		1.55		1.23		1.84								Wo
En	0.27		0.48		0.8	0.37		1.27		1.52		1.09		1.09		0.03		1.89		En
Fs	1.02		0.77		3.4	1.82		2.20		2.10		2.68		1.90		0.86		2.69		Fs
Mt	1.67		1.78		3.0	3.13		3.54		3.40		4.03		2.89		1.39		4.03		Mt
Il	0.23		0.62		1.2	0.53		0.44		0.44		0.29		0.24		0.20		0.29		Il
Ap	0.20		0.75		0.6	0.30		0.10		0.15						0.30				Ar
Total	99.24		100.14		100.1	99.20		100.29		101.73		98.81		99.01		99.16		98.57		Total

	"Oxygen Percent" Norms																				
Qz	35.91		40.65		33.7	34.17		30.11		31.50		28.32		36.11		42.14		40.77		Qz
Or	28.02		28.54		25.7	26.16		19.82		18.53		22.32		20.85		25.86		21.47		Or
Ab	29.49		22.51		24.2	28.59		37.73		37.79		36.71		32.64		24.33		20.23		Ab
An	3.40		4.23		9.7	6.41		5.69		5.77		5.21		5.80		4.31		6.13		An
Cor	0.81		0.89		0.2									0.16		1.43		4.84		Cor
Mn-Pyx	0.06		0.06		0.1	0.08						0.10		0.09		0.09		0.06		Mn-Pyx
Wo						0.43		1.33		1.04		1.61								Wo
En	0.27		0.48		0.8	0.37		1.26		1.48		1.11		1.09		0.03		1.90		En
Fs	0.77		0.57		2.6	1.38		1.66		1.56		2.07		1.44		0.64		2.06		Fs
Mt	0.96		1.02		1.7	1.80		2.03		1.92		2.36		1.66		0.79		2.34		Mt
Il	0.15		0.41		0.8	0.35		0.29		0.28		0.19		0.16		0.13		0.19		Il
Ap	0.17		0.64		0.5	0.26		0.09		0.13						0.26				Ap
Total	100.01		100.00		100.00	100.00		100.01		100.00		100.00		100.00		100.01		99.99		Total

*Iron oxide recalculated using the ratio Fe^{+3} to Fe^{+2} in Daly's average post-Cambrian granite and keeping the total iron constant. The values in this column were used in the norm calculations.

**Also reported

BaO .00X - .0X
SrO .00X - .0X

Elements spectrographically found

Pb, Ag, Sr.
Cr, Mo, V, Zr, Ga, Be
Sc, Y, Yb

1. (KT 411) Granophyre, north side peninsula south of Norway Dam, Matagamon Lake; Jun Ito, analyst.

2. (KT 208, SE 05-515) Groundmass of lava, Black Cat member, Traveler felsite from east flank of The Traveler; Jun Ito, analyst.

2a. (KT 208, SE 05-515). Norms for rock calculated by combining model analysis of phenocrysts with the chemical analysis of groundmass. See text for explanation.

3. (KT 228, SW 26-14) Welded tuff, including phenocrysts, of the Pogy member, Traveler felsite from the western summit of South Traveler; Jun Ito, analyst.

4. (ECS-1,) Lava, Black Cat member, Traveler felsite from the 3040 + foot knob north of Traveler Gap. Analyzed at the General Electric Laboratory, Schnectady, N. Y. (E. S. C. Smith, 1930, Am. Jour. Sci., vol. 19, p. 7).

5. (ECS-2, approximate location SW 34-18) Felsite, Pogy member, Traveler felsite from Snub Pitch, South Pogy Mountain. Analyzed at the General Electric Laboratory, Schnectady, N. Y. (E. S. C. Smith, 1930, Am. Jour. Sci., vol. 19, p. 7).

6. Felsite from Sonbunge Mountain, Harrington Lake quadrangle; George J. Steele, analyst (E. S. C. Smith, 1933, Am. Jour. Sci., vol. 25, p. 228).

7. Felsite from Big Spencer Mountain; George J. Steele, analyst (E. C. S. Smith, 1933, Am. Jour. Sci., vol. 25, p. 228).

8. Felsite from Mt. Kineo; George J. Steele, analyst (E. S. C. Smith, 1933, Am. Jour. Sci., vol. 25, p. 227).

9. Felsite from Coburn Mountain; George J. Steele, analyst (E. S. C. Smith, 1933, Am. Jour. Sci., vol.

specimen. In thin section the rock is seen to have been much fractured. The fractures have been annealed with felsitic material for the most part. However, they also contain epidote, chlorite, and fluorite (?) (isotropic, colorless, strong negative relief, at least 2 oblique cleavages). It is possible, therefore, that the analysis does not represent the original composition of the rock.

The new analyses of felsite are numbers 2 and 3 in table 11. Number 2 is of the groundmass of a flow of the Black Cat member (KT 208, SE 05-515). The groundmass was separated from the phenocrysts by the use of the Franz Isodynamic Magnetic Separator and heavy liquids. A point count of the sample submitted to the analyst showed the separation to be 99 percent effective (9 points out of 1000 were plagioclase phenocrysts). In the succeeding calculations, this 0.9 percent impurity has been ignored. A mode of the phenocrysts in KT 208 is included in table 3, and figures 60 and 61 are photomicrographs of the thin section made from the analyzed specimen. Plagioclase phenocrysts from this rock have a bulk composition of An_{48} (table 8).

Analysis number 3 is of specimen KT 228, a welded tuff of the Pogy member from the summit of the western peak of South Traveler. A mode of the phenocrysts of this rock is included in table 2, and figure 41a is a photo-

graph of the hand specimen. In this welded tuff, plagioclase of bulk composition An_{48} (table 7) coexists with sanidine of composition Or_{67}.

Smith's petrographic and geographic descriptions of the rocks from which analyses 6 through 9 were made, are brief. However, some additional information is now available. A. Griscom placed at the author's disposal several thin sections of the felsite from Soubunge Mountain, a small isolated peak in the northwest corner of the Harrington Lake quadrangle about 8.5 miles west-southwest of Center Mountain (figs. 1 and 4). The thin sections appear identical, in the assemblage of phenocrysts and in texture, with those of the flows in the Black Cat member. Heath (1959) reports both welded tuff and lava on Big Spencer Mountain. The author has hastily examined thin sections of four of Heath's specimens and supports the conclusion that welded tuffs and flows are present. These rocks differ from the Traveler felsite in that the feldspar phenocrysts are predominately sanidine and that sparse garnet was the only mafic silicate observed. Boucot (in preparation and oral communication) states that the felsite on Mt. Kineo is a massive lava probably in the form of a dome. Garnet is rare in the felsite on Mt. Kineo. Finally, the garnet-bearing felsite of Coburn Mountain is intrusive (Boucot, in preparation).

A standard weight percent norm, using one cation oxides as suggested by Eskola (1954), and an "oxygen percent" norm, using a method suggested by J. B. Thompson, have been calculated for each of the analyses. These norms are also presented in table 11.

It should be noted that there is considerable range in the $FeO:Fe_2O_3$ ratio in the analyses. The $FeO:Fe_2O_3$ ratio is essentially a function of the activity of oxygen, which can vary with time and, in lavas, from place to place (Kennedy 1955 and J. B. Thompson, oral communication). In order to have a common basis for comparing the analyses, the total iron (mol. prop.) in each analysis was redistributed between FeO and Fe_2O_3 using a constant $FeO:Fe_2O_3$ ratio for all the analyses. The ratio selected is that in Daly's (1933) average post-Cambrian granite. The recalculated values of FeO and Fe_2O_3 appear in table 11 to the right of the values reported by the analyst for each specimen. The recalculated values of the iron oxides were used in all the petrographic calculations.

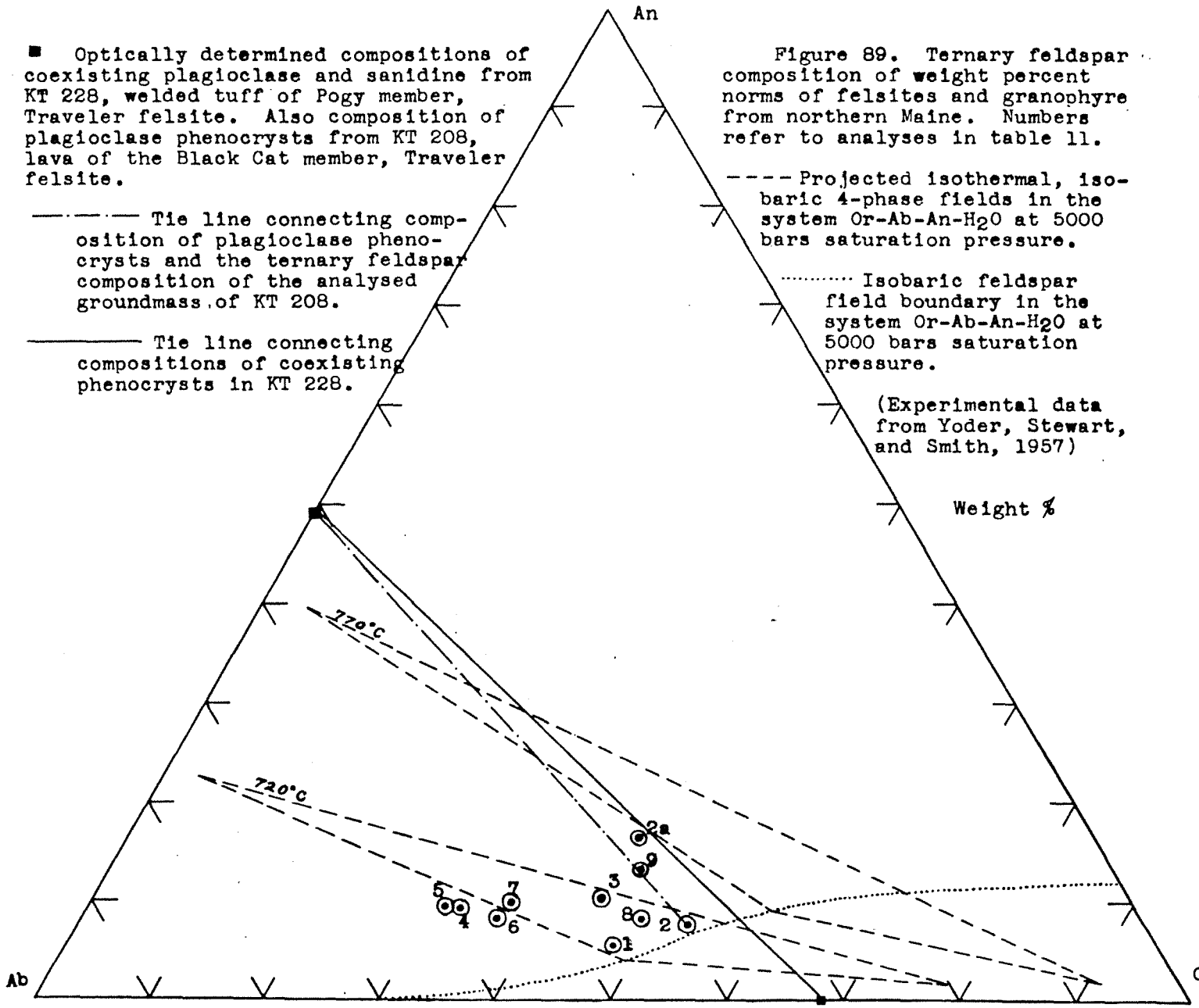
J. B. Thompson (lecture notes, 1954) has pointed out that the number of oxygens in equivalent formula units of minerals (one-cation oxide formulas are used in this report) are, to a first approximation, equal to the relative volumes occupied by the equivalent formula units. Thus, an "oxygen percent" norm, which is roughly equivalent to

a volume percent norm, may be calculated by multiplying the number of equivalent formula units (Niggli's equivalent molecular units) by the number of oxygens in the equivalent formula unit for each component and then converting these products to percents of the sum of the products. This procedure was used to calculate the "oxygen percent" norms in table 11.

In four of the analyses, the molecular proportion of alumina exceeds the combined molecular proportions of lime and alkali oxides. The excess alumina was calculated in the norms as corundum. Shand (1952, p. 228-231) has suggested that rocks with the above relationship between alumina and lime plus the alkali oxides be called peraluminous. He further points out that peraluminous rocks are likely to contain such minerals as muscovite, topaz, garnet and corundum. In agreement with the peraluminous nature of some of the felsite as determined from the analyses, garnet occurs in a number of Devonian felsites of northern Maine. Further, the rocks with the highest percentage of garnet (the intrusive felsite from Coburn Mountain) is the rock with the greatest excess of alumina over the alkali oxides plus lime in the analysis. Smith (1933) and later Boucot (in preparation) report that the dominant phenocryst in the felsite from Coburn Mountain is garnet.

The ternary feldspar composition of the weight

percent norms are plotted in figure 89. As would be expected, the composition of the ternary feldspar of analysis no. 2, the groundmass of a lava from the Black Cat member, lies closer to the Or corner than the ternary feldspars of the other analyses of bulk samples (groundmass plus phenocrysts). From petrographic work it is felt that the Traveler felsite is, to a first approximation, isochemical. Therefore, if the composition of the phenocrysts is added in the observed proportions to the analysis of the groundmass of KT 208, the total composition of this lava should be similar to the compositions of other specimens of Traveler felsite. The phenocryst mode (table 3) and the "oxygen percent" norm of the groundmass of specimen KT 208 were combined in the ratio 14:86 to give the bulk composition of the rock in terms of molecular proportions of one-cation oxides. From these a weight percent norm and an "oxygen percent" norm were calculated for the rock. Certain simplifications and assumptions were necessary in order to calculate the molecular proportions of one-cation oxides from the mode of the phenocrysts. The assumptions made concerning the compositions of the phenocrysts are consistent with determined compositions of phenocrysts in the Black Cat member. The mode of the phenocrysts from KT 208 is reproduced below from table 3 and beside this observed mode is shown the readjusted mode used in



■ Optically determined compositions of coexisting plagioclase and sanidine from KT 228, welded tuff of Pogy member, Traveler felsite. Also composition of plagioclase phenocrysts from KT 208, lava of the Black Cat member, Traveler felsite.

—·—·— Tie line connecting composition of plagioclase phenocrysts and the ternary feldspar composition of the analysed groundmass of KT 208.

———— Tie line connecting compositions of coexisting phenocrysts in KT 228.

Figure 89. Ternary feldspar composition of weight percent norms of felsites and granophyre from northern Maine. Numbers refer to analyses in table 11.

– – – – Projected isothermal, isobaric 4-phase fields in the system Or-Ab-An-H_2O at 5000 bars saturation pressure.

····· Isobaric feldspar field boundary in the system Or-Ab-An-H_2O at 5000 bars saturation pressure.

(Experimental data from Yoder, Stewart, and Smith, 1957)

Weight %

the calculations.

observed mode		mode used in calculations		
plagioclase	66%	66%	Ab 34	
			An 32	
mafic silicates (both clinopyroxene and biotite observed)	23	25	pyroxene 13	Wo 4
				En 3
				Fs 6
			biotite 12	annite 8
				phlog. 4
opaque minerals	11	9	Mt 6	
			Il 3	

The additional norms of KT 208 are also presented in table 11 and the composition of the ternary feldspar is plotted in figure 89 (point 2a).

In terms of weight percent norms, all of the rocks analyzed are rhyodacites (plagioclase components exceed orthoclase components), although several of them have very nearly equal amounts of the plagioclase and orthoclase components and might be called quartz latites. The composition of the groundmass of KT 208 is the only one of the group that can be taken with any confidence to represent the composition of a liquid. This groundmass is a rhyolite (orthoclase components exceed plagioclase components), although it also might be called a quartz latite. There is the question as to whether the phenocrysts were in equilibrium with a liquid of the composition of the

groundmass. A suggestion that the phenocrysts were approximately in equilibrium with a liquid of this composition may be obtained by comparing the ternary feldspar composition of the groundmass with the optically determined compositions of coexisting sanidine and plagioclase in KT 228. These data are plotted in figure 89 along with the location of the projected four-phase fields (two feldspars plus liquid plus gas) determined experimentally by Yoder, Stewart and Smith (1957) in the system $NaAlSi_3O_8$(Ab) - $KAlSi_3O_8$(Or) - $CaAl_2Si_2O_8$(An) - H_2O at 5000 bars pressure in a steam saturated system. There is, of course, no reason to expect precise agreement between the multicomponent felsite and the experimental system (especially as the experimental results were obtained for a higher pressure in a steam saturated system than is envisioned for the felsite magma), because the calcium content of the sanidine and the potassium content of the plagioclase are not known, and because the phenocrysts and groundmass are from different rocks. Nevertheless, the comparison does suggest that a) the analysis of the groundmass of KT 208 is a reasonable one, b) the phenocrysts were essentially in equilibrium with a liquid of the composition of the groundmass. The groundmass itself later and at a much lower temperature devitrified into its own assemblege of minerals, including a nearly pure potassic feldspar and

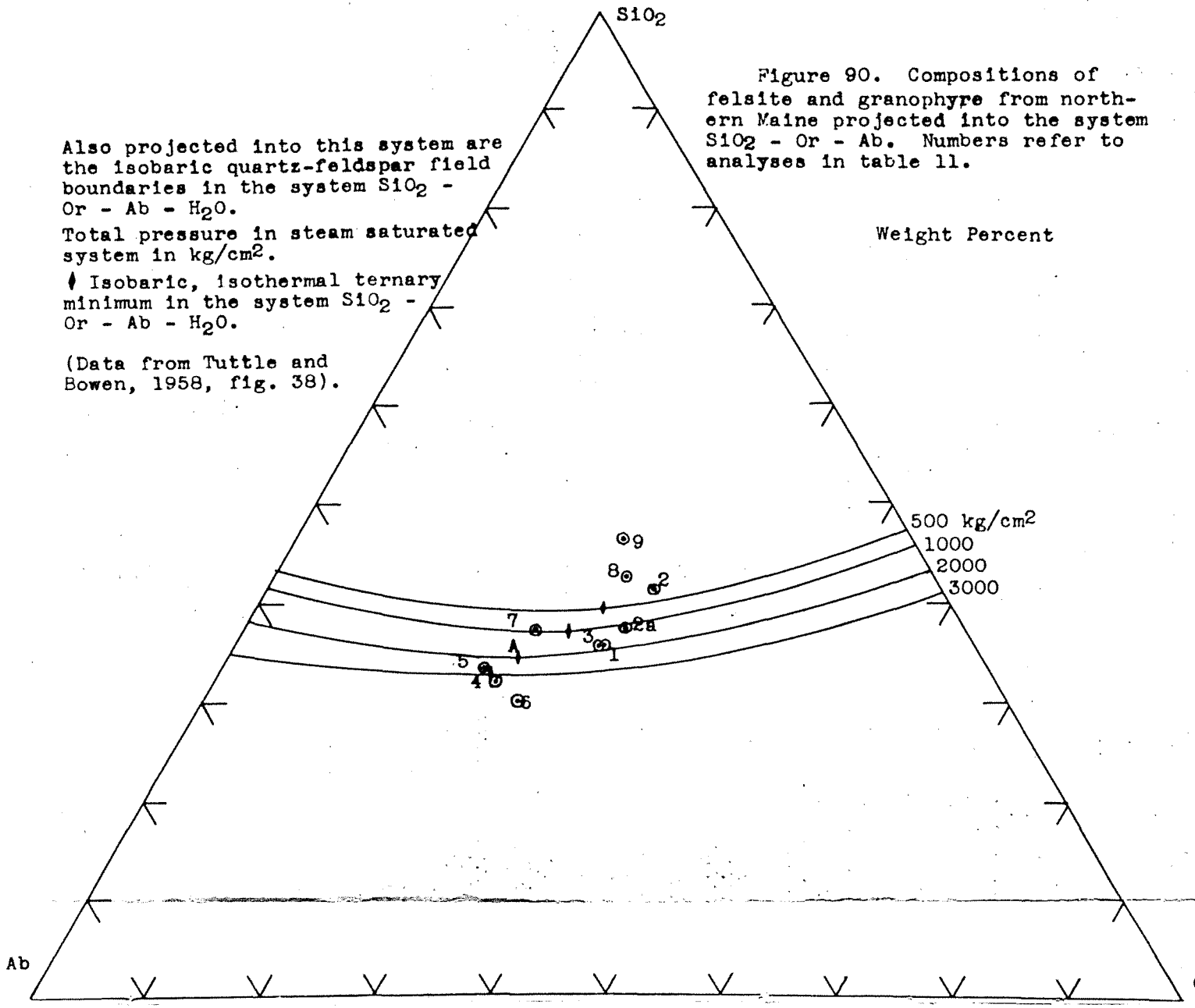


Figure 90. Compositions of felsite and granophyre from northern Maine projected into the system SiO_2 - Or - Ab. Numbers refer to analyses in table 11.

Also projected into this system are the isobaric quartz-feldspar field boundaries in the system SiO_2 - Or - Ab - H_2O.

Total pressure in steam saturated system in kg/cm^2.

Isobaric, isothermal ternary minimum in the system SiO_2 - Or - Ab - H_2O.

(Data from Tuttle and Bowen, 1958, fig. 38).

Weight Percent

X-ray diffraction studies were made of the structural states of the same 17 plagioclase samples whose compositions are known from optical determinations. The data obtained for 10 of these samples is considered adequate, while the remaining 7 determinations should be regarded as provisional.

Diffraction patterns were obtained using smear mounts on a Norelco high angle Geiger-counter diffractometer equipped with a Cu tube and a Ni filter. The scale factor was 4, the multiplier 1, and the time constant 4. The data considered adequate were obtained from runs of two complete oscillations (thereby covering the approximate 2θ regions four times) at a goniometer speed of $1/4^{\circ}$ per minute and a chart scale of 2 inches per degree. Because only relative peak locations were required, no internal standard was used.

Distances between appropriate peaks were measured to the nearest 1/50 inch (0.01° 2θ). A peak location was taken as a point midway between the edges of a peak at two-thirds of the peak height (estimated). There was some uncertainty in estimating two-thirds of the height of some of the broad multi-summit peaks. It was necessary to modify the two-thirds height rule with respect to some peaks in order to get above the "background" of the broad base of the peak and into the portion leading to the highest major summit.

STRUCTURAL STATES

Three sets of data were obtained: the angular separation ($\Delta 2\theta$) between the $(1\bar{3}1)$ and the (131) reflections, between the $(\bar{1}32)$ and the (131) reflections and between the $(24\bar{1})$ and the $(\bar{1}32)$ reflections. These three sets of data for the 10 plagioclase samples for which the information is considered adequate, are presented in table 12. Nearly all of the angular separations given in the table under the heading specimen values are the averages obtained from two single observations. An "observation" (after Chayes and MacKenzie, 1957) is the average of the two angular separations obtained from a single oscillation. Chayes and MacKenzie (1957, p. 537) have pointed out that there is a small but persistent difference between angular separations obtained by scanning in opposite directions. The standard deviations of the $\Delta 2\theta$ of one observation from the other for the three sets of angular separations $(1\bar{3}1)$-$(\bar{1}31)$, $(\bar{1}32$-(131) and $(24\bar{1})$-$(\bar{1}32)$ are respectively 0.012 (10 samples), 0.017 (8 samples), and 0.016° 2θ (5 samples). Smith and Yoder (1956, p. 635) using essentially the same procedure, estimated the probable accuracy of the average value of peak separation for any sample to be $\pm 0.02^{\circ}$ 2θ or better. The results of the present investigation compare favorably with their accuracy.

Provisional data for the remaining seven plagioclase

Table 12

Angular Separation ($\Delta 2\theta$) of certain Reflections of Plagioclase Phenocrysts from the Traveler Felsite

	Specimen No. and Location	Rock Type and Stratigraphic Member	Mol % An From Optics	"Quartz Index" qz / qz+plag	$\Delta 2\theta$ $(1\bar{3}1)$ - (131) in Degrees					$\Delta 2\theta$ $(\bar{1}32)$ - (131) in Degrees					$\Delta 2\theta$ $(2\bar{4}1)$ - $(\bar{1}32)$ in Degrees				
					Scan Speed ¼° per Minute				Scan Speed 1° per Minute; Average in ( )	Scan Speed ¼° per Minute				Scan Speed 1° per Minute; Average in ( )	Scan Speed ¼° per Minute				Scan Speed 1° per Minute; Av. in ( )
					Increasing 2θ	Decreasing 2θ	Observation	Specimen Value		Increasing 2θ	Decreasing 2θ	Observation	Specimen Value		Increasing 2θ	Decreasing 2θ	Observation	Specimen Value	
1	KT 208 SE 05-515	Lava; Black Cat	48	0%	1.85 1.90	1.88 1.89	1.865 1.895	1.88	1.92 1.88 1.92 (1.92)	2.31 not measurable	2.32	2.315	**	2.28 2.24 2.28 (2.28)	1.80 not measurable	1.77	1.785	***	1.80 1.80 1.80 (1.80)
2	KT 236 SC 14-57	Lava; Black Cat	48	0	1.87 1.88	1.87 1.87	1.87 1.875	1.87	1.88 1.88 1.92* (1.88)	2.27 2.29	2.28 2.29	2.275 2.29	2.28	2.28 2.28 2.28* (2.28)	1.83 1.81	1.80 1.79	1.815 1.80	1.81	1.80 1.80 1.80* (1.80)
3	KT 237 SC 16-555	Lava; Black Cat	46	<1	1.89 1.86	1.87 1.88	1.88 1.87	1.88	1.84 1.88 1.84* (1.84)	2.31 not measurable	2.29	2.30	2.30	2.32/ 2.32/ 2.36* (2.32)	1.77 not measurable	not measurable		****	1.76*
4	KT 469 C 35-04	Lava; Black Cat	52	0	1.85 1.85	1.84 1.83	1.845 1.84	1.84	1.84* 1.84* (1.84)	2.32 2.32	2.31 2.31	2.315 2.315	2.32	2.36* 2.32* (2.36)	not measurable not measurable				
5	KT 470 C 37-06	Lava; Black Cat	49	0	1.89 1.89	1.90 1.90	1.895 1.895	1.90	1.92* 1.92* (1.92)	2.24 2.26	2.23 2.24	2.235 2.25	2.24	2.24* 2.24* (2.24)	not measurable not measurable				
6	KT 418 SC 34-32	Laminated Crystal Tuff; Black Cat	45	0	1.79 1.79	1.80 1.80	1.795 1.795	1.80	1.84 1.80 (1.84)	2.33 2.37	2.33 2.34	2.33 2.355	2.34	2.32 2.32 (2.32)	1.70 1.68	1.72 1.69	1.71 1.685	1.69	1.72 1.68 (1.72)
7	KT 424 SE 4-42	Welded Tuff; Black Cat	44	10	1.80 1.81	1.79 1.80	1.795 1.805	1.80	1.80 1.80 (1.80)	2.35 2.32	2.34 2.32	2.345 2.32	2.33	2.36 2.36 (2.36)	1.69 1.69	1.69 1.71	1.69 1.70	1.70	1.72 1.72 (1.72)
8	KT 425 SC 285-475	Felsite; Black Cat	45	<1	1.90 1.88	1.90 1.89	1.90 1.885	1.89	1.88* 1.88* (1.88)	2.27 2.28	2.28 2.30	2.275 2.29	2.28	2.32* 2.28* (2.32)	1.77 1.77	1.77 1.78	1.77 1.775	1.77	1.76* 1.80* (1.80)
9	KT 228 SW 25-32	Welded Tuff; Pogy	48	39	1.75 1.76	1.76 1.75	1.755 1.755	1.76	1.76 1.76 1.76* (1.76)	2.35 2.33	2.38 2.37	2.365 2.35	2.36	2.32 2.32 2.32* (2.32)	1.69 1.69	1.66 1.66	1.675 1.675	1.68	1.72 1.72 1.64* (1.72)
10	KT 374 SW 26-14	Felsite; Pogy	45	50	1.78 1.76	1.77 1.77	1.775 1.765	1.77		2.34 2.33	2.34 2.34	2.34 2.335	2.34		1.69 1.66	1.67 1.65	1.68 1.655	1.67	

* Scale factor 8
** Value used: 2.30
*** Value used: 1.79
**** Value used: 1.77
/ Poor resolution

TABLE 13

Angular Separation ($\Delta 2\theta$) of Certain Reflections of Plagioclase Phenocrysts from the Traveler Felsite
Provisional Values

Spec. No.	Mol % An from optics	"Quartz index" of pheno. ($\frac{qz}{qz+plag.}$)	$\Delta 2\theta$ $(1\bar{3}1)$-(131) in degrees (scan speed 1° per minute)		$\Delta 2\theta$ $(\bar{1}32)$-(131) in degrees (scan speed 1° per minute)		$\Delta 2\theta$ $(2\bar{4}1)$-$(\bar{1}32)$ in degrees (scan speed 1° per minute	
			Increasing 2θ	Average	Increasing 2θ	Average	Increasing 2θ	Average
1	48	1%	1.92 1.96 1.92	1.92	2.28 2.28 2.24	2.28	1.84 1.80 1.84	1.84
2	46	1	1.84 1.84	1.84	2.32 2.32	2.32	1.76 1.80	1.80
3	46	0	1.88 1.88 1.88*	1.88	2.28 2.28 2.32*	2.28	1.84 1.80 1.80	1.80
4	46	0	1.88 1.88 1.88*	1.88	2.32 2.32 2.32*	2.32	1.76 1.80 1.76*	1.76
5	48	1	1.88 1.88	1.88	2.28 2.32	2.32	1.80 1.80	1.80
6	49	17	1.80 1.76	1.80	2.32 2.32	2.32	1.72 1.68	1.72
7	48	24	1.76 1.80 1.76*	1.76	2.32 2.32 2.28*	2.32	1.72 1.68 1.72*	1.72

*Scale factor--8.

Table 13 (Continued)

11. (KT 116, WC 38-16); lava from the Black Cat member.
12. (KT 241, C 08-05); lava from the Black Cat member.
13. (KT 242, C 06-05); lava from the Black Cat member.
14. (KT 297, WC 20-12); lava from the Black Cat member.
15. (KT 245, C 17-09); felsite from the Black Cat member.
16. (KT 225, SW 35-20); welded tuff from the Pogy member.
17. (KT 372, SW 28-15); felsite from the Pogy member.

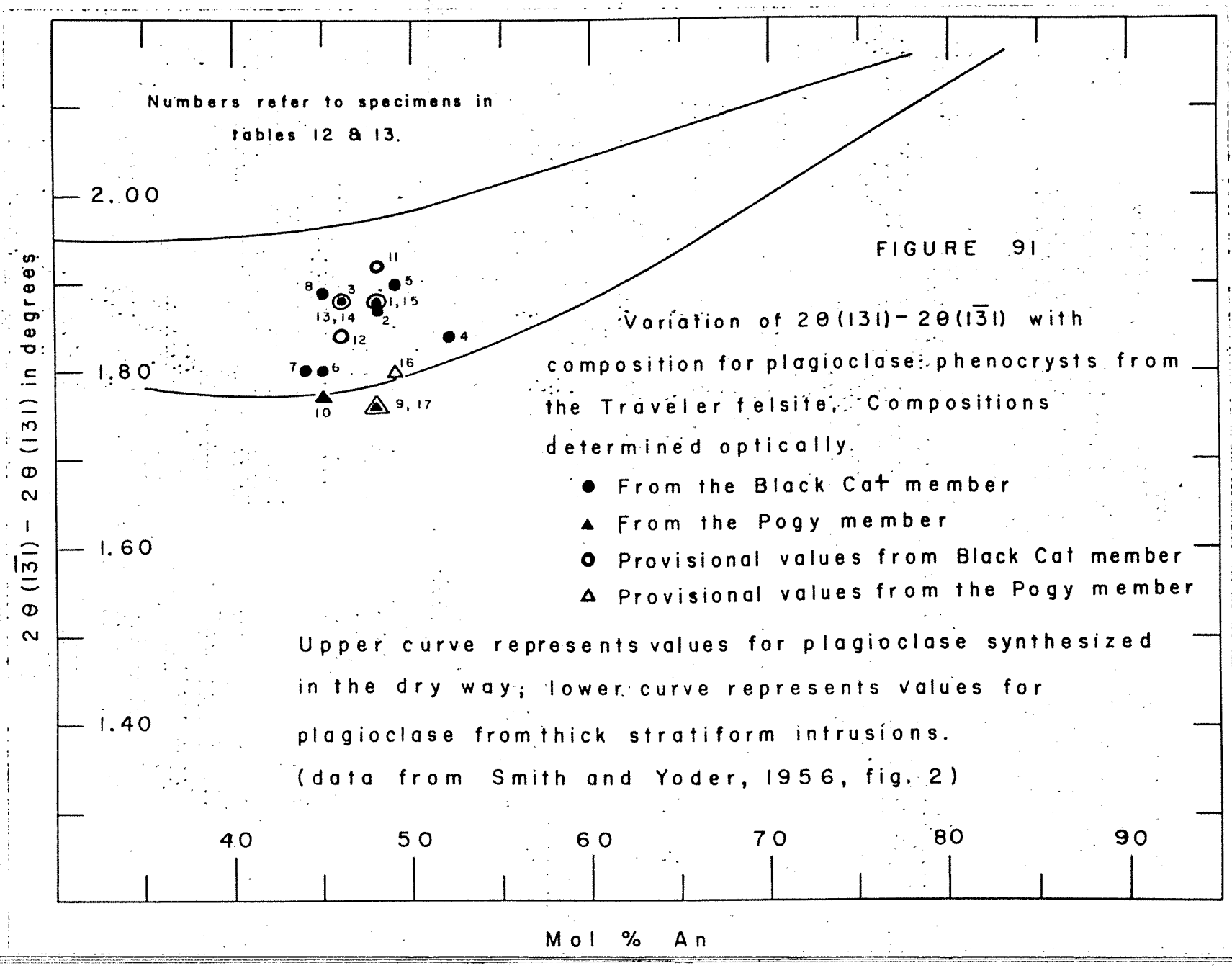


FIGURE 91

Variation of $2\theta(131) - 2\theta(\bar{1}31)$ with composition for plagioclase phenocrysts from the Traveler felsite. Compositions determined optically.

- ● From the Black Cat member
- ▲ From the Pogy member
- O Provisional values from Black Cat member
- △ Provisional values from the Pogy member

Upper curve represents values for plagioclase synthesized in the dry way; lower curve represents values for plagioclase from thick stratiform intrusions. (data from Smith and Yoder, 1956, fig. 2)

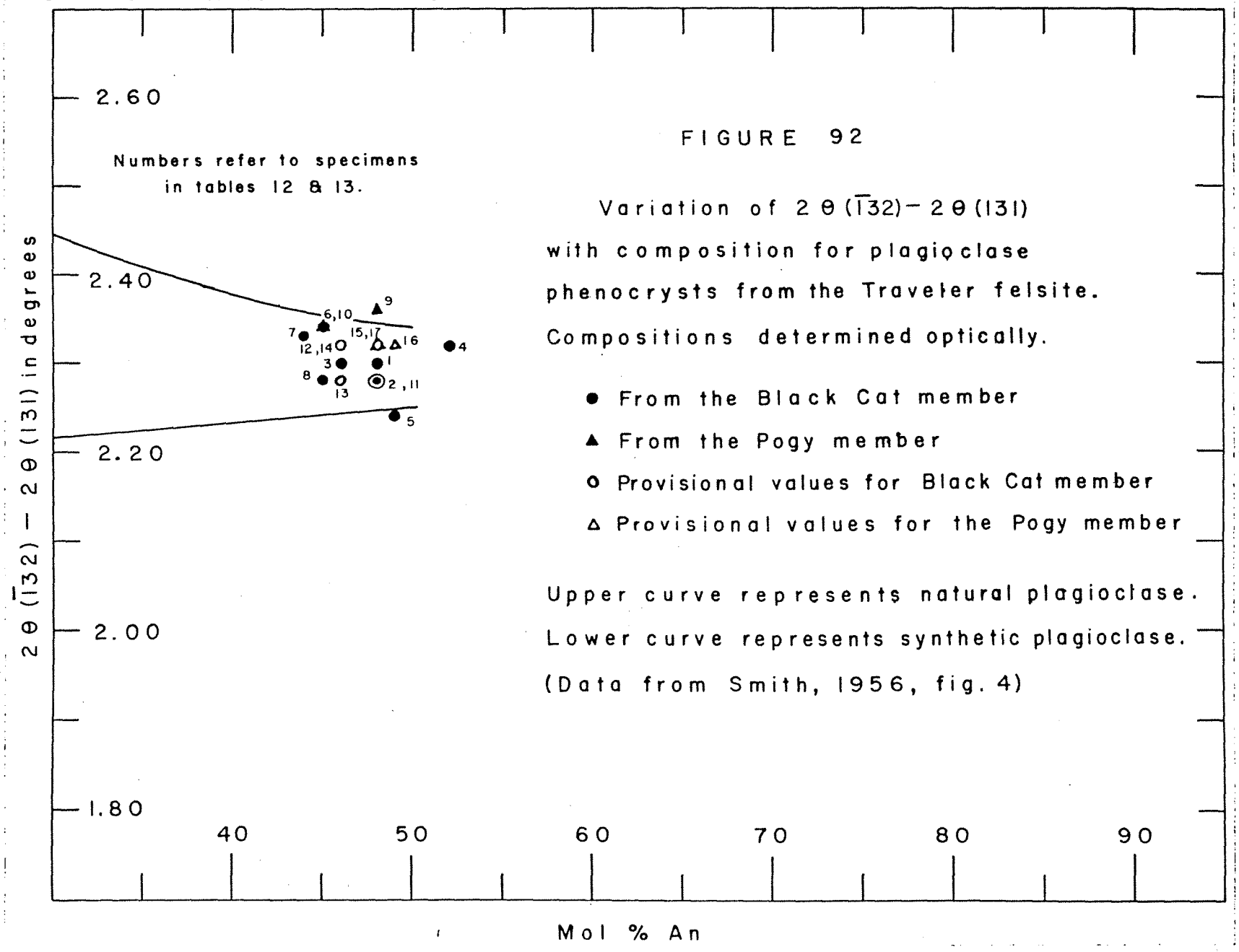


FIGURE 92

Variation of $2\theta(\bar{1}32) - 2\theta(131)$ with composition for plagioclase phenocrysts from the Traveler felsite. Compositions determined optically.

- ● From the Black Cat member
- ▲ From the Pogy member
- o Provisional values for Black Cat member
- △ Provisional values for the Pogy member

Upper curve represents natural plagioclase. Lower curve represents synthetic plagioclase. (Data from Smith, 1956, fig. 4)

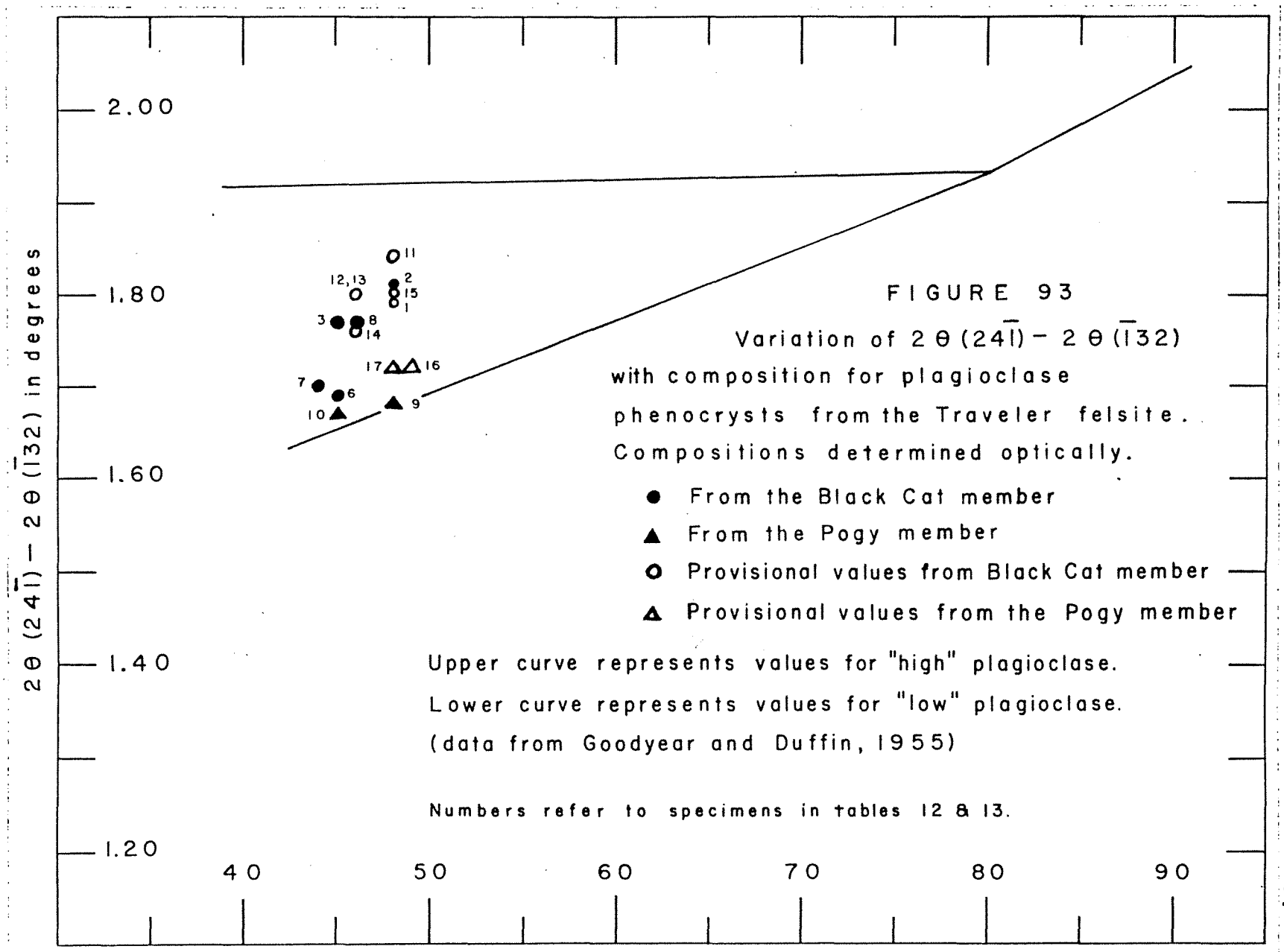


FIGURE 93

Variation of $2\theta(24\bar{1}) - 2\theta(\bar{1}32)$ with composition for plagioclase phenocrysts from the Traveler felsite. Compositions determined optically.

- ● From the Black Cat member
- ▲ From the Pogy member
- O Provisional values from Black Cat member
- △ Provisional values from the Pogy member

Upper curve represents values for "high" plagioclase.
Lower curve represents values for "low" plagioclase.
(data from Goodyear and Duffin, 1955)

Numbers refer to specimens in tables 12 & 13.

$(2\bar{4}1)$-$(\bar{1}32)$ respectively are plotted against the optically determined mol percent An in the plagioclase phenocrysts from the Traveler felsite. Also shown in figures 91, 92 and 93 are curves determined by other authors for the respective limiting values of $\Delta 2\theta$ plotted against mol percent An. (Smith and Yoder, 1956, fig. 3; Smith, 1956, fig. 4; and Goodyear and Duffin, 1955). These authors have demonstrated that the structural state of a plagioclase, as determined from the specific value of the angular separation of each of these sets of reflections, is a function of both the composition and the thermal history. Thus, if the composition of the plagioclase is known (the compositions of the plagioclase phenocrysts from the Traveler felsite were determined optically) a thermal history of the plagioclase may be determined. For a given An content, "high" (high temperature) plagioclase has higher values of $2\theta(1\bar{3}1)$-$2\theta(131)$ and $2\theta(2\bar{4}1)$-$2\theta(\bar{1}32)$ than "low" plagioclase. For a given An content, "high" plagioclase has lower values of $2\theta(\bar{1}32)$-$2\theta(131)$ than "low" plagioclase.

The significant feature common to all three figures is that plagioclase phenocrysts from the Black Cat member have $\Delta 2\theta$ values characteristic of plagioclase of an intermediate thermal state, while the plagioclase phenocrysts from the Pogy member have $\Delta 2\theta$ values characteristic of

plagioclase of a low thermal state. The difference between the structural states of the feldspar phenocrysts from the two members is shown most convincingly by figures 91 and 93. The reason this difference is less pronounced in figure 92 is probably because of the closeness of the limiting values of $2\theta(\bar{1}32)$-$2\theta(131)$ for "high" and "low" plagioclase of a composition between An_{40} and An_{50}.

GEOLOGIC ENVIRONMENT AND PETROLOGY

It has been shown that for the samples investigated plagioclase of an intermediate thermal state is characteristic of the Black Cat member and plagioclase of a low thermal state is characteristic of the Pogy member. It should also be pointed out that the "intermediate" plagioclase is almost exclusively from lava and does not coexist with quartz phenocrysts. Conversely, the "low" plagioclase is primarily from welded tuff and does coexist with quartz phenocrysts. Finally, because the Traveler felsite was probably erupted in a short time interval and because the Pogy member underlies the Black Cat member, the "low" plagioclase may have come from higher in the magma chamber than the "intermediate" plagioclase. The author believes that the above relationships present a picture consistent with ideas of volcanism and phase equilibria.

Before presenting what the author believes to be the most reasonable explanation of the structural states

of the plagioclase phenocrysts, an alternate possibility should be mentioned. By coincidence, all four samples of plagioclase phenocrysts of the Pogy member and the two samples from the Black Cat member which are "low" plagioclase come from outcrops in the vicinity of the contact with the Katahdin granite. These samples were selected solely because they contained the freshest plagioclase phenocrysts, and the pattern of their areal distribution was not realized until after the X-ray study had been completed. Of the six samples KT 418 was collected from the outcrop closest to the granite, about 400 feet vertically away.

It is possible that all of the plagioclase phenocrysts from the Traveler felsite were initially of the intermediate or high thermal modification. Those which were subjected to prolonged and humid heating in the subsolidus region by the cooling of the nearby Katahdin batholith may have inverted to a lower temperature modification.

The felsites samples in question, however, show no contact metamorphic effect either in outcrop or in thin section. The plagioclase phenocrysts are still strongly zoned. In outcrop, the felsite samples are among the blackest, freshest-looking rocks in the entire Traveler felsite. Closer to the contact, the felsite is bleached, less flinty looking and the groundmass has recrystallized

to a coarser-grained texture. Finally, the hypotheses discussed in the remainder of this section are consistent with so many observations and with so much of the predicted behavior of volcanic eruptions that they are believed to be the most reasonable explanation of the structural states of the plagioclase phenocrysts. Supporting evidence should be sought from structural analysis of fresh plagioclase phenocrysts from the Pogy member in the vicinity of Horse Mountain. Such samples are not available at present.

With the exception of rare non-porphyritic tuff in the Pogy member, phenocrysts are present in all samples of the Traveler felsite. The magma must, therefore, have been at the liquidus at the time of eruption. Probably the phenocrysts in the felsite are the ones with which the magma was in equilibrium at the time of eruption (See preceding section). Present data further suggest that phenocrysts from different felsite units are of the same composition. It is believed, therefore, that to a first approximation, the Traveler felsite is isochemical, excluding volatiles. Attempts to demonstrate this by the index of refraction of the fused felsite have not been successful. Repeated heating of the powdered felsite on platinum foil before a gas-oxygen torch, hot enough to melt the platinum foil, has failed to yield a homogeneous glass. The relatively high calcium and iron contents of the felsite

may be responsible for this difficulty.

It has been shown in figure 90 that the bulk composition of the analyzed specimens of the Traveler felsite project onto the liquidus of the system SiO_2-Or-Ab-H_2O in the vicinity of the minimum melting mixture on the silica-feldspar field boundary for some total pressure. Because of other components present in the felsite, however, no quantitative statements should be made concerning the exact projections of the bulk compositions. Schairer (1950) and Tuttle and Bowen (1958) have shown that regardless of the pressure on the steam saturated system, the liquidus surface has a steep thermal slope on the silica side of the field boundary and a very gentle slope on the feldspar side of the field boundary. For liquids in the vicinity of the minimum melting mixture, slight differences in the bulk composition or the temperature would result in differences in the first phase to crystallize from the liquid and hence differences in the assemblage of phenocrysts.

Three assemblages of felsic phenocrysts have been observed in the Traveler felsite:

A. plagioclase alone (Black Cat member mostly)

B. plagioclase + quartz (Pogy member mostly)

C. plagioclase + quartz + sanidine (scarce) (Pogy member).

Because none of the felsite contains quartz phenocrysts

alone, the bulk compositions of all of the units probably lay either in the feldspar field or on the quartz-feldspar field boundary for conditions obtaining at the time of phenocryst crystallization. That the bulk of the feldspar phenocrysts are plagioclase rather than sanidine, is probably explained by the calcium content of the felsite. (See fig. 89).

The most obvious explanation for the difference in assemblages of phenocrysts, assuming an isochemical sequence of felsites, is that those containing plagioclase alone were erupted at a higher temperature than those containing plagioclase and quartz. Support for this conclusion is found in the fact that plagioclase phenocrysts coexisting with quartz phenocrysts are of a lower temperature modification than those which occur without quartz. Further, assemblage A is primarily from the Black Cat member which is younger than the Pogy member containing assemblages B and C. This could be interpreted to mean that assemblages B and C came from the cooler upper portion of the magma chamber, while assemblage A came from the hotter interior.

One more factor must be considered. Assemblage A is found primarily in lava while assemblages B and C are found primarily in welded tuff. Various authors have suggested the importance of the volatile content of a magma upon the type of volcanic eruption. Kennedy (1955, p. 495) has called attention to the sequence of volcanic rocks in

Yellowstone Park. The lowermost beds in this sequence are crystal tuffs and poorly consolidated ash. These are overlain by welded tuff[1] and these in turn by obsidian flows. Kennedy suggests that this stratigraphic sequence indicates a decrease in volatile content during the eruptions. The sequence of volcanic units in the Traveler felsite is grossly the same as in the rhyolites of Yellowstone Park, although the proportions of various rock types may be different. A thin layer of tuff, originally vitroclastic ash, forms the base of the Pogy member. This is overlain by a thick succession of welded tuff (the bulk of the Pogy member) and these in turn by the lavas of the Black Cat member.

The chief volatile component in silicate melts is probably H_2O. Tuttle and Bowen (1958) have shown that the effect of saturating liquids in the system SiO_2-Or-Ab with H_2O is two-fold. First, the greater the water content of the liquid (the greater the total pressure in a steam saturated system), the lower the lower the melting temperatures. It is reasonable, therefore, that the welded tuff should contain evidence of lower temperature at the time

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[1]There is disagreement between Kennedy and Boyd as to whether these units are collapsed froth flows (Kennedy) or welded ash flows (Boyd). The evidence presented by Boyd (1957 and 1961) indicates that most of them are welded ash flows. Either interpretation, however, suffices for this discussion.

of eruption. The second effect of saturating liquids in this system with H_2O is to shift the field boundary between the quartz and feldspar fields first toward the silica corner and then with increasing aH_2O (increasing total pressure) back towards the Or-Ab side (fig. 90). Tuttle and Bowen show the closest approach of this field boundary to the silica corner at a saturation pressure of 500 kg/cm^2 although their figures 20 and 21 show that the closest approach in the system SiO_2-Ab-H_2O occurs at a somewhat lower saturation pressure (about 350 kg/cm^2).

Boyd (1957 and 1961) has demonstrated that it is thermodynamically reasonable in a subaerial eruption to produce a welded tuff in a rhyolitic lava by the ash flow mechanism as long as the lava does not contain more than 4 weight percent H_2O at the time of eruption. This conclusion is based upon relationships between maximum total cooling of the ash flow during emplacement as a function of initial H_2O content of the magma and the difference between the liquidus temperature (minimum melting mixture in the system SiO_2-Or-Ab-H_2O) and the welding temperature also as a function of the initial H_2O content of the magma.

The minimum melting mixture in the system SiO_2-Or-Ab -H_2O containing 4 weight percent water would have a melting temperature of 750°C and a saturation pressure of about 700 kg/cm^2. Boyd's deduction of the maximum water content

of a weld tuff at the time of eruption is based upon a minimum welding temperature of 600°C which he determined experimentally. Subsequently Smith, Friedman and Long (1958 and Smith, 1960, p. 824) found the minimum temperature for incipient welding to be at least as low as 535°C. The major effect of a lower welding temperature upon Boyd's calculations would be to increase the difference between the liquidus temperature and the welding temperature. This should, in turn, increase the permissible initial water content of a magma which could form a welded tuff. Using Boyd's data for the maximum cooling of an ash flow during emplacement as a function of water content and a welding temperature of 535°C, the allowable water content of an ash flow which could weld is increased to about 5 percent.

Point A in figure 90 represents the "ternary minimum" for a liquid containing 5 weight percent H_2O, saturation pressure of about 1000 kg/cm^2 (Tuttle and Bowen, 1958). Suppose that there existed a large magma chamber containing a liquid close to this composition. Further suppose that the upper portion of this magma chamber were saturated with 5 percent water and that the magma were at the liquidus. The saturation pressure of 1000 kg/cm^2 would correspond to the lithostatic pressure at a depth of about 2 miles. (See Kennedy, 1955, fig. 1) Crystals of quartz and feldspar would form in the melt. If this magma gained access to the surface a relatively violent eruption would

ensue and the resulting deposit might be an air-fall ash, or if conditions were right, a welded ash flow. As the eruption proceeded, drier and drier magmas would come to the surface (Kennedy, 1955). As the H_2O content fell, the position of the field boundary in figure 90 would shift toward the SiO_2 corner and the liquid would be in equilibrium with only feldspar phenocrysts. Also the temperature of the drier magma would be higher. This higher temperature should be reflected by the structural characteristics of the plagioclase. A further consequence of the decrease in the volatile content of the magma would be a change from the relatively violent nuée ardente type of eruption to relatively quiet lava flow eruptions. Finally, the eruption would cease when the volatile content had fallen to a sufficiently low level. Of course, the eruptive cycle could be interrupted at any point allowing the volatile content of the upper portion of the magma chamber to increase. Repeated interruption would be reflected by repeated sequences of rock units at the surface and perhaps by the oscillatory zoning of the plagioclase phenocrysts. The volcanic history of the Traveler felsite is believed to have followed approximately this course. It will be noted that no change in bulk composition of the magma, exclusive of volatile components, is required.

SUMMARY

Optical determinations were made of the sanidine, plagioclase, clinopyroxene, and biotite phenocrysts from the Traveler felsite. Sanidine phenocrysts in the Pogy member have a 2V of about 30° and compositions of about Or_{67}. Plagioclase phenocrysts were studied much more extensively than the rest of the phenocrysts. They are strongly zoned, but appear to have about the same bulk composition in both the Pogy and Black Cat members. The average composition is An_{48}. The clinopyroxenes from both members are ferroaugites with an average composition of $Wo_{30}En_{28}Fs_{43}$. Biotite has a Fe:Mg ratio$\left(\frac{FeO}{(FeO + MgO)}\right)$ of 67 percent which is somewhat higher than the Fe:Mg ratio in coexisting pyroxenes (62 percent).

Two chemical analyses of the Traveler felsite were published by E. S. C. Smith in 1930. Two new analyses were made by Dr. Jun Ito for the present study. One was of a welded tuff of the Pogy member and the other of the groundmass of a lava from the Black Cat member. A new analysis of the granophyre near Norway Dam was also made by Dr. Ito. These analyses plus a weight percent norm and an "oxygen percent" norm (roughly comparable to a volume percent norm) for each analysis are presented in table 11. Published analyses of four other Early Devonian felsites from northern Maine are included in table 11 for comparison.

All of the felsites in table 11 are rhyodacites (normative plagioclase exceeds normative orthoclase), although some of the felsites contain nearly equal amounts of normative plagioclase and orthoclase, and might be called quartz latites. The analyzed groundmass of the lava contains normative orthoclase in slight excess of normative plagioclase and is hence a rhyolite or, if one prefers, a quartz latite. Several of the felsites are peraluminous, which is consistent with the occurrence of garnet phenocrysts in a number of the northern Maine felsites. None of them are peralkaline.

Structural states of plagioclase phenocrysts from 17 samples (13 samples from the Black Cat member and 4 from the Pogy member) were determined by X-ray diffraction. Three sets of angular separations of peaks give consistent results (figs. 91, 92, and 93). Plagioclases from lavas of the Black Cat member have structural characteristics intermediate between those of the high and the low thermal modifications. Plagioclases from the Pogy member have structural characteristics of the low thermal modifications.

Thus "low" plagioclase and quartz phenocrysts characterize the Pogy member, which consists predominantely of welded tuff and occurs at the bottom of the Traveler felsite. "Intermediate" plagioclase phenocrysts, typically without coexisting quartz phenocrysts, characterize the

Black Cat member, which consists predominantly of lava and overlies the Pogy member. It is suggested that these relationships may be explained by a decrease in volatile content of the magma in successive eruptions over a short interval of time.

CHAPTER V

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Katahdin-Traveler area is within the folded Northern Appalachians. In contrast to northwestern Maine and much of New England, the grade of metamorphism is low. All of the sedimentary rocks are within the chlorite zone of regional metamorphism. Except for the structures in the pre-Silurian rocks, the folds are open and the major structures may be determined by a combination of outcrop pattern on the geologic map and observed attitudes of bedding. In the following discussion, therefore, major structures are analyzed with little reference to minor ones.

The major structural elements in the Katahdin-Traveler area include the southwesterly plunging Matagamon synclinorium, a collapse structure occupied by the Traveler felsite, and the Katahdin batholith. These features are treated separately below. Such a separation is, of course arbitrary, and the various structural elements have interacted with each other. Faulting, most of which is

believed to be high angle with normal or strike slip movement, is associated with the collapse structure and the synclinorium.

The structures in the "Grand Falls" formation will not be discussed in this report.

MATAGAMON SYNCLINORIUM

All the stratified rocks in the Traveler Mountain quadrangle are involved in the Matagamon synclinorium, which is the structural element of greatest regional importance. It is named for Matagamon Lake which lies athwart its axis. The axis trends east-northeast, approximately along Trout Brook, and plunges slightly to the southwest (plate 4). Lower Devonian rocks occupy the center of the synclinorium and the two limbs are best defined by rocks of Silurian age. On the north limb these rocks constitute a belt trending east-west, and on the southeast limb they trend N.40°E. Thus the synclinorium opens to the southwest.

There is a distinct difference in the structural behavior of the Seboomook formation on the two limbs of this major fold. On the southeast limb the Seboomook formation forms an essentially homoclinal sequence. Dips average about 50 degrees to the northwest. On the north limb of the Matagamon synclinorium, the Seboomook formation is highly folded. These lesser folds have axial traces

roughly parallel to the axial trace of the Matagamon synclinorium and their axes plunge southwest 15 to 25 degrees. The folds typically have wave lengths of 1000 feet and appear to be symmetrical.

The bulk of the Traveler felsite is on the southeast limb of the synclinorium. The small outcrop area of the felsite on the north limb (essentially limited to Wadleigh Mountain) is believed to be partly the result of faulting and partly due to the original rapid thinning of the felsite to the north. Perhaps the position of the axis of the synclinorium was determined to some extent by the locus of the thinning of this massive unit.

HAY MOUNTAIN BASIN

Southeast of the northeast projection of the synclinorial axis in the Trout Valley formation is a structural basin. The Matagamon formation is found in its center and it is partly enclosed by the Seboomook formation. It is called Hay Mountain basin, after the most prominent topographic feature located within it, and is so labeled on the tectonic map (plate 4). The axis of the basin trends about N.40°E. Dips on the sides are moderate and the plunge of the axis from each end toward the center is gentle (10° to 15°). Strike ridges closing the northeast end of the Hay Mountain basin are well shown in figure 5, an aerial photograph of the region. As

Professor M. P. Billings (oral communication) has pointed out, major fold axes are commonly offset in an en échelon manner. Hence, the axis of the basin may be essentially the axis of the Matagamon synclinorium. The northeast plunge of the axis at its southwest end may be related in some way to the formation of the collapse structure associated with the Traveler felsite.

THE TRAVELER CALDERA

Numerous authors, e.g., van Bemmelen (1930) and Williams (1941), have called attention to the association of collapse structures and volcanism. R. L. Smith (1960, p. 818) has suggested that where deposits from ash flows have volumes of more than a few cubic miles, subsidence structures in the source area are to be expected. The condition that favors the formation of a collapse structure is the rapidity with which a large volume of material is extruded. It has been suggested that the Traveler felsite, including both the Pogy and Black Cat members, was extruded rapidly. A conservative estimate of the volume of material erupted is 70 cubic miles or about 290 cubic kilometers. A comparison of this volume with that of other pyroclastic-flow fields (Smith, 1960, fig. 3) shows that, in terms of material erupted, the Traveler felsite is one of the larger felsic volcanic fields in the world. The inclusion of the volume of flows of the Black Cat member in the comparison

is justifiable because of the short time span of the eruption. One would thus expect to find a collapse structure involving the Traveler felsite.

There is considerable structural evidence for the Traveler caldera. The felsite is on the downthrow side of high angle faults that bound it on the north and west. Some of these faults also involve younger rocks, but it is suggested that movement along them, or along similar faults, began at the time of subsidence. These faults will be discussed in a later section.

There is also some evidence of an unconformity between the Pogy member and the Black Cat member. (See structure cross-section BB^1). This may signify that there were at least two stages of subsidence and that one of them took place after the eruption of the welded tuff of the Pogy member.

Further evidence of a caldera is suggested by the thickness of the felsite (in some places at least 9000 feet), the discordance of the major structural features in the felsite with those of synclinorium, and the presence of nearly contemporary subaqueous sediments of the Trout Valley formation immediately overlying the felsite.

Large folds and faults within the felsite are difficult to determine because of the lack of marker units. Observed attitudes of primary planar features in the

felsite are presented on the tectonic map (plate 4). Only those attitudes that were consistent over large outcrops or several small outcrops were recorded. There is a suggestion, particularly in the Black Cat member and in the felsite in the Telos Lake quadrangle, of a few major fold axes trending slightly west of north. The major anticlinal axis passes through South Branch Ponds and plunges about 25° north. Smith, Bailey, and Ross (1960) state that the presence of a central post-subsidence dome is a feature of some claderas. They attribute this dome to the intrusion of a central stock of laccolith. Such a phenomenon may have occurred in the Traveler caldera. It seems unlikely that this doming could have been caused by the Katahdin granite because the Trout Valley formation is not affected.

FAULTING

WADLEIGH MOUNTAIN FAULT: High angle normal faulting with some strike-slip movement is believed to have taken place along the southern margin of Wadleigh Mountain. This fault is believed to extend from the vicinity of Birch Point on Matagamon Lake westward to the north end of Morse Mountain, Telos Lake quadrangle, where it may be cut off by another fault. Evidence for faulting along this line is found at a number of localities. At BM 1071 feet on the North Branch of Trout Brook (north of Burnt Mountain,

Telos Lake quadrangle) rocks of the Seboomook formation are highly deformed and slickensided. They crop out within a few tens of feet of exposures of felsite. Just upstream from the eastern-most road crossing of the North Branch of Trout Brook in the Telos Lake quadrangle, rocks of the Trout Valley formation have northerly strikes, steep easterly dips, and are slickensided. At the point where Trout Brook bends about 90° to the east of the foot of Wadleigh Mountain, rocks of the Trout Valley formation have nearly vertical dips and top to the south. At K.P. Dam on Trout Brook (east of Wadleigh Mountain) the Traveler felsite is highly brecciated and contains much chalcedonic silica between breccia fragments. On high altitude aerial photographs, the southern margin of Wadleigh Mountain is nearly a straight line and bears no discernable relationship to planar features observed in outcrops within the felsite. In a similar fashion, the contact between the Seboomook formation and the felsite north of Trout Brook Mountain appears to truncate structures within the felsite. Finally, shear zones and accompanying drag folds occur in the Seboomook formation on Birch Point and adjacent to the felsite near the Grand Lake Road at the shore of Matagamon Lake.

Along the entire length of this fault, younger rocks occur to the south and older rocks to the north.

Thus the downthrown side is to the south. The steep south dip of the Trout Valley formation at the base of Wadleigh Mountain suggests that the fault plane also dips steeply south. Thus movement along the fault was normal. Evidence for some strike-slip movement comes from drag folds with steeply plunging axes near Burnt Mountain and near Matagamon Lake. The sense of movement is dextral.

It is this writer's interpretation that the felsite of Wadleigh Mountain is bounded on the north by a fault similar in nature to the one on the south side of the Mountain and that there is a third fault between these two, the trace of which is the valley between the series of summits of Wadleigh Mountain. Evidence for these two faults comes largely from strong lineaments on aerial photographs which are discordant with attitudes of planar features in the felsite observed in outcrop. The felsite is also brecciated in thin sections of the few samples available from Wadleigh Mountain.

These faults may have originated during the collapse of the Traveler caldera. Subsequent movement along them may have taken place during the formation of the Matagamon synclinorium. The eastward extension of the major fault is unknown.

The Wadleigh Mountain fault and the southern contact between the Trout Valley formation and the Traveler

felsite are believed to be offset by two sinistral strike-slip faults. The northeastern-most of these two faults probably passes through a shear zone in the Trout Valley formation just south of The Crossing on Trout Brook. The shear zone strikes N.70°W. and dips 40° to the north.

MORSE MOUNTAIN FAULT: In the Telos Lake quadrangle, there is a strong north-south lineament, apparent on aerial photographs and on the topographic map, to the west of Morse and Strickland Mountains. Both of these mountains are held up by the Traveler felsite, and there is an outcrop of felsite north of Morse Mountain beside the North Branch of Trout Brook. On strike with the lineament in a small gorge on the North Branch of Trout Brook are outcrops of the Seboomook formation. It is believed that this lineament is the trace of a high angle normal fault with the younger Traveler felsite on the eastern, downthrown side and the older Seboomook formation on the western, upthrown side. The lineament is also visible on the west side of Center Mountain. Griscom (oral communication) reports that the Morse Mountain fault may continue into the Harrington Lake quadrangle and cause an apparent dextral offset to the contact of the Katahdin granite with the Seboomook formation. If the granite contact slopes outward (to the north), this offset would be consistent with the proposed normal dip-slip movement on the Morse Mountain

fault. Because the Morse Mountain fault may cut the Katahdin granite it may be younger than the Wadleigh Mountain fault. This interpretation is shown on the tectonic map. The alternate interpretation, that the Wadleigh Mountain fault is the younger, cannot, however, be ruled out.

A cross fault passes through the sharp notch separating Strickland and Center Mountains and has caused a sinistral offset of the trace of the Morse Mountain fault. Sediments, presumably of the Seboomook formation, which crop out in this notch were probably dragged there by this cross fault.

FAULTING AT POND PITCH: Faulting at Pond Pitch on the East Branch of the Penobscot River has caused a dexteral offset of the Pond Pitch basalt. It is not within the scope of this study to discuss further the structure of this region along the East Branch.

MODE OF EMPLACEMENT OF THE KATAHDIN BATHOLITH

A comprehensive discussion of the mode of emplacement of the Katahdin batholith is not appropriate at this time. However, a few observations may be made. The zone of xenoliths on the wall of South Basin suggests that piecemeal stoping may have been an important, if not the most important, process. Further evidence for piecemeal

stoping is found outside the area of investigation at the contact of the granite on Black Cat Mountain, Norcross quadrangle. Granite at this locality contains many partially assimilated xenoliths of schists and gneisses.

Forceful injection may also have been involved in the emplacement of the batholith, although no foliation has been observed in the granite. Perhaps the incongruous dextral folds on the southeast limb of the Matagamon synclinorium and the fault with dextral offset at Pond Pitch are related to forceful injection of the Katahdin batholith.

No study of joint patterns or aplite and pegmatite distribution has been made.

Brief reference has been made to the vertical changes in the granite on Mt. Katahdin from the light-gray, medium-grained granite of the Wassataquoik facies at low elevations to the pink, vuggy, granophyric granite of the Pamola facies at high elevations. It is believed that the roof of the magma chamber was not far above Baxter Peak and The Tableland, and that the textural changes may be explained by an increase in volatiles and in the activity of oxygen. The large area of granodiorite on the Cathedral Trail may actually be a roof pendant. The available information suggests that the gradational contact between the Wassataquoik and Pamola facies slopes gently to the

north from about 3800 feet in Great Basin to about 2000 feet on Russell Mountain (a horizontal distance of 4 1/2 miles). It seems probable that the roof of the magma chamber was roughly parallel to this contact. If so, the roof in the vicinity of the Katahdin massif dipped very gently to the north (about 5°). The contact between the granite and the Traveler felsite appears to be somewhat steeper than this, and probably demarcates the beginning of the side of the magma chamber. The textural and structural relationships of the Katahdin granite are similar to those of the Mourne granites of Northern Ireland described by Richey (1927). In the Mourne Mountains the roof of the magma chamber is preserved and is almost flat. The Mourne granite, also, is pink and vuggy in its upper part.

CLEAVAGE

A detailed study of cleavage has not been made. However, cleavage is moderately well developed in fine grained rocks older than the Traveler felsite, and some of the felsite possesses a cleavage. Representative attitudes of cleavage are plotted on the tectonic map. It will be noted that cleavage in the Seboomook formation on the north limb of the Matagamon synclinorium is essentially vertical and parallel to the major axis of the synclinorium as well as to the smaller folds in the formation. Cleavage

on the southeast axis of the synclinorium for the most part is vertical or dips steeply east and strikes north or a few degrees east of north (average about N.15°E). Cleavage in the more tightly folded "Grand Falls" formation is roughly parallel to the cleavage in the younger rocks.

AGE OF THE ACADIAN OROGENY

The major folding and at least some of the faulting in the Katahdin-Traveler area is thought to be related to the Acadian orogeny. This deformation is interpreted as having taken place between the deposition of Trout Valley formation and the intrusion of the Katahdin granite. Elsewhere in Maine, the youngest rocks which are involved in the orogeny are of Schoharie age (the Tomhegan formation in the Moose River synclinorium).

Boucot (oral communication) has suggested that the Mapleton sandstone near Presque Isle, because it is only slightly deformed, may be post-Acadian. The age of the Mapleton sandstone is uncertain. The oldest rocks of known age that are not affected by the orogeny are in the Perry basin near Eastport, Maine. Here, red-beds of the Late Devonian Perry formation (dated by plant fossils only) rest unconformably upon Silurian sediments (Smith and White, 1905; Bastin and Williams, 1914). Further, granites near Calais, Maine (a town about 20 miles northwest of Eastport)

have intruded and metamorphosed Late Silurian slates. One of these granites is overlain by sandstone of Late Devonian age. Faul (1960) has determined the age of these granites, by the K/Ar method, to be 404 ±8 million years. The age of the regional metamorphism affecting the Seboomook formation and the pre-Upper Silurian quartz monzonite near Jackman is about 360 million years (Hurley, et al, 1959). Thus the Acadian orogeny in Maine is bracketed between Onondaga and Late Devonian times by stratigraphic and structural evidence. K/Ar dating methods suggest that the orogeny took place in the early part of the Late Devonian. (See geologic time scale by Kulp, 1961). Prior to the publication of these age determinations, Boucot (1954) had suggested that the Acadian orogeny in Maine took place in Middle Devonian times.

Using evidence found only in the Katahdin-Traveler area, it is possible to argue that the major deformation took place about the time of the eruption of the Traveler felsite, but prior to the deposition of the Trout Valley formation. The major pulse of the Acadian orogeny in this area would thus be placed in the Early Devonian (post-Oriskany), but this interpretation is not favored. The Trout Valley formation is, except for faulting, rather strikingly undeformed. The fine grained sediments lack cleavage and the average dips are 10 to 15 degrees. These gentle dips and the absence of cleavage could be explained

by the formation being post-Acadian. They could also result from the formation being shielded from orogenic forces by the massive felsite. In view of the regional geology, the latter interpretation is preferred. The Trout Valley formation is, therefore, believed to be pre-Acadian.

CHAPTER VI

GEOLOGIC HISTORY

The earliest geologic event preserved by the rocks in the Katahdin-Traveler area is the deposition of the shales and sandstones of the "Grand Falls" formation. This probably took place during Cambrian and/or Early Ordovician times. An interval of folding, uplift and erosion appears to have followed. The best evidence for this comes from the immediately adjoining area to the east where Neuman (1960) has found a Middle Ordovician volcanic conglomerate that overlies the "Grand Falls" formation and contains pebbles of quartzite similar to quartzites found in the "Grand Falls" formation. Not enough is known about Lower Paleozoic rocks in eastern New England to know whether this unconformity is of regional significance.

During the Middle Ordovician, volcanism occurred in the Katahdin-Traveler area. Traces of pillow structures in the Pond Pitch basalts suggest that they were erupted in a subaqueous environment. Following the Middle Ordovician volcanism, there was another break in the stratigraphic record combined with crustal deformation. This deformation presumably corresponds to the Taconic orogeny elsewhere in New England.

Shales, siltstones, graywackes, and conglomerates of the Kimball Brook formation were next deposited upon the Taconic erosion surface. For the most part, these rocks are of Lower Silurian age, although it is possible that some of the basal rocks are uppermost Upper Ordovician age. Coarse conglomerate of the Haskell Rock conglomerate indicates continued crustal movements. The deposition of calcareous siltstones and perhaps limestone of the Wenlockian series initiates, over much of the area, a time of greater crustal stability which extended into the Early Devonian. Volcanism occurred in the northern part of the area during the Upper Silurian.

The deposition of thin graded sets of shale, siltstone and very fine sandstone of the Seboomook formation characterizes Early Devonian times. These graded sets may indicate relatively rapid deposition in a large basin of moderately deep water by turbidity currents moving along bottom slopes into the basin. The recent study by Ericson et al (1961) of Atlantic deep-sea cores indicates that similar sediments are accumulating today in the Atlantic near the mouths of submarine canyons and on submarine plains.

About the time the Oriskany sandstone was being deposited in New York state, it is believed that there were mild crustal movements, probably accompanied by

volcanism, in north-central Maine. These created a source area for the cross-bedded shallow water sandstone of the Matagamon formation. This source area may have lain to the southwest where the Katahdin granite is now found. It was probably only a local source, and deep water sedimentation of graded sets of shale and sandstone continued in deeper seas to the west.

Toward the end of the time during which sandstones of the Matagamon formation were deposited, volcanism abruptly increased and tuffaceous sediments were deposited. Violent volcanic eruptions of felsite ensued as bedded ash and then the welded ash flows of the Pogy member of the Traveler felsite accumulated.

The water must have been shallow during the final stages of accumulation of the sandstone of the Matagamon formation because ash flows, which are believed to require a subaerial environment of deposition, occur a few feet above the base of the Traveler felsite. As the relatively violent eruption of ash flows continued, a volcanic island of considerable size may have been built. Partial collapse of the roof of the magma chamber, causing the formation of a caldera, may have taken place at this time. The volatile content of the magma appears to have decreased with time, and eventually the eruption of ash flows gave way to the relatively quiet eruption of the lava flows of the Black

Cat member. After the lava flows had accumulated to a thickness of several thousand feet, there was a further subsidence within the caldera and volcanic activity ceased. The intrusion of the granophyres on Wassataquoik Mountain and near Norway Dam probably occurred some time during the eruption of the Traveler felsite.

After the final collapse within the caldera, there appears to have been a doming of its central portion. The cause may have been the rise of a central stock or laccolith similar to those reported in other volcanic areas. No central intrusive body is exposed in the Traveler caldera, however.

Sufficient time elapsed after the cessation of volcanism to permit the doming, some erosion, and the development, on that part of the volcanic land which remained above water, of terrestrial flora as old as any known in eastern North America. Then the coarse felsite detritus, black shales and siderite ironstones of the Trout Valley formation accumulated in the shallow brackish water of the submarine slope of the land or in a basin within the caldera. This deposition probably occurred during Schoharie times. Presumed contemporary sediments to the southwest near Moosehead Lake and to the northeast in the Matapedia Valley, Quebec were deposited in a normal marine environment. Contemporary sediments have never

been reported to the northwest or southeast. Dikes and sills of quartz andesite in the Trout Valley formation may have been intruded shortly after the sediments were deposited.

The next events were the folding and faulting associated with the Acadian orogeny which probably occurred in the Middle or early Late Devonian. At or after the close of the Acadian orogeny, the Katahdin granite was intruded. Radioactive age determinations suggest that the granite is of Late Devonian age. Mafic dikes of unknown age cut the granite, and some faulting may have affected the granite. However, there is little trace of the geologic history of the Katahdin-Traveler area between the intrusion of the Katahdin granite in the Devonian period and the glaciation which occurred during the Pleistocene epoch.

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PLATE I

GEOLOGIC MAP OF THE TRAVELER AREA, MAINE

Geology by D.W. Rankin, assisted by W. Powers, W. Sabin and M. Rankin. Geology surveyed in 1955, 1956, 1957 & 1958.

Contacts

- Accurate
- Approximate or gradational
- Inferred

Symbols

- Strike and dip of bedding in sedimentary rocks and banding in felsite.
- Strike of vertical bedding in sedimentary rocks and banding in felsite.
- Strike and plunge of axes of minor folds; axial plane vertical.
- Strike and plunge of axis of minor anticline; axial plane vertical.

Faults

- Location accurate
- Location approximate
- Existence of fault and/or location inferred.

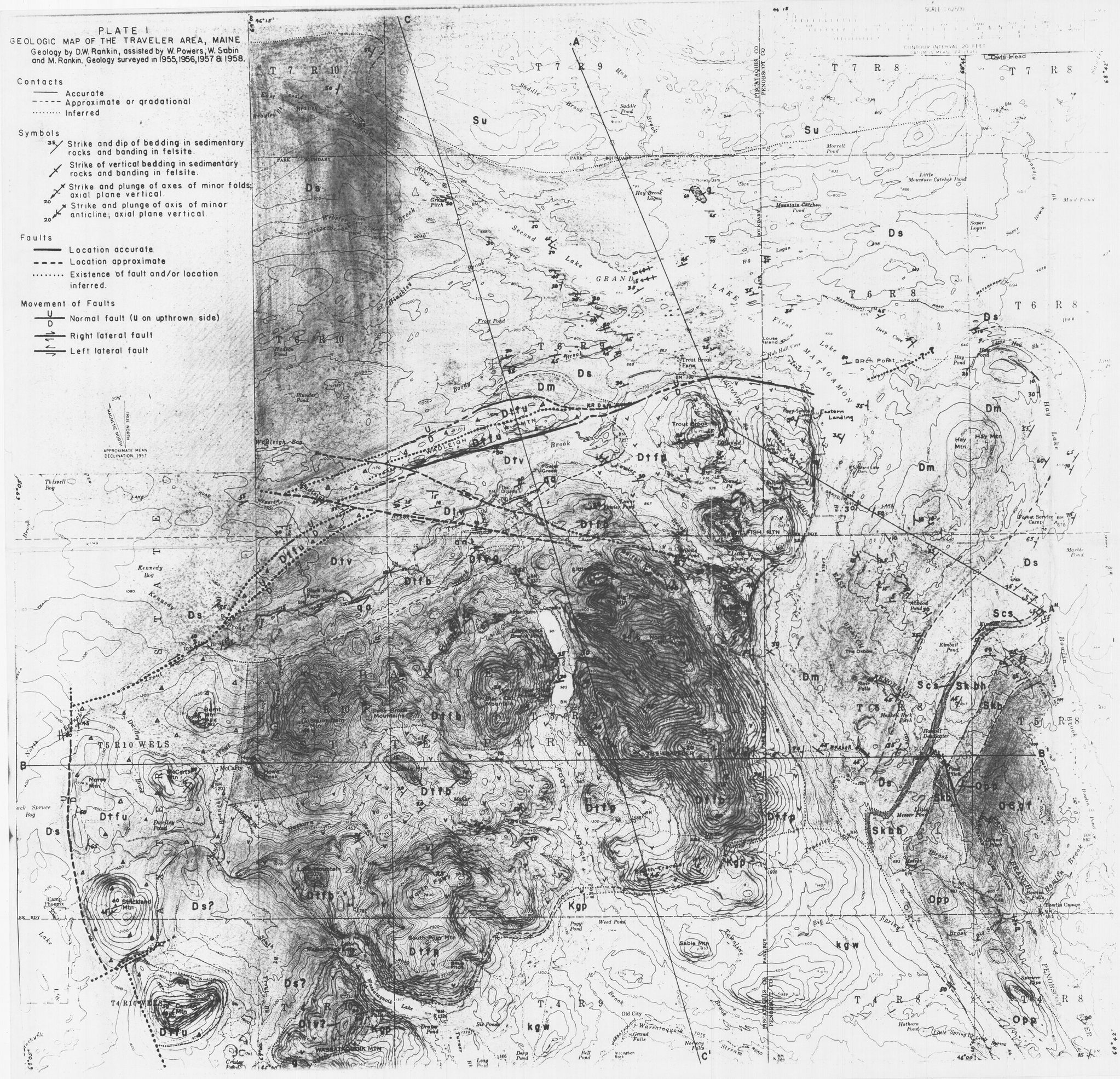
Movement of Faults

- Normal fault (U on upthrown side)
- Right lateral fault
- Left lateral fault

APPROXIMATE MEAN DECLINATION, 1957

SCALE 1:62,500

CONTOUR INTERVAL 20 FEET



LEGEND

Upper Devonian(?)

kgw / kgp

Katahdin granite

Medium-grained light-colored granite composed of quartz, perthite, plagioclase, & biotite.

kgw; Wassataquoik facies: even-grained, light-gray; some is porphyritic with small perthite phenocrysts.

kgp; Pamola facies: porphyritic with biotite phenocrysts; micrographic texture; upper part is pink & vuggy.

---Unconformity---

Lower or Middle Devonian(?)

qa

quartz andesite

qa; dikes & sills of quartz andesite containing plagioclase, amphibole, & minor quartz & pyrite.

Dtv / Dtvg

Trout Valley formation

Dtv; light blue-gray to black shale, siltstone, & lithic graywacke; granule and pebble felsite conglomerate; minor sideritic ironstone.

Dtvg; Gifford conglomerate lentil: cobble & boulder felsite conglomerate; very minor lithic graywacke & black shale.

---Unconformity---

Lower Devonian

g

granophyre

g; intrusive equivalent of Traveler felsite; intrudes some felsite.

Dtfu / Dtfb / Dtfp

Traveler felsite

Dense, flinty, dark-bluish-gray, dark-greenish-gray, or black felsite containing a few percent small phenocrysts.

Dtfb; Black Cat member: plagioclase, biotite, & clinopyroxene phenocrysts; mostly lava; minor welded tuff and laminated tuff.

Dtfp; Pogy member: quartz, plagioclase, & altered mafic silicate phenocrysts; mostly welded tuff; minor lava and non-welded tuff.

Dtfu; Traveler felsite, undifferentiated.

Ds / Dm

Matagamon formation

Dm; medium-bluish-gray or medium-greenish-gray, rusty weathering, very fine- to medium-grained sandstone interbedded with minor darker slate; cross-laminations common in sandstone.

Seboomook formation

Ds; graded beds of medium- to dark-bluish-gray slate & very-fine sandstone; slate predominates.

Silurian

Su

Silurian, undifferentiated

Su; includes Upper Silurian greenish-gray siltstone, greenstone, & red & green tuff.

Middle(?) Silurian

Area of abundant float of clean, light-gray, coarsely crystalline limestone.

Scs

carbonate-rich siltstone

Scs; Thin-bedded light-blue-gray carbonate-rich siltstone; carbonate is calcite or dolomite, or both; calcareous nodules in some strata.

Lower Silurian

Skbh / Skb

Kimball Brook formation

Skbh; Haskell Rock conglomerate: massive congl.

Skb; gray and greenish-gray slate, siltstone, & intercalated with thin beds of conglomerate & slate-chip breccia.

---Unconformity---

Middle Ordovician

Opp

Pond Pitch Basalt

Opp; olivine basalt; rare pillow structure.

---Unconformity---

Cambrian or Ordovician(?)

OEgf

"Grand Falls" formation

OEgf; interbedded slate & quartzite of maroon, greenish-gray, gray, & black colors; minor dark grits.

PLATE 2

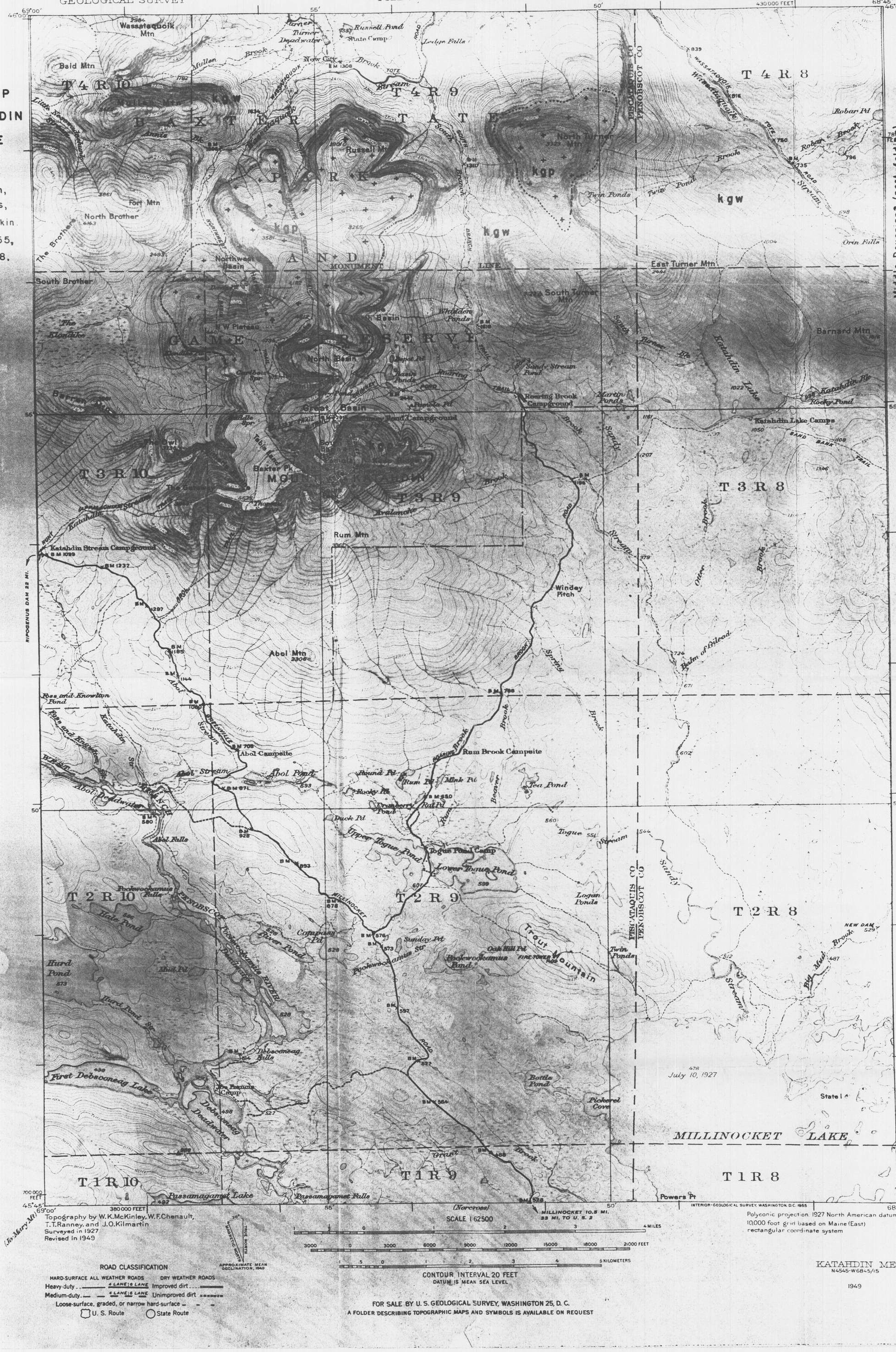
GEOLOGICAL MAP OF THE KATAHDIN AREA, MAINE

Geology by D. W. Rankin, assisted by W. Powers, W. Sabin and M. Rankin.
Geology surveyed 1955, 1956, 1957, and 1958.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF MAINE
REPRESENTED BY THE
PUBLIC UTILITIES COMMISSION

MAINE
KATAHDIN QUADRANGLE



Topography by W. K. McKinley, W. F. Chenault, T. T. Ranney, and J. O. Kilmartin
Surveyed in 1927
Revised in 1949

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS		DRY WEATHER ROADS
Heavy-duty	4 LANE | 2 LANE	Improved dirt
Medium-duty	4 LANE | 2 LANE	Unimproved dirt
Loose-surface, graded, or narrow hard-surface		

U. S. Route State Route

APPROXIMATE MEAN DECLINATION, 1949

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

Polyconic projection. 1927 North American datum
10,000 foot grid based on Maine (East) rectangular coordinate system

KATAHDIN ME.
N4545-W6845/15

1949

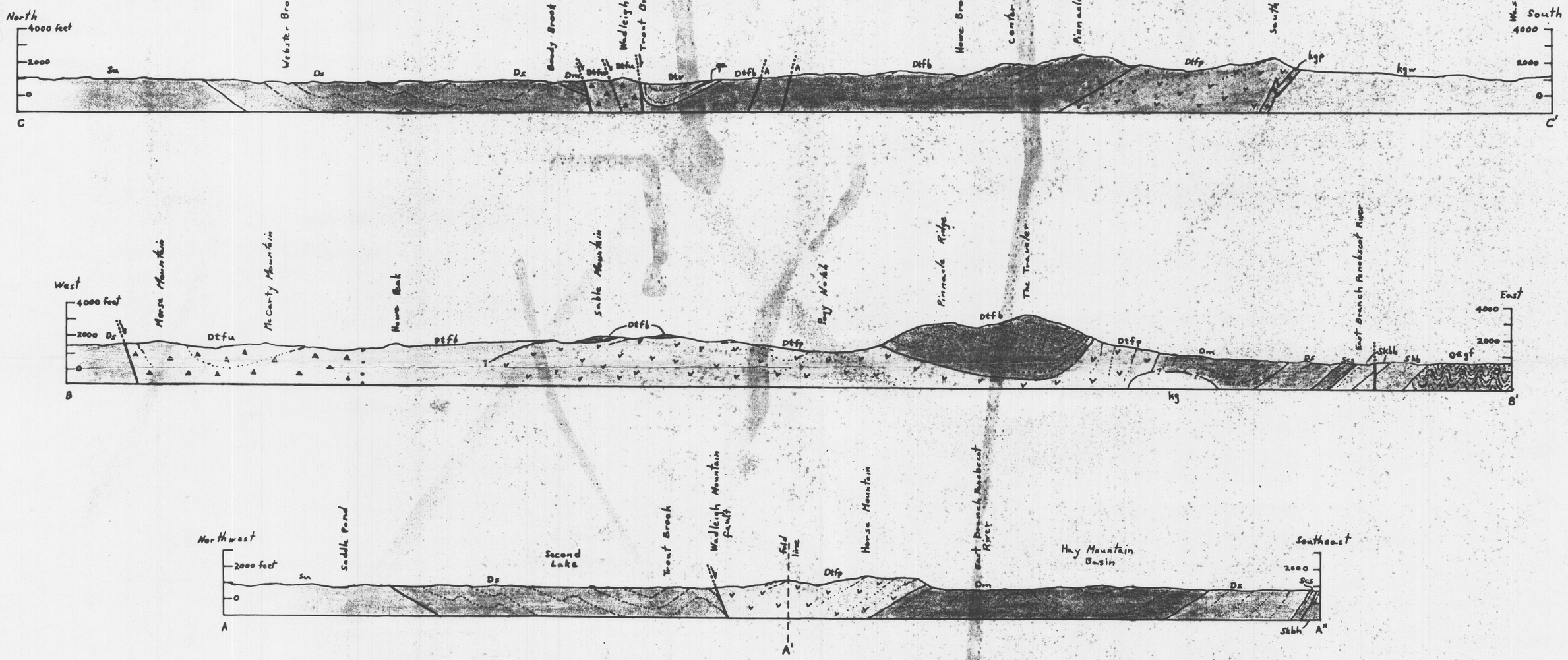


PLATE 3. STRUCTURE SECTIONS

0 ½ 1 2 3 4 5 Miles

Horizontal and vertical scales equal.

See plate 1 for meaning of rock unit symbols.

Symbols

- Contacts
- Arbitrary limit of Dtfu.
- Observed attitude of bedding or banding projected into plane of section.
- Diagramatic trace of bedding or banding.
- Normal fault; arrow indicates downthrown side.
- Left-lateral strike-slip fault; A on side that moved away from observer.
- Fault of uncertain movement.

PLATE 4

TECTONIC MAP OF THE TRAVELER AREA, MAINE

D. W. Rankin

Legend

Symbols

Inclined — Vertical — Horizontal

Attitude of bedding in sedimentary rocks and of banding in felsite.

Graded bedding, inclined — Graded bedding, vertical — Cross-bedding

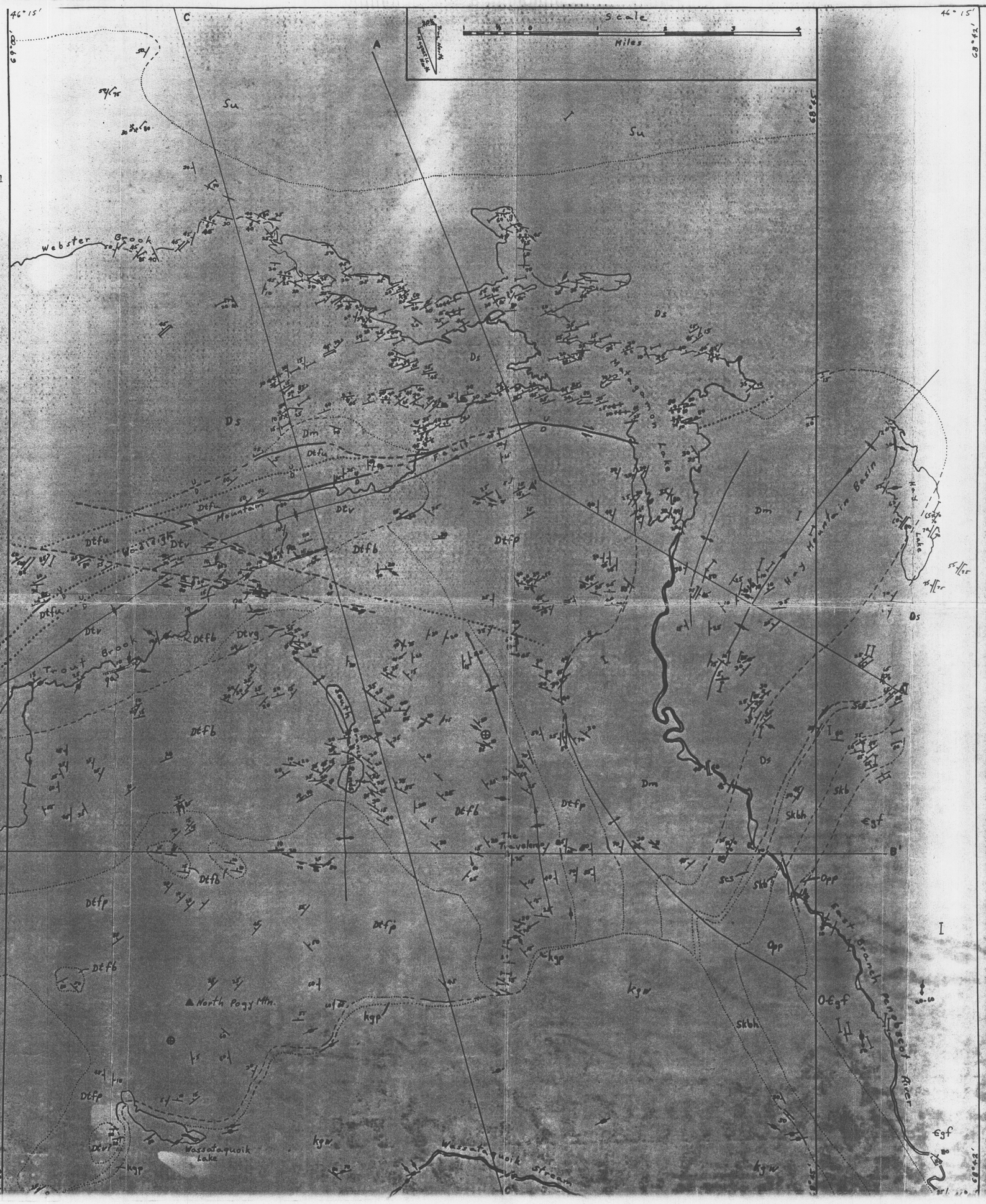
Direction and criterion of top of beds; top in direction of arrow.

Strike and dip of axial plane of dextral fold. Arrow indicates direction and amount of plunge of fold axis.

Plan of fold

Direction and amount of plunge of axis of minor fold; axial plane vertical; shear sense unknown.

Direction and amount of plunge of minor anticline; axial plane vertical.



Symbols (cont.)

Trace of axial surface on topography; arrow indicates the projected sense of the axial plunge.

Axial trends of synclines.

Axial trends of anticlines.

Inclined — Vertical

Attitude of cleavage.

Inclined — Vertical

Attitude of joints.

Plunge of axes of columnar jointing in felsite.

Lithologic contacts

Accurate

Approximate or gradational

Inferred

Faults

Location accurate; arrow indicates direction and amount of dip.

Location approximate

Existence of fault and/or location inferred.

Movement of faults

Normal fault; U on upthrown side.

Right lateral fault.

Left lateral fault.

Lithologic units

kgp	Katahdin granite; Pamola facies
kgw	Katahdin granite; Wassataquoik facies
qa	quartz andesite
Dtv	Trout Valley formation
Dtvg	Gifford conglomerate lentil
g	granophyre
Dtfu	Traveler felsite, undifferentiated
Dtfb	Traveler felsite, Black Cat member
Dtfp	Traveler felsite, Pogy member
Dm	Matagamon formation
Ds	Seboomook formation
Su	Silurian, undifferentiated
Scs	carbonate-rich siltstone
Skbh	Haskell Rock conglomerate
Skb	Kimball Brook formation
Opp	Pond Pitch basalt
OEgf	"Grand Falls" formation