Geologic Data Obtained from Core Samples Drilled in the Vicinity of Chaplin, Windham County, Connecticut

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CONTENTS

ILLUSTRATIONS

/Figures 1-8 follow References Cited/

TABLE

Introduction

During the summer of 1966, a rotary-drill rig and crew were made available for 2 weeks to the U.S. Geological Survey for use specifically in eastern Connecticut. I was able to take advantage of this opportunity and proposed to investigate two geologic problems that had arisen in the vicinity of Chaplin, Conn., as a result of mapping by H. R. Dixon in the Hampton quadrangle (Dixon and Pessl, 1966) and by G. L. Snyder in his reconnaissance of the adjacent Spring Hill quadrangle (Snyder, written commun., 1966). (See figure 1 for the conflicting interpretation along the border of the quadrangle.)

The drill rig was capable of drilling to a depth of about 30 m. A 4-in. (10.6-cm) auger was used to penetrate the overburden; casing was driven to refusal in bedrock; and bx drill rod with a diamond drill bit was used to core the bedrock.

Seven shallow holes were drilled during the allotted time. Site selection was not always optimum because the rig had to be used along roads and at sites where the depth to bedrock was less than 30 m. The holes ranged in depth from 4.7 to 21.4 m; the depth to solid bedrock ranged from about 2 to 20 m; core recovery ranged from 0 to 95 percent and averaged 43 percent.

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Holes 1-3 were drilled to determine the distribution of the intrusive Canterbury Gneiss and the stratified Hebron Formation in the Natchaug River valley. Both these units are structurally beneath a body of pelitic schist mapped as Scotland Schist, which was believed to be younger than the Hebron. Holes 4-7 were drilled to determine the nature of the contact between Canterbury (Eastford) Gneiss and Scotland Schist. This contact follows a prominent topographic lineament.

Bedrock cores were examined from the seven holes, and thin sections from selected core samples were analyzed.

This report includes lithologic logs of each well (figs. 2-8) and a table of modes and thin-section analyses (table 1). The two geologic problems are described, and a discussion of the results of this investigation is presented. No regional interpretation of the data has been made.

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867-100

Problem 1 - Distribution of Canterbury Gneiss

Reconnaissance mapping by G. L. Snyder (unpublished data, 1966) in the Spring Hill quadrangle suggested that the belt of Hebron Formation on the north side of the Natchaug River valley is much thinner than that shown on Dixon's map (Dixon and Pessl, 1966). Snyder considered the Canterbury Gneiss, exposed on the slopes of Tower Hill in the Spring Hill quadrangle and mapped near Darling Pond, to be continuous with the large body of Canterbury Gneiss in the Hampton quadrangle, which is shown on Dixon's map to intertongue with the Hebron Formation.

The Canterbury Gneiss is a light- to medium-gray, medium-grained compositionally homogeneous to weakly banded gneiss. According to Snyder (1964), it ranges in composition from tonalite to quartz monzonite. Most workers who have studied the Canterbury Gneiss agree that it is an orthogneiss intrusive into metasedimentary rocks (Snyder, 1964a, b; Dixon and Pessl, 1966; Lundgren et al., 1971; Pease, 1972). The Hebron Formation is a well-layered but generally compositionally homogeneous, greenish-gray to olive-gray fine-grained quartz feldspar biotite granular schist containing disseminated calc-silicate-bearing minerals. It was derived from a weakly calcareous metasandstone.

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867-100

Drill Hole 1 was drilled on Pumpkin Hill Road at the east edge of the Spring Hill quadrangle (fig. 1) at a locality where Snyder suggested that Canterbury Gneiss was present beneath the overburden. The geologic map of the Hampton quadrangle (Dixon and Pessl, 1966) shows the Hebron Formation in this area. Because of its texture and composition, rock recovered from this hole correlates with the Canterbury orthogneiss; none of the rock resembles the layered gneiss of the Hebron Formation. Core recovered from drill hole 2 on the northwest side of Connecticut Route 198 in the Hampton quadrangle is also orthogneiss similar to that in drill hole 1. Again, the rock cored is Canterbury Gneiss in an area mapped as Hebron.

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867-100

The site of drill hole 3 on on the corner of Bear Hill Road and Singleton Road was chosen to verify the presence of Hebron Formation along the west edge of the large body of Canterbury Gneiss in the Hampton quadrangle. The core recovered from this hole consists of light-gray, felsic, biotite orthogneiss interlayered with dark-gray, well-layered green biotite schist and greenish-gray layered gneiss containing calc-silicate minerals including hornblende, epidote-clinozoisite, and sphene. These darker layers are no more than a few centimeters thick within the Canterbury Gneiss. Lenses of similar lithology as much as a meter thick are exposed in Canterbury Gneiss in the vicinity of this hole. They have been interpreted as tongues of Hebron on the border of the Canterbury (Dixon and Pessl, 1966), but there is no compelling reason to believe that they are more than xenoliths within the Canterbury pluton. Most of the area shown as Hebron in this area (fig. 1) is covered by glacial debris.

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867-100

The writer concludes from the above evidence that the belt of Canterbury Gneiss exposed north of Darling Pond in the Spring Hill quadrangle does extend into the Hampton quadrangle and is probably contiguous with the body of Canterbury Gneiss mapped by Dixon east of the Natchaug River in the Hampton quadrangle. The Hebron apparently has been largely assimilated by the Canterbury in the area south of the Scotland and is represented in this area only by remnant screens of calc-silicate-bearing strata.

Problem 2 - Canterbury-Scotland contact along East Branch lineament

A pronounced topographic lineament along the northeast-trending valley of the East Branch of Stonehouse Brook marks a contact between the "Eastford Gneiss" and the "Scotland Schist" in the Hampton quadrangle (Dixon and Pessl, 1966). Snyder's reconnaissance map of the Spring Hill quadrangle (written commun., 1966) shows a thin outcrop belt of Hebron Formation that was not recognized in the Hampton quadrangle along this valley.

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867-100

The body of rock mapped as Scotland Schist is exposed on the south side of this lineament and extends across the boundary between the Spring Hill and Hampton quadrangles; it consists of strongly layered commonly rusty, orange-gray weathering medium-grained granular quartz-feldspar schist interlayered with more aluminous schist in a ratio of about 4 to 1. Garnet is a conspicuous constituent of most outcrops; staurolite is present locally on muscovite folia. This "Scotland" is quite unlike the silvery-gray highly pelitic muscovite schist of the type Scotland Schist with which it has been correlated (Dixon and Shaw, 1965; Dixon and Pessl, 1966; Snyder, 1964a, b).

The orthogneiss exposed along the north side of the East Branch lineament was mapped as Eastford Gneiss by Gregory and Robinson (1907) and was distinguished from the Canterbury Gneiss by H. R. Dixon (<u>in</u> Dixon and Pessl, 1966) in the Hampton quadrangle and by myself (Pease, 1972) farther north in the Eastford quadrangle. Recent geologic investigations by the writer in the Spring Hill quadrangle, however, have shown that the Eastford is contiguous with the Canterbury and that the two cannot reliably be distinguished in outcrop. Comparison of lithologic descriptions from the accompanying drill-hole records and of modes and descriptive analyses of thin sections (table 1), moreover, has shown no appreciably persistent

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differences between samples of the Eastford and samples of the Canterbury. The name Canterbury is preferred by this author to Eastford, and my investigations suggest that it be assigned to the body of orthogneiss formerly mapped as Eastford Gneiss.

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The cluster of four holes (drill holes 4-7) along Pumpkin Hill Road on both sides of the East Branch lineament (fig. 1) was drilled to obtain more information concerning the contact between Canterbury and "Scotland." Drilling did not intersect the contact because the drilling rig could not be set up directly in the stream valley and because of time and drilling-depth limitations.

Drill hole 4, according to both Dixon and Snyder, is in the body of rock mapped as "Scotland". Drill hole 6 was located to intercept the thin septum of Hebron mapped by Snyder, but it too yielded cores that best correlate with the "Scotland" of this area. Core samples from both holes are brownish-gray granular schist containing the pelitic constituents muscovite, kyanite, sillimanite, and garnet. Staurolite was not recognized in the cores but, as stated above (p. 7), was observed in outcrop on muscovite folia. Sulfide is a ubiquitous constituent of these cores.

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867-100

Drill holes 5 and 7 were located on the northwest side of the East Branch lineament in an effort to cut the northwest-dipping contact between Canterbury (Eastford) Gneiss on the northwest and metasedimentary rock, Hebron or "Scotland," on the southeast. Although drill hole 7 was as close to the center of the lineament as the rig could be located, both holes penetrated only the Canterbury (Eastford). Consequently, the nature of this critical contact was not determined. Drill holes 6 and 7, the two holes closest to the contact, are about 200 feet apart, and a projection from the bottom of drill hole 7 to the top of drill hole 6 makes an angle of about 12°. This is sufficiently less than the 20°-40° dip of foliation in the two holes to allow ample room for Snyder's outcrop belt of Hebron, but it would have to be less than 20 m thick, and no float of Hebron was observed along the projected trace of this outcrop belt in either direction.

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867-100

Some evidence indicates that the East Branch lineament may represent a fault. The foliation in the Canterbury steepens toward the East Branch trough from drill hole 5 to drill hole 7. It also steepens with depth and is locally folded in drill hole 7 nearest the trough as though the foliation were warped by postfoliation drag. The Canterbury Gneiss also shows evidence of increased fracturing and resultant depth of weathering towards the East Branch trough. Thin sections from drill hole 5 show a pattern of fine irregularly spaced fractures that are most conspicuous in large fedlspar grains, but that are parallel to a set of more widely spaced fractures that cut across the entire section. In thin sections from drill hole 7, fractures in plagioclase grains are almost randomly oriented (table 1). Thus, we have further evidence of postmetamorphic deformation increasing toward the contact. Finally, thin sections from drill hole 7 show more sericitization and a greater replacement of plagioclase by potassium feldspar than do thin sections from drill hole 5. The late-forming fractures referred to above also are commonly filled with potassium feldspar. Similar fractures in thin section 9 from drill hole 6 in the "Scotland" closest to the trough also contain potassium feldspar. Modes of thin sections from drill hole 7 are notably higher in potassium feldspar than those from drill hole 5 (table 1). Evidently, the contact between the Canterbury and "Scotland" acted as a conduit for the movement of the K^+ ions. Such K^+ ion mobility is a common feature of hydrothermal solutions in zones of brittle fracture.

U. S. GOVERNMENT PRINTING OFFICE : 1972 O - 457-084
867-100

The above data indicate that the contact along the East Branch lineament is probably a fault, a zone of brittle fracture permeated by weak hydrothermal solutions. The contact is between intrusive Canterbury Gneiss and stratified "Scotland." The evidence, although not conclusive, suggests that no septum of Hebron exists along this lineament.

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867-100

References cited

Dixon, H. R., and Shaw, C. E., Jr., 1965, Geologic map of the Scotland quadrangle, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ-392, scale 1:24,000.

Dixon, H. R., and Pessl, Fred, Jr., 1966, Geologic map of the Hampton quadrangle, Windham County, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ-468, scale 1:24,000.

Goddard, E. N., and others, 1948, Rock-color chart: Washington, D. C., National Research Council, 6 p. /Republished by Geological Society of America, 1951; reprinted 1963/.

Gregory, H. E., and Robinson, H. H., 1907, Preliminary geological map of Connecticut: Connecticut Geol. and Nat. History Survey Bull. 7, 39 p.

Lundgren, Lawrence, Jr., Ashmead, Lawrence, and Snyder, G. L., 1971, The bedrock geology of the Moodus and Colchester quadrangles: Connecticut Geol. and Nat. History Survey Quad. Rept. 27, 24 p., 8 figs.

Pease, M. H., Jr., 1972, Geologic map of the Eastford quadrangle, Windham and Tolland Counties, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ-1023, scale 1:24,000.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-100

Snyder, G. L., 1964a, Petrochemistry and bedrock geology of the Fitchville quadrangle, Connecticut: U.S. Geol. Survey Bull. 1161-I, 64 p.

-----1964b, Bedrock geology of the Willimantic quadrangle, Connecticut: U.S. Geol. Survey Geol. Quad. Map GQ-335, scale 1:24,000.

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867-100

Figure 1.--Map showing the difference in geologic interpretation at the boundary between the Hampton and Spring Hill quadrangles, Connecticut. Geology from Dixon and Pessl (1966) and Snyder (written commun., 1966), respectively. Canterbury Gneiss in the northwest part of the Hampton quadrangle was mapped by Dixon (in Dixon and Pessl, 1966) as Eastford Gneiss.

U. S. GOVERNMENT PRINTING OFFICE : 1972 O - 457-084
867-100

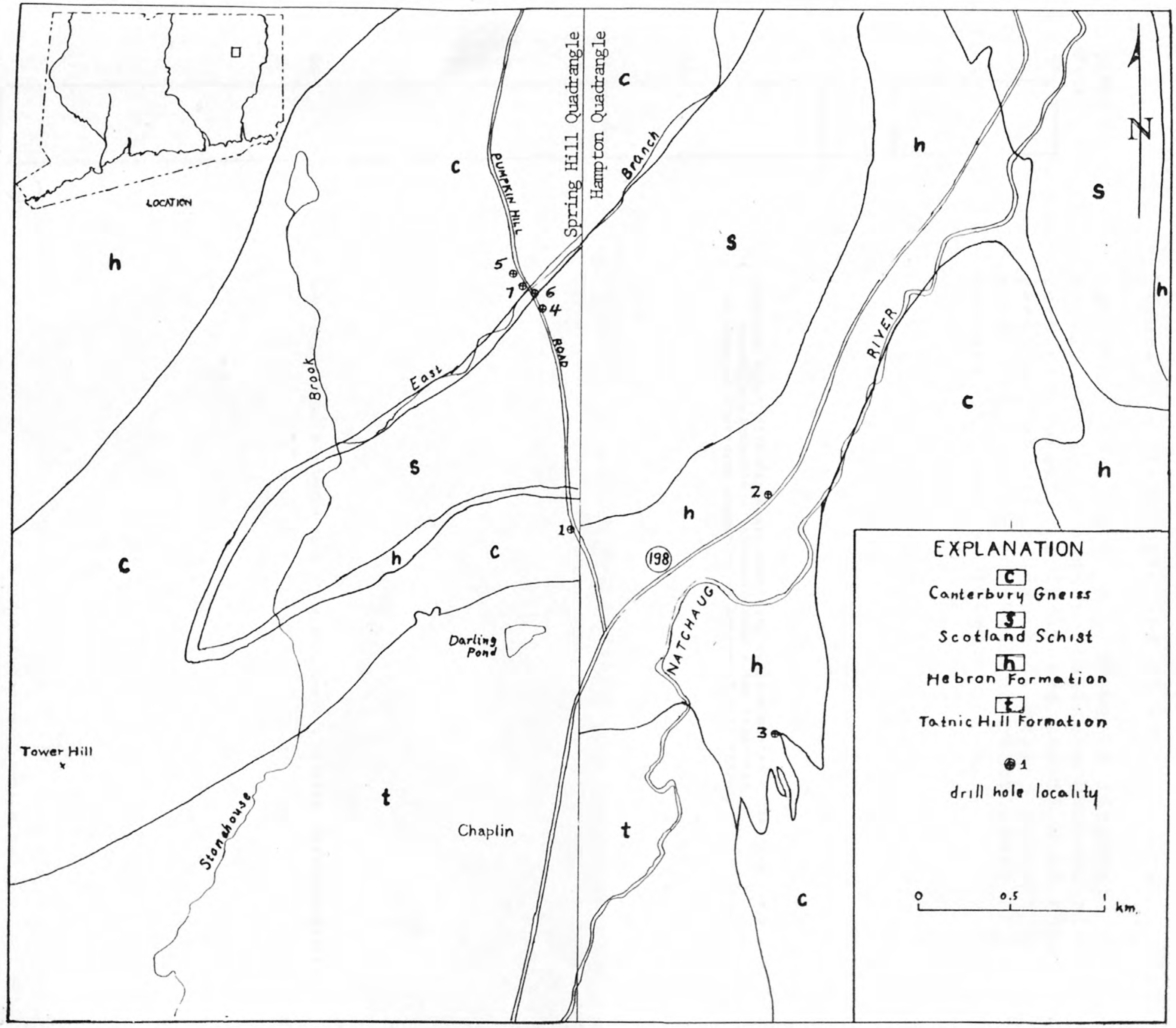

LOCATION
Spring Hill Quadrangle
Hampton Quadrangle
N
PUMPKIN HILL ROAD
Branch
East
Brook
RIVER
NATCHAUG
198
Darling Pond
Tower Hill
Stonehouse
Chaplin
c
h
s
t
1
2
3
4
5
6
7
EXPLANATION
Canterbury Gneiss
Scotland Schist
Hebron Formation
Tatnic Hill Formation
drill hole locality
0
0.5
1
km.

Figure 1

Figure 2.--Lithologic log of drill hole 1.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole. Numbers in parentheses refer to the rock-color chart of Goddard and others (1948).

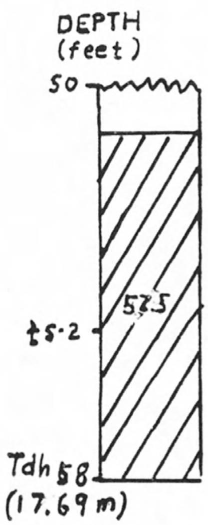
Moderate brown (5YR3/4) rusty weathered biotite schist containing trace of muscovite possible saprolite - recovered only a few fragments
1 mm chip of fractured pegmatite in bottom of core barrel

Few fragments of weathered sandy feldspar, quartz, biotite, muscovite gneiss.

Medium-light-gray, medium-grained, foliated, weakly banded quartz-biotite-muscovite gneiss (thin section 1, table 1). Folia of black biotite and muscovite are warped around feldspar quartz aggregates. Feldspar augen are as much as 5 mm thick. Rock is generally compositionally homogeneous, and the ratio of quartz and feldspar to biotite is about 10:1. A few darker bands are slightly richer in biotite. The principal foliation, defined by alignment of long axes of quartz and feldspar and by preferred orientation of micas, dips 5° to 15°; a faint secondary foliation of biotite dips 30°.

Figure 3.--Lithologic log of drill hole 2.

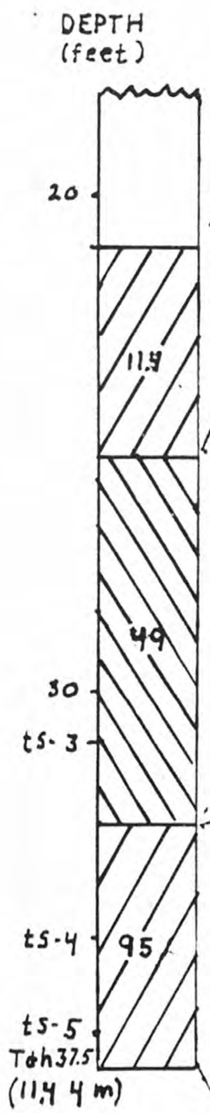
Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole.



Medium-gray, fine- to medium-grained, foliated feldspar-quartz-biotite-muscovite gneiss (thin section 2, table 1). Foliation, defined chiefly by preferred orientation of micas, dips less than 5°. Rock is compositionally homogeneous. The ratio of feldspar and quartz to black biotite is about 8:1. No secondary foliation is apparent.

Figure 4.--Lithologic log of drill hole 3.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole. Numbers in parentheses refer to the rock-color chart of Goddard and others (1948).



6.4 cm - Yellowish-gray (5YR8/1), weathered feldspar-quartz-muscovite granitic gneiss.

3.8 cm - Light-gray, coarse-grained feldspathic pegmatite containing quartz and trace of black biotite. Dip is about 25°.

5.0 cm - Medium-gray, medium-grained, nonweathered, well-foliated feldspar-quartz-black biotite schist. Compositionally homogeneous; biotite amounts to about 20 percent of rock.

15.0 cm - Medium-grained feldspar-quartz-biotite-hornblende gneiss. Black biotite and sparse, 4 mm long, hornblende blades compose 10-20 percent of rock. Sparse garnet porphyroblasts are also associated with the biotite. Principal biotite foliation, parallel to weak compositional banding and to alignment of feldspar and quartz grains, dips about 10°. Discontinuous but locally distinct second biotite foliation dipping about 40° cuts across compositional banding.

35.5 cm - Same as above but foliation and compositional banding are approximately horizontal.

7.0 cm - White feldspar-quartz layer (pegmatite); contains a trace of biotite, hornblende, garnet, and sulfide. Biotite content increases toward bottom.

7.6 cm - Feldspar-quartz-black biotite gneiss with traces of hornblende and garnet. Lithology similar to that above the pegmatite layer. Dip of foliation, parallel to compositional banding is about 10°; a faint, discontinuous secondary biotite foliation observed to dip 25° in opposite direction.

2.5 cm - White feldspathic gneiss; dip of upper contact 30°.

21.6 cm - Feldspar-quartz-biotite gneiss as above the white gneiss.

2.5 cm - Rusty weathered zone; biotite partly altered to chlorite and weathered golden brown.

6.4 cm - Biotite gneiss containing 2.5-cm thick quartz vein. Vein contact in part crosscuts and in part parallels foliation. Grain of pale-bluish-green beryl in vein. A few grains of pyrite and chalcopyrite are adjacent to the quartz vein and in a fracture that crosscuts the veining.

7.6 cm - Medium-gray, medium-grained feldspar-quartz-black biotite-hornblende gneiss (thin section 3, table 1) containing bands of feldspar and quartz of irregular thickness, 1 - 3 mm. Foliation and compositional banding dip about 45°.

5.0 cm - Medium-gray, medium-grained feldspar-quartz-black biotite gneiss. Compositional banding dips about 15°. Three-mm-thick band stained grayish orange (10 yr. 7/4) owing to oxidation of minute sulfide grains.

7.6 cm - Very light gray, pegmatitic, feldspathic gneiss containing less than one percent biotite. Medium- to dark-gray, weathered 5-mm thick biotite schist. Much of biotite is weathered golden brown. Contact with underlying felsic gneiss is uneven, but the dip is about 5°, generally parallel to faint banding and foliation in the felsic gneiss.

27.3 cm - Light-gray, fine- to medium-grained feldspar-quartz-biotite gneiss. Grades downward into coarser more feldspathic pegmatitic gneiss containing sparse garnet porphyroblasts ($<$ 1 mm); dip is 5°-10°.

3.8 cm - Fine-grained, greenish-gray, mottled light-gray, granular gneiss composed of plagioclase, green amphibole, and quartz.

15.1 cm - Mottled light- and dark-gray feldspar-quartz-black biotite gneiss. Rock is compositionally homogeneous except for a faint crude banding produced by slight variation in biotite content from 1 to 5 percent and variation in thickness of feldspar-quartz aggregates. The contact between this biotite gneiss and the overlying amphibole gneiss was recovered in the core (thin section 4, table 1).

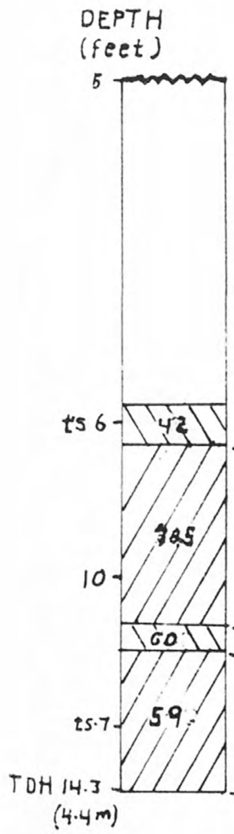
10 cm - Light-gray pegmatitic gneiss.

3.8 cm - Medium-brownish gray (5 yr. 5/1), medium-grained biotite-feldspar-quartz schist that has a light-gray 5-mm thick band in the center containing coarse grains of feldspar. The contact with pegmatitic rock above is sharp but extremely irregular; the base of the schist is gradational with pegmatitic rock. The dip of biotite foliation and layering is less than 5°.

76 cm - Very light gray fine-grained pegmatite or felsic gneiss (thin section 5, table 1). Composed chiefly of feldspar and about 15 percent quartz. Minute biotite flakes present in sparse streaks parallel to foliation. A trace of muscovite and sparse very fine grains of garnet and sulfide are present.

Figure 5.--Lithologic log of drill hole 4.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole. Numbers in parentheses refer to rock-color chart of Goddard and others (1948).



Metapelitic, light brownish-gray (5 YR 7/1) medium-grained quartz-plagioclase-brown biotite-muscovite kyanite-garnet schist (thin section 6, table 1) containing coarse-grained, feldspathic, mica-poor interlayers as much as 3 mm thick. Foliation dips 21°. Drill speed and rusty color of wash indicate at least 5 cm of rusty weathered and sulfidic schist not recovered.

Lithology of /core recovered essentially same as lithologydescribed above. Trace of sulfide present. Foliation dips about 24° near top of core. Dip decreases to 18° near base. Drill speed indicated presence of at least 3 more thin rusty schist layers above 25 cm.

Same lithology as above. Dip is 28°.

Same lithology as above (thin section 7, table 1). Dip is 32°.

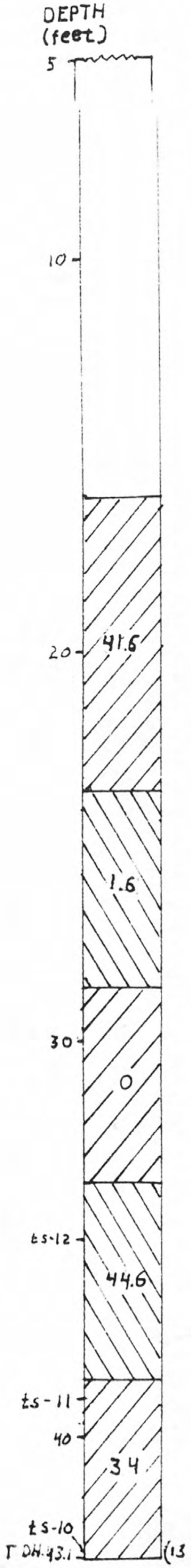


Figure 6.--Lithologic log of drill hole 5.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole.

Very light gray to yellowish-gray, weathered, somewhat friable feldspar-quartz-black biotite-muscovite gneiss. Dip of foliation and compositional banding in upper part is 5°-15°. Below this is a recumbent fold with about 2.5 cm of amplitude.

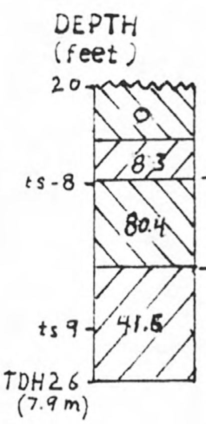
Same lithology as above.

Same lithology as above. Slightly less weathered. Faint compositional banding dips 15°-25°; biotite orientation quite irregular (thin section 12, table 1).

Similar to lithology above but very little weathered (thin sections 10 and 11, table 1). Compositionally homogeneous, poorly foliated, very light gray, speckled black, medium-grained feldspar-quartz-black biotite-muscovite gneiss. Maximum dip of weak compositional banding 15°; parallel weak preferred orientation of micas.

Figure 7.--Lithologic log of drill hole 6.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section; Tdh, total depth of hole. Numbers in parentheses refer to rock-color chart of Goddard and others (1948).



Brownish-gray (5 YR 5/1), banded light-gray, fine-grained, granular quartz-feldspar-brown biotite schist with trace of garnet. Light-gray bands and lenses 1-3 mm wide of feldspar and quartz grains amount to 30 percent of rock. Dip of foliation and compositional banding about 25°.

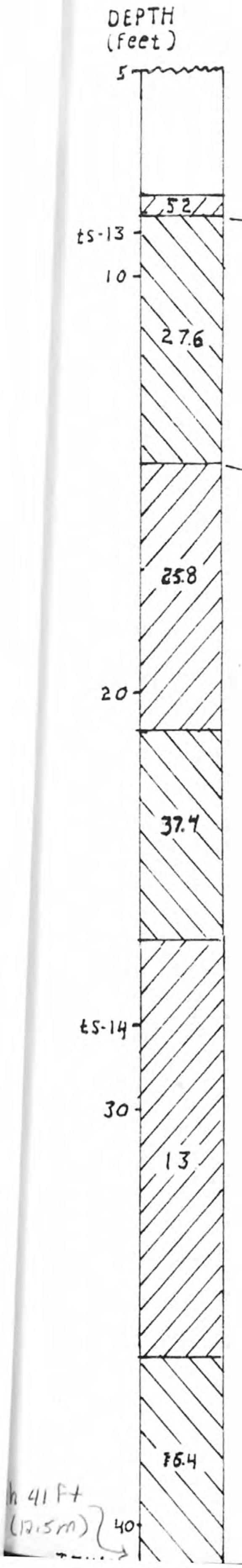
Brownish-gray (5 YR 5/1) fine-grained, granular quartz-feldspar-brown biotite schist with minor muscovite in biotite folia (thin section 8, table 1). Sillimanite is common in some layers where it is mixed with biotite and muscovite. Trace amounts of garnet present. Dips range from 0° to 10° and increase to 20° at bottom of core.

2.5 cm - Brown biotite schist as above. About 30 percent of rock consists of quartz and sillimanite aggregate in layers subparallel to foliation. Dip of foliation is about 20°.

28 cm - Brownish-gray (5 YR 5/1) quartz-feldspar-brown biotite schist (thin section 9, table 1). Muscovite mixed with biotite and sillimanite occurs in wispy lenses but is much less common than in upper 2.5 cm.

Figure 8.--Lithologic log of drill hole 7.

Length of interval cored shown by diagonal lines. Included numbers indicate percent of core recovered. ts indicates location of thin section: Tdh, total depth in hole. Numbers in parentheses refer to rock-color chart of Goddard and others (1948).



Yellowishish -gray (5 YR 7/2), weathered medium-grained feldspathic gneiss containing quartz and traces of biotite and muscovite.

2.5 cm - Very light-yellowish-gray (5 YR 9/1) fine-grained feldspathic gneiss (thin section 13, table 1) with very fine-grained biotite-muscovite folia, mostly weathered dusty yellow (5 Y 6/4) to light olive gray (5 Y 5/2). Dip of compositional banding and foliation is about 30°.

30 cm - Sharp contact with underlying medium-grained feldspathic gneiss which contains augen of feldspar and quartz aggregate less than 1 mm wide. Crude compositional banding by variation in meager biotite-muscovite folia. Rock is stained dusty yellow to light olive gray by weathering. Dip of foliation is irregular, about 25°.

18 cm - Same composition and degree of weathering as above, but foliation and compositional banding are folded. Folds are recumbent, with amplitudes on the order of 2.5 cm. They plunge 25° and dip a maximum of about 55°.

Light-yellowish-gray (5 Y 8/1), weathered feldspar-quartz-biotite-muscovite gneiss; contains a few angular xenoliths of biotite schist, about 1 cm maximum diameter. Most compositional banding dips consistently 38°. Fold near base plunges 15° and dips about 40°.

Alternately banded, dark- and light-yellowish-gray, weathered feldspar-quartz-biotite-muscovite gneiss. In the darker bands biotite-muscovite folia amount to as much as 15 percent of the rock: in the light bands, less than 5 percent. Banding and foliation dip about 40°.

10 cm - Coarse-grained feldspathic gneiss with patches of weathered biotite and muscovite and sparse grains of garnet 1-3 mm in diameter. Dip is about 40°.

30 cm - Mostly light-yellowish-gray (5 Y 8/2) mottled moderate-olive brown (5 Y 4/4), weathered, friable feldspar-quartz-biotite-muscovite gneiss (thin section 14, table 1). Dip of ragged compositional banding and crude preferred orientation of micas is about 60° near base of core.

Lithology same as above, but rock is more weathered and more friable than the rock higher in this hole. The dip steepens to nearly vertical.

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7

/Locations of thin sections are shown in lithologic logs of the cores (figs. 2-8)/

MODES

/X, present; dash leaders (---), not found/

	Distribution of Canterbury Gneiss						East Branch lineament								
Drill hole	1	2	3				4		6		5			7	
Thin section	1	2	3	4*	4*	5	6	7	8	9	10	11	12	13	14
Quartz -------	25.0	30.0	20.0	25.0	40.0	28.0	25.5	65.0	32.0	43.5	30.0	34.0	30.0	28.0	29.0
Plagioclase --	35.0	25.0	39.0	40.0	32.0	29.0	14.0	2.5	28.0	13.5	43.5	31.0	37.0	15.5	26.0
Potassium feldspar ---	30.0	35.0	7.0	--	--	38.0	--	--	--	2.5	16.0	23.0	20.0	44.5	35.5
Biotite ------	7.0	7.0	25.0	--	20.0	4.0	24.5	11.0	36	19.5	9.5	10.0	11.0	6.5	7.0
Muscovite ----	3.0	3.0	--	--	--	1.0	15.5	15.0	X	11.0	1.0	2.0	2.0	5.5	2.5
Hornblende ---	--	--	3.0	30.0	--	--	--	--	--	--	--	--	--	--	--
Sillimanite --	--	--	--	--	--	--	X	--	--	X	--	--	--	--	--
Kyanite ------	--	--	--	--	--	--	13.5	1.0	--	2.0	--	--	--	--	--
Garnet -------	--	--	--	--	--	X	2.5	X	0.5	X	--	--	--	--	X
Epidote-clinozoisite	X	X	5.0	x	X	X	X	--	--	--	--	--	X	--	--
Apatite ------	X	0.5	1.0	1.0	1.0	X	X	1.5	0.5	0.5	X	X	X	X	X
Sphene -------	--	--	X	3.0	2.0	X	X	--	--	X	--	--	--	--	--
Zircon -------	--	--	--	--	X	--	X	X	--	X	--	--	--	--	--
Magnetite-illmenite	--	X	--	--	X	--	--	--	--	--	--	--	--	--	--
Chlorite -----	--	--	--	--	--	--	--	--	--	--	X	--	X	X	X
Tourmaline ---	--	--	--	--	--	--	--	X	--	X	--	--	--	--	--
Sulfide ------	--	--	--	--	--	X	4.5	3.0	2.0	2.5	--	--	--	--	--

*Separate modes of biotite-bearing and hornblende-bearing layers

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7--Continued

DESCRIPTIVE ANALYSES

Thin sections 1-5 from drill holes 1-3

Thin section	Drill hole	Depth (meters)	Description
1	1	21.3	Oligoclase-microcline-quartz-biotite-muscovite gneiss having a bimodal granoblastic texture. Microcline, oligoclase, and quartz occur as coarse anhedra and as fine-grained aggregates with biotite and muscovite between the coarser grains. The micas show a preferred orientation essentially parallel to faint compositional banding and alignment of the felsic minerals. Microcline varies from strongly twinned to untwinned; plagioclase is mostly twinned and faintly sericitized along relic twin plans, and myrmekite is common at contacts between the two feldspars. The biotite is pleochroic from dark olive green to light olive green.
2	2	16.8	Microcline-quartz-oligoclase gneiss. The composition and texture of this rock are nearly identical to those of thin section 1 except that the order of abundance of the 3 principal minerals differs, and the rock is slightly finer-grained. Microcline twinning is most commonly hazy, but in some grains, it is distinct; in others, it is absent. Most oligoclase grains are untwinned and show evidence of weak alteration along cleavages. Myrmekite grains are common in contact with or within microcline. Biotite pleochroism is olive green to olive yellow.
3	3	9.5	Andesine-biotite-quartz-potassium feldspar-hornblende gneiss with a bimodal granoblastic texture. The rock consists mostly of coarse anhedral andesine and quartz; a fine-grained aggregate of andesine, quartz, potassium feldspar, and myrmekite occurs between the coarse

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7--Continued

DESCRIPTIVE ANALYSES

Thin sections 1-5 from drill holes 1-3

Thin section	Drill hole	Depth (meters)	Description
3	3	9.5	grains. Biotite, hornblende, and epidote-group minerals are concentrated in bands and show a preferred mineral orientation. A second discontinuous biotite orientation is apparent at a small angle to the principal orientation. Much of the andesine is clearly twinned; hazy or untwinned plagioclase is present. Wavy extinction, and bent and picket fence twinning are characteristic of the plagioclase. Potassium feldspar occurs as untwinned interstitial grains, and myrmekite commonly is mutually attached to plagioclase and potassium feldspar. Biotite pleochroism is olive brown to olive yellow; hornblende is blue green to pale yellow green. Resorbtion phenomena such as embayment of grain boundaries and poikilitic inclusions are common.
4	3	10.7	Compositionally banded biotite gneiss containing a 6-mm-thick layer of hornblende gneiss. Contacts are sharp with little overlap of biotite and hornblende, and contacts are essentially parallel to preferred mineral orientation. The biotite gneiss consists of coarse grains of quartz-feldspar aggregate with biotite folia amounting to less than 20 percent that are warped around the coarse grains. Potassium feldspar is present at the extreme top of the oriented section, furthest from the hornblende-rich layer. Myrmekite is present in this area commonly touching potassium feldspar grains. A crudely defined band of symplectic vermicular quartz in plagioclase grains is present about midway between the top of the slide and the hornblende-rich layer. The hornblende gneiss is equigranular; hornblende, which amounts to 30 percent of the layer, has a strong preferred orientation. The plagioclase in

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7--Continued

DESCRIPTIVE ANALYSES

Thin sections 1-5 from drill holes 1-3

Thin section	Drill hole	Depth (meters)	Description
4	3	10.7	the entire slide is calcic, probably andesine. A faint increase in the relief of the plagioclase toward the hornblende-rich layer suggests that the plagioclase is more calcic in this layer. Accessory apatite, epidote-clinozoisite, and sphene are common throughout the slide. Epidote-clinozoisite is more common in the biotite gneiss; sphene is more common in the hornblende gneiss.
5	3	11.3	Felsic gneiss or fine-grained pegmatitic gneiss - characteristic of most of the core recovered from below 19.2 m. The texture is granoblastic with preferred orientation of very fine grained biotite, pleochroic olive-brown to olive yellow, and somewhat coarser muscovite occurring in a few thin folia and amounting to about 5 percent of the rock. Rock is similar in composition to thin sections 1, 2, and 3 but is low in micaceous minerals and high in potassium feldspar.

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7--Continued

DESCRIPTIVE ANALYSES--Continued

Thin sections 6-9 from drill holes 4 and 6

Thin sections 6-9 from holes 4 and 6 drilled on the south side of the East Branch are very similar; they are composed of quartz-plagioclase-biotite schist and contain garnet and as much as 5 percent sulfide. Biotite is pleochroic from orange brown to straw yellow.

In thin sections 6 (drill hole 4, 2.1m), 7 (drill hole 4, 4.0m), and 9 (drill hole 6, 7.6 m) muscovite and kyanite accompany the biotite with fine grains of quartz and oligoclase in folia that are warped by coarser grains of oligoclase and quartz. Very fine sillimanite needles are in contact with the muscovite and kyanite in thin sections 6 and 9. A small amount of potassium feldspar is present in thin section 9; it occurs in embayments of plagioclase grains and also in a few veinlets that transect grains of plagioclase and quartz. Potassium feldspar appears to be a late replacement in the aluminous schist of drill hole 6, nearest the East Branch lineament. Thin section 7 shows a gradational enrichment of mica from about 7 percent at the bottom of the oriented section to about 20 percent at the top. This alumina enrichment may represent primary clay enrichment or right-side-up graded bedding. The section is abnormally rich in quartz, 65 percent, at the expense of the feldspars.

The biotite schist of thin section 8 (drill hole 6, 6.7 m) is a finer grained, more evenly foliated, and less aluminous schist than the other three. It consists entirely of biotite, quartz, and plagioclase in almost equal proportions with minor accessory minerals. The plagioclase is andesine at the bottom of the oriented section, and a gradational increase in the plagioclase relief, clearly visible in this section, indicates that the plagioclase is increasingly more calcic toward the top. Many of the more calcic plagioclase grains have been partly altered to sericite. A sharp contact near the bottom of the section separates the biotite-quartz-plagioclase schist from a slightly coarser grained, quartz-poor labradorite(?)-rich layer below.

Table 1.--Modes and descriptive analyses of thin sections of core from drill holes 1-7--Continued

DESCRIPTIVE ANALYSES--Continued

Thin sections 10-14 from drill holes 5 and 7

Thin sections 10, 11, and 12 are from drill hole 5 at 13.1 m, 11.9 m, and 10.5 ~~9.2~~ m respectively; thin sections 13 and 14 are from drill hole 7 at 2.75 m and 8.5 m respectively. Thin sections 10 and 11, from the bottom core-run of drill hole 5, are the least altered or weathered core in either hole. This unweathered rock is a bimodal granoblastic, faintly banded and foliated, compositionally homogeneous, oligoclase-quartz-potassium feldspar-biotite-muscovite gneiss. The rock consists of coarse- to medium-size grains of potassium feldspar, plagioclase, and quartz in a matrix, amounting to less than 20 percent, composed of plagioclase, potassium feldspar, and minor quartz grains with blades of biotite and minor muscovite. Biotite is pleochroic dark olive brown-medium olive brown-straw yellow. The larger grains commonly are poikilitic and have irregular embayed boundaries with the fine-grained matrix material.

Potassium feldspar occurs as large individual grains of weakly twinned microcline but more commonly is in small patches around the borders of plagioclase grains and in the matrix. Poikilitic inclusions of altered plagioclase are common in large microcline grains. Plagioclase apparently was being replaced by potassium feldspar. Grains of myrmekite mutually attached to potassium feldspar and plagioclase grains are common.

A pattern of fine, irregular, closely spaced fractures is characteristic of the large feldspar grains. These fractures are generally restricted to individual grains, but are parallel with a set of more widely spaced fractures that cross-cut the fabric of the rock at a low angle. Biotite and muscovite show a discontinuous preferred orientation that appears more nearly to parallel this set of fractures than compositional banding. Most micas, however, are preferentially oriented along boundaries of the larger grains, and many transect fractures without themselves being fractured.

Thin sections 10 and 11 show evidence of weak alteration which consists mostly of a sprinkling of sericite and brown opaque dust along fractures and cleavages in plagioclase grains. Only a few plagioclase grains have been almost entirely altered to sericite and brown opaque dust. Potassium feldspar shows little evidence of alteration. A few grains of biotite have been chloritized.

Thin section 12 is from a more friable weathered sample from higher in the same drill hole. The composition and texture are essentially the same as those in thin sections 10 and 11; the only significant difference in this thin section is a more pervasive coating of brown opaque dust in fractures, along cleavages, and around grain boundaries. Thin-section 12 also appears to be more severely fractured than thin sections 10 and 11.

The two samples of core from drill hole 7 from which thin sections were made are more friable and more weathered in appearance than cores from drill hole 5. Neither thin section is from as deep as the thin sections from drill hole 5 because we were unable to drill deeper in this critical hole as time ran out.

One third of thin section 13 is a bimodal, granoblastic orthogneiss similar in composition to the core of drill hole 5. The remaining two-thirds of the slide is coarser grained and consists mostly of potassium feldspar and plagioclase with interstitial quartz and fine flakes of biotite and muscovite sparsely distributed around the coarser grains. This is possibly a pegmatitic vein, and the abundance of large potassium feldspar grains at least in part accounts for the high percentage of potassium feldspar in the mode of this thin section. The finer grained third of the slide, however, also appears to be rich in potassium feldspar relative to core from drill hole 5.

Plagioclase grains are highly fractured, but there is no pervasive set of subparallel fractures as was observed in the thin sections of drill hole 5. Fracture patterns in respective plagioclase grains are almost randomly oriented. Potassium feldspar appears to be replacing fractured and altered plagioclase grains; a vein composed entirely of potassium feldspar grains cuts across a plagioclase grain.

Brown opaque dust is common in fractures and cleavages of plagioclase and around grain boundaries. Sericitation is uncommon, but discrete patches of muscovite flakes are scattered through some plagioclase grains. Potassium feldspar shows little evidence of fracturing but is somewhat mottled by opaque dust. A few grains of biotite have been partly altered to chlorite.

Thin section 14 is highly fractured owing to the extremely friable nature of the sample. The composition, texture, and type of alteration observed in the thin-section fragments, however, are very similar to those of thin section 10. The plagioclase grains are more severely altered than in any other thin section. Most are highly fractured and heavily coated with brown opaque dust. Twinning has been obliterated except for a relic polysynthetic twin pattern preserved by distribution of the brown opaque dust.

Relatively coarse grains of muscovite are common in most plagioclase grains, they show a preferred alignment parallel to relic twinning. Several plagioclase grains have developed a grate or sieve texture in which nearly 50 percent of a grain has altered to muscovite.

Deductions from these analyses indicate brittle fracturing followed by later solution and recrystallization. In both holes, the coarse plagioclase grains are highly fractured and sericitized and late crystallising potassium feldspar apparently replaces altered and fractured plagioclase grains mostly around their border, but also in fine veins which cut across the entire thin section. Large potassium feldspar grains show little evidence of fracturing or alteration except for embayment on their borders with the formation of myrmekite. Late crystallizing relatively coarse muscovite and biotite interrupt plagioclase fractures. In drill hole 7, the plagioclase is more highly fractured and more strongly altered and muscovite replacement of plagioclase is more common and coarser than in drill hole 5. The fracture patterns of individual plagioclase grains are randomly oriented with respect to each other as though they had been rotated subsequent to fracturing, and the fine-grained matrix in these thin sections shows evidence of granulation, mortar texture, as well as resorbtion. Modes for drill hole 7 thin sections are richer in potassium feldspar than those from drill hole 5 thin sections. Weathering is most effective on the most altered rocks and preferentially attacks altered plagioclase.