Trip A

SOME ASPECTS OF GRENVILLE GEOLOGY AND THE PRECAMBRIAN/PALEOZOIC UNCONFORMITY, NORTHWEST ADIRONDACKS, NEW YORK

by

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ABSTRACT

This field trip will cover some of the outstanding characteristics of Grenville geology in the Lowlands of the Northwest Adirondacks, with emphasis on both small and large-scale structures. Trip stops will be as follows: 1) "The Snake" roadcut near Canton, a plastically folded, weakly foliated marble with a thin, persistent, similarly folded layer composed chiefly of microcline; 2) The Rock Island roadcut near Gouverneur, which exposes cavity fillings of Potsdam Sandstone in Grenville marble, a trachytic(?) amygdaloidal dike intruding the marble, complex brecciation in gneisses and schists, numerous shear zones, and pyritic mineralization; 3) and 4) The Hyde "phacolith" near Brasie Corners where the relationship between minor and major structures will be stressed, and the controversial question of phacolith origin will be discussed; 5) The Hailesboro roadcut, exposing plastically deformed marble containing gabbroic blocks apparently derived from dikes; 6) The Poplar Hill migmatite roadcut in quartz-biotite-oligoclase gneiss, one of the most extensive metasedimentary rock types in the Grenville of this region; and 7) The Edwards roadcut, a well-known mineral collecting site for diopside, calcite, phlogopite, K-feldspar and apatite.

STOP DESCRIPTIONS

<u>Stop 1. The "Snake"</u>(Figs. 1,2,3)- Large marble roadcut on new section of highway 11 about four miles southwest of Canton. This stop illustrates a remarkable example of the plastic deformation so common in the Grenville marbles. The bulk of the roadcut is coarse-grained calcite marble with minor diopside, tremolite, muscovite and quartz veins. The "Snake" shown in Fig.3, is a nearly continuous thin band, generally less than six inches across, which traverses about half the length of the east side of the cut, and describes numerous sinuous folds. The Snake is more segmented at the northern end and a good example of a refold can be seen. Compositional banding in the marble near the Snake is folded similarly with the Snake. Mineralogically, the Snake consists of microcline with minor sphene, calcite, biotite, and opaque. It is framed by a darker border zone consisting of calcite with abundant diopside, and minor sphene, biotite, opaque, quartz, actinolite, and tourmaline.

The writers believe the Snake and adjacent compositional bands represent original bedding. The Snake itself apparently derives from a thin but persistent

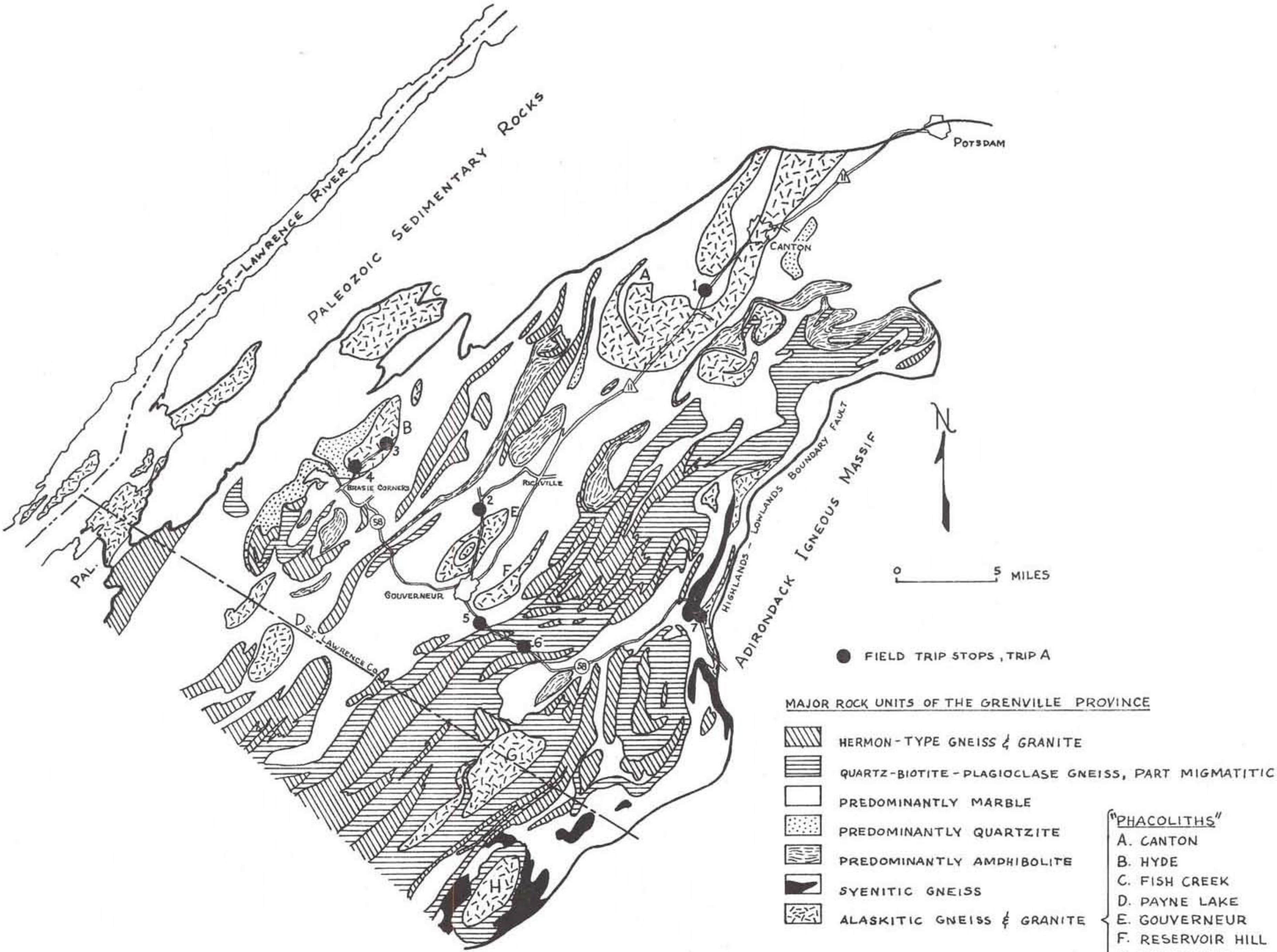


FIG. 2. GENERALIZED GEOLOGIC MAP OF NORTHWEST ADIRONDACKS (AFTER BROUGHTON et.al., 1962)
(PALEOZOIC OUTLIERS OMITTED)

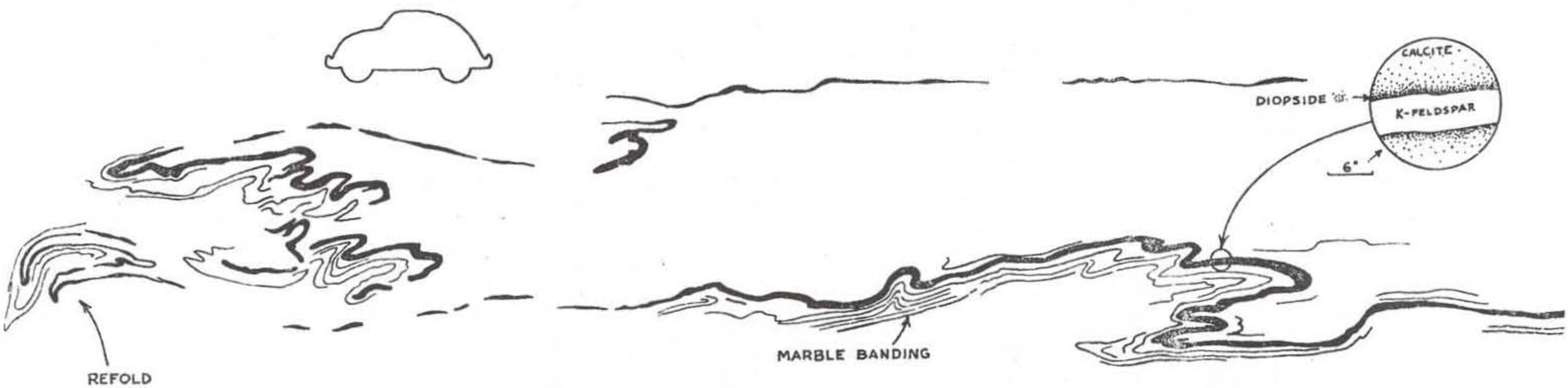


FIG. 3. "SNAKE" ROADCUT

bed of clay, such as an illite-chlorite mixture. Metamorphic reconstitution fixed the clay-derived potassium in microcline. The symmetrically distributed diopside marginal to the Snake indicates outward migration of SiO_2 and Mg, and reaction with calcite to produce the diopside.

Stop 2. Rock Island Roadcut- Located about three miles north of Gouverneur on the Rock Island Road just south of the Oswegatchie River. Cut exposes cavity fillings of Potsdam Sandstone in Grenville marble; structurally and stratigraphically complex, dravite-rich Precambrian rocks; numerous shear zones; an amygdaloidal trachyte dike, and pyritic mineralization.

The following are considered by the authors as evidence for cavity filling of Potsdam sand in marble at south end of cut, and smaller sandstone pockets in other parts of the cut:

1) Outcrop pattern (Fig. 4, 7). The quartzites here identified as outliers of the Potsdam Sandstone form irregular outcrop patterns which bear no consistent relationship to Precambrian structure. They have survived erosional stripping only where they fill deep solution pockets in the marbles.

2) Bedding attitudes (Figs. 4, 5). Gentle, inward-directed dips unrelated to compositional layering in the marble, which is generally steeply dipping and, in part, plastically folded. The inward-direction of dips is attributed to compaction and slump. Cross-bedding is also present but not extensive.

3) Contacts (Figs. 5,6,7). Contacts with the marble are irregular and in part, dip steeply into the marble. They are characterized by breccias containing angular marble clasts derived by natural block caving of the marble by the contact, less conspicious clasts of quartzites, schists, gneisses, and alaskites derived from Grenville lithologies (probably nearby), and some autoclastic fragments of Potsdam Sandstone. The large marble block shown in Fig. 6 appears to be a joint block which has fallen only a short distance into the sand. Release joints in the marble are sub-parallel to the contact on the other (western) side of the cut (Fig. 5). The matrix as a whole is poorly sorted quartz sand with extensive iron staining that diminishes away from the contact. Pyrite is also abundant in the quartzite near the contact, and it occurs sporadically throughout the roadcut in the marbles and in shear zones in various other rock types. Bedding is obscure near the contact at the main exposure at the south end of the cut, but becomes well-defined 20 to 30 feet into the quartzite. The quartzite also becomes cleaner and better sorted away from the contact. On the east side of the cut (Fig. 6, sample 6) the upper part of the quartzite near the contact appears to be a reworked regolith with weathered fragments of all kinds, a dirty appearance, and many voids. Thin quartzite seams occur within the main marble and in marble clasts.

4) Petrography. The cleaner, axial portion of the large quartzite body consists of moderately well-sorted quartzose sand with well-rounded, overgrown grains, with the overgrowths commonly iron-stained. A very common minor accessory, dravite, is rounded, often fractured, and similar to the dravite found in the numerous Grenville lithologies at the north end of the cut. It probably has been derived from them or from similar rocks. The sand

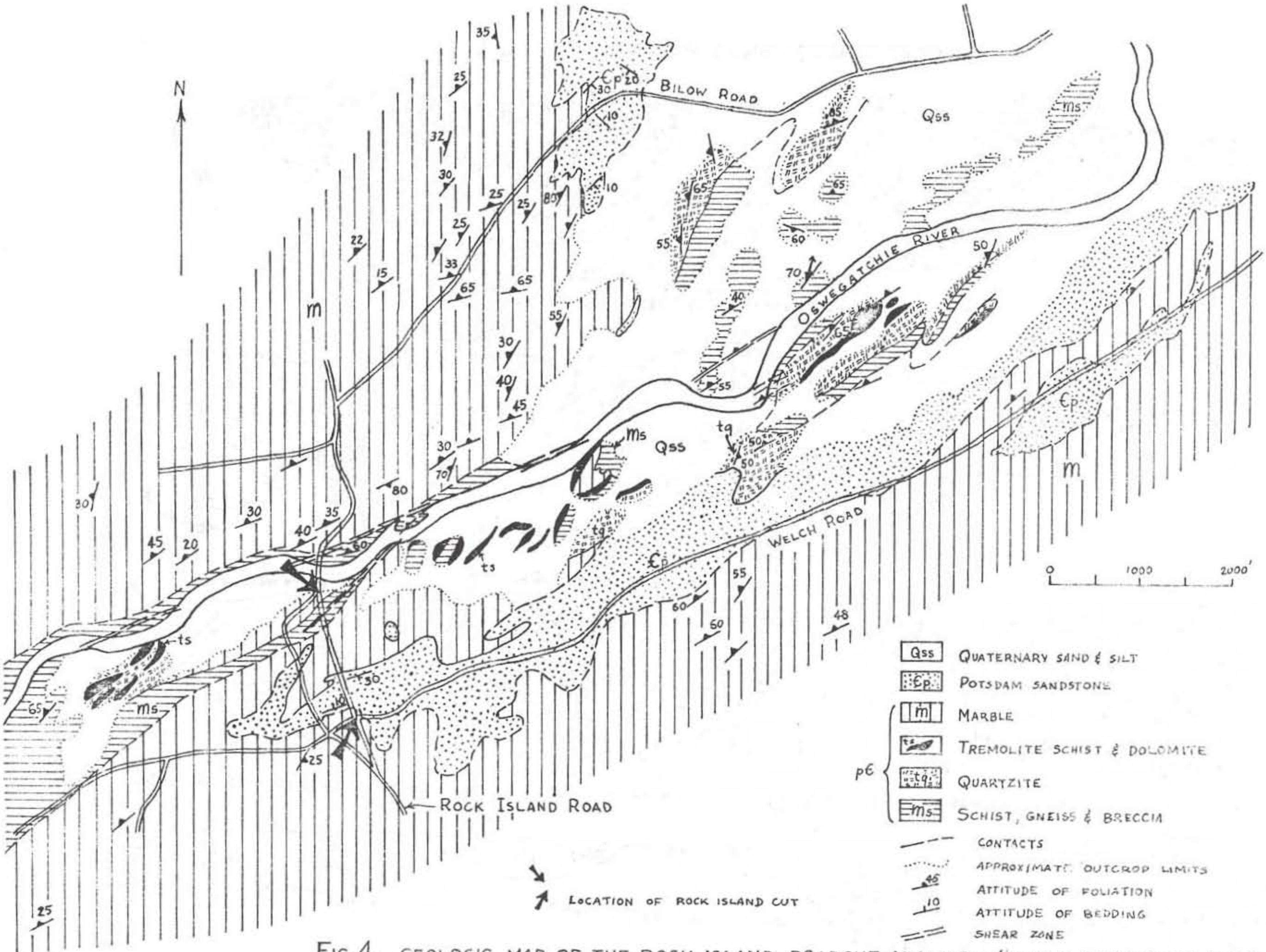


FIG. 4. GEOLOGIC MAP OF THE ROCK ISLAND ROADCUT VICINITY (AFTER BANNERMAN, 1963)

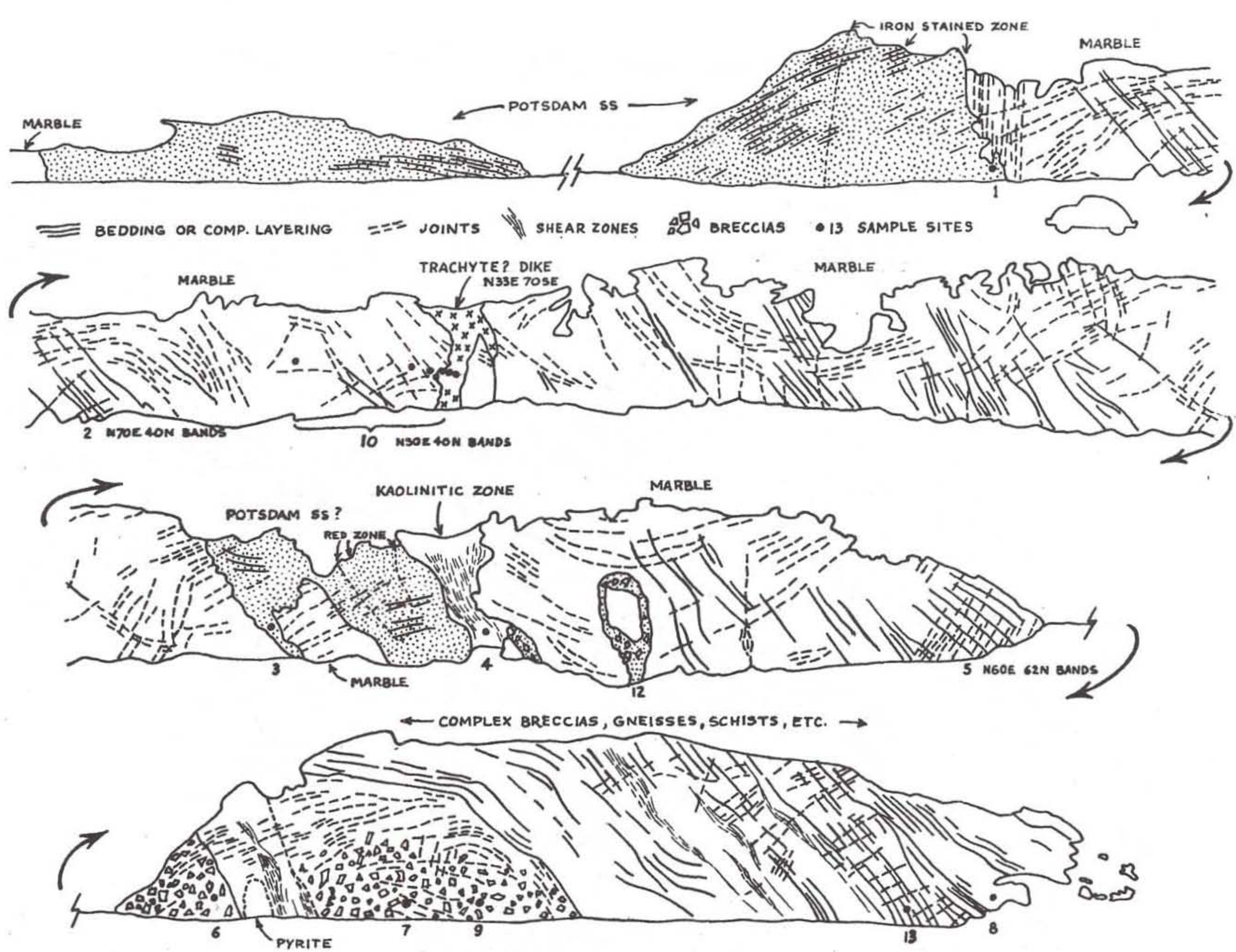


FIG. 5 ROCK ISLAND ROADCUT - WEST SIDE

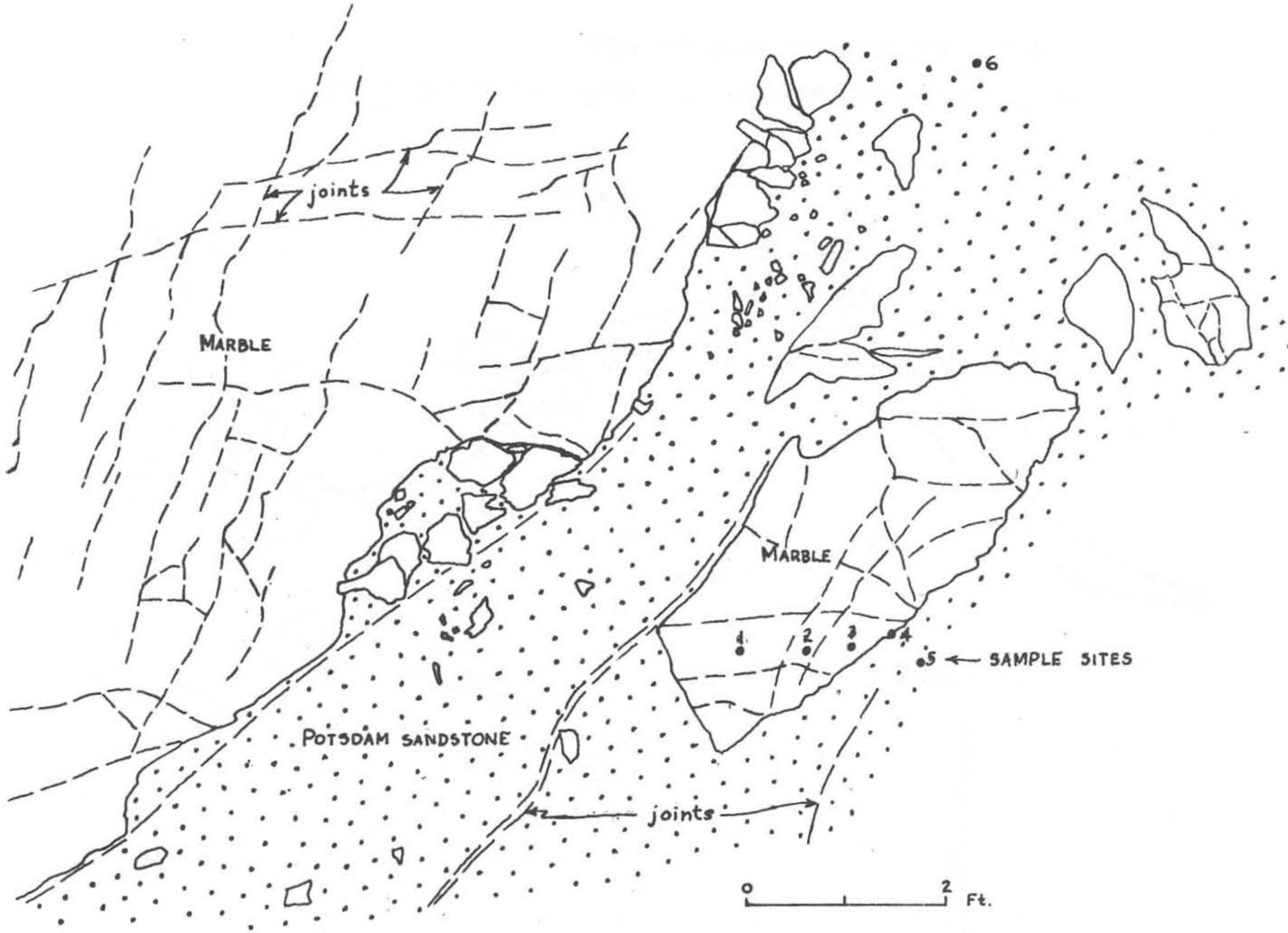


FIG. 6. DETAIL OF EAST SIDE - SOUTH END ROCK ISLAND ROADCUT

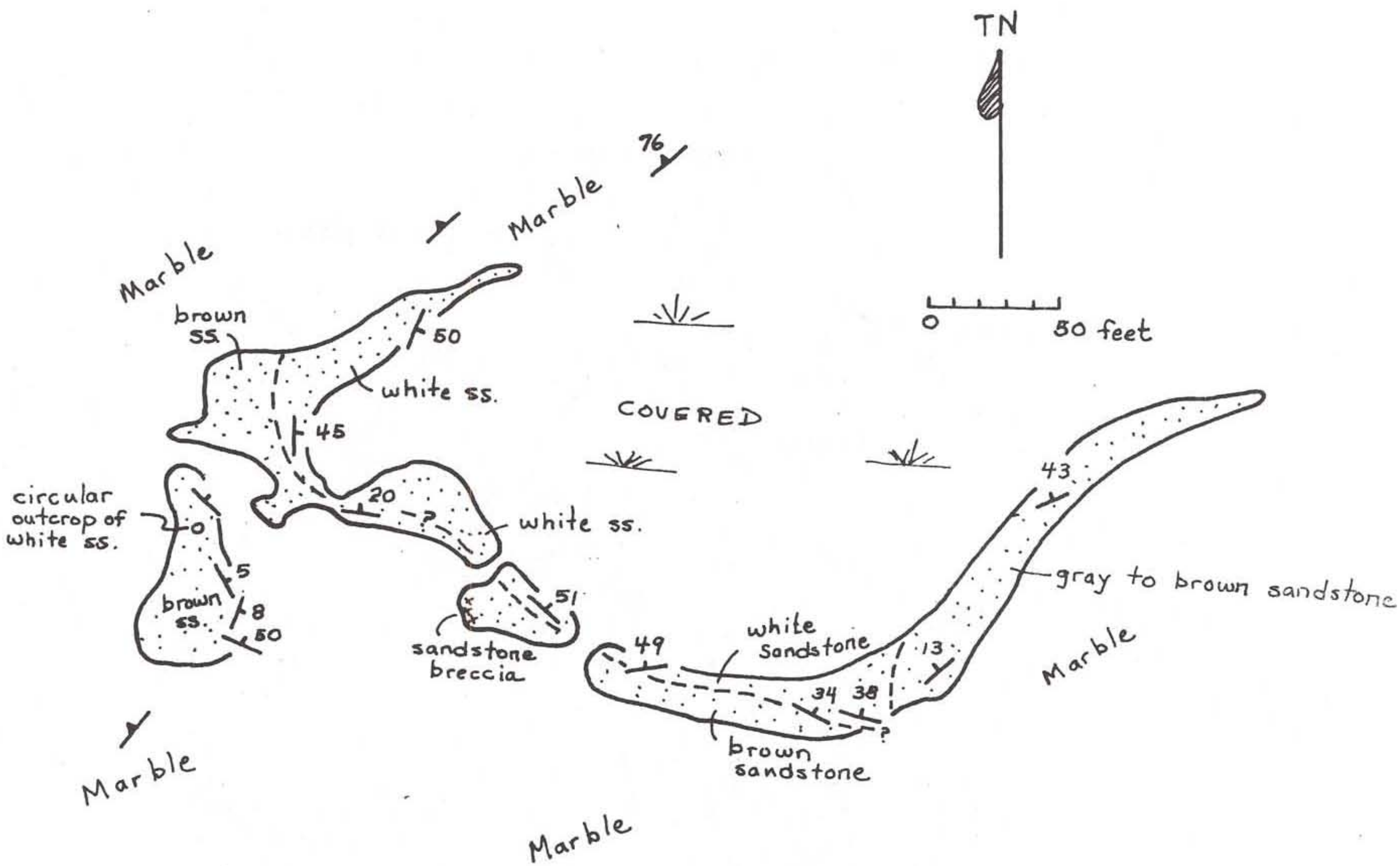


FIG. 7. Geologic Map of Potsdam Sandstone Outlier
0.25 mi. west of Rock Island cut

becomes poorly sorted near the marble contact, more iron-stained, locally pyrite-rich, and contains many fragments of Grenville rocks with crystalloblastic dravite. Calcite is a common cement for sparse, widely-spaced sand grains near the marble contact (samples 4 and 5. Fig. 6). These grains have little or no overgrowth and are partly resorbed. Such features suggest a pH fluctuation at the time of deposition or cementation of the quartzite, leading to alternate solution and deposition of calcite and quartz.

5) Conical, cylindrical or bowl-shaped structures in the quartzite. These are found in many exposures of Potsdam Sandstone north and south of the St. Lawrence River. In the Rock Island roadcut, several are exposed on the upper surface of the large quartzite body, although they are not as well defined as in some areas of northern New York (Fig. 7). It is now generally agreed that these are slump structures formed when unconsolidated sand dropped into solution cavities in the underlying marble (Dietrich, 1953).

We conclude that the large quartzite body exposed in the Rock Island roadcut, and the smaller bodies of similar lithology at stations 3 and 12 (Fig. 5) are remnants of Potsdam Sandstone. The sand was deposited in solution cavities in marble developed during erosion of the Precambrian metamorphic terrain. Marble blocks collapsed and mingled with the unconsolidated sand, and sand filtered into joint seams and smaller solutional voids, some of which appear to be post-depositional. Post-depositional solution of the marble underlying the large quartzite body probably accounts for the fairly steep (30°) inward dip of the bedding.

There has long been controversy over the origin of the many isolated quartzite bodies which occur in the Grenville complex of northern New York. The question is whether they are outliers of Cambrian Potsdam Sandstone or part of the Grenville complex itself. Certainly some are part of the Grenville, or Pre-Grenville for that matter. But the mapping of Potsdam outliers as Grenville lithologies may lead to great confusion, and the distinction is therefore a very important one. Here are some observations summarized by J. S. Brown (1967) that characterize the Potsdam Sandstone of this region.

1) The number of recognized Potsdam remnants in New York is inversely proportional to the distance from the St. Lawrence River and to the depth of the tributary valley in which the remnant is found (Fig. 2 of Trip B). The land surface is higher and the tributary valleys are deeper progressively away from the St. Lawrence River, leading to the conclusion that the Paleozoic cover has been more efficiently removed in that direction. Nearer the river, the outliers merge into large sheets covering both valleys and uplands.

2) Potsdam sandstone which overlies gneiss or granite is commonly flat-lying, white and lightly cemented. Where it overlies marble it is much more variable in attitude, color and particle size. It is generally agreed that the pre-Potsdam surface was a near-perfect peneplain where developed on gneiss, (Fig. 3,4,5, of Trip B), but was an irregular and lower surface where developed on marble.

3) Slump structures, sandstone dikes, and cavity fillings are common in

Potsdam Sandstone resting on marble. These features apparently represent post-depositional collapse of sand into underlying sinkholes prior to silicification (Dietrich 1953).

4) Bedding in the Potsdam generally truncates structures of the underlying Grenville rocks.

5) Sedimentary textures and structures are generally well-preserved because they postdate the Grenville orogeny. Metamorphic minerals in some outliers may be either, a) resistant detritals, or b) residues of solution derived from the underlying marble.

R. O. Bloomer (1965) mapped quartzite bodies in the DeKalb area which he considers to be part of the Grenville complex. His primary evidence is that they protrude down into the marbles in apparent concordant structural relationship, and contain apparently crystalloblastic dravite, phlogopite, K-feldspar, tremolite, apatite, diopside, and talc which are also found in the enclosing metamorphic rocks. The massive bodies of this quartzite, however, are not recrystallized and retain sedimentary textures. Preservation of original texture is attributed to differences in composition and competency. The flowage of adjacent rocks around the quartzite during the Grenville Orogeny was such to cushion the relatively rigid quartzites and to prevent extensive recrystallization.

<u>Trachyte(?) Dike (Fig. 5, Station 10)</u>-A dark green dike about 5 feet thick intrudes the marble in the central part of the roadcut. Thin sections were cut from seven samples located across the contact as shown in Fig. 5. Texturally the rock is fine grained, felted, and porphyritic. It is, however, almost entirely chloritized and zeolitized so that the original mineralogy cannot be determined. Phenocrysts are lath-shaped, euhedral, and the pseudomorphously preserved form and twinning is suggestive of sanidine. The rock is amygdaloidal, with amygdales primarily filled with chlorite. Color index ranges from about 5 to 25.

There is very little evidence of contact metamorphism, but there is a fine-grained, light green chill zone about one centimeter wide in places along the margins of the dike. Microscopic calcite veins are present in the dike and microscopic quartz veins occur in calcite adjacent to the contact. The distribution of tremolite, which is found in small quantities throughout the marble, appears unrelated to dike emplacement. In some parts of the contact there is a one-centimeter zone in which intrusive and marble are intimately interlayered parallel to the contact with numerous feather fractures in the dike material filled with calcite.

The dike clearly postdates the Grenville metamorphism. It was intruded in a rather viscous condition and the amygdaloidal character indicates a loss of volatile content at shallow depths of emplacement. Extensive hydrothermal alteration is indicated by chlorite and zeolite.

<u>Metamorphic complex at north end of cut (Fig. 5, stations 6-9, 13)</u>-Because of its extreme complexity, this section of Fig. 5 is presented in a lithologically schematic manner. The exposure in general, consists of rather dark-colored,

grey to purplish-brown rocks with a confusion of breccias, quartzites, gneisses, marble, albitite, a (Na)scapolitic rock, tremolite schist, and perhaps other lithologies, with northeasterly dipping foliation. In addition, the section is cut by numerous shear zones also dipping northeasterly. Additional shear zones are exposed at various localities up and down the river from here (Fig. 4). Fine-grained idioblastic dravite and some schorl(?), in measured amounts up to 25%, is common to all of the rocks examined in thin section. Two breccia sections examined by the authors contain dravite-rich, angular clasts in a murky, highly oxidized crushed-rock matrix without dravite, indicating post-metamorphic brecciation.

The breccia problem here and elsewhere along the Oswegatchie River to the northeast and southwest, however, is not so simple. The writers are indebted to H. M. Bannerman (personal communication) for the following complex analysis.

Dr. Bannerman believes there are several types and several ages of breccias, in which some of the younger breccias appear to be superimposed upon the older.

> "Many of the breccias exposed along the river in this part of the area appear to be autoclastic. The fragments in them are sharply angular and mineralogically composed of material similar to that of the matrix. Breccias of this kind are characteristically developed in, and in large measure restricted to the fine grained, dravite-bearing purplish-brown feldspar gneiss and its associated quartzites. In lateral distribution these particular breccias tend to parallel fold structures in the Grenville complex, and the brecciation is commonly accentuated along formational boundaries. Neither the mode nor the time of origin of these breccias has been precisely fixed. Conceivably they may not all have been formed in the same way or at the same time. They seem, however, to be Precambrian for at numerous points along the river breccias of this kind have been cut and re-crushed by the post-Precambrian faulting which has so profoundly affected the Grenville structures in this part of the area. In addition to these early breccias, various members of the Grenville assemblage throughout this area, superficially bear resemblance to skims and patches of fragmental rocks which I interpret as recomposed regolith. Areawise and bulkwise this type of material does not amount to much, but when imposed upon an older breccia it is both deceptive and confusing.
>
> Briefly stated, this material is made up of a hodge podge of angular to subrounded fragments of metamorphic rocks, similar to and presumably derived from the underlying formation. The matrix is a mixture of quartz and low to medium grade authigenic silicates, and sometimes calcite, an assemblage compositionally quite unlike the minerals found in the unaltered portions of the fragments or in the underlying, parent rock. As indicated, this type of structure is relatively uncommon, but when found it seems always to be at, or near the projected position of, the interface between the Precambrian erosion surface and the basal members of the Potsdam represented in this area. It seems reasonable, therefore, to believe that this particular type of breccia-like material

represents remnants of a residual soil which had been developed on the Precambrian landscape prior to the advance of the Potsdam sea.

By far the more impressive of the breccias found in the belt along the river however, are the fault breccias that are associated with and presumably born of a system of faults which, in the vicinity of Rock Island Bridge, trend northeasterly, approximately parallel to the course of the river. The breccias associated with these faults run the gamut from huge to small jumbled blocks, embedded in a crushed matrix, to crumpled fissile schists, to gouge.

The fault system, with which these structures are associated, intersect each of the Precambrian rock units that outcrop in this part of the area. The major faulting, hence the associated breccia, is Post-Precambrian in age,-though one cannot overlook the possibility that this particular zone was the scene of recurrent faulting throughout at least some of the Grenville orogeny, thus that displacements of more than one age may be represented here. But be this as it may, some of the Post-Precambrian breccia exposed in the Rock Island Bridge road cut, contain fragments of earlier formed breccia. Note, for example, the blocks of autoclastic feldspar gneiss, and thin bedded quartzite that are caught up in the shear zones exposed in the east face of the road cut, just south of the river.

Younger than any of the above mentioned types are, of course, the collapse breccias referred to in paragraph 2 of this letter. Collapse structures similar to those exposed in the Rock Island Bridge road cut are fairly common features along the margins of sandstone karst fillings all over this area. Presumably they are caused, in the main, by natural block caving, incident to solution of the marble along the walls of the sandstone, though in all likelihood this process may have been augmented by crustal readjustments following the removal of the continental glaciers.

In my judgment, therefore, the breccias along the river in the vicinity of Rock Island Bridge are the result of several different processes, imposed at widely different times, and that in some instances the current mess is the result of a recurrence of brecciation events.

And, as though this was not enough, the rock outcrops in this belt have also suffered a considerable amount of weathering subsequent to the disappearance of the glaciers. As a consequence many of the brecciated parts of the section are now heavily stained, and some are infiltrated by Pleistocene and recent sands, silts, mud, humus and what have you. All of which serves to further mask their identity, confuse the issue and make more difficult the task of unravelling the history of the breccias."

Stops 3 and 4. Hyde School alaskite body near Brasie Corners, New York.- Two stops on the Hyde alaskite body (phacolith?) will point out some important features regarding the origin of these most interesting Grenville rock features. Stop 3 will be in the folded east central part of the body near the intersection of two different directions of major folding. Amphibolite layers are isoclinally folded. Stop 4 will be at the blunt, southwest-plunging nose of the body to observe the topographic contrast between alaskite and surrounding marble solution valley. Amphibolite layers here are ruptured and only slightly displaced, and pegmatite occurs within ruptures. A short downhill walk will show an outcrop of sillimanite-garnet gneiss marginal to the alaskite.

Alaskite Bodies in the Lowlands

Introduction

At least 14 isolated bodies of dominantly alaskite rock lie scattered within the lowlands of the northwest Adirondacks (Fig. 2, only 8 of the major bodies identified). These bodies are interesting as much for structural form and surrounding rock sequence as they are for their unusual chemical composition. Together they provide a sampling of problems encountered with Grenville rocks, problems such as the origin of Grenville alaskites and gneisses (whether they are metamorphosed igneous or sedimentary rocks), the differentiation trends among recognized or presumed suites of igneous rocks, the determination and correlation of stratigraphic sequences in highly folded and metamorphosed rocks, the extent to which original rock compositions have been changed by metasomatic processes, the number and nature of deformation episodes, the origin of amphibolites, the recognition of contact metamorphism in the absence of proven igneous rocks nearby.

The most significant characteristics of the alaskite bodies remain as Buddington reported in 1929: (1) most occupy cores of major antiforms and have foliation conformable with surrounding rock units; (2) most are located within thick marble units and are surrounded by solution valleys; (3) blunt plunging ends are common, even though most of the body may be isoclinally folded; (4) mineralogy is relatively simple with microcline perthite or antiperthite, albite/oligoclase, quartz, biotite and magnetite predominant; (5) a characteristic "border facies" occurs between the alaskite and marble consisting of a trondhjemitic plagioclase-quartz gneiss with pyroxene or hornblende amphibolites and a distinctive marker unit of garnet-sillimanite gneiss; (6) thin amphibole-plagioclase-pyroxene layers (hereafter called amphibolites) occur throughout the bodies in various states of deformation.

The alaskite bodies as phacoliths

As a young geologist working for the New York State Museum in 1916, A. F. Buddington noted the peculiar structural features of the California alaskite body (Fig. 9) or "batholith" as he called it in his report. A general reconnaissance of the Grenville belt the following year showed that the California body was not unique, but that other oval-shaped granite bodies had similar structural characteristics. The occurrence of granitic rocks in crests of major folds suggested that they were phacoliths or "phacolites", a term proposed by A. Harker (1909) for a concordant minor intrusion occupying the crest or trough of a fold. Unlike a laccolith, its form is the consequence of folding and not the cause. In 1929 Buddington elaborated upon the origin and emplacement of Grenville phacoliths.

Grenville phacoliths were believed formed when magma entered low pressure zones in anticlinal crests of rocks that yielded largely by flowage. Since marble yields more readily than gneiss, most magma entered the marbles, but several were emplaced within gneisses in the southeastern part of the lowlands. Granite emplacement, thus, was thought to be contemporaneous with folding and not restricted to any particular rock horizon.

The form of the phacoliths resulted from a combination of orogenic and intrusive forces. The elongation, for example, was explained by tectonic forces acting along northwest-southeast lines. These forces overturned some phacoliths to the southeast and gave rise to extensive northeast-trending foliation. A direction of lesser stress, however, acted NNE - SSW to produce the plunge of major folds, to develop minor folds on the limbs, and to produce west-to-northwest foliation in some phacoliths. In Buddington (1929), this lesser stress field was attributed to pressure exerted by magmatic intrusion.

Partly because of the extensive interfingering of pegmatite, Buddington (1929) believed that foliation within the phacolith had developed prior to consolidation of the magma. This idea was later changed (Buddington, 1939) in favor of complete consolidation of the rocks during metamorphism so that foliation resulted from the plastic flow of solids. But over the years, workers remained impressed by the great disruption of thin amphibolite layers that lay within the alaskite. There was local discordancy in amphibolite foliation with that of the alaskite; many amphibolite layers had been fragmented and lay at angles to the alaskite foliation, and there was some penetration by pegmatite. The amphibolite appeared mechanically intruded and broken up by an alaskite magma.

The amphibolite itself was regarded as a metasomatic replacement of limestone. There is speculation in Buddington's 1929 report whether such replacement occurred by magmatic vapors, the volatile-rich fluids that escaped from a magma, or by solutions residual from crystallization of the major part of the magma. Because amphibolite layers are usually free of pegmatite or quartz, replacement occurred before intrusion and consolidation of the magma.

Similarly, the bordering rock units were interpreted as contaminated products of contact metamorphism. Bordering plagioclase-quartz gneiss units were interpreted as limestone layers metasomatically replaced by solutions or volatiles during emplacement of the magma. The garnet-sillimanite gneiss drew considerable discussion because such aluminum-rich rocks generally are regarded as metasediments. Martin (1916) regarded the gneiss as a sedimentary layer against which the Pyrites Granite had been emplaced. But the widespread occurrence of the gneiss positioned between the alaskite and marble could not be coincidental. Buddington emphasized contact metamorphism and drew upon the association of the gneiss with interlayered amphibole and pyroxene gneisses to obtain the bulk chemistry. Many such mafic units were believed assimilated when solutions rich in volatiles moved from the granite toward the border. The result was a concentration of Fe, Al, Na, Mg, Ti, etc. into the border phase with pegmatite solutions injecting, reacting and replacing many mafic layers.

The phacoliths were given regional perspective (Buddington, 1939) and made part of a successive series of igneous rocks that invaded the entire Adirondack area. He related them genetically to a series of late intrusives, chiefly granites, found in the Adirondack highlands. These granites intruded older, folded stratiform igneous sheets of the Diana, Santa Clara and Tupper-Saranac syenitic complexes, and they possess elongate domical relationships to the older syenitic rocks.

Thus, there are highland alaskites as well as lowland alaskites. The former occur chiefly as facies of hornblende granite masses and lie at or near their roofs in sheet-like form. Or, they may occur as sheets within belts of metasedimentary rocks but do not assume the phacolithic form of lowland alaskites. Hornblende granite gneiss is thought to be the parent magma from which the alaskite is differentiated.

If the hornblende granite is the parent magma for highland alaskite, it must also be the parent of the lowland phacoliths in spite of its sparse occurrence in the lowlands. The reason for this sparsity may be that the alaskite differentiate is very mobile. Pegmatites within alaskite contain tourmaline, and the highland alaskite has fluorite as an accessory mineral. These features, taken with the metamorphic aureoles that surround the phacoliths, suggest that the alaskite magma was highly charged with volatiles and invaded rocks considerably beyond its source. High mobility, thus, may explain why alaskite magma and not the normal hornblende granite found its way into metasedimentary rocks of the lowlands (Buddington and Leonard, 1962, p. 87).

The formation of alaskite and iron ore is thought to be genetically related in the Precambrian magnetite deposits of New York and New Jersey (Leonard and Buddington, 1964; Buddington, 1966). The hornblende granite gneiss is regarded as the source of emanating solutions rich in iron when differentiation produced an alaskite facies. The difference in iron content between hornblende granite gneiss and the alaskite is regarded as sufficient to account for the ore (with the addition of iron leached from the country rock).

Lowland phacoliths, thus, can be regarded as an extension of igneous activity that prevailed in the highlands. Surrounding the anorthosite core of the Adirondacks, the highlands consists of 80 to 85% igneous or equivalent orthogneiss (Buddington, 1963); the lowlands, however, consist of approximately 75% metasedimentary or migmatic sediments. Buddington's reply to Engel and Engel, 1963 (Buddington, 1963, p. 353) is seen in better perspective when he makes the following comments about a metasomatic origin for the phacoliths:

> "...if the granite phacoliths are explained as the product of replacement, independent of any magma, we are faced with a situation where the rocks of many thousands of square miles to the southeast are about 40 percent granite of magmatic origin and there is <u>none</u> in the adjoining area for 30 miles to the northwest....This <u>could</u> be if the Grenville rocks of the northwest area were all younger than those to the southeast, but there is convincing evidence that this is not true."

The alaskite bodies as metasedimentary units

In two papers, R. Dietrich (1954, 1957) interprets the Fish Creek alaskite body (Fig. 2) as defining an isoclinal synform rather than antiform. For reasons similar to those given by Buddington, he favors permissive emplacement by an alaskite magma. Amphibolites are called tabular xenoliths and the trondhjemitic border facies is described as irregular and resulting from magma contamination by calcareous country rock.

This interpretation is reversed in a later paper (Dietrich, 1963) on the basis of recognition of relict stratigraphy. Little evidence is given, but the author reports that zones of alaskitic gneiss are interlayered with rocks of such high silica content (>80%) that they are best described as feldspathic quartzites. He has second thoughts about the preservation of sheet-like xenoliths even with permissive injection of magma, and less difficulty is encountered if they are regarded as accordant layers in a rock sequence. Partial anatexis has occurred in that the alaskite has been partially mobilized. The alaskites are thought to be a sedimentary or volcanic sequence with interlayered rocks that became amphibolites.

Engel and Engel (1963) also state that relict stratigraphic sequences are present within the body. Suggestions of Dr. Robert Bloomer of St. Lawrence University that the Canton phacolith might be a reconstituted arkose or a feldspathic quartzite prompted their mapping (Engel and Engel, 1963, p. 350) of several less complicated alaskite bodies. That detailed work has not yet appeared in print, but in the 1963 paper the authors state that the form, complexity and continuity of those relict sequences are totally inconsistent with magmatic intrusion. The bodies, thus, most likely are apical projections of a basal Grenville formation originally calcareous and arkosic. The calcareous members are now replaced by amphibolite, the arkosic quartzite by granite. The central cores, however, may be partly igneous in the sense that they became mobile granitic rocks in the final stages of metamorphism. But this granite was formed by addition of alkalis, aluminum, iron, etc., to pre-existing sedimentary rock sequences and not by mechanical emplacement of magma.

Zircon studies have been suggestive. Silver (1965) made isotopic studies of U-Pb systems in zircon suites. He suggests that phacolithic granites may be recrystallized, stratified, rhyolitic volcanics that are similar in time of isotopic origin to hornblende-biotite-quartz-plagioclase gneisses from several localities in both the Adirondack highlands and lowlands. These latter gneisses are chemically appropriate as dacitic volcanics, and the time of origin for the isotope systems is 1220 ± 12 m.y.

Eckelmann (1966) studied zircon concentrates from four alaskite bodies. He reports that zircons from different outcrops and from different lithologies at a single outcrop vary greatly in quantity, elongation, average grain size, degree of faceting and mantle development. He states that such variability is expected in sedimentary sequences. Furthermore, the highly modified zircons with distinct core-mantle structures are different from the regular zonal growth patterns of igneous zircons. The large overgrowths are characteristic of rocks subjected to alkali metasomatism and support the metasedimentary-metasomatic origin proposed by Engel and Engel (1963).

Grenville Stratigraphic studies

Attempts to work out the gross stratigraphy of Northwest Adirondack Precambrian rocks may prove of great importance for interpretation of the alaskite bodies. Particularly comprehensive studies with stratigraphic columns have been carried out in the Westport, Ontario area (Wynne-Edwards, 1967) and in the Balmat-Edwards mining district (Brown and Engel, 1956). More detailed information in the latter area is held by mining companies where interest centers upon recognition of marble horizons in the search for ore.

Robert Bloomer has long regarded the alaskite as formational units and, in his stratigraphic sequence for the Canton area (Bloomer, 1969), lists interlayered alaskite, gneiss and amphibolite as a unit underlain by marble and quartzite. All formations are thought to maintain definite relationships in the Canton area, but intense folding and thickness changes make the total thickness difficult to estimate.

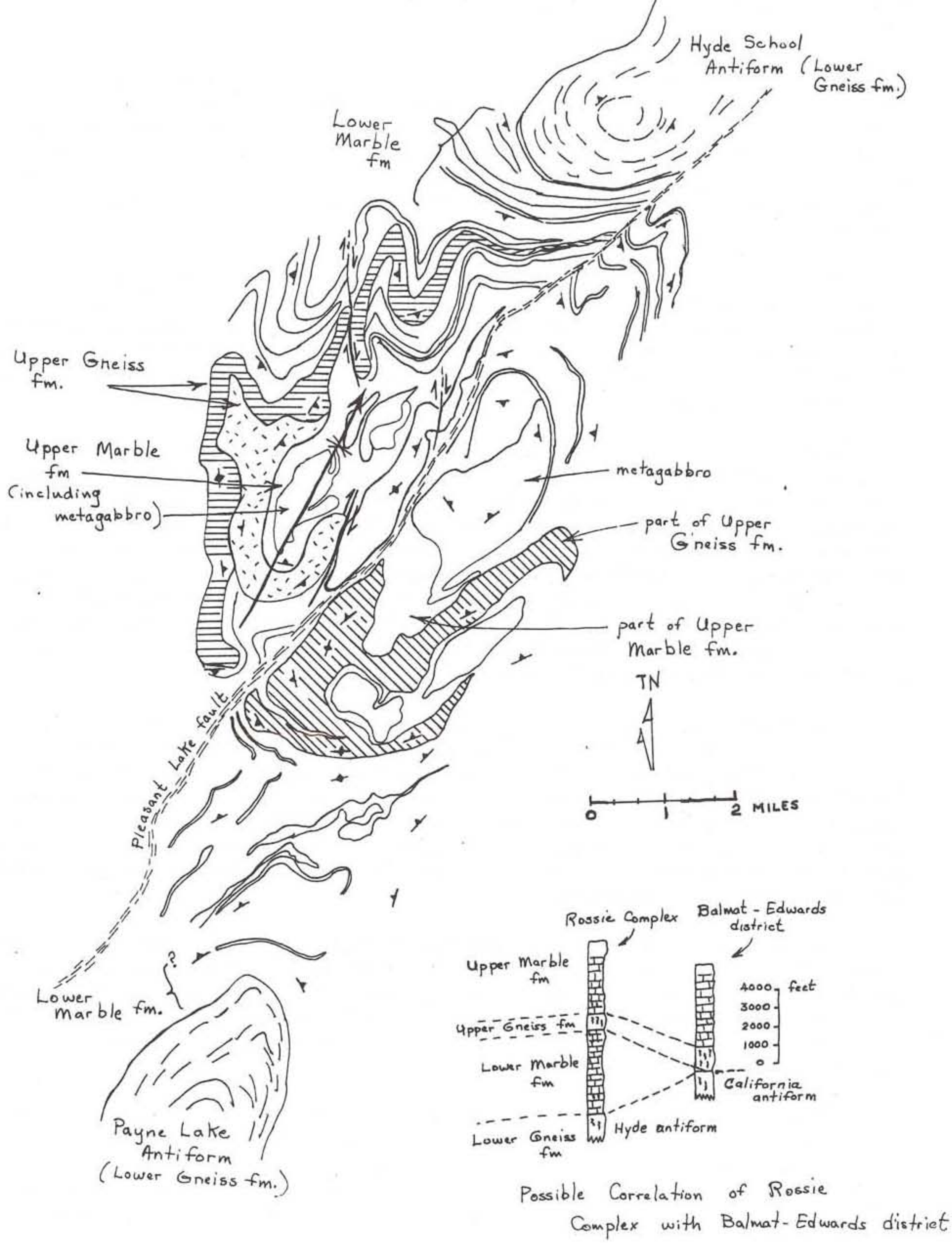
A Ph.D. dissertation by Lewis (1970) at the University of Syracuse is of particular interest in this matter. Lewis made a detailed map of Precambrian rocks (Fig.8) between the Hyde and Payne Lake antiforms. He recognizes four formations for which he proposes the term "Northwest Adirondack Group" and correlates them with the grouping of Brown and Engel (1956) in the Balmat-Edwards district. Lewis actually mapped up to 20 rock units in an attempt to document faulting. There is a general absence of large scale crushing even within major fault zones (note the Pleasant Lake fault zone that divides the map of Fig. 8), and faults are characterized chiefly by truncation of stratigraphic units on both sides.

The basal formation of Lewis' stratigraphic column is most interesting because it includes rocks that make up the inner core and outer sheath of the "phacoliths" as outlined by Engel and Engel (1963). These rocks are called the lower gneiss formation and are characterized by alaskite, biotite gneiss, amphibolites and the plagioclase gneiss "border facies". The garnet-sillimanite gneiss, however, is designated as the basal unit of the overlying Lower Marble formation. Total thickness of the four formations is estimated at ten to twelve thousand feet.

Several alaskite bodies in the field trip area, thus, are regarded by Lewis (1970) as having a common stratigraphic level which is a necessary postulate of the proposal that they represent apical projections of a basal Grenville formation. If correct, this proposal makes the alaskite an excellent stratigraphic marker upon which correlations and structural interpretations can be based.

Alaskite bodies in the southeastern part of the NW Adirondacks, however, are surrounded by paragneiss units and not by marbles, seemingly in conflict with ideas about common stratigraphic levels. Did the Clark Pond and California alaskite masses become mobilized and pierce the overlying rock units by means of diapiric folding? Were they emplaced in the stratigraphically higher

FIG. 8. Geology of the Rossie Complex
(SW of Hyde alaskite body)
Modified after Lewis (1970)



Possible Correlation of Rossie Complex with Balmat-Edwards district gneisses in this manner (Engel and Engel, 1963)? Lewis prefers an explanation in which the Lower Marble formation thins and pinches out to the southeast as a result of original patterns of sedimentation. Note the proposed correlation of stratigraphic units between the Rossie Complex (southwest of the Hyde) and the Balmat-Edwards district to the southeast (Fig. 8).

The California, Reservoir Hill and Hyde Alaskite Bodies

Introduction

Three alaskite bodies have been mapped and sampled in some detail during the summers of 1969 and 1970 by Carl, and deformation of amphibolite and alaskite is illustrated with sketches in proper location and orientation (Figs. 9, 10, and 11). The Hyde and Reservoir Hill bodies have been sampled on a grid, and petrographic and X-ray fluorescent studies are underway by Carl and Van Diver to determine relict stratigraphy by means of mineral and chemical variation.

The California body (Fig. 9) is the largest of the three. It is isoclinally folded along its eastern edge and is overturned to the southeast. The blunt northern end is indented about several major open folds, and a synform exists along the west central margin. The southern half of the California body lies on the Camp Drum Military Reservation and was not accessible for this study. The body divides into two segments further to the south (Fig. 2).

The Reservoir Hill body is isoclinally folded, overturned to the southeast, and bluntly rounded at the southwestern end with the antiform axis plunging 50° to S 60 W. It narrows to the northeast and, with surrounding garnet gneiss and marble, is folded along the east central part.

The Hyde body has the form of an elongate dome with two nodes. The nodes have nearly horizontal foliation and are separated by an open northwest synform and an area of intense isoclinal folding. Dips of foliation and amphibolite are generally low as shown by the equal area net of Fig. 11.

Foliation is essentially concordant with margins of the bodies and results from alignment of biotite and amphibole grains, usually disseminated in hand specimens but occasionally in layers to form a banded gneiss. In mafic-free alaskite, quartz grains are generally aligned, but the rock may be without foliation. Amphibolite layers in most areas give reliable attitude readings; layers vary in thickness from 1/4 inch to 8 feet and more in amphibole-pyroxene?-plagioclase gneisses.

Lineations are defined by crestal axes of small folds or by ribbing within amphibolite layers. They plunge south to southeast with major fold A on the Hyde (Fig. 11) where they are b-lineations.

Relationship between major and minor folds

Deformation of alaskite and contained amphibolites is not random but varies with location within a single body. Minor folds occur chiefly within

FIG. 9

STRUCTURES OF THE NORTH HALF OF THE CALIFORNIA BODY

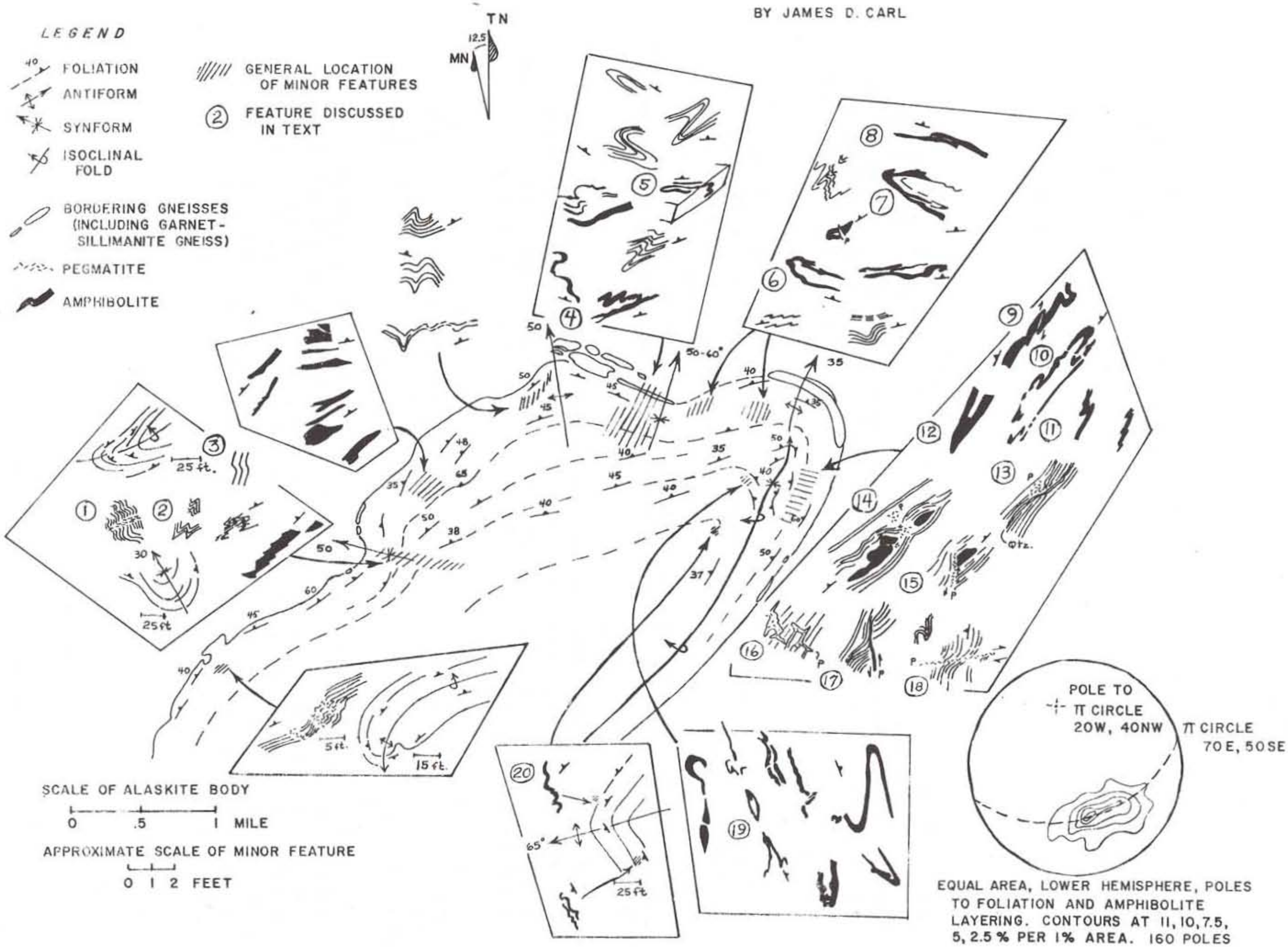
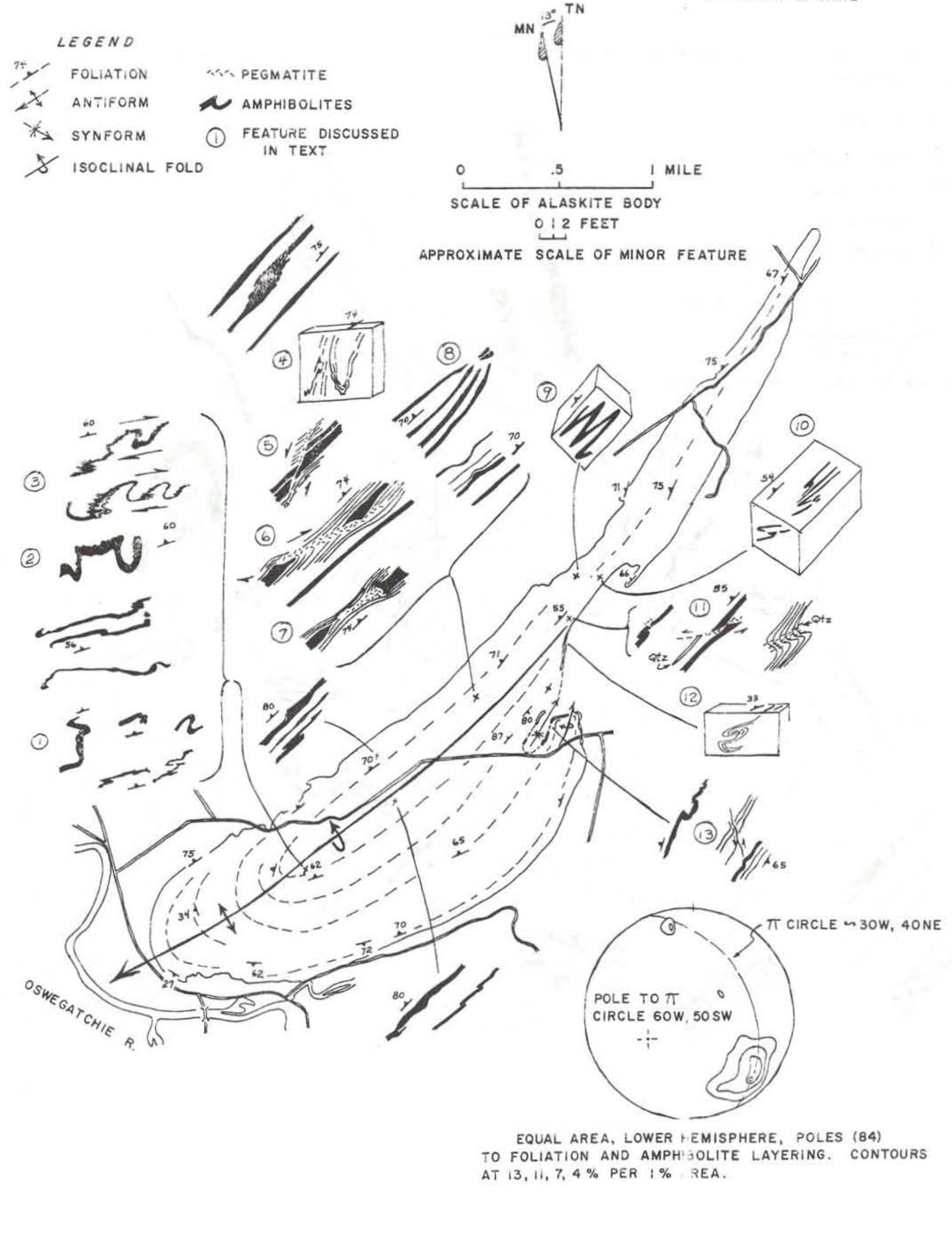


FIG. 10

STRUCTURES OF THE RESERVOIR HILL ALASKITE BODY

BY JAMES D. CARL

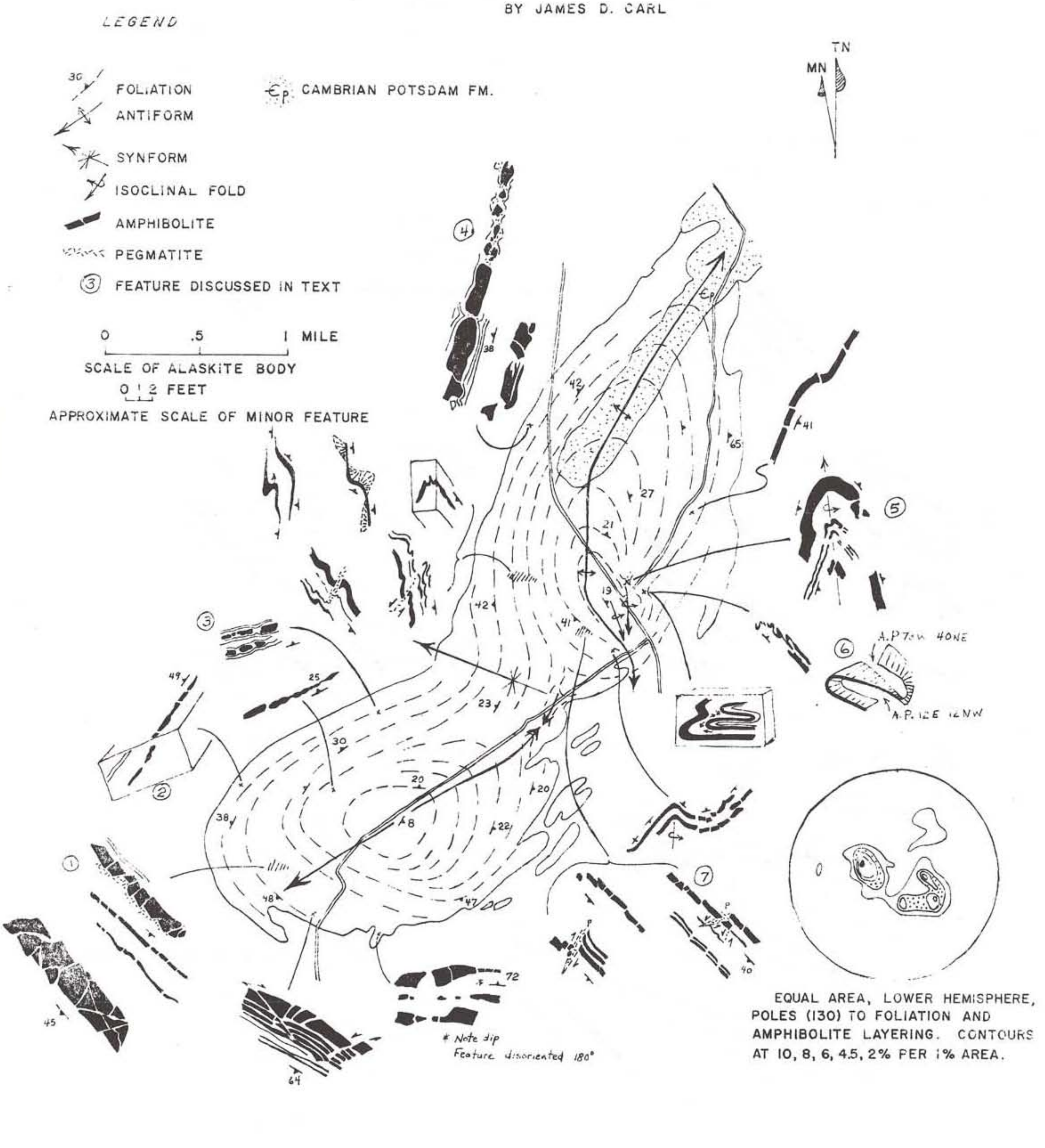


EQUAL AREA, LOWER HEMISPHERE, POLES (84) TO FOLIATION AND AMPHIBOLITE LAYERING. CONTOURS AT 13, 11, 7, 4 % PER 1 % AREA.

FIG. II

STRUCTURES OF THE HYDE ALASKITE BODY

BY JAMES D. CARL



hinge areas of major folds and can be related to large scale deformation. This relationship needs to be appreciated because single outcrops have often been cited as evidence for random folding of xenoliths or stratified units by an incoming alaskite magma.

Amphibolites along the blunt, plunging ends of the Hyde and Reservoir Hill bodies are undisturbed or fractured with segments only slightly displaced. Extension in the direction of plunge or laterally in the plane of foliation produced tension within these competent layers.

In contrast, tight, complex minor folds are confined chiefly to areas where foliation attitudes abruptly change about major fold axes. Minor isoclinal folds occur in the east central part of the Hyde, in the area of overturning of major folds in the Reservoir Hill and California bodies, and in the area surrounding the asymmetrical synform on the west side of the California body. Isoclinal folds also occur along the southwestern side of the California body suggesting that the smaller alaskite segment bordering the body (Fig. 2) is not a sill (Buddington, 1929) but a protruberance of alaskite infolded with other rock units. The blunt northern end of the California body contains isoclinal minor folds with axial planes inclined at a slight angle with the foliation. Two major open antiforms and a synform, however, indicate complexity of stress not present in plunging ends of the Hyde or Reservoir Hill. The paragneiss unit at the northern end of the California body is folded much like that of the body itself. There is little difference in fold style and orientation.

Deformation by flowage is indicated by thickening of amphibolites in the hinge areas of minor folds (with hornblende grains curved with the fold), by necking of boudinage, and by scar folds in alaskite between amphibolite boudinage. Shear is suggested by sillimanite orientation (at 90° to foliation near the synform west side of the California body), in the garnet-sillimanite border gneiss by thin fracture-fillings of pegmatite that parallel the axial planes of some minor folds, and by "smeared out" limbs of folds in the intensely folded central part of the Reservoir Hill body (Fig. 10-3). The northeastern limbs of these asymmetric minor folds are "necked" or plastically drawn out whereas the southwestern limbs appear sheared. Possibly these amphibolites have been subjected to coupling stresses.

Small scale deformational features

Experimental work on kink bands may prove useful in understanding the manner of deformation within alaskite bodies. Paterson and Weiss (1966, 1968) describe the behavior of competent quartz-rich layers that occur within incompetent phyllitic matrix that is undergoing experimental deformation. Striking similarity exists between features produced in phyllite cores and in alaskite bodies in spite of differing materials and scale (compare plates of the two papers with Figs. 9, 10 and 11). Competency is used in the sense that higher stresses existed in quartz layers than in phyllite.

When compressed in the plane of foliation, quartz layers are initially kinked with the phyllite matrix. The form of early folds is monoclinal or box-like, but kink hinges may be rounded and concentric like those in the gneiss of Fig. 9-3. With further deformation, small reverse faults appear in the quartz layers much like the ruptured amphibolites of Figs. 9-9,-11,-14.

Increasing deformation leads to chevron folding of the phyllitic matrix. Note the chevron folds in alaskite (Fig. 9-2). Folds in alaskite are commonly smaller, tighter, and tend toward disharmonic when they occur near deformed amphibolites. Planar fabric is lost adjacent to intensely folded amphibolites, possibly due to recrystallization or replacement.

Increasing deformation closes the quartz layers into more rounded folds because the difference in competency between quartz and matrix is lessened. Forms like that of Fig. 9-20 develop. Quartz layers that were oriented at a large initial angle to the plane of foliation and compression were made augen-shaped. Such features are rare in alaskite bodies.

Many deformation features of the alaskite bodies, thus, can be explained by horizontal (lateral) and vertical (inclined) movements of narrow zones (or concentric shells at blunt ends) that lay parallel to foliation. These zones may be single amphibolite layers that deformed within mobile alaskite, or for some larger features, zones several feet wide consisting of several amphibolite layers and intervening alaskite. Individual zones were compressed and subjected to tension and/or couple.

Vertical or inclined components of movement are indicated in areas where fold axial planes lie within the foliation plane. Two parallel amphibolite layers a foot or more apart may be limbs of a single isoclinal fold whose axial plane parallels the foliation. If the hinge area is unexposed or the fold axis is horizontal, the fold is apparent only in the third dimension (Figs. 9-5, 10-4,-10, -12). The northern end of the California body shows several folds of this type where axial planes lie within the north-dipping foliation plane or are inclined at a lesser angle. Isoclinal folding, thus, may be more abundant than outcrops indicated, even in apparently undeformed parts of the body.

Evidence of refolding, if present, will probably involve recognition of refolded isoclinal folds of this sort by larger isoclinal folds whose axial planes do not lie in the foliation plane. Fig. 9-19 suggests that a small isoclinal fold has undergone boudinage. Other isoclinal folds show deformation of limbs (Fig. 9-4,-6,-7).

Horizontal or lateral components of movement are indicated by boudinage and fracturing that evidently occurred simultaneous with flexuring and flowage. Lewis (1970) points to the lack of brittle deformation within major fault zones and states that faulting occurred within an environment which allowed flow mechanisms of the rock to remain operable. He suggests that the asymmetry of some major folds (Fig. 8) may be a function of movement along adjacent faults. Simultaneous rupture and flexure is indicated in the amphibolite of Fig. 10-13 where a small fault ends in a flexure. Flowage is suggested by enlarged hinge areas of amphibolites, but limbs of the same fold may also be ruptured (Fig. 9-10; 11-5). Boudinage shows both rigid and plastic behavior. Some segments are necked with re-entrants filled with pegmatite (Fig. 10-7). Others have blunted or tapered ends (Figs. 9-14; 11-3, -4) or remain angular (Fig. 11-1). Incipient boudinage is indicated in Fig. 10-8 and by "parentheses structures" [illegible] parallel to foliation of garnet-sillimanite gneiss along the east side of the California body.

Compression is indicated by overlapping of the amphibolite layer of Fig. 9-8 (upper layer only is rounded), by the piled boudins of Fig. 9-14, and by small, low-angle reverse faults of Fig. 9-9; 10-11.

Coupling is suggested by Fig. 10-3 where amphibolite appears to have undergone necking and shearing at the same time.

Pegmatite is present wherever rocks are deformed. It was mobile and available at the time of deformation and marks the path of movement of displaced rock segments (Figs. 9-15,-18; 10-5,-6). Quartz occupies a tension fracture within the foliation plane (Fig. 10-11) that was opened in response to movement along a small fault. Pegmatite was emplaced within the fault plane. Other thin quartz seams, however, are highly folded as are the adjacent amphibolites.

There is little evidence in the California body to suggest that the body evolved as a rising dome and punctured the overlying marble. Such a mechanism was suggested by Engel and Engel (1963) to account for location of the California and Clark Pond alaskites within paragneiss rather than marble. On the contrary, minor folds in the California body lie distributed about major folds in much the same manner as in the stratigraphically "correct" Hyde and Reservoir Hill bodies. Movement of the body would seemingly disrupt amphibolite layering on a large scale like that proposed for an incoming magma, and this does not appear to be the case.

Large Isoclinal Folds in the Hyde Alaskite Body

The Hyde body, like the California, Reservoir Hill and others, is isoclinally folded in spite of its elongate domical form. South to southeast-plunging isoclinal minor folds, larger than minor folds elsewhere (up to several tens of feet across), occur in the east central part of the Hyde body at the intersection of major open antiforms and a northwest synform. Most isoclinal folds lie along the northeast limbs of open fold A (Fig. 12), but clusters also occur where foliation attitudes are abruptly changed.

These minor folds are believed to define two major isoclinal folds. Note that minor fold axial planes are consistently oriented at an angle with the foliation plane east of major fold A, and that both foliation (Fig. 13) and folds (Fig. 12) define a plunging structure in spite of the apparent extension of open fold A beyond the minor fold area. Major isoclinal folds E and F are believed responsible for minor folds which occur in drag relationships.

Folding occurred chiefly by flowage of alaskite into the hinge area. Most amphibolites are flexured with little thickening of the hinge area in contrast with smaller isoclinal folds elsewhere. Thin amphibolites in the hinge area are intensely folded, but thicker layers are often segmented.

FIG. 12

MAJOR AND MINOR FOLDS, EAST CENTRAL PART OF THE HYDE ALASKITE BODY

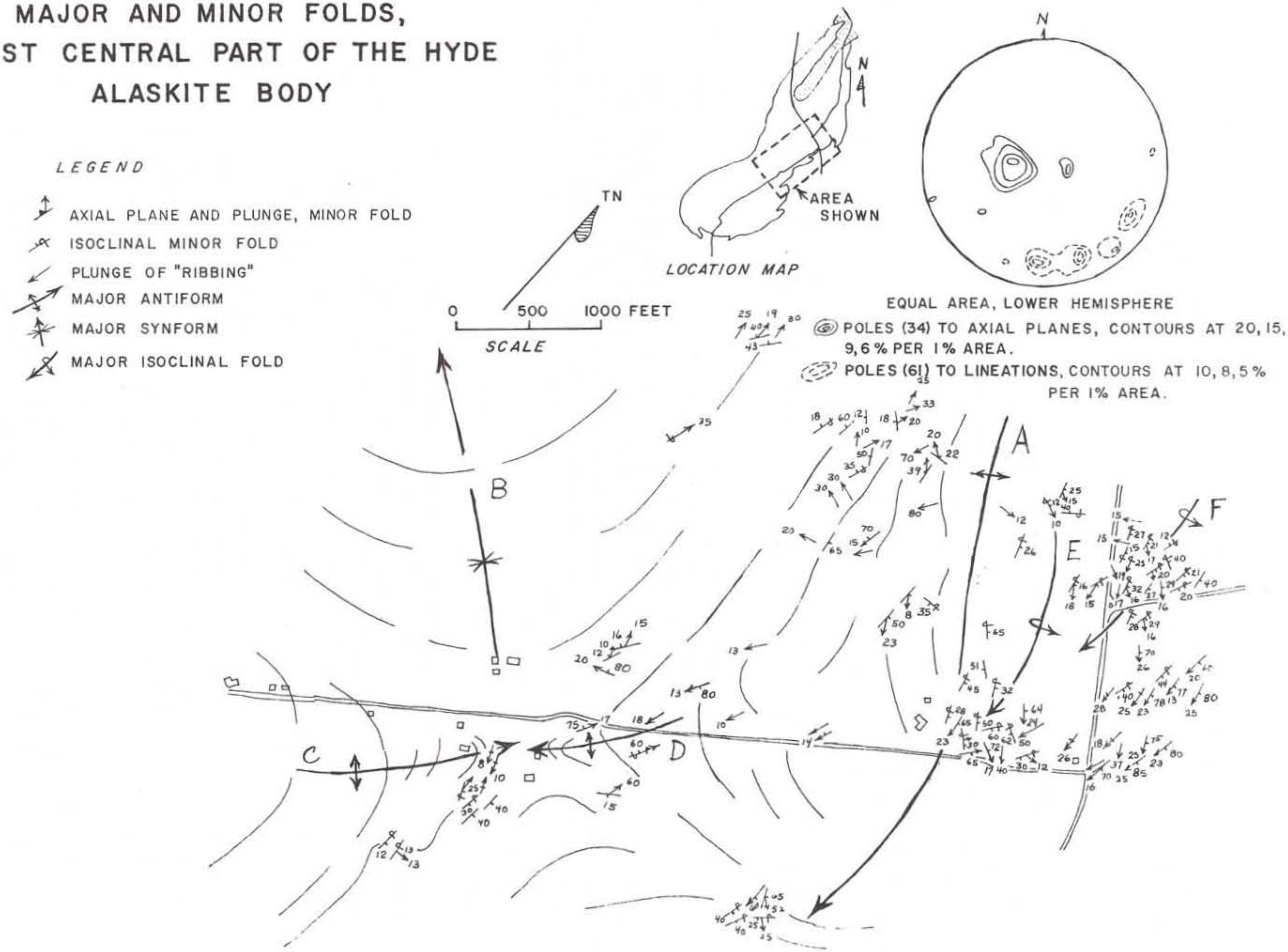
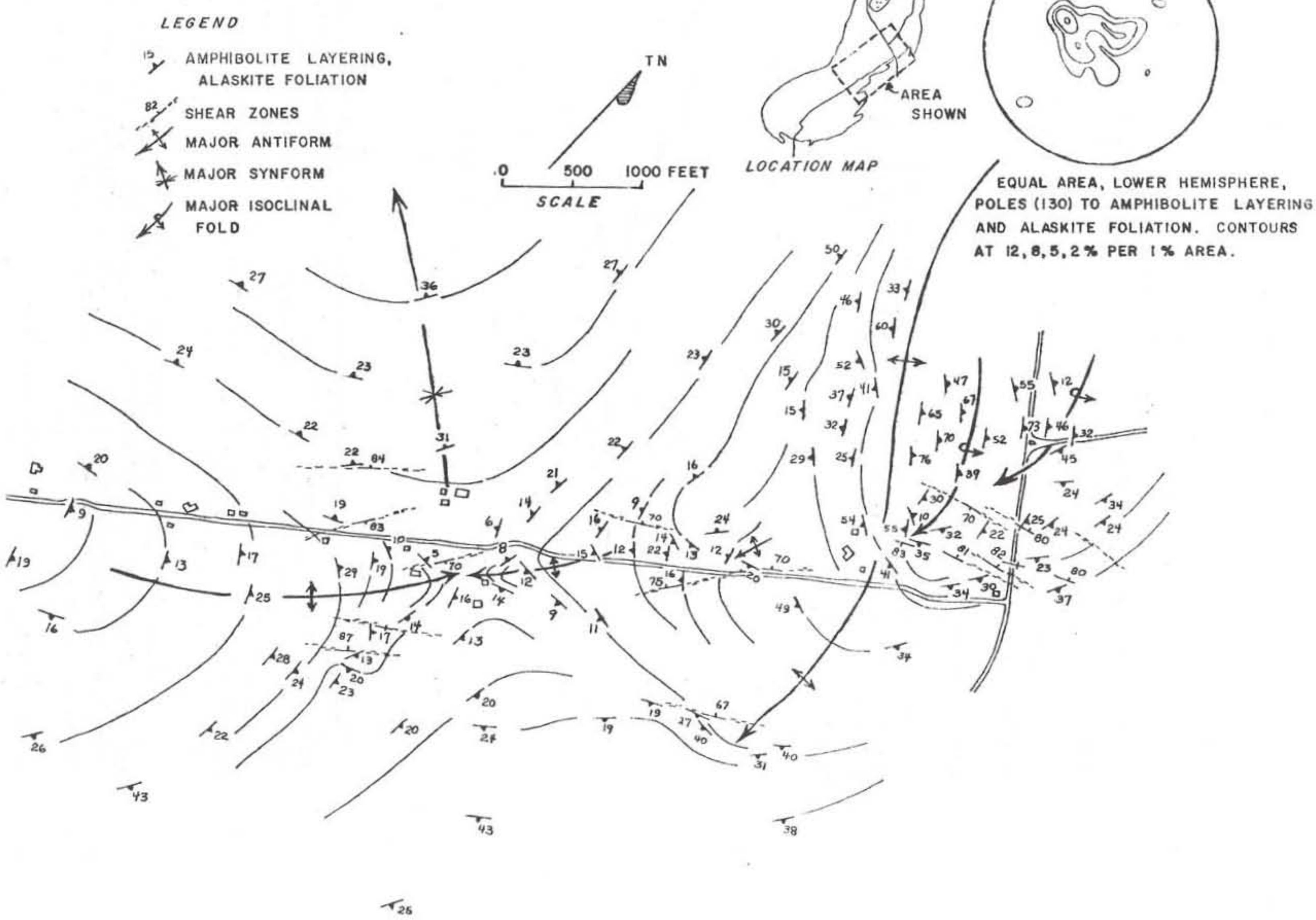


FIG. 13

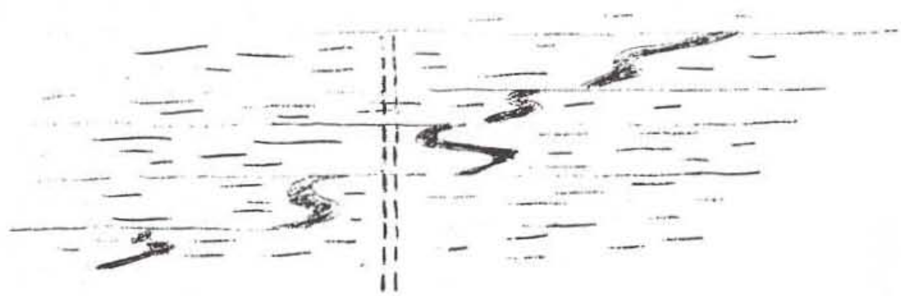
FOLIATION AND MAJOR FOLDS EAST CENTRAL PART OF THE HYDE ALASKITE BODY



Evidence of refolding is sparce and there is little suggestion of age differences among major and minor isoclinal and open folds. Axial planes of one doubly folded amphibolite layer (Fig. 11-6) are curved and variable from N 12 E, 12 NW to N 73 W, 40 NE, but such folds are uncommon. Development of the Hyde body's domical form was either accompanied by or followed by generation of a major open synform along the west side. The east side, however, was isoclinally folded.

Amphibolites as concordant layers

Most amphibolites were accordant layers such as sills or calcareous beds prior to folding. There is little resemblance to deformed amphibolites in the Vernon area of British Columbia (Jones, 1959) where layers were discordant prior to folding:



Amphibolites generally parallel foliation where isoclinally folded (where alaskite often has axial plane foliation). Even amphibolite boudinage with discordant foliation did not necessarily move as blocks floating free in the alaskite. Both amphibolite and alaskite were segmented, and foliation of the latter also is discordant with the general foliation. Pegmatite marks the path of movement (Fig. 9-15).

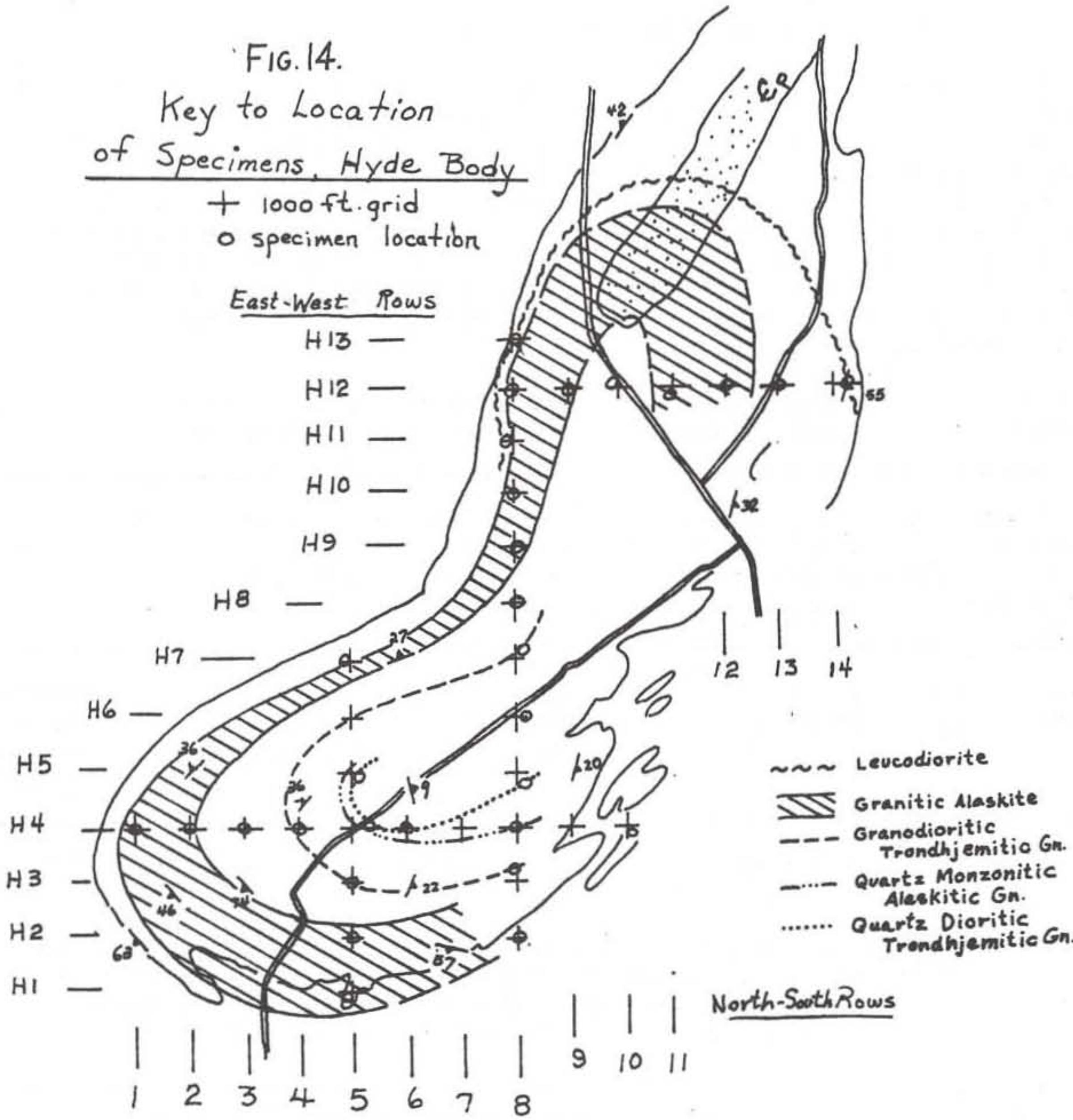
Possibly a discordant layer was folded (Fig. 10-1,-2) to give non-alignment of the layer with the general foliation trend. It is more likely, however, that the surrounding alaskite is as highly deformed as is the amphibolite, but recrystallization and intense folding have destroyed the planar fabric.

Petrography of the Hyde Alaskite Body

Preliminary petrographic studies have been made by the authors of samples collected from two east-west and two north-south traverses across the Hyde Alaskite body (Fig. 14). These are part of a sampling grid which is the basis for broader petrographic and x-ray fluorescent studies of relict stratigraphy presently in progress.

The preliminary studies indicate a fairly well-defined compositional layering

FIG. 14.
Key to Location of Specimens, Hyde Body



which approximately follows the structure contours established independently from field data (Fig. 11). The rock types observed are the following:

Granitic Alaskite (number of samples-13)
Quartz Monzonitic Alaskitic Gneiss (3)
Granodioritic Trondhjemitic Gneiss (6)
Quartz Dioritic Trondhjemitic Gneiss (3)
Oligoclasic Gneiss (80% oligoclase) (1)
Biotite Leucodioritic Gneiss (4)
Dioritic Gneiss (1)
(Classification after Peterson, 1961)

All of these rock types, with the exception of the dioritic gneiss, are leucocratic, and distinction among them is based primarily on different proportions of a small number of principle rock-forming minerals: alkalic feldspar, plagioclase, quartz and accessory biotite and hornblende. The different proportions, however, are remarkably consistent in the samples studied as are the concomitant changes in character of the alkali feldspar and anorthite-content of the plagioclase. Of particular interest are the alaskites, trondhjemites and leucodiorites because their distribution gives the best indication of mappable compositional layering. A summary of their mineralogy follows:

Granitic Alaskite	Quartz Monz. Alaskitic Gneiss	Granodioritic Trondhjemitic Gneiss	Quartz Dioritic Trondhjemitic Gneiss	Leucodiorite
50-70% stringy microperthitic or microantiperthitic microcline	35-40% cryptoperthitic or microantiperthitic microcline	10-20% cryptoperthitic orthoclase	0-10% orthoclase, slightly perthitic	0-15% orthoclase
2-15% plagioclase An_{9-14}	20-30% plagioclase An_{17-25}	50-70% plagioclase An_{17-27}	55-75% plagioclase An_{17-28}	70-80% plagioclase An_{20-29} slight zoning
25-40% quartz	20-35% quartz	10-30% quartz	15-30% quartz	0-5% quartz

Note: Distinction between microcline and orthoclase is made by optical means only. Microcline is grid-twinned and has a large $2V_\alpha$. Orthoclase appears untwinned in thin section and has a smaller $2V_\alpha$. Distinction by X-ray diffraction is in progress.

Mineralogical and textural differences, if correctly mapped, are suggestive of relict sedimentary stratigraphy. Other features which also point to a metasedimentary origin are the following:

1) Xenomorphic textures, an almost total lack of euhedral crystal forms
2) Replacement textures
3) Symplectites of biotite and quartz

4) Crystallization schistosity of biotite, hornblende and quartz
5) High quartz contents typical of many sediments but atypical of igneous rocks
6) Well-rounded and locally clustered zircons.

The authors will withhold further comment on the significance of these features until studies of the grid samples are complete.

Stop 4. Hailesboro Roadcut (Fig. 15)- Located on new section of Highway 58 near Hailesboro. This cut exposes a large section of plastically folded marble with local clusters of black, predominantly rectangular, blocks of a gabbroic rock. The striking rectangularity of the blocks and their clustering, suggest that these were tabular bodies, probably dikes, which behaved in brittle fashion during deformation of the marble. The position of the blocks indicates that they were carried along with the marble and, to some extent, rotated.

Dike blocks near the marble contact consist of about 60% diopside, 20% meionitic scapolite, with about 5% each of microcline, sphene, and tremolite, and minor biotite, quartz, opaque, tourmaline and apatite. Contact with the marble is gradational with decreasing calc-silicate minerals, increasing quartz, and increasing carbonate progressing into the marble. Low-temperature alteration is very minor, and the mineral assemblages appear well adjusted to the metamorphic conditions. Cataclastic textures are almost totally absent. The reactions suggested by the mineralogy of the contact zone are:

$$\underset{\text{Anorthite}}{3\ Ca\ Al_2Si_2\ O_8} + \underset{\text{Calcite}}{CaCO_3} \rightarrow \underset{\text{Meionite}}{Ca_4\ Al_6\ Si_6\ O_{24}\ CO_3}$$

and, calcite + biotite → Microcline + diopside + CO_2 + H_2O

There is no plagioclase in the contact zones of the dike rocks examined, presumably because it has been completely replaced by meionite and by-products.

The observed characteristics indicate that the dike was either pre- or synmetamorphic, and there has been sufficient post-deformational recrystallization for complete mineralogical adjustment between the dike blocks and the marble.

Stop 5. Migmatitic Quartz-biotite-oligoclase Paragneiss (Fig. 16)- Located in a long roadcut through Poplar Hill on a new section of Highway 58 about one mile northwest of Fowler, New York. This cut exposes the migmatitic phase of the quartz-biotite-oligoclase paragneiss which in all its phases, comprises one of the second most abundant metasedimentary rock types in the Grenville series (second to the marble-see Fig.2). In general, the Grenville meta-sedimentary stratigraphic section consists approximately of 8000' of basal marble, overlain by 3000' of paragneiss, overlain by 4000' of marble with feldspathic quartzite near its top. The paragneiss has been studied in detail by Engel and Engel (1953). The exposure lies on the northwest side of the Sylvia Lake-Edwards syncline just north of a large body of Hermon-type porphyritic or porphyroblastic granitic gneiss (Brown and Engel, 1956,Fig. 1).

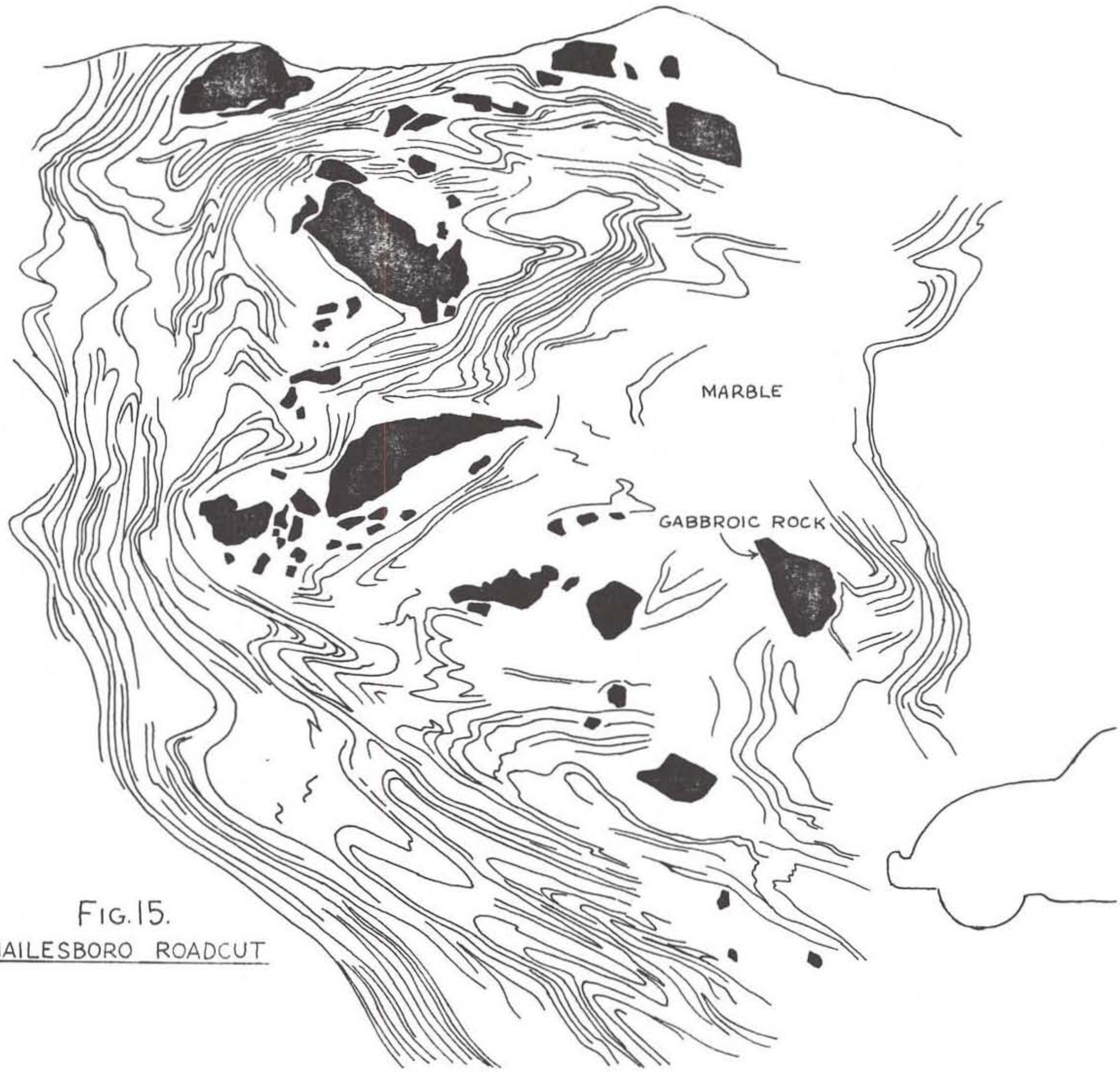


FIG. 15.
HAILESBORO ROADCUT

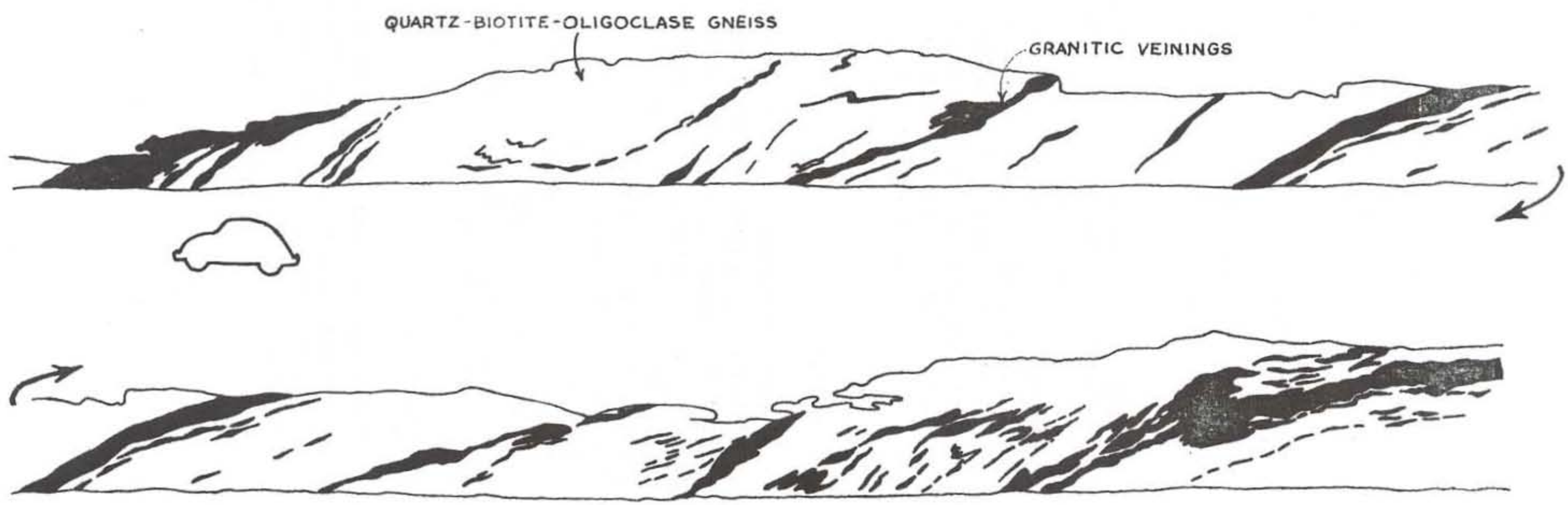


FIG.16. MIGMATITE ROADCUT

Description

The paragneiss here consists of a fine-grained grey-brown gneiss with variable foliation, and with extensive lit-par-lit granitic veining. The veins vary from a few millimeters to several feet wide and those which parallel the foliation are extensively boudinaged. Transverse veins, especially thin ones, form intricate ptygmatic folds which apparently result from the combined effects of flowage, shear folding, compaction, and recrystallization. The veins are coarse-grained to pegmatitic, and white to red in color with the thicker veins commonly having white borders with red cores.

The average mineral composition of the presumably isochemical phases of this unit, here and elsewhere in northwestern New York, consists of about 40% quartz, 39% plagioclase (An_{25-35}), 1% K-feldspar, and 17% green-brown biotite (Engel and Engel, 1953). Garnet is locally present at this outcrop, especially adjacent to granitic veins. Elsewhere the unit contains sillimanite. The veinous granite primarily consists of coarse-grained K-feldspar and quartz with variable but generally small amounts of highly-sericitized plagioclase and red-brown biotite. Replacement textures, especially of K-feldspar after green-brown biotite, are exceedingly common along vein margins.

Origin

The composition of presumed isochemical phases of the quartz-biotite-oligoclase paragneiss is closest to that of a graywacke (Engel and Engel, 1953). The formational environment of a graywacke, however, is one of minimal weathering with rapid transport and deposition, and this is anathema to the environment demanded by thick sections of thin-bedded persistent marbles and clean quartzites which lie conformably above and below the paragneiss. Shale is the more compatible sediment, but the paragneiss has an unusually high $Na_2O:K_2O$ ratio (1:3) not found in normal shales ($Na_2O:K_2O$ typically about 0.4). A mode of origin suggested by Engel and Engel (1953) is one in which shale is chemically modified, either during deposition or diagenetically, so as to yield the relatively high Na-content, perhaps by interaction with salty Precambrian seawater.

Feldspathization

Presumed isochemical phases of the quartz-biotite-oligoclase paragneiss throughout the northwest Adirondacks typically lie in areas farthest from large bodies of alaskitic granite of the Hermon type (a type transitional to Hermon gneiss). Furthermore, all gradations appear to exist from the isochemical phase to veinous migmatites to Hermon gneiss to Hermon-type alaskite. The migmatitic phase exposed in the Poplar Hill roadcut characterizes the incipiently to moderately feldspathized and injected gneiss. The Hermon-type inequigranular gneiss which appears to represent a more extensively feldspathized phase, occurs in numerous large and small bodies within the paragneiss (Fig. 2). It typically contains large, often sieved, euhedral to subhedral grains of microcline.

The Hermon-type alaskitic end-member, an exposure of which may be found near Hyatt, N.Y., is relatively equigranular and directionless.

These features suggest progressive granitization of the paragneiss. Mineralogically, the progression involves a marked increase in K-feldspar, largely at the expense of biotite, and an increase in the albite-content of plagioclase without much change in plagioclase mode. Quartz also appears to decrease slightly, but not linearly.

One of the most significant chemical aspects of the progression is the change in the Na_2O/K_2O ratio from 1.3 to less than 1.

Stop 7. Edwards Roadcut- Brief stop if time permits. This roadcut is well known to mineral collectors in St. Lawrence County for green diopside, calcite of several colors, phlogopite, actinolite, apatite, molybdenite, pyrite and other sulfides and K-feldspar crystals.

This Irish green roadcut intersects one of several diopsidic marble units that are interlayered with feldspathic gneisses to the northwest of the outcrop face. These units are less than 100 feet thick with attitudes approximating N 50 E, 50 NW.

An outstanding feature here is the great quantity of green diopside, particularly in the form of coarse, well-parted crystals that extend into calcite veins. Contrast the occurrence of diopside here with that of Stop 1 southwest of Canton where the diopside is granular, disseminated within the marble, and partially a product of the reaction between marble and intrafolded silicic rock layers.

The outcrop consists chiefly of diopside except at the eastern edge of the roadcut where phlogopite-bearing marble with faint foliation can be seen. Megascopically, the diopside assumes several forms: (1) granular, green masses exclusive of marble, yet cut with calcite veinlets and with fine-grained, faintly foliated mica, (2) clusters or vein-like bladed diopside within granular diopside, and (3) large, parted crystals in the larger calcite veins typically oriented perpendicular to vein walls and surrounded more or less by gray calcite. Molybdenite, pyrite, phlogopite and apatite occur between diopside crystals. One molybdenite crystal collected here was 2 x 4 cm. in diameter and 2 mm. thick.

Diopside crystals measuring 2 feet 8 inches across in coarsely crystalline pink calcite masses were found with apatite and pyritohedral pyrite during road construction. Apatite crystals, 2 x 1/2 inches and doubly terminated with hexagonal bipyramids have also been reported in pink calcite.

Veins appear to be joint fillings by mobilized calcite accompanied by recrystallization of diopsidic host rock adjacent to the vein. Growth of crystals from the joint plane outward into the host rock is suggested in one vein. Note the vein with a sharp planar contact against granular diopsidic rock on one side (evidently the joint plane), and an irregular contact on the other side where coarse diopside crystals extend into the granular variety. In other veins, coarse diopside crystals extend only part way into the calcite matrix, and direction of growth appears to be inward toward the vein. Other diopside crystals are reported enclosed by marble with no apparent point of attachment.

Large diopside crystals show development of basal parting much better than cleavage, particularly where crystals extend into calcite matrix. Parting lamellae are generally of uniform thickness (about 2 mm) but may be wedge-shaped where crystals are bent (Fig. 17). Other crystals show lengthwise "feather" type parting, dividing the crystal into two unequal segments (Fig. 17). Broadly curved, concentrically parted segments are present in thicker diopside crystals.

Calcite is coarse, well cleaved, and shows pronounced color change from gray at vein margins in contact with diopside to pink toward the center of the vein. Gray calcite (by x-ray analysis) borders the larger diopside crystals (Fig. 17) and accentuates the margins of small veins. Bright orange calcite occurs on the hill behind the roadcut. It may occur as blotches of coarsely crystalline grains in a finer, lighter colored marble.

The hydrous minerals phlogopite and actinolite represent the more mobile, fluidized portion of vein filling. They are particularly abundant in the smaller veins or seams in granular diopside. Veins of calcite-phlogopite-pyrite-molybdenite (and other sulfides) extend outward from the larger joint fillings, and are usually devoid of diopside crystals. These veins contain phlogopite and pyrite which typically crowd the vein margins. Where the vein tapers to a thin seam, phlogopite is particularly abundant and the granular diopside host may be slightly discolored and impregnated with pyrite. Within the veins, pyrite is intergrown and often rimmed with an unidentified black metallic mineral. These smaller veins also have pink calcite cores and gray calcite margins.

Emplacement of hydrous minerals seems localized by foliation planes or tight joints. Actinolite occurs in clots or lenses, seemingly replacing the granular diopside host rock, but in crude alignment with the foliation. Or, the actinolite may occur as clots along calcite-phlogopite veinlets like knots in a rope. These clots vary from 1/2 to 2 inches in diameter and commonly consist of stubby, green, glassy actinolite crystals, phlogopite and pyrite. Coarse crystals of diopside, and perthitic K-feldspar (microcline?) occur several hundred feet northwest of the roadcut. The diopside and K-feldspar occur in aggregates enclosed by marble. Crystals often penetrate each other suggesting simultaneous growth of K-feldspar and diopside.

BIBLIOGRAPHY

Bannerman, H. M., 1963, Preliminary geologic map of strip along the Oswegatchie River from Little Bow to Richville, St. Lawrence Co., N.Y., U.S. Geol. Surv. open file map.

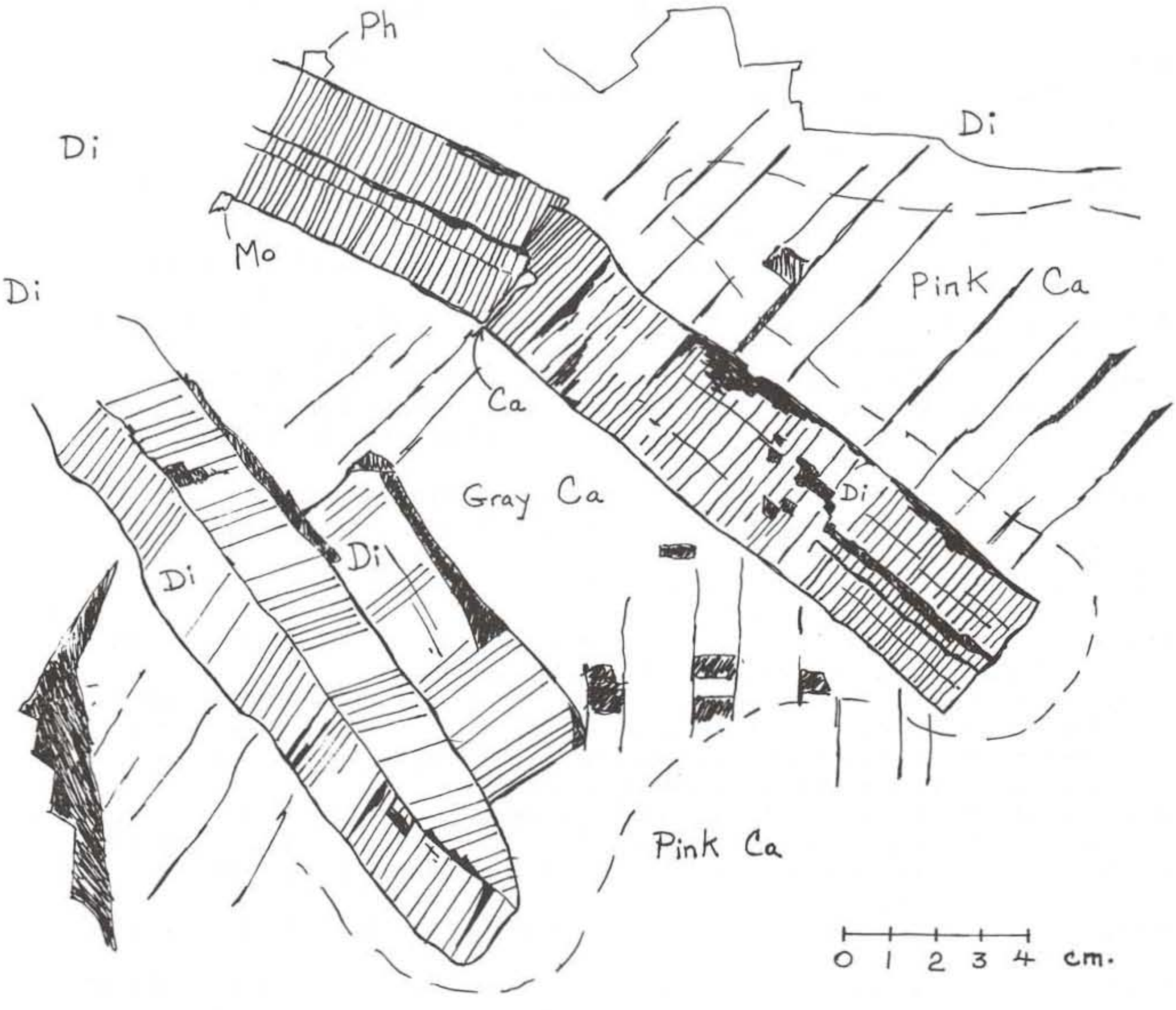
Bloomer, R. O., 1965, Precambrian Grenville or Paleozoic quartzite in the DeKalb area in northern New York, Geol. Soc. Amer. Bull., v. 76, p. 1015-1025.

Bloomer, R. O., 1967, Precambrian Grenville or Paleozoic quartzite in the DeKalb area in northern New York, Reply, Geol. Soc. Am. Bull., v. 78, p. 931.

Bloomer, R. O., 1969, Garnets in various rock types in the Canton area in northern New York, Annals of the New York Acad. of Science, v. 172, art. 3, p. 31-48.

Broughton, J. G., Fisher, D. W., Isachsen, Y. W., Rickard, L. V., Offield, T.W., 1962, Geologic map of New York, Adirondack Sheet, N.Y. St. Mus. and Sci. Serv., Geologic Survey.

Figure 17 Stop 7 near Edwards, N.Y.



Basal parting in diopside crystals that extend into calcite veins.

Ca = calcite Di = diopside

Mo = molybdenite Ph = phlogopite

Brown, J. S., 1967, Precambrian Grenville or Paleozoic quartzite in the DeKalb area in northern New York: Discussion, Geol. Soc. Am. Bull, v. 78, p. 921-930.

Brown, J. S. and Engel, A. E. J., 1956, Revision of Grenville stratigraphy and structure in the Balmat-Edwards District, Northwest Adirondacks, New York, Geol. Soc. Am. Bull., v. 67, p. 1599-1622.

Buddington, A. F., 1929, Granite phacoliths and their contact zones in the Northwest Adirondacks, New York State Museum Bull. 281, p. 51-107.

Buddington, A. F., 1939, Adirondack igneous rocks and their metamorphism, Geol. Soc. Am. Memoir 7., 354 p.

Buddington, A. F., and Leonard, B. F., 1962, Regional geology of the St. Lawrence County magnetite district, Northwest Adirondacks, New York: U. S. Geol. Surv. Prof. Paper 376, 145 p.

Buddington, A. F., 1963, Metasomatic origin of large parts of the Adirondack phacoliths: a discussion, Geol. Soc. of Am. Bull., v. 74, p. 353.

Buddington, A. F., 1966, The Precambrian magnetite deposits of New York and New Jersey, Economic Geology, v. 61, no. 3, p. 484-510.

Dietrich, R. V., 1953, Conical and cylindrical structures in the Potsdam sandstone, Redwood, New York, New York State Museum circular 34, 19 p.

Dietrich, R. V., 1954, Fish Creek phacolith, Northwestern New York, Am. Jour. Sci., v. 252, p. 513-531.

Dietrich, R. V., 1957, Precambrian geology and mineral resources of the Brier Hill quadrangle, New York, New York State Museum and Science Service Bull. 354, 121 p.

Dietrich, R. V., 1963, Banded gneisses of eight localities, Norsk Geologisk Tidsskrift, v. 43, p. 89-119.

Eckelmann, F. Donald, 1966, Zircon paragenesis studies in metamorphic rock, The Empire State Geogram, vol. 4, no. 3, p. 1-6.

Engel, A. E. J., and Engel, C. G., 1953, Grenville series in the northwest Adirondack Mountains, New York, pt. 1-General features of the Grenville series, pt. 2-Origin and metamorphism of the major paragneiss, Geol. Soc. Am. Bull., v. 64, p. 1013-1048, 1049-1098.

Engel, A. E. J., and Engel, C. G., 1963, Metasomatic origin of large parts of the Adirondack phacoliths, Geol. Soc. Am. Bull., v. 74, p. 349-352.

Harker, Alfred, 1909, The natural history of igneous rocks, New York, MacMillan, 384 p.

Jones, A. G., 1959, Vernon map-area, British Columbia, Geol. Surv. Canada, Memoir 296.

Leonard, B. F., and Buddington, A. F., 1964, Ore deposits of the St. Lawrence County magnetite district, Northwest Adirondacks, New York, U. S. Geol. Survey Professional Paper 377, 259 p.

Lewis, J. R., 1970, Structure and stratigraphy of the Rossie Complex, Northwest Adirondacks, New York, Syracuse University Ph.D. thesis, 136 p.

Martin, J. C., 1916, The Precambrian rocks of the Canton quadrangle, New York State Museum Bull. 185, p. 1-112.

Paterson, M. S., and Weiss, L. E., 1966, Experimental deformation and folding in phyllite, Geol. Soc. Am. Bull., v. 77, p. 343-374.

Paterson, M. S., and Weiss, L. E., 1968, Folding and boudinage of quartz-rich layers in experimentally deformed phyllite, Geol. Soc. Am. Bull., v. 79, p. 795-812.

Peterson, D. W., 1961, Descriptive modal classification of igneous rocks, AGI Data Sheet 23, Geotimes, v. V, No. 6, p. 30-36.

Silver, L. T., 1965, Isotopic data in zircons of the Grenville series of the Adirondack Mountains, New York, Transactions of the Amer. Geophys. Union, v. 46, no. 1, p. 164.

Wynne-Edwards, H. R., 1967, Westport map-area, Ontario, with special emphasis on the Precambrian rocks, Geol. Surv. Canada Mem. 346, 142 p.

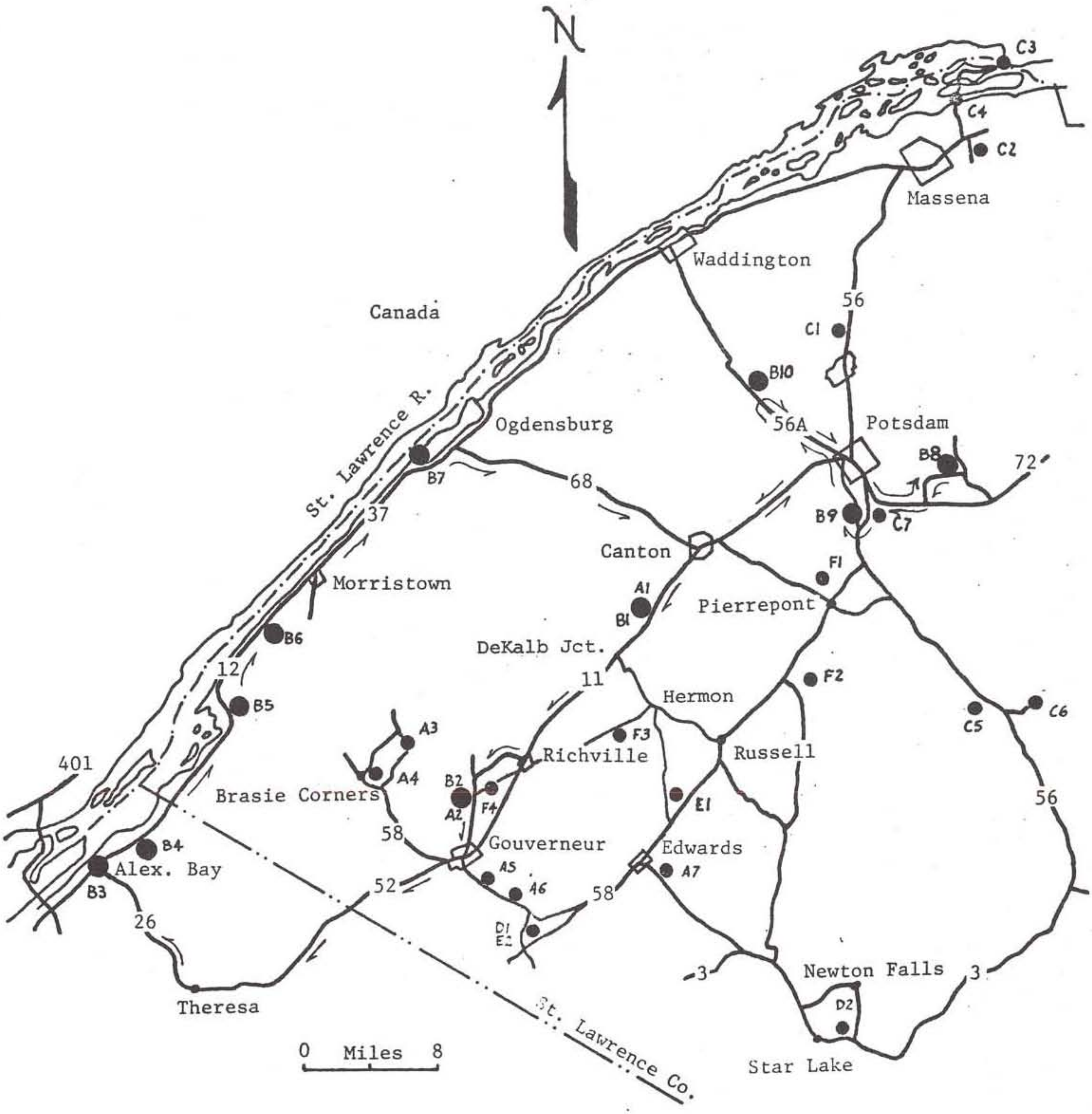


Figure 1. STOP MAY FOR TRIP B

Large dots indicate stops for this trip and arrows show route.
Stops for other trips in guidebook are indicated by smaller dots.