GEOLOGICAL STUDIES OF THE NORTHWEST ADIRONDACKS REGION

FIELD TRIP GUIDE BOOK

43rd
ANNUAL MEETING
Potsdam, New York
May 7, 8, 9, 1971

THE NEW YORK STATE GEOLOGICAL ASSOCIATION

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Field Trip Guidebook

43rd Annual Meeting

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Editor

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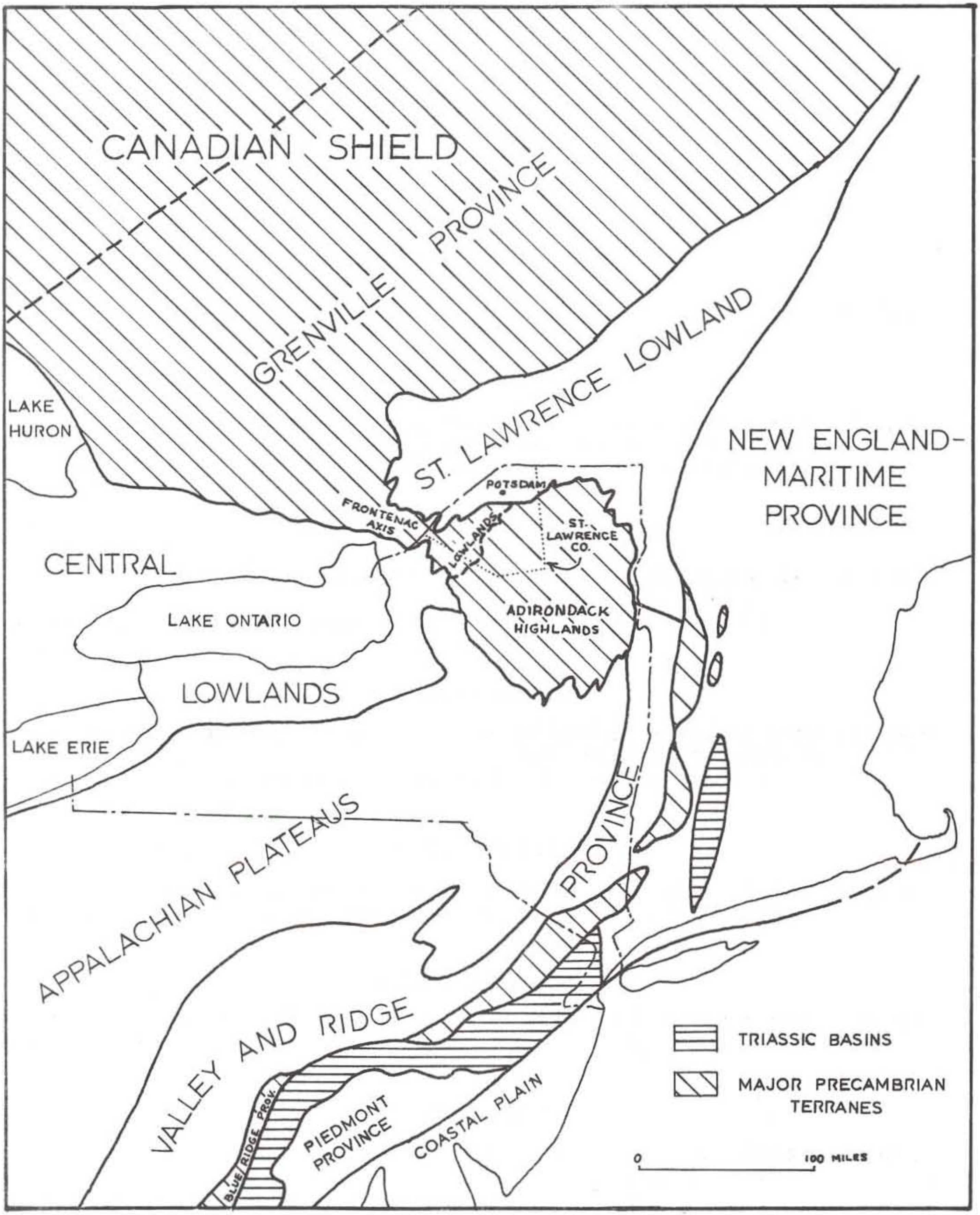

Fig. 1 (Editor's Preface). Location map for Northwest Adirondacks region relative to major physiographic and tectonic provinces. Field trips principally will be in Adirondack Lowlands, the St. Lawrence Lowland and the Frontenac Axis. (Adapted from Broughton et. al. 1962).

PREFACE

On behalf of the Department of Geological Sciences of the State University of New York, College at Potsdam, I extend a most cordial welcome to all participants in the 43rd annual meeting of the New York State Geological Association.

The area to be covered by the six field trips of this guidebook lies in the northwestern part of New York State approximately enclosed by the St. Lawrence River and a line from Alexandria Bay to Gouverneur to Edwards to South Colton to Massena. The area lies entirely within St. Lawrence County with the exception of a small portion of Jefferson County. Regional physiographic and tectonic location is shown in Figure 1 of this Preface. Field trips are principally in the Adirondack Lowlands, the St. Lawrence Lowland and the Frontenac Axis. Major observable rock assemblages of the area are shown in the form of a generalized stratigraphic column in Figure 2. The column may help to orient the visitor to the Northwest Adirondack region.

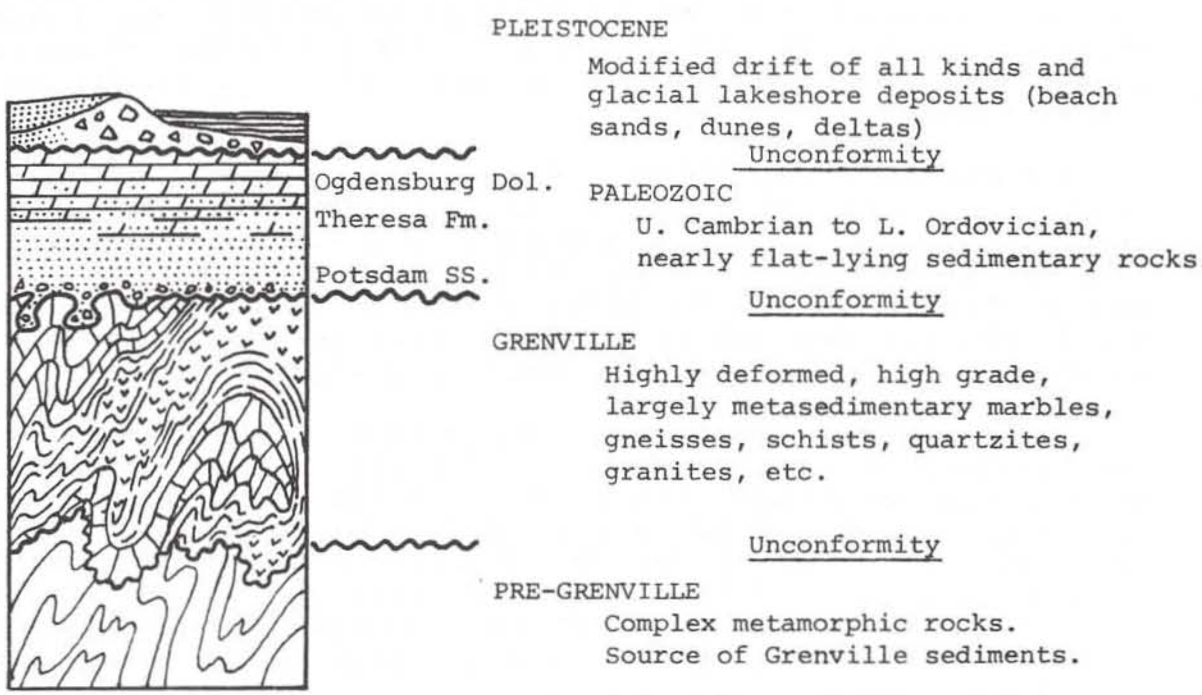

Fig. 2 (Editor's Preface): Generalized stratigraphic column for the Northwest Adirondacks region. Adapted from Walton and DeWaard (1963), Bloomer and Elberty (1967), and MacClintock and Stewart (1965).

The Adirondack Mountains as a whole are a domical uplift of Precambrian basement rocks lithologically similar to the Grenville Province of the Canadian Shield and connected to the shield by the Frontenac Axis. Rocks of high grade metamorphism are lithologically and physiographically subdivided into a Highlands and Lowlands portion of the Adirondacks. The Highlands are principally underlain by anorthosites, charnockitic, syenitic, granitic and mixed gneisses, and metasedimentary rocks. The Lowlands are chiefly underlain by tightly folded metasedimentary and metavolcanic rocks with a predominance of marbles and quartz-biotite-oligoclase gneisses. They are characterized by complex, largely plastic folding developed in two principle structural trends probably at different times. The rocks of the Lowlands have been reliably dated at 1100 m.y. which is the timing of the last major metamorphic event (Grenville Orogeny). Trip A will be concerned with this complex and interesting Precambrian terrane.

Sedimentary rocks of the St. Lawrence Lowland to be examined on trip B belong to the upper Cambrian to lower Ordovician Potsdam, Theresa and Ogdensburg formations. These lie unconformably on the underlying Grenville complex and represent shoreline and near-shore deposits of a westward advancing (or eastward retreating) sea. The Adirondack Mountains formed a large peninsula during advance of the early Paleozoic sea and were connected to the mainland Canadian Shield by the narrow neck of the Frontenac Axis. The Precambrian gneissic surfaces of the Adirondack Lowlands were nearly peneplained at that time. Karsts were extensively developed in the marbles and the stage was set for a rather peculiar pattern of patchy sinkhole and valley preservation of sandstone when the region was subjected to later epeirogenic uplift and erosion. Nearly continuous sedimentary units are presently exposed near the St. Lawrence River, and numerous outliers, chiefly of Potsdam Sandstone, occur on the Grenville surface with the number and size of outliers decreasing southward away from the river.

The Adirondack Mountains also served as an impediment to glacial advances in Pleistocene time, and terminal glacial features are extensively developed in the Lowlands as are shoreline features related to the St. Lawrence Embayment, Lake Fort Ann and "Lake Iroquois". The Pleistocene geology of the St. Lawrence Lowland is well known through the work of MacClintock and Stewart(1965). Trip E. will view some textbook examples of drift and ice contact features associated with the Fort Covington (late Wisconsin)glaciation.

Students of mineralogy recognize the international reputation of St. Lawrence County for mineral and crystal collecting. A survey of Dana's Manual of Mineralogy, any edition, reveals frequent mention of the County as a prime collecting site, particularly for silicate minerals of high grade metamorphic origin. Most of the well-known sites are surficially mined out, but good specimens are still to be had. No comprehensive geologic study of this region would be complete without some reference to mineral occurrences, and trip F will show participants four world-famous localities with opportunity for collection and discussion of genesis.

Economic mineral deposits are also abundant in St. Lawrence County and the Adirondack region. Trip D is an important part of the comprehensive geologic study in that participants will visit two of the largest open pit operations in the region, the International Talc Company Mine at Balmat where tremolite (commercial talc) is the principle ore, and the Jones and Laughlin Company's Benson Mine near Star Lake where magnetite/hematite is mined.

Geologists are becoming increasingly aware of the man-oriented aspects of their science, and we thought it appropriate to incorporate a trip dealing primarily with the geologic engineering aspects of the enormous St. Lawrence Seaway project and the somewhat smaller Raquette River power dam project. Trip C is being led by two geologically oriented Civil Engineers from Clarkson College of Technology who have been closely associated with development of these projects.

A word about the guidebook. To aid in correlating trips, the same stop map appears as Figure 1 for each trip description. The major geologic maps, Figures 2 for trips A, B, and E are similarly coordinated and tie in with the stop map. Drawings rather than photographs are used to cut costs. A number of roadcut "maps" have been drawn directly from panoramic photographs (30 for the Rock Island roadcut).

This guidebook, with one exception, has been written by local geologists and engineers from the State University of New York College at Potsdam, St. Lawrence University and Clarkson College of Technology. The one exception is Dr. George Theokritoff of Rutgers University, who, however, was formerly at St. Lawrence University. Some of what is presented here represents original work by the authors, but much of it is drawn from the literature. In any case, it is the result of an enormous amount of cumulative effort, and, as Editor, I would like to express my sincere thanks to all contributors. For the most part, they have done their own editing, thus reducing the professional contributions of the Editor to a minimum.

We are also grateful for the assistance of the following individuals and departments: Dr. Thomas M. Barrington, President of the State College, for use of campus facilities; Dr. Robert E. Johnson, Director of Continuing Education, for organizational help; Mrs. Judy Moriarty, Mrs. Judy Fairbridge and Mrs. Lorraine Richards,for typing; the duplicating departments of the State and Clarkson Colleges, for printing; geology students at State, for collating and; the Learning Resources Center at State, for help in the cover layout.

My personal thanks go to Dr. Harold M. Bannerman for his generous contribution of field data in the area of the Rock Island roadcut.

Bradford B. Van Diver
Editor

REFERENCES CITED

Bloomer, R. O. and Elberty, W. T.,1967, The Adirondack Region, Three Billion Years in the Making, Bull. N.Y. St. Tech. Serv. Prog., Geol. Inf. Ref. Serv., v. 1, 23 p.

Broughton, J. G., Fisher, D. W., Isachsen, Y.W., Rickard, L. F., Offield, T.W., 1962, Geologic Map of New York, N.Y. St. Mus. and Sci. Serv. Geological Survey.

MacClintock, P. and Stewart, D. P., 1965, Pleistocene Geology of the St. Lawrence Lowland, N.Y. St. Mus. and Sci. Serv. Bull. 394, 152 p.

Walton, M. S., and DeWaard, D., 1963, Orogenic Evolution of the Precambrian in the Adirondack Highlands, a new synthesis, Proc. Kon. Ned. Akad. Wetensch., Amsterdam, Ser. B, v. 66, p. 98-106.

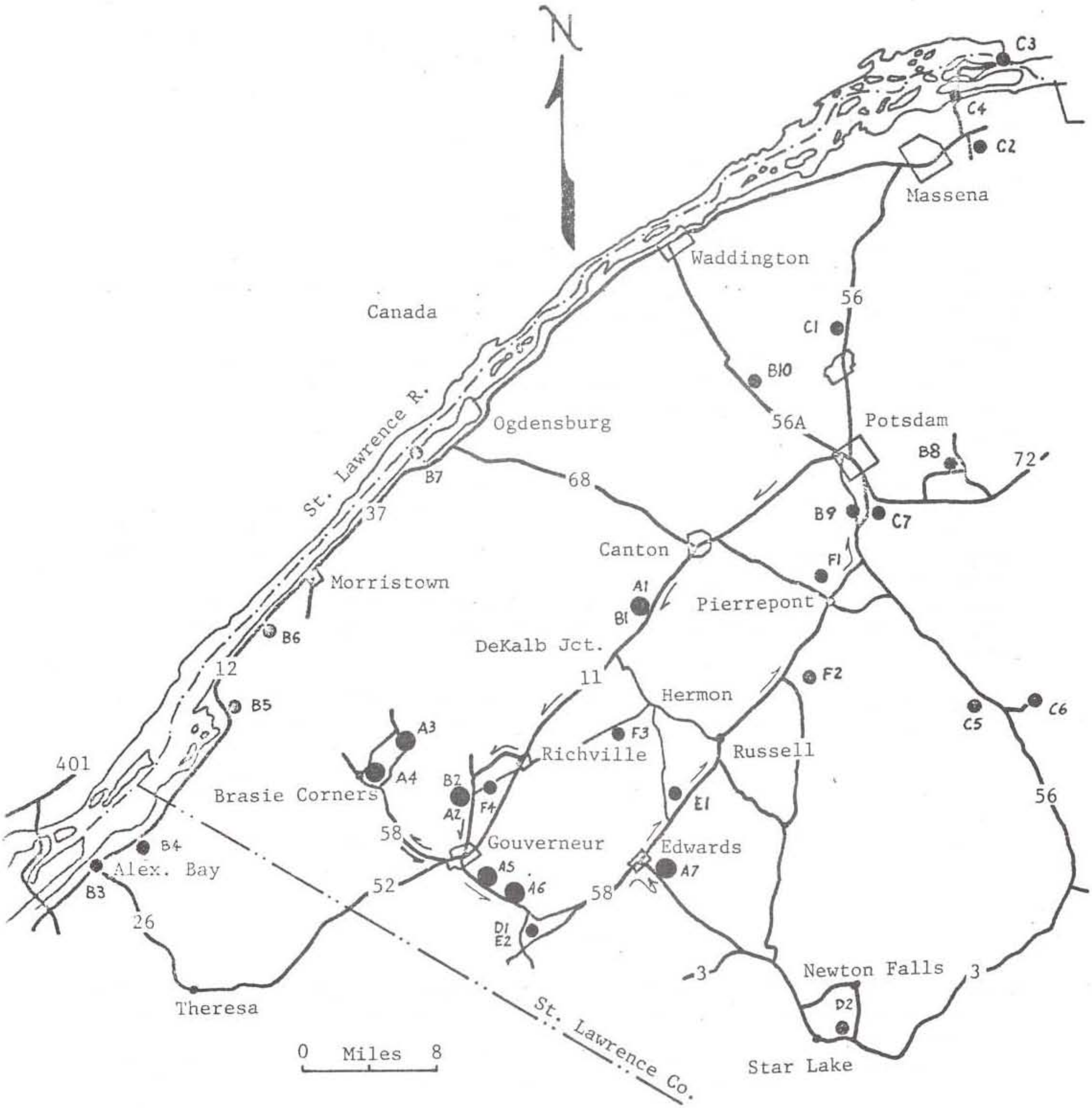

Figure 1. STOP MAP FOR TRIP A

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

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

Stop 1. The "Snake"(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

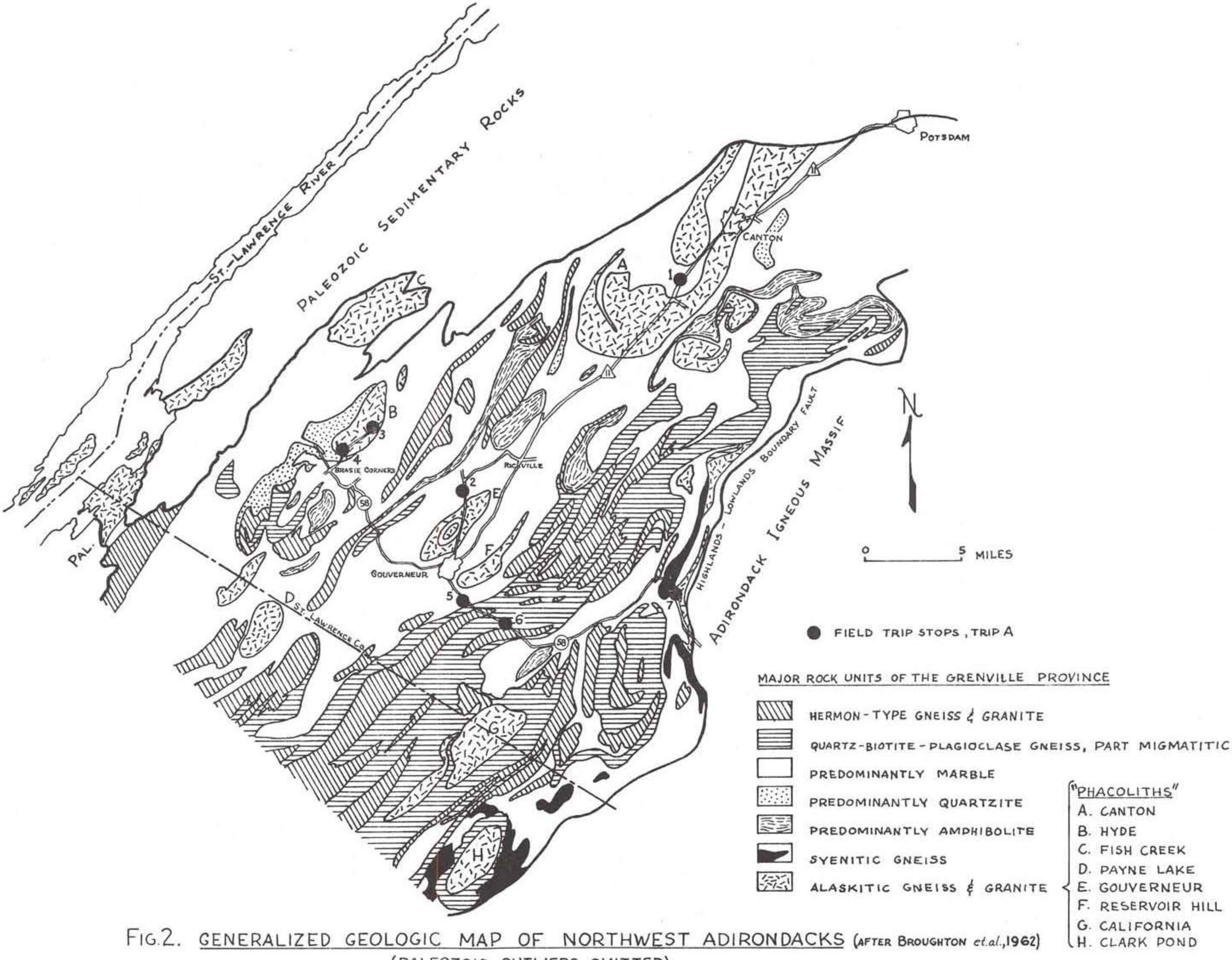


FIG. 2. GENERALIZED GEOLOGIC MAP OF NORTHWEST ADIRONDACKS (AFTER BROUGHTON et.al., 1962)
(PALEOZOIC OUTLIERS OMITTED)

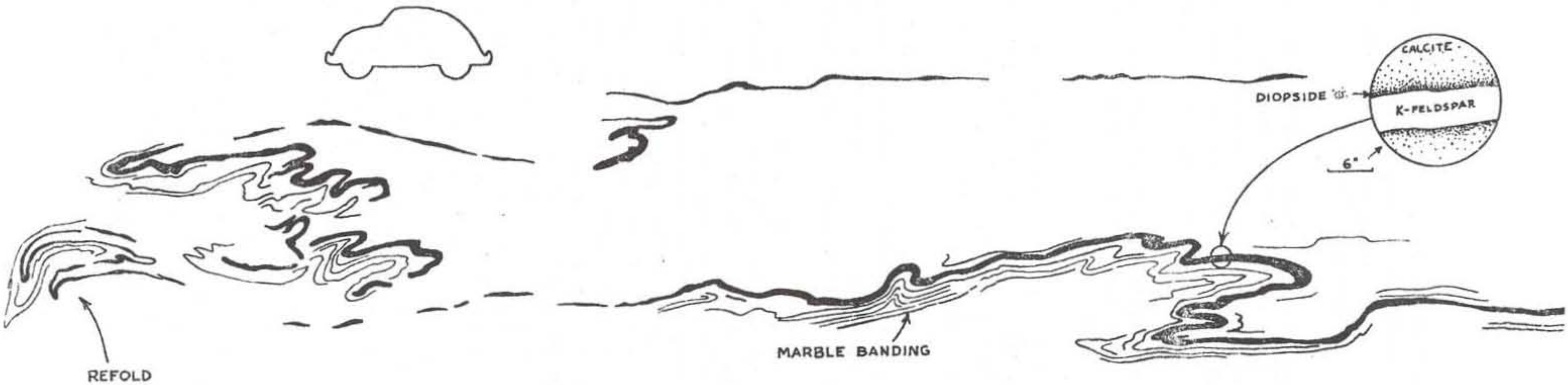


FIG. 3. "SNAKE" ROADCUT

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

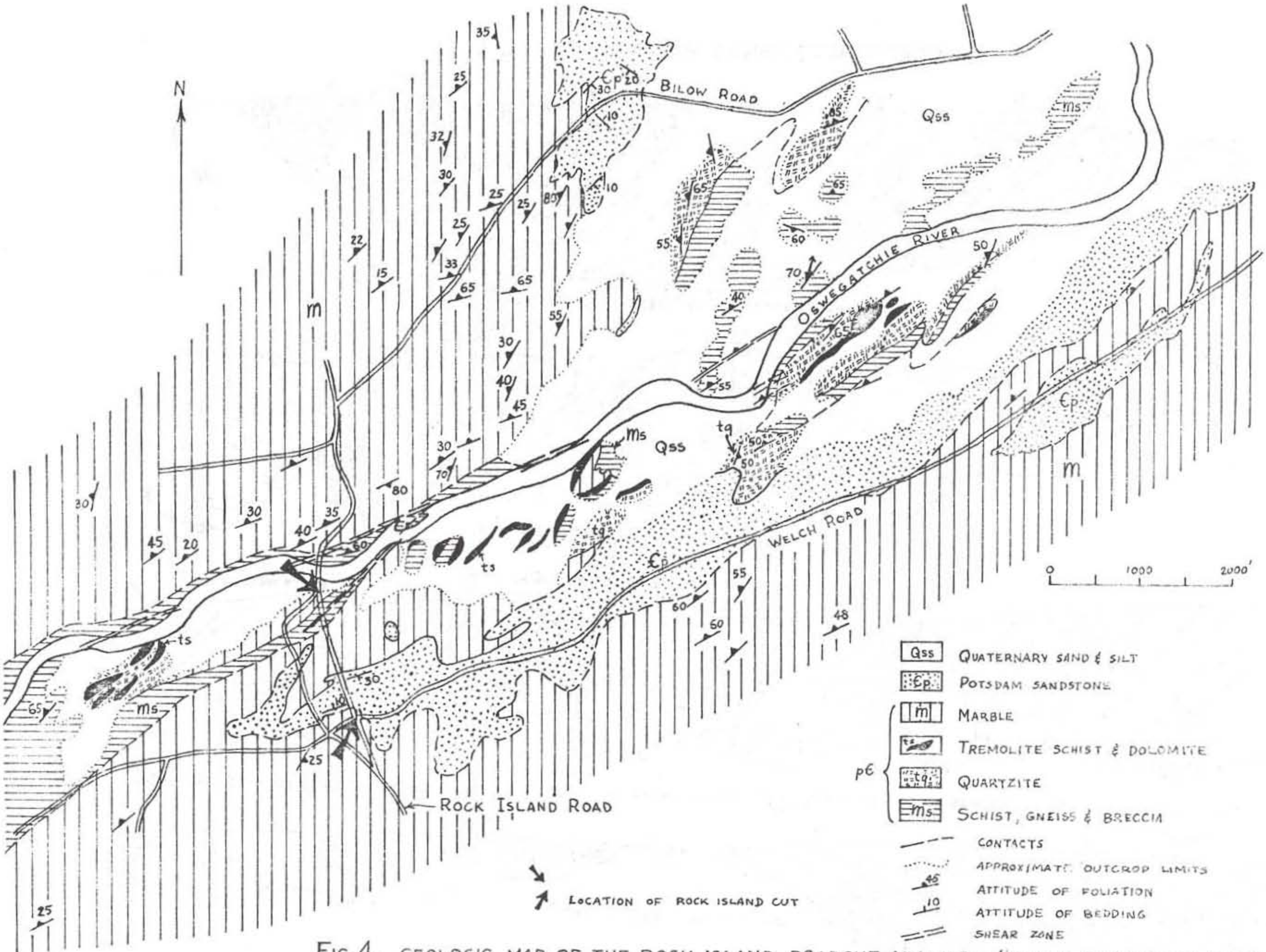


FIG. 4. GEOLOGIC MAP OF THE ROCK ISLAND ROADCUT VICINITY (AFTER BANNERMAN, 1963)

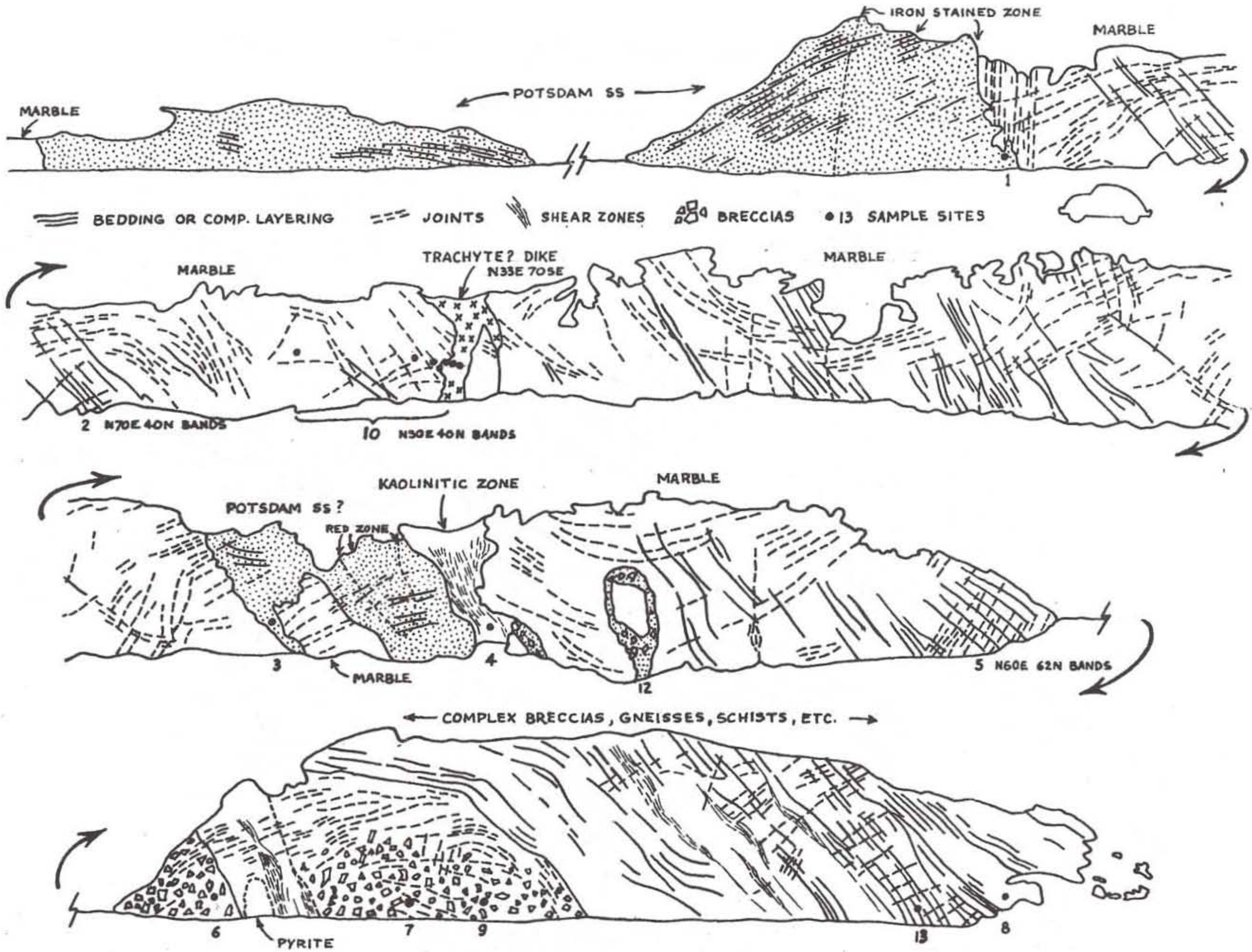


FIG. 5 ROCK ISLAND ROADCUT - WEST SIDE

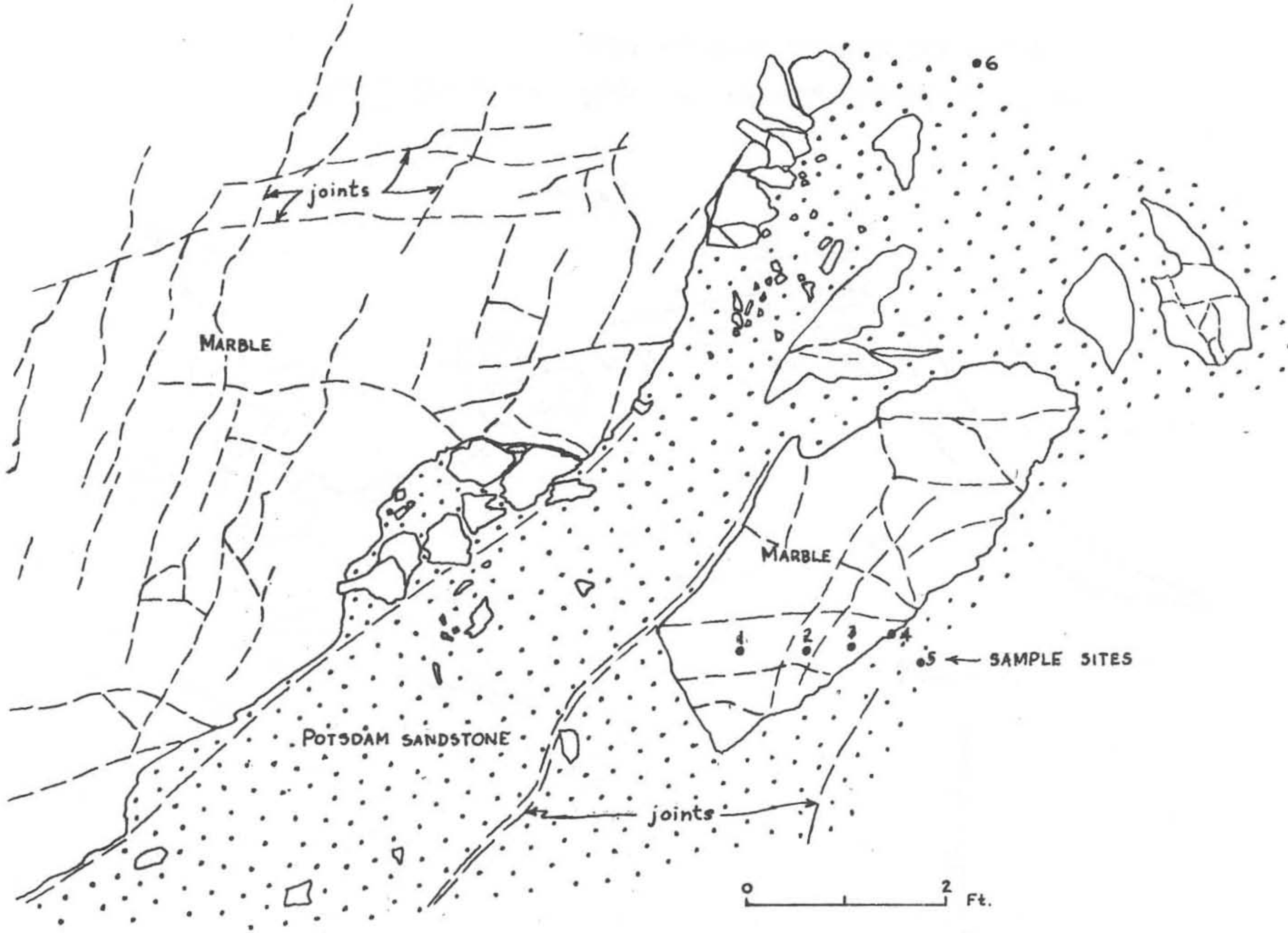


FIG. 6. DETAIL OF EAST SIDE - SOUTH END ROCK ISLAND ROADCUT

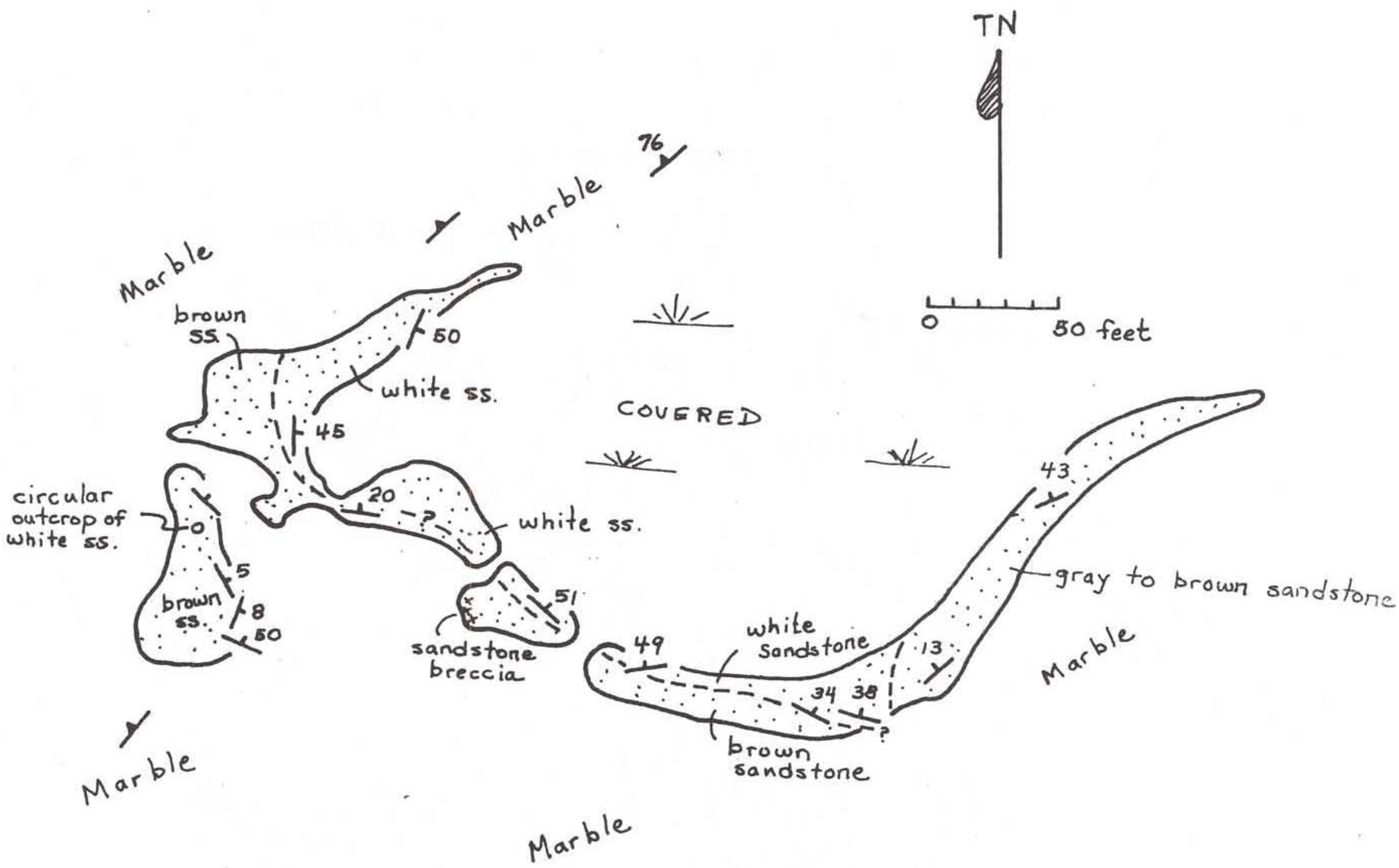


FIG. 7. Geologic Map of Potsdam Sandstone Outlier

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.

Trachyte(?) Dike (Fig. 5, Station 10)-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.

Metamorphic complex at north end of cut (Fig. 5, stations 6-9, 13)-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.

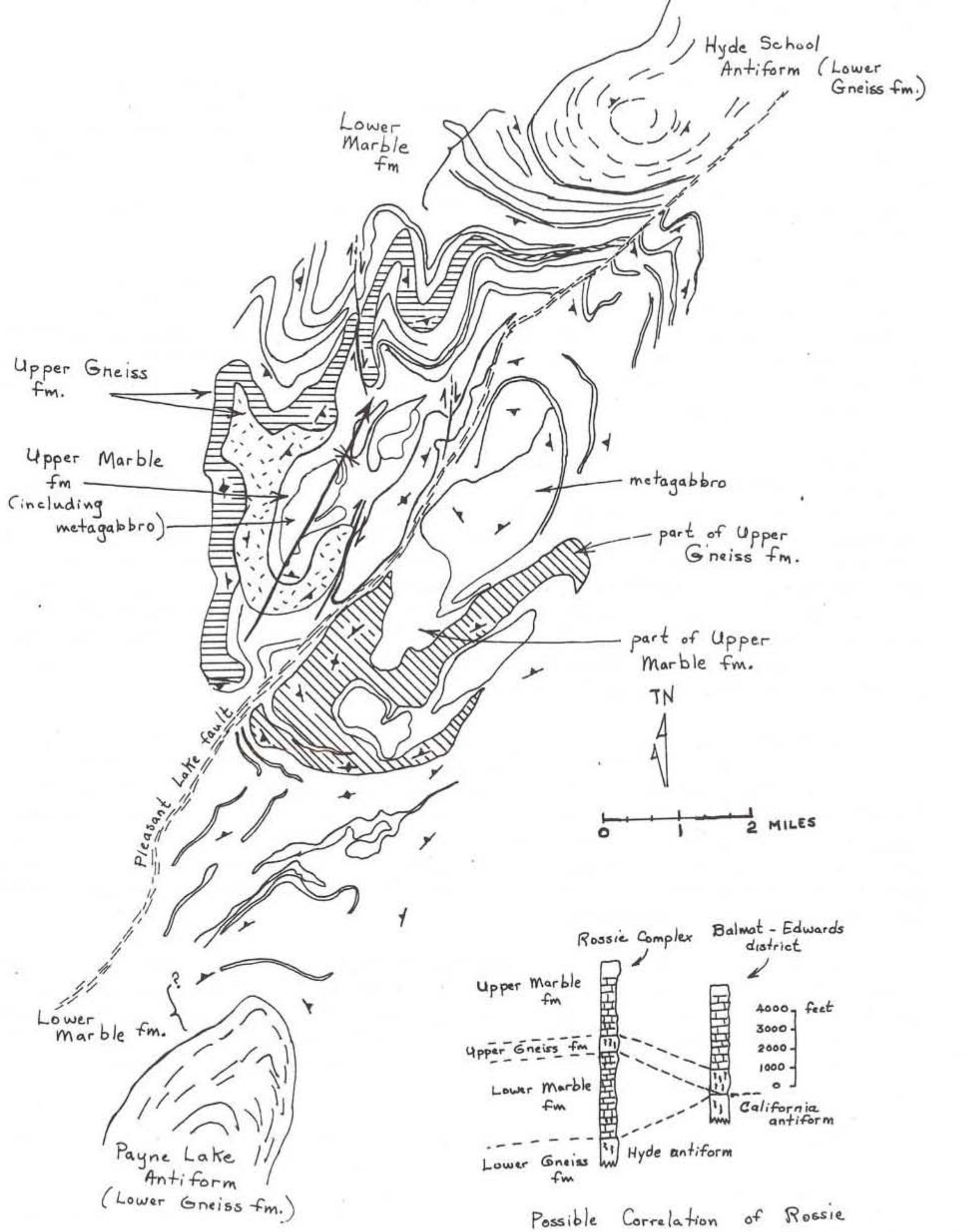
A Ph.D. dissertation by Lewis (1970) at the University of Syracuse is of particular interest in this matter. Lewis made a detailed map of Precambrian rocks (Fig.8) between the Hyde and Payne Lake antiforms. He recognizes four formations for which he proposes the term "Northwest Adirondack Group" and 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

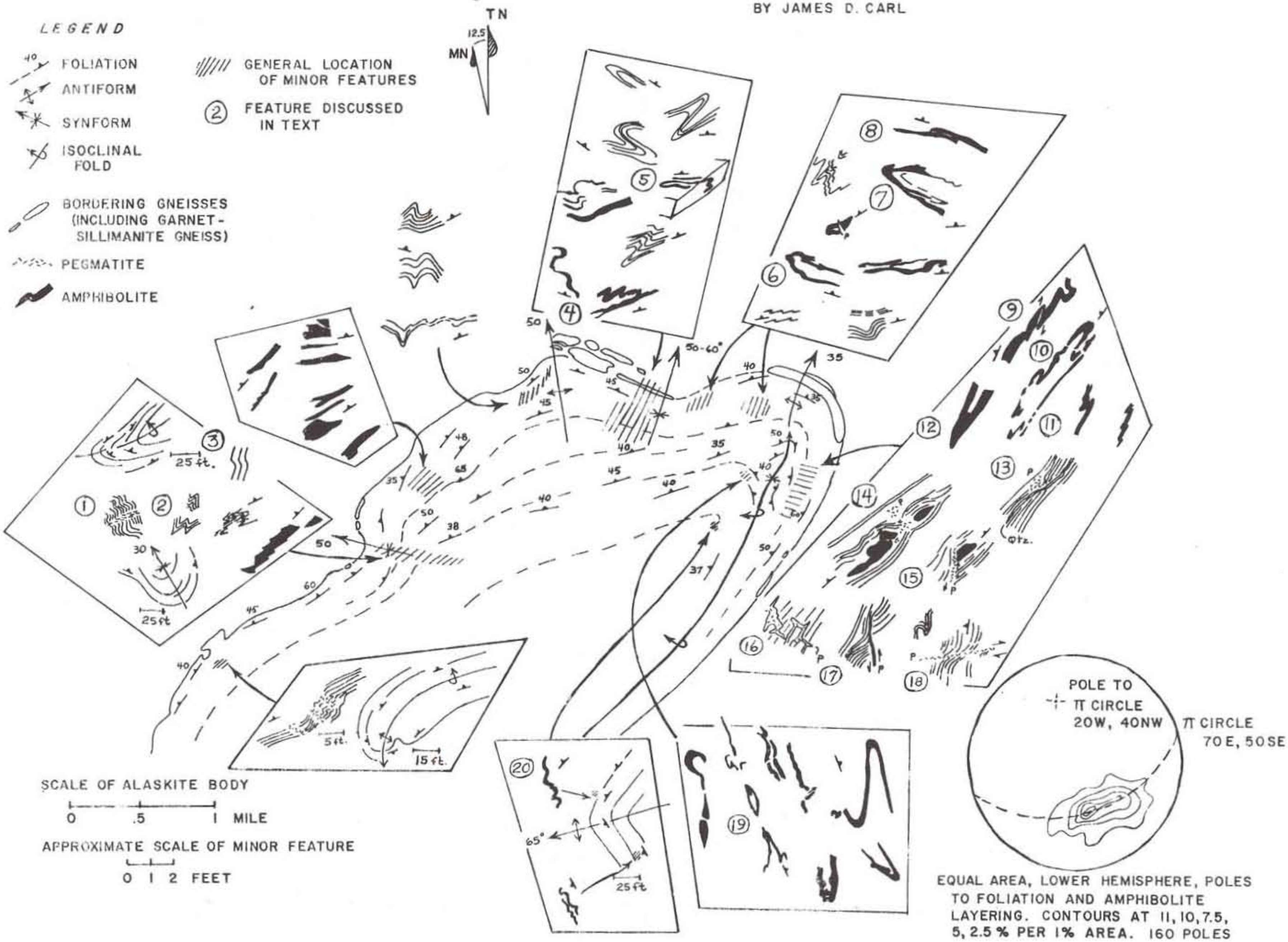
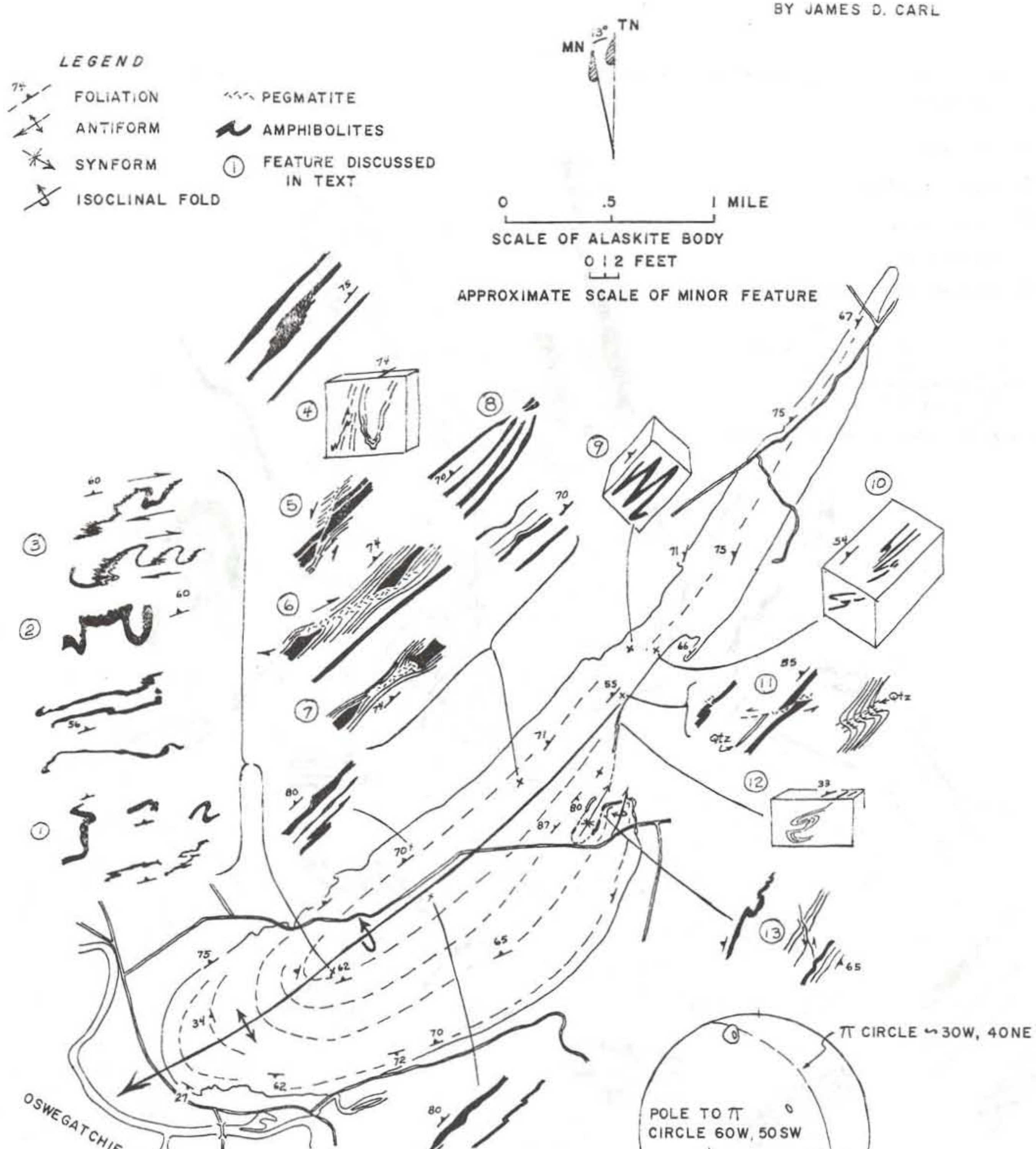


FIG. 10

STRUCTURES OF THE RESERVOIR HILL ALASKITE BODY

BY JAMES D. CARL

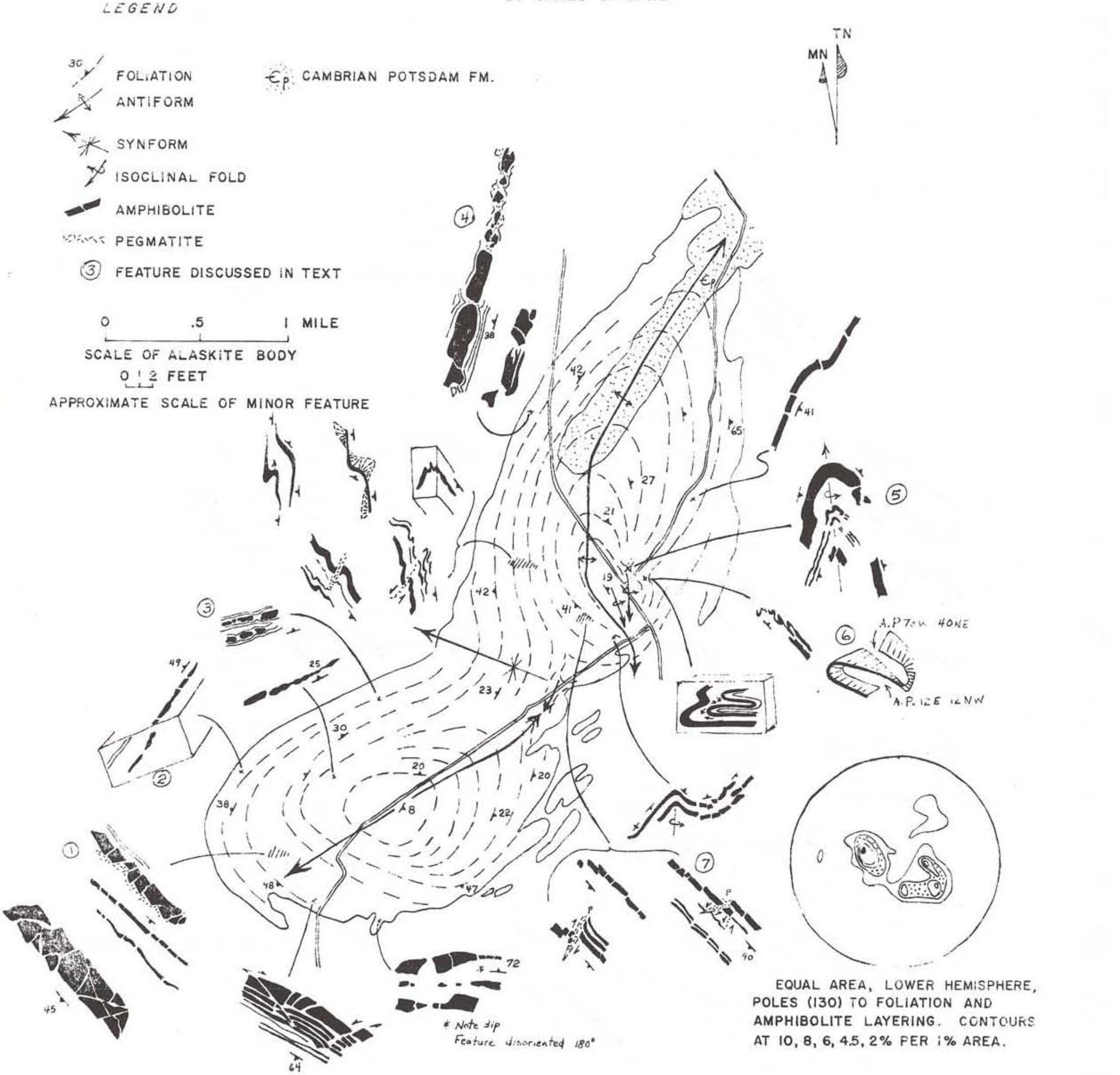


EQUAL AREA, LOWER HEMISPHERE, POLES (84) TO FOLIATION AND AMPHIBOLITE LAYERING. CONTOURS AT 13, 11, 7, 4 % PER 1% AREA.

FIG. II

STRUCTURES OF THE HYDE ALASKITE BODY

BY JAMES D. CARL



EQUAL AREA, LOWER HEMISPHERE, POLES (130) TO FOLIATION AND AMPHIBOLITE LAYERING. CONTOURS AT 10, 8, 6, 4.5, 2% PER 1% AREA.

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" 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

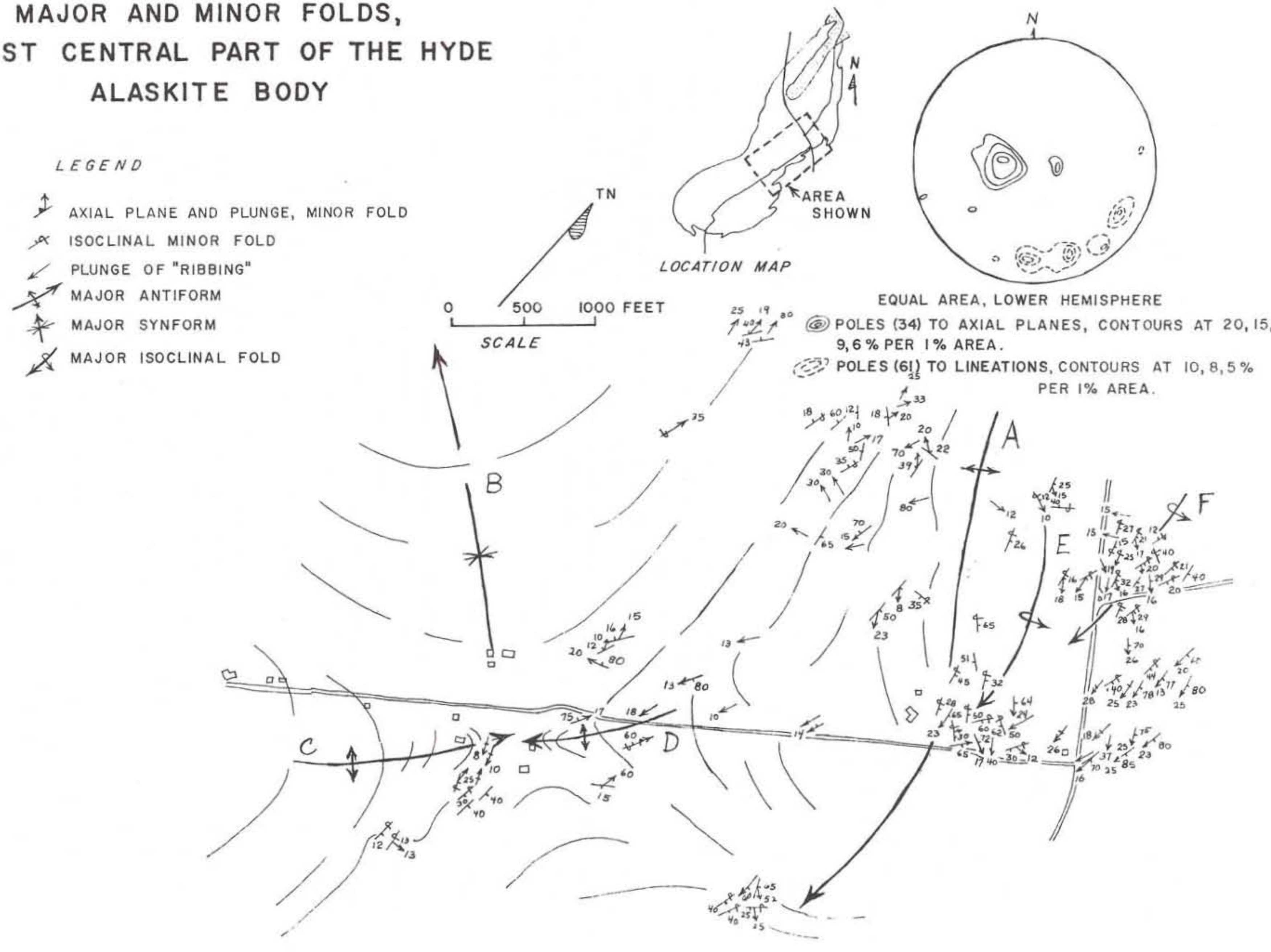
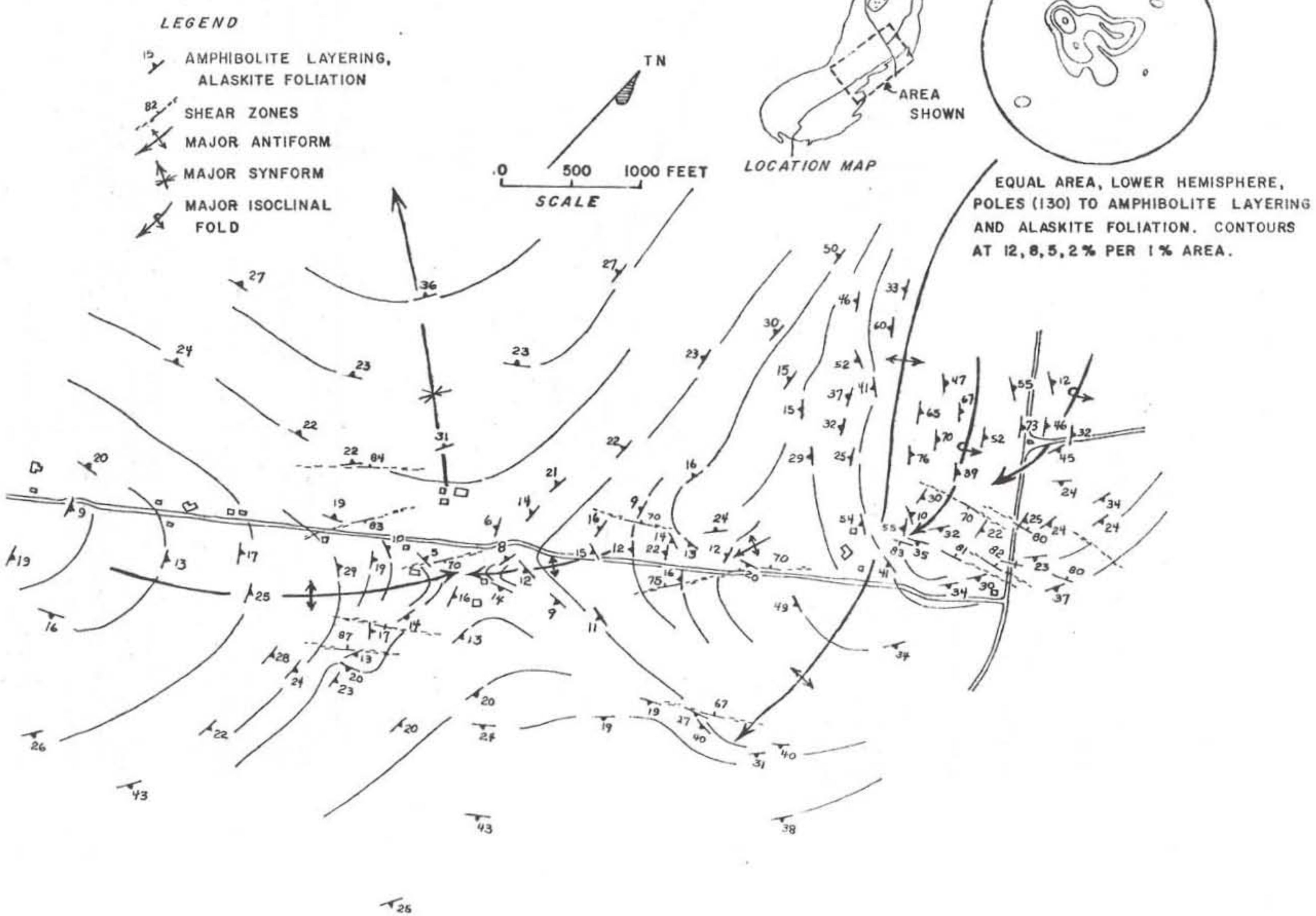


FIG. 13

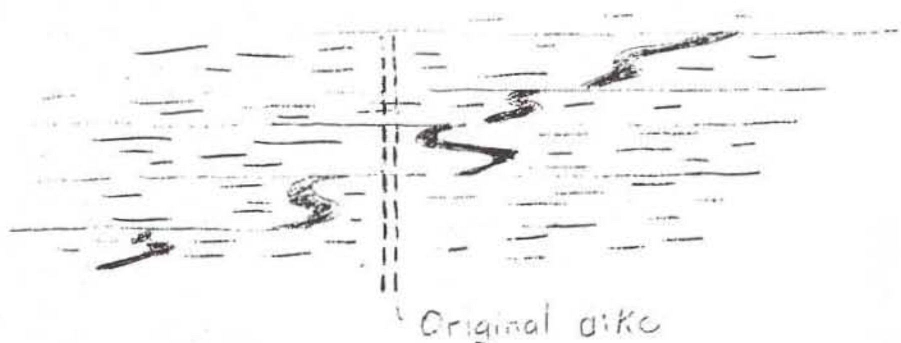
FOLIATION AND MAJOR FOLDS EAST CENTRAL PART OF THE HYDE ALASKITE BODY



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).

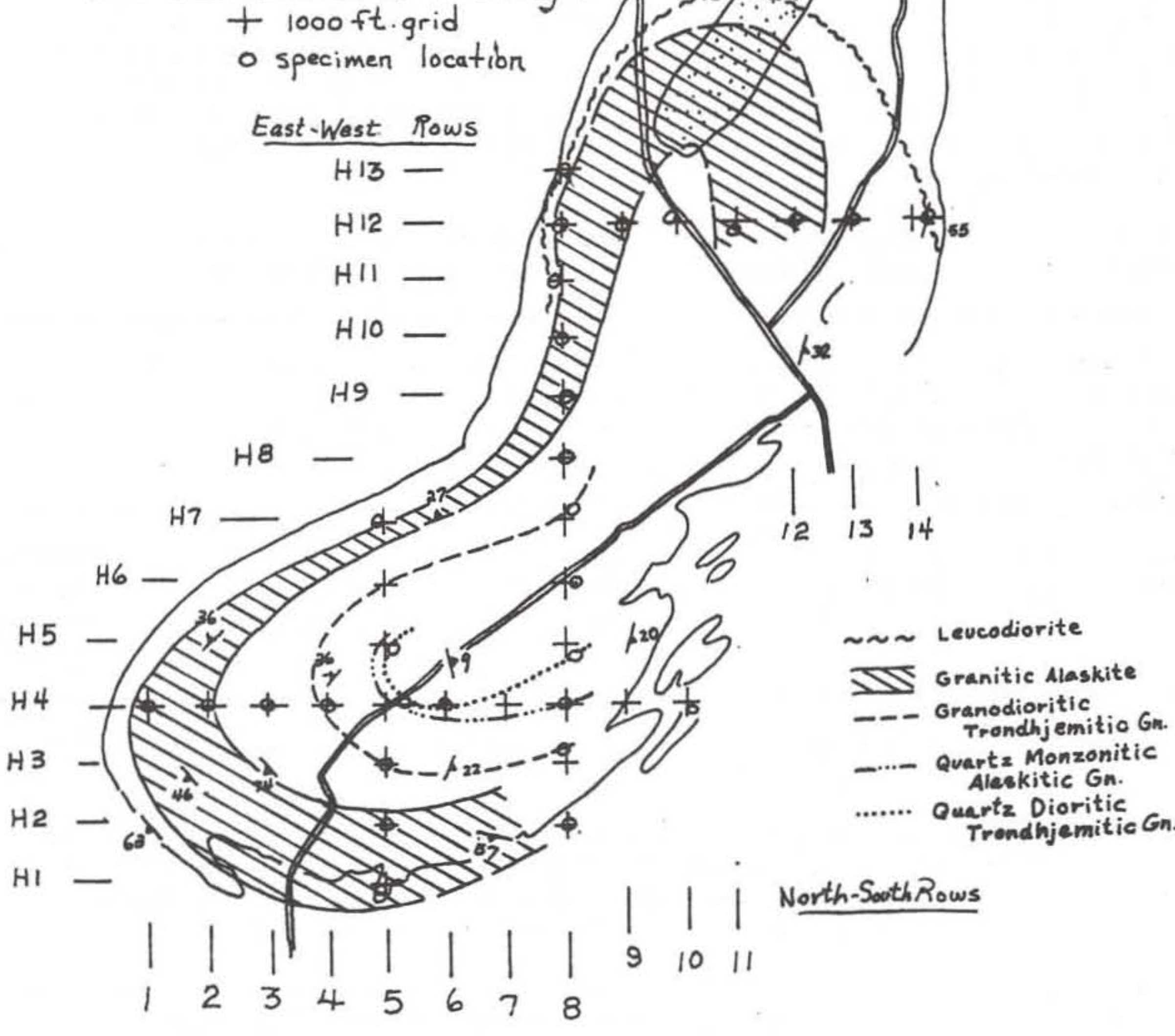
Possibly a discordant layer was folded (Fig. 10-1,-2) to give non-alignment of the layer with the general foliation trend. It is more likely, however, that the surrounding alaskite is as highly deformed as is the amphibolite, but recrystallization and intense folding have destroyed the planar fabric.

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 micro-antiperthitic 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 $\rightarrow$ 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).

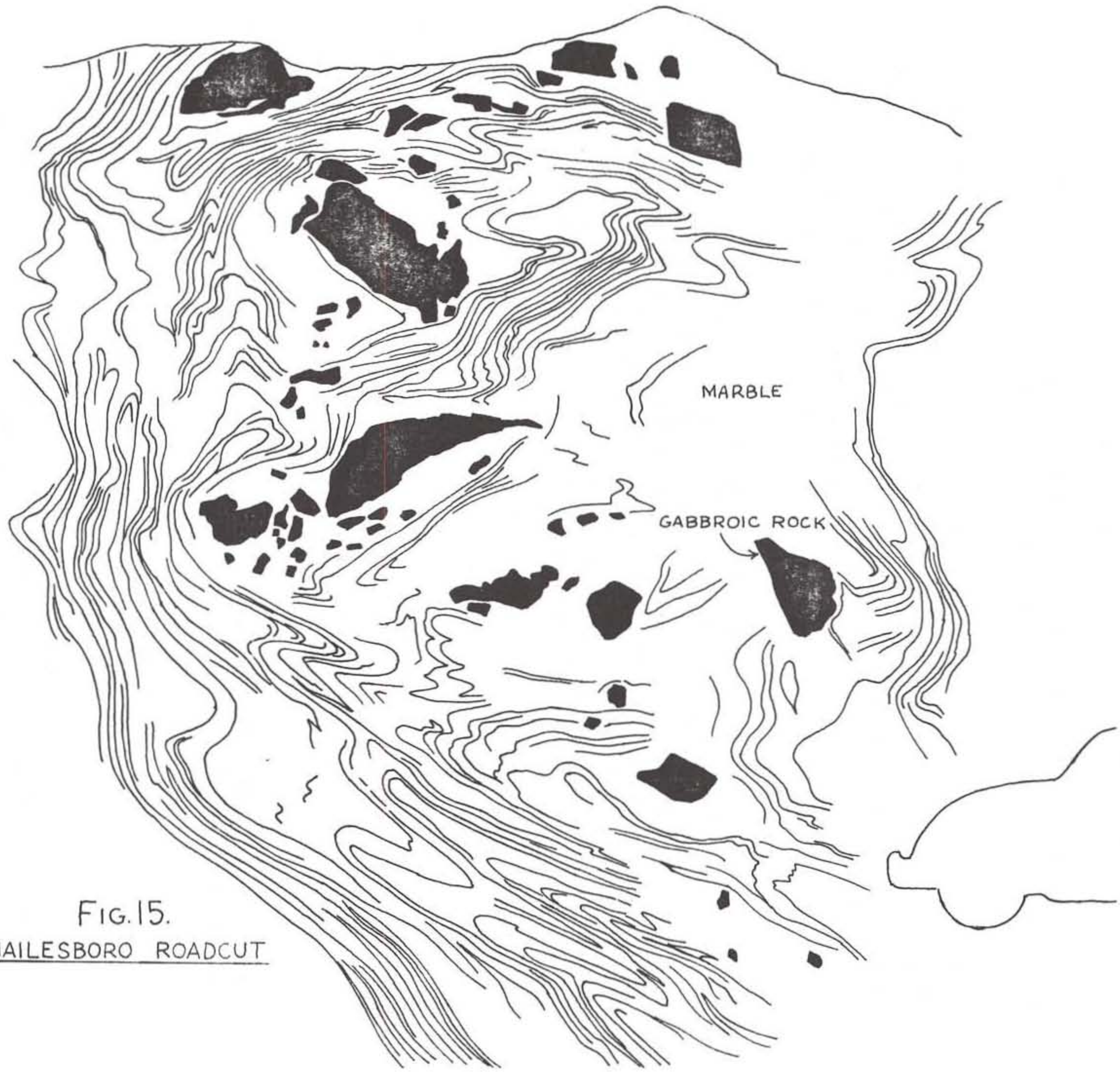


FIG. 15.
HAILESBORO ROADCUT

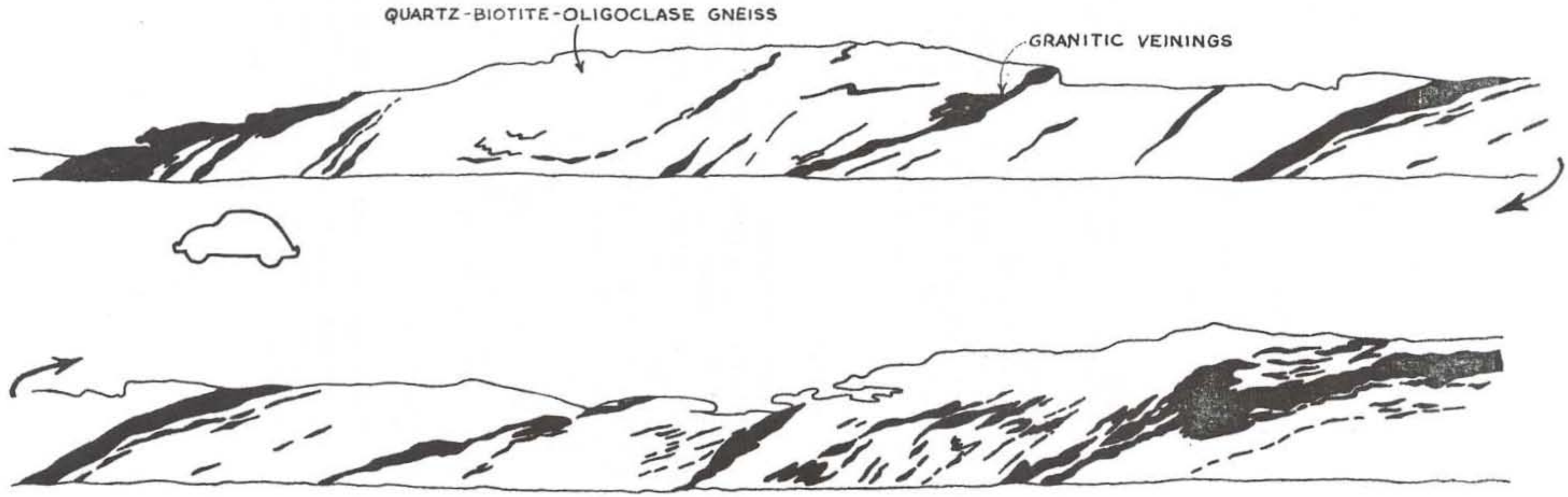


FIG. 16. MIGMATITE ROADCUT

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.

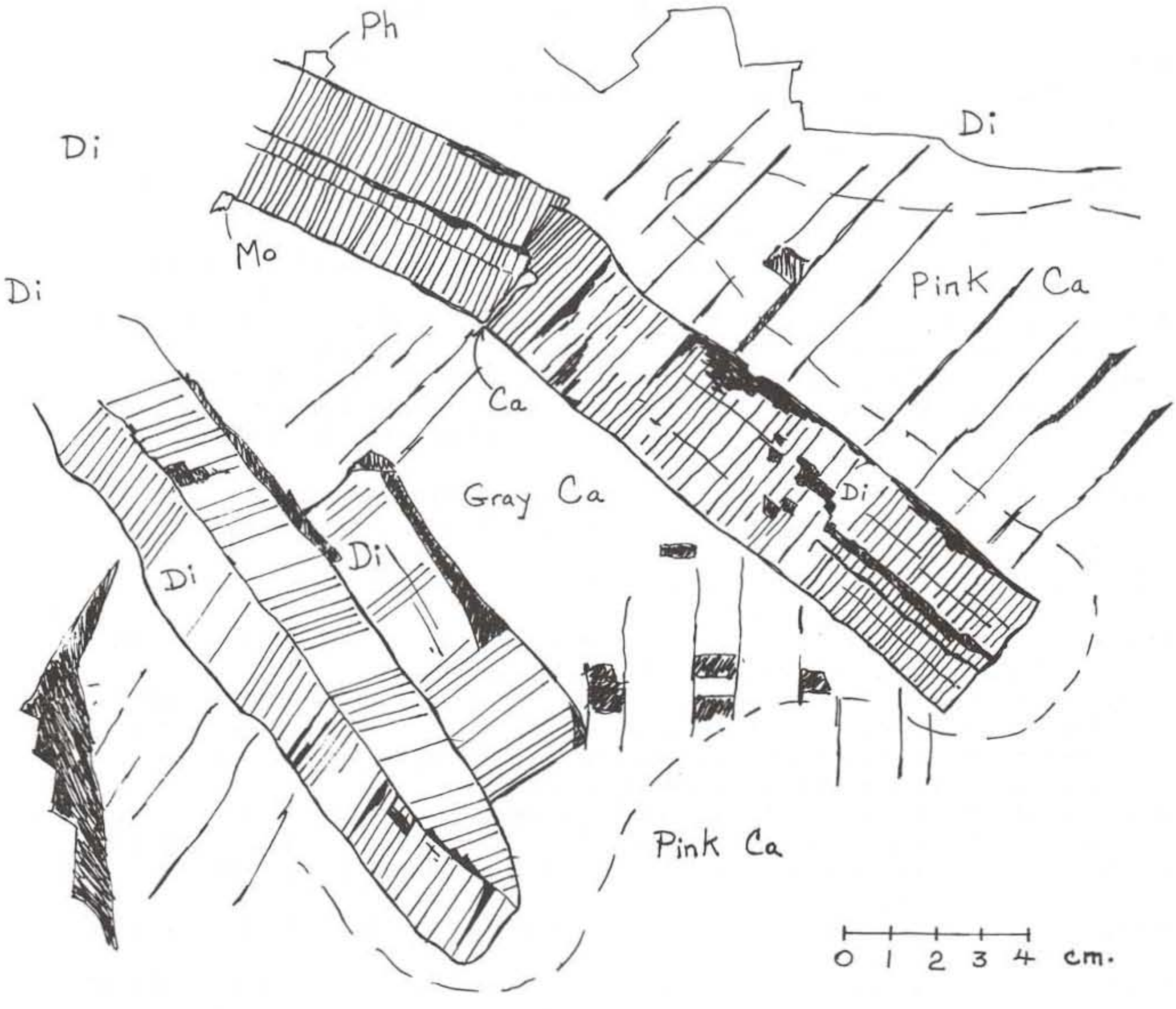
Bloomer, R. O., 1965, Precambrian Grenville or Paleozoic quartzite in the DeKalb area in northern New York, Geol. Soc. Amer. Bull., v. 76, p. 1015-1025.

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.

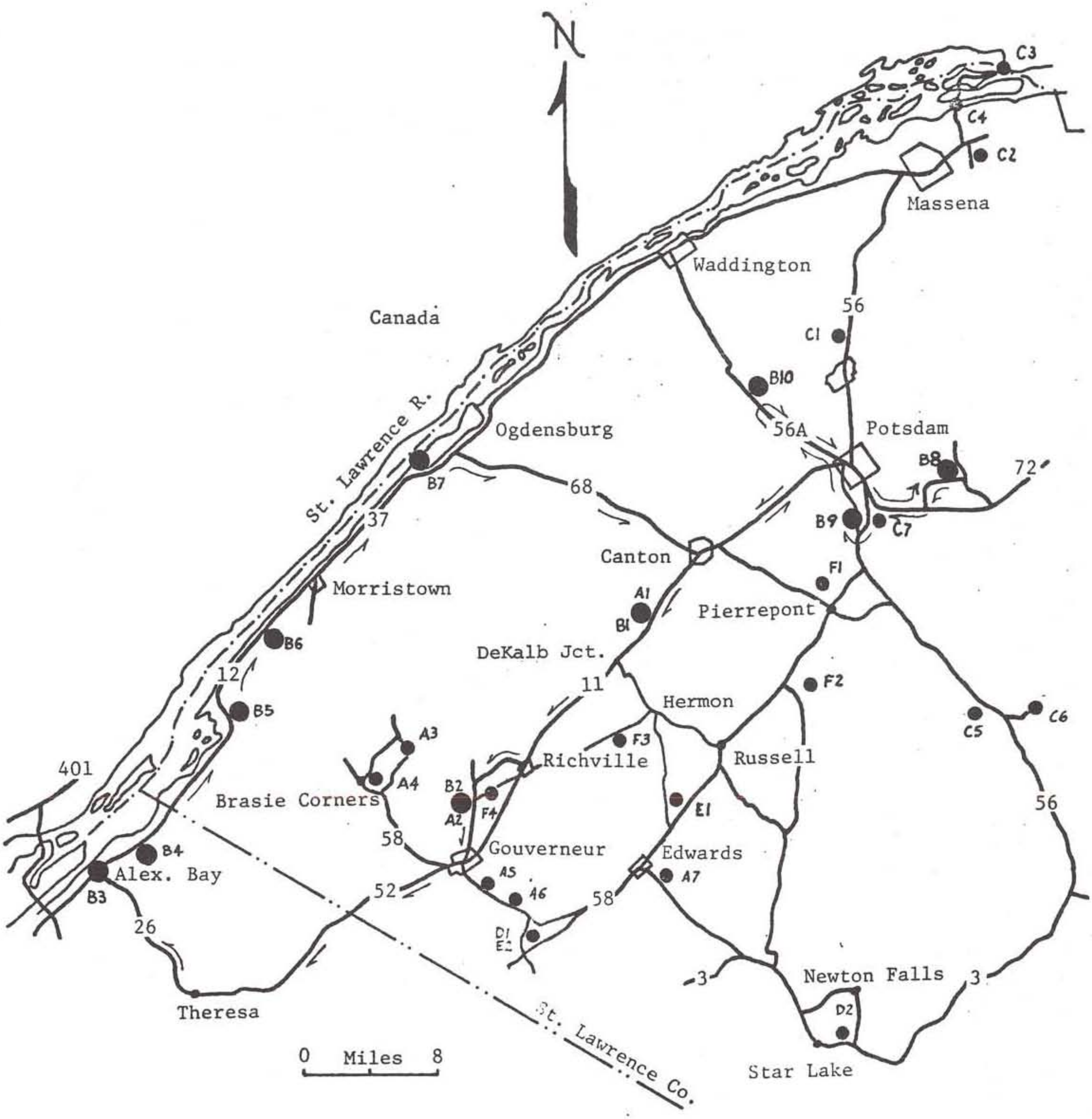


Figure 1. STOP MAY FOR TRIP B

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

Trip B

PRECAMBRIAN AND LOWER PALEOZOIC STRATIGRAPHY, NORTHWEST ST. LAWRENCE AND NORTH JEFFERSON COUNTIES, NEW YORK

by

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ABSTRACT

The field trip is designed to demonstrate general features of the lower Paleozoic sequence with emphasis on the stratigraphic relations with the Precambrian basement and environments of deposition. The strata form part of a complex Upper Cambrian-Lower Ordovician transgressive sequence that blankets an erosion surface on the Precambrian of low but variable relief. Basal quartzose sandstones (Potsdam Sandstone), with local conglomerate and breccia, grade and intertongue seaward (eastward) through calcareous and dolomitic sandstones and sandy dolomites (Theresa and Bucks Bridge Formations) into purer dolomites in the Champlain Valley. In St. Lawrence County, the Theresa and the Bucks Bridge Formations are overlain by dolomites and sandy dolomites (Ogdensburg Dolomite). Sedimentological and paleontological features (particularly trace fossils and algal stromatolites) will be seen that document and refine the general interpretation of the various facies as shallow water shelf deposits.

The excursion is divided into Saturday and Sunday morning parts (Fig. 1). The Saturday trip begins with a brief examination of the complex flow folding in the Grenville marbles south of Canton followed by examination of outliers of Potsdam Sandstone within the marbles north of Gouverneur, in an area where there have been problems in the differentiation of Paleozoic and Precambrian quartzites and breccias. Lunch will be in a park at Alexandria Bay, overlooking the Thousand Islands; here we will discuss the influence of the Frontenac Axis on the distribution of the Paleozoic rocks.

In the afternoon, the trip continues at an excellent exposure of an angular unconformity between the Potsdam Sandstone and Precambrian meta-sedimentary rocks just east of Alexandria Bay. We will then proceed down the St. Lawrence Valley and examine in stratigraphic succession 1). the Potsdam Sandstone and lower Theresa Formation near Chippawa Bay, 2). the Theresa Formation near Brier Hill and 3). the Ogdensburg Dolomite at Ogdensburg.

The localities to be visited on Sunday are 1). the Allens Falls Fanglomerate or "basal breccia" at Allens Falls, 2). the type exposure of

the Potsdam Sandstone at Hannawa Falls and 3). the dendroid graptolite locality in the Bucks Bridge Formation near Madrid described by Berry and Theokritoff (1966).

INTRODUCTION

The bedrock in the upper St. Lawrence valley includes metamorphosed Precambrian overlain unconformably by Paleozoic sedimentary rocks (Fig.2). The Precambrian rocks are part of the Grenville orogen and are structurally complex (Stops 1-4). The unconformity at the base of the Paleozoic is exposed at very few localities in the upper St. Lawrence valley; three localities, which illustrate distinct aspects of the contact, will be visited (Stops 2, 4, and 8).

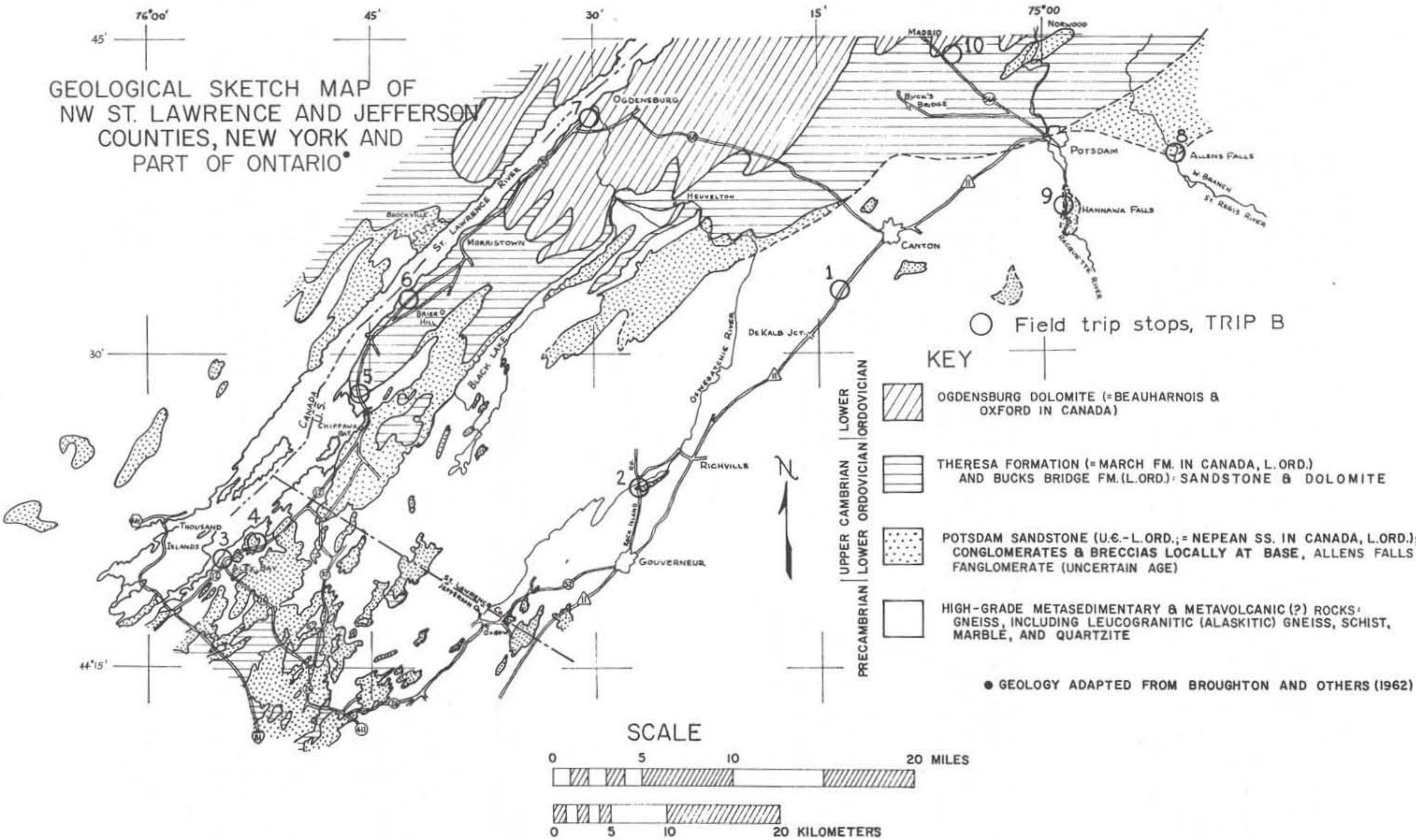
The basal Paleozoic unit is generally a quartzose sandstone (orthoquartzite) named the Potsdam Sandstone (Emmons, 1838). Locally, conglomerates, "basal breccias" and fanglomerates (Allens Falls Fanglomerate), are developed at or near the base of the Potsdam Sandstone. Although the Potsdam Sandstone yields Late Cambrian trilobites from localities in Washington, Clinton, and Franklin counties, New York (Fisher, 1955; 1956; 1968), no chronostratigraphically indicative fossils have been reported from this unit in St. Lawrence or Jefferson counties; in eastern Ontario, the lithologically equivalent Nepean Sandstone yields fossils indicating Early Ordovician age (Kirwan, 1963). Trace fossils, in the form of U-shaped vertical spreite burrows (*Diplocraterion?)* will be seen at Stop 5.

The Potsdam Sandstone is overlain by calcite- and dolomite-cemented sandstones which Chadwick (1915) divided, in stratigraphic order, into three units: Theresa mixed beds, Heuvelton Sandstone, and Bucks Bridge mixed beds (Stop 10). Berry and Theokritoff (1966) were unable to find criteria to support this sub-division in central St. Lawrence County and extended the Bucks Bridge Formation downward to include Chadwick's Heuvelton and Theresa; however, they recognized the Heuvelton Sandstone as a member of their extended Bucks Bridge Formation. Fisher (1968) recognized the Theresa Formation (Cushing, 1908) in the Plattsburgh and Rouses Point areas and applied the names Theresa Dolomite and Bucks Bridge Dolomite in the St. Lawrence Valley (1968, p.29). Neither the Heuvelton Sandstone nor the Bucks Bridge mixed beds of Chadwick are recognized within the Theresa Formation in its type area (Theresa, Jefferson County) or in northwesternmost St. Lawrence County.

The lower part of the Bucks Bridge Formation, as used by Berry and Theokritoff (1966), or the Theresa Dolomite, as used by Fisher, yields rare inarticulate brachiopods (*Lingulepis)*. The Bucks Bridge Dolomite (the upper part of the Bucks Bridge Formation of Berry and Theokritoff) yields poorly preserved discoidal gastropods that suggest correlation with the Tremadoc, as well as, at one locality (Stop 10), *Dictyonema potsdamense*.

A dolomite, locally sandy, overlies the Bucks Bridge Formation and Theresa Formation; this dolomite was named the Ogdensburg Dolomite by Chadwick (1915, p. 289) and recognized by Berry and Theokritoff (1966) and Fisher (1962B; 1968). It is the highest Paleozoic unit to be seen on this trip (Stops 7 and 10). It contains a fairly limited molluscan fauna as well as algal stromatolite horizons.

FIGURE 2.



GEOLOGICAL SKETCH MAP OF NW ST. LAWRENCE AND JEFFERSON COUNTIES, NEW YORK AND PART OF ONTARIO*
76°00'
45'
30'
15'
75°00
44°15'
Ogdensburg
Madrid
Norwood
Buck's Bridge
Potsdam
Allens Falls
W. Branch St. Regis River
Hannawa Falls
Raquette River
Heuvelton
Canton
Brockville
St. Lawrence River
Morristown
Briar Hill
Black Lake
DeKalb Jct.
Oswegatchie River
Canada
U.S.
Chippewa Bay
Richville
Gouverneur
Thousand Islands
Alex. Bay
St. Lawrence Co.
Jefferson Co.
Field trip stops, TRIP B
KEY
LOWER ORDOVICIAN
OGDENSBURG DOLOMITE (=BEAUHARNOIS & OXFORD IN CANADA)
UPPER CAMBRIAN | LOWER ORDOVICIAN
THERESA FORMATION (= MARCH FM. IN CANADA, L. ORD.) AND BUCKS BRIDGE FM. (L. ORD.): SANDSTONE & DOLOMITE
POTSDAM SANDSTONE (U.Є.-L.ORD.; = NEPEAN SS. IN CANADA, L.ORD.); CONGLOMERATES & BRECCIAS LOCALLY AT BASE, ALLENS FALLS FANGLOMERATE (UNCERTAIN AGE)
PRECAMBRIAN
HIGH-GRADE METASEDIMENTARY & METAVOLCANIC (?) ROCKS: GNEISS, INCLUDING LEUCOGRANITIC (ALASKITIC) GNEISS, SCHIST, MARBLE, AND QUARTZITE
● GEOLOGY ADAPTED FROM BROUGHTON AND OTHERS (1962)
SCALE
0 5 10 20 MILES
0 5 10 20 KILOMETERS

The relationships of the several Paleozoic units have been variously interpreted. Chadwick (1915; 1920), Cushing and others (1910), and Cushing (1916) interpreted the section essentially in "layer-cake geology" terms, seeing the contacts as isochronous. On the other hand, Fisher (1955; 1956; 1962A) and Berry and Theokritoff (1966) interpreted the section in terms of lateral facies gradations within the deposits of a westward transgressing sea. Interpretation of the Paleozoic of the upper St. Lawrence Valley is complicated by the paucity of chronostratigraphically significant fossils, the low density of outcrops, and the presence of lateral lithofacies gradations.

ACKNOWLEDGEMENTS AND NOTES

We gratefully acknowledge the assistance of Dr. Bradford B. Van Diver in the preparation of Figures 1-5 and thank Mrs. Judy Moriarty for typing the final manuscript. We also wish to thank Mr. C. M. Sandwith of McConville, Inc. of Ogdensburg, New York and Mr. Richard Bicknell of Bicknell Brothers, Inc. of Potsdam, New York for permission to visit their quarries (Stops 7 and 9).

The classification of Folk (1962) was used in the description of the carbonate rocks. Calcite was distinguished from dolomite by staining with Alizarin red-S in dilute-HCL (Sabins, 1962). Figures 10, 11, 13, 14 and 16 were traced from acetate peels and Figures 9 and 15 were traced from photographs of acetate peels.

STOP DESCRIPTIONS

General

Stops 1 and 2. Refer to Stops 1 and 2 of Trip A (p. A-1; A-4) for stop descriptions.

Stop 3. Scenic View Park, Alexandria Bay, New York.- Lunch Stop; leucogranitic (alaskitic) gneiss; Frontenac Axis.

The Frontenac Axis is a narrow southeastward extension of the Canadian Shield connecting the Laurentian Plateau with the "Lowlands" region of the Adirondack Mountains. This terrane of resistant Precambrian crystalline rocks forms the Thousand Islands where the axis is crossed by the postglacial St. Lawrence River a few miles from where the river spills out of Lake Ontario.

In the Thousand Islands area, the basement rocks are a highly folded and intensely metamorphosed complex of metamorphic rocks dominated by pink or red leucogranitic (alaskitic) gneiss (Alexandria Granite; Rockport-type granite in Canada) with white metaquartzites and a variety of layered gneisses; the sequence is broadly monoclinal, with a northwesterly dip (Wynne-Edwards, 1959, 1962, 1963).

The axis separates the lowermost Paleozoic strata of the Ottawa-St. Lawrence Lowland to the northeast from the similar but less complete succession of the

Ontario Lowland to the southwest. It is difficult to document the influence of the axis on early Paleozoic sedimentation because of the scarcity of outcrop in the immediate area (Fig. 2). Numerous outliers of the Potsdam Sandstone (Nepean in Canada) and a few of the Theresa Formation indicate that the axis was covered by a westward-transgressing sea during Late Cambrian-Early Ordovician (Early Canadian) time. In the St. Lawrence Valley, the sandstones and dolomites of the Theresa-Bucks Bridge Formations (March Formation in Canada) are succeeded by the Ogdensburg Dolomite (Oxford Formation in Canada) of Medial and Late Canadian age; the Ogdensburg Dolomite is unconformably overlain by a Middle Ordovician limestone sequence of Chazyan (Rockcliff and St. Martin Formations) and Mohawkian (Ottawa Formation) age(Fisher 1968, p.29).

West of the Frontenac Axis, the Ogdensburg Dolomite and Chazyan limestones are missing and here the limestone sequence of Mohawkian age (Black River and Trenton Groups) rests unconformably on the Theresa Formation and older rocks. The Black River and Trenton limestones were deposited in a transgressing sea that crossed the Frontenac Axis and entered the Ottawa-St. Lawrence basin from the southwest (Wilson, 1946, p.7). There is no indication of later Paleozoic sedimentation over the axis. Any deposits that may have accumulated have since been removed by post-Ordovician erosion that has stripped the lower Paleozoic sequence away from the crest to leave a sequence of stair-like terraces and scarps.

Glacial deposits are rare and thin in the Alexandria Bay area and the Precambrian and Paleozoic rock display evidence of glacial erosion, especially on the Potsdam Sandstone. The features include glacial polishing, striae and grooves (direction to SW about parallel to the St. Lawrence River) and chatter marks (MacClintock and Stewart, 1965, p. 120).

Stop 4. Precambrian-Paleozoic angular unconformity at Alexandria Bay.-
Roadcut on N.Y. 12, 2 miles east of Alexandria Bay, N.Y.

The east end of the roadcut exposes a knoll on the pre-Potsdam erosion surface formed on steeply inclined to vertical Precambrian metasedimentary rocks which are overlapped by nearly horizontal orthoquartzites of the Potsdam Sandstone (Figs. 3-5). The Precambrian rocks include medium-grained leucogranitic (alaskitic) gneiss which form resistant masses at the west and east ends of the outcrop. Between these rocks are darker layered gneisses, including red and pink leuco-quartz diorites, pink alaskitic gneiss and green and white diopsidic quartz diorites. The layered gneisses are mostly highly altered, especially in the intensely weathered zone in the first few feet below the erosion surface.

The basal Potsdam Sandstone is well bedded, medium- and thick-bedded, medium-grained, white orthoquartzite. The basal part of the sandstone sequence thins over the crest of the knoll, as the lowermost beds pinch out against the erosion surface. The quartz grains are mostly well rounded, highly spherical, and frosted and are thoroughly cemented by silica overgrowths in optical continuity with the grains, a feature for which the Potsdam Sandstone has long been noted. Cross- and horizontal laminae within the beds are defined by minor fluctuations in grain size from very fine- to coarse-grained,texture and accessory mineral content. Heavy minerals are

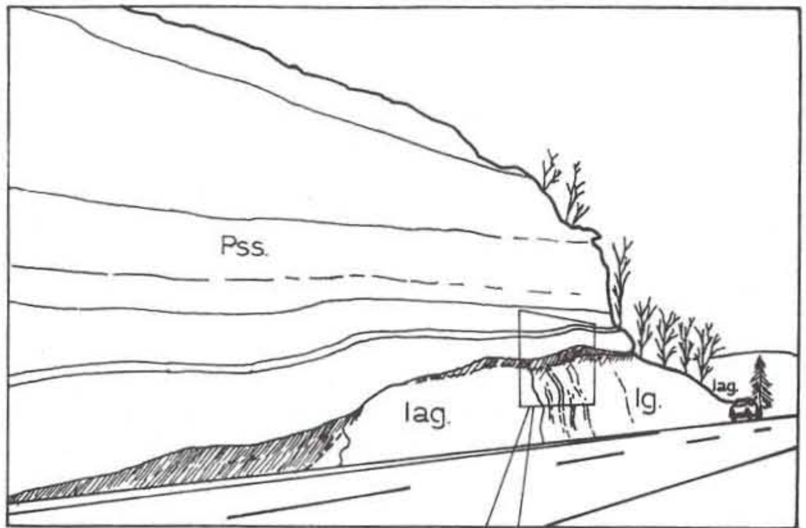


Fig. 3. STOP 4: Precambrian-Paleozoic angular unconformity at Alexandria Bay. Lag, leucogranitic (alaskitic) gneiss; lg, layered gneiss; Pss., Potsdam Sandstone. Ruled area, intensely weathered zone. East end of roadcut on north side of N.Y. 12, 2 mi. east of Alexandria Bay, N.Y.

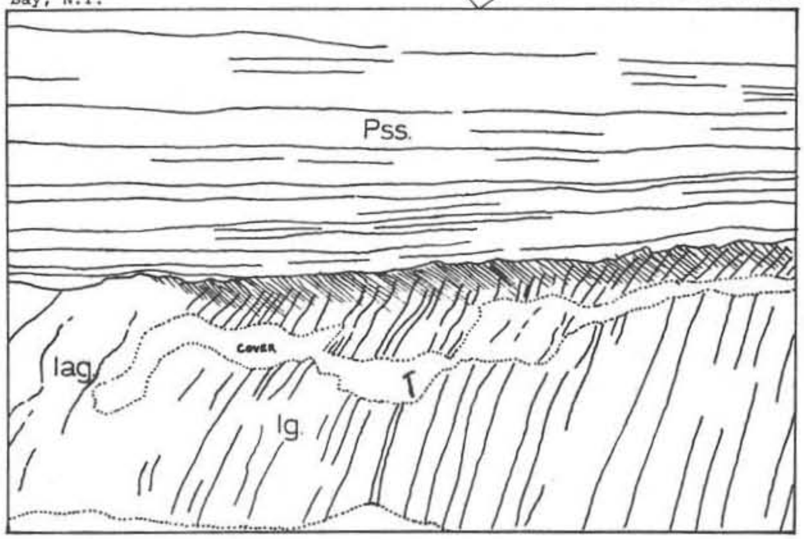


Fig. 4. STOP 4: Detail of unconformity seen in Fig. 3. Geologic hammer is two feet in length.

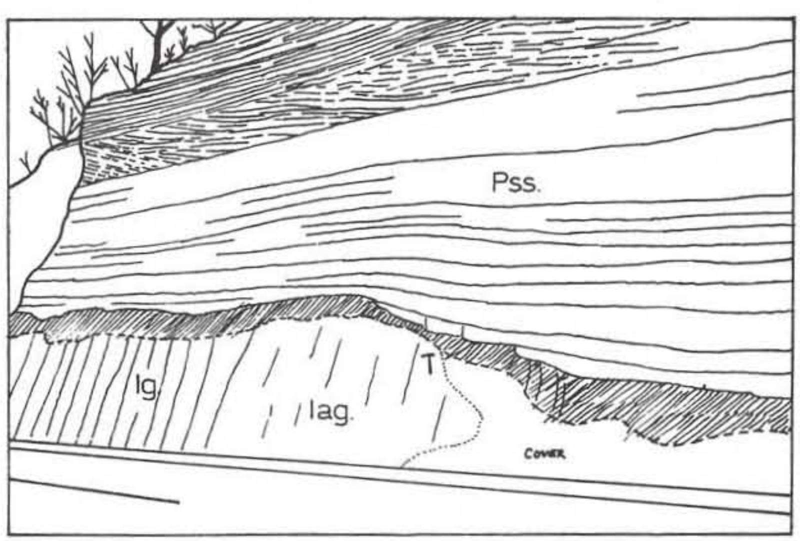


Fig. 5. STOP 4: Precambrian-Paleozoic angular unconformity at Alexandria Bay. Notation as in Fig. 3. East end of roadcut on south side of N.Y. 12, 2 miles east of Alexandria Bay, N.Y.

generally rare throughout the orthoquartzite facies of the Potsdam Sandstone; in this area tourmaline and zircon are the most common.

Above the basal strata the beds become more nearly horizontal and the bed thickness gradually decreases (medium-bedded). The beds include red, pink and white, laminated, medium-grained orthoquartzite with conspicuous "dusty" hematite rimming the rounded quart grains. Similar, but less mature, friable, white, gray and pink, fine- to medium-grained orthoquartzites also occur which weather greenish-yellow. Tourmaline and hematite are conspicuous in these rocks, along with interstitial clay and occasional rock fragments. The red and pink "banded" sandstones continue to the top of the section. In the upper third of the section is a well defined band of large-scale, planar cross-stratified beds.

The high textural and mineralogical maturity and the absence of clasts of the Precambrian rocks in the lowermost beds suggests that the sediments described above were derived from reworking of fluvial sands (floodplain alluvium) by an encroaching sea. The detrital material carried seaward by currents accumulated on and eventually blanketed the irregular pre-Potsdam erosion surface. Sedimentary features in the sandstones (especially the laminated bedding) indicate deposition in the "low energy, littoral to nearshore environment" of the Potsdam Sandstone described by Otvos (1966); Fisher (1968, p. 16) interprets what appears to be a similar facies of the Potsdam Sandstone in the Champlain Valley as, in part, the deposits of low energy outer intertidal and inner subtidal environments. The cross-stratified beds in the upper part of the section may indicate somewhat higher-energy conditions in which currents built solitary banks into shallow water just off a beach (Allen, 1963, p. 101).

Stop 5. Chippawa Bay.- Upper Potsdam Sandstone and lower Theresa Formation exposed in roadcut on N.Y. 12, 0.2 miles northeast of intersection with Pleasant Valley Road, 2.7 miles east of Chippawa Bay, New York.

Potsdam Sandstone

The Potsdam Sandstone exposed at this locality is a thin- to medium-bedded, white orthoquartzite with minor cross-stratification and ripple marks, especially in the lower part of the section (Fig. 6). Vertical U-shaped organismal burrows *(Diplocraterion?)* occur in Horizon 5-1 (Stop 5, Horizon 1) and are well displayed in the southeastern wall at the southwestern end of the roadcut (Fig. 8). Simple vertical burrows are also seen at this level but these are believed to be U-shaped burrows that are only partly displayed by the available section.

Close examination shows that the burrows are *Spreitenbauten* (Seilacher, 1967, p. 418-421) as they display laminations reflecting the shape of the terminal bend that are indicative of a shift of the tube through the sediment. Some of the burrows are infilled and the infilling can be traced into the lowest part of the burrows; the burrows appear to be entirely protrusive in vertical direction and thus reflect a response to growth of the organism rather than a response to fluctuations in the depositional rate (Seilacher, 1967, p. 418-420). The rather deep penetration of the burrows at this horizon indicates a slowing down of the rate of sedimentation.

FIGURE 7.

STOP 6: Brier Hill

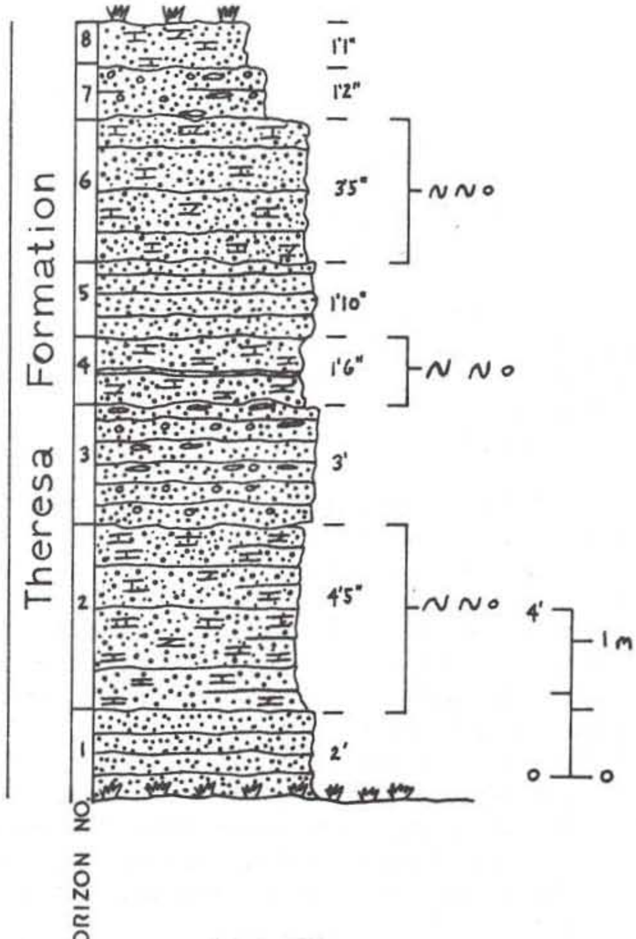
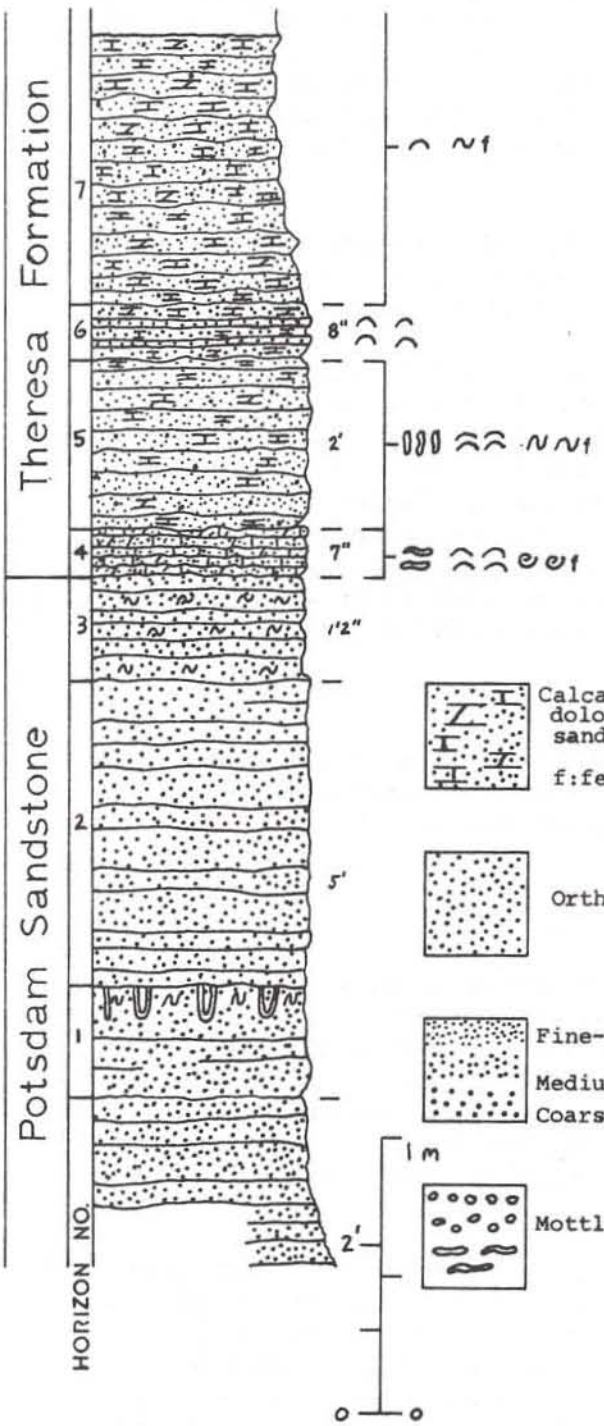
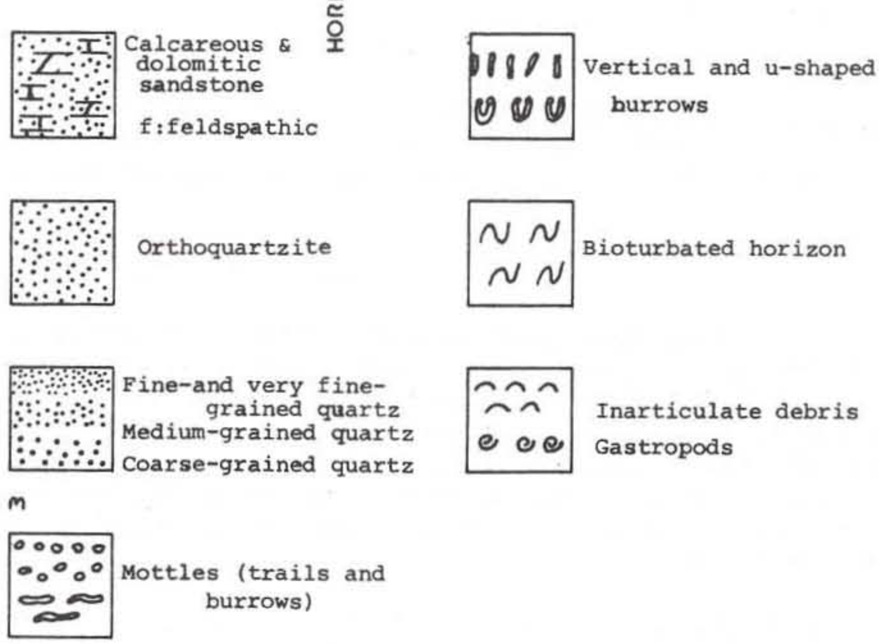


FIGURE 6.

STOP 5: Chippawa Bay





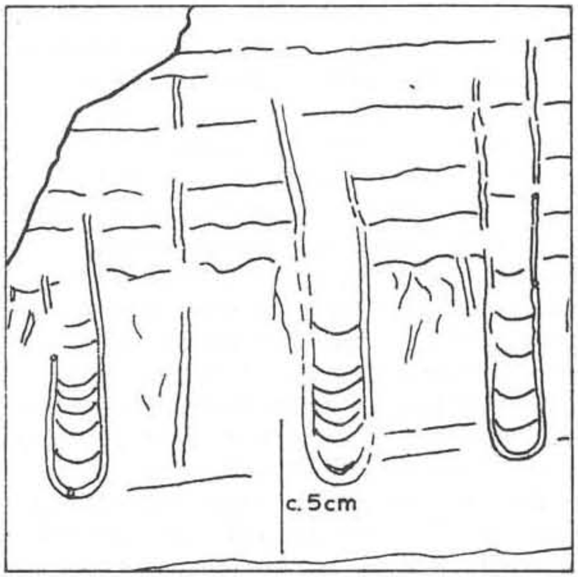


Fig. 8. Spreite burrows (*Diplocraterion?*) in the Potsdam Sandstone. STOP 5-1, N.Y. 12 near Chippawa Bay, N.Y.

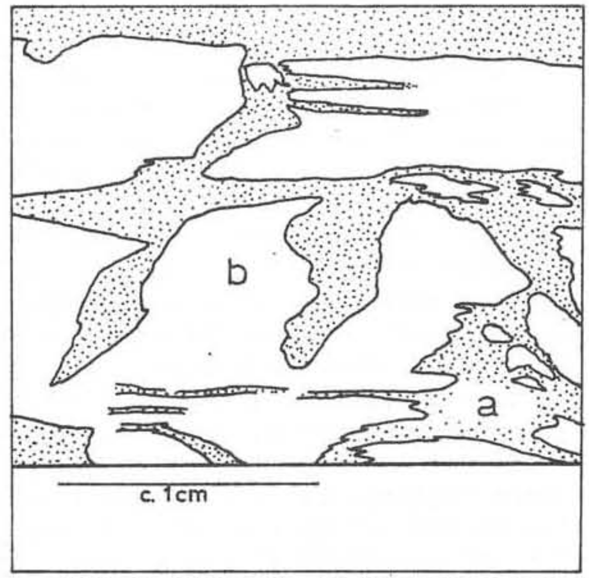


Fig. 9. Mudcracks in Ogdensburg Dolomite. a) very fine-and fine-grained quartz. b) very finely and finely crystalline dolomite. STOP 7-6, McConville Inc. Quarry, Ogdensburg, N.Y.

Fig. 10. Mudcracks and intraformational breccia in Ogdensburg Dolomite. a) very finely crystalline (aphanocrystalline) dolomite b) finely crystalline dolomite with medium-grained, coarse-and very coarse-grained quartz. STOP 7-9, McConville Inc. Quarry, Ogdensburg, N.Y.

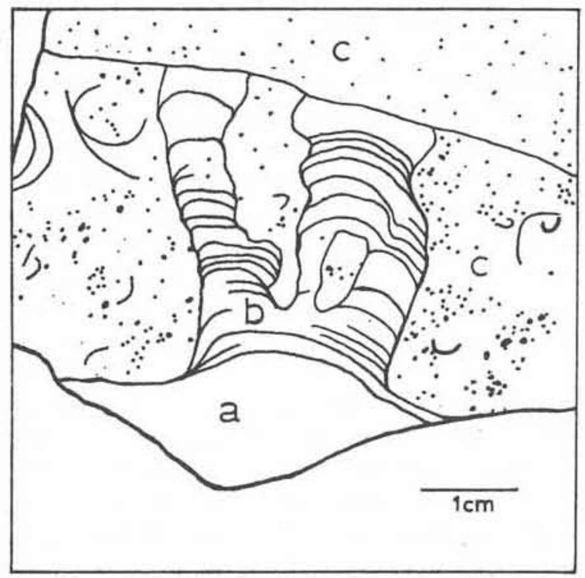


Fig. 11. Algal stromatolites in Ogdensburg Dolomite. a) medium crystalline dolomite b) algal stromatolite: space-linked hemispheroids (*Collenia* structure) and digitate vertically stacked hemispherioids (*Cryptozoon* structure) c) interareas:finely and medium crystalline sandy dolomite with oolites, gastropod and orthocone fragments and clasts broken from stromatolites. Quartz grains (bk) are medium-and coarse-grained. STOP 7-12, McConville Inc. Quarry, Ogdensburg, N.Y.

The organism that made these burrows can be postulated as an elongate animal that depended on the development of incurrent and excurrent water movements. It was thus a suspension feeder and its burrow a protective shelter. Currents above the sediment-water interface had sufficient turbulance to transport food particles and keep them in suspension, but not enough to introduce a significant amount of sediment or cause significant erosion. Such burrows are known from modern intertidal and shallow subtidal environments as well as more off-shore areas (Seilacher, 1967; Frey, 1970), and are made by a variety of organisms: amphipod crustaceans (Seilacher, 1967, p. 414, 422), polychaete annelids (Seilacher, 1967, p. 414; Rhoades, 1967, p. 464-467; Frey, 1970, p. 512-513) and hemichordates (Frey, 1970, p. 512). Studies by Rhoades (1967) and Seilacher (1967) indicate that deep burrows are generally characteristic of intertidal environments, in which the burrows provide shelter from fluctuations in temperature, salinity and dessication at the sediment-water interface. Such conditions might account for the relatively low density of burrows and the apparent absence of other fossils in Horizon 5-1 and elsewhere in the section. It thus seems a reasonable hypothesis that the white orthoquartzite facies of the Potsdam Sandstone in this area records a nearshore intertidal environment.

Theresa Formation

The lower Theresa Formation in this section consists of gray and blue-gray, fine-grained, feldspathic, calcareous and dolomitic sandstone. The original sedimentary fabric of the rock has been modified to varying degrees by burrowing and general bioturbation. Remarkably well rounded, spherical, medium- and coarse-grained quartz is scattered throughout the succession. The carbonate cement, which locally approaches 50% of the rock, is predominantly calcite which appears to have largely replaced an earlier dolomite cement. Locally the detrital grains float in a matrix of sparry calcite, forming the distinctive lustrous cleavage surfaces ("sand crystals" or "crystal sandstone") noted by early workers (Cushing and others, 1910; Cushing, 1916). The quartz grains, which appear frosted in hand specimen, are etched and corroded by the calcareous cement; siliceous overgrowths similar to those which characterize the underlying Potsdam Sandstone occur where the quartz grains are concentrated.

Relatively shallow vertical and nearly vertical burrows (*Skolithos*) infilled with calcite-cemented quartz are well displayed in Horizon 5-5. Lenses and lamellae of comminuted inarticulate brachipod debris (*Lingulepis acuminatus*) are concentrated at several levels in the lowermost horizons; the best material may be collected from Horizons 5-5 and 5-6 on the north side of the roadcut. Poorly preserved discoidal gastropods and grazing trails may be seen on some bedding surfaces in Horizon 5-4.

The immaturity of these sandstones and their carbonate content and fauna indicate accumulation in a relatively uniform low energy environment (possibly subtidal), offshore from the intertidal environment suggested for the underlying white orthoquartzites of the Potsdam Sandstone.

Stop 6. Brier Hill- Roadcut along N.Y. 12, just south of turnoff to Brier Hill and Jacques Cartier State Park. Theresa Formation.

The outcrop exposes a gently folded and faulted section in the upper part of the Theresa Formation (Fig. 7) consisting of medium-grained, white orthoquartzites alternating with gray and blue-gray, coarse-, medium- and fine-grained, calcareous and dolomitic sandstones. The white orthoquartzites are like those of the upper Potsdam Sandstone seen at Stop 5. At Horizons 6-3 and 6-7, the quartzites are riddled with dark brown mottles and elongate patches of limonite-stained quartz floating in sparry calcite cement. These features trend nearly parallel to bedding surfaces and are interpreted as infillings of burrows.

The gray calcareous and dolomitic sandstones are thoroughly bioturbated (mottled) and original sedimentary fabrics have been nearly obliterated. Cut-and-fill structure may be seen at several levels, indicating relatively strong current activity. The rock consists of a mixture of about equal amounts of coarse-, medium- and fine-grained quartz, the coarser grains being remarkably well rounded, spherical, and frosted. The grains are notably etched and corroded by the predominantly calcitic cement, but optically conformable silica overgrowths occur where quartz grains are concentrated. The calcite appears to have almost completely replaced an earlier dolomite cement and the lustrous cleavage surfaces produced by pockets of sparry calcite cement (crystal sandstone)are a distinctive feature of the rock in the field (Horizons 6-2, 6-6). Inarticulate debris, detrital feldspar and rock fragments are less conspicuous in the Theresa Formation at this locality than at Stop 5.

The relatively thorough bioturbation of the gray and blue-gray calcareous and dolomitic sandstones (Horizons 6-2, 6-4, 6-6) again suggests that the sediments accumulated in a more offshore (subtidal) environment than that of the less biogenically disturbed orthoquartzites. Moore and Scrutton (1957) and Rhoades (1967) have noted that prolonged activity of subtidal bottom communities near the sediment-water interface under conditions of relatively slow sediment accumulation results in the complete reworking of the sediment.

Cushing (1916, p. 24) reported about 140 feet of Theresa Formation in this area and Dietrich (1957, p. 706) documented the variation in lithofacies within the unit. In addition to the types described above, Dietrich reported blue-gray, sandy limestones and buff and gray, sandy, dolomitic limestones. Chadwick (1915, p. 289) introduced the name Heuvelton Sandstone for a 0 to 20 foot thick lens of white orthoquartzite lying above the Theresa mixed beds in central St. Lawrence County. Although Cushing (1916) used the name, the presence of the unit among the white orthoquartzites in the Brier Hill area is uncertain (Dietrich, 1957, p. 105). As noted above, Berry and Theokritoff (1966) regard the Heuvelton Sandstone as a member of their extended Bucks Bridge Formation. Although the Theresa Formation (northwesternmost St. Lawrence and Jefferson Counties) and the Bucks Bridge Formation (central St. Lawrence County) of Berry and Theokritoff (1966) occupy the interval between the Potsdam Sandstone and the Ogdensburg Dolomite, their precise stratigraphic relationships have yet to be established.

Stop 7. McConville, Inc. Quarry in Ogdensburg Dolomite on the west side of Ogdensburg.- Driving east on N.Y. 37 from Morristown, N.Y. turn left at the Ogdensburg bypass and follow the sign for downtown Ogdensburg. Continue on old N.Y. 37 for 0.8 miles and turn right at the fork onto Ogden Street. Proceed for two blocks and turn right onto Madison Avenue. Park in field opposite intersection with Gates Street (0.1 miles). Ogdensburg Dolomite.

Introduction

Cushing (1916) recognized around 140 feet of Ogdensburg Dolomite in this region and measured sections from roadcuts and quarries (now mostly overgrown) between Morristown and Ogdensburg and northward to Red Mills, New York. In spite of scattered outcrop and apparent rapid facies changes, he pieced together the composite section summarized here, beginning at the base: 1. small thickness of basal sandy beds transitional with the underlying Theresa Formation 2. thick-bedded, blue, sandy dolomites (15 ft.) and thin-bedded, gray dolomites (20 ft.) 3. alternating thick-bedded, dark blue and gray, sandy dolomites, locally with abundant but poorly preserved gastropods (especially in the lower part) and occasional thin sandstones (white orthoquartzites) and *Cryptozoon* layers (80 ft.) 4. thin-bedded ("flinty") dolomites (20 ft.).

The thirty foot section exposed in the abandoned southeast part of the quarry (Fig. 12; Appendix) represents the transition between intervals 3 and 4 described above. Detailed examination reveals a remarkably varied sequence with numerous structures of sedimentological and paleoecological interest especially in light of the wealth of data now available on the environments and characteristics of recent shallow water carbonate sediments. Walker and LaPorte (1970, p. 931-933) provide a concise review of the literature and a summary of lithologic, paleontologic and primary structural criteria for recognition of subtidal to supratidal carbonate environments in ancient rocks. Reconstructions of paleoenvironments must of necessity follow and build upon an understanding of regional stratigraphic relations (for example, LaPorte, 1969, Walker and LaPorte, 1970, Thompson, 1970) but in the case of the Ogdensburg Dolomite (and the Theresa and Bucks Bridge Formations as well) such a stratigraphic synthesis is not available. Perhaps in the case of the Ogdensburg Dolomite attempts to analyze sedimentological and paleoecologic features of local sections will stimulate new attempts to work out the regional stratigraphy. The horizons are briefly described in the Appendix and some tentative correlations are made with Cushing's (1916) sections.

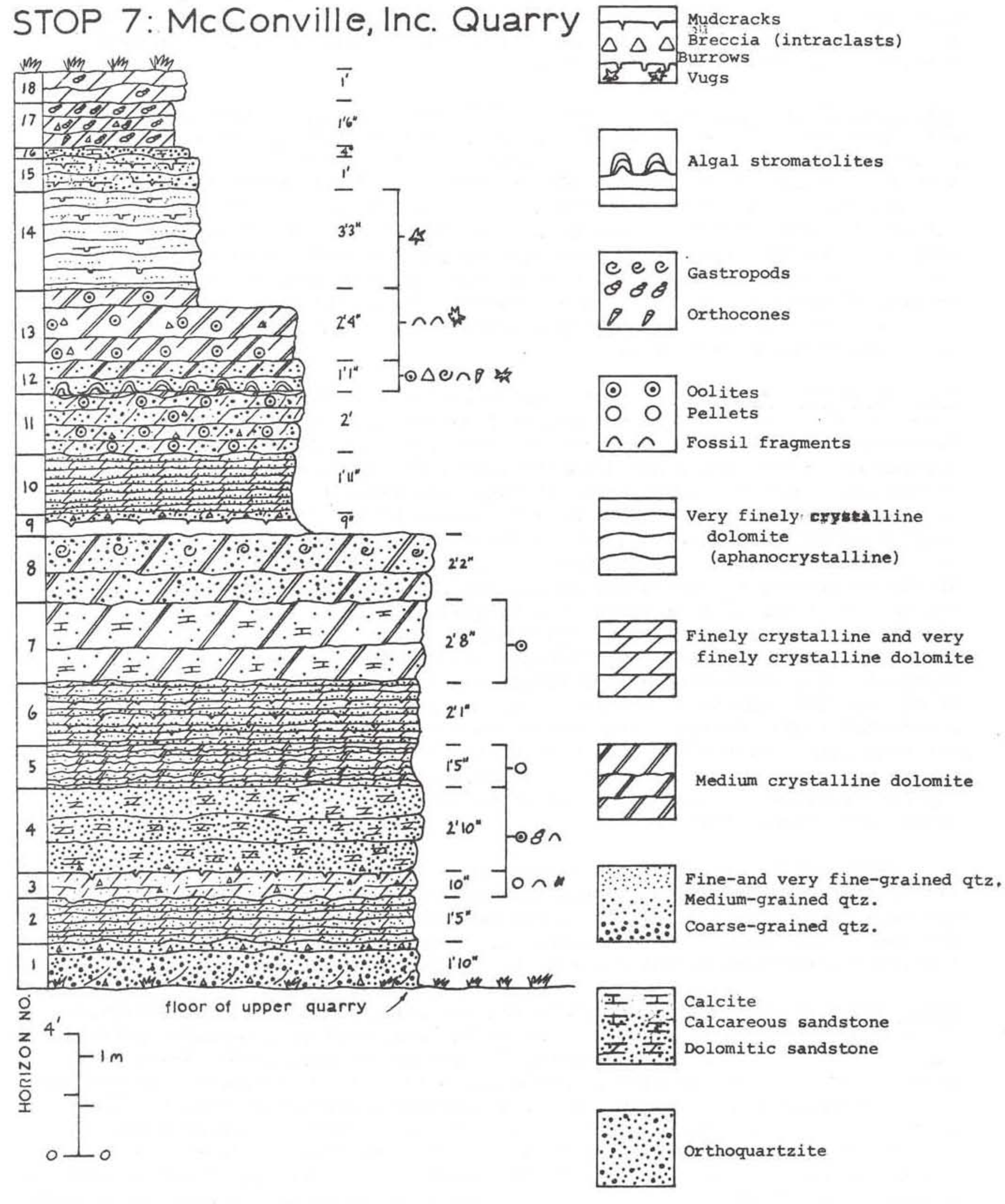
Interpretation

The combination of various features in the section suggests that the sediments accumulated in a protected (high intertidal) carbonate flat environment. Fluctuations in physical conditions are indicated by evidence of alternating flooding (influx of quartz sand, oolites, pellets, shell debris and lime mud) and subaerial exposure.

Laminated, mudcracked, carbonate muds- Thin bedded to laminated (ribbon-laminated), mudcracked, finely crystalline to aphanocrystalline carbonates characterize the tidal flat environment where lime muds are subjected to

FIGURE 12 Ogdensburg Dolomite

STOP 7: McConville, Inc. Quarry



subaerial exposure; the irregular and regularly laminated horizons (e.g. 7-2, 7-5, 7-6, Fig. 9, 7-10) are believed to indicate sediment trapping by algal mats. Flooding of the tidal flat during storms or extreme tides would tend to break up the limy crust and resediment the clasts, forming intraformational breccias (7-9, Fig. 10).

Fossils, oolites, pellets- The lenses of fossil debris, especially the small gastropods (7-8, 7-12, 7-13, 7-17, Fig. 15) and the oolites (7-11, 7-13) and pellets (7-3, 7-5) as well, represent material transported in from more seaward environments (low intertidal to subtidal) during times of flooding. A wind-blown origin of some of the quartz is indicated by frosted grains haphazardly distributed in some beds. The paucity of fossils believed to be indigenous to the deposits and the general lack of evidence of infaunal reworking also suggest the ecologically adverse conditions of the high intertidal environment (Walker and LaPorte, 1970); Horizons 7-3, and 7-5, however, show evidence of bioturbation and vertical burrows occur in Horizons, 7-14 and 7-15 (Fig. 14).

Algal stromatolites- Algal stromatolites are perhaps the least equivocal evidence of intertidal and supratidal environments although they have also been reported from recent subtidal environments (Gebelein, 1969). Studies of present day algal stromatolites indicate that most active mat growth and sediment binding requires subaerial exposure whereas prolonged wetting inhibits mat growth (Logan and others, 1964). Tidal and splash water accumulating in depressions on the mat surface leads to differentiation of the laminae into discrete domes and interareas. Linkage of the lamellae in the interareas between domes is further inhibited by scour-and-fill. Changes in stromatolite morphology with growth reflect minor fluctuations in the physical environment (Logan and others, 1964). For example, the change from initial space-linked hemispheroids (*Collenia* structure) to digitate vertically stacked hemispheroids (*Cryptozoon* structure) seen in Horizon 7-12 (Figs. 11, 13) indicate a change in environment from protected intertidal to a somewhat higher energy, more exposed intertidal environment. Larger, well differentiated, club-shaped, stacked hemispheroids (*Cryptozoon* structure) are known from other levels within the Ogdensburg Dolomite (Fig. 16) and in present day stromatolite environments these occur on exposed intertidal headlands (Logan and others, 1964, p. 80).

Stromatolite growth ceased at Horizon 7-12 when the laminae were flooded and blanketed with skeletal debris and other sediment carried in from offshore. The relatively fossiliferous levels in the upper part of Horizon 12 and Horizon 13 may indicate subtidal deposits, with Horizons 14 and 15 (Fig. 14) marking a withdrawal of the sea and the return of the intertidal conditions.

Early dolomitization- Penecontemporaneous or early diagenetic dolomitization of carbonate sediments is known to occur in tidal flat environments, particularly supratidal, in areas of high aridity (Illings and others, 1965; Shinn and others 1965). Magnesium-rich brines developing on or just beneath the surface in the supratidal and high intertidal environments percolate through and replace the original carbonate sediment. Dolomitization of the original sediment in the Ogdensburg Dolomite appears to have been complete; the minor amounts of calcite occurring at several levels is interpreted as late diagenetic void-fillings (7-17, Fig. 15). Early dolomitization in the Ogdensburg Dolomite

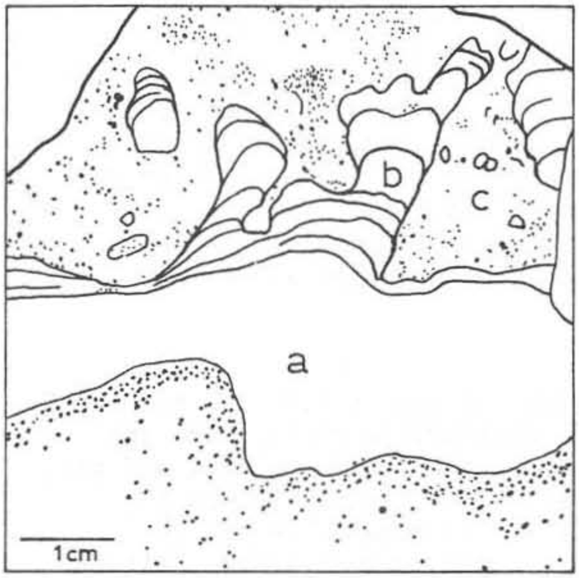


Fig. 13. Algal stromatolites in Ogdensburg Dolomite. Notation as in Fig. 11. STOP 7-12, McConville Inc. Quarry, Ogdensburg, N.Y.

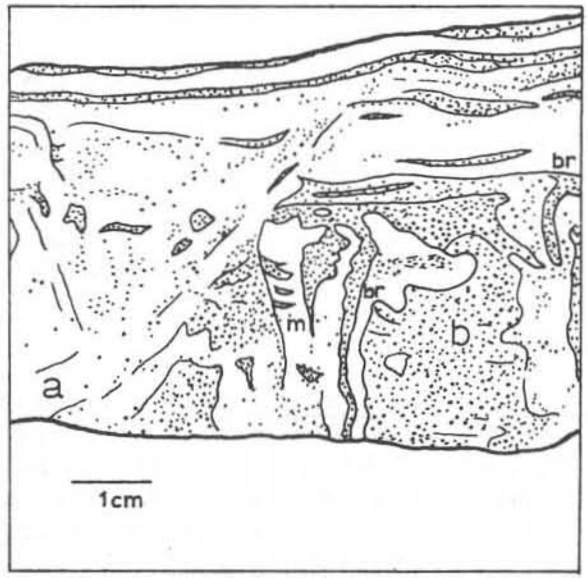


Fig. 14. Mudcracks(m), burrows(br), & slump bedding in Ogdensburg Dolomite. a) very finely crystalline (aphanocrystalline) dolomite b) dolomite as in (a) with coarse- and medium-grained quartz. STOP 7-15, McConville Inc. Quarry, Ogdensburg, N.Y.

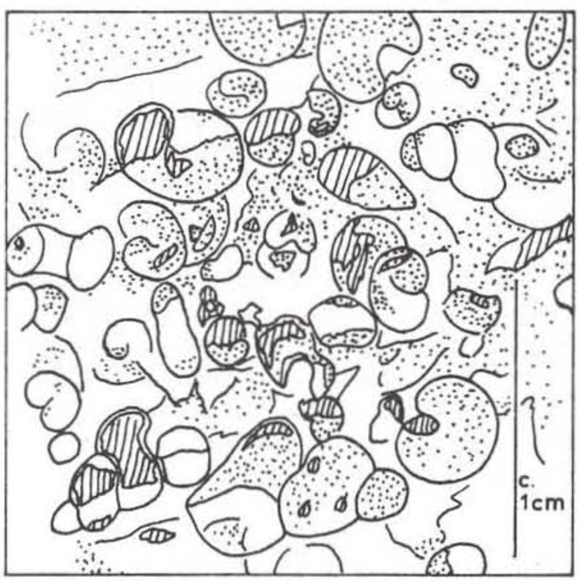


Fig. 15. Snail bed in Ogdensburg Dolomite. Stipple: medium crystalline dolomite, Blank: very finely and finely crystalline dolomite, Ruled: calcite. Clasts include gastropods (abundant), finely crystalline sandy dolomite, oolites and orthocones (rare). *Hormotoma* horizon (?) of Cushing 1916. STOP 7-17, McConville Inc. Quarry, Ogdensburg, N.Y.

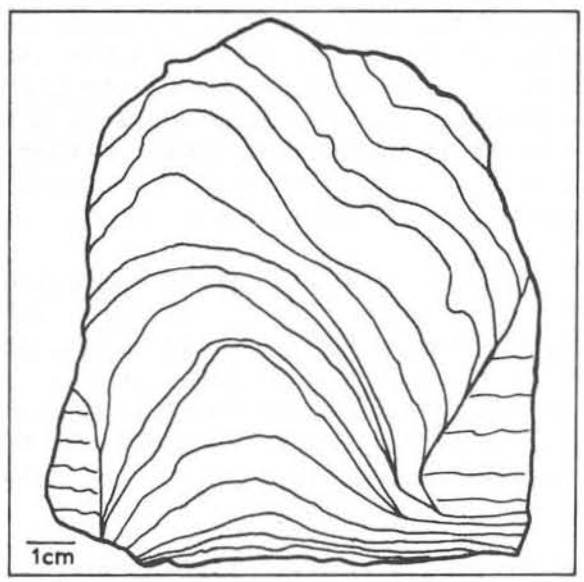


Fig. 16. Algal stromatolite in Ogdensburg Dolomite. Space-linked vertical stacked hemispheroid (*Cryptozoon* structure) with initial constant basal radius giving way to variable basal radius. A few feet above road level and in abandoned quarry on south side of N.Y. 37, west of Ogdensburg, about 0.5 mi. west of turnoff to downtown Ogdensburg.

7-3	0' 10"	Dark gray, irregularly bedded, mudcracked, finely crystalline, slightly calcareous, sandy dolomite with very fine- to fine-grained quartz. Dolomite matrix masks ghosts of fossil fragments, intraclasts of finely crystalline dolomite and pellets(?).
7-2	1' 5"	Dark brownish-gray to light gray, thin-bedded to ribbon-laminated, finely crystalline, sandy dolomite, alternating with very fine-grained, dolomitic sandstone.
7-1	1' 10"	White to light gray,coarse- to medium-grained, slightly calcareous, cross-laminated, orthoquartzite with dark gray clasts of sandy dolomite. Quartz grains well-rounded and spherical and cemented by silica over-growths. This distinctive white band, which can be traced in all the quarry walls, may correspond to Bed 9 of Cushing's (1916, p. 45) section on the west side of Ogdensburg.
		Base of section.

BIBLIOGRAPHY

Allen, J. R. L., 1963, The classification of cross-stratified units, with notes on their origin. Sedimentology, Vol. 2, p. 93-114.

Berry, W. B. N., and Theokritoff, George, 1966, Description and paleoecology of a Tremadoc dendroid graptolite from northern New York. Geol. Soc. Amer. Bull., v. 77, p. 873-878.

Broughton, J. G., Fisher, D.W., Isachsen, Y. W., Rickard, L.V., Offield, T. W., 1962, The Geology of New York State, N.Y. St. Mus. Sci. Serv. Map and Chart Ser. No. 5.

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

Chadwick, G. H., 1915, Post-Ordovician deformation in the St. Lawrence Valley, New York: Geol. Soc. Amer. Bull., v. 26, p. 287-294.

Chadwick, G. H., 1920, The Paleozoic rocks of the Canton quadrangle: N.Y. St. Mus. Bull. 217-218, 60 p.

Cushing, H.P., 1908, Lower portion of the Paleozoic section in northwestern New York: Geol. Soc. Amer. Bull., v. 19, p. 155-176.

Cushing, H. P., 1916, Geology of the vicinity of Ogdensburg (Brier Hill, Ogdensburg and Red Mills quadrangles): N.Y. St. Mus. Bull. 191, 64 p.

Cushing, H.P., Fairchild, H.L., Ruedemann, R. and Smyth, C. H. Jr., 1910, Geology of the Thousand Island region--Alexandria Bay, Cape Vincent, Clayton, Grindstone and Theresa quadrangles. N.Y. St. Mus. Bull. 145, 194 p.

Dietrich, Richard V., 1957, Precambrian geology and mineral resources of the Brier Hill Quadrangle. N.Y. St. Mus. Bull. 354, 121 p.

Emmons, Ebenezer, 1838, Report of the second geological district of the State of New York: N.Y. St. Geol. Surv., 2nd Ann. Rpt., p. 185-252.

Fisher, D. W., 1955, Time span of the Theresa and Potsdam Formations in the region peripheral to the Adirondack Mountains, New York (abs.). Geol. Soc. Amer. Bull., v. 66, p. 1558-1559.

Fisher, D. W., 1956, The Cambrian System in New York: Cambrian Symposium, 20th Intern. Geol. Congress, Mexico City, p. 321-351.

Fisher, D. W., 1962A, Correlation of the Cambrian rocks in New York State: N.Y. St. Mus. Sci. Serv., Map and Chart Ser. No. 2.

Fisher, D. W., 1962B, Correlation of the Ordovician rocks in New York State: N. Y. St. Mus. Sci. Serv., Map and Chart Ser. No. 3.

Fisher, D. W. 1968, Geology of the Plattsburgh and Rouses Point, New York-Vermont Quadrangles. N.Y. St. Mus. Sci. Serv. Map and Chart Ser. No. 10, 51 p.

Folk, R. L., 1962, Spectral subdivision of limestone types: p. 62-84 in Ham, W. E., Ed., Classifications of carbonate rocks, Am. Assoc. Petrol. Geol. Mem. 1, 279 p.

Frey, R. W., 1970, Environmental significance of Recent marine lebenspuren near Beaufort, North Carolina: Jour. Paleo., v. 44, pp. 507-519.

Gebelein, C. D., 1969, Distribution, morphology, and accretion rate of Recent subtidal algal stromatolites, Bermuda: Jour. Sed. Pet., v. 39, p. 49-69.

Illing, L . V., Wells, A. J., and Taylor, J.C.M., 1965, Penecontemporary dolomite in the Persian Gulf: p. 89-111 in Pray, L. C. and Murray, R.C., Eds. Dolomitization and Limestone diagenesis, Soc. Econ. Paleo. Min. Spec. Pub. 13, 180 p.

Kirwan, J.L., 1963, The age of the Nepean (Potsdam) Sandstone in eastern Ontario: Amer. Jour. Sci., v. 261, p. 108-110.

Krynine, P.H., 1948, Possible Algonkian in New York State (abs.): Geol. Soc. Am. Bull., v. 59, p. 1333-1334.

LaPorte, L. F., 1969, Recognition of a transgressive carbonate sequence within an epeiric sea: Helderberg Group (Lower Devonian) of New York State, p. 98-119, in Friedman, G.M., Depositional environments in carbonate rocks, Soc. Econ. Paleo. Min. Spec. Pub. 14, 209 p.

Logan, B. W., Rezak, R., and Ginsburg, R.N., 1964, Classification and environmental significance of algal stromatolites: Jour. Geol., v. 72, p. 68-83.

MacClintock, Paul, and Stewart, D.P., 1965, Pleistocene geology of the St. Lawrence Lowland: N.Y. St. Mus. Sci. Serv. Bull. 394, 152 p.

Moore, D. G., and Scruton, P. C., 1957, Minor internal structures of some Recent unconsolidated sediments: Am. Assoc. Petrol. Geol., Bull., v. 4, pp. 2723-2751.

Otvos, E. G. Jr., 1966, Sedimentary structures and depositional environments, Potsdam Formation, Upper Cambrian: Am. Assoc. Petrol. Geol. Bull. 50, No. 1, p. 159-168.

Postel, A. W., Nelson, A.E., and Wiesnet, D. R., 1959, Geologic map of the Nicholville quadrangle, New York: U.S.Geol. Surv., Geol. Quad. Map GQ-123.

Reed, J.C., 1934, Geology of the Potsdam Quadrangle: N.Y. St. Mus. Bull. 297, 98 p.

Rhoades, D. C., 1967, Biogenic reworking of intertidal and subtidal sediments in Barnstable Harbor and Buzzards Bay, Mass.: Jour. Geol, v. 75, p. 461-476.

Sabins, F. F., 1962, Grains of detrital, secondary and primary dolomite from Cretaceous strata of the Western Interior: Geol. Soc. Amer. Bull.,v. 73, p. 1183-1196.

Seilacher, Adolf, 1967, Bathymetry of trace fossils, Marine Geology, v. 5, p. 413-428.

Shinn, E. A., Ginsburg, R. N., and Lloyd, R.M., 1965, Recent supratidal dolomite from Andros Island, Bahamas, p. 112-123: in Pray, L. C. and Murray, R.C., Eds., Dolomitization and limestone diagenesis, Soc. Econ. Paleo. Min., Spec. Pub. 13, 180 p.

Shinn, E. A., 1968, Practical significance of birdseye structures in carbonate rocks: Jour. Sed. Pet., V. 38, p. 215-223.

Thompson, A.M., 1970, Tidal-flat deposition and early dolomitization in Upper Ordovician Rocks of Southern Appalachian Valley and Ridge: Jour. Sed. Pet., v. 40, p. 1271-1286.

Walker, K. R., and LaPorte, L. F., 1970, Congruent fossil communities from Ordovician and Devonian carbonates of New York: Jour. Paleo. v. 44, p. 928-944.

Wiesnet, Donald R., 1961, Composition, grain size, roundness and sphericity of the Potsdam Sandstone (Cambrian) in northeastern New York: Jour. Sed. Pet., v. 31, p. 5-14.

Wilson, A. E., 1946, Geology of the Ottawa-St. Lawrence Lowland, Ontario and Quebec: Canada Geol. Surv. Mem. 241, 65 p.

Wynne-Edwards, H. R., 1959, Geology Westport-Leeds, Frontenac, and Lanark Counties, Ontario: Canada Geol. Surv. Prelim. Ser. Map 28-1959.

Wynne-Edwards, H. R., 1962, Geology Gananoque, Ontario: Canada Geol. Surv. Prelim. Ser. Map 27-1962.

Wynne-Edwards, H. R., 1963, Geology Brockville-Mallorytown, Ontario: Canada Geol. Surv. Prelim. Ser. Map 7-1963.

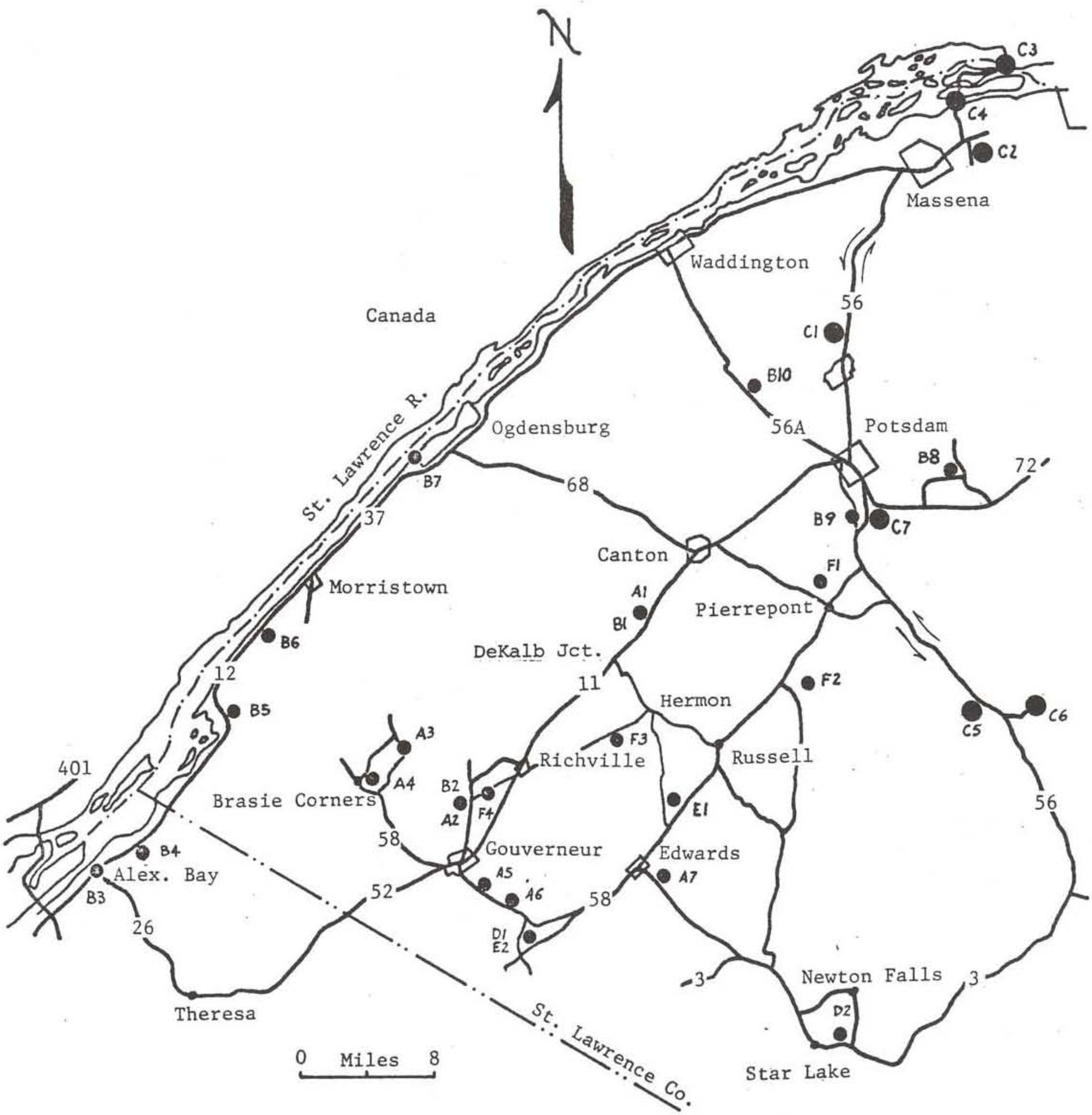


Figure 1. STOP MAP FOR TRIP C

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

Trip C

SOME ASPECTS OF ENGINEERING GEOLOGY IN THE ST. LAWRENCE VALLEY AND NORTHWEST ADIRONDACK LOWLANDS

by

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Potsdam, New York

ABSTRACT

The purpose of this field trip is to illustrate the interdependence of geology and civil engineering by means of several examples from the St. Lawrence Valley and the Lowlands of the Northwest Adirondacks. We will make seven stops in the vicinity of Norfolk, Massena, Potsdam, and South Colton, New York.

Stop 1 will be at a limestone quarry where the rock is processed for Portland cement and asphalt concrete aggregate. Here we will emphasize the interrelationship between the bedrock type and the physiography. Stops 5 and 7 will be at gravel quarries of very different geologic and physiographic character. The relationship of physiography and bedrock to gravel characteristics will be stressed. Stop 6 will be at concrete gravity dams on the Racquette River, for which much of the crushed stone and concrete aggregate was taken from the gravel pit at stop 5. We will indicate some of the desirable and undesirable properties of this fill for use in this particular dam project. At stop 2 we will visit the site of a landslide in the sensitive Leda Clay. Stops 3 and 4 will be in the Moses-Saunders Power Dam and Eisenhower Lock, respectively. Here the geologic parameters and problems of construction will be stressed.

STOP DESCRIPTIONS

The trip will consist of seven stops.

Stop 1 - Barrett Allied Chemical Pit, Norwood, N.Y. (Figs. 1,2,3 and Table 1)

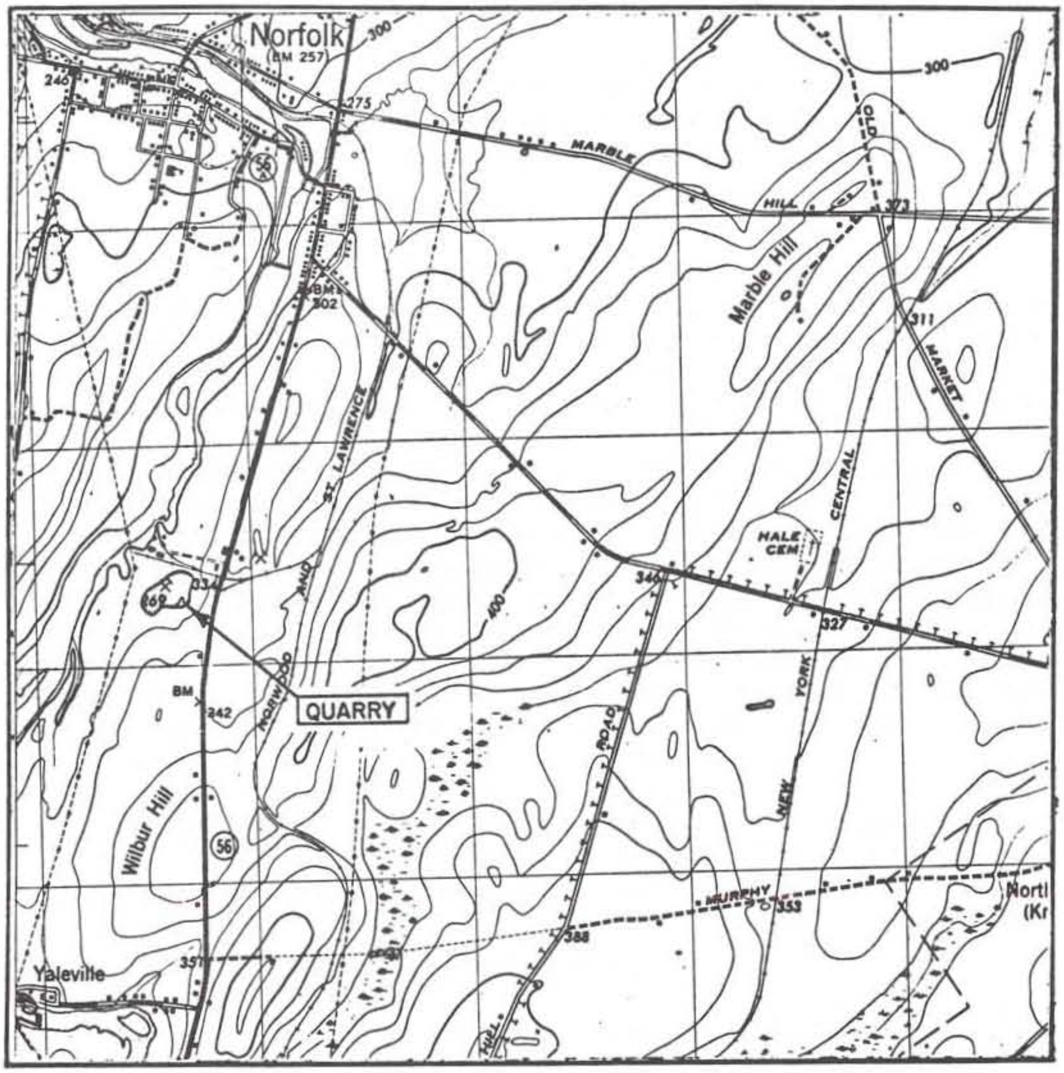
The ten to fifteen feet of glacial cover can be clearly seen at the southern end of the pit, and the fairly clean character of the overlying till is evident, as is the thin soil cover at the grass line near the top.

The rock is drilled, blasted, broken down further by the large steel ball, and trucked to the primary crusher, where it is sized, recrushed and stocked in piles according to size for use as Portland cement aggregates, asphalt concrete aggregates, and general engineering use as fills, drains, etc.

LOCATION MAP

BARRETT DIVISION OF ALLIED CHEMICAL

ST. LAWRENCE COUNTY: TOWN OF NORFOLK



SCALE 1" = 2000'

PHYSIOGRAPHIC PROVINCE: St. Lawrence Lowland

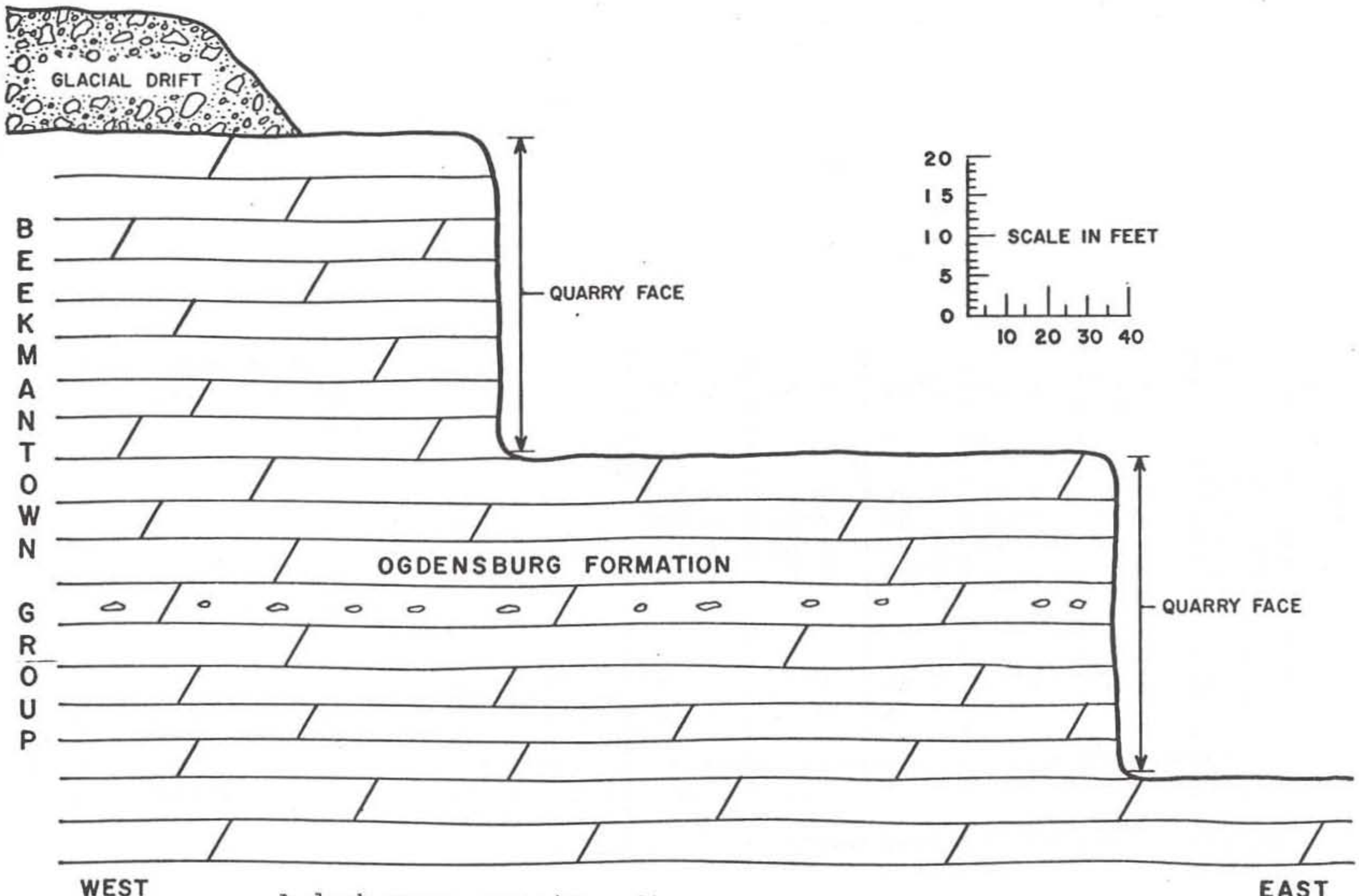
ARTIFICIAL SAND: Dolomite Quarry

MATERIAL ORIGIN: Dolomite

GEOLOGIC FORMATIONS: BEEKMANTOWN (Dol.)

STRUCTURE: HORIZONTAL BEDDING

Fig. 2



A dark gray, massive, fine-to-medium-grained dolomite, which contains small aggregates of white to pinkish dolomite and dolomite cyrstals. A prominent horizon of the dolomite crystals occurs about 15 feet above the quarry floor. Bedding ranges from 3 inches to a foot in thickness.

ELEVATION OF PIT
BARRETT DIVISION, ALLIED CHEMICAL

Fig. 3

ENGINEERING DATA

Commercial Gravel Pits — Stops 1, 5, 7

Pit & Location	PI	MG504 Loss 4 cyl	Sieve Analysis (% finer than by wt.) 2"	1"	1/4"	#4	#10	#40	#200	% #200/#40
1. Barrett, Norwood, N.Y. St. Lawrence Lowland	NP	2.4	100.0	89.6	59.6	49.3	30.7	3.5	0.8	22.9
	NP	1.7	100.0	88.4	58.6	54.6	43.7	9.1	1.1	11.6
6. Edson Martin, Colton, N.Y. Adirondack Mountain	NP	4.1	100.0	79.2	60.4	57.2	50.1	31.8	7.5	23.6
	NP	4.6	100.0	80.4	61.2	58.6	50.5	26.8	3.9	14.6
	NP	2.3	100.0	77.0	60.8	57.7	50.8	27.9	3.4	12.2
	NP	4.2	100.0	67.8	52.7	49.2	40.6	26.3	6.5	24.6
7. Bicknell, Potsdam, N.Y. Transition Area - St. Lawrence Lowland and Adirondack	NP	7.4	100.0	74.3	56.7	55.5	53.4	40.2	2.4	5.9

Table 1

The rock which usually is hard and dense, probably extends 100 feet deeper than the present base of the pit.

Its denseness is apparent on the west side of the pit, where minimum pumping operation is required to keep out the water infiltrating from the river just over the hill, and whose elevation is considerably higher than the base of the pit.

Stop 2 - Landslide in Leda Clay on the Massena Springs Road Near the Massena Airport (Racquette Cemetery Site)

The general area of the Racquette cemetery site has been exposed to many earthquakes, the most severe that of September 5, 1944. Many smaller tremors have been recorded prior to and after this shock.

Structures founded on the marine (Leda) clay were most affected by earthquake shock, while those founded on glacial till showed much less response. The epicenter of the 1944 earthquake was located in Massena Springs, approximately one mile north of the cemetery site.

The last glacial ice sheet deposited many very dense glacial till moraines near the St. Lawrence River. Streams with their headwaters in the Adirondacks encountered these moraines, and generally cut through glacial outwash deposits and the clays, these offering the least resistance.

The cemetery site consists of marine clay deposited between two moraines. The moraines existed prior to the formation of Lake Iroquois, which deposited clay in the valley between the moraines. The highest points of these moraines are 250 feet and 230 feet above sea level for the south and north shore respectively.

Soil borings performed at the site on the north shore indicated a clay layer thickness of about 65 feet, where surface elevation was 200 feet. Since till was encountered below the clay, the valley between the moraines was at or below 140 feet. The clay offered very little resistance so that the water was confined between these two moraines.

The clay at the site is rather strong and somewhat preconsolidated in the undisturbed state, but remolding causes a drop in shear strength to a very small value. If one looks closely at the surface topography immediately adjacent to the river as the bus proceeds along the road to this stop, old landslide scars will be evident in the form of small surface scarps.

The landslide located at this stop resulted from the combination of heavy loads on top of the slope (logs from cut elms, sand piles), and erosion of the clay by the river at the foot of the slope. Many graves were lost and the trees near the river were tilted. The small island nearest the cemetery is probably a remnant of an old slide.

Mr. Spencer Thew of Clarkson College has placed observation wells in the slide area, and has taken samples of the undisturbed clay. The failure plane of the slide can be seen in the field, and it is possible that the soil strength parameters existing before the slide occurred can be inferred from the data he will collect. Such studies of field failures may make it possible to prevent future slides and property damage and personal injury. Note how close the next group of houses to the right of the cemetery is to an apparent old slump scarp.

Stop 3 - Moses-Saunders Power Dam; St. Lawrence Seaway, Massena, New York

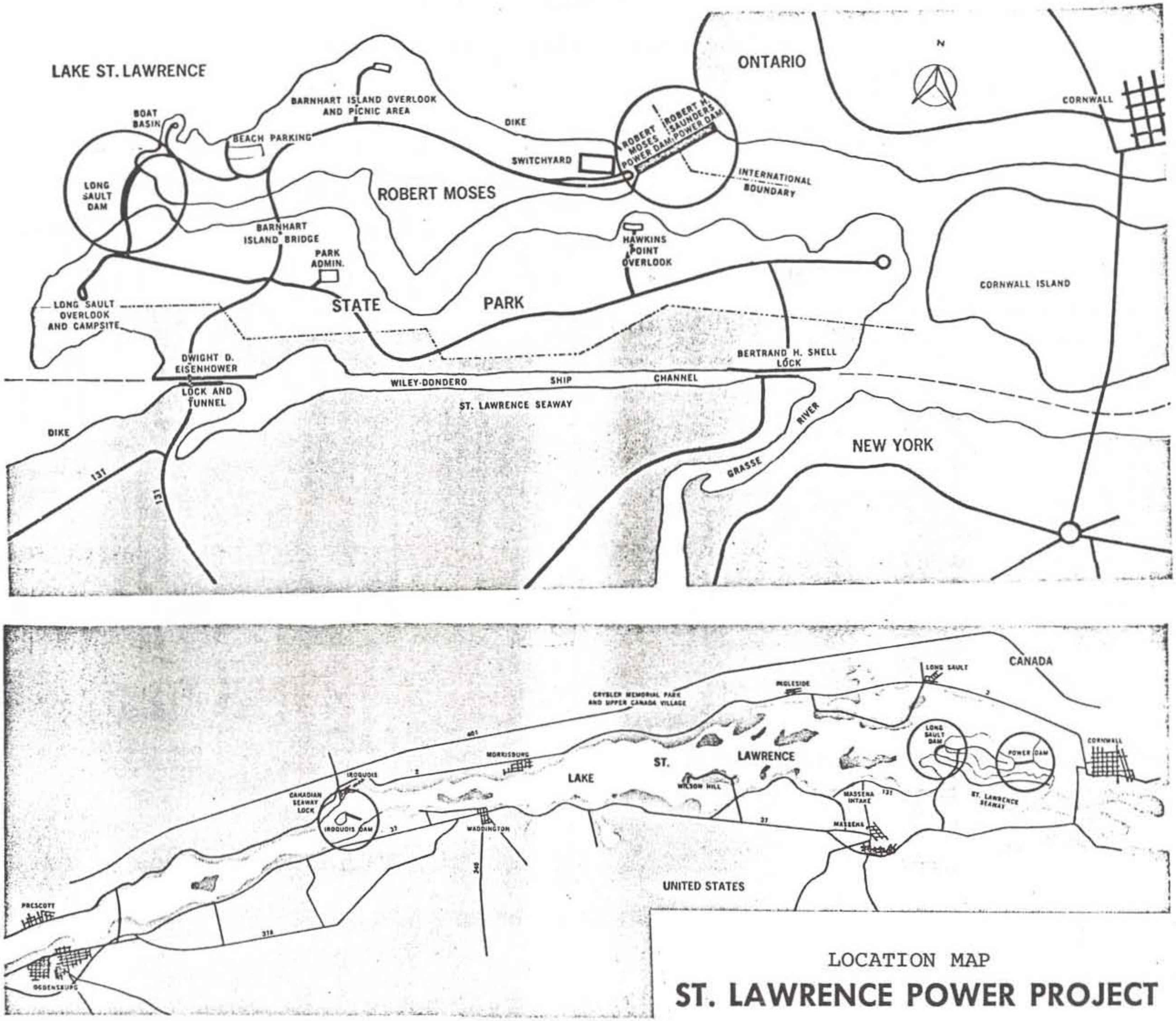
The location map is shown in Fig. 4. This dam provides approximately 912,000 kilowatts of power. The dam has a head of 81 feet, and behind it is Lake St. Lawrence, with its fine marina and Barnhart Island Beach. A section through the Moses Power Dam is shown on Fig. 5, and of the Long Sault Control Dam on Fig. 6.

A thirty minute film will be shown in the auditorium at the dam, which will illustrate the methods and problems of construction.

A tour of the dam will be made, and from the top of the building Lake St. Lawrence can be clearly seen, with some of the zoned and rip-rapped dikes bounding it composed of compacted glacial till with dry densities on the order of 140 pcf (concrete is 150 pcf).

Stop 4 - Eisenhower Lock, St. Lawrence Seaway

This structure enables ships traveling the St. Lawrence River to pass around the Moses Saunders Power Dam and, along with Snell Lock five miles farther east, lowers the ships through a total of 95 feet of elevation. Both locks have dimensions of 860 feet by 80 feet and are of concrete construction. The locks are huge bathtubs in a sense, with openings along the sides into a passageway (about 13' wide by 15' high) on each side which slopes to the upstream end of the lock. When a ship comes down the St. Lawrence River and through the canal to the lock, the lower lock gates are closed, and the water is at the upper canal elevation. The ship moves slowly into the "bathtub", the upstream gates are closed, and then the water is let out of the locks through the openings in their sides, down the passageway on either side and discharged below the lock. A system of

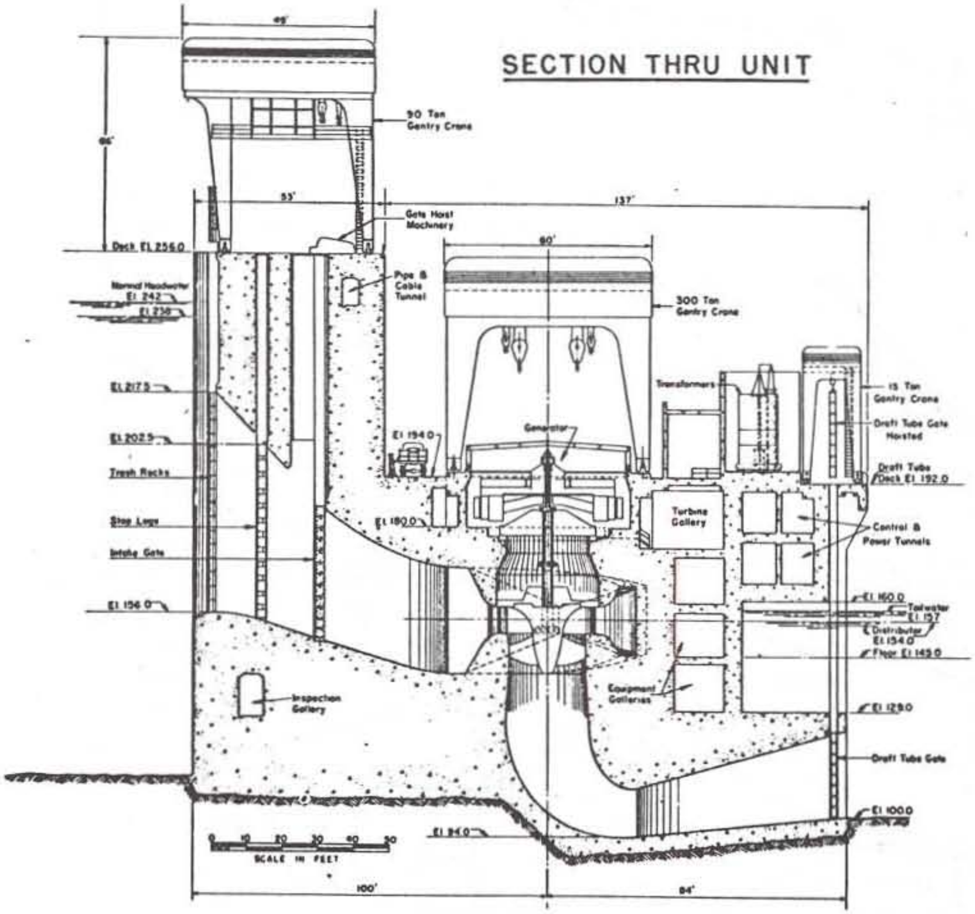


LOCATION MAP

ST. LAWRENCE POWER PROJECT

Fig. 4

ROBERT MOSES POWER DAM



UNITED STATES HALF—ROBERT MOSES POWER DAM

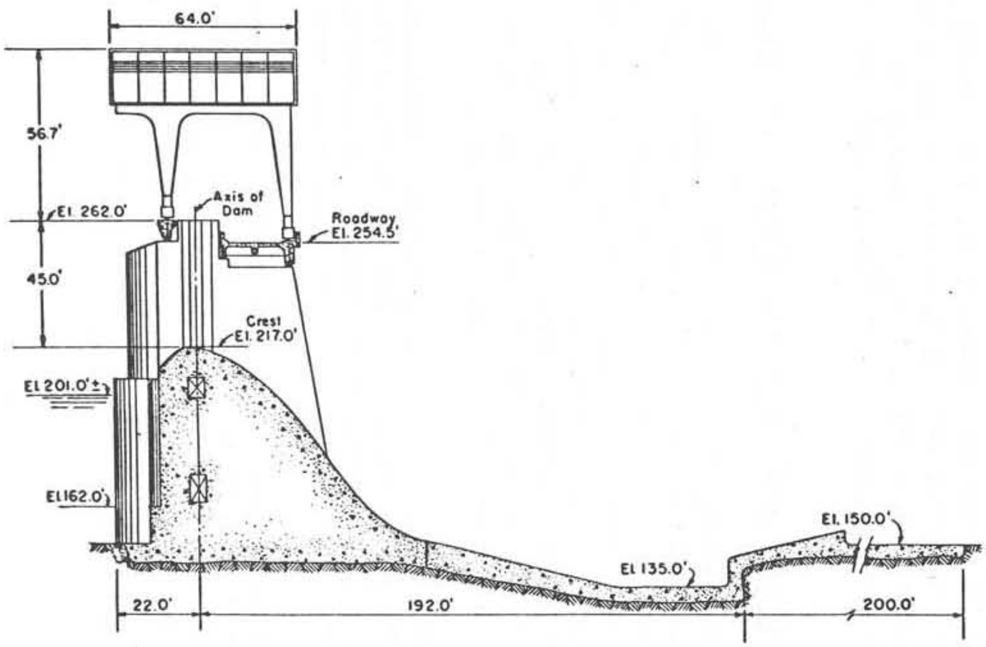
STATISTICS

Length of structure	1,608 feet
Width (face of intake to downstream face)	184 feet
Height—intake deck	167 feet
Height—observation roof	195.5 feet
Excavation, earth	2,587,000 cubic yards
rock	275,000 cubic yards
borrow	1,031,000 cubic yards
Excavation, total	3,893,000 cubic yards
Embankment and Riprap	1,458,000 cubic yards
Miscellaneous earth fill	450,000 cubic yards
Concrete	985,000 cubic yards
Cement	1,111,000 barrels
Reinforcing steel	49,767,000 pounds
Structural steel	6,793,000 pounds
Towers, gates, crane and guides	18,471,000 pounds

The general contractor for the structure was a joint venture of B. Perini & Sons, Inc., Peter Kiewit Sons' Co., Walsh Construction Co., Morrison-Knudsen Co., Inc., and Utah Construction Co.

Section Thru Robert Moses Power Dam

Fig. 5



LONG SAULT DAM

STATISTICS

Height above foundation	132	feet
Length	2,960	feet
Length of spillway	1,800	feet
Width (including apron)	414	feet
Number of spillway sections	30	
Type of spillway gates	vertical	
Size of spillway gates	52′ x 30′	
Gantry cranes (2 each) capacity	275	tons
Excavation:		
Earth	7,522,000	cubic yards
Rock	479,000	cubic yards
Embankment and riprap	627,000	cubic yards
Concrete	675,000	cubic yards
Cement	703,000	barrels
Reinforcing steel	16,142,000	pounds
Structural steel	6,429,000	pounds
Gates, stop logs and hoists	12,459,000	pounds
Two 275-ton gantry cranes	1,672,000	pounds

The general contractor for the structure was a joint venture of Walsh Construction Co., B. Perini & Sons, Inc., Morrison-Knudsen Co., Inc., Peter Kiewit Sons' Co. and Utah Construction. Total Cost: $35,900,000.

LONG SAULT DAM

Section Thru Long Sault Dam

Fig. 6

baffles on the downstream end prevents excessive turbulence.

When a ship comes upstream to the lock, the upper gates are closed and the water level is at the same elevation as the water surface downstream from the lock. The ship moves into the lock, the lower gates are closed, and water is introduced into the side passageways from the upstream end of the locks flowing into the lock through the side openings, thus filling the lock and raising the ship to the elevation of the canal on the upstream side. Then the upper gates are opened and the ship moves out of the lock upstream. Recently, some deterioration of the lock concrete has been observed, and an extensive study has been made by the Corps of Engineers, which is resulting in appropriate remedial measures.

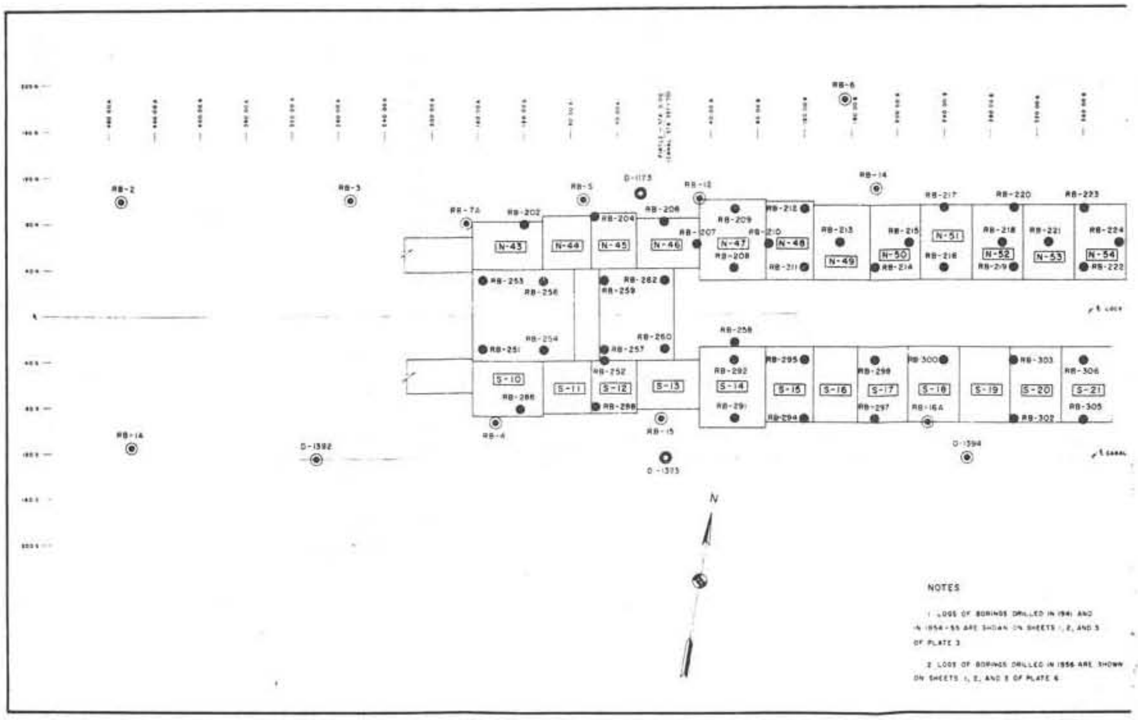
Since the overburden materials and lock location problems at Eisenhower and Snell Lock are very different, Figures 7 through 10 are included to show, for Eisenhower Lock, boring locations, exploratory core borings, some laboratory test data on overburden material and geologic sections. Figures 11, 12, 13a, 13b, 14 and 15 show the same data for Snell Lock. Note the difference in the overburden at the two sites 5 miles apart. Also note in Figure 13b boring D-1302, which shows evidence of a possible fault at the site. This fault area is shown in Figure 12.

Stop 5 - The Martin Gravel Pit, "The Plains", South Colton

This pit is twenty miles from Potsdam on Route 56 towards Tupper Lake in the Adirondack Physiographic Province. The pit is part of a Kame Terrace deposit of very clean and uniform quality, largely composed of reddish brown gneiss. Excellent quality fine and coarse aggregate are produced from this pit. Due to its proximity to the construction site, most of the aggregate used in the construction of the five Niagara Mohawk dams on the Racquette River, completed in 1957, came from this pit.

At the site of the pit the company installed a large crushing, screening and washing plant for producing the aggregates for making concrete. This plant also produced several sizes of unwashed material for use in road and dike construction.

The processing plant was about 400 feet long and 100 feet wide covering about 2 acres. Stock piles of sand and various sizes of processed stone surrounded the plant, some of which were 100 feet in diameter, forty feet high, and contained as much as 8000 tons of product. The plant had a capacity of 200 tons per hour, and 15 men worked full time.



Note: Borings are located with reference to Monoliths (poured concrete lock sections)

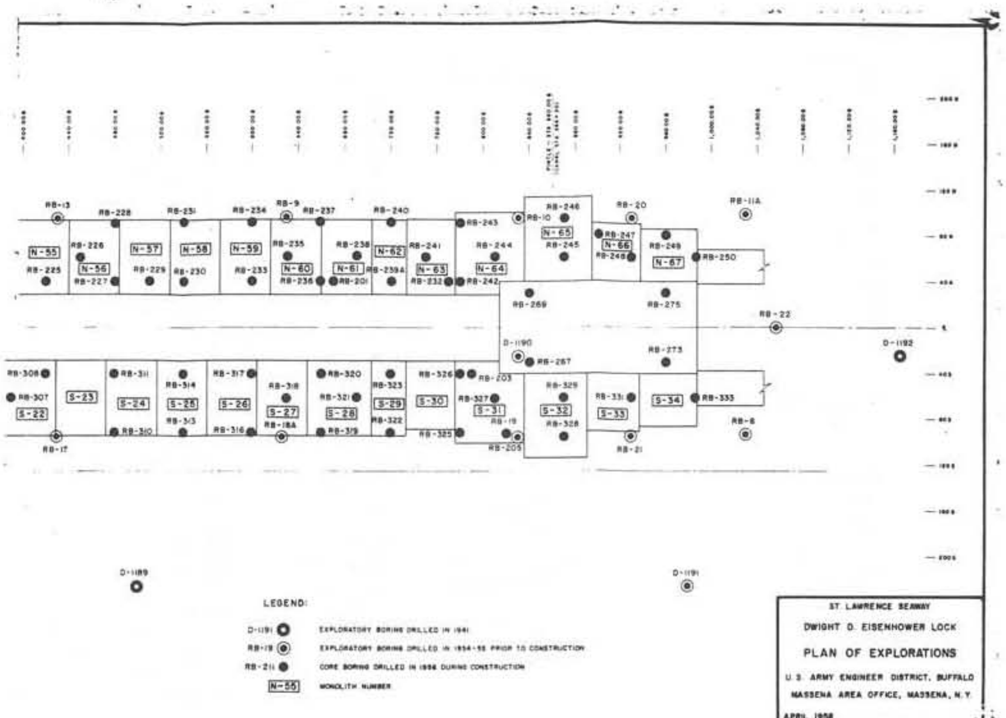


Fig. 7

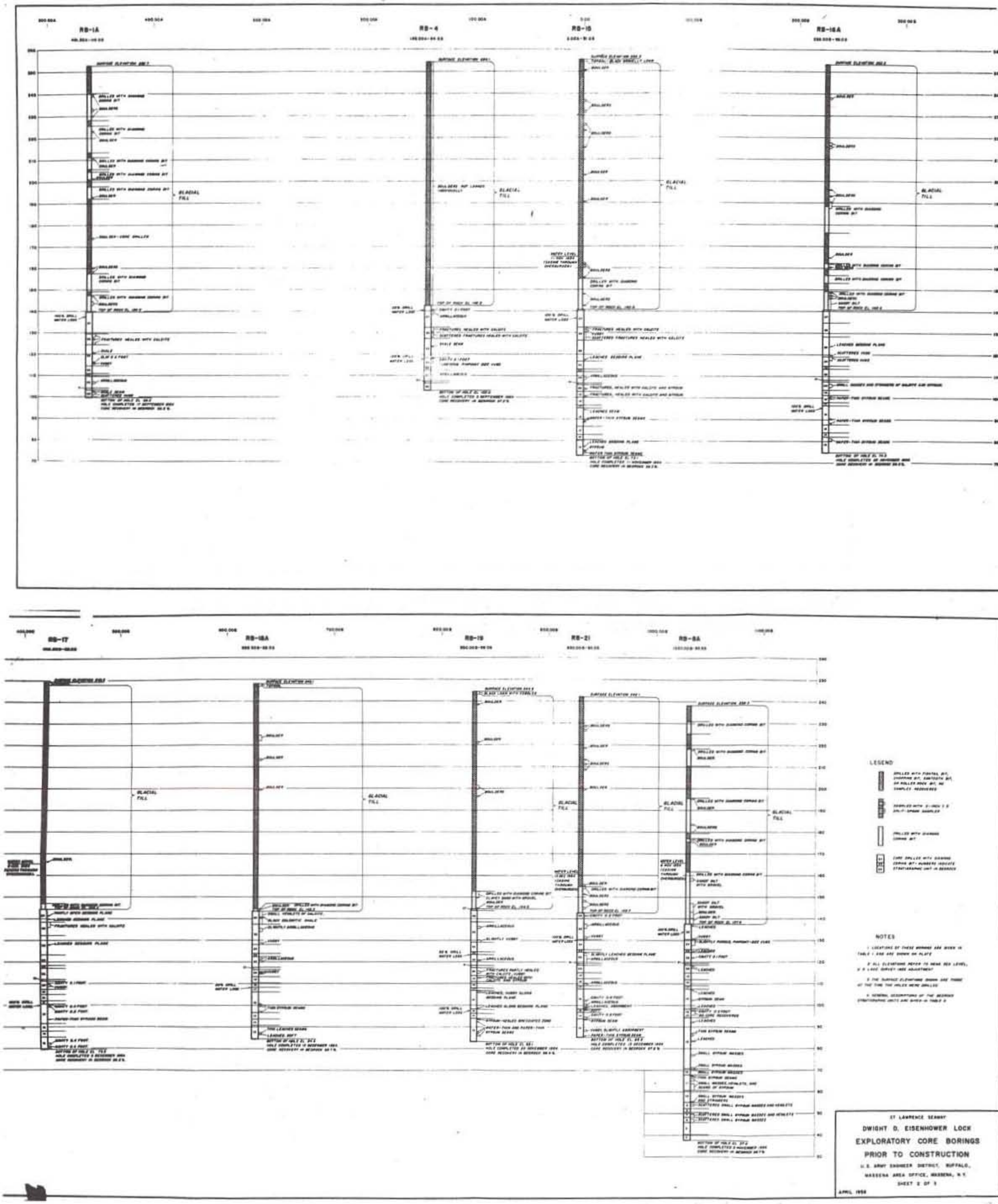

RB-1A
RB-4
RB-15
RB-16A
RB-17
RB-18A
RB-19
RB-21
RB-8A
GLACIAL TILL
LEGEND
NOTES
DWIGHT D. EISENHOWER LOCK
EXPLORATORY CORE BORINGS
PRIOR TO CONSTRUCTION

Fig. 8

DEPTH OF SAMPLES FT.	ELEVATION OF SAMPLES	MECHANICAL ANALYSIS			*	ATTERBERG LIMITS		MOISTURE CONTENT %	SPECIFIC GRAVITY G	DENSITY (DRY) lbs./cu.ft.	VOID RATIO e	SATURATION %	ANGLE INTERNAL FRICTION ∅	COHESION (C) Tons/sq.ft.	TRIAXIAL COMPRESSION STRENGTH DATA (UNCONSOLIDATED - UNDRAINED)			
		GRAVEL %	SAND %	FINES %	CLASSIFICATION	LIQUID LIMITS	PLASTIC LIMITS								LATERAL LOAD Tons/sq.ft.	COMPRESSIVE STRENGTH Tons/sq.ft.	SHEAR STRENGTH Tons/sq.ft.	PERCENT STRAIN AT FAILURE
HOLE RB-2 (DRIVE SAMPLES)																		
10.0 - 11.0	241.2 - 240.2	25	37	38	SM - SC	19.8	10.8	9.3	2.81	132.8	0.32	82.5			2.0	2.9	1.45	4.2
15.0 - 16.6	236.2 - 235.6	22	36	42	SM - SC	16.3	11.8	19.2		105.6								
20.0 - 20.8	231.2 - 230.4	6	38	56	ML - CL	18.8	10.8	10.4		131.8								
50.0 - 51.1	201.6 - 200.1	2	44	54	ML	13.2	8.6	7.8		128.9								
60.0 - 61.5	191.2 - 189.7	25	33	42	SM - SC	14.3	9.7	7.6	2.76	140.0	0.23	85.0			0.5	9.2	4.64	5.5
								7.0	2.75	140.4	0.22	88.6			1.0	4.8	2.38	6.0
								6.2	2.74	141.4	0.21	78.7			2.0	10.2	5.10	3.5
65.0 - 66.5	186.2 - 184.7	14	33	53	CL - ML	18.8	9.5	6.8	2.76	142.1	0.21	90.1			1.8	18.2	6.50	4.8
								6.8	2.74	142.4	0.20	81.3			2.0	17.0	8.50	4.6
70.0 - 71.5	181.2 - 179.7	16	32	52	ML - CL	19.8	9.0	8.1	2.78	138.8	0.24	84.0			2.0	5.6	2.80	8.5
84.8 - 85.6	166.6 - 165.6	5	40	55	CL - ML	16.4	8.7	6.9	2.75	142.0	0.21	81.1			2.0	9.8	4.80	12.5
105.0 - 106.6	146.2 - 145.6	15	27	58	CL - ML	18.5	10.2	7.5	2.74	138.8	0.24	90.8			2.0	6.4	3.20	5.6
HOLE RB - 7A (NX CORES)																		
100.2 - 104.5	156.2 - 151.8	3	32	65	CL - ML	19.2	11.4	8.6	2.75	136.1	0.27	88.9			2.0	13.7	6.85	4.7
		8	29	63	CL - ML	19.4	10.8	8.1	2.74	136.7	0.25	88.5			3.0	13.9	6.95	7.0
		8	29	63	CL - ML	18.3	11.0	9.0	2.73	137.6	0.24	90.2			4.0	12.0	6.00	7.2
104.5 - 110.4	151.8 - 146.0	5	32	63	CL - ML	19.8	11.1	6.4	2.73	131.1	0.30	75.6			2.0	8.7	4.35	5.1
		10	33	57	CL - ML	18.7	10.7	7.4	2.74	133.8	0.28	73.1			3.0	10.7	5.35	2.2
		6	32	62	CL - ML	18.7	10.6	8.4	2.73	125.8	0.37	64.6			4.0	7.5	3.75	2.5
HOLE RB - 8A (NX CORES)																		
78.4 - 80.7	158.8 - 157.5	7	35	58	CL - ML	17.2	10.2	7.2	2.73	142.1	0.20	97.0			2.0	14.6	7.30	3.5
					CL - ML	18.3	10.5	7.5	2.74	141.2	0.21	97.5			3.0	11.8	5.90	2.5
					CL - ML	16.6	11.0	6.9	2.75	143.0	0.20	96.5			4.0	12.9	6.45	3.8
81.1 - 86.1	157.1 - 152.1	14	31	55	CL - ML	18.4	10.8	6.7	2.74	143.5	0.18	95.8			2.0	22.3	11.15	4.2
		10	35	55	ML - CL	18.2	9.7	7.5	2.74	141.2	0.21	97.5			3.0	13.1	6.55	7.0
		10	35	55	CL - ML	18.9	10.6	7.3	2.73	142.0	0.20	98.1			4.0	17.3	8.65	5.0
97.8 - 100.4	140.3 - 137.8	6	26	68	CL - ML	21.9	10.7	7.5	2.75	141.8	0.21	100.0			2.0	28.5	14.00	4.8
		5	21	74	CL	23.2	12.0	9.2	2.73	130.5	0.25	99.6			3.0	22.3	11.15	4.1
		4	14	82	CL	27.5	13.1	11.0	2.74	131.3	0.30	99.6			4.0	18.3	9.15	8.8
HOLE RB -12 (DRIVE SAMPLES)																		
39.8 - 40.4	222.1 - 221.6	2	88	10	SM - SP			18.8										
61.8 - 71.2	200.1 - 190.8	10	37	53	ML - CL	13.9	8.4	8.2	2.75	140.5	0.22	91.6			2.0	5.2	2.60	14.3
79.8 - 81.1	183.2 - 180.9	15	33	52	ML - CL	14.6	8.4	7.0	2.74	141.5	0.21	90.5			2.0	9.4	4.75	9.3
89.9 - 91.4	172.1 - 170.6	4	22	74	CL	26.3	16.8	10.7	2.75	132.2	0.30	98.9			1.0	2.3	1.12	12.1
100.2 - 101.2	161.8 - 160.8	10	33	57	CL - ML	15.6	9.7	7.5	2.75	140.6	0.22	83.3			1.0	6.6	3.31	12.8
								7.2	2.76	142.1	0.21	84.7			2.0	11.1	5.54	11.0
105.1 - 106.2	156.9 - 155.8	10	33	57	CL	19.0	8.8	7.6	2.76	141.2	0.22	89.8			1.0	8.1	4.05	14.0
								6.2	2.76	139.9	0.23	88.9			2.0	6.9	2.95	16.0

*Unified classification system.

DWIGHT D. EISENHOWER LOCK

LABORATORY TEST DATA

OVERBURDEN MATERIAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 1 OF 2
APRIL 1958

Fig. 9

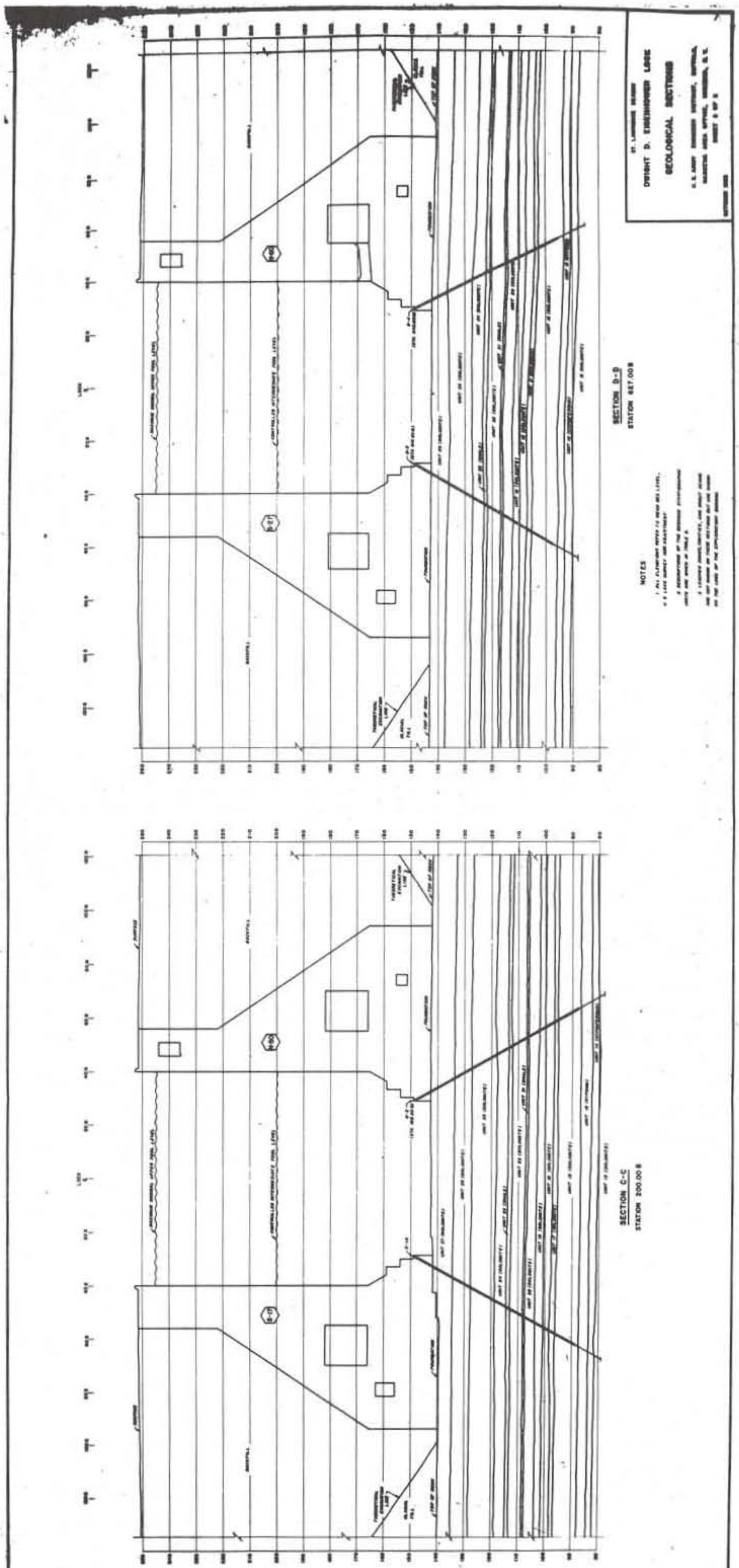

DWIGHT D. EISENHOWER LOCK
GEOLOGICAL SECTIONS
SECTION D-D
SECTION C-C
NOTES

Fig. 10

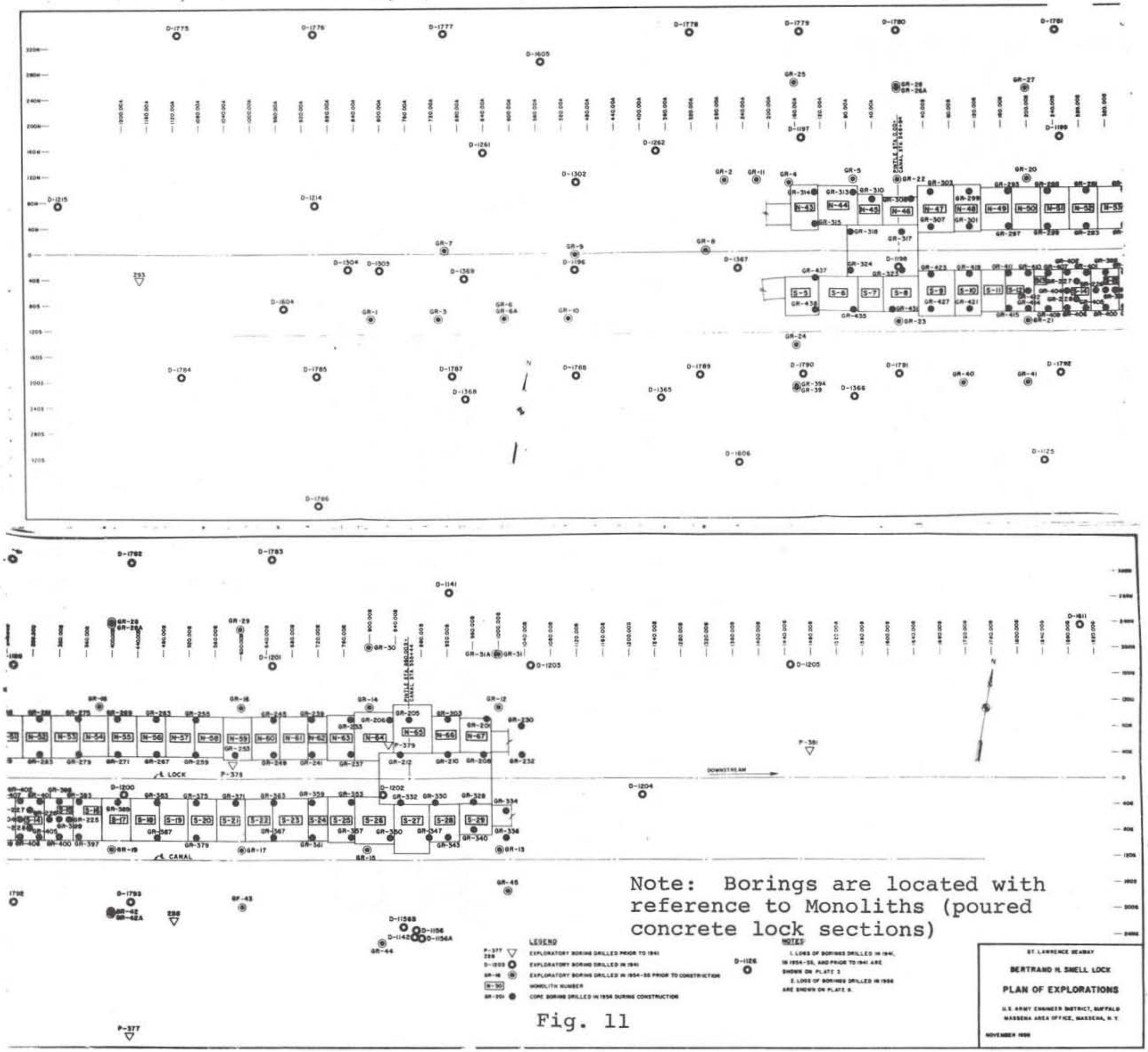
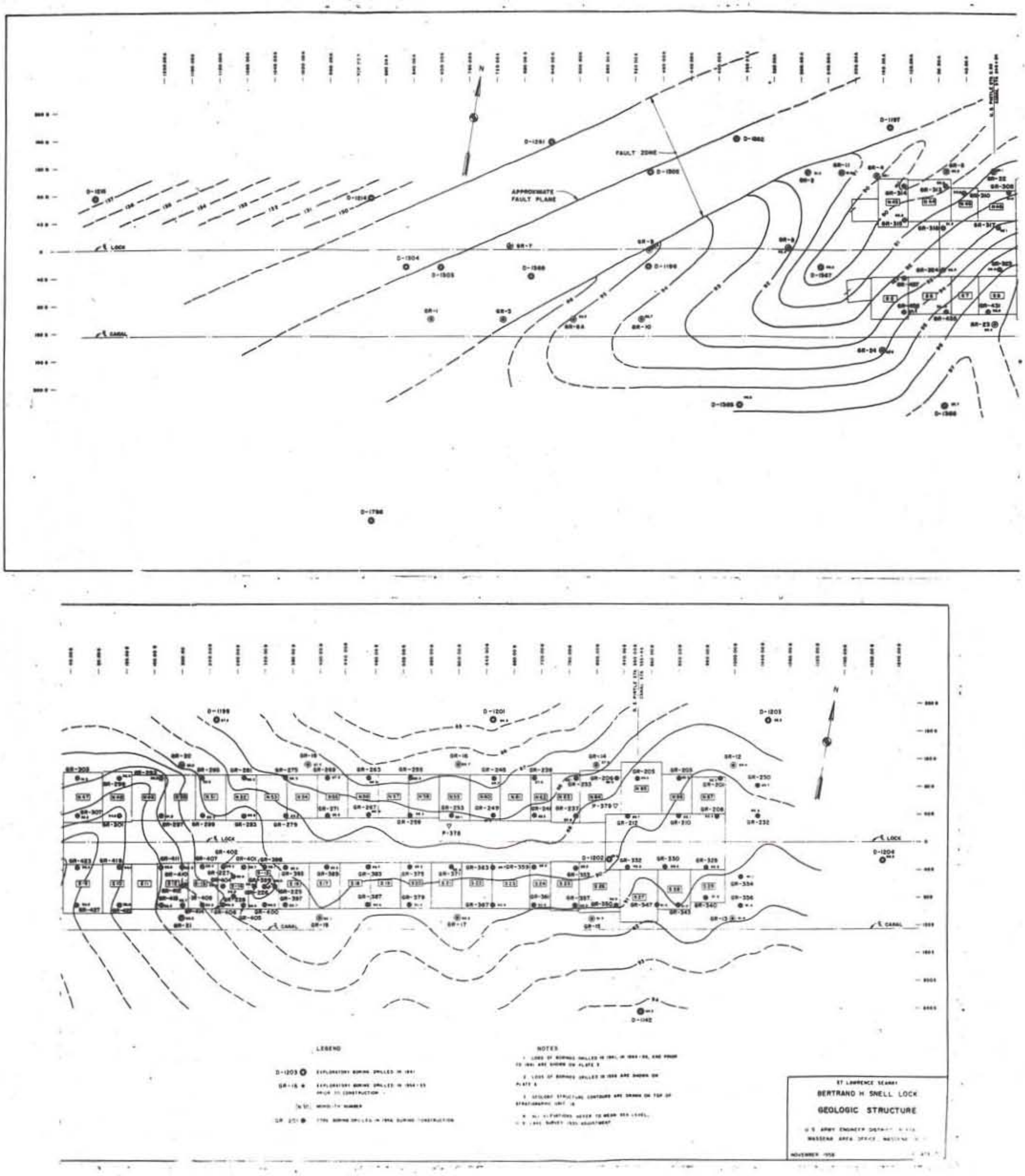

Note: Borings are located with reference to Monoliths (poured concrete lock sections)
LEGEND
EXPLORATORY BORING DRILLED PRIOR TO 1941
EXPLORATORY BORING DRILLED IN 1941
EXPLORATORY BORING DRILLED IN 1954-55 PRIOR TO CONSTRUCTION
MONOLITH NUMBER
CORE BORING DRILLED IN 1956 DURING CONSTRUCTION
NOTES:
1. LOGS OF BORINGS DRILLED IN 1941, IN 1954-55, AND PRIOR TO 1941 ARE SHOWN ON PLATE 3
2. LOGS OF BORINGS DRILLED IN 1956 ARE SHOWN ON PLATE 8.
ST. LAWRENCE SEAWAY
BERTRAND H. SNELL LOCK
PLAN OF EXPLORATIONS
U.S. ARMY ENGINEER DISTRICT, BUFFALO
MASSENA AREA OFFICE, MASSENA, N.Y.
DOWNSTREAM
℄ LOCK
℄ CANAL

Fig. 11



Note: Borings are located with reference to Monoliths (poured concrete lock sections)

Fig. 12

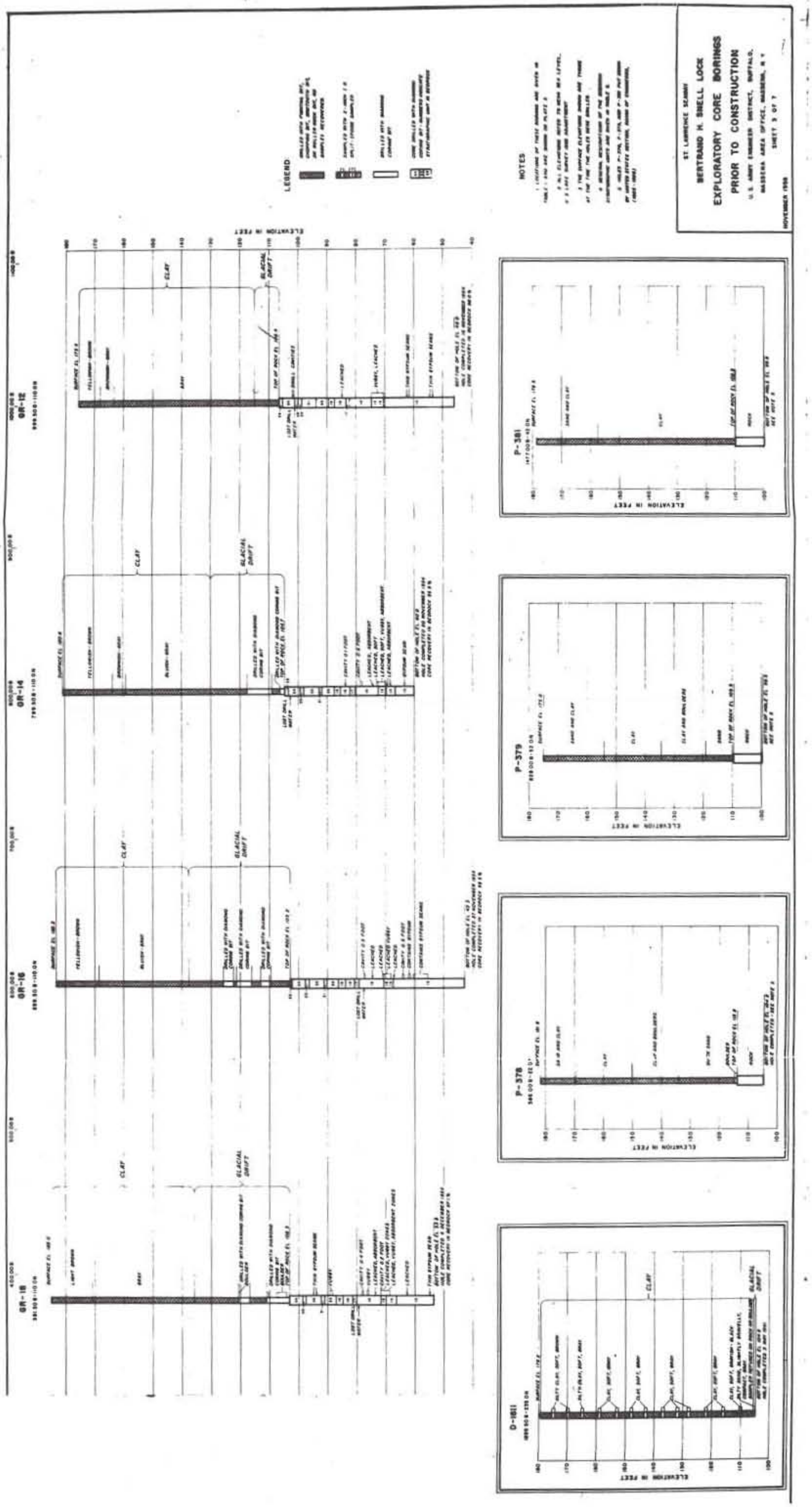

ST. LAWRENCE SEAWAY
BERTRAND H. SNELL LOCK
EXPLORATORY CORE BORINGS
PRIOR TO CONSTRUCTION
LEGEND
NOTES
GR-18
GR-16
GR-14
GR-12
P-381
P-379
P-378
D-1611
CLAY
GLACIAL DRIFT
ELEVATION IN FEET

Fig. 13a

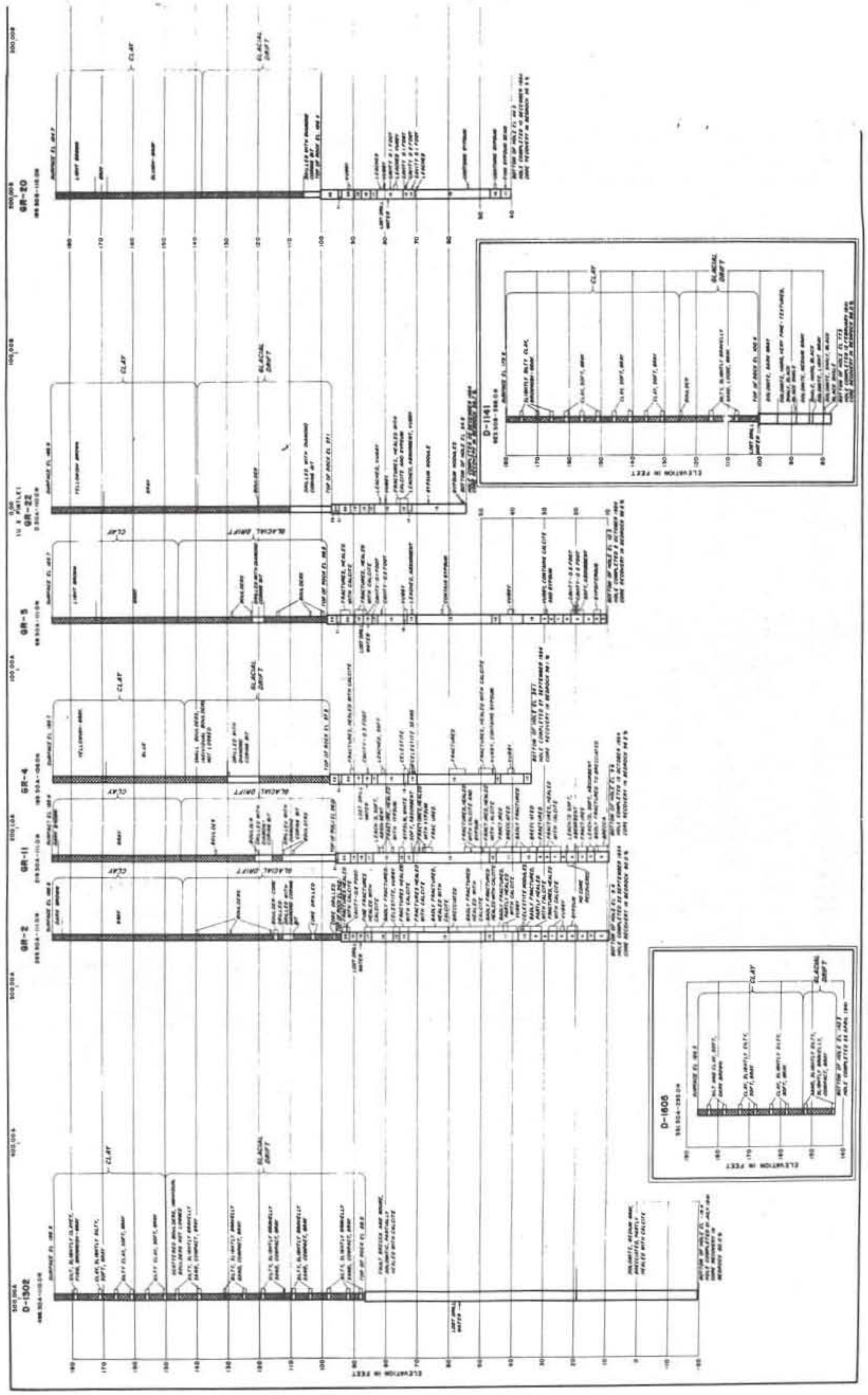

D-1302
GR-2
GR-11
GR-4
GR-5
GR-22
GR-20
D-1141
D-1605
CLAY
GLACIAL DRIFT
ELEVATION IN FEET

Fig. 13b

DEPTH OF SAMPLES FT.	ELEVATION OF SAMPLES	CLASSI-FICATION	ATTERBERG LIMITS		MOISTURE CONTENT %	DENSITY (DRY) lbs./cu.ft.	VOID RATIO	SATUR-ATION %	TRIAXIAL COMPRESSION STRENGTH DATA (UNCONSOLIDATED - UNDRAINED)			
			LIQUID LIMITS	PLASTIC LIMITS					LATERAL PRESSURE Tons/sq.ft.	COMPRESSIVE STRENGTH Tons/sq.ft.	SHEAR STRENGTH Tons/sq.ft.	PERCENT STRAIN AT FAILURE
HOLE GR-25												
10.0-12.5	176.8-174.3	CH	52.2	24.2	47.6	72.8	1.40	95.3	0.0	0.47	0.24	2.5
		CL	43.4	21.7	42.4	77.7	1.25	94.9	0.0	0.44	0.22	5.0
10.0-11.5	176.8-175.3	CH	55.2	24.2	47.6	72.8	1.40	95.3	0.0	0.47	0.24	2.5
		CH	55.1	28.1	53.3	68.2	1.56	95.5	1.0	0.71	0.36	6.1
		CH	55.1	28.1	53.0	62.8	1.62	91.7	2.0	0.68	0.34	5.7
		CH	53.3	19.7	44.6	72.4	1.41	88.4	4.0	0.68	0.34	2.3
11.5-12.5	175.3-174.3	CL	43.2	21.7	42.4	77.7	1.25	94.9	0.0	0.44	0.22	4.7
20.0-22.5	166.8-164.3	CH	53.8	25.3	61.2	63.4	1.76	97.8	0.0	0.53	0.26	1.8
		CH	53.0	23.0	59.5	64.6	1.70	96.1	1.0	0.67	0.34	3.2
		CL	48.2	23.2	58.1	64.2	1.72	96.1	2.0	0.74	0.37	2.1
		CH	55.8	24.9	61.0	63.7	[illegible]	98.0	4.0	0.62	0.31	2.5
30.0-32.5	156.8-154.3	CH-MH	66.9	27.7	64.8	61.1	[illegible]	97.5	0.0	0.22	0.11	1.1
		CH	72.1	20.3	70.0	56.6	1.96	99.0	1.0	0.83	0.42	1.8
		CH	71.8	27.7	69.2	56.5	1.96	97.8	2.0	0.73	0.36	3.8
		CH	73.3	27.5	68.5	56.1	1.95	98.0	4.0	0.66	0.33	2.8
HOLE GR-28												
10.0-12.5	175.7-173.2	CH	51.0	22.2	41.5	77.8	1.25	93.3	0.0	1.04	0.52	1.8
		CH	56.8	24.2	45.5	73.0	1.30	91.4	1.0	0.64	0.32	1.1
		CH	55.9	21.2	42.3	75.9	1.30	90.9	2.0	0.73	0.36	1.4
		CH	58.2	20.6	42.5	76.0	1.24	96.0	4.0	1.10	0.55	1.1
20.0-22.5	165.7-163.2	CH-MH	50.9	26.5	50.6	70.9	1.48	97.2	0.0	0.78	0.39	2.8
		CH-MH	52.9	27.1	52.5	68.8	1.50	97.8	1.0	0.81	0.40	2.1
		CH-MH	53.5	28.2	52.3	69.8	1.50	97.4	2.0	0.93	0.46	3.2
		CH-MH	52.8	26.7	51.5	70.5	1.48	97.5	4.0	0.93	0.46	2.5
30.0-32.5	155.7-153.2	CL	47.7	24.7	48.7	72.9	1.40	97.8	0.0	1.03	0.52	1.4
		CL-ML	48.3	26.0	48.1	73.6	1.37	98.1	1.0	1.25	0.62	2.9
		CL-ML	48.9	26.4	48.9	72.1	1.42	96.2	2.0	1.50	0.75	1.5
		CL	48.2	25.0	48.0	74.0	1.36	96.5	4.0	1.31	0.66	2.8
40.0-42.5	145.7-143.2	CL	44.8	24.4	43.4	77.5	1.25	97.0	0.0	0.58	0.29	2.5
		CL	43.1	21.8	43.1	77.8	1.25	96.8	1.0	0.90	0.45	3.3
		CL	43.1	21.8	42.5	78.1	1.24	96.1	2.0	1.01	0.50	2.8
		CL	43.8	22.8	39.7	81.1	1.16	98.2	4.0	1.47	0.74	2.7
42.5-43.5	143.2-142.2	CL	43.1	23.4	40.0	80.0	1.18	96.8	0.0	1.20	0.60	4.0
HOLE GR-31												
10.0-12.2	167.6-165.4	CL-ML	40.7	20.4	39.2	82.1	1.13	94.4	0.0	1.16	0.58	2.1
		CH	53.4	24.0	60.6	77.0	1.27	94.4	1.0	1.00	0.58	1.8
		CH	56.5	25.9	57.0	74.3	1.35	96.3	2.0	1.17	0.58	1.8
		CH	58.2	27.6	57.7	72.9	1.40	93.3	4.0	0.71	0.38	1.8
20.0-22.2	157.6-155.4	CL-ML	48.2	26.4	50.2	69.3	1.72	96.5	0.0	0.86	0.43	1.8
		CH	59.1	24.0	60.8	63.8	1.74	97.8	1.0	1.26	0.63	1.4
		CL-ML	50.8	25.9	57.0	66.8	1.65	95.5	2.0	1.32	0.66	1.4
		CL-ML	50.2	27.6	57.7	66.4	1.67	96.6	4.0	0.94	0.47	2.1
30.0-32.2	147.6-145.4	CL-ML	44.7	25.0	50.7	63.6	1.72	96.8	0.0	0.71	0.36	2.9
		CL-ML	43.9	24.8	58.5	65.4	1.67	97.8	1.0	0.93	0.46	1.8
		CL-ML	40.3	26.1	56.7	64.9	1.66	97.1	2.0	0.69	0.34	2.9
		CL-ML	40.8	27.9	57.8	66.4	1.63	97.5	4.0	0.61	0.30	2.9
40.0-42.2	137.6-135.4	CL-ML	42.6	24.0	58.6	64.5	1.71	98.0	0.0	0.71	0.36	3.6
		CL-ML	41.5	22.9	58.5	64.3	1.72	97.0	1.0	0.44	0.22	5.4
		CL-ML	42.6	26.0	56.6	64.5	1.71	97.7	2.0	0.71	0.36	3.6
		CL-ML	42.6	25.3	58.6	65.0	1.69	97.4	4.0	0.69	0.34	2.5
49.6-50.6	128.0-127.0	CL-ML	41.2	20.7	62.2	62.3	1.80	96.6	0.0	0.40	0.20	3.6
		CL-ML	45.2	25.1	62.1	62.5	1.80	96.6	1.0	0.59	0.30	8.3
		CL-ML	50.2	25.1	63.0	61.7	1.83	98.3	2.0	0.59	0.30	5.0
		CL-ML	48.2	25.1	62.8	62.0	1.82	96.6	4.0	0.56	0.28	6.9
51.5-53.5	126.1-124.1	CH-MH	52.0	26.7	63.4	61.8	1.83	97.3	0.0	1.03	0.56	1.4
		CH-MH	52.8	30.6	60.2	63.0	1.77	96.2	1.0	0.56	0.28	2.5
		CL-ML	43.8	26.2	59.3	66.3	1.66	97.4	2.0	0.61	0.28	3.6
		CL-ML	47.0	30.0	61.9	63.3	1.76	96.4	4.0	0.41	0.20	4.7
54.0-56.2	123.6-121.4	CL-ML	44.6	25.5	55.9	67.2	1.60	97.6	0.0	0.66	0.34	1.8
		CL-ML	48.6	25.4	52.0	71.0	1.48	99.7	1.0	0.76	0.38	2.1
		CL-ML	40.9	26.0	46.2	72.7	1.41	98.1	2.0	0.58	0.28	4.2
		CL-ML	38.0	22.8	44.1	77.4	1.28	96.5	4.0	0.60	0.29	4.6

ST. LAWRENCE SEAWAY

BERTRAND H. SNELL LOCK

LABORATORY TEST DATA
CLAY OVERBURDEN MATERIALS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
MASSENA AREA OFFICE, MASSENA, N.Y.
SHEET 1 OF 2
NOVEMBER 1958

Fig. 14

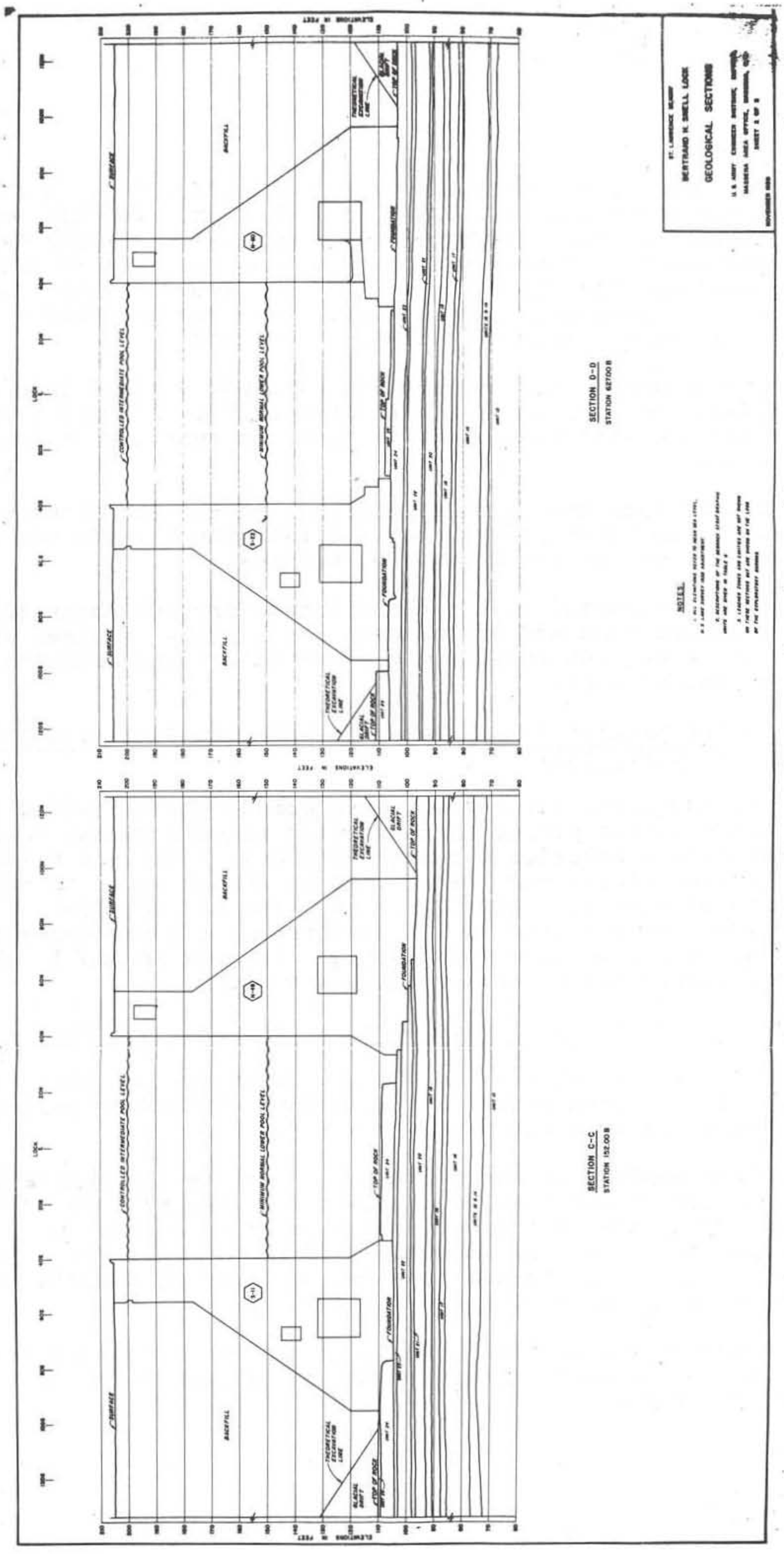

BACKFILL
SECTION C-C
STATION 152.00 B
SECTION D-D
BERTRAND H. SNELL LOCK
GEOLOGICAL SECTIONS
NOTES:

Fig. 15

The operation starts with the "run of the bank" gravel and rocks which are fed into one end of the plant. As this material moves along the plant conveyor belts, the sand is separated and the rocks crushed, screened to size and washed. Waste material is screened out and the balance runs the gamut of vibrating screens, scrubbers and washers until there are a number of neat piles of various sized crushed stone and sand.

The crushed stone for the concrete was divided into 3 stockpiles, one with stone graded from 1/2" to 1"; one from 1" to 2"; and one with sand which varied from near a #200 sieve-size to 1/4".

Trucks took the various materials to the job sites where it was handled in batch plants as its first step towards becoming concrete for one of the project structures.

It is estimated that for the entire project about 400,000 tons of washed sand and gravel were used. This required excavating about 600,000 tons from the gravel pit and crushing about 300,000 tons of rock.

Stop 6 - The Niagara Mohawk Power Corporation Dams, South Colton to Carry Falls

The Racquette River Power Development Project added five new hydro-electric plants which boosted Niagara Mohawk Power Corporation's production capacity to almost 1 billion kilowatt hours of electricity per year. This is enough power to supply the needs of more than 400,000 homes. The project cost $33,000,000 and resulted in the creation of six new lakes and public areas for boating and fishing. Figures 16 and 17 show the plan and statistics of the project (also Table 2).

Stop 7 - Bicknell Gravel Pit, West Parishville, New York

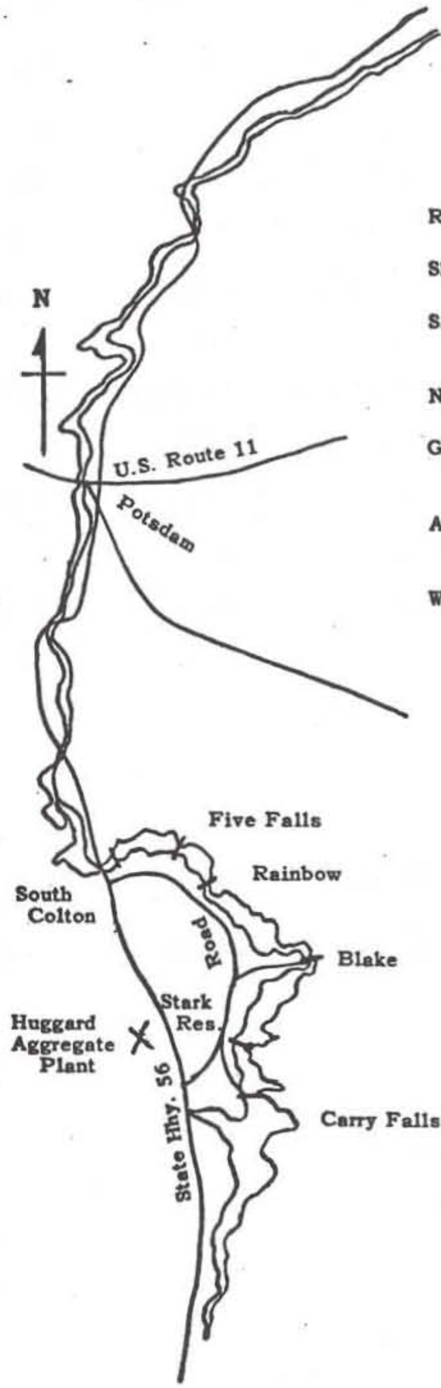
This site is also a Kame Terrace deposit, but the rock utilized for crushed gravel and sand shows different geologic characteristics from the Martin Pit of stop 5.

Cross bedding of sand, boulder pavements (concentrations of large cobbles in one area of the deposit), the effects of water-working and a wide variety of rock types can be seen here, allowing comparison to be made between different physiographic areas visited, the very different types of engineering material types and their relation to the area geology.

Sandstone, quartzite, gneiss, limestone can be observed at this pit, contrasting markedly with the uniform material at the Martin Gravel Pit.

NIAGARA MOHAWK

UPPER RAQUETTE DEVELOPMENT



GENERAL DATA

Raquette River Construction Corp. - General Contractor:

Shellet Electric	- Electric Contractor
S. Morgan Smith	- All turbines, intake and sluice gates.
Newport News	- Tainter Gates
General Electric	- Generators at Five Falls, Rainbow and Stark.
Allis Chalmers	- Generators at South Colton and Blake.
Westinghouse	- All transformers and switchgear.

Est. total yds. of concrete -	286,000
Est. total yds. of embankments -	756,000
Est. total yds. of earth excav. -	1,250,000
Est. total yds. of rock excav. -	170,000

Location Map - Upper Raquette Development

Fig. 16

	CARRY FALLS	STARK	BLAKE	RAINBOW	FIVE FALLS	SOUTH COLTON
Generator	*	22,500 KW	14,400 KW	22,500 KW	22,500 KW	19,350 KW
Turbine		30,600 HP	18,650 HP	30,600 HP	30,600 HP	25,400 HP
Gross Hd.	Varies to 35'	105'	69'	103'	104'	85'
Dam Height	70'	35'	55'	100'	55'	45'
Spillway Dam Length	830' **	340'	600'	760'	500'	600'
Concrete Cu. Yds.	36,000	42,000	44,000	99,000	37,000	28,000
Embankments Cu. Yds.	90,000	143,000	155,000	227,000	104,000	37,000
Resv. Acres	3,300	600	660	710	120	225
Resv. Volume Cu. Ft.	5 Billion	560 Million	550 Million	530 Million	100 Million	130 Million
Normal Res. Elev.	1,385	1,355	1,250	1,181	1,077	973
Length of Reservior	6 Mi. ***	1½ Mi.	3 Mi.	3½ Mi.	1½ Mi.	2
Pipe Diam.		18'	18'	18'	18'	18'
Pipe Length		590'	670'	585'	1,620'	1,300'
Tainter Gates 2		2				
Tainter Gate Size	27' x 15'	27' x 15'				—
Sluice Gates 2		1				
Sluice Gate Size'	10' x 10'	12' x 12'				
Surge Tank Size	None	None	None	None	65' Dia. 85' High	60' Dia. 70' High
Generator Voltage	—	11,500	6,900	11,500	11,500	11,500

NOTE * Intake provided for approximately 3,500 KW Generator in future.

** Five earth dikes or dams around reservoir.

*** About 25 miles perimeter at flow line.

AGGREGATE PLANT

Input - 200 tons per hour.

Output - 180 tons of washed #3, #2, #1 stone and sand.

Also makes filter stone for use on dikes #3, #2, and #1 stone sizes unwashed.

Table 2. Upper Raquette Power Station Data

ST. LAWRENCE COUNTY: TOWN OF PARISHVILLE

SCALE 1" = 1 MILE

PHYSIOGRAPHIC PROVINCE: **Adirondack Mts.— St. Lawrence Lowland**

DEPOSITIONAL UNIT: **Kame-type**

PEDOLOGICAL SOIL SERIES: Hinckley

MATERIAL ORIGIN: **Crystalline**

Location Map for Bicknell Gravel Pit
(formerly Putnam-Hawley Pit)

Fig. 17

APPENDIX

Dwight D. Eisenhower Lock

GEOLOGY

Physiography

Dwight D. Eisenhower lock is constructed diagonally through a northeast-southwest-trending ridge. The ridge is between 1,500 and 2,000 feet wide and is bounded by the valley of Robinson Creek on the southeast and by a small valley or low area on the northwest. Relief is about 70 feet. Top of the ridge varies around elevation 255 with the highest point along the alignment for the lock prior to excavation being about elevation 263. Robinson Creek valley downstream from the lock varies around elevation 195, and Robinson Creek is at about elevation 175. The small valley upstream from the lock is around elevation 215. The location of the lock, except for the guidewalls is within the limits of the ridge.

Overburden

The material composing the ridge at the lock site is principally glacial till of late Pleistocene age. In the excavation and foundation area for the lock it ranged in thickness from 100 feet to 123 feet except at each end where excavation for ramps into the work area extended out onto and beyond the sides of the ridge and the depth was less. The glacial till is gray in color except in the oxidized zone near the surface and consists of a compact, unsorted mixture of clay, silt, sand, gravel, cobbles, and boulders in non-uniform proportions. The predominant constituents are silt and sand, but the till also contains a considerable quantity of gravel; cobbles are abundant, and boulders are common. Pockets and lenses of sorted and stratified materials are contained within the till.

The till is separated into three distinct layers by zones of stratified glacial drift, which contain finely stratified or varved silt and clay. These layers and zones were exposed in the sides of the excavation prior to backfilling, but they were not mapped and only a few measurements were made of them. The lower till layer is about 18 to 30 feet thick in the immediate vicinity of the lock depending on the elevation of top of bedrock. The zone of stratified drift separating it from the middle till layer is about at elevation 165 and is principally a layer of finely stratified silt and clay. The finely stratified silt and clay ranges in thickness from a featheredge to about 10 feet and is cut out in places by lenses of stratified sand and by glacial till. The silt and clay are overlain by 10 feet or more of well-sorted horizontal and cross-bedded sand interstratified with poorly sorted coarse sand and gravel at the northeastern corner of the lock excavation behind the downstream guide wall. The middle layer of till is around 20 to 35 feet thick. The stratified drift zone that separates it from the upper till layer is about at elevation 200 and is about 10 feet or so thick. The upper layer of glacial till is around 50 feet thick.

The lower and middle layers of glacial till in the Eisenhower lock area are correlated by MacClintock (1958) with the Malone till of his classification. This till is considered tentatively by him to belong to the Cary substage of Wisconsin glaciation. The upper till layer is correlated by MacClintock with the Fort Covington till of his classification, which he tentatively considers to belong to the Valders substage of Wisconsin glaciation.

A deposit of fossil-bearing gravel that was formed as a beach in a body of marine water at the close of the Pleistocene Epoch following Wisconsin glaciation overlies the glacial till near the crest of the ridge in the Eisenhower lock area.

Bedrock Stratigraphy

Bedrock in the Eisenhower lock area penetrated by core borings belongs to the upper part of the Beekmantown Formation, or the Oxford Formation of Wilson (1946), and is Ordovician in age. The rock is dolomite for the most part but contains shale and dolomitic shale layers interbedded with it. Two gypsum beds occur at depths around 50 and 100 feet, respectively, below top of the unit. Gypsum also is irregularly distributed through some of the dolomite layers as paper- and wafer-thin seams along partings, as small stringers or veinlets, and as small irregularly-shaped replacement bodies. The core log for bedrock borings is given in Table 1. Stratigraphic units in this log have the same number as correlative units in the core log for the Snell Lock (Table 2).

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
27	10.4+	Dolomite, dense to very finely crystalline gray to dark gray. Contains a dolomite conglomerate zone from 0.1 to 1.0 foot thick at or near the base and another from 0.2 to 0.9 foot thick from 1.8 to 3.2 feet above the base in many of the cores. The conglomerate consists of small gray dolo-

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
		mite pebbles in a slightly lighter gray dolomite mortar (probably intraformational conglomerate zone). The unit also contains a few thin shaly zones and thin shale seams.
26	4.5-6.4	Dolomite, dense, argillaceous, dark gray. Contains a black shale seam from 0.1 to 0.35 foot thick at bottom that, in many of the cores, has a sandy appearance because of light colored dolomite or quartz impregnated into or disseminated through it. Other thin black shale seams and partings are scattered through the unit. The unit also contains zones and pockets in which are veinlets and irregular masses of white calcite.
25	8.9-10.2	Dolomite, dense to very finely crystalline, gray. Contains argillaceous zones and thin black shale seams and partings. Most of the cores show a dolomite conglomerate zone between 0.1 foot and 1.7 feet thick and a vuggy zone between 0.1 foot and 1.4 feet thick near the bottom. The conglomerate consists of pebble-size dolomite particles or lenses in a slightly lighter gray dolomite matrix. The vugs range in size from pinpoint to about 1.5 inches in diameter.
24	3.4-4.9	Dolomite, very finely crystalline, brownish-gray. Contains a mottled zone 1.5 to 2.0 feet thick about 2 feet below the top of the unit. Tiny vugs or pores about pinpoint size are contained in the mottled zone. The lower 0.4 to 0.8 feet of the unit is dense.
23	1.0-1.4	Shale, black. Dolomitic in some cores.
22	5.1-5.6	Dolomite, dense, gray to dark gray. Argillaceous in some cores and contains argillaceous and black shale seams in others.

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
21	0.6-0.9	Shale, dark brownish-gray to black. Logged as dolomitic shale in some cores and as argillaceous dolomite in others. Contains black shale zones at top and at bottom of unit where it appears as argillaceious dolomite.
20	3.1-4.2	Dolomite, dense, gray. A dark gray argillaceous zone about 0.3 foot thick occurs around 0.6 to 0.9 foot below the top of the unit. The unit contains thin vuggy zones in some cores. The vuggy zones are in the lower 2.5 feet of the unit, and the vugs are mostly pinpoint-size to 1/8 inch in diameter.
19	2.4-3.0	Dolomite, dense, very argillaceous, very dark gray to black. Contains a black shale seam at the base from 0.1 to 0.3 foot thick and other thin black shale seams. A zone from 0.2 foot to about 1.0 foot thick containing white calcite in veinlets and in small irregularly shaped masses occur in most of the cores at around 1.5 feet above the base of the unit.
18	2.0-3.6	Dolomite, dense, gray. Lower 1.1 feet in some cores is dark gray, argillaceous or contains thin, dark dray argillaceous zones.
17	1.1-2.1	Dolomite, dense, very argillaceous, very dark gray to black. Contains black shale seams.
16	8.4-9.5	Dolomite, dense, gray. Contains scattered dark gray argillaceous zones in some cores.
15	1.4-3.8	Gypsum, finely to coarsely crystalline, white to dark gray or dark brown.
14	1.9-3.8	Dolomite, dense, argillaceous, gypsiferous, gray. The gypsum occurs as white or very light gray lenses and irregularly shaped

Table 1. Core Log for bedrock beneath Eisenhower lock.

Strati-graphic Unit	Thickness ft.	Description
		masses in the dolomite and in seams paper-thin to 0.3 foot or more thick.
13	21.1-24.4	Dolomite, dense, gray. Contains slightly darker gray argillaceous zones.
12	2.1-2.7	Dolomite, dense, argillaceous, dark brownish-gray. Penetrated only by holes RB-7A and 8A.
11	7.1-10.7	Dolomite, dense, gray. Contains scattered thin black shale seams and partings. Lower part apparently is gypsiferous. Penetrated only by holes RB-7A and 8A.
10	5.6±	Dolomite, dense, argillaceous, dark gray to dark brownish-gray. Contains scattered thin black shale seams and partings. Penetrated only by holes RB-7A and 8A.
9	2.9±	Dolomite, dense, gray. Penetrated only by hole RB-8A.
8	1.7±	Dolomite, dense, argillaceous, dark brownish-gray. Penetrated only by hole RB-8A.
7	2.4±	Dolomite, very finely crystalline, brownish-gray. Contains scattered, wavy, paper-thin shale seams. Penetrated only by hole RB-8A.
6	2.2±	Dolomite, dense to very finely crystalline, gray. Penetrated only by hole RB-8A.
5	5.7±	Gypsum, very finely crystalline, argillaceous, brownish-gray. Penetrated only by hole RB-8A.
4	2.6±	Dolomite, dense to very finely crystalline, gray. Contains scattered thin black shale seams. Penetrated only by hole RB-8A.

Bedrock Structure

The rock strata at Eisenhower Lock are very nearly horizontal but have a slight general dip north-westward and contain small undulations. The dip for the most part is less than 1°43' or 3 feet per 100 feet.

The foundation rock contains three major sets of nearly vertical joints. Those belonging to the most prominent set strike between N 8°W and N 20°W, and the other two sets strike between N 26°E and N 43°E and N 70°E and S 85°E, respectively.

Bedrock Weathering

The rock in the Eisenhower Lock area is virtually unweathered, except for some yellowish-brown or rust-colored staining observed along partings in the upper 5 feet of rock in a few cores. Weathered rock probably was removed by glacial erosion during the Pleistocene, and the bedrock since has been protected by the mantle of glacial till.

Leaching and Solution in Bedrock

Thin zones of leached rock and small solution cavities are widely distributed in certain stratigraphic zones in the foundation rock. They apparently are more common in the downstream portion of the foundation rock than in the upstream portion. Those which are most persistent occur about 3 feet below the top of stratigraphic unit 13, at the top of stratigraphic unit 15, near the bottom and at the top of unit 16, and near the bottom and near the middle of unit 25. For the most part, these are parallel to the bedding. The leached zones range in thickness from 0.1 inch along bedding planes or partings to about 7.8 inches and in degree of leaching from just a slight difference in color to earthy-appearing rock with high absorption. The cavities range in thickness from about 0.1 foot to 0.9 foot.

Ground Water

The ground-water level in drill hole D-1173 (Fig. 7) over the till ridge fluctuated between 11 and 17 feet below the ground surface, or between elevations 245 and 251, during the periods prior to construction when measurements on that hole were made. This one drill hole was the only observation well or piezometer in the overburden prior to construction, and the water levels in it were interpreted as indicating the ground-water level in the overburden across the top of the ridge. Test pits dug on the upstream and downstream sides of the ridge in November and in December 1954 by the Power Authority of the State of New York filled with water to within 4 to 6 feet of the ground surface at the time they were dug. The ground water level adjacent to the lock area was lowered during excavation for the lock by drainage into the excavated area but has risen again since the space between the lock walls and the excavation slope was backfilled.

The water in the bedrock has a lower pressure head than that in the overburden materials. Water levels measured in core holes drilled into bedrock in 1954 and in 1955 prior to construction, for the most part, were between elevations 160 and 170 feet, and thus were about 80 to 90 feet below the ground-water levels that were observed in drill hole D-1173. The piezometric level of the water in the bedrock prior to construction was about 20 to 30 feet above the bedrock surface, and fluctuations in that piezometric level tended to reflect fluctuations in the level of St. Lawrence River. During construction after the overburden had been removed, the piezometric level or pressurehead of the water in the bedrock was lowered to top of rock in the lock area by relief through joints and through core holes that were drilled for foundation exploration and to a level below top of rock in the downstream portion of the lock area by relief into the excavation for the lower sill. The piezometric level in these areas rose again after the core holes were backfilled and concrete placed in the foundation areas. By December 1956, the piezometric level for the water in bedrock in the lock area had recovered to an elevation of 149 feet as indicated by water rising to that elevation in observation holes drilled into bedrock from benches on the chamber side of the lock walls.

No chemical analyses of the ground water at Eisenhower Lock were made. An analysis made in 1955 of a sample of water from a farm well 1,920 feet upstream from the upstream gate location and 135 feet north from the centerline for the lock in connection with the determination of acceptable sources of concrete mixing and curing water is given below:

Iron	0.2	PPM
Sulphates	102	PPM
Chlorides	19	PPM
pH	7.5	

The water in the bedrock has a slight odor of hydrogen sulphide.

Engineering Characteristics of the Glacial Till

The glacial till, except where it has been disturbed by frost action or by other means and except for pockets and lenses of loose stratified materials, is compact and dense, and parts of it are very tough. The characteristics of the undisturbed till at Eisenhower Lock, on an average, are:

Classification	Sandy silt (ML-CL) with gravel, cobbles and boulders. (Unified classification system)
Mechanical analysis (not including cobbles and boulders)	
gravel.	13 percent
sand.	34 percent
fines	53 percent
Unit weight in place (wet weight). . .	149 pounds/cubic foot
Density (dry weight)	139 pounds/cubic foot
Specific gravity, G.	2.74
Liquid limit	17.4
Plastic limit.	10.7
Moisture content	7.5 percent
Void ratio	0.24
*Angle of internal friction, Ø.	35 degrees
*Cohesion, c.	2.1 tons/square foot
*Coefficient of permeability, K	48×10^{-6} centimeters/second

*Averages from tests on only three samples.

These characteristics except for coefficient of permeability were obtained from the test data given on figure 14.

Bertrand H. Snell Lock

GEOLOGY

Physiography

Bertrand H. Snell Lock is constructed above the left bank of Grass River near where that stream empties into St. Lawrence River. It lies in a flat area, a short distance beyond the northeast end of a gentle, northeast-trending ridge. Before construction, a small stream tributary to Grass River flowed along the south side of the lock excavation area between the lock site and the end of the ridge. Topography at the lock site prior to construction was nearly flat, with a relief about 25 to 30 feet. Grass River varies around elevation 157. Top of the bank above Grass River was about elevation 175, and the surface in the lock area, for the most part, was between elevations 180 and 185. The small tributary stream along the south side of the lock area was about elevation 160. The topography at the lock site has been altered somewhat by the construction of dikes north and south from the lock; the placement of backfill behind the lock walls; and the construction of spoil piles north of the lock. The roadway on top of the dikes is about elevation 212; backfill behind the lock walls was placed to elevation 205; and spoil was placed in the spoil areas to about elevation 205. About 3,000 feet southwest from the lock area, the gentle ridge rises to elevation 250.

Overburden

The material overlying bedrock in the area of Snell Lock is glacial drift and soft clay, both of which are of late Pleistocene Age. Before excavation was started it ranged in thickness at the lock site from about 60 feet to about 100 feet, with an average of about 80 feet.

The glacial drift lies directly on bedrock and consists principally of till but includes water-lain sand and gravel. The till is gray and is a more or less tough, compact mixture of clay, silt, sand, gravel, cobbles and boulders. The predominant constituents are silt and sand. Water-lain sand and gravel occur as lenses and layers of loose sandy gravel and gravelly sand within, above, and at the eastern margin of the till. Prior to excavation and construction, the glacial material ranged in thickness from a feather edge to about 6 feet in the downstream lock approach area and was absent in places. It increased in thickness upstream from there to about 55 feet near the upstream limits of the lock walls and to about 72 feet near the upstream limit for the upstream guide wall. The glacial drift surface rose in elevation from downstream to upstream more or less corresponding to the increase in thickness. No mineralogical studies were made on the till at Snell Lock site, but studies at U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, on five samples taken from the excavation for Wiley-Dondero ship channel show the major constituents of the till to be carbonate rocks and minerals, quartz, feldspar, and clay. These made up 85 percent or more of each of the five samples studied. Most of the gravel-size particles are dense, dark gray limestone and dolomite, but gravels of quartzite and granite also are contained in the till. The average composition of the five samples are:

	Percent
Carbonate rocks and minerals	26
Quartz and feldspar	53
Igneous rocks and gneiss	3
Graywacke	1
Sandstone	trace
Shale, slate	1
Clay	11
Miscellaneous	5

Soft clay overlies the glacial material where the overburden has not been disturbed by construction and lies directly on bedrock where glacial material is absent. It consists of soft silty clay ranging in color from brown in the zone of oxidation to gray to blue-gray below that zone. The clay contains marine shell fossils and small, thin, fine-grained sand lenses. Varves were observed in the lower part of the clay. Prior to excavation, the clay ranged in thickness at the lock site from about 10 or 12 feet near the upstream limits for the upstream approach wall to about 70 feet in the downstream approach area. In general, the thickness of clay was least where the thickness of glacial material was greatest and greatest where the thickness of glacial material was least.

Mineralogical analyses of samples of clay from the Massena area by R. Torrence Martin, Massachusetts Institute of Technology, Cambridge, Massachusetts, indicate the clay to be predominantly hydrous mica and chlorite and to contain appreciable carbonate minerals. Near the surface, the carbonate minerals have been leached. The results of the analyses on two samples from the downstream approach wall area for Snell Lock, one sample from the oxidized brown clay zone and one from the lower gray clay zone, are:

	Percent by Weight	
	Brown Clay Zone (depth 10.0-12.4 feet-Lab Sample 3)	Gray Clay Zone (depth 35.0-37.4 feet-Lab Sample 13)
Illite	30±6	30±3
Montmorillonoid	10±2	-
Chlorite	20±6	15±5
Carbonates (calcite and dolomite)	-	25±3
Quartz	20±2	10±2
Feldspar	20±10	20±10

The soft clay was called "Leda Clay", "Massena" clay, or just "marine" clay prior to construction of the lock and was considered to be a marine deposit formed in an arm of the late Pleistocene Champlain Sea that extended up the St. Lawrence valley after the Wisconsin ice sheet had receded from the mouth of St. Lawrence River. Dr. MacClintock and others, however, have observed varves in the lower part of the clay where it was exposed in excavations in the Massena area and have concluded that the lower part of the clay is a fresh-water deposit. MacClintock (1958) considers the lower clay to have been deposited in a fresh-water lake that was confluent with the Fort Ann stage of Lake Vermont. Fossiliferous marine clay was deposited over the fresh-water clay after the ice barrier had receded from the mouth of St. Lawrence River and the level of marine water had risen to where it could back up into the St. Lawrence Valley.

Bedrock Stratigraphy

Bedrock in the Snell Lock area explored by core borings belongs to the upper part of the Beekmantown formation, or the Oxford formation as classified by Wilson (1946) and is Ordovician in age. The uppermost rock layer at Snell Lock is 70 to 80 feet below the top of the Beekmantown formation. The rock is dolomite for the most part but contains shale and dolomitic shale layers interbedded with it. Two stratigraphic units that were at depths around 35 and 85, respectively, below top of rock before construction, are replaced or partly replaced by gypsum and/or celestite in and near the fault zone upstream from the limits of the lock walls but are unreplaced dolomite under the foundation. The upper one of these two units, at least, is badly leached under the foundation area. Both of these units are replaced by gypsum in the Eisenhower Lock area. The rock penetrated by the borings has been separated into stratigraphic units on the basis of lithology, and brief descriptions of these units are given in table 2 below. The units are numbered from unit 25, the uppermost unit at Snell Lock, in decreasing sequence downward and correlate with same-numbered units at Dwight D. Eisenhower Lock (Robinson

Bay Lock). Unit 2 is the lowermost unit penetrated by exploratory borings in or near the foundation area for Snell Lock, but one boring in the fault zone penetrated below unit 1.

Table 2. Core Log for bedrock beneath Snell Lock.

Strati-graphic Unit	Thickness ft.	Description
25	4.4+	Dolomite, dense to very finely crystalline, gray. Contains a dolomite conglomerate zone from 0.1 to 1.0 foot thick at or near the base. The conglomerate consists of small gray dolomite pebbles in a slightly lighter gray dolomite mortar (probably intraformational conglomerate zone).
24	4.0 - 5.0	Dolomite, very finely crystalline, brownish-gray to dark gray. Contains a mottled zone from 1.5 to 2.0 feet thick about 2 feet below the top of the unit. The mottled zone contains tiny vugs or pore spaces most of which are about pinpoint size. The lower 0.4 to 0.7 foot of the unit is dense.
23	1.0 - 1.4	Shale, black. Dolomitic in some cores.
22	4.7 - 5.6	Dolomite, dense, gray to dark gray. Argillaceous in some cores and contains argillaceous and black shale seams in others.
21	0.7 - 1.4	Dolomite, dense, argillaceous to very argillaceous, dark brownish-black to black. Contains a black shale seam from about 1 to 8 inches thick at the top of the unit. Also contains thin shale or shaly seams at or near the bottom.
20	3.6 - 4.6	Dolomite, dense, gray. A dark gray argillaceous zone about 3.5 to 8.5 inches thick occurs around 1.0 to 1.5 feet below the top. The lower half of the unit contains vuggy zones in some cores. The vugs range in size from pinpoint size to 0.5 inch or larger.
19	2.0 - 3.0	Dolomite, dense, very argillaceous, very dark gray to black. Contains a black shale seam at the base from 0.1 to 0.3 foot thick and other thin black shale seams.

Table 2. Core Log for bedrock beneath Snell Lock.

Strati-graphic Unit	Thickness ft.	Description
18	2.4 - 3.8	Dolomite, dense, gray.
17	1.5 - 2.2	Dolomite, dense, argillaceous to very argillaceous, very dark gray to black. Contains black shale seams. Logged as dolomitic shale in one core.
16	7.6 - 9.2	Dolomite, dense, gray.
15	0.5 - 2.6	Dolomite, dense, argillaceous, gray. Is leached and vuggy in most cores. Replaced by gypsum and/or celestite in some cores in and near the fault zone upstream from the limits of the lock walls.
14	1.3 - 4.5	Dolomite, dense, argillaceous, laminated, dark gray. Some cores show leached zones.
13	22.5 - 24.8	Dolomite, dense, gray. Contains slightly darker gray argillaceous zones and scattered thin black shale seams.
12	1.0 - 3.3	Dolomite, dense, argillaceous, dark brownish-gray.
11	7.3 - 8.1	Dolomite, dense to very finely crystalline, gray.
10	4.9 - 5.9	Dolomite, dense, argillaceous, dark gray to black. Contains scattered thin black shale seams.
9	2.1 - 3.1	Dolomite, dense to very finely crystalline, gray.
8	1.8 - 2.2	Dolomite, dense, argillaceous, dark gray to dark brownish-gray. Contains thin black shale seams.
7	2.3 - 3.4	Dolomite, very finely crystalline, brownish gray.

Table 2. Core Log for bedrock beneath Snell Lock.

Stratigraphic Unit	Thickness ft.	Description
6	1.4 - 3.2	Dolomite, dense to very finely crystalline, gray.
5	3.3 - 5.8	Dolomite, dense, argillaceous, gray to dark brownish-gray. Logged as gypsum in core from hole GR-2 and as gypsiferous in core from hole GR-13.
4	2.8 - 3.3	Dolomite, dense, gray. Contains scattered thin shale seams.
3	2.2 - 3.0	Dolomite, dense, argillaceous, dark gray to very dark brownish-gray. Gypsiferous in hold GR-5.
2	15.0±	Dolomite, dense, gray. Total thickness of unit penetrated only in hole GR-1.
1	1.4±	Dolomite, very finely crystalline, agrillaceous brownish-gray. Upper 0.8 foot of unit is slightly vuggy. Penetrated only in hole GR-1.
0	12.3±	Dolomite, very finely crystalline, gray to dark gray. Contains thin argillaceous seams. Penetrated only in hole GR-1.

Bedrock Structure

The rock strata in the upstream one-fourth of the foundation area for Snell Lock are folded in a small plunging anticline, the crest of which crosses the foundation diagonally from the foundation for monolith S-8 to the foundation for monolith N-49 (see figures 11 and 12 for monolith orientation) and plunges northeastward. Downstream from the anticline, the rock strata are only very slightly undulated and have a slight dip northward. The dip at most places, except on the flanks of the small anticline, is less than 2 feet per 100 feet.

The rock is broken by a fault upstream from the limits of the lock walls. The fault crosses the center line for the lock about 760 feet upstream from the upstream lock gate station and strikes about N 56°E. It probably dips very steeply northwestward. The rock at and adjacent to the fault is badly brecciated and fractured in a zone around 300 feet wide. Vertical displacement of beds is about 35 feet with the upthrown side on the northwest.

The foundation rock contains two major sets of joints. Joints belonging to one of these, for the most part, strike between N 37°E and N 56°E, and those belonging to the other, for the most part, strike between N 80°W and N 90°W. A few joints belonging to a third set strike around N 10°W. The joints are nearly vertical or dip at a very steep angle.

Weathering in Bedrock

Bedrock in the Snell Lock area is virtually unweathered, except for some yellowish-brown or rust-colored staining along partings or bedding planes in the upper 10 feet in one or two cores drilled before construction.

Leaching and Solution in Bedrock

Zones of leached rock and small cavities or solution voids are widely distributed in certain stratigraphic zones in the foundation rock. These are mostly parallel to the bedding. The leached zones range in thickness from 0.1 inch to about 3.0 feet and in degree of leaching from a slight change in color to soft, earthy-appearing rock exhibiting honey-combing by solution and high absorption. The solutional cavities range in thickness from about 0.5 inch to about 7 inches. Most of the leached zones and cavities are in stratigraphic units 16, 15, 14, and 13 although they were encountered in nearly all units. Some of the leached zones and cavities are persistent under a fairly large portion of the foundation area. One such persistent zone is about 2 feet below the top of stratigraphic unit 16, characterized in many cores as a leached or a soft absorbent zone, or as a cavity. Unit 15 contains cavities and is composed of or contains zones of soft, absorbent, honeycombed rock under most of the foundation area. Unit 14 also contains persistent zones that are absorbent and that are honeycombed by solution.

Ground Water

No measurements of ground-water levels in the overburden materials were made prior to excavation, but measurements of water levels in piezometers that were installed in the clay portion of the overburden less than 2 months after excavation was commenced, showed a piezometric level from 7 to 9 feet below the ground surface at that time. The piezometric level adjacent to the lock area was lowered during excavation, and has risen again since the space between the lock walls and the excavation slope has been backfilled.

The piezometric level of water in the bedrock is lower than that in the overburden materials. Water levels that were measured in those core holes that were drilled in bedrock in 1954 and in 1955 prior to construction were about elevation 158, or about 26 feet below the ground surface at the time of measurement. This was 46 to 72 feet above the bedrock surface in the lock foundation area and very close to the level of Grass River. Fluctuations in water levels in those holes tended to reflect fluctuations in Grass River. During construction, the piezometric level of the water in the bedrock was lowered to top of bedrock or lower in the lock area by pumping from drain wells in the bedrock and by relief through joints and through core holes and relief into the excavation for the lower sill. The piezometric level in these areas rose again slightly after concrete had been placed in the foundation areas and pumping from the drain wells was stopped. Complete recovery of the piezometric level for the water in bedrock occurred in June 1958 when the lock area was flooded preparatory to opening the lock and canal to navigation. Since the lock has been in operation, the piezometric level of the water in bedrock has fluctuated with the filling and emptying of the lock chamber.

The water in the bedrock has a slight odor of hydrogen sulphide. A chemical analysis of a sample taken from core hole GR-23 on 4 May 1955 in connection with the determination of acceptable sources of concrete mixing and curing water is given below. Approximately 50 gallons of water were bailed from the hole before the sample was taken. The analysis was performed in the U.S. Army Engineer Division Laboratories, Ohio River, Cincinnati, Ohio.

Iron	2.5	PPM
Sulphates	639	PPM
Chlorides	79	PPM
pH	7.3	

Engineering Characteristics of the Overburden Materials

The marine and fresh-water clay is a soft, low-strength, sensitive material. The average characteristics of the undisturbed clay at Snell Lock, based on the laboratory test data contained on Fig. 14, are

Classification.	Clay (CL-CH)
Unit Weight in place (wet weight) . . .	106.6 pounds/cubic foot
Density (dry weight).	69.4 pounds/cubic foot
Specific gravity, G	2.82
Liquid limit.	50.3
Plastic limit	25.1
Moisture content.	53.6 percent
Void ratio.	1.54
Cohesion, c	0.43 tons/square foot

The glacial till, except where it has been disturbed and except for pockets and lenses of loose stratified materials, is compact and dense, and parts of it are very tough. No tests were performed on glacial till samples from the Snell Lock area, but the average characteristics of undisturbed till at Eisenhower Lock are:

Classification.	Sandy silt (ML-CL) with gravel, cobbles and boulders
Unit weight in place (wet weight) . . .	149 pounds/cubic foot
Density (dry weight).	139 pounds/cubic foot
Specific gravity.	2.74
Liquid limit.	17.4
Plastic limit	10.7
Moisture content.	7.5 percent
Void ratio.	0.24
Angle of internal friction.	35 degrees
Cohesion.	2.1 tons/square foot

Effect of Glaciation on Bedrock

Weathered rock probably was removed by glacial erosion during the Pleistocene Epoch, and the bedrock since then has been protected from weathering by the mantle of glacial till and of clay covering it. The movement of the ice across the bedrock, however, caused fracturing or jointing in the rock and left scratches or striations on the rock surface. The lower part of stratigraphic unit 25, which made up the upper layer of rock over the downstream portion of the foundation area was badly jointed or fractured and was removed with a bulldozer in places without blasting. Drag joints also occurred in stratigraphic unit 24 over parts of the foundation area. These were nearly vertical at the top of the stratigraphic unit but curved in the lower part of the unit to nearly horizontal. These joints in unit 24 also were very tightly filled with glacial till material that apparently was forced into the joints by the ice as the joints were formed. Two sets of glacial striae were exposed on the rock surface over approximately the downstream third of the foundation area before bedrock excavation. One set had a strike around S 50°W and the other around S 9°E.

BIBLIOGRAPHY

1. Chapman, L. J. and Putnam, D. F., 1951, The Physiography of Southern Ontario: Univ. Toronto Press.

2. Crawford, C. B. and Eden, W. J., A Comparison of Laboratory Results With In-Situ Properties of Leda Clay: National Research Council, Ottawa, Research paper 274.

3. Eden, W. J. and Crawford, C. B., 1957, Geotechnical Properties of Leda Clay in the Ottawa Area: Proc. 4th International Conference on Soil Mechanics and Foundation Engineering, v. 1, p. 22-27.

4. Fenneman, Nevin M., 1938, Physiography of Eastern United States, McGraw-Hill Book Co.

5. ____________, 1958, Foundation Report, Dwight D. Eisenhower Lock, U.S. Corps of Engineers.

6. ____________, 1958, Foundation Report, Bertrand H. Snell Lock, U.S. Corps of Engineers.

7. Kemp, J. F., 1906, The Physiography of the Adirondacks: Popular Science Monthly, v. 68, p. 195-210.

8. MacClintock, Paul, 1958, Glacial Geology of the St. Lawrence Seaway and Power Projects: N.Y.S. Museum and Science Service.

9. Reed, John Calvin, 1934, Geology of the Potsdam Quadrangle: N.Y.S. Museum Bulletin No. 297, December.

10. Wilson, Alice E., 1946, Geology of the Ottawa, St. Lawrence Lowland: Canada Dept. of Mines and Resources, Geol. Survey Memoir 241.

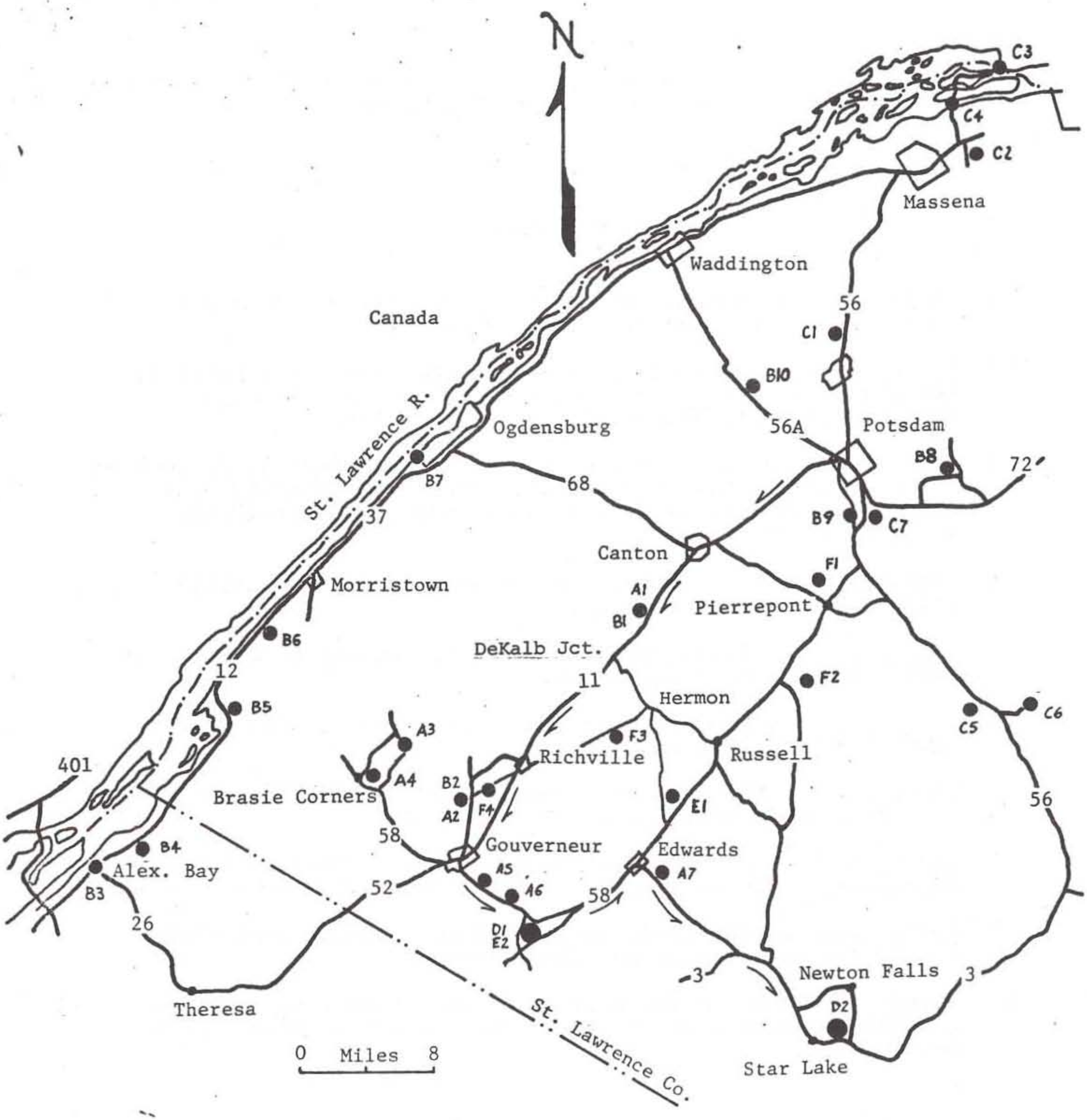


Figure 1. STOP MAP FOR TRIP D

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

TRIP D

ECONOMIC GEOLOGY OF INTERNATIONAL TALC AND BENSON IRON MINES

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ABSTRACT

Since 1964 International Talc Co. has mined commercial talc from its open pit at Fowler, New York. The minable product is tremolite-talc schist, a Grenville metasedimentary unit of the Balmat-Edwards district. Production of 80,000 tons annually accounts for 45 percent of New York State talc. The mineralogy of this complexly folded, Mg-rich unit is typical greenschist facies. The petrogenesis is complex and speculative, but replacement and/or isochemical metamorphism is suggested.

Iron ore, principally magnetite and hematite, are extracted by open pit methods at Benson Mines, New York. The 2.5 mile-long pit is located in the overturned eastern limb of a northerly-plunging syncline. Ore occurs disseminated in Grenville gneisses that average 23 percent iron. Average annual tonnage is 1.1 million, which yields a concentrate of 62 percent iron. A metasedimentary or replacement origin is postulated.

ACKNOWLEDGEMENT

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STOP DESCRIPTIONS

Stop 1. International Talc Open Pit (Fig. 1) New York talc was originally discovered by Colonel Henry Palmer and in 1878 he opened the first commercial talc mine in New York at Talcville. Over the past 93 years talc has steadily grown in economic importance. Commercial talc from the Balmat-Edwards district is the only source in New York State and accounts for 22 percent of U.S. production or approximately 200,000 tons per year.

All of the producing and abandoned talc mines were underground operations until 1964 when International Talc started production from their open pit at Fowler. All mining operations in the district are confined to unit 13, a tremolite-talc schist that varies in thickness from 0 to 400 feet. It can be traced more or less continuously from Balmat to Edwards, some 10 miles.

Regional Geology

The Balmat-Edwards belt is a northeast - trending marble belt approximately 10 miles long and ½ to 2 miles wide. It is part of the Grenville metasedimentary sequence of northern New York. Within the marble belt 16 lithologic units have been identified (Brown and Engel, 1956). These stratigraphic units can be traced with a fair degree of accuracy, the entire length of the belt. They are numbered 1 to 16 with number 1 presumably oldest (Table 1, Fig. 2). All units have been extensively folded and there is abundant evidence of cross-folding, flowage, and intricate contortions. The interested reader is referred to Brown and Engel (1956), Buddington and Leonard (1962), and Lea and Dill (1968) for complete descriptions and detailed maps. The area has been subjected to regional metamorphism of the upper amphibolite and lower granulite facies. This high grade metamorphism is characteristic of the silicate gneisses that surround the Balmat-Edwards marble belt. However, the marble itself exhibits a mineralogy typical of greenschist and lower amphibolite facies.

Mine Geology

Structure

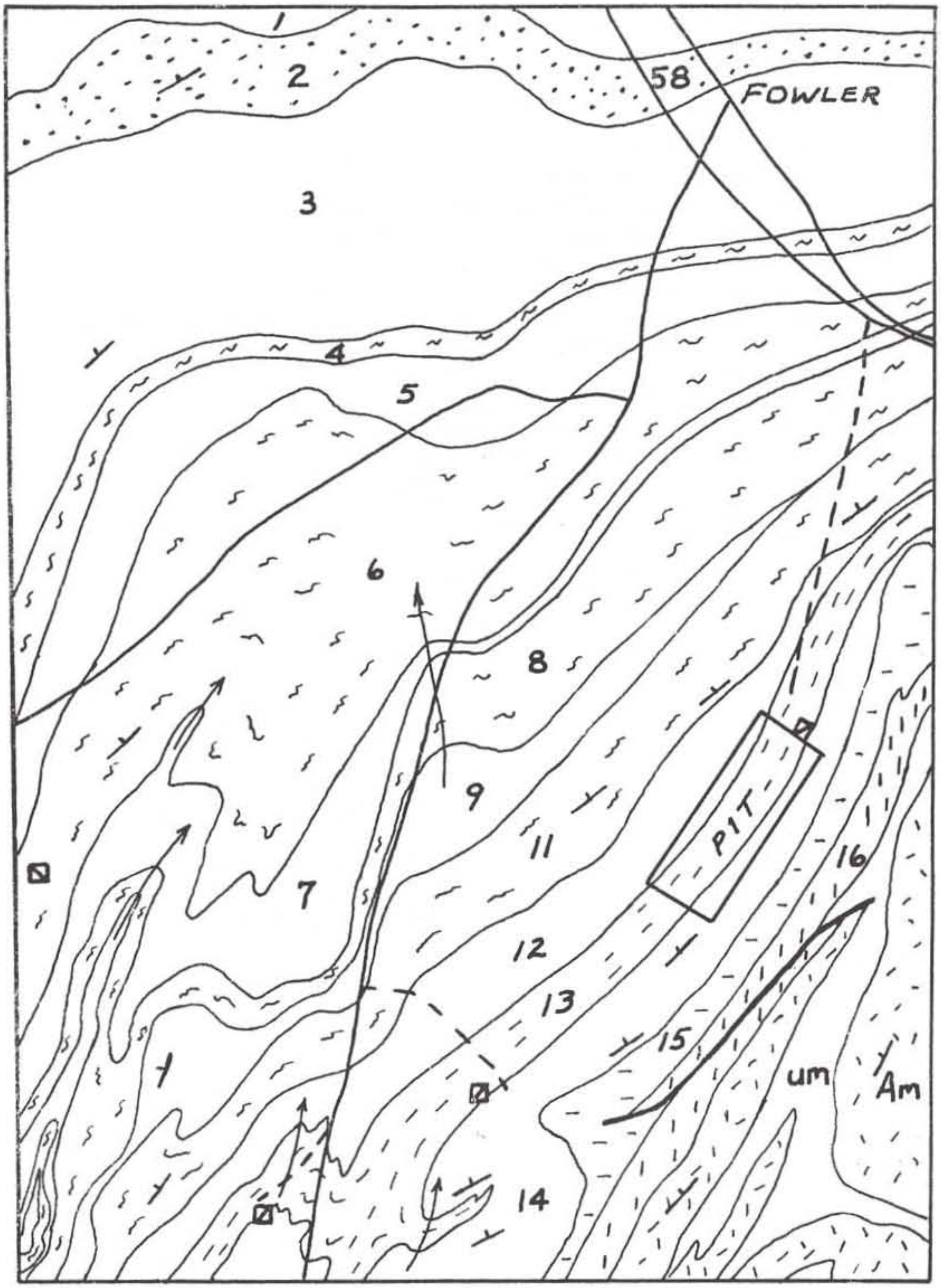
The International Talc Co. open pit is located in the tremolite-talc schist of unit 13 of the Balmat-Edwards district (Fig. 2). Initial stripping of overburden was begun in 1962 and production started in 1964. Since that time the pit has been expanded to its present size of 1200 x 450 feet with a depth of approximately 60 feet.

Unit 13 strikes northeast and is overturned to the southeast. Dips generally vary from 45 to 50 degrees. The tremolite-talc schist persists to a proven depth of at least 1000 feet and probably greater. Along strike to the south are remains of abandoned shafts to Wight, Woodcock and American mines and the producing Gouverneur Talc mine. There is evidence of fracturing, faulting, complex folding, and boudinage in many of the exposed surfaces. Minor and major folds plunge north at 15 to 50 degrees.

Mineralogy & Chemistry

Unit 13 is generally referred to as tremolite-talc schist, these being the major minerals present. All of the common minerals found in unit 13 are listed in Table 2. Mineral compositions of unit 13 are given in Table 3.

Figure 2.



GEOLOGY OF THE FOWLER AREA

(NUMBERS REFER TO UNITS OF TABLE 1)

After Brown and Engel 1956

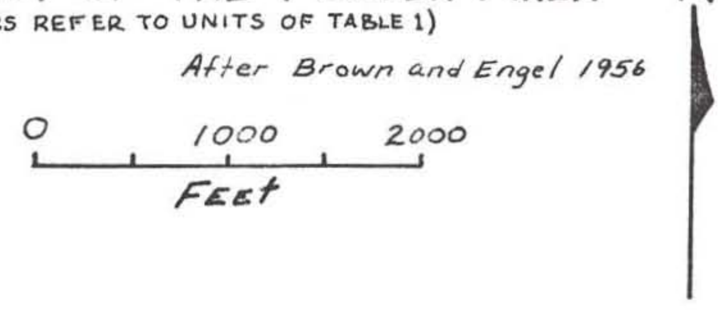


Table 1. Stratigraphic units of the Balmat-Edwards district (pre sumably oldest at bottom).

16	-	Median gneiss
15	-	Rusty marble
14	-	Calcitic-dolomitic marble
13	-	Tremolite-talc schist
12	-	Dolomitic marble
11	-	Dolomitic-diopside marble
10	-	Anhydrite-gypsum marble (not exposed)
9	-	Dolomitic marble
8	-	Silicated dolomite
7	-	Dolomitic marble
6	-	Silicated dolomite
5	-	Dolomitic marble
4	-	Silicated dolomite
3	-	Dolomitic marble
2	-	Pyritic schist
1	-	Dolomitic marble

Table 2. Common minerals of unit 13.

Diopside	$CaMgSi_2O_6$
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Anthophyllite	$Mg_7Si_8O_{22}(OH)_2$
Serpentine	$Mg_6Si_4O_{10}(OH)_8$
Talc	$Mg_3Si_4O_{10}(OH)_2$
Dolomite	$CaMg(CO_3)_2$
Calcite	$CaCO_3$
Quartz	SiO_2
Anhydrite	$CaSO_4$
Biotite	$K(MgFe)_3(AlSi_3)O_{10}(OH)_2$
K-feldspar	$KAlSi_3O_8$
Phlogopite	$K(Mg)_3(AlSi_3)O_{10}(OH)_2$
Pyrite	FeS_2

Table 3. Mineral composition of talc unit (volume %). (after Brown and Engel, 1956)

	1	2	3
Tremolite	38	47.6	84.8
Anthophyllite	7	38.4	4.5
Serpentine	12	4.1	4.2
Talc	24	5.4	3.2
Quartz	3.6	3.5	2.3
Calcite	14.4	3.0	0.2
Dolomite	tr	tr	-
Others	0.5	tr	0.8

1. Average of talc unit, 5th level, Woodcock Mine.
2. Commercial talc, Woodcock Mine.
3. Average of talc unit, Balmat zinc mine.

Table 4. Chemical analyses of channel samples across 5 commercial talc zones in the Balmat-Edwards district, (after Engel, 1962).

	1	2	3	4	5	Average
SiO_2	57.46	57.58	59.40	59.40	66.13	60.07
Al_2O_3	1.14	0.57	0.74	0.57	1.05	0.81
Fe_2O_3	0.23**	0.03	0.02	0.05	0.13	0.09
FeO	0.05	0.09	0.12	0.15	0.22	0.12
MnO	0.51	0.31	0.20	0.39	0.16	0.31
MgO	29.18	28.65	30.09	27.25	25.71	28.91
CaO	6.50	6.86	4.94	6.80	2.26	5.49
H_2O-	0.34	0.54	0.47	0.44	0.25	0.41
H_2O+	3.98	5.39*	4.09*	4.75*	3.86	3.86
CO_2	0.29	1.28	0.31	1.18	0.56	0.72

* = Total loss on ignition (includes CO_2)

** = Contamination (?)

The mineralogy represents typical hydrous assemblages of the greenschist facies. Distinction between tremolite, anthophyllite, and fibrous talc generally requires x-ray diffraction and/or optical examination. Most mineral percentages vary greatly throughout the schist. In general, however, the footwall (east) is tremolitic with tan serpentine (antigorite?), and the hanging wall (west) is enriched in fibrous and scaly talc.

Chemical analyses of 5 channel samples are given in Table 4. SiO_2, CaO, MgO, and H_2O total more than 98 percent.

Pleistocene

Of interest to "The Friends" are some extraordinary glacial features exposed in the pit. A conglomeratic "cement" no more than ¼ inch thick is plastered over much of the polished and striated bedrock, even in places where the glaciated surface is vertical or overhanging.

On the northwest end of the pit the overburden is typically gravel, while at the southeast it consists of a thixotropic clay. This facies change is rather abrupt and needless to say presented difficulties during stripping operations. A more complete discussion of the Pleistocene at this locality can be found in the field Trip E guide.

Economic Geology

At the northern end of the pit are the remains of the old Arnold Mine. This underground operation had 15 levels, 45 to 65 feet apart, branching from a shaft that followed the dip for 850 feet (Engel, 1962). International Talc purchased the Arnold Mine property from Loomis Talc in 1956 and began production via open pit methods in 1964.

Mining methods are relatively simple. Talc ore is drilled, blasted, and truck-hauled to the jaw crusher, which is located just north of the pit. The Telesmith jaw crusher is 36 inches wide and 20 inches between adjustable jaws. At a 6 inch spread, the crusher has a maximum capacity of 500 tons per hour. Usual runs at the pit are approximately 100 tons per hour, or lower if smaller sizes are required.

The crushed ore is screened and separated usually at 4 inches with coarser material stored and the finer material hauled to the mill. The coarse-ground ore is trucked to the mill when supply warrants.

International's pit produces an average of 80,000 tons per year. This represents 45 percent of New York talc and 9 percent of U.S. production. The value varies depending on grade. Coarse commercial talc (80 percent less than 325 mesh or 44 microns) runs $30 per ton.

Top grade talc ore (average 1.4 microns) and fiber products sell at \$90 per ton. Most of the products go to the paint and ceramic industries.

Petrogenesis

The origin of the tremolite-talc schist represents a complex problem as does that of the zinc deposits so intimately associated with the schist. There are no definitive answers, but certain facts place limits on interpretations.

1. The Balmat-Edwards district is predominantly dolomite and associated Mg-silicates.
2. The stratigraphy is reliable throughout the length of the belt.
3. Associated anhydrite, gypsum, and halite suggest an evaporite sequence.
4. Metamorphic foliation and primary layering are generally in good agreement.
5. Tremolite-talc ore was present prior to deformation.
6. Commercial talc is only found in unit 13.

Engel (1962) suggests that the talc unit is a product of the replacement of a siliceous dolomite. He notes that relict carbonate layers and lenses in the talc support this interpretation. If such a replacement occurred it was remarkably selective since tremolite and talc are almost exclusively restricted to unit 13. No other units of presumably similar composition contain commercial tremolite and talc.

Any hypothesis regarding petrogenesis must consider original composition and the stability of the present assemblage. Major variables that must be considered are T, P_1, P_{H_2O}, and P_{CO_2}. Geothermometry in the district (Engel, 1962; Lessing and Grout, 1971) indicates metamorphic temperatures of approximately 500°C. Pressures are more difficult to determine, but P_{CO_2} was probably high as suggested by coexisting quartz and dolomite and lack of dissociated carbonate. Water is a minor phase suggesting low P_{H_2O}. The stability of anthophyllite at Balmat (Greenwood, 1963) also supports a low water pressure; perhaps only 2-3 bars. Load pressure is estimated at 2-4 kilobars.

The chemical composition of the schist is essentially a hydrous calcium-magnesium silicate. A replacement origin is certainly possible as Engel has suggested. However, the stratigraphic restriction of unit 13 may indicate a metasedimentary origin that was essentially isochemical. A possible parent material of siliceous dolomite with trapped connate water would provide the necessary chemistry. Metamorphism of this unit would require the loss of CO_2 while retaining H_2O. The separation of CO_2 and H_2O may be controlled by permeability and/or osmotic pressure.

Brown and Engel (1956) have pointed out a retrograde metamorphic sequence tremolite → anthophyllite → serpentine → talc. Elsewhere, Elberty and Lessing have noted the reaction diopside → serpentine and excellent examples of dedolomitization (Fig. 3) in which Mg has been removed from dolomite to make diopside, and leaving a selvage of calcite. This phenomenon is common in diopsidic dolomites. The characteristic greenschist assemblage is in large part due to retrograde metamorphism that did not noticeably affect the surrounding gneisses.

Stop 2. Benson Mines Iron Ore Deposit (Fig. 1). The Benson Mines magnetite-hematite deposit is located on the northwest slope of the Adirondacks in the Grenville province of the Canadian Shield. Knowledge of the deposit dates back to about 1810. Production of magnetite began around 1889 and the deposit was worked intermittantly until 1941 when it was leased by Jones and Laughlin Ore Company. In 1952, a merger formed the New York Ore Division of Jones and Laughlin Steel Company. At the present time, the plant facility has an annual production capacity of about 1,100,000 long tons of magnetite and 700,000 long tons of hematite concentrates. The deposit is 400 to 600 feet thick and about 2½ miles long making it the largest known deposit of its kind.

Much of the following information was obtained from Leonard and Buddington (1964); Crump and Buetner (1968) and Palmer (1970). The reader is referred to these sources for more detailed discussion.

Regional Geology

Magnetite and hematite ores are confined to a relatively narrow horizon within a sequence of paragneisses which are infolded into granitic rocks of the Adirondack Highlands. Figure 4 shows the general geology of the area around Benson Mines. Palmer (1970, p. 31) recognizes four major units in the paragneiss sequence.

1. Mixed garnet- and pyroxene-feldspar gneiss.
2. Garnet- and sillimanite-quartz-feldspar gneiss (ore and mineralized horizon)
3. Migmatitic plagioclase gneiss.
4. Pyroxene-quartz-feldspar gneiss.

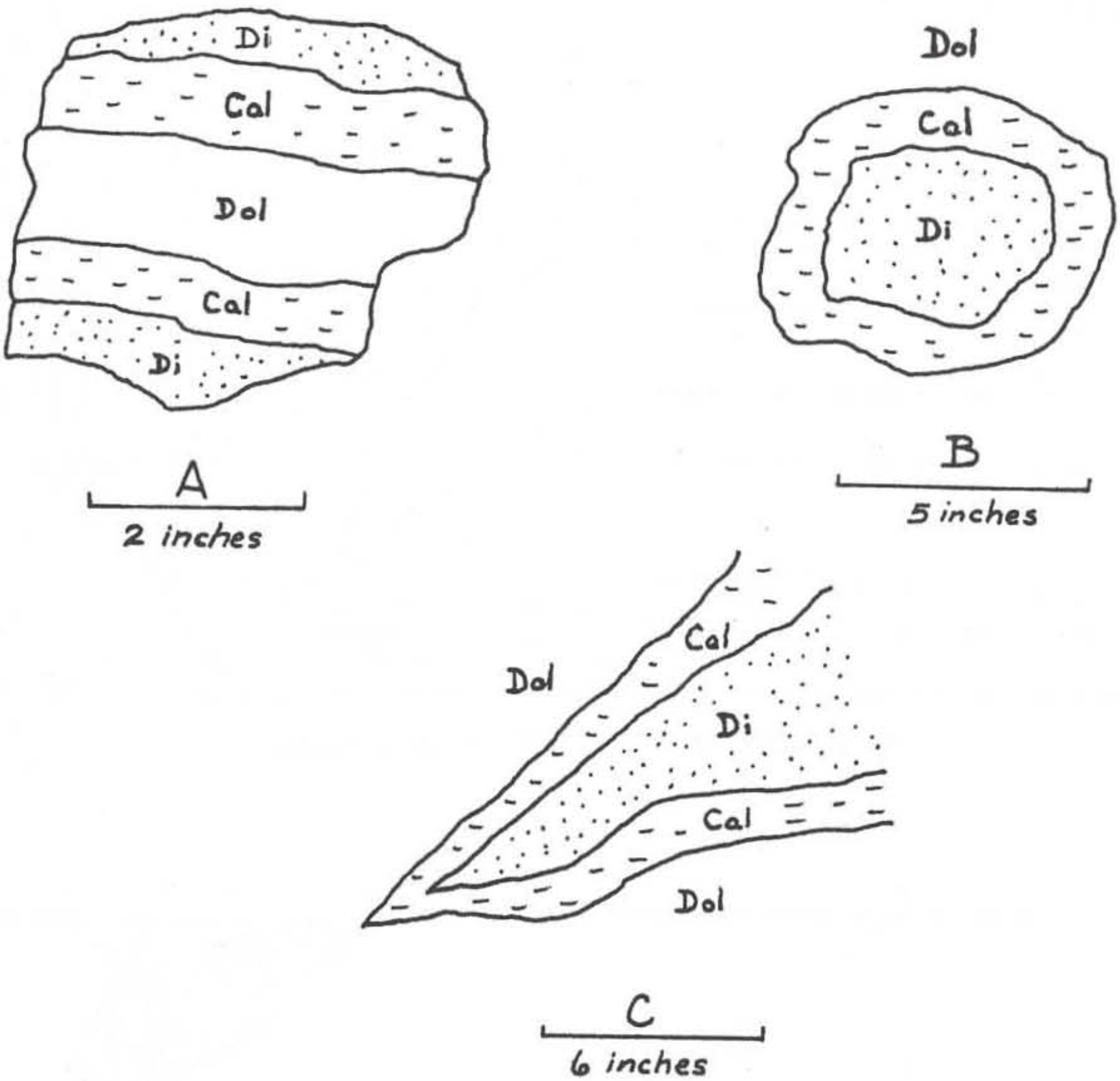
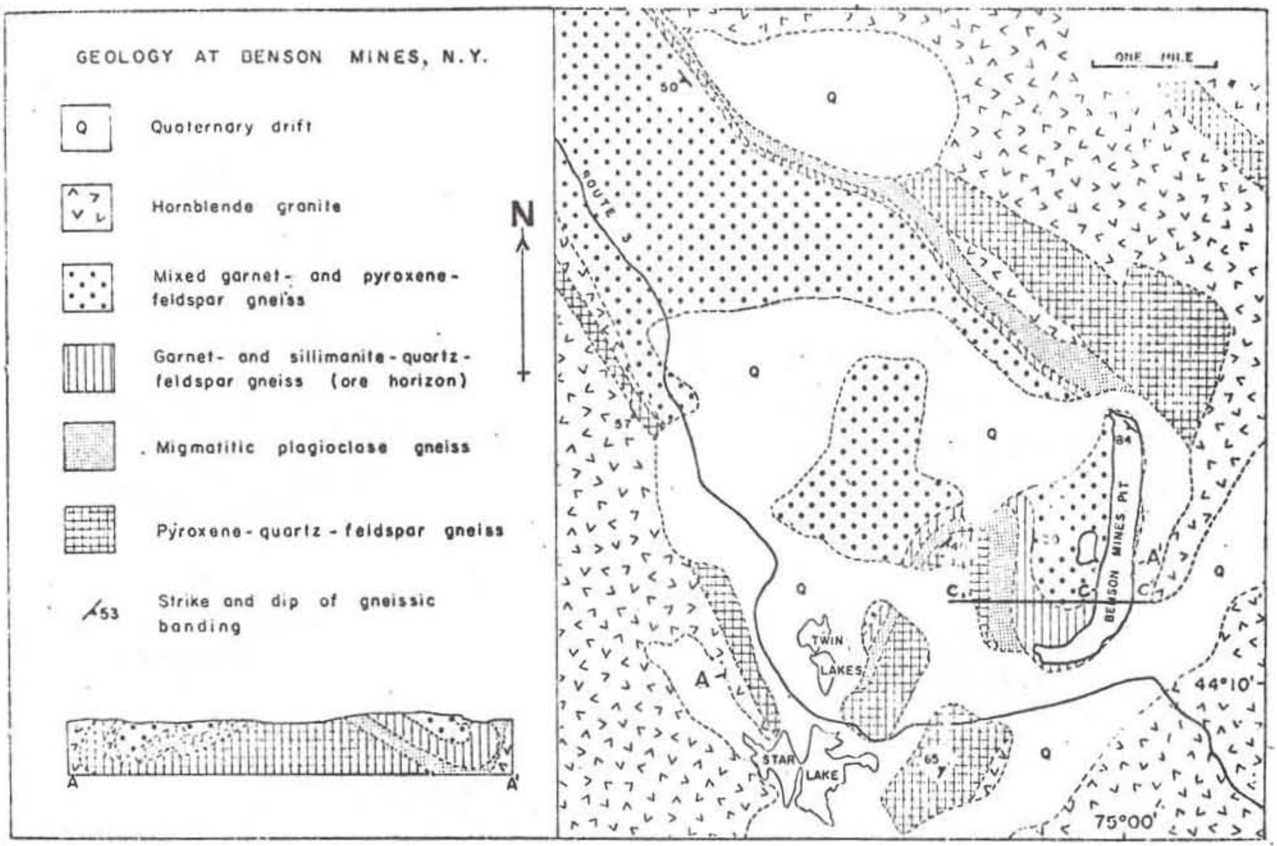


Figure 3. Examples of dedolomitization. A - layering, B - knots, C - pinchouts



SECTION OF MAJOR STRUCTURE

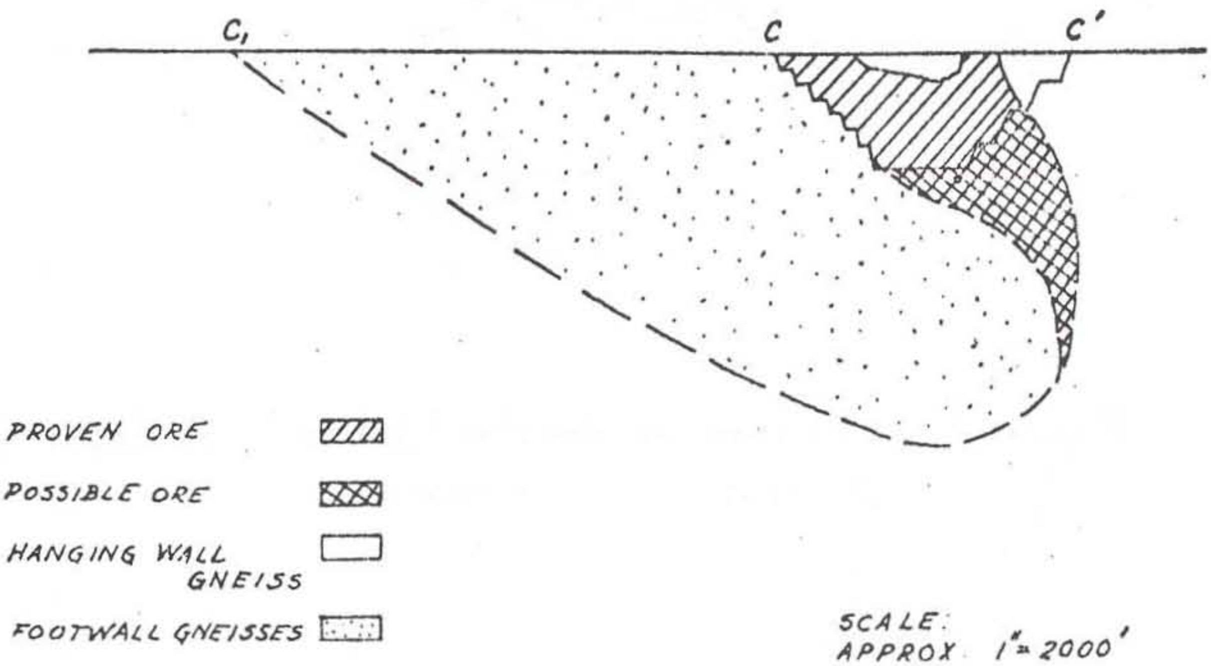


Fig. 4.- General geology of Benson Mines (after Palmer, 1970) and section showing the mine with respect to the major structure.

The surrounding crystalline rocks consist of alaskite and hornblende granites and their gneissic equivalents.

Mine Geology

The paragneisses comprise a large, structural synform overturned to the west and plunging north about 20° in the vicinity of the mine. The paragneisses are subdivided into six lithologic units: 1) hanging-wall gneiss, 2) disseminated-garnet gneiss, 3) sillimanite gneiss, 4) ferromagnesian gneiss, 5) blotchy garnet gneiss, and 6) biotite gneiss. Important concentrations of ore are confined to units 2, 3, and 4, and some ore is found in unit 5. Thicknesses, mineral composition, and appearance of the units vary considerably. Sequence is an important aid to identification within the mine. Rocks similar to those exposed in the Benson Mine have been traced approximately 8 miles along the strike.

Hanging-wall gneiss. An extremely heterogeneous unit composed of a variety of different rock types including diopside, marble, quartzite, and hornblendite in bands 5 to 50 feet thick. Most of the unit consists of pink or gray hornblende and/or pyroxene gneiss. A pink, microcline pegmatite marks the immediate hanging wall throughout the deposit. Hornblendite and diopside rock are encountered in drill holes. Minerals include quartz, orthoclase, microcline, perthite, oligoclase, biotite, muscovite, hornblende, pyroxene, chlorite, with local garnet and sillimanite near the ore contact. Common accessory minerals are apatite, zircon, leucoxene, magnetite, and hematite.

Disseminated-garnet gneiss. Largely a potash feldspar-quartz gneiss with disseminated grains of garnet. Quartz with magnetite and disseminated garnet and biotite characterize the contact with the hanging-wall gneiss. Other minerals are pyroxene, hornblende, chlorite, muscovite, sillimanite, biotite and accessory apatite, zircon, pyrite and sphene. The ore is largely magnetic and the highest-grade ore in the southern half of the ore body was concentrated in this unit. The unit varies in thickness from zero to 350 feet.

Sillimanite gneiss. This unit is generally composed of orthoclase or microcline with low quartz and ferromagnesian content. Sillimanite is a common constituent of many sections, but there are thick sections exposed in the pit and in drill cores which do not contain sillimanite. The unit averages 350 feet thick with a maximum of 650 feet. It is absent locally in the northern end of the pit. Sillimanite gneiss contains most of the non-magnetic ore and the nature of the gneiss changes with the ratio of magnetic to non-magnetic ore. Biotite, chlorite, muscovite, and accessory apatite, zircon, sphene and leucoxene may be present.

Biotite-garnet gneiss. A light-gray, coarse-grained, orthoclase-quartz-biotite rock with knots or blotches of garnet. The rock is similar to the disseminated garnet gneiss and forms the footwall of the Benson Mines ore body. Pyrite, pyrrhotite, sillimanite, magnetite, apatite and zircon are present.

Ferromagnesian gneiss. This unit contains the high-grade magnetic ore of the northern part of the mine. It is lens-shaped with a strike length of about 3300 feet, an average width of 200 feet, and it pinches out in depth. The rock contains orthoclase and quartz with the quantity of hornblende, biotite, and pyroxene varying inversely to the quantity of magnetite. Other minerals present, in more or less abundance, are garnet, pyrite, pyrrhotite, sillimanite, and accessory zircon, spinel, and apatite.

Biotite gneiss. A medium- to fine-grained quartz-feldspar gneiss with biotite and local disseminations of garnet, sillimanite, chlorite, and hornblende.

There are no sharp boundaries between any of the above units. Units containing important concentrations of ore minerals may be traced for considerable lengths. Magnetic and non-magnetic ore are generally confined to specific lithologic units (Crump and Beutner, 1968, p. 66).

Assuming some potassium metasomatism as evidenced by the presence of K-feldspar pegmatites, Palmer (1970, p. 37-38) postulates "illitic siltstones, calcareous silt or sandstone and carbonate lenses with either graywacke or soda shale" as original sediments.

In addition to the minerals mentioned in the description of the gneiss units, copper occurs rarely as native copper, chalcopyrite, chalcocite, bornite, covellite, azurite and malachite. Molybdenite occurs in pegmatite dikes and disseminated in some ore zones (Crump and Beutner, 1968, p. 61). Fluorite is present in some pegmatites.

A generalized plan and section of the major structure is given in Fig. 4 and a more detailed plan of the mine showing the distribution of the various units in Fig. 5. The ore body is located on the eastern limb of a synform, the Benson Syncline, which is overturned towards the west and plunges 20° to N30°E. Smaller folds plunge 12° to S30°W and form an anticline and syncline in the overturned east limb of the Benson Syncline. They are of economic significance because they more than double the volume of ore-bearing rock. The Amoeba pit (Fig. 5) is interpreted as the bottom of one of the subsidiary synclinal rolls developed in the eastern limb of the Benson Syncline (Crump and Beutner, 1968, p. 53-54). It is the only place where the blotchy garnet gneiss (unit 5) has been found to contain sufficient iron mineralization to constitute ore.

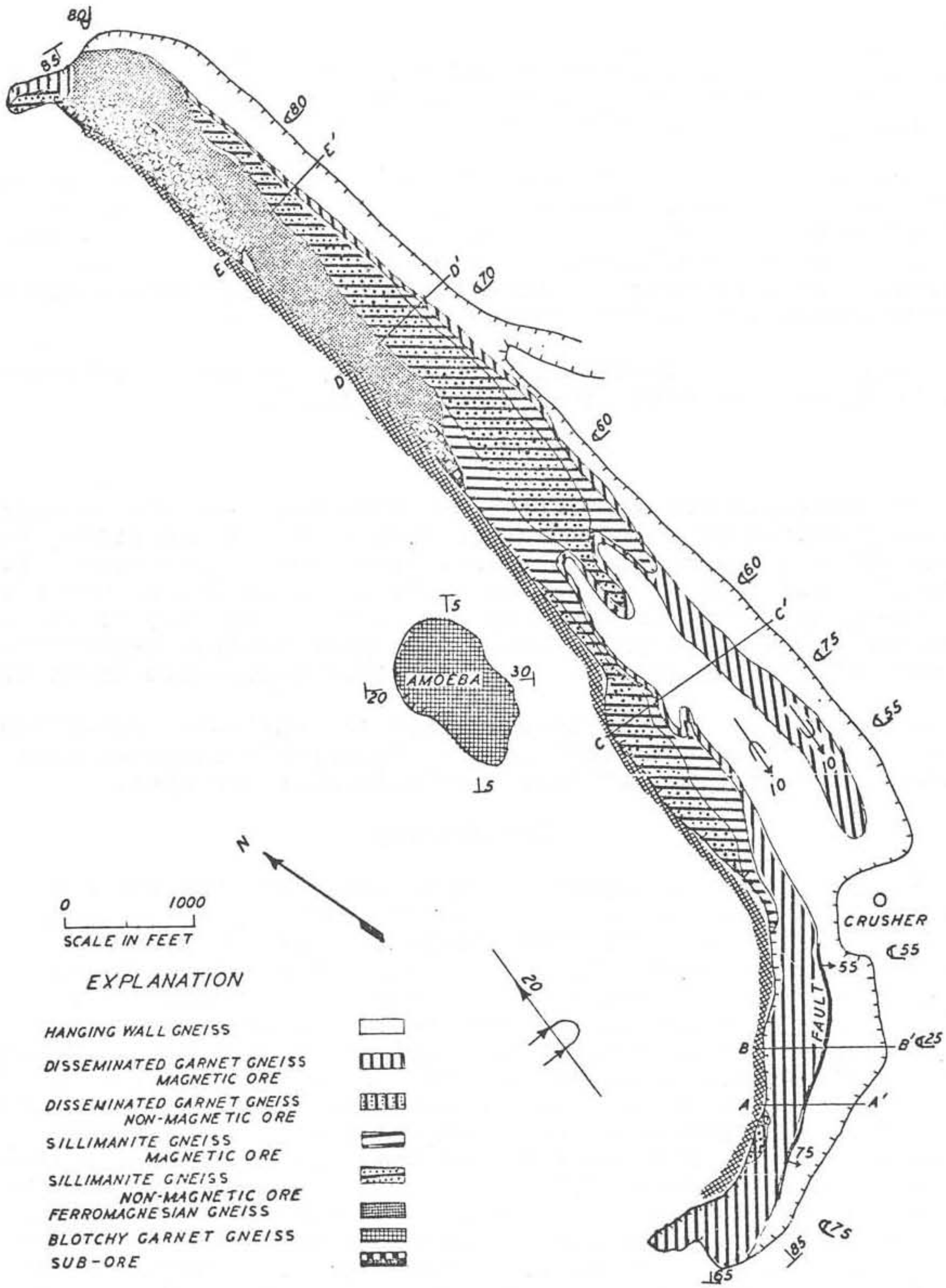


Fig. 5.- Geologic Map of Benson Mines pit.

Palmer (1970, p. 32) recognizes two stages of folding. Flow folding is shown by thickening and axial-plane schistosity in fold hinges, with accompanying mineral lineations. The latter were deformed by flexure-slip folding.

Ore is found where the stratigraphic footwall is overturned to form the structural hanging-wall. Ore stops at both the northern and southern ends of the pit where this hanging-wall relation ceases. Drilling, however, has penetrated 35 feet of ore-grade rock, resting on "hanging-wall" gneiss where there is no overturning (Crump and Beutner, 1968, p. 54).

Many of the relationships discussed above are illustrated in Fig. 6-10, with section lines given in Fig. 5.

Ore

Ore minerals are magnetite and hematite. The ore is classified as magnetic if 80 per cent or more of it is magnetite, and non-magnetic if magnetite comprises less than 80 per cent. Average grade is a function of economics. The distribution of the magnetic and non-magnetic ore is shown in Fig. 5 and a summary of their characteristics is given in Table 5. Table 6 gives representative analyses of the two kinds of ore and their respective concentrates.

Although the Benson Mines deposit is considered non-titaniferous, there is enough TiO_2 present in the concentrate obtained from the Humphrey spirals to constitute a metallurgical problem.

Ore Genesis

Palmer (1970) discusses three possible origins for the magnetite-hematite ore in the Benson Mines deposit, 1) as a product of metamorphic differentiation, 2) as an epithermal replacement in the metasediments, and 3) as a metamorphosed iron-rich sediment. Each of these origins can explain the confinement of the ore to a restricted lithologic horizon; the fact that the ores have apparently been present during deformation and recrystallization of the host rock (Hagni, et al., 1968; Palmer, 1970); the presence of hematite and magnetite in different areas of the ore deposit; etc. Leonard and Buddington (1964), Buddington (1966), and Crump and Beutner (1968) favor a hydrothermal origin, because of the lithologic heterogeneity of the host rocks; the presence of skarn; a low-angle, cross-cutting relation between the ore and the host rocks; and the presence of veins of fluorite, calcite, quartz, and other minerals typically associated with hydrothermal activity. Palmer (1970) rejects both metamorphic differentiation and hydrothermal replacement in favor of a syngenetic, metasedimentary origin. Palmer feels that the confinement of the ore to a specific horizon within the paragneiss sequence; the relatively great lateral continuity of this horizon; the lack of any evidence of replacement of the host

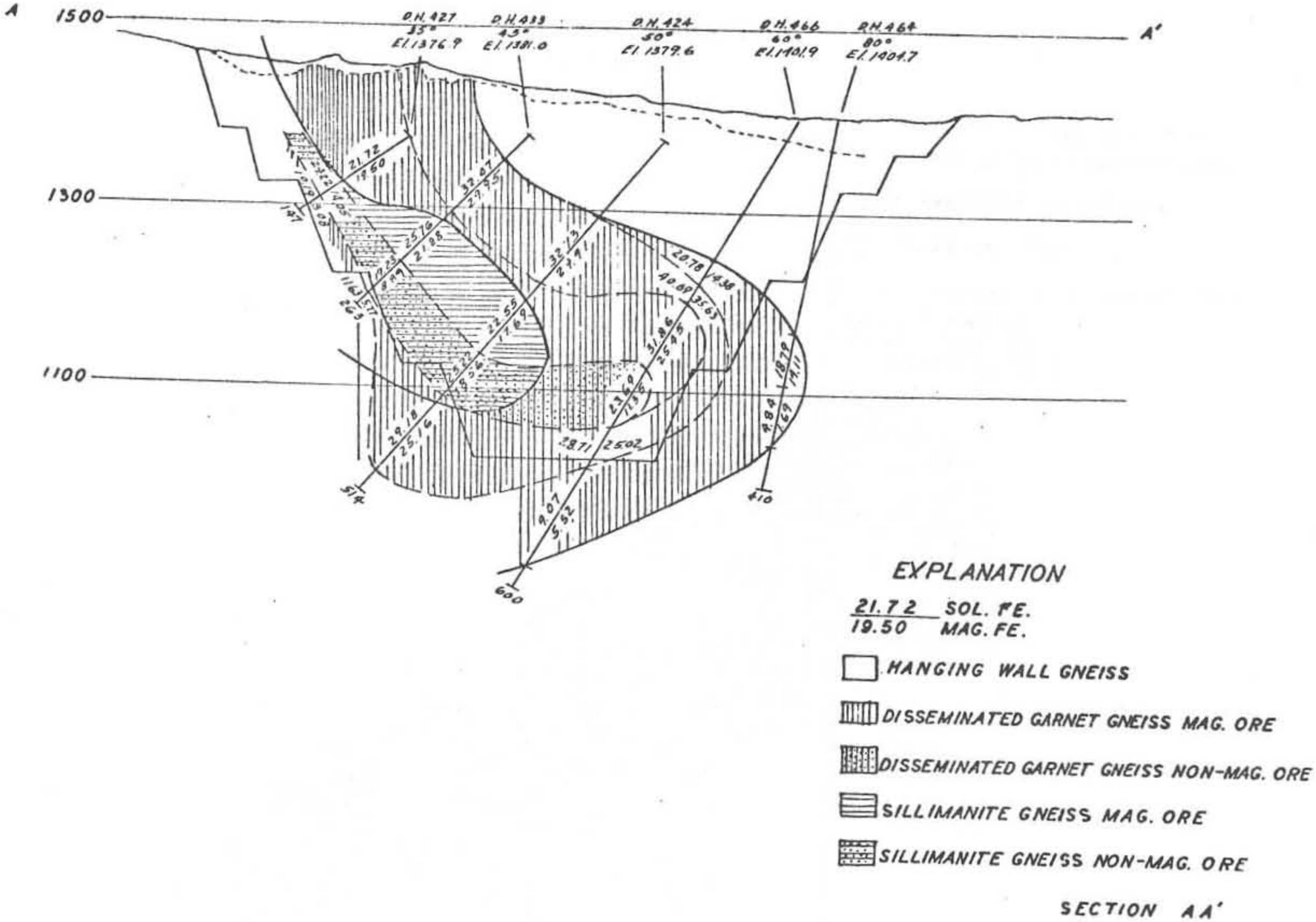


Fig. 6.- Section A-A'

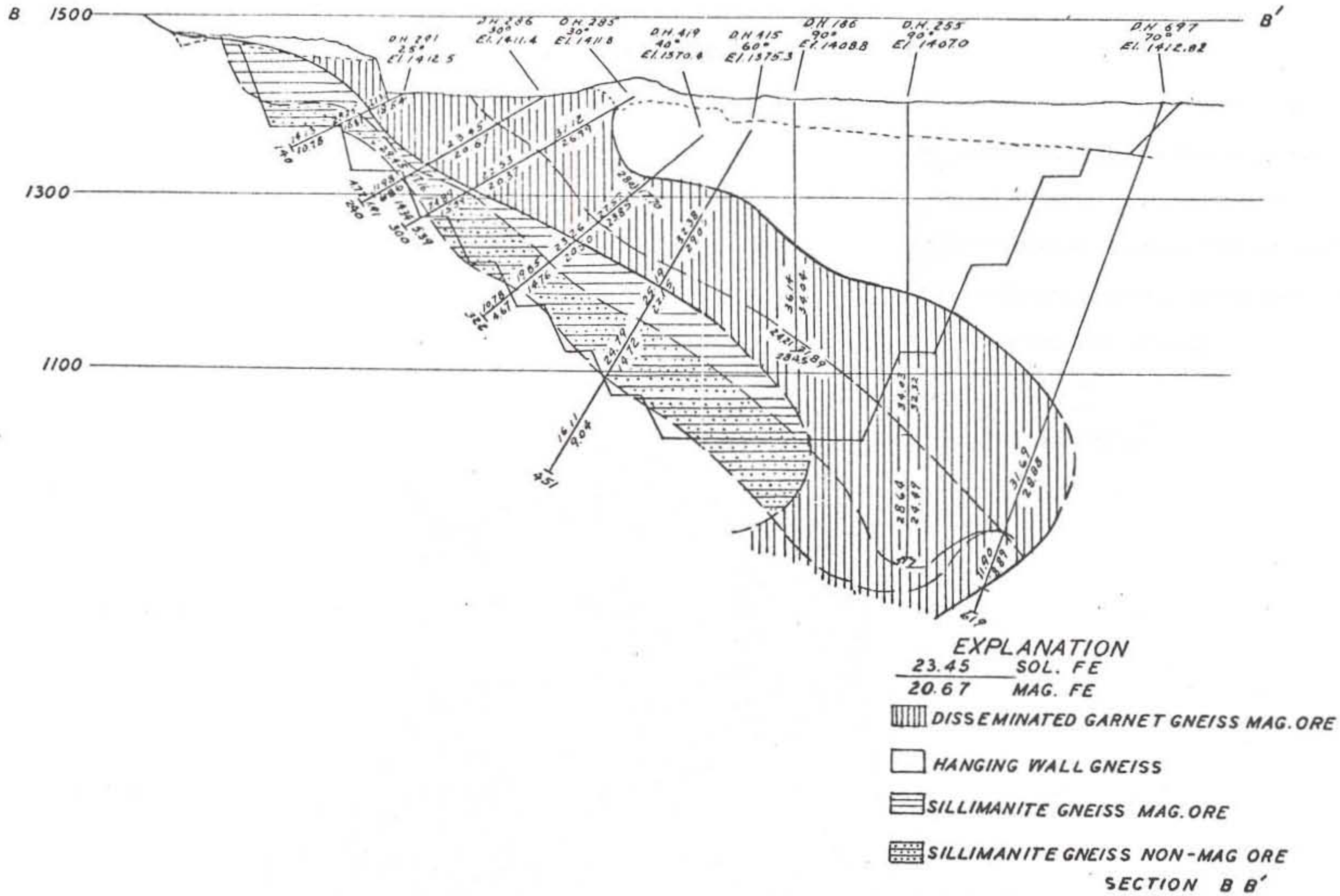


Fig. 7.- Section B-B'

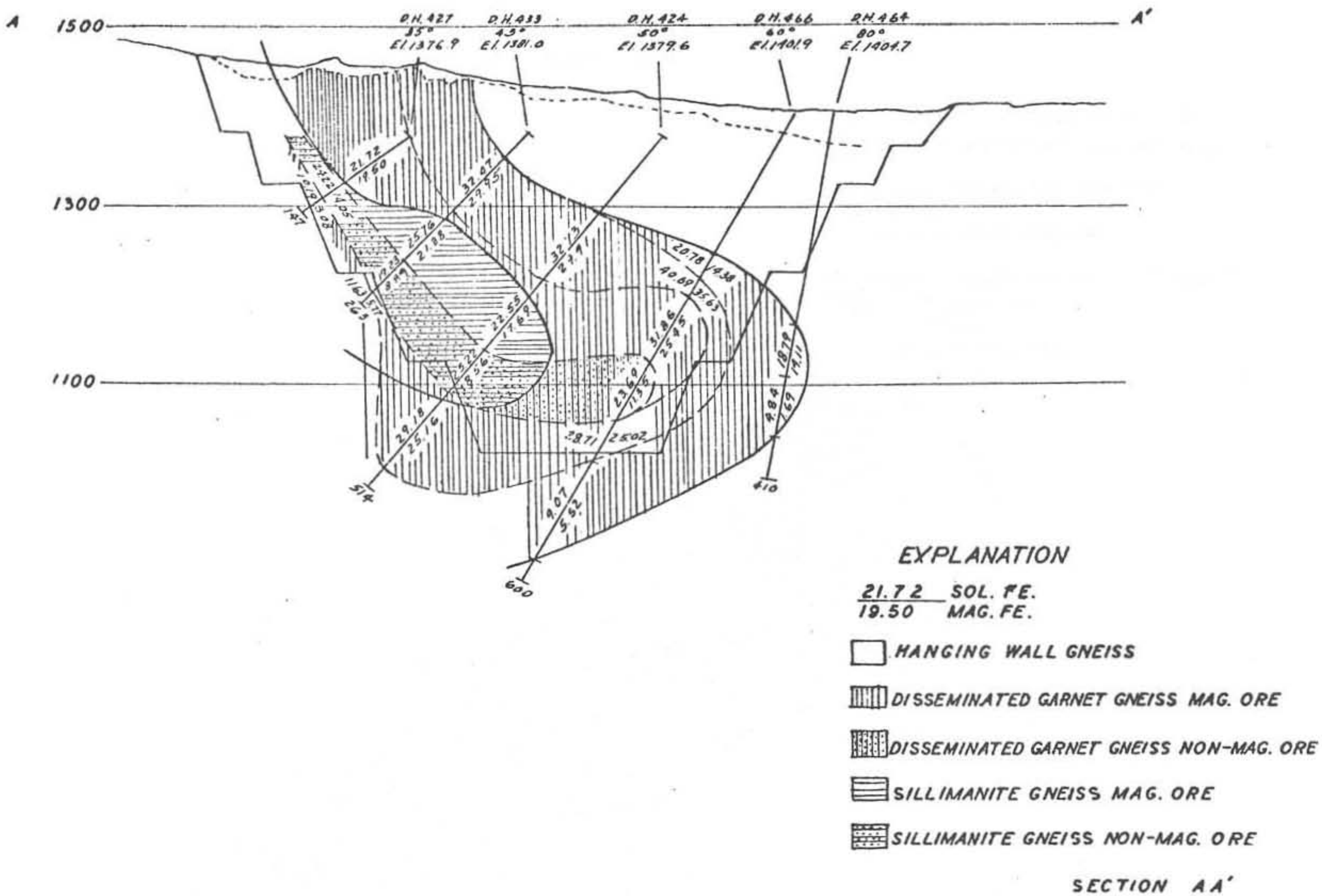


Fig. 6.- Section A-A'

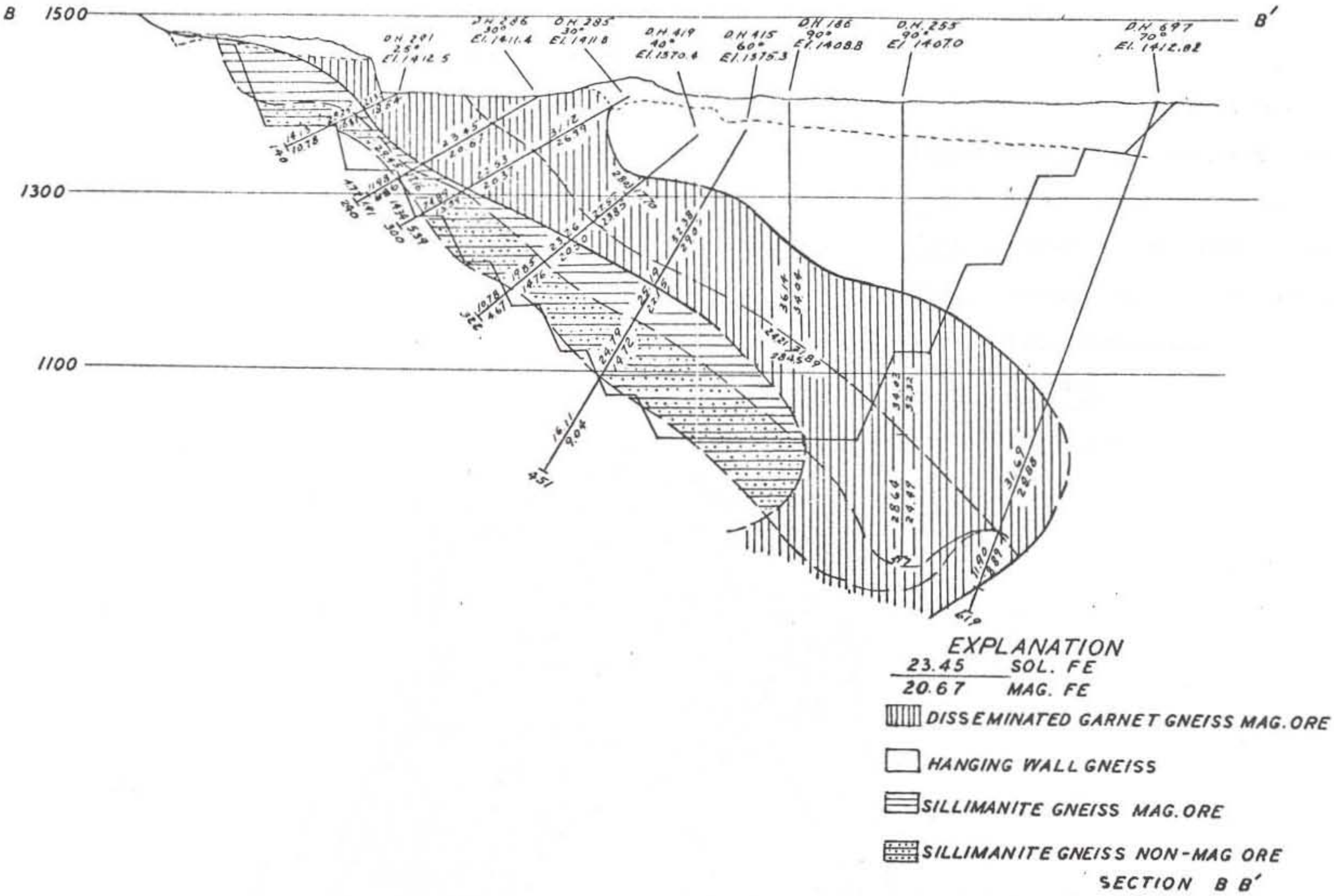


Fig. 7.- Section B-B'

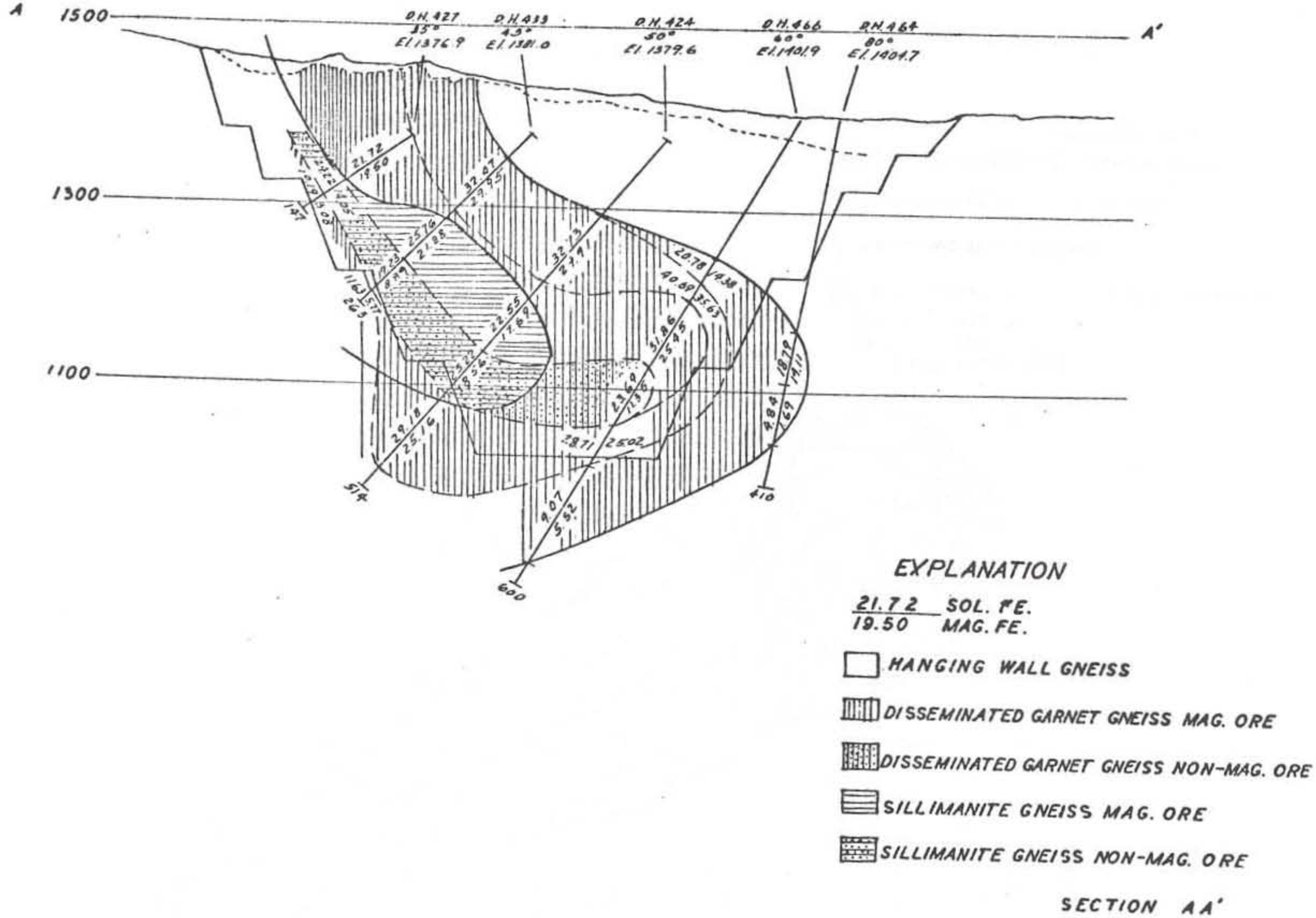


Fig. 6.- Section A-A'

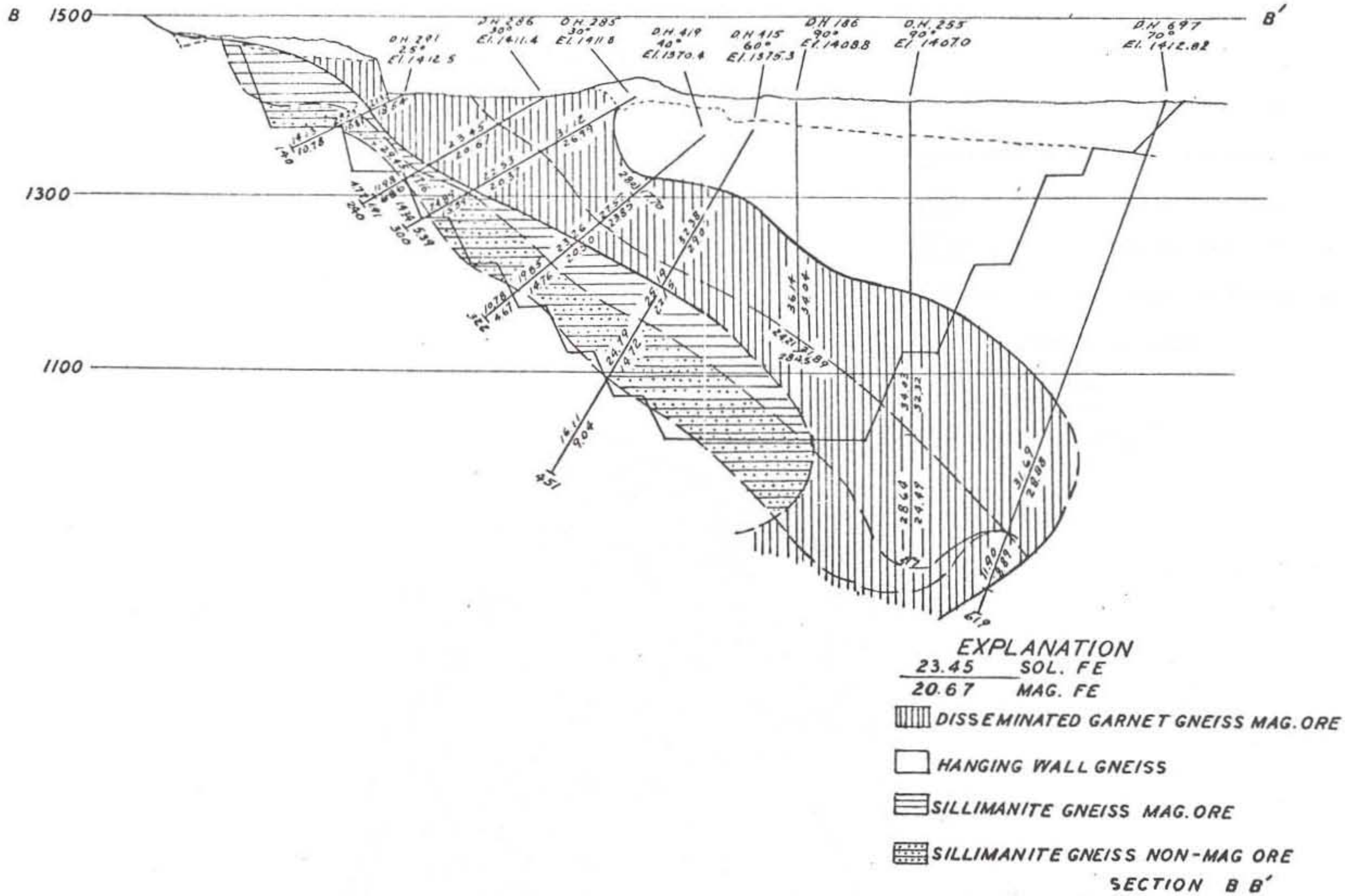


Fig. 7.- Section B-B'

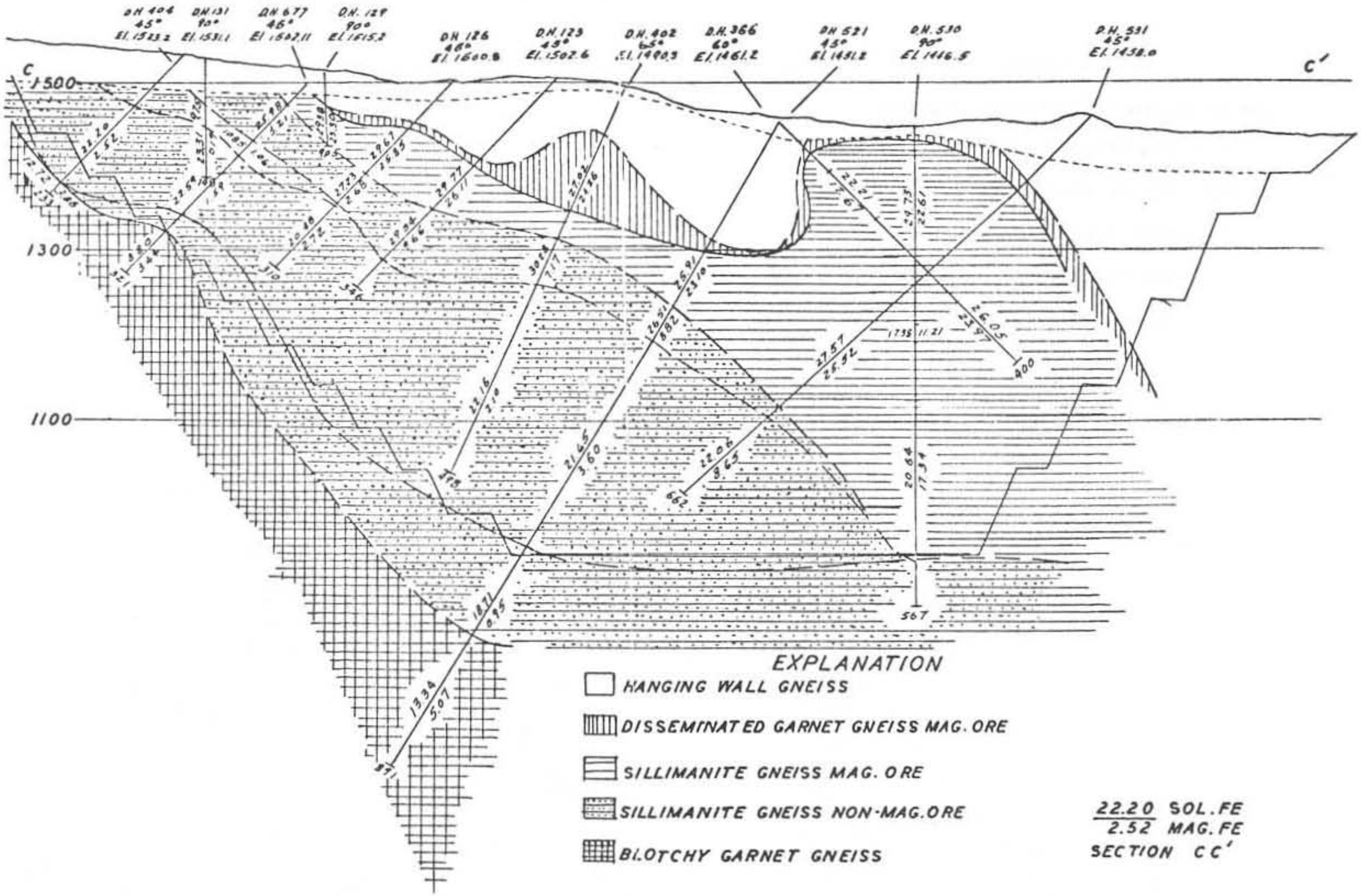


Fig. 8.- Section C-C'

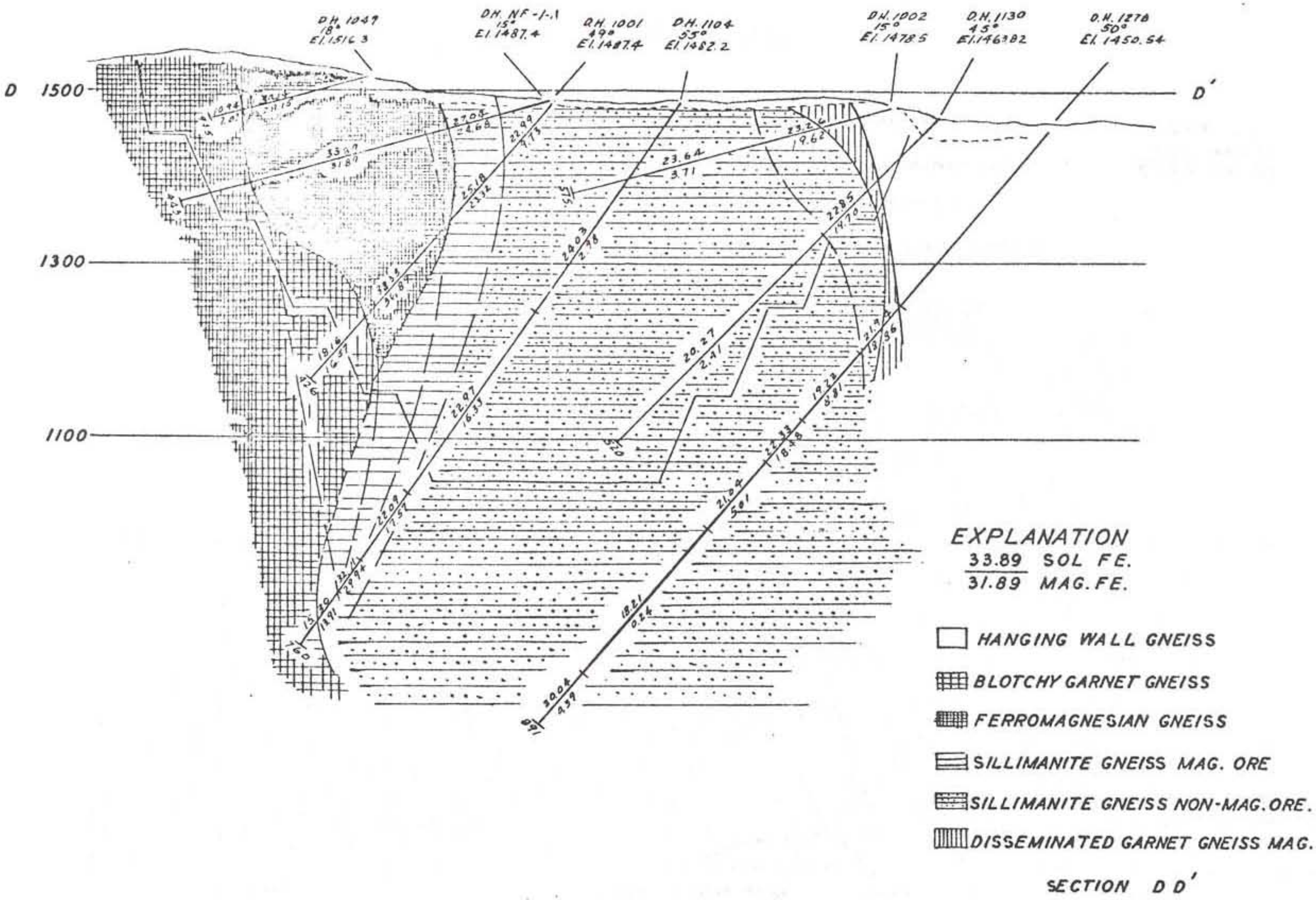


Fig. 9.- Section D-D'

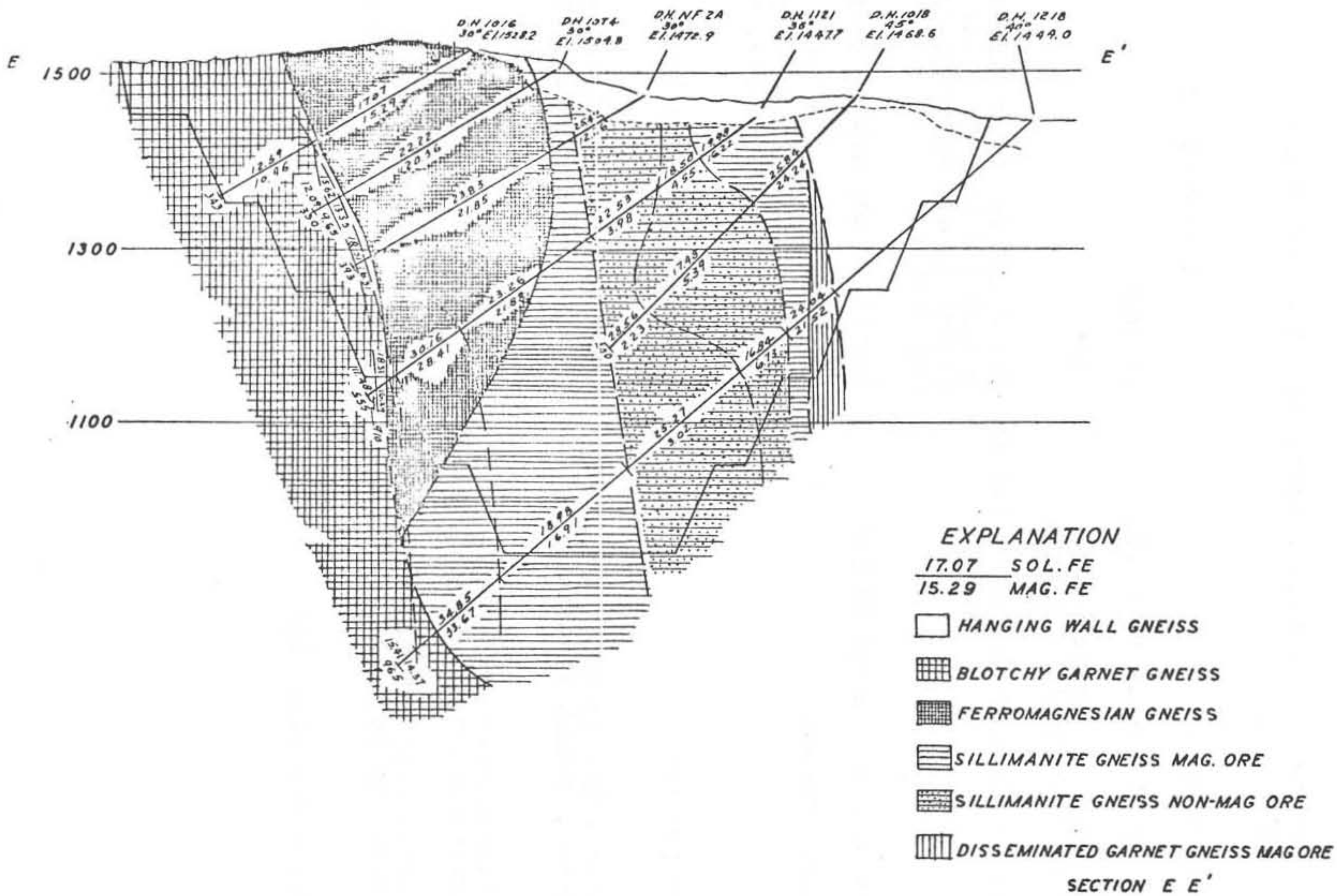


Fig. 10.- Section E-E'

Table 5. Summary of ore characteristics (after Crump and Beutner, 1968)

	MAGNETIC	NON-MAGNETIC
1)	Generally difficult to crush	Friable
2)	Distribution generally confined to lithologic horizons	Same
3)	Occurs in all lithologic horizons	Not found in ferromagnesian gneiss and only to minor extent in disseminated garnet gneiss
4)	Generally high quartz gangue	Generally low quartz gangue
5)	Sulfides present	Sulfides absent but with many limonite-filled vugs of a size corresponding to sulfides
6)	Sphene present	No sphene but some leucoxene
7)	Contains green or colorless, untwinned, potash feldspar	Contains pink or colorless, twinned and strained, potash feldspar
8)	Rare labradorite grains in ferromagnesian gneiss ore	No plagioclase
9)	Has fairly uniform gneissic structure and texture	Ptygmatic folding and pegmatitic lenses are quite common
10)	Average grain size 1mm	Same

Table 6. Representative chemical analyses (after Crump and Beutner, 1968 and Palmer, 1970)

MAGNETITE

	Crude	Conc.	Crude	Conc.	A*
Fe	25.80	63.62	20.80	63.04	
FeO	12.35	-	1.74	-	28.40
SiO	42.28	5.44	46.28	4.35	49.45
MnO^2	0.45	0.338	0.10	-	-
P_2O_5	0.506	0.067	0.55	1.008	0.3
CaO	1.07	0.210	0.83	-	1.3
Al_2O_3	9.56	3.53	12.78	3.51	9.90
MgO	0.79	0.314	0.44	0.45	1.45
NiO	0.02	0.01	0.009	-	-
C_2O_3	tr	tr	0.012	-	-
V_2O_5	0.018	-	0.027	-	-
TiO_2	0.61	0.725	0.55	1.88	0.83
S	0.70	0.262	0.028	0.078	-
CuO	0.066	-	0.016	-	-
Alkali	5.45	-	6.97	-	7.19

* Average of 8 whole rock analyses of ore (Palmer, 1970).

rock by magnetite or hematite; and the apparent presence of ore prior to deformation and metamorphism is best explained by metamorphism of iron-rich sediments.

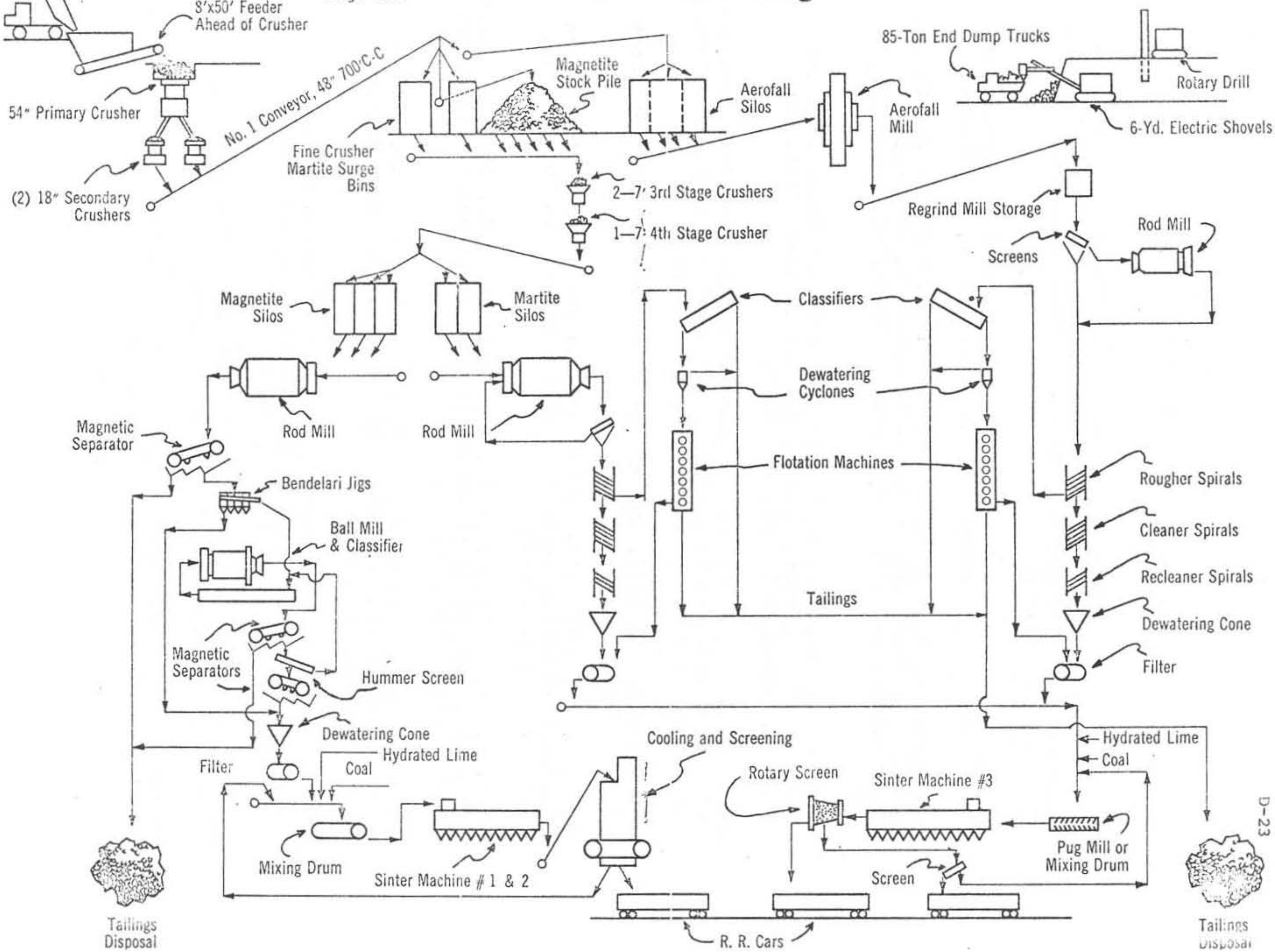
Mining and Processing

Mining is carried out by open-pit methods. Magnetic and non-magnetic ores are differentiated by diamond drilling and are mined selectively. Operating faces are generally about 50 feet high. Blast-hole drilling is done with rotary drills. Ammonium nitrate explosives are used. Crude ore is loaded by 6-yard, electric shovels into 85-ton dump trucks for transport to the primary crusher. The plant is capable of handling 16,000 tons of ore per day.

Figure 11 illustrates by flow diagram the methods used to concentrate the magnetic and non-magnetic ores. Magnetic ore is concentrated by magnetic separators, with the final concentrate (minus 20 mesh) containing 63 to 65 percent iron. Non-magnetic ore is concentrated by gravity methods with auxiliary magnetic separation to collect magnetite, or by flotation to collect hematite and magnetite fines (minus 100 mesh). The concentrates are transported to the sintering plant where they are thoroughly mixed with fine anthracite coal, lime, and sinter fines in the ratio of 64 per cent concentrate: 5 per cent anthracite: 1 per cent lime: 30 per cent sinter fines. The sintering cycle takes about 11 minutes.

Sinter is shipped by rail to the Jones and Laughlin steel plants at Pittsburgh and Aliquippa, Pa. and Cleveland, Ohio.

Fig. 11.- Benson Mines Flow Diagram



BIBLIOGRAPHY

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

Buddington, A. F., 1966, The Precambrian magnetite deposits of New York and New Jersey. Econ. Geol., v. 61, p. 484-510.

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

Crump, R. and Beutner, E. L., 1968, The Benson Mines iron ore deposit, St. Lawrence County, New York. Amer. Inst. Min. Eng. Graton-Sales Volume, p. 49-71.

Engel, A. E. J., 1962, The Precambrian geology and talc deposits of the Balmat-Edwards district, Northwest Adirondack Mountains, New York. U.S. Geol. Survey Open File report. 357 p.

Greenwood, H. J., 1963, The synthesis and stability of anthophyllite. J. Petrol., v. 4, p. 317-351.

Hagni, R. D., 1968, Titanium occurrence and distribution in the magnetite-hematite deposit at Benson Mines, New York. Econ. Geol. v. 63, p. 151-155.

Hagni, R. D., Masiello, R. A., and Tumialan, P.H., 1969, Metamorphic aspects of the magnetite-hematite deposit at Benson Mines, New York. Econ. Geol., v. 64, p. 183-190.

Lea, E. R. and Dill, D. B., 1968, Zinc deposits of the Balmat-Edwards district, New York. Amer. Inst. Min. Eng. Graton-Sales Volume, p. 20-48.

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

Lessing, P. and Grout, C. M., 1971, Hauynite from Edwards, New York. Amer. Min., v. 56, (in press).

Palmer, D. F., 1970, Geology and ore deposits near Benson Mines, New York. Econ. Geol., v. 65, p. 31-39.

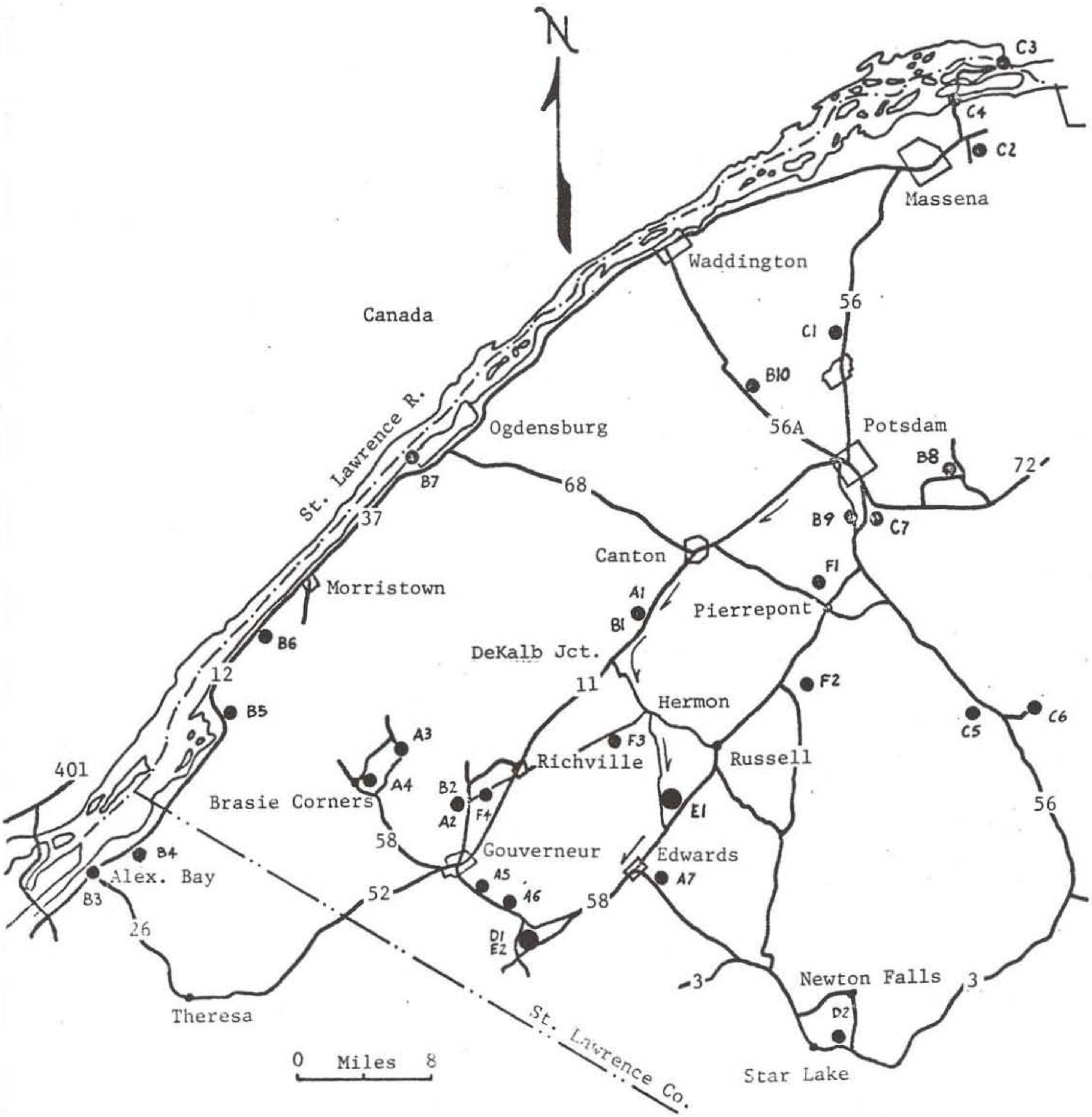


Figure 1. STOP MAP FOR TRIP E

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

Trip E

SOME PLEISTOCENE FEATURES OF ST. LAWRENCE COUNTY, NEW YORK (Fig. 1)

by

James S. Street
St. Lawrence University
Canton, New York

ABSTRACT

The field trip route from Potsdam to International Talc's open pit mine at Fowler crosses uneven ground moraine and a series of ice contact features. The latter have been mapped as part of the frontal Fort Covington Moraine. Kames, kettles, discontinuous eskers, and extensive sand plains are well displayed. Stop 1 will examine the core of one of these ice contact features, in Elm Creek Valley north of Edwards, New York.

Stop 2, at the International Talc open pit, will provide an opportunity to examine striae, gouges, and the remnants of highly polished flutes preserved on the bedrock surface. Patches of sand and gravel cemented to the rock surface form an unusual pavement. Drift exposures adjacent to the pit show Fort Covington sand, gravel and clay deposits. Stop 2 of this trip is same as Stop 1 of Trip D.

INTRODUCTION

Pleistocene glacial events of a major part of St. Lawrence County have been interpreted by MacClintock and Stewart (1965). Their report on the St. Lawrence Lowland gives an excellent summary of previous investigations in the area and presents substantial evidence supporting the concept of two ice flow directions in the St. Lawrence Valley during the late Wisconsin Stage.

Using glacial striations and till fabrics as primary criteria for flow direction, MacClintock and Stewart identify an ice mass moving from northeast to southwest (Malone Glaciation) which, at maximum extent, spread over the Adirondack mountains. A later ice mass (Fort Covington Glaciation) radiating from a new source on the Ottawa Highlands moved from northwest to southeast. Malone drift, described as red-brown till and assorted ablation debris, is said to be leached usually 5 to 8 feet, whereas Fort Covington drift is grey-buff till and other debris that are leached only a foot or two. The southern boundary of Fort Covington drift extends diagonally across St. Lawrence County from Nicholville to Harrisville (Fig. 2). This uneven boundary forms many loops and re-entrants in a typically lobate pattern marked in places by strong frontal moraine topography (MacClintock and Stewart, 1965). Deglaciation accompanied by the draining of ice-dammed lakes in the lowland was followed by a westward incursion of marine water.

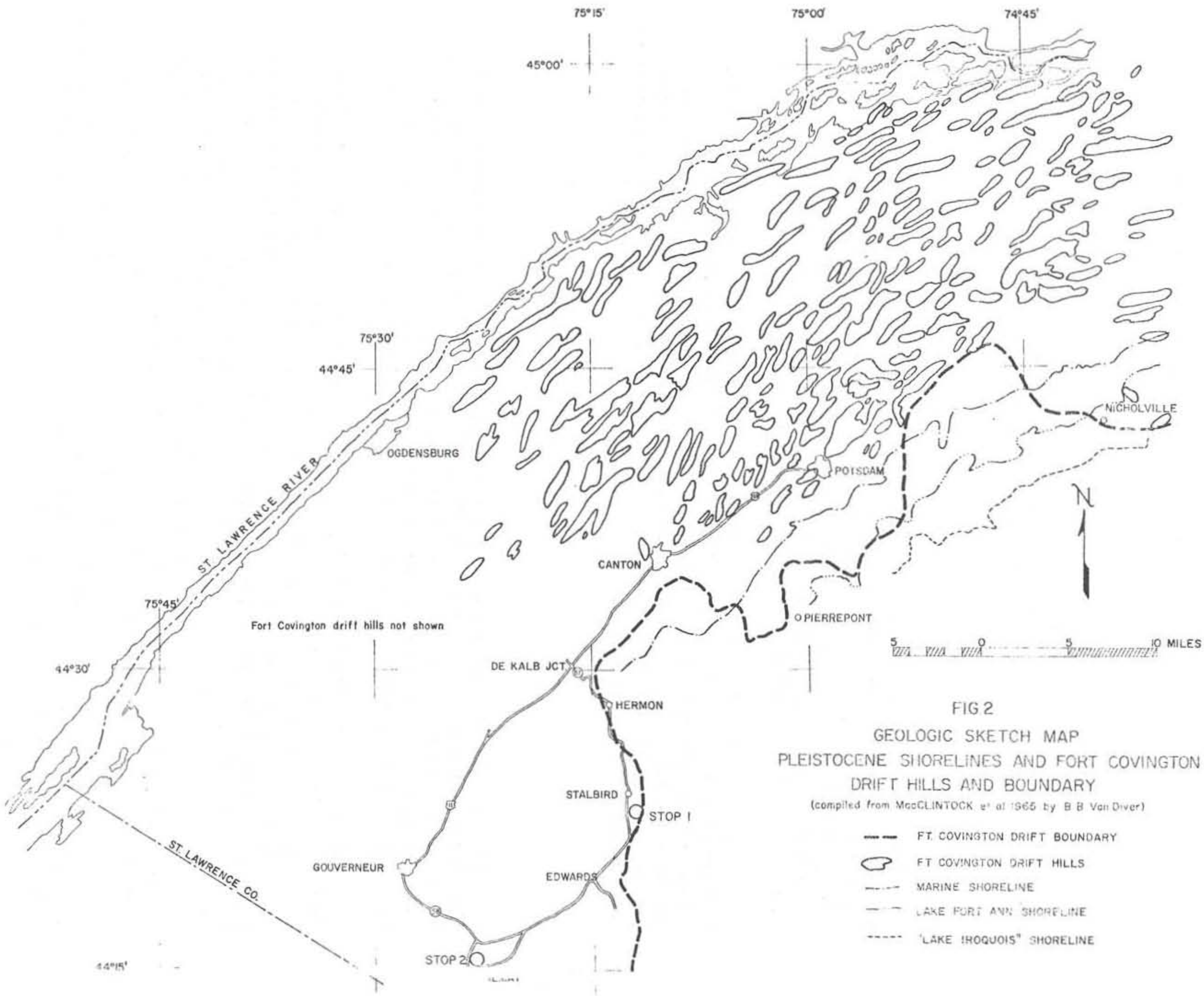


FIG.2

GEOLOGIC SKETCH MAP
PLEISTOCENE SHORELINES AND FORT COVINGTON DRIFT HILLS AND BOUNDARY
(compiled from MacCLINTOCK et al 1965 by B.B. Van Diver)

ACKNOWLEDGEMENT

Mr. Fred Totten and the management of International Talc Co. have kindly permitted access to the open pit operation at Fowler, N.Y.

STOP DESCRIPTIONS

General

The field trip route along U. S. 11 between Potsdam and Canton traverses an uneven till-covered surface with several broad, ridge-like hills of till having long axes oriented approximately northeast-southwest. The hills are part of a broad belt of similarly-oriented topographic features which cover the northern portion of St. Lawrence County. Interpreted by MacClintock and Stewart as part of the recessional Fort Covington drift sheet, the hills are described as having formed perpendicular to the flow of Fort Covington ice. The hills have cores of Malone drift that have been "pushed into place" (1965, p. 7-8). Exposures into these features have not been found in the vicinity of the trip route.

Southwest of Canton the trip follows N.Y. 87 to Hermon thence via Marshville and Stalbird toward Edwards along a series of ice contact features trending approximately north-south parallel to Elm Creek valley. Where internal structures are exposed, there are varying degrees of sorting and a chaotic arrangement of stratified drift. Precambrian rock types predominate but a variety of sedimentary rocks can be found in the gravel.

These deposits lie along the Fort Covington frontal moraine and are composed of Fort Covington Drift (MacClintock and Stewart, 1965, p. 102-105).

Stop 1. Ice contact debris south of Stalbird.- This stop provides an opportunity to examine the structure and composition of a "textbook" example of ice contact debris.

Continuing south on the Marshville-Stalbird road, the trip route rejoins N.Y. 87 with a turn toward Edwards. After crossing the Oswegatchie River in Edwards, the trip continues westward on an old segment of N.Y. 58 to merge with new highway 58 (shown on Edwards 7.5' quad., 1956 ed. as "under construction") 1.2 miles west of the village. Buff Till in a steep roadcut 1/2 mile north of this location shows a fabric with a northwest maximum (MacClintock and Stewart, 1965, pp. 113,143). Continuing westward, N.Y. 58 crosses a level sand-covered surface approximately 1/2 mile wide. Rising from near the Oswegatchie River at about 700 feet to about 800 feet above mean sea level near Harrisville, the surface is composed of pebbly sand ("Fullerville Sand") interpreted as deltaic material deposited into Lake Fort Ann during retreat of the Fort Covington Ice Margin (MacClintock and Stewart, 1965, p. 113).

Approximately 1 1/2 miles west of the West Branch of the Oswegatchie the field trip route passes under the Penn-Central Railroad and turns left into the access road of International Talc's Open Pit Mine (the "Arnold Mine").

Stop 2. Open pit mine of International Talc Co.- Several glacial erosional features are preserved on the bedrock surface. Mineralogy and petrology of the mine are discussed in detail under trip D of this guidebook.

In several places the bare bedrock surface shows broad, highly polished grooves trending northeast-southwest (N 20°, azimuth). Prominent striations having a parallel orientation are well displayed in the grooves. A major set of fractures from 2-12" long can be seen across the rock surface. The fractures strike N 8° at the northeastern end of the pit but their orientation gradually swings more easterly (N 20°) toward the crest of a 15' bedrock rise. A second fracture zone west of the crest produces a series of small step-like features, some of which are slightly curved, having a strike of N 280° nearly perpendicular to both the more easterly set of features and the prominent striations. The orientation of these step-like features, and some of the associated fractures might stimulate discussion on the origin and directional properties of crescentic marks.

Patches of cemented sand and gravel adhere tightly to the bedrock in several places. Usually 1/4 inch thick, these patches are remnants of a pavement which covered the entire surface prior to the mining operation. Several flutes in the bedrock show the cemented material preserved in a vertical position.

Exposures of drift at the edges of the pit show approximately 5 feet of red-brown till overlain by oxidized sand and laminated silt and clay totalling some 30 feet. The stripping operation combined with slump of the walls prevents a clear understanding of drift relationships.

BIBLIOGRAPHY

MacClintock, P. and Stewart, D. P., 1965, Pleistocene geology of the St. Lawrence Lowland, New York State Museum and Science Service, Bull. 394, 152 pages.

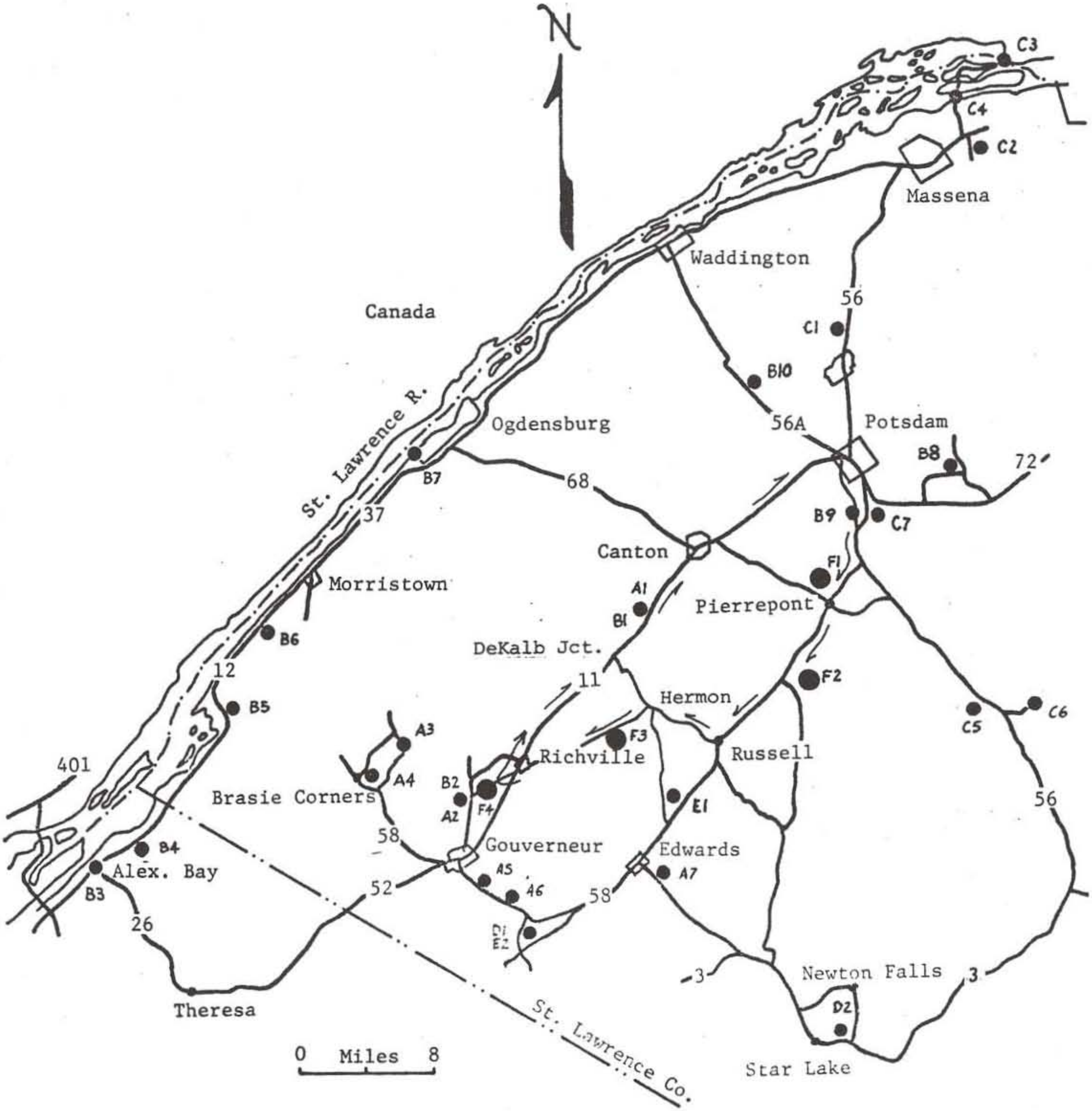


Figure 1. STOP MAP FOR TRIP F

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

Trip F

MINERAL COLLECTING IN ST. LAWRENCE COUNTY

BY

George Robinson
Fort Jackson, New York

ABSTRACT

The purpose of this trip is to visit some of the classic mineral collecting sites of St. Lawrence County, observe their geology, and collect specimens. Stops will be made at: 1) the Bower Powers farm in Pierrepont, a world-famous locality for doubly-terminated tourmaline; 2) the West Pierrepont actinolite locality; 3) the gem diopside locality near DeKalb; and 4) the Gomer Jones farm in Richville, a well-known occurrence of dravite. Other minerals which may be found at these stops are apatite, biotite, calcite, chlorite, pyrite, quartz, schorl, tremolite and uralite.

The mineral collecting sites of St. Lawrence County may be classified as: 1) those of sedimentary origin; 2) those formed by fracture filling and 3) those of metamorphic and complex origin. These will be briefly discussed, as will their typical mineralogy and their collecting history.

INTRODUCTION

General

The following discussion is an attempt to cover the major information concerning the more important mineral collecting sites of St. Lawrence County, and is not intended to delve deeply into their genesis. The sites can be grouped into three general types: 1) those of sedimentary origin, 2) mineralization along fractures, and 3) those of metamorphic and complex origin. A brief discussion of each follows.

Type 1: Localities of Sedimentary Origin

Of the three types of localities described, those of sedimentary origin number the fewest. Although numerous quarries have been sunk into both the Potsdam sandstone and Ogdensburg dolomite, very few have ever produced noteworthy mineral specimens. Probably the most important of these is Allied Chemical's Barrett Stone Quarry, near the village of Norfolk.

Here, there are many small cavities in the dolomite located in a band five to ten feet below the top of the second bench in the main pit. Their sizes range from less than an inch to more than a foot across, and are always lined with crystals of dolomite and/or quartz. The quartz appears to have been the first to form, followed by dolomite, calcite, and more rarely marcasite, fluorite, and celestite (in very minor amounts). Often the quartz crystals assume the habit of the more famous "Little Falls Diamonds", and contain hydrocarbon inclusions.

Probably the most abundant and well known species to occur here is dolomite. Although white, gray, and tan crystals have been found, the bright pink, saddle-shaped rhombohedra are the best formed, and sometimes measure nearly 3/4 of an inch across. They are quite likely to be among the world's finest representatives of pink dolomite euhedra.

Type 2: Mineralization Along Fractures

Many excellent crystal specimens have formed in fracture zones throughout the county. Open spaces along fault planes and in brecciated host rock provided convenient channels for mineralizing solutions to enter and form free-growing crystals of many varieties. The Rossie Lead mines, Macomb Fluorite mine, and St.Joseph Lead mines at Balmat are the county's three most prolific mineral occurrences of this type.

Since its opening in 1836, the Cole Hill vein at Rossie has produced hundreds of huge and unique calcite crystals, as well as fine specimens of galena, fluorite, celestite, chalcopyrite, and pyrite. The vein consists of a breccia containing granitic rocks and marble, and hosting many seams and open cavities lined with calcite crystals. The most common habit is the simple rhombohedron with scalenohedral modifications, but complex and twinned forms are not uncommon (see Fig. 2). Equally unique crystals of pyrite were also encountered (Fig. 3).

The Macomb fluorite mine is located along a fault plane in the Grenville marble. Numerous seams and pockets of calcite with sea-green cubes of fluorite are present, and occasionally reach large dimensions. G. F. Kunz described one such pocket found in 1827. (Kunz, 1831)

"The cave is 22 feet north and south, and is 18 feet

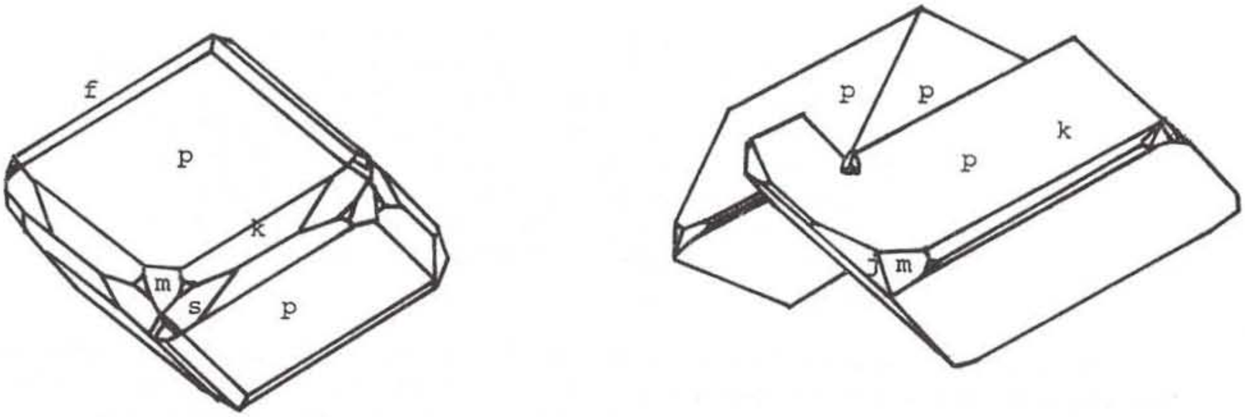


Figure 2.

Calcites, Rossie, N.Y. (after Whitlock, 1909)

major forms

f	$(7.2.\bar{9}.11)$
p	$(10\bar{1}1)$
m	$(40\bar{4}1)$
s	$(4.6.\overline{10}.1)$
k	$(21\bar{3}1)$
j	$(62\bar{8}1)$

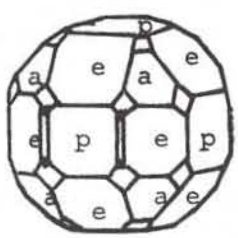


Figure 3.
Pyrite, Rossie
(after Beck, 1844)

major forms

p	cube
e	pyritohedron
a	octahedron

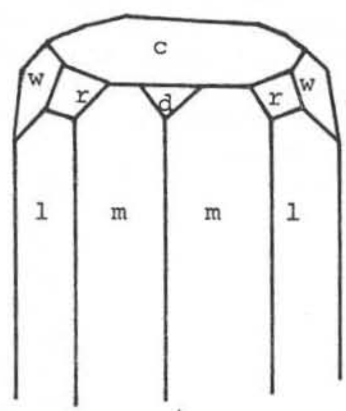


Figure 4.
Danburite, Russell
(after Brush & Dana, 1880)

prisms	m,l
domes	d,w
pyramids	r
pinacoid	c

> east and west, and is 8 feet below the surface.... the top, bottom, and sides were lined with a magnificent sheet of crystals, varying from one to six inches in diameter, each in turn forming part of larger composite crystals....groups of crystals weighing from ten to several hundred pounds each, and one of them measuring 2 x 3 feet were easily detached. The cavity contained at least fifteen tons of fluorite."

The present mining operations by the St. Joseph Lead Co. have unearthed some equally magnificent specimens. Some beautifully twinned clear iceland spar crystals, often coated with tiny glittering pyrite euhedra, have recently been discovered near a fracture zone on the 500 foot level of the number three mine near Balmat. Transparent crystals weighing several hundred pounds have been encountered. Associated with the calcites are large radiating groups of bladed, white celestite crystals, specular hematite, and mountain leather. Very few, but fine quality, lustrous tetrahedrite crystals were also found associated with pyrite, and coating the calcite crystals. Smaller vugs nearby contained gem quality yellow sphalerite crystals perched on a matrix of clear quartz and specular hematite.

Type 3: Localities of Metamorphic and Complex Origin

The marbles and associated calcium silicate rocks furnish a wealth of mineral specimens. In an area of more than 500 square miles from Canton to Oxbow, and Black Lake to Edwards, outcrops of Grenville marble are in contact with many coarse grained rocks of complex origins. In these contact zones are found large, well-formed crystals of various minerals. Quite often the less resistant marble has been eroded away, exposing exceptionally well-formed single crystals and crystal aggregates free from matrix. The following listing associates some of the species with their more important localities.

Actinolite - Pierrepont, Macomb, Russell
Albite - Oligoclase - Fine, Rossie, Benson Mines
Apatite - Rossie, Hammond, Gouverneur
Biotite - Pierrepont, Russell
Chondrodite - Gouverneur, Rossie
Danburite - Russell (see Fig. 4)
Diopside - DeKalb, Russell, Edwards, Fine
Dravite - Gouverneur, Richville, DeKalb, Macomb
Galena - Rossie, Edwards, Macomb
Graphite - Pope Mills, Rossie, Macomb

Groutite - Talcville
Hexagonite - Talcville, Fowler
Lazurite - Edwards
Loxoclase - Hammond, Rossie
Microcline - Edwards, Fine, Rossie, DeKalb
Molybdenite - Benson Mines, Colton
Muscovite - Rossie, Benson Mines
Phlogopite - Edwards, Rossie, Talcville
Peristerite - Macomb, Pierrepont
Pyrite - Rossie, Pyrites, Stellaville
Quartz - Rossie, Macomb, Hermon
Schorl - Pierrepont
Serpentine - Edwards, Fowler, Talcville
Sphalerite - Balmat, Edwards, Rossie, Macomb
Spinel - Rossie
Talc - Talcville, Fowler, Edwards
Tremolite - Gouverneur, Rossie, DeKalb, Macomb, Fowler
Cr-tremolite - Balmat, Macomb
Tirodite - Balmat, Fowler, Talcville
Titanite - Fine, Pitcairn, Rossie, DeKalb
Uralite - Pierrepont, Russell
Wernerite - Pierrepont, Rossie, Gouverneur
Wollastonite - Fowler, Gouverneur
Zircon - Hammond, Rossie

In addition, the following minerals have also been found, or reported as occurring, in or near St. Lawrence county.

Achroite, Agate, Amethyst, Anglesite, Ankerite, Aragonite, Augite, Azurite, Barite, Bornite, Celestite, Chalcodite, Chalcedony, Chlorite, Corundum, Cordierite, Cyrtolite, Datolite, Dysyntribite, Garnet, Guitermanite, Hornblende, Houghite, Hydrozincite, Labradorite, Lederite, Limonite, Magnetite, Malachite, Marcasite, Martite, Malachite, Melanterite, Millerite, Mizzonite, Nutallite, Pargasite, Pyrrhotite, Rensselaerite, Rose Quartz, Sahlite, Selenite, Siderite, Sillimanite, Silver, Stilpnomelane, Sunstone, Willemite, Uraninite, Vesuvianite, Wilsonite, and other minerals.

STOP DESCRIPTION

General

The trip will consist of four stops which are located on the stop map, (Figure 1) . Please note that nearly all the stops are on privately owned land. Please do not litter, and kindly abide by any restrictions or regulations set forth by the land owners regarding the use of their properties.

Stop 1. Bower Powers farm, Pierrepont, N.Y. - This locality is one of the world's most famous for doubly terminated black tourmaline crystals. The tourmaline appears to be of metamorphic origin, and occurs in contacts between Grenville Marble, and a quartz-tourmaline-biotite schist. Nearly perfect crystals are observed both within the quartz-tourmaline rock and separated from it, enclosed by marble. Often crystals are found loose in the soil where they have freed from the marble. It is interesting to note the absence of feldspar at this tourmaline deposit.

Mineralogy

1) Tourmaline occurs as near perfect trigonal crystals with shortened c-axes and lacking the usual prismatic striations typical of the species. Riggs' analyses indicate this is an iron-magnesium tourmaline (Clarke, 1899). Crystals and crystal aggregates are commonly found associated with quartz and uralite. The common habit includes the following forms illustrated by Fig. 5: trigonal prism (m), ditrigonal prism (a), rhombohedra (e) and (r), basal pedion (c), trigonal pyramids (o) , and more rarely ditrigonal pyramids and second order hexagonal prisms (not shown).

2) Quartz is typically milky and shows poor development, but occasionally clear to smoky crystals are found associated with the tourmaline. They are commonly prismatic, with hexagonal prisms and terminating rhombohedra being the only faces developed. The physical development of these crystals does not illustrate enantiomorphism.

3) Uralite is an amphibole replacement of pyroxene. Actinolite commonly replaces diopside, and is a relatively common phenomenon in metamorphic rocks. However, complete, free-standing pseudomorphs are uncommon and the ones from this locality are well known for their perfection and sharp definition. They are usually associated with the tourmaline. Occasionally they grade into unaltered diopside or more rarely into rensselaerite.

4) Apatite is uncommon, but sometimes is found in the calcite as small hexagonal prisms seldom over an inch long. The most common color is light green to brown.

5) Biotite Pseudohexagonal sheets approaching four inches in diameter may be found. It is interesting to note that in areas where the mica abounds, tourmaline is not common.

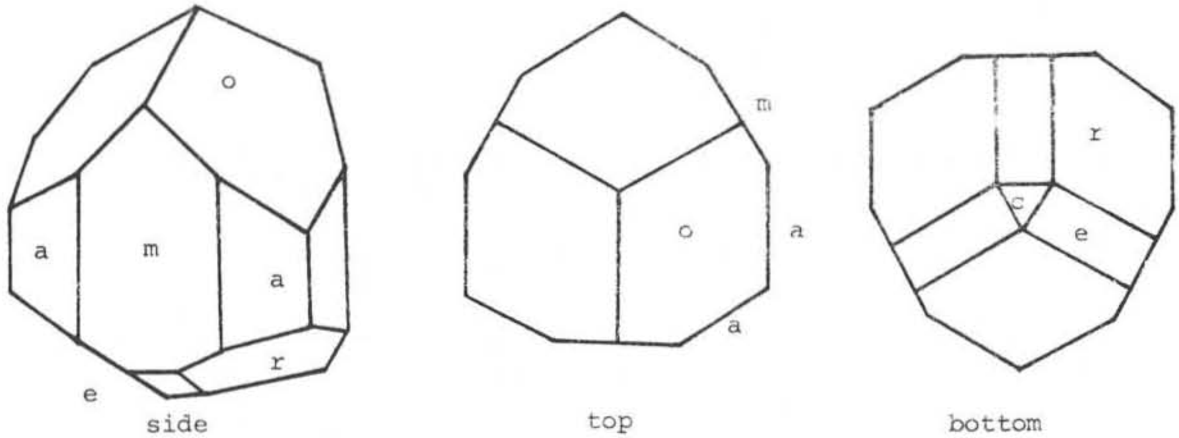


Figure 5. Tourmaline, Pierrepont

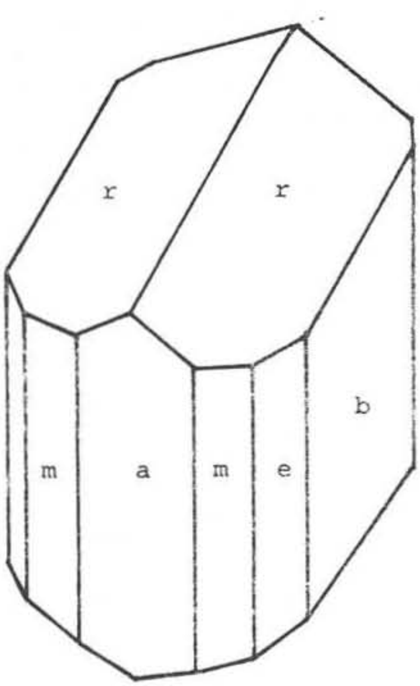


Figure 6.
Actinolite, W. Pierrepont

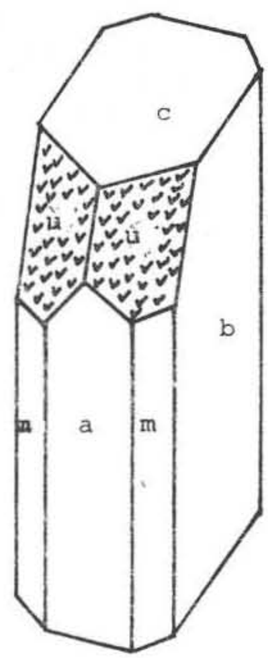


Figure 7.
Diopside, DeKalb

6) Others Chlorite, pyrrhotite, pyrite, calcite, scapolite, and diopside are also likely to be encountered here, but usually not as desirable specimens.

Stop 2. Actinolite locality, near West Pierrepont, N.Y.- Most commonly observed as radiating fibers, or matted masses of acicular crystals, actinolite is seldom seen as large, perfectly developed euhedra. At this stop, actinolite occurs in the latter mentioned form, and is found in a marble-calc-silicate rock. A few crystals of pyrite, quartz, and dravite have been found here, but are relatively uncommon. The most striking feature here is a fifteen foot outcrop of solid actinolite crystals. Each crystal is remarkably well formed and was probably formerly in contact with marble which has since eroded away.

Figure 5 illustrates the typical habit of the actinolite here. The following forms are usually well developed: orthopinacoid (a), prism (m), prism (e), clinopinacoid (b), and clinodome (r).

Stop 3. Gem Diopside locality, near DeKalb, N.Y.- This is the famous Calvin Mitchell farm to which all mineralogy texts refer when citing DeKalb, N.Y. as a noted locality for diopside. The crystals from here are without any doubt the world's finest gem diopsides. They occur in seams and pockets within the diopsidic host rock which is part of a long ridge composed chiefly of interbedded quartzite and silicated marble. The ridge trends northeast-southwest, and dips 45° to the northwest.

A typical diopside crystal is shown in Figure 7. The common forms include orthopinacoid (a), clinopinacoid (b), prism (m), pyramid (u), and basal pinacoid (c). The pyramids (u) are typically heavily etched, whereas all the other faces are smooth and glassy. Sometimes an asbestiform tremolite is observed growing into and parallel with the diopside, as if it were in the process of replacing it. A few complete tremolite pseudomorphs after diopside have been found here. Unlike other diopside in the Grenville rocks, this diopside seldom shows basal parting, and always exhibits good cleavage (110).

Note: This locality is presently being mined for gem diopside, and mineral collecting is NOT permitted anywhere on the property.

Stop 4. Gomer Jones farm, Richville, N.Y.- Nearly all the famous large brown dravite crystals labelled as coming from Gouverneur, N.Y., probably came from this locality. Here coarse white tremolite crystals, as much as a foot in length, form a major part of the calc-silicate-marble bedrock. Associated with these large tremolites are white pyroxene crystals, apatite, and dravite.

Mineralogy

1) Dravite — occurs as masses, grains, and complete crystals scattered locally throughout the deposit. The largest and best crystals are usually in intimate association with the tremolite and coarsely crystalline calcite. Occasional small, free growing crystals are found in the marble, and loose in the soil. The habit is similar to the Pierrepont tourmalines, with the exception of a few longer, more prismatic crystals.

2) Pyroxene — occurs as small, white to light tan colored crystals in veins in the hard calc-silicate rock. They are presumably diopside, but lack the familiar green color.

3) Apatite — has been found enclosed in the coarse calcite in the floor of the pit at the east end of the hill. The crystals are sharp hexagonal prisms of blue color, and are not commonly encountered.

End of Trip. Return to Potsdam

BIBLIOGRAPHY (* cited in text)

Agar, W. M. , 1921, The Minerals of St. Lawrence, Jefferson, and Lewis Counties, N.Y., Jour. Min. Soc. America, v. 6, p. 148-164.

*Beck, L. C., 1844, Mineralogy of New York, Am. Jour. Sci.,ser. 1, v. 46, p. 25-37.

Brush, G. L., 1858, On Chalcodite, Am. Jour. Sci., ser. 2, v. 25, p. 198-201.

*Brush, G. L., and Dana, E. S., 1880, On Crystallized Danburite from Russell, St. Lawrence County, N. Y., Am. Jour. Sci., ser. 3, v. 20, p. 111-118.

*Clarke, F. W., 1899, The Constitution of Tourmaline, Am. Jour. Sci.,ser. 4, v. 8, p. 111-121.

Craw, W. J., 1850, Analyses of Phlogopite from St. Lawrence Co., New York, Am. Jour. Sci., ser. 2, v. 10, p. 383-385.

Cushing, H. P., and Newland, D. H., 1925, Geology of the Gouverneur Quadrangle, N.Y.S. Museum Bull. 259, Albany, N. Y.

Hough, F. B., 1850, On the Discovery of Sulphuret of Nickel in Northern New York, Am. Jour. Sci., ser. 2, v. 9, p. 287-288.

________________ 1850, New Mineral Localities in New York, Am. Jour. Sci., ser. 2, v. 9, p. 288-289.

________________ 1850, On the Existing Mineral Localities of Lewis, Jefferson, and St. Lawrence Co., N.Y., Am. Jour. Sci., ser. 2, v. 9, p. 424-431.

*Kunz, G. F., 1831, Mineralogical Notes on Fluorite, Opal, Amber, and Diamond, Am. Jour. Sci., Art. IX, p. 72-73.

Nason, F. L., 1888, Some New York Minerals and their Localities, N.Y.S. Museum Bull. 4., Albany, N.Y., p. 10-12.

Prucha, J. J., 1957, Pyrite deposits of St. Lawrence and Jefferson Counties, N.Y., N. Y. S. Mus. and Sci. Serv. Bull. 357, Albany, N.Y.

*Whitlock, H. P., 1909, Calcites of New York, N.Y.S. Museum, Memoir 13, p. 59-71, 138, 140.

Williams, G. H., 1834, Barite Crystals from DeKalb, N.Y., Johns Hopkins Univ. Circ., v. 3, p. 61.

________________ 1890, On the Hornblende of St. Lawrence Co., N.Y., Am. Jour. Sci., ser. 3, v. 39, p. 352-358.

TECHNICAL SESSION

of

43rd Annual Meeting

NEW YORK STATE GEOLOGICAL ASSOCIATION

Abstracts of Papers Presented

May 7, 1971

LOWER BARNEVELD (SHOREHAM) FAUNAL ASPECTS OF THE MARTINSBURG SHALE, NEW PALTZ-KINGSTON AREA, ULSTER COUNTY, NEW YORK

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College at New Paltz
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Seven fossil localities in the Martinsburg Shale of the New Paltz-Kingston area have yielded a fauna resembling that reported from the Shoreham Limestone of north-central New York State. Although fossils are not generally common, the fauna is fairly diverse and consists of the following (in decreasing order of abundance): brachiopods (*Dalmanella rogata, Sowerbyella sp., Rafinesquina sp.)*; "crinoid stems"; trilobites (*Cryptolithus tesselatus, Cryptolithus lorettensis, Flexicalymene senaria, Calliopos callicephala, Bumastoides milleri, Isotelus sp.)*; gastropods; cephalopods (cf. *Spyroceras bilineatum); conularids (Metaconularia trentonensis)*. Ostracods and a tabulate coral (*Paleoalveolites sp.)* are known from single occurrences. Fragmentary remains of eurypterids and graptolites have also been found.

Of the taxa identified thus far, ten of twelve have been reported from the Shoreham Limestone. None of the twelve appears to have stratigraphic range which excludes the Shoreham.

Differences in depositional environments between the Martinsburg and the Shoreham (i.e. shale and siltstone vs. limestone) may account for the apparent absence of some Shoreham faunal elements. *Trematis terminalis* and *Ceraurus dentatus* have yet to be found in the New Paltz area. Environmental differences may also account for the relatively smaller size of individual Martinsburg specimens compared with specimens of the same species from the Shoreham.

The near absence of graptolites in the Martinsburg Shale may be more apparent than real due to a slatey cleavage which rarely parallels the bedding planes. In addition, occurrences of some species of other fossils may also be masked to various degrees in a similar fashion.

PALEOCURRENT DIRECTION AND DEPOSITIONAL ENVIRONMENT OF A BINNEWATER SANDSTONE SECTION (UPPER SILURIAN) NEAR ROSENDALE, ULSTER COUNTY, NEW YORK.

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A complete 30.2 foot section of Binnewater Sandstone one mile south of Rosendale on State Highway 32 is disconformably overlain by the Rosendale

Member (dolostone) of the Rondout Formation and questionably gradational with the underlying High Falls Shale. Beds strike N40°E and dip 25°NW. The exposure trends N40°W.

Lithology consists predominately of buff, grey and white medium- to fine-grained quartz arenite but minor shale beds occur. Bedding ranges from 0.05 to 0.9 feet in thickness and averages 0.2 feet. Tabular, tangential cross-laminated beds comprise 20 percent of the total thickness. Remaining beds are either massive or laminate.

Paleocurrent directions from corner readings of cross-laminae (double azimuth) average N35°W (9 readings) with a reverse direction of S51°E (2 readings). This general trend is supported by single azimuth readings with an average direction of N36°W (64 readings) and a reverse trend averaging S31°E (22 readings). Fore-set inclinations of cross-laminae projected from corners average 19° with a maximum of 24°. Inclinations in single azimuth readings average 14° ranging up to 24°.

Environmental features are indicated by tabular, tangential cross-laminae, translation ripple marks, sand-filled mud cracks, rare salt casts, numerous shale partings and a general absence of fossils except in the top 4.4 feet of the section (silicified stromatoporoids, brachiopods and favositid corals). These features are tentatively interpreted as indicating frequently subaerial and occasionally arid tidal flat conditions with a net shift of sediment to the northwest.

PYRITIZATION IN FOSSILS FROM THE SILICA FORMATION, MEDUSA QUARRY, OHIO

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Previous studies of the geochemistry of pyritization indicate that pyrite deposition takes place in neutral or alkaline reducing environments, that the activities of autotropic sulfate-reducing and sulfide-oxidizing bacteria greatly increase the rate of pyrite deposition, and that the necessary sulfide and iron are probably derived respectively from dissolved sulfate and from the iron oxides associated with clay minerals. Methods of the present investigation of the pyritization of the Silica fossils include X-ray diffraction analysis and transmission photography, thin-section examination, bacteriological experimentation, and hopefully electron microprobe investigation. It seems possible that patterns of pyrite distribution in sediments and selectivity of pyritization among fossil groups may be related to amount and nature of original organic material, and that pyrite distribution within shell material may give an indication of whether or not the pyrite was introduced prior to the latest crystallization of the calcium carbonate in the shell.

STRUCTURAL AND GRAVIMETRIC ANALYSIS OF THE MIDDLEBURY SYNCLINORIUM NEAR ORWELL, VERMONT

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Structural and gravimetric data were collected along the southern termination of the west limb of the Middlebury Synclinorium between Shoreham and Orwell, Vermont. The Orwell Thrust dominates the western portion of this area, bringing Cambrian Danby quartzite in thrust contact with Upper Ordovician Stony Point Shale. Decreasing displacement along the thrust to its termination in Orwell indicate a possible structural hinge. The lower plate comprises steeply-dipping and folded rocks. The predominant fold pattern on the upper plate was developed in mid-Trenton time with the emplacement of the Taconic allochthon by gravity sliding. This recumbent, asymmetrical folding may have been refolded during the Acadian orogeny, but such deformation was not observed in the field area. The large-scale thrusting is the outstanding manifestation of the Acadian. Regional joints and fractures post-date the last orogenic phase. Most of the structures trend north-south and are concordant with the larger scale tectonic trends.

INTERRELATIONSHIPS OF SURFACE AND GROUND WATER AND SOME ENVIRONMENTAL IMPLICATIONS NEAR THE NATIONAL FISH HATCHERY, CORTLAND, NEW YORK

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A study is being undertaken with the cooperation of the United States Geological Survey and the Bureau of Sports Fisheries and Wildlife to ascertain the interrelationships between ground water and surface water recharge-discharge phases in the area of the Cortland National Fish Hatchery. Due to the availability of data, stream and ground water flow are being closely monitored, and recharge-discharge relationships studied.

A number of well water level recorders, staff and rain gauges were placed in the study area to measure these various geohydrologic parameters. Any variations or stress on the hydrologic environment are traceable to their source, thus allowing for the control and manipulation of these factors.

This area is believed to be typical of glaciated terrane with high water tables in Central New York, and thus the results of this study should prove useful in future hydrogeologic investigations in areas of this type.

ZONED ANDRADITE FROM CRIPPLE CREEK, COLORADO

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Anisotropic andradite from Cripple Creek, Colorado shows strong oscillatory zoning and cyclic twinning. Microprobe analyses reveal alternating zones that chemically vary between pure andradite and $andradite_{50}$-$grossularite_{50}$. The possibility of fluctuating hydrothermal solution and oxidation may explain the zoning. The specific cause of anisotropism and twinning is unresolved at this time.

THE PRECAMBRIAN PILLOW LAVAS OF THE TIBBIT HILL MEMBER, PINNACLE FORMATION, ENOSBURG FALLS, VERMONT

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The Tibbit Hill member of the Pinnacle Formation has been metamorphosed to the lowest temperature subfacies of the greenschist facies. Three principal rock types were recognized in the field and studied under the microscope: a "tuffaceous" schist, a vesicular schist, and pillowed lavas. Mineralogically similar, all three contain an albite-epidote-chlorite-actinolite-stilpnomelane-magnetite assemblage. The texture is very fine grained intersertal-divergent, with grains generally smaller than 0.5 mm.

In the tuffaceous schist, quartz and white mica are also present in variable amounts. Albite in the vesicular schist is slightly more sodic in the vesicles than in the matrix, indicating some soda migration. Detailed microscope and correlative x-ray work have shown the pillowed lavas to be composed of: pistacite with 20-30 mol% $OHCa_2Fe_3Si_3O_{12}$ and minor amounts of the manganian epidote piemontite; a chlorite of rumpfitic or delessitic composition, indicating 30% iron over total Fe and Mg; ferrostilpnomelane having roughly 20-30% Fe^{3+} over total femics; actinolite with an Fe:Mg ratio of 2:3; and magnetite with occasional calcite and sphene.

Chlorite-quartz-actinolite phase relationships indicate a minimum metamorphic temperature of 400 to 425°C. Recalculation of the protolith, based on modes and composition, and assuming a semi-closed system, indicates a basaltic rock composed of: augite, labradoritic plagioclase, and olivine. K_2O percentages are similar to those of Atlantic Series tholeiites. There are virtually no primary internal structures preserved in the pillows, such as mineralogical and textural zoning from core to margin, suggesting that they did not develop because of shallow marine emplacement or that they have been obliterated by metamorphism.

THE PRECAMBRIAN TIBBIT HILL MEMBER OF THE PINNACLE

FORMATION IN BERKSHIRE TOWNSHIP, VERMONT

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The Tibbit Hill member of the Pinnacle Formation in Berkshire Township, north-central Vermont, is a metamorphosed series of basaltic lava flows and associated volcanic tuffs. The stratigraphically lower parts of each flow consist of pillows in strings up to 100 m. long; the individual pillows are no larger than 75 x 150 cm. Stratigraphically higher in a single flow sequence, the pillows become smaller and more scattered, with an increasing proportion of matrix material. Some of the smallest pillows are mineralogically zoned, with epidote-rich cores and albite-actinolite coronas. In the matrix above the pillows, crystal aggregates of epidote 1 cm. in diameter occur; these give way to similar albite clots still farther up.

The larger pillows consist of coarse-grained epidotes. Their matrix is a schist that contains epidotes, chlorite, actinolite, magnetite, and sphene. Two generations of quartz and albite occur also. The older generation are very small crystals in the matrix of the schist. The younger occurs in (dilation) veins and as filling for primary vacuoles. The veins occur both in the schist and the pillows. Hexagonal aggregates of quartz and epidote are interpreted as pseudomorphous replacement of labradoritic plagioclase.

The structure of the pillows indicates that the Tibbit Hill rests on the lower Pinnacle Formation, which was previously considered to be younger than the volcanic rocks in the area. This necessitates reinterpretation of the "synclines" as anticlines, and since the base of the formation is exposed, allows a determination of the thickness of the unit.

LAKE ONTARIO - ROCHESTER MARINE GEOPHYSICAL SURVEY

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A marine geophysical survey was conducted in the near offshore waters of Lake Ontario - in the Rochester area. The geophysical survey consisted of a series of continuous seismic reflection lines in grid formation, lake bottom bathymetry, and a number of subbottom sediment cores. The geological question to be resolved by the survey was to establish the nature of the lake subbottom, whether it be hard rock or sediment. Thick deposits of sediments were found to exist immediately offshore of Rochester under Lake Ontario. The bedrock, where encountered, was relatively deep, and probably reflects the nature of the lake coastal bedrock topography. The sediments consist of sands, gravels and clays.

TILL COLOR BOUNDARY IN ERIE COUNTY, NEW YORK

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Two till types, a red and a grey, are easily distinguished in Erie County. The boundary between the two types is linear in an east-west direction and is often as little as 50 feet in width. Red till lies to the north of this boundary and grey till to the south. Samples were taken in a pipeline trench 5 feet deep which crossed this boundary and subjected to sedimentological, heavy mineral, clay mineral, and iron and carbonate content analysis. Depth to bedrock data allowed the definition of a small subsurface scarp or rise of the more resistant Stafford limestone (Skaneateles Fm) which closely parallels the color boundary.

Investigation has shown that both tills are of Port Huron age and that the change of color is caused by the incorporation of dark brown Oatka Creek shale (Marcellus Fm) into the base of the predominately red glacial load. Apparently the basal load has been forced to override the small scarp of the Stafford limestone to produce the color boundary. Presumably overriding also resulted in admixture and dilution of the red till to a grey color in exposures of tills of the same age in the southern part of the area.

Cover design of contorted migmatite adapted from: Engel, A.E.J., 1963, Geologic evolution of North America, Science v. 140, p. 143-152. Copyright 1963 by the American Association for the Advancement of Science.