Geology of the Canada Lake Nappe,
Southern Adirondacks

by

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Introduction

The area considered in this report covers large portions of the Little Falls, Lasselsville, and Gloversville 15 minute quadrangles (Fig. 1). Small portions of the Piseco Lake, Lake Pleasant, and Broadalbin 15 minute quadrangles are also included.

Until recently, this area has received very little geological attention. Cushing (1905) mapped the Little Falls 15 minute quadrangle and Miller (1909, 1916, 1920) conducted mapping in the Broadalbin, Lake Pleasant, and Gloversville 15 minute quadrangles. His report on the Gloversville quadrangle was never published. Cannon (1937) published an excellent report on the Piseco quadrangle, but this was principally concerned with the Piseco Dome in the northern third on the map area. Nelson (1968) published a U.S.G.S. Bulletin describing the Ohio 15 minute quadrangle immediately to the N.W. of Fig. 2. Thompson (1955-59) studied the Harrisburg 15 minute quadrangle to the N.E. of Fig. 2.

For the most part, the above studies did not concern themselves with the stratigraphic detail presented in this report. This is in part fortuitous since the best, and most revealing,

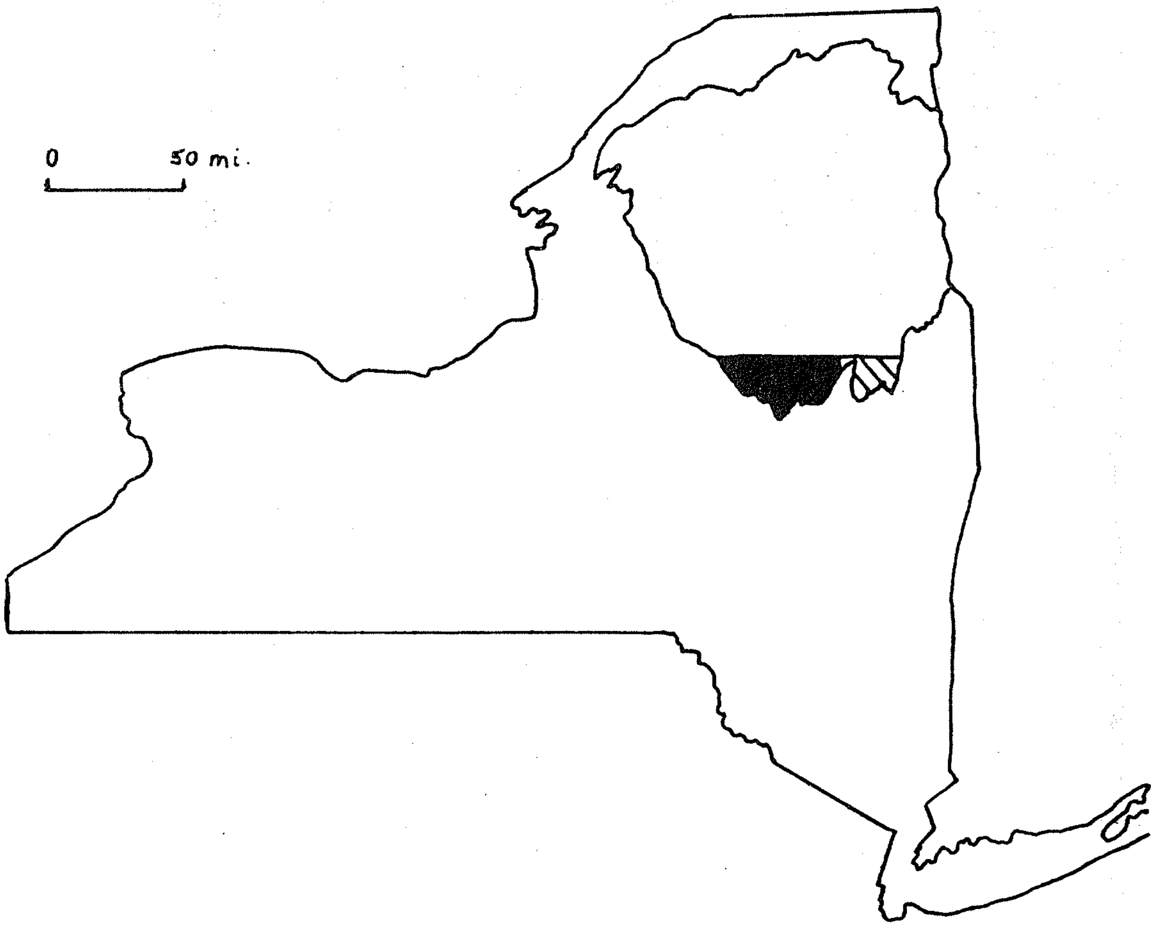

Fig. 1. Blackened area shows approximate location of the Precambrian units discussed here. Ruled area gives location of the hypothesized extension of the Canada Lake nappe.

stratigraphy lies in those areas which were either unmapped or mapped only in reconnaissance fashion.

The results of the present study (1965-1972) show that the southern Adirondacks are underlain by at least one regional isoclinal structure (Canada Lake nappe) that has been folded about several other axes. There probably exist three major periods of folding and each has occurred on a large scale. Axial traces can be followed over tens of miles. Two of the fold events (F_1 and F_2) appear to be coaxial and trend NW with a gentle plunge to the SE. The other is a NE trending fold ($F_?$) whose existence is postulated in this report. In addition to these folds there exists at least one other event (F_3) that has resulted in gentle warping of all other axes.

The stratigraphy of the area demonstrates that few, if any, of the major units had an intrusive origin. Charnockitic gneisses are stratigraphically coherent over several tens of miles. These and several other units, appear to be of metavolcanic origin, although a metasedimentary origin is not ruled out. Rocks of definitely metasedimentary origin are well represented by quartzites, quartzo-feldspathic gneisses, and biotite-garnet-quartz-oligoclase gneisses all of which exhibit good compositional banding (usually parallel to foliation).

It does not as yet seem possible to unravel the pre-metamorphic history of the Adirondacks. Continued field work should hasten the day when this can be done.

Stratigraphy

The absolute ages of the bedrock units remains unknown. Numerous age determinations of Adirondack rocks continually yield a single age of $\sim 1.1 \times 10^9$ years (see Silver, L.T., 1968). Nor is it known which is the top or bottom of the section. Since the Canada Lake nappe is antiformal, we set the stratigraphic section outwards from the Irving Pond formation which is folded back on itself and cores the major structure. Thicknesses are approximate and do not take tectonic thinning and thickening into account.

Irving Pond formation

The Irving Pond formation is named for its exposures around part of Irving Pond which is the lake just east of Canada Lake on Fig. two. As measured from mapped contacts, the Irving Pond formation is approximately 2000 ft. (600m) thick. Lithologically, the Irving Pond formation is dominated by quartzites and feldspathic quartzites. At least 50% of the formation is composed of nearly pure quartzites. Most of these are white and glassy, but some are rose colored. Individual bands commonly measure 6 inches (.15m.) to 10 feet (.25 m.) in thickness.

Feldspathic quartzites and quartzo-feldspathic gneisses make up from 30-40% of the formation. For the most part, these lithologies are highly quartzitic and could correctly be termed impure quartzites. Many of them exhibit fine scale layering represented by thin pelitic sheets less than .05 inches in thickness. In other instances 1-2 inch thick bands of pure quartzite alternate with equally narrow bands of pink quartzo-feldspathic gneiss.

Most of the impure quartzites and quartzo-feldspathic bands show the development of pale pink garnets. These are substantially different in color from garnets observed in the Peck Lake formation. The latter are a much deeper red.

Throughout the Irving Pond formation, there occur numerous bands, lenses, and boudins of dense, hard, dark calc-silicate and amphibolitic mineralogies. Microscopically, these are seen to consist of plagioclase, hornblende, quartz, and pyroxene. Generally, both

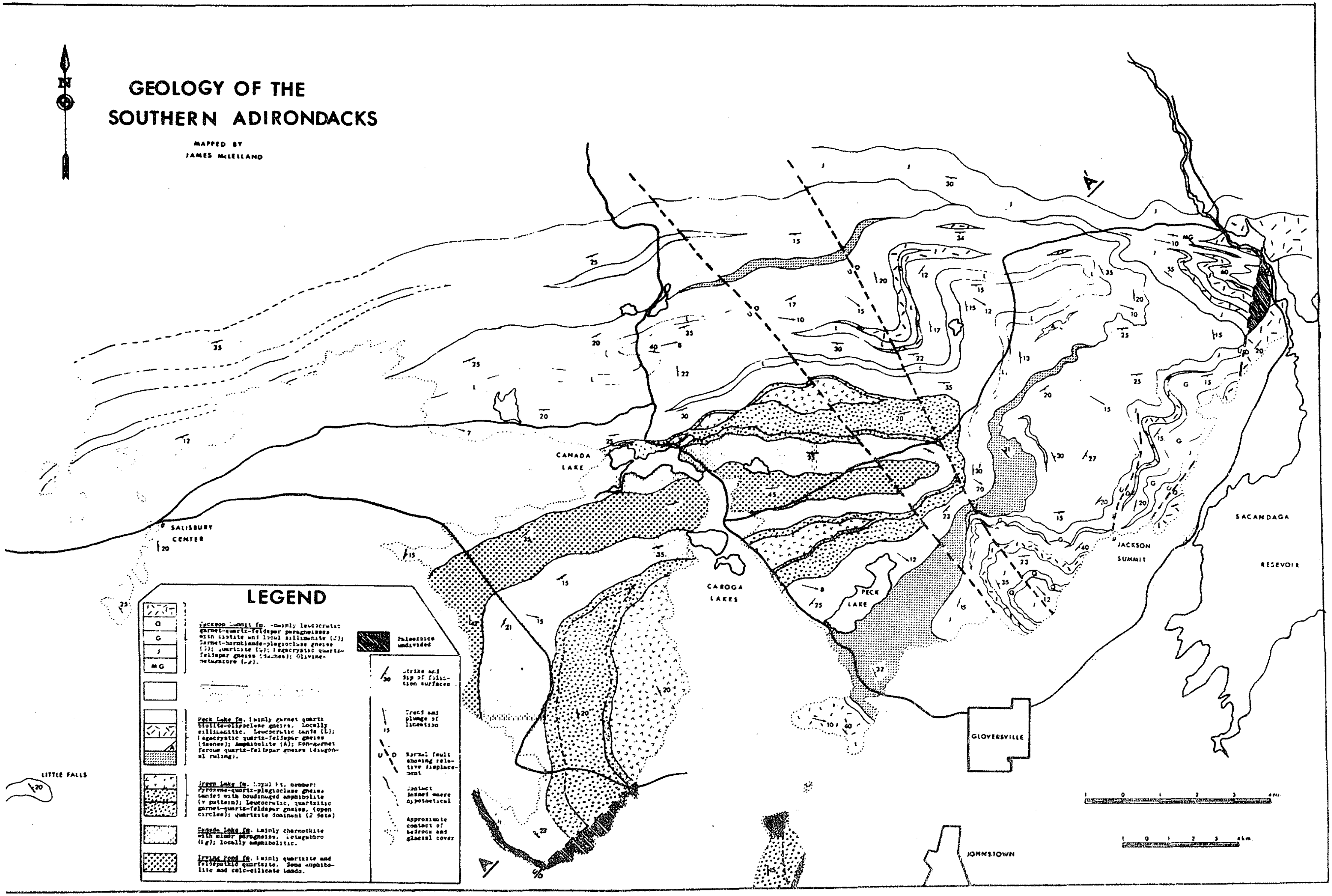

Fig. 2. Geologic map of the southern Adirondacks.

ortho and clinopyroxenes are represented with one or the other dominating, depending on the thin section. In some instances diopsidic clinopyroxene is so abundant as to give the rock a greenish hue.

It is believed that the calc-silicate and amphibolitic layers represent metamorphosed carbonate bearing lithologies. No marble has been found in the region of Fig. 2 , but east of Sacandaga Resevoir, units correlated with the Irving Pond formation exhibit fairly abundant development of marbles. Associated with these are calc-silicate and amphibolitic bands identical to those here described. The percentage of these may have been analagous to the carbonate-pelite mixed zone observed in the Balmville limestone - Walloomsac shale transition of the Cambrio-Ordivician shelf sequence of north-eastern North America.

Near its contacts with the Canada Lake charnockites, the Irving Pond formation grades from dominantly quartzitic lithologies into garnetiferous biotite-quartz-plagioclase gneisses that closely resemble lithologies dominating the Peck Lake formation. This transitional zone is no more than 100 feet (30 m.) thick and averages close to 50 feet (20 m.) across. The localizations of this zone to the vicinity of the contact may provide a clue to absolute tops and bottoms of the formations. This problem remains unresolved, but a speculative hypothesis might be that the transition zone reflects a change in sedimentary environment attendant upon an onset of volcanism associated with the Canada Lake charnockites. There are several assumptions involved here and the assignment of relative ages can be reversed. Our object in so stating the problem is to point out that detailed studies of the transition zone might well allow relative ages to be established.

Over its exposed extent shown in Fig. 2 , the Irving Pond formation exhibits no marked change in its overall character. It probably represents a metamorphosed sequence of thick sandstones, less abundant feldspathic sandstones, minor shales, and minor carbonate rich layers. It appears to be a shelf type deposit.

Canada Lake formation

This formation is named for its excellent exposures along Rte. 29A-10 at the east end of Canada Lake. According to its mapped contacts, the Canada Lake formation has a thickness ranging from 2000 to 3000 ft.

(600 – 900 meters). These figures do not take tectonic thickening, thinning, or repitition into account.

The Canada Lake formation is almost wholly comprised of quartzo-feldspathic and charnockitic gneisses. Within these lithologies, hypersthene is only locally developed and in many instances, has been largely altered to amphibole and, to a lesser extent, biotite. It is possible that much of the amphibole in these rocks is due to retrograde metamorphism of orthopyroxene.

Within the gneisses of the Canada Lake formation, micro and mesoperthite is very widely developed. This is the same situation noted by DeWaard in the Little Moose Mt. area (DeWaard, 1962). Given the almost ubiquitous occurrence of micro- and mesoperthite in these units, they might best be referred as mesoperthite gneisses. However, we wish to stress their charnockitic affinities and, thus, refer to them as such.

Compositional banding is not strongly developed in the Canada Lake formation. However, it may be recognized by noting thin biotite rich zones and/or amphibolites. The latter occur only sporadically within the formation. Thin quartzites appear locally in the sequence, but it is rarely certain whether these are vein quartz or metasediments. By and large, the Canada Lake formation is a monotonous series of compositionally identical layers of charnockitic gneiss each measuring several tens of feet in thickness, and set apart from each other by weakly developed compositional banding.

Within the formation, there is local development of pegmatite and coarse grained quartzo-feldspathic areas. The occurrence of mafic minerals also varies throuhout, but none of these variations has been mapped separately.

The charnockitic gneisses of the Canada Lake formation show features typical of the so-called "syenitic" gneisses of the Adirondacks -e.g.- flattening and stretching of quartz grains; a dark greenish color on fresh surfaces; pinkish weathering of woodland outcrops; and a white to brown weathered surface on outcrops long exposed to the sun.

Garnet is virtually absent from the charnockitic gneisses and has been recognized only at one outcrop. Likewise clinopyroxene occurs only rarely. Almost certainly, this represents original compositional variation in the gneisses.

The contact with the Irving Pond formation is sharp and the charnockitic gneisses show no gradation into the Irving Pond lithologies. On the other hand, the Irving Pond formation shows a weakly gradational contact with the Green Lake formation; the gradation being represented by an increasing number of quartzite bands in the charnockitic gneisses.

The overall homogeneity and poor banding of the Canada Lake formation suggests that it is composed of a metamorphosed sequence of dacitic lava flows. Local amphibolite layers may represent more basic volcanism or ash falls.

The Green Lake formation

This formation is named for its conveniently located exposures along the eastern shore of Green Lake. Its thickness, as measured from mapped contacts, varies between 2000 ft. (600 meters) and 200 feet (60 meters).

The Green Lake formation is dominated by leucocratic and quartzitic garnet-quartz -two feldspar gneisses. Near its contact with the Canada Lake and Royal Mountain formations, pure and impure quartzite layers dominate. Interlayered with the leucocratic lithologies are subordinate units of amphibolite, calc-silicate, and biotite rich gneisses. Within the quartzitic and leucocratic units, garnets exhibit a characteristic pale pink color. Sillimanite is present in small amounts in almost every thin section examined.

Certain lithic similarities exist between the Green Lake and Irving Pond formations. However, the latter contains a great deal more quartzite than the former, and the quartzite occurs in much thicker bands within the Irving Pond formation. The Green Lake quartzo-feldspathic units contain much more feldspar than quartzo-feldspathic lithologies in the Irving Pond area. Concomitantly, garnet is much more ubiqutous in the Green Lake formation. Of course, the Green Lake and Irving Pond formations may be lithically gradational, were it not for the intervening Canada Lake charnockitic gneisses. The presence of this intervening and stratigraphically continuous unit makes it possible to draw the formational boundaries here observed.

The Royal Mountain member of the Green Lake formation was originally assigned a separate formational status. However, it occurs wholly within the Green Lake formation; is stratigraphically discontinuous; and occurs at several stratigraphic horizons. Therefore the unit is herein included as a member of the Greek Lake formation.

The Royal Mountain member is named for its excellent exposures on the ski slopes of Royal Mountain which lies within the largest area of this gneiss shown on Fig. 2 . It is composed of a monotonous series of medium grained, white weathering, pyroxene-quartz-plagioclase gneisses banded with much boudinaged layers of amphibolite. The quantity of amphibolite varies from less than 5% to approximately 50% with the variation not appearing to have any stratigraphic continuity.

The Royal Mountain unit looks very much like the charnockitic gneisses of the Canada Lake formation and was originally mistaken for them. However, K-feldspar is very sparse (10% maximum) within the Royal Mountain. It is often necessary to stain the rocks to tell them apart. It is possible that a significant percentage of "syenitic" and "charnockitic" gneisses of the Adirondacks are analogues of the Royal Mountain pyroxene-quartz-plagioclase gneiss.

The plagioclase in the Royal Mountain member has an An content straddling calcic oligoclase and sodic andesine. This makes it more calcic than the majority of plagioclases in non mafic rocks of the southern Adirondacks.

The mineralogy, physical appearance, and lenticular aspects of the Royal Mountain formation suggest that it represents a metamorphosed series of tonalitic volcanic centers. The individual flows were intermittenly layered with more basic flows or ash falls that are now preserved as amphibolite bands.

The bulk of the Green Lake formation presumably represents the metamorphosed equivalents of pure and feldspathic sandstones. Shales and graywackes appear to have been minor. Amphibolites and calc-silicate layers may represent carbonate rich portions or basic volcanic material.

Peck Lake formation

This formation is named for its good exposures along Route 29A-10, where the highway crosses the western end of Peck Lake. Excellent roadcuts are also exposed along Route 29A between Stratford and Canada Lake.

The Peck Lake formation has the greatest exposed thickness in the area. Its greatest approximate thickness is 5000 feet (1.5 km.).

The formation is composed overwhelmingly of garnetiferous biotite-quartz-oligoclase gneisses which contain small quantities of sillimanite and K-feldspar layers and streaks of quartzo-feldspathic material, give the unit a banded appearance. Amphibolite and quartzite layers also accentuate the banding. Throughout the gneiss are pods and lenses of two feldspar-quartz rocks. These are believed to have an anatectic origin and in places can be seen to cross-cut the surrounding gneisses. Garnets within the anatectites may represent refractory material.

It has proven extremely difficult to subdivide the Peck Lake formation. Leucocratic variations are easily recognizable but generally do not exhibit stratigraphic continuity. Extensive folding of incompetent units further complicates the problem. However, several continuous leucocratic horizons have been recognized and are shown on Fig. 2 . The units are dominated by garnetiferous quartzo-feldspathic gneisses. Garnets in these units have a pale pink color in contrast to the burgundy color of most Peck Lake garnets.

Within the Peck Lake formation, there occur several bands of gneisses containing large (1-4 inches long) megacrysts of microcline and/or microperthite. The lithology of these is identical to rocks of the Rooster Hill formation.

The Peck Lake and Green Lake formations show a fairly abrupt contact although the lithologies are gradational. Many Peck Lake leucocratic units resemble the dominant lithologies of the Green Lake formation. The abruptness of the change in biotite content and garnet coloration permits the contact to be drawn with considerable confidence.

Another discontinuous unit in the Peck Lake formation is the non-garnetiferous biotite-quartz-two feldspar member. This lithology occupies a stratigraphic position just below the Rooster Hill megacrystic gneisses. Aside from the lack of garnet and greater percentage of K-feldspar, the unit is quite similar in appearance to the dominant lithology of the Peck Lake formation, bands of which occur within the non-garnetiferous member. Near the contact with the Rooster Hill formation, it becomes streaked with quartzo-feldspathic material and K-feldspar porphyroblasts. In this aspect the unit has a migmatitic appearance. In addition the greater percentage of K-feldspar enhances partial fusion and numerous anatectic pods are present. The higher degree of partial fusion has resulted in a great deal of flowage folding which increases the migmatectic appearance.

The Peck Lake formation is similar to Engle and Engle's (1956) "least altered gneiss". It is believed to represent a metamorphosed sequence of shales and/or greywackes with minor sandy layers and volcanics. The uppermost migmatectic unit probably representsa change in environment following or attendant upon Rooster Hill volcanism. Whether the formation is eugeosynclinal or not is unknown.

Rooster Hill formation

This formation is named for its excellent and accessible exposures on Rooster Hill just North and East of Stoner Lakes (STOP H).

The Rooster Hill formation is a discontinuous unit but its thickness as measured on the map averages close to 8000 ft.(250meters). This formation is comprised of two textural varieties of compositionally identical biotite-hornblende-quartz-two feldspar leaf gneiss. In addition to these, there occur in the unit isolated bands of garnetiferous biotite-quartz-oligoclase gneiss identical to the dominant lithology of the Peck Lake formation.

By far the most abundant variation of Rooster Hill is a very distinctive inequigranular variety containing 1-4 inch long megacrysts of K-feldspar set in a medium grained groundmass of biotite-hornblende-two feldspar gneiss. The megacrysts are microcline and microperthite with the latter dominating. These megacrysts are generally flattened and aligned within planes of foliation. In a few outcrops the megacrysts exhibit an almost random orientation. Granulation of the

the megacrysts is variable. In most instances granulation is confined to margins of single crystals and the interiors are sufficiently preserved so that Carlsbad twinning may be observed.

The second textural variant of the Rooster Hill formation is an equigranular equivalent of the megacrystic unit. This equigranular member occurs at all positions in the formation, but its principal development is at the margins of the formation. It is believed that this member is a granulated variant of the more abundant megacrystic variety.

In an earlier publication (McLelland, 1969) it was suggested that the Rooster Hill formation had an intrusive origin. This arguement has since been invalidated by further field work. Contacts that had been supposed to be transgressive have since been demonstrated to be conformable. New field work has uncovered over three miles of exposed contacts with the Peck Lake and Jackson Summit formations. These occur mainly in the northeastern and eastern portions of Fig. 2 .. Clean, sharp, conformable contacts are everywhere seen. Similar relationships have been observed relative to similar megacrystic units within the Peck Lake and Jackson Summit formations.

Based on the above observations, it seems virtually certain that the Rooster Hill gneisses do not have an intrusive parentage. They probably represent a series of volcanics of dacitic to quartz-latitic character. The origin of the megacrysts remains obscure, but they are presumably porphyroblasts. It seems unnecessary to ascribe them to metasomatic processes as was done by Nelson (1969). Arguments that they grow across foliation are not only non-sequitors but they are also incorrect. Close inspection of apparently cross-cutting megacrysts shows that they are actually rotated by movement along foliation planes.

The discontinuous nature of the Rooster Hill may reflect volcanism restricted to a few centers around which relatively thick lava piles developed. These lavas may have been more viscous than those presumed to have been the parents of the less siliceous Canada Lake charnockitic gneisses. This would explain the differences in stratigraphic continuity.

The Rooster Hill lithologies are similar to Buddington's (1939) Hermon Granite.

Jackson Summit formation

This formation is named for its good and representative exposures in the vicinity of the hamlet of Jackson Summit. The maximum thickness is uncertain, but the formation is at least 3000 ft. (900 meters) thick.

The Jackson Summit formation is dominantly composed of garnetiferous gneisses intermediate in mafic and quartzite content between the Peck Lake and Green Lake formations respectively. It is decidedly more leucocratic than the former and less quartzitic than the former. It also contains more minor amphibolite bands than either of the above.

Like the Peck Lake formation, the Jackson Summit formation contains conformable bands of megacrystic gneiss, lithically identical to the Rooster Hill formation. The unit labelled "G" on Fig. 2 and referred to as a garnetiferous variety is actually a garnetiferous phase of the Rooster Hill equigranular lithology.

A rare, but exceedingly important member of the formation, is the band of olivine-metagabbro exposed in the fold nose at the northeastern extremity of Fig. 2 . This unit is conformable and was presumably intruded as a sill. The largest band is .75 mile (1.2km.) long and at its widest is 750 feet (.25km.) across. In the interior of the band ophitic and subophitic textures are preserved. The development of coronas in the rock enable us to set P,T conditions for the lost metamorphism of the area. This is further discussed on page E-13.

The Jackson Summit formation presumably represents the metamorphosed equivalent of a thick sequence of feldspathic sandstones, sandstones, minor shales and graywackes, and acidic volcanics. It is the most variegated formation in the area.

Structural Geology

Folding

The structure of the area shown in Fig. 3 is fairly straightforward, once it has been mapped. The major structure is a recumbent isoclinal antiform F_1 cored by the Irving Pond formation and referred to as the Canada Lake nappe. The axial plane of the nappe has been refolded by several relatively open folds F_2 which cause the nappe to zig-zag from southwest to northeast across the mapped area. A third set of gentle folds F_3 cause the F_2 axes to undulate. In addition to these fold sets there probably exists a N.E. trending major fold whose position in time lies between F_1 and the currently designated F_2. At present this fold is conjectural. It will be further discussed in section

The F_1 and F_2 folds appear to have parallel or subparallel axes, at least where they intersect one other. These axes trend approximately N.W. to E-W and plunge gently eastward. The coaxiality of these folds is best shown in the outcrops at stop K.

The geometry of the F_1 and F_2 is shown in Figs. 2 and 3. In addition, Fig. 3 shows the manner in which the F_1 axis is folded slightly to the NE in the vicinity of Canada Lake.

It is clear from Figs. 2 and 3 that the F_1 fold has undergone axial plane folding by F_2. This may represent the continuation of the same force field during the two fold events. First the rocks were detached from their original basement and folded into a recumbent isocline which rode forward (northward?). In the process of being thrust forward the F_1 fold was thrown into a series of more open F_2 folds. The parallelism of the axes may reflect the continued action of the same stress field (subduction? continental collision?).

In the northeastern corner of the area the F_1 axial trace swings eastward. This area is one of the very few in which the F_1 fold hinge is well exposed. Here can be seen excellent examples of rodding, minor folding, and transposed bedding. As shown in Figs. 2 and 3 , this region is crossed by two F_1 fold axes trending N70W. These folds are considered to be drags near the nose of F_1. Note that the apparent relative motion is in the proper sense. In general the drag folds on F_1 are consistent in their sense of rotation, being sinistral on the

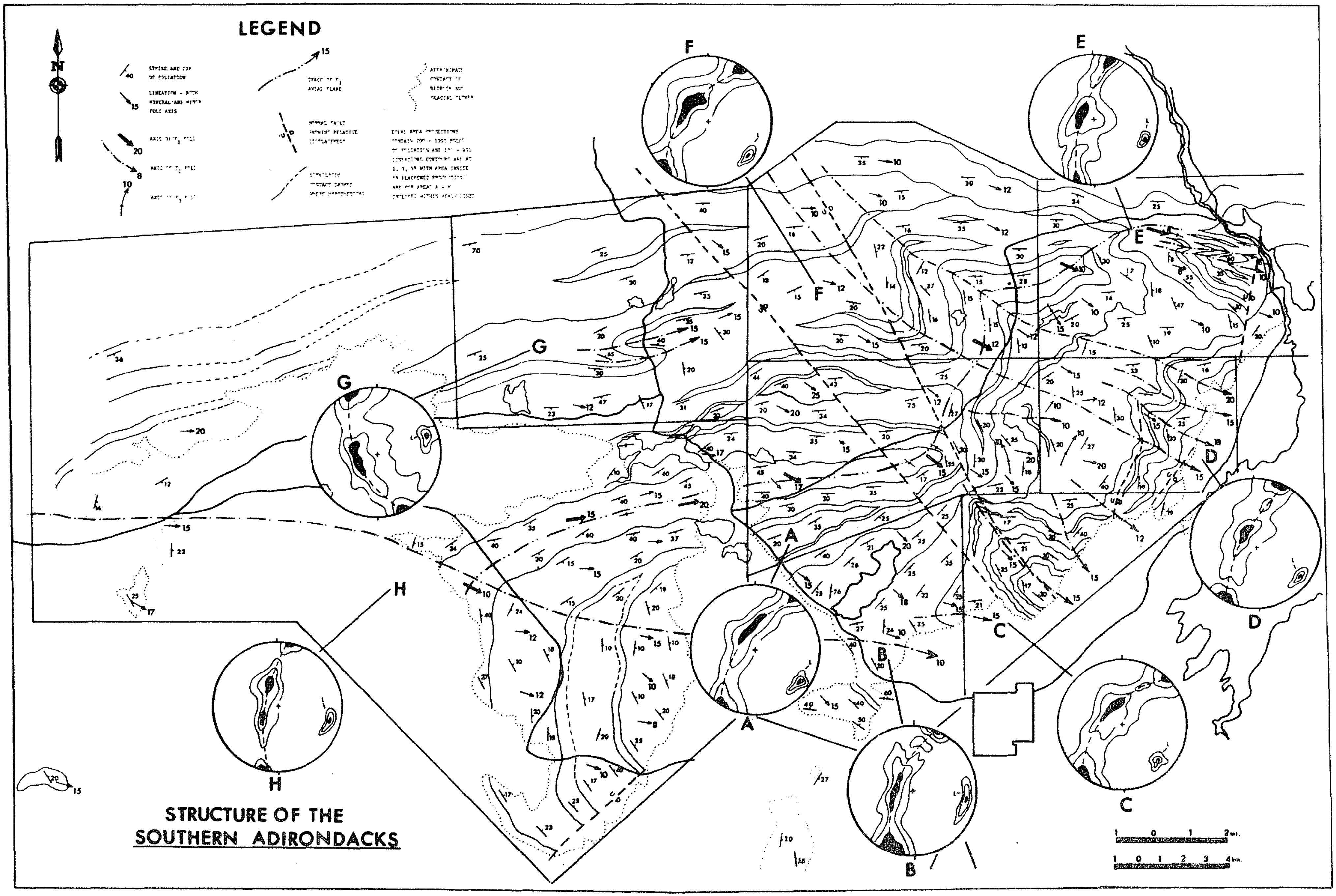

Fig. 3. Structural geology of the southern Adirondacks.

lower (northern) limb and dextral on the upper (southern) limb. The long axes of boudins are also consistent with the mapped fold axes.

North of Canada Lake there exists a sharp NE fold outlined by a unit of leucocratic gneiss in the Peck Lake formation. It is uncertain as to which event this fold corresponds. The axial plane of this fold is only slightly overturned, and it does not appear to be of the F_1 generation. However, its trend and tightness of folding is unlike that of F_2.

It appears that during F_1 folding, the Irving Pond and Canada Lake formations behaved competently while the Peck Lake formation underwent relatively less competent deformation. This is consistent with the mineralogies of these units. The Royal Mt. member appears to have behaved incompetently relative to internal amphibolite bands. It may have been more competent than other units in the Green Lake formation. Thus the discontinuous aspect of the Royal Mt. formation may be due to mega-boudinage. This is suggested by the intense deformation of Green Lake quartzo-feldspathic units in the "necked-down" region of the northern band of Royal Mt. on Fig. 2. Alternatively, the "pinch and swell" appearance of the Royal Mt. formation could be the result of separate centers of volcanism. Similar considerations may hold for the Rooster Hill formation.

A major structural problem in the area is whether the nappe is underlain by a thrust zone. No such zone has yet been definitely located. It is postulated that the highly lineated Piseco Dome trend may represent such a zone of detachment. This speculation gains some support from the fact that the Canada Lake lithologies are uncommon north of the dome. As the dome is approached from the south, all rock units acquire an increasing degree of rodding. This may be the result of rolling in response to thrust movement. At present the problem remains an open one.

Cross sectional and 3-d schematic news are shown in Fig. 4 and 5. Given the accompanying maps and figures, there seems little else that needs to be added in terms of words. Regional structural correlation is discussed under the section entitled "Hypothetical Extension of the Nappe".

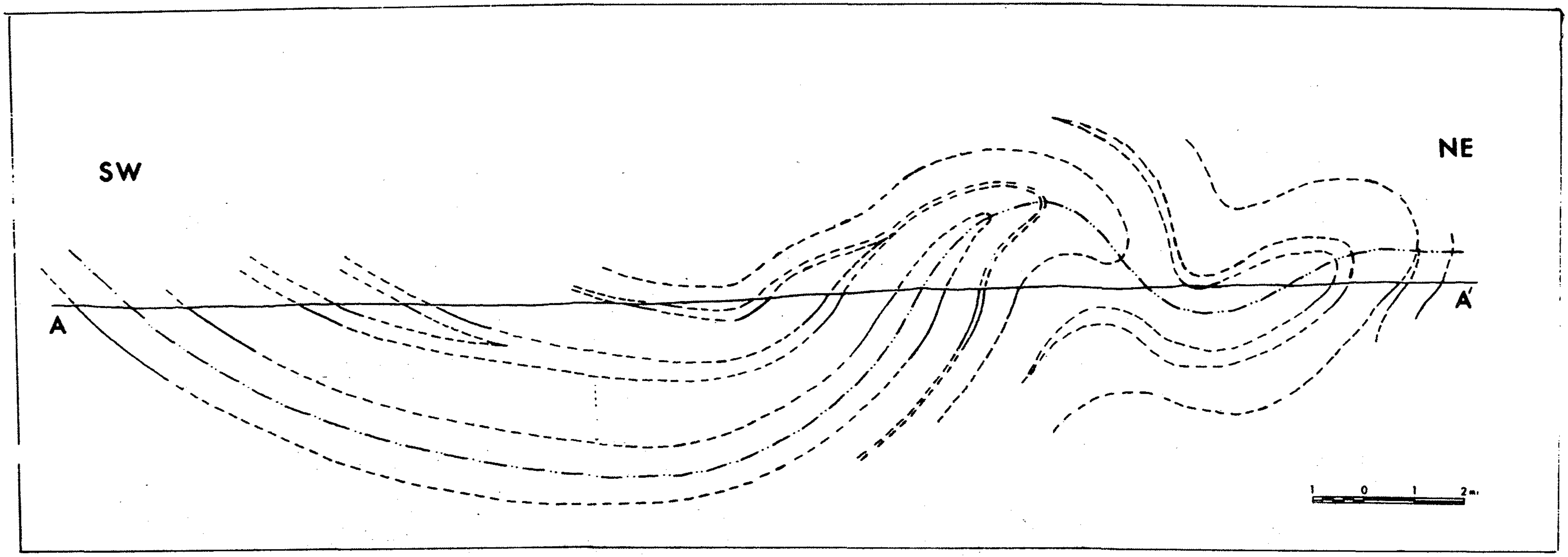

Fig. 4. Cross section across the Canada Lake nappe from A-A' of Canada Lake formation shown in vertical dash pattern.

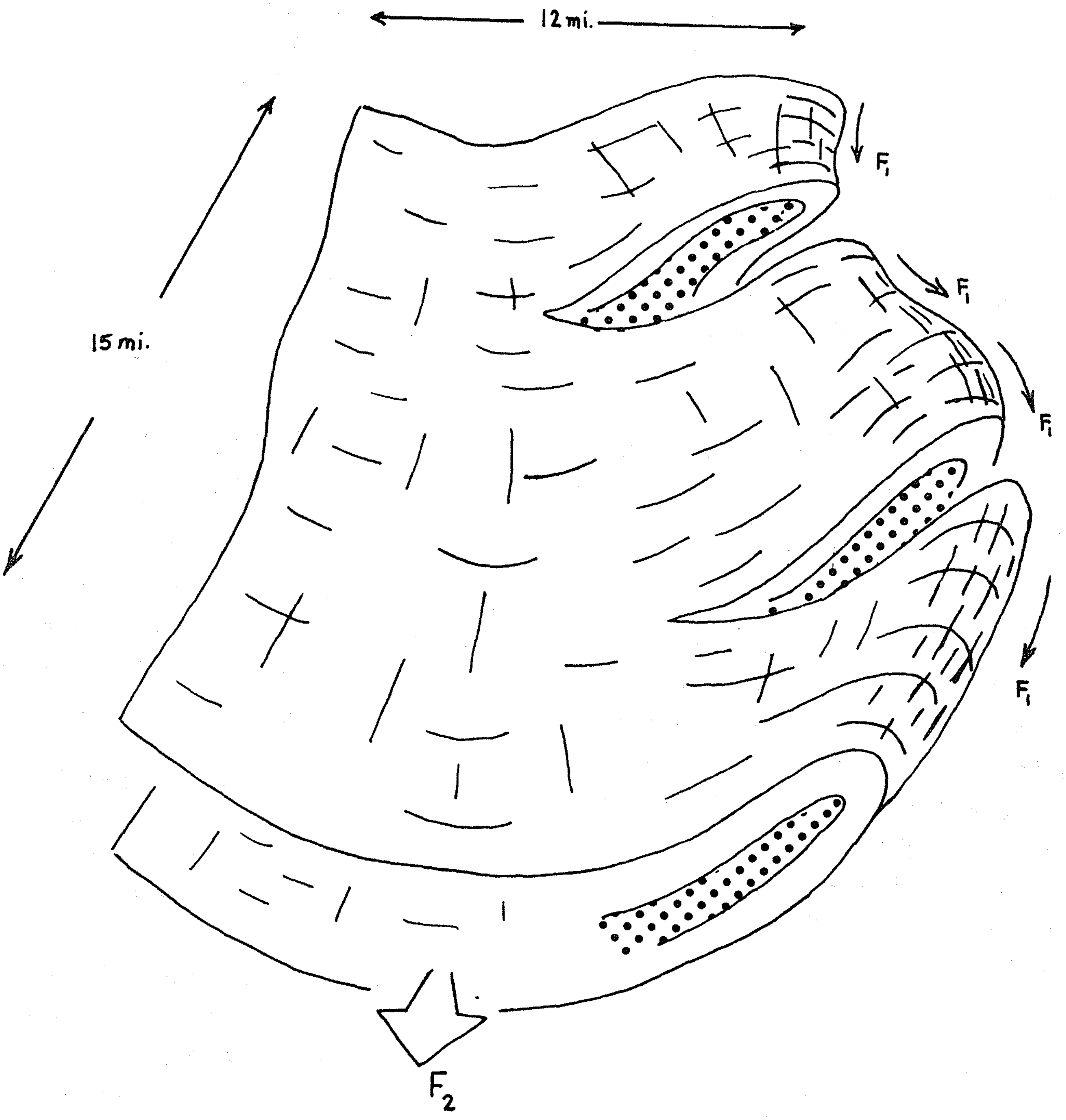

Fig. 5. Schematic 3-dimensional representation of the Canada Lake nappe. Looking from East to West. Irving Pond formation shown in dot pattern.

Hypothetical Extension of the Nappe

The detailed mapping shown in Figures 2 and 3 extends eastward to Sacandaga Resevoir. Within this area, the geological relationships are rather well understood. Beginning in 1971, the author began to reconnaissance the geology to the north and to the east of Figures 2 and 3 . It became apparent that the stratigraphy of the Canada Lake nappe was repeated in the area lying between Sacandaga Resevoir and Saratoga Springs. During the summer of 1972, this work has been continued on a more detailed scale by two of the author's students, Paul Dankworth and Robert Kuhlman, both of whom are participants in an NSF Undergraduate Research Participation grant made to Colgate's Department of Geology.

Dankworth and Kuhlman have shown that a recumbunt fold underlies the area east of Sacandaga Resevoir and that its axial trace trends northeastward in the southern part of the region (see Fig. 6). Moreover, they have demonstrated that the stratigraphy is remarkably like that of the Canada Lake nappe. Thus the fold (antiformal) is cored by a sequence of quartzites, impure quartzites, calc-silicates and marble. This band is correlated with the Irving Pond formation which it closely resembles except for the presence of marbles. This latter difference is easily explained in terms of a sedimentary facies change. On either side of this central quartzitic band are quartzo-feldspathic charnockitic gneisses whose small and large scale properties appear identical to the canada Lake formation. Bordering the charnockitic gneisses are quartzites and highly quartzitic leucogneisses. These are correlated with the Green Lake formation. These units grade outward in garnetiferous biotite-quartz-oligoclase gneisses that resemble the Peck Lake formation in every way except that quartzite layers are thicker and more abundant than in the Canada Lake area. Intercalated with these units are conformable bands of megacrystic gneisses resembling the Rooster Hill lithology.

From the above description, it appears extremely likely that the sequence east of Sacandage Resevoir is a continuation of the Canada Lake-Gloversville sequence. The absence of the Royal Mountain member and the thinning of the Rooster Hill formation can be understood in terms of increasing distances from centers of volcanic activity.

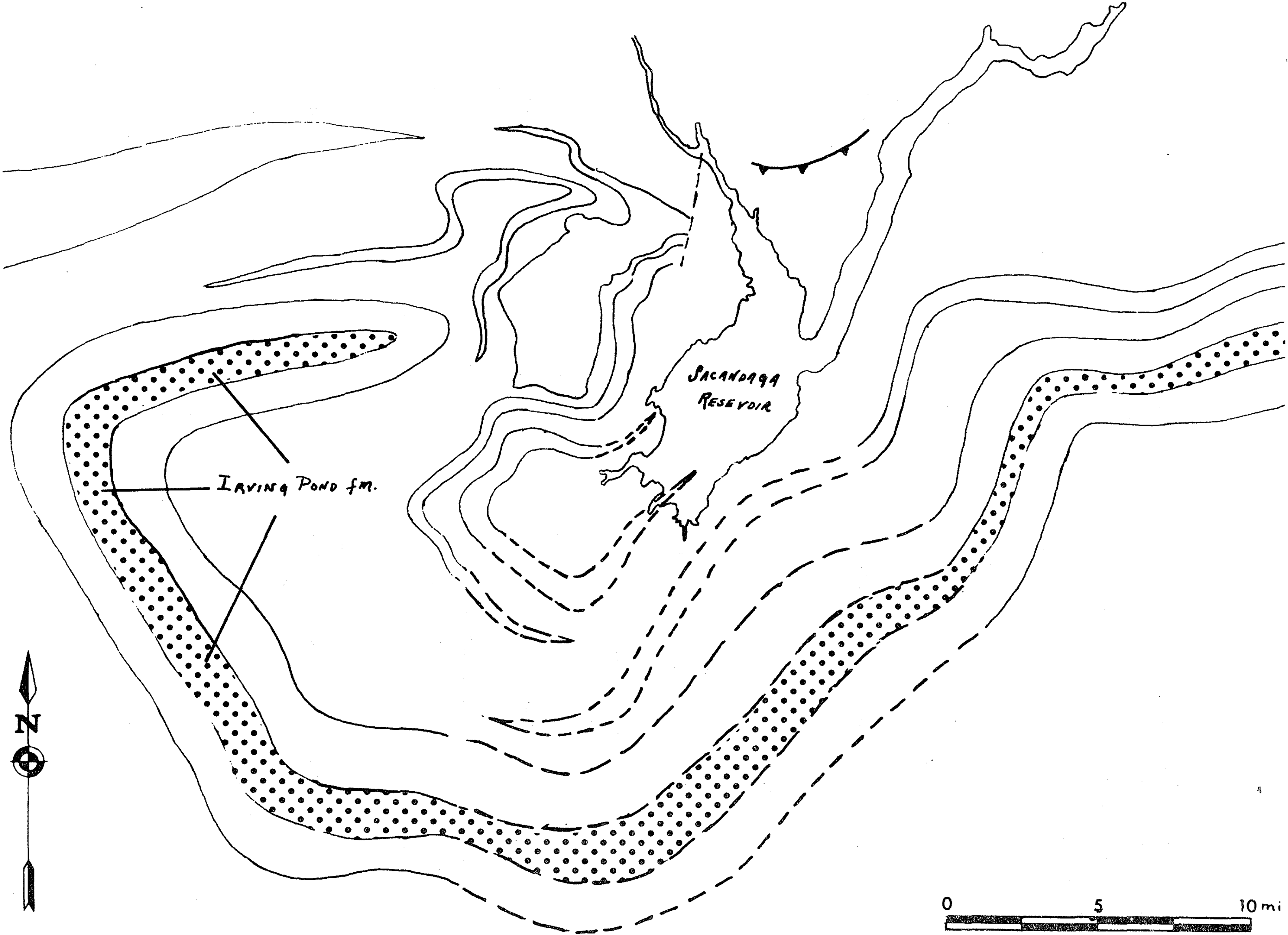

Fig. 6. Geologic sketch map showing hypothetical eastward extension of Canada Lake nappe. Dashed lines refer to areas under paleozoic cover.

As this article is being prepared, we have spent only four weeks doing detailed field work in the highlands east of Sacandaga Resevoir. Clearly, a great deal remains to be done. However, it is with considerable confidence that we offer the hypothesis that the Canada Lake nappe and stratigraphic section extends eastward towards Saratoga Springs as shown in Fig. 6 . Of course, the extrapolation involved must be carried out beneath an extensive cover of Paleozoics that blanket the southern portion of the area.

In the area described above the extension of the Canada Lake nappe has an axial trend averaging close to E-W. Its axial plane dips southward at moderate angles (20°-30°). It is crossed by a large N.W. trending F_2 synform that plunges gently S.E.. Within the core of the F_1 fold, lineation and rodding are well developed and preliminary measurements indicate that F_1 and F_2 are not coaxial, but rather, that F_2 has folded F_1.

In order to swing the Canada Lake nappe eastward, as shown in Fig. 6 , it is necessary to introduce a N.E. trending fold that passes almost directly through Sacandaga Resevoir. The existence of this fold gains support from the existence of several north and northeastward trending folds and lineations in the area. A few of these are shown on Fig. 3 , but they are so uncommon as not to influence the equal area projections which are comprised of hundreds of points. To some extent, the foliation pattern in the eastern limb of the Rooster Hill formation is consistent with the NE folding. Similarly, the somewhat peculiar pattern of the southeastern exposure of the Jackson Summit formation is more easily explained by introducing this NE fold. Greater support is provided by the foliation pattern directly north of Sacandaga Resevoir. In this area the strikes swing from E-W to NE so as to define a broad, gentle anticline. This is consistent with the fold structure hypothesized herein. However, we are not yet ready to speculate with any certainty on the actual style of the folding.

The temporal position of the fold is still uncertain. We tentatively believe that it falls between F_1 and the currently designated F_2 fold. However, continued field work may alter this hypothesis.

Finally, we note that the current aeromagnetic map of the southern Adirondacks indicates anomaly patterns beneath the southern

Palezoic blanket that are highly consistent with our hypothesis.

If our extrapolation is correct, the Canada Lake nappe has an E-W extent of approximately 45 miles and a total extent of at least 65-70 miles. This makes it a truly enormous structure. We suspect that many, if not most, Adirondack folds have similar dimensions. Presumably this reflects the scale on which deep crustal deformations occur.

Faults

Northeast trending faults and fracture zones are common in the area and have received topographic emphasis due to glaciation. They are often accompanied by considerable breccia.

The northeast trending faults account for many of the Precambrian-Paleozoic contacts, and therefore, must have substantial throw along them. However, within the Precambrian they do not manifest offsets large enough to show up on the scale of 7½ minute quadrangle mapping.

Northwest trending faults do not show the topographic definition of the northeast fracture zones, but they generally exhibit a greater throw. Two such faults cross the Precambrian exposures of the area and are shown on Figs. 2 and 3 . Neither one of these appears to extend into the Paleozoics. Whether these faults are strictly Precambrian in age is not known.

P-T Conditions of Metamorphism

Within the Jackson Summit formation there occur a few sill like intrusions of olivine metagabbro. These have been folded by F_1 movements. Since we believe the F_1 folding to precede or be approximately contemporaneous with the major metamorphism, it seems likely that the metagabbro has undergone the same progressive metamorphism as other rocks in the area. Thus any information regarding P,T conditions related to its metamorphic mineralogy, will be directly applicable to the rest of the area.

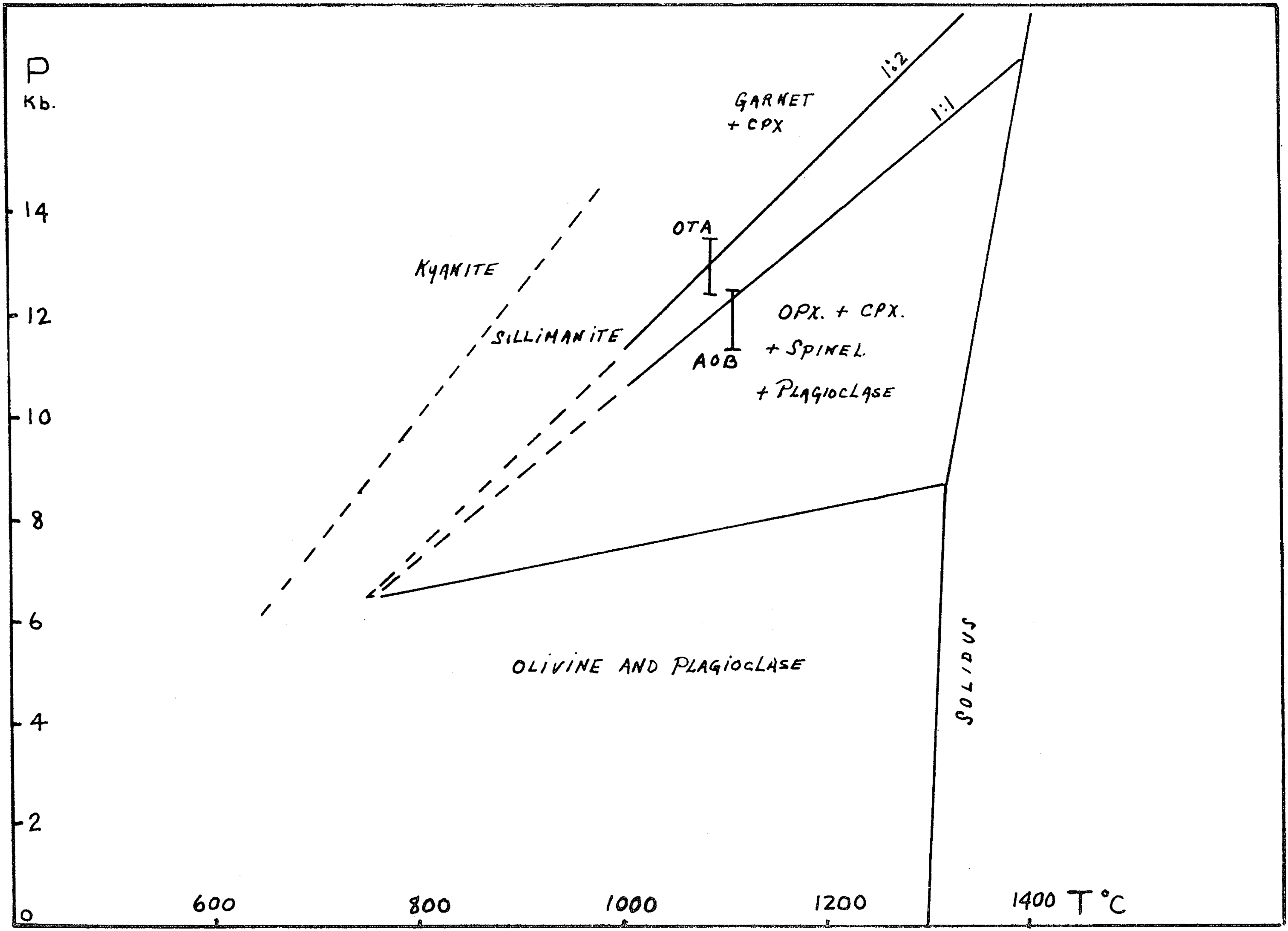

Fig. 7. Experimental P-T diagram for the anorthite-forsterite as ascertained by Kushiro and Yoder (1966). 1:1 and 1:2 refer to anorthite-forsterite ratio. The lines OTA and AOB refer to the incoming of garnet in olivine tholeiite and alkali olivine basalt respectively (Green and Ringwood, 1967).

Within the metagabbro there are developed beautiful examples of coronas. These consist of an olivine core surrounded by a shell of orthopyroxene rimmed, in turn, by a vermicular intergrowth (symplectite) of clinopyroxene and green spinel. These symplectites embay into surrounding plagioclase crystals.

During 1971 and 1972, the author and Philip Whitney of the New York Geological Survey studied these coronas and garnet bearing analogues of the N.E. Adirondacks. On the basis of microprobe data, we have substantiated their mode of origin. This work has been submitted for publication elsewhere. For coronas of the southern Adirondacks, we believe that the gross mineralogies can be explained by a reaction of the following type:

$$(6-4x)\ \overset{\text{olivine}}{(Mg,Fe)_2SiO_4} + \overset{\text{anorthite}}{3CaAl_2Si_2O_8} = (6-4x)\ \overset{\text{Al-orthopyroxene}}{(Mg,Fe)SiO_3\cdot 2x(Mg,Fe)Al_2Si_2O_6}$$

$$+\ \overset{\text{Al-clinopyroxene}}{(3-2x)Ca(Mg,Fe)Si_2O_6\cdot 2xCaAl_2SiO_6} + (3-4x)\ \overset{\text{spinel}}{(Mg,Fe)Al_2O_4}$$

This reaction represents the sum of three partial reactions which serve to explain corona zonation, plagioclase clouding by spinel, and the behavior of the albite molecule in the process. For our present purposes, we need only consider the total reaction as given above.

Fig. 7 is a diagram in the PT plane showing the reaction boundaries found by Kushiro and Yoder (1966) for the anorthite-forsterite system. The lower line shows the boundary between the olivine-plagioclase and pyroxene-spinel fields. The upper two lines show the boundary between the pyroxene-spinel and garnet fields, for An: Fo ratios of 1:1 and 1:2. The bars labelled (OTA) and (AOB) are from Green and Ringwood (1967) and illustrate the range of pressures for the incoming of garnet in an olivine tholeiite and an alkali olivine basalt, respectively. Both rocks,and the olivine tholeiite in particular, are similar in bulk composition to the coronites of this study. Green and Hibberson (1970) have shown that addition of albite to plagioclase delays the initial olivine-plagioclase reaction to somewhat higher pressures, and addition of fayalite to olivine lowers the pressure for the initial appearance of garnet. Hence, the wedge-shaped pyroxene-spinel field is probably smaller for natural olivine/plagioclase rocks than

than for the pure forsterite anorthite system studied by Kushire and Yoder.

While due caution must be taken in applying this data directly to natural assembleges, it seems appropriate to utilize the diagram to ascertain approximate P,T, conditions of metamorphism. Accordingly, we believe the minimum metamorphic conditions to have been in the range of 800°C and pressures of the order of 7kb. Both pressure and temperature could have been somewhat higher. These conditions are consistent with those proposed by DeWaard (1967) for the Adirondack Highlands. Clearly, we are dealing with deep crustal burial and thickening.

ACKNOWLEDGEMENTS

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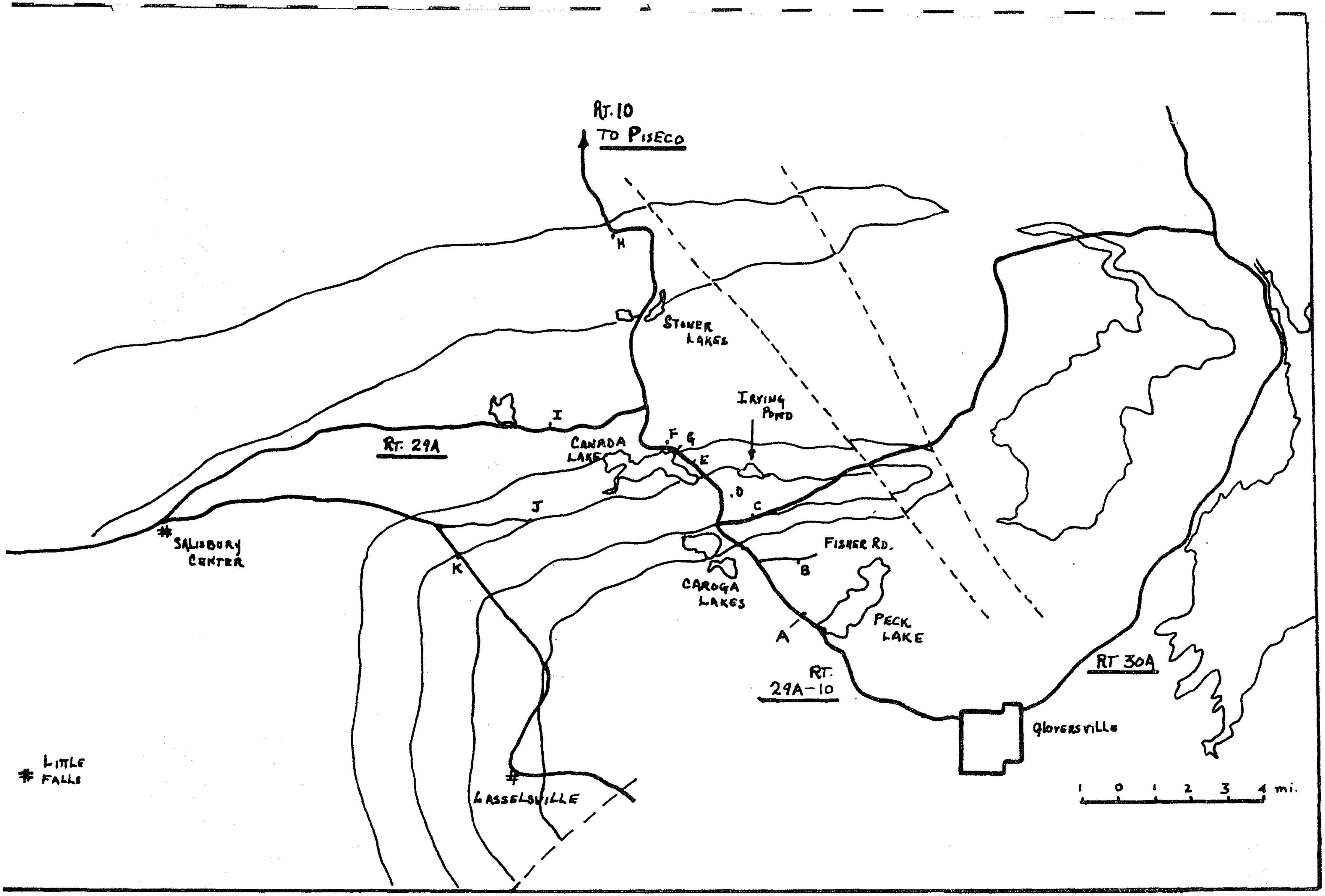
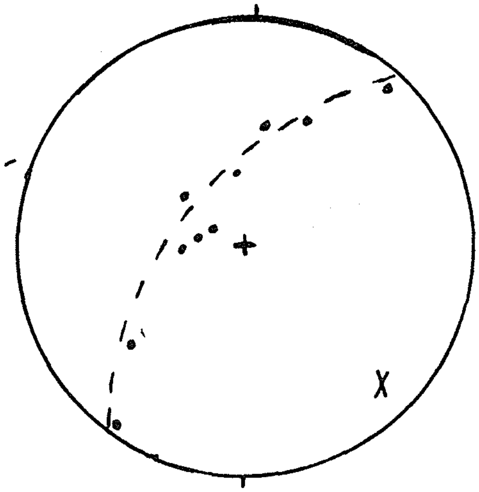


Fig. 8. Location of stops in Road Log. A complete log with mileage will be found in NEIGC Guidebook for 1969.

STOP A The Peck Lake Formation

Roadcut of garnetiferous quartz-biotite-oligoclase gneiss. Minor amphibolite and calc-silicate bands. These gneisses are the dominant lithology of the Peck Lake formation which is exposed here on the south limb of the F_1 fold. Needles of sillimanite and/or fibrolite can be seen in some specimens.

In a little overhang near ground level there is a minor fold with an axial trend of N50W, plunging 15 SE. Axial plane cleavage and lineation cut across the compositional layering of this fold. It appears that such folding and cleavage are prevalent throughout outcrops of Peck Lake gneiss. Often these features are obscurred by poorly developed compositional banding. Polishing and staining reveal both folds and cleavage in many specimens and, therefore, suggest that their abundance vastly exceeds their recognition.



The entire outcrop is a "large minor" fold. Note the change of dip from one end to the other. The accompanying equal area plot is for poles of foliation in this roadcut and in outcrops directly NE of the road.

The lithologies and structures represented in this cut are typical of the Peck Lake formation. It is the structural complexities that make the Peck Lake formation difficult to work with and subdivide. It is, by far, the least competent unit in the sequence.

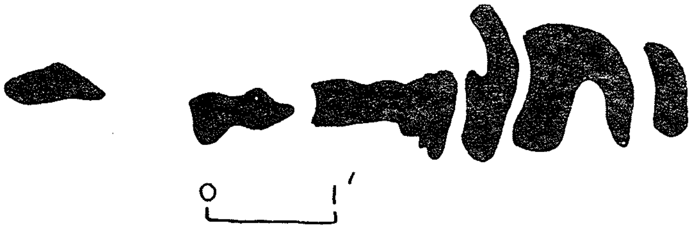
STOP B Royal Mt. pyroxene-quartz-plagioclase gneiss

Just to the south of the road are good exposures of the Royal Mt. pyroxene-quartz-plagioclase gneiss. This locality is near the outer contact of the Royal Mt. unit, and the latter displays its fairly well banded border phase. Most of the banding is due to this amphibolites. Also present are bands and veins of granite and/or pegmatite.

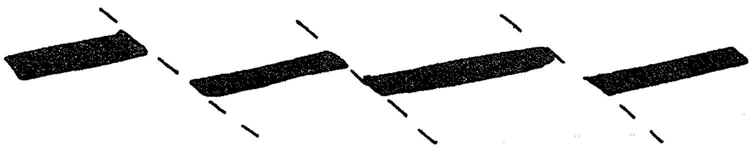
STOP B (continued)

These exposures show a number of interesting features. In the first place boudinage is developed in most of the amphibolite bands. Some of the boudinage represents rather classical examples while other instances seem unusual. Consider the example exposed at the base of the large boulder just inside the woods. This is shown in the accompanying diagram.

Another example is displayed in the ledge at the top of the hill.



Neither of these features replicates the conventional concept of boudinage. Indeed, they give the appearance of igneous disruption. However, the igneous hypothesis is superfluous for these outcrops contain a good many examples of bona fide boudinage which coexist with, and are part of the systems shown above. Furthermore, the igneous hypothesis lacks merit based on the lack of disruption of some extremely thin amphibolite bands. Of course, the country rock may have been near, or at, temperatures of partial fusion. It seems more plausible that cases of peculiar looking boudinage may be of the "chocolate tablet" type (Ramsey, "Folding and Fracturing of Rocks", p. 113). This suggestion gains credence from the observation that some boudins appear to lack extension into a third dimension. In addition to this, some examples of boudinaged folds are present (Ramsey, ibid, fig. 3-59, p. 116). Still another type of boudinage results from systematic offset along shears:



In most cases the shear fractures are barely visible in the country rock. This implies that the quartz-plagioclase gneiss was in a mobile state at the time of shearing.

At the north end of the outcrop, an example of an F_1 recumbent fold is observed. The fold axis trends N40 - 50W and plunges gently south. A set of drag folds is developed on the F_1 fold.

STOP C Contact between Canada Lake and Irving Pond formations

To the south of the road are several small ledges of Canada Lake charnockitic gneisses and associated quartzo-feldspathic rocks. These exhibit the typical pinkish color of weathered outcrops in the woods. Fresh surfaces are generally dark in color.

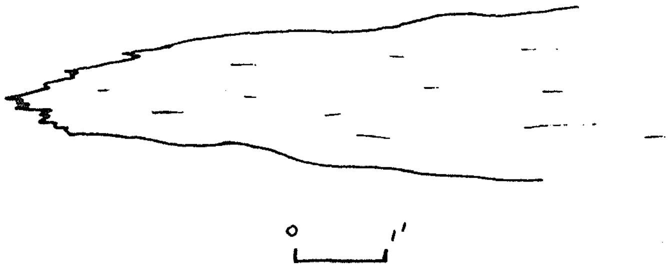
Proceed north along the old logging road to the north of the paved highway. At the intersection of it with a second logging road (grass covered) enter the woods. Here there are a number of small outcrops of quartzites and quartzo-feldspathic gneisses of the Irving Pond fm.. The contact between the two formations runs approximately along the paved road.

Immediately to the south of the small cliffs discussed above are quartzites and leucogneisses of the Green Lake formation.

STOP D Irving Pond fm. at the Core of Canada Lake Nappe

Parking area on west side of road. On the east side of the road, there is an old logging road that goes east for about ¼ mile. This road has been marked with tin can tops nailed to trees. At the eastern end of the road there is a tin can top with a square dug out around it. Upon seeing this mark, turn right and proceed directly up the hill.

(1) About 50' up on the hillside there occur good exposures of Irving Pond quartzite and feldspathic quartzite. Interbeeded with these are layers of calc-silicate granulites. In this outcrop the pyroxenitic layers are particularly marked. The largest band of calc-silicate runs about 2' above ground level. It strongly resembles a fold (see figure below). However, the feature is a boudin. This contention is supported by the fact that what appear to be drag folds at, and near, the nose of the pyroxenitic layer, have an orientation of N20E, 15 S, whereas tight minor folds in the outcrop trend N60W, 15 SE. The lineation trends approximately N60W, 15 S. It is possible

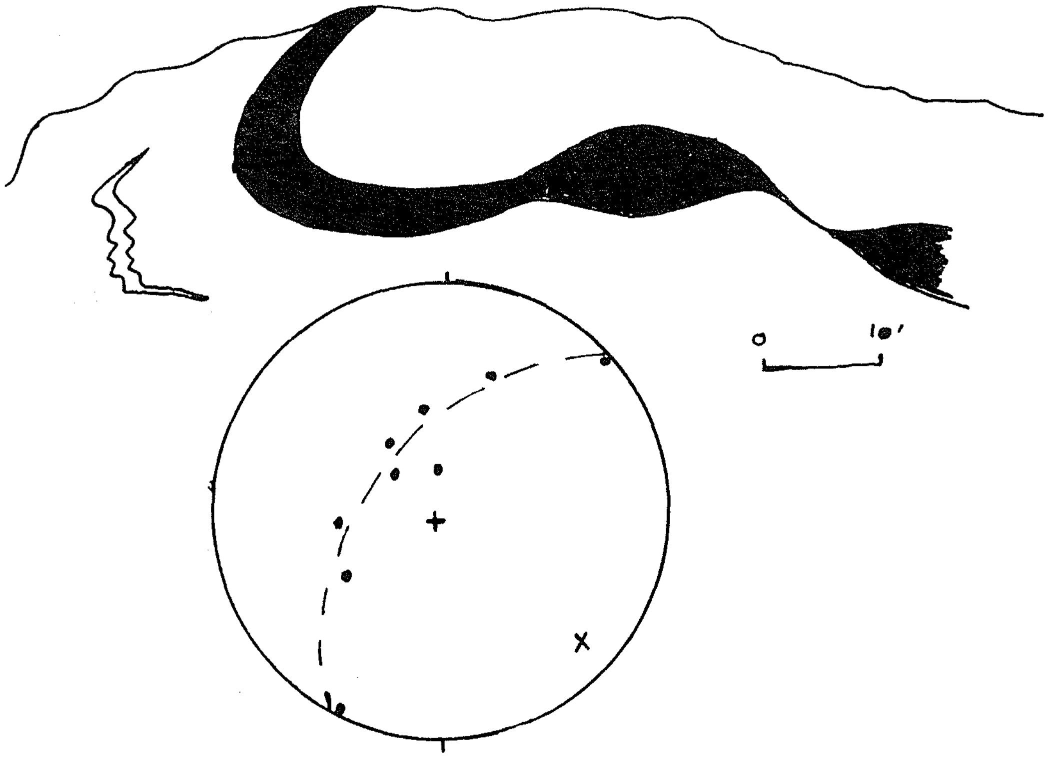


STOP D (continued)

to argue that this shows only that the pyroxenite represents a fortuitously F_0 fold. However, the evidence inveighs against this. At other places on the hillside there are features which are definitely pyroxenite boudins. The axes of these boudins trend NS to N20E and plunge down dip southward. A half a day on this hill provides strong evidence that what appear to be tight folds cored by pyroxenites are really elongate boudins.

(2) Proceed on up the hillside. Several minor folds are exposed. These have axes that range from EW to N30W. All Plunge gently (10° - 15°) to the south. All have axial planes within the plane of the foliation.

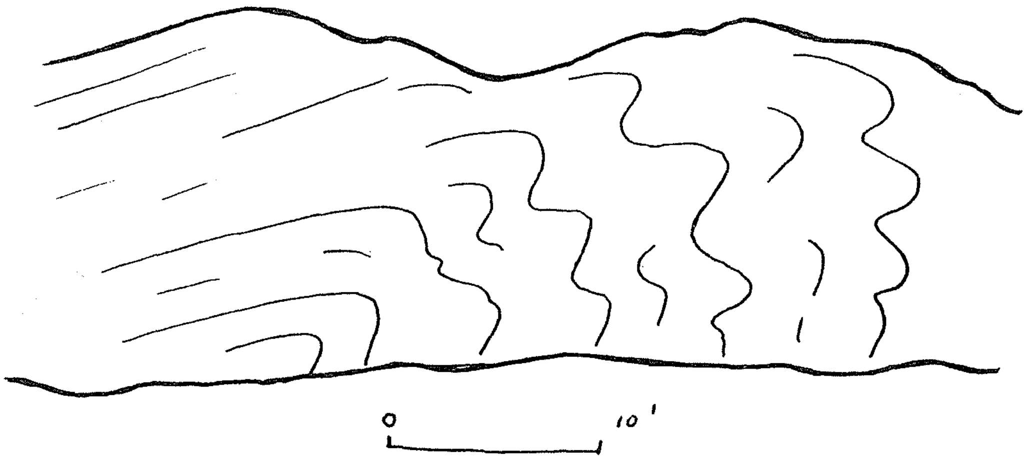
(3) Follow the trail markers to a well exposed EW ledge. Here there is exposed both boudinage and F_1 folding, marked by a large layer of calc-silicate. A sketch of these features is given below, and an equal area projection of the poles to foliation is also given.



(4) Exposed in the cliff face are several excellent boudins of pyroxenitic granulite. The boudin axes trend N20E and plunge 10 S. Note the marked similarity between these boudins and the feature at station 1.

STOP D (continued)

(5) Proceed down the hill and over a 20' cliff. In the cliff face one can see a portion of a large fold. Vertical dips trend N40W. Presumably these dips are associated with an F_1 fold.



(6) Follow the marked trail to a small ledge where two F_1 folds are exposed. These are typical examples of F_1 folding. Because of weathering, one can easily measure the axes as N50W, 20S.

Just a few feet father on is station (1). For those not desiring to make the above hike, there are good exposures of the Irving Pond formation a short distance northward along 29A-10. These show the gradation from pure quartzite into garnitiferous quartzo-feldspathic gneisses near the contact with charnockitic gneisses of the Canada Lake formation. This is the same contact seen at STOP C and at STOP J. Note the excellent development of minor folds with drag folds.

STOP E Canada Lake fm.

Large roadcuts in the Canada Lake formation expose typical examples of the charnockitic (mesoperthite gneisses) that comprise this thick and competent unit.

The rocks exposed here are good representatives of Adirondack "syenites" and "quartz-syenites". Not only is this genetic nomenclature misleading, but it is locally incorrect since the present rocks contain some 25-30% modal quartz (most of which is highly strung out).

Compositional layering is not particularly well developed in the Canada Lake charnockites and this observation is consistent with their proposed metavolcanic origin.

STOP E (continued)

Orthopyroxene is locally developed in the roadcuts.

Note the difference in appearance of fresh and weathered surfaces. Also note the strong resemblance of the charnockitic gneisses to the pyroxene-quartz-plagioclase gneisses of the Royal Mt. unit. It is often necessary to employ staining in order to properly distinguish these two lithologies. In stained specimens a hand lens examination often reveals the perthitic nature of the feldspars.

STOP F Royal Mt. gneiss on north limb of F_1

Across from the Canada Lake Store and Post Office, there is a large ledge of Royal Mt. pyroxene quartz-plagioclase gneiss. As at STOP C, these gneisses tend to be homogeneous except for bands of amphibolite. Unlike STOP C, the evidence here favors igneous disruption of the amphibolite bands. The most satisfactory way of explaining the features seen at road level is by partial fusion of the pyroxene-quartz-plagioclase host rock.

STOP G Green Lake fm.

Proceed east along the road between Green Lake (N) and Canada Lake (S). Looking north, note the rugged mountain known as Camelhump. The break between the two humps marks the contact between the Royal Mt. quartz-plagioclase gneiss and the quartz-biotite-oligoclase gneisses of the 29A formation. Green Lake itself straddles the contact between the Royal Mt. gneiss and a narrow band of Green Lake quartzites. Rising above the east shore of Green Lake is a steep hillside of Canada Lake charnockitic gneiss.

At the east end of Green Lake, enter the woods and observe a well exposed section of Green Lake quartzites. Proceeding up the hillside, note the well exposed contact between the microperthite gneiss and the quartzites.

Near the base of the hillside is a well exposed F_1 minor fold whose axial elements are clearly developed on the weathered quartzite band. This fold has an axial trend of N40W, 10 S. Farther up the hillside, folds in the charnockite have axial trends N50E, 10 S, etc.. It is believed that these aberrant orientations are due to the influence of a small metagabbro intrusion that defines the peak of Green Lake Mountain.

STOP H Rooster Hill metacrystic gneiss

On either side of the road, new roadcuts provide good examples of fresh and weathered surfaces of Rooster Hill megacrystic gneiss. The megacrysts consist of K-feldspar which occurs most generally as microperthite; however, orthoclase (cryptoperthite?) and microcline are also present. Microcline is best developed where shearing is most intense. Plagioclase is restricted to the groundmass where it

STOP H (continued)

occurs as single crystals and as mortar aggregates. Compositionally, the plagioclase ranges around calcic oligoclase. Quartz content ranges from 20-30%. This latter parameter places the rock out of the syenite or quartz-syenite clan to which others have assigned it (Cannon, Miller, & Nelson). Mafics include biotite, hornblende, and orthopyroxene (variable occurrence). Garnet is developed locally. Myrmekite is common. The rock can be assigned a position in the charnockite family.

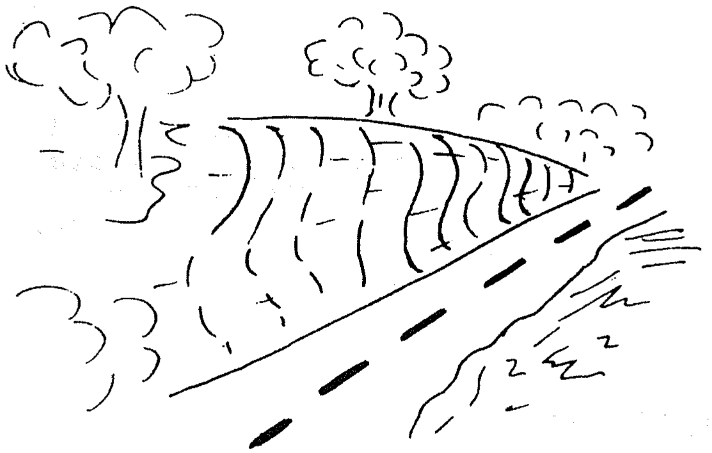
An interesting feature is the variable appearance of the gneiss on fresh and on weathered surfaces. Furthermore, the color of the megacrysts may be either dark green, pink, or white.

Throughout most of its occurrence, the megacrystic unit remains relatively homogeneous and unbanded. Foliation is usually defined by planes of fracture and mineral flattening and orientation. Locally, banding increases where bands of Peck Lake gneiss occur. This is especially true near the outer contacts. Banding also occurs in the interior, but it is rare.

STOP I Peck Lake fm. on north limb of F_1

Large roadcuts of biotite-quartz-oligoclase gneiss of the 29A formation. A cursory examination shows that these gneisses are lithologically identical to those seen at stop B. Note the leucocratic character of the apparently anatectic material. Also note the garnets in some of it.

Beginning at the east end of the outcrop, the dips change in a fashion that indicate a recumbent Z-shaped fold whose axis trends N70W and which plunges gently (5^0) to the east. Of particular interest is the degree to which lineation and rodding are developed in the outcrop. On some surfaces the foliation is almost obliterated and the texture approaches that of a pencil gneiss. Good examples of F_1 minor folds are present.



Sketch showing
Z shaped fold
(sinistral fold).

STOP J Northern Contact of Irving Pond and Canada Lake fms.

Stewart's Landing. Along the shores of Sprite Creek are exposures of Irving Pond quartzites and feldspathic quartzites. In this area quartzo-feldspathic and pelitic layers increase in abundance because of proximity to the contact with the Canada Lake formation charnockitic gneisses. More typical of the Irving Pond unit are the white and rose quartzites in the side of the stream bank. West of the bridge, the percentage of quartzite increases markedly.

Just below the dam, there is a beautifully exposed Z-fold. This fold is rather open, and is thought to represent a minor F_2 fold. Drag folds in the outcrop reflect the major fold orientation. Note the development of axial plane cleavage in the fold.

On the west shore just above the dam, clean quartzites contact garnetiferous and biotite rich layers that occur near the outer contacts of the Irving Pond formation. This contact is exposed alongside the dirt road heading uphill. This exposure demonstrates the variable response of different competencies to a given force field.

STOP K F_1 folded by F_2. Axial region of F_2

In Sprite Creek below highway bridge. Exposed along the creek are boulders and outcrops of Canada Lake microperthite and charnockitic gneisses. The dark layers are pyrobolic. Both ortho and clinopyroxene occur in the charnockites.

The point of major interest at this stop is the excellent exposure of F_1 folds folded along F_2 axes. Note the presence of shear slippage along one of the F_2 axes. Note also that the F_1 and F_2 axes appear to be parallel to subparallel. Lineation is strongly developed.