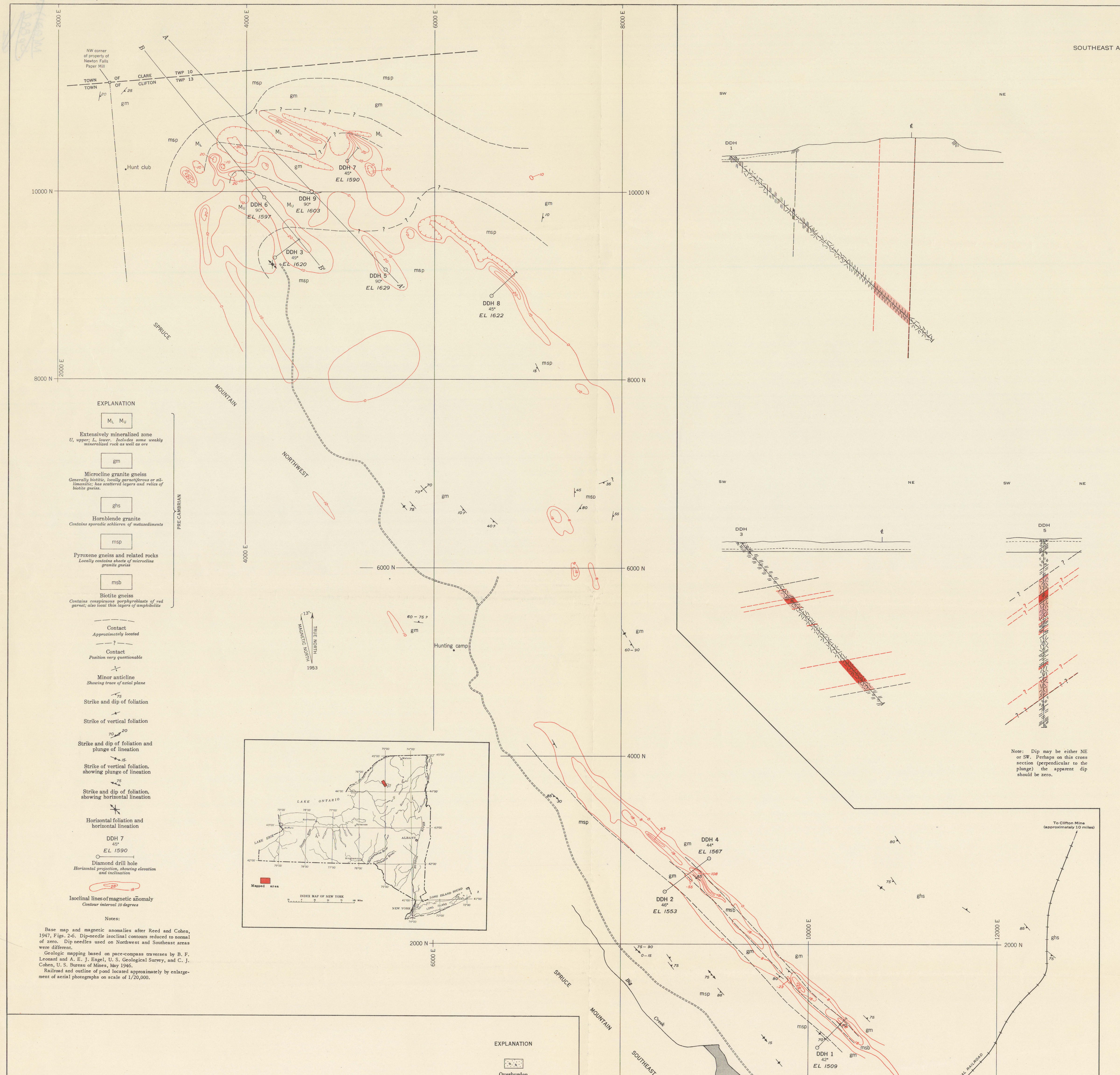

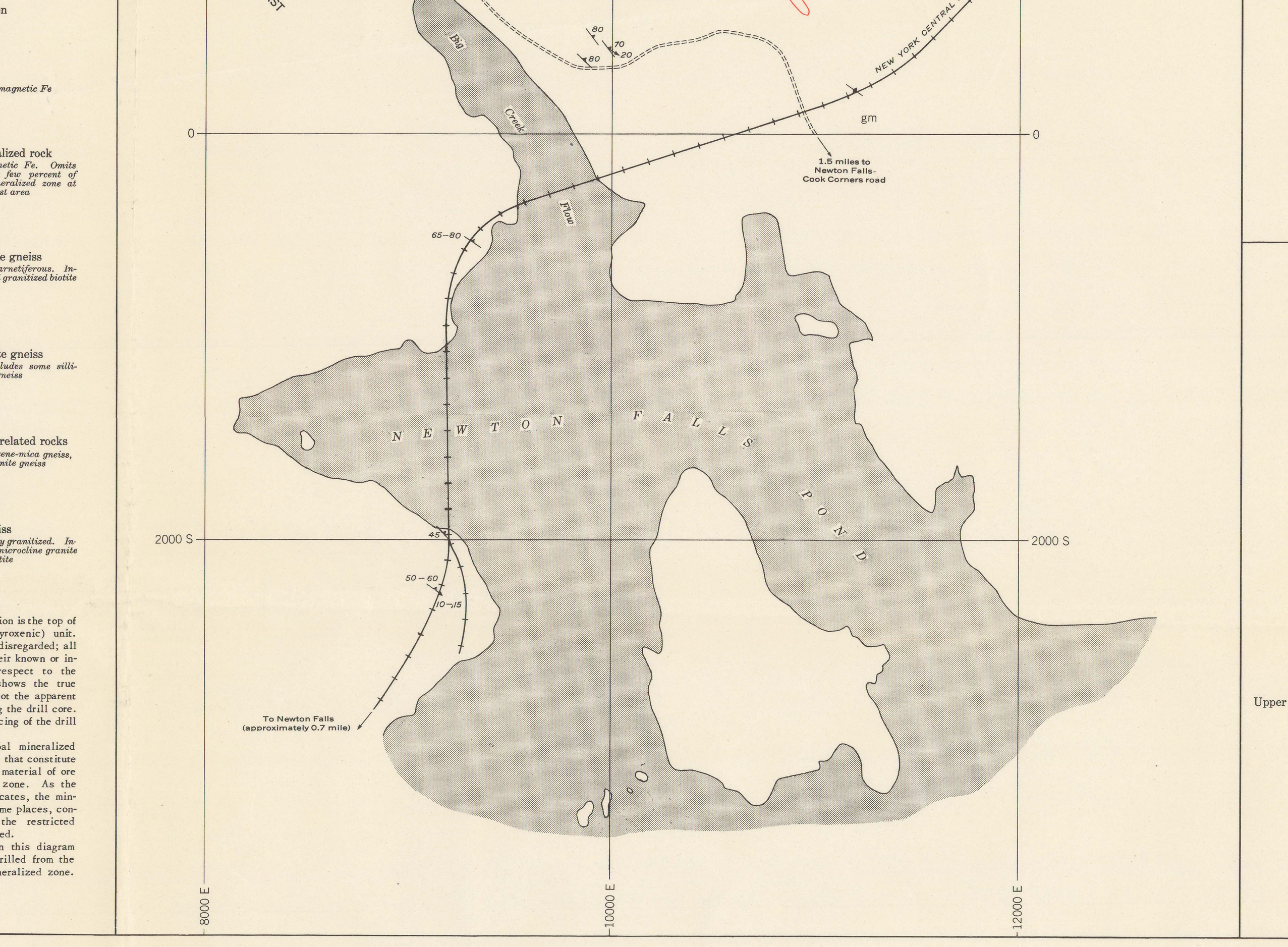

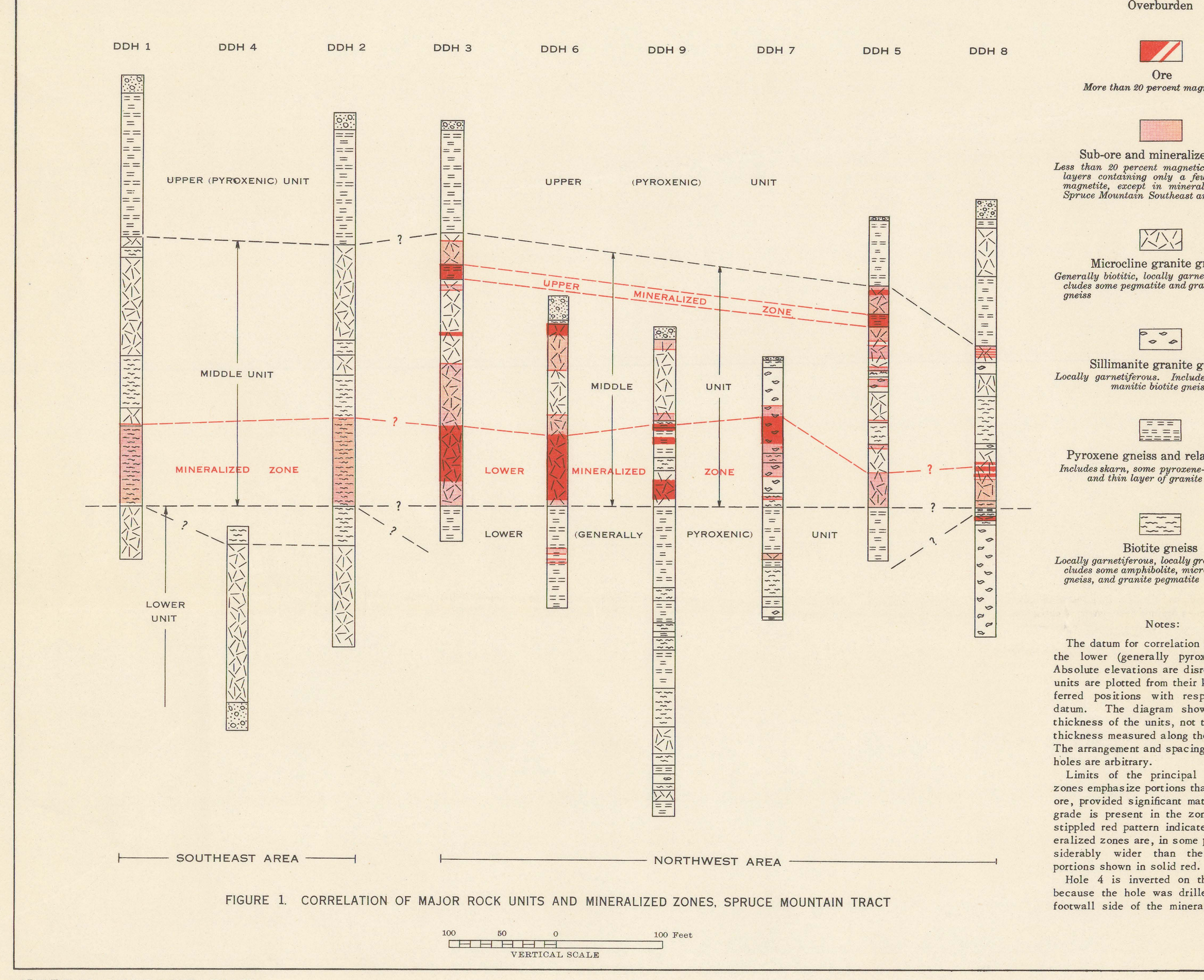

FIGURE 1. CORRELATION OF MAJOR ROCK UNITS AND MINERALIZED ZONES, SPRUCE MOUNTAIN TRACT

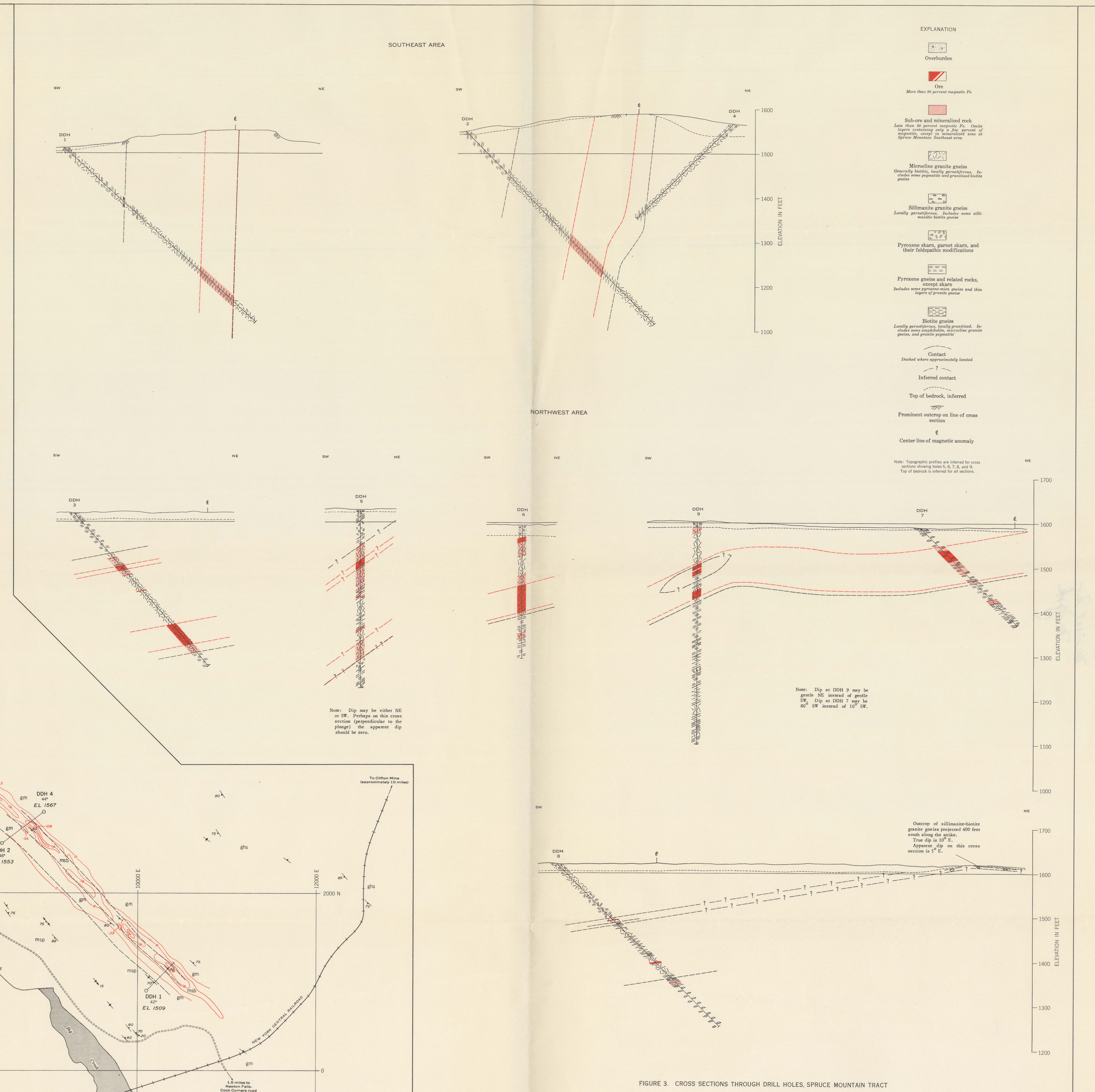

FIGURE 3. CROSS SECTIONS THROUGH DRILL HOLES, SPRUCE MOUNTAIN TRACT

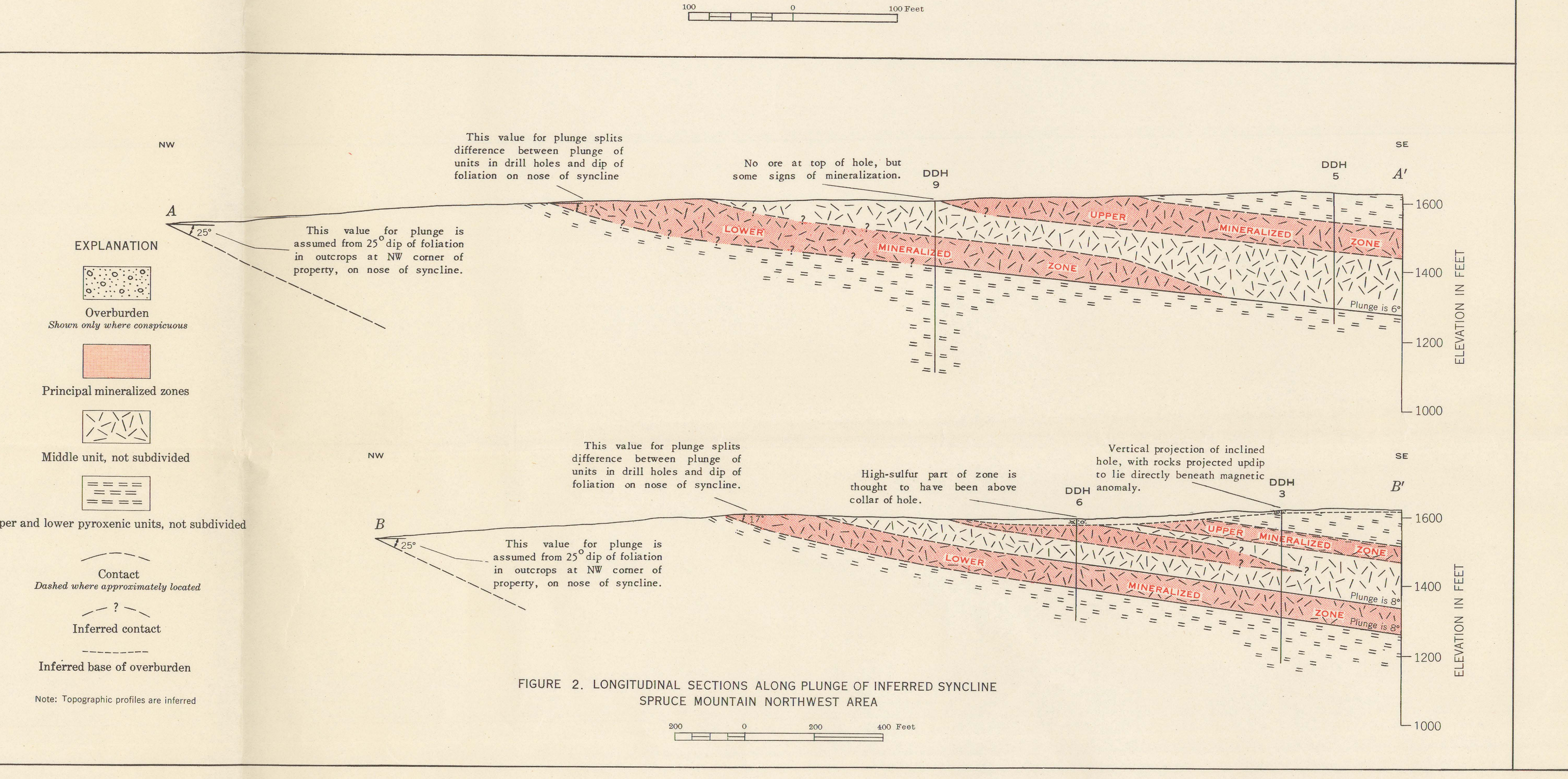

FIGURE 2. LONGITUDINAL SECTIONS ALONG PLUNGE OF INFERRED SYNCLINE SPRUCE MOUNTAIN NORTHWEST AREA

SPRUCE MOUNTAIN TRACT, ST. LAWRENCE COUNTY, NEW YORK

By B. F. Leonard

INTRODUCTION

The Spruce Mountain tract, north and northeast of Newton Falls, St. Lawrence County, N. Y., consists of two magnetically anomalous areas separated by a mile of weak magnetic indications. The tract is interpreted as a syncline of metasediments and granite gneiss sheets plunging gently southeast. The exact structural relations of the ends of the tract are uncertain. Ore is restricted to the Northwest area, which may have a reserve of 8 million tons or more of ore averaging 24 to 25 percent magnetic Fe. Magnetite has replaced two zones within a continuous sheet of microcline granite gneiss. The upper, pyritic, zone is not included in the tonnage estimate. The Southeast area has no direct economic interest.

Magnetite deposits of the St. Lawrence County district have been discussed briefly by Buddington and Leonard (1944, 1945), who interpret them as high-temperature replacement deposits genetically related to younger granite. Their preliminary maps give the geologic setting of the Spruce Mountain area, but structural details shown for that area have since been revised. Reed and Cohen (1947) have summarized the exploratory work of the U. S. Bureau of Mines. Members of the U. S. Geological Survey logged drill core and mapped the area. Most of the mapping was done by B. F. Leonard and A. E. J. Engel in the spring of 1946. Some structural observations made by C. J. Cohen, formerly an engineer of the Bureau of Mines, have been incorporated in the geologic map. The relation of the Spruce Mountain area to the regional magnetic picture may be seen on the aeromagnetic map of Balsley et al. (1950). The origin of the microcline granite, a general problem related to the genesis of the magnetite deposits of the district, has been treated at length by Buddington (1948).

LOCATION, OWNERSHIP, AND ACCESS

The Spruce Mountain group of anomalies may be divided for convenience into two principal areas: Spruce Mountain Northwest and Spruce Mountain Southeast. Both are on land owned by the Newton Falls Paper Mill and take their name from Spruce Mountain,[1] an elongate ridge 1.8 miles north-northeast of Newton Falls village, n.w.r.,[2] Cranberry Lake quadrangle.

Spruce Mountain Northwest is the area of commercial interest. It lies on the intersection of the Russell, Stark, Cranberry Lake, and Oswegatchie quadrangles, principally on the first two, with its center about 3 miles north-northwest of Newton Falls village. A bulldozed access road extends northwest to it from Jarvis Bridge, n.w.r., Cranberry Lake quadrangle, crossing the Clifton extension of the New York Central Railroad at a point 1.3 miles northeast of Newton Falls village. An old hunters' trail from the neighborhood of Browns Bridge, n.e.r., Oswegatchie quadrangle, runs northeast to the area.

Spruce Mountain Southeast anomaly, n.w.r., Cranberry Lake quadrangle, centers 1.5 miles north-northeast of Newton Falls village. It lies southwest of Spruce Mountain, between the ridge and Big Creek. The bulldozed access road from Jarvis Bridge runs past the anomaly.

DISCOVERY AND EXPLORATION

The anomalies were discovered by A. M. Ross, Woods Superintendent of the Newton Falls Paper Mill. Ross made reconnaissance dip-needle surveys of both areas in 1943, 1944, and 1945 (personal communication, 1949). The U. S. Bureau of Mines made detailed dip-needle surveys of the anomalies during 1944, 1945, and 1946 and drilled 10 holes on the property in 1946. Both groups of anomalies were partly explored by this diamond drilling, and a sizable deposit of low-grade ore was found at Spruce Mountain Northwest. The work of the Bureau of Mines have been summarized by Reed and Cohen (1947, pp. 6-7, 17-25).

MAGNETIC ANOMALIES AND FLOAT ORE

The Spruce Mountain Southeast anomaly begins 500 feet north of the railroad and runs northwest for 4800 feet within the +8° isoclinal (see map). It is a simple strip or belt averaging 100 to 150 feet in width and enclosing several peaks of moderate to high intensity. Float of low-grade ore was found about 1200 feet northwest of hole 1. Presumably this float was derived from the Spruce Mountain Northwest area, as the four outcrops along the Southeast anomaly show only a little disseminated magnetite in granitic garnet-biotite gneiss. Elsewhere along the ridge on which the anomaly lies, the overburden is probably very thin. The fact that the magnetite-bearing gneiss is at or very close to the surface presumably accounts for the relative strength of the anomaly.

The Spruce Mountain Northwest anomaly is a U-shaped group of anomalies with a total length (following around the U) of 7000 feet. The individual members of the group are disconnected strips of low positive anomalies with two prominent negatives along the northeast half. The U, which opens toward the southeast, is divided almost symmetrically by a 1500-foot strip or lobe of readings within the +10° isoclinal. A shorter lobe, 1000 feet east of the first, is 700 feet long within the +10° isoclinal. The ore that causes the Spruce Mountain Northwest anomaly does not crop out.

If the Spruce Mountain Southeast anomaly were projected northwest, it would join the southwest limb of the U-shaped Spruce Mountain Northwest anomaly to form a fishhook-shaped structure. However, the two anomalous areas are now separated by 5000 feet of neutral or weak magnetic readings. Toward the southeast, the Spruce Mountain Southeast anomaly is almost continuous with the northwest end of the Jarvis Bridge anomaly.

ROCKS

Three main rock units can be distinguished in the Spruce Mountain area and used for correlation. These units are composite, comprising a number of rock types. Attempts to correlate individual members of the units, except ore zones, succeed only in obscuring a relation that is otherwise reasonably clear. For that reason, an admittedly subjective presentation is adopted here. Exceptions and other interpretations will be noted below.

All the rocks are of old pre-Cambrian age. The metasedimentary rocks, including such general types as pyroxene gneiss, skarn, biotite gneiss, and amphibolite, belong to the Grenville series. The granitic rocks, chiefly microcline granite gneiss, are of complex origin (Buddington, 1948).

Upper (pyroxenic) unit. The uppermost unit exposed at the surface or cut in drill holes may be termed "pyroxene gneiss," a catchall designation for interlayered pyroxene-quartz-feldspar gneiss, pyroxenic migmatites, and pyroxene skarn. The proportion of these types varies widely. In holes 1 and 2, considerable brown mica is present in pyroxene-mica gneiss or in biotite gneiss. Dark-brown garnet is present sporadically in some cores from the Northwest area. Scapolite occurs locally. A sheet of slightly pyroxenic or biotitic microcline granite gneiss, 45 feet thick, is present in the unit at hole 8. Some migmatitic amphibolite is present in holes from the Southeast area. Holes 1, 2, 3, 5, and 8 cut part of the upper (pyroxenic) unit, whose thickness is unknown but may be 800 feet or more.

Middle unit. The middle unit, 150 to 255 feet thick, comprises microcline granite gneiss and biotite gneiss, with their variants. Pyroxene gneiss is present locally. In detail, the unit is a most heterogeneous one, owing to differences in quantity of injected granite magma, degree of granitization, and effect of mineralization. This unit contains the ore, a description of which is given in a separate section.

The rock type broadly termed "microcline granite gneiss" is pink, white, gray, or greenish, generally fine-grained but commonly medium and locally coarse. Its foliation may be well or poorly marked. In some places, a foliation is given by thin seams of granite pegmatite. The rock ranges in composition from syenite to quartz-rich granite, though "granite" is appropriate for the bulk of it. In addition to quartz and microcline, biotite is usually present. It is very frequently accompanied by red garnet--less often by sillimanite. Garnet and sillimanite also occur singly or together without biotite; or magnetite may be the only visible accessory. Distribution of the sillimanite is discussed below. A striking feature of some of the granite gneiss is the presence of thin laminae (one to several millimeters thick) of magnetite and red garnet granules. Some of this particular garnet may be spessartite.

The biotite gneiss is gray to slightly pinkish, fine-grained, and locally migmatitic. A number of layers are garnetiferous, and large porphyroblasts of red garnet are characteristic of the weakly mineralized zone at Spruce Mountain Southeast. Rarely, the rock is slightly hornblendic or pyroxenic. Certain zones are sillimanitic; these are interlayered with quartz-rich sillimanite-muscovite gneiss or are adjacent to sillimanite-microcline granite gneiss. By an increase in the amount of microcline, shown by the pinker color of the rock, the biotite gneiss loses its character and comes to resemble the microcline granite already described.

Pyroxene gneiss appears at two horizons within the unit. The upper layer, 13 feet thick, was cut by holes 3 and 5 at a distance of 26 to 30 feet below the top of the middle unit. Except for hole 8, where the layer is missing, the other holes in the Northwest area entered the unit below this layer. Little of the original character of the gneiss is preserved, for it has been replaced by magnetite, pyrite, chlorite, epidote, and apatite to yield a highly pyritic low-grade ore. The second pyroxene gneiss layer is a lens cut only by hole 9. It occurs within the principal ore zone, centered about 60 feet above the bottom of the unit, and has a total thickness of 28 feet. This pyroxene gneiss is barren, weakly mineralized, or ore-bearing. Part of it is metasedimentary, with thin skarn laminae; part of it represents a contaminated granite.

Lower (generally pyroxenic) unit. The lowermost unit, like the uppermost, may be termed "pyroxene gneiss," as that rock type is the one most frequently encountered, if not the most abundant. Also present are pyroxene skarn, feldspathic pyroxene skarn, garnet skarn (hole 5), and sporadic layers of "clean" granite and granite gneiss contaminated with pyroxene or hornblende. The pyroxene gneiss itself is fine-to medium-grained, foliated or laminated, commonly interlayered with skarn, and locally migmatitic. One or two zones of sub-ore are present in holes 3 and 6.

The maximum thickness of the lower unit is more than 300 feet. However, most holes cut only the top 50 or 100 feet. If the correlation discussed below is correct, an upper pyroxenic zone, 45 to 85 feet thick, thins to 5 feet at hole 8 and is absent at Spruce Mountain Southeast (see fig. 1). As this pyroxenic zone thins, there is a corresponding thickening of the underlying zones comprising garnet-biotite gneiss, biotite gneiss, biotitic granite gneiss (locally garnetiferous), and sillimanite granite gneiss. At hole 9, these zones are enclosed within the pyroxene gneiss unit. Perhaps the lower pyroxenic rocks also lens out on the northeast limb of the syncline. At Spruce Mountain Southeast, no trace of them was found at the surface or in drill cores.

Finally, there are within the rocks of the several units veins of granite pegmatite, syenite pegmatite, and quartz. In places, these veins carry small amounts of magnetite or sulfides, or both. At a number of places, the core shows small vugs, a millimeter or so in diameter, lined with pumpellyite, chlorite, pyrite, or chabazite (?). Elsewhere, thin veinlets of calcite, calcite-epidote, or chlorite-pyrite have been observed. The vugs and their coating, and most or all of the vein material, have formed from hydrothermal solutions. Only in the uppermost few feet of drill core and along a few micaceous zones is there any evidence of supergene alteration.

Correlation of major units. The main units described above can, with a few exceptions, be correlated with assurance from hole to hole in the Northwest area. Similar units are present in the Southeast area, but their equivalence to those in the Northwest area is open to doubt. The units recognized in both areas have been correlated as shown in fig. 1, with the understanding that the correlation is only tentative.

The datum selected for correlation of the holes at Spruce Mountain Northwest is the top of the lower (generally pyroxenic) unit; i.e., the first part of the pyroxene gneiss unit appearing *below* the main ore-bearing zone. This horizon is readily identified in all holes except hole 8. There the writer has assumed that the horizon is the top of 5 feet of garnet-biotite-pyroxene-feldspar gneiss with thin layers of garnet skarn and pyroxene skarn, overlying more than 100 feet of sillimanite granite gneiss. The only reason for this assumption is that one principal mineralized zone is present in hole 8, and rocks originally of calcareous composition occur at and near the base of it, as in other holes of the Northwest area.

Other ways of correlating hole 8 deserve mention:

1. The hole may have entered bedrock below the top of the horizon used for a datum in the other holes. One would, in effect, assume that the main ore zone of the other holes had been eroded at hole 8. Then the main mineralized zone of hole 8 represents material stratigraphically 230 feet or more below the bottom of the principal mineralized zone of the other holes.
2. The pyroxene gneiss stratigraphically 54 feet below the bedrock surface in hole 8 may correspond to the datum. The granite gneiss just above it should correspond to the principal mineralized zone, but it is barren and perhaps greatly thinned. The main mineralized zone of hole 8 represents material stratigraphically 175 feet below the bottom of the principal mineralized zone of the other holes.
3. The thick zone of "hanging-wall pyroxene gneiss" (upper, pyroxenic, unit) in hole 8 is just that. The 5-foot layer of garnet-biotite-pyroxene-feldspar gneiss below the main mineralized zone is an incidental feature: the true "footwall pyroxene gneiss" (lower, generally pyroxenic, unit) lies somewhere below the bottom of hole 8. This means that the granite gneiss and biotite gneiss of the middle unit have been thickened enormously. The main mineralized zone of hole 8 may or may not correspond to the main zone cut in the other holes.

Other horizons that might have been used for correlation are the bottom of the upper (pyroxenic) unit and the top or bottom of the principal mineralized zone. The first would be extremely useful in guiding depth of drilling to ore. Unfortunately, only three out of six holes in the Northwest area entered bedrock *above* this horizon. Owing to the replacement origin of the ore, the position of the top of the principal mineralized zone varies greatly with respect to the recognizable rock units, and for this reason it has not been used as a datum. Its use would, of course, emphasize the possible equivalence of units in the Northwest and Southeast areas. The bottom of the principal mineralized zone is almost the same horizon as the top of the lower (generally pyroxenic) unit.

The correlation adopted in this report suggests the following features:

1. Two significant mineralized zones are generally recognizable: a subordinate one in the upper part of the middle unit, and the principal one in the lower part of the same unit. (The mineralized zones are not everywhere of sufficient grade or thickness to constitute ore, but they contain conspicuously more magnetite than the rest of the middle unit.)
2. There is a progressive eastward thinning (holes 3, 5, 8) of the rocks between the upper and lower pyroxenic units. The thickness of the middle unit decreases from 256 to 144 feet. Moreover, the proportion of granite to metasediments decreases from west to east:

Hole 3 shows 70 percent granite.
Hole 5 shows 60 percent granite.
Hole 8 shows 45 percent granite.

Also, the metasediments of the western part of the unit are more granitized than their eastern counterparts. These observations are consistent with the concept that more granite magma was injected in the western part.

3. The composition of the footwall rocks changes northeastward, with more (originally) argillaceous material interlayered with the (originally) calcareous material in the upper part of the unit.
4. Southeastward along the northeast limb of the syncline, the "pyroxene gneiss" part of the footwall unit thins out almost completely, leaving only a few feet in hole 8.
5. If hole 8 is properly correlated, the site of granitization has become inverted at that place, with more metasedimentary biotitic material than usual preserved above the datum and less below.

The stratigraphic sequence at Spruce Mountain Southeast is similar to that found in the Northwest area, except that there is no "pyroxene gneiss" unit beneath the mineralized zone. Instead, only biotite granite gneiss, locally garnetiferous, is present. It is possible that the "pyroxene gneiss" has pinched out or has been squeezed out, just as it apparently thinned greatly along the northeast limb at Spruce Mountain Northwest. Because we have no surface or subsurface data on the geology of the area between the Northwest and Southeast areas, we can only infer that the upper (pyroxenic) units, the intermediate rocks, and the principal mineralized zones are equivalent in the two areas. Support for this inference is given by the remarkably close agreement between the thickness of rocks between the bottom of the upper (pyroxenic) unit and the bottom of the principal mineralized zone, and the thickness of the principal mineralized zones, in holes 1 and 2 (Southeast area) and hole 3 (Northwest area).

[1]This Spruce Mountain, locally known as Big Creek Mountain (Ross, personal communication), is not to be confused with Spruce Mountain, s.c.r., Stark quadrangle, near the Deerlick Rapids and Wolf Hole anomalies.

[2]This and similar abbreviations are used throughout the report to designate rectangles or ninths of quadrangles. Thus n.w.r. stands for northwest rectangle, w.c.r. for west-central rectangle, c.r. for central rectangle, s.w.r. for southwest rectangle, and the like.

STRUCTURE

The tract as a whole constitutes a syncline of metasediments and granite gneiss, plunging gently southeast from a culmination north of the northwest corner of the property. The syncline is flanked by medium-grained granite or granite gneiss. The Spruce Mountain Northwest area contains the nose and parts of both limbs of the syncline where it is relatively open. The structure is outlined by the curving pattern of the magnetic anomalies. The Spruce Mountain Southeast area probably represents the limb of the same syncline, at this latitude tightly and isoclinally folded and dipping steeply southwestward. Though the Southeast segment can be projected through a swamp to meet the southwest limb of the Northwest segment, the relation of the two areas is still uncertain. If, as it appears, Spruce Mountain Southeast corresponds to the southwest limb of an appressed syncline, where is the northeast limb? Neither outcrops nor float of metasediments could be found for 2000 feet northeast of the Southeast belt.[3] Perhaps the northeast limb has been severed during deformation, or cut out by granite. If the southeast belt corresponds to the northeast limb of the appressed syncline, the only place for the missing southwest limb is in the bed of Big Creek Flow: the rocks farther southwest are granites. If this is so, the fold axis must have been offset between Spruce Mountain Northwest and Spruce Mountain Southeast. Such an offset might be explained by transverse faulting (for which there is no evidence in the immediate area), or by very tight folding. Prospecting for the missing limb would be desirable if there were some assurance of finding ore in it. However, the fishhook pattern of magnetite deposits is so well established, and the missing limb so elusive, that the problem is of interest for its bearing on the structure of the known bodies at Spruce Mountain, rather than for the discovery of new deposits.

Spruce Mountain Northwest. The U-shape of the Spruce Mountain Northwest anomaly reflects a syncline, plunging gently southeast, whose nose fits neatly into the northwest corner of the Newton Falls Paper Mill property. Foliation in outcrops near the corner post strikes NNE. to NE. and dips 20-25° SE., suggesting that the axis plunges 25° SE. Mineral lineation in an outcrop near the collar of hole 3 trends S. 55° E., parallel to the fold axis, and is horizontal. The apparent plunge of recognizable units between holes 6 and 3 is 8° to 8½° SE; between holes 9 and 5 it is 6½° to 10½° SE. Thus the inferred plunge of the major synclinal axis is about 8° to 10° SE., steepening toward the nose (see fig. 2). There are no outcrops or drill holes along the southwest limb; hence the amount of dip of the limb is unknown. The northeast limb dips either gently or steeply southwest (see discussion below). Drag folds with an amplitude of tens or a hundred feet may exist on these limbs. The dip in the axial zone is gently rolling but essentially horizontal. One may expect that the axes of these gentle warps will parallel the major synclinal axis in trend and perhaps in plunge. The attitude of the axial plane is unknown; that plane may be vertical, or it may dip steeply southwest.

Spruce Mountain Southeast. Outcrops are fairly abundant in the Southeast area. They indicate a series of steeply dipping minor isoclinal folds that undoubtedly reflect a major isoclinal fold, presumably a syncline. Many outcrops of pyroxenic migmatite show minor isoclinal folds, less than 2 feet in height and with limbs a few inches apart, having axes horizontal or plunging less than 30° SE. The strike of the foliation is quite uniformly N. 50°-55° W., but in cross section the dip is seen to wobble. Recorded dips range through vertical from about 60° SW. to 75° NE., and variations of that magnitude are often observed in one small outcrop. An average value is 80°-85° SW. This dip, moreover, is most commonly seen in individual exposures.

A belt of "pyroxene gneiss" about 1000 feet wide crops out along the northeast side of Big Creek, between the creek and the anomaly. The unit includes pyroxene-quartz-feldspar gneiss, pyroxenic migmatites, and subordinate pyroxene skarn. It is succeeded northeastward by a 700-foot-wide belt of granite gneiss and granitic garnet-biotite gneiss. Some of the granite gneiss has disseminated red garnets or carries granite pegmatite veins blotched with garnet. The magnetic anomaly lies along the middle of this belt. An area of drift, 1000 feet wide, separates these scattered outcrops from the hornblende granite mass to the northeast.

Structure at hole 8. The dip of the foliation at hole 8 must be either 10° SW. or 80° SW., according to alternative interpretations of the angle between foliation and core axis. The gentler dip agrees better with the very meager information now at hand, and for that reason it has been shown on the cross section, fig. 3. The pattern of the anomaly, however, suggests a steep dip rather than a gentle one. The outcrop nearest to hole 8 is folded pyroxene gneiss, 900 feet southeast of the hole, dipping about 15° SW. The collar of hole 8 is almost on the strike of this outcrop. A second outcrop, 1050 feet northeast of the hole, is sillimanite-biotite granite gneiss, striking north and dipping 10° E. This rock may correspond to some sillimanite-biotite granite gneiss just below the hanging-wall pyroxene gneiss and skarn of hole 8. If so, a minor anticlinal fold is present between the hole and the second outcrop.

Section through holes 7 and 9. Holes 7 and 9 provide the only section through the ore body (see fig. 3). This section is far from satisfactory, owing to the ambiguity in interpreting structure from the drill cores. The foliation at hole 9 dips about 25°, but whether NE. or SW. we do not know. Because the hole lies a bit northeast of the axis of the syncline, the southwest dip has been shown on the cross section, fig. 3. At hole 7, the dip must be southwest; but we do not know if it is 10° SW. or 80° SW. (A short hole--7A--, started at the site of hole 7 to check the amount of dip of the foliation, was lost at 12 feet. The core from hole 7A was useless--first, because part of it may have been from a boulder; second, because the foliation was indistinct. Trenching through the shallow overburden was not attempted.) The gentler dip has been selected for the cross section for two reasons:

1. Apparently, three horizons can be correlated between holes 9 and 7. They are the top of the mineralized zone, the bottom of the zone, and the top of the footwall pyroxene gneiss and related rocks. The structural picture is simpler if these horizons are joined by a gentle southwest dip.

2. Holes 7 and 8, at roughly the same elevation, appear to be on the strike of the foliation, roughly the same distance from the anomaly, and directed toward the same mineralized zone. An imaginary line connecting the points at which the two holes entered the mineralized zone plunges 4° SE., that is, it is essentially horizontal. This suggests, but does not prove, that the dip of the foliation is in effect the same at both holes. The weight of evidence favors a gentle southwest dip at hole 8, and therefore a gentle dip at hole 7 seems likely.

With one gentle and one steep dip, with steep dips at both holes, or even with gentle dips, there remains the possibility that a sharp but small isoclinal anticline exists between holes 9 and 7.

The correct interpretation of structure along this section is particularly important because of its bearing on additional exploratory drilling, both here and elsewhere in the syncline. If the dip is gentle at hole 9 and steep at hole 7, it is possible that the mineralized zone cut by hole 7 represents rocks that lie stratigraphically far below those carrying the ore in hole 9. To cut this lower zone, if it exists, hole 9 should have been drilled to a depth of 800 or 900 feet. The existence of two separate mineralized zones, 700 feet apart stratigraphically, seems doubtful in view of the reasonably good correlation of rock units and mineralized zones in the various drill holes. However, the possibility of finding such a lower zone should be borne in mind during further prospecting.

ORE

Occurrence. The ore at Spruce Mountain is confined to the Northwest area, where it occurs chiefly in a facies of the microcline granite gneiss of the middle unit. In addition, biotite gneiss, pyroxene-feldspar gneiss, and granitized or migmatized pyroxene skarn serve locally as the host for ore. The ore is generally disseminated or streaky in habit. With two exceptions (holes 5 and 8), the better-grade ore is in the lower half of the middle unit. With one exception (hole 6), the mineralization has avoided--or is weakest in--the middle of the unit. Though granite gneiss is the preferred host, the volume of ore does not depend solely on the volume of granite gneiss in the middle unit. Where granite gneiss is conspicuously less abundant and metasediments predominate (hole 8), there is no true ore--only some layers of ore grade too thin to mine.

Ore types and mineralogy. Two principal ore types are present: low-sulfur and high-sulfur. The low-sulfur ore consists of magnetite, with little or no pyrite, replacing various facies of the granite gneiss. This type occurs more frequently, forms thicker layers, has a higher content of magnetic Fe, and constitutes the bulk of the deposit. Assays suggest that a very little ilmenite and a variable but small quantity of hematite accompany the magnetite. The gangue minerals are mostly those of the country rock: quartz, untwinned potash feldspar--often rather glassy in appearance--biotite, garnet, and sporadic sillimanite. Apatite is present in microscopic amount. Some of the garnet may well be spessartite. Where the ore has replaced pyroxene gneiss (hole 9), remnants of pyroxene are visible. A little scapolite is present locally in both the granite gneiss and pyroxene gneiss varieties.

The high-sulfur ore has abundant pyrite--10 to 15 percent by volume. Rare chalcopyrite accompanies pyrite or is present in nearby layers of nonpyritic sub-ore. Granular yellow epidote is frequently present and is very abundant in places. Chlorite is often visible with the epidote, and it may occur as extensive replacement areas in the host rock. The potash feldspar of the host is reddened, or earthy and pinkish. The mafic mineral, pyroxene, is either fresh or chloritized. Brown or pale-green apatite is conspicuous in hand specimens; it forms 5 to 10 percent of the ore in some places. This pyritic ore, 12 to 13 feet thick, was cut only in holes 3 and 5 at a stratigraphic distance of 26 to 30 feet below the upper (pyroxenic) unit. (Holes 6, 7, and 9 entered bedrock below the pyritic zone.) It is limited to a layer of pyroxene-feldspar gneiss enclosed in granite gneiss, and its boundaries are rather sharp, in spite of the fact that it is adjacent to sub-ore and mineralized granite gneiss. Of course, scattered zones with magnetite and considerable sulfides are found at other places in the Spruce Mountain rocks, but they are either too thin or too lean to be called ore.

Special structures of ore bodies. The drilling data now at hand indicate that the ore bodies are more or less sheetlike, generally conformable to the foliation of the enclosing rocks, and confined to two significant zones within a single, continuous middle unit that is overlain and underlain by "pyroxene gneiss." At hole 9, however, the lower (main) ore zone either replaces a lens of pyroxenic rocks now forming part of the middle unit or transects a "formational contact" and replaces the upper part of what is elsewhere the lower (generally pyroxenic) unit. The first interpretation has been adopted for purposes of emphasizing correlation of all units, ore included, but the second may be nearer the truth (cf. the magnetite deposits at Benson Mines, n.e.r., Oswegatchie quadrangle, and n.w.r., Cranberry Lake quadrangle; Deerlick Rapids, s.c.r., Stark quadrangle; and Skate Creek, n.e.r., Oswegatchie quadrangle--all in the St. Lawrence County district, New York).

Linear structures have already been described under general structure. Whether lineation trending southeast and plunging about 10° SE., essentially parallel to the synclinal axis, has given a shoot structure to the ore bodies, we cannot tell until the deposit has been further explored. Certainly the two lobes or strands of magnetic anomaly within the "U" suggest it, and the possibility should be kept in mind during exploration.

Grade. The ore is consistently low grade. One or two 5-foot samples of core assayed 37 to 40 percent total Fe (perhaps 35 to 38 percent magnetic Fe), only to be balanced by samples in the same ore zone assaying about 17 percent magnetic Fe. Much of the material now classed as "waste" carries perhaps 10 percent magnetic Fe. Reed and Cohen (1947, Appendix A, pp. 17-25) give all the available analytical data. This information has been summarized in tables 1 and 2 of the present report. Total Fe alone was determined on much of the core. In places, at least a rough value for magnetic Fe was desirable; here the writer converted total Fe to magnetic Fe by using variable but conservative factors based on knowledge of the mineralogy of the sampled core.

[3]Two other and more remote possibilities deserve mention: the valley east-northeast of Spruce Mountain, and the valley southwest of Moosehead Pond (see topographic map of Cranberry Lake quadrangle, n.w.r.). Both valleys are filled with glacial debris. The first valley lies 500 to 600 feet beyond the last outcrops that could be found when the area was mapped. The second valley is a possible site for the missing limb only if the structure of Spruce Mountain Northwest is highly convolute.

Table 2 points out the grade and thickness of the two distinct ore zones. In this recalculation, thickness has been increased at the expense of grade, particularly at hole 7, to give the maximum thickness of ore averaging 23 to 26 percent magnetic Fe. It is at once apparent that the lower zone is generally thicker and slightly higher in grade.

Unfortunately, there is no analysis of ore from the upper zone for P, S, TiO_2, etc. The pyritic, apatite-rich type of ore forms much of this zone in holes 3 and 5. However, the bulk of the sulfur from pyrite and phosphorus from apatite would be removed by magnetic separation. Analyses of the magnetic fraction of ore from the lower zone were made for holes 7 and 9 only. These may be roughly representative of the zone as a whole. The "composite of all composites" (Reed and Cohen, 1947, p. 19) is not particularly meaningful, as it represents sub-ore as well as ore and includes material from two different ore zones.

Table 2.--Ore zones, Spruce Mountain Northwest deposit[a]

Hole	Footage	Apparent thickness (feet)	True thickness (feet)	Grade (percent magnetic Fe)
	UPPER ZONE			
3	155-170	15	13	[b]14.5
5	105-150	45	36	21.5
6	28.5-42	13.5	13	23
7	Collar is below zone.			
8	Zone is too thin to constitute ore.			
9	Collar is below most of zone ?			
	LOWER ZONE			
3	320-416	96	83	ca. 24
5	Zone is only weakly mineralized.			
6	129-204	75	73	ca. 25
7	69-124	55	45	ca. 24
8	Zone is too thin to constitute ore.			
9	152-172	20	18	25.9

[a]Based on data from table 1. Grade and thickness of ore have been balanced to give maximum thickness of ore averaging 23 to 26 percent magnetic Fe.
[b]Value seems low. Visually estimated as low-grade ore in logging.

In the absence of mineragraphic studies and systematic assays for both soluble Fe and magnetic Fe, it is impossible to say how much iron oxide is in the form of hematite. Comparison of the available pairs total Fe-magnetic Fe and the logs suggest that there is roughly 1 percent Fe in hematite for every 10 percent Fe in magnetite.

Extent. Any estimate of tonnage based on widely spaced holes in an ore body whose structure is incompletely known, is bound to be hazardous. Yet such an estimate, or guess, gives something to look at, talk from, and look for. The data for holes 3, 5, 6, 7, and 9 (in table 2) have been treated by the method of triangles (Peele, 1941, sec. 25, p. 19), assuming that the lower ore zone is a single, continuous layer. The assumed tonnage factor is 11 cubic feet per ton. An estimate of the tonnage of "indicated ore" and two of "inferred ore" are given in table 3. The effect of shoot structure might be negligible, or it might increase or decrease the tonnage considerably. If hole 7 cuts an ore zone stratigraphically below that cut by the other four holes, the tonnage estimate is probably too low. The estimate disregards the possibility of finding ore on the outside of the "U" of the magnetic anomaly or in the area south of the latitude of hole 5.

So little is known about the extent of the upper ore zone that no estimate of its tonnage can now be made.

Table 3.--Estimate of tonnage of crude ore (24 to 25 percent magnetic Fe) in lower ore zone, Spruce Mountain Northwest[a]

Area	Indicated ore (tons)	Inferred ore (tons)
A. Bounded by holes 3, 5, 6, 7, 9	3,000,000	
B. Bounded by holes 5 and 7 and points a (N. 8900, E. 4000), b (N. 9440, E. 3560) and c (N. 10460, E. 3900) on magnetic anomaly		
1. Assuming thickness of ore at a, b, c to be zero[b]		4,000,000
or		
2. Assuming thickness of ore at a, b, c to be 36½ feet (the average thickness in holes 3, 5, 6, 7, 9)		6,000,000

A. Indicated 3,000,000 tons		A. Indicated 3,000,000 tons	
B 1. Inferred 4,000,000 tons	or	B 2. Inferred 6,000,000 tons	
Total 7,000,000 tons		Total 9,000,000 tons	

[a]The estimate disregards the possibility of finding ore on the outside of the "U" of the magnetic anomaly or in the area south of the latitude of hole 5.
[b]This is probably not true at all, but it is a conservative assumption for inferring ore beyond the limits of holes 3, 5, 6, 7, and 9.

ADDITIONAL PROSPECTING

The main area for prospecting is on and within the "U" of the Spruce Mountain Northwest anomaly. In addition, part of the central area between the Northwest and Southeast anomalies deserves attention. An outline and a discussion of certain features of the prospecting is presented below.

Diamond drilling. Further diamond drilling at Spruce Mountain Northwest should be directed toward solving structural problems, as well as toward proving up tonnage. Several of these structural problems might be solved incidentally in the search for ore, but keeping them in mind as separate problems should prevent more intelligent exploration and prevent their being disregarded as economically unimportant. Such problems include:

1. The identity of the principal ore zone in holes 7 and 9, a problem directly related to number 2.
2. The dip of the northeast limb--10° SW. or 80° SW.
3. The dip and existence of ore on the southwest limb of the syncline.
4. The existence of ore shoots parallel to the synclinal axis.
5. The structural relation of the Northwest and Southeast areas. This problem is not of immediate concern but might become important if ore were found in the area between latitudes 6000 N. and 8000 N.

Bulldozing and trenching could supplement drilling to advantage in 2 and perhaps 3, above.

Magnetic work. Additional magnetic work in this area warrants discussion.

1. Detailed work with sensitive instruments. A large area between latitudes 4000 N. and 9000 N. was covered by reconnaissance dip-needle traverses, followed by detailed work in one small area. The readings were low--generally less than +10°. In spite of the low readings, at least the northern half of this central area may be favorable prospecting ground, provided the syncline has maintained its gentle southeastward plunge. A plunge of 8° to 10° SE. will cause the rock units to decline southeastward about 16 feet vertically for every 100 feet of horizontal distance along the plunge. Thus the top of the ore shoot cut at 129 feet in hole 6 would, if continuous, occur at a depth of 529 feet at latitude 8000 N., 2500 feet southeast of hole 6, assuming ground elevations to be about the same. Now a magnetite body with 500 feet of cover is considerably beyond the effective "reach" of the dip needle, and its detection would require a more sensitive magnetic instrument, such as a vertical magnetometer. A magnetometer survey might be of particular aid in detecting and outlining ore *shoots*, as opposed to *sheets*, if they exist. The considerable cost and uncertain prospect of such a survey would have to be balanced against the cost of wildcat drilling that might still leave a favorable area inadequately prospected. Possibly a Hotchkiss superdip could be used instead of a vertical magnetometer. Regardless of the instrument used, the magnetic pattern will almost certainly be complex, owing to multiple mineralized zones, shoots, structural complications, termination of ore, or the combined effect of these features.

2. Reconnaissance dip-needle work. Two areas deserve attention in the future. Scattered magnetic highs have been found east of the Northwest area by A. M. Ross. Systematic reconnaissance of these highs and determination of their relation to the main Spruce Mountain anomaly may disclose other magnetite deposits of interest.

The problem of the "missing limb" of the inferred tight fold at Spruce Mountain Southeast was discussed in the section on structure. Whether the undiscovered limb has any economic importance in its own right, we obviously cannot tell. It has an indirect importance that may become great if ore is found in the central area, for it may be necessary to know something about the "missing limb" in order to understand the structure of the central area. There are two reasonable sites for the limb: southwest of the Southeast anomaly, in the bed of Big Creek Flow; and within 1000 feet northeast of the anomaly, in an area of drift. If the limb carries more magnetite than the enclosing granite gneiss does, it should be possible to detect the limb by reconnaissance dip-needle traverses, in the hope of putting it to geologic or economic use.

ECONOMIC POSSIBILITIES OF SPRUCE MOUNTAIN SOUTHEAST

The economic possibilities of the Southeast area are extremely poor. The weakly-mineralized garnet-biotite gneiss underlying the anomaly averages 6 to 7 percent total Fe (Reed and Cohen, 1947, pp. 17-18), of which one-fifth to one-fourth would be in the silicates garnet and biotite. Unless microcline granite gneiss takes the place of the garnet-biotite gneiss at greater depth, there is little likelihood that the weakly mineralized rock is masking a deeply buried ore body. In the district, ore in garnet-biotite gneiss is restricted to thin layers forming parts of granite gneiss sheets; garnet-biotite gneiss alone never is the host for an ore body.

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Table 1.--The more important magnetite-bearing layers, Spruce Mountain Northwest deposit[a]

Hole	Footage[b]	Apparent thickness (feet)	True thickness (feet)	Total Fe (percent)	Magnetic Fe (percent)	P	S	TiO_2	SiO_2	Mn	Fe
						Analysis, magnetic fraction only (percent)					
3	155 - 170	15	12.9	21.5	14.5						
	270 - 290	20	17.2	17.4	15.2						
	320 - 335	15	12.9	20.1	[c]18						
	335 - 365	30	25.8	26.4	23.5						
	365 - 390	25	21.5	34.5	32.5						
	390 - 410	20	17.2	24.2	22.0						
	410 - 416	6	5.2	20.3	[c]18						
5	80 - 105	25	20.2	18.1	13.3						
	105 - 150	45	36.4	26.6	21.5						
	150 - 179	29	23.5	16.3	11.0						
	179 - 197	18	14.6	ca. 13.5	[c]9 ?						
	240 - 270	30	24.3	13.0	[c]8 ?						
	290 - 363	73	59.1	ca. 12.7	[c]8 ?						
6	28.5 - 38	9.5	9.2	26.8	25.4						
	38 - 59	21	20.4	18.8	17.1						
	59 - 129	70	67.9	13.6	[c]9 ?						
	129 - 194	65	63.0	28.9	26.6						
	194 - 204	10	9.7	16.5	[c]14 ?						
	244 - 249	5	4.9	21.4	20.1						
	254 - 259	5	4.9	16.6	[c]14 ?						
7	56.7 - 69	12.3	10.1	13.6	[c]9 ?						
	69 - 104	35	28.7	33.9	30.6	0.014	0.21	0.80	2.29	0.32	67.2
	104 - 124	20	16.4	15.4	[c]11.5 ?						
8	[d]314 - 318.1	4.1	3.3	Low-grade							
9	11.7 - 22	10.3	9.3	14.8	[c]10.5 ?						
	92 - 122	30	27.0	21.1	[c]17 ?						
	152 - 172	20	18.0	28.8	25.9	0.004	0.14	0.74	1.73	0.21	68.2

[a]Includes all layers of ore grade having an apparent thickness of 5 feet or more, as well as certain thick layers of sub-ore and mineralized rock. All analytical data from Reed and Cohen, 1947, Appendix A, pp. 17-25. Some figures represent averages of their data.
[b]Footages correspond to those sampled and assayed by the Bureau of Mines. These may differ slightly from those given in the logs prepared by the Geological Survey.
[c]Calculated from value for total Fe where value for magnetic Fe had not been determined chemically. The conversion factors are variable and conservative.
[d]This is the thickest layer of ore grade in hole 8.

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