A Detailed Economic Investigation of Aeromagnetic Anomalies in Eastern Penobscot County, Maine

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Special Economic Studies Series No. 1

Maine Geological Survey

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A DETAILED ECONOMIC INVESTIGATION OF AEROMAGNETIC ANOMALIES IN EASTERN PENOBSCOT COUNTY, MAINE

by Robert G. Doyle, Robert S. Young and Lawrence A. Wing

ABSTRACT

The Maine Geological Survey conducted a detailed economic study in 1960 of certain elongate aeromagnetic anomalies discovered by an earlier survey in eastern Penobscot County, Maine. Field work included geological mapping, magnetic and self-potential surveys and detailed geochemical stream sediment sampling.

The area, located a few miles east of Lincoln, Maine, is approximately 100 square miles in size. It is underlain by an undetermined thickness of lower Paleozoic (?) schists, phyllites, quartzites and metasiltstones. Two granite bodies intrude the area, and rimming one of them, the Lucerne granite, is a 2 mile wide zone of schistose contact alteration hornfels rock.

The principal structural element is a southwesterly plunging syncline, complicated by a series of major drag folds on its southeast flank. A north-south trending shear zone is also important to structural interpretation.

Zones of sulphide enrichment, mostly confined to the hornfels, were determined to be the cause of the aeromagnetic anomalies. The sulphides occur in narrow zones paralleling the northern granite contact. Pyrrhotite and pyrite are the principal sulphide minerals, with minor traces of chalcopyrite and hematite. The sulphides are present in various lithologies and appear to transect stratigraphic and structural elements.

Ground magnetic traverses were conducted normal to the trend of the sulphide zones. The magnetic profiles located the position of the sulphides, even in places where no sulphide surface shows were found. Many of the magnetic peaks could be directly related to pyrrhotite mineralization, but in some cases this relationship was not established. A complex origin and distribution of the sulphides is postulated from the magnetic data.

Self-potential data was obtained from short, magnetically oriented traverses. These data generally harmonized with the magnetics, but showed marked variation in other places, emphasizing the complex nature of the conducting bodies.

Geochemical stream sediment sampling and analysis outlined several localities in and near the sulphide zones where anomalous readings were reported. Cold tube tests for zinc were performed in the field, and laboratory tests for copper were made on all samples. A method of drainage basin sample influence was used in presentation of the data.

In order to demonstrate specific methods of geophysical and geochemical technique, especially applicable to geologic conditions in Maine, the authors present a complete discussion of basic geophysical and geochemical technique which was used in this study.

On the basis of the data and interpretations presented, the authors recommend further detailed economic exploration in the area.

INTRODUCTION

by R. G. Doyle

Purpose and Scope

Recent aeromagnetic surveys in northern and eastern Maine (3,25) have indicated the presence of several magnetic anomalies of sufficient size and intensity to become interesting targets for detailed economic exploration. Supporting reconnaissance geologic mapping has been conducted over much of the survey area. The combination of significant anomalies and noteworthy geologic features caused the Maine Geological Survey to consider an economic study of some of these areas as an aid in future interpretation of reconnaissance data from northern Maine. This report summarizes the results of the first of these economic studies. The area chosen is located in eastern Penobscot County, northeast of Bangor, Maine.

The primary objective of the study was to determine with geology and geophysics the source of a series of elongate magnetic highs associated with sediments adjacent to the northern limit of the Lucerne granite. In addition, detailed geochemical stream sediment analyses were performed to evaluate lake water geochemical spectrography conducted in the area by Kleinkopf (16). Also, several base metal shows reported by local prospectors were to be field checked during the course of the mapping.

ACCESSIBILITY AND TOPOGRAPHY

The area, covering 100 square miles, lies 65 miles northeast of Bangor. It is reached from Bangor along U. S. Route 2 to Lincoln. Route 6, east from Lincoln, transects the area with the towns of Lee, Springfield, and Carroll lying along the route. Lee, the largest of these towns, was the site of the Survey base camp. Numerous logging roads and farm tracks leading away from Route 6 provided easy access to all parts of the area.

The area forms part of the northwestern edge of the Central Upland Province (Toppan, 21) located in a broad belt extending from the eastern end of the Presidential Range in New Hampshire northeastward to the New Brunswick border. Regional relief is not extreme, averaging approximately 500 feet. In the study area the most extreme relief is 800 feet near Getchell Mountain. An average sea level elevation of 700 feet would blanket 75 per cent of the area. The principal peaks rising above this median level are Bowers Mountain (1120′), Brown Hill (1140′), Dill Hill (1025′)and Almanac Mountain (1052′).

Local topographic control is exercised by differences in the bedrock, with the resistant hornfels contact zones creating the rugged southern and eastern relief, surrounding the softer granite masses like the rim of an open bowl. The uniformly softer metasediments away from the contact zone have been molded into a complex of rolling hills and swampy lowlands. Glacial features are evident throughout the area north of Highway 6.

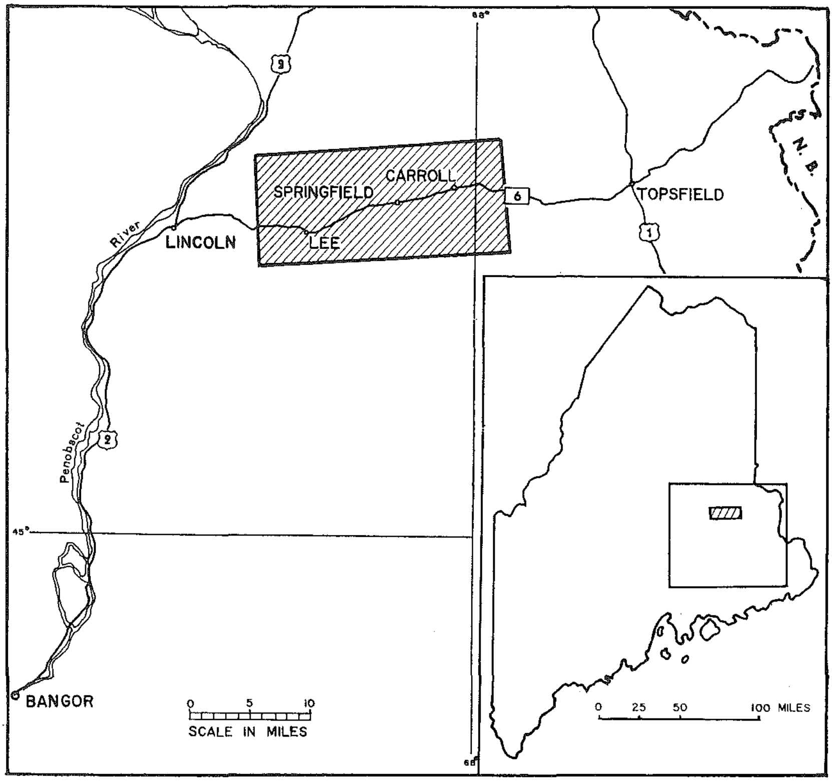


Figure 1. Index map showing location of the study area.

Drainage

The area is variably drained. Swamps and bogs predominate in the northern argillite section. No through flowing streams are noted except within the mass of the Lucerne granite. Local drainage is controlled by the distribution of glacial debris, excepting the hornfels area where a resistant buttress creates a local east-west drainage divide.

Field Control

Topographic control for all field work was established with aerial photographs and enlargements of the 15′ Series topographic quadrangles — Winn, Springfield, Scraggly Lake — U. S. Geological Survey Topographic Service.

Field scale for the maps and photographs was one-half inch to the mile. Alidade elevation control was exercised for most of the geophysical traverses and detailed mapping in the sulphide zones.

Previous Investigations

The present study represents the first detailed geologic mapping in the Lee - Springfield area. C. M. Hitchcock (12) in 1862 noted that the area was underlain by " clay slate " and " micaschist and quartzrock." Hitchcock's map accompanying the report shows the outline of the Lincoln granite. George Otis Smith (20) outlined the Lucerne granite body in 1907, utilizing a 1900 U. S. Geological Survey Bulletin by Williams (24) who visited the area briefly several years before. The Preliminary Geologic Map of Maine, by Keith, 1933 (15) was a compilation of the work of Hitchcock and the Smith-Williams reports. Keith describes the sediments in the area as Cambro-Ordovician quartzites, argillites and vari-colored slates and interbedded sandstones of presumed Silurian age.

Wing, in 1953, (26) described some of the granites and associated sulphide mineralization to the south and east. Two aeromagnetic surveys conducted by the Maine Geological Survey in 1954 (22) in the Forest City and Meddybemps areas to the east and south outlined a granite mass extending eastward from the study area. Forsyth, in 1955, (9) described the geology of these two areas. In the Forest City report, Forsyth discussed the metasedimentary sequence and the presumed eastward extension of the Lucerne granite complex to the New Brunswick border.

In 1957, the Maine Geological Survey conducted an aeromagnetic survey and geological reconnaissance of a 920 square mile tract in central Penobscot County which covered the area included in this report. The published results, GP&G #3, interpreted by Wing (25), provided a working basis for the development of this present work.

The only other recent work of interest was a geochemical study of lake waters of northern Maine by Kleinkopf (16). Several lakes in the Lee - Springfield area were sampled, and for three of them, Caribou, Weir and No. 3, anomalous total metal values were recorded.

Organization of the Field Program

After the area was chosen, a coordinated three - part program was started, beginning with detailed geologic mapping. This detailed mapping showed, after a few weeks work, that a sulphide zone (or zones) was located near the granite contact both in and out of the rimming hornfels. No areas of economic interest were uncovered north of Highway 6. Greater emphasis, therefore, was placed upon mapping near the granite contact with just enough work north of this zone to allow for a reasonable structural and stratigraphic interpretation.

When sufficient geologic control was established, several long, cross-strike magnetic traverses were conducted to establish a basis for comparative interpretation of future data. A background magnetic datum for the barren metasedimentary units was set and detailed lines laid out to locate and measure the magnetic intensity of the sulphide zones.

Detailed geochemical sampling of stream sediments was started as soon as the sulphides were delineated. This program was especially effective in its ability to detect and trace possible heavy metal zones in areas of scant outcrop and swamp. Since a surprising degree of surface weathering with related sulphuric acid development had oxidized almost all evidence of heavy metal values on the outcrop surface, some basic chemical measurement was necessary. The results of this technique and its specialized application were very successful.

Late in the field season, self-potential traverses, all oriented to magnetic information, were conducted to provide additional data for interpretation of the composition of the magnetic source bodies. The wedding of the self-potential data to the geochemical and magnetic profiles was a most important addition to the total sum of useable data.

This report is presented in three separate sections: geology, geophysics, and geochemistry. Each section is written by one of the authors; the conclusions and recommendations resulted from mutual discussion by all three writers.

The Introduction, and Part I, the geology section, was written by Robert G. Doyle, Maine State Geologist. Part II, the geophysical section, was written by Robert S. Young, geological consultant, Charlottesville, Virginia. Young also directed the geophysical studies. Part III, the geochemical section, was prepared and written by Lawrence A. Wing, consulting geologist for the James W. Sewall Company, Old Town, Maine. Wing was responsible for the sampling and chemical analyses of the entire stream sediment program. Ultimate responsibility for the methods, results and interpretation of the entire program rests with the State Geologist who initiated the project and supervised its progress.

Acknowledgements

The authors in concert wish to make full acknowledgement to all those who contributed their time and experience to this study. The continuing geologic field party consisted of Webster F. Stickney, staff geologist with the Maine Survey, and Dabney W. Caldwell, Associate Professor of Geology, Wellesley College, Wellesley, Massachusetts. The geophysical field work

and preliminary data reduction was conducted by John A. Cole of the University of Virginia. Cole also assisted in geologic mapping. Mr. Fred J. Bagnall, now staff geologist with the Dragon Cement Company, conducted the bulk of the geochemical sampling, performing field tests on each sample.

Mr. Cole and Mrs. Muriel B. Austin of the Geology Department staff at Colby College, Waterville, Maine, prepared and analyzed rock thin sections of the metasediments. In addition, Mr. Cole is making a complete petrographic thin section study of the Lucerne granite contact zone and will report the petrofabrics and petrography of that zone in presentation of a Master's thesis at the University of Virginia.

The authors wish also to thank Father Daniel Linehan, S. J., Director of the Weston Geophysical Laboratories, Weston, Massachusetts, for providing daily magnetic - storm control data to the geophysical crew. Finally, to all those residents of the Lee - Springfield area who courteously allowed project geologists to work on their property, the Maine Geological Survey expresses its most appreciative thanks.

PART I. GEOLOGY

General Considerations

The sedimentary rocks in the entire region are presumed to be all of lower Paleozoic age. Silurian and Ordovician rocks in Danforth and other areas to the north and east (Larrabee and Pavlides, U. S. G. S., personal communication), provide the basis for a lower Paleozoic age of the rocks of the Lee - Springfield area. Steep isoclinal folding and very well developed regional flow cleavage is present in all the finer grained rocks. The regional strike is northeast; but several major drag - fold patterns within the area bring the strike locally to northwest. The dip of both cleavage and bedding is close to vertical.

The fine - grained sediments may be included in the green schist metamorphic facies with quartz, muscovite, sericite and biotite as the major constituents. The presumed base of the exposed section is a massive quartzite and quartz - graywacke, overlain by phyllites, slates, fine - grained arenites, and an undetermined thickness of meta-argillites. The uppermost unit mapped is a fine-grained calcareous quartzite, typically light and dark color banded.

Two granite areas have been mapped; one is the Lucerne granite, a major granite intrusion exposed along the entire southern part of the mapped area. The other mass, tentatively named the Lincoln granite, is a smaller body of approximately 30 square miles, centered around Lincoln. It is exposed on the western boundary, forming the mapping limit on that side of the area. The contact of the Lucerne body and the adjacent sediments is characterized by a zone of contact alteration, varying from a few hundred yards to over one-half mile in width. The actual granite contact is frequently masked by a complex of aplite dikes, coarse grained gneiss and pegmatite masses.

The following description of the mapped units and subsequent structural and stratigraphic interpretation is based on the results of 15 field man-weeks during the 1960 season. It is recognized that this period of time is not sufficient to provide enough data for first order geologic interpretation of this 100 square miles of complexly folded Paleozoic rocks. As a finite academic contribution, this study is therefore subject to future revision. However, as the background for anomaly interpretation and sulphide zone control, it is considered adequate.

— Description of Mapped Units —

Approximately 1000 outcrops were seen during the course of the mapping program. The resulting structural relations and rock descriptions were delineated on the basis of outcrop and hand specimen examination. In addition, 35 rock thin sections were examined microscopically. The results of thin section petrography provided data for accurate lithologic description and nomenclature.

Metasediments

Massive gray-green quartzite and graywacke. This unit is presumed to be the oldest rock type found in the mapped area. It is a very massive, light gray-green and gray very fine-grained resistant quartzite. The addition of coarse plagioclase-rich foreign material gives a porphyritic texture to much of the section. Microcrystalline quartz constitutes a large percentage of the rock. Plagioclase (as albite) and orthoclase feldspars, with large percentages of secondary calcite crystals are present as porphyritic material. Biotite and muscovite, with related sericite, occur as minor constituents.

South of Highway 6, this unit becomes a "dirty" quartzite, described as a true graywacke. The rock is medium to fine grained in texture, with a large percentage of feldspar porphyroblasts and secondary calcite. Microcrystalline quartz still is the major constituent, but the large feldspar crystals and massive secondary calcite make up to 30% of the total composition. Binary mica, traces of horneblende and up to 5% opaques complete the rock description. The opaques occur as pyrite and secondary limonite.

This unit occurs on both the eastern and western sides of the area. On the west, at East Winn village, a type section 300 feet wide is recorded. It cannot be traced to a great distance along strike because of the swampy terrain to the northeast. The western section is a much cleaner quartzite than the exposures in Carroll; bedding is almost absent. The northwestern limit of this rock was not found, and the map thickness is only a projection.

The unit was more closely defined in Carroll Township on the east. It extends northeastward in a drag fold pattern from Lowell Lake to the Washington County line on Route 6. The average mapped width is from one - half mile to one mile. Excellent outcrops occur near the radio towers on Tolman Hill.

Dark gray phyllite and schist. This rock is described as a dark gray and black, strongly cleaved phyllite composed of fine - grained quartz, biotite and sericite. Minor thickness of poorly bedded gray quartz-muscovite-sericite schist are also noted.

Accessory minerals include horneblende, chlorite and occasional crystals of cordierite. The sulphide zones of possible economic significance are widely exposed in this black schist and phyllite unit. Pyrite occurs throughout as individual undeformed cubic crystals. Pyrrhotite and the occasional chalcopyrite showings are confined to well defined zones within the unit, and are often sheared into lineations parallel to the strike.

The phyllite and schistose bands are well developed and separate. Microbedding of the argillitic layers may be traced from tens of feet across the larger outcrops. Drag folding is also well defined in the coarser elements. In the phyllite sections, flow cleavage is strongly developed but separation follows micaceous parting planes rather than along the more parallel cleavages. Chlorite is visible along some parting planes.

In the vicinity of Getchell Creek within this black phyllite unit, a massive meta-mudstone member has been mapped. It is characterized by its lack of structure, deep gray-black color and high percentage of secondary sulphides. Small amounts of graphite, close to the granite contact but still within the black massive mudstone member was noted during the mapping.

The dark phyllite and schist unit is distributed on both sides of the eastern belt of the gray-green quartzite. Its greatest measured width is 2 miles, measured near Getchell Creek. On the west, it lies adjacent and conformable to the gray-green quartzite southeast of East Winn village. The outcrop pattern width shown on the geologic map is tentative because of a similarity of this unit to the fissle siltstone rock to the southeast.

Light gray quartz biotite schist. This rock unit is described as a rusty weathering light gray schist composed of fine-grained, poorly sorted quartz, biotite and cordierite. It is characterized in the field by numerous narrow, highly sheared quartz veins and lack of original structure. Argillitic lenses are scattered randomly throughout a finer grained, medium gray, rusty schist. Pyrite, but almost never pyrrhotite, is present in almost every locality. The pyrite is rarely in fresh crystals; but occurs as orange pits and casts, limonite blebs and rusting oxidation nuclei.

The map pattern of Plate 1 shows that the eastern limb of this unit is most intimately related to the major Springfield shear zone. In the eastern part of the area, there is a general northeast trend to the unit, widening in that direction. Secondary sulphides are present near the granite contact at Treadwell Hill and also in the western exposures which are limited to a small area east of Bagley Mountain. In fact, the only good evidence of secondary sulphide mineralization (as pyrrhotite) found in the western rock section occurs in the outcrops of this gray, poorly sorted schist unit.

Gray-blue and gray metasiltstone. The rock comprises the largest areal distribution of any rock type in the study area. It is typically exposed throughout the north central part of the area. The unit is described as a very fine-grained chocolate-brown weathering metasiltstone. It is very well cleaved and shows muscovite on the individual parting planes. Most of the exposures of the metasiltstones are fissle and slightly limy. A blue-gray color on the fresh surface is characteristic. Biotite, very fine-grained quartz, sericite and minor amounts of calcite are usually present. Horneblende has been seen as a trace mineral. The unit is often described in the field as sub-phyllitic. Extremely incompetent, the rock is finely cleaved and sub-phyllitic in many exposures. Both flow and shear cleavage is developed, with a mutually cross cutting relationship which frequently results in the break up of the rock into rod-like shards. Bedding is traceable in the schistose sandy bands.

The metasiltstone unit is marked by a strong development of mica on the cleavage planes. In the phyllitic sections, cleavage planes lose their integrity and parting occurs randomly along platy separations of the micas. Coarse, quartz rich lenses 1/16 - 1/4 inch thick do occur, mostly in the western part of the study area, but they do not constitute a significant fraction of the rock. Quartz, biotite, muscovite and sericite with occasional chlorite all in the extremely fine grain size range were noted in thin section examination of the sandy lenses.

Alternating banded calcareous quartzite. The lithology of this rock unit differs significantly from any other unit in the area. It is characterized by a very regular alternation of light and dark colored bands ranging in thickness from 1/16" to 1/2". The mineral composition of each sample examined contained some calcite, usually confined to the darker bands. The dark bands are composed of very fine-grained biotite and chlorite, with some quartz, calcite and sericite present. The light bands have a preponderance of fine-grained quartz, muscovite and sericite with occasional secondary calcite crystals. As reported by Wing, (25) the rock is quite soft and easily eroded. Flow cleavage is not well developed, except as axial cleavage in the axial zone in drag folds.

On the southeast flank of the banded unit, there is an area of several outcrops which, in the field, are very similar to the calcareous thin banded rocks. The rocks in this zone show the same thin bedded alternating light and dark banded character as the calcareous rocks. Microscopically, however, there are significant differences. Thin section analyses show that this southeast sub-unit contains more finer grained quartz, frequent horneblende flecks, and the complete absence of calcite.

Since this small area is closed to known hornfels outcrops, this rock type may be a unique contact alteration section of the calcareous banded unit. It is separated on the geologic map only because of its possible significance as an acceptable host for sulphide mineralization. As will be discussed under Economic Geology, there is no sulphide concentration noted in the calcareous banded unit.

Igneous Rocks

The rock description of the two granite masses is taken directly from Wing's geologic discussion in GP&G #3, Maine Geological Survey, 1958 (25). A more complete description of the Lucerne granite will appear in Cole's projected Master's thesis presentation later this year. The names Lucerne and Lincoln are tentative and used here merely for rapid identification.

Lucerne granite. As noted above, this rock comprises the entire southern part of the mapped area. From Wing, (25) the intrusive is described " as a coarse textured porphyritic biotite granite with individual phenocrysts from one to two inches long. Both pink and gray colors are common. In a few areas the pink orthoclase phenocrysts are rimmed by white albite-oligoclase in a Rapakivi fashion. At one point along the northern contact of this granite with the sediments, on Getchell Mountain a fairly large coarse grained pegmatite makes up the actual contact. The location of this pegmatite is reported by Rand in 1957 (17) and shown on one of the maps of his report. The pegmatite appears to be made up mostly of large crystals of perthite and quartz and much of the quartz is rose colored. Very close to the contact which is about vertical, coarse biotite and some magnetite crystals occur. This narrow zone including biotite and magnetite has been described as quite radio active by local prospectors. This pegmatite is the only one of any size reported in eastern Maine and even here the limits are not known other than that it runs southward from the contact for several hundred feet."

The granite contact is known from several localities near Lee to be at a shallow depth for several hundred yards north of the observed line of contact. This hood effect of the sediments does not appear to exist farther to the east. In detail, the contact between the granite and metasediments is very irregular, occurring more as a zone than a finite line. Tongues and lobes of aplitic material have been mapped to a distance of several hundred feet into the sediments. These aplites become almost pegmatitic in places, but not to the extent noted on Getchell Mountain.

Another characteristic of the granite contact merits special consideration. At several localities along the contact, in particular on Almanac Mountain, south of South Springfield; north of Lombard Lake; and around Porcupine Mountain southwest of Lee, there are deep embayments into the granite. These embayments are significant in that they are the loci of the larger geochemical and geophysical anomalies. The reason for this spatial relationship has not been determined, but should be emphasized.

Lincoln granite. This body covers most of the western part of the study area. It is described as medium to coarse grained gray granite but phenocrysts characteristic of the Lucerne are entirely absent in this type. The percentage of biotite also appears to be somewhat higher than the Lucerne, especially in the vicinity of Lincoln. The color ranges from a light pink to gray with some areas in the south grading from the gray toward a greenish gray.

Contact alteration in most localities is absent. Caldwell, in mapping the contact near East Winn, describes an increase in the schistose character of the sediments as he approached the contact. An exposure of the contact on Route 6, however, shows no evidence of the hornfels typically developed at the Lucerne contact.

Metamorphic Rocks

It has been previously noted that the entire area has been subjected to regional metamorphism, typical of rocks in the Appalachian geosyncline. In the study area this metamorphism is limited to low grade, green schist rank, away from the Lucerne granite contact hornfels zone. As the contact is approached metamorphism increases until the original features of the rock are destroyed and a quartz-biotite + accessory schist is developed. The composition of this hornfels schist varies considerably from place to place, but generally a more equigranular and better indurated rock results. Fine-grained euhedral quartz always occurs, sometimes as a pure alteration quartzite.

The most significant characteristic of the hornfels rocks is the extent and intensity of plastic flow folding developed. On Almanac Mountain near South Springfield, this plastic flow folding becomes completely serpent-like. The wrapping and contortion shows a history of complete flow when the rocks must have behaved as a thick, hot pudding being cooked in an enclosed vessel.

Plastic flow folding occurs in several other localities, but not with the degree of intensity or clarity as that exposed on Almanac Mountain.

This plastic flow is the most amazing micro-structural configuration ever seen by the geologists who worked in the area this past season. The authors consider it unique in structural geology and believe further that a detailed study of the area covering Almanac Mountain may provide new information on basic structural geology.

The major structural elements and this unique plastic flow folding do not appear to have any direct relationship. There is no mutual interference of fold patterns and it is presumed that the plastic flow folds are related directly to some force-heat stress originating with the granitic intrusion.

Sulphide mineralization is nearly all confined to the hornfels rim zone. The pyrrhotite, hematite and the few localities of chalcopyrite mineralization found, all were located in the hornfels. The hornfels cuts across the stratigraphy without regard to original lithology and in this study it is considered only as a single alteration zone regardless of mineral or chemical composition.

Structural Geology

The principal structural element in the area is a southwestern plunging syncline (Plate 1). The axis of this structure passes through Mattakeunk Pond, a mile south of Lee, and extends northeast into an unmapped swamp area near Webster Pond. The plunge is steep near Mattakeunk Lake, measured at 40° - 70° southwest on several outcrops along the lake. To the northeast, the plunge flattens and local reverses occur. The fingering of the map pattern of the thin bedded limy quartzite at the flanks of the structure are gross indications of this local reversal at Dwinal Pond, a few miles north of Lee. There are several indications that this syncline has a local steepening of the southwestern plunge. This local steepening was plotted on several outcrops where competent sandy lenses in the gray argillite unit retained traces of original bedding.

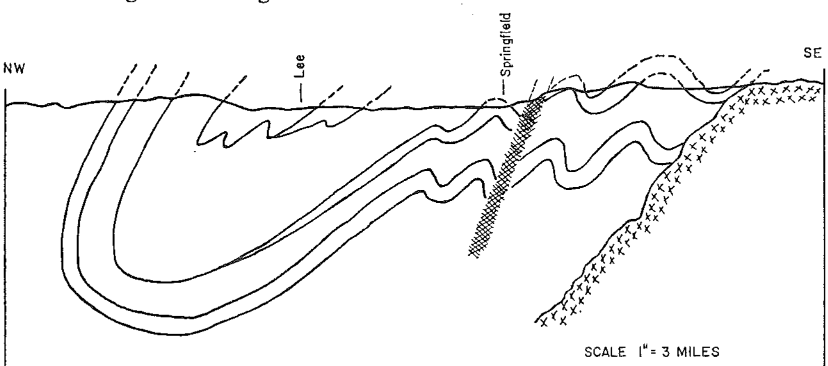


Figure 2. Generalized cross-section of the principal structural elements in the Lee-Springfield-Carroll area.

Figure 2 is a generalized structure section of the area. It shows the principal synclinal structure complicated on the southeast by a series of tight drag folds which have brought to the surface the units stratigraphically underlying the metasiltstone unit. A northwest dip of the structure is difficult to demonstrate in the field, outcrop by outcrop, but there is enough discontinuous evidence to assume that the entire structure is dipping toward the Penobscot River to the north. It is probable that drag folding is as strongly developed in the siltstone unit as that mapped on the southeast flank. Outcrop evidence in widely separated localities supports this idea, but the fine-grained homogeneous character of the rock does not provide sufficient connectable data.

The north-south oriented shear zone, shown on the geologic map, in the South Springfield area complicated the mapping problem to a great extent. Field evidence for that shear zone was difficult to obtain because its location coincides in part with a possible line of unconformity between pre and post-Taconic rocks. The presumed pre-Taconic rocks — the dark phyllite and schist unit and the quartz biotite schist unit — are much more heavily contorted, injected and altered. Structural evidence and the map plan of the rock units, however, necessitate a shear interpretation upon the area. In addition, segments of the contact between the contorted and uncontorted units away from this major shear are well mapped. It is generally agreed that the sharp difference in rock types near Springfield cannot all be attributed to an unconformity. Shear movement must also be a consideration. This shear zone must be considered actually as a zone, and not merely a single line representation of movement. It is strongly suggested that this more than one mile wide " shattered " zone is the result of an 'en-echelon' step movement of many N 70° E segments which in sum make up the north trending zone. Most of the cleavage linears strike in this N 70° E direction. The position of the shear zone in partial coincidence with a presumed unconformity of major importance may have had an effect in limiting its position in space.

As may be demonstrated by the distribution of the schist unit, the west side of the shear has moved northeast. This direction of movement is in agreement with drag fold evidence throughout the area. The trace of this major shear is obscured as it enters the contact hornfels rocks. Topographic expression and the extremely complicated outcrop pattern in the hornfels offers indirect evidence of its continuation to the contact. Beyond the contact in the granite, the shear zone cannot be traced.

Several other occurrences of local shearing have been noted, especially in the tightly drag folded section below the metasiltstone unit. There is no continuity to the outcrop pattern, so that the authors could not project any of these additional shear traces on the geologic map. The separation of the small wedge of the quartzite unit in the northeastern corner of the map from the main trend may be a result of shear movement. Outcrop information was not sufficient to prove this point.

A multitude of small magnitude drag folds, bedding shear traces and sheared quartz blebs mapped from all parts of the area demonstrate strong evidence for a major northeast-southwest couple acting on the entire rock section. The north side of the block has presumably moved to the east. The one shear zone shown on the geologic map supports this proposal, especially if the en-echelon pattern of the zone is accepted as a possibility.

Stratigraphic Discussion

The physical characteristics of the metasiltstone unit are radically different from the units underlying it. The degree of alteration, sulphide content and lack of original structures in the lower units is in marked contrast to the visibly regular bedding and uncontorted fold patterns of the upper units. This difference strongly suggests the presence of a time unconformity between the metasiltstones and the lower units. Field evidence for this unconformity is lacking because of the coincidence of a major shear zone along much of the trace of the contact between the upper and lower rock units.

Using information from other areas to the north and east, there is a possibility of relating the metasiltstone unit to lower Silurian slates and siltstones in Danforth and Forest City. Stretching this correlation to its absolute limits, a comparison of the upper metasiltstone unit to the lower Silurian Seboomook slate belt might be postulated. A possible stratigraphic interpretation is available, using this admittedly weak correlation. The lower contorted and altered units may be assigned a pre-Taconic Cambro-Ordovician age. Taconic activity would be represented by the strong alteration and quartz injection of these lower units. After a long period of erosion, the post-Taconic lower Silurian siltstones and sands would be deposited on the older phyllite-schist surface.

The effects of the mid-Silurian Acadian activity would be represented possibly by the formation of the major synclinal structure and intense but regularly oriented drag fold patterns and shear cleavage found throughout the area. The structural effects of the Taconic orogeny on the lower phyllite units would have been complicated beyond present identification by the Acadian stresses. Without fossil dating, this is pure speculation, but some reasonable stratigraphic control is at least suggested.

Economic Geology

The sulphide zones occurring along the north contact of the Lucerne granite are considered to be the cause of the elongate aeromagnetic anomalies, shown in GP&G #3, (25) which first focused attention to the Lee-Springfield area. The origin and economic implications of these sulphides are more difficult to interpret.

The sulphides occur as a discontinuous zone generally parallel to the granite contact. There is no field evidence to support a genetic relation of the sulphides to the adjacent granite, but such a relationship must still be a consideration.

Description of the sulphides. The sulphides occur in well defined zones, restricted mostly to the hornfels contact rim. Mineralization in these zones is essentially pyrrhotite, with traces of hematite and chalcopyrite. Pyrite is noted in a few localities; but it is presumed that this pyrite may be an original mineral constituent of the rock. The host rock is generally described as a gray-black resistant schist composed of fine-grained quartz, biotite muscovite and accessory chlorite and garnet. A rusty surface oxidation cover is always present, giving the outcrops a reddish brown color. Ground vegetation near the outcrops is rusted and killed by presumed sulphuric acid activity. Surface oxidation occasionally penetrates up to 2 inches into the rock, removing a large percentage of original metallic mineralization. This active oxidation may be responsible for the scarcity of base metal minerals and the equally anomalous increase in base metal readings of nearby stream sediment sampling.

Distribution and structure of the sulphide zones. There are two separate geologic environments of sulphide mineralization; the western, South Lee zone; and the eastern, Brown Hill zone. The north-south shear shown on Plate 1 at South Springfield is apparently the dividing line between the two environments. The suggested pre-Taconic line of unconformity located in this same area does not appear to be a separating influence since each sulphide zone crosses this line indiscriminately.

The western sulphide zone is characterized by a single 200 to 800 foot wide belt of almost continuous sulphide outcrop extending from No. 2 Hill almost in the granite contact, southeast of Mattakeunk Lake, eastward to the east side of Granite Ridge, on the north shore of Lombard Lake. The western limit of this sulphide zone extends into one of the smaller granite pockets discussed earlier and was mapped to within 500 feet of the actual clean granite contact. At this contact point, a rusty colored, deeply weathered aplite tongue occurs, but the small hornfels sediment outcrop adjacent to the aplite does not show a high sulphide contact. It is only at this contact point and one other on Almanac Mountain (in another pocket) that the sulphide rocks come very close to the granite contact. A structural-genetic relationship could be factually determined in neither locality.

There is an average of 7 to 10 per cent sulphide present over the entire western sulphide zone, with the exception of Granite Ridge, where 10 to 15 per cent sulphides, including traces of chalcopyrite and hematite, occur in several outcrops. Because of their high sulphide content and contorted character, these outcrops may be more closely associated with the eastern sulphide zone.

On Treadwell and Porcupine Hill, southeast of Lee, the sulphide zone appears to have the same structural configuration as the adjacent non-sulphide rocks. It was at first considered that the major drag folding of sediments and sulphides zone resulted from the violently forceful injection of the granite. The lack of any structural field relations between the granite and the adjacent major drag folding makes this thesis difficult to maintain. There is no positive field evidence for an age relationship between the intrusion and drag folding of the sulphide zones. Local plastic flow folding is present in and around the sulphide zone area. These latter structures are the more obvious evidence of the effects of intrusion.

The sulphide distribution in the eastern, Brown Hill area is much more complex than that of the western zone. Young, in his geophysical interpretation of the geology of the sulphides (Part II) describes four separate zones, all distinguishable on the magnetic profiles. From the results of field mapping alone, it was not possible to achieve the refinements available with magnetic data. Complex geology and difficulties in geologic traversing and location control caused the geologic data to be of limited value. The structural interpretation here will thus draw heavily upon geophysical data for its development.

The sulphides in the eastern area have a much wider distribution than those in the single narrow belt characterizing the western zone. Without attempting to resolve the sulphide distribution into separate belts, as is postulated from the magnetics, a zone one-half to 2 miles wide was mapped. The outcrop pattern is not well defined and structural data is largely lacking. There is difficulty in maintaining strike direction continuity from outcrop to outcrop. Because of the more highly sheared and contorted nature of the rocks, major folds are unmappable. In Lowell Brook and Getchell Creek there are at least two wide sulphide zones which were mapped in detail. There is a wide variation in host rock type and sulphide content in both these detailed sections. The rocks vary from black, massive mudstones to banded siltstones and thin bedded argillaceous quartzites. The sulphide content, not obviously related to rock type, varies from 4 per cent to 12 and 15 per cent. Over-all, the rocks average 10 to 12 per cent sulphides with pyrrhotite as the predominant mineral. Pyrite is less common than in the rocks of the western zone, but more chalcopyrite was recorded. In Getchell Creek, 2 miles east of South Springfield, the only graphite in the entire area was found. It occurs in a black massive well sheared and contorted mudstone; with pyrrhotite content estimated as 12 per cent. The magnetic profile over this locality does not appear to be significantly different than those over non-graphitic sulphide zones.

Lithology does not appear to have much control over the distribution of the sulphides. It was at first considered that the massive, contorted black mudstones were significantly higher in sulphides than the more arenaceous rocks, but in several localities, notably in Getchell Brook, south of McKinney School, where mudstone units occur, there is no evidence of sulphide mineralization. Neither syngenetic pyrite crystals nor cubic casts were found. Most of the rocks in this eastern mineralized area may be generally classed as fine-grained, dark colored, metamorphosed silts, sands and muds. Within this broad lithologic framework, the distribution sulphide mineralization does not appear to be controlled by rock type.

The principal zone, or zones, of sulphides occur in a one to two mile wide belt extending northeast from Drake Place to the south side of Brown Hill. East of Dill Hill, the sulphides do not crop out except for one exposure of rusty schist on Highway 6 near the Carroll and T-7, R-2 town lines. This eastern sulphide belt is poorly defined, varying in width and lacking in continuity of outcrop. Magnetic information is more accurate in plotting its eastward course, but even this data does not completely resolve the contorted distribution pattern.

Two significant features of this belt or series of zones should be emphasized. The first of these is the north-south trending appendix of sulphide outcrops originating near the granite on Almanac Mountain. This trend of sulphides is not more than 100 feet wide. Its southern limit crops out only 200 feet from the granite contact in an area where one of the major contact embayments occurs. This sulphide outcrop trends northward for about one mile, at which point they turn sharply to the east and appear to join a major belt of sulphides which are mapped near Moose Pond at the South Springfield crossroad. This north-south trend does not follow any single lithologic unit, and there is no conclusive evidence that structural control is the predominant force in localizing its outcrop distribution. The rocks of the immediate area are largely within the hornfels zone, where complex folding and contortion makes structural mapping of little significance.

The other feature in this eastern belt of sulphides which merits special consideration is the area across Bowers Mountain. Stickney and Cole mapped a well defined narrow zone of sulphides across the northeast trending ridge top of the mountain. Pyrrhotite and pyrite are present, with a total of 6 to 8 per cent of such minerals noted. They described the host rock as dark gray, thin bedded to massive argillaceous quartzite, locally described as a " dirty quartzite." From their description, this narrow trend of sulphide rocks is very similar to the western South Lee sulphide zone.

The entire Bowers Mountain sulphide zone is at least one mile south of the next nearest sulphide outcrop. These more northerly outcrops are part of the main zone from South Springfield to Dill Hill. There appears to be no relation between the wide main belt and this narrow tightly defined Bowers Mountain trend.

There are only two localities in this eastern area where an attempt was made to establish a stratigraphic position for the sulphide zone. One of these localities is on the south side of Brown Hill in Lindsey Bog. Here the sulphides lie adjacent to the basal gray-green quartzite unit, presumably in argillaceous rocks younger than the quartzite. Even in this locality with almost continuous outcrop, this stratigraphic position is tentative. The sulphides, occurring in a hornfels host rock, are located in the apex of a northeasterly plunging drag fold which also may possibly be the locus of major shear movement.

On Dill Hill, at the easternmost part of the study area, there is another well exposed section which contains elements of the eastern sulphide zone. The rocks in this locality strike northeast and dip almost vertically. North of the sulphide zone the section is described as a massive fine-grained, light gray, quartz-rich argillite. The lithology of this rock type is monotonously similar across the section. Bedding evidence was completely lacking, with only drag folded quartz veins and clots to vary the character of the section. The sulphide mineralization occurs in a wide section of blocky argillite, showing some evidence of original bedding. Cleavage, lacking in the gray argillite, is well developed. The main hornfels zone begins just south of the sulphide zone. It is possible that the sulphides are included within the hornfels zone.

These two localities have been described in detail to demonstrate a significant fact observed throughout the area of the eastern sulphide zone. There does not appear to be any single lithology, structural element or stratigraphic sequence which may be considered a controlling factor on the distribution of sulphide mineralization.

Equally significant is the fact that there is a wide variation in the location of the eastern sulphides relative to the hornfels zone. There is, on the east side of the sulphide zone at Brown Hill and Dill Hill a general association of the sulphides to the northern limit of the hornfels zone. At South Springfield and in the area east of the shear zone south of Drake Place, the sulphides are distributed deep within the hornfels zone and closer to the granite contact.

PART II. GEOPHYSICS
by R. S. Young

Introduction

> "Experience teaches that it is only by the intelligent correlation of geophysical data with all available geologic data that the greatest ultimate practical value of a geophysical survey can be realized."
>
> Jakosky, 1950

Geophysical surveying is a recognized adjunct to geologic mapping and a necessary component of the total geologic evaluation of any large area. Frequently, the justification for areal geologic studies lies in the economic potential of the natural resources of the area of consideration. If the subject area has been deeply weathered, as the Piedmont of the Southeast, or glaciated by continental ice-sheets, as the Northeast United States, geophysical and geochemical surveying constitute indispensable tools.

The application of geophysical surveying to a prospect area necessarily demands consideration of several factors. Foremost among these factors is the ultimate aim of the prospecting program; that is, for what metal, or other material, is the search being conducted? Other interrelated factors which have a direct bearing on choice of instrumentation and procedures are: (a) fundamental geology, especially the rock types to be encountered and the amount and character of cover; (b) the size of the area to be surveyed; (c) the time interval within which the geophysical survey must be completed; (d) finances available to the total program; (e) desired spacing of data, reconnaissance vs. detail. Obviously, there are many other minor considerations which also influence the over-all aspect of the geophysical evaluation; certain of these considerations will appear in the following discussion.

Initial exploratory studies of reconnaissance nature, both geological and geophysical, were carried out by the Maine Geological Survey in this general area (Wing, 25). These studies delineated the major geological features of probable importance and indicated that additional investigations should be carried out with geophysical methods or techniques of greater selectivity. In this case, both confirmation and more detail were required for certain parts of the area.

The choice, then, of the Lee-Springfield-Carroll area, in Penobscot County, as a prospect for more detailed geologic-geophysical work was based on two fundamental considerations: (a) a favorable geologic environment, in which a large granitic mass intrudes a series of metasediments, and (b) anomalous magnetic variations recorded during a reconnaissance-type aeromagnetic survey. On the basis of known geology and preliminary magnetic surveying, a program was laid out to be completed within the following operating parameters: to evaluate the potential of significant ferro-magnetic and/or basemetal sulfide deposits in a relatively large area with a low-budget, detail-reconnaissance survey to be completed during the 1960 field season.

Geophysical Principles

One of the initial steps in the development of a general exploration program is the determination of the applicability of various geophysical methods to the problem existing and the choosing of one or more methods which best fit the conditions. In this case, where the area was large and geological information meager, economics indicated a detail-reconnaissance by one of the more rapidly operated and less costly methods, after which specific parts of the area would be selected for detailed surveying by a slower, perhaps more costly, method. In this frame of reference, it should be emphasized that certain geophysical methods and techniques are uniquely applicable to specific conditions of terrain and geology. In most instances, the ultimate selection of a method necessitates a feasibility study of the various methods to the specific problem. Such a feasibility study should include the limit set forth in the statement that "Economic justification for the use of geophysics in any case is mainly to decrease the financial risk of subsequent exploration." (Jakosky, p. 20, 14).

The reconnaissance aeromagnetic survey which covered a part of the area of consideration GP&G #3, (24) was obviously successful in detecting anomalous concentrations of magnetic materials. The choice of fundamental instrumentation for more detailed ground surveying was thereby resolved; specifically, a vertical-force, Schmidt-balance type magnetometer was chosen for the primary, detailed-reconnaissance work. However, there are many conditions which can cause magnetic deviations in an area, such as concentrations of magnetite or pyrrhotite and intrusive basic rocks. In order to differentiate between possible sulfide ore and some other magnetic condition, a supplementary electrical method, self-potential, was selected to explore specific anomalies. In the case of both methods the purpose of the geophysical data recorded is to assist in the location of a subsurface body, or condition, through anomalous readings which are the direct result of the body.

It is appropriate at this point to briefly review certain aspects of earth magnetism and the phenomon of spontaneous polarization, to emphasize the reasons behind and the importance of the anomalies described and depicted on succeeding pages.

Magnetic principles. The earth is a huge, but rather irregular, magnet, with a magnetic field covering the entire surface. In a meridian section of

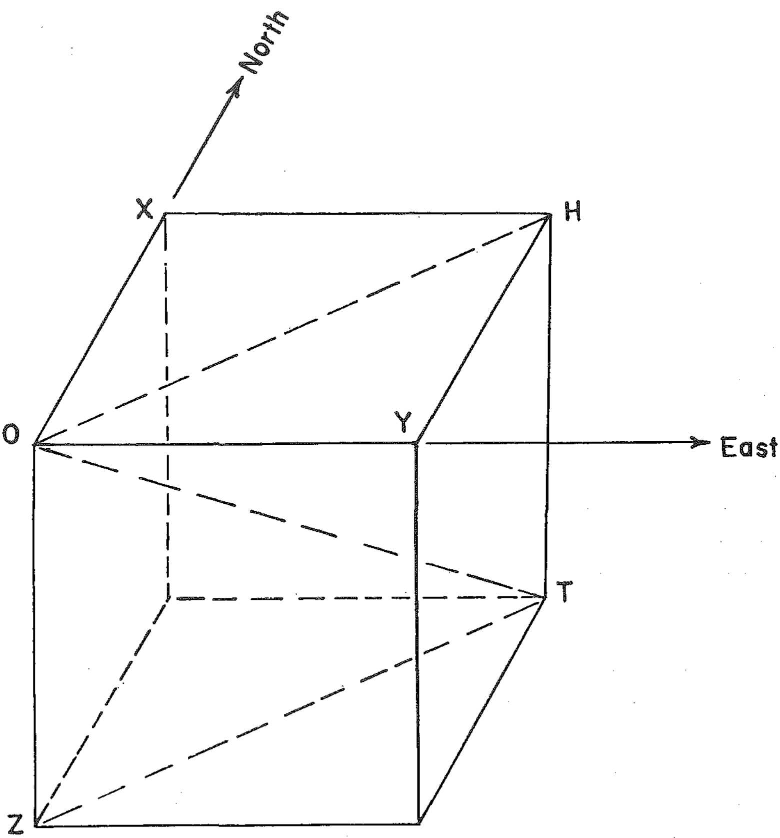


Figure 3. Vector diagram of Earth's magnetic field.

the Earth, the magnetic lines of force have the same general pattern as those about a bar magnet. The magnetic poles do not coincide with the geographic poles and neither are they symmetrically disposed; the North magnetic pole is on the west side of Hudson Bay at approximately 70° N. latitude and a line joining the North and South magnetic poles (actually regions) misses the Earth's center by approximately 750 miles. As the lithosphere is not homogeneous in its magnetic properties the magnetic field of the earth is not uniform over the entire surface. Because of variation in mineral composition, some rocks are highly magnetic while others are only slightly so. Obviously, then, there are many places on the Earth's surface which, due to variations in magnetic intensity and attitude of lines of force, constitute departures from the Earth's normal magnetism. A "neutral field" is one where only the Earth's magnetism exists, and a "disturbed field" is one in which there is a local magnetic body. Variations or departures recorded in a disturbed field are termed "anomalies." *

Figure 3 is a vectorial representation of the Earth's magnetic field at a given point of observation in the Northern Hemisphere. In this illustration OX is geographic north and OY is geographic east. OT lies in the plane of the magnetic meridian (OHTZ) and is the value (intensity) of magnetic force at a given point in space (O). OH is the horizontal component of the total intensity; OZ is the vertical component. The magnetic inclination (I) is the angle TOH, measured in the plane of the magnetic meridian. The magnetic declination (D) is the angle XOH, measured in the plane HXOY. Magnetometers are available to measure variations in either the horizontal or vertical component, or the total field itself. In this field survey, conducted at a moderately high latitude, the magnetometer used measured variations in the vertical component (Z). The aeromagnetic survey, previously accomplished, utilized a "proton free precession" magnetometer which measured the intensity of the Earth's total field. The standard unit of measurement of magnetic field intensity is the oersted (or the numerically equivalent gauss). In view of the fact that the normal total field of the Earth is about one-half oersted, it is obvious that this unit is much too gross for practical prospecting use. For this reason, the gamma was defined as 10^{-5} oersted and the most commonly used unit of magnetic field intensity insofar as applied geophysics is concerned.

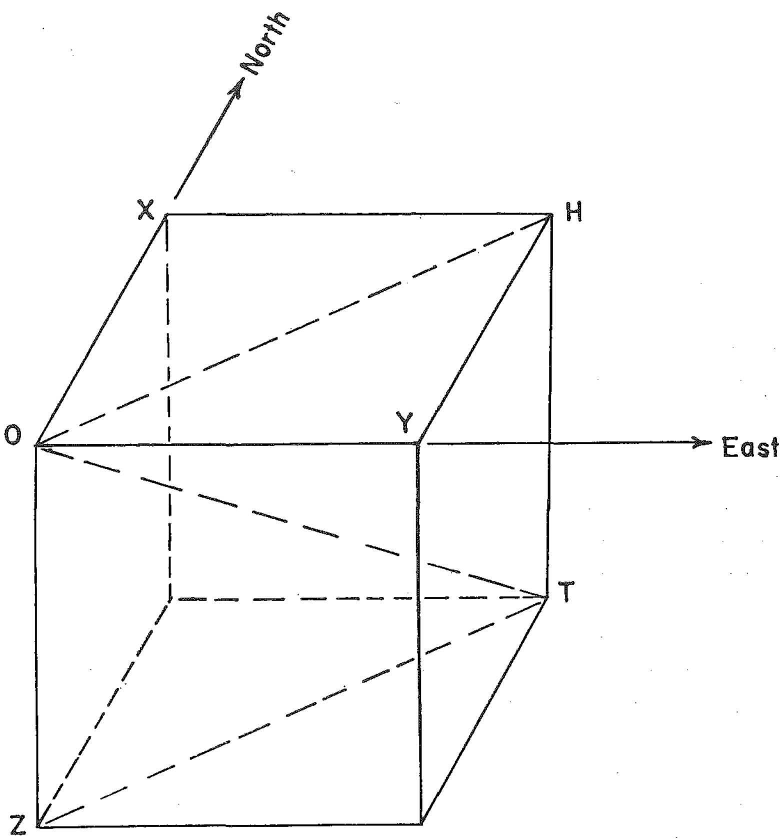
The minerals which are in large part responsible for local magnetic anomalies are magnetite (Fe_3O_4), pyrrhotite (Fe_7S_8), and ilmenite ($FeTiO_2$). These minerals are referred to as having a relatively high magnetic susceptibility, and they impart this property to the rocks in which they occur. In view of the fact that all of these minerals occur in economic concentrations at a number of places in the world, prospecting with a magnetometer is an extremely sound practice.

Table I. Examples of Measured Magnetic Susceptibility (after Dobrin, 1960)

Material	$k \times 10^6$, c.g.s.†	at H (oersteds)
Magnetite	300,000-800,000	0.6
Pyrrhotite	125,000	0.5
Ilmenite	36,000	—
Granite	28-2,700	1.0
Diorite	46.8	1.0
Olivine diabase	2,000	0.5

* Because of the widespread and frequent use of this term in geophysical prospecting, it must be emphasized that "anomaly" per se carries no connotation of ore, orebody, rock type, or monetary value. Many anomalies have led to ore, but in technical usage they represent only variations from the normal.

† These values are at considerable variance with those listed by Eve & Keys (1956, p. 21, 8), but are preferred as they were measured in fields of an oersted or less.



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† These values are at considerable variance with those listed by Eve & Keys (1956, p. 21, 8), but are preferred as they were measured in fields of an oersted or less.

Commercial ore minerals, other than the three with high susceptibility, cannot be directly detected by ordinary magnetic techniques; this fact, of course, does not necessarily exclude the application of a magnetic method in the search for such commercial minerals. In many cases, metallic mineral deposits are mineralogically complex, often containing several economically desirable constituents. This is especially true of the sulfide deposits. For example, sulfide bodies predominantly pyrrhotite may be also relatively rich copper and nickel deposits. Unfortunately, the magnetometer does not distinguish between concentrations of the various ferromagnetic minerals.

In addition to the possibility of locating orebodies of the highly magnetic minerals, magnetic methods have the potential of providing structural information by tracing geological contacts in covered areas. Such methods are especially important in delineating igneous bodies which contrast, even slightly, with adjacent sediments. In many areas of metasedimentary rocks the various stratigraphic units show sufficient contrasts in magnetic susceptibility to allow accurate tracing of contacts or provide markers for outlining structure.

Self potential principles. In an effort to secure additional evidence pertaining to the cause of the magnetic anomalies, a supplemental geophysical survey was performed. This supplemental survey, measuring spontaneous polarization, was far less comprehensive areally than the magnetic survey, being restricted to selected magnetic anomalies. Spontaneous polarization, or self-potential, is an electrical-conductive technique, measuring variations in natural earth currents. Such natural earth currents are dependent upon electrochemical activity in the zone of oxidation. For practical purposes, significant S-P anomalies are caused only by (1) sulfide bodies at least partly in the zone of oxidation, or (2) graphitic material. It should be pointed out that magnetite is reported to give rise to observable S-P patterns under certain conditions (Dobrin, 1960, p. 342, 7). It is probable, however, that S-P anomalies due solely to magnetite will be of low magnitude regardless of the amount of magnetite and degree of oxidation.

Self-potential instrumentation, like the magnetometer, is ideal for reconnaissance or semi-detailed geophysical surveying. The method does not require the application of an external electrical field; the equipment is simple to operate and easily transported; the data are easily reduced. The S-P method makes use of the fact that a near-surface sulfide body may act as a large-scale, natural battery; the differential oxidation between the top (above water table) and bottom (below water table) portions of the body gives rise to a potential difference. The upper part of the sulphide mass acts as the positive pole; the "electrolyte" is the very weak acid formed as a result of oxidation. The potential difference (frequently as great as 500-1000 millivolts) causes a current flow between the upper and lower parts of the sulfide mass; the return flow through the ground outside the body creates a potential anomaly which is measurable on the surface. The center of the upper part of the oxidizing sulfide mass, projected to the surface, is termed the "negative center." A simplified illustration of the S-P phenomenon is shown in Figure 4.

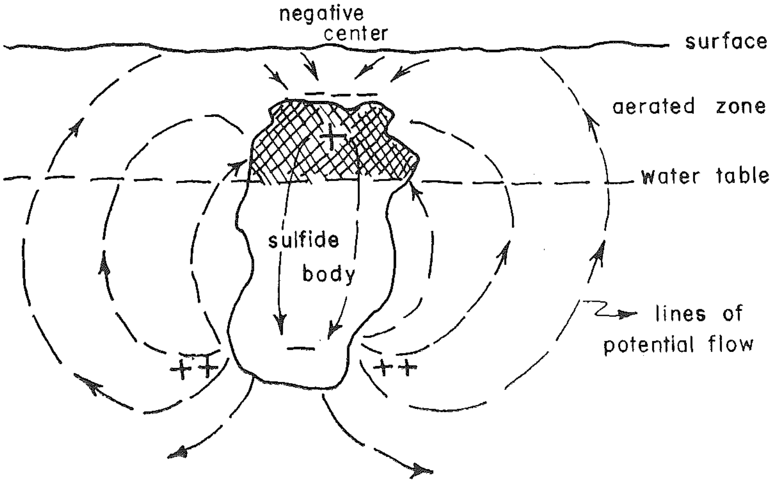

Figure 4. Natural currents produced by an oxidizing sulfide body.

The principal limitation of this method is that a part of the sulfide body must lie within the aerated zone, thus limiting the "penetration" effect to relatively shallow depths. In addition to this prime disadvantage, spurious potentials may modify legitimate anomalies; spurious potential sources are elevation changes, temperature changes, and telluric currents. None of these is important in the S-P surveying performed in the Lee-Springfield-Carroll area.

OPERATIONAL PROCEDURES

Magnetic survey: the magnetometer used in this survey was a vertical-force, Schmidt balance manufactured by Sharpe Instruments of Canada, and designated "Model A-2". This instrument, with compensating (auxiliary) magnets, had a total field range of approximately 15,000 gammas. Readings are taken to 0.1 scale division, giving a reading accuracy of approximately 2 gammas. To minimize both operational and instrument error, two readings were taken on each survey station (N-E; N-W) and the average of the two readings recorded.

A master base station was established near Lee and at least two readings were taken on this station each day of magnetometer operation. Because of the large area of study, it was not always feasible to return to the master base station to establish diurnal control. For this reason, numerous base stations were established throughout the area; the base nearest the magnetic traverse was used to define the diurnal variation. Day-to-day variations were established by readings on the master base station.

On the traverse lines magnetic data were recorded on stations separated by 100 feet. In the presence of metal culture (fences, cars, culverts) or where anomaly detail was desired the station spacing was reduced to that required by the situation. Most of the traverses were laid out to cut the geologic trend at ninety degrees, and were spaced to provide a near-equal distribution of data. After the preliminary, control traverses were completed, nearly all of the magnetometer lines were designed to originate in the magnetically barren metasediments on the northwest, cross the magnetically anomalous area, and terminate in the granite on the southeast. After the approximate position of the granite/metasediment contact was delineated by the preliminary geologic mapping, traverse limits and directions were established on aerial photographs. Field stations on the traverses were accurately located with respect to culture recognizable on the aerial photographs (trail curves or intersections, clearings, prominent outcrops, property lines, etc.). Control stations (100-foot or 500-foot spacing) were marked with colored plastic flagging identifying the station coordinates. In all cases, the ends of the traverse lines were marked by either a stone monument, tree blaze or plastic flagging.

The average value of the readings taken on the field station was converted to gammas, adjusted by the value of the auxiliary magnet (if one was used), and corrected as needed for diurnal and day-to-day departures. Daily magnetic-storm control was maintained by contact with the Weston Observatory, Geophysical Laboratories of Boston College, Weston, Massachusetts.

Self-potential survey: The fundamental S-P instrumentation was that manufactured by the Georator Corporation, Manassas, Virginia. Certain field modifications were adopted to facilitate transportation, but the surveys were carried out in the standard manner. The S-P unit consisted of two copper electrodes, each in a non-polarized porous pot containing a saturated copper sulfate solution; reel with 500 feet of low-resistance, insulated wire; instrument box with "null" indicator and meter calibrated to read 0-1000 millivolts; and connecting leads.

The philosophy of exploration governing the S-P work differed from that governing the magnetic surveying in that, with one exception, only previously established anomalies (magnetic) were investigated. As the magnetic anomalies were sharply defined, non-productive, barren-ground traverses with S-P were cut to a minimum. In all cases, the S-P traverses were designed to cover 500 feet of barren ground on both sides of the magnetic zone, in order to establish background or " noise " levels. Potential values were taken at 50-foot stations, with the 100-foot stations duplicating the position of the previously established magnetometer stations. As many readings as possible were taken from one set-up; the entire system then being moved forward to the last station read on the previous set-up. The survey procedure was repeated as many times as necessary to traverse the desired area. All readings are referenced to the point of origin, which is arbitrarily assigned a value of " zero ".

It is possible that repeating the S-P traverses, run at some future date, may reveal potential values slightly different from those reported herein. The S-P work was carried out during August, 1960, and the soil had an abnormally low moisture content. However, even though the total potential values may change with more ideal conditions, they will remain some function of the values recorded in this report.

Discussion of Anomalies

The location and extent of all geophysical traverses are shown on the accompanying index map (Plate II). However, only the geophysical data which appear significant are presented in profile form. All of the traverses are assigned names which, in general, describe their location. In addition to the geographic title, each traverse also bears a letter designation, and this means of reference is the more frequently used. " A " is assigned to the westernmost traverse (Mattakeunk Pond South) and " V " to the easternmost (Dill Hill). For traverse orientation or terminal points, Plate II should be consulted. Identifying letter designations appear on the index map and profiles as well as in this text.

The accompanying profiles are the heart of the geophysical work; they are the graphic presentation of the anomalous geophysical data and are, therefore, one key to the economic potential of the area. Further, the profiles contain a great deal of information bearing on areal structural geology. In the interpretation of both S-P and magnetic profiles, it should be kept in mind that anomalous field data may vary from place to place for a number of reasons. Jakosky's (p. 45, 14) statement on this point is quite concise: " The magnetic or electrical effects produced at the surface by an orebody or a structure depend primarily upon (1) the difference between the magnetic susceptibility or electrical conductivity of an ore body, or the structure, and the same property of the surrounding country rock;

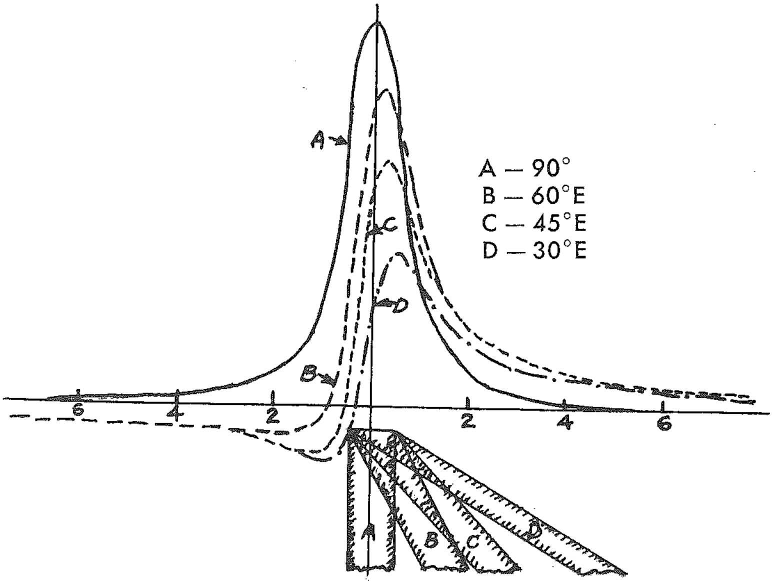

Figure 5. Variations in profiles of vertical intensity over vertical and dipping planar magnetic bodies (beds or dikes). After Cook (1950) and Dobrin (1960).

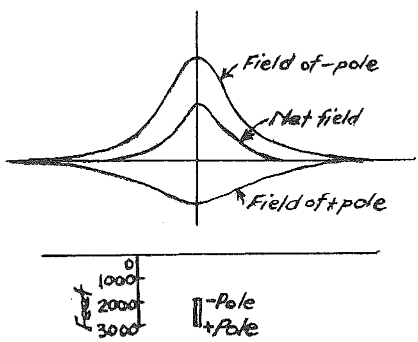

Figure 6. Vertical intensity effects over a buried vertical dipole. After Dobrin (1960).

(2) the size, form, and orientation of the subsurface ore body or structure; and (3) the effective depth of the subsurface ore body or structure." For these reasons, brief discussions are included for each profiled anomaly; a comprehensive interpretation is offered later in the report. As an aid in the interpretation of magnetic profiles, Figures 5 and 6 show certain fundamental relationships based on the attitude and thickness of the magnetic body. On the graphic presentation of geophysical data no attempt is made to contour the magnetic readings, instead a series of profiles, Plates III and IV, oriented at approximately right angles to the magnetic trend, were prepared. On the profiles, the abscissa represents the traverse distance in feet and the ordinate represents the magnetic intensity in gammas. The zero magnetic datum is arbitrary, but constant for the entire survey. Those points on the magnetic profiles identified with the letter " C " are of dubious validity, the value of the station is probably influenced by metal culture.

Traverse " A ": Mattakeunk Pond South. This 3,000 foot traverse was run along a recently-cut, logging access road, south from the Lee Back Road. The traverse was made in an attempt to detect the sedimentary/granite rock contact; as can be seen on Profile " A ", the attempt was successful. As will be noted after inspection of several profiles, the granite/sediment contact is not an outstanding magnetic feature, usually being expressed as a 50-100 gamma change in background level or a low-value one or two station positive* anomaly. On Traverse " A ", the contact is placed in the interval between survey stations 17S and 18S.

Traverse " B ": Mattakeunk Pond Southeast. There is no clearly defined pattern in the magnetic profile of this traverse. It is, however, an unusual case wherein the magnetometer readings may frequently be related to outcrop. The contact in this area is not simple; xenolithic inclusions are common. The complexity of the contact is reflected in the profile. In general, the readings consistently above background (about -340 gammas) correlate with granite outcrop; background readings and below apparently represent the metasedimentary sequence. Whether the granite in the area 15S - 20S is a tongue or whether the sediments exposed between 20S and 30S are xenolithic cannot be determined; therefore, the exact position of the contact is problematic.

* In the northern hemisphere, if a magnetic body (dipole) is magnetized by the Earth's field the positive pole (north-seeking) will lie at a greater depth than the negative one. The total effect is that a buried negative pole reinforces the Earth's normal field, thus its field is defined as positive. Poles always exist in pairs, but if the poles are widely separated in space one pole may not be perceptibly affected by the other and each appears, for mapping purposes as an isolated pole. (after Dobrin, 1960, 7)

Traverses " C-1 " and " C-2 ": Lookout Mountain-Jefferson Mountain. Contrary to the poorly defined picture of the contact shown on the profile of " B ", the composite profile of the data taken on " C-1 " and " C-2 " indicates a clear change in magnetic characteristics. On the basis of the magnetic data, the fundamental granite/metasediment contact lies in the interval 58N - 60N. The minor positive peak in the traverse area 65N-80N may represent the " intertonguing " relationship postulated for Traverse " B "; there is insufficient outcrop to demonstrate such a relationship, however. The 250 gamma, positive anomaly, centered at 108N, is interpreted as the expression of a key stratigraphic unit. If this interpretation is correct, this general area must be one of considerable structural complexity, as shown on the geologic map, Plate I.

Traverses " D-1 " and " D-2 ": Porcupine Mountain East and Offset Extension. When plotted at a large scale ($1'' = 100$ gammas), Traverse " D-1 " shows two definite levels as well as a moderate-value 200 gamma anomaly. Although the two levels are considerably displaced (more than usual), the contact appears to lie in the area of Station 15N or 16N. The anomaly in the area 42N-53N is reminiscent of those appearing over the thinner sulfide-bearing zones in the metasedimentary sequence, although somewhat reduced in intensity.

Traverse " E ": Weir Pond Road. This profile shows a well-developed noise level (330-340 gammas) which is interpreted as representing the granite mass. For a distance of 300-400 feet, the level shifts into the 300-310 gamma range; the latitude of Station 50N is considered the contact zone. Between Stations 60N and 70N a typical sedimentary-sequence anomaly of low-magnitude (450 gammas) was mapped. This anomaly is probably an expression of the sulfide-bearing zone.

A 2000 foot S-P traverse was run over the major anomaly. The entire extent of the S-P line was covered with glacial till of unknown, but probably great, thickness and this fact probably accounts for the indefinite nature of the S-P data. An S-P anomaly was mapped in the interval between Stations 61N and 68N, but its subdued expression is not characteristic of the zone. The fact that there is S-P expression indicates that the magnetic anomaly is due, at least in part, to sulfides.

Traverse " F ": Lee-Springfield Town Line. This long traverse was run early in the survey program to establish one regional cross-section. Only two significant magnetic trends were mapped on this traverse. The first, and southeasternmost, is a small positive anomaly (150 gammas) above a rather constant background level. This magnetic departure is interpreted as originating in the sediments immediately on the west side of the contact.

The contact zone would, therefore, lie at approximately 15N. The apparent lack of the negative side of the dipole indicates that the magnetic zone (beds?) is vertical or nearly so.

The second anomaly occurs approximately 3,500 feet northwest of the inferred contact. This is a major magnetic zone with an indicated width of 700 feet. The high intensity suggests that the magnetic material is present at very shallow depths. Two, closley spaced, steep zones are indicated by the profile, one centering at Station 54N and the other at 57N. It should be noted that the northwesternmost zone is dipolar. An S-P survey of 3,200 feet was run across the major magnetic anomaly, with an additional 500 feet of coverage on either side. Comparison of the S-P and magnetic profiles reveals a rather spectacular confirmation, one of the other. S-P data reveal more clearly the presence of two principal members in the zone, separated by some 200 feet of " barren " material. There is a considerable amount of S-P " noise " northwest of the major zone, with one low-magnitude, but well-defined, negative center at 67N-68N. It is possible that these small departures may represent the positions of non-magnetic pyrite-bearing beds.

There are no zones of significant magnetic departure northwest of the described anomalies.

Traverse " G ": Southwest Tredwell Hill. The traverse intersected only the major magnetic zone, first delineated on Traverse " F ". With the exception of diminished values, the profile for " G " is nearly identical with that of " F ". Two magnetic members are again indicated, separated by 100-150 feet of barren ground. The magnetic bodies are steep in physical attitude, although a slight west dip is probable, for the northwest member at least. S-P was not run on this line because of the obvious similarity of the magnetic zone to that of " F ".

Traverse " H ": Bartlett Bog. The profile of this traverse shows several departures from " F " and " G ". The granite contact is marked only by a slight change in background level and lies between Stations 29S and 30S. The area of the main anomaly is greatly extended over that of the previous traverses and its nature is somewhat changed. The magnetic zone consists almost entirely of small, separated positive anomalies and has very little similarity with other profiles; the dominant positive peak of profiles " F " and " G " may be represented by the bed at Station 7N.

The anomaly belt was definitely mapped by S-P, but also without a great deal of resolution. Actually, the S-P profile is considerably more definitive than the magnetic profile, because of the 50-foot spacing of readings. In this instance, the " usual " relationship of high magnetic values indicating zones of high spontaneous polarization does not hold. The zone of highest polarization values (10S to 5N) correlates with only moderate magnetic activity; the major magnetic peaks (7N and 16N) show only slight spontaneous polarization effects; the minor magnetic peak at 23N shows good S-P confirmation.

There is good correlation between the S-P profile here and that of Traverse " F ", especially in the detection of the minor zones. As a matter of fact, the S-P profile of " F " nearly duplicates the magnetic profile of " H ". Despite the variation in magnetic profile, it is probable that the same units are present in both anomalies.

Traverse " I ": Granite Ridge - Route 6. The profile of magnetic data recorded on this traverse reveals a rather spectacular anomaly, both in intensity (5,442 gammas relief) and cross-sectional extent (about 2,500 feet). Once again, most of the magnetic departures are in the positive direction; the outstanding exception is the strongly dipolar anomaly in the interval 80N-85N. Unless there is unusually well-developed linear polarity present, the magnetic zones are very steep in attitude.

Because of the good expression of the magnetic zone, an S-P traverse was run to establish the nature of the magnetic minerals. The S-P profile, when compared to the magnetic data, reveals some unusual features. The zone of anomalous magnetism is clearly delineated by spontaneous polarization; however, the details of the two profiles are significantly different. The strongest, best defined magnetic anomaly (80N-85N) shows weak S-P confirmation; the second magnetic peak (88N-89N) shows no S-P confirmation. The positive magnetic peaks at 94N and 97N correlate well with S-P departures; that at 104N has no S-P counterpart. The maximum S-P values (92N-93N) are not reflected by anomalous magnetic values.

In this case at least, there is justification to postulate a complex origin for the magnetic belt. Because of the excellent geophysical correlation (S-P; magnetometer) of certain members of the zone, it appears certain that pyrrhotite is responsible for parts of the total anomaly. On the other hand, the lack of polarization expression of other magnetic zones points up the probability of magnetite accumulations. Further, S-P anomalies without magnetite expression indicated pyritic or graphitic beds.

Although there is little in the way of agreement between this magnetic profile and that of Traverse " H ", the width of the zone at " H " may have considerable geologic significance.

From the magnetic data alone, there are two possibilities as to the location of the granite contact, 42N-43N and 49N. Both localities are marked by significant changes in magnetic background. Geologic investigation in the area shows the contact to be near Station 49N.

Traverse I-2: Granite Ridge #2. The profile of this traverse, which was run along a newly-cut, logging road east of Granite Ridge, is reproduced in this report only for comparative purposes. More precisely, it is used as an illustration of the changes which may be expected along the strike of the magnetic zone. The same gross elements are present in both profiles, and the positive nature of the individual anomalies is retained. The striking departure is the change in magnetic intensity in the 2,300-2,500 foot interval between the two traverses. The importance of the similarities of the profiles is that they provide precise strike determination of the magnetic belt.

Traverse "J": Lombard Mountain - Drake Place. This traverse, presented as a unit, is actually the composite of six traverses. The justification of the presentation as an entity is that together they form an apparent cross-section. The composite profile contains three separate magnetic anomalies; the first of which is that over the granite contact. On Lombard Mountain, the contact is expressed as a small positive anomaly; on the Lombard Lake Trail, there is a definite change in magnetic background. The second zone is well-defined magnetically and occupies the zone 75N-95N. An S-P line was completed over this anomaly. The northwesternmost members of the magnetic zone are well expressed potentially; other members show some correlation but not to the same extent. The belt appears to be of the mixed-origin variety, magnetic sulfides playing an important part, but with significant magnetite present.

The third anomaly belt was detected on the short traverse run west-to-east along the abandoned road (116N-142N). Its north-south profile was subsequently mapped on the traverse run north from Drake Place. The mapped width of this third anomaly is approximately 2,000 feet. It is conspicuously positive in nature, with the exception of one strong negative reading at Station 117N.

Traverse "K": not profiled. This traverse was run to determine if the magnetic zone mapped on "J-2" turned northward. Result — negative.

Traverse "L": South Springfield-Spaulding Pond. The traverse is probably the least definitive of all run in this general area. There are two low-magnitude magnetic trends, the first of which (0-10S) may be an extension of the magnetic zone subsequently mapped on Traverse "M". The second zone is about 2,000 feet wide and consists largely of positive readings with minor dipolar configurations. The granite contact does not appear on this profile.

Traverse "M": South Springfield-Philips School. This traverse revealed the existence of a magnetic zone with spectacular expression. The boundaries appear to be well-defined and the magnetic intensities are among the highest recorded in the entire area. As is most frequently the case, positive values predominate; but well-developed dipoles are present. Judging from the strength of the anomaly alone, there must be significant accumulations of magnetite in this zone.

Traverse " N ": South Springfield North. The magnetic profile of the data taken on this traverse reveals a moderate value, sharply defined zone. Because this is one of the few places in the area where sulfide-bearing beds outcrop (pyrrhotite in black argillite), a confirming S-P line was run. As may be seen on the matched profiles, the confirmation is excellent, and the conclusion must necessarily be that sulfides play an important part in causing the anomaly.

Traverse " O ": Bottle Lake - Route 6. This traverse, one of the major, control lines, was designed to be dual purpose. First, it was anticipated that the granite/sediment contact could be accurately located to the east of Almanac Mountain. Second, a continuous profile was needed through the area of suspect contact metamorphism to establish some manner of stratigraphic control. Many of the later, short traverses were run in attempts to trace anomalies detected on this cross-section.

The granite contact is marked by both a minor change in background level and a one-station positive anomaly. This and the Duck Lake traverse are the only ones which penetrated a significant distance into the granite. Near the beginning of the traverse, well into the granite mass, a marked change in background was mapped, the reason for which is not apparent.

A small dipolar anomaly is present between 50N and 60N, but the major belt (over 4,000 feet wide) does not begin until 76N. The profile for the area between 76N and 121N nearly duplicates the Traverse " M " anomaly, indicating once again the relative unimportance of linear polarization. The only place where this phenomenon may be present is in the expression of the low-magnitude anomaly between 20N and 30N. There is a great deal of magnetic activity in the interval 122N-190N, but it is difficult to relate this to any adjacent magnetic zone. Comparison with the " quiet " zone mapped beyond 200N indicates that this inter-anomaly zone may represent a magnetically " noisy " stratigraphic unit.

The third significant magnetic departure is that 500 foot belt mapped between Station 190N and 200N. This anomaly appears to mark the northwestern limit of the magnetically disturbed area.

Traverse " P ": Lowell Brook. This traverse, with its offset continuation (" Q "), constituted somewhat of a departure from the " expected " when the line was run. It was anticipated that both the granite contact and part of the large anomalies on " O " and " R " would clearly appear. The contact zone along Lowell Brook is not obvious in the magnetic profile, even when the data are plotted at a large scale. Two possibilities exist, 18S and 28S. Geologic information places the contact nearer the 28S profile inflection. The only other magnetic disturbance recorded on this line was a weak zone between O and 10S.

Traverse " Q ": Lowell Lake. It is probable that Station O on Traverse " P " corresponds with Station 14N on this line; thus, the two profiles constitute a 10,000 foot cross-section. The major magnetic trend, although well defined, is of low magnitude when compared with " R " on the east and " O " on the west. Direct comparison of the three profiles indicates, however, that it is the same magnetic belt in each instance.

In order to establish some basis for evaluating the origin of the anomaly, an S-P line was completed over this trend. Comparison of the S-P and magnetic profiles demonstrates again a remarkable correlation, in which departures, one from the other, provide significant data. For example, the positive magnetic peak at 14N has no S-P correlative and is, thus, considered to originate from magnetite alone. The series of magnetic peaks between 20N and 35N with corresponding S-P departures are assumed to be due, at least in part, to sulfide accumulations. The high-value S-P anomaly at 52N-53N is without a magnetic counterpart and probably originates from a pyritic (or graphitic?) zone. The adjacent S-P peak (56N-57N) is expressed magnetically and must be due, partly or entirely, to pyrrhotite.

Traverse " R ": Duck Lake - Route 6. " R ", another of the major regional traverses, revealed virtually the same magnetic information as that previously discussed for " O " and " P-Q ". The granite contact is clearly marked by a change in background intensity and is placed at Station 52N. The slight change in background within the granite, previously mentioned in the discussion of Traverse " O ", is present on this profile as well (16N-27N).

The apparent width of the major magnetic zone here appears in profile to be significantly wider than on " O " (4,500 feet vs. 6,000 feet). This is due to the fact that " R " does not intersect the trend at a right angle as " O " did. The values of the individual magnetic units change rather significantly from both Traverses " O " and " P-Q ", but the general characteristics of the belt remain constant. Note should be made of the gross positive nature of the zone.

The most obvious departure between this and the profiles previously described is the existence of the high-value, 200-300 foot anomaly centering at 112N. Profile " O " does not appear to have a counterpart of this unit, unless it is the low-value negative peak at 142N.

One point which may indicate the degree of stratigraphic constancy which some magnetic units may display is in the comparison of the anomaly present on " O " at 205N-206N and that on " R " at 105N-106N. The larger anomalies about 800 feet to the south are of such size that they would be expected to persist over considerable distance.

Traverse " S ": Brown Hill. This traverse adds little to previously established data. The anomalous values recorded in the interval O-5E are reflections of the anomaly mapped at Stations 140N-145N on " R "; the anomaly appearing on " S " at 40E-50E is undoubtedly that at 112N on " R ".

Traverse " T ": Tolman Hill - Thompson Corners. Traverse " T " is part of a major, regional traverse designed to detect and delineate stratigraphic units with magnetic expression which might be used as structure markers. That part of the traverse which is profiled centers on Thompson Corners. This traverse was run on one of the few days classified by the Weston Observatory as of " strong magnetic activity " (storm intensity with deviations of 200 gammas). Base station control during the day indicated more than average changes (50 gammas), but the data are considered usable.

The only magnetic features of significance on the entire traverse are: (1) the small positive anomaly at Stations 362N-363N, and (2) the high-value belt which first appears at Station 375N and extends to 384N.

Traverse " U ": Bowers Mountain. This line was laid out, principally, to further evaluate an anomaly discovered through aeromagnetic surveying. It was also designed to locate the granite contact, which could not be accurately placed through geologic mapping.

The major magnetic zone nearly straddles the top of Bowers Mountain, and can be correlated, at least in part, with outcropping, sulfide-bearing, black argillites. Although negative values are present, the major belt is for most part a positive anomaly. The S-P line run on the same traverse faithfully reproduced the anomaly limits and the individual elements. The intensity confirmation between S-P and magnetometer on Station 60N is noteworthy.

The granite contact is not well defined on the Bowers Mountain traverse profile. However, on the basis of both magnetic and electrical expression, the contact is placed, questionably, at Station 6N.

Traverse " V ": Dill Hill. The profile of these data bears little resemblance to the previous curves. There are two, general, low-intensity zones separated by some 1,800 feet of " quiet " beds. The northernmost zone has no identifying characteristics; the southern belt contains two nearly identical peaks, both of which indicate southward dipping magnetic units. The S-P profile contain little in the way of confirming information.

It is possible that the southern belt may correlate with some elements of the Bowers Mountain anomaly.

Traverse " W ": Stephens Farm. Early in the exploration program, notice was made of a so-called " copper prospect " on the Stephens Farm, on Route 6, Carroll Township. An S-P traverse (S. 34° E. for 1200 feet) was run over the diggings, S. 34° E. for 1200 feet. The plotted profile shows a good S-P anomaly, but not over the pit area. The only outcrop in the anomaly zone is a rusty-weathering, chloritic metasiltstone. Quite obviously, this stratigraphic unit can be mapped by S-P and could, therefore, be used as a structural key horizon.

GEOLOGICAL INTERPRETATION OF GEOPHYSICAL DATA

Examination of the anomalies shows that there are certain geophysical facts to be emphasized and inferences to be drawn which are most effective when presented in the light of geology. The structural interpretations suggested herein are based on the spatial distribution of geophysical anomalies, topographic trends and published reconnaissance geology (Wing, 25), and should, therefore, be used only as an adjunct to geologic data in the final interpretation. Perhaps the most significant attribute of the structural interpretations is that they all indicate a relatively small area as being the key to the problem. It appears that this small area is one of considerable structural complexity.

The facts are these: (1) the magnetic zones are concentrated in the metasediments near the granite contact; (2) there are at least two magnetic environments; (3) the magnetic zone (s) of the different environments cannot be traced from one to the other.

Inspection of the magnetic profiles, with the index map, Plate II, and the structural interpretation, will immediately validate Fact #1, the spatial relations of the magnetic zone (s) and the granite contact. Exceptions to this are (a) the sharp magnetic peak at Thompson Corners, Prentiss Twp. (Traverse " T "), and (b) a minor aeromagnetically-detected anomaly in the Cole School-Spruce Brook area (GP&G #3). It appears likely that these two anomalies are segments of the same zone. It should be emphasized that this zone, on the basis of admittedly sparse data, is thin and of low magnetic intensity.

As for the specific relationship between the granite mass and the magnetic zone — on the basis of magnetic data alone — relatively little can be said. There can be little doubt but that the granite truncates certain of the magnetic belts (Bowers Mountain and Zone No. 1), but whether there is a genetic relationship cannot be resolved. Where they can be seen, the beds in the magnetic zones do not appear to be significantly altered; neither is there evidence of large scale remobilization, or introduction, of sulfides. Nonetheless, outcrops are scarce. The purpose of these comments is to direct attention to the problem in order that field or petrographic studies may be used to the utmost. If a genetic relation cannot be demonstrated, it seems probable that the position of the magnetic zones adjacent to or near the granite is one of pure geological fortuity.

Fact #2, the existence of two magnetic " environments ", is also readily demonstrated by examination of the attached maps. Basically, the two areas may be designated: " Southwestern Magnetic Zone ", relatively simple in all respects, and the " Northeastern Magnetic Area ", which contains at least four mappable zones, exclusive of the Bowers Mountain belt. The Bowers Mountain belt, mapped on only one profile, apparently terminates against the Lucerne granite mass.

The Southwestern Zone extends from a point south of Lee northeastward to the longitude of Springfield. On the southwestern end of the zone is thin, weak and simple in magnetic configuration. These conditions persist to Connecticut Ridge where the magnetic intensity increases significantly. Farther to the northeast this belt widens (Bartlett Bog and Granite Ridge), but the general magnetic elements persist. It may be significant to note that the major change in the profile form is the addition of a " new " magnetic bed, about 1,000 feet southeast (toward the granite) of the principal zone. Comparison of the Granite Ridge (#1 and #2) profiles and that for the Spaulding Pond-Drake Place traverse reveals outstanding differences: on Traverse " J " the " East " zone disappears and the principal zone is apparently replaced by two magnetic belts, separated by 2,000 feet. In short, between " I " and " J ", the character of the magnetic zone changes radically and the magnetic characteristics, relatively constant for miles along the strike, no longer persist. The profiles do not match (Fact #3). Note also that the S-P maxima shift from the east side (" I ") to the west side (" J ").

At this juncture, the " Northeastern Magnetic Area " must be considered as a unit. The picture here is considerably more complex than that of the Southwestern Zone and becomes apparent only upon examination of many magnetic profiles (especially " M ", " O ", " P-Q ", " R ", and " S "). In its simplest aspect, the Northeastern Area contains four strong magnetic zones (Bowers Mountain, Zones 1, 2 and 3) and a problematic, weak belt (Zone 4). The general sequence is repeated in several places and the characteristics are usually sufficiently definitive as to allow recognition of the individual elements. The two principal elements, Bowers Mountain belt and Zone #1, do not appear to be involved in complex structures; the Bowers Mountain belt is truncated by the granite mass of Getchell Mountain and Zone #1 is cut off by the granite near Almanac Mountain. The problem, then, is to relate an apparently complex zone with an apparently simple one.

Structural interpretation of the sulphide zones. Of all the possible structural interpretations available from magnetic data, only one is selected for discussion. This interpretation is certainly more complex than the other interpretations considered. However, it is the one which most closely fits the geologic thinking developed by the mapping geologists. Utilizing the synclinal fold axis present on Wing's 1958 map (25), the magnetic zones are arranged to conform with this general structure. The eastern side of the nose is complicated by a series of folds similar to the fold pattern shown on Figure 2 in Part I of this report.

This structural configuration was suggested by a study of the topography in the area between Almanac Mountain and Springfield. It has the principal virtue of having Zones #2 and #3 " strong " and Zone #4 " weak " throughout their extent. Further, the presence of such " drag " folds would support the postulated shear zone in the Lombard Lake-Springfield area.

Unless geologic data are specifically to the contrary, the geologic picture can be greatly simplified by dismissing the syncline concept and considering the area as one of a straight-forward stratigraphic sequence with five or six (Bowers Mountain to Thompson Corners) magnetic units in steep, but unrepeated, attitude.

The granite contact is accurately placed from Traverse " A ", southwest of Lee, to Bowers Mountain. The selection of the physical positions, as shown, is on the basis of geomagnetics; geology was considered only in a general manner. It is believed that this map presentation of the granite boundary is quite precise. Justification for the specific location of the contact is contained in the various magnetic profiles.

Throughout the area of study, the surface trace of granite contact is generally only slightly curved. The two notable exceptions to this condition occur at Almanac Mountain, where the sediments embay the granite, and south of Mattakeunk Pond, where the reverse is true. At Mattakeunk the contact departure appears to be reflected by local folds in the adjacent sedimentary sequence. The straight trace of the contact elsewhere indicates that in most cases the granite contact is steep, an observation frequently supported by magnetic data. Because it may represent an unusual geological situation, attention is called to the Almanac Mountain area. First, the granite contact turns sharply to the south in this area; second, the general area is one of strongly anomalous magnetism; third, Almanac Mountain, and environs, is an area of intense structural deformation of an unusual type (plastic, disharmonic folding) observed nowhere else in the district. It is suggested here that Almanac Mountain is a hood remnant, a relatively thin sedimentary shell preserved by its physical elevation and a flattening in the attitude of the granite contact. It seems probable that granite is present under Almanac Mountain, at a relatively shallow depth.

PART III. GEOCHEMISTRY

by L. A. Wing

GENERAL CONSIDERATIONS

The geochemical methods utilized for this survey are essentially those of a reconnaissance type in that only selected elements and cold methods of extraction were used and anomalies were not outlined in detail. The work departs from routine reconnaissance in two significant ways; first, the area and boundaries were selected by the State Geologist partly on the basis of earlier reconnaissance work by airborne magnetic and ground geologic techniques by Wing (25), and second, the relative degree of adequate coverage is appreciably more complete than much of the reconnaissance work in this field and this coverage is presented in such a way on the geochemical map as to clearly indicate the areas of influence of each sample and, therefore, the qualitative effects of dilution. It is obvious that more sample stations, measurement of additional elements and further refinement of analytical methods would all be highly desirable but in this area such additional work is more properly left to private endeavor rather than carried on with public funds.

Previous Work

References to earlier work of a geological or geophysical nature are cited elsewhere in this report. The only published work on geochemistry for this area is that of Kleinkopf (16), in which he outlines anomalies for nine elements either within or immediately adjacent to this survey area. The nine elements are: zirconium, copper, lead, silver, zinc, nickel, chromium, vanadium and molybdenum. The summary nature of the Kleinkopf report referred to above does not allow for evaluation of individual lake samples but review of his original notes shows that four lakes were sampled and analyzed within the area of the present survey, they are; Caribou Pond, Mattakeunk Pond, Weir Pond and No. 3 Pond. The data for these four samples, as reported by Kleinkopf, are listed below in Table 1.

Table 1 — Lake Water Trace Elements *

(weight percentage of evaporated residue)

Element	Caribou P.	Mattakeunk P.	Weir P.	No. 3 P.
Salinity (mg./2 liters)	10	32	10	18
Manganese	0.05	0.001	0.05	0.005
Lead	0.05	0.001	0.1	0.005

* The underlined values either equal or exceed anomalous levels as interpreted by Kleinkopf in the 1960 report.

Table 1 — continued

Element	Caribou P.	Mattakeunk P.	Weir P.	No. 3 P.
Tin	0	0	0	0.0001
Molybdenum	0	0	0	0.0001
Copper	0.5	0.05	0.01	0.05
Silver	0.005	0.0001	0.001	0.001
Zinc	0.01	0.005	0.05	0.01
Titanium	0.05	0.001	0.05	0.01
Zirconium	0.01	0.001	0.001	0.001
Nickel	0.001	0.001	0.0005	0.001
Chromium	0.005	0.005	0.0005	0.001
Vanadium	0	0.005	0	0.005

Some of the values from Table 1 are referred to later in the section dealing with interpretation and conclusions. It is interesting to note here the average and median values that can be calculated from Kleinkopf, Table 6, p. 1240 (16), as compared to similar elements in the residue from fresh waters as summarized by Hawkes, Table 2, p. 229 (10). The information from these two sources is compared below as Table 2.

Table 2 — Comparison of Trace Elements in the Residue from Fresh Waters as Reported by Hawkes (1957) and Kleinkopf (1960), as Weight Percentages of the Evaporated Residue.

	Hawkes (1957)		Kleinkopf (1960)	
Element	Average	Median	Average	Median
Chromium	.0036	.0014	.0017	.0005
Copper (a)	.048	.02	.085	.05
Copper (b)	.014	.0034	——	——
Lead	.0023	.0014	.0019	.005
Manganese	.036	.007	.03	.01
Nickel	.01	.0027	.0018	.001
Silver (c)	.0000048	.0000023	.0086	.0005
Titanium	.017	.014	.0147	.005
Zinc	——	.007	.02	.01

(a) Spectrographic determination
(b) Wet chemical determination
(c) Silver values (Hawkes) based on work in 1925

Exploration Geochemistry

It is not within the scope of this work to present a complete discussion of the principle of geochemical exploration and the reader is referred to the work of Hawkes (11). It is, however, worthwhile here to re-state some of his conclusions and briefly review types of sample materials and measurements as they apply to specific environments. In the past few years there has been a tendency within the exploration industry to misuse such terms as " exchangeable ", " partial extraction " and " total extraction " and to compare one survey or method to another without proper consideration of testing detail and sampling environment. These comparisons can be made with appropriate conversion factors and interpretation but are analagous to joining the contours on two adjacent sheets, each mapped independently for different uses, under different specifications, scales and assumed datum planes.

Sample materials commonly available in any area are; outcrop, soils of many types, water and vegetation. The choice of sample material for a particular survey involves a number of factors and these may be categorized as; one, those based on the local natural environment such as—anticipated mineralization, topography, drainage characteristics of both ground and surface waters and the local weathering history, and; two, those factors which involve analytical methods, time and cost. The latter group of factors allow some flexibility but those above based on natural causes cannot be ignored or slighted in any way without risking incomplete and misleading results.

Geochemical methods have been useful in the discovery and development of deeply concealed ore deposits and, it is anticipated that this application will become increasingly important in future years, but the far more common usage is directed to near-surface deposits covered by a relatively thin veneer of soil and subject to both mechanical and chemical weathering. Mineral deposits exist as highly anomalous chemical concentrations in which one or more elements will show an enrichment up to several thousand times their average content in the upper few thousand feet of the earth's crust. The role of the geochemical survey is to detect the presence and approximate location of the anomalous concentration by measurement of the materials associated with, or in proximity to, the potential ore deposit.

Mobility: The environment to which rocks and included metal concentrations are exposed at the earth's surface differs sharply from the conditions prevailing at depth where many of the mineral deposits were formed. Those compounds which were stable when formed in the deeper environment are generally chemically altered, moved to some degree and redeposited as a new suite of stable secondary minerals in the surface zone. The fact that movement is involved in this process of adjustment is critical to the exploration geochemist and planning a geochemical survey is, to a considerable degree, dependent upon the relative mobility of the various ions and their behavior in transit. Hawkes (11) includes an excellent discussion of both the physical and chemical factors which control mobility and these are not further elaborated upon here except as they may apply to the Lee-Springfield area and the elements used for this survey. Considering copper, lead, zinc as used in this survey and further considering such factors as hydrogen ion concentration, ionization potential, ionic radii, solubility of the salts of these metals and the effects of sorption as related to mineralogy and grain size of the samples, it would appear that an order of increasing mobility is: lead, copper, zinc, with zinc much more mobile than either of the other two. The molybdenum value reported by Kleinkopf (16) for No. 3 Pond is significant and this element lies somewhere between copper and zinc in respect to mobility.

Mobility, and the factors which control it, for the ions involved in this survey, are closely concerned with two geochemical features. First is the distance away from a mineral deposit at which it may be detected by chemical measurement. Second are the factors which tend to retard the mobility of an ion and also those which explain how and where the temporarily halted ion should be sought and the analytical treatment necessary to release and measure it.

In the weathering of a mineral deposit and the enclosing rocks the relatively insoluble constituents must move mostly under the influence of the agents of mechanical weathering, principally gravity and running water. Quartz is the most common mineral of the insoluble group but also included are the economically important heavy mineral resistates. Thus the time honored method of panning and analysis of the heavy fraction is an important geochemical technique.

The soluble constituents become a part of the ground water solution and migrate from the original site at variable rates dependent upon soil permeability and water table gradients. The soluble constituents, including the ions and radicals utilized in geochemistry are transported by ground water, unless precipitated or firmly attached to soil grains. These constituents will eventually reach the surface drainage system and continue migration at a much higher velocity.

Insoluble particles will also move faster once they reach the surficial drainages and the creep, flows and slides which bring such particles to the streams are themselves accelerated by excess soil moisture. It is therefore apparent that ground and surface waters play a dominant role, as solvent and transporting agent, in all processes of shallow zone geochemistry. The importance of mobility as related to water transport cannot be over-emphasized in any sampling program. Water, soils from various depths, transported stream sediments and vegetation may all be utilized and still take advantage of the concept of water transport of the desired elements. The merits and disadvantages of each material are briefly summarized below.

Sample Materials: Water — A water sample may be used to advantage if only the soluble materials are to be sought. The sample is an ionic solution readily conditioned for many analytical techniques but at the same time the concentration of some elements is so low that some process of concentrating the sample such as evaporation, Kleinkopf (16), or collection in resins, as described by Canney (5), must often be employed. Daily and seasonal variations due to the effects of dilution are to be expected. Large samples are frequently required and present problems in collection and storage and, after collected, water is undoubtedly the most readily contaminated type of sample.

Soils — Soils have been widely used as the sampling material for geochemical surveys in nearly all parts of the world. Results must be subjected to careful interpretation, especially in respect to mineralogical composition of the sample, local weathering history and genesis of the soil deposit (particularly transported soils). Some of the problems associated with soil samples are further discussed under the section dealing with analytical methods.

Stream Sediments — The product of both mechanical and chemical weathering within any drainage basin tend to work their way downslope and eventually into the active stream channels. Stream waters and their transported load will, if properly collected and measured, yield much information on the geologic nature of the upstream portion of the basin. This type of sample is much more effectively used in areas of moderate to high relief than in flat regions where drainage patterns are poorly developed and erosion is slow. If uniformity is to be approached, the stream sediment samples must clearly be transported material, relatively free from organic matter and the sampler must attempt to take materials made up of about the same grain size range throughout the area.

Vegetation — The work of Warren (23) and associates, and others, has demonstrated the validity of this technique. Vegetation samples require somewhat more elaborate preparation than other material and problems may arise in respect to distribution of satisfactory species for some areas. This type of sample has not been as widely used as the others in the past few years but the reasons for this are not entirely clear.

For a general review of sample materials and analytical methods recently used in Canada the reader is referred to the recent paper by Riddell (18).

Stream Sediment Geochemistry

Both reconnaissance and detailed geochemical prospecting in a terrain such as New England, can be most effectively accomplished with stream sediment samples. The transported sediment sample will be dominantly made up of resistant rock fragments and unweathered (chemically) mineral grains. For a great many areas quartz will be the only major constituent. Secondary products of weathering will also be a part of the sample and the proportion of secondary products and the unaltered primary grains may vary widely from one area to another as well as from one sample to the next within the same area. Samples taken close to a mineral deposit may include both primary and secondary ore minerals. The stream waters which are responsible for transport of the sediment sample also carry a solution load and a representative of this solution load will be found with the sediment. The ions extracted or precipitated from the water may become a part of the sediment sample in three ways;

(a) relatively stable secondary minerals formed as chemical precipitates.

(b) ions taken into the crystal structure of the clastic grains either by occupying a void site or by exchange. This is more important for the sheet structures present in such minerals as the clay group or the micas.

(c) cations loosely held to the surface of clastic grains by the negatively charged surface. The negative charge is due to broken bonds and the ions thus attached are readily exchanged.

These three ways in which materials in solution may become a part of the sediment sample can be more briefly referred to as precipitates, absorbed ions and adsorbed ions. The precipitates and absorbed ions can be considered a more or less permanent part of the clastic load whereas the adsorbed ions are readily exchangeable and move rather freely from one grain to another and also migrate back and forth between the soil grains and the aqueous solution. The total adsorbed load on the clastic grains that make up the sample medium is essentially a function of the concentration of the water solution but it appears that variation due to short term dilution is less noticeable in stream sediments than in the waters with which they should be in approximate equilibrium.

Measurements may be made upon all or part of a stream sediment sample and they may be further refined to include a single element, several elements or element groups. Since complete analysis is rarely practical, the exploration geochemist must choose that fraction of the sample and those tests that are in keeping with local geology and economics. The well known associations of geology and mineralogy can be heavily leaned upon if properly tempered by the concept of mobility in the surface environment. Thus, a geochemical survey in a geologic setting favorable for the development of a nickel ore deposit will find cobalt a more useful element than nickel itself. Highly mobile zinc might better be prospected for by utilizing the zinc-cadmium ratio. Molybdenum might be as useful as copper in searching for the porphyry coppers. Several other possibilities of this nature exist and much more has yet to be done with elemental ratios. If the data from any geochemical survey are to be fully utilized, the information acquired by measurement must be interpreted in the light of geology, in the broadest sense of the word, crystal chemistry, ore genesis and weathering.

Geochemical Measurements:

A rather impressive number of analytical methods are now available for the determination of trace amounts of many elements. " Trace " is described by Sandell (19) as; " Both from the logical and historical standpoint there is good reason for setting the upper limit of a trace or microconstituent at about 0.01 percent — There is no necessity for making the boundary a rigid one."

Sandell (19) includes an excellent summary of the methods in common use and is an invaluable reference in the field of colorimetric analysis. While most of the measurements made in geochemical work require great sensitivity they have not, as yet, required the accuracy attained by the analytical chemist. To state this another way, it is frequently desirable for the detection limit to be less than one part per million (0.000001 grams/gram) while at the same time a reproducibility of fifty percent might be easily tolerated. This is further discussed under the meaning of such terms as " background " and " threshold " in subsequent pages.

Total Methods: The use of the word " total " implies that all of the desired element present in the sample has been measured with some stated degree of precision or reproducibility. Unfortunately, it is not uncommon within the exploration field to find that partial measurements described in the next paragraph, are used in the same sense, and often interchangeably, with total values as herein defined. Total measurements are best used when the sample consists of rocks or individual minerals and perhaps to a lessor extent residual soils. Considering the generally higher costs and longer times involved in this type of measurement and the fact that it has been no more successful in the discovery of mineral deposits than some of the simpler tests, this measurement does not seem to be justified as a general approach to the geochemical survey. The choice of wet chemical or spectrographic instrumentation depends on the desired elements and relative costs.

Partial Methods: The term partial methods needs more in the way of definition and may often be more accurately described as " hot extraction methods ". This type of measurement has been used quite extensively and has been responsible for some erroneous impressions regarding what percentage of the metal present was measured and also the source, within the sample, of the reported metal values. Most of the commonly used partial methods are based on extraction of the metal by warm or hot acids (frequently nitric or hydrochloric) and therefore do not liberate material incorporated within the structure of the resistate grains. Most of the secondary minerals are soluble under this attack but even these may dissolve at quite different rates so that both time and temperatures are important factors.

This type of measurement does have a number of important applications but must be used with caution and local experimentation. In areas of residual soils, the sample may be composed of nearly one hundred percent acid soluble material that does not give up its metal values to cold exchange methods, and here the contrast between the two would be great. In regions underlain by acid intrusives and covered by a relatively young glacial soil, the sample may consist almost entirely of quartz and the difference between cold exchange and hot acids methods may be quite minor.

Cold Exchange Methods: There are several excellent references to the details of this method, Bloom's (1, 2) work still serves as the basis for much stream sediment geochemical prospecting and is also essentially the basis for most of the field kits now on the market. With minor modifications, the Bloom test is the type used in this survey as described in following sections. The work by Hawkes (10) in New Brunswick is an excellent example of the utility of this method as is also the work in Nova Scotia by Holman (13).

In this method only those ions which are loosely attached to the surface of sample particles are measured. Such ions are subject to easy exchange, even in their natural aqueous solution, and are therefore adaptable to cold and rapid field tests. That portion of the total metal content of the sample that is tightly bonded within a clastic fragment, either as a normal component or an exotic absorbed ion, is of little consequence to this test since the cold exchange solution is not capable of freeing such ions in any appreciable amounts.

The stream sediment sample as used with cold extraction methods represents a collector for the very dilute aqueous solution of stream waters and may be qualitatively compared to an ion collecting resin. Since the sample is used as a collector or concentrator this method is more closely a measure of the metal content of stream waters than anything else but it does not require the extreme sensitivity needed for the water test nor is the sample as susceptible to contamination as is water itself. Surface water samples are liable to contain appreciable amounts of metal concentrating algae, especially on warm sunny days, and this variable is also avoided by use of stream sediments.

THE LEE - SPRINGFIELD AREA

Discussions of geology and geophysics of the area chosen for this survey are found in other portions of this report and Part III deals primarily with the details of the geochemical survey. Conclusions of both a geological and geophysical nature must be utilized in the geochemical interpretation.

The base map shows the hilly and well drained nature of the Lee-Springfield area. Stream patterns are nearly all dendritic and valleys as well as stream channels are well defined in all but a few of the swampy areas. This terrain is ideally developed for the application of the methods of stream sediment geochemistry.

Field Control:

Throughout much of the area the field party was able to pinpoint sample locations with ease from the U.S.G.S. topographic quadrangles covering the area, (Winn, Springfield and Scraggly Lake, all at 1:62,500). The topographic maps were supplemented by aerial photographic coverage at a scale of one inch equals one-half mile, the photographs are especially useful in planning traverses for maximum economy. Since tests were performed in the field at the site of the sampling station, it was possible to experiment with the local area of the station to avoid obvious local contamination and evaluate some of the variations associated with variable grain size and organic percentages. The samples for laboratory use were taken only after the field measurements were completed.

Field Measurements:

All field measurements were made by a cold exchange method very similar to that reported by Bloom (1) and the details of each portion of the test and the reagents are described below.

Sample — The choice of the sediment is one of the most important parts of this test. Hawkes (10) in nearby New Brunswick concludes, in part, that (a) the content of exchangeable metal varies inversely with grain size, (b) the floodplain sediment is comparable to the active sediment at the same site, (c) high metal values in the waters are associated with high metal content of the sediments, (d) sediment samples eliminate the effect of weather variations, allow sampling of dry channels, are easier to test and the sample may be stored conveniently for future use. Based on several thousand tests in Maine, many checked in both the field and laboratory, the further comments below may be added; (a) the coarse (plus 60 to 80 mesh) material should be avoided, (b) plastic clays should be avoided, (c) organic material is an efficient metal collector and sampling should aim at uniformity of this fraction if it is to be utilized at all and, (d) samples should be retained from each station for further laboratory measurements.

Extractant Solution — The extractant solution used in this survey is essentially unchanged from the original Bloom test, i.e., an aqueous solution containing 4.5 percent ammonium citrate and 0.8 percent hydroxylamine hydrochloride. The efficiency of hydroxylamine hydrochloride as a reducing agent decreases with time so that it is advisable to dispose of old solutions periodically. The loss of ammonia to evaporation with a resultant change in pH is possible and enough thymol blue indicator may be added to the field solutions to impart a definite blue-green color comparable to pH 8.5 and small losses of ammonia will show up as a yellow color in the solution.

Colorimetric Agent — Dithizone has the only colorimetric agent used to measure the extracted metals for this survey. Dithizone in several organic solvents will form metal dithizonates with a number of elements, Sandell, (19), Table 22, p. 142, lists nineteen such elements. The tests for single elements or element groups may be made more specific by; (a) adjustment of pH which is highly effective if extraction coefficients of the elements involved vary by a factor of 1000 or more, (b) altering the oxidation state of the ions and, (c) adding a complex-forming agent to tie up some of the undesired reacting metals. To this may be added the fact that some of the reacting elements are present in most environments in such low concentrations as to be insignificant for many tests.

Dithizone solutions are susceptible to rapid oxidation in strong sunlight and at elevated temperatures and the problem is more serious with low concentrations. Two strengths are used in the field method; one, the stock solution consists of a 0.01 percent solution of dithizone in toluene and this is relatively stable if kept away from high temperatures and covered with foil, two, the field solution which is prepared daily or more often if needed, by diluting the stock solution with additional toluene to 0.001 percent strength. In practice it is advisable to dispose of any remaining field solution at the end of each day and the stock solution at the end of each week. Deterioration of the field solution is subtle and this can create serious problems if the solution is allowed to age. Discarding on a period basis helps to solve this problem but it is also advisable to check against standard solutions both periodically and whenever deterioration is suspected. The check against a standard solution also serves as a check against laboratory measurement of the dithizone crystals and the mixing procedure.

The Heavy Metals Test — The test as used in this survey is essentially a zinc test although some of the copper and lead present are also measured. Other elements may be present in smaller amounts such as; nickel, tin and possibly secondary dithizonates of silver and mercury but, with the exception of station number 158, it does not appear that these present a problem for this area. From experimental work on some of the samples from this area as well as on controlled standards, it appears that this test measures nearly all of the exchangeable zinc and roughly twenty-five percent each of the exchangeable copper and lead. The test procedure is as follows:

1. place one scoop of sample in graduated tube or cylinder
2. add 3 ml. of extractant solution

3. add 1 ml. of field dithizone
4. cap and shake for 15 seconds
5. allow dithizone-toluene layer to separate and note color, if
   green — record as 0 ml.
   blue green — record as ½ ml.
   blue — record as 1 ml.
   purple, red or salmon — proceed with step 6 but make a note if salmon color, indicative of copper, is present.
6. continue to add dithizone with 10 second shakes in increments of 1, 2, 2, 4, 5, 5 ml. until the blue-green end point color is reached and record the number of ml. of dithizone used.

Conversion Factors — At a concentration of 0.001 percent, one milliliter of dithizone solution will complex 0.34 micrograms or about the same amount of copper or lead. Since micrograms per gram read directly as parts per million it is only necessary to divide 0.34 by the weight of the sample to read directly as parts per million (ppm. w/w). The scoop used in this survey measures 0.15 cubic centimeters so that a conversion of milliliters of dithizone solution to ppm. w/v can be stated as (0.34/0.15) 2.26 ppm. per one ml. of dithizone. This is also roughly equivalent to the same value expressed as weight/weight since the density of the sample is such that weight and volume are approximately equal. The results of this survey are all reported as parts per million zinc equivalents expressed as a weight/volume measure. If appreciable percentages of organic material are a part of the sample, the equality between weight and volume no longer holds, and to this is added the fact that organic material is a more efficient collector of metals than most of the soil grains. If organic variation is common in an area, samples should be weighed rather than measured in a volumetric scoop and even then the results will not be entirely satisfactory until experimental work has been carried to the point where increasing organic percentages may be equated to clean soil equivalents.

One further note on conversion is appropriate. Throughout this survey both field and laboratory results are based on a conversion factor of about 2 ppm. per milliliter of dithizone and at the same time, the field sample was generally moist or wet while the laboratory sample was dried and sieved. The true weight of the contained soil grains in each case was measured for a large number of samples and the variation is not significant.

Laboratory Checks — It was originally planned to run laboratory checks on every tenth sample taken in the field but as this work progressed it became apparent that on several different occasions the values showed a discrepancy that exceeded anticipated limits. It was then decided to re-run all of the samples by laboratory methods and in the process it became apparent that the earlier problem was confined to a few specific days. It appears that the higher field values on these few days was probably due to deterioration of the field strength dithizone and the problem was eased for the remainder of the survey by emptying the field bottles each half day if temperatures were relatively high.

The laboratory procedure was identical to that used in the field with the exceptions that the samples were dried, passed through a number 65 mesh stainless steel sieve and then tested. In addition to these changes in procedure it must also be assumed that laboratory methods introduce improvements in the way of standardization of both materials and techniques. The laboratory values are those used to produce the geochemical map.

In addition to the re-testing of field values, all of those samples showing values over threshold (defined later) were also tested for cold exchangeable copper. The exchange solution for this test is made up of ammonium citrate and hydroxylamine hydrochloride adjusted to pH2 with hydrochloric acid. The colorimetric agent is 0.001 percent dithizone in hexane. It is the experience of the writer that while many heavy metal anomalies may be due to rather minor zinc deposits or to a few-fold zinc enrichment in rocks, the copper anomalies by cold exchangeable methods are generally associated with quite nearby copper mineralization. The cold methods as described by Canney (4) yield about the same results as the method described above for a rather limited number of tests on which both have been run by the writer.

Method Evaluation — The only way of evaluating the usefulness of the methods used in this particular survey that is available at this time is to analyze the variation in the several samples at each station and, the field results as compared to the laboratory results. These comparisons are summarized below as Table 3.

Table 3 — Comparison of Results

Field active, average ppm.	9.5
Field bank, average ppm.	11.5
Laboratory active, average ppm.	8.0
Laboratory bank, average ppm.	8.7

The values from Table 3 may be compared to similar data from New Brunswick as reported by Hawkes (10) with the condition that the field values for this work are measured with moisture as collected, were unsieved and, the laboratory values are restricted to the minus #65 mesh sieve. These comparisons are made below as Table 4 and the grain size limits used by Hawkes are stated in the table.

Table 4 — Bank/Active Ratios

Hawkes		This Survey	
— 12 mesh	— 200 mesh	unsieved, field	— 65 mesh
1.33	1.06	1.21	1.08

The results from Table 4 are based on samples from a single site in the case of Hawkes while in this survey the unsieved field ratio is based on 267 sites and about 1300 individual measurements and the minus #65 mesh ratio is based on 228 sites and about 500 individual measurements.

Contamination:

The problems associated with contamination have been grossly exaggerated by a number of individuals in the exploration field. It is obvious that a sample taken next to an abandoned galvanized bucket and similar objects will show an abnormal amount of zinc and it is possible to list a rather impressive number of common items that will produce serious contamination of other elements in addition to zinc. It should be realized that all of the metal from most of these objects, if spread over a few tens of tons of stream sediment, amount to a few parts per million at the most and that the highest concentrations must lie quite close to the contaminating source. Two field techniques can almost guarantee that the problems of contamination will be entirely removed from a survey, even in areas where contaminating objects are quite common. The first of these is to use the concept of sample site as opposed to single sample. Here, at least two active (underwater) samples and two bank (transported material left above the normal water levels) are tested over an area of not less than 100 linear feet of stream channel and the possibility of a contaminating source which will reach all of these samples is remote. If one is present and the values are erratic, further investigation at the time and on the spot is called for. The second of these precautions lies in the use of active versus flood plain samples. In this situation the normal values will show bank samples slightly higher than active samples, mostly due to finer grain size and higher percentage of organic material. If contamination is present in or close to the stream channel, the active samples may show appreciably higher values than the bank samples which have been exposed to the contaminating waters for relatively short periods of time. In well over 20,000 measurements made in Maine, Quebec and New Brunswick, the writer has yet to see one source of contamination which could not be readily explained and eliminated within less than one hour's work at the site and in a majority of these sites the sampler could have disposed of the problem during the original survey at a cost of a few dollars.

Data Presentation:

The results of all tests performed in both field and laboratory are tabulated in the appendix of this report. Most of the laboratory values have also been included on the geochemical map although not all stations are plotted since some measure duplicate areas or follow-up within a small area and a few were from such small drainage areas that they cannot be included at the scale used. The geochemical overlay registers with the base geologic map.

The method of presentation chosen assigns definite areas of influence to each sample station and since these may vary greatly in size, the method allows at least some qualitative means of evaluating dilution and places clear boundaries on areas of interest. These boundaries represent outer limits but do definitely imply that any anomalous source of metal at a given station must come from within the assigned area. The larger drainage systems are enclosed by a solid line while lesser areas within a larger drainage are enclosed by a broken line. If only point values at each station are considered, as has commonly been the method of many surveys, station 34 would be considered a more significant point than station 25 close beside it (both on the southeastern edge of the mapped area). The lower value at station 25 measures about five times as much area as 34 and includes two highly anomalous value as shown at 27 and 158 and perhaps also as important are six other stations within the same drainage. The significance of the group of values north of No. 3 Pond is much more readily noted by this method of presentation.

The relative values used to produce the patterns on the geochemical map are based on average laboratory results for each station and these have been subdivided as:

0 to 6 ppm	—	Background, approximately 14 squares per inch
6 to 11 ppm	—	Threshold, approximately 28 squares per inch
12 to 19 ppm	—	Anomalous, approximately 42 squares per inch
20 & 20 plus	—	Anomalous, approximately 56 squares per inch

The map is made more readable by hand coloring the various areas and it is also possible for the reader to modify the value ranges or use the field measurements rather than those from the laboratory.

Interpretation and Conclusions:

Of the total area covered by geochemical measurements a relatively small proportion can be considered anomalous enough to warrant follow-up by this and other methods. The relatively small area referred to above is based solely upon geochemical data and can be shown more clearly as tabulated below:

Background values,	70.1	percent of the total area
Threshold values,	18.5	percent of the total area

Anomalous values,	8.1	percent of the total area
Anomalous (20 plus)	3.2	percent of the total area
Copper values,	0.67	percent of the total area

Stated another way this would indicate that perhaps a little less than 6000 acres out of more than 50,000 acres warrants additional work and this area can be further reduced when both the geological and geophysical data are added to the geochemical interpretation.

Two anomalous areas stand out along with several other anomalies based on one or two stations. The significant anomalies or anomalous areas are listed and discussed below in an order of decreasing interest from the geochemical viewpoint;

No. 3 Pond (North) — The positive copper values noted from sample stations along Thurlow Brook as well as the associated heavy metals values leaves this as probably the most significant geochemical anomaly on the map. The high values associated with station 134 are probably due to seasonal spillover from Thurlow Brook and it should be noted that these values fade rapidly downstream at station number 261. Stations 132 and 260 are outside of the Thurlow Brook drainage but do drain either nearby areas or reverse slopes. The molybdenum value reported by Kleinkopf (16) for No. 3 Pond further strengthens the anomalous nature of this area. Copper, lead and zinc are not reported as anomalous in the lake water but it should be noted that Kleinkopf's sample was taken from the center of the pond and waters from Thurlow Brook would probably not influence that sample.

The coincidence of this anomalous area with the granite sediment contact can be noted by overlaying the geochemical map on the geologic sheet. Geophysical methods did not cover the area in enough detail to either substantiate or discount the geochemical values.

Lombard Lake (North) — The drainage into the north end of Lombard Lake, as shown by stations 191 through 194, are uniformly anomalous in heavy metal values. Stations 199, 205 and 208 should also be considered a part of this area. When compared to geological and geophysical data it is noted that sulphides are present in the area as well as geophysical anomalies.

Lowell Lake Area — The entire area drained by stations 25 and 34 is anomalous although values are somewhat erratic. Sulphides and geophysical anomalies are both present and in addition this is an area where structure seems to be somewhat more complicated than elsewhere. Contamination is a factor in samples from stations 26 and 27 but the importance is difficult to evaluate since sulphides can also be seen in the same area. Station 158 shows very high heavy metal values and a copper value but the colors of the dithizone layer for these samples are not standard and may either be due to other elements or oxidation of the dithizone by materials present in the samples, further chemical work should be done on this immediate area.

Station 270 (East Edge of Map) — The uniformly high values reported for this station are in sharp contrast to a large area of surrounding background values. Sulphides are known to be present in the northern part of this drainage area and additional work is warranted here.

Getchell and Barker Brooks — Several anomalous stations are present in this area but the values are neither extremely high nor uniform. Heavy concentrations of sulphides in the sediment are known from Bowers Mountain and pronounced geophysical anomalies also coincide with the high values to some extent.

A number of other anomalies could be listed here but in general they seem to be less significant than those listed above and some of them are marginal enough to the area so they are not covered by geologic or geophysical information.

GENERAL SUMMARY AND RECOMMENDATIONS

The rocks in the study area are characterized by an undetermined thickness of very fine grained slates, quartzites and argillites of presumed lower Paleozoic age. They have been folded into a southwesterly plunging syncline and regionally metamorphosed to about a green schist rank. The southerly part of the area has been intruded by granite of varied composition and texture. Rimming the granitic body is a zone of hornfels described as a massive, equigranular quartz biotite rock, schistose in places.

Paralleling the granite contact and lying largely within the hornfels, are several zones of sulphide enrichment consisting primarily of pyrrhotite and some pyrite. The sulphide enrichment cross-cuts both lithology and stratigraphy. Geologic mapping has defined an east and west area of enrichment separated by a north-south trending major shear zone. To the west the sulphides occur as a single narrow belt while to the east a geologically complex series of at least four sub-parallel belts have been mapped.

The geophysical work by both self potential and magnetic methods identified and refined the boundaries of the sulphide zones. In addition, a comparison of the detailed geophysical information provided by each instrument indicates four types of anomalies suggesting four possible geologic conditions: (a) anomalies due to accumulations of minerals of high magnetic susceptibility alone, (b) anomalies due to oxidizing sulphides, the sulphides themselves being moderately magnetic, (c) anomalies due to oxidizing sulphides which are non-magnetic, (d) anomalies of complex origin. Because of the extreme scarcity of observed graphite it is doubtful if any of the major S-P anomalies can be attributed to graphite accumulations. Although a brief examination was made at the time of geophysical surveying, the principal anomaly areas should be considered unexplored until the precise determination of the anomaly-causing minerals is completed. In many cases, the magnitude of the anomalous geophysical data, the width and length of the anomaly zone, and the frequently spectacular correlation of the two techniques are better than similar characteristics of known ore zones.

The geochemical survey indicated that anomalous values of combined heavy metals (zinc, lead, copper) are confined to slightly more than ten per cent of the area. The most significant anomalies were confined to either those areas known to contain sulphides or areas immediately adjacent to the granite contact.

Recommendations for further work in the area should consider:

1. An east-west extension of geologic mapping in the metasediments lying adjacent to the granite contact.

2. Implementation of the geophysical data with further magnetic traverses in areas of weak geophysical control, specifically north of No. 3 Pond and the region near Almanac Mountain.

3. An electro-magnetic survey should be conducted over the entire area of anomalous character.

4. Further refinement of analytical techniques and geochemical measurements for specific elements, in addition to those tested, would be advisable.

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APPENDIX I to PART III
TABULATION OF GEOCHEMICAL VALUES

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
1	3	4	3	4	—	—
2	3	5,6	—	—	—	—
3	8	4	2	4	X	—
4	8,10	9	3	4	—	—
5	10	10	4	4	—	—
6	4	4	—	—	—	—
7	8	8	5	6	—	—
8	5	—	4	—	—	—
9	3,4	6,8	4	4	X	—
10	16	18	8	12	X	—
11	3,5	6,8	—	—	—	—
12	6,8	2,3	2	—	—	—
13	8	6	2	3	—	—
14	8	8	2	4	X	—
15	4	5	2	4	—	—
16	12	10	4	4	X	—
17	10	12	4	6	—	—
18	2,3	4	1	3	—	—
19	5,4	7,4	2	4	—	—
20	8,10	12,12	12	12	X	—
21	12,14	18,12	6	6	X	X
22	12,14	12,14	6	8	—	X
23	10,12	14,12	8	10	—	X
24	6,6	4,6	2	4	—	—
25	8,12	20,20	8	14	X	X
26	18,16	10	16	18	X	X
27	20,20	10,20	38	8	X	X
28	6,8	16,20	8	12	—	X
29	8,8	8,10	4	3	X	—
30	4,4	8,12	6	12	X	X
31	4,8	8,8	8	8	—	—
32	20,20	20,24	18	16	X	—
33	4,8	4,6	1	4	—	—
34	12,20	—	20	—	X	—
35	16,16	16,12	16	12	—	X
36	10,8	12,16	8	12	—	X
37	6,10	16,12	7	8	—	—
38	6,8	14,12	5	8	X	—
39	14,10	14,14	8	8	—	X
40	8,8	8,6	2	4	—	—
41	10,10	18,14	6	8	—	—
42	4,6	10,16	2	4	—	X
43	1	8,10	4	6	—	—

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
44	10,8	14,12	4	2	—	—
45	8,10	16,18	4	5	X	—
46	12,12	12,14	3	6	—	—
47	20,24	22,16	12	12	X	X
48	16,16	6,8	16	6	X	X
49	6,10	8,6	—	4	X	—
50	10,12	12,12	8	10	X	X
51	14,14	20,20	12	16	X	X
52	14,24	36,36	14	20	6	24
53	20	6	18	8	X	—
54	12,12	16,14	12	12	X	X
55	10,8	8,8	8	8	—	—
56	4	2	3	—	—	—
57	8,6	8,12	4	4	—	—
58	10,10	14,16	16	12	X	X
59	12,10	14,20	14	—	X	X
60	8	14	10	6	—	X
61	8	12	4	7	—	—
62	3	4	2	—	—	—
63	4	4	4	—	—	—
64	5	6	4	—	—	—
65	8	8	6	10	—	—
66	16	12	8	10	—	—
67	4	8	—	3	—	—
68	8	12	4	—	—	—
69	6	5	3	4	—	—
70	8	7	3	6	—	—
71	6	14	8	7	—	—
72	12,10	16,16	12	16	X	X
73	8,8	10,10	8	10	X	—
74	6,10	12,12	4	6	—	—
75	12,16	16,20	12	18	X	X
76	2,4	8,8	4	6	—	—
77	2,6	8,12	6	6	—	—
78	10,10	—	12,8	—	x,x	—
79	10,8	8,8	3	4	—	—
80	8,4	10,12	6	6	—	—
81	12,16	8,2	5	4	—	—
82	8,6	8,12	8	8	—	—
83	16	8	4	4	—	X
84	8,12	16,12	8	8	X	X
85	4,4	4,4	—	—	—	—
86	4,6	2,4	—	—	—	—
87	8,2	2,2	—	—	—	—
88	4,2	8,10	3	4	—	—
89	8,10	20,12	4	20	X	X

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
90	16,12	12,12	4	6	X	—
91	12,8	12,12	4	8	—	X
92	10,8	1,6	7	4	—	—
93	8,10	8,12	2	2	—	—
94	8,6	—	7	—	—	—
95	8,6	12,8	4	8	—	X
96	6,6	8,12	4	4	—	—
97	4,4	—	3,4	—	—	—
98	8,8	10,14	4	6	—	—
99	6,6	10,12	6	—	—	—
100	10,14	8,10	6	4	—	—
101	10,10	14,8	4	4	—	—
102	8,10	8,2	4	3	—	X
103	6	8	2	3	—	—
104	6,6	6,10	6	—	—	—
105	6,8	8,10	4	4	X	X
106	20,16	16,16	11	8	X	—
107	8,8	10,6	4	4	—	—
108	10,10	6,8	6	4	—	—
109	8,8	8,8	4	6	—	—
110	10,12	—	8,10	—	X	—
111	6,8	6,6	2	6	—	—
112	6,8	4,6	4	6	—	—
113	8,12	2,12	4	8	—	X
114	2,4	2,4	3	3	—	—
115	12	12,16	12	12	10	10
116	12	6,16	6	8	X	X
117	20,20	18,20	14	16	X	X
118	18,20	20,20	12	16	X	X
119	6,6	8,12	4	8	—	—
120	4,6	10,4	3	4	—	—
121	2,4	6,6	2	4	—	—
122	16,16	6,10	8	12	X	X
123	8,8	8,6	7	8	—	X
124	10,12	10,12	10	10	X	—
125	20,20	20,20	8	8	X	—
126	8,6	14,16	6	16	X	X
127	8,8	14,16	6	12	—	—
128	6,8	10,12	8	—	—	—
129	10,12	12,16	12	14	X	—
130	8,10	10,12	4	8	—	—
131	10,12	20,24	6	20	3	X
132	8,10	8,2	12	16	X	X
133	—	2	—	—	—	—
134	44,44	44,44	30	28	6	8
135	10,14	8,8	8	6	3	10

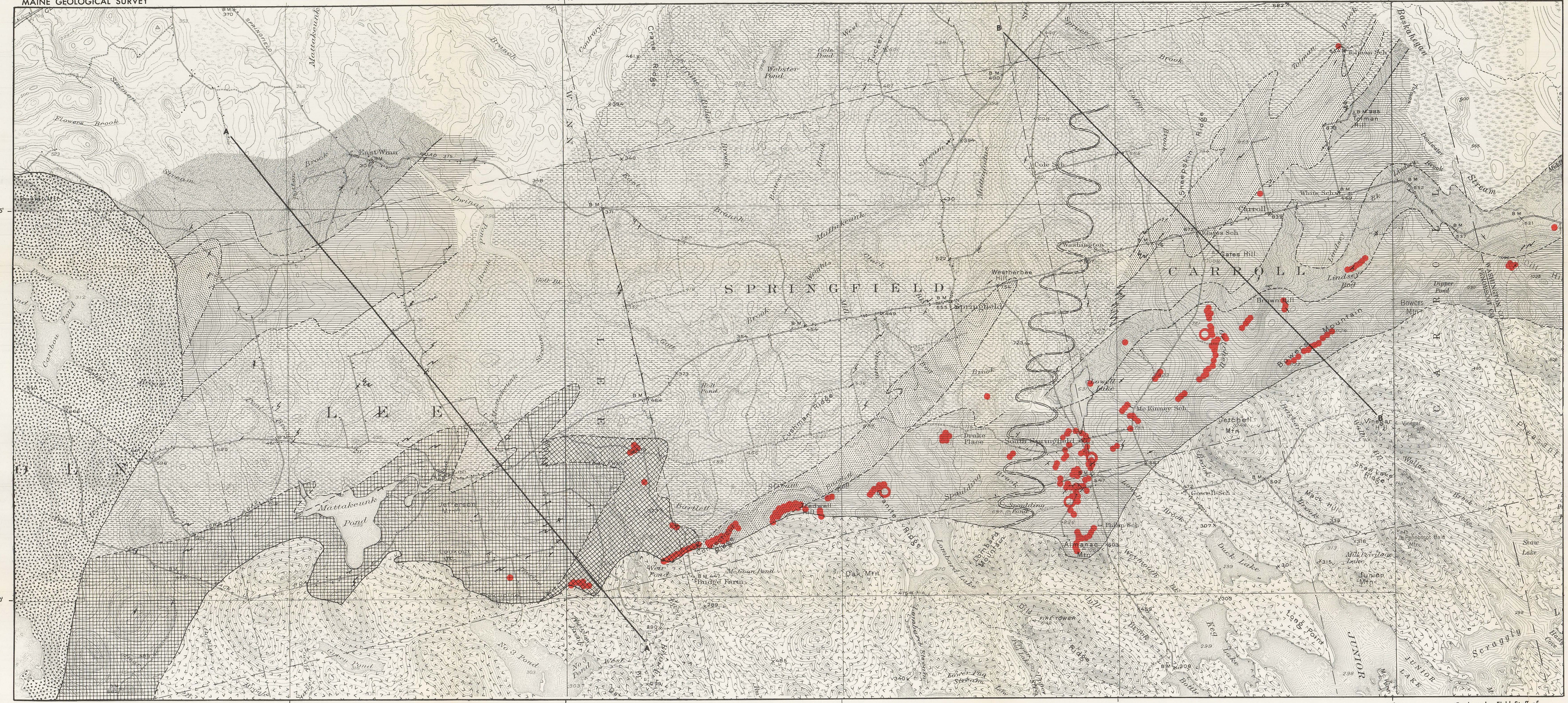
	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
136	10,14	14,18	10	8	X	X
137	10,12	12,12	8	8	8	6
138	—	12,24	—	28,24	5	—
139	12	12	4	5	2	8
140	6,8	10,6	4	6	X	X
141	8,12	10,16	8	8	X	—
142	4,8	8,8	6	7	X	—
143	2,3	2,2	3	—	—	—
144	2,4	8,8	1	4	—	—
145	4,8	6,6	8	—	—	—
146	4	2	2	2	—	—
147	16,12	4,16	7	4	—	—
148	12,16	12,12	12	16	—	X
149	20,20	28,32	18	20	X	X
150	24	20	18	20	—	X
151	6,6	8,8	1	4	—	—
152	8,6	6,6	10	8	X	—
153	4,4	6,6	4	—	—	—
154	3,4	6,4	3	—	—	—
155	6,6	8,8	2	3	—	—
156	2,3	4,4	1	3	—	—
157	2,6	4,8	8	14	—	X
158	12,14	18,20	18	22	X	2
159	6,8	10,12	7	11	—	—
160	6,10	10,12	12	8	—	X
161	6,8	8,8	8	—	—	—
162	10,12	4,4	10	6	—	—
163	6,6	6,12	12	12	—	—
164	12,12	6,12	8	6	—	—
165	16,16	18,20	4	6	—	—
166	12,18	14,14	4	4	—	X
167	14,16	10,12	6	4	X	—
168	12,12	12,16	4	6	—	—
169	3,3	2,2	4	—	—	—
170	6,6	6,10	4	5	—	—
171	6,10	8,10	4	6	—	—
172	6,8	10,12	3	8	—	—
173	16,20	18,28	12	20	X	X
174	18,20	10,20	12	4	X	—
175	6	12	4	8	—	X
176	6	12	2	12	—	—
177	8,2	8	4	4	—	—
178	8	4	4	5	—	—
179	8	8	4	4	—	—
180	2	2	1	—	—	—
181	12,14	8,12	6	10	—	—

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
182	10,10	6,12	10	7	X	—
183	3,6	8,8	5	4	—	—
184	4,6	14	3	6	—	—
185	6	12	2	4	—	—
186	8,12	8,8	4	6	—	—
187	8,8	20,24	4	14	—	—
188	10,10	14,14	4	10	—	—
189	12,12	12,18	7	12	—	—
190	8,10	14,16	8	10	—	—
191	30,32	24,32	24	26	X	—
192	24	24,28	24	26	X	—
193	36	32	24	24	X	—
194	14	16	16	10	—	—
195	16	2	8	2	—	—
196	20	28	20	28	X	—
197	6	12	4	8	—	—
198	12	6	8	6	—	—
199	32	16	40	16	X	—
200	16,16	2,6	8	4	—	—
201	6,10	20,20	4	16	—	X
202	12,12	14,16	4	14	—	—
203	20,28	28,28	24	26	—	X
204	1	3	—	—	—	—
205	4,8	28,36	—	34	—	X
206	16,24	28,36	16	56	—	6
207	12,16	20,16	8	6	—	—
208	10,16	16,16	—	12	—	—
209	20,22	20,24	6	8	—	—
210	4,6	10,12	4	4	—	—
211	2,2	10,10	2	10	—	—
212	4,6	10,12	4	4	—	—
213	6,10	12,14	4	6	—	—
214	6,10	14,18	3	5	—	—
215	8,8	12,10	6	4	—	—
216	16,16	16,18	—	10	—	X
217	8,10	12,14	4	6	—	—
218	2,2	8,10	2	8	—	—
219	10,10	14,16	—	12	—	X
220	2	4	2	—	X	X
221	4	12	10	16	X	X
222	8,8	10,12	3	—	—	—
223	3,4	4,6	4	—	—	—
224	8,12	20,20	12	12	—	—
225	8,8	8,10	4	12	—	—
226	2,6	36,36	3	8	—	X
227	4,6	12,16	3	4	—	X

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
228	6,10	28,28	18	14	X	—
229	10,12	12,14	8	12	—	X
230	4,3	1,4	—	—	—	—
231	6,6	8,8	4	6	—	—
232	2,3	4,4	—	—	—	—
233	1	—	—	—	—	—
234	1	2,4	—	—	—	—
235	2,2	4,2	—	—	—	—
236	6,6	6,8	2	3	—	—
237	3	4	—	—	—	—
238	5	6	—	—	—	—
239	2	3	—	—	—	—
240	8	4	4	3	—	—
241	8	10	4	3	—	—
242	4,6	10,10	3	4	—	—
243	8,8	10,10	8	6	—	—
244	8,8	14,16	8	8	—	—
245	8,8	16,18	3	10	—	X
246	8	12	3	7	—	—
247	6	8	2	6	—	—
248	1	4	1	—	—	—
249	6	6	—	—	—	—
250	6,6	6,8	4	4	—	X
251	8,8	6,6	4	8	—	—
252	16,20	16,20	12	8	—	X
253	16,20	20,20	18	12	X	—
254	4,6	8,8	2	5	—	—
255	6	6	4	6	—	—
256	6,6	6,8	4	6	—	—
257	12,12	12,12	6	6	X	X
258	8,12	12,12	8	10	—	—
259	10,12	16,16	20	20	—	X
260	12	20	20	24	X	X
261	8,6	12,8	6	8	X	X
262	2	3	—	—	—	—
263	4,4	3,4	—	—	X	—
264	8,8	8,10	8	—	—	—
265	8,8	14,16	24	24	—	—
266	6,8	8,10	8	8	—	—
267	8,8	6,4	6	6	—	—
268	4,6	6,6	3	7	—	—
269	8,8	8,8	18	18	—	X
270	20,20	24,20	16	18	X	X
271	8,8	8,10	6	4	—	—
272	8,4	4,4	2	4	—	—
273	4,4	8,8	2	6	—	—

	Field Value ppm w/v		Lab. Values ppm w/v		Cold Cu ppm w/v	
Sample No.	Active	Bank	Active	Bank	Active	Bank
274	8,8	8,10	4	4	—	—
275	8,10	10,10	4	4	—	—
276	8,10	12,10	8	12	—	X
277	—	—	2	2	—	—
278	—	—	6	—	—	—
279	—	—	4	3	—	—
280	—	—	3	3	—	—
281	—	—	2	5	—	—
282	—	—	1	—	—	—
283	—	—	10	10	—	—
284	—	—	4	—	—	—
285	—	—	3	—	—	—
286	—	—	—	6	—	—

* The designation X indicates the sample was tested with negative results.



EXPLANATION

METASEDIMENTS

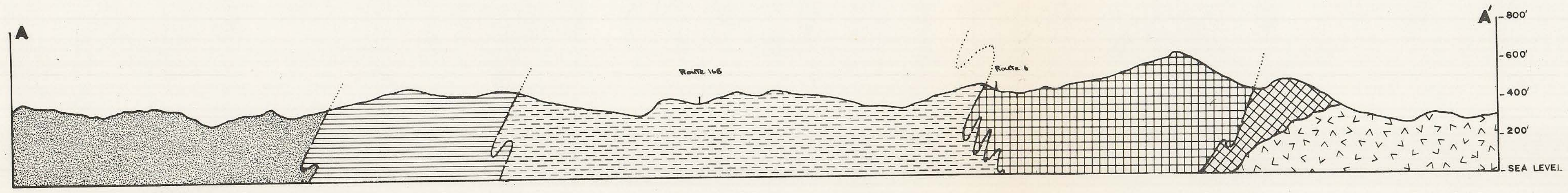
- Alternating color banded calcareous quartzite
- Alternating color banded non calcareous member of quartzite unit
- Grey-blue and grey metasiltstone
- Light grey quartz biotite schist
- Dark grey phyllite and schist
- Massive grey-green quartzite and graywacke

IGNEOUS ROCKS

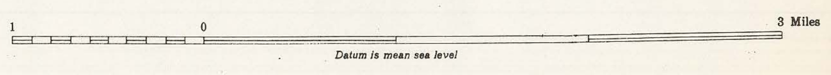
- Lincoln granite
- Lucerne granite

- Contact, inferred
- Contact
- Shear zone, inferred
- Nose of plunging fold
- Plunge direction
- Drag fold
- Strike and dip of inclined beds
- Attitude of vertical beds
- Overturned fold
- Strike and dip of cleavage planes
- Attitude of vertical cleavage
- Attitude of vertical foliation
- Dip of axial plane of plunging fold
- Iron sulphide shows
- Copper sulphide shows

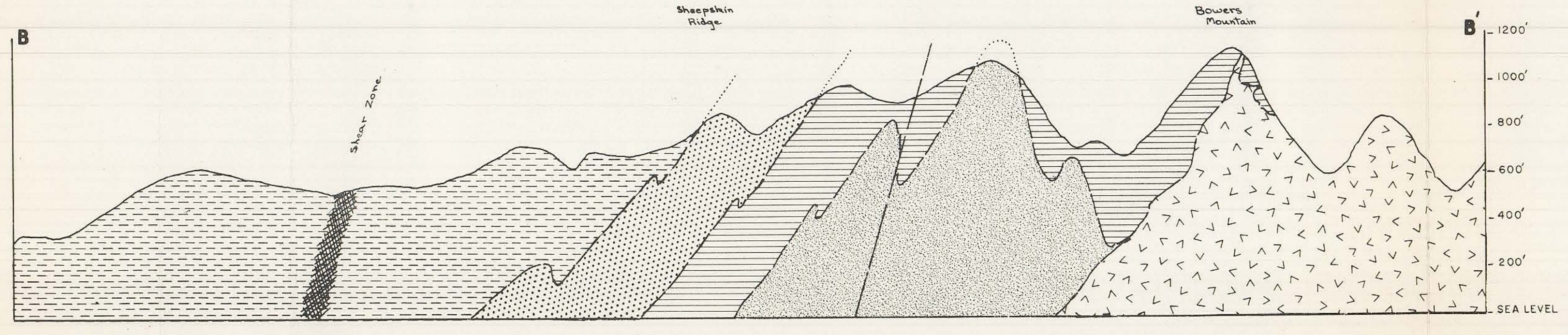
Geology by Field Staff of Maine Geological Survey 1960



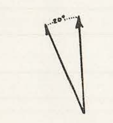
SECTION ALONG A – A'



CONTOUR INTERVAL 20 FEET



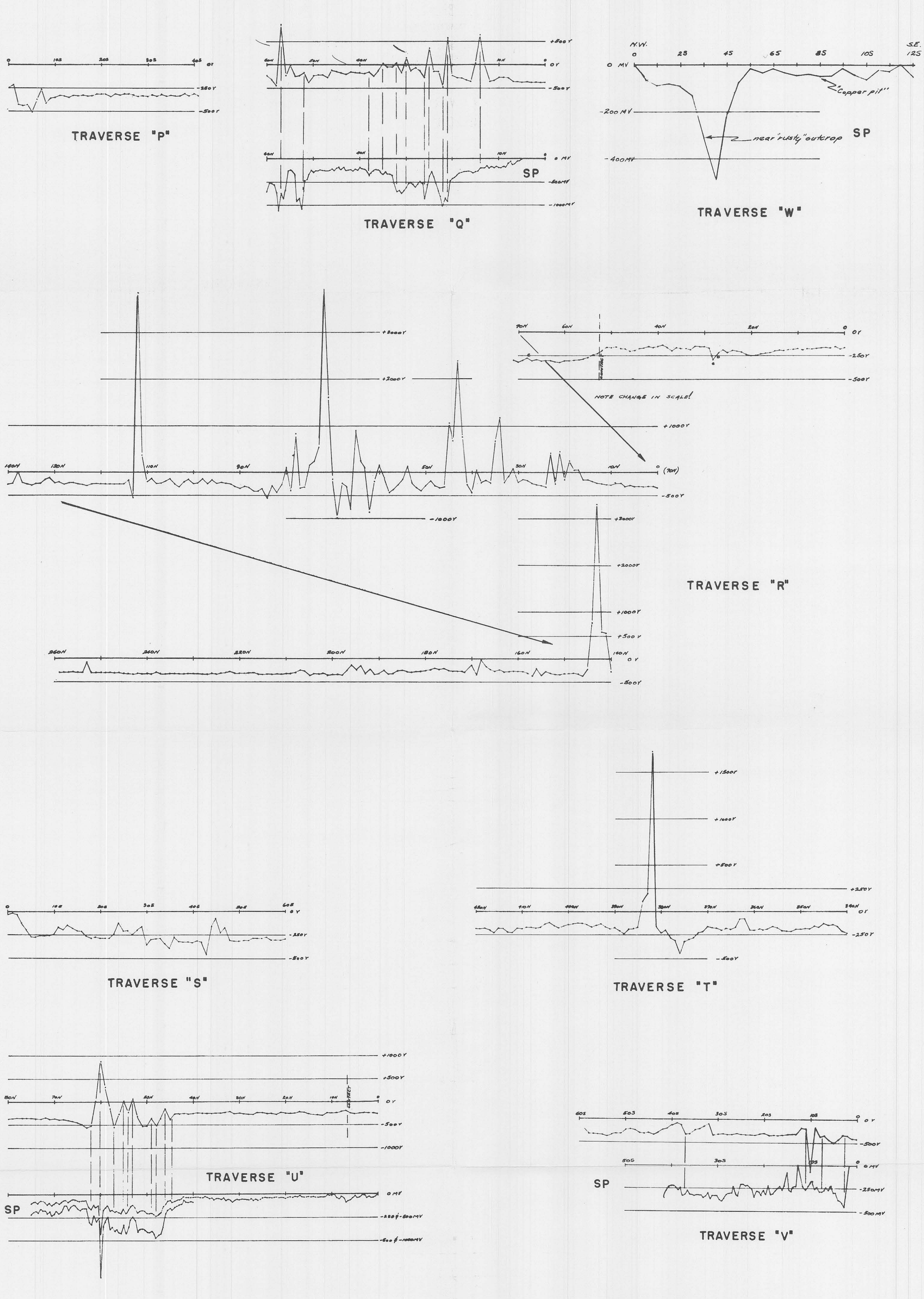
SECTION ALONG B – B'



Declination 1937

Base Map by Topographic Division, U. S. Geological Survey of the Winn (1916), Springfield (1931) and Scraggly Lake (1941) Quadrangles

GEOLOGIC MAP AND SECTIONS OF THE LEE-SPRINGFIELD-CARROLL AREA OF PENOBSCOT COUNTY, MAINE SHOWING SULFIDE DISTRIBUTION



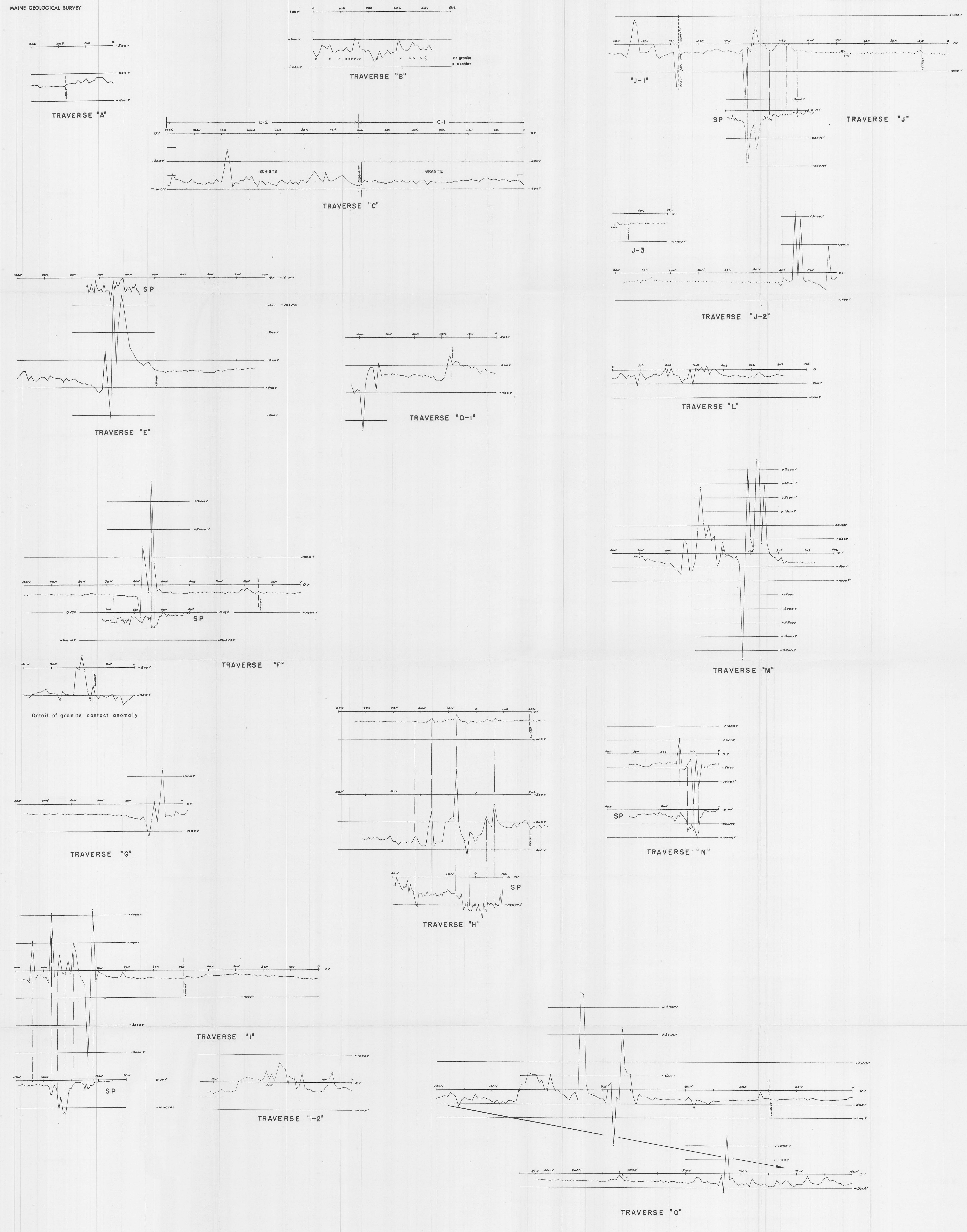
MAGNETIC AND SELF-POTENTIAL PROFILES IN LEE-SPRINGFIELD-CARROLL AREA PENOBSCOT COUNTY, MAINE

SCALE
MAGNETIC: ONE INCH = 2 000 γ
SELF-POTENTIAL: ONE INCH = 1 000 mv

STATION INTERVAL 100 FEET

10s 20s 30s
2000′

Data reduced and profiled by R. S. Young and J. Cole



MAGNETIC AND SELF-POTENTIAL PROFILES IN
LEE-SPRINGFIELD-CARROLL AREA PENOBSCOT COUNTY, MAINE

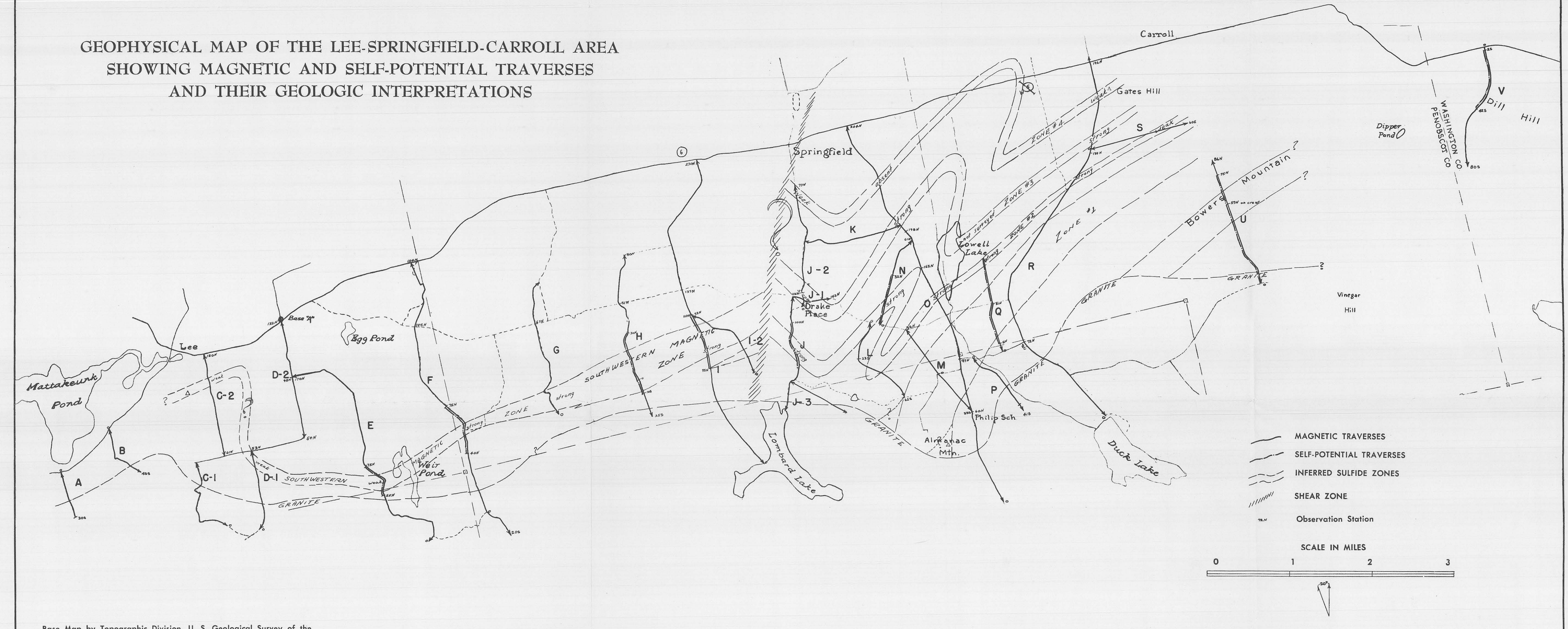
SCALE
MAGNETIC: ONE INCH = 2 000 γ
SELF-POTENTIAL: ONE INCH = 1 000 mv

STATION INTERVAL 100 FEET

10s 20s 30s
2000'

Data reduced and profiled by R. S. Young and J. Cole

GEOPHYSICAL MAP OF THE LEE-SPRINGFIELD-CARROLL AREA SHOWING MAGNETIC AND SELF-POTENTIAL TRAVERSES AND THEIR GEOLOGIC INTERPRETATIONS



Base Map by Topographic Division, U. S. Geological Survey of the Winn (1916), Springfield (1931) and Scraggly Lake (1914) Quadrangles

Interpretations by R. S. Young

GEOCHEMICAL SURVEY OF THE LEE—SPRINGFIELD AREA PENOBSCOT COUNTY, MAINE

MAINE GEOLOGICAL SURVEY—ROBERT G. DOYLE, STATE GEOLOGIST
DEPARTMENT OF ECONOMIC DEVELOPMENT

By Lawrence A. Wing —— James W. Sewall Company
Old Town, Maine October 1960