Geology and magnetic anomalies of T. 42 N., R. 30 W., Dickinson County, Michigan

by

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Introduction

Scope and purpose of report

This report summarizes the results of field work done in T. 42 N., R. 30 W., Dickinson County, Michigan, during the summer of 1948. This study is part of a continuing cooperative survey of the iron-bearing districts of Michigan undertaken by the U. S. Geological Survey and the Geological Survey Division of the Michigan Department of Conservation.

The area covered by this report includes all of T. 42 N., R. 30 W., and parts of adjacent areas, namely, sec. 1, T. 41 N., R. 31 W., sec. 6, T. 41 N., R. 30 W., sec. 36, T. 43 N., R. 31 W., secs. 30 and 31, T. 42 N., R. 29 W., and secs. 31, 32, 33, and 34, T. 43 N., R. 30 W. (fig. 1).

The western end of the Felch trough crosses the southern part of the township. This area is not discussed in detail here inasmuch as it is described by C. A. Lamey in open-file reports of the U. S. Geological Survey issued in 1947 and 1949. (Lamey, 1947, 1949)

The age relations of some of the lithologic units within the mapped area are not entirely clear. The conclusions presented in this report do not necessarily coincide with those held by other members of the U. S. Geological Survey working in this region.

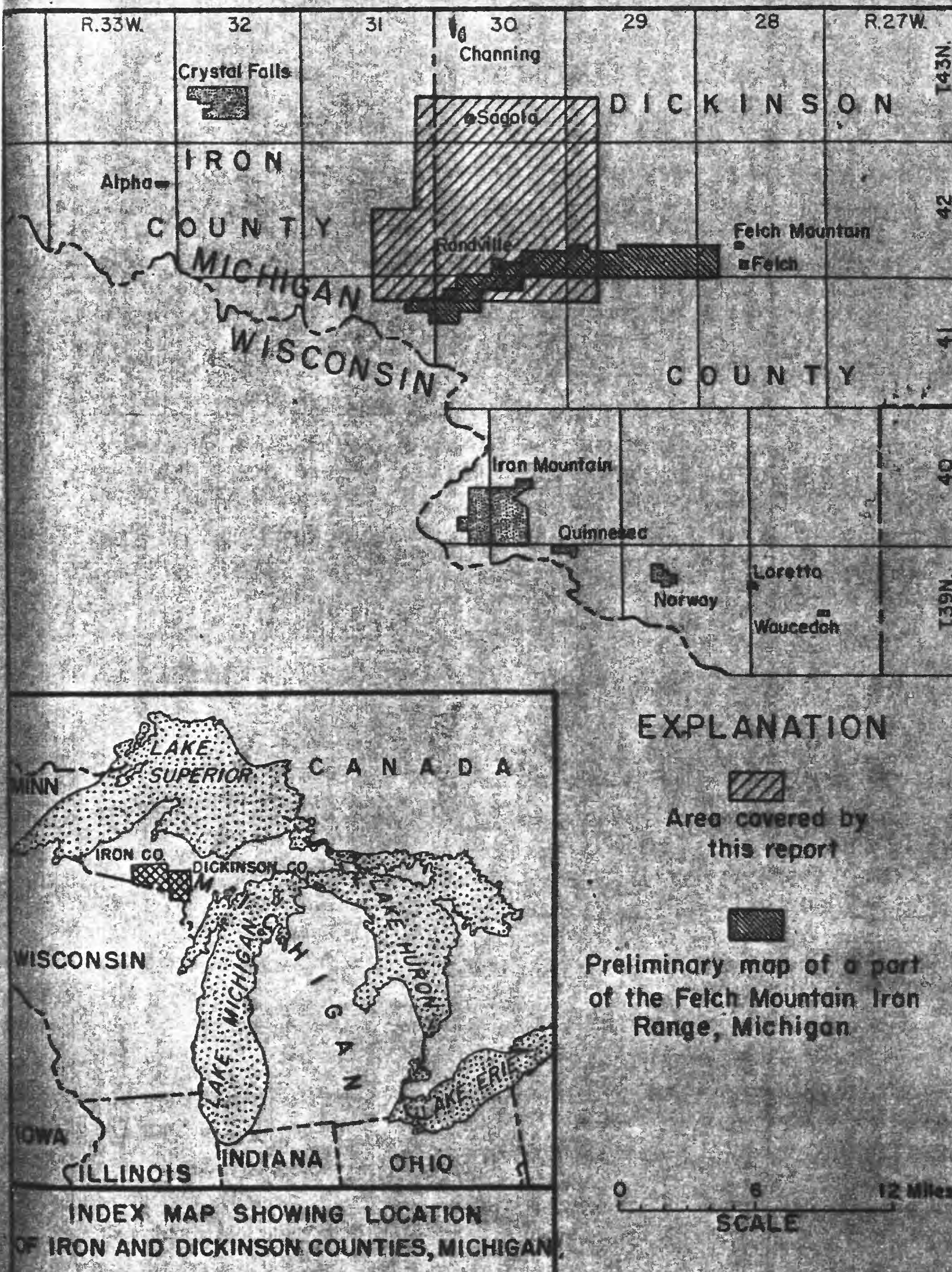

Figure 1. Index map of Iron and Dickinson Counties, Michigan, showing location of the area covered by this report.

Field methods

The outcrops in the area were plotted at a 1:20,000 scale on a base map compiled from aerial photographs. Outcrops were first located on the photographs and then examined in the field; all data were later transferred from the photographs to the map sheet with a camera lucida. See plate 1.

The magnetic observations were made with a Hotchkiss Superdip oriented perpendicular to the magnetic meridian and set with a 2 degree angle between the magnetic and gravitational arms. The swinging assembly was balanced in about the horizontal position (90°). Readings of the first downswing, the first backswing doubled, and the second downswing were averaged for each station. The mean thus computed was temperature- and base-corrected. The differences between the corrected readings and 90 were plotted on the map and contoured. The Superdip used was calibrated against an Askania vertical magnetometer. Each scale division was found to represent about 35 gammas. The magnetic readings were later converted to gammas and replotted (pl. 2). Stations occupied were located by pace and compass traverses.

Additional data on the magnetic anomalies of this area were obtained from J. R. Balsley, Jr., who kindly made the aeromagnetic profiles, recorded in 1948, available to the author. In addition, M. W. Leighton ran several profiles with a Wolfson vertical magnetometer during the summer of 1949 (pl. 3).

Significant results

The use of aerial photographs made it possible to find and map virtually all existing outcrops of the crystalline rocks in the township and to demonstrate an extension of these rocks farther southwest (into sec. 1, T. 41 N., R. 31 W.) than shown on any published maps. Field work showed that the green schists of the Hemlock complex are present in the northwest part of the area, and it is possible that some of the granite-injected amphibolite elsewhere in the township also is of Hemlock age. The Huronian rocks between Randville and Sagola (in the vicinity of Carey's Spur) were found to occur in a narrow northeast-trending trough bounded on the north side by a major fault.

The magnetic anomaly which extends south and east from Sagola was mapped in detail. The aeromagnetic profiles disclose virtually all the anomalies in the township.

Acknowledgments

The author was ably assisted in the field by Bruce Kennedy of the Geological Survey Division of the Michigan Department of Conservation. He is also indebted to F. G. Pardee and G. E. Eddy of this organization for the use of unpublished maps on the geology of the township. M. W. Leighton made several check traverses with a Wolfson vertical magnetometer in 1949. The author is grateful to H. L. James and C. E. Dutton for critical reading of the manuscript. He is also indebted to Kenneth Wier and Waldemar Pratt for a helpful discussion of the magnetic anomalies and their interpretation and to Kenneth Wier for assistance in plotting of the aeromagnetic traverses and crest points.

Physiography and drainage

The area mapped lies within the Lake Superior Upland. Most of it is underlain by pre-Cambrian rocks and mantled by a more or less continuous cover of glacial drift.

The topography of the area is a product of pre-glacial erosion, ice scour, and deposition. In general the granites and gneisses tend to form low rocky plateaus whereas the intervening weaker Huronian rocks produce lowlands. Tom King's Creek, for example, flows through the low ground underlain by the Huronian strata of the Felch trough. Rocky plateau-like areas of granite gneiss lie both north and south of this lowland. Even the course of the West Fork of the West Branch of the Sturgeon River is controlled in large part by bedrock lithology and structure. This stream, which arises in the back slope of a large moraine, flows southward parallel to the moraine until it reaches the rocky area underlain by a gneissic, porphyritic red granite. At this place it detours westward somewhat and crosses the area between two granite domes and then flows eastward south of the largest dome. The East Fork of the West Branch of the Sturgeon River, on the other hand, flows southwestward across the gneissic terrane in a course possibly controlled either by a shear zone or a fault.

A most conspicuous feature of the township is the high morainic upland along the west margin of the area. On the east or back side of this recessional moraine is a low ground moraine area marked by large swamps.

Bedrock lithology

General statement

The bedrock of the township is chiefly of pre-Cambrian age. Also present, however, are some Cambrian sandstones and an extensive though incomplete cover of deposits of Pleistocene and Recent age.

The pre-Cambrian rocks are in part crystalline gneisses and schists of probable Archean age and in part metasedimentary rocks of Huronian age. The Archean rocks occur in horst-like anticlinal blocks between which are the graben-like "troughs" of Huronian sediments. There are three such Archean blocks in the township and three troughs or basins of Huronian strata.

The Cambrian is limited to several small outliers.

Archean

The Archean consists of gneisses, schists, and amphibolites, all of which are cut by basic and acid dikes. Archean rocks occur along the southernmost edge of the mapped area and are also found in a belt, about 3 miles wide, which extends northeasterly across the township from the southwest corner of the area studied to sections 13 and 24.

Several mappable rock types occur within the Archean complex. These include an extensive red porphyritic gneissic granite, a complex consisting of hornblende schists and amphibolites injected by gray and pink granite gneiss, a pegmatized gneissic complex, and numerous altered basic dikes and cross-cutting pegmatites and aplites.

Gray gneiss complex.—The area designated "gray gneiss" on the geologic map (pl. 1) is underlain by an injection gneiss consisting of a heterogeneous group of gneisses and schists. No large outcrop is homogeneous. Each is marked by strong compositional layering. Much of the exposed rock consists of medium-grained pink to gray gneiss consisting of feldspar, quartz, and biotite. Layers rich in biotite alternate with layers poor in this mineral. In many outcrops dark layers of amphibolite or hornblende schist are concordant layers that range in width from less than a foot to 100 feet or more. They are especially well displayed in the outcrops of the gray gneiss at Randville and in the group of outcrops of this formation in sec. 30, T. 42 N., R. 29 W. At the latter place, one of the wide amphibolite layers is quarried. It seems probable that much of the low and heavily covered area is underlain principally by hornblende schist. The more massive gneissic phases commonly crop out; the weaker schists are not as erosion-resistant.

Red porphyritic gneissic granite.—The reddish porphyritic gneissic granite is, in most places, a very homogeneous rock and is nearly everywhere of the same color, composition, and texture. It is not marked by bands of unlike composition. Outcrops are conspicuous, massive, and dome-like. In general, the area underlain by the porphyritic granite is a rocky one.

The granite is present in two, possibly three, somewhat elongate oval areas. The largest of these, traversed by the railroad and by Highway M-95, is well exposed at its western end. The structure of the area is apparently that of a dome. The gneissic structure, characterized by oriented, tabular feldspars and mica, dips outward from the center of the dome. A lesser oval lies in sections 19, 20, and 30. The outlines and size of this body are less clear though the available evidence suggests that it too is a dome.

The granite is coarse grained. Pink feldspars up to one-half inch in length are very abundant. These tend to be euhedral and to impart a porphyritic appearance to the rock. The feldspars form about two-thirds of the whole rock whereas quartz and biotite together make up the remaining one-third. Quartz itself makes up 10 to 20 percent of the rock.

On a horizontal surface a foliation produced by oriented feldspars and biotite is faint to distinct. In a vertical section, however, the structure is always pronounced. The biotite in particular forms a strong lineation in the plane of the foliation.

Inclusions are rare. Most outcrops show none. The granite is cut by a few dikelike bodies of amphibolite. These were probably originally basic dikes, perhaps diabase. They are in turn cut by fresh pegmatites and pink aplites.

Pegmatites and migmatized gray gneiss.--In the eastern part of the township, pegmatites are very numerous. In some places, as in secs. 24 and 26, they are so common as to constitute the bulk of the exposed bedrock. It is possible, however, that much of the covered area between outcrops is schist, which is less resistant to erosion than the massive pegmatites.

For the most part the host rock appears to be both the gray injection gneiss complex and the red porphyritic granite. In many places the contacts between the pegmatites and the gneiss are concealed or are so poorly defined that it is impossible to delineate individual pegmatites. Therefore, the complex of pegmatites and the gneiss that contains them has been designated as "pegmatized gneiss" and is so shown on the geologic map (pl. 1).

The pegmatites proper range from small, well-defined dikes a few feet wide, to massive bodies a hundred or more feet across. Nearly all strike N. 75° to 80° W. The rock is always coarse textured. Crystals of feldspar 12 to 18 inches long are common. In composition the pegmatites consist almost solely of potash feldspar, quartz, and muscovite. The only other constituents identified are a few small scattered grains of a pink garnet and an isolated crystal or two of beryl.

In places the pegmatites are well-defined tabular bodies. More commonly the margins are less sharp and in some places no discernible contacts between pegmatite and host rock can be found. Instead, the gneiss seems only to contain zones with numerous giant feldspar euhedra which alternate with zones of normal granite gneiss.

Engulfed in the pegmatites are large xenolithic blocks of amphibolite. These are probably the undigested remnants of basic dikes or of amphibolitic layers of the gray gneiss.

Basic dikes.—Altered basic dikes are rather common in the red porphyritic granite. These rocks, probably once diabase, are now rather fine-grained amphibolites and consist mainly of black hornblende needles. These dikes range in width from a foot or so to 20 or 30 feet. They are somewhat irregular in form and although they are tabular and dikelike bodies, they tend to pinch and swell. Many are substantially concordant with the foliation, but others are clearly cross-cutting. All are slightly schistose with schistosity parallel to the walls. Many have a narrow border zone of biotite schist. These dikes antedate the fresh aplites and pegmatites, and the biotitic border zone may be a metamorphic reaction zone between the dike and the granitic country rock.

Relative ages of the crystalline rocks.—It is clear that the red prophyritic granite has been cut by basic dikes, which have in turn been cut by aplites and pegmatites. The gray gneiss complex is cut by the younger aplites and pegmatites, but its relation to the porphyritic granite is obscure. In most places low drift-covered country separates the outcrops of the two rocks, although in one or two places rather poorly defined bodies of the porphyritic granite appeared to intrude the gray gneiss and related schists. The outlines and internal domical structure of the red porphyritic granites suggest that they form well-defined plutons which are younger than the gray gneiss complex. The apparent slight deflection of magnetic crest lines associated with the amphibolite and injection gneiss by the porphyritic granite domes supports this view.

Hemlock green schists (age uncertain)

The term "Hemlock formation" was applied by Clements to the volcanic rocks (greenstones), both acid and basic, and the crystalline schists derived from them, which occur along the Hemlock River in the vicinity of Amasa in Iron County. (Clements and Smyth, 1899.) From this area, the Hemlock greenstones and schists have been traced southeastward into T. 42 N., R. 31 W., and T. 43 N., R. 31 W. (Barrett, et al., 1929).

The northwestern part of T. 42 N., R. 30 W., is also underlain by green schists which apparently belong to the Hemlock formation. These rocks, poorly exposed and much oxidized, crop out on the Peavy Falls road near the center of sec. 36, T. 43 N., R. 31 W. They were also encountered in test pits and are poorly exposed in the SW¼SW¼ sec. 31, T. 43 N., R. 30 W., near the west line of the township. Similar material occurs on the rock piles of a test pit in the SW¼SW¼ sec. 4, T. 42 N., R. 30 W., about 200 feet west of Highway M-95.

Most of the rock assigned to the Hemlock is a dark chloritic schist locally rich in magnetite that in part is altered to martite. Less common is light-colored schist containing numerous small milky-blue quartz "eyes". The dark chloritic schists were probably once greenstone flows or basic tuffs whereas the quartz-bearing schists were probably much altered acid flows or tuffs.

As noted above, some of these rocks contain scattered magnetite that no doubt is the cause of some of the relatively weak magnetic anomalies which characterize the green schist area. These anomalies and the observed strikes of the schists trend northwest-southeast. This trend, as well as the lithology, supports the view that these rocks are a southeastward extension of the Hemlock complex.

As pointed out elsewhere in this report, the green schists of the Hemlock formation are cut off on the southeast by a major fault. Several lines of evidence suggest that the hornblende schists and amphibolites of the gray gneiss complex southeast of the fault in this township, as well as the rocks of like character in T. 42 N., Rs. 28 and 29 W., are modified Hemlock schists. The metamorphic grade increases from northwest to southeast. It is to be expected, therefore, that basic lavas, which are greenstones in the Mansfield area, T. 43 N., R. 31 W., would be altered to hornblende schists and amphibolites in the southern part of T. 42 N., R. 30 W., where they are injected by sill-like masses of gray granite and the red porphyritic granite plutons.

Unlike most of the crystalline block south of the Felch trough, that north of the trough is characterized by numerous weak magnetic lines. This might be interpreted as caused by minor magnetite-bearing tuff beds within the Hemlock. Moreover, the occurrence of strongly magnetic layers within the complex, especially in Rs. 28 and 29 W., of T. 42 N., and in sec. 23, T. 42 N., R. 31 W., suggests the presence of metamorphosed iron-formation. Several belts of iron-formation are known to occur in the Hemlock greenstones of T. 43 N., Rs. 31 and 32 W. The most notable bed is that at Mansfield, where iron ore once was mined. The bed is generally a weak rock that underlies low ground and is rarely exposed. It is possible that the magnetic anomalies of sec. 23, T. 42 N., R. 31 W., and those in the townships to the east, near Six Mile Lake and along Skunk Creek, are produced by this bed. If so, the quantity of magnetite (and probably the iron content) in T. 42 N., R. 30 W., must be low inasmuch as the anomaly within this township is relatively weak. The rock is probably mainly a schist (derived from the Mansfield slate) which underlies Gestner Lake and portions of the valley of the West Branch of the Sturgeon River.

Another characteristic of the Hemlock complex is the presence of rather large, sill-like intrusions of gabbroic rock within it. The hornblende schist-gray gneiss complex of T. 42 N., R. 30 W., and the two adjoining townships lying to the east contain several such bodies. The largest, mainly in T. 42 N., R. 28 W., was mapped in 1948 by Clark (Clark, L. D., in preparation). In secs. 29 and 30, T. 42 N., R. 30 W., there is a small body of coarse gabbroic rock, which may belong to this family of intrusives.

If the hornblende schists and related rocks of the southern part of T. 42 N., R. 30 W., are equivalent to the Hemlock formation, then two possibilities must be considered. If the Hemlock formation is of Middle Huronian age as stated by Clements and generally believed today, then the injection gneiss complex north of the Felch trough cannot be Archean as heretofore believed; or, if this complex be Archean, then the Hemlock formation cannot be Huronian. The crystalline block seems to be flanked on the north and the south by Huronian dolomite. It would seem to have an anticlinal or at least a horst-like structure and be, therefore, pre-Huronian. Moreover, the gneissic complex south of the Felch trough, which in some places contains amphibolite bands, is overlain unconformably by Sturgeon quartzite and conglomerate in sec. 20, T. 41 N., R. 30 W. (Pettijohn, 1943). The weight of the evidence in this area seems to favor a pre-Huronian age for the injection gneiss and associated rocks and an Archean or at least pre-Huronian age for the Hemlock formation.

Huronian

The Huronian rocks of the township consist of a quartzite (Sturgeon) and a dolomite (Randville) of Lower Huronian age, an iron-formation (Groveland or Vulcan) and associated schists of Middle Huronian age, and several formations of uncertain character of Upper Huronian age. The sequence and character of the Huronian rocks in the several areas underlain by these rocks are so different that the Huronian is best described by considering each of these areas in turn.

Felch trough.—In T. 42 N., R. 30 W., the southernmost area underlain by Huronian rocks is a westward extension of the Felch trough. The rocks of this trough have been described in detail by Lamey (1949) and others.

Only one important outcrop of Sturgeon quartzite is known in this township. This outcrop, found along the east side of Highway M-95 in the NW¼SW¼ sec. 34, is a rather pure vitreous quartzite. It is cut by a brick-red coarse-grained granite dike.

The Randville dolomite of the Felch trough is a coarse sacchareidal tremolite-bearing marble. It is well exposed in several small quarries in secs. 34 and 35. In the quarry in the NW¼SW¼ sec. 35 the dolomite is cut by several even-grained granite dikes.

The Groveland or Vulcan iron-bearing formation is exposed in outcrop in the NW¼SE¼ sec. 5, T. 41 N., R. 30 W., and at the Groveland mine in sec. 31, T. 42 N., R. 29 W. At the latter place it is cut by granite dikes. The iron-formation contains much magnetite and produces, therefore, a strong anomaly in the earth's field, which enables one to follow it readily beneath a glacial drift or Cambrian cover. The character of this formation and its relation to the other rocks have been discussed by Lamey (1947, 1949).

The magnetic anomalies of sec. 35, T. 42 N., R. 31 W., are probably due to the Vulcan formation.

Carey's Spur trough.--It is believed that Huronian rocks occupy a narrow trough that extends from sec. 16 northeastward across T. 42 N., R. 30 W., to sec. 1. This structure, about a mile wide, is here referred to as the Carey's Spur trough. The Huronian rocks within this trough are very poorly exposed. Randville dolomite crops out along the railroad track in sec. 16, and in the NW¼NE¼ of the same section. The dolomite of these outcrops is fine grained and quite unlike that of the Felch trough. In sec. 11 and also in sec. 1 there are outcrops interpreted as silicified dolomite and dolomite breccia. The rock exposed is very fine grained and chertlike. In one outcrop it has the brecciated structure characteristic of the Randville in many places.

The absence of any important magnetic anomaly in the Carey's Spur trough and the narrowness of this structure lead to the conclusion that the structure is a shallow one containing only Lower Huronian strata.

The Carey's Spur trough appears to transgress the structures in the green schist complex. The contact between Huronian and the green schists is therefore probably a fault.

Sagola basin.--A large Huronian area, structurally a basin, lies between the granites of the southern complex of the Marquette district on the east, the greenstones and granites of the Fence River area on the west, and the Archean crystalline block of the Felch Mountain area on the south. A strong magnetic line (B_2) marks the probable southwestern margin of this structure. This line crosses the northern part of T. 42 N., R. 30 W. It was mapped in some detail with the Hotchkiss Superdip (See pl. 2).

The nature of the Huronian rocks of the Sagola basin within the confines of T. 42 N., R. 30 W., is very poorly known. The only outcrops seen are those in the N½SE¼ sec. 2. These consist of some bedded chert-like rocks with numerous large rounded clastic quartz grains and, more commonly, somewhat massive rocks with large milky-blue quartz "eyes" and vague much altered angular fragments of dark color. The rock is thought to be altered acidic tuffs and silicified ash.

The altered tuffs are north of the magnetic crest and are therefore younger than the beds responsible for the anomaly. There is no evidence within the township to show what formation produced the anomaly. The anomaly apparently extends northwestward to the Michigamme Mountain area where it seems to be due to a dark quartzite rich in magnetite and specular hematite (Lemmon, 1946). This dark quartzite contains conglomeratic zones with jasper pebbles. It may be the correlative of the Goodrich quartzite of the Marquette district. If these interpretations are correct, the Huronian rocks in the Sagola basin within T. 42 N., R. 30 W., are mainly Upper Huronian in age and consist of magnetic quartzite overlain by acidic volcanic rocks (Clarksburg?) and younger strata (Michigamme?). It is not known whether Lower or Middle Huronian rocks are present beneath the Goodrich although such appears to be the case in the Michigamme Mountain area.

Post-Huronian intrusive rocks

Dikes of a reddish granite and pegmatite cut the Huronian strata of the Felch trough. The total surface outcrop of such rocks appears small. It is not known whether the pegmatites of the Archean areas are post-Huronian. Very probably those in the Archean block north of the Felch trough are post-Huronian, and, if so, the volume of younger granite would be somewhat augmented though it would still form only a small part of the crystalline rock of the area studied.

Cambrian

A coarse, heavy-bedded sandstone crops out along Highway M-95 in sec. 4. It may underlie much of the high ridge that extends eastward from this place. A smaller outlier is present in the Groveland mine area. Though there is lack of evidence of its age in this area, it is known elsewhere in the region to be of Upper Cambrian age (Bayley, 1904).

Structure

The Felch trough and other belts of Huronian strata have been regarded as infolded or synclinal structures. The Archean areas that separate the Huronian belts were regarded as anticlinal in nature. This concept remains substantially correct. Detailed mapping, however, makes it necessary to modify this interpretation somewhat. The infolded Huronian strata are apparently much faulted.

The faulting is both transverse and longitudinal to the Huronian troughs. The continuity of the iron-formation of the Felch trough in T. 42 N., R. 30 W., is apparently broken by northeast-striking faults. The iron-formation is not repeated as a southern limb as it should be if the Felch trough were a simple syncline. It is probable, therefore, that one or more strike faults must be present in this trough. This conclusion was also reached by C. A. Lamey.

A major northeast-trending fault appears to mark the north side of the Carey's Spur trough. On the north side of the fault the strata have a northwest strike whereas on the south side of the fault the strike of the rocks is apparently the same as that of the fault. Furthermore, the rocks on the north side of the structure are the green schists of the Hemlock group whereas the gneisses of the Archean complex are exposed south of the syncline. Manifestly, the structure is not a simple syncline.

Magnetic anomalies

Introduction

The magnetic anomalies of T. 42 N., R. 30 W., and vicinity, are known from dip needle surveys of earlier workers, from a Superdip survey made in 1948 by Bruce Kennedy and the author, and from aeromagnetic surveys made in 1948 by the U. S. Geological Survey.

The results of the Superdip survey are shown on plate 2 and are discussed elsewhere in this report.

The magnetic crests represented on the aeromagnetic profiles are shown on plate 1. The crest points are shown as circles of several sizes, which are proportional to the strength of the anomalies which they represent. The corresponding crest points have been joined by the author. In some cases the correlations are somewhat uncertain (broken lines). The plot of the aeromagnetic work is provisional. The map location of the crest points and lines connecting them is approximate only and is subject to large errors. In extreme cases the crests shown may be as much as 1,000 feet from their true positions. The anomalies in this report are grouped according to their geological occurrence; in the Dickinson County report (Wier and others, in preparation), according to geographical position.

Interpretation

The interpretation of the magnetic anomalies of T. 42 N., R. 30 W., is very difficult inasmuch as only one of those anomalies shown on plate 1 has been correlated in the field with any outcropping rock.

"A" line.—The anomaly designated "A" (pl. 1) is a very broad and strong anomaly which extends for a distance of about 6 miles from west to east across the northeastern part of the mapped area. Eastward it dies out in sec. 33, T. 43 N., R. 29 W.; westward it merges with anomaly B_2 in sec. 33, T. 43 N., R. 30 W. Because this anomaly is several miles wide it is probably due to a deeply buried body of rock. Moreover, it does not conform to the pattern of the other anomalies in the area in which it occurs. It is due, therefore, to a rock in the pre-Huronian basement or to a deeply buried intrusive body.

"B" group.—The "B" group of anomalies is due to a series of concordant beds with northwest strike. Most notable feature of the group is the termination along a common line. This line is probably either an unconformity or a fault. For reasons stated elsewhere it is thought to be a fault. Because the fault passes near Bush Lake in sec. 18, T. 42 N., R. 30 W., it is here called the Bush Lake fault and is so labeled on plate 1.

The beds that produce the several magnetic lines northwest of the Bush Lake fault have not been identified in the field. B_2 is the strongest line of the group. In several places it exceeds 1,000 gammas at the ground level. It has been mapped in some detail with a Hotchkiss Superdip in secs. 1, 2, and 3, T. 42 N., R. 30 W., and in secs. 33 and 34, T. 43 N., R. 30 W. (see pl. 2). The line is known to extend northwestward for some miles to the Michigamme Mountain area in sec. 4, T. 43 N., R. 31 W. It is apparently due to the dark gray hematitic quartzite at this locality (Lemmon, 1946; Clements and Smyth, 1899).

In sec. 33, T. 43 N., R. 30 W., and sec. 3, T. 42 N., R. 30 W., the B_2 line is perched on top of the large, broad anomaly, "A". The magnetic readings on the crest are exceptionally high, but only a modest part of the total is due to B_2.

A short but locally pronounced crest in secs. 31 and 32, T. 43 N., R. 30 W., is shown as B_{2A} on plate 1. Along the midsection line of sec. 32, this anomaly exceeds 1,000 gammas at the ground level (see pl. 3, fig. 3). Some uncertainties, which might be resolved by ground survey, exist concerning the relation of this line and B_2 proper.

Line B_1 is a weaker line and is in most places merely a "shoulder" on the airborne magnetometer profiles. On the ground, however, this should become a distinct magnetic line of considerable strength. Because it closely parallels the B_2 line, it must be due to a stratum which is some 1,200 to 1,500 feet above the layer producing B_2. The tuff-like beds of sec. 2, T. 42 N., R. 30 W., contain some magnetite, and possibly the B_1 line is caused by a magnetite-rich tuff.

Of the remaining lines of the B group, B_3 is much the strongest and most continuous. In sec. 36, T. 43 N., R. 31 W. (pl. 3, fig. 2), it reaches a value on the ground of over 500 gammas. It may in places equal B_2, but owing to the fact that it is not superimposed on the magnetic "high", "A", it never reaches the total values achieved by the B_2 crest. The B_3 anomaly was discovered some years ago by a dip needle survey of sec. 9, T. 42 N., R. 30 W., where it exceeds 700 gammas at the ground level (see pl. 3, fig. 4). This B_3 anomaly is very likely due to a sedimentary bed or tuff within the Hemlock schist complex. This complex is known elsewhere to contain interbeds of tuff, slate, and iron-formation that are magnetic.

B_4 and B_5 are weaker lines probably related to flows or tuffs within the Hemlock complex.

"C" group.—Most of the "C" group of anomalies lie just south of the Carey's Spur trough and between this structure and the porphyritic gneiss dome. All lines are very weak.

The most notable feature of this group is the northeast strike, which is in contrast to the northwest trend of the "B" group. Lines C_3, C_4, and C_6 are almost certainly due to rocks within the crystalline basement. Lines C_1 and C_2 may be due to rocks within the Huronian sequence of the Carey's Spur trough. C_4 has a more nearly east-west strike and is notably stronger than the others. It is traceable many miles east of the area under discussion and may be related to a younger cross-cutting dike or to a metamorphic derivative of the Hemlock tuff.

"D" group.—The "D" group of lines is mainly related to the rocks of the gray gneiss complex. All these lines are rather weak and, with the exception of D_3 and D_4, rather discontinuous. Most noteworthy are the lines D_3 and D_4. These "twins" are traceable with some assurance across most of T. 42 N., R. 30 W. D_3 apparently extends without break into T. 42 N., R. 29 W., where it becomes exceedingly strong. On the ground in sec. 33, T. 42 N., R. 30 W., D_3 and D_4 anomalies attain values of about 400 and 500 gammas, respectively (see pl. 3, fig. 1).

As in the case of the "C" group, none of the rocks responsible for the "D" group have been identified. Field work has shown that the exposed amphibolites in the gray gneiss complex are practically non-magnetic. The rocks producing the more persistent lines D_3 and D_4 must be relatively weak rocks as they follow the lowest ground fairly closely. As suggested elsewhere in this report, D_3 may be due to an extension of the Mansfield iron-bearing formation.

The "C" and "D" groups outline in some detail the structure within the Archean complex. Noteworthy is the almost complete absence of magnetic anomalies within the area of porphyritic gneissic granite. If the "C" and "D" groups are due to the same kind of bedrock, as seems probable, then it is likely that the gray gneiss and amphibolites lie between the porphyritic granite domes and the Huronian rocks of the Carey's Spur trough. Such a distribution would be reasonable in view of the domal structure of the granitic masses. The magnetic crests seem to conform to the outlines of the domal bodies in somewhat the same manner that schistosity of other areas is known to be deflected locally by granite plutons. The numerous weak anomalies in the eastern part of the township would suggest that the bedrock of this area is the older complex and that the porphyritic granite does not extend into T. 43 N., R. 29 W.

In the eastern part of T. 42 N., R. 30 W., the "D" group of lines strikes about N. 70° E. Just west of Randville the trend is nearly east-west. In sec. 30 of T. 42 N., R. 30 W., it seems to be a little northwesterly.

In several places the "D" group of lines may be displaced by small northeast-trending cross faults.

"E" line.--The "E" line is the anomaly produced by the Vulcan iron-formation of the Felch trough. This anomaly has been mapped in detail by C. A. Laney (1949).

Economic geology

Marble

The Randville dolomite of the Felch trough is a marble of medium to coarse grain. To the best of the writer's knowledge it has not been quarried as a building stone and has no special qualities which would recommend it as such.

Terrazo

The Superior Rock Products Co. operates several quarries. The principal quarry and the crushing plant are located in the NW¼SW¼ sec. 35 where the Randville dolomite is quarried, crushed, and screened to size. The crushed rock is shipped and used in the manufacture of ornamental concrete. The same company quarries one of the amphibolite layers in the gray gneiss in the SW¼SE¼ sec. 30, T. 42 N., R. 29 W., as well as the pink pegmatite in the SE¼SE¼ sec. 19, T. 42 N., R. 29 W. These materials are trucked to the crusher, broken, and screened to be used for the same purposes as is the dolomite.

Building stone

No building stone is quarried in the township at present. Some of the red porphyritic gneiss is, however, a stone with attractive color and texture. It is massive, has widely spaced joints, and is readily accessible. It is certainly the equal of several stones now on the market.

Iron

There are no active iron mines in the township. The Groveland mine shipped a hard gray siliceous hematite ore in the period 1891-1913. In all, approximately 156,032 tons was mined (Lake Superior Iron Ore Association).

The Groveland iron-formation, now regarded as the correlative of the Vulcan of the Menominee district (Leith and others, 1935, table facing p. 10), has been extensively prospected. Very recently the M. A. Hanna Co. has carried out a large drilling program with a view to discovery of low-grade ore suitable for beneficiation.

No iron-formation is known to be present anywhere in the township other than that in the Felch trough. For reasons noted elsewhere, the Carey's Spur trough is thought to be too shallow to contain the Vulcan iron-formation. It is possible, however, that owing to the low grade of metamorphism shown by rocks in this structure, the iron-formation, even if present, might be non-magnetic and so far has escaped detection. It might also be oxidized to a non-magnetic state. The Carey's Spur structure is not much narrower than the Felch trough, which does contain the Vulcan.

The strong anomaly of secs. 1, 2, and 3, T. 42 N., R. 30 W., and secs. 33 and 34, T. 43 N., R. 30 W., is probably due to the dark magnetic quartzite present at Michigamme Mountain. If this formation is the Goodrich, possibly the Negaunee (i.e., Vulcan) formation is present beneath the quartzite in question. The writer knows of no drilling on the anomaly within the mapped area.

The most important conclusion reached from a study of this township is the probable equivalency of the granite-injected amphibolite complex and the Hemlock greenstones. This concept suggests that the strong magnetic anomalies of sec. 23, T. 42 N., R. 31 W., and the strong anomalies near Six Mile Lake in T. 42 N., R. 29 W., and along Skunk Creek in T. 42 N., R. 28 W., are due to metamorphosed iron-formation of the Mansfield type. A magnetite-rich rock suitable for beneficiation may be present in these belts.

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