GEOLOGY AND AEROMAGNETIC SURVEYS

OF THE

CUYUNA RANGE, MINNESOTA

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OF THE

CARLTON - THOMSON AREA

J. S. Owens
December, 1984

JSO/dl

INTRODUCTION

This report includes aeromagnetic and geological data in a portion of the area covered by an airborne survey flown in 1951 for the M. A. Hanna Company by Aero Service Corporation of Philadelphia (see introduction to Cuyuna Range report). The purpose of the survey was to determine whether pyrite-pyrrhotite deposits, similar to those which were being explored in Glen Township, Aitkin County, existed to the east and/or west, along the regional strike. Such a possibility was indicated by known geology and by magnetic trends shown on the reconnaissance airborne survey maps published earlier by th federal and state gological surveys. The outline of the area surveyed was therefore quite arbitrary, and is shown as an accompanying map (Map No. 1).

In accordance with the agreement with Meridian Minerals Company dated Sept. 28, 1984. The "sulfide area" has been divided into a western portion, designated the Mille Lacs/Glen/Denham area; and an eastern portion designated the Carlton/Thomson area. This division was arbitrarily made at the north-south line between townships 22 and 23 west (see map), through an area with no drilling or known outcrops. This report covers the Carlton/Thomson area.

MAPS AND DATA BASE

Hanna became interested in the iron sulfides in Glen Township (T46N, R25W) in about 1950, due to previous drilling of the principal deposit by the Iron Range Resources and Rehabilitation Commission and by Butler Brothers. Work was then in progress by the U. S. Bureau of Mines in an adjacent Glen deposit and in Carlton County (Pennington and Davis, 1953). Leases were obtained and a detailed development drillings program was carried out in 1951-52. During this period the airborne survey was flown, exploration drilling was done on several magnetic anomalies, outcrops were mapped and an attempt was made to interpret the geology of the area. This work was started by the author and completed by and under the direction of P. W. Zimmer. Although the principle products of interest were sulfur, with iron as a by-product, some analytical work was done to determine the base and precious metals content in drill samples.

Recently the geology of the east-central part of Minnesota has been re-mapped and compiled by G. B. Morey and others of the Minnesota Geological Survey, published by the Survey (1981). In 1983, total intensity magnetic maps were published by the M. G. S. for a large area in northeastern and east-central Minnesota, including the present report area. (Chandler, 1983).

For this report the following maps are included:

(1) Map No. 1, portions of the 1983 M. G. S. magnetic maps A-3 and A-4, enlarged to approximatelly 2.4 miles per inch and joined together. Outlines of the Hanna airbourne surveys are plotted, showing the three present report areas. Hanna drill and outcrop data are plotted in color as well as those of the M. G. S. taken from the 1:250,000 scale 1981 map. Some of the Hanna mapping was south and east of the magnetic survey area in Carlton and Pine Counties.

(2) A composite of the Hanna aeromagnetic map at a scale of 1"=2,000'. Due to its size, it is in three sections, each covering from 20 to 28 miles east-west. Hanna drilling and outcrop data are plotted in color. Geological contacts, outcrop and drill locations from the M. G. S. 1981 map are plotted in black for comparison and to indicate the total published information available.

(3) Set of township plats, 1"=1 mile, showing principal aeromagnetic anomalies, with matching plats showing drilling, outcrops and geology, and summaries for each township by P. W. Zimmer (1953). These maps and summary sheets are included in the Appendix. It should be noted that in 1953, when this report was written, the Thomson Formation was considered the equivalent of the Knife Lake, the iron formations were Upper Huronian, and the McGrath gneiss was believed to be intrusive into the

Thomson.

Since the Hanna and M. G. S. magnetic surveys were flown with different instruments and about thirty years apart, it was interesting to compare them as to location of features, relative intensities etc. In general, they appear to compare very well, considering that the M. G. S. maps have been reduced from the 1:24,000 7.5 - minute quadrangle maps (contour interval 10 gammas) eliminating all but the 50 - gamma contours. The Hanna maps have a 10 - gamma contour interval. A few of the 7.5 minute M. G. S. maps were compared with the Hanna maps, and it is evident that some detail has been lost in the reduction and elimination of some contours.

Specifications of the Hanna aeromagnetic survey are given in the Cuyuna Range report.

As in the Mille Lacs-Glen-Denham area to the west, geological information is very limited and widely scattered. Outcrops as mapped and described by Zimmer are included in the Appendix. Those on the M. G. S. map are only designated by formation. Zimmer's mapping extended south of the Hanna magnetic survey area, to the vicinity of the contact with overlying Fond du Lac formation. Drill hole data is especially inadequate, although Hanna reconnaissance drilling (seven holes) did indicate the cause of several magnetic anomilies. About ten of the drill hole data points shown on the M. G. S. geological map (Morey

et al, 1981) are not of record in the Hanna files.

GEOLOGY

Range 22 West

This tier of townships (45, 46, 47N) is almost completely lacking in geological bedrock information. In the northwest corner of T47N, the M. G. S. shows three drill hole locations, one in iron formation assumed to be Trommald fm., and two to the north in Rabbit Lake fm. This iron formation is assumed to connect, through several major folds, with that near Portage Lake, twelve miles to the west. Some doubt about this connection and identification is caused by the lack of any recognisable magnetic anomaly over this point, or indicating its direction. However, there is a distinct east-west anomaly farther to the north which has not been explained by drilling, and another weak anomaly striking ESE about a mile to the south, more distinct on the Hanna survey.

Striking northwest across T46N is the narrow, reversely polarized anomaly which originates near the Fond du Lac contact in the vicinity of Denham, identified by the M. G. S. as caused by augite porphyritic basalt. No McGrath gneiss is known to occur east of this dike. It has a bearing nearly identical to that of several faults which offset the sandstones to the south. In the southeast part of the township is an intersecting north-

east striking broad anomaly which was drilled by Hanna holes SR-1, 2, and 3 in the adjacent Split Rock KTownship. These holes were in phyllite with narrow nonmagnetic pyritic slate layers, and one hole intersected twenty-one feet of "dark green, magnetic, fine-grained diabasic diorite" (Zimmer). This dike was considered too small to cause the anomaly. It is concluded that pyrrhotite associated with the pyrite but not intersected by the drill holes, or additional magnetic dikes, or both are responsible for the anomaly.

To the south, in T45N, R22W, are several drill holes and two outcrops in McGrath gneiss and Denham formation, in an area crossed by an east-west fault as drawn by the M. G. S. There is a short E-W weak anomaly in Section 20 and 21, approximately at the location of the assumed fault; however, it also is aligned with the east end of the basic dike extending from Mille Lacs Lake (see Glen report). It is possible that the fault follows the dike to the west.

Range 21 West

These three townships, 45N to 47N, are crossed by a possible fault striking N 20° W, with unknown dip or offset. It is predicated by the M. G. S. on the basis of quartzitic rocks to the west and Thomson rocks to the east, in drill holes or outcrops within a mile of the fault at several places (see M. G. S. 1981 map). The fault has no obvious magnetic expression.

The principal evidence is in outcrops along the Dead Moose River, Otter Brook and Split Rock River, flowing easterly across the fault to the Kettle River (See M. G. S. 1981 map).

In the western part of T47N, R21W, Sections 17 and 19, the M. G. S. shows three outcrops of Mahnomen formation and one drill hole in Thomson formation along the Dead Moose River. Zimmer apparently did not see these outcrops, but mapped one about a half-mile to the west, near the township line, as a medium to coarse-grained metadiorite or metagabbro containing hornblende, pyroxene, and plagioclase, with minor pyrite and magnetite; also a small area of oxidized iron carbonate with quartz (see plat and report).

In T46N, R21W, the Hanna drilling has been described above. The rocks penetrated are shown as Denham formation by the M. G. S., but contain a mixture of quartz plyllite and pyritic graphitic slate, the latter suggesting Thomson formation. The outcrops along the Split Rock River shown as Denham formation on the M. G. S. map are described by Zimmer as diabase or diorite, fine to coarse quartz-mica schist, and some beds of dark graphitic slate. These seem to be mixtures of lithologies characteristic of both Denham and Thomson formation, as are those cut by the drill holes. Pyritic-graphitic rocks are not included in the M. G. S. description of Denham formation while the quartz-rich meta- sediments are not characteristic of the Thomson, so this is an area of some problems.

East of the fault in Sections 4, 14 and 15 are outcrops shown by the M. G. S. as Thomson formation, mapped by Zimmer as fine to medium-grained metadiabase containing plagioclose (altered in part to calcite), hornblende, pyroxene, local mica, and minor pyrite and magnetite; locally sheared and fractured with quartz and pegmatite veins. Apparently they are considered by the M. G. S. as "associated hypabyssal rocks" in the Thomson but they are not limited to or diagnostic of that formation.

Proceeding southward, in T45N, R21W, north of the M. G. S. east-west fault, a Denham formation outcrop in Section 8 and a drill hole in Section 12 are not in Hanna records. South of the fault are numerous outcrops of McGrath gneiss and Denham formations, some of which were not mapped by Zimmer. Denham quartzite and marble south of Denham were described but their relationship to the gneiss was not determined. The dike (?) indicated by the magnetic low striking diagonally to the south east across the township crosses the east-west fault without offset.

Ranges 20, 19 and 18 West

The Hanna magnetic survey covered a width of only six to ten miles in these ranges, but outcrops were mapped southward to the vicinity of the sandstone contact. Linear magnetic anomalies of interest for sulfides are limited to the survey area as had been indicated by the governments' pre-existing reconnaissance airborne survey. To a large extent this sulfide

"belt" also contains a larger proportion of mafic intrusive rocks, commonly closely associated with sulfide-bearing slates, than the area to the south. It also contains most of the strong N 60° E linear anomalies, a major one of which is reversely polarized. These are interpreted by the M. G. S. as mafic dikes and or sills, equivalent to those in the Duluth complex, but the major one, with normal polarization, was found to be caused by pyrrhotite in metasediments in the U. S. B. M. and Hanna drilling west of Kettle River. As usual, these anomalies are much more distinct on the Hanna Survey than on the reduced M. G. S. magnetic map.

Hanna drilled four holes in this area: K-1 and K-2 in T47N, R20W (Kalevala), KR-1 in T46N, R20W (Kettle River) and M-1 in T47N, R18W (Mahtowa). Geological logs and analyses shown in the Appendix.

Hole K-1 penetrated interbedded quartz-phyllite and graphitic slate, partially brecciated, with moderate ammounts of pyrite (92 feet averaged 6.63% S). Drift was 36 feet deep. No pyrrhotite or magnetite was recognized, so the cause of the anomaly is unknown. Zinc in the 92-foot pyritic interval averaged 0.8%, with a trace of gold and 0.1 oz. per ton of silver (Appendix ii). The anomaly has an irregular shape, and may be on an intersection of fractures; the narrow breccia intervals were composed of graphitic slate fragments in quartz. Assays of shorter intervals would be of interest.

Hole K-2 penetrated 209 feet of unconsolidated drift (?) which was not sampled or inspected, and 28 feet of green schistose rock with very little pyrite. The unusual depth of overburden, below a winding anomaly extending for about 15 miles to the northwest, suggests the presence of magnetite in a channel, as found recently in another location by M. G. S. drilling, although the abrupt southern termination of the anomaly is puzzling.

Hole KR-1 was drilled on the extension of an anomaly which had been drilled a mile to the southwest by the U. S. Bureau of Mines (Pennington, 1953). The U. S. B. M. drilling found pyrite and pyrrhotite in "graphitic" slate, with substantial footages containing over 10% S. and reaching 20% for short intervals. KR-1 found 24 feet of drift and 163 feet of graphitic slate, quartz phyllite and pyrite, with some pyrrhotite. However, it was lean, with only 4.05% S. Composite assays gave a trace of gold and 0.1 oz. per ton of silver (Appendix ii). U. S. B. M. assays on composites from their holes gave none of either.

Hole M-1, near the east end of the magnetic survey, had only six feet of drift above "graphitic" slate with some pyrite and interbedded quartzose beds. The only analyses available are for gold, varying from trace to 0.010 oz. per ton in one 25-foot composite (Appendix iv) in the quartz-rich interval.

General

The geology of the McGrath and Thomson formations is briefly described by Keighin, Morey and Goldich (1972). The Denham formation had not then been distinguished from the Thomson, but the quartzite and marble near Denham were recognized as containing quartz, feldspar and rock detritus from the gneiss. The east to west progression in metamorphism from chlorite zone at Thomson to staurolite-almandine at Denham had been previously decribed. Zimmer also mentions a possible north limit of the garnet zone in the north part of T45N, R20W, and an increase in garnet grain size to the south.

All of the mapping indicated a predominance of moderate dips to the south and southeast, with generally sub-parallel schistosity. An anticline in the vicinity of Park Lake and Atkinson in T48N, R18W was mapped by Zimmer and is indicated by north dips on the M. G. S. map. The dikes are parallel to the regional strike but have a much more uniform bearing than do the intruded sediments; their symmetrical magnetic profiles suggest near vertical dips.

The sulfide-bearing carbonaceous or "graphitic" metasediments in this area are very similar to those in Glen Township, as are the closely associated mafic, schistose, altered igneous rocks. It can be speculated that they were formerly continuous, which would eliminate the Mille Lacs Group

as an older series and include the Denham formation as the lowest part of the quartzitic basal Animikie rocks, as it appears to be in the vicinity of Lawler. The regional structual pattern suggests that the fault extending north-northwest from Denham separates major crustal blocks, with the western block moving relatively northward due to the isoclinal folding in the North and South Cuyuna Range. This folding becomes less severe south of the Clearwater Lake iron formation, which probably dips to the North, in contrast to the almost universal south dips of the major Cuyuna folds to the north. The more open folding continues to be characteristic of the quartzites and sulfide-bearing sediments to the south in Glen township, and also in the Thomson formation. The greater susceptibility of the Cuyuna rocks to tight folding might be explained by the elongation of that portion of the basin perpendicular to the compressional direction of the Penokean orogency. The greater resistance to folding at Glen and in the Thomson could be due to the larger proportions of mafic sills and dikes in the sequence, and the nature and thickness of the lower quartzites. The outcrop of the pre-Thomson Animikie rocks in this hypothesis would be underneath the Fond du Lac and Hinkley sandstones.

On the eastern sheet of the Hanna aeromagnetic map possible contacts have been drawn on the basis of outcrops, drill holes and magnetic intensities, for comparison with the M. G. S. geology, also shown. The principle differences are in the distinguishing of sulfide-rich sedimentary zones, and a large

mafic intrusive, in the area designated only as Thomson formation on the M. G. S. map. The sulfide-rich zones appear to occur either adjacent to the intrusive (below?) as in D. H. K-1, or bounded on both sides by mafic intrusives as in D. H. KR-1, SR 1 and 2, and the U. S. B. M. drilling. Both of these relationships are similar to those in Glen Township.

The major fault (?) separating "Thomson" from "Glen Township" formations is not well indicated by the magnetics or known geological data. Except for the Mahnomen quartzite outcrops in T47N, R21W, similar rocks occur on both sides of the fault, and several linear anomalies cross it or are aligned with each other east and west of the fault. The trace of the fault could be shifted slightly to avoid the cross-overs, and the apparent alignments could be coincidental. The drill hole in Thomson fm. (?) in Sec. 20, T47N, R21W is a critical point. Some of the problems could be solved by moving the fault westward to the location of the reverse-polarized dike (?) striking northwest from Denham, which appears to offset the McGrath gneiss. This possibility is shown by the contacts drawn on the aeromagnetic map.

ECONOMIC POSSIBILITIES

Minor amounts of zinc are apparently present in much of the pyrite-pyrrhotite-bearing graphitic sediments. It is probably syngenetic, and the quantity does not seem to be related to the

quantities of iron sulfides. The variations in amounts of iron sulfides do not seem to be controlled by structure or intrusives. However, the intrusives do carry some zinc and copper.

Several laboratories have reported trace amounts of silver and gold in the sulfide-bearing sediments. In all cases the sample intervals were too large for determining detailed distribution, but there is some indication that the gold accompanies vein quartz. In general, analyses are insufficient, and many rock types have not been systematically sampled or analyzed at all. Quartz-carbonate veins are mentioned in several outcrops, but the only attempt at exploitation has been in a few test pits near Mahtowa. We do not know of any assays from these pits.

The coarser-grained basal quartzites may be of some interest; the upper portions of the Mahnomen formation have been exposed in many places by mining and drilling with no reports of mineralization.

Slightly anomalous uranium (?) was reported a few years ago in a test pit in the Carlton area, but several samples from the black slates at Glen were extremely low in radioactivity.

The very limited areas of oxide or carbonate iron formation, some possibly manganiferous, are not considered to be

of interest, although the very strong anomaly west of Mille Lacs Lake deserves a drill hole, if only for academic reasons. (Maybe by the M. G. S. or D. N. R.?)

There is some curiosity about the contents of the channel apparently found in D. H. K-2, and whether it is the cause of the large anomaly.

The iron sulfides remain the only known resource in the area.

REFERENCE

Keighin, C. W., Morey, G. B., and Goldich, S. S., 1972, East-Central Minnesota, in Geology of Minnesota: A Centennial Volume, Minn. Geol. Surv., pp. 240-254.

Morey, G. B., Olsen, B. M., and Southwick, D. L., 1981, Geologic Maps of East-Central Minnesota, Bedrock Geology, Minnesota Geological Survey.

Pennington, James, and Davis, Vernon C., 1953, Investigation of iron sulfide deposits in south-central Aitkin County and Carlton County, Minn: U. S. Bur. of Mines R. I. 4937.

APPENDIX

Carlton / Thomson Area

i Core descriptions, drill holes SR-1, SR-2, SR-3, KR-1, K-1, K-2, M-1

ii Chemical analyses, K-1, KR-1

iii Zinc analyses, K-1

iv Gold assays, M-1

v Report with maps by P. W. Zimmer, 1953 (separate)

FOOTAGE	DESCRIPTION
Drill Hole SR - 1	
0 - 40	Surface
40 - 41	Graphitic mica slate with very little pyrite, - Dip 35°.
41 - 116	Fine grained quartz mica phyllite with fine carbonate and pyrite specks.
Drill Hole SR - 2	
0 - 37	Surface
37 - 39	Graphitic slate with little pyrite 45o Dip
39 - 67	Quartz mica phyllite
Drill Hole SR - 3	
0 - 38	Surface
38 - 53	Gray quartz phyllite.
53 - 74	Diabase or diorite magnetic
74 - 93	Quartz phyllite.
Drill Hole [illegible]R - 1	
0 - 24	Surface
24 - 45	Contorted quartz carbonate and graphitic slate with pyrite.
45 - 111	Alternating coarse and fine grained quartz, schist, or phyllite.
111 - 115	Graphitic slate with pyrite
115 - 146	Quartz phyllite.
146 - 187	Graphitic slate with both sulfides, but lean.
Drill Hole K - 1	
0 - 36	Surface
36 - 108	Quartz phyllite
108 - 112	Breccia graphitic slate in quartz
112 - 200	Graphitic slate with lean pyrite, another breccia zone, 192 - 196.
Drill Hole K - 2	
0 - 209	Surface
209 - 237	Green schistose rock with very little pyrite.
Drill Hole M - 1	
0 - 6	Surface
6 - 30	Contorted graphitic slate (bedding flat with cleavage of 45° at start) very little pyrite.
30 - 55	Similar, but with coarse quartz fm. bands.
55 - 201	Dark black slate with lean pyrite, - cleavage and bedding at 20°.

THE M. A. HANNA CO., AGENTS

HIBBING, MINNESOTA

RESEARCH LABORATORY

Date November 1, 1952

TO: P. W. Zimmer

FROM: H. W. Hard

SUBJECT: Assays Carlton County Sulphides
DH K1 and DH KR1

Assays on Drill Hole K1 were as follows:

Interval	Fe	S
108-112	11.81	5.16
112-123	20.22	6.43
123-136	10.35	5.03
136-143	8.31	4.45
143-148	13.48	7.11
148-161	14.32	8.46
161-173	13.84	7.17
173-187	9.63	5.30
187-200	11.31	6.65
108-200 Assayed	13.72	6.63
108-200 Calc.	12.65	6.31

108-200 Assayed

Fe	13.72%	Au	Trace
S	6.63%	Ag	0.1 oz. per ton
Ni	None	Pb	None
Cu	None	Zn	0.8%

Assays on Drill Hole KR1 were as follows:

Interval	Fe	S
24-36	10.23	3.62
36-45	11.31	3.65
111-115	9.25	1.73
146-156	11.80	2.58
156-163	10.35	2.83
163-173	12.40	4.89
173-183	12.40	4.97
183-187	12.52	4.86
Compo assayed	11.19	4.05
Compo Calc.	11.36	3.74

Compo 24-45, 111-115, 146-187 assayed

Fe	11.19%	Au	Trace
S	4.05%	Ag	0.1 oz. per ton
Ni	None	Pb	None
Cu	None	Zn	None

H. W. H.

cc: J. S. Owens
A. E. Walker
J. K. Gustafson
L. J. Bechaud

THE M. A. HANNA CO., AGENTS

HIBBING, MINNESOTA

RESEARCH LABORATORY

Date November 24, 1952

TO: P. W. Zimmer

FROM: H. W. Hard

SUBJECT: Zinc Assays DH K1

Assays for zinc on individual intervals of DH K1 were as follows:

Interval		% Zn
108-112		0
112-123	11	1.6
123-136	13	0.8
136-143	7	0.1
143-148	5	1.0
148-161	13	0.9
161-173	12	0.9
173-187	61	0
187-200		0.8
Calculated 108-200		0.72
Assayed Compo 108-200		0.8% zn

H. W. H.

cc:
J. S. Owens
A. E. Walker
J. K. Gustafson
L. J. Bechaud, Jr.

THE M. A. HANNA CO., AGENTS

HIBBING, MINNESOTA

RESEARCH LABORATORY

Date November 10, 1952

TO: P. W. Zimmer

FROM: H. W. Herd

SUBJECT: Gold Assays on Samples from DH M1

Assays were as follows:

DH M1	9' - 35'	trace
DH M1	35' - 60'	0.010 oz. per ton of 2000 lbs.
DH M1	60' - 86'	trace
DH M1	86' -105'	trace

We would appreciate it if you would send us a memo when odd samples are sent or assays requested so that we can keep our files complete with information on where the samples came from and to whom the assays should be reported.

H. W. H.

HWH/j

cc: L. J. Bechaud, Jr.