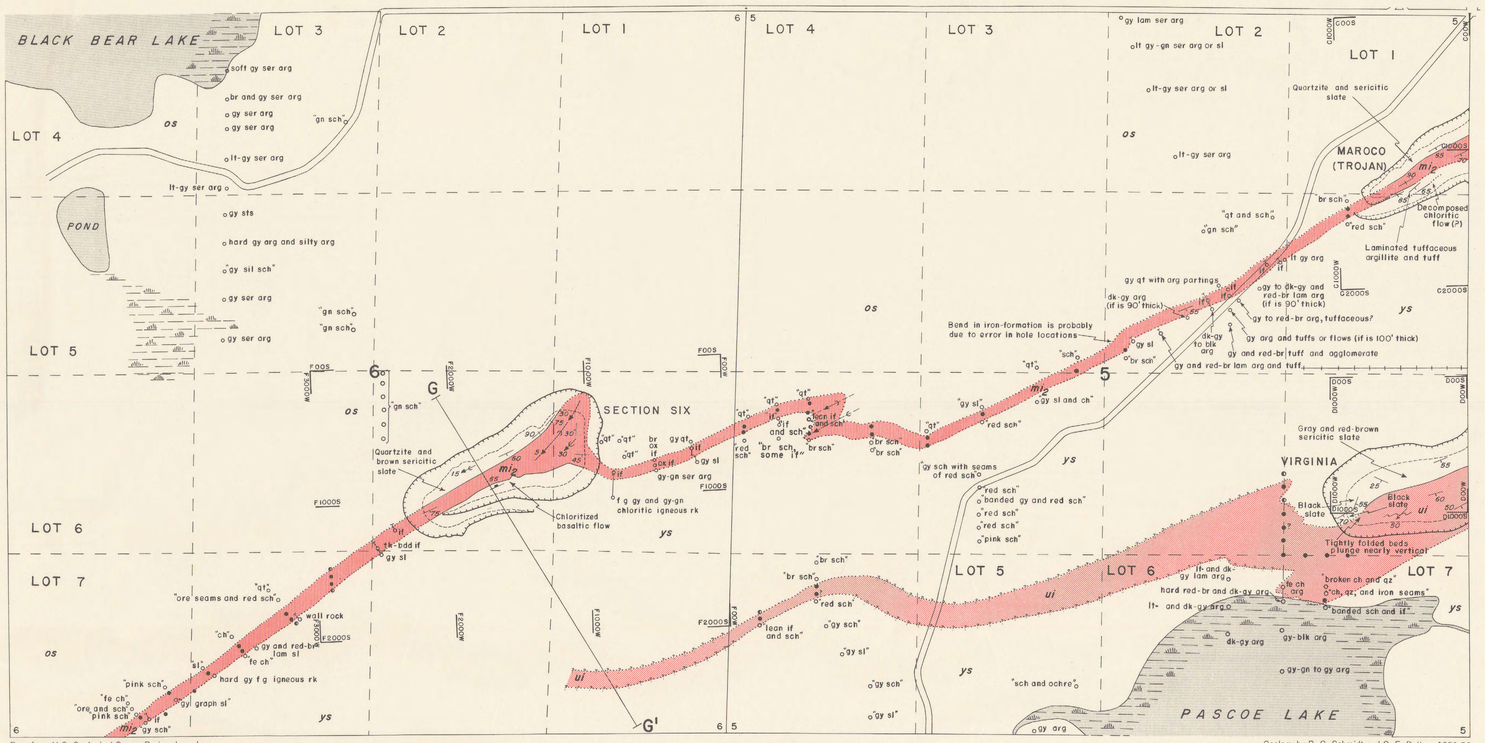
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF 181
SHEET 6 (3 OF 3)*



Base from U.S. Geological Survey Brainerd quadrangle and from maps provided by the M. A. Hanna Company. Published with permission of the operating mining companies

Geology by R. G. Schmidt and C. E. Dutton, 1951-56

EXPLANATION

QUATERNARY

Glacial drift
Shown on sections only

PRECAMBRIAN

Argillite and slate
Gray and black, generally ferruginous, and interbedded tuffs and flows near the base; partly oxidized to red, brown, or buff; includes upper iron-formation lenses, ui, that are siliceous, thin-bedded, and partly argillaceous

Thick-bedded facies of main iron-formation

Sericitic argillite and siltstone
Gray, light-green, or light-brown. Locally includes lenses of quartzite near the contact with the overlying iron-formation

Geologic contact, map
Solid where exposed continuously or at short intervals; dotted where established by drill holes and projection of mine data; queried where position is not well defined

Geologic contact, sections
Solid where exposed at the surface or closely limited by adjacent outcrops; dotted where established by drill holes and projection of mine data; queried where position is not well defined

Plunge of minor anticline
Dashed where approximately located

Plunge of minor syncline
Dashed where approximately located

Strike and dip of beds

Strike of vertical beds

Generalized strike of folded beds
Showing plunge of fold axes

Strike and dip of joints

Outline of pit bank
Dashed line represents bottom of bank

Vertical drill hole
Shown rock at bedrock surface

Inclined drill hole
Shown rock at bedrock surface

Drill hole
Iron analyses indicate that bedrock is probably iron-formation

Drill hole
Iron analyses indicate that bedrock is probably wall rock

Mine coordinates are identified by letter as follows:
C: Maroco
D: Virginia
F: Section Six

Abbreviations

arg	Argillite
bdd	Bedded
blk	Black
br	Brown
ch	Chert
dk	Dark
f	Fine
fe	Ferruginous
g	Grained
gn	Green
graph	Graphitic
gy	Gray
if	Iron-formation
interbdd	Interbedded
lam	Laminated
lt	Light
ox	Oxidized
qz	Quartz
qt	Quartzite
rk	Rock
sch	Schist
ser	Sericitic
sil	Siliceous
sl	Slate
sts	Siltstone
tk	Thick

NOTE: Quotation marks indicate the description of the rock is from mining company records. All other descriptions are the result of studies by the U.S. Geological Survey

APPROXIMATE MEAN DECLINATION, 1958

STRUCTURE CROSS SECTION ALONG LINE G-G'

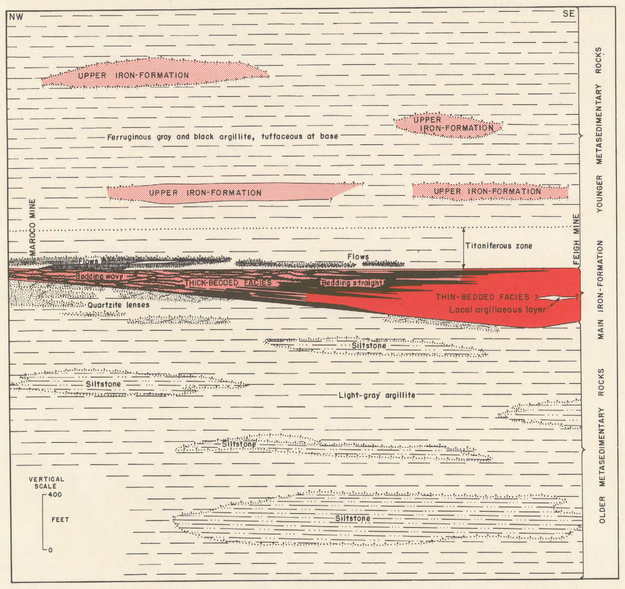


FIGURE 3. HYPOTHETICAL UNFOLDED STRATIGRAPHIC SECTION ALONG LINE B-B', SHEET 2 ,LOOKING NORTHEAST AND SHOWING CHANGES IN THE IRON-FORMATION FACIES AND PROBABLE RELATIONSHIPS OF FACIES IN THE OLDER AND YOUNGER STRATA

The horizontal distance represents perhaps 16,000 feet before and 9,500 feet after folding

GEOLOGY OF THE SOUTHWESTERN PART OF THE NORTH RANGE, CUYUNA DISTRICT, MINNESOTA

By
R. G. Schmidt

INTRODUCTION

The Cuyuna manganiferous iron-ore district is in central Minnesota in Morrison, Crow Wing, and Aitkin Counties. The length of the district is about 68 miles, extending northeastward from a point near Randall, in Morrison County, to a point 11 miles east of the community of Hassmann in Aitkin County; the maximum known width is about 25 miles near the center of the district. Current mining activity is confined to a much smaller area, commonly called the North range, about 10 miles long and 3 miles wide near Crosby and Ironton in Crow Wing County. The average annual production of iron ore and manganiferous iron ore during 1940-50 was slightly less than 3 million tons.

This investigation has been restricted to the active area plus a marginal strip in which much exploration drilling has been done. Exposures of bedrock are limited to the dewatered open pits and underground mines, and the detailed geology was mapped on a scale of 50 feet to the inch. The resulting maps were generalized for presentation on the accompanying sheets at a scale of 600 feet to the inch. Mapping outside the pits was based upon examination of drilling samples wherever possible; where company drill-hole logs were used, the descriptions are in quotation marks. Some drill holes, too closely spaced to be shown clearly, have been omitted, and within the main iron-formation only those holes that control the position of geologic contacts have been shown on the maps.

Comprehensive studies of the district were made about 1915-17 by Harder and Johnston, (1918), and over many years by Wolff (1951), and Grout and Wolff (1955).

The courtesies extended by the M. A. Hanna Co., and Pickands Mather & Co., including permission to examine drill samples, copy exploration records, and visit operating mines, are gratefully acknowledged. Generous assistance in obtaining data for the maps was also given by: Adams Brothers Co., W. S. Moore Co., Oliver Iron Mining Division of the United States Steel Corp., and Zontelli Brothers, Inc.

GENERAL GEOLOGY

The iron-formations of the Cuyuna district are included in a sequence of slightly metamorphosed Precambrian rocks consisting of argillite and slate and lesser amounts of coarser clastic rocks, volcanic tuffs, and flows. The bedrock is covered with Pleistocene glacial drift to depths of 25 to 200 feet throughout the area studied, except where laid bare by mining operations.

Almost all the iron ore and manganiferous iron ore produced in the district is mined from one well-defined stratigraphic unit, here referred to as the main iron-formation. Other metasedimentary rocks are grouped as older or younger than the main iron-formation, the top or bottom of which serve as the reference horizons for stratigraphic measurements. It is believed that drilling samples studied during this investigation include representative material from about 2,000 feet stratigraphically below the main iron-formation to about 2,000 feet above it. The main iron-formation is underlain by a sequence of argillites and siltstones, and, locally, lenses of quartzite are interbedded near the contact with the iron-formation.

The main iron-formation is the best known stratigraphic unit in the district, and two general types, a thin-bedded and a thick-bedded facies, have been separated in mapping wherever possible. There are pronounced changes in mineralogy, texture, and thickness of this rock unit within short distances along its strike.

The strata overlying the main iron-formation are mostly fine-grained argillites, in part ferruginous and in part carbonaceous (containing black carbon), but tuffaceous argillites, tuffs, and lava flows make up the basal 300 feet. Parts of the younger argillites are abnormally ferruginous and locally grade into lenses of lean upper iron-formation. The relation of these lenses to a particular stratigraphic horizon is not known, but they are probably of different ages. Except for a few layers less than 10 feet thick, they have not been found stratigraphically closer to the main iron-formation than 500 feet. The transitional contacts of these lenses contrast with the sharp contacts of the main iron-formation.

The metasedimentary rocks have been intruded by igneous rock in many places along the southeast side of the active part of the district. The intrusives are generally chloritized and where exposed in the mines are in part so sheared that original textures are destroyed. It is probable that none of the bedrock in the area of this group of maps is intrusive.

The metasedimentary rocks have been deformed into doubly plunging folds trending about N. 65° E. Geologic map patterns are commonly irregular ellipses, but some are shown open at one end where exploration has not traced the iron-formation farther. Drag folds are very common on these folds, especially near the axes. The southeastern flanks of most of the synclines are overturned.

Little evidence of major faulting has been found although some thrusting might be expected to parallel the fold axes, particularly along the overturned flanks. Minor faulting, in part related to breaking of drag folds, is common.

STRATIGRAPHY

The Cuyuna district contains only a few varieties of strata, and the sequence has been divided into three principal units in this investigation. The stratigraphic column proposed at this time is shown on figure 3 sheet 7, and descriptions of the units follow.

ARGILLITES AND SILTSTONES OLDER THAN THE MAIN IRON-FORMATION

The older argillites and siltstones were deposited as normal clays and silts with sandy lenses especially common near the upper contact. There are no stratigraphic markers within the series, but it is believed from structural relations that the nature of the series is known for about 2,000 feet stratigraphically below the iron-formation. Quartzite lenses seem to be commoner where the iron-formation is thin, particularly where only the thick-bedded facies is present. The argillites are sericitic and are light gray to dark gray, light green, and light brown. The light-brown rock has probably been oxidized. Black argillites similar to those in the younger sedimentary rocks have not been found. Excellent exposures of the upper part of this older series may be seen in the Sagamore mine, sec. 19 (sheet 4), where some quartzite lenses are interbedded with argillite in the SE¼NW¼, and siltstone and argillite predominate in the NE¼NE¼.

THE MAIN IRON-FORMATION

The term "main iron-formation" is used for convenience in distinguishing this unit from lenses of siliceous iron-formation interbedded with the younger argillites described later. With the exception of the Virginia mine and the Snowshoe mine, all the ore from the district has come from this unit.

In this study, the main iron-formation has been divided into two mappable types, the thick-bedded and the thin-bedded facies. In part of the district the entire iron-formation is thick bedded, in part it is all thin bedded, and in about one-third of the area, the thick-bedded facies overlaps the thin-bedded facies and grades downward into it. There are no examples of transitional overlap in the area of these maps, but it is probable that the thin-bedded facies is present beneath the thick-bedded facies at the east end of the Rowe mine (sheet 5).

The iron-formation changes gradually in thickness from less than 45 feet to 500 feet or more. It is thinnest in a northeast-trending belt extending from the NW¼ sec. 18, T. 46 N., R. 29 W., to the SE¼ sec. 33, T. 47 N., R. 29 W., and it thickens both to the northwest and the southeast. Near the west end of the Sagamore mine the iron-formation is about 250 feet thick; in the Section Six mine (sheet 6), it is about 115 feet thick.

Thin-bedded facies.—The minerals in the unoxidized thin-bedded facies are quartz, minnesotaite, stilpnomelane, siderite, and probably other carbonates, magnetite, and sparse pyrite. The rock is dense, gray or gray green, and thinly bedded. Many of the individual bedding laminae are less than one-eighth of an inch thick, and some are less than one thirty-second of an inch thick. One typical slab was studied in which 220 layers could be recognized in 12 inches with the unaided eye. The layers are produced by variations in proportions of minerals, rarely by alternation of layers of essentially "pure" minerals. Some of the iron-formation with good cleavage contains well-oriented minnesotaite parallel to the cleavage direction.

Thick-bedded facies.—The minerals in the least deconnosed thick-bedded iron-formation are red and brown iron oxides, quartz, minor amounts of magnetite, and minor amounts of minnesotaite. This facies is characterized by hard cherty beds ranging from an inch to several feet in thickness; most of the beds have a mottled, granular, or oolitic texture, and may or may not be indistinctly laminated. The thick beds, especially near the transition to the thin-bedded facies, may be separated by several feet of thin-bedded iron-formation. At the Section Six mine and the west end of the Maroco mine and also probably at the Rowe mine, the alternating layers of cherty and ferruginous rock are wavy or irregularly bedded. This is probably true of most of the thick-bedded iron-formation in this mapped area. Wavy bedding is difficult to distinguish from straight bedding in some diamond-drill cores.

The general lack of silicates and carbonates in the thick-bedded facies may indicate either that the original minerals were oxides or that the thick chert beds were more readily fractured and therefore more susceptible to oxidation than the thin-bedded facies.

In most places the general features of the two facies have survived the oxidation and leaching that produced ore, and the facies can also be recognized in some of the drill samples.

Argillaceous layers within the main iron-formation.—In the Sagamore mine an argillaceous layer known as the "paint rock" has long been recognized by mining company geologists as a persistent bed near the middle of the iron-formation. In this study the layer was mapped in part of the mine, and further study would doubtless extend the layer over more area. Parts of this intermediate argillite contain as much as 10 percent tourmaline in fine needles. Parts of it are titaniferous, and along the southeast side of the Sagamore mine in the SE¼NE¼, and the SE¼SW¼, sec. 19, there are textures suggestive of tuffs. Titaniferous tourmaline-rich rock, which is also present in the Feigh, Portsmouth, and other mines, is thought to consist of tuffaceous beds or thin sills within the iron-formation.

YOUNGER ARGILLITES AND INTERBEDDED UPPER IRON-FORMATION

The younger sequence of metasedimentary rocks is dominantly argillite and slate and smaller amounts of silty material, one or more interbedded siliceous iron-formations, and a group of volcanic rocks near the base.

The argillite and slate are gray to black or brown, red, green, or almost white. Gray and black are believed to be the original colors; other colors are probably the result of oxidation and leaching. The rock is finely laminated or almost without bedding. In contrast with the older argillite, rocks in this sequence are darker, more ferruginous, and partly pyritic; they include silty or sandy lenses in only a very few places.

In many places the main iron-formation is immediately succeeded stratigraphically by gray to black laminated argillite or slate. At several localities this argillite contains interbedded layers of gray rock that is believed to be tuff. In parts of the district deconnosed basaltic rocks that are wrinkled has intermeted as flows rest directly on the iron-formation or are separated from it by a few inches to about 30 feet of argillite and tuff. The presumed flows have been found above the iron-formation in this area in secs. 5 and 6, and probably are present northwest of Little Rabbit Lake in sec. 18, T. 46 N., R. 29 W., and in sec. 13, T. 46 N., R. 30 W. The deconnosed basalts were well exposed on the south side of the Section Six mine when it was in operation.

The igneous rocks and part of the younger metasedimentary rocks in the district are titaniferous. The distribution of titania has been studied by making about 700 field analyses and has been found useful in correlation. The rocks intermeted to be flows have been analyzed in many places for TiO_2 by field test and found to contain 1.0 to 2.0 percent. The tuffs, laminated argillites, and slates for 300 feet stratigraphically above the main iron-formation contain higher-than-normal amounts of TiO_2, ranging from about 1.0 to 3.7 percent and averaging about 2.0 percent. The amounts of TiO_2 are expectable in the basaltic igneous rocks, but percentages as high as 3.7 in black laminated argillites are more difficult to explain. The clays in the highly titaniferous argillites were probably derived from the weathering of basaltic rocks on the land mass supplying sediments to the depositional basin.

Most samples of the older argillites contain 0.5 percent TiO_2 or less; only a few contain 1.0 percent, and still fewer contain as much as 2.0 percent. The TiO_2 content may be used as an aid in distinguishing the 300 feet of argillites and slates overlying the main iron-formation from other sedimentary rocks in the sequence, and it is particularly useful when alteration has made visual distinction from the older argillites difficult. As mentioned previously, a part of the intermediate argillite in the Sagamore mine is titaniferous.

The gray schist in the Sagamore mine in the NE¼SW¼, sec. 19, is a steeply dipping tabular mass about 1,000 feet long and 60-100 feet wide. The rock may be a tuff or flow at the top of the iron-formation or it may be a concordant intrusive. It is somewhat sheared and chloritized; contacts, where observed, parallel the bedding of the iron-formation, but no traces of bedding have been found in the schist. The iron-formation near the contact is not visibly metamorphosed. The gray schist is probably a tuff or flow in a tightly folded syncline at the top of the iron-formation, as this stratigraphic position is occupied by volcanic rocks in other parts of the district. The possibility that the rock is intrusive cannot be excluded.

The nature and amount of the black carbonaceous matter in the argillites and slates is not known. Change to light colors along cracks and joints is common. In the Virginia mine the lightered and green slates beneath the iron-formation were probably all gray or black originally. Part of the carbon has been removed since deformation, perhaps as carbon dioxide later recombined in carbonates, beginning along joints and bedding planes and working inward.

Some of the younger argillites and slates above the flows—and possibly also below—are abnormally ferruginous, ranging from 12 to 20 percent iron. Though the original iron mineral is not known in the black and gray sedimentary rocks it was probably very finely divided pyrite. Some of the iron is now present as a red oxide and some as pyrite.

In the Virginia mine, in sec. 5, a very siliceous thin-bedded layer of iron-formation is interbedded in the younger metasedimentary rocks. For convenience this layer has been designated the upper iron-formation. Its contacts are transitional into gray, black, and light-brown slates, and parts of it are argillaceous.

Much less exploratory drilling has taken place in the upper iron-formation than in the main producing unit; so data are generally sparse and the actual thickness of the unit is not known. It may be lenticular, inasmuch as some drilling suggests disappearance along the strike; where it has been penetrated by drilling in other parts of the district it is not known if the rock is a continuation of the same strata, another lens in the same stratigraphic position, or a lens or layer of different age. The upper iron-formation shown on these maps is perhaps about 500-700 feet above the top of the main iron-formation, and there are probably similar lenses or layers higher in the sedimentary sequence in other parts of the North range.

No unoxidized samples from the upper iron-formation have been observed, so the primary minerals are not known. The iron in the ores is in the form of brown and red oxides.

Samples were examined from beds as much as 2,000 feet stratigraphically above the main iron-formation. The youngest metasedimentary rock seen, in another part of the district, was a black argillite with associated thin layers of argillaceous iron-formation, similar to rocks found nearer the base of this unit.

INTRUSIVE ROCKS

Intrusive igneous rocks are common along the southeast side of the actively mined part of the district, and small bodies are found in the mines from the Manuel mine in sec. 1 to the Huntington mine in sec. 9, T. 46 N., R. 29 W. Diamond-drill cores of unsheared medium-grained igneous rock have been examined from secs. 11, 16, and 20, T. 46 N., R. 29 W. The rock is largely chloritized, and grains of sphene, now altered to leucoxene, are common. The intrusive rocks were probably normal rocks of dioritic to gabbroic composition. Most of the large igneous bodies have been altered to chlorite schists where observed in the mines. The igneous rock in sec. 20 probably extends southwestward into the southeast corner of sec. 19, near the Sagamore mine, but no samples from the drill holes there have been examined by the author. None of the original logs of the drill holes in sec. 20 mention igneous rock so it might not have been reported if present in sec. 19.

GEOLOGIC STRUCTURES

The dominant structures in the district are folds that trend about N. 65° E. These folds are complicated by many drag folds and by reversals of plunge of the fold axes.

Two large synclines are prominent in the area described in this report. Both were described in the report on the area to the east (Schmidt and Dutton, 1957). The center of the northernmost syncline plunges southwestward from a point north of the Joan mine (fig. 2) in sec. 3, T. 46 N., R. 29 W., and crosses the area of sheet 5 near the center of sec. 7, and lot 2, sec. 13. The syncline widens continuously westward until the limbs, as marked by the main iron-formation, are no longer traced by exploration drilling. Drilling on the north limb has tested the main iron-formation as far southwest as the NE¼NE¼, sec. 12. Beyond this location, near the center and in lot 1 of sec. 12, the drilling in ferruginous rocks has probably all been in the upper iron-formation and in the ferruginous younger argillites. The drilling in the NE¼NE¼, sec. 12, indicates that the main iron-formation is folded in a large drag fold that probably offsets the bedrock outcrop to the northwest of the drill holes near the center of the section. Parts of the samples from one hole northwest of the iron-formation near the center of the section were examined and found to be black argillite of the type found only in the younger series. The iron-formation on the south limb of the syncline has been traced westward by numerous drill holes almost to the Mississippi River, but the extension beyond the river is based on the records of only a few holes.

The center of the southernmost syncline extends from the vicinity of the Mangan No. 2 mine in sec. 10, T. 46 N., R. 29 W., to the Rowe mine in sec. 18 of the same township. The axis plunges northeastward at the Rowe mine as shown on sheet 5 and southwestward near the Mangan No. 2 mine. Drag folding near the axis of this fold is well shown at the Rowe mine.

In the Sagamore mine, sec. 19, T. 46 N., R. 29 W., the iron-formation is folded into a series of southwest-plunging drag folds. There is little information from which to judge the extent of the iron-formation south and west of the mine, and it is not possible to determine whether the drag folds are north of the axis of a major syncline or roughly symmetrical about the axis. Argillites and siltstones older than the iron-formation are found northwest and east of the Sagamore mine and extend southwestward along the east side to the middle of the NW¼SE¼, sec. 19. Beyond this, in the E½SW¼, the intermediate argillite is exposed in the pit wall and penetrated in drill holes indicating that the lower part of the iron-formation is toward the southeast and has been explored by only a very few drill holes. In the SE¼SW¼, sec. 19, very little is known about the relationship of the iron-formation to the wallrock.

In the westernmost part of the Sagamore mine, the iron-formation dips uniformly to the south and is overlain by soft buff argillites and siltstones that resemble the older metasedimentary rocks and are unlike younger argillites elsewhere in the district. The iron-formation outcrop beneath the glacial drift rapidly decreases in width westward, and it probably pinches out about 500 feet west of the section line. This thinning may be the result of a fault that brings older siltstones against the iron-formation. Nondeposition or an erosional unconformity would also explain the thinning but not the difference in the overlying strata. It was also recognized that the iron-formation in this part of the mine might be folded into a tight, overturned syncline with a reversed plunge to the east. The disappearance of the iron-formation to the west would be a result of this eastward plunge; but the iron-formation is very well exposed in the mine, and detailed structural mapping shows that the south edge of the iron-formation is indeed the top and that no syncline is present. The contact between the iron-formation and the south wallrock was not exposed at the times the area was examined, but the bedding in the two rocks is conformable within a few feet of the contact. The author believes that faulting provides the best explanation of the narrowing of the iron-formation.

Faulting is probably not of major importance elsewhere in the district although small strike faults are common on the flanks of folds. These faults generally cut the bedding at a low angle and have small, stratigraphic displacements, probably not exceeding 20 or 30 feet. Deformation is generally more intense along the southeast edge of the area studied, and some overturned beds are shown along the southeast side of the Sagamore mine.

ORE DEPOSITS

Direct-shipping iron ores and manganiferous iron ores have generally formed by oxidation and leaching of the thin-bedded facies of the main iron-formation, less commonly of the thick-bedded facies. "Wash ores," in which leaching has weakened the grain boundaries of the silica, have formed in the thick-bedded facies, in siliceous parts of the thin-bedded facies of the main iron-formation, and in the upper iron-formation.

Analyses of unoxidized iron-formation indicate an iron content of 18 to 35 percent and from less than 1 to about 11 percent manganese. These quantities of the elements are probably sufficient to account for the amounts in the ores without assuming any introduction from outside the iron-formation.

Iron minerals in replacement textures and open-space fillings indicate that there has been some local transportation of iron in solution, but the writer does not believe that movement of iron has been a major factor in the development of Cuyuna ore deposits. Most ores probably formed by oxidation and the removal of silica from the iron-formation leaving the iron oxides porous or vuggy; soft porous ores are abundant in the Sagamore mine. In contrast to the Mesabi district, evidence that slumping accompanied the development of ore bodies has been observed in only a few isolated places and evidence that the beds have not slumped is fairly common.

The location of manganiferous ores has not been studied thoroughly. Replacement textures and fracture fillings indicate local solution and redeposition of manganese. Such evidence is generally lacking in the Sagamore mine where the manganiferous ores occur in a zone stratigraphically above the intermediate argillite.

RECOMMENDATIONS FOR FURTHER EXPLORATION

The probable westward extension of the main iron-formation in sec. 12 deserves a moderate amount of further exploration. As previously discussed under geologic structures, the iron-formation reported from drill holes near the center of the section and in lot 1 is probably upper iron-formation interbedded with the younger argillites. If so, the main iron-formation has not been explored beyond the NE¼NE¼ of the section. Study of systematic thickness changes in the rest of the district suggest that the iron-formation will be found to have about the same thickness as at the Section Six mine. The thick-bedded facies will dominate or be the only one present so that if any ores occur, they will probably be wash ores. Because many of the ore bodies in the thick-bedded facies are in drag folds, the proof of similar structures in this area may be assumed to increase the probability of finding an ore body.

The iron-formation on the south limb of this same syncline in section 13 and southwestward in sec. 33, T. 135 N., R. 27 W., is probably all too thin—perhaps about 50 feet in stratigraphic thickness—to warrant further exploration.

Future exploration southeast and southwest of the Sagamore mine may lead to a better understanding of the geology of the area and may reveal areas of undrilled iron-formation.

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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C., W68880

SHEET 6

BEDROCK GEOLOGY OF THE SOUTHWESTERN PART OF THE NORTH RANGE, CUYUNA DISTRICT, MINNESOTA

By
R. G. Schmidt

Scale 1:7 200
1000 500 0 1000 2000 Feet

1958

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF 181
SHEET 6 (3 OF 3)*
*Sheets are numbered consecutively with MF99