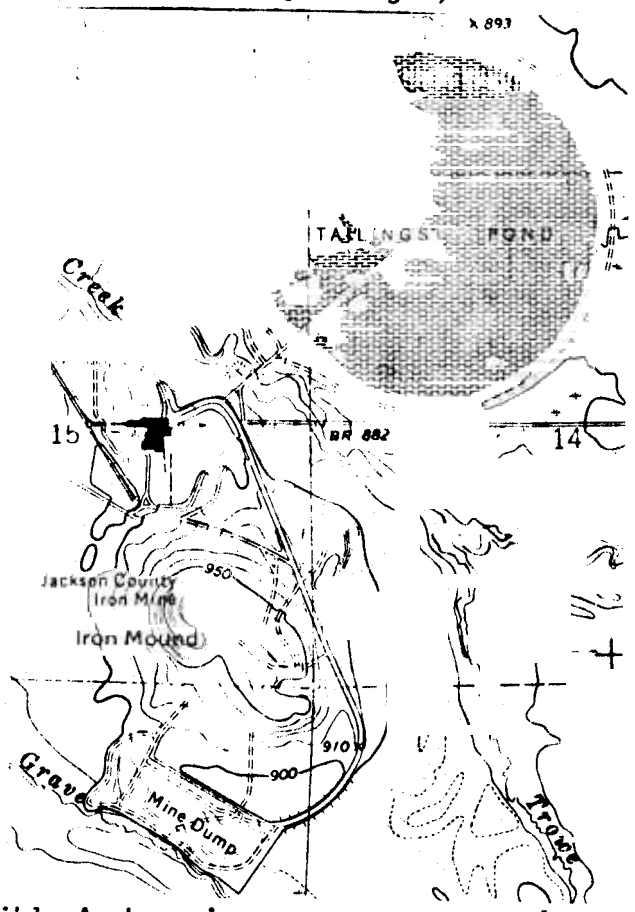
TITLE: Geology of the Jackson County Iron Mine

LOCATION: SE 1/4, Sec. 15, T 21 N, R 3 W, Hatfield SW Quadrangle, Jackson County, Wisconsin



AUTHOR: David G. Jones, UW-Madison

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SUMMARY OF FEATURES:

A Precambrian iron formation, possibly Archean in age, crops out as low isolated mounds in Jackson County, Wisconsin. The Jackson County Iron Company owns and operates an open pit taconite mine and plant on the largest of these mounds. The iron formation is compositionally banded and composed primarily of quartz, magnetite, and grunerite. Surrounding the iron formation is a quartz-biotite-garnet schist that has been highly weathered southwest of the ore body. An elongate zone of nearly pure talc schist is located near the center of the ore body.

Outcrop patterns, minor structures, and geophysical data suggest that the rocks of the area have been isoclinally folded along a nearly vertical fold axes. The rocks have been metamorphosed to the lower amphibolite grade, and textural evidence indicates they have been sheared and recrystallized.

The Precambrian terrane is unconformably overlain by an Upper Cambrian conglomerate and sandstone.

INTRODUCTION:

The Jackson County Iron Mine located in Jackson County, Wisconsin, is an open pit taconite operation producing about 750,000 tons of pellets per year. The ore body is a lens-shaped body 915 meters in maximum length within the mine and 150 meters in maximum width. The ore mineral is magnetite, and the grade of the iron formation usually varies between

20-50%, the average being 35% magnetite. Weathering has oxidized the iron formation to hematite, and the depth of oxidation seems to be controlled by the amount of fracturing in the rock. The iron formation strikes approximately NW-SE and dips 70-75 degrees SW and has undergone penetrative deformation. A highly sheared and recrystallized schist surrounds the iron formation. The lower or footwall schist is composed predominantly of quartz, biotite, chlorite, and garnet. Near the surface the upper or hangingwall schist is a soft, crumbly quartz-biotite-sericite schist, but at depth it resembles the footwall schist. A zone of talc schist is situated within the iron formation near the central portion of the pit and may have been structurally emplaced.

Within the Black River Falls area local deposits of iron formation rise above the surrounding area in the form of low hills or knobs. Besides the site of the current operation there are three other potentially economic deposits. Ground magnetic surveys best delineate the location of the iron formation in the area.

DESCRIPTION OF ROCK UNITS:

Footwall Schist: This unit is a dark colored, highly foliated siliceous schist. It is structurally situated directly NE of the iron formation (see Fig. 1) and is in sharp contact with the iron formation. The mineral assemblages within the schist are:

1. quartz-biotite-plagioclase-garnet
2. quartz-biotite-muscovite-chlorite-andalusite
3. quartz-biotite-muscovite-garnet-staurolite-chlorite-plagioclase

Modal variations in quartz and biotite are obvious in hand sample, and compositional banding of quartz-rich and biotite-rich layers is evident locally. The banding parallels foliation, and is in places intensely folded.

Texturally the footwall schist is extremely variable ranging from a highly foliated coarse-grained schist to a fine-grained, nearly granular rock within a few meters. The mineral assemblage, however, is constant.

Hangingwall Schist: The weathered rock which is located along the SW side and sweeps around the NW end of the iron formation is called the hangingwall schist (see Fig. 1). The schist is composed primarily of quartz, biotite, and sericite. The depth of the weathered zone within the hangingwall schist seems to increase to the NW and varies between 6 meters and 50 meters. Weathering is apparently controlled by some type of fracture pattern that locally increases the permeability of the rock.

Drill cores through the hangingwall schist exhibit a gradual decrease of weathering and clay content with depth until the unweathered schist is reached. The mineralogic assemblage and textural characteristics of this unweathered material are strikingly similar to those of the footwall schist. Even in thin section no distinction can be made between the hangingwall and footwall schists

Iron Formation: The iron formation is a highly deformed unit composed almost entirely of the following minerals:

quartz
magnetite
cummingtonite-grunerite
biotite
garnet
calcite
ferroactinolite
Ca-rich hornblende (hastingsite)
sphene
apatite
pyrite

Compositional banding of the magnetite and quartz is prominent. The quartz band range from a few millimeters to nearly a meter in thickness. This variation in thickness is in part structurally controlled. Some bands are formed of the assemblage garnet-amphibole-quartz. These bands may be distinct, having sharp contacts with the surrounding magnetite and containing very coarse-grained, reddish-brown garnet, or they may be zones of fine-grained pink garnets and chlorite. Band thickness varies from 0.5-5.0 cm. The garnet-amphibole-quartz assemblage also occurs as elongate pods up to 15 cm. long. Other mineralogic assemblages exhibit compositional banding which contributes to the overall banded character of the iron formation. Some of the mineral assemblages are:

1. quartz-ferroactinolite-grunerite-magnetite
2. magnetite-grunerite-quartz-calcite
3. quartz-biotite-cummingtonite-magnetite
4. quartz-magnetite-ferroactinolite-Ca-rich hornblende
5. quartz-grunerite-Ca-rich hornblende-magnetite
6. quartz-magnetite-garnet-ferroactinolite-calcite-K-feldspar
7. quartz-garnet-biotite-Ca-rich hornblende

Garnets commonly appear in the iron formation as isolated porphyroblasts rimmed with either Ca-rich hornblende and biotite or pure Ca-rich hornblende which appears to replace the garnets. These porphyroblasts vary from a few millimeters to 3.0 cm. in diameter. The amount of dark green Ca-rich hornblende can vary from a thin rim to a total replacement of the garnets. The crystal form of the original prophyroblasts decreases with increased replacement of garnets. Many of the porphyroblasts are ellipsoidal in cross-section with long axes parallel to foliation.

Another rock type found sporadically within iron formation is dark green, non-foliated to poorly-foliated amphibolite. Amphibolites are apparently concordant with the foliation in the iron formation and vary in thickness from 0.5 meters to 3 or 4 meters. They are usually in sharp contact with the iron formation. Again the mineralogy is extremely variable. The assemblages present include:

1. biotite-Ca-rich hornblende-epidote-K-feldspar
2. talc-grunerite-biotite-chlorite
3. grunerite-Ca-rich hornblende-magnetite
4. biotite-Ca-rich hornblende-scapolite-epidote

One striking characteristic of the amphibolites is that most of them display a distinctly splotchy texture owing to the presence of spherical aggregates of chlorite and/or Ca-rich hornblende surrounded by ploygonized biotite. Dark green amphibolite layers are also found within the talc schist horizon and sometimes within the hangingwall and footwall schists.

Drill cores show zones of schist, texturally and mineralogically similar to the footwall schist, locally interlayered with the iron formation. Whether the schist layers are primary or structurally emplaced is not known.

The compositional banding in the iron formation provides an excellent means of viewing the minor structures in the rock. The structural style is more complex than initially evident. Parallel banding is the most conspicuous structural feature of the iron formation and probably represents transposed primary bedding parallel to foliation. Further examination reveals tight small-scale isoclinal folding of some of these layers. The limbs of the minor folds have commonly been thinned while the hinge areas are thickened, rotated, and detached. Amphiboles within amphibole-rich layers define a lineation parallel to the axes of the minor isoclinal folds. The relationship between

the folds and the straight banding is not everywhere apparent. In a few areas in the NE wall of the pit, however, minor isoclinal folds can be found in place. Fold axes plunge 70-75 degrees in a southwesterly direction and parallel the lineations as defined by the amphiboles. In such places it is apparent that the parallel and the highly deformed bands represent the limbs and hinges, respectively, of isoclinal folds. Quartz boudins of all sizes up to a meter in thickness occur in the iron formation. Boudins represent both isolated fold hinges and thickened, separated portions of fold limbs.

A series of two, possibly three, broad, open fold patterns has been imprinted onto the isoclinal folds. The broad, open folds can only be seen within the iron formation in the NE wall of the mine.

Drilling indicates that the iron formation continues at depth in approximately the same attitude. The bottom of the ore body has not been located. Magnetic data show that locally the iron formation pinches out rapidly to the NW but pinches and swells for about a mile to the SE of the present pit.

The local outcrop pattern of the iron formation (see Fig. 1) indicates a distinct thickening and thinning. Presumably, this represents large-scale boudinage with nearly vertical axes and is a result of the same forces that produced the saml1-scale penetrative deformation.

Talc Schist: A zone of talc schist is located within the iron formation in the eastern portion of the mine (see Fig. 1). The long axis of the talc zone is about 200 meters long and is parallel to the structural grain of the iron formation. At its widest portion the talc schist approaches 50 meters. For the most part, the talc schist is coarse-grained and nearly pure. One striking assemblage within the talc schist is composed of garnet prophyroblasts rimmed with cummingtonite and biotite associated with long (1.5 cm.) prismatic blades of andalusite. The talc schist contains variable amounts of magnetite which increases toward the contact with the iron formation. Pyrite appears to be concentrated in the iron formation and in a chlorite-biotite-talc schist, both located near the edge of the talc schist zone, but pyrite is not found in the nearly pure talc schist. Near the SW side of the talc schist zone, partially chloritized garnets weather out of a biotite-chlorite-talc-garnet schist and are found as small green nodules at the surface. Other mineral assemblages that occur locally within the talc zone or at the contact between the talc zone and the iron formation are:

1. talc-cummingtonite
2. quartz-biotite-talc-magnetite
3. talc-Ca-rich hornblende-biotite-magnetite-apatite
4. talc-garnet-andalusite-cummingtonite

The talc is too incompetent and the out crop too limited for structural determinations, but some of the nearly pure talc does exhibit well developed crenulations.

Other Rock Units: In the NE wall, on the upper bench, at the NW end of the mine a zone of granitic material crops out. The contacts of this zone and the footwall schist are sharp and parallel with the foliation in the footwall schist. From the far side of the mine the granite is conspicuous as a narrow white vertical band in the dark footwall schist. The granite is a highly sheared rock with large augen (1 cm.) of K-feldspar embedded in a predominantly quartz-K-feldspar matrix. The recrystallized texture and concordant position indicate its formatin prior to regional metamorphism and deformation.

Five diabase dikes ranging in size from 2 meters to approximately 20 meters in thickness transect the mine in various orientations. The largest of the five displays a coarse-grained center and fine-grained margins. There is no evidence of any chemical alteration of the adjacent rock due to the intrusions.

UNCONFORMITY:

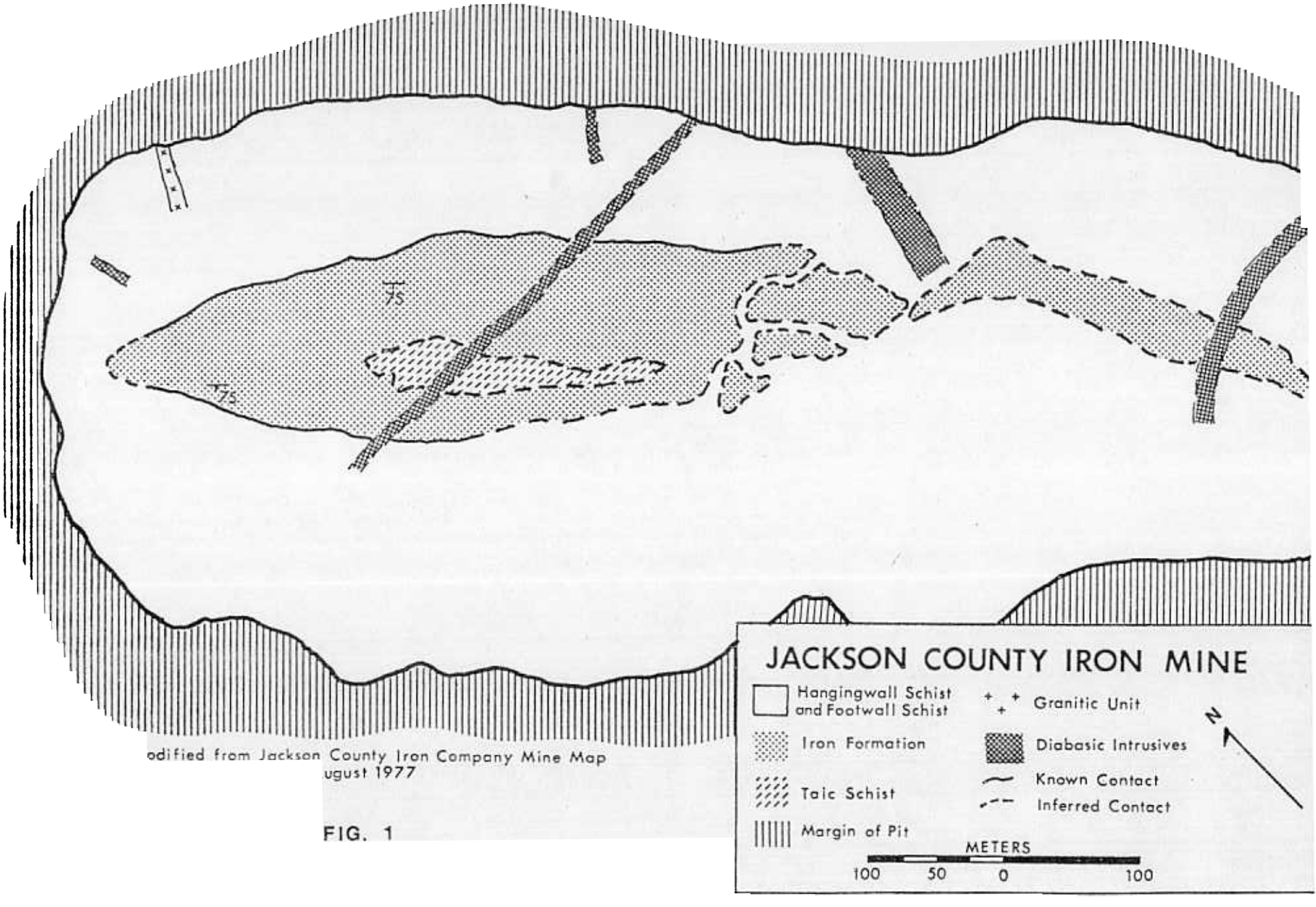
Overlying the Precambrian rocks are Upper Cambrian sandstones. The contact is unconformable, and immediately above the undulating surface is a conglomerate containing clasts of angular to subangular hematitic iron formation and a matrix of well sorted and well rounded, coarse-grained, quartz sand. The hematitic clasts range up to nearly 2 meters in diameter. The conglomerate grades rapidly upward into poorly indurated Upper Cambrian sandstone which thickens locally to the SE and in places contains thin clay partings.

CONCLUSION:

The outcrop pattern suggests that large-scale boudinage of competent iron formation within incompetent schist is a dominant structure. The iron formation appears to have been isoclinally folded aobut a near vertical axis. Small-scale features within the iron formation supporting this hypothesis include isolated and rotated fold hinges, mineral lineations, and the predominance of paraliel, compositional bands.

The mineralogic and textural similarities between the footwall schist and the unweathered portion of the hangingwall schist suggest that the two schists are a single folded stratigraphic unit.

Fig. 1 illustrates that the major part of the ore body is a partially detached hinge of an isoclinal fold. One line of evidence supporting the occurrence of the hinge is that the pattern of the magnetic survey does not extend the ore body to the NW beyond what is exposed in the mine. The SW limb of the fold has been attenuated just beyond the zone of talc schist. The NE limb, however, seems to continue disjointedly to the SE in what appears to be a slightly offset segment of the iron formation with a more northerly trend.



odified from Jackson County Iron Company Mine Map
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FIG. 1