Weathering of Ferruginous Beds in the Pennsylvanian of Greene County, Indiana[1]

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The Pennsylvanian in Greene County, Indiana (and in adjoining counties as well), contains occasional thin, hard and tough, ferruginous layers composed largely of iron carbonate and fine silt with minor amounts of calcium carbonate and organic matter. The rock is unusually heavy because of the large amount of iron and breaks down readily under normal surface weathering. Iron carbonate is changed to limonite and is left in successive thin shells concentric to the unweathered kernel of original rock (Fig. 1); calcium carbonate, if present, is dissolved by percolating ground waters and carried away; and the fine silt and organic matter are probably removed as suspended material. Ultimately, much of the iron is released during continued weathering, and it finds its way into contiguous strata and adjacent stream deposits where it becomes both coloring matter and cement.

The weathering cycle begins with circulation of ground water through the jointed layer (Fig. 1) and ends when the original rock has been destroyed completely and its constituents deposited elsewhere. Almost any stage in the cycle may be seen in an extensive outcrop.

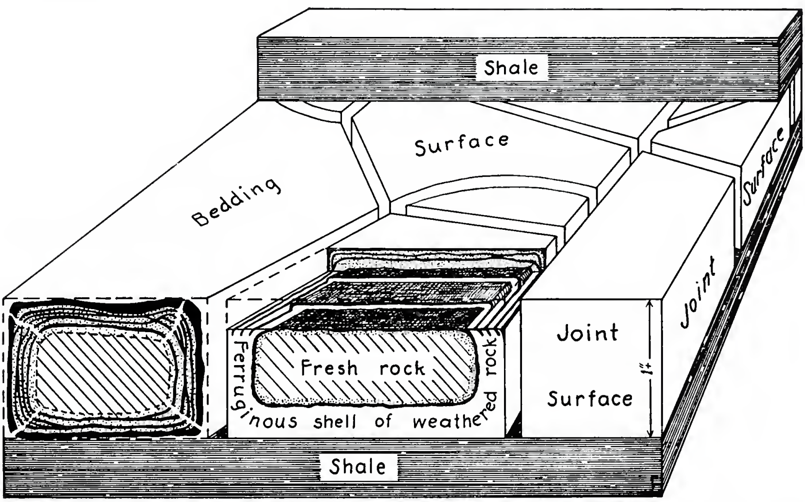

Fig. 1. Diagram showing how a jointed ironband weathers into polyhedra with rounded edges and successive concentric shells of limonite surrounding a core of fresh rock. Sketch based on exposures in a ravine in the N.W. ¼ Sec. 6, T. 6 N., R. 4 W., 2½ miles southeast of Bloomfield.

[1]Observations on which this discussion is based were made during field work for the Sun Oil Company, Philadelphia, in the summer of 1938. Permission to publish has kindly been granted by the Sun Oil Company.

The ferruginous sediment is believed to have been deposited in a quiet, shallow body of fresh water into which streams and wind were bringing the constituents from the surrounding land surface.

Stratigraphic associations.—The ferruginous rock occurs as thin bands ("ironbands") and zones of concretionary masses ("ironstones") at irregular intervals in the lower 300 feet of the Pennsylvanian in the eastern half of Greene County. The bands and concretionary zones lie in a sequence of sandstones, shales, and thin coal beds, as is apparent from the following sections:

Section in ravine in the N.W. ¼ Sec. 6, T. 6 N., R. 4 W., about 2½ miles southeast of Bloomfield, Greene County (in descending order).

9.	Blue shale weathering to gray clay	3′ 00″
8.	IRONBAND	01″
7.	Blue gritless shale breaking into chips and weathering to gray clay (mud)	2′ 06″
6.	IRONBAND (furnished specimens shown in Figs. 2 and 3)	01.5″
5.	Gritless blue shale	1′ 00″
4.	Iron-stained sandstone with small, kidney-like shale flakes	02″
3.	Black bituminous sandstone which is bedded, but is tough because of the strong bituminous cement	1′ 00″
2.	IRONBAND, which is well jointed and releases "boulders" on weathering	02″
1.	Blue, somewhat sandy shale	8′ 00″+

(Section bottomed in ravine just below the exposure of ironband No. 2).

Section measured along a ravine in the N.W. ¼ Sec. 21, T. 7 N., R. 4 W., just south of Highway 54 and about 4 miles east of Bloomfield, Greene County (in descending order).

6.	Thin-bedded sandstone	2′ 00″
5.	Blue gritless shale	4′ 00″
4.	IRONBAND, well jointed	02″
3.	Coal	04″
2.	Underclay	04″
1.	Blue, gritless shale	4′ 04″

(Section bottomed in ravine at base of shale unit No. 1).

Physical and chemical nature of the ferruginous rock.—The rock of the bands and concretionary masses is usually dark colored when freshly broken and is both hard and tough. When thoroughly weathered, it takes on a gray color and may be soft and porous or ashlike. The unusual weight of the rock is at once apparent when a specimen is lifted and indicates a large amount of iron. In the following list the specific gravity of fresh and weathered ferruginous rock is compared with that of several well-known rocks of southern Indiana.

Table of Comparative Specific Gravities

1.	Fresh ironband rock, Greene County	3.58
2.	Fresh ironstone, Greene County	3.26
3.	Weathered ironstone, Greene County (of No. 1)	3.02
4.	Limonitic shell of weathered band (of No. 1)	2.90
5.	Pennsylvanian shale, northwest of Worthington	2.47
6.	West Franklin limestone, Evansville	2.70
7.	Lithographic St. Louis limestone, west of Bloomington	2.65
8.	Beech Creek limestone, Owen County	2.62
9.	Salem limestone	2.48

Layers of the ferruginous rock are always well jointed (Fig. 1) and, as a consequence, are really thin pavements of small rhombic blocks. These blocks have many shapes and are as much as 16 inches in greatest dimension. They slump down over weathered shale slopes as the band breaks up and collect as "boulders" in the ravines below the outcrops of the ironbands. A number of them are shown in Fig. 2, and they will be mentioned again later.

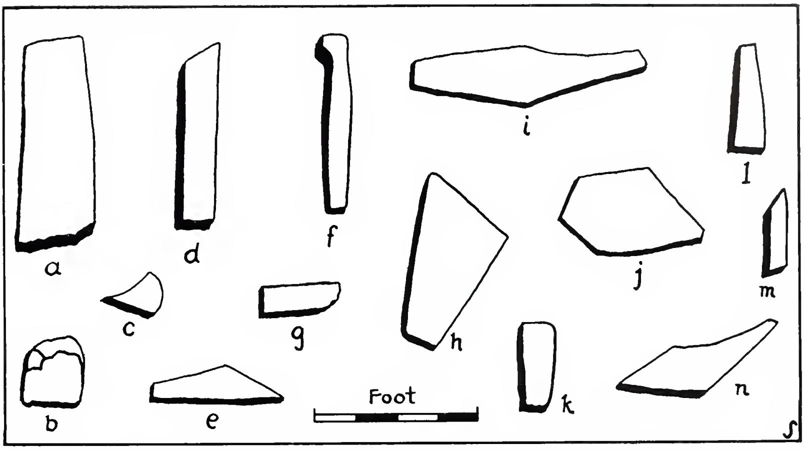

Fig. 2. Joint blocks released from a weathered ironband in a ravine in the N. W. ¼ Sec. 6, T. 6 N, R. 4 W., about 2½ miles southeast of Bloomfield. They owe their peculiar polyhedral shapes to joint planes and bedding or separation surfaces. Sketch based on a photograph.

Some of the shales associated with the ironbands contain large discoidal masses, several feet across, that have septarian structure in which the radial cracks are filled with calcite and small, irregular concretionary masses, which resemble sweet potatoes and are solid, dense, and tough, breaking conchoidally.

Chemically the ferruginous rock is quite variable in the percentages of the several constituents, and no single analysis conveys a true picture of this variation. The chief constituents, however, are iron carbonate (presumably ferrous carbonate), very fine silt (probably highly quartzose and containing some clay), calcium carbonate, and organic matter. Analyses listed by Logan[2] show that the iron averages slightly over 55% although the iron content probably varies considerably at different localities.

Weathering of the layers.—The weathering cycle affecting the ironbands begins when the first ground water circulates through the jointed layer and ends when the rock of the layer has been completely destroyed and its original materials scattered over the surrounding countryside. Since the layers usually lie between contiguous shale beds (Fig. 1) and appear to have been jointed almost from the time they were uplifted

[2]Logan, W. N., 1922. Handbook of Indiana geology. Pp. 761-762.

from the sea floor, they have always furnished excellent channels for circulating groundwater. This water, charged with carbon dioxide and oxygen, circulates through the openings in the ironband, attacking the blocks on the joint faces and bedding surfaces at first and later penetrating them by following cracks that develop along the edges (Fig. 1). In this manner weathering can continue until the entire block has been altered.

In the weathering, the ferrous carbonate is oxidized and hydrated to limonite, which remains as a thin shell around the unweathered core:

$$4FeCO_3 + O_2 + 3H_2O \longrightarrow 2Fe_2O_3 \cdot 3H_2O + 4\ CO_2$$

Any calcium carbonate present is changed into the bicarbonate and removed in solution:

$$4CaCO_3 + 4H_2O + 4CO_2 \longrightarrow 4Ca(HCO_3)_2$$

The silt or clay released during these reactions is carried out, probably as a colloid, or at least in a suspended state. Organic matter may go out in colloidal form, thereby increasing the efficacy of the water to dissolve calcium and ferrous carbonates; some may also act to stabilize any ferric oxide hydrosol that is being removed; and some may be trapped in the limonite shell.

Partial alteration, as shown in Fig. 1, produces rounded blocks composed of a core of unweathered rock surrounded by concentric shells of limonite (Fig. 3). Complete alteration produces rounded or polygonal hollow blocks (Fig. 4), which sometimes have small cores that act as rattles. In some instances, after a layer has been completely altered but before it has had a chance to disintegrate, the hollow blocks are cemented together by limonite into a continuous stratum with a mud-cracked appearance (Fig. 5). When such a layer is cracked open, however, one sees that the individual blocks are hollow, and the cavity

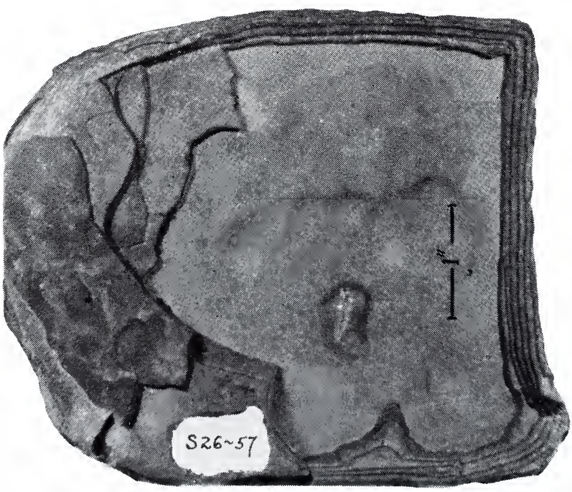

Fig. 3. A partly weathered joint block with rounded edges, showing the gray, unweathered core of fresh rock surrounded by concentric shells of dark, limonitic material which have exfoliated to a considerable degree on the upper side of the specimen. The bedding is in the plane of the page.

Fig. 4. Weathered joint block, now rounded into concretionary form, which has been completely altered with a hollow cavity remaining. The concentric shells are largely limonite that is firmly cemented.

Fig. 5. Weathered ironband in which the original joint blocks have been completely altered and then cemented by limonite into a continuous stratum. Most of the individual blocks are now hollow.

may be partly filled with yellow limonitic powder or it may contain a small fragment of original core, free to move about in the cavity as a rattle.

As the weathered ironband is uncovered and undercut by stream erosion and mass wasting, it disintegrates into the joint blocks (Fig. 2), which move downward to the drainage channels. When these leave the mother ledge, they are usually polyhedral slabs bounded by two smooth, parallel surfaces—the separation or stratification planes—and a number of plane or curved joint surfaces (Fig. 2). The weaker of these, especially those which are hollow, will soon be broken up by impact. Some will lose the limonitic shell, also because of impact with other boulders, and the core of unweathered rock will then continue as a rounded "boulder" that may be mistaken easily for a limestone boulder. These may persist for long distances from the source. In some instances, only part of the concentrically laminated shell is lost; the rest remains with the core, and the resulting block has a concretionary appearance (Fig. 3).

Regardless of the nature of the ferruginous boulders, however, it seems very likely that sooner or later they will yield their iron to circulating ground waters, and this iron will be removed to become coloring matter and cement in other rocks and rock materials. Cases were observed where such iron had been carried downward into porous sandstones and had cemented them firmly; elsewhere, it had been deposited on stream gravels so that the pebbles and boulders not only were cemented together, conglomerate-like, but they also appeared to be composed of iron. A few taps from a hammer, however, usually sufficed to reveal this iron as a thin coating over the particles.

Conditions of sedimentation.—It may be postulated that the original ferruginous sediment was deposited as a fine silt and clay with a high iron content in a shallow body of fresh water to which it was being brought by streams and wind. Since the iron now exists in the unweathered rock as ferrous carbonate, it may be assumed that the sediment was deposited in a reducing environment. Moore and Maynard[3] have pointed out that most of the iron transported in river waters high in organic matter is probably carried as a ferric oxide hydrosol, which is stabilized by organic colloids. Some of the iron may also have been dissolved by carbonated ground waters and carried as ferrous carbonate.

If the iron was transported as a ferric oxide hydrosol, it would be co-precipitated together with the stabilizing organic colloids by the negatively charged muds. After deposition the oxide would then be reduced to ferrous carbonate within the mud. If, however, it were carried as ferrous carbonate originally, it would be precipitated directly in that form. This postulated sequence of events agrees best with the observed behavior of iron compounds in fresh water.[4]

During diagenesis, and perhaps to some extent later, the several constituents of the ferruginous deposit were cemented together into the tough rock which may be seen today in unweathered outcrops. The iron-bands, as a consequence, are much more resistant to weathering and erosion than the shales and other contiguous sediments with which they are associated. They became jointed early, and, by the time the rock had been elevated above the water table, channels were in existence for free circulation of groundwaters through the layer. Each block of the mosaic or pavement was subjected to weathering. Hence, each shows in miniature the history of the layer or band as a whole.

[3]Moore, E. S., and J. E. Maynard, 1929. Solution, transportation, and precipitation of iron and silica. Econ. Geol. 24:301.

[4]Hatch, F. H., R. H. Rastall, and M. Black, 1938. The petrology of the sedimentary rocks. George Allen and Unwin (3d ed. rev.). Pp. 147-149.