

The Heavy Minerals of the Mansfield Sandstone of Indiana

H. RICHARD GAULT
University of Missouri¹

Introduction

This investigation was undertaken for the purpose of obtaining any evidence which might distinguish stratigraphic horizons in the Mansfield formation and give information as to its source. With this objective in mind, the writer collected samples and studied sections of the formation throughout the area in which it outcrops during the summer of

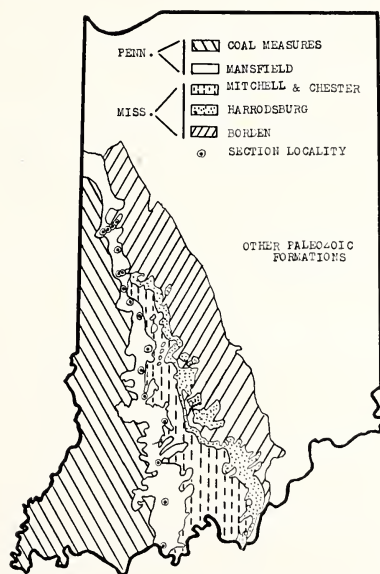


Fig. 1.

1937. A total of 239 samples were taken from 16 localities (Fig. 1), and the material was studied by various laboratory methods, chiefly heavy mineral determinations and mechanical analyses, at the University of Missouri during the school year of 1937-38.

The Mansfield Sandstone

The Mansfield sandstone, named by Hopkins (1) in 1895, is a basal Pennsylvanian sandstone of Pottsville age, resting unconformably on the underlying formations. The stratigraphic hiatus reaches a known max-

¹ Now at The Pennsylvania State College.

imum of about 1500 feet in the northern part of the area, where the Mansfield rests on the New Albany (Dev.) shale near Remington, Indiana (2). Toward the south the Mansfield rests on successively younger formations. In Turkey Run State Park the underlying formation is the Borden (Miss.), and near Greencastle, the Mansfield lies on the St. Louis (Miss.) limestone. At the Ohio River, over 600 feet of Chester (Miss.) sediments lie below the Mansfield (2), in addition to the Borden shale, and the Harrodsburg, Salem, and St. Louis limestones.

The outcrop is a long narrow belt striking NNW-SSE in western Indiana for a distance of some 170 miles along the west flank of the northwest arm of the Cincinnati Arch. The formation is covered by glacial drift in Illinois (3), but the outcrop is continuous across the Ohio River into Kentucky.

The base of the Mansfield is very uneven, having local hills and valleys which sometimes show a relief of 150 feet or more (4). The maximum thickness of the formation in the northern part of the area is less than 100 feet but to the southward increases to over 300 feet near the Ohio River.

The Mansfield is a brown, red, purple, buff, tan, or white sandstone at the outcrop with occasional local conglomeratic, shale, and coal phases. The color depends on the amount and nature of the iron oxide present and changes from section to section, although differences in surface color in individual sections are ordinarily slight.

The sandstone is usually massive, but thin-bedded phases are present. Cross-bedding is a characteristic feature of the Mansfield sandstone. The sandstone is medium-grained, the majority of the grains ranging from .15 mm. to .6 mm. with sub-angular to sub-rounded shape. Modification of the quartz grains by secondary growth is quite evident. The chief cementing materials are silica and iron oxide, although rarely calcium carbonate and pyrite cements were noted. Despite the secondary growth on quartz grains, the friability is determined largely by the amount of iron oxide cement. In most cases the sandstone is easily crushed.

Field and Laboratory Procedure

A sample of the fresh rock was taken every five feet vertically in each section. All samples were crushed and coned and quartered until a portion weighing about 25 grams was obtained. This portion, from which the excess iron oxide was removed with warm dilute hydrochloric acid, was used in the heavy mineral separation. All samples were washed by decantation to remove the fine material.

The heavy liquid employed in the separation was tetrabromoethane (Sp. gr. 2.9), a modification of the procedure described by Milner (5) being used. The heavy liquid was washed from the grains with naphtha and recovered by evaporating the naphtha.

The actual study of the heavy fractions was made with a binocular microscope. Several samples were studied in great detail and the minerals identified by the oil immersion method with a petrographic microscope. Whenever a new mineral or a new form of a previously

known mineral appeared, a petrographic microscope was used for positive identification. Approximately 400 grains of the entire fraction of each sample were counted and the percentages of each mineral computed from this count. The light fractions were cursorily examined under a binocular and petrographic microscope to determine the minerals and the amount and variety of feldspar.

Minerals of the Mansfield Sandstone

Light Minerals.—The light minerals (Sp. gr. less than 2.9) in the Mansfield are quartz, feldspar, and chert.

Quartz.—The quartz grains generally compose 95% or more of the sandstone and range in size from .05 mm. to .6 mm. The larger grains are frequently well rounded and frosted, but the smaller grains are more angular and clear. Secondary growth has taken place to some extent on most of the grains, with the later quartz in optical continuity with the original grain. Almost all quartz grains carry inclusions of rutile, gas bubbles, or unidentified particles.

Feldspar.—Feldspar grains do not exceed 2% in the samples studied. In the order of abundance the varieties are orthoclase, microcline, and probably albite (Ab^b), for a few grains have fine plagioclase twinning striations with indices equal to or below 1.540. Most grains are cloudy and anhedral, but some grains are clear or have clear borders and are subhedral. It is not known whether the clear borders indicate authigenic growth.

Chert.—Usually the percentage of chert is less than two, although some conglomeratic phases consist quite largely of reworked chert from the St. Louis limestone.

Heavy Minerals.—The heavy minerals make up a minor portion of the sand, less than 1% by weight. The following minerals with a specific gravity of more than 2.9 were identified; biotite, brookite, chlorite, garnet, hornblende, ilmenite, leucoxene, magnetite, muscovite, pyrite, rutile, tourmaline and zircon.

Biotite.—The biotite grains are cleavage flakes which have been battered and bent. All grains have been bleached to some extent and occasionally approach muscovite in color.

Brookite.—Brookite was identified by its optical properties: indices of refraction much greater than 2.06, birefringence very high, and positive biaxial interference figure with very strong dispersion. It occurs as tabular and prismatic grains, brown to yellow in color and usually cloudy in transmitted light. The average size of the grains is .05 mm.

Small well-developed crystals are sometimes found projecting from leucoxene grains which resemble the material identified as brookite in form, color, and often in size. These crystals were probably developed *in situ*, as evidenced by their sharp edges and the soft nature of the leucoxene matrix. The action of moving water would soon tear the crystals loose from such soft material.

McCartney (6) describes a similar occurrence in the Chester sands

of Indiana and also concludes that they were developed *in situ*. The small crystals were identified by McCartney as brookite, but Tyler and Marsden (7), in an X-ray study of leucoxene, worked over McCartney's slides and could not identify brookite.

Chlorite.—Thin books and flakes of chlorite with smooth white edges range in color from deep bright green to light silver green. Biotite is usually present in those samples containing chlorite.

Garnet.—A light pink variety of garnet is most common, but dark, almost opaque varieties, and light cinnamon colored grains were seen. The light colored grains often show a rectangular patterning and are not worn. The dark brown grains are sub-angular. Grains vary in size from .1 mm. to .4 mm.

Hornblende.—Dark green cleavage flakes of hornblende are present. All grains observed were fresh in appearance.

Ilmenite.—Ilmenite occurs as sub-angular to rounded grains which have a sub-metallic luster. Very rarely ilmenite was found altering to leucoxene. It is recognized that other opaque minerals may have been confused with ilmenite.

Leucoxene.—Leucoxene grains are smooth and polished, white to buff or even brown, and also earthy, porous, and sometimes pitted. Micro-crystalline material, almost opaque under the petrographic microscope, was identified as leucoxene and may be an early stage in the alteration of this mineral to rutile or brookite. Grains of this description were fused with borax and the purple titanium bead obtained. Brown (8) has also reported leucoxene of this same general description. The description of Tyler and Marsden is typical of the material in the Mansfield.

Magnetite.—The octohedral habit is the most common form, but occasional grains are nearly spherical. The crystal forms and magnetism serve to distinguish magnetite from ilmenite. The grains average .1 mm. in diameter.

Muscovite.—Clear ragged flakes of muscovite are most abundant. Aggregates of very fine material occur, and, in samples rich in mica, small books of clear muscovite with smooth white edges are numerous. The white edges seem to be the result of bumping and grinding between coarser material.

Pyrite.—Pyrite occurs in the form of aggregates and clusters with some poorly developed cubes of pyritohedrons. The crystal forms and the cementing nature indicate that the pyrite is secondary.

Rutile.—Rutile grains are straw yellow to fox-red and silver gray to black. The dark grains have a strong, satiny, metallic luster showing a deep, rich, ruby red color in transmitted light. The light colored grains are rounded whereas the dark grains are sub-angular. Lath-shaped and knee-shaped grains were found occasionally.

Tourmaline.—The dominant color of the tourmaline is brown with green, blue, grey, and colorless grains much less common. The shades of brown vary from almost colorless to nearly black. Light green and blue grains are more abundant than the dark shades. The black and

deep brown grains are at times spherical, pitted, and frosted. The common shapes are long prismatic grains with fractured ends, biscuit-shaped fragments, and irregular grains. Grain sizes range from .06 mm. to .4 mm. averaging .15 mm. Some tourmaline grains contain unidentified inclusions.

Zircon.—A pink variety is the most abundant, but purple, pale yellow, and colorless grains also appear. A complete gradation from purple to colorless is found. Spherical grains and prismatic forms with rounded terminations prevail, but prismatic grains with slightly worn or fresh pyramidal faces occur in every sample. The yellow and purple varieties are spherical and frequently frosted. Grains vary in size from .04 mm. to .2 mm. but the average is .1 mm. The larger sub-hedral grains often carry inclusions of crystals and other material.

Mechanical Analysis of the Mansfield Sandstone

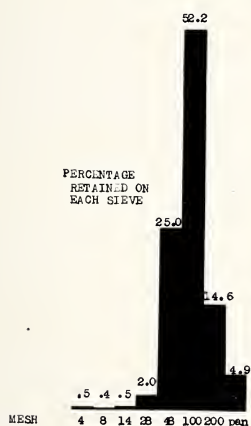


Fig. 2.

In addition to the heavy mineral studies, the writer also made mechanical analyses of 222 samples to determine the size distribution of the sands. The accompanying histogram (Fig. 2) is made from the average figures of all samples. All tests were made on a Tyler Ro-Tap testing machine. The effective size is .100, and the uniformity coefficient is 2.66. The majority of the individual analyses show good sorting, and their cumulative curves are similar to those of the St. Peter made by Dake (9).

Discussion of the Heavy Mineral Suite

The dominant allothogenic minerals of the 239 samples studied are leucoxene and zircon, with ilmenite, tourmaline, rutile, muscovite, and brookite, common but less abundant. Biotite, chlorite, garnet, hornblende, magnetite, and pyrite occur sporadically.

Heavy Mineral Percentages

Persistent Minerals	Sporadic Minerals
Leucoxene40-70%	Chlorite
Zircon20-50%	Biotite
Ilmenite 5-20%	Garnet
Tourmaline 5-20%	Hornblende
Rutile 1-10%	Magnetite
Muscovite 1-10%	Pyrite
Brookite 1-10%	

A change in the percentage of leucoxene results in a change in the percentage of zircon, but there is no change in the percentage of the other minerals. Ilmenite is more or less abundant than tourmaline in a particular section, but the relative percentages for each locality do not

vary greatly. Rutile grains constitute about 5% of the heavy fraction in the majority of samples, and the lighter colored varieties are more numerous. Muscovite is usually low except in shale samples. Brookite may disappear almost completely from any one sample or series of samples but is present in all sections.

The sporadic minerals may be present in all samples, but the amount is so slight that they could easily be missed in the grain counts. Chlorite and biotite are usually associated with each other. Garnet grains were seen in very small numbers and in many samples were not observed. The pyrite is probably secondary in all cases.

The heavy mineral species of the Mansfield are uniform in their occurrence and distribution. The suite is always the same regardless of regional location or stratigraphic position. The percentages of individual minerals vary somewhat from sample to sample, but the relative magnitude for each mineral is constant.

The suite is not characterized in any way by mineral content, peculiarities, or percentages which would permit the differentiation of the Mansfield into units within itself or distinguish it definitely from some other sandstones. Evidence for this statement is presented below in the discussion of the source of the sediments. It would be unwise to use the heavy minerals for placing the Mansfield in well logs. Perhaps with information about the formations above and below the Mansfield, such as heavy minerals, insoluble residues, lithologic characters, and paleontological evidence, the data presented in this paper might be of some value for that purpose. The heavy mineral suite alone, however, is inadequate evidence for recognizing the presence of the Mansfield in wells or for correlation between wells and outcrops.

Source of the Mansfield Sediments

The dominant heavy minerals are few in number, are all very stable minerals, and may well have had a long previous history as clastic grains. It appears, then, that the immediate source should be sought for in pre-existing sediments.

Schuchert (10) states that at the beginning of the Pennsylvanian, the United States was a lowland surrounded on the south and east by a mountainous borderland. Cumings (11) pictures the Mansfield sea as having its eastern edge near the eastern edge of Indiana. During the interval between the deposition of the Mississippian and Pennsylvanian sediments, Mississippian and older rocks were extensively weathered and the less stable minerals removed. The area covered by the Mansfield sea was underlain by sedimentary rocks, and the land mass to the northeast and east had many sediments exposed. On the advance of the Mansfield sea, the source, then, of most of the detrital material was the old erosion surface, and the greater part of the material had undergone at least two erosion periods. It seems likely that, since the land mass to the northeast and east was adjacent to the Mansfield sea, a greater amount of material would come from this area than from more distant land masses.

The presence of any of the less resistant minerals, for example, the fresh grains of hornblende, may be due to exposure to erosion for

the first time in the Pennsylvanian period of igneous and metamorphic rocks. Russell (12) has shown that minerals, even the less resistant species, may be transported at least 900 miles and show neither wear nor alteration.

It would be difficult to say exactly what pre-existing sediments furnished the Mansfield material. The presence of chert in the sand indicates that the surrounding Mississippian and older limestones were contributors. The distance materials were brought is also a difficult question, but undoubtedly much of it was local, i. e., the area in which the Mansfield now occurs. At Attica, the Mansfield rests on the Borden, and the lower two feet of the Mansfield contains small fragments of the Borden shale. As drainage developed, the later sediments were brought in from more distant places.

The small and constant number of minerals might indicate a very local and protected area of source, but the size of the region studied, the thickness of the formation, and the findings of other writers seem to refute this and support the view that the source area was rather general.

Other writers have reported suites similar to the Mansfield from various formations. Derry (13) reported a similar suite in some Ordovician rocks of Ontario; Thiel (14) and Tyler (15) found a similar group of minerals in the St. Peter sandstone of Wisconsin and Minnesota; McCartney (6) had an almost identical suite from the Chester sands of Indiana; Lucas (16) reported a comparable assemblage in some Pennsylvanian rocks of Oklahoma; Kelly and Beutner (17) found a very small group of minerals, all of which are present in the Mansfield, in some Pennsylvanian sandstones of Michigan which may be time-equivalents of the Mansfield; Cordry (18) found a similar group in Pennsylvanian and older rocks in the Ozark region of Missouri; Brown (8) reported a large amount of leucoxene and other Mansfield minerals in some Permian sands of the Mid-Continent region; and there have been other suites reported in this country and abroad, which, although not quite like the Mansfield suite, yet have a small number and constant number of the more stable minerals most of which are found in the Mansfield.²

These findings show that the heavy minerals of the Mansfield or a similar group are common and evidence that reworked sediments of a general area of some size were the source of the Mansfield detritals. These findings also show that it would be unwise to use the heavy mineral suite alone for identifying the Mansfield as discussed earlier.

McCartney suggested that the Chester sands represented material from igneous rocks with no intermediate period of deposition. The writer questions the lack of intermediate deposition but favors, instead, the idea of a similar origin of the Chester sands as for the Mansfield.

Acknowledgments

The writer is greatly indebted to Dr. W. A. Tarr and Dr. W. D. Keller, of the University of Missouri, for assistance and criticism in the

² See abstracts in Boswell (19).

laboratory and in the preparation of the paper; to Professor E. R. Smith, of DePauw University, for aid in the field and the reading and presenting of this paper; and to Dr. C. A. Malott, of Indiana University, for information and aid in locating sections.

Bibliography

1. Hopkins, T. C., 1895. The Carboniferous sandstones of western Indiana. Indiana Dept. Geol. and Nat. Res., Ann. Rept. 20:188-329.
2. Malott, C. A., Personal communication.
3. Ekblaw, G. E., Personal communication.
4. Malott, C. A., 1930. Geologic structure in the Indian and Trinity Springs locality, Martin County, Indiana. Proc. Indiana Acad. Sci. 40:217-231.
5. Milner, Henry B., 1929. Sedimentary petrography. Thomas Murby, London.
6. McCartney, C. C., 1931. A petrographic study of the Chester sandstones of Indiana. Journ. Sed. Petrology 1:82-90.
7. Tyler, S. A., and Marsden, R. W., 1938. The nature of Leucoxene. Journ. Sed. Petrology 8:55-59.
8. Brown, Levi S., 1928. The occurrence of Leucoxene in some of the Permian Mid-Continent sediments. Amer. Min. 13:233-235.
9. Dake, C. L., 1921. The problem of the St. Peter sandstone. Missouri Univ. School of Mines and Met., Tech. ser., 6:1-225.
10. Schuchert, Charles, and Dunbar, Carl O., 1933. Historical Geology. John Wiley, New York.
11. Cumings, E. R., 1922. Nomenclature and description of the geological formations of Indiana. Handbook of Indiana Geology. Indiana Dept. Cons., Pub. 21:403-570.
12. Russell, R. D., 1937. Mineral composition of Mississippi River sands. Geol. Soc. Amer. Bull. 48:1307-1348.
13. Derry, Duncan R., 1934. Heavy minerals of the Ordovician sediments of Ontario. Journ. Sed. Petrology 4:83-88.
14. Thiel, George A., 1935. Sedimentary and petrographic analysis of the St. Peter sandstone. Geol. Soc. Amer. Bull. 46:559-614.
15. Tyler, Stanley A., 1936. Heavy minerals of the St. Peter sandstone in Wisconsin. Journ. Sed. Petrology 6:55-84.
16. Lucas, Elmer L., 1935. Petrographic character of the Pennsylvanian in the Ardmore Basin. Journ. Sed. Petrology 5:96-105.
17. Kelly, W. A., and Beutner, E. C., 1931. Heavy minerals from some Pennsylvanian sandstones of Michigan. Michigan Acad. Sci., Papers, 14:471-474.
18. Cordry, C. D., 1929. Heavy minerals in the Roubidoux and other sandstones in the Ozark Region, Missouri. Journ. Paleo. 3:59-65.
19. Boswell, P. G. H., 1933. Mineralogy of sedimentary rocks. Thomas Murby, London.