HEAVY MINERALS AS A GUIDE IN STRATIGRAPHIC STUDIES

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ABSTRACT

Heavy minerals are one of the accepted means of stratigraphic correlation and they have served as an invaluable stratigraphic guide in Mid-continent correlations. Proper well sampling and laboratory methods of analysis to correlate both surface and underground formations are explained. Important geological data that may be deduced from these analyses are suggested. The results obtained from the application of these methods to the study of sandstones of Ordovician age in the Mid-continent oil field are discussed.

INTRODUCTION

Several thousand heavy mineral analyses, extending over a period of some years, have been made by the writer, primarily of Ordovician sandstones encountered by wells drilled for petroleum in the Mid-continent field, but also of Ordovician sandstones which out crop in central United States. The results of this work have been of sufficient importance to warrant its continuance.

It seems to the writer that some workers have expected too much of heavy minerals. Is there any one method, if used alone, that is infallible and entirely adequate to correlate one isolated outcrop with another, or the samples encountered by one well with those from another well? Heavy minerals, like fossils, lithology, stratigraphic sequence, evidences of diastrophism and other methods, can be made to serve as a valuable *guide* in stratigraphic studies; the present paper will attempt to suggest a possible explanation for the adverse conclusions in regard to the efficacy of heavy mineral correlations that have been reached by some workers, and to suggest a method that may yield more favorable results.

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Sampling

To obtain usable correlations from heavy mineral analyses, let it be assumed that several wells are drilled near together in a sedimentary basin, through a complete normal succession of beds in a given formation, and that an additional series of wells, cutting the same beds, is drilled from the center toward the margin of the basin. Samples should be taken at five foot intervals in all the wells, records kept of the lithology of all strata penetrated, and analyses made of each sandstone sample. At the margin of the basin, samples should likewise be collected at five foot intervals across the outcrop of the same succession of beds, preferably at several different localities, and analyses made of the outcropping sandstones.

Analyses

In making the analyses, it has been found advisable to take cognizance of several factors such as position within the formation and the lithology of the bulk sample, component heavy minerals, percentage in which each is present, size, assortment, and shape of the mineral grains. Besides giving the location and depth (stratigraphic position) of a sample, a typical analysis might read as follows: "sandstone, little green shale; zircon 45 per cent, tourmaline 40 per cent, barite 5 per cent, rutile 5 per cent, garnet 3 per cent, anatase 2 per cent. Grains irregular in size. Large, well rounded. Small, angular to subangular. Tourmaline larger than zircon. Barite secondary." Such analyses, made of the well and outcrop samples described above, should be tabulated with the stratigraphically highest analysis at the top of the table.

Facts Deduced From Analyses

Tables of heavy mineral analyses permit correlation and interpretation of geologic conditions of sedimentation such as is listed below:

1. The complete lithologic sequence, in descending order, is for example: dolomite; sandy dolomite; coarse sandstone; dolomite; irregular-grained, round and frosted sandstone; fine, even-grained, subangular, less frosted sandstone; green and maroon shale; sandy green shale; coarse sandstone; dolomite.

2. The first bed of an objective group encountered at one locality is not necessarily the bed at the top of the sequence in another locality, or some of the beds lower in the sequence may be absent

locally. Such conditions suggest unconformities and periods of uplift.

3. If, when uplift or erosion has interrupted the normal stratigraphic relationship of the beds at two different localities, only a few analyses were made at each locality, the analyses might be very dissimilar and lead to the conclusion that the analyses were of different formations. If, however, many samples were taken at five foot intervals and analyzed as described above, the membership of the two beds in the same formation and their relationship to each other would be entirely clear.

4. The same component minerals occur over and over again in beds of different age; perhaps no bed has an unusual and diagnostic mineral or suite of minerals.

5. The heavy mineral grains in one sandstone are irregular in size and shape; in another sandstone the same minerals are very uniform in size and shape; the two sandstones can, therefore, be distinguished one from another in spite of the community of their component minerals.

6. The first sandy dolomite in the group is characterized by analyses which are similar wherever this member is present.

7. The analyses of this sandy dolomite differ from those of the underlying pure sandstone member.

8. The analyses of the first pure sandstone member fall into a distinct type, as do those of the other sandstones in the succession, and each has some diagnostic difference from the other.

9. A certain lithologic type of sandstone within the group may always yield similar analyses, in these cases, a relationship between the lithology of a sandstone and its heavy mineral content can be established.

Summary

The writer admits that the same minerals may be present in each standstone analyzed, that the relative percentages are as variable within any single formation as they are throughout the entire group of formations, that those minerals which seem to be present in a single formation occur too infrequently to be conclusively diagnostic, that entirely different heavy minerals may occur in the same formation in different parts of a given area, and wishes to emphasize the fact that a few analyses made of haphazard samples from widely separated outcrops would be of little or no value for correlative purposes.

The writer does not agree, for example with the statements that it is impossible to discriminate between the Lamotte, Roubidoux, Jefferson City, Cotter, St. Peter and Pennsylvanian sandstones by means of heavy mineral analyses,[1,2] nor with the statement that heavy mineral analyses are valueless for long range correlations.[3]

Heavy Minerals in the Mid-Continent Region

Experience in the Mid-continent region has shown that the analyses of Ordovician, Mississippian and Pennsylvanian sandstones, each have distinctive group characteristics. It is, therefore, entirely possible to determine that even an isolated analysis is of an Ordovician, or Mississippian, or Pennsylvanian sandstone; it is, also, not difficult to recognize that an analysis has been made from a sandstone derived from an older, analyzed bed.

The most notable fact that has been observed from extensive sets of heavy mineral analyses made of Mid-continent sandstones, laid down in one depositional province, is that the heavy mineral zones, even within a single sandstone, are very thin (measured in tens of feet) in a vertical direction, and remarkably persistent horizontally for miles.

Ordovician Sandstones

Many analyses of buried Ordovician sandstones in the Mid-continent oil fields and of outcropping Ordovician sandstones in the Arbuckle Mountains of northeastern Oklahoma, the Ozark region in Arkansas and Missouri, and along the Mississippi and tributary rivers in Illinois, Wisconsin, Iowa and Minnesota have made the following observations possible:

1. Exact well-to-well correlations within a given oil field.
2. Formation correlations from oil-field to oil-field.
3. Correlations from the wells drilled for oil to outcrops in the Arbuckle mountains and in northeastern Oklahoma.
4. Correlations from the outcrops in northeastern Oklahoma to those in Arkansas, Missouri and the Mississippi River valley including the type St. Peter sandstone in Minnesota.

[1] Cordry, Cletus D., Heavy minerals in the Roubidoux and other sandstones of the Ozark region, Missouri: *Journal of Paleontology*, Vol. **3** (1929), No. 1, p. 82.

[2] Grawe, Oliver R. and Cullison, James S., A study of sandstone members of the Jefferson City and Cotter formations at Rolla, Missouri: *Journ. Geol.*, Vol. **XXXIX,** No. 4, May-June, 1931, p. 323.

[3] Twenhofel, W. H., Personal communication.

5. Establishment of overlaps, disconformities and erosional periods.

6. Determination of the character of the source rock, direction from which the sediments were derived, methods of transportation, and the conditions and environment of deposition.

Conclusion

In conclusion, the writer calls attention to the fact that the same component heavy mineral grains may be common to sandstones of different age, that the relative percentages of these minerals may vary as much within a given formation as between different formations, but believes that if enough samples are properly taken and analyzed, the community of mineral grains does not preclude the use of heavy minerals as a guide in stratigraphic correlations, and has proved the value of this type of analysis by work in the Mid-continent region.

EXAMPLES

Sample 1

Heavy minerals from a sandy limestone bed near the middle of the Tulip Creek formation of Ordovician age, cropping out in section 21, T 2 S, R 1 E, Arbuckle Mountains, Oklahoma.

Analysis:	Zircon	65 per cent
	Tourmaline	13 " "
	Rutile	7 " "
	Garnet	5 " "
	Hornblende	1 " "
	Anatase	6 " "
	Unknown "*X*"	3 " "

Grams are irregular in size and shape.

Sample 2 (Fig. 1)

Heavy minerals from a sandstone at the base of the Tulip Creek formation of Ordovician age cropping out in section 21, T 2 S, R 1 E, Arbuckle Mountains, Oklahoma

Analysis:	Zircon	25 per cent
	Tourmaline	75 " "
	Rutile	present
	Garnet	present
	Topaz	present
	Epidote	present
	Anatase	present
	Unknown "*X*"	present

Grains are large, uniform in size, and well rounded.

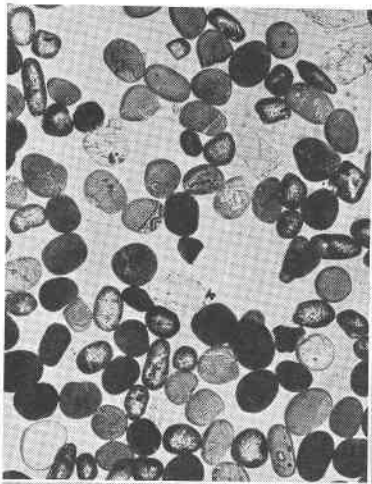

FIG. 1

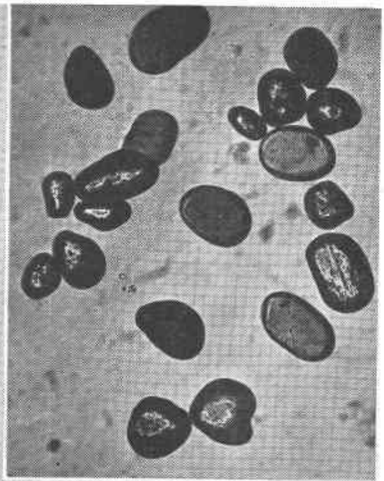

FIG. 2

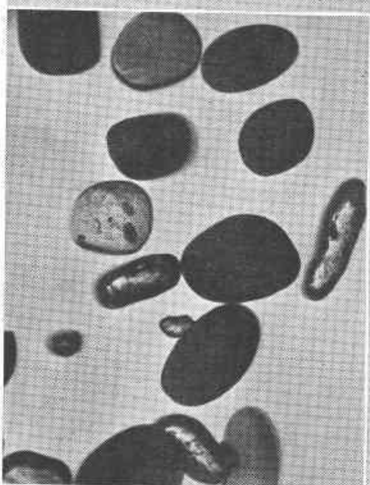

FIG. 3

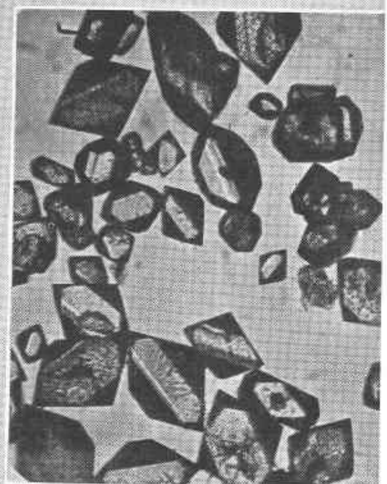

FIG. 4

SAMPLE 3

Heavy minerals from Ordovician sandstone between 3490 and 3508 feet, encountered by Sinclair Oil and Gas Company's Gardner No. 1, section 6, T 4 N, R 6 E, Oklahoma (about 40 miles northeast of Sample 2).

Analysis:	Zircon	17 per cent
	Tourmaline	80 " "
	Garnet	1 " "
	Rutile	1 " "
	Fluorite	1 " "

Grains large, even in size, and well rounded.

SAMPLE 4

Heavy minerals from Ordovician sandstone between 4350 and 4360 feet, encountered by Gypsy Oil Company's Barkus No. 9, section 6, T 8 N, R 6 E, Greater Seminole area, Oklahoma (24 miles north of Sample 3).

Analysis:	Zircon	45 per cent
	Tourmaline	51 " "
	Barite	4 " "
	Rutile	present

Grains large, even in size, and well rounded.

SAMPLE 5 (Fig. 2)

Heavy minerals from outcrop of Ordovician Burgen sandstone in section 11, T 20 N, R 24 E, northeastern Oklahoma (about 100 miles northeast of Sample 4).

Analysis:	Zircon	27 per cent
	Tourmaline	68 " "
	Anatase	4 " "
	Rutile	1 " "

Grains large, even in size, and well rounded.

SAMPLE 6

Heavy minerals from a sample collected 3 feet above the base of the Ordovician St. Peter sandstone outcrop at Pilot Knob, Izard County, Arkansas.

Analysis:	Zircon	26 per cent
	Tourmaline	71 " "
	Anatase	3 " "

Grains large, even in size and well rounded.

SAMPLE 7

Heavy minerals from the Ordovician St. Peter-Joachim contact zone at outcrop on highway 69, 2 miles southeast of Mount Pleasant, Arkansas.

Analysis:	Zircon	56 per cent
	Tourmaline	41 " "
	Rutile	1 " "
	Anatase	1 " "
	Unknown "X"	1 " "

Grains mostly very small, subangular. Some larger and better rounded.

SAMPLE 8 (Fig. 3)

Heavy minerals from a bed in the middle of the lower half of the Ordovician St. Peter sandstone outcrop in south half of section 12, T 30 N, R 12 E, Cape Girardeau County, Missouri.

Analysis:	Zircon	24 per cent
	Tourmaline	73 " "
	Hornblende	2 " "
	Anatase	1 " "

Grains large, even, well rounded.

SAMPLE 9

Heavy minerals from near the middle of the Ordovician St. Peter sandstone encountered by a water well drilled at Bowling, Green, Pike County, Missouri.

Analysis:	Zircon	34 per cent
	Tourmaline	63 " "
	Spinel	2 " "
	Anatase	1 " "

Grains mostly large, even, well rounded. Some zircons smaller, subangular.

SAMPLE 10

Heavy minerals from a bed 4 feet above the Mississippi River and 30 feet below the top of the Ordovician St. Peter sandstone outcrop of the University of Minnesota campus, Minneapolis, Minnesota.

Analysis:	Zircon	39 per cent
	Tourmaline	46 " "
	Ilmenite (?)	10 " "
	Staurolite	4 " "
	Garnet	1 " "

Grains large, fairly even, quite well rounded.

SAMPLE 11 (Fig. 4)

Heavy minerals from basal Kinderhookian sand encountered between 3465 and 3472 feet by Tatlock Oil Company's Goldner No. 1, section 6, T 29 S, R 2 E., Kansas.

Analysis:	Zircon	100 per cent

Perfect euhedral crystals.