References and Notes

1. J. M. Hunt, Geochemical data on organic matter in sediments, *Proc. Intern. Scientific Oil Conference*, October 8–13, 1962, Budapest; P. H. Abelson, Organic geochemistry and the formation of petroleum, *World Petroleum Cong. 1963*, Section 1, paper 41; P. H. Abelson and T. C. Hoering, Abstracts for the meeting of the Geochem. Soc., New York, November 17–20, 1963; J. D. Mulik and J. G. Erdman, *Science* **141**, 806 (1963); R. Robinson, *Nature* **199**, no. 4889, 113 (1963).
2. J. E. Cooper and E. E. Bray, A postulated role of fatty acids in the formation of petroleum, Am. Chem. Soc. Spring Meeting, 1963, Los Angeles; J. A. Bedov, S. D. Pustilnikova, L. V. Ratnikova, Al A. Petrov, *Neftekhimija* **2**, 213 (1962); J. G. Erdman, *Geochim. Cosmochim. Acta* **22**, 16–36 (1961).
3. N. P. Stevens, E. E. Bray, E. D. Evans, *Bull. Am. Assoc. Petrol. Geolog.* **40**, 975 (1956).
4. B. S. Greensfelder, H. H. Voge and G. M. Good, *Ind. Eng. Chem.* **41**, 2573 (1949).
5. A. Kossiakoff and F. O. Rice, *J. Am. Chem. Soc.* **65**, 590 (1943).

6. We are indebted to Professor Dr. G. C. A. Schuit of Eindhoven Technological University for valuable discussions.

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Garnet Ratios and Provenance in The Glacial Drift of Western New York

Abstract. *The ratio of purple to red garnet identifies drift provenance. Low ratios indicate glacier flow from the central Adirondacks. Ratios of 1.4 or greater indicate flow from Canada, by way of the St. Lawrence lowland. The heavy mineral assemblages were evidently undiluted by local sources in western New York.*

The heavy minerals in tills of Ontario and adjacent areas have been studied (*1*). The results indicate that heavy minerals give evidence of the source of the glaciers that deposited the tills. Dreimanis and Terasmae (*2*), Dreimanis (*3*), and Connally (*4*) extended this work in Ontario and into western New York State. I published a complete list of heavy minerals in the drift of western New York in 1960. More recently Sitler (*5*) published a similar list for northwestern Pennsylvania and northeastern Ohio. However, Connally (*6*) has subsequently found garnet more useful than other heavy minerals for distinguishing drift units.

During 1960 and 1961, in conjunction with mapping the glacial geology of the western Finger Lakes region (*7*), I collected samples of both stratified drift and till in western New York from the Olean, Almond, and Valley Heads drift (Fig. 1). Samples were disaggregated and sieved. Heavy mineral grains in the size range between 0.062 and 0.350 mm were separated by use of bromoform, according to the standard procedure of Krumbein and Pettijohn (*8*). The heavy minerals were mounted in Canada balsam, and the grains were counted with a petrographic microscope.

The two categories with which this report is concerned are red garnet and purple garnet. "Purple garnet" includes both purple and colorless garnet, whereas "red garnet" includes both red and pink varieties. A ratio of purple garnet to red garnet (purple/red) was established for each locality sampled, according to the procedure of Dreimanis *et al.* (*1*). These ratios are illustrated in Fig. 1, and their distribution permits the map to be divided into two areas. North of the Almond moraine in the west, and north of the Valley Heads moraine in the east where the Valley Heads glacier evidently overrode the Almond deposits, purple garnet is clearly dominant. The ratios are almost all 1.4 or greater. The drift of this area is termed purple-garnet drift.

South of the Almond or Valley Heads moraine, all but three of the ratios are 1.2 or less. This is the area of Olean drift, termed mixed-garnet drift in this report. Four exceptions (underlined) are north of the Almond-Valley Heads border. These were identified as Olean drift in the field, and are so grouped for statistical analysis.

As a check on the observed data, the 90 percent confidence interval was calculated for the mixed-garnet and purple-garnet population means. The confidence coefficient indicates the degree of belief that the interval contains the population mean. The confidence interval for mixed-garnet drift is between 0.93 and 1.41 and was calculated from 15 samples. The confidence interval for purple-garnet drift is between 1.44 and 1.66 and was calculated from 37 samples. The lack of overlap between these confidence intervals suggests that there is a real difference between these garnet populations and therefore a difference in provenance for the two drift units.

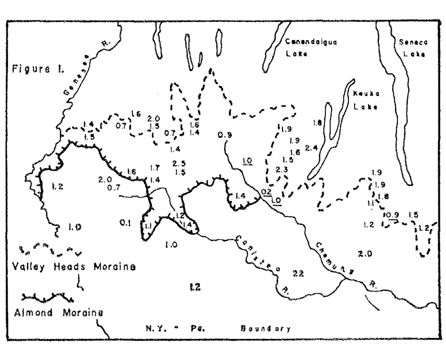

Fig. 1. Garnet ratios (purple/red) in the drift of the western Finger Lakes region, New York.

Dreimanis (*3*) demonstrated two possible source areas for purple-garnet drift and three for mixed-garnet drift. Connally (*6*) has shown that the purple-garnet drift probably had its source north of Montreal while the mixed-garnet drift probably originated in the north and central Adirondacks.

Dreimanis (*3*) suggested probable flow lines for purple-garnet and mixed-garnet drift in Ontario and New York. These flow lines are supported by the present study, as well as by topographic evidence described elsewhere (*6, 9*) and a study by Moss and Ritter (*10*). Ice depositing purple-garnet drift flowed into the Lake Ontario depression from the St. Lawrence lowland and was then diverted southward. Thus the glacier traversed the Paleozoic beds of western New York, perpendicular to their strike. In the area of mixed-garnet drift the glacier is presumed to have traveled southwest, subparallel to the regional strike of the Devonian strata.

Two of the three exceptional ratios in the mixed-garnet drift area are located in the southeast corner of Fig. 1. These localities show a dominance of purple garnet. Dreimanis's (*3*) report of similar ratios in samples from this area suggests to me flow from the southern Adirondacks for the eastern deposits of Olean drift. The third exception is located in the western part of the map. It is unexplainable at present and is treated as a random variation.

The question naturally arises whether the observed heavy mineral assemblages show significant dilution by sources in the Paleozoic sedimentary rocks. The major sources for sand-sized grains are the Silurian Grimsby sandstone adjacent to Lake Ontario and the Middle and Upper Devonian clastic strata of the northern Appalachian Plateau. Hoyt (*11*) reported that the dominant non-opaque heavy minerals in the Grimsby are tourmaline and zircon. Manley (*12*) reported similar results for the clastics of the Devonian sequence in central New York. Thus, if the garnet assemblages were enriched, tourmaline and zircon would have been added in even greater abundance. Tourmaline and zircon are only trace minerals (*4*) in both mixed- and purple-garnet assemblages; therefore I believe that dilution was insignificant.

During deposition of Olean drift,

glacier flow was southwestward into western New York from the Adirondacks. The glacier carried an undiluted heavy mineral assemblage containing red garnets as well as purple garnets. In contrast, garnet ratios in the younger, Almond and Valley Heads drift suggest glacier flow from north of Montreal, southwestward into the Lake Ontario depression and thence southward into western New York, carrying an undiluted heavy mineral assemblage that contains little red garnet.

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References and Notes

1. A. Dreimanis, G. H. Reavely, R. J. B. Cook, K. S. Knox, F. J. Moretti, *J. Sediment. Petrol.* **27**, 148 (1957).
2. A. Dreimanis and J. Terasmae, *Proc. Geol. Assoc. Can.* **10**, 119 (1958).
3. A. Dreimanis, *Intern. Geol. Congress*, 21st Session Rpts. (1960), part IV, p. 108.
4. G. G. Connally, *Proc. Rochester Acad. Sci.* **10**, 241 (1960).
5. R. F. Sitler, *J. Sediment. Petrol.* **33**, 365 (1963).
6. G. G. Connally, Thesis, Michigan State Univ. (1964).
7. The field work was supported by two grants from the New York State Museum and Science Service.
8. W. Krumbein and F. J. Pettijohn, *Manual of Sedimentary Petrology* (Appleton-Century, New York, 1938), pp. 238–61.
9. Glacial Map of the United States east of the Rocky Mountains (Geol. Soc. Am., 1959).
10. J. Moss and D. Ritter, *Am. J. Sci.* **260**, 81 (1962).
11. V. Hoyt, Thesis, Univ. of Rochester (1943).
12. F. H. Manley, Thesis, Univ. of Rochester (1959).
13. I thank Ernest Muller and Aleksis Dreimanis for critical reading of this report.

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Clinoptilolite: A New Occurrence in North Carolina Phosphorite

Abstract. *The zeolite, clinoptilolite, has been identified in a Miocene phosphorite deposit in North Carolina. It occurs in great abundance in the clay fraction of the phosphorite both as well-formed, separate crystals and as clusters of crystals attached to granular particles.*

Zeolites are found in many localities as alteration products of pyroclastic rocks and volcanic glass. Here we describe a unique occurrence of the zeolite mineral clinoptilolite in the clay fraction of an extensive phosphorite deposit in Atlantic coastal plain sediments.

The zeolite was discovered in a representative drill core furnished by the Texas Gulf Sulphur Company, from Beaufort County, North Carolina. The stratigraphic section at this point includes (from youngest to oldest): post-Miocene unconsolidated quartz sands and clays; Upper Miocene Yorktown formation composed of marl (that is, calcareous clay) and clayey silts; Middle(?) Miocene phosphorite which overlies, unconformably, Middle Eocene Castle Hayne limestone. The phosphorite consists of pellets of brown, fine sand-size collophane and phosphatic shell, bone, and tooth fragments mixed with abundant angular quartz sand and clay. The phosphate mineral is isotropic, but x-ray and chemical data identify it as a fluorapatite. Many of the pellets contain included material such as quartz fossil debris, organic matter and glauconite.

Indications of the zeolite were first observed during x-ray diffraction analysis of clay from the phosphorite zone. Subsequent microscopic examination of the clay mixture revealed numerous, transparent, blade-like crystals with an average length of about 10 μ (Fig. 1). The crystals have perfect cleavage in one direction and exhibit interference colors of extremely low order. The indices of refraction are $n_\alpha = 1.483$ and $n_\gamma = 1.488$ (Na D), which lie within the range for clinoptilolite.

The interplanar spacings (Table 1) also agree with those of clinoptilolite, but another zeolite, heulandite, gives a similar x-ray pattern. Following the method of Mumpton (*1*), we heated a sample overnight at 450°C. This treatment causes the heulandite pattern to disappear, while the clinoptilolite pattern is unaffected. Although a decrease in peak intensity could be noted, the North Carolina material was essentially unchanged after heating.

Further microscopic study of a concentrate of the zeolite showed that it is present both in isolated crystals and in clusters of crystals attached to granular particles. These particles are green, appear slightly anisotropic, and have *n* (Na D) approximately equal to 1.53. They contain no obvious minerals or structures, such as shards, although some opaque inclusions are present. The grains apparently form nuclei for the growth of the crystals. The relationship suggests that the zeolite has been derived by alteration of these grains. It may be significant that clinoptilolite (a zeolite of low calcium content) has formed rather than the more calcic heulandite. This association of zeolite and granular matter is like that described by Bonatti (*2*) in recent Pacific pelagic sediments, where palagonite (devitrified basic glass) is altering to the zeolite, phillipsite.

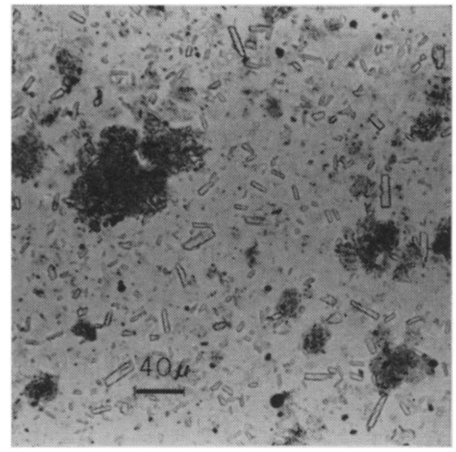

Fig. 1. Photomicrograph of zeolite crystals.

Table 1. X-ray diffraction data for clinoptilolite from North Carolina and Hector, California. (Ni-filtered CuK$_\alpha$ radiation.)

North Carolina (oriented sample)		Hector, California (data from Mumpton, *1*)	
d(Å)	I/I$_0$	d(Å)	I/I$_0$
8.98	10	9.00	10
7.91	7	7.94	4
5.90	1	5.91	1
5.24	1	5.24	3
4.48	1	4.48	2
3.96	10	3.96	10
3.90	4	3.90	8
3.75	1	3.73	1
3.45	1	3.46	2
3.12	1	3.12	3
2.97	2	2.97	5
2.79	3	2.82	3
2.70	1	2.72	1
2.69	1	2.68	1

The top of the phosphorite lies 30 m below the surface and the zone is 20 m thick. Large quantities of clinoptilolite exist uniformly throughout the phosphorite, but none is found in the sediments above or below this zone. Information is lacking as yet on the lateral distribution of the mineral.

The unusually high fluorine content of marine phosphorite has been commented upon by many authors. A number of explanations have been given for this excess fluorine, but none has been definitely established. It is worthy of consideration that volcanic detritus may be a partial source of fluorine in the North Carolina phosphorite.

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References and Notes

1. F. A. Mumpton, *Am. Mineralogist* **45**, 351 (1960).
2. E. Bonatti, *Trans. N.Y. Acad. Sci.* **25**, 938 (1963).
3. This work was supported by a grant from the Texas Gulf Sulphur Co. We thank Leo J. Miller and N. Güven for assistance.

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