

NOTES

CHLORITE AND MICA AS INDICATORS OF PROVENANCE

Key Words—Argillite, Chlorite, Mica, Provenance, Sedimentation, Weathering.

During the late Devonian, erosion of the Acadian Highlands in New England provided great quantities of debris from which was formed a vast, westwardly prograding apron of alluvial plain sediments (Barrell, 1913, 1914a, 1914b; Chadwick, 1944). The clay mineralogy of samples collected from a portion of these continental beds, the Upper Devonian Walton Formation, yielded information on the petrology of the corresponding source rocks (Liebling and Scherp, 1976). The sampled section, previously described by Allen and Friend (1968), is exposed at the South Fallsburg exit off N.Y. Route 17. Here, the rocks accumulated essentially contemporaneously under oxbow-lake, slip-off slope, and overbank-floodplain conditions (Allen and Friend, 1968). A comparison of the clay mineralogy of the oxidized slip-off slope deposits with that of the unoxidized overbank-floodplain and stagnant oxbow-lake deposits demonstrated that iron-rich chlorite is preferentially destroyed by hydrolysis and oxidation under the more intense leaching conditions of the slip-off slope (Liebling and Scherp, 1976). The oxbow-lake and overbank-floodplain deposits were considered to contain relatively unchanged clay minerals more closely representative of those in the source area. These less altered deposits were characterized by distinct ranges of chlorite:mica ratios and chlorite compositions. In the present investigation, these ratios and compositions were compared with those of the chlorite-bearing pelitic rocks now nearest in exposure to the east—a thick section of largely Ordovician argillites underlying the Hudson River Valley in the New Paltz-Poughkeepsie area (Figure 1).

SAMPLE ANALYSIS

Sixty-five samples of shale, slate, and phyllite were collected from exposures of the Late Ordovician Snake Hill Formation along Routes N. Y. 299 and N. Y. 55 (Figure 1). Slurries of each sample were pipetted onto glass slides and allowed to air dry. Since chlorite and mica do not have significantly different settling rates, their relative proportions are not substantially affected by this pipetting procedure (Gibbs, 1965). The samples were then analyzed by X-ray powder diffraction techniques using a Philips diffractometer, Ni-filtered $\text{CuK}\alpha$ radiation, and a monochromator to minimize the masking effects of iron fluorescence.

Clay mineral determinations were based on diffraction-peak behavior as observed after employing each of four separate techniques: air-drying without further treatment; heating for 1 hr at 550°C; ethylene glycol vapor saturation for 1 hr at 60°C; and contact with dilute HCl for 24 hr at 80°C (Brindley, 1961; Carroll, 1970). Chlorite and mica were identified in all samples; no other clay minerals were observed. The identification of chlorite was based on the presence of well-defined 00 l reflections conforming to a 14-Å periodicity. These peaks were unaffected by the ethylene glycol treatment; heating at 550°C reduced or destroyed all peaks except for the 001 reflection, which became more intense. After HCl treatment, chlorite was destroyed. Well-defined basal reflections based on a 10-Å periodicity showed the presence of mica. Distinct 002 reflections, about half as intense as the first-order reflections, identified the mica as aluminous illite or muscovite (Grim, 1968, p. 142).

Relative proportions of Mg^{2+} , $\text{Fe}^{2+,3+}$, and Al^{3+} in the chlorite were determined from basal reflections according to meth-

ods described by Brindley and Gillery (1956). These determinations are semiquantitative because of random cation substitutions and imperfections in the orientation of chlorite flakes. In terms of atoms per unit formula, Al^{3+} equalled approximately 1.0; Mg^{2+} and $\text{Fe}^{2+,3+}$ displayed considerable variation (Figure 2a).

Relative proportions of chlorite to mica were based on the relative peak intensities of the 003 chlorite and 001 mica reflections which are also influenced by the relative degree of flake orientation. Odd-order chlorite reflections were used be-

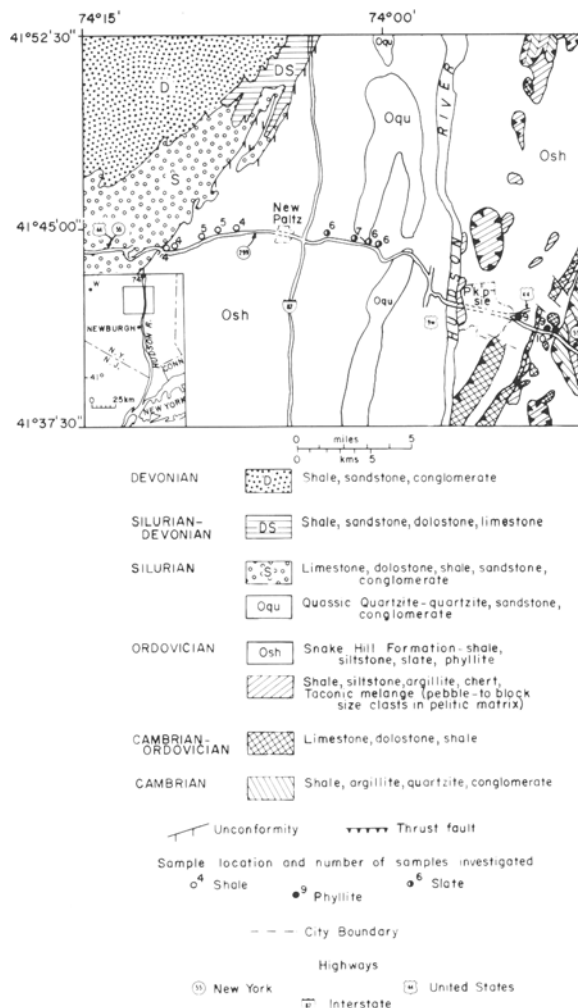


Figure 1. Location map of samples. Inset map shows area sampled (rectangle) and Late Devonian Walton Formation (W) investigated by Liebling and Scherp (1976) and Allen and Friend (1968). Map sources: Fisher *et al.* (1971) and Fisher (1977).

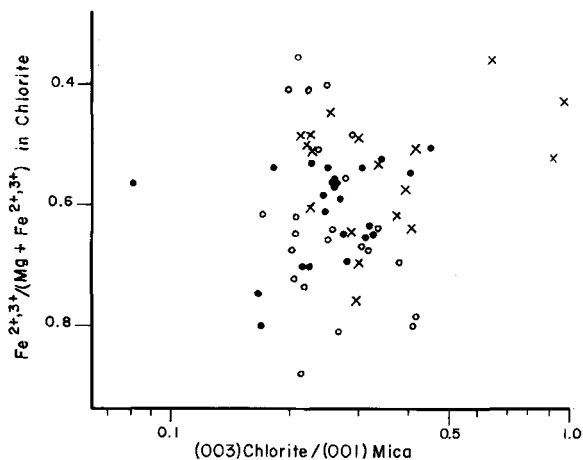


Figure 2a. Distribution of chlorite:mica ratios and relative abundances of iron and magnesium in chlorite for Ordovician shale (open circles), slate (shaded circles), and phyllite (x).

cause they are least responsive to variations in Mg-Fe content. In the authors' earlier work on the Walton Formation (Liebling and Scherp, 1976), the abundance of chlorite was considered to be most accurately reflected by even-order basal spacings. This assumption was based on conclusions reached by Towe and Grim (1963); however, reconsideration of their results and a comparison of the sensitivities to composition displayed by chlorite (00 ℓ) structure amplitudes (Brindley and Gillery, 1956), indicate that odd-order, rather than even-order, chlorite basal reflections are least affected by variations in the Mg:Fe ratio. The Walton Formation chlorite:mica ratios plotted in Figure 2b are recalculated values, based on the preferred 003 chlorite reflection.

Nonclay constituents are quartz and sodic plagioclase.

RESULTS AND DISCUSSION

A comparison of chlorite:mica ratios and chlorite Fe/(Mg + Fe) ranges of the Ordovician Snake Hill argillites (Figure 2a) with those of the unoxidized alluvial plain deposits of the Walton Formation shows a close correspondence (Figure 2b). In view of this close correspondence, as well as the fact that the sources for the late Devonian clastic sequence were to the east of today's exposure of the Walton Formation, it would appear that pelitic rocks similar to those currently underlying the Hudson River Valley were major source rocks of the fine-grained detritus of the Walton Formation. On today's erosional surface in eastern New York State and western New England, chlorite-bearing rocks occur largely within a relatively narrow north-south trending band between Lower Silurian units on the west and a parallel belt of chlorite-free schist and gneiss exposed just east of the area studied (Thompson and Norton, 1968). These medium- and high-grade metamorphic rocks extend into New England and encompass the biotite, almandine, staurolite, and sillimanite isograds. In the area investigated, the shale west of the Hudson River was probably not exposed during the Acadian Orogeny (personal communication, D. W. Fisher, New York State Geological Survey, New York State Museum, Albany, New York 12234). Thus, it is likely that at the time of the Acadian Orogeny, the chlorite-bearing slate and phyllite, now restricted to a relatively narrow region bordering the Hudson River were exposed over a much larger area, east of the Hudson River, than

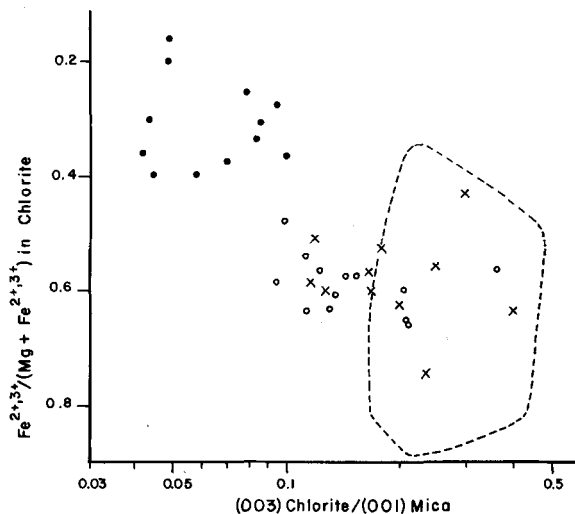


Figure 2b. Relationship of chlorite:mica ratios to relative abundances of iron and magnesium in chlorite in Late Devonian Walton Formation (Liebling and Scherp, 1976). Slip-off slope deposits represented by shaded circles, floodplain deposits by x, and oxbow-lake deposits by open circles. Values for Ordovician argillites indicated by dashed line.

presently. Samples from the reducing environment, displaying somewhat smaller chlorite:mica ratios than those observed in the Ordovician rocks, probably contain mica derived from sources lacking chlorite entirely. During the Acadian Orogeny, streams vigorously cutting into the highlands probably exposed medium- and high-grade metamorphic rocks similar to those which presently underlie much of the region east of the Hudson River.

CONCLUSIONS

This paper, by using a reasonably well established source-deposit geologic setting, demonstrates that clay mineral assemblages, deposited under reducing conditions in stagnant fresh waters, best serve to define the mineralogical character of friable, pelitic source rock. Such assemblages may be of particular value when the nature or location of a source area is in question. Further, such assemblages, if available in a vertical sequence of strata, may also be useful in establishing broad trends in source area composition through time.

In the particular area studied, chlorite-bearing, low-grade metamorphic rocks appear to have been exposed over a much larger area east of the Hudson River during late Devonian time than presently.

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REFERENCES

- Allen, J. R. L. and Friend, F. F. (1968) Deposition of the Catskill facies, Appalachian region: with notes on some other Old Red Stone basins: in *Late Paleozoic and Mesozoic Continental Sedimentation, Northeast North America*, G. de V. Klein, ed., *Geol. Soc. Amer. Spec. Paper* **106**, 21-74.
- Barrell, J. (1913) The Upper Devonian delta of the Appalachian geosyncline, pt. 1: *Amer. Jour. Sci.* **36**, 429-472.
- Barrell, J. (1914a) The Upper Devonian delta of the Appalachian geosyncline, pt. 2: *Amer. Jour. Sci.* **37**, 87-109.

- Barrell, J. (1914b) The Upper Devonian delta of the Appalachian geosyncline, pt. 3: *Amer. Jour. Sci.* **37**, 225–253.
- Brindley, G. W. (1961) Chlorite minerals: in *The X-ray Identification and Crystal Structures of Clay Minerals*, G. Brown, ed., Mineral. Soc., London, 242–296.
- Brindley, G. W. and Gillery, F. H. (1956) X-ray identification of chlorite species: *Amer. Mineral.* **41**, 169–186.
- Carroll, D. (1970) Clay Minerals: A Guide to Their X-ray Identification: *Geol. Soc. Amer. Spec. Paper* **125**, 80 pp.
- Chadwick, G. H. (1944) Geology of the Catskill and Kaaterskill quadrangles, pt. 2: *N.Y. State Mus. Bull.* **336**, 251 pp.
- Fisher, D. W. (1977) Correlation of the Hadrynian, Cambrian, and Ordovician rocks in New York State: *N.Y. State Museum Map and Chart Series* **25**, 75 pp.
- Fisher, D. W., Isachsen, Y. W., and Rickard, L. W. (1971) Geologic Map of New York (1970): *N.Y. State Museum Map Chart Series* **15**.
- Gibbs, R. J. (1965) Error due to segregation in quantitative clay mineral X-ray diffraction mounting techniques: *Amer. Mineral.* **50**, 741–751.
- Grim, R. E. (1968) *Clay Mineralogy*: 2nd ed., McGraw-Hill, New York, 596 pp.
- Liebling, R. S. and Scherp, H. S. (1976) Chlorite and mica as indicators of depositional environment and provenance: *Geol. Soc. Amer. Bull.* **87**, 513–514.
- Thompson, J. B. and Norton, S. A. (1968) Paleozoic regional metamorphism in New England and adjacent areas: in *Studies of Appalachian Geology: Northern and Maritime*, E. Zen, W. S. White, and J. B. Hadley, eds., Interscience, New York, 319–327.
- Towe, K. M. and Grim, R. E. (1963) Variations in clay mineralogy across facies boundaries in the Middle Devonian (Ludlowville), New York: *Amer. Jour. Sci.* **261**, 839–861.

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