seems reasonable that small quantities of sulphur could have moved through these rocks with water during serpentinization. This could be somewhat analogous to the manner in which finely disseminated pentlandite appears to have developed in the "secondary sulphide zone" of the Muskox intrusion (Chamberlain, in press). The process may also be similar to the one mentioned by Naldrett (1965) in which heazlewoodite developed in peridotite at the Alexo property, Timmins, Ontario.

Repetition of the two-phase assemblages magnetite-awaruite and magnetite-heazlewoodite in different zones suggests an antipathy between awaruite and heazlewoodite. It seems more than fortuitous that the two phases were not observed in the same polished sections, yet nothing in the geometry of the phase relations in the Fe-Ni-S system (Kullerud, 1963) suggests that an incompatability exists. If the antipathy is real, it must be related to fluctuating chemical activities of sulphur and/or oxygen in various parts of the system. Such fluctuations did not disturb equilibrium relations between the major phases present (serpentine and magnetite) and probably operated over a narrow, though apparently critical, range.

References

CHAMBERLAIN, J. A., MCLEOD, C. R., TRAILL, R. J., & LACHANCE, G. R. (1965): Native metals in the Muskox intrusion, *Can. J. Earth Sci.*, **2**, 188–215.

CHAMBERLAIN, J. A., Sulphides in the Muskox intrusion, *Can. J. Earth Sci.*, in press.

KULLERUD, G. (1963): The Fe-Ni-S system, *Carnegie Institute of Washington Year Book*, **62**, pp. 175–189.

NALDRETT, A. J. (1965): Heazlewoodite in the Porcupine district, Ontario, *Can. Mineral.*, **8**, 383–385.

NICKEL, E. H. (1959): The occurrence of native nickel-iron in the serpentine rock of the Eastern Townships of Quebec Province, *Can. Mineral.*, **6**, 307–319.

Manuscript received October 28, 1965

TRANSMISSION ELECTRON MICROSCOPY OF FINE-GRAINED ROCKS

RONALD V. ALLEN, RICHARD W. BRAMAN, ROBERT K. MCCONNELL, JR., JOHN L. O'BRIEN

Arthur D. Little, Inc., Cambridge, Massachusetts

The resolving power of the petrographic microscope has limited the study of rocks to systems in which the grain size is larger than several microns. During the past several years techniques have been developed

for the study of glass-ceramic systems by transmission electron microscopy (Doherty & Leombruno, 1964). This paper is intended to illustrate the application of these techniques to the study of fine-grained rock systems.

Figures 1 and 2 show typical optical thin sections of a sample of a fine-grained rock brought into our laboratory for identification. Except for the quartz veinlet crossing the slide most of the minerals are too small to be distinguishable. Routine x-ray fluorescence and diffraction studies were made. The x-ray fluorescence shows strong peaks of silicon, iron, titanium, potassium and calcium. X-ray diffraction shows strong peaks of quartz, a phyllosilicate, and some unidentified phases. There is, of course, no information on the morphology of the materials within the rock making it impossible to determine the paragenetic relationships between the various minerals.

An ultra-thin section of the rock less than 0.1 microns thick was prepared using the mechanical polishing technique described by Doherty & Leombruno (1964). Unlike the chemical thinning techniques which have been used for the preparation of transmission sections for single crystals the mechanical technique can be applied successfully to polycrystalline aggregates of brittle materials (Allen, 1965). Grinding of the

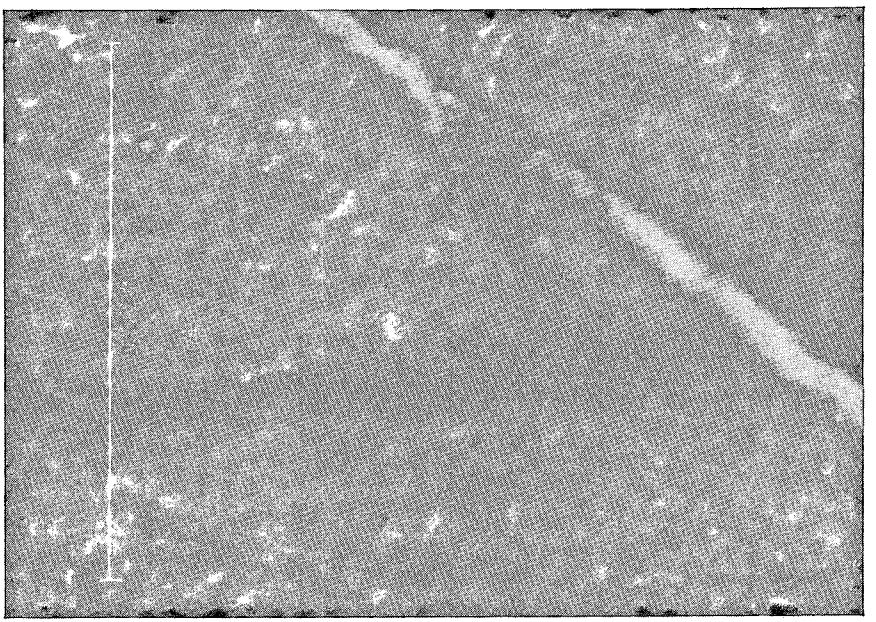

FIG. 1. Low power optical photomicrograph of fine-grained argillite (without polarizer).

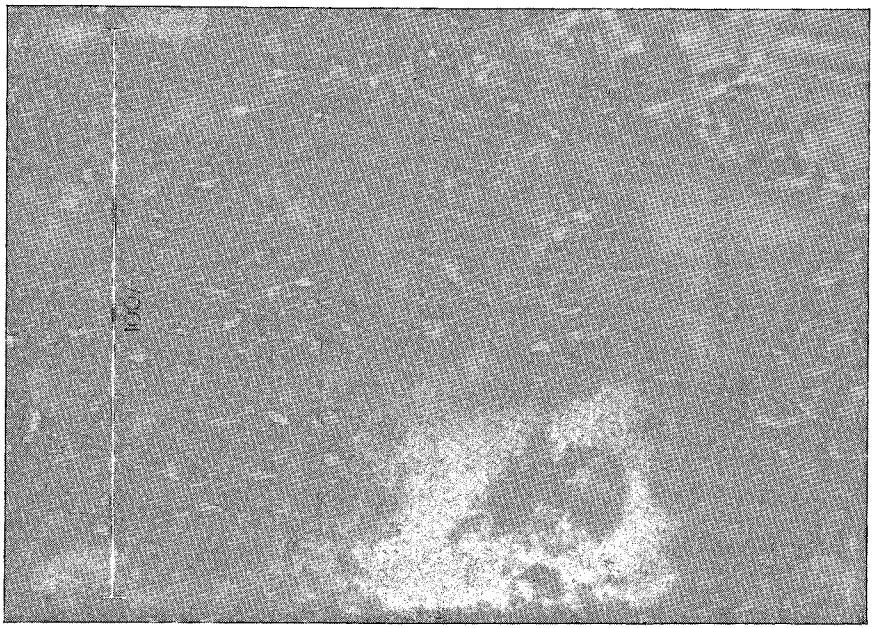

FIG. 2. High magnification optical photomicrograph (without polarizer).

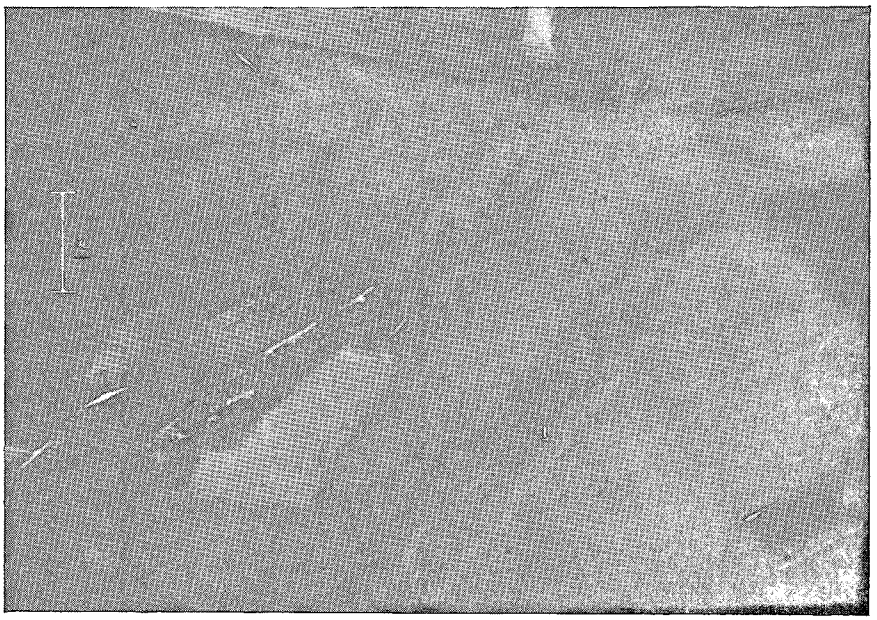

FIG. 3. Low power electron photomicrograph of fine-grained argillite.

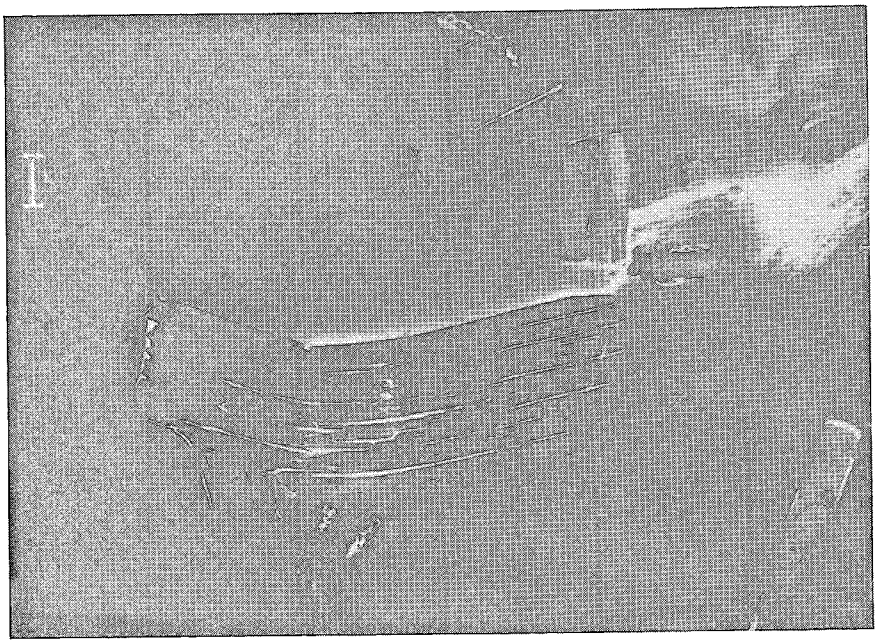

FIG. 4. Different area of specimen shown in Fig. 3.

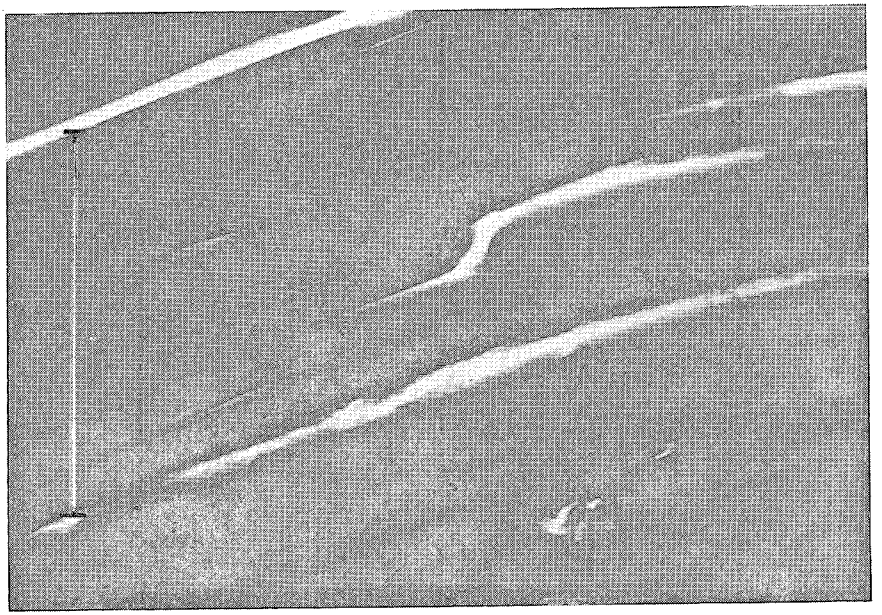

FIG. 5. Closeup of mica-like material showing cleavage.

FIG. 6. Diffraction pattern from mica of Fig. 5.

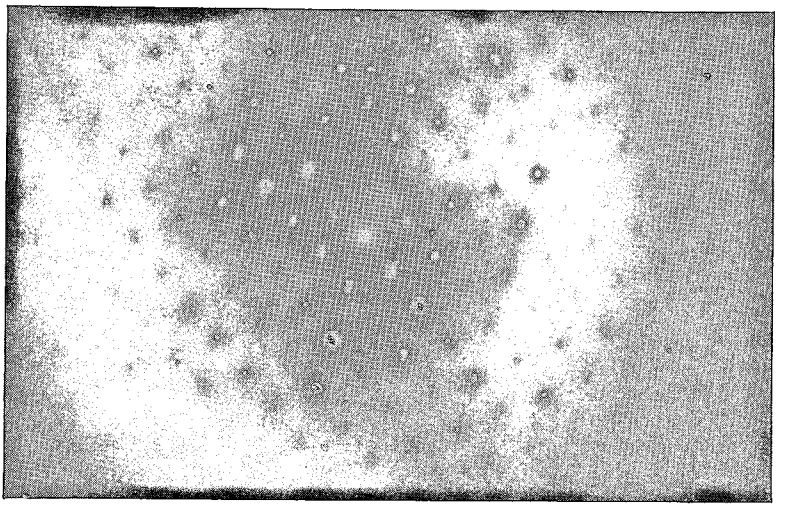

FIG. 7. Diffraction pattern from crystalline matrix material.

thin section normally requires one to two days for a skilled technician. Several more hours, distributed over a period of one week or so, are devoted to the mounting procedure. The finished section may provide up to ten or so individual thin sections for observation on the microscope.

Figures 3 and 4 show low magnification electron photomicrographs of two different areas of the thinned specimen from the rock. The contrast between these and Figures 1 and 2 is striking. There appear to be at least three main phases present: large tabular crystals of a micaceous material; fine-grained polycrystalline aggregates; and a relatively structureless matrix material.

The well developed crystals shown in the center of Figure 4 are similar in appearance to micas observed in optical thin sections. A closeup of one of these crystals is shown in Figure 5. The electron diffraction pattern of the crystal (Figure 6) shows that the *d*-spacings between planes which are normal to the length are much smaller than those of planes parallel to the length of the crystal, thus confirming the micaceous character. In principal, it is possible to make use of these single crystal diffraction patterns to determine the structure of the mineral in the same way as an *x*-ray diffraction pattern but if the phases present are known from *x*-ray data, it is usually not necessary to perform a detailed analysis of the electron diffraction pattern. Figure 7 shows a diffraction pattern of the matrix material. This pattern shows symmetry and interplanar distances consistent with the quartz indicated by the *x*-ray diffraction.

References

ALLEN, R. (1965): Electron microscopy in geology: *Geotimes*, February, 10–11.

DOHERTY, P., & LEOMBRUNO, R. (1964): Transmission electron microscopy of glass-ceramics: *J. Am. Ceram. Soc.*, **47**, 368–370.

Manuscript submitted March 15, 1965

CONSTITUENTS OF CACOCLASITE

J. L. JAMBOR*

Under the title *An Interesting Mineral From Canada*, H. C. Lewis in 1884 provisionally gave the name cacoclasite to a mineral from Wakefield, Ottawa County, Quebec, which occurred as white or greyish-white, nearly square prisms with truncated corners. The crystals, up to an inch in

*Geological Survey of Canada, Ottawa.