aligned in the foliation plane (Figs. 2–4). The groundmass is composed chiefly of quartz and muscovite, with subordinate iron ore and minor sillimanite, plagioclase, biotite, cordierite, and green tourmaline. The total proportion of porphyroblasts in the schist ranges from about 10 to 50 per cent. However, as is rather characteristic of cordierite, these porphyroblasts are crowded with inclusions of quartz and iron ore so that cordierite does not constitute more than 60 or 70 per cent of the porphyroblasts. Small quantities of muscovite, biotite and green tourmaline also are included. Professor N. Cyril Schieltz kindly prepared an *x*-ray powder pattern, and pointed out that it is identical with one of a cordierite-quartz mixture which he had included in a paper on *x*-ray analysis techniques in 1950 (Schieltz,[1] Plate 7).

The inclusions form conspicuous trains coinciding with the foliation of the schist and, in places, delineate relic microfolds. It seems reasonable to conclude, even on such cursory examination, that the cordierite was formed by contact metamorphism of quartz-mica schist. The tourmaline is probably a relic constituent, as it conforms closely to the foliation.

Although these porphyroblasts are small compared to the classic 30 cm. ones in Finland described by P. Eskola, and although larger ones can probably be found in the Front Range, their size and easy accessibility make them worth noting.

[1] Schieltz, N. C. (1950), *X*-ray Analysis, pp. 211–239 in subsurface geologic methods, L. W. LeRoy, editor, *Colorado School of Mines, Golden, Colorado.*

HYDROTHERMAL ALTERATION OF MUSCOVITE IN STEAM GAGE-GLASSES[1]

WILLIAM T. HOLSER,[2] *Battelle Memorial Institute, Columbus, Ohio.*

Sheet muscovite is used to protect sight glasses in the water-level gages of steam power stations (Ptacek, 1952), but under certain conditions the mica becomes clouded and must be replaced after as little as two weeks use. Examination of several such replaced glasses from various power stations reveals an interesting mode of hydrothermal alteration that has not been described previously for this mineral.

Mica for a gage glass consists of a sheaf of 4 or 5 splits of clear muscovite, about 3×12 in., trimmed to shape. The mica is assembled with a thick glass plate and clamped around the edge, using asbestos gaskets. All the gage-glass samples examined were muscovite, either clear or very

[1] Publication No. 61, Institute of Geophysics, University of California, Los Angeles 24, California.

[2] Present address: Institute of Geophysics, University of California, Los Angeles 24, California.

pale red or green. One surface of the mica assembly is in contact with the water or steam of the gage. In the gages examined, the 2-phase water-steam system is at about 315° C., the resulting pressure being about 100 bars. The pH as measured at room temperature is in the range 11.0–11.5.

The cloudy portions of the mica surface were examined by microscopy and x-ray diffraction. The principal phase was diaspore in 0.001 by 0.01 mm. colorless needles, similar to those described by Ervin and Osborn (1951). Other important phases were 0.01 mm. colorless euhedral plates of boehmite, 0.005 mm. dark reddish brown euhedral plates of hematite, and 0.01 mm. crystals of a nonmagnetic opaque spinel-type mineral with $a_0 = 8.42$.

The textures of these products, in relation to the surface of the mica and to each other, are best described in terms of suggested stages in their origin. These stages apparently overlap in time and space.

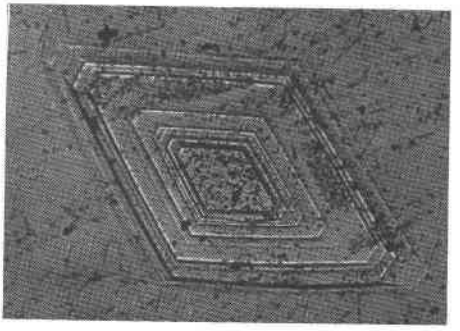

FIG. 1. Pit etched on muscovite cleavage by water, in plane-polarized light, ×120. Long edges are parallel to (110), short edges to (010). Note multiple levels of the pit, and their uniform width.

Stage 1: Etching of shallow pits in the surface of the mica by steam or water. The largest pits may be seen with the unaided eye as diamond-shaped markings a millimeter or more in length. As seen under the microscope (Fig. 1), the principal edges of the etch pits are of the form (110), cut off by minor (010) surfaces. The pit illustrated in Fig. 1 is composed of at least 10 parallel steps, but most pits have fewer steps, as illustrated in Fig. 2. The latter figure also illustrated the random distribution of the pits on the cleavage surface.

If etch pits are generated at the intersection of screw dislocations with the surface, as suggested by Gevers (1953), these dislocations must be much more numerous on a mica cleavage surface than found by interferometry (Amelinckx, 1952*a*). Some of the pits resemble the shallow "*B*" type described by Gevers for SiC and topaz (1953, p. 323), but they are not arranged along regular linear or helical patterns. On the other

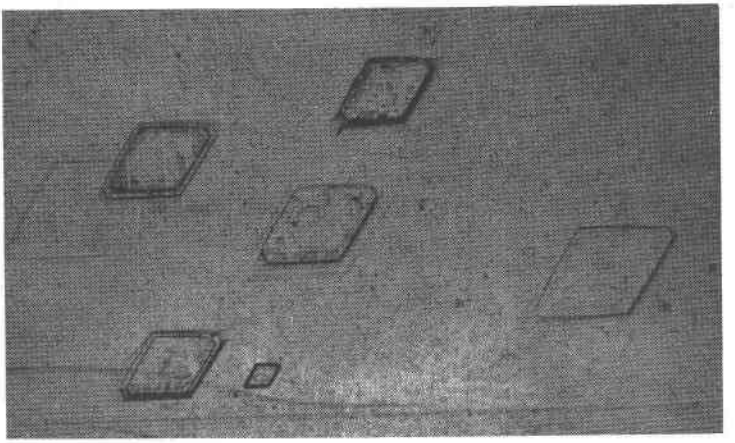

FIG. 2. Array of pits etched on muscovite, plane-polarized light, ×60. Pits have only one or a few levels, and seem to be distributed randomly on the cleavage surface.

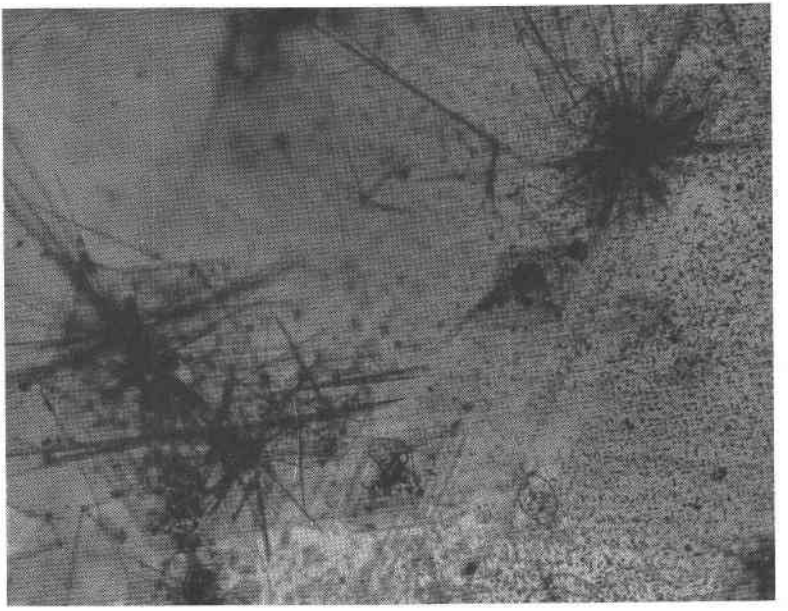

FIG. 3. Needles of diaspore altering mica around etch pits, plane-polarized light, ×53. Needles show a preferred orientation along prismatic directions in the muscovite. In most cases the needles enter between layers of the mica from the edges of the pits.

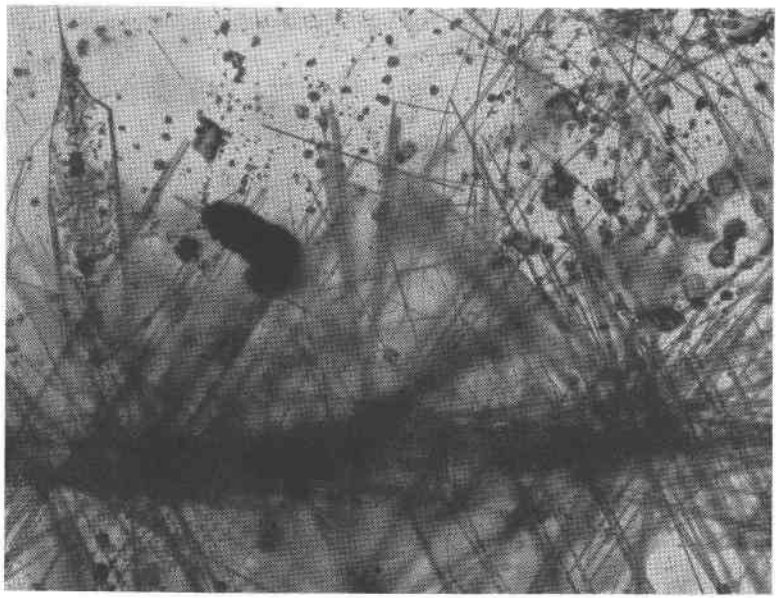

FIG. 4. Needles of diaspore radiating into the muscovite from a scratch in the surface. Smaller equant crystals are boehmite. In plane-polarized light, ×107.

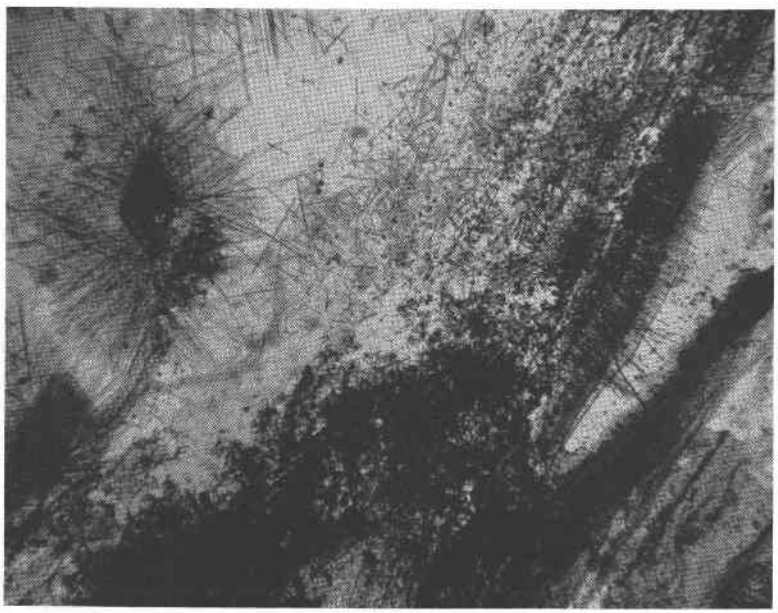

FIG. 5. Intense alteration of muscovite to diaspore and boehmite around an etch pit (upper left) and a shear plane (lower right). In the lower half of the photograph much of the muscovite surface is covered by a dark deposit of boehmite, disapore, hematite, and the spinel-group mineral. In plane-polarized light, ×53.

hand, the pits do not resemble the growth spirals found on biotite (Amelinckx, 1952*b*), as the latter show a continuous spiral with a more equal development of the six straight edges. Although the pits may be seen easily on the dry mica, they do not contribute significantly to the cloudiness of the mica sheet when it is in contact with water, which has a higher refractive index than air.

Stage 2: Chemical alteration of mica at the edges of pits, scratches and bent or sheared regions. In the latter case, the shear produced where the mica is bent along the inner edge of the gasket seemed particularly vulnerable. The alteration consists principally of the growth of fibrous diaspore edgewise into the mica layers, beginning with a few fibers aligned along the (110) directions of the mica crystal. As the amount of diaspore increases, it becomes a mat of fibers in random orientation (Fig. 3). Some boehmite may be crystallized along with the diaspore (Fig. 4).

Stage 3: Deposition on the mica surface of an aggregate of boehmite, hematite, and diaspore (Fig. 5). A black crust of the spinel-group mineral is found in a few places. Most of this material appears to have been deposited from solution rather than by direct alteration of the mica, but the aluminum for the boehmite and diaspore was certainly furnished by the mica. The hematite and spinel-mineral probably represent material in solution from slight metallic corrosion elsewhere in the steam system.

According to the published data (Ervin and Osborn, 1951), boehmite is the stable phase in contact with a saturated solution in the system Al_2O_3-H_2O under these conditions of temperature and pressure, with diaspore stable only above 300 C. and 140 bars. However, more recent work (Kennedy, 1956) proves that the diaspore field extends down to at least 220 C., and the observations made here suggest that it extends down to the vapor line. The other components of the mica, potassium and silicon, have apparently been removed in solution. At this temperature and pressure, SiO_2 attains the appreciable solubility of 0.07 weight per cent, according to Kennedy (1950), which would account for the removal of the silica from the mica. No comparable data are available for the solubility of AlOOH, but an analogous leaching of potassium and silicon from microcline has been demonstrated at somewhat higher temperatures by Morey and Hesselgesser (1951).

The clouding of gage-glass was investigated for the Diamond Power Speciality Corporation of Lancaster, Ohio.

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CONFIRMATION OF THE CRYSTAL STRUCTURE OF PENTLANDITE

A. DAVID PEARSON AND M. J. BUERGER,
Massachusetts Institute of Technology.

Because of the comparative weakness of the powder method to give symmetry information, and because of its absolute inability to provide adequate intensity data for structures having many of the merohedral symmetries, there is always doubt as to the validity of a complicated structure based upon data derived by the powder method. The structure of pentlandite was proposed by Lindqvist, Lundqvist, and Westgren[1] (herein referred to as LLW) on the basis of powder diffraction data. For this reason it was thought desirable to check it by a single-crystal method.

Professor Clifford Frondel of Harvard University kindly furnished us with a sample of pentlandite from the Creighton Mine, Sudbury, Ontario. While the material consisted of fragments, one of the smaller pieces had the form of a plate with two parallel plane surfaces, and appeared to be a possible single crystal. Assuming this to be the case, it was mounted for the precession camera so that the normal to the plane surface was the precessing axis. The resulting precession photographs had the appearance of being based upon a single crystal, and showed plane symmetry *6mm* for the zero level and *3m* for the upper levels.

A cone axis photograph taken with the same fragment showed a period along the precessing axis of 17.56 Å. Because of the trigonal symmetry of the axis it was a candidate for the direction [111] of an isometric crystal. If so, the period along [100] is $17.56/\sqrt{3}=10.14$ Å. Since this value is close to the value for a given by LLW, namely 10.02 Å, this correlation of the precessing axis with [111] was tentatively accepted as correct.

[1] Lindqvist, Märta, Lundqvist, Dick, and Westgren, A., The crystal structure of Co_9S_8 and of pentlandite $(Ni, Fe)_9S_8$: *Svensk. Kemisk. Tidskrift*, **48**, 156–160 (1936).