SHORT COMMUNICATION

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Metamorphic anhydrite in a kyanite-bearing schist from Churchill Falls, Labrador

IN August 1970 one of us (R.M.) collected a few samples of rocks excavated during the construction of the tail-race tunnels of the hydro-electric project at Churchill Falls, Labrador, Canada (53° 35′ N., 64° 15′ W.). The Falls lie in the headwaters of the Churchill River, both having been recently renamed; they were previously 'Grand Falls' and 'Hamilton River'.

The rocks are coarse-grained migmatitic gneisses and schists, which are associated with intrusive bodies of gabbro and diorite. They form part of the Canadian Shield, near the Grenville Front (Stockwell, 1968) in an area for which there are limited published data (Eade, 1952).

One of the migmatite samples examined in thin section has a neosome that includes microcline, plagioclase (An_{23}), quartz, and biotite and a palaeosome comprising biotite, hornblende, epidote, and clinopyroxene. The rock we are concerned with in this note is a mica schist (University College catalogue number P.2988), which contains anhydrite as a metamorphic phase. The hand specimen has a distinctive pale mauve colour, which may prove to be diagnostic since anhydrite is occasionally coloured blue or violet by radiation effects (Deer, Howie, and Zussman, 1962, p. 222). It consists of the following assemblage, with the minerals in decreasing order of abundance: quartz+anhydrite+biotite+opaque minerals+kyanite. The opaque minerals have been identified in polished samples under reflected light as mostly pyrite with some sphalerite.

The anhydrite shows varied moderate to low surface relief, strong birefringence (3rd order colours) and an optical orientation and $2V_\gamma$ (= 42°) that agree precisely with the data given by Deer, Howie, and Zussman (1962) p. 219. Other distinctive properties include the existence of three pinacoidal cleavages and common lamellar twinning on {011}. The identification was confirmed by X-ray diffractometer measurements on a powdered anhydrite concentrate. Some grains of anhydrite show a small amount of alteration to gypsum. A dark brown, high relief mineral (probably sphene) occurs in accessory amounts.

The textural relations suggest that this is an equilibrium regional metamorphic assemblage (fig. 1). The textures of the quartz and anhydrite are similar, both occurring as equant grains of similar size. The schistosity is defined by preferred orientation of the mica flakes and a degree of elongation of aggregates of pyrite and sphalerite. The kyanite occurs as small, mainly granular crystals, often clustered together in streaks parallel to the schistosity. There is no sign of any other aluminium silicate polymorph in the rock.

Anhydrite has been reported in metamorphic rocks from Queensland, Australia (Phillips, 1962), Shikoku, Japan (Shibata, 1972), and Swakopmund, South-West Africa (Nash, 1972). The Australian occurrence is in a contact aureole, and the Japanese is associated with an ultramafic complex in the Sanbagawa high-pressure, low-temperature metamorphic belt. The South-West African occurrence is the one most comparable with that at Churchill Falls. The rocks are high-grade gneisses of Pre-Cambrian age but the metamorphic assemblages are rather different from those at Churchill Falls. Anhydrite occurs in lime-rich rocks containing plagioclase (An_{20-35}), clinopyroxene, and hornblende, and no aluminium silicate. The opaque phase is oxide, not sulphide. Associated pelitic rocks, which are not anhydrite bearing, contain cordierite and sillimanite, suggesting a lower pressure of formation than that of the Churchill Falls specimens.

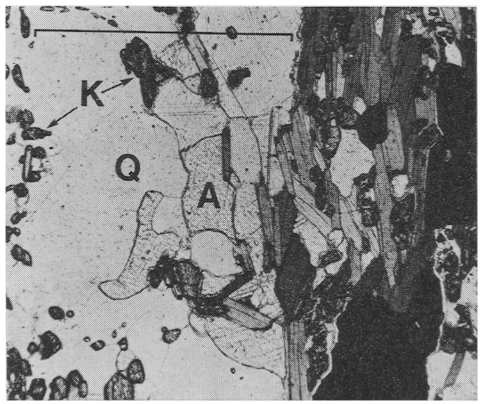

FIG. 1. Photomicrograph of the anhydrite-bearing schist, showing grains of quartz (Q), anhydrite (A), some showing twin lamellae, kyanite (K), and biotite. Note the colourless reaction rims around some of the ore grains. Plane polarized light. Scale bar 1 mm.

The absence of an oxide phase, the abundance of sulphide and the presence of aluminium silicate suggest that the Labrador rock may be a metamorphosed sulphide-rich pelite. Mesozoic clays in England frequently contain appreciable quantities of sulphides and gypsum, and the latter would invert to anhydrite under the conditions of metamorphism of the sample.

However, anhydrite has been found in veins during the excavation of the power-house chamber of the Churchill Falls hydro-electric project (A. P. Beavon, pers. comm.), so there is a possibility that the rock described here may be due to metasomatic alteration in the vicinity of such a vein. The equilibrium texture of the anhydrite, with the other metamorphic minerals (fig. 1), suggests that if this is the case, such an impregnation took place before or during the formation of the schistose fabric. Therefore, anhydrite would appear to be stable under the conditions of formation of the other metamorphic phases, even though the sulphate may have been introduced from outside the original rock.

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BOOK REVIEWS

AMSTUTZ (G. C.) and BERNARD (A. J.), Editors. *Ores in sediments*. VIII International Sedimentological Congress, Heidelberg, August 31–September 3, 1971. Intern. Union Geol. Sci., Ser. A, no. 3. Berlin, Heidelberg, & New York (Springer-Verlag), 1973. viii+350 pp., 184 figs. Price DM 48 ($15.30).

This well-produced volume contains the proceedings of a Symposium organized in connection with the 8th International Sedimentological Congress held in Heidelberg in 1971. It is the second symposium on the subject, and reveals appreciable progress since the previous one in 1963. A list of contents will be found in M.A. 73-2299.

As might be expected, there is a distinct gitological flavour about some of the material, by which I mean some of the authors go out of their way to attempt to show that the ore deposits were formed as normal sediments, with nothing introduced from far away, and particularly nothing brought in by hydrothermal fluids. It is a pity that the case is marred by some specious and pseudo-philosophical arguments. For example, Professor Bernard begins his introductory review of processes by saying 'A few years ago, eminent scientists still postulated seriously a deep-seated, magmatic origin of petroleum . . . This was a typical example of a dogmatic way of thinking or behaviour . . . it allowed the theorists to cling to their ideas, whereas the prospectors, the practical men, were expected to restrict their interest to oil reservoirs and traps . . . the concept of magmatism yields progressively to a concept which assigns more importance to synsedimentary traps . . . the accumulated oil is fossilised almost *in situ* together with its connate waters.' This travesty of the present state of hydrocarbon genetics is surprising; those who have advocated a plutonic origin for oil form a negligible proportion of workers in the field, almost as negligible as those who believe that oil and gas concentrations form almost without fluid migrations. The dogmatic thinking, it may be suggested, comes from the rigidly anti-epigenetic gitologists, rather than from a few plutonically inclined oil men.

The fact is that most lead, zinc, copper, and uranium concentrations in sediments, though admittedly influenced by the sedimentological history of the host rocks in so far as this has affected permeability conditions, are difficult or impossible to explain as normal sediments.

Thus Professor Bernard himself contributes a valuable paper on the control of mineralization by Karstic conditions, where epigenesis, not syngenesis, is clearly implied. Even here, however, he is quite unwilling to admit activity by warm solutions