THE OCCURRENCE OF PREHNITE IN A HIGH GRADE METAMORPHIC SEQUENCE FROM SOUTH NORWAY

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Prehnite interleaving biotite and graphite is reported from the Pre-Cambrian Kongsberg-Bamble Series. The mineral is regionally developed within plagioclase-biotite bearing rocks that have been metamorphosed under almandine-amphibolite and granulite facies conditions. The evidence suggests that hydrothermal sericitisation of the plagioclase feldspars has been responsible for the genesis of prehnite.

INTRODUCTION

The Kongsberg-Bamble Series of south-east Norway has been studied in the area between Risør and Tvedestrand. The sequence has been subjected to a regional metamorphism ranging from upper alamandine-amphibolite facies conditions in the north-west to hornblende—granulite subfacies conditions in the south-east. The dominant strike of the foliation is NE-SW.

The Series consists essentially of a metamorphosed supracrustal sequence of sediments and basic volcanics intruded by discrete bodies of hyperite. These intrusions are generally elongated in the strike direction and are often partially ampibolitised. There is a regional development of syntectonic foliated granites and granitic gneisses, in part migmatic, together with associated pegmatites.

Prehnite is most abundant in the migmatite zone and in major fault zones. Only twice before has prehnite developed in biotite been reported from the Kongsberg-Bamble Series (Burrell 1964, Starmer 1967) but no detailed explanation of its paragenesis has been advanced by these authors. Two other recorded occurrences of the prehnite-biotite association are known to the authors. Hall (1965) describes prehnite in a hornblendite and an appinite from Donegal, Ireland, and reports that a magmatic origin is unlikely. He suggests the two minerals were formed contemporaneously from hornblende as a consequence of low-temperature potassium metamorphism. Wrucke (1965) associates the development of prehnite in the Boulder Creek batholith and surrounding country rocks with lime-rich fluids emanating from the batholith.

THE OCCURRENCE OF PREHNITE IN BIOTITE

Prehnite is widely developed in a variety of biotite-plagioclase bearing rocks including pegmatites, and has been observed associated with the following mineral assemblages:

Quartz — plagioclase — biotite ± hornblende ± epidote ± garnet ± graphite.
Quartz — plagioclase — biotite — sillimanite ± microcline.
Quartz — plagioclase — microcline — biotite ± graphite.
Diopside — plagioclase — biotite ± hornblende ± quartz.
Hornblende — plagioclase — biotite ± quartz.

The prehnite forms colourless, non-pleochroic, orientated aggregates, interleaving biotites along cleavage planes. The maximum polarisation colours are high first order and extinction is straight, paralleling a faint longitudinal cleavage. The identification of prehnite was confirmed by X-ray powder photographs.

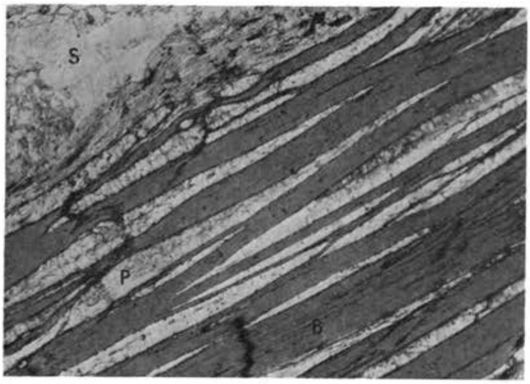
In sections normal to the biotite cleavages the prehnite aggregates are generally lensoidal or wedge-shaped (Fig. 1). Occasionally they are bulbous (Fig. 2), and bow-tie structures are common only in these forms. The prehnite lenses range in length from 0.6 mm. to 6.0 mm., yet the length : breadth ratio remains relatively constant and is of the order of 5 : 1. Prehnite may be completely absent from any individual biotite or present in any proportion up to 1 : 1. Commonly the biotite : prehnite ratio is in the range of 10 : 1 to 20 : 1. Curved lamellae and progressive variation in extinction position in the host biotites show that the biotites are bent round the prehnite agggregates (see Fig. 2). This indicates that the prehnite has grown in the biotites and that the curvature of the biotites is due to the separation of cleavage planes caused by the crystallisation of the prehnite. There is no suggestion of any direct reaction or replacement involving the two minerals; the junctions are sharp.

Sections parallel to the biotite cleavage planes show that the prehnite has crystallised in a fibro-radiate manner from several centres within each aggregate (Fig.4). From this it would appear that this development in biotite has been influenced by the planar structure of the host. Moreover, the distribution of these radiating crystalline structures suggests that they have been developed from discontinuous films of aqueous alkaline alumino-silicates which have penetrated the cleavages. The constant length : breadth ratios of the prehnite lenses support this contention.

THE OCCURRENCE OF PREHNITE IN GRAPHITE

Graphite is common throughout the metasediments and in two instances it has been found to contain prehnite. In both cases the prehnite is completely enclosed within the graphite flakes in the plane of the thin section (Fig 3). Preliminary pyrochromatographic tests have shown that the graphite contains substantial quantities of hydrocarbons and the significance of this is at present being investigated.

The development of prehnite within graphite flakes adds to the argument that the prehnite crystallisation is genetically divorced from its hosts, and confirms that the structure of the enclosing mineral is of paramount importance in determining the sites of crystallisation.



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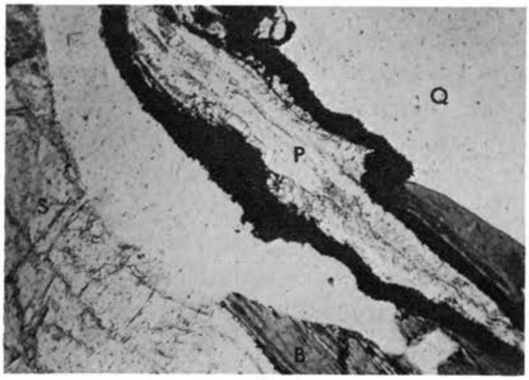

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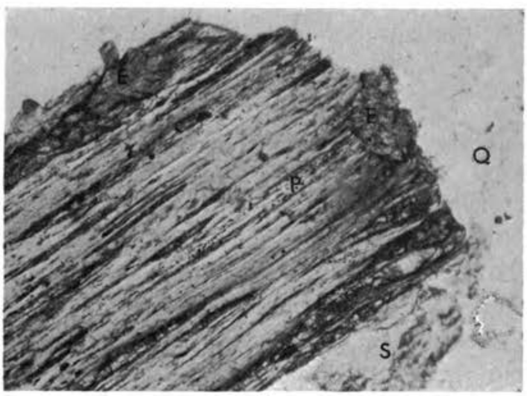

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Fig. 1. Wedges of prehnite (P) within a biotite (B) adjacent to sericitised plagioclase feldspar (S). (×80, ordinary light).

Fig. 2. Prehnite in bulbous form within biotite. The biotite lamellae are curved. (×80, ordinary light).

Fig. 3. Prehnite (P) enclosed within a graphite flake in close proximity to sericitised plagioclase (S). There is incipient development of prehnite within the adjacent biotite (B). Quartz (Q) is the other mineral present. (×80, ordinary light).

Fig. 4. Prehnite exhibiting a radiating rosette form in a section cut parallel to the biotite cleavages. (×50, crossed nicols).

Fig. 5. Epidote (E) replacing the prehnite (P) - biotite pair. The biotite is adjacent to partially sericitised plagioclase (S) and quartz (Q). (×50, ordinary light).

THE ASSOCIATION OF PREHNITE AND BIOTITE WITH EPIDOTE

In four specimens of quartz - plagioclase - biotite - prehnite gneisses, epidote occurs with the biotite. As shown in Fig. 5 it replaces both biotite and prehnite but in the other three specimens it appears to pseudomorph the prehnite. In these instances the diffuse epidote-biotite juctions indicate that reaction with the biotites has occurred.

THE ASSOCIATION OF PREHNITE WITH SERICITE

Plagioclase feldspar in the range $Ab_{80}An_{20}$ to $Ab_{50}An_{50}$ is an essential constituent of the rocks containing prehnite, which only occurs when the plagioclase has been sericitised to some degree. The sericitisation of the feldspars is a widespread phenomenon and sericite is most commonly developed within the less competent metasedimentary horizons in the migmatite zone and in major fault zones. X-ray powder photographs of three samples of sericite suggest that these micas are muscovite or hydromuscovite. Partial chemical analyses confirm that they are rich in potash (average K_2O:Na_2O ratio of three analyses = 23.6 ± 5.6). This indicates that the breakdown of plagioclase was induced by late stage, potash rich, hydrothermal solutions.

There is a correlation between the degree of sericitisation and the degree of prehnitisation. Prehnite is most abundant in those rocks where sericitisation of the plagioclase is complete. Here the majority, and in some cases all, of the biotites contain prehnite. Where the feldspar breakdown is incomplete only the biotites directly adjacent to the partially sericitised plagioclases contain prehnite.

This close association between prehnite and sericite is regarded as significant and is believed to indicate that the processes leading to their formation were intimately connected. Steiner (1953), concerned with depth zones of hydrothermal alteration, shows that certain hot solutions may, indeed, effect both the alteration of plagioclase and the development of prehnite. It is postulated by the present authors that, in the rocks of the Bamble Series, the alteration of the plagioclase feldspars to sericite has directly contributed to the genesis of prehnite. It is envisaged that calcium was released during the sericitisation process and that, as a consequence, the hydrothermal solutions locally became calcium enriched. Prehnite subsequently crystallised out within biotites and graphite flakes which were in close proximity to the altered feldspars. Experimental work (Gruner 1944, Yoder & Eugster 1955, Fyfe et al. 1958, Coombes et al. 1959) appears to confirm that, under relatively low pressures, prehnite and sericite are both stable between approximately 350°C and 450°C.

CONCLUSIONS

A genetic relationship between prehnite and sericite in high-grade metamorphic rocks from South Norway is indicated by the close associaton of the two minerals. The prehnite has most probably developed as a consequence of the late stage hydrothermal sericitisation of plagioclase feldspar; which reaction released calcium into solution. The crystallisation of prehnite was effected in the nearest suitable structural sites which were provided by the cleavage planes of biotite and graphite flakes. The solutions penetrated these as discontinuos films.

The association of prehnite and sericite suggests that the temperatures of formation were of the order of 350° C to 450° C, under relatively low pressures.

The occurrence of epidote pseudomorphing prehnite and partially replacing the prehnite-biotite pair appears to indicate local increases in P—T conditions.

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