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Tourmaline greisenization in Langkawi— a reinterpretation using the available composition model

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Abstract: Tourmalinized granites in Langkawi containing muscovite are interpreted by Hutchison and Leow (1963) to have suffered tourmalinization and greisenization. The petrography of the tourmalinized granites appears to be better explained using the available composition model of Atherton and Brotherton (1972). The development of muscovite and other features are the consequences of boron metasomatism (tourmalinization) and other processes need not be invoked.

This note is prompted by a paper by Hutchison and Leow (1963) on tourmaline greisenization in Langkawi, northwest Peninsular Malaysia. The good descriptions given in the paper permit the interpretation given below.

THE LANGKAWI GRANITE

The Langkawi granite exposed along the coast near the Country Club Hotel has been described by Hutchison and Leow (1963) to be porphyritic biotite granite containing essential minerals such as microcline (45%), quartz (35%), oligoclase (15%) and biotite (5%). They reported that the granite is cut by quartz-tourmaline veins which also contain muscovite and that in the veins tourmaline appears to be the earliest formed mineral. They also reported that adjacent to the quartz-tourmaline bodies, the tourmaline commonly, 'segregated into round clots up to 2 inches diameter' and the granite host contains secondary muscovite, quartz and tourmaline. They said that 'fine-grained quartz is also associated with the muscovite' and 'the secondary nature of this fine-grained quartz is demonstrated by its mode of occurrence as blebs in the microcline as well as the close association with tourmaline and muscovite'. They concluded that 'the tourmaline greisenization quite clearly spread from the dikes into the granite' and textural features indicate that the tourmalinization precedes the introduction of potassium to form muscovite, but both processes are not actually separated by any major time break.

It is interesting to note that the fine-grained quartz which is interpreted to be secondary by Hutchison and Leow (1963) is enclosed in the microcline. It appears that in the tourmalinized granite there is late growth of microline as well. In Penang, tourmaline clots in granite similar to those in Langkawi are found by Gan (1976) to contain perthites which enclose grains of plagioclase, quartz and biotite and she interpreted that 'this shows that the microcline have continued growth'. Late growth of microcline does not appear to occur only in the tourmalinized granite of Langkawi but elsewhere as well.

There is no mention of biotite in the tourmalinized granite adjacent to the quartz-tourmaline veins in Langkawi in Hutchison and Leow (1963). However, from 20 thin sections of a specimen of granite (R285) from the same locality, 4 contain biotite and no tourmaline, 13 contain tourmaline and biotite and 3 contain tourmaline and no biotite. In the rock the biotite is often ragged and chloritized and sometimes clearly replaced by tourmaline (Fig. 1) and sometimes by muscovite (Fig. 2). There is no doubt that biotite will diminish with increasing degree of tourmalinization. The formation of tourmaline in place of biotite in granitic rocks is also known elsewhere in Peninsular Malaysia such as Gunung Jerai, Penang and Sungai Way (Selangor) and also in Cornwall.

The thin sections also show that plagioclase is replaced by some fine white mica and fine grains of garnet (Fig. 3) are present which also occur rarely in the matrix (Fig. 4). However, most interestingly, the coexisting microcline remains fresh and unaltered. The plagiocase, which is sodic oligoclase, is replaced by white mica but not the microcline (Fig. 5).

Summarizing, the petrography of the tourmalinized granite shows the following interesting features.

(a) There is late development of muscovite, quartz and microcline.

(b) Biotite is replaced by tourmaline and muscovite.

(c) Plagioclase is replaced by some fine white mica.

(d) Garnet is present.

How can these features be explained?

INTERPRETATIONS

Hutchison and Leow (1963) interpreted that the quartz-tourmaline veins are responsible for tourmalinization and greisenization of the granite. They envisaged the tourmalinization is due to boron metasomatism and the formation of muscovite (greisenization) is due to introduction of potassium. However, introduction of potassium into the granite will not cause the formation of muscovite (Khoo, 1981).What then is the origin of the muscovite? It is well known that greisenization, which is not due to the introduction of potassium, will result in the formation of muscovite. In greisenization, white mica is formed by replacing aluminous minerals such as feldspars and often the feldspars are pseudomorphed by white mica aggregates (Hatch, Wells and Wells, 1961, p. 208–210). Indeed many greisenized granites in Peninsular Malaysia show feldspars replaced by white mica e.g. in the Kinta Valley (Ingham and Bradford, 1960, p. 66) and Sungai Way (Goh, 1976). However, in Langkawi the muscovite occurs interstitially (Hutchison and Leow, 1963, Fig. 2), does not replace the microcline but only mildly replaces the plagioclase. This is not characteristic of greisenization. In fact there is evidence that in Langkawi, the alkali feldspar instead of being replaced has shown remarkable late growth! The suggestion of Hutchison and Leow (1963) that boron and alkali metasomatism or tourmalinization and greisenization had occurred cannot explain the petrographic features except the development of tourmaline.

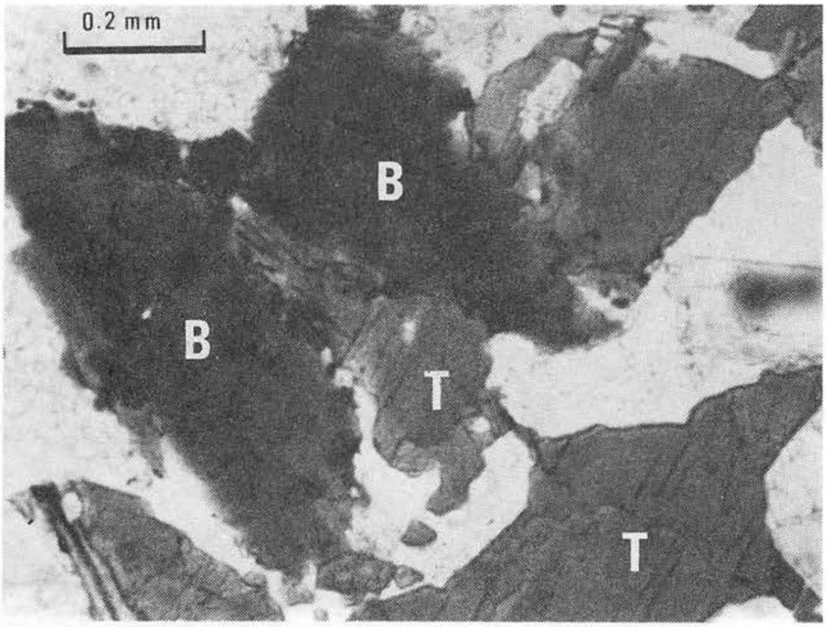

Fig. 1. Photomicrograph showing biotite (B) replaced by tourmaline (T) (Specimen R285, Kuah, Langkawi).

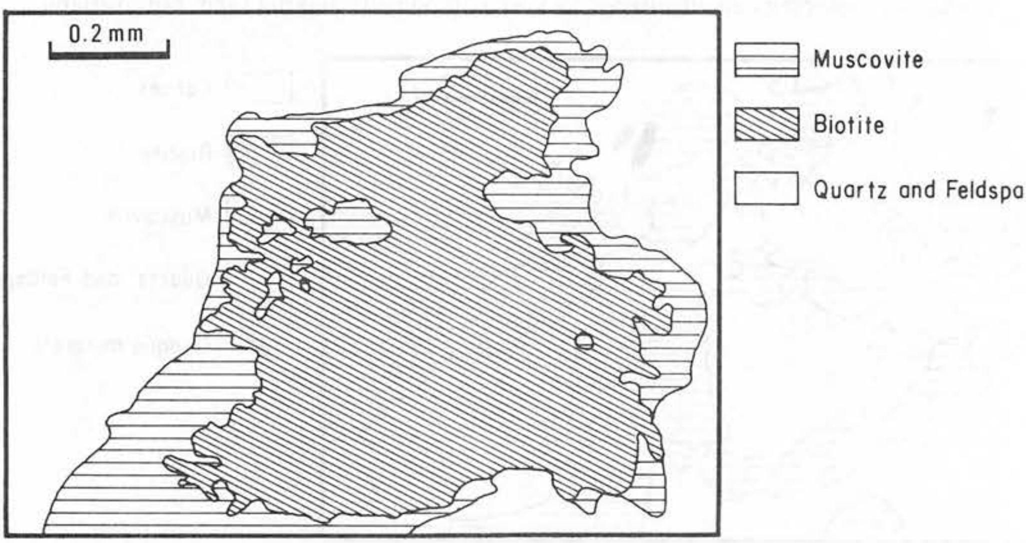

Fig. 2. Sketch from photomicrograph showing biotite replaced by muscovite (Specimen R285, Kuah, Langkawi).

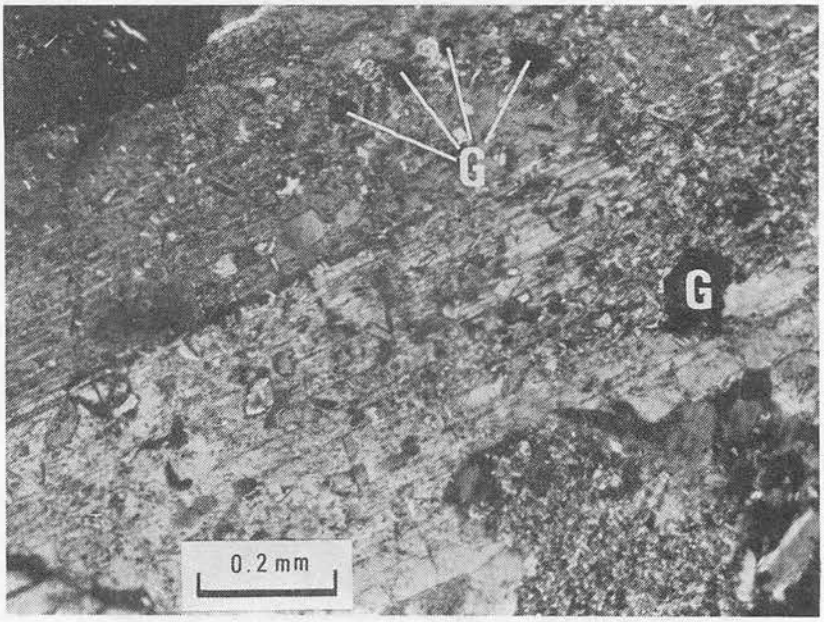

Fig. 3. Photomicrograph showing plagioclase replaced by plates of muscovite. Note presence of garnet (G). Cross-polars. (Specimen R285, Kuah, Langkawi).

A better model which can be invoked to explain the petrographic features is the available composition model of Atherton and Brotherton (1972). In this model it is believed that the matrix composition of a rock undergoing metamorphism will change if phases developing can effectively 'lock-in' components making them not available

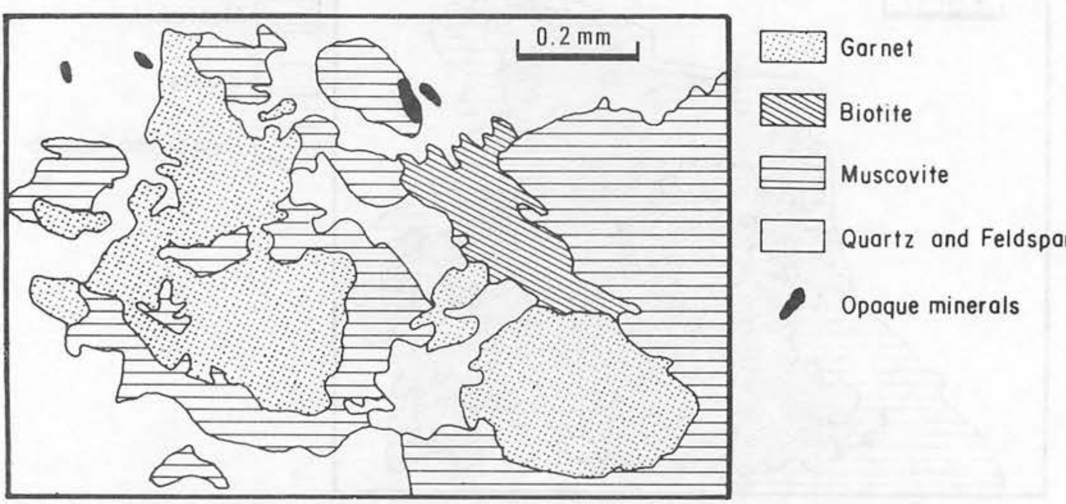

Fig. 4. Sketch from photomicrograph of garnet in matrix of tourmalinized granite (Specimen R285, Kuah, Langkawi).

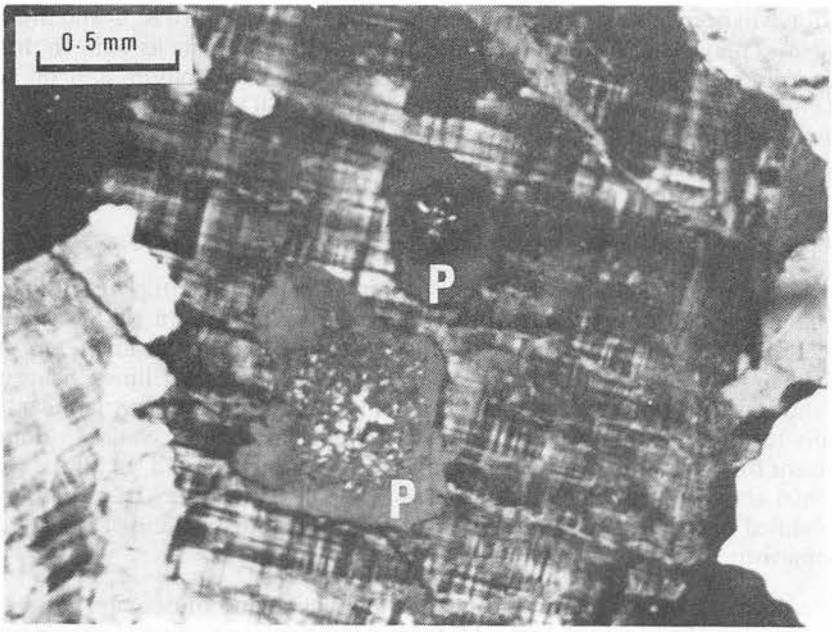

Fig. 5. Photomicrograph showing cross-hatched microcline enclosing sericitized inclusions of plagioclase (P). Also compare Fig. 3. Cross-polars. (Specimen R285, Kuah, Langkawi).

for further participation in reactions. The occurrence of compositionally zoned crystals of garnet and staurolite in metamorphic rocks clearly shows the variability of the matrix composition during metamorphism. However, it is uncertain what minerals can effectively 'lock-in' components during metamorphism and what minerals do not. The sheet silicates such as biotite and chlorite apparently do not but the orthosilicates such as garnet and staurolite do 'lock-in'. This model has been successfully applied to explain the presence of minerals such as kyanite in rocks of unfavourable whole-rock compositions (Atherton and Brotherton, 1972).

Here it is believed that the ring silicate tourmaline can effectively 'lock-in' components once formed. This belief is further strengthened by the common occurrence of tourmaline showing colour zoning in schists and also tourmalinized granites. The colour zoning may reflect compositional zoning.

In agreement with Hutchison and Leow (1963) the tourmaline in the Langkawi granite is formed by boron metasomatism spreading out from the veins which must be emplaced in the granite which by now should be solidified or almost so. However, the formation of tourmaline has various consequences. The most obvious consequence, because it is also the most visible, is the destruction of biotite. The ferromagnesian components in the tourmaline are derived from the destroyed biotite. Another consequence, which is not so obvious, is the destruction of the albite component of plagioclase and also possibly also in microcline. The albite component is the only source of soda in the granite for the formation of tourmaline. The destruction of biotite will release K_2O, Al_2O_3 and SiO_2 and the breaking up of the albite component will release Al_2O_3 and SiO_2. Excess Al_2O_3 after subtracting those needed for tourmaline formation will be available to form microcline and muscovite wth K_2O and SiO_2. Any excess Na_2O may occur as the paragonite molecule in muscovite as well. In this way, the occurrence of secondary muscovite which also replaces biotite and microcline which showed late growth can be explained. Excess SiO_2 will form the secondary quartz considering that biotite, albite and tourmaline each has about 6 molecular proportions of SiO_2. The release of SiO_2 from breaking-up of albite can be written as follows:

3 Albite component + 2 Water → Paragonite component + 12 Quartz + $2Na_2O$ (to tourmaline).

The withdrawal of the albite component from plagioclase will either result in a more calcic palgioclase or formation of other lime-bearing phases. In the tourmalinized granite R285, the plagioclase is still sodic oligoclase like in the unaltered granite described by Hutchison and Leow (1963). However, there is a lime-silicate in the tourmalinized granite R285 garnet. The temperature of the tourmalinization is probably too low for the formation of calcic plagioclase or the available alumina is insufficient for the amount of lime available and so garnet formed. In all the changes mentioned above it is assumed that water is available. Water may be available in the just solidified or solidifying granite itself or from the aqueous fluids associated with metasomatism.

The development of the potash phases, microcline and muscovite, can be more easily understood by considering the AKF diagram shown in figure 6. The composition of a granite should plot near point P in figure 6. Removal of ferromagnesian components from the system by formation of tourmaline and destruction of biotite will shift the available composition towards the K-corner via point Q as alumina is also "locked-in" by the tourmaline. But the necessary withdrawal of soda from the albite component in the rock made available excess alumina to the available composition and so the available composition should move via point R into the three-phase field of muscovite-biotite-microcline. If the biotite is completely destroyed resulting in total withdrawal of ferromagnesian components from the system, the trend of the available compositional changes should hit the AK line at point S. Moving of the available composition into the three-phase field will result in the formation of muscovite and microcline.

CONCLUSIONS

Application of the available composition model appears to be able to account for the observed petrographic features of the tourmalinized granite in Langkawi such as late growth of microcline, secondary formation of muscovite and quartz, the development of garnet, the replacement of plagioclase by white mica but not the microcline and also the observation that tourmalinization precedes greisenization by Hutchison and Leow (1963). These features are the result of tourmalinization or metasomatic introduction of boron into the system. The development of white mica in the tourmalinized granite need not be due to greisenization and indeed the petrography does not indicate that it has happened. Greisenization is more due to removal of alkali from the system. How else can a granite be converted to a greisen consisting of quartz and white mica other than by massive removal of alkali and other components? Removal of alkali will not promote late growth of alkali feldspar and in fact it will be

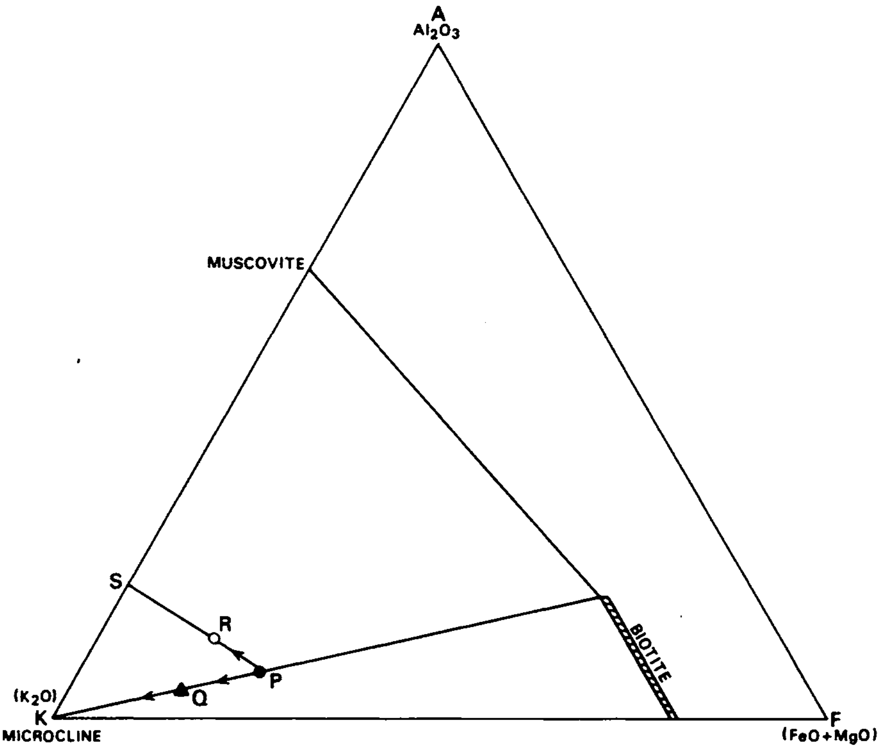

Fig. 6. AKF diagram showing trend on change of available composition. P = granite compositon Q = available composition after removal of FeO and MgO. R = available composition after removal of FeO and MgO but with addition of Al_2O_3 after breakdown of albite component.

replaced by white mica. Tourmalinization-induced development of white mica cannot ultimately produce a greisen according to the predictions of the available composition model.

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