Geological Society of Malaysia Bulletin 52
June 2006 p.55-58

Field Evidence of Magma Mixing in Plutonic Rock from the Benom Complex, Central Belt of Peninsular Malaysia

Azman A Ghani

Department of Geology
University of Malaya
50603, Kuala Lumpur

Abstract: The alkalic series of the Benom Complex, Pahang, consists of monzonite, syenite and gabbroic rock. The contact between monzonite and gabbroic rock suggest that both magmas are mixed. Evidence of the mixing can be seen at the new roadcut outcrop along the Benta township by-pass such as dispersion of K-feldspar from monzonite in the gabbroic rock. The end stage of this dispersion is the free swimming of K-feldspar individual crystals in the gabbroic material. This structure is interpreted as the result of mechanical transfer during the mafic-felsic magma interaction and mixing event. All these features suggest an origin for the alkalic intermediate rocks of the Benom Complex involving a magma mixing process..

INTRODUCTION

Magmatic interaction processes have been widely recognized and studied in both plutonic and volcanic environments (e.g. Poli et al., 1996; De Rosa et al., 1996; Thomas and Tait, 1997; Blake and Fink, 2000). The interaction between crust- and mantle-derived magmas resulted in a wide variety of hybrid rocks ranging from homogeneous, completely blended tonalites, to heterogeneous, mechanically mixed, mafic enclave-bearing granites. There is abundant field, petrographic and petrochemical evidence that co-mingling and mixing do occur in the plutonic environment, at least on a local scale (e.g Hibbard 1991). Most calc-alkaline plutons in different orogenic belts show mafic microgranular enclaves (see Didier and Barbarin, 1991, for definition) as a common feature and it is commonly accepted that they are the result of mingling and mixing processes between basic and acid magmas (e.g. Vernon, 1984; Williams and Tobisch, 1994; Poli et al., 1996, Flinders and Clemens, 1996).

This paper will describe the field occurrence of mixing and mingling found in the alkalic series rocks of the Benom Complex, Central Belt of Peninsular Malaysia. The role of magma mixing in this rock complex is demonstrated by several lines of evidence: (1) Evolution of machanical mixing, characterized by progressive fragmentation of K-feldspar in monzonitic magma, (2) Coarsening of the gabbroic minerals in the mixed rock and (3) dispersion of K-feldspar phenocrysts from monzonitic composition into the gabbro rock.

GENERAL GEOLOGY

The Central Belt has less published information of its geochemical affinities than the Main Range, however, it is comparable to the Eastern belt (Cobbing et al.1992). One of the main plutonic com-plexes in the Central Belt is the Benom complex. The Benom Plutonic Complex is constituted by a number of igneous intrusions that form a narrow and well defined line of single plutons emplaced into Permo-Triassic rocks. The intrusions are mainly granitic of calc alkali affinities associated with mafic to intermediate (syenite, monzonite and gabbro) of alkalic series (Jaafar Ahmad

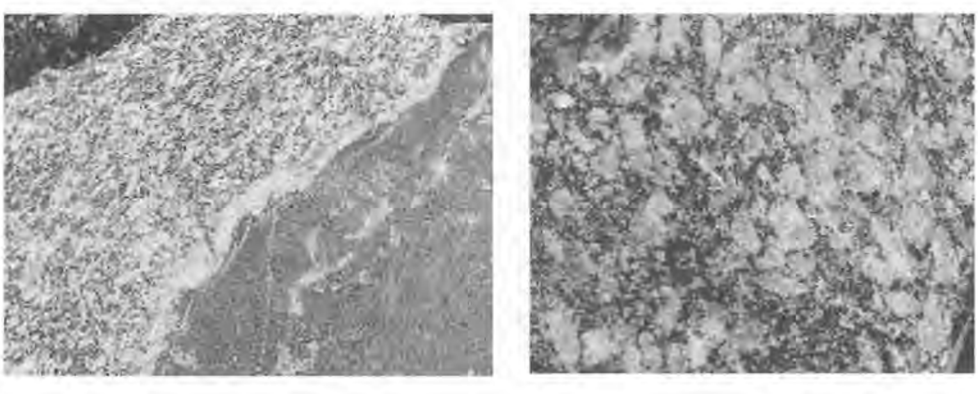

Figure 1: Comparison between syenite (left) and monzonite in the field. Syenite dominated by tabular euhedral K-feldspar forms a flow-like foliation. Monzonite packed with subhedral to anhedral K-feldspar. The size of the K feldspars is coarser compared to those in syenite.

1979). The latter is also known as Benta migmatite complex by Hutchison, 1971. The complex occurs very close to the Bentong-Raub line, which may suggest an underlying structural control for its emplacement. Geochemical study shows that the alkalic series rocks of the complex contain very high contents of large ion lithophile elements (Ba and Sr) (Azman et al. 2002, 2003; Mustaffa Kamal & Azman 2003; Azman & Mustaffa Kamal 2004). This paper describes the outcrop of the new road cut that by-passes Benta town, built in 2004. The road cut runs between the two important localities of the 'Benta Migmatite' (Hutchison 1971) that is Jeram Besu and Benta JKR quarry.

FIELD DESCRIPTION

In general, three rock types occur in the study area, that is gabbro, monzonite and syenite. The syenitic rock is coarse grained, well foliated (Fig 1) and dominated by numerous large tabular euhedral to ellipsoidal crystals of alkali feldspar of maximum dimension 1 to 3 cm and width of 1 cm. The rock is essentially made up of K-feldspar, hornblende, plagioclase, quartz, biotite, sphene, apatite and epidote. The microcline phenocrysts in the syenite are usually pale pink in colour. Carlsbad twinning in these tabular crystals is obvious even in hand specimen. It is observed that the oriented K-feldspar often contain inclusions of plagioclase laths arranged in a zonal manner. The green hornblende sometimes contains inclusions of apatite and quartz. Opaque mineral, probably magnetite is sparsely distributed in the syenite. The hornblende and biotite are sometimes aligned parallel to K-feldspar and plagioclase enhancing the foliation. In general the syenitic rock is homogeneous with very few enclaves and with sharp contacts with both gabbro and monzonite

Monzonite is coarser grained (Fig 1) compared to the syenitic rock and dominated by subhedral to anhedral K-feldspar.The size of the K-feldspar ranges from 0.5 cm to 5 cm. A comparison between the monzonitic and syenitic rock is shown in Figure 2. Monzonite is holocrystalline inequigranular and coarse grained comprising K-feldspar, plagioclase, augite, hornblende, biotite, epidote, sphene and apatite. The K-feldspar is microcline and their perthite varieties. It occurs as big crystals showing good Carsbad twinning and sometimes faint zoning outlined by dust inclusions. Plagioclase occurs as lath-shaped crystals showing distinct lamellar twins. Their compositions vary from An_{24} to An_{37}. Small lath shaped plagioclase crystals are also found in the big K-feldspar crystals. Some plagioclase is sericitised with fine mica along twin-planes. Individual hornblende crystals are subhedral and twinning is not uncommon. Clinopyroxene, mainly augite, is commonly twinned and exhibits corona texture made up of hornblende. Biotite occurs as subhedral crystals occasionally containing inclusions of equant apatite. Granophyric intergrowth between quartz and K-feldspar occurs both in the interstices and inside K-feldspar phenocrysts.

Gabbroic rock is fine to medium grained (Fig 3 and Fig 4), black to greenish black in colour and consists of augite, hornblende, biotite and plagioclase. The augite is commonly twinned and rimmed by hornblende in turn is rimmed by biotite. In fact the occurrence of successive rims made up of augite, hornblende and biotite is not uncommon. Some augite crystals are weakly pleochroic from yellowish brown to pale brown. Primary hornblende usually forms subhedral grains showing parallel intergrowth with augite. It is usually pleochroic from green to pale green. Biotite occurs as flakes with distinct cleavage, forming up to 35% in some gabbroic samples. Inclusions of ilmenite and sphene are common along cleavage traces and ragged edges of biotite.

Mixing between Gabbroic and Monzonitic rock.

The contact between monzonite and the gabbroic rock is rather enigmatic in places. Both sharp and gradational contacts were observed between these two rocks. Both types of contacts, however, suggest that the relationship between the monzonite and the gabbro is magmatic. In places the gabbroic rock forms numerous rounded enclaves in the monzonitic host giving rise to a pillow-like structure. The gabbroic enclave morphologies are extremely variable ranging from rounded to ellipsoidal. The contacts between syenite and monzonite are always sharp.

In other parts, the contacts between the gabbroic rock and the monzonite are diffuse and the whole rock is more homogeneous. Medium to large K-feldspar crystals can be seen dispersed in the gabbroic rock in varying degrees. The crystals form a train of K feldspar or schlieren-like texture in gabbroic material. The extreme case is the occurrence of individual K-feldspar of various sizes from monzonitic rock in the gabbroic rock (Fig. 5 and Fig.6). In this case, it is not possible to discriminate a precise boundary between enclaves and hosts because of the continuous interlocking of crystals of the two rocks. In the area where the monzonitic material forms a flow-like or a schlieren-like texture in the gabbroic rock, the later is usually coarser grained compared to the gabbroic rock that are far from the monzonitic material. Occasionally the K-feldspar that dispersed from the monzonitic rock formed a net complex around the gabbroic 'enclave' (Fig. 7)

CONCLUDING REMARKS

The mixing structure observed in the study area strongly suggests an igneous origin of the alkalic series of the Benom Complex. This supports the findings of Yong et al. (2004) that the complex is magmatic and not metamorphic (cf Hutchison 1971).

There are fundamentally three different types of plutonic events on settings in which co-mingling between contrasted magma may occur: (1) both mafic and granitic magmas may be injected more or less simultaneously into the same set or sets of fracture, (2) an established chamber of granitic magmas may be invade by mafic magma (3) granitic magma may invaded an established chamber of mafic magma. Examples of all three settings have been identified in the study of plutonic rocks (Wiebe 1973, 1974; Wiebe and Wild 1983). Each setting provides different opportunities for interaction between the two magmas and each setting has distinctive characteristics that can normally be recognized in the field. From the mixing texture observed in the study area, setting (1) is more likely for the alkalic series of the Benom Complex.

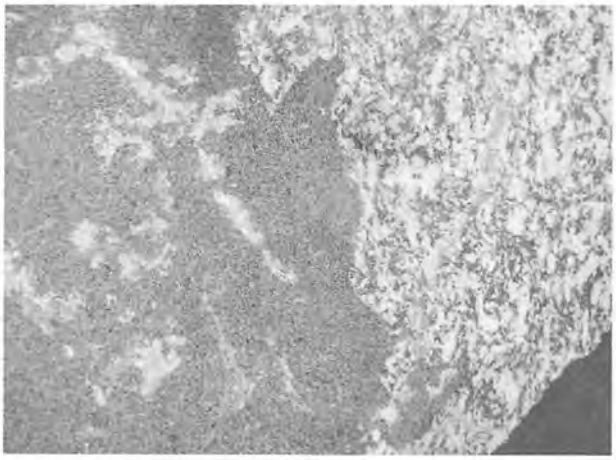

Figure 2: Contact between gabbro and foliated syenite. Note the crenulated and irregular shape of the contacts.

Figure 3: Contact between gabbro and monzonite. Note the crenulated and irregular shape of the contact.

Figure 4: : An early stage of the dispersion of monzonitic K-feldspar in the gabbroic rock.

Figure 5: : End stages of K-feldspar dispersion in the gabbroic rock. In this stage the euhedral K-feldspar forms a schlieren–like texture in gabbroic

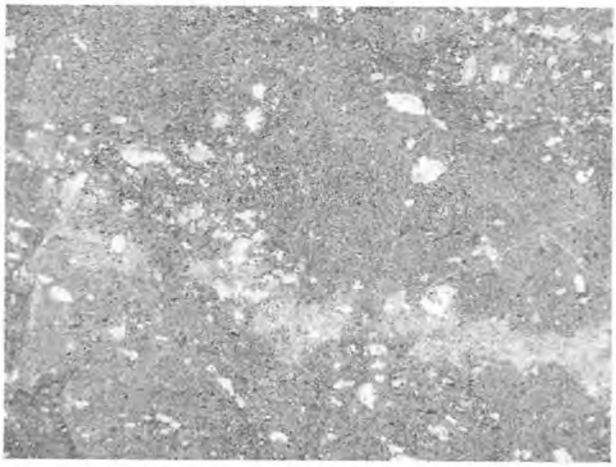

Figure 6: : End stages of K-feldspar dispersion in the gabbroic rock. Note the various sizes of the K – feldspar crystals.

Figure 7: : K-feldspar surrounding the gabbroic enclave as a net-vein like structure.

The synplutonic textures observed in the study area are: (1) dispersion of K-feldspar from monzonitic rock in the gabbroic magma and (2) formation of monzonitic net vein surrounding the rounded gabbroic enclaves. The monzonitic rock may have been 90% crystallised as seen from the areas not affected by the mixing process. The ability of K-feldspar from monzonite dispersed into the gabbroic rock may suggest that the gabbroic magma contained more liquid and thus helped to mechanically move the K-feldspar from the gabbro-monzonite interface. Rounded enclaves and the contact between the gabbroic and monzonitic magmas are devoid of chilled margins implying a small temperature contrast between the magmas.

REFERENCES

AZMAN A GHANI AND MUSTAFFA KAMAL SHUIB. 2004. High Ba-Sr magmatism from the Central Belt of Peninsular Malaysia: implication to the geotectonic development of Peninsular Malaysia. Abstract *International Symposium on Geologic Evolution of East and Southeast Asia-Microcontinent accretaion and formation of marginal sea: Featuring a celebration in honour of retirement of Profesor Shigeki Hada, the leader of IGCP 411*, 8-14 February 2004, Bangkok, Thailand. 35 - 36

AZMAN A GHANI, MUSTAFFA KAMAL SHUIB AND MOHD ROZI UMOR. 2005. Geotectonic implication of the high Ba-Sr from alkalic series igneous rocks of the Benom Complex, Central Belt of Peninsular Malaysia. *Aturcara dan kumpulan kertas kerja Seminar sehari kumpulan kerja Sedimentaologi & Tektonik. 48 - 55*

AZMAN A GHANI, REMESH, V., YONG, B.T., KHOO, T.T. AND SHAFARI MUDA. 2002. High Ba rocks from the Central Belt of Peninsular Malaysia and its implication. *Bull. Geol. Soc. Malaysia, 45*, 45 - 49

BLAKE, S AND FINK, J.H. 2000. On the deformation and freezing of enclaves during magma mixing. *Jour. Volcanol. Geotherm. Res. 95*, 1–8

COBBING, E. J., PITFIELD, P. E. J., DARBYSHIRE, D. P. F., & MALLICK, D. I. J. 1992. *The granites of the South-East Asian tin belt.* Overseas Memoir 10, B.G.S.

DE ROSA, R, MAZZUOLI, R AND VENTURA, G. 1996. Relationships between deformation and mixing processes in lava flows: a case study from Salina (Aeolian Islands, Tyrrhenian Sea). *Bull. Volcanol. 58*, 286–297

DIDIER, J AND BARBARIN, B. 1991. *Enclaves and granite petrology*. Elsevier, Amsterdam (Dev. Petrol 13), 623 pp.

FILINDERS. J, AND CLEMENS. J.D. 1996. Non-linear dynamics, chaos, complexity and enclaves in granitoid magmas. *Trans. Roy. Soc. Edinburgh. Earth Sci. 87*. 225–232

HIBBARD, M.J.1991. Textural anatomy of twelve magma-mixed granitoid systems. In: Didier J, Barbarin J (eds) Enclaves and granite petrology. Elsevier, Amsterdam, pp 431–443

HUTCHISON, C.S. 1971. The Benta migmatite Complex: Petrology of two important localities. *Geol. Soc. Malaysia Bulletin, 4*, 49 –70

JAAFAR AHMAD. 1979. The petrology of the Benom igneous complex. *Geol. Surv. Malaysia Spec. Paper 2*, 141 pp

MUSTAFFA KAMAL AND AZMAN A GHANI. High Ba Sr rocks from the Central Belt of Peninsular Malaysia and its implication. *Bull. Geol. Soc. Malaysia, 46*, 2003, pp.365 –371

POLI, G., TOMMASINI, S. AND HALLIDAY, A.N., 1996. Trace element and isotopic exchange during acid–basic magma interaction processes. *Trans. R. Soc. Edinb. 87*, 225–232.

THOMAS, N AND TAIT, S.R. 1997. The dimensions of magmatic inclusions as a constraint on the physical mechanism of mixing. *Jour. Volcanol. Geotherm. Res. 75*, 167–178

VERNON, R.H.1984. Microgranitoid enclaves in granites: globules of hybrid magma quenched in a plutonic environment. *Nature 309*, 438–439

WILLIAM, Q, AND TOBISH, T. 1994. Microgranitic enclave shapes and magmatic strain histories: constraints from drop deformation theory. *Jour. Geophys. Res. 99*, 24359–24368

WIEBE, R.A. 1973. Relations between coexisting basaltic and granitic magmas in a composite dike. *American Jour. Sci., 273*, 130 – 151

WIEBE, R.A. 1974. Coexisting intermediate and basic magmas, Ingonish, Cape Breton, Island. *Jour. Geol., 82*, 74 – 87

WIEBE, R.A. AND WILD, T. 1983. Fractional crystallization and magma mixing in the Tigalak layered intrusions, Nain , Labrador. *Jour. Petrol. 29*, 383 – 411.

YONG. B.T., AZMAN A GHANI, KHOO, T.T AND SHAFARI MUDA. 2004. Benom Complex: Evidence of magmatic Origin. *Geol Soc Malaysia Bulletin 48*, 55 – 60

Manuscript received 27 March 2006