COMMENT

Contrasting volcanic suites in Naga Hills and their bearing on the tectonic evolution of the Naga Hills ophiolite belt, N. E. India.

(A comment on the paper by P. Venkataramana and A. K. Dutta, published in the Journal of the Geological Society of India, v. 30, no. 1, pp. 33-47).

The paper highlights two contrasting tectonic settings of the volcanic rocks associated with the ophiolites of Naga Hills. These authors have classified the mafic volcanics merely on the basis of Mg' value ($100 Mg/Mg + Fe^{+2}$ atomic) to high-Mg basalts (Mg' > 50) and low-Mg basalts (Mg' < 50), taking into consideration of differences in Archaean and modern low-K tholeiites shown by Gill (1979). Further, based upon normative composition, these volcanic rocks have been classified into two major groups viz., olivine tholeiite (olivine and hypersthene normative) and alkali basalt (nepheline normative). The criteria adopted are rather arbitrary and do not have adequate petrographic support when dealing with the Meso-Cenozoic volcanics of oceanic environment.

I have made a detailed survey of these volcanic rocks in the last one decade and arrived at a conclusion that spilites form the dominant mafic volcanics in the ophiolite belt of Naga Hills (Ghose and Singh, 1980; Singh and Ghose, 1981; Ghose *et al.*, 1986). This gets further support from high Na_2O content of these rocks (av. 3.82: Venkataramana and Dutta, 1987 and av. 4.02: Venkataramana *et al.*, 1986). Consequently, majority of these rocks show higher normative albite than anorthite. Mere presence of secondary calcite, which is ubiquitous in these rocks, is bound to affect the analytical results. Such high alkali content would consume greater silica (six times) in the formation of normative minerals (feldspars) and is bound to make the rock undersaturated (nepheline normative). Therefore, nomenclature of basaltic rocks of oceanic environment should be made with proper caution and due consideration must be taken of both the present petrography and chemistry. Such nomenclature as alkali basalt, merely on the appearance of normative nepheline, is misleading and may lead to misinterpretation of the tectonic setting of the eruptive rocks. Incidentally, the average composition of the Naga Hills volcanics (Venkataramana *et al.*, 1986) is comparable with the average spilites (Hyndman, 1985, p. 558).

It has been noticed that the mafic volcanics of Naga Hills are represented by spilite, pyroclastics (hyaloclastite, agglomerate, breccia, tuff and ash), basalt, amphibolite, glaucophane schist and eclogite in order of abundance, the last two being high-P subducted protolith of ocean floor rocks (Ghose *et al.*, 1986, 1987). Each of these individual rock types shows subtle chemical changes, both in magnitude and fractionation trend. The tholeiitic nature of the lava flows (spilite and basalt) with high concentration of transition metals viz. Ti, Ni, Cr, Co, Cu and V, with low Sr are characteristic of the Naga Hills mafic volcanics. The plots of discriminant elements (viz. V, Co, Y, Zr and Ti) of the mafic volcanics give unequivocal support of their similarity with the MORB distinguishing them from the basalts formed either at island arc or within plate environments.

The metabasic rocks, viz., eclogite, glaucophane schist and amphibolite differ significantly from the mafic volcanics both in the degree of abundance and distribution pattern of major and trace elements. High partitioning of incompatible RE and transition elements in the eclogites has been related to an early fraction of low degree partial melting of a fertile garnet lherzolite. They represent the oldest protolith as compared to the glaucophane schist and amphibolite. The latter shows enrichment of both Ni and Cr and depletion of Ba, REE and FeO/MgO ratio, suggesting that the parent rocks of these two have formed by high degree partial melting of a depleted mantle source.

The three distinct groups of basaltic rocks viz. a basalt/spilite, eclogite and glaucophane schist/amphibolite, characterised by distinct chemical changes, not only show a time gap between their formation but also exhibit differences in the degree of melting and heterogeneity of mantle.

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REPLY

The comments of Prof. Ghose are welcome. Our reply to the points raised by Dr. Ghose are as follows:

(1) Contrary to the contention of Dr. Ghose, grouping of the volcanic rocks associated with Naga Hills ophiolites into two suites on the basis of Mg# was suggested after much thought. The Mg# (100 Mg/Mg + Fe atomic) was used as an index of differentiation, as this ratio is known to be a sensitive indication of mafic mineral/silicate liquid fractionation (Frey and Prinz, 1978). It is to be noted that Mg#, as an index of differentiation, has been widely adopted for Mesozoic and Tertiary lavas of oceanic origin (*cf.*, Bryan, 1979; Wilkinson, 1982; Cameron, 1965). In the case of Naga Hills ophiolites, the two lava types (high-Mg with Mg# 52 to 71 and low-Mg lavas with Mg# 23 to 49) give significantly different trends when Mg# is plotted against various major and trace elements. The difference in their mode of

crystallisation and depth of origin is also well reflected in O' Hara's olivine projection on the CS-MS-A plane. Petrographically also the two lava types are different: The high-Mg lavas are characterised by subophitic texture and comprises plagioclase (An_{50-70}), diopsidic augite, olivine and titaniferous magnetite in a groundmass containing microlaths of plagioclose, augite, opaques and palagonite. On the other-hand, the low-Mg lavas typically have pilotaxitic texture and comprise plagioclase (An_{30-50}), pigeonite, augite in a groundmass of fine-grained K-feldspar, plagioclase, palagonite and probably nepheline.

(2) We agree with Dr. Ghose that normative Ne and Albite depends on Na_2O and any contamination by sea-water would affect the normative mineral composition. However, we must point out that normative minerals were used for rock nomenclature and have not been used for petrogenetic discussion or for interpretation of the tectonic setting.

(3) Though some of our analysis are comparable to the composition of spilite, we were constrained to avoid using the term as one of the referees (Prof. I. G. Gass, Open University, Milton Keynes) who reviewed the Memoir on Nagaland ophiolites (G S I Memoir v. 119, 1987) objected to its use on the ground that it has neither petrogenetic nor has tectonic significance.

(4) In view of the fact that elements like V, Cr, Co, Ti, Ni, Y, Zr, Nb, REE, Ta and Hf are comparatively insensitive to sea-floor alteration processes and metamorphism (cf., Humpris and Thompson, 1978; Furner, 1980; Menzies *et al.*, 1979) some of these elements were used in well documented discriminant diagrams to distinguish the two volcanic suites associated with the Naga Hills ophiolite belt and for interpreting their tectonic setting,

(5) Dr. Ghose's observation that eclogites, glaucophane schists and amphibolites associated with Naga Hills ophiolites show subtle chemical differences when compared with basic volcanics is a welcome addition to our knowledge on the Naga Hills ophiolites. We, however, have no suggestions to offer at present.

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