Geochemistry and geotectonic implication of basic volcanic rocks in the Lower Gondwana sequence (Upper Palaeozoic) of the Sikkim Himalayas

SIR – Sinha-Roy & Furnes (*Geol. Mag.* **115**, 1978, 427–36) described chemical and Rare Earth Element characters of mantle-derived basic lavas interbedded with the basal Gondwana (Late Palaeozoic) pebble-slates from the Rangit tectonic window, Sikkim Himalayas. They have ignored the nature of contemporaneous volcanics and volcaniclastics associated with the same unit from the foothill belt or those associated with homotaxial beds in other adjacent areas of the same or different tectonic belts (Acharyya, 1973). Geochemical characters of only basic alkaline variety of the contemporaneous calc-alkaline Panjal volcanic suite from Kashmir have been compared with those of Sikkim. Available geological data on Late Palaeozoic Himalayan volcanics have been supplemented in this note and their implications on the geotectonic models proposed by Sinha-Roy (1976), Sinha-Roy & Furnes (1978) or that proposed by Acharyya (1973, 1979*a*), Ray & Acharyya (1976) involving the Himalayas and the Gondwanic India have been discussed. It is shown that the later models are more consistent with total available data.

Rhyolitic vitric tuff beds and rhyolitic and andesitic rock fragments have been recorded from the same basal Gondwana pebble-slate from the foothill zone immediately to the S (Acharyya, 1972, 1973). Along the foothills, the formation may be traced eastward up to the Abor type area with increased pyroclastics and volcanic intercalations E of 91° E (Acharyya, Ghosh & Ghosh, 1975). Lower Gondwana sporomorphs have been recorded recently from the Abor intertrappeans in the Siang (Dihang/Brahmaputra) valley type area (Anon, 1977; Laskar & Roy Chowdhury, 1979).

In the Tibetan sedimentary belt, overlying the Central Crystallines, rhyolitic or tuff pebbles have been reported from the lithologically similar and homotaxial Lachi Pebble-Bed, North Sikkim (Auden, 1935) (NE corner of figure 1B of Sinha-Roy & Furnes, 1978). Sporadic occurrences of spilites homotaxial with Late Palaeozoic tilloidic conglomerates have been recorded from central Nepal Tibetan zone by Le Fort (1975).

The Panjal Trap of Kashmir was regarded essentially as an alkaline suite with 'a compositional range from alkali basalt to high alumina basalt' by Sinha-Roy & Furnes (1978). Instead, it is essentially calc-alkaline, containing in addition to basalt nearly equally dominant andesite with minor components of rhyolite, dacite, trachyte, spilite and alkali basalt (Ganju, 1944; Hazra & Prasad, 1963; Nakazawa & Kapoor, 1973; Chatterjee, 1974; Pareek, 1976). The calc-alkalinity of the suite is also corroborated by their chemical characters (Ganju, 1944; Pareek, 1976).

Similarly the Abor Volcanics are also calc-alkaline and consist of basaltic to andesitic flows, subaerial to aquagene rhyolitic-dacitic tuffs and pyroclastics (Acharyya, 1976; Talukdar & Majumder, 1976). SiO_2 content of basaltic suite varies from 48.2% to 53.9% (Laskar & Roy Chowdhury, 1979).

The Late Palaeozoic volcanics and volcaniclastics though not well developed in the Sikkim–Darjeeling area broadly correspond to the same suite.

Contrary to the claim by Sinha-Roy & Furnes (1978), the lithofacies and also the biota of the sedimentary rocks associated with or immediately underlying and overlying the calc-alkaline Panjal–Abor and related volcanics, especially the pebble-slate-diamictite-bearing formations from Kashmir, Sikkim–Darjeeling, Arunachal Pradesh and other areas, are remarkably similar over a distance of 2400 km (Acharyya, 1973, 1976, 1979*a*). The diamictite- and pyroclastics-bearing formations and the associated volcanics also have wide lateral extensions and occur in the Lesser and the Tibetan Himalayan belts, structurally underlying and overlying the Central Crystallines respectively and also in the Trans-Himalayan Aghil Range, NW Tibet and Lhasa area, SE Tibet (Ray & Acharyya, 1976; Acharyya, 1979*a*). The Late Palaeozoic marine faunae associated with the Himalayan diamictites are often followed by *Glossopteris* flora or microflora within the continental to paralic carbonaceous sediments. This relation is also valid for the Aghil Range. Much of this lateral scatter is an effect of Himalayan nappe movement as will be described later.

Stratigraphic and structural studies in the Lesser Himalayas, the Central Crystallines and limited areas of the Tibetan Himalayas, and available Rb/Sr radiometric dates on granitoids and metamorphics from western and central sectors indicate essentially pre-Tertiary magmatic-metamorphic derivation with Himalayan (Oligo-Miocene) neometamorphism (Acharyya, 1979*a*; Mehta, 1977; Frank, Thoni & Purtscheller, 1977; Hamet, 1977). There is repeated reactivation during Precambrian, Early

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Palaeozoic and Late Palaeozoic. The Late Palaeozoic event is corroborated by clustering around 350–300 Ma of Rb/Sr total-rock isochron, K/Ar total-rock and respective minerals dates. An early Mesozoic regional thermal or other disturbance is also indicated by consistent K/Ar total-rock ages from widely separated areas of eastern, central and western sectors (Acharyya, 1979*a*).

Broad coincidence in time and space between the Late Palaeozoic reworking of granitoid and metamorphic rocks in the Himalayas as well as in South-Central Tibet, and calc-alkaline volcanism in these areas, suggest partial melting of *thickened and shortened continental crust*, possibly as a result of increased geothermal heat at their base. Contemporaneous but subordinate alkaline basalts may also be related to crustal-shortening process with mantle-reaching fractures.

Neither the total compositional characters of the Late Palaeozoic volcanics, the lithofacial characters of the associated sediments, nor the lack of any central symmetry in their distribution extending from the outer Lesser Himalayan to inner Tibetan zones is consistent with continental, oceanic or even 'mature' back arc rifting (Lordkipanidze, Zakariadze & Popolitov, 1979).

Late Cenozoic calc-alkaline and subordinate alkaline volcanics in the Turkish–Iranian plateau and possibly those of Tibetan plateau have also been ascribed to partial melting of shortened and thickened continental crust with minor mantle-derived alkaline components (Dewey & Burke, 1973; Sengör & Kidd, 1979).

As regards geotectonic relation between the Gondwanic India, the Himalayas and the Tibet, there is lack of direct physical connection between intracratonic continental Gondwana basins of Peninsular India and the paralic, fluxoturbiditic and volcani-sedimentary Himalayan Gondwana basins (Acharyya, 1973, 1979*a*). The Himalayan Gondwana and other pre-Tertiary sedimentary and metamorphic rocks of the Lesser Himalayas were regarded as parautochthonous by Sinha-Roy (1976) but were considered essentially allochthonous by Acharyya (1973, 1979*a*, *b*) and Ray & Acharyya (1976). Sedimentary, magmatic and metamorphic histories of the Himalayan pre-Tertiary rocks are broadly comparable and coeval with those of South-Central Tibet, indicating active plate marginal condition rather than those of the Precambrian consolidated Peninsular Indian shield with half-graben-type continental Gondwana basins. South-Central Tibet possibly represents the homeland for the Himalayan nappes, which essentially conceal the subjacent shelf-miogeosynclinal Mesozoic–Cenozoic sediments (Ray & Acharyya, 1976; Acharyya, 1979*a*, *b*).

Besides evidence discussed earlier, the model has also been corroborated by some recent finds, a few of which are mentioned here. In the Siang (Brahmaputra) valley, representing the Abor type area, thick flyschoid sediments resembling the frontal zone Palaeogene–Early Neogene sediments and locally containing angiospermous leaf assemblage (C. Tripathi, G.S.I., pers. comm.) occur deeply enclosed within (about 50 km N of the frontal zone) and structurally below the nappe rocks, consisting of Abor Volcanics and Miri Group (Palaeozoic). In the U.P. Himalayan foothills (west-central sector) sporadic but consistent Late Mesozoic–Palaeogene marine faunae have been recorded by the present author located between the Ganges valley and the Nainital foothills over 170 km apart and occurring on the subthrust side of the Blaini–Krol–Tal (Krol nappe) succession (Acharyya & Ray, 1980). The overthrust succession contains Late Palaeozoic Gondwana diamictite and lower (Permian) and upper (Early Cretaceous) Gondwana micro-floral intercalations (Acharyya, 1976). The Krol nappe rocks of the western Himalayas structurally correlate with the allochthonous Gondwana and associated metasediments of the eastern Himalayas. Some of the Himalayan windows in the western and central sectors, exposing Late Mesozoic–Palaeogene rocks are located 20–70 km N of the foothill zone (Acharyya, 1979*b*).

It may thus be concluded that dominantly calc-alkaline Late Palaeozoic volcanism in South-Central Tibet, and Lesser and Tibetan Himalayan nappe homeland is possibly caused by partial melting of thickened and shortened continental crust. Late Palaeozoic and earlier phases of repeated basement remobilization and crustal thickening process appear to be located N of Palaeozoic–Mesozoic northern marine shelf of the Gondwanic India. There is as yet no compelling evidence in favour of rift-related volcanism and crustal thinning either on the northern edge of Gondwanic India nor in the Lesser Himalayan nappe rocks.

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Alkaline vs calc-alkaline continental magmatism: implications for Gondwanic Rift in the Himalayas

SIR – In the discussion of our paper (Sinha-Roy & Furnes, 1978) Acharyya has raised several points that need clarification. As some aspects of Himalayan geotectonics that we considered to be beyond the scope of our paper which in fact described for the first time the Upper Palaeozoic volcanics from Sikkim Himalayas have been indicated by him, an elucidation of these aspects would be in order for this communication. This we propose to do under the following topics in order to deal clearly and specifically with the issues that pertain to the discussion.

1. Geochemistry of Himalayan Gondwanic volcanics

In our paper (Sinha-Roy & Furnes, 1978) we concluded from the major and trace element geochemistry that the Upper Palaeozoic basic volcanics of Sikkim are strongly alkaline, and that most probably these were derived by a small degree of partial melting from a titan-phlogopite bearing peridotite mantle. The steep slope of the REE pattern compares well with that of potassic basalts and nephelinites (fig. 3, cf. Sinha-Roy & Furnes, 1978), and the average Y/Nb ratio of these volcanics is 0.73 (± 0.07). The latter feature is an additional evidence for the alkaline nature of the rocks, because Y/Nb ratios of calc-alkaline basalts are around 10 or higher (Pearce & Cann, 1973).

From the geochemistry of the rocks and the general geology we fail to find any link of the situation under discussion with volcanic evolution of the marginal and interarc basin that is dealt with by Lordkipanidze, Zakariadze & Popolitov (1979), and quoted by Acharyya. Nonetheless, the geochemistry of Sikkim volcanics and the varied magma types of Panjal and Abor volcanics fit in the geochemical scheme indicated by Lordkipanidze *et al.* (1979) for rift tectonics, and in terms of TiO_2/K_2O and Zr/K_2O ratios Sikkim volcanics match well with the chemistry of East African rift potassic series. In view of these and the geochemistry already reported, the alkaline character of the volcanics is beyond dispute.

The Panjal Traps of Kashmir are referred to by Acharyya as a calc-alkaline suite, although one of the references (Nakazawa & Kapoor, 1973, p. 91) he cited in favour of this conclusion has categorically mentioned these volcanics as alkaline basalt. Our information on and designation of magma type to the Panjal Traps were drawn from Nakazawa & Kapoor (1973), a fact that was made amply clear in our paper (Sinha-Roy & Furnes, 1978, p. 434). A variety of lava types has been reported from the Panjal volcanics, but it would require rigorous geochemical work to prove their calc-alkaline affinity. In fact, Wadia (1957) considered these rocks as a differentiated basic volcanic suite. In drawing a correspondence between the volcanics of Kashmir and Sikkim we also mentioned the differences in their chemistry (Sinha-Roy & Furnes, 1978, p. 434), and it was made clear that 'although the two volcanic suites belong to a similar geologic age, but are widely separated in space, the magma type and the volcanic history in the two areas may not be identical'. The differences in the magma type of the known Upper Palaeozoic volcanic areas of the Himalayas, and as would be evident from the following, the variety of the volcanic rocks described from each area is consistent with continental rift magmatism.

2. Continental rift magmatism

In a summary of the characteristics of rift systems, Neumann and Ramberg (1977) stated that 'rift magmatic products are generally mildly to strongly alkaline, but tholeiitic and calc-alkaline rock types may occur'. The type of rift magmatism is certainly related to the general tectonic situation of the region as well as to the stage of rift development. A few examples would suffice to illustrate the variable compositions of the volcanic rocks that are generated through continental rift magmatism.

Evidence for a progressive change from continental rifting to incipient ocean floor formation, i.e. various stages of rifting, is provided by the development of the southern part of the Red Sea (Gass, 1970). This progression is reflected in the recent magmatic evolution. Thus, the islands of Hanish-Zukur group at the southern end of the Red Sea, and which overlie the continental crust consist of strongly alkaline basalts and trachytes (Gass, Mallick & Cox, 1973). Approximately 200 km farther N, however, on the island of Jebel at Tair which is underlain by young oceanic crust, the basalts are compositionally similar to ocean-floor basalts, and on the island of Zubair, located between Jabel at Tair and Hanish-Zukur group, the basalts are mildly alkaline (Gass, Mallick & Cox, 1973). Continental rift-related volcanism in the Danakil depression, Ethiopia, has given rise to a complete differentiation series with several rock types like basalt, trachyte, alkali rhyolite and basaltic andesite (Barberi *et al.* 1970).

Many examples of mildly to strongly alkaline magmatism are provided by the long history of development of the African rift valleys from Triassic time to the recent (e.g. Scrutton, 1973). In the Kenya rift basalts, trachytes and phonolites have erupted since Miocene time with a general progressive decrease in the alkaline nature with time (King & Chapman, 1972).

Antarctica offers an example of relatively close spatial and temporal relationship between strongly alkaline and calc-alkaline volcanics. In west Antarctica along the Transantarctic mountains, the Ross-Wedded Province (Ford, 1972) is supposed to represent an area of crustal thinning (Smithson, 1972) with recent eruptions of strongly alkaline lavas (basanites, trachytes and phonolites) of the McMurdo Volcanic Group (Sun & Hanson, 1976; Kyle & Rankin, 1976). In the westernmost Antarctica, adjacent to the Ross-Wedded Province calc-alkaline magmatism has taken place since the Early Jurassic, and at present it is active on the South Shetland Islands (Saunders, Tarney & Weaver, 1980). Gondwanic volcanic associations with possible graben tectonics are represented by Carboniferous andesites and keratophyres in Graham Land, Antarctica (Adie, 1972).

The late Cenozoic rift system of the Basin and Range Province, North America, shows a magmatic evolution that contrasts strongly, for example, with the African rift system. Here typical calc-alkaline volcanism gave way to a bimodal suite of basalts and rhyolites some 20–30 Ma (Elston, 1977).

From the consideration of the general characters of continental rift-related magmatism we find no reason to assign the Upper Palaeozoic volcanics of the Lower Himalayas any other tectonic significance than distensional tectonics.

3. Sedimentary response of Himalayan Gondwanic rift

The stress on the similarity of the pebble-slate (diamictite)-bearing formation all along the Himalayas by Acharyya is in fact not in contradiction to what was mentioned in Sinha-Roy & Furnes (1978, p. 434), where the remarkable persistence of the basal boulder-bed unit of the Himalayan Upper Palaeozoic sequences is considered as one of the evidences for continental rift tectonics, and generation of a linear graben structure where the initial depositional facies comprises coarse clastics and conglomerates. The lithological heterogeneity mentioned there pertains to the overlying sedimentary sequences, and relates to the sedimentological response to evolving rift structure. In the Kashmir area the plant-bearing sandstones and shales occurring above the Agglomeratic slates and Panjal volcanics become calcareous upwards and grade into marine Permian limestones developing into Triassic carbonate sequences. Eastward in the Kumaon Himalayas the Blaini boulder-bed is overlain by Permo-Triassic Infra-Krol (shale-carbonate, often sulphurous, cf. Krishnan, 1956), and Krol carbonate sequence. The overlying Tal Formation marks a drastic change in lithofacies to detrital sequences of mainly arenites. In western Kashmir and Hazara area the Upper Carboniferous Tanakki boulder-bed is overlain by purple sandstone and shale that pass up into dolomite intercalated with basaltic lava-flows (Krishnan, 1956). The Jammu Limestone, located *c.* 25 km south of the Main Boundary Thrust and overlain unconformably by Eocene nummulitic shale, both features meaning a possible autochthonous position for the sequences, contains Panjal-type volcanic agglomerates at the base (Wadia, 1928), and serpentinized dunite dykes (Gansser, 1964). Assuming either a Permo-Carboniferous (Wadia, 1928) or even an older (Raha & Sastry, 1973) age for these limestones, these rocks reflect the unstable platformal character of the basin-margin at the northern edge of the Indian shield. These basin-marginal sequences are well developed in the Salt Range where the Cambrian evaporites are unconformably overlain by the Upper Carboniferous boulder-bed that passes up into continental to shallow marine shales, culminating in Permo-Triassic platform carbonates. The Lower Permian Speckled Sandstone contains gypsum bands (Krishnan, 1956). A laterite horizon separates Triassic and Jurassic limestones. Thus, the Salt Range Late Palaeozoic–Mesozoic rock sequences are consistent with sea-level fluctuations and even non-depositional cycles at the margin of the evolving rift basin.

In central Nepal, Permo-Carboniferous Benighat Slates with boulder-beds and lenses of carbonates rest unconformably on Early Cambrian Dhading Dolomite along contacts that show traces of laterite (Stöcklin, 1980). This relation corresponds well with lateritic palaeo-weathering surface reported between the Upper Palaeozoic pebble-slate and the Riphean-Lower Cambrian Buxa Dolomite from the Rangit valley, Sikkim (Sinha-Roy, 1972). The boulder-bed horizon in central Nepal is succeeded upward through a carbonate sequence by slates and quartzites containing synsedimentary metavolcanics and gabbroic/dioritic intrusives which are suspected to be equivalent to the Panjal Traps (Stöcklin, 1980). Eastward in Sikkim, as enumerated in Sinha-Roy & Furnes (1978), the Permo-Carboniferous lithology is essentially paralic with sandstones, carbonaceous shales and coal beds (the former two lithologies often contain traces of phosphate (unpubl. data of SSR)). The paralic lithology contrasting strongly with the Lower Himalayan Upper Palaeozoic–Early Mesozoic carbonate facies of the Western Himalaya, including most part of Nepal, persists in Bhutan and a great part of Arunachal Pradesh in the E. In Abor area, however, apart from the paralic sequence, the volcanics are associated with carbonate-quartzite sequences.

The purpose of the above brief description of the Upper Palaeozoic–Early Mesozoic sedimentary sequences of the Lower Himalayas is to bring out the variations in the lithofacies within the Himalayan basin. This type of variation and the presence of platform/paralic sequences with sporadic gypsum-sulphur-phosphate occurrences are indeed consistent with rift valley sedimentation as judged from the Red Sea pattern (Hutchinson & Engels, 1970).

4. Geotectonic considerations

Although whether or not there has been direct physical connection between the intracratonic Peninsular Gondwana basins which are indeed rift graben (or half-graben) structures, and the Himalayan Gondwana basin is a point that is not central to the model of rift origin of the Himalayan Gondwana basin, it may be mentioned that no convincing evidence has yet emerged to refute the idea of such connection proposed by many authors (Fox, 1931; Ahmad, 1961; Sastry & Shah, 1964). Faunal and lithological differences that might exist between these basins and the Tethyan domain are in response to the presence of a continental mass termed as the Central barrier (Saxena, 1971), geanticline (Wadia, 1966), miogeanticline (Sinha-Roy, 1977*a*) that separated the Himalayan Gondwana basin and the Tethys in the N. It is this continental mass that rifted away from the Indian continental margin to generate the Himalayan rift basin with volcanics in the Upper Palaeozoic times, and this continental mass (microcontinent) was 'digested' in the Himalayas during the Himalayan orogeny in Cenozoic times (Sinha-Roy, 1976).

In Sinha-Roy (1976) the Himalayan Gondwana rocks are considered to be parautochthonous, a view still maintained by SSR, but such a status has not been given to all the metamorphic rock sequences of the Lower Himalayas as indicated by Acharyya. The parautochthonous character of the Upper Palaeozoic–Mesozoic rock sequences of the Lower Himalayas is exemplified in the different windows where these rocks occur unconformably over the older substrate. That these rock sequences are parautochthonous is an unavoidable conclusion in the context of the suggestion that even the crystalline older rock sequences (Almora-Garhwal, etc.) that tectonically overlie the former rocks could themselves be parautochthonous (Saxena & Rao, 1975; Hashimoto, Ohta & Akiba, 1973). Tectonic and geologic considerations, however, suggest an allochthonous nature of the crystalline rocks, but the magnitude of their dislocation seems to have been highly overestimated by Acharyya because he suggests that these rocks, including the Gondwana sequence, have been transported from their 'homeland' in South-Central Tibet. This involves a stupendous amount of nappe transport, but the magnitude of thrusting of the lower Himalayan rocks has been suggested to be only 14 km (Frank & Fuchs, 1970) or 20 km (Stöcklin, 1980). If the large-scale transport of thrust-sheets from Tibet is correct then it would lead to an interesting situation where the Himalayan nappes being generated in Tibet travelled from N to S across the Indus Suture zone, and concealed the shelf-miogeosynclinal sediments, but the eugeosynclinal counterpart remained unaffected or undefined. This quite unlikely situation would also relegate thrusts such as the Main Boundary Thrust and the Krol thrust at the Himalayan foothills to the status of sub-horizontal thrusts, extending *over* the Indus Suture and being rooted somewhere in Tibet. The existence of Late Mesozoic–Palaeogene rocks below the crystalline thrust has been known for many years, for example, in the Kumaon Himalayas (West, 1939), and these rocks are reported from many areas in Nepal (Frank & Fuchs, 1970). These rocks occurring in isolated windows neither give an indication of the magnitude of thrust transport of the tectonic cover nor do they disprove the existence of the Himalayan rift basin. In fact, the Himalayan basin, originating as a rift valley, evolved into a sedimentary basin with restricted deposition of Late Mesozoic–Palaeogene platform facies that got deformed and thrust over by the older rocks. The available information is consistent with the derivation of the crystalline thrusts of the Lower Himalayas from the Central barrier (Frank & Fuchs, 1970) or from the microcontinent (Sinha-Roy, 1976), rather than from South-Central Tibet.

If, as contended by Acharyya, the Himalayan rocks, including the frontal Gondwana sequences, are derived from Tibet, then radiometric age considerations into repeated reactivation of these rocks from Precambrian times have no relevance to Himalayan geology. On the other hand, the similarity and the homotaxiality between the Precambrian–Proterozoic rock sequences of N India and the rocks of similar age of the Himalayas (Valdiya, 1964) justifies the geochronologic considerations in that these provide information on the tectonic/thermal events in the Himalayan sector. Apart from a strong Cenozoic (50–10 Ma) tectonometamorphic event, Late Palaeozoic (Hercynian) and Precambrian events (Mehta, 1977) are consistent with polyphased deformational structures and polymetamorphism of the Himalayan crystalline rocks (Sinha-Roy, 1977*b*, 1979). The Late Palaeozoic event, considered to be responsible for graben formation (Mehta, 1977) fits well with volcanic response to rifting in the Himalayan Gondwana basin.

In the discussion on the geotectonic implications of Sikkim volcanics in Sinha-Roy & Furnes (1978), consideration of volcanics of similar age in other geotectonic belts, namely, Tibet and Agil Range, Karakoram, is avoided, but not ignored. The reason obviously is that the discussion was restricted to the Himalayan domain. Moreover, the magma types and the geochemistry of these volcanic rocks are not clearly known, and hence, as these details are also not forthcoming from the discussion by Acharyya, it is difficult and possibly undesirable to correlate one rock suite with another in different tectonic belts on the basis of contemporaneity of events. Basic volcanic rocks occur extensively in W. Yunnan, the Nyenchen Thangla belt of S Tibet, and continue into Karakoram (Gansser, 1964; Chang, 1963). These Upper Palaeozoic volcanics and associated sedimentary sequences are related to early stage of rifting of neo-Tethys, and to the separation of Tibet from India (Sinha-Roy, 1978). Similar separation of Central Iran–Afghanistan block by Palaeozoic fragmentation of India-Arabian platform was suggested by Stöcklin (1974). It is this phase of rifting that created the Himalayan microcontinent and the Himalayan rift-basin with volcanics. It is the mechanism of contemporaneous magma generation in different geotectonic domains that links the Upper Palaeozoic volcanics of the Himalayas with those of Tibet and Karakoram. It is difficult to conceive of any type of 'Himalayan nappe movement' that could cause 'much of this lateral scatter' in the Upper Palaeozoic volcanics occurring in Karakoram, Tibet, Yunnan and Himalayas, as suggested by Acharyya. There is also no evidence for the conclusion that broad coincidence in time and space between Late Palaeozoic rocks and calc-alkaline volcanism in the Himalayas and Tibet might suggest partial melting of thickened and shortened continental crust. Late Cenozoic calc-alkaline magmatism is surely not relevant in the present discussion because the geotectonic situation and hence the volcanism in Upper Palaeozoic times with which the present discussion is concerned could not have been similar to Cenozoic collisional tectonics and related magmatism.

Basement reactivation model (Dewey & Burke, 1973) may be one of the explanations for the double-thickness of Tibetan continental crust which is a consequence of neo-Tethys subduction in Late Mesozoic–Cenozoic times, but no evidence exists for a compressional plate boundary at the northern marine shelf of India in Palaeozoic times. The information contained in Sinha-Roy & Furnes

(1978) and in the present discussion compel us to reiterate distensional Upper Palaeozoic tectonics in the Himalayan region. The supposed derivation of the Himalayan nappes from Tibet, and the idea of the Upper Palaeozoic volcanics contained in these nappes being generated by partial melting of thickened continental crust (Tibet?) are, at the least, highly constrained in the present state of knowledge.

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