DISCUSSION

1

(Comment on the paper, **Petrography and Geochemistry of the Sandstones of Murree Group around Laren, Udhampur, Jammu Himalaya'** B. P. Singh, B. K. Fotedar and A. S. Rao, published in Journal of the Geological Society of India, Vol. 36, No. 5, 1990, pp. 502-511).

The paper, in brief, is an additional information on the palaeoenvironment of the Murree Group.

There is very little information on the geochemistry of the sediments. Dr. Singh and his team have not given due attention to the mineral feldspar.

It is not clear whether feldspar in the Murree sediments is authigenic or not. Authigenic feldspars are very commonly formed in volcaniclasties associated with marginal seas, island arcs and subduction zones. In the absence of geochemical data, the interpretation on palaeoenvironment drawn for Murree Group is premature.

The chemical analysis (Table IV) for the samples of Lower and Upper Murrees shows very little difference. It is generally accepted that depositional environment conditions from Lower to Upper Murrees changed from marine to non-marine. This would also cause changes in chemical conditions. The insignificant variation in chemical analysis of the Lower and Upper Murrees needs some more clarification in the light of the change in environment of deposition.

The granodiorite source for the sandstones clearly indicates its inflow from the uprising Himalaya. The incorporation of terrestrial sediments into the near-shore/ brackish environment can well be understood in the light of the fact that the then sea was under constant regression. However, the chemical influence of the near-shore/brackish environment on the terrestrial sediments seems to have been overlooked by the authors.

More geochemical investigations are required to ascertain the physico-chemical environment of deposition, particularly when the sea was under gradual regression and the fresh-water conditions were setting in slowly but steadily.

Department of Archaeology
Deccan College, PGRI, Pune 411 006

R. K. GANJOO

Reply

We want to thank Dr. Ganjoo for his kind interest in our work on the geochemistry of sediments, and particularly the mineral feldspar. We wish to say that this mineral is present in small amount and that too mostly in altered form. In general, there is absence of authigenic feldspar.

We are of the opinion that the Lower Murree rocks were deposited as mixed tidal flat sediments and Upper Murree rocks as sandy tidal flat deposits. The tidal influence is well-marked by the presence of herringbone cross-bedding. These similar physicochemical conditions have not changed the chemical composition of the rocks much.

The granodioritic source has been inferred on the basis of least mobile constituents. We are not ruling out the presence of sedimentary rock fragments and low to medium-grade metamorphic minerals. Further, the palaeoslope reversal model proposed by Srivastava and Casshyap (1983) clearly explains the drastic change in relief of the land due to the rising Himalaya in Middle Eocene times causing a complete palaeoslope reversal from an earlier northward direction to a southward tilted one.

We are still working on the sedimentological problems related to the Murree Group of rocks and want to substantiate our findings with further research.

P.G. Department of Geology
University of Jammu, Jammu 180001

B. P. SINGH

Reference

SRIVASTAVA, V. K. and CASSHYAP, S. M. (1983) Evolution of Pre-Siwalik basin of Himachal, Himalaya. Jour. Geol. Soc. India, v. 24, pp. 134-147.

2

(Comment on the paper, '**The Albitite Line of Northern Rajasthan—A Fossil Intracontinental Rift Zone**'. Sumit Kumar Ray, Published in Journal of the Geological Society of India, Vol. 36, No. 4, 1990, pp. 413–423)

The Albitites of Rajasthan belong to the category of linear albitites. The extensive occurrence of albitites along well defined fissures with no visible links to large igneous bodies suggests their genesis from postmagmatic chemically active solutions related to acid magmatism (silicic magmas of alkalic and subalkalic character), the crystallization of feldspars having been very much aided by volatiles as shown by the ubiquitous presence of calcite and fluorite. The association of pyroxenite and amphibolite need not necessarily mean positive cogenetic relation.

The author mentions modal and normal albite as constituting 80–90% while the ab values given in the Table (Table I, p. 417) do not exceed 65%. Cannot the mafics be products of contamination? Cannot they be just xenoliths brought up by the albitite solutions? The scatter in the silica-alkali diagram suggests complete lack of a distinct differentiation trend.

It is felt that albitites can be related to post-Delhi acid magmatism. Their exact stratigraphic position has to be determined keeping in mind their possible affiliation to the Malani volcanics or the post-Cretaceous alkaline massifs. The use of the term 'Albitite Line' on the lines of the Andesite line at this juncture is, however, considered too premature.

10, Bapuji Apartment
Rajendra Prasad Road, Dombivli (E) 421 201

S. VISWANATHAN

Reply

Viswanathan has put forth some suggestions regarding genesis of the albitite and ultramafic bodies described in the paper. Unfortunately, no evidence or argument supporting these suggestions has been given and as such no critical discussion on these suggestions is possible.

Albitite is a descriptive term and there are different genetic types of albitites. (Many text books and research papers, in addition to those mentioned by Viswanathan, deal with albitites). Smirnov (1976) has discussed only one such genetic type, which is a product of alkali metasomatism (and closely associated with greisenisation). The fact that the albitites of Rajasthan belong to a different genetic type (as is evident from their $Na_2O : K_2O$ ratio and trace element content given in Table I), indicates that the views of Smirnov on the genesis of albitites are not applicable in the present case. The term 'linear albitites' has also been taken by Viswanathan from Smirnov (1976). Moreover, Viswanathan's suggestion on the genesis of the albitites is based on the assumption that they have no visible links with large igneous bodies. This assumption is not tenable in view of the fact that large albitite dykes and plutons have been described by Ray (1987) and Ray and Ghosh (1989). Viswanathan has mentioned about a hypothetical 'post-magmatic chemically active solution' which, according to him, has emplaced the albitites. Formation of large intrusive bodies from any such solution is difficult to explain. It is interesting to note that according to Smirnov (1976, p. 204) albitites (the type described by him) developed from 'chemically active solutions resulting from ultrametamorphism'. Viswanathan in his comments has dropped the reference to ultrametamorphism and describes the solution as 'post-magmatic'. In the next paragraph, however, Viswanathan switches over to a different type of solution, viz., 'albitite solution' to explain the formation of the albitites. It is not clear what is meant by 'albitite solution'.

It has been suggested that the ultramafics may be xenoliths. A careful reading of the paper (Ray, 1990) would have revealed that in the proposed genetic model, the ultramafics have been explained as separate cumulate fractions brought up by the albitites.

The alkali-silica diagram in my paper has been used in a different context and the scatter in the diagram has been explained in the paper.

The term 'Albitite Line' has been introduced in my paper as a descriptive term, to describe an 170 km long crustal feature. The term 'Andesite Line' has altogether different connotation.

The normative albite content given in Table I (p. 417, Ray, 1990) has been misquoted in the comments. Table I (*op cit.*) records 81.90% ab content. The reference list is also not correct.

Geological Survey of India
Calcutta 700 016

SUMIT KUMAR RAY

References

RAY, S. K. (1987) Albitite occurrences and associated ore minerals in the Khetri copper belt, north-eastern Rajasthan. Rec. Geol. Surv. India, v. 113, pt. 7, pp. 41-49.

RAY, S. K. and GHOSH, S. P. (1989) The albitite dykes of Dudu sector in Jaipur district, Rajasthan, and their tectonic significance. Indian Journal of Geology, v. 61, no. 2, pp. 128-132.

SMIRNOV, V. I. (1978) Geology of mineral deposits. Mir Publishers. Moscow, pp. 520.

3

(Comment on the paper, '**Kinematic Framework of Heterogeneous Deformation within Pratapnagar Thrust Sheet, Bhagirathi Valley, in Lesser Garhwal Himalaya, U.P.**' S. C. Bhatt and P. S. Saklani published in Journal of the Geological Society of India, Vol. 36, No. 3, 1990, pp. 247-261).

Bhatt and Saklani (1990) have shown that different shapes of strain ellipsoids within Pratapnagar thrust sheet in the Garhwal Himalaya are linked to their spatial positions within the thrust sheet. While such a relation is common in many areas, the results presented by the authors need clarification.

1. Bhatt and Saklani (1990) have applied the R_f/ϕ technique to determine the ellipticity (R_S) on the XZ and YZ sections of the finite strain ellipsoid (for sample 5 the data for YZ section is wrongly shown for XY section in Table I (A). The authors have not discussed the effects of volume change and of later deformations, if any, in this analysis.

The ellipticity data for all the samples, except sample 8, fall in the field of apparent flattening in Flinn diagram (Fig. 6). This implies that the area as a whole was subjected either to true flattening or to volume change along with any other strain condition (plane strain/constrictional strain/flattening strain). In the kinematic interpretation Bhatt and Saklani (1990) are of the opinion that volume loss was one of the strain factors in the area (p. 260). If change of volume did take place in the area, the measured strains would depart from the true strain.

From the Rf/ϕ diagrams the ellipticity data for sample 8, shown in Table IB, are found to be correct. However, in Flinn graph (Fig. 6) as well as in Hossack's plot (Fig. 7) this sample is wrongly shown in the field of prolate ellipsoid. The K-value for this sample is also wrongly shown as 8.106 instead of its correct value of 0.130. I wonder how all these errors for a particular sample could occur at several places. When we consider these errors, it is obvious that the interpretations drawn by Bhatt and Saklani (1990) regarding constrictional type strain at this sample locality need modification.

2. It is not clear as to how Bhatt and Saklani (1990) have determined the values of principal logarithmic strains (E_1, E_2, and E_3) from two dimensional *strain ratios* (*see* Tables II A and B), since mathematically *it is impossible to determine the absolute values of two unknown variables from their ratio.*

3. The kinematic picture presented by Bhatt and Saklani (1990) is mainly based on the calculation of two parameters – $\bar{Y}_{Oct}$ and $\bar{E}_S$. It should be pointed out that the calculations of these two parameters are dependent upon the

assumption of irrotational strain path. Bhatt and Saklani (1990) have not given any evidence to prove that the strain in the area was of irrotational type.

4. There are, in addition, several mistakes in the text.

a. The equation for k-parameter of Flinn is correctly given in text (p. 253) but it is incorrect in Fig. 6.

b. The correct equation for 'bulk finite strain' ($\bar{E}s$) is given by the relation

$$\bar{E}_s = \frac{\sqrt{3}}{2} \bar{Y}_{oct}$$

c. The columns for k-parameter (of Flinn in Tables IA and B do not contain the correct values of this parameter; the values match with those of the K-parameter (of Ramsay). Reference to these values in the text has also been made as k-parameter (p. 257).

d. The correct K-value for samples 2, 5, 7 and 8 should read as 0.043, 0.027, 0.077 and 0.130, respectively.

e. The correct value of Lode's parameter (V) for sample 6 is 0.025.

Department of Applied Geology
Indian School of Mines
Dhanbad 826004

S. MOHANTY

Reply

The authors express their sincere thanks to Mohanty for pointing out the errors which were inadvertently left in the paper. The querries raised by Dr. Mohanty are clarified below:

1. The values of two dimentional strain ratio of YZ section for all specimens except 5 are correctly shown in Table IA and B. This value of specimen 5 shown for XY section pertains to YZ section. Though the volume change and later deformation are beyond the scope of the paper yet, it may be remarked that the elongation of quartz grains was initially parallel to Y axis and later these were oriented towards X direction. However, the ratio of X, Y and Z remained constant which produced the oblate ellipsoids. Such strain ellipsoids fall in the field of apparent flattening and these ellipsoids are directly proportional to flattening type of strain causing loss of volume. Possibly the apparent volume loss occurred in the vicinity of the thrust. Ramsay and Huber (1983) have also drawn similar type of inferences (Page 172 and 178). Therefore, the area was dominantly affected by flattening strain associated with volume loss. The authors on rechecking the thin sections found that the K values for specimen 8 need modification. The modified value is 0.123. Mohanty has correctly mentioned about these errors.

2. The values of principal logarithmic strain E_1, E_2 and E_3 from two dimensional strain ratios (Table IIA and B) are very much possible. Ramsay and Huber (1983) have described such methods and equations on pages 170, 172, 178 and 197 to 208. In the present paper, the logarithmic strain parameters

(E_1, E_2 and E_3) have been determined by making use of the following equations as described by Ramsay and Huber (1983, page 200 and 201):

$$E_1 - E_2, E_2 - E_3, l_n (1 + \triangle V)$$

$$ln R_{xy} - l_n (1 + e_1) - ln (1 + e_2) = E_1 - E_2$$

3. According to Ramsay and Huber (1983, pages 16 and 21) in the irrotational type of deformation, the direction of the principal axes of strain (X) does not change and is more or less, unidirectional. In the case of ratational strain the direction of the X axis in the deformed grains is variable. It is evident from the photomicrographs given in plate 1b and 2a that the X axes of the elongated quartz grains are aligned in one direction and the grains do not show change in their orientation. Such grains may be attributed to irrotational type of strain. Contrary to this, the X axes of the grains are characterized by variable orientation of grains due to rotational effects in photomicrograph given in Plate 2b. The parameters $\bar{Y}_{oct}$ and $\bar{E}_s$ were determined by taking these grains as strain markers.

4. a. The error pertaining to the equations for strain parameters (k and $\bar{E}_s$) in figures 6 and 7 (subscript) is regretted.

   b. Similarly, the error in the equation for bulk finite strain ($\bar{E}_s$) escaped the attention of the authors while going through the proofs of the paper. In fact, the correct equation used for estimation of bulk finite strain ($\bar{E}_s$) is:

$$\bar{E}_s = \frac{\sqrt{3}}{2} \bar{Y}_{oct}.$$

   c. The value of k parameter (Flinn, 1962) have been shown in figure 6 while in Table 1A and 1B these refer to K (Ramsay and Huber, 1983).

   d. It may be mentioned that due to typing error in the manuscript the decimal point was wrongly placed and it should have preceded zero of each of the K values for specimens 2, 5 and 7. The K values as calculated by Mohanty for specimens 2, 5, 7 and 8 are 0.043, 0.027, 0.077 and 0.13. However, these should be 0.0428, 0.026, 0.070 and 0.123 respectively. Again, due to wrong placement of decimal, the value for Lode's parameter (V) for sample 6 should be 0.025 instead of 0.25.

The main aim of the paper is to discuss the micro-structural deformation of the stretched quartz fabrics within the Pratapnagar thrust sheet and from the strain ellipticity data it has been inferred that the Pratapnagar quartzite was deformed by non-coaxial flattening type of strain at the base of the thrust sheet while away from the thrust, i.e., in the body of thrust sheet, progressive plane strain (coaxial) prevailed.

References

FLINN, D. (1962) On the folding during three dimensional progressive deformaiion, Quart. Jour. Geol. Soc. London, v. 118, pp. 385-488.

RAMSAY, J. G. and HUBER, M. I. (1983) The techniques of Modern Structural Geology, 1: Strain Analysis, Academic Press, London. pp. 301.

The following further clarifications are offered: These natural – or logarithmic principal strain values are in fact, estimated from their relationship with semi axes of strain ellipsoid ($1+e_1$, $1+e_2$ and $1+e_3$), i.e., $E_1 = \ln(1+e_1)$ (in Ramsay and Huber, 1983, p. 200). Nowhere we have stated that the principal logarithmic strain values were determined from their ratios. The intermediate ($1+e_2$) semi axis of most of the strain ellipsoids shows uniformal elongation. Therefore, its value was assumed 1; whose natural logarithmic value will be, $E_2 = 0$ and it has been consistently shown 0 in Table IIA and IIB. We have not determined the values of principal strains by assuming biaxial deformation. Such deformation is possible in an ideal situation where the grains are affected by plane strain (Figure 6, Flinn graph). It is clear from Figure 6 that most of the strain ellipsoids fall in the field of apparent flattening in which the oblate strain ellipsoids are characterized by maximum elongation along Y axis $\{(1+e_2)^2 > (1+e_1)(1+e_3)\}$. Therefore, it was correctly stated that the elongation was parallel to Y. It is well-known, if the strain ellipsoids fall in the field of flattening or constriction, the deformation should be triaxial.

As mentioned by Ramsay and Huber (1983) on page 200 and, also followed by us, it is very clear that the values of three logarithmic principal strain can be calculated from the logarithmic values of two ellipsoid semi axes.

It is well-established, the domains of Himalayan rocks were folded, faulted and thrust during the Himalayan orogeny. During the thrusting events, multidirectional stresses were prevalent, which even caused the rotation of the rock fabrics. In the present case, during the thrusting of Pratapnagar quartzite, the quartz grains were rotated with reference to main orientation direction. The tectonic transport of Pratapnagar thrust sheet was from NE-SW and the lineation/elongation direction (X) which was caused due to this, trends NW-SE in Pratapnagar tectonites. In the present work, the rotation of quartz grains was analysed with reference to lineation, i.e., the main orientation (NW-SE). This main orientation (X) is different than the X axis of a strain ellipsoid of quartz grains. Oriented thin sections parallel to XZ and YZ planes were prepared and about 200 elliptical grains in each of the thin sections were analysed for strain estimation. Their $R_f \left(\frac{L}{W}\right)$ and ϕ (Figure 2) were measured for each of the grains and plotted on standard curves of Lisle (1985). The variation in the amount and direction of ϕ with reference to main orientation direction is most conclusive evidence of rotation which has been already emphasized in the paper (Figures 2, 3, 4 and 5). To supplement this, photo-micrographs of the Pratapnagar quartzite were also given in which the quartz grains having straight X axis are characterised by rotation. However, the rotation of quartz grains was established by taking average of about 200 grains in each of the thin sections and not on the basis of a few grains which are present in the photomicrographs (Plate 1b, and 2a and b). Dr. Mohanty will perhaps agree with us that the analysis of R_f and ϕ values mainly pertain to the aspects of the rotational strain in the deformed rocks.

Department of Geology
Delhi University
Delhi 110 007

S. C. BHATT AND P. S. SAKLANI

I take this opportunity to express a few words of appreciation on the above paper and outline certain conceptual thinking evoked in my mind in respect of this fundamental work.

1. The Pratapnagar quartzites and Gwar phyllites of Dharmandal Group (under reference) are in fact a part of a conspicuous Lesser Himalayan Thrust Tectonite Belt presenting quartzite/phyllite/schist sequence often associated with metabasics complex showing greenschist to amphibolite facies of low to medium grade of metamorphism (often retrograded and reversed). This thrust belt is exposed throughout the length of the Lesser Himalaya from Himachal in the west to Arunachal in the east in juxtaposition to the Main Central Thrust (MCT) in the north followed by the Central Crystalline Thrust Sheet. These tectonites have been described under different names such as Chails, Kulu-Manikaran quartzites in the west and Pratapnagar-Berinag quartzites in Garhwal and Dalings, Paro metamorphics, and Siang Group in the Eastern Himalaya.

2. These metamorphites have a Precambrian parentage forming the northern extension of the subducting wedge of the Indian Peninsular Continental Plate (now widely accepted). The heterogeneous, deformations presented by these tectonites indicate multiple orogeny and successive reactivations including the Precambrian and Phanerozoic periods which are not precisely accountable due to large scale obliteration during subsequent orogenic transformations culminating in Himalayan Orogeny. The orogenic episodes introduced several phases of tectonothermometamorphic transformations and reconstitutions of the physical, mineralogical and geochemical characteristics of the rocks.

3. Geochemical fractionation initiated and controlled by the strain episodes favouring simultaneous migration, mobilisation and remobilisation of the pre-existing mobile elements like Li, Be, B, F, Cu, Zn, V, Mo, As and LIL elements like 'U' giving rise to syngenetic-remobilised type of base metal sulphides and oxidised-reduced uranium mineralisation at various locations within this lesser Himalayan Thrust Tectonites often close to the MCT Zone.

The present type of fundamental petrotectonic work in the selected area should be extended. The petrotectonic work integrated with trace element geochemistry, geophysical studies including Natural Remanent Magnetism (NRM), chargeability and resistivity would be of immense assistance to mineral exploration.

A-491, Malavia Nagar
Jaipur 302 017

A. K. BHATTACHARYA

Reply

We thank Dr. A. K. Bhattacharya for his appreciative remarks.

1. The Pratapnagar/Berinag quartzites and the Gwar/Chandpur phyllites are analogues to the composite Chail nappe as suggested by Fuchs and Sinha (1978). However, the authors do not agree with Fuchs (1982 and 1983), and Valdiya (1978) as regards low-grade gneisses, lying over the Pratapnagar/

Berinag quartzites, as a part of the Chail nappe. The authors prefer to group these low-grade Gwar phyllite into Chail nappe 3 and the Pratapnagar/Berinag quartzites as Chail nappe 2.

2. Dr. Bhattacharya has correctly pointed out about the Pre-Cambrian parentage of these low grade metamorphites.

We have examined the fabrics of these mylonitised rocks and are of the view that the tectonites away from the thrust were initially subjected to coaxial deformation characterised by symmetrical girdles of C-axes. The quartzites exposed at the base of the thrust plane were predominantly deformed by non-coaxial deformation as indicated by asymmetrical, atypical and typical girdle pattern of C-axes. The angular relationship of the mylonitic (S-C mylonite) foliation with the C-axes girdles supports sinistral (– ve) sense of shear movement. In fact, during the orogenic events, the tectonometamorphic environment was responsible for the reconstitution of chemical and mineralogical components of the rocks.

3. It appears that the thrusting events in the Himalayan orogeny controlled the mineralisation in rocks of the Himalaya (Narayan Das *et al.* 1981). The authors have also noticed that the mylonitic fractures of the Pratapnagar quartzite are at times, characterised by encrustations of malachite, azurite and galena. The migration of mobile geochemical elements in relation to major strain paths must be investigated with particular reference to the S-C mylonites (Lister and Snoks 1984). Such mylonitised rocks mainly exposed along thrust zones were affected by ductile deformation.

The authors have made use of regional dips of the rock structure to locate the depth of the decollement where they were affected by the footwall collapse. The sites of decollement structures are potential zones for the migration of mineralised solutions. The geophysical investigations can be very helpful to locate the exact depth of decollement of the Main Central and Chail thrust-sheets in the Himalaya. The determination of Natural Remanent Magnetism (NRM) can also provide important clues about the deformation history of the Himalayan tectonites.

Department of Geology
University of Delhi
Delhi 110 007

S. C. BHATT AND P. C. SAKLANI

References

FUCHS, G. (1983) The Chail Thrust and Chail Nappes in the Himalaya, *In:* P. S. Saklani (Ed.), Himalayan Shears, pp. 33-44, Himalayan Books, New Delhi.

FUCHS, G. and SINHA, A. K. (1978) The Tectonics of the Garhwal-Kumaun Lesser Himalayan, Jahrb. Geol. B.-A., Band, pp. 121, 219-241.

LISTER, G. S. and SNOKE, A. W. (1984) S-C Mylonites, Jour. Struct. Geol. v. 6 (6), pp. 617-638.

NARAYAN DAS, G. R. BHATNAGAR, G. S. BHATTACHARYA, A. K. and SHARMA, Y. C. (1981) Uranium in metamorphites around Brijranigad, Raunsal, Tehri Garhwal (U.P.) *In:* P. S. Saklani (Ed.). Metamorphic Tectonites of the Himalaya, pp. 111-122, Today and Tomorrow's Publishers, New Delhi.

VALDIYA, K. S. (1978) Extension and Analogues of the Chail nappe in the Kumaun Himalaya. Indian Jour. Earth Sciences, v. 5 (1), pp. 1-9.