DISCUSSION

Comment

(Comment on the paper '**Strain Analysis of deformed pebbly horizon from the Garhwal Group, Pharsaun, District Chamoli, U.P.**' By V. K. Gairola and Deepak Hatwal, published in the Journal of the Geological Society of India, Vol. 37, May 1991, pp. 457-468).

The results of and the interpretations made on the strain study by employing the triangular diagram after Burns and Spry (1969) are open to criticism. I have the following comments to make:

(i) In Fig. 3 (p. 461), the mean 5° plunge of Y is not the arithmetic average of plunges of axes of 40 pebbles analysed, rather it has simply been plotted as a pole to the XZ plane cyclographic trace. Nearly the entire scatter of Y points have plunge values that exceed 5° and, therefore, the average plunge of Y would take a value greater than this.

(ii) The contouring in the triangular diagram (Fig. 5) is incorrect. There is not a single value of log x/r $=0.55$ in Table I (which gives $X=3.5481$ (p. 465, last line, first para). The contours must not extend beyond the point log x/r $=0.45$) (giving $X=2.818$), and even if the contours do, if drawn on the basis of equal area circle method, the deformation path should not. This path is, therefore, extrapolated well beyond the data bank, thus giving exaggerated values of prolateness. Besides the % contour values are not given.

(iii) In Table II, S.No. 34, the value of v (Lode's parameter) should read -0.48 and not -4.8; this presumably is a printing error.

(iv) The deformation path in Fig. 5 can never be curvilinear. It consists on Burns and Spry diagram of several rectilinear segments since even the rotational strain history can be represented by such rectilinear segments on this logarithmic plot. Derived from the original Nadai 3 axes or Hsu-Hossack diagrams, the actual triangle is a part of the hexagon and deformation path would, therefore, lie along one or more of the six straight line segments; three of these being X–, Y– and Z-invariant and the other three parallel to log x/r (continuous rotationol prolate), log z/r (continuous rotational oblate) and log y/r (complex swappings between principal strains). This is clearly spelt out in Burns and Spry (1969, Fig. 5) and *would hold good for the positive triangle of the hexagon only with* $X>Y>Z$.

(v) The choice of the inferred initial shape made by the authors is incorrect. The choice depends on the data from several localities (two or more widely separated) and then matching the contour values by superimposing the data from several localities. The initial shape chosen by the authors is extremely oblate ($X:Y:Z=1.2168:1.1614:0.7079$, $k=0.0744$, Flinn, 1962) which is an extreme shape and could not be the starting shape, even though it may lie close to the point of origin. To convert this into a highly prolate shape would require tremendous amount of mechanical work.

(vi) The starting shape quoted by the authors is extremely oblate (*see* above) and the final shape extremely prolate (p. 465, first para, last line: X : Y : Z = 3.5481 : 0.7499 : 0.3758, k = 3.748, presumably due to incorrect contouring). Taking both shapes, the overall shortening in Y is 41.15 per cent but in Z only 33.21 per cent. This entails a situation Z > Y and the contours should transgress the log x/r side of the triangle (*see* Fig. 5 in Burns and Spry, 1969) which is not suggested by the data. All this has stemmed in because of incorrect contouring and due presumably to plotting some of the data points incorrectly. I think the mistake incurred because of plotting some of the data points as on a normal triangular diagram rather than one with obliquely oriented cartesian co-ordinates.

(vii) From the authors' data, it is obvious that there are principally two modes and a dispersion about these, one with X : Y : Z = 1.7782 : 0.955 : 0.589 (left hand side maximum in Figure 5 with k = 1.387, here called (p) and the other with X : Y : Z = 2.0653 : 1.0715 : 0.452 (right hand side maximum in Figure 5 with k = 0.6767 here called (q). The dispersion in the former case extends on the log y/r < 0 side up to a point with X : Y : Z = 2.818 : 0.8128 : 0.437 (k = 2.868, here called (r) and on the long y/r > 0 side (mean) with X : Y : Z = 1.3963 : 1.047 : 0.684 (k = 0.6284, here called (s). The dispersion of the second modal shape (q) extends very slightly in the prolate field (almost plane strain, log y/r = 1.995) with X : Y : Z = 2.6915 : 0.988 : 0.376 (k = 1.0593, here designated t) and on the oblate side with X : Y : Z = 1.862 : 1.2 : 0.4475 (k = 0.328, here designated (u).

(viii) The actual deformation path would, therefore, consist of a straight line segment joining s with p with r (*see* above) or alternatively another parallel segment joining u with q with t, both involving continuous constriction and a rotational strain history with positive extension in X and negative extension in both Y and Z.

(ix) Finally, it is dangerous to deduce information on deformation paths on Burns and Spry diagram, especially for scanty data from a single locality. To my knowledge, no subsequent worker has used this plot. The path does not take into account the component of purely rigid body rotation. Some of the shapes analysed by the authors may well represent almost initial shapes and may have undergone rigid body rotation with little distortion (in places of higher viscosity contrast between pebbles and pebbles-matrix system). Of course it is easier to convert an initially prolate shape into an oblate one rather than the other way round (depending again on the viscosity values and their changes during progressive deformation).

The authors have drawn a very plausible conclusion in the end suggesting that the complex deformation path may reflect deformative pulses succeeding F_1. The subsequent dextral faulting (entirely strike slip ?) may not have had much to do in altering the X directions of pebbles as suggested by the authors. This would depend on the magnitude of displacement, the amount of ductile deformation associated with the fault and the initial angle between X axes of pebbles with respect to tne maximum displacement vector along the fault plane.

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Reply

I am thankful to Dr. P. P. Roday for his keen interest and comments on the paper 'Strain analysis of deformed pebbly horizon from the Garhwal Group, Pharsaun, District Chamoli, U.P.' Reply to comments is being given itemwise

(i) In nature it is difficult to get pebbles deformed into perfectly ellipsoidal shapes as their initial shape is rarely spherical, orientation and magnitude of the stresses may vary with time, and the rheological properties of the matrix may not be the same all around the pebbles. The deformed pebbles in quartzite phyllites from Pharsaun area are also not perfectly ellipsoidal and it is not possible to precisely demarcate the X, Y and Z directions in all the pebbles. Therefore, the direction of the intermediate strain Y has been plotted as the pole to the best-fit great circle girdle defined by the mean directions of principal strains X and Z. However, in Figure 3 (p. 461) the plots represent data measured in the field.

(ii) The plotting and contouring of the data in Figure 5 (p. 464) was done by normal procedure by the co-author, Deepak Hatwal. The contour interval is 2.5, 5, 10, 15 and 20% per unit area (Hatwal, 1988, Fig. 24). A plot depending on its location, may have to be counted all around it up to a distance of the radius of the counting circle (defining 1% of the area). Thus, when the contouring is done it automatically incorporates a larger area which may extend up to the radius of the counting circle from the peripheral most plot. Moreover, the contours are always drawn as smooth curves and not by straight lines, and hence, they cover a larger area than the area defined by joining different plots by straight lines. Thus, obviously the contours would include the data which are not in the data bank. In the text (p. 465) it has been mentioned that the deformation path has been traced by taking the mean positions of the plots and then extended. This has resulted in the exaggerated value of the prolateness of deformed pebbles, obtained from the contour diagram.

(iii) In Table II, S. no. 34 the value of υ has been printed as -4.8 instead of -0.48. This is due to typographical error.

(iv) Burns and Spry (1969) have shown that the deformation path may be a combination of several rectilinear transformations during the incremental strain. However, they have not discussed how one transformation may lead to another in a complex deformation. For example, there may be rapid variations in the transformations within and between dominant constriction along X (direction 1) and dominant plane strain in YZ (direction 4), or between any other combination of transformations. The deformation path interpreted on the basis of finite strain data in Figure 5 (p. 464), is also a combination of rectilinear transformations (mainly along directions 1, 2, 3 and 12 of Burns and Spry, 1969). Burns and Spry (1969) are also of the opinion that the most common deformation paths vary between transformations 1 (constriction), 2 (plane strain) and 3 (flattening). Further that the points in deformation path move along a straight line in approximate direction (Burns and Spry, 1969, p. 188). Therefore, the deformation path in Figure 5 has been shown as smooth line along the respective transformation directions. Different transformation lines have been joined by smooth curve as there may have been different kinds of transformations for short phases during the complex deformation history. The kind of transformation between any two points on the deformation path can be visualised by comparing the log values of X/r, Y/r and Z/r.

(v) Deformed pebbles were observed only in one locality. Therefore, the inferences on the mean initial shape of pebbles, deformation path and the mean final shape of the pebbles was drawn from the data collected from this locality. The mean initial shape of the pebbles is based on the position of the contour of minimum value nearest to the point of origin on the triangular graph. It has already been mentioned in the paper (p. 464) that the deformation path had been plotted on the basis of Ramsay's (1967) views that in deformed rocks strain markers which have undergone different stages of deformation in a domain get arrested. These arrested stages of deformation reveal the intermediate stage of deformation. If it is considered that the initial shape of the pebbles was prolate then it will be difficult to explain simultaneous transformations of different pebbles embedded in similar matrix from the same locality, in different directions. Moreover, the deformation of pebbles has been related to the first phase of deformation during the Himalayan Orogeny which was responsible for the isoclinal folding as well as the peak of metamorphism (where the temperature was suitable). Therefore, it is not surprising that the stresses were high enough to deform the oblate pebbles into prolate pebbles.

(vi) The deformation of an oblate ellipsoid to a prolate ellipsoid does not necessarily require a condition where Z becomes greater than Y. Comparing the values of x, y and z in the initial (1.21 : 1.16 : 0.70) and mean final (3.34 : 0.74 : 0.37) shape of pebbles it is observed that the +ve extension along X is compensated by -ve extension along Y (> 36%) and Z (> 47%). Therefore, the situation Z > Y does not arise.

(vii) The contour diagram (Fig. 5, p. 464) does not display a well marked central concentration with a uniform dispersion around it. Rather two maxima are observed. Thus, Figure 5 does not describe a well-defined mode. Lisle (1979, p. 271) while discussing the pebble mode shape of Burns and Spry (1969), has also suggested that the mode on the Nadai (1963) diagram (Same as triangular diagram of Burns and Spry) is of little value in determining the tectonic strains. Further, the mode will vary, depending on the type of graphical representation (Lisle, 1979). Thus, the description of the mode becomes meaningless and, therefore, it was not discussed in the paper.

(viii) Dr. Roday has interpreted that there is + ve extension along X and —ve extension along Y and Z. The initial and final values of x, y and z on the deformation path also suggest that this was the dominant deformation history. In the paper (p. 465) the incremental changes in X, Y and Z directions have also been suggested on the basis of different intermediate positions in the deformation path.

(ix) The details of rigid body rotation have not been discussed in the paper. The initially prolate pebbles would have undergone rigid body rotation towards the principal extension direction depending on their orientation, their viscosity contrast with the matrix, and the amount of bulk shortening. In the paper (p. 467) it has been mentioned that due to the movement of fault blocks the deformed pebbles were rotated. Furtheer, it may be said that ductile deformation is generally associated with faulting in the Himalaya.

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ADDENDUM

The following two additional paragraphs may be included in the reply to the Comment published in Journal Geological Society of India, Vol. 39 (2), pp. 171-174.

The nomenclature of Kaul *et al.* (1988) and Mukerjee *et al.* (1988) was tentative, based on limited field and analytical data and hence, open to refinement.

In the same R_1-R_2 diagram we have shown that most of the analysis for Gabo Suite, Polarforschung Glacier area and Ruin area, which are established A-type granites, do not plot in the anorogenic field.

CORRECTION

Following corrections may please be made in the paper "Petrographic and Geochemical characteristics of the Kamthi and Lower Maleri Formations, Adilabad and Karimnagar Districts (A.P.)" published in Jour. Geol. Soc. India, Vol. 39 (2), pp, 125-140.

i) King, W. (1881) : The Geology of the Pranhita Godhavari Valley, Mem. Geol. Surv. India, Vol. 18 (3) pp. 151-311 :

ii) In fig. 2, the percentages of quartz should be 50 and 70 instead of 5.0 and 7.0 ; the percentage of Feldspar should be 10 and 15 instead of 1.0 and 1.5 ; for the lithic fragments in place of % mark, it should be mm and instead of mm it should be % mark, the percentage being 2.0 and 3.0 instead of 20 and 30.

iii) In fig. 3, the percentage of quartz should be 25 and 30 instead of 2.5 and 3.0.