**T.C. Devaraju**, Department of Studies in Geology, Karnatak University, Dharwad - 580 003 and **T.T. Alapieti** and **R.J. Kaukonen**, Institute of Geosciences, University of Oulu, PO Box 3000, Finland reply

We are thankful to Vidyadharan et al for evincing considerable interest in our above cited publication and offering many detailed comments

We have duly quoted the reference of the previous reports on the chromite bearing ultramafic lenses of the area As one would note it that our emphasis is on the geochemistry and whatever data we obtained on PGE distribution and occurrence of PGM specially in the layered ultramafic body near Rangapura We have faithfully described those field features which we were able to distinguish Having examined only a part of the large complex, it is possible that we have missed some of the distinctive features of extrusive phases in association It is true that the sizes of the ultramafic lenses in our map are exaggerated

We have noted that GSI has undertaken an overall mapping of the ultramafic complex lying to the southeast of Shimoga belt (to which they have given the name of Antharaghatta belt) and they have several observations indicative of association of intrusive and extrusive phases constituting the complex We look forward to their publications of the map of the entire complex and also description and discussion of the various additional data/observations mentioned by them We wish the GSI good luck in discovering commercially important PGE mineralization, if any, in this complex

We might also add here that we have generated a large amount of EPMA data for Fe-Cr oxides occurring at various locations of the complex We are coming up soon with a separate publication based exclusively on our study of Fe-Cr oxides in Hanumalapura, Rangapura and Nuggihalli ultramafites

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# EVOLUTION OF THE GREAT BOUNDARY FAULT: A RE-EVALUATION

by A Rai Choudhuri and D.B. Guha, Jour. Geol. Soc India, v.64, 2004, pp 21-31.

**Amit Sahay,** Department of Earth Sciences, IIT Roorkee, Roorkee - 247 667, **Email:** amitsdes@iitr emet in, comments

I would like to offer the following comments and seek clarification from the authors of the above paper

### Structural Discordance Between the Hindoli and Ranthambhor Groups

1 'Structural Analysis in the Hindoli Group is based on the assumption of cylindrical $F_3$ folding (Fig 6A) As the Stereoplots of $F_3$ axes/$L_3$ lineations display a wide scatter, 60° (N 7-67°) in the NE quadrant, and 33° (N 211-244°) in the SW quadrant, it is evident that the $F_3$ folds are non-cylindrical If so, the $\beta$ axis shown in Fig 6A does not indicate the attitude of $F_3$ axis in subarea-2

2 Contrary to the interpretation that $F_2$ and $F_3$ folds are coaxial, the lineations/axes of these folds do not overlap (Fig 6A)

3 The correlation of $F_3$ folds in the Hindoli Group with $FV_1$ folds in the Ranthambhor Group, and the inference

of a structural discordance between these two Groups, are questionable for the following reasons (i) Whereas the $F_3$ folds are open to gentle and symmetric, $FV_1$ folds are asymmetric or overturned (Fig 6A-B) (ii) In Fig 6B, the great circle through $S_0$ poles is not the best fit because it does not pass through the middle of the maximum and sub-maximum contours Furthermore, it also does not contain most of the poles to $FV_1$ axial planes It is because of these reasons that the b-axis does not fall within the main cluster of $FV_1$ lineations A proper best-fit great circle would imply that the b-axes for the Ranthambhor and Hindoli Groups are almost identical

4 Even if the great circle in Fig 6B is plausible, it only implies an angular relationship between the $S_1$-surfaces in the Hindoli Group and the $S_0$-surfaces in the Ranthambhor Group For the existence of an angular unconformity, a discordance has to be demonstrated between the $S_0$-surfaces in the above mentioned two Groups

**Thrust and Normal Fault**

1 Data in Fig 5 show slickenside lineations pitching at 31-33° on the fault/mylonite planes that dip at 57-82° towards variable directions In the absence of any data on sense of shear, these structures can, at best, be inferred as oblique-slip reverse/normal faults, rather than thrusts Is the variation in dip direction *due to folding?*

2 Contrary to the author's claim (p 29), Fig 5 shows that, barring the exception of two faults, none of the post-GBF faults parallel the GBF The relative lack of these faults in the Hindoli and Vindhyan rocks remains unexplained

**Correaltion of the GBF Related Stuctures**

1 The correlation of vein arrays with $F_3/FV_1$ folding is not correct, because these two types of structures are developed in two contrasting tectonic regimes, namely, strike-slip and thrust, respectively (Fig 10A-B)

2 It is not cleai as to how the intermediate and minimum principal stresses are determined from the axial plane orientations of $F_3/FV_1$ folds (Fig 10B)

3 Being based only on the orientation, the classification of joints and normal faults, into four sets each, is not sound As the joints are inferred to be of extensional origin, their correlation with shear surfaces, e g , normal faults, is dynamically impossible Similarly, the correlation of strike-slip vein arrays with normal faults is also dynamically inconsistent

**Ductile Deformation**

1 Whereas the text at p 27 mentions that the Vindhyan sandstone shows recrystallisation and crude foliation, the captions to Figs 8A-B reveals that these textures are observed in rocks near Phalodi and Halonda, both of which fall within the Hindoli Group (Fig 2) It is not surprising that the Hindoli rocks show ductile deformation but such a deformation need not be necessarily related to the GBF

2 The only evidence in favour of ductile deformation is the occurrence of mylonite shown in Fig 13 However, neither the location nor the stratigraphic position of this mylonite is known

The meaning of the term 'undisturbed remnant of mylonite' is not clear Fig 13 does not show any breccia that contains fragment of mylonite (p 29) The perfect matching of at least, some grains across the discontinuity implies that the so-called brittle fault in Fig 13 is, in fact, an extension fracture

Due to lack of precise locations and stratigraphic positions, it is likely that the evidences of ductile deformation presented in this article are from the rocks of the Hindoli Group and this deformation could as well predate the GBF I agree that there are distinct evidences, e g , en-echelon vein arrays, indicating a brittle-ductile deformation along the GBF The unambiguous evidence of ductile shearing and mylonitisation along the GBF remains yet to be *established*

**A. Rai Choudhuri** and **D. B. Guha**, Geological Survey of India, Kolkata - 700 009 reply

We first of all thank Dr Amit Sahay for his keen interest on our paper Following is our point wise reply to the comments made by Dr Sahay regarding structural discordance between Hindoli and Ranthambhor groups

1 In spite of the scatter shown by the $F_3$ lineations only one pi-circle can be drawn to fit in the pi-pole girdle, which conforms to the major cluster of $F_3$ lineations towards northeast

2 It is clearly mentioned in our article that the interference between $F_2$ and $F_3$ folds is coaxial to near coaxial

3 (i) Grouping of $F_3$ or $FV_1$ folds into same generation (correlation of $F_3$ folds to $FV_1$) is based on their style and overprinting relations, both of which are studied in mesoscopic scale (Turner and Weiss, 1963, Williams, 1985) Fold style is also dependent on rock type (Ramsay, 1967) Stereo-projections, which are used to

interpret geometry of large-scale structures, are therefore not suitable for the purpose

However, regarding the points made by Dr Sahay we would like to mention that younging directions recorded in Ranthambhor Sandstone do not suggest any overturning of limbs Fold asymmetry is not distinguished from projection diagrams alone (Marshak and Mitra, 1988)

It seems Dr Sahay has meant inclined folds, which are indicated by the asymmetric girdle pattern and also by the concentration of axial plane poles to the southeastern quadrant of the projection diagram The cluster of axial plane poles suggests that the axial plane of the large-scale fold steeply dips towards northwest This fold structure is actually in conformity with our description of $F_3$ and $FV_1$ folds, where it has been mentioned that these folds grow in tightness and asymmetry towards the GBF, and close to the GBF the folds have become inclined with a steep northwesterly dipping axial plane The Hindoli Group, constituted of foliated rocks, is intensely deformed into short wavelength folds, the inclined nature of the $F_3$ folds occur near the GBF and they cease to be inclined away from the GBF The inclined nature persists for a longer distance in Ranthambhor Group because it is constituted of thick sandstone and shale beds, which have deformed into large wavelength folds

(ii) The best fit pi-circle divides the pi-pole distribution of all data points into two nearly equal and symmetrical halves so that the distribution of all data points are more or less equally distributed on either side of the line This line may not always coincide exactly with the centre of the maximum (see e g Fig 6 in Naha et al 1969, Fig 5 in Sinha-Roy and Malhotra, 1989, Fig 7(a) in Curtis, 1999) For sub-area 1 any pi-circle drawn to pass through the centre of the maximum would deviate from the distribution given by the rest of data points and would represent only horizontal to near horizontal bedding planes which are least affected by folding

We can look into this problem from a different angle From the data on bedding plane attitudes on the synform in Ranthambhor Group (Sub-area 1), the crestal surface is estimated to strike N43E Due to the inclined nature of the fold, the axial plane would not coincide with the crestal surface but would strike parallel to it Therefore in a stereogram the axial plane can be plotted as a great circle dipping towards NW (as indicated in the pi-pole diagram) and striking N43E The fold axis of the northeasterly plunging synform (northeasterly plunge indicated in the pi-pole diagram) must lie on this great circle Therefore, the trend of the fold axis must lie between N and N43E This is consistent with the projection diagram in Fig 6B and its interpretations

4 It has been clearly mentioned in the article that in Hindoli Group $S_0$ is parallel to $S_1$ in most of the area

Regarding thrusts and normal faults we would like to point out that the planar structures with slickenside lineations (in Fig 5) are obviously post-GBF normal faults because slickenside lineations are characteristic of brittle deformation Contrary to Dr Sahay's criticism, we have not described these faults as thrusts In support of our claim that normal faults in both mesoscopic and macroscopic scale have developed parallel to the GBF we have shown in Fig 12 several NE-SW striking faults, which are all parallel to GBF

All brittle-ductile/ductile structures have been grouped as structures associated with the origin of the GBF In Fig 10B, we only intended to show that the origin of the arrays of tension gashes and the $F_3/FV_1$ folds is explained by a common bulk stress ellipsoid In Fig 10A, the principal stress directions were determined from the orientation of the brittle-ductile conjugate shear zones and the slip senses recorded on them

Joints and faults are post-GBF structures and are related to late brittle reactivation of the GBF No attempt has been made to physically relate joints with faults We have only tried to show that a common extensional stress has produced both of these structures

Regarding evidence on ductile deformation in Fig 8a-b, we could not avoid referring to Halonda and Phalodi as these are the only prominent habitats closest to our sample points Captions to Figs 8a-b are indicated as near Phalodi and south of Halonda which obviously do not mean Phalodi and Halonda locations Precisely speaking the first sample was collected from Vindhyan sandstone nearly 2 km southwest of Phalodi where the hunch shaped Vindhyan outcrop is transected by the GBF The second sample showing recrystallised fabric (Fig 8b) is of Ranthambhor Sandstone present adjacent to the GBF, south of Halonda Sandstones with recrystallised grains or weakly developed fabric were also observed at different points along the southeastern branch of the GBF as well as in Ranthambhor Sandstone (e g near fault $F_1$-$F_1$, close to the point of cross over between road to Jaipur and the fault trace $F_2$-$F_2$ etc )

Contrary to Dr Sahay's comment, mylonite is not the only evidence for ductile deformation Folds themselves cannot develop unless the rocks behave in a ductile manner Recrystallisation of grains and development of oriented fabrics are microscopic evidence favoring ductile deformation Presence of mylonite foliation indicates zones where ductile deformation was concentrated into high finite strain It has been clearly stated that the sample of mylonite shown in Fig 13 was found as a disoriented fabric in the brecciated zone delineating the GBF south of Halonda This evidence has been given in the paper to support our view that the GBF was subjected to a late brittle movement, which has obliterated the early ductile fabric from most part along the GBF

However, mylonites in some incipient form were observed in its original orientation in the northeastern comer of the mapped area and in some small patches along the southeastern branch of the GBF These portions along the GBF have been referred to as the 'undisturbed remnant of mylonite' i e mylonites whose fabric is not obscured by later brittle deformation

We are not in agreement with Dr Sahay regarding tensional origin of the fracture transecting the mylonite foliation in Fig 13 Fine angular grains filling up the fracture clearly indicate that it is a fault

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# BOOK REVIEW

## PRINCIPLES OF RADIOMETRY IN RADIOACTIVE METAL EXPLORATION

by B K Bhaumik, T Bhattacharya, A A P S R. Acharyulu, D Srinivas and M K Sandilya

A.M D Complex, Khasmahal, Jasmshedpur - 831 002, Jharkhand 292p Price Rs 600/-

This book is to be viewed in the context of more than 50 years of tradition in instrumentation fostered and developed meticulously by the pioneering physicists of the Atomic Minerals Division (now the Atomic Minerals Directorate for Exploration and Research), a wing of the Department of Atomic Energy, to aid in the main task of ensuring adequate fuel resources for the national atomic energy program In keeping with the high traditions of the DAE in the field of instrumentation, the AMD had indigenously designed and fabricated the entire gamut of radiometric instruments necessary for exploration for radioactive minerals from both airborne and ground platforms, bore hole evaluation and ore grade control in their exploratory mines The technology was also transferred to the uranium mines for grade control and planning development and to Electronics Corporation of India (ECIL) for large-scale manufacture of select instruments In fact there is no instrumentation used in radioactive mineral exploration that is not locally fabricated It is heartening to recall that there are field set-ups in several centers for the repair and maintenance of the equipments that ensure timely maintenance of instruments Backed by this tradition, the book under review is comprehensive in relation to the tasks of exploration for radioactive minerals and a welcome addition to the existing mostly foreign publications

The book is divided into six chapters dealing with physics of radioactivity, radiation detectors, radiation survey meters, including air-borne gamma ray spectrometric system, radiometric assaying, natural gamma ray logging and connected instrumentation The chapters are well written and well illustrated, though several diagrams could