DISCUSSION

SHRIMP U-Pb ages of Detrital Zircons in Sargurs


I congratulate Nutman et al. (1992) for producing new geochronological data on Indian Archaean rocks, the kind of which probably we will never be able to generate ourselves. Following clarifications, additional information and elaborations are, however, needed to understand the meaning of these data.

(1) The authors may give the exact location of the sample on published map of Holenarasipur schist belt because garnet mica schists are found in both the Sargur and Bababudan sequences of this belt and the unconformity between the two groups is not found in this belt (see Naqvi, 1981). We agree with the concept (Radhakrishna, 1967) of the existence of supracrustal rocks older than Dharwars (Naqvi and Hussain, 1972), but we do not find evidence for the derivation of the sedimentary protoliths of the Sargur/Holenarasipur group in the widespread granitoid terrain. Though our inferences made more than 15 years ago were based on the data available at that time (Naqvi et al. 1978), recent isotopic work also on various Archaean sedimentary rocks have shown that about 70% of the crust around 3.0 Ga was made up of granitoids and 30% by mafic-ultramafic rocks like komatiites (Jacobsen, 1988; Dia et al. 1990).

(2) Do we have real detrital zircon grains derived from granitoids in any of the rocks of Holenarasipur/Sargur group? In another paper by Chadwick et al. (1981) photograph of one zircon from the schists of Holenarasipur belt and two from Banavar have been published. The morphologies of the zircons from schists, Banavar quartzite and Tattakere conglomerate are not similar to those of detrital zircons and show no difference from the morphologies of the zircons found in Peninsular (ortho) gneisses. One small ovoid zircon (f) from Tattakere conglomerate appears to have been derived from volcanic rocks (see fig. 3 of Chadwick et al. 1981). In the present paper also we do not find the photographs of the zircons, demonstrating their detrital nature. According to the authors the zircons of ovoidal shape are ‘rare’ and mostly are prismatic with the 1:4 length-breadth ratio. The reduction of length-breadth ratio is one of the most important criteria to recognise detrital nature of the zircons. In a rock suite of higher amphibolite facies with 4–8 cm long crystals of kyanite-staurolite and garnet, and which are also affected by post-crystallization deformation, growth pseudo-rounding of the pyramidal tips of zircons may occur. Detrital nature of ‘dated’ zircons is essential to be unequivocally established before interpreting their age data (see Ireland, 1992; Machado et al. 1990). When the Pilbara zircons were dated at 4.2 Ga their unequivocal detrital nature was demonstrated through photographs (ANU report 1983; Froude et al. 1983).

(3) Authors have stated that the zircons are poorly sorted (p. 369). According to the model of Chadwick et al. (1986). Tattakere conglomerate is a basal oligomictic quartz pebble conglomerate, fuchsite quartzite is a mature arenite and kyanite staurolite-garnet-mica schists are metapelites; all products of high degree of mineralogical and chemical maturity. Presence of poorly sorted prismatic zircons in such
highly mature sediments requires a satisfactory explanation. The protoliths of these high grade metamorphic rocks were fine grained extremely mature sediments and show a very unusual chemistry (see Naqvi et al. 1983). In 1978-82 we tried our best to identify detrital zircons and could succeed in identifying and separating only metamorphic, prismatic zircons with perfect length-breadth ratios of non-detrital zircons.

(4) With the development of giant crystals of kyanite, staurolite and garnets in the Sargur Group of the Holenarasipur belt, absence of the in situ growth (p. 369) of zircons is surprising. Authors have made contrasting statements on p. 371 regarding zircons of Banavar chromite, fuchsite quartzite where they state that 'this older age may be attributed to overlap of the analysis spot on to an unrecognised core and that low Th/U ratios, their euhedral form and delicate structures suggest that this younger group of zircons grew in situ during the high grade metamorphism of their host quartzite 2961 ± 13 Ma ago. An explanation for in situ growth of zircons in one rock and its absence in another, remains unexplained in the paper. The range from 3500 to 3093 Ma, a difference of about 500 Ma in the ages of the zircon grains in the absence of the older ages of granitoids in 3500 Ma range is also unexplained. In view of the non-detrital morphologies of zircons it is possible that these zircons are also formed through in situ metamorphic growths. In such case the 3,585 Ma may be the age of the earliest metamorphic grain. To rule out this possibility, on this grain, determinations at various sites/spots must be made to substantiate inferences of this paper.

(5) The authors should have searched for detrital zircons in Tattakere conglomerate (Chadwick et al. 1981), kyanite schist and fuchsite quartzite of the Sargurs of Holenarasipur belt. Instead they have gone to an absolutely isolated outcrop north of Banavar (100 km away from the Holenarasipur schist belt) to find and date metamorphic zircons: Banavar outcrop consists of banded rhythmic layers of chromite and fuchsite quartzite with δ18O= 12.5% indicating its chemical origin. This outcrop does not lead us to those granitoids which are assumed to have existed in the provenance of Sargur group sediments. If zircon ages of garnetiferous schist (3586 ± 04 Ma), are also from metamorphic grains as those of Banavar banded chromite-quartzite (Nutman et al. 1992, p. 370) then Naqvi et al. (1978) were right to suggest that Sargur/Holenarasipur group represents early Archaean processes and if the age of Sargurs is 3130-2960 Ma as proposed in this paper, the separation of Sargur group from rest of the Dharwar rocks cannot be sustained, as the age of the Bababudan group is estimated at about 3000-2900 Ma. The Rb/Sr age of intrusives into Bababudan group of Holenarasipur belt is 3,100 Ma (Monrad, 1983; Stroh et al. 1983). The age of the volcanics of the Bababudan group at Kudremukh is estimated at 2,900 Ma (Drury et al. 1983). Halekote trondhjemite (3071 ± 67 Ma) intrudes both the Sargur ultramafics and kyanite schist and members of Bababudan group at Kuncha. The ages by Monrad (1983) and Stroh et al. (1983) put the youngest age limit of 3000-2900 Ma for the deposition of the protoliths of the Bababudan Group in the Holenarasipur schist belt. Considering all the uncertainties of Rb-Sr, Sm-Nd data of Monrad (1983), Stroh et al. (1983) and Drury et al. (1983), the zircon ages given in this paper do not leave any gap to produce the QPC unconformity at the base of the Bababudan Group. Therefore, this overlap between the ages of Sargur and Bababudan Groups creates further problems for classification of the schistose rocks of Karnataka Nucleus. The relationship between Sargur and the Peninsular gneisses and Sargur and Dharwars become more confused now by the interpretation of Nutman et al. (1992).
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Nutman et al. (1992) accept that the margins of the Sargur rocks are intruded by sheets of orthogneiss (p. 369) ranging in age from 3358 to 3071 Ma (p. 372). They contradict their own statement by declaring that none of them are found in contact with the Sargur rocks which are supposed to be deposited in the period 3130 - 2960 Ma. They have misquoted Monrad (1983). He has suggested that Halekote trondhjemites intrude Bababudan Group, not Sargur Group. Monrad's (1983) data puts the lower age limit for Bababudan group later than 3071 Ma. I invite them to visit with me to Katya and Kuncha locations in Holenarasipur belt to see the contact between dated granitoids and supracrustals of both the rock groups. My overall assessment of the data produced by Nutman et al. (1992) is that if they are not dealing with metamorphic zircons they have probably dated the protoliths of Bababudan Group.

(6) Kudinerkatte is about 60 kms northeast of Banavar, not 20 km as given in the paper on p. 372. I do not understand the meaning of citing the Sm-Nd (T_{dm}) modal ages of the kyanite, when the authors write on the same page that 'interpretation of the depositional and magmatic setting of the Sargur group is fraught with difficulty because the tracts and enclaves in the orthogneisses may include protolith of widely different ages (and settings) which were juxtaposed tectonically during the series of gneiss forming events 3400 - 2900 Ma. The orthogneisses of Gorur and north Goa dated at 3,400 Ma and 3,500 Ma (Beckinsale et al. 1980; Dhoundial et al. 1987) contain enclaves of supracrustals of various dimensions and according to their own statement on p. 372 - 373, their refusal to accept the inference of Naqvi et al. (1978) that the Sargur group are remnants of early Archaean processes is not justified. Even if it is assumed that they have succeeded in separating real detrital zircons (3586\pm 0.4 Ma) which have been deposited as a part of poorly sorted sediment of exceptionally high Al_{2}O_{3} - these sediments would have come from nearby source, therefore, early Archaean processes in Sargur terrains are more firmly established.

(7) Naqvi et al. (1981) have not proposed that the entire Sargur schists in this belt are chemogenic. They have described the composition of chemical sediments such as BIF, fuchsite, quartzite and barites. It is reiterated that most of the sedimentary parts of older schist belts are made up of chemogenic and argillaceous sediments. Our inferences about the source of the Holenarasipur metasediments are based on the consideration of chemical composition of the total rock assemblage which does not satisfy the law of mass balance, if a widespread sial is assumed to weather and provide the debris (Naqvi et al. 1983). However, existence of some acidic volcanic rocks at that time in the source area cannot be ruled out. Availability of free plutonic quartz to weather and get deposited as arenites at that time in these belts is still not unequivocal. To understand the genesis of the entire rock assemblage of Holenarasipur belt an understanding of the chemical-mechanical interaction between Archaean atmosphere, hydrosphere and lithosphere is essential.

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DISCUSSION

Reply

We are grateful to Dr. Naqvi for his comments on our paper. We are pleased to respond to the points he has made as follows:

1. With reference to Hussain and Naqvi (Fig. 1b, 1983), the specimen of garnetiferous schist (BC 790508) was collected approximately 2 km southeast of Tattekere. We have no doubts that it is from the Sargur Group. Dr. Naqvi remarks that 'the unconformity between the two groups (Sargur and Bababudan) is not found in this (Holenarasipur) belt.’ We should like to clarify this point. The original unconformable relationships have been strongly modified by the complex deformation in the Holenarasipur belt. As a consequence, the contacts between the two groups are broadly concordant on a regional scale. In spite of the concordant relationships, it is possible to make a distinction between the two groups on the grounds of their regional relationships. Dr. Naqvi refers to estimates which suggest that the crust (presumably he means sialic crust) about 3000 Ma ago comprised about 70% granitoid material and about 30% mafic-ultramafic rocks such as komatiites. We do not dispute this estimate.

2. Dr. Naqvi asks whether there are ‘real detrital zircon grains derived from granitoids in any of the rocks of the Holenarasipur/Sargur Group?’ We presented SEM photographs (Chadwick et al., Fig. 3, 1986) which show that zircon grains from the Sargur chromite-bearing fuchsite quartzites at Banavara and from the Sargur semi-pelitic schists and the Tattekere Conglomerate in the Holenarasipur belt are subhedral to strongly rounded. Their size and degree of rounding are broadly similar to that of detrital grains of zircon from quartz-pebble conglomerates (examples from the Neralkatte Conglomerate, the basal quartz-pebble conglomerate of the Dharwar Supergroup on the west of the Chitradurga belt, and an Ordovician conglomerate in Anglesey, UK, are shown in Chadwick et al., Fig. 3, 1986).

The shapes of zircon grains in these Sargur specimens are different from those from the Peninsular Gneiss and the Chitradurga Granite as illustrated by Chadwick et al. (Fig. 3, 1986). Dr. Naqvi suggests that one of the zircon grains from the Tattekere Conglomerate (Chadwick et al., Fig. 3, 1986) appears to have been derived from volcanic rocks. We agree with this possibility because it is compatible with the detrital origin of the Tattekere Conglomerate. Our view that detrital grains of zircon exist in the Sargur Group is supported by the presence of unambiguous detrital grains of chromite in the fuchsite quartzites at Banavara (Chadwick et al., Fig. 2, 1986). Dr. Naqvi’s claim (in his comments 3) that he could only find metamorphic zircon in the fuchsite quartzite at Banavara is in marked contrast not only with our findings, but also those of Raase et al. (1983).

3. Dr. Naqvi is mistaken in his claim that Chadwick et al. (1986) regarded the Tattekere Conglomerate as a basal oligomictic quartz-pebble conglomerate. We made no reference to this possibility. Although Ramakrishnan and Viswanatha (1981, p. 119) regarded the Tattekere Conglomerate as the strike extension of the Kumkumna Hosur oligomict conglomerate, we maintain their view (Ramakrishnan and Viswanatha, 1981, p. 121-123) that the origin of the Tattekere Conglomerate is controversial, although we favour a detrital origin. However, its stratigraphic position is uncertain because of poor exposure. For these reasons, we did not use zircon grains from the Tattekere Conglomerate for the SHRIMP analyses.
Dr. Naqvi suggests that the presence of poorly sorted prismatic zircon grains in... 'highly mature sediments requires a satisfactory explanation.' We have discussed the shapes of the zircon grains in the garnetiferous schist (BC 790508) and the chromite-bearing fuchsite quartzite (BC 790301) at some length in our paper. The degree of rounding of detrital zircon grains is a function of their original shape in the host rock in the provenance of the sediments, the distance they were transported, their residence time in, say, a beach environment, and post-depositional effects. Whilst some of the zircon grains in the fuchsite quartzite are clearly rounded, the majority have only rounded pyramidal terminations. Their association with detrital grains of chromite supports a detrital origin, but they may not have been transported far from their provenance. A similar case can be made for the zircon grains with markedly rounded pyramidal terminations in the garnetiferous schist.

Pertinent to this debate are the results of an analysis of detrital grains of zircon from the Kalasapura Conglomerate (Kartikere Conglomerate of Chadwick et al. 1985) at the base of the Bababudan Group in Bababudan by Fareeduddin et al. (1988). They show that the detrital zircons range from sub-hedral to rounded types, but they are closely comparable to those in the Chikmagalur Granodiorite which forms an immediately adjacent part of the basement. Fareeduddin and his co-workers drew attention to the subangular terminations in the detrital zircons which they interpreted in terms of a relatively short transport distance from their source.

4. Dr. Naqvi draws attention to the issue of the apparent lack of zircon growth during metamorphism of the garnetiferous schist (BC790508) and the growth of in situ metamorphic zircon in the fuchsite quartzite (BC790301). The fact that the zircons grains with rounded pyramidal terminations in the garnetiferous schist are comparable with those with rounded pyramidal terminations in the fuchsite quartzites with abundant detrital chromite is indicative of a detrital origin. Moreover, the euhedral zoning in the zircon grains in the garnetiferous schist is typical of zircons that have crystallised from granitoid melts. Furthermore, they do not have low Th/U (<0.05) ratios or delicate twin structures that characterise the metamorphic euhedral zircons in the fuchsite quartzite. Consequently, we regard the zircon grains in the garnetiferous schist as detrital. We suggest that the apparent lack of post-depositional (metamorphic) zircon growth in the garnetiferous schist compared with the growth of metamorphic zircon grains (only a small percentage of the total zircon population) in the fuchsite quartzite may be a function of variations in fluid activity (including solution transfer) between the two lithologies.

5. Dr. Naqvi suggests that we should have used zircon grains from the Tattekere Conglomerate for our SHRIMP analyses. We have explained above why we did not use grains from this particular lithology. We chose the chromite-bearing fuchsite quartzite at Banavara because it contains unambiguous detrital grains of chromite and zircon. It is for Dr. Naqvi to explain why the $\delta^{18}$O value is incompatible with a detrital origin for this fuchsite quartzite. We have no difficulty in accepting that the fuchsite quartzite at Banavara is part of the Sargur Group and that it was derived from a mixed provenance which included granitoid rocks and chromite-bearing stratiform gabbroic complexes (Chadwick et al. 1986).

We question Dr. Naqvi's suggestion that the Sargur Group cannot be separated from the Bababudan Group of the Dharwar Supergroup. There is unambiguous field evidence of unconformable relationships between the Bababudan Group
and tracts of the older Sargur Group in, for example, the southeast of Bababudan, at Sigegudda, on the west of the Chitradurga belt and on the west of the Kibbannahalli arm of this belt (Chadwick et al. 1981; Viswanatha et al. 1982; Ramakrishnan and Viswanatha, 1987; Venkata Dasu et al. 1991). We question Dr. Naqvi's estimate that the age of the Bababudan Group is about 3000 - 2900 Ma. As far as we are aware, no unambiguous isotopic age data have been published to substantiate this estimate.

Dr. Naqvi points to Rb-Sr isotopic age data reported by Monrad (1983) and Stroh et al. (1983) from granitoid rocks that are alleged to intrude the Bababudan Group in the north of the Holenarasipur belt. Ramakrishnan and Viswanatha (1981, p. 128) have reported that the Mavinkere Granite (Halekote Trondhjemite of Monrad (1983) and Stroh et al. (1983) is distinctly intrusive into the Sargur Group, but its relation with the Bababudan Group is ambiguous and an intrusive relationship has not been proved, although later remobilisation may have led to local emplacement of pegmatites and quartz-schorl veins in the Dharwar rocks. We would be happy to accept Dr. Naqvi's invitation to examine the contacts at Katya and Kuncha.

Dr. Naqvi's claim that we accept 'that the margins of the Sargur rocks are intruded by sheets of orthogneiss (p. 369) ranging in age from 3358 to 3071 Ma (p. 372)' is unjustified. We do not say this in our paper. Moreover, we do not contradict ourselves 'by declaring that none of them are found in contact with the Sargur rocks which are supposed to be deposited in the period 3130 - 2960 Ma.' Dr. Naqvi also claims that we have misquoted Monrad (1983). Monrad (p. 345) wrote 'The Halekote trondhjemite has intruded into both the HNSB (Holenarasipur schist belt) and surrounding Peninsular Gneiss near the junction of the western and northern portions of the schist belt.' Monrad (Fig. 1, 1983) showed that his samples of 'Marginal gneisses' which include the Halekote trondhjemite, were drawn from suites which intrude the Sargur Group. We reject Dr. Naqvi's claim that we have misquoted Monrad (1983).

Finally, we wish to emphasise that there is no difficulty in distinguishing between the Sargur Group (older) and the Bababudan Group of the Dharwar Supergroup (younger). Nevertheless, we accept that the period which included the deposition of the Sargur Group, its invasion by the precursors of the quartzo-feldspathic gneisses which form much of the Peninsular Gneiss and the stabilisation and uplift of the sialic basement to the Bababudan Group may have been relatively short. Moreover, the Bababudan Group may have been deposited soon after these events. Unambiguous isotopic age data (Taylor et al. 1984) indicate that the Dharwar Supergroup, including the older Bababudan Group, was deposited in the period 2900-2600 Ma. The age of the Bababudan Group within this period remains to be investigated by more sophisticated isotopic techniques than have been applied hitherto.

6. Dr. Naqvi is correct in pointing out that Kudineerkatte is about 60 km north of Banavara, not 20 km as we indicated in our paper. The Sm-Nd model ages of 3180-3090 Ma are highly relevant in the context of the depositional age of rocks of the Sargur Group because their protoliths were deposited only a short time prior to the emplacement of the host gneisses c. 3000 Ma. This relationship in not inconsistent with our statement that the interpretation of the depositional and magmatic setting of the Sargur Group in fraught with difficulty because the tracts...
and enclaves (of the Group) may include protoliths of widely different ages and depositional setting.

Backinsdale et al. (1980) described the Gorur gneisses as a range from dioritic amphibolites to trondhjemitic compositions. They described no enclaves as Dr. Naqvi claims. They made reference to a personal communication from B. Chadwick which indicated the presence of supracrustal enclaves within the gneisses of the Hassan District in general, but not specifically in the Gorur gneisses. Moreover, Dhoundial et al. (1987) made no specific reference to unambiguous supracrustal enclaves in the Anmod Ghat trondhjemitic gneisses in Goa which yielded an Rb-Sr whole-rock isochron age of $3400 \pm 140$ Ma. They described some co-folded enclaves of metabasic rocks which they suggested might have been volcanic. However, these metabasic rocks may also be interpreted as synplutonic components of the gneisses.

7. Dr. Naqvi reiterates his claim that most of the sedimentary component of the Sargur Group comprises chemogenic and argillaceous sediments. We have always accepted that the quartz-magnetite rocks (BIF) and some of the fuchsitic quartzites are chemogenic (cherts), but a detrital origin is indicated for certain of the fuchsite quartzites on the grounds of the presence of detrital chromite and zircon. We wish to emphasise that the Sargur Group (Supergroup) as defined originally by Swami Nath et al. (1976) probably includes a wide range of supracrustal rocks of different ages and tectonic (depositional) setting. However, the limited isotopic data available so far suggest that the major tracts of the Sargur Group in western Karnataka formed relatively late in the Archaean and they are not representatives of early Archaean or primitive crust.

References


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DISCUSSION


