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Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 05

October 2016, P.P.1983-1988

Petrography and Geochemistry of Proterozoic Clastic Sediments of Naragund, Karnataka: Implications for their Provenance and Tectonic Setting

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Abstract: The Proterozoic clastic sediments exposed at Naragund, Karnataka belongs to the Kaladgi Group, which are unconformably under lain (Eparchean unconformity) and surrounded by Archaean gneiss. The rocks are characteristically bedded with individual beds having variable thickness. Based on the color variation, four varieties of quartz arenite have been distinguished as the grey, white, red and pink quartz arenites. The primary sedimentary structure like stratification, ripple marks, current bedding and graded bedding are commonly seen in the study area. The petrographic analysis has revealed that the clastic sediments are quartz-rich and were primarily derived from felsic sources. The chemical composition of 10 quartz arenite samples corroborates the petrographic observations. The provenance and geodynamic studies indicate that the clastic sediments were derived predominantly from felsic source region and were deposited in a passive margin type tectonic setting.

Keywords: *Clastic sediments, petrography, geochemistry, quartz arenites, provenance, tectonic setting*

1. Introduction

The Proterozoic sedimentary sequences occur extensively over the world and typically in southern Peninsular India distributed in Karnataka, Andhra Pradesh, Tamil Nadu and Kerala. The rocks at these places cover the highly deformed, metamorphosed and intruded sequences of Archaean crystalline rocks. The sedimentary sequences are mostly undeformed to feebly deformed and unmetamorphosed. The initiation of sedimentation in the Proterozoic sedimentary basins have begun around 1,800 m.y. [1] The pronounced angular unconformity separates the strongly deformed and metamorphosed rocks of the Archaean basement from the rocks of sedimentary sequence. This angular unconformity is referred to as the *Eparchaean Unconformity*.

Huge piles of undeformed and unmetamorphosed cratonic sediments belonging to KaladgiGroup occupy the well-known Kaladgi-Badami basin that spreads over an area of 8,300 sq.km in northern Karnataka. The bulk of exposures of late Proterozoic Kaladgi super group sediments are confined to Belgaum, Bijapur and Bagalkot districts. Kaladgi basin has gained lot of importance in recent years as it forms one of the most favorable targets for uranium, especially after the location of arenite-hosted uranium mineralization at Tugunshi and Deshnur in the eastern and western parts of the basin respectively [2-3].Similar types of sediments resembling Kaladgis occur in the form of conspicuous outliers in the Archaean gneisses and schistose formations at Naragund (Gadag district), Navalgund and Dhumwad (Dharwad district). The sequences of sediments in these localities are least disturbed and are partially subjected to deformation and metamorphism. They differ distinctly in their lithological character and stratigraphic relation from the unconformably underlying and surrounding Archaean gneisses and schistose rocks. While sediments of proper Kaladgi-Badami basin have been extensively studied by various workers [4-7], attention has not been given to the sedimentary formations exposed at Naragund. The present paper deals with the field, petrography and geochemistry of clastic sediments of Naragund, Karnataka to understand the provenance and tectonic setting.

2. Geology

The Naragund hillock lies to the NNW of Naragund town, extending for about 788m in the NNW-SSE direction (Fig. 1). It forms another isolated patch of thick quartz arenites belonging to the Kaladgi Group. At Naragunda highly altered mica schist along with minor banded iron formation constitutes part of the Archaean supracrustals sequence. The mica schist is also intruded by quartz veins ranging in width from about 5 to 20 cm. The bedding foliation plane of the mica schist show a general strike of N30°-35°W and S30°-35°E with steep easterly dipping foliation. In the southern part of the Naragund hillock the schist is intruded by about one meter wide apliticveins. Few minor faults are observed affecting the basement schist with intrusions of thick quartz veins. At some places the schisthas been converted to carbonatized schist due to hydrothermal activity.

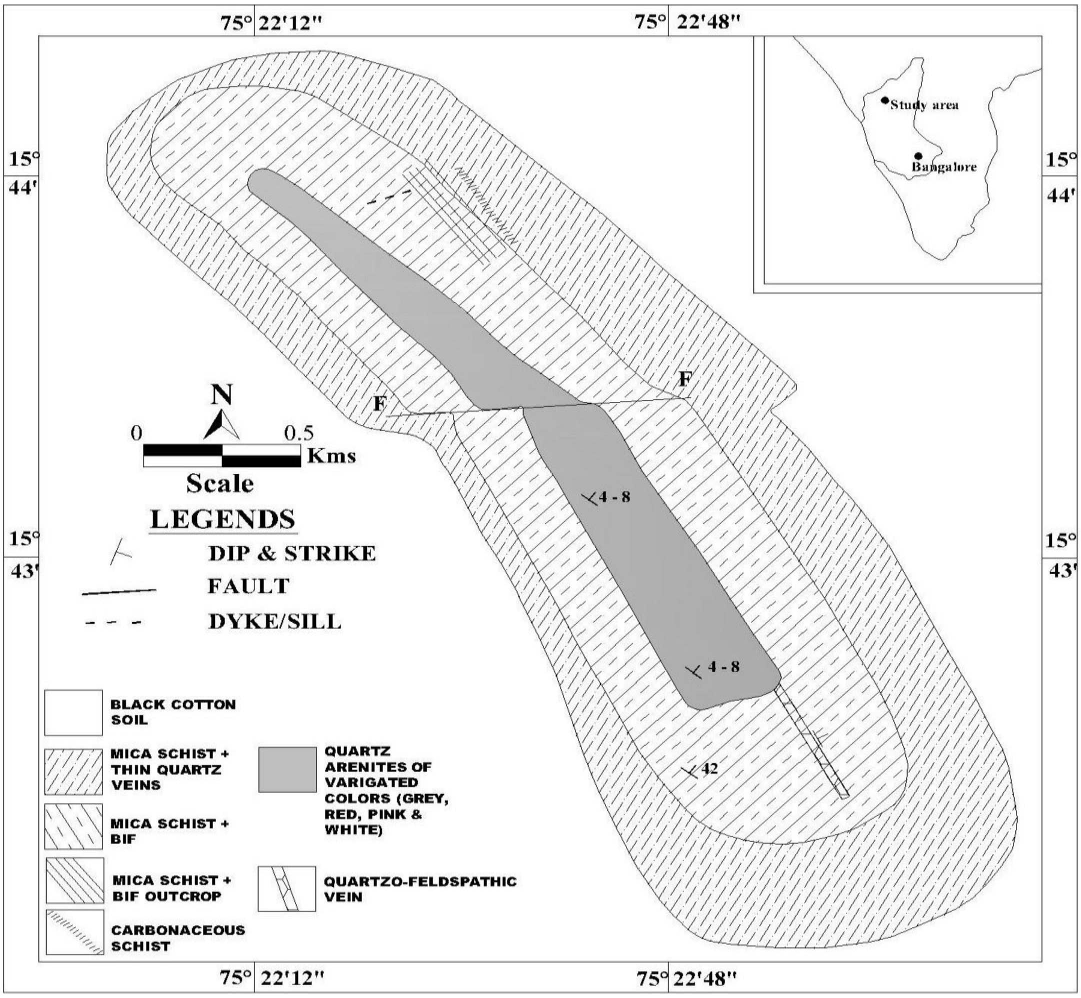

Fig. 1: *Geological map of Naragund*

Based on the color variation, four varieties of quartz arenite are distinguished as the grey, white, red and pink quartz arenites (Fig 2a), out of which the pink and white categories are most common. Quartz arenites show a general strike of N40°W and S40°E.They are compact and show well defined bedding planes, which are almost horizontal having a dip of 4-8^0(Fig 2b) disposition resting over the Dharwar supracrustals, which are having a dip of 42^0 due east. The graded bedding is seen in the quartz arenites at occasional places mostly in the reddish quartz arenites. The primary sedimentary structure like stratification, ripple marks, current bedding and graded bedding are common in the quartz arenites. The secondary structures like joints and faults are seen in the competent arenites due to structural disturbances. At some places in the quartz arenites tiger skin markings due to solution activity and enrichment of FeO are observed.

3. Petrography

Naragund clastic sediments consist of sub-angular, sub-rounded to well-rounded grains of mainly quartz, cemented together by siliceous-ferruginous material (Fig.2c, d). Thin section studies indicated minor shear fabric. Quartz grains are colorless, monocrystalline, often traversed by irregular fractures. It shows typical undulose extinction. Absence of feldspar indicates mineralogical maturity. Lithic fragments are mainly chert/quartzite, making up <5% of rock composition. The shape and size of the clasts vary considerably indicating bimodality and moderate sorting. These clastic sediments based on their texture, mineralogy and major element composition, are designated as quartz-arenites. Earlier workers have studied such quartz rich sandstone and named them as quartzite, orthoquartzite, metaquartzite while describing unmetamorphosed and metamorphosed quartz rich assemblages [8].

Quartz arenites [9] are generally composed of over 80% of grains of quartz, chert and quartzite and is usually almost devoid of muddy matrix. Typical heavy minerals are sparse zircon, tourmaline and rutile. Most authors [8] would restrict allowable "contaminants" to 5% or less, so that quartz arenites have a detrital fraction of 95% or more of quartz.

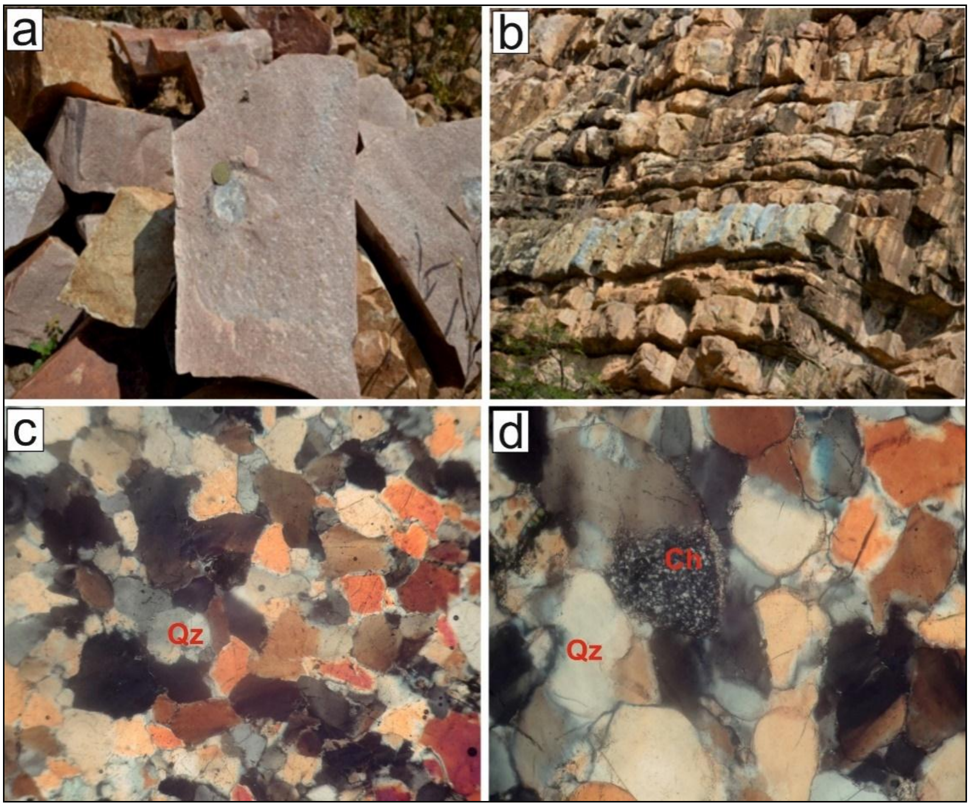

Fig.2: *Field and photomicrograph of Naragundclastic sediments*

Fig.2. (a) Field photograph showing pinkinsh quartz arenite;(b)Field photograph showing horizontal bedding of quartzarenites; (c) Photomicrograph showing sub-angular to sub-rounded quartz grains; (d)Photomicrograph showing well-rounded quartz grains with minor chert fragments.

4. Geochemistry of clastic sediments

A total of 10 samples of clastic sediments from Naragund area have been analysed at Geological Survey of India laboratory at Bangalore for major and trace elements using XRF. The samples collected show no visible effect of weathering, veining or open system behavior. In the laboratory, analysis was carried out in a sequential WDXRF (Bruker S8 Tiger) with a Rh tube. Major elements data was generated from fused beads and trace element data was generated from pressed pellets. The equipment was calibrated using International Standard Reference Materials form USGS, NIST, CCRMP, GSJ, MINTEK, IGGE, IGEM and ANRT. The glass beds beads were made out of 0.5 g of sample (-200 mesh) fused with borate flux (4750mg of $Li_2B_4O_7$ + 390mg Li_2CO_3) in a platinum crucible with automated bead making unit (pearl'X3). Initial fusion started at a temperature of 500°C for oxidation and gradually rose to 1200°C. Final melt was poured into a Pt moulding dish and cooled under controlled environment. The final glass bead was analyzed. The pressed pellets were made out of 4.5 g of finely ground sample (-200 mesh) mixed with 1.13g of boric acid binder. The sample binder mixture was transferred to a 40mm aluminum cup filled with around 3g of boric acid powder as backup and pressed in an automatic hydraulic press (Insmart) to make a pellet of 40mm diameter. The trace elements data was generated using Geoquant program for trace elements analysis of geological materials.

Table 1: *Major and trace element data of Naragund clastic sediments*

Sample	NR1	NR2	NR3	NR4	NR5	NR6	NR7	NR8	NR9	NR10	Av
SiO_2	96.65	97.46	96.31	98.33	98.25	98.88	93.28	97.055	98.565	97.32	**97.21**
TiO_2	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.065	0.07	**0.0685**
Al_2O_3	1.85	1.23	2.1	1.27	1.14	0.91	4.24	1.54	1.025	1.685	**1.699**
Fe_2O_3	0.41	0.29	0.24	0.28	0.51	0.2	0.27	0.35	0.355	0.26	**0.3165**
MnO	0.01							0.005			**0.0075**
MgO	0.22	0.2	0.16	0.29	0.22	0.16	0.12	0.21	0.19	0.225	**0.1995**
CaO	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	**0.039**
Na_2O	0.35	0.32	0.35	0.35	0.33	0.34	0.38	0.335	0.335	0.35	**0.344**
K_2O	0.35	0.25	0.46	0.19	0.23	0.24	1.17	0.3	0.235	0.325	**0.375**

LOI	0	0.05	0.21	0.09	0.01	0	0.36	0.025	0.005	0.15	**0.09**
SUM	***99.95***	***99.91***	***99.94***	***100.92***	***100.80***	***100.83***	***99.92***	***99.93***	***100.82***	***100.43***	***100.34***
V	7	3	3	2	4	2	4	5	3	2.5	**3.55**
Cr	39	16	64	18	27	50	29	28	39	41	**35**
Co	61	70	78	81	48	49	45	66	49	80	**63**
Ni	1	2	2	2	3	1	1	1.5	2	2	**1.75**
Zn	4	5	4	6	4	5	4	4.5	4.5	5	**4.6**
Ga	2	2	3	2	2	2	4	2	2	2.5	**2.35**
Rb	1	3	1				7	2		0.5	**2.42**
Sr	10	9	10	8	7	8	9	9.5	7.5	9	**8.7**
Y	4	4	2	4	3	2	3	4	2.5	3	**3.15**
Zr	62	38	57	47	33	42	56	50	38	52	**47**
Nb	3	2	3	3	2	2	3	2.5	2	3	**2.55**
Ba	28	52	41	13	14	14	18	40	14	27	**26.1**
Pb	3	2	2	2	2	3	2	2.5	2.5	2	**2.3**
K_2O/Na_2O	1.00	0.78	1.31	0.54	0.70	0.71	3.08	0.90	0.70	0.93	**1.06**
Fe_2O_3+MgO	0.63	0.49	0.40	0.57	0.73	0.36	0.39	0.56	0.55	0.49	**0.52**
Al_2O_3/TiO_2	26	18	30	18	16	15	61	22	16	24	**24.60**
Na_2O/Al_2O_3	0.19	0.26	0.17	0.28	0.29	0.37	0.09	0.22	0.33	0.21	**0.24**
Zr/Y	15.50	9.50	28.50	11.75	11.00	21.00	18.67	12.50	15.00	17.33	**16.08**
Al_2O_3/SiO_2	0.02	0.01	0.02	0.01	0.01	0.01	0.05	0.02	0.01	0.02	**0.02**

The studied clastic sediments, comparable to quartz arenites of Pettijohn[10], have SiO_2 content varying from 93-99 wt% with TiO_2 concentrations averaging 0.07 wt%, Al_2O_3 contents of about 1.70 wt% and Fe_2O_3+MgO content of 0.52 wt%. Compared to the average sandstone composition proposed by Turekian and Wedepohl[11], the studied samples are depleted in CaO, Al_2O_3, Fe_2O_3 and Na_2O (Table 1). The negative correlation of SiO_2 with most major elements is due to most of the silica being secreted in quartz [12]. Depletion of Na_2O is attributed to the relatively small amount of Na-rich plagioclase present. The strong negative correlation between Al and Si (r=-0.98) suggests that sedimentary sorting and fractionation of framework silicate and phyllosilicate minerals between bedload and suspended load took place in the catchment area [13]. In comparison with average upper continental crust (UCC), the concentrations of most trace elements are generally low with exception of Co that is consistently enriched relative to UCC for all the analysed samples. The result of chemical analysis of clastic sediments from the study area is in conformity with the above observation made by several researchers.

5. Provenance and Tectonic Setting

Several classifications have been proposed to discriminate various origins and tectonic settings [14-18]. To infer provenance, unstandardized discriminant function scores of the samples (F1 and F2) for major elements were plotted following the boundaries between fields (P1-P4), as proposed by Roser and Korsch[18](Fig.3). The studied samples plot within the P4 field, which represents recycled mature polycyclic quartzose detritus. Recycled sources represent quartzose sediments of mature continental provenance and the derivation of the sediments could be from a highly weathered granite-gneiss terrain. Al_2O_3/TiO_2 ratio varies from 3 to 8 for clastic sedimentary rocks with mafic source, 8 to 21 with intermediate sources and 21 to 70 with felsic sources [19]. Al_2O_3/TiO_2 ratio of studied samples varies between 15 and 61 (av. 24.60), which indicate that they were derived from felsic igneous rocks. Na_2O/Al_2O_3 ratio can be used to infer source of provenance, higher ratios indicate dominance of sodic/tonalitic source rocks. The average value of Na_2O/Al_2O_3 ratio of studied clastic sediments ranges between 0.09 and 0.37 (av. 0.24) which indicates that the sodic/tonalitic rocks were not predominant in the source region.

The abundance of Cr and Ni in clastic sediments is considered as useful indicator of source rock composition. Low Cr and Ni composition in sediments indicate felsic provenance, while higher Cr and Ni content indicate mafic provenance [20]. The average value of Cr in the studied clastic sediments is 35 ppm and average value of Ni is 1.75 ppm, which accounts for felsic provenance. Zr/Y ratio is helpful in identifying the source rock for sediments. Average Zr/Y ratio of UCC is 8.64 [21] and for basalt is 3.06 [22]. The Zr/Y ratio of the studied clastic sediments ranges from 10-29 (average 16) which accounts for felsic source.

6. Geodynamics

On the basis of sedimentary geochemistry, the optimum discriminations of the tectonic settings of sedimentary basins have been previously achieved using major, rare earth and trace elements [15-26, 30].

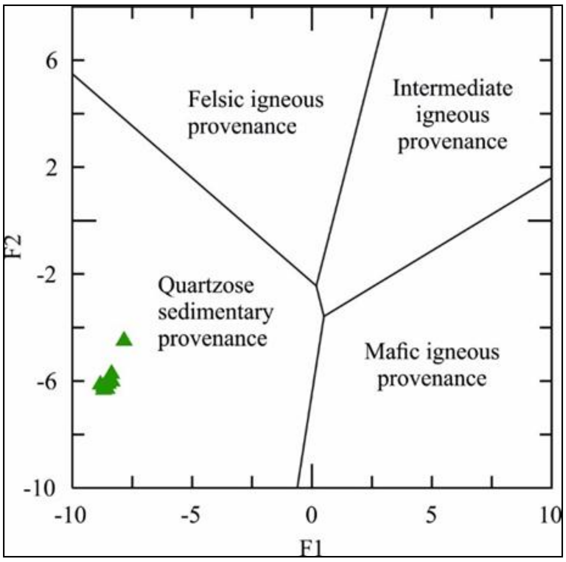

Fig. 3: *Provenance discriminant function diagram using major elements (using the method from Roser and Korsch[18].*

In general, TiO_2, Fe_2O_3+MgO contents and Al_2O_3/SiO_2ratios decrease and K_2O/Na_2O, $Al_2O_3/(CaO+Na_2O)$ ratios progressively increase in sandstones from oceanic island arc to continental island arc to active continental margin to passive margin settings [15,27-29]. The studied samples have low abundance of TiO_2 (av. 0.065 wt%) and Fe_2O_3+MgO (av. 0.36-0.73 wt%) contents, lower Al_2O_3/SiO_2 (0.01-0.05) ratio with relatively higher K_2O/Na_2O (0.54-3.08) and Al_2O_3/(CaO+Na2O) (2.39-10.34) ratios, which indicate passive margin setting. Moreover, in the K_2O/Na_2O-SiO_2 and Fe_2O_3+MgO-Al_2O_3/SiO_2 discrimination diagrams (Fig.4 and 5; after Roser and Korsch [17]; Bhatia [15]), the studied samples mainly plot in the passive margin field. Furthermore, distinctly similar geochemical characteristics of the studied clastic sediments samples suggest that they were sourced from same provenance.

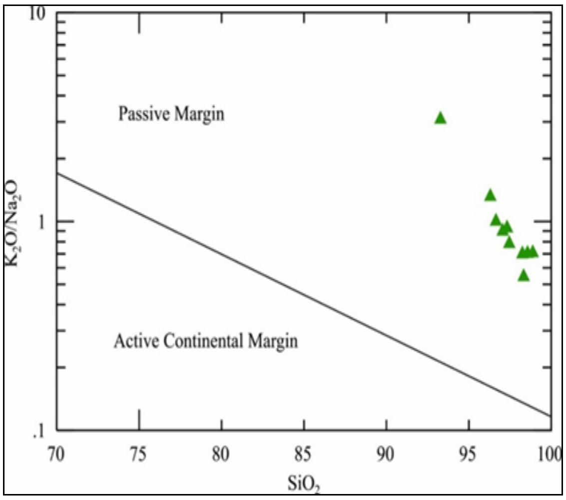

Fig. 4:*K_2O/Na_2O versus SiO_2 diagram (Roser and Korsch [17]).*

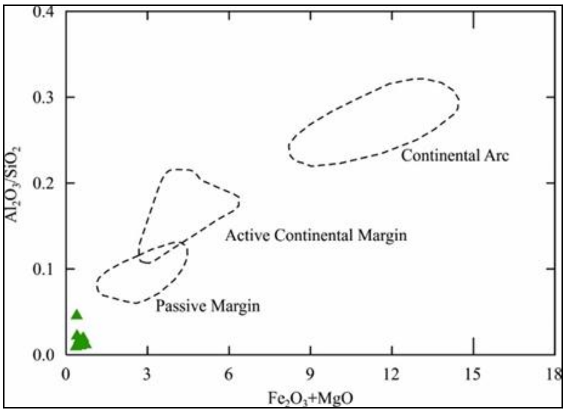

Fig. 5:*Al_2O_3/SiO_2–Fe_2O_3+MgO diagram (Bhatia [15]).*

7. Conclusions

Study of Proterozoic clastic sediments exposed at Naragund, Karnataka have been carried out in detail along with their field characters, disposition, petrological characteristics and geochemical analyses, which attribute these clastic sediments to the "quartz arenite", having variegated colors like grey, pink, white and red. Mineralogical and textural maturity is indicated by the presence predominant quartz clasts with less than 10% matrix content and complete absence of feldspars. The chemical composition of these clastic sediments corresponds with that of quartz arenites being consistent with their petrography. The provenance and geodynamic studies indicate that the clastic sediments were derived predominantly from felsic source region and were deposited in passive margin type plate tectonic setting.

The petrographical studies of these clastic sediments ascertain the sanctity of quartz arenites, while geochemical analysis throws light on provenance of source rock, and both the studies support these facts.

8. Acknowledgments

The present study was funded by University Grant Commission, New Delhi under the Major Research project to Dr. S. Manjunatha (UGC.F.No.42-68/2013 (SR) dated 12-03-2013). We thank Dr. J. N. Das, Dircetor, PPOD, Geological Survey of India, Bangalore and Dr. Mahadevappa, Geologist, Geological Survey of India, Bangalore for extending facilities to analyse the samples.

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