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Petrography and Geochemistry of Archaean Greywackes from Northern Part of the Dharwar-Shimoga Greenstone Belt, Western Dharwar Craton: Implications for Nature of Provenance

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ABSTRACT

Greywackes (Dharwar greywackes) are the most abundant rock types in the northern part of the Dharwar-Shimoga greenstone belt of the western Dharwar craton. They are distinctly immature rocks with poorly-sorted angular to sub-angular grains, comprising largely quartz, plagioclase feldspar and lithic fragments of volcanics (mafic+felsic), chert and quartzite, with subordinate biotite, K-feldspar and muscovite. They are characterized by almost uniform silica (59.78-67.96 wt%; av. 62.58), alkali (4.62-7.35 wt%; av. 5.41) contents, SiO_2/Al_2O_3 (3.71-5.25) ratios, and compositionally are comparable to the andesite and dacite. As compared to Ranibennur greywackes, located about 100 km south of Dharwad in the Dharwar-Shimoga greenstone belt, the Dharwar greywackes have higher K_2O, CaO, Zr, Y, ΣREE, Th/Sc, Zr/Cr, La/Sc and lower Sr, Cr, Ni, Sc, Cr/Th values. The chondrite normalized patterns of Dharwar greywackes are characterized by moderately fractionated REE patterns with moderate to high LREE enrichment, with almost flat HREE patterns and small negative Eu anomalies, suggesting felsic dominated source rocks in the provenance. The frame work grains comprising felsic and mafic volcanics, feldspars and quartz suggest a mixed source in the provenance. The moderate CIA values ranging between 57 and 73, indicate derivation of detritus from fresh basement rocks and from nearby volcanic sources.The mixing calculations suggest that the average REE pattern is closely matching with a provenance having 40% dacite, 30% granite, 20% basalt and 10% tonalite. These greywackes were deposited in a subduction related fore-arc basin than a continental margin basin. Their La/Sc ratios are high (av. 4.07) compared to the Ranibennur greywackes (1.79), suggesting that the greywackes of the northern part of the basin received detritus from a more evolved continental crust than the greywackes of the central part of the Dharwar-Shimoga basin.

INTRODUCTION

Among clastic sediments, greywackes constitute the most abundant rocks of the Archaean sedimentation. As they retain significant concentrations of a variety of trace elements due to their diverse framework mineralogy and matrix characteristics, they are the extensively studied clastic metasediments of the greenstone belts all over the world (Taylor and McLennan, 1985; Naqvi et al., 1988; Srinivasan et al, 1989; Feng and Kerrich, 1990; Manikyamba et al., 1997; Ugarkar and Nyamati, 2002; Ootes et al., 2009; Devaraju et al., 2010; Absar and Sreenivas, 2015). The overall abundance of any clastic sedimentary component in the greenstone belts is of considerable significance. For example, the occurrence of detrital sediments like greywackes has a clear significance in terms of the then prevailing exogenic processes and environment. Such sediments contain important information about the source compositions, weathering conditions, nature of provenance and geodynamic settings of the depositional basins. In the Neoarchaean Dharwar-Shimoga greenstone belt of the western Dharwar craton greywackes are the most abundant clastic metasediments. In this paper, we present and discuss the petrography and geochemistry of greywackes from the northern part (Dharwar greywackes) of the Dharwar-Shimoga greenstone belt, with an aim of understanding sedimentation environment and nature of the provenance in the northern part of the western Dharwar craton.

GEOLOGY

The Dharwar-Shimoga greenstone belt of western Dharwar craton, comprises greywackes, shales, mafic-felsic volcanic rocks along with arenites, limestones, stromatolitic dolomite, carbon phyllites, banded iron formations and banded manganese formations (Harinadha Babu et al., 1981; Chadwick et al., 1988). The rock formations are metamorphosed to greenschist facies and unconformably overlie the older gneiss and mafic/ultramafic enclaves with a basal or near-basal polymictic conglomerate marking the unconformity (Harinadha Babu et al., 1981; Naqvi and Rogers, 1987). The Ranibennur Formation, an upper part of the Chitradurga Group in the Dharwar-Shimoga greenstone belt is composed of greywacke-argillite, chert and volcanic rocks.The litho-units of present study area (Fig. 1) belong to this formation.

The study area comprises a thick sequence of metasediments with greywackes, polymict conglomerate and banded iron formations, with occasional metavolcanic sequences (Fig. 1). In general, the foliation and schistosity of these rocks strike NNW-SSE and their dip varies from 75°to sub-vertical, due east as well as west. The conglomerate, overlying the metavolcanics, occurs as a prominent litho-unit in the eastern margin of the belt in the study area. It has pebbles of granite gneiss, quartzite, mafic and felsic volcanic rocks and banded iron formations. Metamorphosed greywackes constitute the bulk of the supracrustal sequences of the northern part of the Dharwar-Shimoga greenstone belt and are best exposed in the quarries at Mandihal and Someshwar near Dharwad. Some outcrops are also located at Uppin Betageri, Gudikatti, Anigol and Bailhongal. The banded iron formations occupy ridges with a general NNW-SSE trend. These iron formations occur interlayered with the thick sequences of greywackes and are at places intensely deformed and brecciated. The metavolcanics occur as flows, pillowed and pyroclastic rocks (volcanic breccia). Based on the geochemical characteristics, Ugarkar et al., (2012, 2014) have classified the flows and pillowed metavolcanics into basaltic komatiites, tholeiitic basalts and tholeiitic basaltic andesites, while the clasts of the pyroclastic breccias are felsic in composition. Doleritic dykes and sills cut across the metavolcanics and metasediments.

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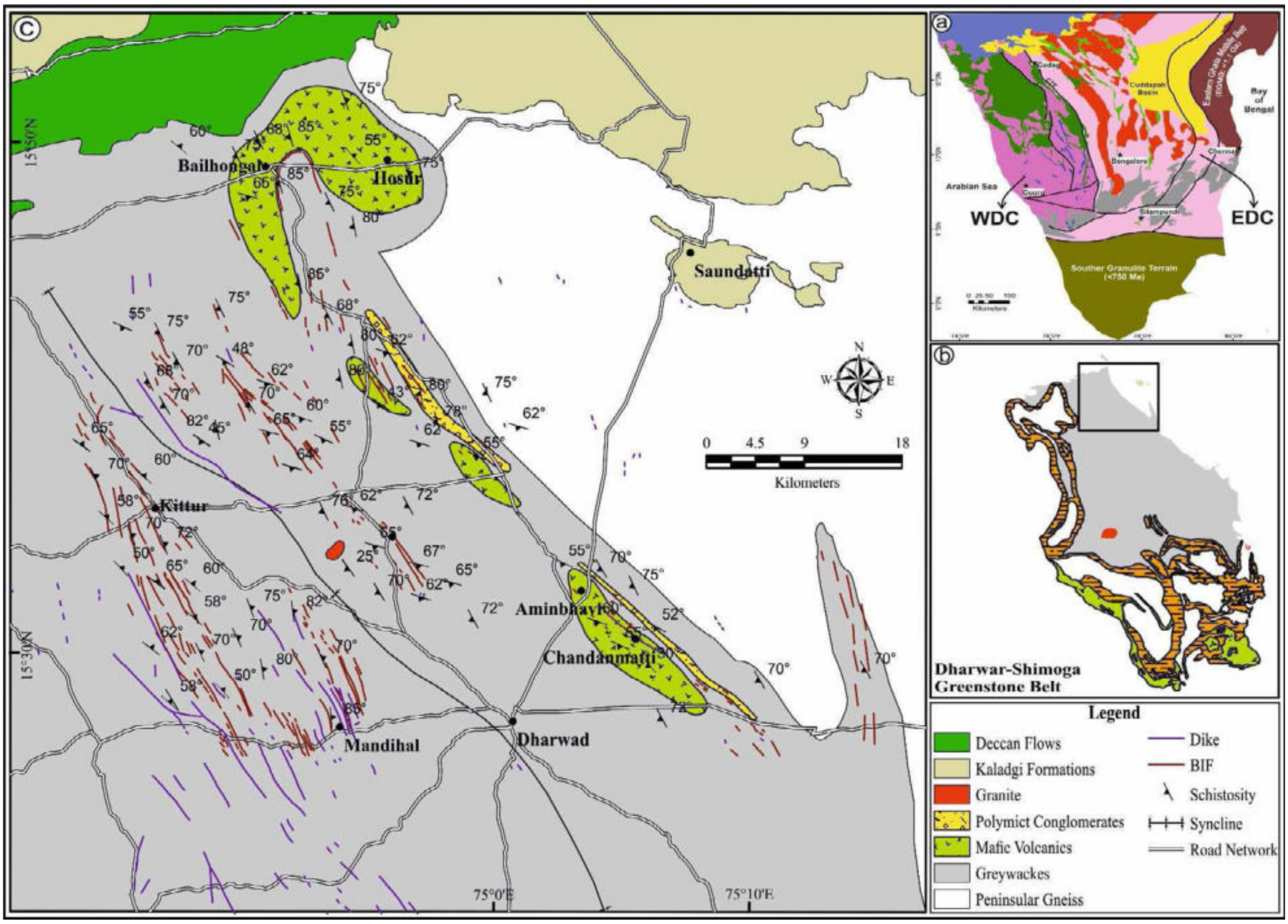

Fig.1. Detailed geological map of northern part of the Dharwar-Shimoga greenstone belt (modified after Ugarkar et al., 2012)

PETROGRAPHY

The greywackes are greenish grey to ash grey in colour, fine to medium grained and at places show the typical shear characteristics of phyllites. They contain sub-angular sand sized mineral grains of quartz, feldspar and deep greenish black rock fragments embedded in a green microcrystalline matrix. Filling of the foliation planes and randomly oriented fracture planes with quartz veinlets (and in some places with calcite) of more than one generation is common.

Petrographically, they are distinctly immature with poorly-sorted angular to sub-angular grains, and generally lack uniformity in the distribution of individual coarse grains. The coarse grains are largely quartz, plagioclase feldspar and lithic fragments of volcanic (mafic+felsic) rocks, chert and quartzite, with subordinate biotite, K-feldspar and muscovite (Figs. 2a-d). In general, the plagioclase feldspars derived from the plutonic rocks are of comparatively larger dimension (0.3 to 0.8 mm) than those derived from the volcanic rocks (≤ 0.2 mm). Occasionally the plutonic feldspars are well rounded (Fig. 2a). Felsic volcanic lithic fragments are more than the mafic volcanic lithic fragments. In places, fine chlorite needles and scales penetrate clasts of quartz along grain boundaries, which probably is the result of compaction and diagenesis. Quartz is mostly mono-crystalline, although polycrystalline variety is also noted. Poly-crystalline quartz, characterized by serrated grain boundaries with individual grain size of 0.4 to 0.2 mm (Fig. 2a), is probably derived from gneisses, while the polycrystalline quartz with individual grain size less than 0.02 mm probably indicates recrystallized chert. The grain boundaries of the quartz, feldspars and lithic fragments are serrated and diffused, which could be due to a short transport time and subsequent diagenetic reactions between grains and groundmass. The groundmass consists of chlorite, sericite, plagioclase, quartz and calcareous material. Serrated and diffused grain boundaries of framework grains indicate formation of secondary matrix. It is difficult to determine whether the recrystallized interstitial material originated as detrital matrix or from labile framework grains (see Cox and Lowe, 1996). It is recognized that development of secondary matrix causes problems in determination of QFL percentage and also in the interpretation of provenance based on QFL scheme (Cox and Lowe, 1996). However, the Dharwar greywackes have an average modal composition of 31%quartz, 22% feldspars (plagioclase dominates), 8% lithic fragments (cherts + quartzites + volcanics) and 23% matrix. The lithic fragments are comparatively larger than mineral clasts (Fig. 2a–d).

SAMPLING AND ANALYTICAL METHODS

Relatively fresh homogeneous representative samples of greywackes from northern part of the Dharwar-Shimoga greenstone belt were collected from quarries, road cuttings and natural outcrops. Weathered and jointed surfaces with quartz/calcite veins were discarded. The sample chips were reduced to sand size by crushing and were then powdered to ~ 200 mesh in an agate mortar to avoid contamination. Major element concentrations were estimated by X-ray fluorescence (XRF: Phillips MAGIX PRO Model 2440) on pressed pellets at the National Geophysical Research Institute, Hyderabad. Determination of trace elements and REEs was carried out using inductively coupled plasma mass spectrometry (ICP-MS: Perkin Elmer Elan DRC II) after dissolving the finely powdered samples by open digestion method using HF-HNO_3-$HClO_4$ in Teflon beakers at the National Geophysical Research Institute, Hyderabad, following the

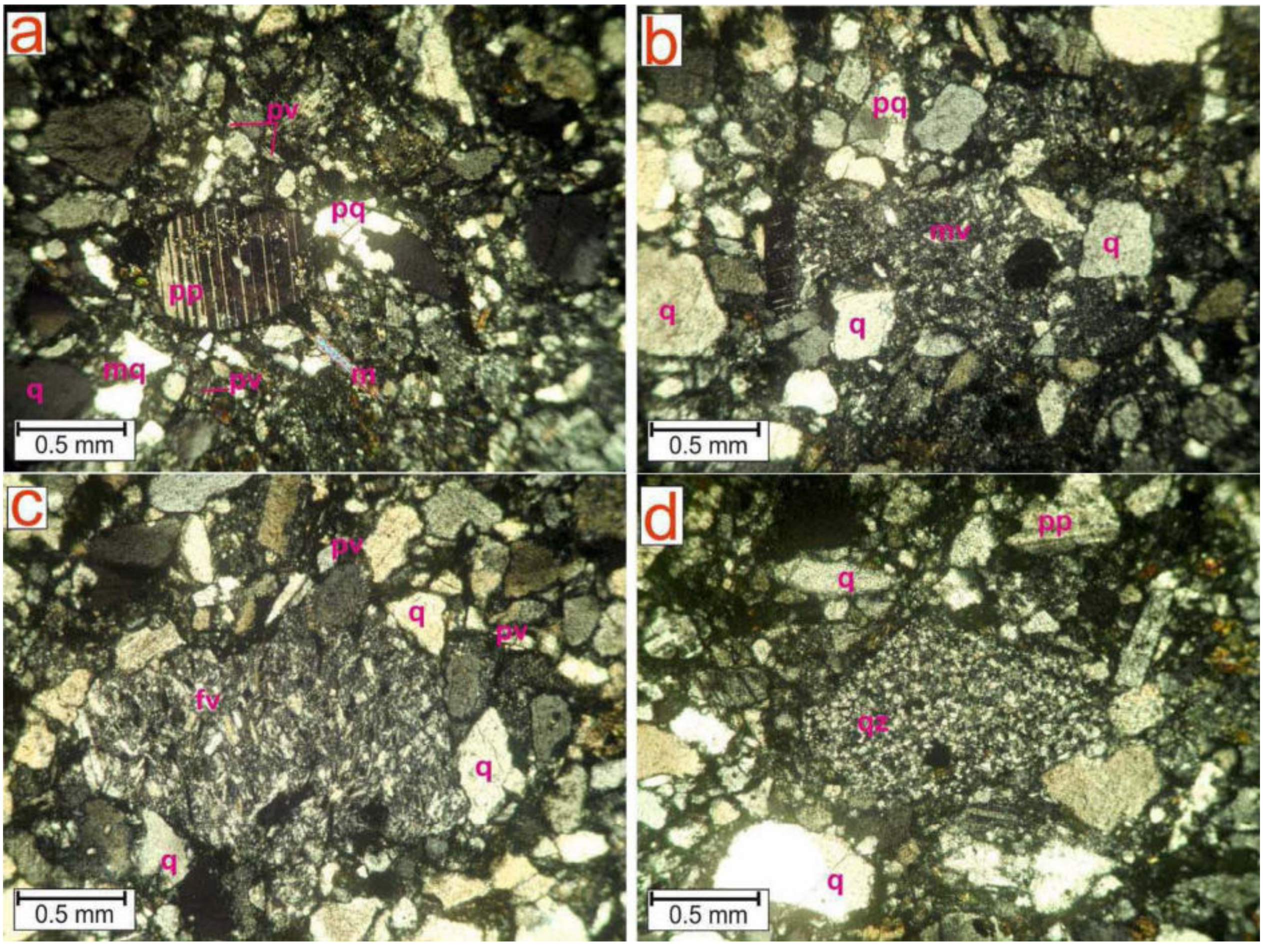

Fig.2. Photomicrographs: **(a)** Plagioclase feldspar (pv-volcanic and pp-plutonic source), polycrystalline (pq) and monocrystalline (mq) quartz grains and flakes of mica (m). **(b)** Lithic fragment of mafic volcanic (at the centre. Also note the bimodality and angularity of the grains, as well as the larger dimensions of the rock fragments compared to quartzo-feldspathic grains. **(c)** Lithic fragment of felsic volcanics. **(d)** Quartzite lithic fragment. pv: volcanic and pp: plutonic source. pq: polycrystalline and mq: monocrystalline quartz grains. m: flakes of mica. fv: felsic and mv: mafic volcanic lithic fragments. qz: quartzite lithic fragment.

procedure of Balaram et al. (1996). Loss on ignition (LOI) was determined by heating 1 gm of finely powdered sample in platinum crucible at temperature range between 550 and 600ºC in a muffle furnace.

GEOCHEMISTRY AND PROVENANCE

The greywackes of the present study area are characterized by almost uniform silica (59.78-67.96 wt%; av. 62.58), alkali (4.62-7.35 wt%; av. 5.41) contents and SiO_2/Al_2O_3 (3.71-5.25) ratios (Table 1), and compositionally are comparable to the andesite and dacite (Fig. 3a). Moderately higher contents of Al_2O_3 (12.92 to 16.70 wt%), FeO (5.04 to 9.29 wt%) and MgO (3.2 to 6.58 wt%) are suggestive of abundant content of matrix rich in chlorite, clay minerals and iron oxides. As compared to Ranibennur greywackes (Hegde and Chavadi, 2009), the Dharwar greywackes have higher K_2O, CaO, Zr, Y, ΣREE, Th/Sc, Zr/Cr, La/Sc and lower Sr, Cr, Ni, Sc, Cr/Th values (Table 1). The chondrite normalized patterns of these greywackes are characterized by moderately fractionated REE patterns (La_N/Yb_N = 8.5)with moderate to high LREE enrichment (La_N/Sm_N = 4.2), with almost flat HREE patterns (Gd_N/Yb_N = average 1.5) and moderate negative Eu anomalies (Fig. 3b).

The intensity of chemical weathering of a source terrain can be quantitatively evaluated by the Chemical Index of Alteration (CIA) of clastic rocks (Nesbitt and Young, 1984). The CIA values for Dharwar greywackes range between 57 and 73 with an average value of 63, indicating a moderate degree of weathering. Climatic conditions in the source region also play an important role in weathering and on the maturity of sediment that is formed. When plotted on a SiO_2-(Al_2O_3+K_2O+Na_2O) diagram (Suttner and Dutta, 1986), the composition of the Dharwar greywackes indicate a source area with arid climatic conditions (Fig. 4a). Recently, Ojakangas et al (2014) have suggested glaciomarine origin for the diamictites of Chitradurga Group which would imply that during the initial stages of Chitradurga Group sedimentation a cold arid climate prevailed. The Dharwar greywackes belong to the upper part of the Chitradurga Group, their moderate CIA values may indicate derivation of detritus from fresh basement rocks and from nearby volcanic sources.The initial composition of the source rocks can be obtained from the weathering trend line in the A-CN-K diagram (Fig. 4b) of Nesbitt and Young (1984). The trend line of Dharwar greywackes trace back to dacite, andesite and granodiorite fields.

Cr and Ni abundances in clastic sedimentary rocks are useful in deciphering the contribution from mafic and ultramafic components in the provenance (McLennan and Taylor, 1984). Cr (53 ppm) and Ni (36 ppm) contents of Dharwar greywackes are low, which suggest that the felsic component was dominant in the provenance. Th/Sc ratios are used to discriminate felsic and mafic sources in the provenance (McLennan and Taylor, 1980). Th/Sc ratios more than 1 reflect an input of sediments from felsic igneous sources, while ratios <0.8 are indicative of mafic sources. The Dharwar greywackes haveTh/Sc ratios more than 1 (average 1.13), which suggest that the detritus was derived from a felsic dominated igneous source. The chondrite normalized

Table 1. Major, trace and rare earth element analyses of greywackes around Dharwar

Sample	D18	D18/A	D21	D38	D40	S1	S2	S3	N1	N2	N3	N4	Av	RG*
SiO_2	63.93	60.35	59.78	67.96	67.84	61.97	63.79	62.29	60.08	59.95	59.96	63.04	62.58	63.07
TiO_2	0.54	0.64	0.61	0.52	0.51	0.55	0.51	0.61	0.65	0.71	0.65	0.61	0.59	0.45
Al_2O_3	13.39	13.93	14.13	13.29	12.92	16.7	15.62	15.89	13.62	14	14.61	14.45	14.38	13.90
MnO	0.17	0.17	0.13	0.06	0.07	0.09	0.12	0.1	0.15	0.15	0.15	0.1	0.12	0.09
Fe_2O_3	7.71	8.7	7.5	5.04	5.62	8.92	8.18	8.22	8.1	9.285	8.68	6.68	7.72	8.98
CaO	3.59	3.51	5.84	1.77	2.26	1.33	2.59	3.23	4.03	3.69	3	3.9	3.23	1.95
MgO	4.3	6.58	5.86	3.2	3.48	4.82	3.42	3.78	4.7	5.37	4.52	4.5	4.54	3.92
Na_2O	3.91	3.18	2.03	4.95	4.44	2.43	2.67	2.77	3.13	3.32	3.65	3.13	3.3	3.65
K_2O	1.79	1.85	2.59	2.4	2.19	2.52	2.36	2.34	1.7	1.67	1.38	2.56	2.11	1.50
P_2O_5	0.17	0.13	0.14	0.2	0.16	0.16	0.13	0.18	0.15	0.16	0.15	0.15	0.16	0.10
Total	**99.5**	**99.04**	**98.61**	**99.39**	**99.49**	**99.49**	**99.39**	**99.41**	**96.31**	**98.31**	**96.75**	**99.12**	**98.73**	**99.99**
Ba	443	477	41	712	582	467	398	460	382	391	412	588	446	
Rb	55	67	94	51	73	80	78	87	56	51	68	70	69	65
Sr	283	313	339	262	185	141	146	81	356	352	347	290	258	401
Ga	19	14	13	19	20	19	17	21	16	14	17	14	17	
Ta	0.65	0.82	0.43	0.57	0.62	0.84	0.59	0.73	0.91	0.91	0.91	0.72	0.73	
Nb	8.20	10.47	6.75	7.57	7.64	10.48	7.08	9.33	8.23	7.73	8.23	4.87	8	
Zr	503	31	33	608	582	639	554	695	97	91	87	95	335	176
Y	27	34	29	25	27	28	21	29	26	28	27	22	27	17.4
Cr	15	92	83	9	11	15	14	16	104	110	91	73	53	176
Ni	39	31	26	22	28	40	40	45	33	58	29	38	36	121
Co	23	26	23	9	16	21	18	20	26	26	25	22	21	24
V	95	96	97	81	90	104	100	115	110	99	106	86	98	131
Cu	27	39	28	23	23	28	26	23	53	32	35	34	31	62
Pb	13	8	5	13	16	15	12	12	10	7	2	12	11	
Zn	23	27	34	19	23	27	23	24	53	60	53	51	35	49
Cs	1.37	1.33	1.59	1.07	1.03	2.51	2.13	1.29	1.67	1.17	1.67	1.30	1.51	
Hf	14	1	1	17	16	18	16	20	2	2	2	2	9	4.15
Th	9	9	7	9	9	9	8	11	9	8	8	8	9	7.35
U	2.65	1.48	1.14	2.52	3.51	2.93	2.64	3.07	2.24	2.24	1.74	1.57	2.31	2.32
Sc	6	13	12	5	5	7	7	7	—	—	—	—	8	13.50
La	29.83	36.59	37.27	32.27	31.39	30.69	27.65	33.91	33.34	32.34	35.2	36.93	33.12	23.70
Ce	56.62	70.74	67.24	60.21	59.56	59.97	53.26	65.62	63.24	63.57	65.32	68.52	62.82	42.70
Pr	6.45	8.29	7.67	7.09	6.96	6.98	6.13	7.60	7.30	7.07	7.56	7.39	7.21	6.40
Nd	23.61	30.40	28.45	25.82	24.82	25.50	22.51	27.35	27.11	27.15	28.13	28.57	26.62	21.0
Sm	4.29	5.68	5.37	4.63	4.52	4.82	4.17	5.03	5.03	5.06	5.26	5.13	4.92	4.60
Eu	1.23	1.64	1.41	1.45	1.35	1.26	1.10	1.32	1.41	1.45	1.54	1.39	1.38	1.00
Gd	4.41	5.58	5.09	4.58	4.67	4.88	4.06	5.14	4.67	5.16	4.93	4.98	4.85	4.00
Tb	0.78	1.03	0.98	0.76	0.82	0.86	0.68	0.88	0.83	0.81	0.86	0.75	0.84	0.50
Dy	4.46	5.96	5.23	4.29	4.71	4.76	3.89	4.98	4.64	4.73	4.86	4.03	4.71	2.90
Ho	0.87	1.19	1.02	0.84	0.95	0.95	0.75	1.01	0.92	0.96	0.97	0.79	0.94	
Er	2.58	3.08	2.72	2.39	2.64	2.81	2.19	2.94	2.44	2.58	2.57	2.16	2.59	
Tm	0.43	0.49	0.44	0.42	0.46	0.51	0.42	0.54	0.38	0.38	0.40	0.32	0.43	0.21
Yb	2.59	2.66	2.67	2.53	2.74	3.24	2.76	3.37	2.19	2.29	2.32	2.04	2.62	1.80
Lu	0.42	0.41	0.40	0.42	0.45	0.53	0.47	0.57	0.32	0.34	0.34	0.31	0.42	
SiO_2/Al_2O_3	4.77	4.33	4.23	5.11	5.25	3.71	4.08	3.92	4.41	4.28	4.1	4.36	4.35	4.54
Th/Sc	1.44	0.72	0.61	1.79	1.66	1.38	1.25	1.5					1.29	0.55
Zr/Cr	33.53	0.34	0.40	67.56	52.91	42.60	39.57	43.44	0.93	0.83	0.96	1.30	23.70	1
Cr/Th	2	10	12	1	1	2	2	1	12	14	11	9	6	24
La/Sc	4.69	2.76	3.09	5.8	5.3	4.32	3.92	4.42					4.07	1.76
“REE	139	174	165	147	146	147	130	160	153	153	160	163	153	119
La_N/Yb_N	7.78	9.3	9.43	8.62	7.74	6.4	6.77	6.8	10.29	9.54	10.25	12.23	8.54	8.90
La_N/Sm_N	4.38	4.05	4.37	4.39	4.37	4.01	4.17	4.24	4.17	4.02	4.21	4.53	4.24	3.24
Gd_N/Yb_N	1.38	1.69	1.54	1.46	1.38	1.22	1.19	1.23	1.72	1.82	1.72	1.97	1.5	1.79
CIA	59	62	57	59	59	73	67	66	61	62	65	60	62	66

Sample locations: D-around Dharwad, N-north of Dharwad and S-south of Dharwad. *RG – Average values of Ranibennur Greywackes (after Hegde and Chavadi, 2009)

patterns of Dharwar greywackes are characterized by moderately fractionated REE patterns with moderate to high LREE enrichment, with almost flat HREE patterns and small negative Eu anomalies, suggesting felsic dominated source rocks in the provenance. The relative contribution of felsic and mafic end members (volcanic as well as plutonic rocks) in the provenance can be modeled using rare earth elements. For this purpose, the average REE data of granites and tonalities that occur on either side of the study area, and REE data of dacites and metabasalts from the study area (Devaraju et al, 2007; Dey et al, 2012; Ugarkar, 2012; Ugarkar et al, 2014) are used as the end members in the provenance (Table 2). The mixing calculations suggest that the average REE pattern is closely matching with a provenance having 40% dacite, 30% granite, 20% basalt and 10% tonalite (Fig. 4c).

DISCUSSION AND CONCLUSION

Petrographic evidence, such as the presence of fresh angular plagioclase and volcanic lithic fragments suggest that the Dharwar greywackes were deposited in a turbidite regime very close to provenance in an unstable environment in which erosion, transportation and deposition were so rapid that there was very little scope for weathering and sorting of the clastic material. The detritus comprising

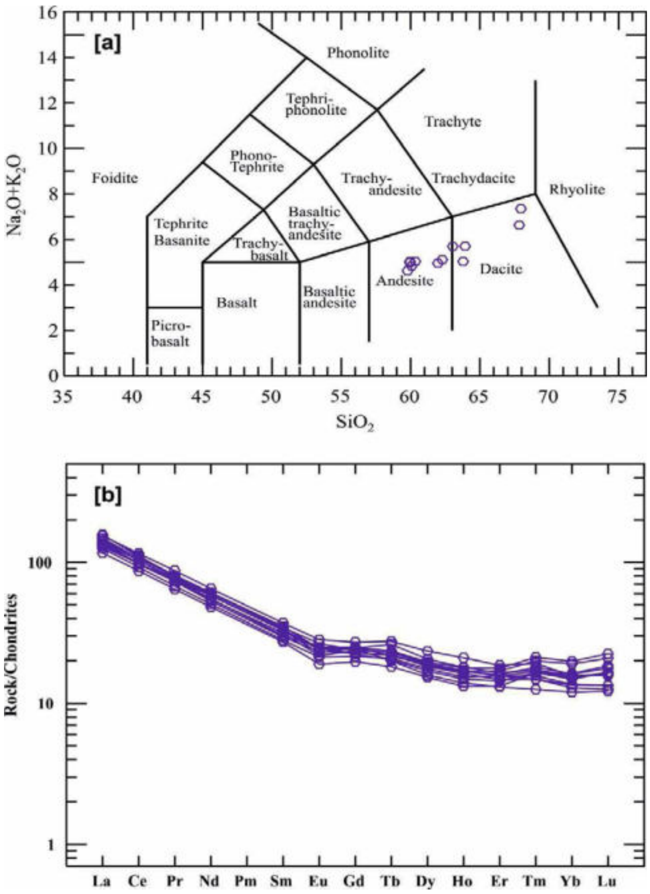

Fig.3. (a) Na_2O+K_2O vs. SiO_2 diagram of Le Bas et al. (1986). **(b)** Chondrite normalized REE diagrams for Dharwar greywackes (chondrite values from Taylor and McLennan, 1985).

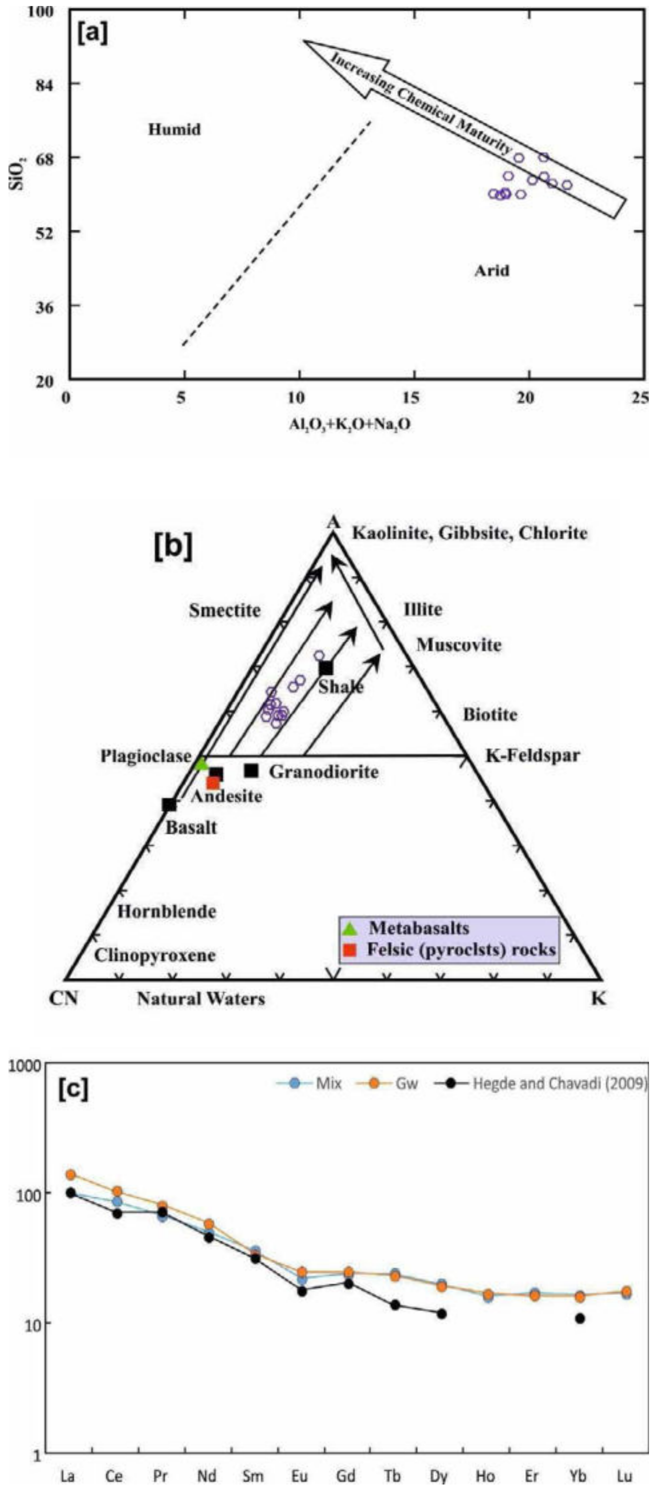

Fig.4. (a) SiO_2 vs. $Al_2O_3+Na_2O+K_2O$ diagram of Suttner and Dutta (1986). **(b)** Ternary plot of A-CN-K (after Nesbitt and Young, 1984). Solid squares are plots of average compositions of typical rock types, Open circles indicate Dharwar greywackes. **(c)** Chondrite normalized REE pattern of average greywackes of study area and estimated REE mixed provenance after mixing the end members in the proportion of 40% dacite, 30% granite, 20% basalt and 10% tonalite.

felsic and mafic volcanics, feldspars and quartz suggest a mixed source in the provenance. Mafic trace elements and immobile element abundances and their ratios are compatible with a felsic dominated provenance. REE mixing calculations indicate 40% dacite, 30% granite, 20% basalt and 10% tonalite composition for the provenance.

It is a well-established fact that the sedimentary basins of western Dharwar craton received clastic detritus from an evolved continental crust which had witnessed upper granodiorite crustal differentiation (Srinivasan et al., 1989; Srinivasan and Naqvi, 1990; Srinivasan and Naha, 1993; Chadwick et al., 2000). While subduction related tectonic settings like foreland, back-arc foreland, forearc basins have been suggested by various workers for the deposition of greywackes of the western Dharwar craton, (Naqvi et al., 1988; Srinivasan et al., 1989; Ugarkar and Nyamati, 2002, Hegde and Chavadi, 2009; Devaraju et al., 2010). The plots on Th-La-Sc tectonic discrimination diagrams of Bhatia and Crook (1986), greywackes of study area indicate continental island arc tectonic setting for their deposition (Fig. 5a). To distinguish between back-arc foreland and forearc basins, the greywackes were

Table 2. REE mixing calculations taking 40% dacite (D), 30% granite (G), 20% basalt (B) and 10% tonalite (T)

	D	B	T	G	Mix*	Gw**
La	24.53	7.54	24.20	32.8	23.59	33.12
Ce	59.98	18.78	26.30	72.7	52.18	62.82
Pr	7.14	2.34	2.61	7.8	5.92	7.21
Nd	30.79	12.50	9.65	22.4	22.50	26.62
Sm	7.87	3.19	2.60	4.2	5.31	4.92
Eu	1.80	0.99	0.39	0.9	1.24	1.38
Gd	7.16	3.98	1.86	2.9	4.72	4.85
Tb	1.45	0.67	0.23	0.5	0.87	0.84
Dy	7.97	3.81	0.75	2.9	4.88	4.71
Ho	1.52	0.75	0.12	0.4	0.90	0.94
Er	4.64	2.27	0.34	1.2	2.70	2.59
Yb	4.75	2.08	0.25	1.1	2.68	2.62
Lu	0.68	0.44	—	0.2	0.41	0.42

Provenance sources: Dacite (Ugarkar, 2012), granite (Devaraju et al, 2007), basalt (Ugarkar et al, 2014) and tonalite (Dey et al, 2012)

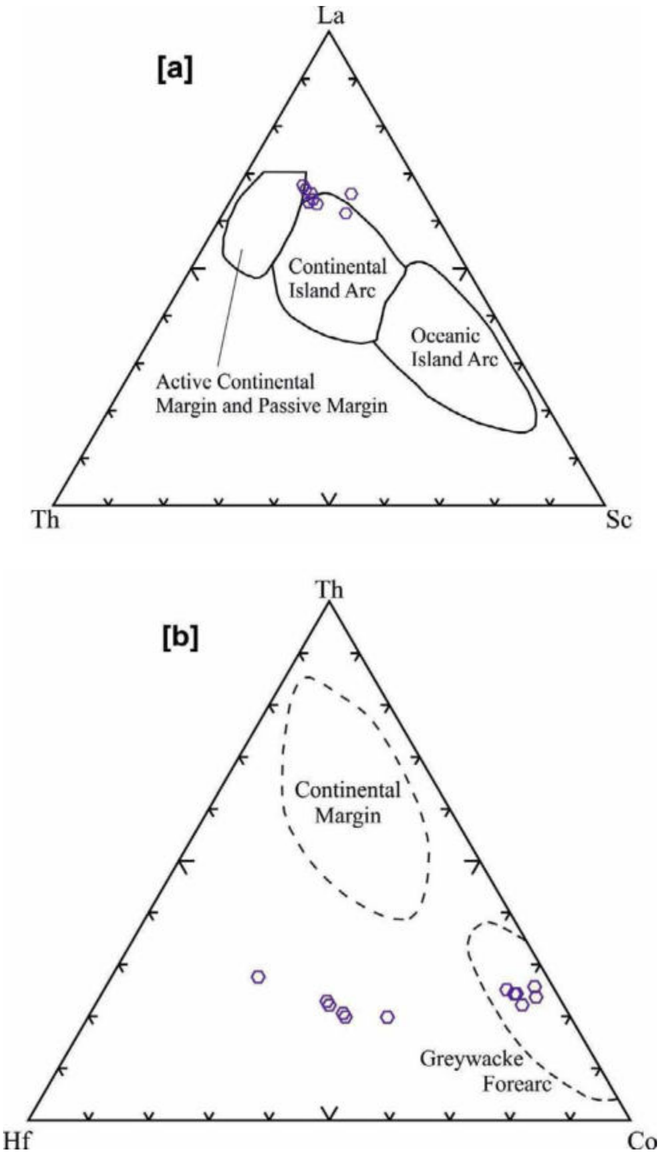

Fig. 5. (a) Th-La-Sc and **(b)** Hf-Th-Co tectonic discrimination diagrams of Bhatia and Crook (1986) and Naqvi et al. (2002) respectively.

plotted on Hf-Th-Co diagram (Fig. 5b; adopted from Naqvi et al., 2002), wherein the plots spread close to forearc basin than a continental margin basin, indicating a possible sedimentation in a subduction related forearc basin.

In most tectonic settings where stable crust or recycled sediments are exposed, Th/Sc values are more than1.0. The Th/Sc ratio of the studied samples (av. 1.13) suggests a source area with a predominant granodioritic component and a relatively minor contribution from mafic igneous rocks. The Archaean western Dharwar craton was highly evolved at the time of Dharwar sedimentation, as indicated by La/Sc ratios of the greywackes of study area ranging from 2.8-5.8 (av. 4.07), well in excess of upper continental crust (2.2, Taylor and McLennan, 1985). La/Sc ratios in greywackes of study area are also high compared to the Ranibennur greywackes, located about 100 km south of Dharwad in the greenstone belt (1.79, Hedge and Chavadi, 2009), suggesting that the greywackes of the northern part of the basin received detritus from more evolved continental crust than the greywackes of the central part of the Dharwar-Shimoga basin. Further, the La/Sc ratio of greywackes of Archaean age from the Canadian Shield (1.45; Camiré et al., 1993), Kalgoorlie, Australia (1.06; Taylor and McLennan, 1985), Fig Tree, Barberton, South Africa (0.54; Hofmann, 2005) and for shales from Zimbabwe (0.94; Fedo et al., 1996) are all significantly less than the greywackes of the study area (av. 4.07). These features indicate that the Archaean crust in the northern part of the WDC was markedly more evolved compared to all the above well-known Archaean cratons.

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