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Chemical Character of Detrital Garnet in Cauvery River Sediment and Its Provenance, South India

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Abstract: *The study attempts to determine the chemical characters of detrital garnets provenance in the Cauvery River Basin. The geochemical results reveal that the detrital garnets are derived from biotite schist, charnockite, and gneisses of intermediate felsic, moderate to strong weathered provenance. The end member composition of the garnets indicates almandine species that are metamorphosed in amphibolite to granulite facies P-T conditions. The angular outline of detrital garnet in the upstream and sub-rounded to rounded grains in the downstream attribute it's transport from the upstream of the Cauvery River.*

Keywords: *Detrital garnet, Mineral chemistry, Provenance, Cauvery River*

1. Introduction

The chemistry of heavy minerals is used as proxies to the textural characters of the sediments and their provenance. The detrital garnet chemistry in sediments is a measure of its stability in a particular range of P-T conditions and useful to demarcate the metamorphic provenance and its stability during transportation (Wright, 1938; Troger, 1952; Zemann, 1962; Nandi, 1967; Morton, 1985; Deer *et al*, 1992; Morton et al., 2004; Mange and Morton, 2007; Aubrecht *et al*., 2009; Biernacka and Jozefiak, 2009; Meinhold *et al.*, 2010; Morton *et al*. 2010; Wotzlaw *et al*., 2011; Ando *et al.* 2013; Suggate & Hall, 2013). The chemistry of the detrital garnets from river, dune and beach sediments has been utilized successfully to reconstruct the provenance (Sabeen *et al*., 2002). The chemical composition of suspended matter and surface micro-texture of quartz grains of the Cauvery River has been investigated to its provenance (Dekov *et al*., 1997; Gobala krishnan *et al*., 2015). Further, this study is focused on the variation of chemical composition, source and surface micro-texture of the detrital garnet.

2. Geological setting

The Cauvery River flows in a trellis drainage pattern from the upstream-Talacauvery (Karnataka state) and debouch to the Bay of Bengal at Poombugar (TamilNadu state) (Fig.1). The upstream river flows through granitoids-gneisses, granulite, and ancient supra-crustal belts composed of meta-igneous, meta-sedimentary rocks and carbonate bands (Ramakrishna and Swaminath,1981;Prakash Narasimha *et al*. 2009). In the penultimate stage it traverses through the quaternary alluvium, Cretaceous and Mio-Pliocene sediments.

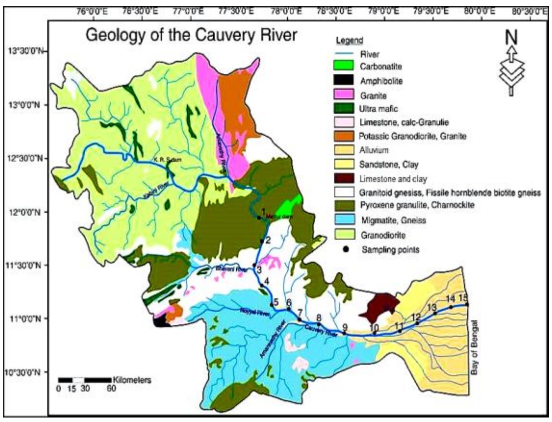

Fig.1 *Geology of the Cauvery River course with sediment sampling locations*

3. Material and Methods

Thirteen sediment samples (Fig.1) were selected for this study. After washing 100grams of sample, 2mm size particles are separated by sieving method. The 120 ASTM size fractions were treated with H_2O_2 and HCl for removal of organic matter and $CaCO_3$. The heavy minerals were separated from 120 ASTM sieve by using the gravity separation method. The 25 numbers of garnet grains from each location were hand-picked from the separated heavy mineral assemblage using a binocular stereomicroscope. The garnet chemistry was carried out using the EPMA-CAMECA SX100 at Geological Survey of India, Bangalore. The 120 ASTM fraction of the garnet was examined for surface micro-textures using SEM-HitachiS-3400N.

4. Results and discussion

4.1. Mineral chemistry of detrital garnet

The SiO_2 (39.06% to 36.61%), Al_2O_3 (19.33% to 22.07 and the range of 24.13% to 31.13% FeO in

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detrital garnet denotes that it derived by the leaching, oxidation and hydration process from the source rock (Mikkel and Henderson, 1983). The major oxides concentration is in the increased trend; SiO_2>FeO>Al_2O_3>MgO>CaO>MnO>Cr_2O_3>TiO_2> Na_2O>K_2O. The positive correlation between the MgO % and Al_2O_3 % attribute to the alumino-silicate phases and MgO % v/s. Al_2O_3% (Fig.2) deduced the associations with chlorite, illite and gibbsite (Mikkel & Henderson, 1983). The end members are calculated from the major oxides of Fe, Ca, Mg and Mn, accordingly the Almandine garnets range from 60.16 to 75.41%, Grossular is 1.62 to 17.37%, Spessartine is 0.69 to26.85%) and Pyrope is from 2.57 to 20.69 % (Table.1), the detrital garnets are almandine in composition. The Pyrope-Alamandine+Spessartine-Grossular diagram (Wright, 1983) interprets that the majority of the end members of garnet group plots in the field of biotite schist (except sample locations 5, 6 &12), which is in the field of granite and granite pegmatite (Fig.3a). This suggests that the biotite schist, granite and granite pegmatite are the source rocks. Further, the samples are in the Type A, B, B ii and C i field infer that the source rocks of the detrital garnets derived from the intermediate felsic and high-grade mafic rock (Mange & Morton, 2007) (Fig.3b). The majority of the end members are in the field of gneisses metamorphosed under pressure and temperature conditions transitional to granulite and amphibolite metamorphism facies (Aubrecht *et al.,* 2009) (Fig. 3c). The mineral assemblage and texture of the garnet bearing rocks of the Cauvery River corroborates with the P-T conditions of the rocks of the upper region of the Cauvery River Basin (Srikantappa *et al.,* 1994).

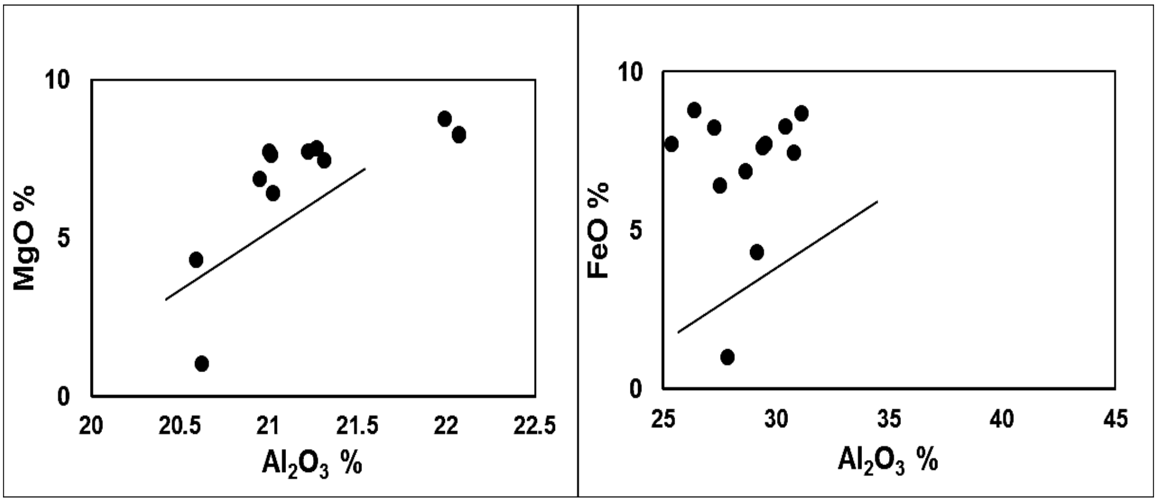

Fig. 2 *Al_2O_3% V/s. MgO% and FeO% V/s Al_2O_3%*

4.2. Micro- textures of detrital garnet and implications for provenance

The surface micro-textures of detrital minerals are formed due to the contact between grains or grain with water during the sediment transport. These surface micro-texture features are used to describe the transport mechanism and provenance of sediments (Krinsley and Marshall, 1987; Helland and Diffenda, 1993; Mahaney, *et al.,* 2001). Surface micro-textures features on the detrital garnet are classified into three groups; mechanical features; conchoidal fracture, arcuate steps, furrows, striations (Figs.4&5), which attribute the garnets, are derived from Charnockite, granite and gneissic rocks. The chemical features; chemical precipitation and grooves (Figs.4&5) are representing the resistant time taken during the transportation.

The angular outlines of morphological features on the upper region of the detrital grains merits that the source rocks are near to the river (less transportation), whereas the rounded outline in the lower region, denote that the sediments are transported for a long distance and derived from the upper region.

Conclusions

- The detrital garnets are almandine garnet in composition. Garnets are derived from intermediate to felsic ~~n~~ rocks like Charnockite, biotite schist, granite, and gneisses in the upper region of the Cauvery River.
- The source rocks are Charnockite and gneisses are equilibrated under transitional amphibolite to granulite facies metamorphism.
- The conchoidal fracture, arcuate steps, and striations on the detrital garnet denote that the garnets are derived from the crystalline rocks.
- The angular outline of grains in the upper region, suggest that the source rocks are nearer to the river, whereas the rounded outline encounter in the lower regions indicates that the long distance of transportation.

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Table.1 *Geochemistry of detrital garnets from Cauvery River sediments*

Wt % oxide	Sample locations from the upstream of the Cauvery river												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
SiO_2	37.58	37.98	39.46	36.61	37	38.2	38.75	38.09	38.68	38.7	39.06	38.47	38.67
TiO_2	0.05	0.02	0.02	0.06	0.07	0.02	0.04	0	0.1	0.05	0	0.02	0.02
Al_2O_2	21.02	20.59	19.33	20.62	22.07	21.01	22.07	21	21.27	21.22	21.99	21.31	20.95
FeO	27.51	29.15	31.13	27.85	30.42	29.39	27.25	29.53	24.13	25.36	26.4	30.8	28.66
MnO	0.92	1.1	0.39	11.94	1.53	1.53	0.48	0.83	0.79	0.7	0.44	0.3	0.7
MgO	6.43	4.32	8.7	1.03	8.28	7.62	8.24	7.72	7.85	7.72	8.78	7.44	6.87
CaO	6.58	6.82	0.75	1.88	0.62	2.04	3.06	2.55	6.46	6.18	3.09	1.76	4.04
Na_2O	0.03	0.02	0.03	0	0	0.08	0.03	0.03	0.01	0.01	0.03	0	0.05
K_2O	0.01	0	0.02	0	0	0.05	0	0	0.02	0	0	0	0
Cr_2O_2	0.02	0	0.17	0.02	0	0.01	0.08	0.2	0.49	0.09	0.24	0.09	0.1
Total	100.15	100	100.01	100.01	99.99	99.94	100	99.95	99.8	100.03	100.03	100.19	100.06
Formula calculated on the basis of 12 oxygen													
Si	2.903	2.891	2.985	2.767	2.803	2.893	2.924	2.891	2.953	2.946	2.947	2.898	2.927
Al^{VI}	0.097	0.109	0.015	0.233	0.197	0.107	0.076	0.109	0.047	0.054	0.053	0.102	0.073
Ti	0.005	0.001	0.001	0.003	0.004	0.001	0.002	0.000	0.006	0.003	0.000	0.001	0.001
Al^{IV}	1.898	1.739	1.709	1.605	1.775	1.769	1.887	1.769	1.868	1.850	1.903	1.790	1.797
Fe	1.619	1.754	1.862	1.664	1.822	1.760	1.625	1.772	1.456	1.526	1.575	1.834	1.715
Mn	0.026	0.063	0.022	0.679	0.087	0.087	0.027	0.047	0.045	0.040	0.025	0.017	0.040
Mg	0.657	0.275	0.550	0.065	0.525	0.483	0.520	0.490	0.501	0.491	0.554	0.469	0.435
Ca	0.050	0.440	0.048	0.120	0.040	0.131	0.196	0.164	0.418	0.398	0.197	0.112	0.259
Na	0.009	0.002	0.003	0.000	0.000	0.009	0.003	0.003	0.001	0.001	0.003	0.000	0.006
K	0.000	0.000	0.002	0.000	0.000	0.004	0.000	0.000	0.002	0.000	0.000	0.000	0.000
Cr	0.018	0.000	0.025	0.003	0.000	0.001	0.012	0.029	0.073	0.013	0.035	0.013	0.015
End members													
Alm (Fe)	68.835	69.273	75.020	65.823	73.646	71.516	68.623	71.683	60.165	62.159	66.993	75.411	70.029
Ade, Grs (Ca)	2.126	17.378	1.934	4.747	1.617	5.323	8.277	6.634	17.273	16.212	8.379	4.605	10.576
Pyr (Mg)	27.934	10.861	22.160	2.571	21.221	19.626	21.959	19.822	20.702	20.000	23.564	19.285	17.762
Sps(Mn)	1.105	2.488	0.886	26.859	3.517	3.535	1.140	1.861	1.860	1.629	1.063	0.699	1.633
Si /Al	4.764	4.739	4.709	4.605	4.774	4.769	4.887	4.770	4.867	4.850	4.903	4.790	4.797
Fe /Al	3.554	3.602	3.448	3.502	3.660	3.636	3.588	3.651	3.370	3.430	3.531	3.726	3.585

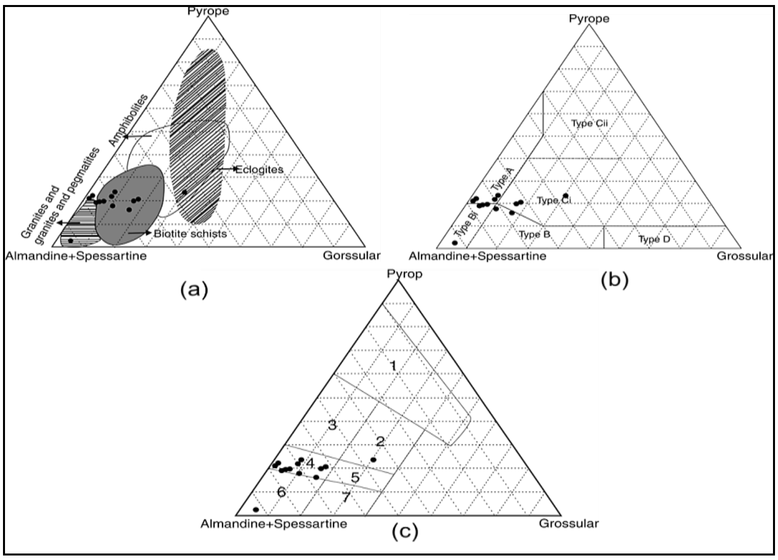

Fig. 3 *(a) Ternary discrimination diagram with proportion of Pyrope, almandine + Spessartine and grossular of source rocks of detrital garnet (after Wright, 1938). (b) Ternary discrimination diagram of composition of source rocks (after Mange and Morton, 2007).A- high-grade granulite-facies metasediments or charnockites and intermediate felsic igneous rocks, B- Amphibolite-facies metasedimentary rocks, Bi- Intermediate to felsic igneous rocks, C- high-grade mafic rocks, Ci- Ultramafic with high Mg (pyroxenites and peridotites), D- Metasomatic rocks, very low-grade metamafic rocks and ultrahigh temperature metamorphosed*

calc-silicate granulites (c). Ternary discrimination diagram of provenance and geological conditions of source rocks rocks (after Aubrecht et al., 2009) 1- UHP eclogites or garnet peridotite, 2- HP eclogites and HP mafic granulites, 3- Felsic and intermediate granulites, 4- Gneisses metamorphosed under pressure and temperature conditions transitional to granulites and amphibolites metamorphism, 5- Amphibolites metamorphosed under pressure conditions transitional to granulite and amphibolite-facies metamorphism, 6- Gneisses metamorphosed under amphibolite-facies conditions, 7- Amphibolites metamorphosed under amphibolite-facies conditions.

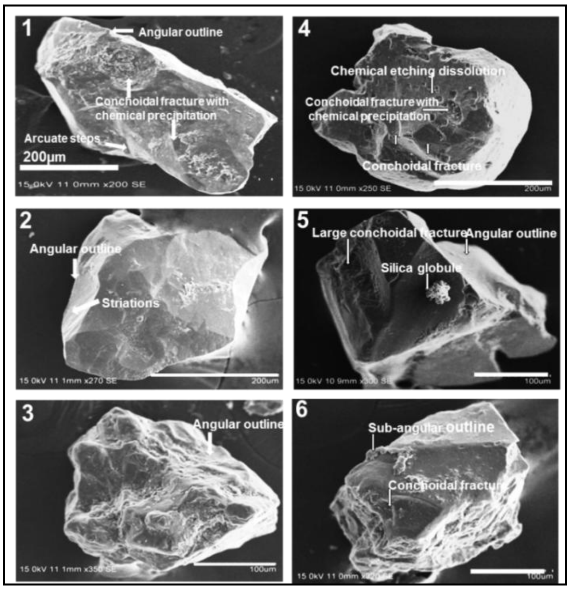

Fig. 4 *Surface microtextures of detrital garnet of the Cauvery River*

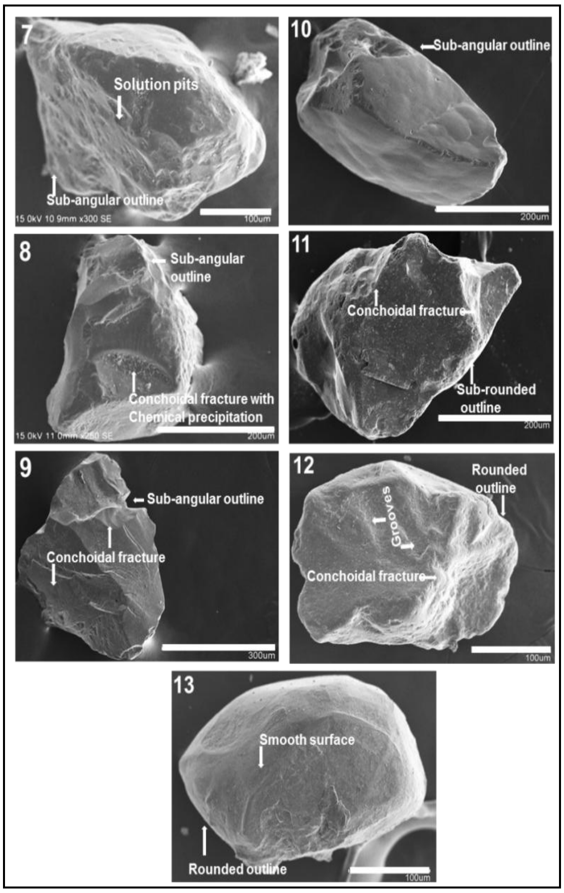

Fig. 4.1 *Surface microtextures of detrital garnet of the Cauvery River*

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