Heavy mineral chemistry studies of the Kabini River, South India: an implication for provenance.

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ABSTRACT: River Kabini is one of the interstate river flowing Eastwards. River Kabini originates in the Pakramthalam hills of Wayanad district in Kerala state and its confluence point is at Tirumakudalu - Narasipura, Mysore district in Karnataka state , where it joints the river Cauvery. It flows between latitude 11°72' North and 12°21' North and longitude 75°84' East and 76°91' East. River Kabini flows along a stretch of 220 Kms. It flows through high grade lithologies in both the states. The present studies is made on the heavy mineral chemistry along Kabini river. Eight Sediment samples were collected along the course of the river Kabini at an interval of 30kms. The heavy mineral analyses were done by electron probe micro analyzer. Garnet, Rutile, Ilmenite, Sillimanite, Zircon, Hornblende and Epidote are the heavy minerals found along the course of river Kabini. Garnets are rich in Fe which holds good for almandine compositionGarnets are derived from the mixed source such as meta-sedimentary and acidic rock. The Ilmenite grains indicate their derivation from the meta-igneous source as reflected by its TiO_2 content. Sillimanites owe their derivation to meta sedimentary rocks. Zircons found are sourced from mainly charnockites and Gabbro. Hornblendes are pargasite tschermakite in composition which is the characteristic feature of high grade metamorphic rocks. Epidote in river Kabini are derived from the alteration of primary minerals of medium to high grade metamorphic rocks. Mineral chemistry studies of heavy minerals of Kabini river indicate their lithogenic character and attribute to their derivation from multiple rock sources.

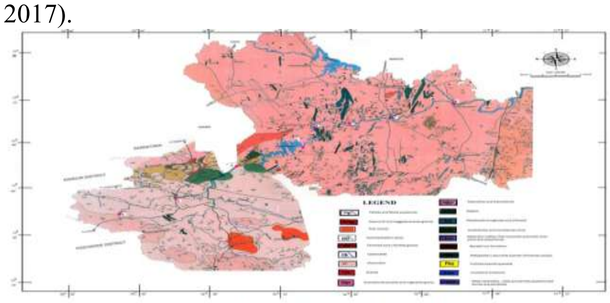
KEY WORDS: Heavy minerals, Supracrustals, Charnockites, gneisses.

1.INTRODUCTION

Minerals having specific gravity more than 2.8 are termed as heavy minerals (Mange and Maurer.,1992). Heavy minerals are sensitive indicators of provenance(N,Gobalkrishnaet.al2017:Morton,A,C., 1985).When heavy minerals are liberated by weathering of their parent rock, resistant species show relative concentration and less resistant species decrease in relative abundance or disappear completely(Lincoln Dryden.,1946). The present study is focused on the chemistry of heavy minerals along the course of River Kabini which flows at a stretch of 220 km and the heavy minerals that are encountered along the stretch are Garnet, Ilmenite, Zircon, Rutile, Sillimanite, Hornblende and Epidote.

2.STUDY AREA:

Kabini is an important tributary of river Cauvery and is an inter-state river with 22% in Kerala and 78% in Karnataka, out of the total drainage area of 6693 sq.kms. It flows in between latitude 11°72'N and 12°21'N and longitude 75°84'E and 76°91'E. Its source lies in the Western Ghats in Wayanad district of Keralastate at an elevation of 2134 meters. The river enters Karnataka near Bavali from south western side of the state. It flows for a total distance of 220 kms and joins the river Cauvery at Tirumakudalu-Narasipur. The river drains a hilly and forested catchment in the upper reaches, where the average rainfall is 2322mm. The main tributary of Kabini river is the Nugu river which also originates in the western Ghats and joins the Kabini river about 3 kms south of Hampapura in Karnataka state(Dhanya,A,V,et.al 2017).



SAMPLING LOCATIONS : 1.Niravilpuzha bridge 2.Changadakadavu bridge 3.Machur 4.K R Puram 5.Sargur 6.Hirenanandi (near Hampapura) 7.Nanjangud 8.T.Narasipura

Fig: 1 Geological map of the study area showing sample locations.

3.METHODOLOGY

Sediments were collected from eight locations along the stretch of River Kabini at 30Kms interval by coning and quartering method. Sediments are dried naturally and then subjected to sieving, samples collected in 120mm mesh were taken for analysis. Heavy minerals are separated by bromoform method, a funnel with pinching cork is filled with bromoform the sieved sediments were added to it with pinching cork in closed position. The heavy minerals sink at the bottom and lighter minerals floats. The heavy minerals are removed slowly by opening the cork, it is allowed to flow through a filter paper so that heavy minerals are separated from the liquid bromoform. The heavy minerals are dried in the hot air oven at 75^0c for 4 hours then the separated minerals are observed using a stereo binocular microscope and heavy mineral grains are picked form all the locations and it is mounted on the slide with epoxy and is slightly polished. These slides are subjected to EPMA analysis at NCEGR lab, Geological Survey of India, Bangalore.

4.HEAVY MINERAL STUDIES

The distribution of heavy minerals obtained for each location against the distance is shown on the bar graph. (Fig.2). There is a increasing trend from location 1 to location 2 (Nirvilpuzha and changadakadavu bridge) which indicates the weathering action is high, these are the catchment area which includes forest area and are elevated and steep land where the river flows. At locations 3and 4 (Machur and K R Puram) there is a decreasing trend which indicates that the less resistant minerals are weathered out completel, where as in location 5 to 8 (which includes Sargur, Hirenandi, Nanjangud, T. Narasipura areas), there is a decrease in the number of heavy minerals which attributes to intense weathering as a result disassociation of minerals in the river water. Garnet is found in all the locations followed by Zircon and Rutile. In the foregoing paragraphs the mineral chemistry of individual heavy minerals are discussed.

4.1 Garnet: The mineral chemistry of Garnet serves as the most widely used mineral-chemical tool for determination and discrimination of sediment provenance (Mange and Morton.,2007). Garnet is relatively a stable mineral under weathering and diagenetic conditions (Morton and Hallsworth.,1999; Morton and Hallsworth.,2007).

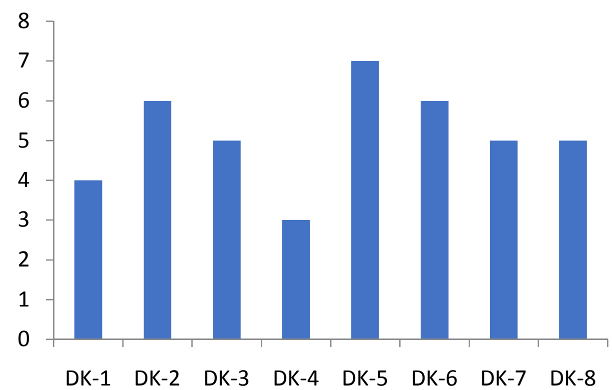


Fig2: Variation in occurrence of heavy minerals in different locations.

Table. 1: Major element chemistry of garnet

Wt%	DKS1	DKS2	DKS3	DKS4	DKS5	DKS6	DKS7	DKS8
SiO_2	38.6	37.5	38	37.8	37.4	36.9	36.6	38.9
TiO_2	0.04	0.09	0.11	0.07	0.0	0.0	0.05	0.0
Al_2O_3	21.4	21.3	21.5	21.4	21	22.2	20.8	22.1
Cr_2O_3	0.03	0.08	0.04	0.01	0.03	0.03	0.02	0.03
FeO	26.6	27.7	26.4	28.7	29.2	28.9	34.5	25.5
MnO	1.1	1.08	0.76	1.3	1.43	2.2	1.93	1.03
MgO	5.77	5.36	6.3	4.29	4.07	3.34	1.75	6.82
CaO	6.7	7.04	6.81	7.05	6.87	6.94	4.66	6.27
Na_2O	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.0
K_2O	0.0	0.01	0.0	0.01	0.0	0.02	0.0	0.0
ZrO_2	0.0	0.04	0.0	0.0	0.04	0.06	0.02	0.0
Total	100	100	100	101	100	101	100	101

.The present study area Garnets are reddish in colour and are almost angular in the upper reaches of the river which includes the locations 1 and 2. At location 3, it is sub rounded and in the location 4 at K R Puram, which is back water of the Kabini dam garnet grains are angular. The angularity seen in garnet grains suggest their derivation from not much weathered garnet bearing rocks. Garnet grains of locations 5&6, show sub rounded morphology. The garnet grains achieve sub rounded to spherical shape at locations 7 and 8, where the confluence of the river Cauvery and kabini are found. The mineral chemistry of the garnet from the study area are presented in the Table 1. The values of SiO2 vary from 36.64% to 38.92%, Al2O3 values are varying from 20.84% to 22.22%. The FeO values show variation from 25.52% to 34.53%. FeO values are significantly higher and indicate that the garnets of the studied area are almandine in composition.In Pyrope Almandine+Spessartine-Grossular trilinear plot (Wright.,1938)(Fig.3) majority of garnet chemistry falls in the field of biotite schist and one samples fall in the field of the granite and granite pegmatite. Thus, indicating the garnets are derived from the mixed source such as meta-sedimentary and acidic rock source. On the Mg-Fe+Mn-Ca, trilinear plot of garnet (Manage and Morton.,2007)(Fig.4), Garnet chemistry fall in the field of type Bii and type Ci, which is an indication that garnet grains are derived from high grade metabasic and amphibolite grade metasedimenary rocks.

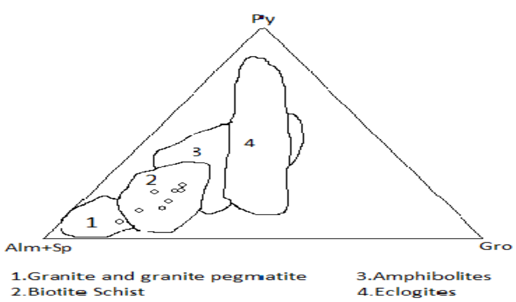


Fig.3:Pyrope-Almandine+Spessartine-Grossular plot of garnetshowing the provenance (Wright 1938 and Preston et al., 2002).

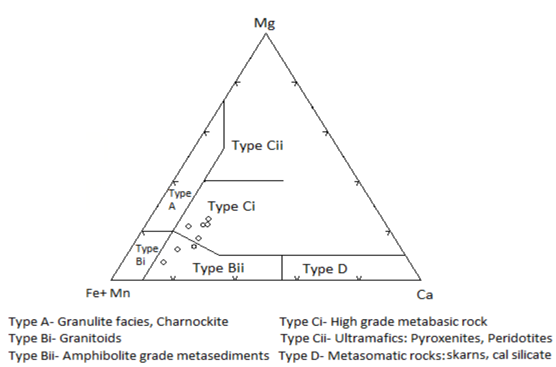


Fig 4: Mg-Fe+Mn-Ca trilinear plot for garnet chemistry showing the provenance of the sediments (Morton,2007).

4.2 Ilmenite:

Chemical composition of the ilmenite throws light on the identification of the provenance of the sediments (Darby.,1984; Darby and Tsang.,1987; Grigsby.,1991 and Asiedu et al., 2000, Pownceby.,2005; Pownceby and Bourne.,2006; Pirkle et al., 2007). Ilmenite grains were found throughout the stretch of the River Kabini. These grains are angular in the upper reaches of river Kabini up to Location 4, further the ilmenite grains become angular to sub rounded as seen in the locations 5 to 8.

It is observed that ilmenite grains are transported throughout the river and the morphological changes of the grains vary from angular to subrounded. Ilmenites grains are black in colour and show metallic luster. The near roundness of the ilmenite grains found at confluence point indicate that they are transported from the catchment area.The major element chemistry of the Ilmenite are presented in Table 2. The TiO_2 content of the Ilmenitevary from 49.73% to 53.83% and that of FeO varies from 40.14% to 47.25%. TheIlmenites from metamorphic source are richer in TiO_2 than that of igneous origin (Shcneiderman.,1995). Ilmenite grains with TiO_2 content between 50% to 60% are derived from metamorphic origin and the grains with TiO_2 ranging between 40% to 50% are derived from igneous origin (Basu and Molinaroli.,1991). Since the TiO_2 values of ilmenite grains vary from 49.73% to 53.83%, it indicates their derivation from the meta-igneous source.

Table. 2: Major element chemistry of Ilmenite

Wt%	DKS1	DKS2	DKS3	DKS5	DKS7
SiO_2	0.16	0.3	0.0	0.03	0.14
TiO_2	52.2	53.8	49.7	51.1	51.3
Al_2O_3	0.02	0.12	0.0	0.09	0.04
Cr_2O_3	0.1	0.04	0.0	0.01	0.04
FeO	44	40.1	47.3	46.1	44.6
MnO	0.39	1.02	1.3	0.46	1.32
MgO	1.07	0.52	0.3	0.74	0.34
CaO	0.01	0.17	0.0	0.04	0.06
Na_2O	0.04	0.03	0.03	0.01	0.04
K_2O	0.0	0.03	0.0	0.0	0.0
ZrO_2	0.04	0.0	0.0	0.0	0.07
Total	98	96.2	98.6	98.6	97.9

4.3 Zircon:

Zircon is found in wide variety of igneous and metamorphic rocks but it is basically abundant inacidic igneous rocks. Zircons from the sediments of River Kabini basin is found in seven locations. The shapes of the zircon grains are highly variable.At locations from 2 and 3 zircons are angular in shape and in the meandering part of the river Kabinisubrounded grains are observed. At locations 6, 7 and 8 the grains are rounded, which indicate their derivation from upper reaches of the river, the angular grains attribute their source to the catchment area of the river.

The zircons are reddish brown colour with transparent diaphaneity and vitreous luster.The major element chemistry of the Zircon grains from the study area are presented in Table 3. Theyare rich in SiO_2 and ZrO_2. The SiO_2 values are varying from 32.31% to 34.26% and the ZrO_2 values are varying from 66.06% to 67.28%. These zircon grains possibly may be having mixed sources and derived from both the charnockites and gneisses, as these rocks are being basically metamorphosed from the felsic igneous rocks.

Table. 3: Major element chemistry of Zircon

Wt%	DKS 2	DKS 3	DKS 4	DKS 5	DKS 6	DKS 7	DKS 8
SiO2	34.3	33.9	32.7	32.3	32.4	34	34.2
TiO2	0.0	0.0	0.07	0.02	0.04	0.03	0.04
Al2O3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cr2O3	0.0	0.0	0.18	0.34	0.0	0.01	0.0
FeO	0.0	0.05	0.0	0.0	0.08	0.06	0.0
MnO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MgO	0.0	0.0	0.0	0.13	0.0	0.0	0.0
CaO	0.0	0.02	0.03	0.19	0.02	0.0	0.0
Na2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K2O	0.02	0.01	0.01	0.02	0.04	0.0	0.01
ZrO2	66.1	66.8	66.4	66.3	67.1	66.3	66.6
Total	100	101	99.4	99.3	99.6	100	101

4.4 Rutile:

Rutile is one of the ultra stable mineral which occurs in both ancient and young sediments (Mange and Morton.,2007). Rutile is mainly formed during medium to high grade metamorphic processes and is usually absent in igneous and low grade metamorphic rocks(Force.,1980).Rutile is chemically and physically stable and not prone to destruction during the sedimentation cycle, it can provide important information about source area lithologies, and therefore, it can be used for sedimentary provenance analysis (Meinhold et al., 2008).In the initial stages of the Kabini river flow (locations 1 to 3), the rutile are angular, at locations 6 and 7 the grains are almost rounded, this explains that these rutile grains are transported from a longer distance. Rutiles are reddish brown colour with semi metallic luster and are opaque.Chemistry of Rutile are presented in the Table.4.The microprobe data of rutile shows that they are rich in TiO_2 composition and it ranges from 67.09% to 98.22% and other components are very subtle.

Table. 5: Major element chemistry of Sillimanite

Wt%	DKS1	DKS3	DKS5	DKS6	DKS8
SiO2	34.4	34	35.1	37.2	38
TiO2	0.0	0.0	0.01	0.02	0.0
Al2O3	66.5	65.2	63.6	64.7	65.1
Cr2O3	0.01	0.31	0.69	0.48	0.14
FeO	0.26	0.16	0.32	0.26	0.18
MnO	0.0	0.03	0.0	0.04	0.0
MgO	0.08	0.0	0.04	0.0	0.0
CaO	0.01	0.03	0.1	0.0	0.01
Na2O	0.02	0.01	0.07	0.01	0.03
K2O	0.03	0.01	0.02	0.02	0.0
ZrO2	0.05	0.0	0.0	0.01	0.02
Total	101	100	100	103	103

4.5 Hornblende:

Hornblende grains are columnar in shape and in the catchment area green incolour green in colour compared to the brown coloured angular to sub rounded nature of the hornblende grains as seen towards confluence point. Chemistry of hornblende are presented in Table .6.

Table. 6: Major element chemistry of Hornblende

Wt%	DKS2	DKS5	DKS6	DKS7
SiO2	41.7	44	48.8	42
TiO2	2.15	1.93	0.08	0.77
Al2O3	14.8	10	8.63	11.8
Cr2O3	0.0	0.87	0.64	0.09
FeO	15.1	8.5	6.3	16.2
MnO	0.08	0.1	0.26	0.15
MgO	10.5	15.2	18.1	10.8
CaO	11.9	11.8	11.7	11.7
Na2O	1.54	1.56	1.26	1.72
K2O	1.83	0.95	0.19	0.57
ZrO2	0.0	1.93	0.0	0.07
Total	100	94.9	95.9	96

SiO_2values vary from 41.72% to 48.8, Al_2O_3 values range from 8.63% to 14.8%, the FeO values are varying from 6.3% to 16.15%, the MgO values are varying from 10.53% to 18.05% and the CaO values are varying from 11.69% to 11.88%.

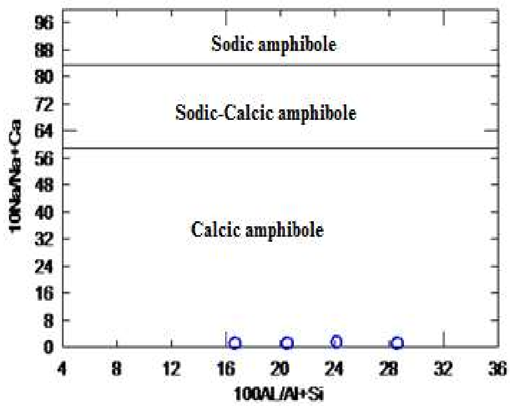


Fig 5: 100 Al/ (Al+Si) vs 10Na/(Na +Ca) bivariate diagram for the classification of Hornblende (Mange and Morton.,2007)

Alkalies occur in subtle quantities. The chemistry of the hornblende plotted on the 100 Al/ (Al+Si) vs 10Na/(Na +Ca) scatter diagram (Mange and Morton.,2007)(Fig:5) indicate that the hornblendes are calcic amphibole in composition, whereas on the discriminant diagram Al vs Mg/(Mg+Fe) given by (Hawthorne.,1983), (Fig:6), hornblende chemistry fall in the field of paragasitictschermakite hornblende. Tschermakitic amphiboles characteristically occur in rocks of high metamorphic grade.

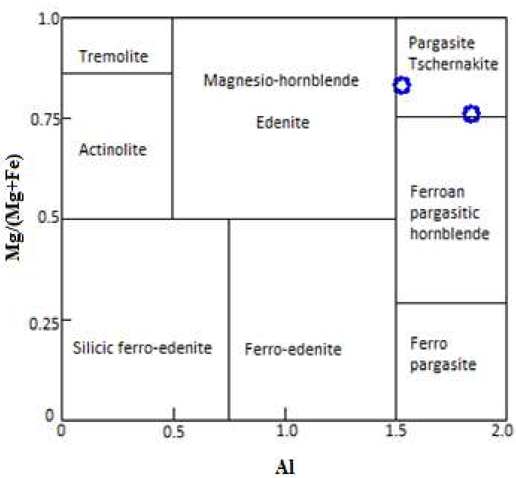


Fig 6: Al vs Mg/(Mg+Fe) hornblende classification diagram (Hawthorne.,1983).

4.6 Epidote:

Epidote is formed mainly in the regional metamorphism and also in the wide variety of the igneous processes and in many sedimentary formations (Manage and Morton.,2007). Due to the wide range of its lithological occurrence of epidotes, the exact identification of the provenance is notpossible (Manage and Morton.,2007). The epidote grains of the present study show angular shapes inthe catchmentarea and in the upper reaches. sub rounded to rounded grains are seen indicating their derivation from the source region. The epidote grains are greenish in colour with tabular habit and transparent to translucent diaphaneity. Most of the epidote grains are the product of the alteration of plagioclase feldspars.

Table. 7: Major element chemistry of Epidote

Wt%	DKS2	DKS5	DKS8
SiO2	37.7	38.6	38
TiO2	0.1	0.05	0.0
Al2O3	26.7	26.3	22.5
Cr2O3	0.01	0.02	0.01
FeO	9.98	9.99	12.2
MnO	0.17	0.21	0.07
MgO	0.02	0.06	0.0
CaO	23.3	21.5	23
Na2O	0.01	1.0	0.0
K2O	0.0	0.01	0.02
ZrO2	0.05	0.0	0.0
Total	98	97.8	95.7

The major element chemistry of the epidote mineral are presented in the Table.7. The chemistry of the epidote shows SiO_2 values are varying from 37.72% to 38.64%, Al_2O_3 values vary from 22.45% to 26.68%, FeO values vary from 9.98% to 12.19% and CaO values varying from 21.46% to 23.26%. The compositional variation of the epidote can be understood with the help of the ratio of Fe/(Al+Fe) which helps in determining the provenance (Yokoyama et al., 1990).The ratio of Fe/(Al+Fe) of epidote from Kabini river sediments range between 0.354 to 0.44, which indicates epidote are derived from a medium grade metamorphic to high grade metamorphic sources. Epidote is the alteration product of plagioclase feldspars,which are associated with high grade metamorphic rocks.Fe/(Al+Fe) values of epidote from mafic rock is 0.27 and a similar ratio is also found in felsic rock (Donald Lee et.al.,1971).The ratio of Fe/(Al+Fe) of epidote from Kabini river sediments is ranging between 0.80 to 1.38, which indicates that these epidotes are derived from medium to high grade metamorphic source.

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