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Paleocurrent, Deformation and Geochemical studies of Lower part of the Bagalkot Group of Kaladgi Basin at Ramthal and Salgundi: Implications on Sedimentation History

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Abstract: The lithounit **c**onglomerate of the thickness about 6m - 30m is seen exposed at Ramthal and Salgundi belonging to the Salgundi Conglomerate Member of the Ramdurg Formation in the Bagalkot Group of the Kaladgi-Badami sequence of rocks. Even though this basin is studied extensively by many workers on a larger scale, the minute intricacies have remained untouched. This includes studies on individual lithounit with respect to its lithological characters, textural features, provenance, deformation history, paleocurrent directions and mapping on a larger scale of the area. Therefore, this lowermost rock unit provides an opportunity to understand the paleocurrents, provenance and deformation history of the Mesoproterozoic Bagalkot Group. To understand this, field studies were combined with analytical studies to come to a conclusive result. To understand the deformation history of the area, field studies were combined with micro section observations. The deformational mechanisms of grain boundary migration, overgrowths in crystallographic continuity, recrystallisation of quartz, neocrystallisation of micas, indicate the deformation involved a low temperature (<300°C) regime. Further, based on the imbrications of the pebbles observed in the field and reconstruction to a prefolding position of the limbs of the fold based on the dip directions recorded at two places Ramthal (dipping North) and Salgundi (dipping South) suggests the upstream side of the basin to be probably towards the western side of the basin. The rock is mineralogically matured with abundance of silica varieties and lack in feldspars. While percentage of Fe2O3 increases along with SiO2 at both places that of Al2O3, K2O, CaO and Na2O is much less. The Al2O3+Na2O+K2O versus SiO2 plot indicates Compositional Maturity Index is relatively higher at both the study areas suggesting removal or lack of mobile elements like Na2O and MgO. The lower concentrations of U and Th in the samples with lower ΣREE probably reflects a control by grain size fractionation during transport suggest a contribution from a mafic source with lesser concentration of such elements. Bivariant log/log plot of the ratio of Qp/F + R values represent the region to have been a moderate to low lying plain experiencing hot, tropical, oxidizing, humid climatic conditions.
Keywords: Mesoproterozoic, provenance, deformation, imbrications

Introduction

The rock conglomerate has varied composition both with respect to the matrix as well as the framework clasts. Therefore, this rock can be used to decipher the provenance, paleocurrents, deformation history and thereby the tectonic setting of the area. A geochemical analysis of the matrix can throw more light on the provenances whereas the framework clasts can be used to deduce the paleocurrent directions. Provenance studies and prevailing paleocurrents provide an insight in understanding the physiography and climatic conditions of the region, as also, the geological history of the deposited sediments. A relationship can thus be drawn between the conglomerate composition and the conditions the prevailed in the source area. Penetrative features observed in the field in association with microscopic studies of the rock help to understand the deformation history of a region. A substantial study has been carried out on the Kaladgi-Badami basin occupying the northern part of the state of Karnataka by many workers, but still a lot remains to be studied with respect to individual lithounits, their large scale mapping, mineralogy, provenance and deformational history. Here, we make an attempt in putting forth a detailed study involving field and microscopic observations of the conglomerates from the Mesoproterozoic Member, the Salgundi Conglomerate of

Ramdurg Formation of the Bagalkot Group from the Kaladgi basin. These studies were used to understand how the paleoclimatic conditions that prevailed during their deposition and the source rock constituents had an effect on the composition of the rock. A geochemical analysis of the rock for the major oxides as well as trace and rare earth element concentrations are used to deduce the provenance based on discriminant functions and to determine the chemical maturity of the rock. An attempt is also made to relate the structural and primary features noted in the field and those observed in microsections to the tectonic history of the region and deduce paleocurrent directions respectively.

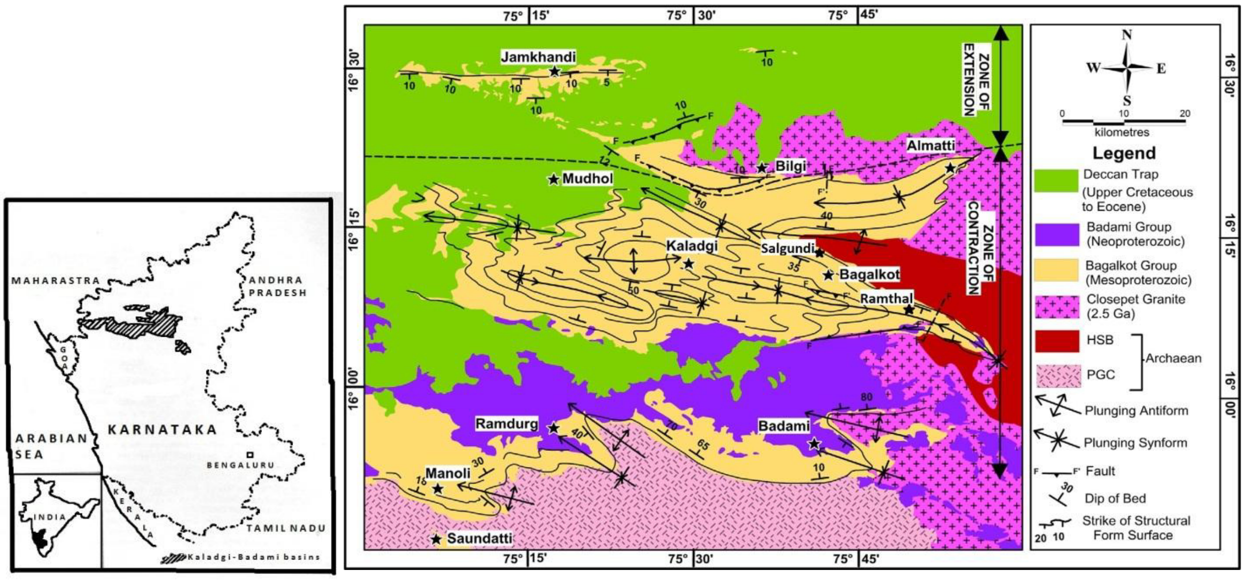

Figure 1: Geological and structural map of the Kaladgi-Badami basin (after Mukerjee et. al, 2016)

Geological setting of the Kaladgi basin

The Kaladgi sequence of rocks cover an area of 8300km2 occupying an East-West trending basin that stretches for nearly 500kms. They unconformably rest over the Archaean Peninsular Gneissic Complex and in turn are overlain by the Deccan Traps of Cretaceous-Eocene age (Jayaprakash et at., 1987; Figure 1).

The sedimentary sequence of the Kaladgi basin situated towards the northern borders of the Dharwar craton has been divided into an older Bagalkot Group and an younger Badami Group. The two are separated by an angular unconformity (Kale and Pillai, 2011). Recent geochronological studies (Padmakumari et al, 1998; Balesh Kumar et al 1999) have indicated that the Bagalkot Group was deposited around 1800 + 100Ma supporting a previous suggestion of their Late Palaeoproterozoic age based on stromatolitic studies (Sharma et al., 1998). The Badami Group has been estimated to be of Neoproterozoic age based on trace fossil occurrences (Kulkarni and Borkar, 1997).

Basement rock at the study area

The basement rocks for the Kaladgi sequence of rocks include Peninsular Gneissic Complex (PGC) towards the south of the basin, Hungund Schist Belts (HSB) towards the eastern part and Granites (Closepet Granites) towards the North, central and south-eastern parts of the basin. In the study area the Mesoproterozoic sedimentary cover rocks rest unconformably over the Banded Hematite Quartzite of the Hungund Schist Belt (HSB).

The HSB, trending NW-SE extends from Ramagiri in the south to Hungund in the north (Naqvi et al., 2006) and forming one of the components of the basement cratonic assemblage is exposed in the eastern part of the study area beneath the Kaladgi sedimentary cover rocks. The HSB is an assemblage of (1) metabasalts with minor metaultramafics (2) metasediments with intercalated basic and minor acid metavolcanics and (3) greywacke with intercalated Banded Iron Formations (BIF) (Roy, 1983). The metabasalts of the HSB are now represented by amphibolite, hornblende-chlorite schist, hornblende-plagioclase schist and hornblende-tremolite-actinolite schist. The metasediments (referred as metapelites) occur interbanded with metavolcanics as bands and lenses. They are mainly chlorite schist, quartz-chlorite schists and carbonaceous phyllites. The BIF horizons are 50-100m thick and occur as bands alternating with the metapelites. The components of BIF's include banded hematite quartzite (BHQ), chert and banded hematite jasper (BHJ) and ferruginous meta-argillites. The metapelites occur as thick horizons, exhibit thin compositional bands and are composed of muscovite, chlorite, and quartz. Lensoidal patches of polymictic conglomerates also occur within the metapelites with the long axis of the lens parallel to the compositional bands of the metapelites and are composed of hornblende, chlorite, plagioclase feldspars and minor amounts of quartz and iron oxides. The HSB is intruded by 5-10m thick gabbro dykes that are massive and are oriented E-W.

Mesoproterozoic sedimentary cover rocks at the study area

The areas of Ramthal, situated between latitude 16° 05'13"N to and longitude75° 52'29" E (Figure 2a); and Salgundi, located between 15°40'0"N to and longitude 76°50'0"E (Figure 2b) are chosen for the study as the rocks representing the lower part of the Kaladgi sequence are well exposed and represented here. While, exposures at Ramthal are over a small hillock with scanty vegetation, at Salgundi; the rocks are exposed over a ridge trending E-W.

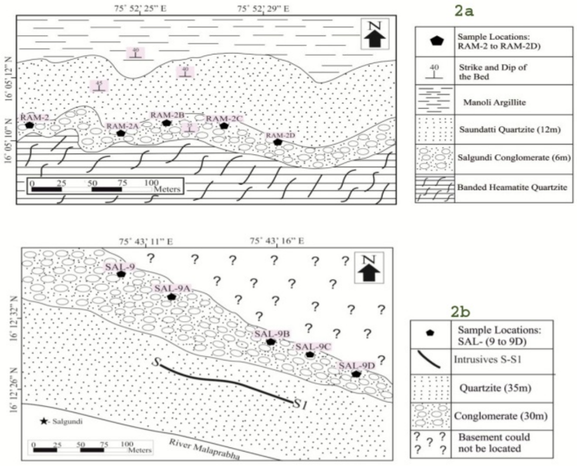

Figure 2: Geological and structural map along with sample locations at (a) Ramthal and (b) Salgundi.

At Ramthal, Banded Heamatite Quartzites of the Archaean Hungund Schist Belt exposed at the base of the hill are overlain successively by Mesoproterozoic conglomerates and quartzites having an East-West strike and a dip due North, while the conglomerate is about 6m thick, the overlying quartzites range upto 13m in thickness (Figure 3a). At Salgundi the underlying conglomerate is about 30m thick maintaining the same strike but dipping due South (Figure 3b).

Large cobbles and elliptical pebbles of jasper, chert, banded chert and banded hematite quartzite that are subrounded to subangular constitute the framework clasts of conglomerate (Figure 4a). These are bound within a ferruginous-siliceous matrix, are found to be clast-supported and show point contacts giving the sediment a grain-support fabric. The matrix has warped around the clasts at a few spots giving a folded structure (Figure 4b). The pebbles appear stretched and are elongated. On the vertical face their longer axis is oriented parallel and also, they are aligned imparting imbrication (Figure 4c). A vertical strike joint cuts through the matrix as well as the clasts of

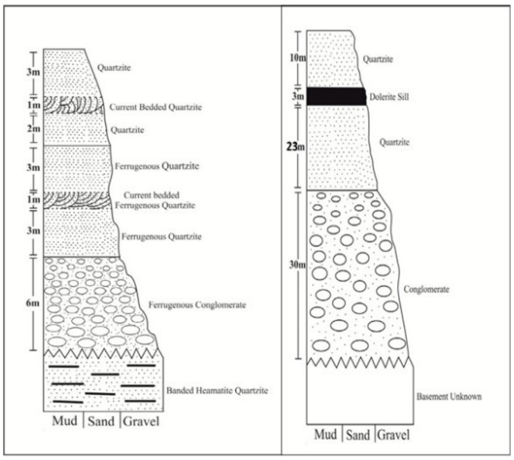

Figure 3: Lithologs at (a) Ramthal and (b) Salgundi

cryptocrystalline varieties of silica. The joint surface is straight and smooth with no evidence of shearing. Bedding joints are also prominent. The overlying quartzites are ferruginous marked by a sharp contact with the conglomerates and display cross-bedded structures on the vertical surface with the cross beds inclined towards west (Figure 4d).

The conglomerate exposed at Salgundi is compact, massive and polymictic with rounded to sub rounded cobbles and pebbles of banded chert, jasper, banded jasper, milky quartz, banded hematite quartzite (Figure 5a). The framework clasts are ovoid and elliptical ranging in size from 1cm to 18cms. These appear matrix-supported and oriented with their longer axis along the strike direction with imbrications (Figure 5b). The overlying quartzites constituted of siliceous to ferruginous matrix are about 35m thick and much more massive and resistant. Apart from three prominent joints sets, en echelon fractures (Figure 5c) and box joints are significant. Many of these are filled with secondary silica. A thick vein of quartz cuts through quartzite, while several sills of dolerite ranging upto 3m in thickness (Figure 5d) intrude along the strike joint maintaining sharp contacts with the host rock. Shearing along the margin has led to intense fracturing and blocks of the rock are found trapped within the intrusive sills.

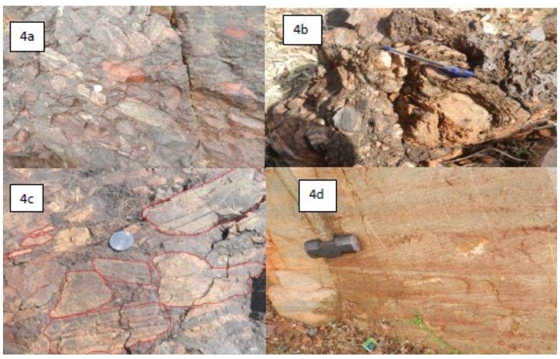

Figure 4: (a) Pebbly conglomerate with preferred orientation of the pebbles and cobbles (b) folding of the matrix around the pebble (c) Imbrications (d) cross bedding in quartzite at Ramthal

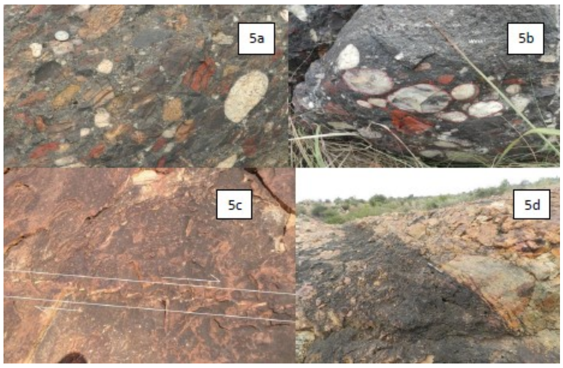

Figure 5: (a) Pebbly conglomerate showing stretched and preferred alignment (b) Imbrications (c) en echelon fractures (d) dolerite sill.

Sampling and Methodology

Fresh rock samples were collected at regular interval of 10 – 15m horizontally along the strata, as well as vertically wherever a change in texture was noticed. The collected field samples were cleaned with distilled water and dried to remove dust contamination for the purpose of analyses. Fifteen samples were selected for the purpose of micro section studies. Part of the matrix portion of selected rock samples was crushed to smaller pieces using a brass pestle and powdered to < 0.004mm size using an agate mortar and pestle, avoiding the larger clasts inorder to attain uniformity for the detection of major, trace and rare earth elements.

Six such powdered bulk rock samples were analyzed for major oxide analysis using X-ray Fluorescence machine; (Make Axios; Model PAN Alytical). For the study of major oxides 0.5gms of the dry powdered sample was weighed using an electronic balance. 5gms of Lithium Metaborate flux was added to the sample in a platinum crucible inorder to lower the temperature of melting. The sample was mixed thoroughly. It was then heated to a temperature of 250ºC for 2minutes inorder to ensure through mixing. Later the temperature was increased by 450ºC and heated for about 7minutes for the sample to melt completely. It was immediately poured into the platinum dish and allowed to cool forming a glass bead which was used for the purpose of analysis. For trace element and Rare Earth Element (REE) analysis six selected representative finely powdered samples were digested using the triple acid digestion (Jarvis, 1988). About 30mg samples were transferred to an acid mixture of HClO4 – HNO3 – HF in a clean Teflon beaker and digested on Q Block system at 200ºC. The addition of acid mixture was repeated to ensure the complete dissolution of samples. The solution was evaporated to incipient dryness. Finally the dry residue was dissolved in 2% HNO3 solution and made to a standard volume of 50ml. blanks were prepared and with addition of all ingredients and processes except for the addition of samples. Geochemical measurements were carried out using an Inductively Coupled Plasma-Mass Spectrometer (Agilent 7700x). Internal Standard Rhodium was added in all samples to estimate the recovery during the digestion process and the recovery was found to be excellent. Calibration was done by Inorganic Ventures Multi element Standards. Analytical precision was estimated using the digestion and analysis of USGS standard reference materials SGR-1b (Green River Shale), GSP-2 (Silver Plume Granodiorite) and NIST 688 (Basalt). Comparison with the certified values revealed excellent quality with the analytical error. Final concentration is given in ppm for all trace elements and for major elements it is given in %.

Petrographic studies

In the microsections of conglomerate from Ramthal subrounded clasts of quartz are seen enclosed within ferruginous matrix, also dispersed are grains of opaque minerals and cryptocrystalline silica. The quartz grains some of which are fractured show point as well as sutured contacts, with a thin film of iron oxide around them.

Microscopic observation of the conglomerate from Salgundi on the other hand shows angular to rounded quartz and cryptocrystalline silica with small flakes of muscovite mica within a ferruginous to siliceous matrix, along with opaque minerals. The mica flakes showing high interference colours are clustered around the larger clasts and appear oriented at high angles to the incipient cleavage (Figure 6a) and the quartz grain show signs of recrystallisation (Figure 6b). The

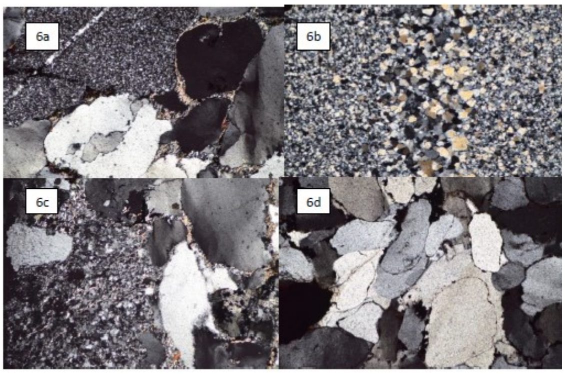

Figure 6: (a) Neocrystallisation of mica around detrital quartz at high angle (b) Recrystallisation of quartz seen as triple junctions at 120° (c) microfolding of mica indicating deformation assisted recrystallisation and neocrystallisation along with undulose extinction (d) overgrowths around quartz grains in crystallographic continuity. (Scale of photograph 10x = 1.54mm base of the photograph).

phyllosilicates are seen developing incipient microfolding seen as sub parallel alignment of the mica flakes (Figure 6c).

Overgrowth on quartz grains in crystallographic continuity is very significant (Figure 6d). Most of these grans exhibit sweeping undulose extinction. Thin sections of the rock from around the margin with the sills show highly angular fragments of quartz.

1

Bulk rock sample	SiO_2	TiO_2	Al_2O_3	FeOT	Fe_2O_3* adj	FeO adj	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	Al_2O_3+K_2O+ Na_2O
RAM-2	92.12	0.05	0.55	6.32	2.19	4.37	0.06	0.09	0.06	0.13	0.03	99.40	0.74
RAM-2A	92.12	0.04	0.55	6.29	2.18	4.36	0.06	0.10	0.05	0.13	0.01	99.35	0.73
RAM-2B	92.11	0.04	0.55	6.31	2.19	4.37	0.06	0.09	0.07	0.13	0.02	99.37	0.75
RAM-2C	92.12	0.05	0.54	6.29	2.18	4.36	0.05	0.09	0.05	0.13	0.01	99.33	0.72
RAM-2D	92.14	0.05	0.54	6.29	2.18	4.36	0.05	0.08	0.06	0.12	0.02	99.35	0.72
SAL-9	83.32	0.187	3.98	8.21	2.92	5.83	0.48	0.09	0.26	0.28	0.03	105.58	4.52
SAL-9A	83.21	0.19	3.97	8.12	2.89	5.78	0.44	0.08	0.27	0.29	0.02	105.26	4.53
SAL-9B	83.28	0.182	3.89	8.19	2.92	5.83	0.48	0.08	0.26	0.25	0.03	105.39	4.4
SAL-9C	82.98	0.185	3.89	8.19	2.92	5.83	0.45	0.09	0.26	0.23	0.02	105.04	4.38
SAL-9D	83.54	0.179	3.67	8.21	2.92	5.83	0.50	0.08	0.26	0.24	0.03	105.45	4.17

Abbreviations: The subscript 'adj' refers to adjusted data (anhydrous 100% adjusted basis); FeOT = Total iron expressed as FeO. Iron split using Fe_2O_3/FeO ratio after Middlemost (1989).
Fe_2O_3* = Total Fe expressed as Fe_2O_3

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Table1: Major oxide concentrations in weight percent (wt. %) for the Ramthal and Salgundi conglomerate

Bulk rock sample	Ag	Ba	Cd	Co	Ni	Cr	Cs	Ga	Mn	Pb	Rb	Sn
RAM-2	1.3167	15.200	0.2667	0.4333	23.05281	6.3000	0.1000	1.5333	3.9333	148.5833	1.4333	43.54785
RAM-2A	1.0500	17.9233	0.5167	0.4167	29.74832	6.7333	0.1167	1.4167	2.9167	182.5500	1.7000	58.28859
RAM-2B	0.6167	17.1833	0.3333	0.4167	28.11075	6.7333	0.1000	1.3333	2.9833	201.4667	1.6667	58.82736
RAM-2C	1.0833	17.3500	0.4833	0.5333	30.36667	7.2167	0.2333	1.7000	3.4167	210.7167	1.8333	64.28333
RAM-2D	1.0278	17.4562	0.4537	0.4125	29.3612	6.7834	0.1341	1.5646	3.5923	195.673	1.6789	58.7842
SAL-9	1.2000	52.7000	0.4500	2.3667	45.428	15.733	0.0667	3.8500	12.7667	234.6500	2.7833	87.24315
SAL-9A	1.3667	55.7333	0.3833	2.4333	42.578	18.050	0.0833	4.1667	12.5167	241.1667	2.7500	82.37113
SAL-9B	2.0667	52.8667	0.3833	2.2833	37.550	15.600	0.0833	3.8500	12.0167	221.9167	2.7000	66.87919
SAL-9C	1.2167	54.2167	0.4333	2.3833	42.897	15.600	0.0833	3.9000	12.7167	239.3333	2.7333	82.9862
SAL-9D	1.3657	55.7453	0.3562	2.4522	42.673	15.453	0.0835	3.8671	12.7682	245.924	2.7143	82.9780
UCC	50	30	0.098	17	44	85	550	17	-	17	112	5.5

Table 2: Trace-element concentrations in ppm for the samples from Ramthal and Salgundi conglomerate.

Bulk rock sample	Yb	Sr	Th	U	V	Cr/Th	Cr/V	Th/U	Th/Co	La/Co
RAM-2	0.082508	6.5833	1.5333	0.4500	2.4500	4.1087	2.571	3.407	3.538	3.807
RAM-2A	0.167785	8.4833	1.8333	0.5167	2.8333	3.6727	2.376	3.548	3.679	4.039
RAM-2B	0.09772	8.0500	1.5667	0.5167	2.7833	4.2977	2.419	3.032	3.759	3.959
RAM-2C	0.23333	8.2167	2.2667	0.6833	3.1000	3.1838	2.327	3.317	4.250	5.312
RAM-2D	0.09356	8.2011	2.1978	0.5280	2.9457	3.0864	2.303	4.1625	5.328	4.053
SAL-9	0.7833	22.4167	3.5500	0.8000	23.9333	4.431	0.657	4.438	1.499	3.619
SAL-9A	0.8167	22.4667	4.0333	0.8667	24.1667	4.475	0.747	4.653	1.657	3.788
SAL-9B	0.6833	22.0167	3.8167	0.8167	23.2667	4.087	0.670	4.673	1.671	3.832
SAL-9C	0.8500	22.6333	3.7167	0.8000	24.4000	4.197	0.639	4.645	1.559	3.699
SAL-9D	0.85612	22.4120	3.5894	0.8000	24.200	4.305	0.638	4.487	1.463	3.626
UCC	----	-----	10.7	28	1.07					

UCC = Average Upper Continental Crust values, UCC (Taylor and McLennan, 1985)

Table 2 (contd): Trace-element concentrations in ppm for the samples from Ramthal and Salgundi conglomerate

Bulk rock sample	La	Nd	Sm	Eu	Dy	Yb	Gd	ΣREE	(La/Yb)n	(La/Sm)n	(Gd/Yb)n	Eu/Eu*
RAM-2	1.6500	2.9500	0.4333	0.1167	0.314	0.3167	0.37	6.1507	4.344	2.396	0.947	0.87
RAM-2A	1.6833	2.7333	0.5167	0.1500	0.436	0.3667	0.38	6.266	3.828	0.752	0.839	0.99
RAM-2B	1.6500	2.5667	0.5500	0.1000	0.261	0.3167	0.32	5.7644	4.344	1.888	0.251	0.68
RAM-2C	2.8333	3.6667	0.8000	0.3000	0.617	0.5333	0.76	9.511	1.626	2.229	1.155	0.58
RAM-2D	1.6720	2.9675	0.5326	0.1500	0.424	0.3320	0.28	6.358	1.541	1.973	0.68	0.34
SAL-9	8.5667	11.30	2.17	0.5667	1.045	0.599	1.23	25.478	9.66	2.48	1.66	0.97
SAL-9A	9.2167	12.35	2.25	0.6000	1.340	0.687	1.27	27.71	9.07	2.59	1.50	0.99
SAL-9B	8.7500	11.45	2.17	0.5833	1.091	0.587	1.23	25.86	10.07	2.54	1.69	0.99
SAL-9C	8.8167	11.68	2.33	0.6000	1.098	0.598	1.25	26.37	10.00	2.38	1.69	0.99
SAL-9D	8.8912	11.60	2.2	0.5922	1.095	0.600	1.55	26.52	10.01	2.54	2.09	0.93
Chondrite-normalised	0.367	0.711	0.231	0.087		0.248	0.306	1.644				
UCC	64	4.5	0.88	3.8		0.32	3.8	73.5				

Table 3: Rare Earth Elements concentrations in ppm for conglomerate from Ramthal and Salgundi.

Geo chemical studies

Geochemical studies with respect to major oxides, trace element, rare earth element analysis of the samples from Ramthal and Salgundi was used to deduce the provenance and weathering conditions of the source rocks and shown in table 1, 2 and 3 respectively. At both places the percentage content of SiO2 in the conglomerate is quite evidently high; it being 92.12% at Ramthal and 83.21% at Salgundi. While percentage of Fe2O3 increases along with SiO_2 at both places that of Al_2O_3, K_2O, CaO and Na_2O are much less.

The lesser concentrations of the high-field-strength elements (HFSE) within the rock samples of the studied area were preferentially partitioned into melts during crystallization (Feng and Kerrich 1990), and as a result the mafic rock sources are depleted in these elements rather than felsic rock sources. Additionally, they are thought to reflect provenance compositions as a consequence of their generally immobile behavior (Taylor and McLennan 1985). In the samples analysed, concentrations of U (0.45 – 0.68ppm) and Th (1.53 – 2.2ppm) are found to be very low compared to UCC (U: 28ppm and Th: 10.7ppm; Taylor and McLennan, 1995).

Discussion

The conglomerates exposed in the two localities are resting over the Archaean Banded Iron Formation (BIF) giving the cherry red streak of hematite. Having been dated as of Post Archean age they are found to be matured, polymineralic and clast-supported. The crystalline and cryptocrystalline clasts of silica are well rounded and well sorted. There is also an apparent increase in the content of monocrystalline quartz and decrease in polycrystalline quartz. Microsections of the conglomerate from the study areas revealing the growth of mica around thedetrital quartz display pinning and microfolding. The minute mica flakes appear to be preferentially aligned. A rock cleavage has apparently developed through the interaction of heat and stress. Grains of quartz on being subjected to these factors show overgrowths in structural continuity. The process involving pressure solution transfer, recrystallisation and neocrystallisation subsequently resulted in elongation of the grains with their longer edges aligning parallel thereby generating incipient cleavage plane. The mica during the process has got oriented along an easiest direction to grow which was almost perpendicular to the cleavage. Such grain scale mechanisms are known to occur under low temperatures (<300°C) of deformation (Passchier and Trouw, 2005) suggesting the mega and micro structures observed in the conglomerate to have developed under a low temperature (<300°C) regime.

The percentage of SiO_2 is expectedly high with the dominance of varieties of silica in the rock at both Ramthal and Salgundi indicating a mineralogical maturity. The high concentrations of FeO (6.29% at Ramthal and 8.12% at Salgundi as compared to UCC (4.49% , Taylor and McLennan, 2001) is due to dominance of iron oxides in the matrix. Also, lack of feldspars reflects in the neglible amounts of Al_2O_3, K_2O, CaO and Na_2O. The K_2O/Al_2O_3 ratios in accordance are found to be low. Further, since the $Al_2O_3+Na_2O+K_2O$ versus SiO_2 plot indicates Compositional Maturity Index (CMI; Suttner and Dutta 1986; Figure 7) is relatively higher at both the study areas (Ramthal: 7.71 – 11 and Salgundi: 14.7 – 15) suggesting removal or lack of mobile elements like Na_2O and MgO. Ti bearing opaque minerals in the conglomerate at Salgundi might be contributing to a relatively higher TiO_2 (0.19%) than that at Ramthal (0.05%). The lower concentrations of U and Th in the samples with lower ΣREE probably reflects a control by grain size fractionation during transport, and may also suggest a contribution from a mafic source with lesser concentration of such elements.

Discrimination plots are drawn using various ratios of the oxides to determine the provenance for the sediments. In the discriminant function classification of provenance (Roser and Korsch, 1988) the plots fall in the mafic igneous field (Figure 8a). Based on ternary plots of Q-F-RF

(Quartz-Feldspars-Rock Fragments) of the framework clasts, the plots lie within a metamorphic domain (Figure 8b). In the Bivariant log/log plot of the ratio of Qp/F + R (Sutter and Dutta, 1986; Figure 9) the values represent the region to have been a moderate to low lying plain experiencing tropical humid climatic conditions. The underlying BIF and the hot, humid and oxidizing conditions that might have prevailed during and after the depositional history of the sequence must have been responsible for the ferruginous character of the rocks.

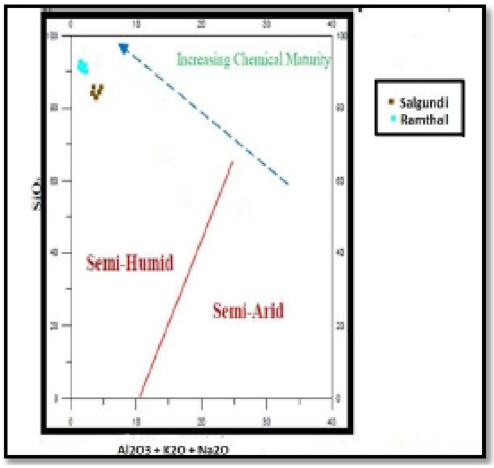

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Figure 7: Plot of Al2O3+Na2O+K2O versus SiO2 indicating Compositional Maturity Index (CMI; Suttner and Dutta, 1986).

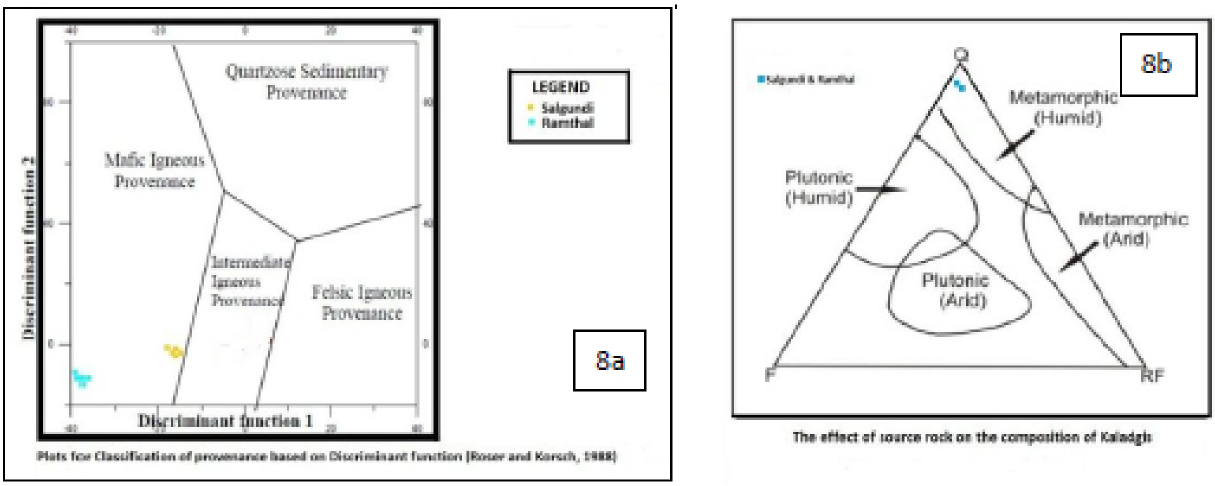
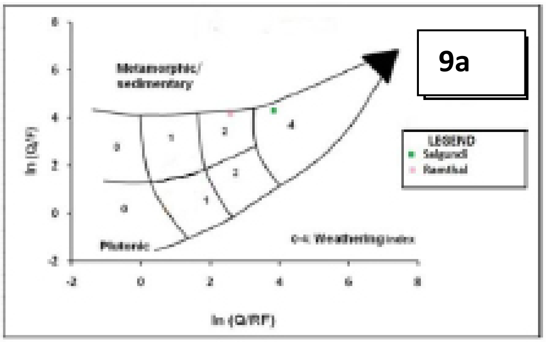


Figure 8: (a) Major element provenance discriminant function diagram for Kaladgi sediments (Roser and Korsch, 1988). The discriminant functions are for the ratio plots are: discriminant function 1 = 30.638 (TiO2/Al2O3) – 12.541 (Fe2O3*/Al2O3) + 7.329 (MgO/Al2O3) + 12.031 (Na2O/Al2O3) + 35.402 (K2O/Al2O3); discriminant function 2 = 56.5 (TiO2/Al2O3) – 10.879 (Fe2O3*/Al2O3)+ 30.875 (MgO/Al2O3) – 5.404 (Na2O/Al2O3) + 11.1112 (K2O/Al2O3) – 3.89 (b) the effect of source rock on the composition of the conglomerate at Ramthal and Salgundi.

The beds at Ramthal dip towards North, while at Salgundi they are inclined towards South. It is envisaged that the sedimentary succession at these two places represent parts of two limbs of a major synclinal fold, the river Malaprabha sinuating along the axis. Field observations of exposures report imbrication created by orientation of elongated pebbles both at Ramthal and Salgundi. At Ramthal the alignment suggests the upstream end to be towards east with paleocurrents flowing down west (Fig 4c &10). The overlying quartzites displaying cross-bedded structures have their cross-beds inclined westwards substantiating the westward flow of currents (Fig. 4d). The conglomerate at Salgundi on the other hand displays elongated pebbles whose orientation based on imbrications is suggestive of an eastward flow of paleocurrents with the upstream end towards west (Fig. 5b & 10).



9b

Semi-quantitative Weathering index		Physiography (relief) High (mountains) 0	Moderate (hills) 1	Low (plains) 2
Climate (precipitation)	(semi) Arid and Mediterranean 0	0	0	0
	Temperate subhumid 1	0	1	2
	Tropical humid 2	0	2	4

1

Figure 9: (a) Bivariant log/log plot of the ratio Qp/F+R versus Qt/F+R of the conglomerates at Ramthal and Salgundi. (Suttner and Dutta, 1986) (b) Log ratio after Weltje et al. (1998) Q=Quartz, F=Feldspar;, RF=Rock Fragments. Fields 1-4 refer to the semi-quantitative weathering indices deduced on the basis of relief and climate as shown in the table respectively.

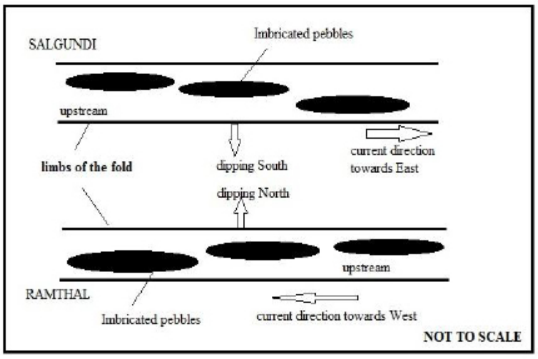


Figure 10 Paleocurrent directions based on imbrications

As observed in the field at Ramthal and Salgundi, the vertical face of the conglomeratic bed exhibits parallelism of the long axes of the elongated (prolate) pebbles. These axes are visibly parallel to the strike of the beds. The shorter axes accordingly, as seen on the surface are oriented in the direction of dip. Such a parallelism of the long axes of the pebbles is generated in water lain deposits. Smoothly flowing streams loaded with large sized pebbles, which are normally dragged along the floor of the channel, orient them during travel and bring about a parallelism of the axes on slowing down. On offloading this will create imbrication and the orientation thus developed will be in line with the direction of flow of the current.

Mukerjee *et al.,* (2016) suggest decoupling effect along a detachment surface, the unconformity acting as one in this case led to separation of the Mesoproterozoic sedimentary cover from the basement rocks in the Kaladgi basin (Fig. 11; Stage 3). A part that got detached from northern block on a regional high slid down southwards under gravity gliding to get compressed against the stable southern margin of the basin producing folds. The stable northern part remained stationary and undeformed maintaining its original tilt towards south. In the folded system that got created, the study areas of Ramthal and Salgundi occupy a synclinal fold. The northern limb of the fold on which Salgundi is located has maintained the original tilt (South) while the other limb (Southern-Ramthal) got rotated to reverse the tilt of the beds towards north as a result of the folding. On unfolding to revert to original prefolding position the southern limb would be in line with the northern limb to dip southwards. In accordance now, the paleocurrent direction at Ramthal deduced from the imbrication should be pointing towards east, in line with that observed at Salgundi where the beds have maintained original tilt. It can thus be inferred that the western side marks the upstream end and the paleocurrents moved down eastwards during the initial deposition of the sediments within the basin (Fig. 11).

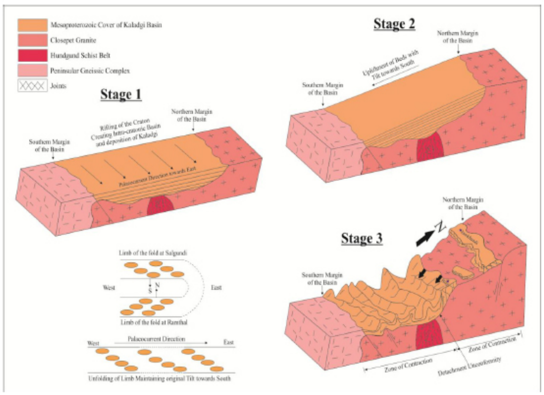


Figure 11 Schematic diagrams representing the depositional history along with paleocurrent directions

Conclusion

The conglomerate from Ramthal as well as Salgundi is oligomictic. It becomes monocrystalline in the direction of dip. The framework clasts of the size of cobbles and pebbles give a textural character to the rock. These are rounded to sub angular in nature and of a varied composition with constituents ranging from varieties of silica to rock fragments of BHQ. The size of the framework clasts suggests deposition having occurred along marginal parts of the basin with a proximity to the source area. The source from which the constituents were drawn must have been originally a mafic igneous rock which was later metamorphosed. Hot, humid and oxidizing conditions must have prevailed during the depositional history of the rock that underwent low temperature (<300°C) deformation The imbrications preserved within the conglomerates indicate paleocurrents to flow from east towards west at Ramthal (South of the basin) whereas at Salgundi (North of the basin) from west to east suggesting the basin to have been at a higher elevation towards the east. The transporting agency, which must have been a swiftly flowing stream having a sufficient velocity, would generally carry pebbles and boulders and align their longer axis in the direction of flow. Presence of cross-bedded feature in the immediately succeeding quartzites is a clear indication of the basin having been shallower at times.

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