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PETROGRAPHY, DIAGENESIS AND DEPOSITIONAL ENVIRONMENT OF THE LATE PROTEROZOIC CAVE-TEMPLE ARENITES OF BADAMI GROUP, KARNATAKA

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ABSTRACT

The Late Proterozoic Cave-Temple Arenite member of Badami Group comprising predominantly of sandstone forms one of the most interesting litho-units exposed around Badami for its prominent topographic expression (flat topped barren hillocks) along with a host of sedimentary structures viz. Cross-bedding, ripple marks, groove casts, convolute lamination etc. These sandstones are medium to coarse grained, moderate well sorted, subrounded to well rounded and belong to the quartz arenite to sub-arkose categories. Compositionally these rocks show considerable maturity with abundant quartz (78-96%) and subordinate feldspars having undergone both the physical (compaction and pressure solution) and chemical (silica, calcite and hematite cementation) diagenetic changes. Mineralogical composition of these sandstones indicates a principal recycled orogen source. The variety of sedimentary structures and the textural characters suggest a shallow marine depositional environment of the sandstones.

INTRODUCTION

The Proterozoic is an era of great significance in the evolution of the earth. Although an uninterrupted record of geological history is preserved, the study of the Proterozoic basins received much less attention, as they deserve presumably because of their unfossiliferous character and absence of important economic resources. The Kaladgi, Badami and Bhima Group of sediments occurring over a wide areal extent in parts of northern Karnataka represents the younger Proterozoic Sequence characterized by unique stratigraphy and depositional history. The last three decades have witnessed a phenomenal growth in the study of the Proterozoic sedimentary basins for understanding the origin and structural development of these basins (Vishwanthaiah, 1968,79; Narayana Murthy, 1978; Jayaprakash et. al., 1987; Ganesh & Sathyanarayan, 1991; Sathyanarayan, 1994; Sathyanarayan et. al., 1987 etc.,)

Kaladgi basin is one of the seven supra-crustal epicratonic basins characterized by unmetamorphosed, marginally deformed shallow marine sediments and forms an important sedimentary basin of the Peninsular India. The Badami Group of rocks exposed in Kaladgi basin consists of a succession of horizontally bedded to gently inclined quartzarenites, argillites and flaggy carbonates resting unconformably on the Kaladgis and Dharwar Group, and is confined to the southern fringes of the Kaladgi Basin. These rocks are typically exposed all around the

Badami Town in a chain of most picturesque outcrops stretching east-west from Gajendragad to Gokak (Fig.1). The stratigraphic succession of Badami Group (Jaiprakash et. al. 1987) is given in Table-1. Badami Group comprises of two major facies of sedimentation represented by Kerur Formation (predominantly an arenaceous facies) and Katageri Formation (Carbonate-shale facies). The present study is restricted to the cave Temple Arenite member of Kerur Formation.

Table - 1 Lithostratigraphic succession of Badami Group. (Jaiprakash et. al. 1987)

Group	Formation	Member	Thickness(m)
BADAMI	Katageri	Konkankoppa L.st.	85
		Halkurki Shale	67
	Kerur	Belkhindi Arenite	39
		Halgeri Shale	3
		Cave-Temple Arenite	89
		Kendur Conglomerate	3
Kaladgi Group	------------- Angular Unconformity --------------		
	Metasedimentary, sedimentary and intrusive rocks		

CAVE-TEMPLE ARENITE

The Cave-Temple Arenite with an estimated thickness of over 100m. forms an important lithostratigraphic unit of Badami Group. This unit is well developed around Badami in the form of flat topped barren hillocks with vertical scarps. In general, this arenite unit is hard, compact, well lithified to semifriable character displaying white, buff to different shades of red colours and hosts a number of sedimentary structures like cross-bedding (herringbone cross-bedding with opposed azimuths recording ebb-and-flood tidal currents, tabular and tangential cross-bedding (Plate - 1.1)), ripple marks, parting lineation and convolute laminations(Plate - 1.2) etc. In the outcrops around Badami, trace fossil like structures making epirelief resembling to those of resting or crawling marks made by mobile animals characterizing the tidal flat environments are also observed (Plate - 1.3). More than 60 readings of dip azimuths of the cross-bedding strata of Badami arenites are recorded from various localities order to calculate the vector mean direction. The vector mean of the cross-bedding strata, as calculated by geometric method of Curray (1956), indicate a mean vector of 247 suggesting northeast-southwest direction of movement of the sediments(Fig.2).

The grain size of these arenites ranging from -0.75 to 1.9φ and can be classified into very coarse to medium grained sand. Sorting (0.38 - 0.55) is

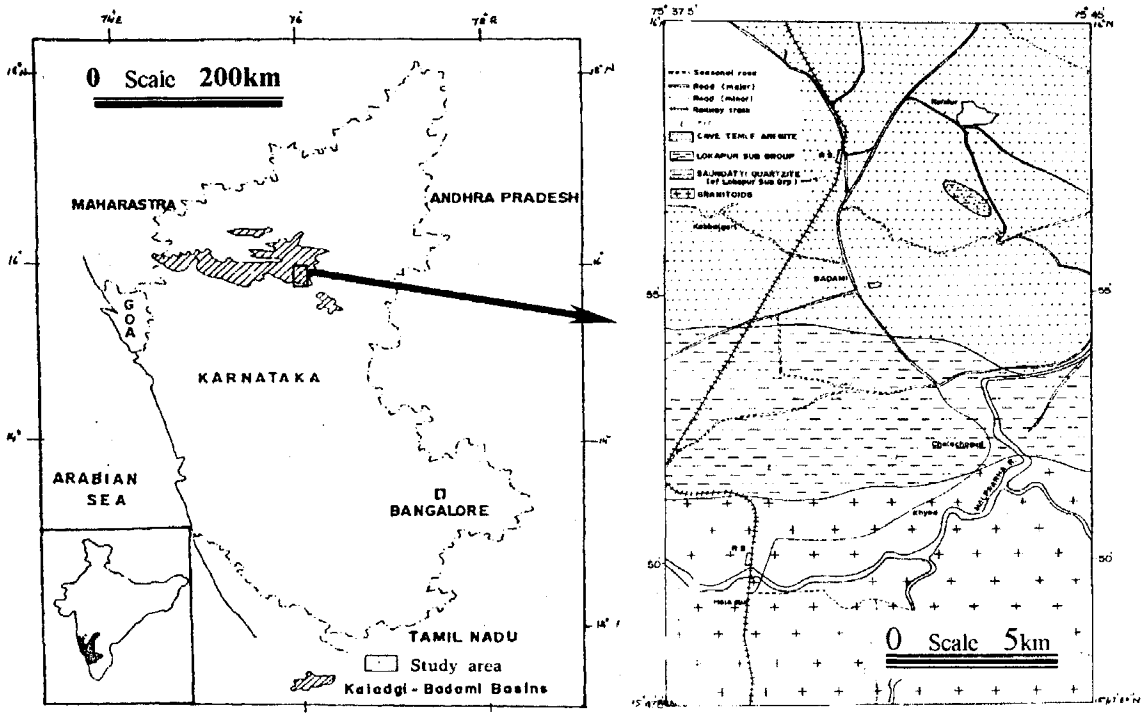


Fig.1 Location and Geological map of the study area showing the distribution of Proterozoic rocks around Badami, Karnataka.

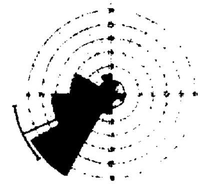
Class Interval(degrees)	30
Population	62
Maximum %	34.20
Mean %	10.90
Standard Deviation	9.34
Vector Mean (degrees)	246.90
Confidence Interval(degrees)	16.25
R-mag	0.592
Composite Current Rose Diagram N=62 Vector Mean = 247 Current Direction = NE - SW	

Fig- 2 : Rose Dagram of Cross - bedding data of Badami arenties

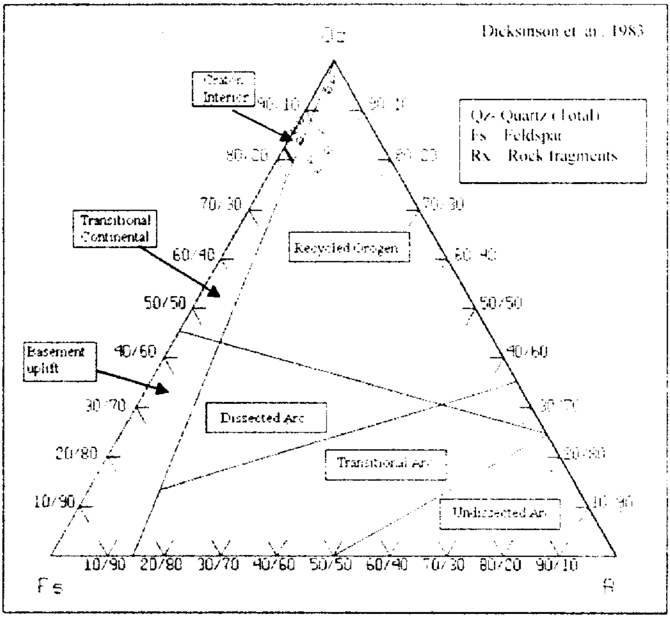


Fig- 3 : Tectonic provenance diagram (Dickinson et. al. 1983) of Cave-Temple Arenites of Badami showing Recycled Orogen and Craton Interior Settings

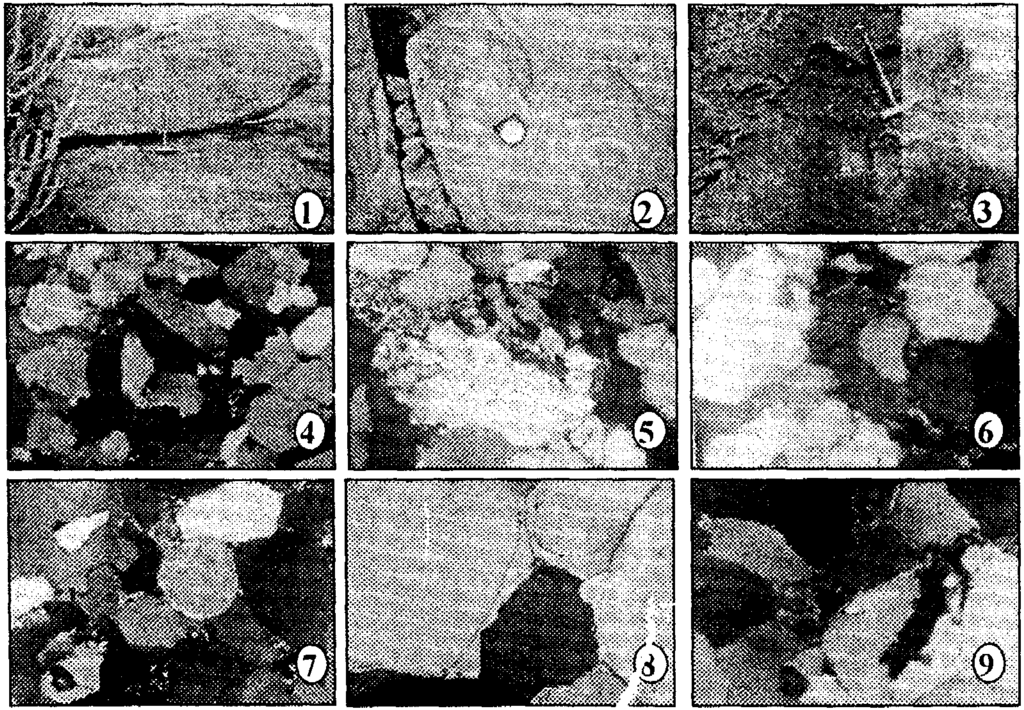


Plate - I Field Photographs and Photomicrographs

Field Photographs (1-3) : 1. Cross-bedding displayed by Badami arentites. 2. Convolute lamination of some arenites around Badami. 3. Unidentified Trace fossils observed in Badami Arenites. (Size of hammer is 12" long).
Photomicrographs (4-9) : 4. Moderately well-sorted, quartz-cemented, Cave-Temple Arenite displaying the carlsbad-twinning in a feldspar grain. (36X). 5. Sandstone diplaying rock fragments and feldspar alteration (36X). 6. Detrital Tourmaline grain in a Badami arenites (100X). 7. Well-rounded detrital rutile grain in the sandstone. Also seen in the section the inclusions of euhedral mineral in quartz grain (100X). 8. Quartzarenite displaying the silica cementation in the form of syntaxial overgrowth. Grain and the overgrowth are clearly distinguishable by a thin iron-oxide coating over the detrital quartz grain (180X). 9. Calcite cemented arenites showing corroded corner of quartz grains (110X).

moderate to good in most cases. The grains are mostly spherical, sub-rounded to well rounded nature. Texturally these arenites are mostly mature to supermature. Long polygonal grain contacts and sutured contacts where there is a mutual stylolitic interpenetration of grains have been displayed by these arenites(Plate - 1.4, 1.6). Mineralogically the rocks containing abundant quartz grains with subordinate feldspar indicate mature nature of the rocks.

PETROGRAPHY

The important frame work grains of these sandstones comprises predominant quartz, sub-ordinate amounts of feldspar and rock fragments and a few accessory mineral grains (opaques, rutile, tourmaline etc.). The modal composition of these arenites as shown in Table -2, which according to the classification of Dott(1964) fall in the fields of quartz arenite to subarkose and in some cases to sublitharenite.

Table - 2. Modal Composition of Cave-Temple Arenites

S. No.	Sample No.	Frame work composition (%)		
		Quartz (Total Qz)	Feldspar	Rock fragments
1	BSE1	94	4	2
2	BSE2	96	2	2
3	BSE3	86	9	5
4	BSE4	84	14	2
5	BSE5	78	14	8
6	BSE6	82	10	8
7	BSE7	84	14	2
8	BSE8	88	12	0
9	BSE9	80	14	6
10	BSE10	86	14	0

The quartz seen in these arenites is low quartz as it is the only thermodynamically stable variety under sedimentary conditions. Chert or opaline silica is not seen. Both the monocrystalline as well as polycrystalline quartz grains are present. Both the types of quartz show undulose extinction indicating considerable deformation. The quartz grains occur both as detrital and as secondary quartz overgrowths. The shape of the detrital grains varies from well rounded to subangular. Besides, a few detrital grains contain inclusions possibly of ferromagnesian silicates.

Orthoclase is the predominant feldspar present in these arenites some grains of which exhibit the characteristic Carlsbad twinning (Plate.1.4). Other feldspars like sodic feldspars and plagioclases are totally absent. The grains of the feldspars are subangular to subrounded. A relatively low degree of alteration of feldspar and their better preservation observed in these rocks as compared to the older rocks indicate a nearby source and possibly an early cementation.

The rock fragments present in these arenites belong mainly to the silica group which include the quartz and chert fragments. The fragments comprises of either polycrystalline quartz and orthoclase feldspar (Plate.1.5) or of monocrystalline and polycrystalline quartz indicating a probable metamorphic source.

Other minerals observed in these rocks include tourmaline, rutile and opaque minerals present in small quantities as accessories (Plate. 1.6 & 1.7). The tourmaline grains exhibit slightly elongated shapes and irregular boundaries. The well rounded detrital nature of the tourmaline and rutile indicate a recycled provenance (Pettijohn, 1987).

DIAGENESIS

The quartz arenites of Badami have undergone both the physical and the chemical diagenetic changes. The physical processes are seen in the form of compaction and pressure solution. Presence of close packing and long planar to sutured contacts suggests the compaction. Sometimes the sutured grains are even seen to cut across grain boundaries. This indicates considerable pressure solution. The compaction and resulting pressure solution and stylolitization could be the possible source for the supply of cementing materials.

Cementation (silica/calcite/hematite cementation) and authigenesis are important chemical diagenetic changes observed in these rocks which have considerably modified the primary fabric of the sediments.

SILICA CEMENTATION

The silica cementation is observed in the form of quartz overgrowth. The silica cement is precipitated around the quartz grain in optical continuity so that the detrital grain and cement extinguish together under cross nicols (Plate -1.8). The syntaxial overgrowths are seen giving the grains euhedral shape. The shape of the original grain can be delineated from the overgrowth of a thin iron oxide clay coating between the overgrowth and coating (Plate-1.8). The origin of the silica cement can be attributed to pressure solution action. The overgrowths result in making the rock hard and compact with an accompanying decrease in porosity.

CALCITE CEMENTATION

Calcite is another important type of cement observed in these arenites. This microspar to microgranular calcite cement shows a patchy distribution(Plate -1.7 & 1.9). The drusy calcite mosaic consisting of fine crystals has been observed filling the pore spaces between the grains. The quartz grains cemented by calcite are often corroded and etched at their margins to produce irregularly shaped grains (Plate-1.9). Calcite cementation is common in grain-supported sandstones and many cases it is an early diagenetic and first cement. The early precipitation of calcite inhibits later quartz overgrowth formation and feldspar alteration. In the present samples the presence of unaltered feldspars and the absence of secondary quartz overgrowths in the vicinity of calcite cements suggests the early diagenetic change.

HAEMATITE COATINGS

In many samples, the hematite coatings are seen around the grains as a thin brown layer. The formation of the hematite coatings is a result of the late diagenetic process of aging and dehydration of brown amorphous ferric oxide.

PROVENANCE AND DEPOSITIONAL ENVIRONMENT

The Cave-Temple arenites of Badami have been interpreted to be deposited in a Coastal tidal flat - Beach environment. The Badami group of sediments in general represent a separate facies of sediments initiated and deposited on a tidal flat as post-Kaladgi event of sedimentation (Sathyanarayan, 1994). The trace element and isotopic geochemical observations of Badami group accomplishes further the post-Kaladgi event of sedimentation of Badamis (Sathyanarayan et. al., 1987).

The mineralogical maturity of these arenites is manifested by the occurrence of quartz as the predominant mineral. The composition of sandstone is generally controlled by the various factors viz. Source rock (Blatt, 1967); tectonic setting (Mack et al., 1983); Climate-dependent weathering (Krainer and Spotl, 1989); depositional environment and diagenesis (Pettijohn, 1975 and Tucker, 1981). The compositional and textural maturity of the these arenites point to craton orogenic recycling from older clastics and also from direct contribution from the nearby metamorphosed crystallines and older sedimentary rocks (Lokapur Group). General textural charcteristics of these arenites and presence of well rounded grains of torumaline and rutile are suggestive of recycled provenance. The plotting of the modal composition on Dickinson et al.,(1983) plot indicate a principal recycled orogen source and a subordinate continental block source. Clasts of quartzarenites, fresh feldspars constituting the framework fraction of arenites and conglomerates suggest the reworking process. The rock fragments of quartz and polycrystalline quartz and orthoclase indicate a possible metamorphic source. The quartz showing undulose extinction indicates considerable strain and accompanying deformation pointing to a metamorphic source. The polycrystalline nature of quartz attests to their being of a second cycle. Relatively coarser size of the sediment and moderate sorting is indicative of a nearby source.

The depositional sedimentary structures viz. low-angle cross-bedding, ripple marks etc., are suggestive of shallow water deposition. The herringbone cross-bedding structures are indicative of sedimentation in a tidal flat environment. The textural parameters (grain-size, sorting, shape and roundness) are indicative of reworking in a beach environment. Presence of microsparitic calcite cement in association with the depositional structures is indicative of a shallow normal marine oxidizing depositional environment, possibly on a continental margin. This is supported by the well to moderate rounding of the grains and the good sorting indicating a well worn and washed sediment characteristic of beach environments.

The quartz over growths, calcite cementation and hematite coatings and absence of chert cements are supportive of an oxidizing shallow burial diagenetic environment. The silica cementation, which is well developed, indicates a late diagenetic change since early compaction inhibits the overgrowths. This is supported by the fact that the calcite cement, which is usually of early diagenetic origin, is subordinate.

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