Neoproterozoic Cave Temple Arenite of Badami Basin- Paleoenvironmental and Petrological Implications

Thesis submitted for partial fulfilment
of
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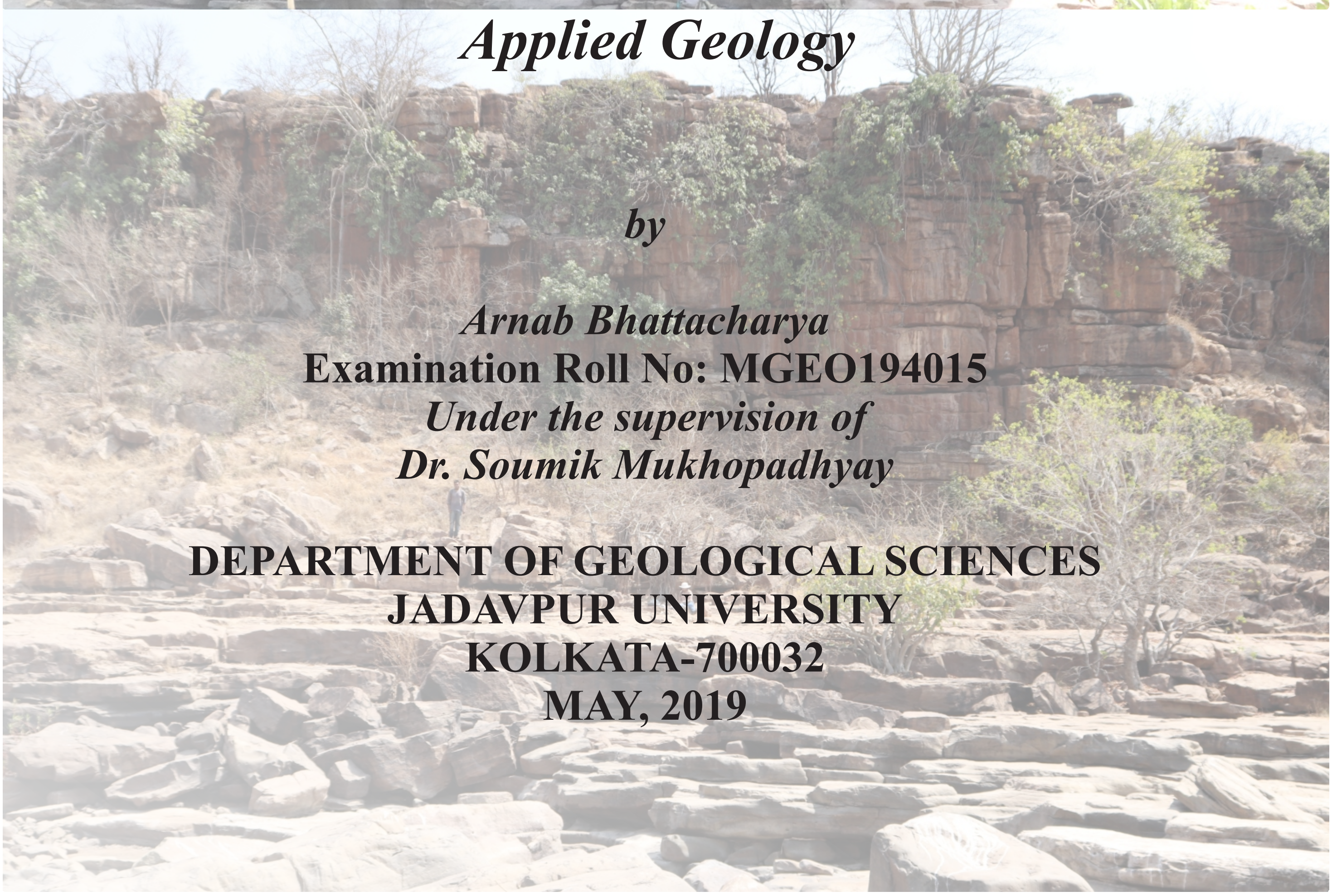
in



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CERTIFICATE

This is to certify that **Mr. ARNAB BHATTACHARYA** of M.Sc. Final Year, 2019, bearing Exam Roll Number **MGEO194015** and Registration Number **128258** of **2014-15**, has worked under my guidance in the Department of Geological Sciences and completed his M.Sc. Thesis Dissertation entitled **"Neoproterozoic Cave Temple Arenite of Badami Basin-Paleoenvironmental and Petrological Implications"** which is being submitted towards the partial fulfilment of his M.Sc. Final examination in Applied Geology in Jadavpur University.

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Author

Arnab Bhattacharya

“Soft as the earth is mankind and both need to be altered.”

-W. H. Auden

Abstract

Meso- to Neo-Proterozoic Kaladgi Basin,located on the north-western fringe of the western Dharwarcraton,is comprised of deformed, older Bagalkot Group and the overlying undeformed, younger Badami Group, exposed mainly in the western and central portion of the Basin. The terrestrial sedimentary units overlying the Chitradurga Schist Belt and/or Peninsular Gneiss in the southeastern margin of the western portion of the Kaladgi Basin, is characterised by multistoried conglomerate and sandstone bodies, belonging to the basal KendurConglomerate Member and Cave Temple AreniteMember of the Badami Group. The entire succession is made up of threevalley fills, the lower one of which is studied in detail in this occasion.Amply preserved primary structures though, enable one to apply state-of-the-art facies analysis scheme for the lower valley fill, which revealed ten genetic facies, combined in to three distinct facies associations. The first of which represents alluvial fan association, while the other two are chiefly fluvial, braided in pattern, but with gradually increasing flow durabilities within channels, thus representing ephemeral to perennial nature of the fluvial system, respectively. Apparently the fan association developed locally, along the high slope areas near the basin margin, followed by the fluvial associations vertically, as the depositional slope reduced due to basin filling. Nonetheless, ephemeral fluvial association I demands higher slope than the perennial fluvial association II.

Sequence architectural analysis revealed five vertically juxtaposed channel belts within the lower valley fill. The emplacement of one valley fill over another undoubtedly requires sufficient tectonic acitvities to generate new accommodation space, while vertical juxtaposition of channel belts, one above another, can also be prompted by climatic variationsTo unravel the controlling factor, in case of the lower valley filling, recourse to the petrographic analysis are taken. The lower valley fill characteristically possessarkosic to subarkosic nature of their constituent sandstone bodies. The preservation of feldspar in sandstone requires either extreme climatic condition or high slope, leading to short transportation and quick dumping of the sediments. Detailed petrographic studies revealed a positive correlation between grain size and

the feldspar content, along with a systematicdecrease in feldspar content both within as well as across channel belt, from bottom to top. This signifies tectonics generated slope as the prime mover in controlling the feldspar preservation within the lower valley fill.The QFR plot of these sandstone bodies also supported their deposition in a transitional continental area, which conforms well with the intracratonic rift origin of the basin. The overall fining upward trend of each channel fill accords well with the general aggradational nature of the fluvial system, leading to the gradual filling and concomitant reduction in the depositional slope. Overall, the multistoried lower valley fillsuccession in the western part of the Badami basin margin, documents gradual filling of the valleyby fluvial sedimentation, frequently disrupted by the tectonic movements leading to rejuvenation of depositional slope.

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CHAPTER 1

Introduction

1.1 Introduction

During the Proterozoic widespread platform sedimentation took place in several independent basins (termed ‘Purana basins’ in Indian geological literature) over the Indian Peninsular Shield(Kale &Phansalkar 1991; Chakraborty et al. 2010).Mainly two major types of sedimentary basins have been identified within Indian shield during Proterozoic time. The older commonly deformed and highly metamorphosed, basins are generally of Paleoproterozoic age, represented by Aravalli-Delhi-Bijawar-Sausar-Sakoli etc. The other comparatively less metamorphosed as well as less deformed ones show Meso to Neoproterozoic age, represented by Cuddapah-Vindhyan-Kaladgi-Bhima, although recent discoveries of Paleoproterozoic age of Vindhyan (Rasmussen et al., 2002; Ray et al., 2002) preclude its Mesoproterozoic age. Never the less these sedimentary field basins of Meso to Neoproterozoic are also known as ‘’Purana Basins’ of India. Among them the Kaladgi–Badami and Bhima basins, occurring over the northern part of the Dharwar craton, southern India, are typical intracratonic basins. The sediment packages of the two basins overlie a denuded basement comprising Archaean granitoid–greenstone belts. Kaladgi Basin is one of the purana basin of India situated in south-western part of Indian shield. It is confined between 73º to 76º30’E longitudes and 15º30’ to 17ºN latitude covering area of about 8000 kms extending over Bijapur, Belgaum, Bagalkot and Dharwar districts of Karnataka and Kolhapur and Sangi districts of Maharashtra. Presumably a higher aerial extend is expected as the basin is covered in eastern and southern side by Deccan Trap Volcanics. The Kaladgi Basin earns its name after a place called Kaladgi which is placed almost in the central part of the basin and around which rocks of these basin had first observed.There are some controversies regarding the structural thickness of Kaladgi Basin. According to Kale (1991) geophysically estimated maximum thickness is about 7000 mts. among which only 2800 mts. is exposed, distributed along the total extent of the basin. Whereas according to Jayaprakash et al. (1987) the total thickness of entire Kaladgi Supergroup is 4527mts. The basin is saucer shaped with east-west stretching in which direction it is about maximum 200 kms long compared to the maximum 100 km long N-S direction (Hegde et al., 1994). Kaladgi–Badami and Bhima basins have goodpotential in understanding the mechanism of intracratonic basinformation, reconstructing Proterozoic supercontinents and studyingthe evolution of the atmosphere and primitive life forms.

1.2 Previous Works

There are several ideas regarding the origin of Kaladgi Basin due to the similarity and outcrop distribution between Kaladgi and Gondwana Basin it has been considered to be a graben like basin (Hegde et al., 1994). Jayaprakash et al. (1987) attributed the initiation of Kaladgi basin to a set of lineaments trending E-W Hegde et al. (1994) inferred that the Kaladgi basin probably initiated through E-W trending rough faults over the Precambrian basement rocks, which is supported by the presence of an E-W trending about 10km long fault along the present southern boundary of the Kaladgi basin (Foote, 1876). Radhakrishna and Vaidyanathan (1997) considered Kaladgi as an “epicratonic” basin which have formed over already stabilized Dharwarcraton (cratonisation of Karnataka had occurred by 2500 my). The mature orthoquartzite sediment has likely to be derived from the stable Dharwar craton.

1.2.1 Stratigraphy

The name “Kaladgi Series” was originally coined by Foote (1876) for the rocks deposited in an intracratonic basin around the town Kaladgi. Initially the Kaladgi Series was divided into a lower and upper series by Foote mainly by lithology and structure.Foote included that the sandstones around Badami and other similar horizons as the uppermost division of lower Kaladgi Series. Later workers described the Kaladgi Series as almost horizontal series of sedimentary rocks resting unconformably on the crystalline schist and gneisses of the Dharwar system. Pascoe (1949) and Krishnan (1982) rearranged the classification into a four-fold division considering lithology as well as grade of deformation. Nautiyal (1996) classified the Kaladgi sediments on the basis of metamorphism, tectonic cycle and igneous activity of the Precambrians. A sheared unconformable contact of the Kaladgi with the underlying Dharwar has been postulated (Nautiyal, 1996). Another unconformable contact between the lower and upper Kaladgi Series has been identified on the basis of which a new group has been recognized (Viswanathiah, 1968). There has been a controversy regarding the recognition of this new group. Recent work has considered the existence of Badami as an younger group within the Kaladgi, separated by an angular unconformity. Viswanathaiah (1977) classified the younger Precambrian sediment of this area (excluding Badami sediments) into Kaladgi and Badami Groups with a clearly recognizable unconformity between them. Kaladgi Group represents a more deformed as well as metamorphosed and is about 1400mts thick breccia-conglomerate-quartz, arenite-argillite-carbonate assemblage, whereas Badami represents a mildly metamorphosed and less deformed gentle dipping quartz-dolomite assemblage (Viswanathaiah, 1977). The recent and most popular classification of Kaladgi Basin has been put forward by Jayprakash et al. (1987), where Kaladgi gets the status of super group which is subdivided into a lower Bagalkot and upper Badami Group, with an angular unconformity within them. Petrologically the composition of quartzite between these two groups differ significantly (Radhakrishnan and Vaidyanathaiah, 1997). These two groups occupied relatively different positions within the Kaladgi basin, while Bagalkot Group is restricted in the eastern part of the basin bordering the Badami Group, the Badami Group is mainly exposed in western part of the basin (Fig. 1.A.).Kaladgi Super Group is divided into lower Bagalkot and upper Badami Group.

Badami Group is subdivided further into lower Kerur Formation and upper Katageri Formations. Kerur Formation is subdivided into four members, from bottom to top, which are Kendur Conglomerate, Cave Temple Arenite, Halgeri Shale and Belikhindi Arenite. Main attention in this thesis paper has been given to Cave Temple Arenite Member of Kerur Formation at the western sector of Badami Basin. Underlying Kendur Conglomerate Member shows very restricted occurrences, only around the south margin of Kendur village. Studies revealed that this conglomerate can be best explained as the channel thalweg deposits, or in other terms, channel lag conglomerates, instead of forming any significant conglomeratic horizon (Mukhopadhyay et al., in press).

The angular unconformity dividing Bagalkot and Badami Groups is well exposed in areas like Mahakoot and B.N. Jalihal. Badami Group of sediments initiated with very thin and lenticular bodies of conglomerate over the basal formation of Bagalkot Group. In most of the cases it overlies Saundatti Quartzite Member and rarely Mahakoot Chert Breccia Member of Bagalkot Group.

1.2.2 Lithology

As stated earlier Badami Group shows less metamorphism and deformation compared to Bagalkot Group. The total succession is made up of sandstones mainly with limestone and rare shale and conglomerate. The basal thin Kendur Conglomerate Member is characterized by matrix supported polymicticlensoid bodies, followed by Cave Temple Arenite member which is characteristically quartz arenitic in nature with very coarse to medium grain size, poor sorting as well as angularity. The dominant internal structure is trough cross-stratifications, with tens of meters set thickness. This member shows overall fining upward trend with several cycles within. Each cycle itself shows fining upward trend as well.

Overlying Halgeri Shale and Belikhindi Arenite Member made up a minor proportion of the group. Belikhindi Arenite, although laterally restricted in occurrence, shows good quality exposures. This member is composed of comparatively well sorted and well rounded, medium to fine sand-sized materials, forming broadlytabular bodies. The dominant primary structure appears to be tabular cross-stratification and ripple lamination. The Kerur Formation is followed by Katageri Formation, made up of a thin shale and overlying limestone unit.

Both the shales on the other hand are characterized by planar lamination, rare wave ripples and reddish colour. The only limestone member of the group, Konkankoppa Limestone Member, is characterized by dark colour, wave features and fine grain size.

1.2.3 Depositional Environment

Overall the Kaladgi Basin is considered to be an intra-cratonic one initiated over Dharwar Super Group (Hegde et al., 1994). Badami, being the younger counter part, deposited over meta-sedimentary Bagalkot Group of rocks, which is evident by the presence of quartzite and vein quartz pebbles within Kendur Conglomerate member, the basal member of Badami Group. From grain size analysis Hegde et al. (1994) concluded that the sandstones are surely continental in origin. Internal structures and cyclicity within the Cave Temple Areniteclearly indicate its fluvial origin. The Belikhindi Arenite, on the other hand, documents plenty of evidence of deposition under wave influence. Both the shales depict deposition in condition under wave influence. Geochemical studies of these shales indicate a shallow marine origin. Konkankappa Limestone also indicates shallow marine depositional setting. Gowda et al. (1980) considered the limestone member to be deposited in a shallow marine agitated environment under high pH and CO_2 condition. The dark colour indicates a closed marine condition for this limestone (Radhakrishna and Vaidyanathaiah, 1997).

1.2.4 Age

In absence of reliable geo-chronological age data, the identification of micro-fossils within the Proterozoic segments are the common procedure for any “Purana Basin”. The basement has been dated as 3.29-2.6 Ga on the basis of Rb-Sr ratio using [$^{87}Sr/^{86}Sr$] vs. [$^{87}Rb/^{86}Sr$] plot (Jayaram et al., 1983; Rao et al., 1999). Bagalkot Group has been assigned a Middle Riphean age on the basis of stromatolite assemblage (Garuraja, 1983; Raha et al., 1982; Viswanathaiah, 1975). Subsequently Badami Group is considered to be post Middle Riphean. Sandstones in Badami Group enriched in a variety of organic micro-fossils, about

22 taxa of Coccoidalnano fossils with diameter- micron along with some Acritarchs have been identified.

1.3 Badami Group at Western and Eastern sector of Kaladgi Basin

The western sector of the Kaladgi Basin holds the Badami Group chiefly, overlying the Archean basement of Chitradurga Schist Belt, at places with a thin layer of lowermost Salgundi Conglomerate Member of Bagalkot Group in between. The Badami group of rocks, though extensively developed, is represented by only the lower portion of the Kerur Formation, namely the Kendur Conglomerate and Cave Temple Arenite Member. Overlying members of the Kerur Formation as well as the Katageri Formation are not developed in this sector. Hence, study in this thesis paper concerns mainly with the Cave Temple Arenite Member only. The field work was carried around Belgavi, Karnataka at different places, namely, Deshnur, Marihal, Gokak, Islampur, Godihal and Benchinmardi. Deshnur and Marihal are present at the southern part of the western margin of the Badami Basin. These two places are situated north-east of Belgavi with the distance from Marihal and Deshnur being 25kms and 35kms, respectively. Benchinmardi is placed more towards north of Belgavi. Gokak is situated at the northernmost boundary of the basin about 60 kms from Belagavi and Kadapkatti is towards South from Gokak about 50 kms from Belagavi. Godihal is at the westernmost margin of the basin about 14 km from Belagavi. Kabalapur ia towards SE from Godihal towards the basin interior about 10 kms from Belagavi.

All the places are characterized by the presence of the Cave Temple Arenite Member, which is presumably underlain by thin sediments of Bagalkot Group. At Benchinmardi, despite it being well within the basin, the basement was exposed, as the geophysical studies revealed the presence of a basement high, just south of the area.

These field areas were dominated by beds which were dipping 25º towards West. The successions observed in these areas were mainly sandstones with some conglomeratic beds also occurring. These successions were fining upward, and made up of several cycles and each of these cycles were fining upward as well, though some coarsening upward sequence were also observed. Each of the fining upward cycles started with conglomeratic beds which gave way to sandstones vertically which then again fine upwards. Also there were variations in the conglomeratic bodies. Towards the base of the successions we get clast supported conglomeratic beds and as we move up we encounter some matrix supported conglomeratic bodies as well embedded within the individual cycles. The conglomerates and sandstones show coarse to medium grains with poor sorting. The sandstone beds were characterized by trough cross stratification, ripple lamination and planar laminations, but some were massive as well. Conglomeratic beds were massive or occasionally crudely cross stratified.

The western and Eastern sectors of Kaladgi Basin were separated by a basement high. In the Eastern Sector both the Badami and Bagalkot Groups of sediments were exposed with the Badami Group occupying more central position of the basin. Best exposures of Cave temple areniteare found near Badami town, along with some patchy occurrences along Timapur and Torgal Tanda area. The palaeocurrent direction changes in eastern sector from West to slightly S-W.

1.4 Scope of Work

With the aim set at beginning the following work plans are proposed:

1. Selection of locations and attitude study of beds in Deshnur, Marihal, Godihal, Islampur, Kabalapur, Benchinmardi, Timapur, Badami areas.
2. Detail facies analysis in Cave Temple Arenite Member of Kerur Formation and petrological study of facieses.
3. Interpretation of depositional processes from the facies attributes.
4. Determination of facies which are found to be associated with each other throughout the succession.
5. Documentation of vertical and lateral transition of facies and facies association.
6. Reconstruction of palaeogeography and palaeoenvironment of deposition.

1.5 Procedures

For execution of the self-imposed task the following work procedure was adopted.

- Identification, documentation and measurements of various sedimentary structures and their mutual relationship.
- Identification and characterization of different facies and their distribution.
- Distribution of different facies association both laterally and vertically
- Vertical logging of these facies in available good section in order to demonstrate facies sequence pattern.
- Study of detail mineralogy (Feldspar content) and grain size from bottom and top of Channel Belt in different area both in eastern and western boundary.

1.6 Equipment

- Extensive fieldwork was the mainstay of the present work. For field purpose toposheets (bearing no. 48 I/9 and 47 L/12), hammer, clinometers, bran ton-compass,
- scales, tapes and camera were used. Well known methodologies like vertical logging were used most frequently.
- Petrographic studies made on reflected light microscope in direct correlation with specific field attribute that augmented the study. Specification of instrument used for petrographic studies in laboratories is given below.
    - LEICA DMLP microscope
    - Canon 150 IS, Canon 120 IS camera for taking microphotograph.

1.7 ORGANIZATION:

Organization of the dissertation follows the scope of work outlined above. The present author deals with Cave Temple Arenite Member of Kerur Formation. It also establishes what we already know about it from published literature in **Chapter 1.**

In **Chapter 2** detailed facies analysis vis-a-vis petrographic attributes of this conglomerate and sandstone beds exposed at Deshnur, Marihal and Benchinmardi are will be discussed.

Chapter 3 describes the facies association in the studied area.

Chapter 4 Sequence Architectural Elements

Chapter 5 Discussions and Conclusions

CHAPTER 1

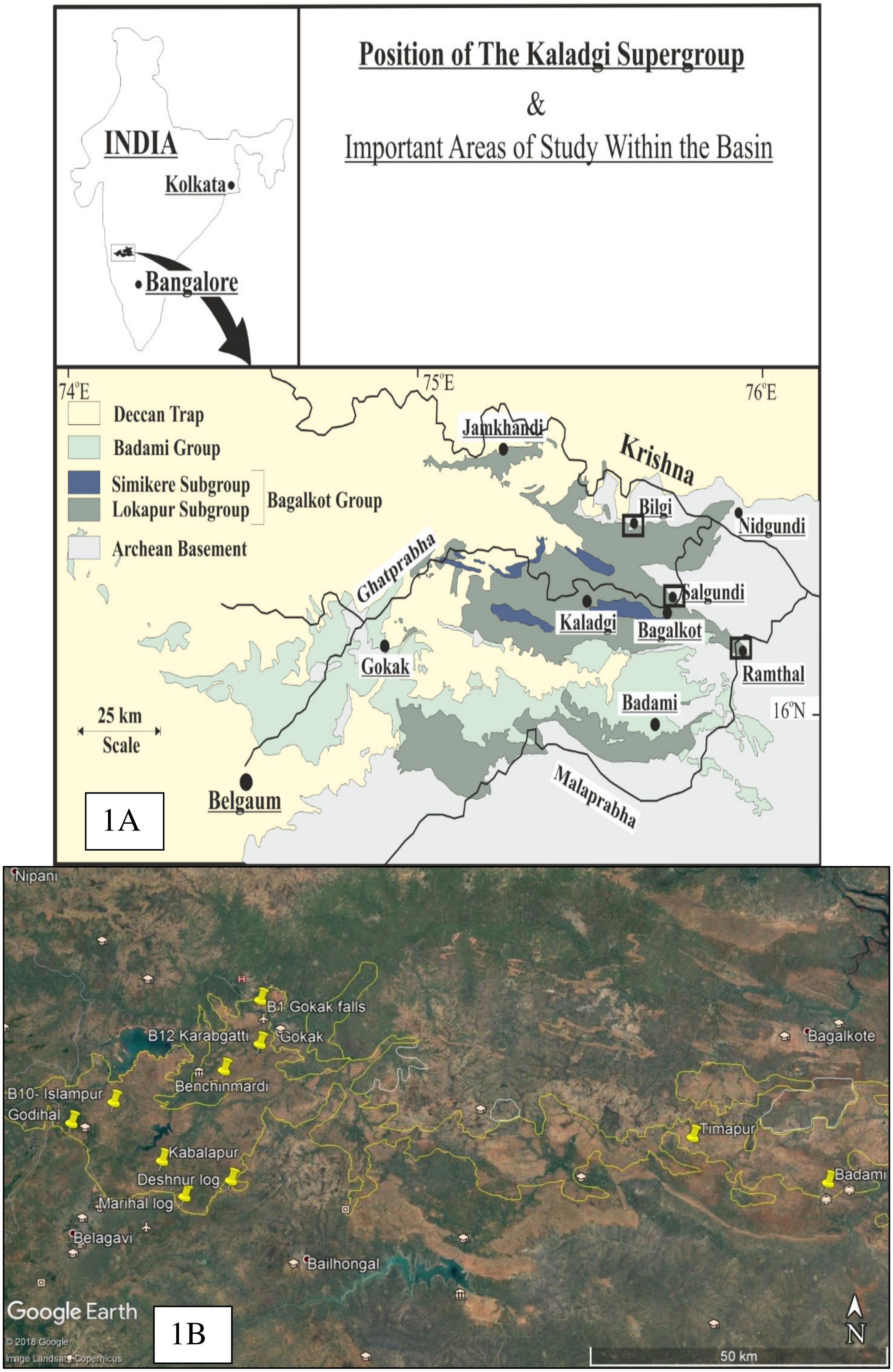


Fig 1A: Geographic Location and lithologic map of Kaladgi Basin (after Jayaprakash et.al., 1987). 1B. Location of the studied sections in the Kaladgi basin, with traced southern boundary of the basin

	GROUP	SUBGROUP	FROMATION	MEMBER	THICKNESS(m.)
KALADGI SUPERGROUP	BADAMI		Katager	Konkankoppa Limestone	85
				Halkurki Shale	67
			Kerur	Belikhindi Arenite	39
				Halgeri Shale	3
				Cave-temple Arenite	89
				Kendur Conglomerate	3
	Angular Unconformity				
	BAGALKOT	SIMIKERI	Hoskatti	Mallapur Intrusive	7
				Dadanhatti Argillite	695
			Arlikatti	Lakshanhatti Dolomite	87
				Kerkalmatti Haematite Schist	42
				Niralkeri Chert-breccia	39
			Kundargi	Govindkoppa Argillite	80
				Muchkundi Quartzite	182
				Bevinmatti Conglomerate	15
		Disconformity			
		LOKAPUR	Yadhalli	Argillite	58
			Muddapur	Bamanbundi Dolomite	402
				Petlur Limestone	121
				Jalikatti Argillite	43
			Yendigere	Naganur Dolomite	93
				Chikkshelikere Limestone	883
				Hebbal Argillite	16
			Yargatti	Chitrabhanukot Dolomite	218
				Muttalgeri Argillite	502
				Mahakut Chert-breccia	133
			Ramdurg	Manoli Argillite	61
				Saundatti Quartzite	383
				Salgundi Conglomerate	31
Non-conformity					
Granitoids, gneisses and metasediments					

CHAPTER 2

FACIES ANALYSIS

What is Sedimentary Facies?

Sedimentary facies are bodies of sediment that are recognizably distinct from adjacent sediments that resulted from different depositional environment.

What is sedimentary facies analysis?

Facies analysis is concerned with the identification of depositional processes and recognition of ancient sedimentary environments in stratigraphic rock record.

An organized classification of the rocks deposited in an ancient sedimentary basin is an essential prerequisite to understand the modes of deposition therein. Therefore a detailed facies analysis is needed which deals with the genetic aspects of co-existing rocks for the above mentioned goal (Miall, 1980; Hallam, 1981; Walker, 1984; Reading, 1996). The ultimate goal is the reconstruction of the palaeogeograhy and palaeo-depositional environment of the studied succession in terms of palaeohydro dynamics and depositional agents. Keeping that in mind attempts had been made, in this thesis paper, to carry out the state-of-the-art facies analysis. Primarily, facies classification is based upon criteria such as lithologies, overall geometry, internal structures and nature of bounding surfaces of the sedimentary bodies (Walker, 1983), along with some basic petrographic characters, like mineralogical and textural maturity, which are also very much informative to delineate genetically different facies. State-of-the-art facies analysis not only encompasses erection of different genetically related facies, but also takes into account their distribution in time and space along with the nature of contact among themselves, to reveal a unique paleogeogrphic model for the studied area.

The details of facies analysis in the chosen segment of Badami Group, more precisely the Cave Temple Arenite Member of Kerur Formation of Badami Group, following the aforementioned guidelines have been presented in this chapter.

Kerur Formation in and around the study area

Best preserved exposures of Cave Temple Arenite Member are distributed in more or less continuous steep sided flat topped hillock systems along both the eastern and western sectror of the Kaladgi Basin. In central part of the eastern sector, Badami Group of rocks are well developed and overlie the Bagalkot Group of rocks with angular unconformity. Towards the western sector though, only Cave Temple Arenite member is developed into greater extent, but the younger Formation is absent. In this sector, the studied member directly overlies the meta-sedimentary basement of Chitradurga Group in majority of portion, while a thin layer of Salgundi Conglomerate Member, the basal Member of Bagalkot Group, occur locally in between them. Main emphasis in this thesis paper is given towards western sector, as this part received lesser attention previously. Study concentrates mainly around Belgaum, along the hillocks exposed near Deshnur, Kadapkatti, Benchinmardi and Marhal village (Fig 1B). This thesis paper aims to elaborate the facies constituents and their interrelationship within the studied stratigraphic interval in and around Belgaum town, which marks the eastern margin of the western sector of the Badami Basin (Fig 1B). Rocks in this area exposed along northeast-southwest trending hill ranges, with well-preserved primary structures. The main lithology varies between conglomerate, in the lower part, to sandstone, pebbly to medium sand-sized. The beds are horizontal to subhorizontal, at places gently dipping with no major structural unit like folds or faults. Direct contact with the metasediments and volcanics of Chitradurga Group, is observed locally, as in Benchinmardi, although in other areas basement outcrops are observed in near vicinity. The studied section is mainly made up of sandstone, with minor pebbly sandstone, rare conglomerate and siltstone. The composition of the trough cross-stratified channel sandstone showed variation from sub-arkosic arenite (Fig 2.1.A) to lithic arenite (Fig 2.1. F) to arenite (Fig 2.1. B), which contained lithic fragments of varied composition. The grains of quartz and feldspar were sub-rounded to angular, and showed poor to moderate sorting (Fig 2.1. D). The rock fragments were sub-rounded to angular in shape (Fig 2.1.C). The lithic fragments were identified to be of chert (Fig 2.1.C), quartzite and felsic plutonic rock. The overall composition of the clast showed consistency with the immediate basement rocks of quartzite, schist and intermediate granitic plutons. Some of the rock fragments were seen to be composed of deformed grains showing folding as well (Fig 2.1.D), which further supports the before mentioned fact.

In the Eastern Sector maximum extent of subhorizontally disposed multistoried Cave Temple Areniteis around Badami area. It overlies meta-sedimentary basement and in some parts over Saundatti Quartzite, appearing as hillocks with steep slope, with a distinct angular unconformity. The multistoried look of this Member is imparted by the presence of several smaller scale cycles (representing channel belt and/or channel fill cycles). Gritty sandstone units are present at the base of channel fills as well as channel belts, while top part is mostly devoid of pebbles, and made up of coarse to moderate sand-sized maerials. It shows overall fining upward succession with fining-upward individual channel belt and channel fill cycles.

2.1. Facies in the studied succession

An unified facies classification covering all the exposed rock bodies in this area is done on the basis of lithology, texture and internal structures along with their body geometry, association and inter-relationship among themselves. Ten fluvial and alluvial facies have been identified. These are described below.

Facies A: Clast supported breccia facies:

This facies is characterized by clast-supported, polymictic breccia bodieswith chaotic arrangement of highly angular clasts (Fig 2.2.A). These beds are slightly convex-upward and wedge-shaped in three-dimensions, but have bases rather jagged due to the sinking of large clasts beneath the base while resting on a sandy substratum. Clasts of granite, quartzite, vein quartz, chert, BHJ and BHQ account for the range of clasts. Average clast-size is about 8cm. The sandy matrix between the clasts is granular and poorly sorted, mineralogically and texturally immature. This facies appeared in association with Facies B (discussed later).

Interpretation

Comparatively large grain-size, highly angular clasts with haphazard orientation and clast-supported framework indicate very short-lived transportation of the sediment pile. Restricted abrasion left inherited angularity of clasts almost intact and impingement of clastsinto the base, at places, suggests free fall of grains (Selley, 1965; Blair and McPherson, 1994). Impingement of clasts through the base of some beds imply landing of the clasts with a heavy thud. That would, in turn, imply free fall most probably in sub-aerial condition; the thud would be negligible on descent through water. All these points along with the rapidly wedging body geometry, probably firmly indicate towards the scree or free-fall origin for these deposits (Mueller et al., 1991; Martins-Neto, 1996; Bertran et al., 1997).These are typically alluvial deposit.

Facies B: Matrix supported massive conglomerate facies:

This facies is characterized by broadly lenticular bodies of matrix-supported massive conglomerate (Fig 2.2.B). Beds generally show planar basal and rugged, broadly convex upward upper contact. The rugged top surface is produced by frequent protrusion of clasts above surface (Fig 3.1). Conglomerate bodiesare polymictic, with major portion of clasts are contributed by cherts, quartzite, BHJ and BHQ, with the former two being the dominant constituent. Clasts show high angularity with average 4cm size, although clasts as large as 8 cm are also found. Clasts are haphazardly oriented within a matrix of poorly sorted granular sand. This facies is mostly associated with Facies G, Facies A and Facies E.

Interpretation

From the body geometry, matrix-supported framework, haphazard clast orientation with no discernible grading pattern and protrusion of clasts over the top surface the depositional mechanism for this facies is identified as cohesive debris flow (Johnson, 1970; Nemec et al., 1980; Schultz, 1984; Mack and Rasmussen, 1984; Nemec and Postma, 1993; Mulder and

Alexander, 2001; Davis et al., 2002; Gani, 2004; Mazumder and Sarkar, 2004). Profound matrix strength is responsible for the protrusion of clasts and development of no substantial grading, as it facilitates transportation of the clasts in suspension (Lowe, 1982; Blair and McPherson, 1994; Blair, 1999). Preservation of inherited angularity also points towards the high matrix strength, as it will reduce the chance of abrasion. Substantial proportion of stable chert and quartzite clasts along with unstable BHQ/BHJ indicate a longer transportation, but not too long to obsolete the unstable compounds totally. This facies represent sediment gravity flow on a slope-break, where the gradient is higher enough to produce debris flows.

Facies C: Graded conglomerate facies:

This conglomerate facies is characterized by broad lenticular geometry, slightly convex upward tops and planar bases (Fig 2.2.C). Internally, the basal clast-supported nature gradually changes upward into matrix supported and then further upward dominantly sandy with occasional oversized pebbles floating within it (Fig 2.2). Sandy part although chiefly is massive, locally bears crude cross-stratification. The clasts of this conglomeratic body are made up of durable components like quartzite, chert, jasper and clasts of quartz vein. Pebbly clasts are very poorly sorted. The interstitial spaces are filled up by very poorly sorted coarse sand.

Interpretation:

The massiveness of this facies points towards rapid deposition. Upward convex body geometry and internal massive character indicate sediment gravity flow origin for this facies (Lowe, 1982). Sudden increase of sand towards top pointed towards sand infiltration from top as a result of downward draining out of water (Bose et al, 2008) and consequent infiltration of sand from suspension during the waning stage of the flow (Lowe, 1982; Hofmann et al., 2004). The sand percolated downward through the space between the larger clasts (Todd, 1989). Occasional existence of crude cross-stratification within the upper sandy part of this facies also supports the contention of rapid freezing of migrating bedforms. The deposit is comparable with sieve deposits on sub-aerial fans (Einsele, 1992; Collinson, 1996; Mazumder, 2002; Mazumder and Sarkar, 2004; Bose et al., 2008, Mukhopadhyay, 2012).

Facies D: Clast supported lenticular conglomerate facies

This facies is characterized by clast supported polymictic conglomerate bodies with strongly lenticular body geometry showing sharp and erosional concave-up bases and comparatively less sharp, rarely gradational, planar tops (Fig. 2.2.D). Crudely developed normal grading can be discernible locally within such bodies. These bodies are almost always overlain either by pebbly sandstone bodies with no or crudely developed internal structures, or by thoroughly trough cross stratified facies. Clasts are subangular to subrounded with average 3cm size and chiefly made up of quartz veins, quartzites, with subordinate basement clasts.

Interpretation

Subrounded grains, compared to angular matrix of previous facies probably indicate more transportation. Presence of lags, demarcating the channel base, proved presence of erosion. These are considered to be the channel thalweg deposits, designated as channel lags by Allen (1982). The highest velocity of tractive flow achieved within the channels understandably drove them. The pebbles almost certainly moved as rolling or sliding load and thus are better rounded for being subjected to greater abrasion during transport. Hence, such conglomeratic bodies are likely to be the channel thalweg deposits (Bose et al., 2008; Mukhopadhyay, 2012).

Facies E: Inversely graded clast supported conglomerate facies

This facies is broadly similar with Facies B, except that the clast packing is rather intense and individual beds show feeble reverse grading (Fig2.2.E). Clast composition and angularity remains almost same, with a slight increase in grain size and concentration. Bodies are more rapidly wedging compared to facies B (Fig 3.1). This facies constitute a small portion of the succession and generally associated with facies B, in close lateral and vertical juxtaposition.

Interpretation:

Depositional mechanism for this facies presumably stands as modified grain flow (Lowe, 1976, 1982; Middleton and Hampton, 1976; Schultz, 1984; Mack and Rasmussen, 1984; Nemec and Postma, 1993; Mulder and Alexander, 2001; Davis et al., 2002; Gani, 2004). In general, to transform from debris flow to grain flow amount of water within a sediment-gravity flow reduces as well as sediment concentration increases (Bagnold, 1962; Dott, 1992; Enos, 1977; Lowe, 1982; Shanmugam, 2000). These phenomena are supported by the increase in clast packing, which in turn increases the grain-to-grain contact. As a result, mutual collision or near-collision between the clasts, that is, the dispersive pressure played important roles in transportation of the clasts in suspension and did not allow the coarser clasts to sink (Bagnold, 1954; Middleton and Hampton, 1976; Mulder and Alexander, 2001; Gani, 2004). This phenomenon leads to the formation of reverse grading, along with kinetic sieving, which allows smaller clasts to sink between the larger clasts during transportation. Rapidly wedging body geometry of such beds owes their origin from relatively short flow extent of grain flows.

Facies F: Crudely cross-stratified granular sandstone facies

This facies is characterized by granular sandstone bodies showing strongly lenticular body geometry with sharp, erosional, concave-up bases and generally flat and less sharp tops (Fig 2.2.F). Internally these bodies are massive or crudely cross-stratified; pebbles are preferably concentrated at the base of such bodies and, in case of crudely cross-stratified bodies, along the foresets of the cross-strata. These facies are rare within the succession and appear as isolated patches.

Interpretation

Poorly-sorted granular sandstone with pebbles strewn randomly within it is possibly of high-velocity flashflood origin (Pfluger and Seilacher, 1991; Bose et al., 2008). Lenticular body geometry indicates channelised flow. Rapid deposition from high sediment-laden flows is empirical.

Facies G: Thoroughly trough cross-stratified facies

This facies is characterized by strongly lensoid body geometry in transverse section, with concave upward erosional bases and flat tops, and internal thorough trough cross-stratification (Fig 2.2.G). Internally this facies shows cosets of trough cross-stratification with average 10 cm set thickness (Fig 3.1). Pebble concentrations along the trough set or foreset boundaries are a frequently occurring feature of this facies, although some bodies, preferably towards upper part of the succession are devoid of any pebbles. Trough set thickness reduces upward within the body without any significant change in grain size. Petrographically, such bodies are texturally immature, with poor sorting and angular to subangular very coarse to medium sand-sized clasts. Unidirectional paleocurrent direction towards W to NNW is recorded. This facies appears to be the dominant facies within the studied interval and found to overlie the granular sandstone facies F commonly and the clast supported lenticular conglomeratic facies D rarely.

Interpretation

The presence of thorough trough cross-stratification clearly designated this facies as a fluid-gravity flow-product, where traction current is the sediment-transporting agent (Miall, 1992). The textural immaturity of the facies reflects relatively poor efficiency of the depositional agent. Such bodies manifest dune migration presumably along the channel floor (Miall, 1996). Common in-channel upward decrease in trough cross-set thickness without accompanying grain-size reduction within the sandstone bodies record gradual decline in the flow regime (Harms et al., 1975), probably in rising water stage. These lenticular sandstone bodies, along with their angular, poorly sorted grains and subarkosic nature, and erosional concave-up bases can easily be identified as fluvial channel-fill sandstone (Miall, 1996; Collinson, 1996; Eriksson et al., 1998; Bose et al., 2008; Sarkar et al., 2012).

Facies H: Compound cross-stratified facies

This facies is characterized by poorly sorted coarse sand-sized sandstone bodies showing lenticular geometry in transverse section with flat bases and convex-up tops (Fig). Petrographically such facies shows mineralogical immaturity with high angularity and poor sorting. Rare pebbles are observed concentrating along the larger foresets of such bodies. Internally this facies is compound trough cross-stratified, characterized by larger gently sloping tabular foresets (Fig 2.3.D) encasing steeper smaller trough foresets, both dipping towards same direction. Rarely some large scale trough sets found to underlie the compound cross-strata. Interestingly the grain-size ofthis facies is slightly coarser than the trough cross-stratified facies, with which this facies associate laterally as well as vertically. Also, the larger trough sets, whenever found, are wider than higher compared to the trough sets of the previous facies. This facies constitute only minor fraction of the total succession though.

Interpretation

Compound trough cross-stratified nature of the facies indicates migration of large curve crested bedforms or bar along channel floor (Collinson and Thompson, 1989; Smith and Rogers, 1999, Eriksson et al., 2006; Bose et al., 2008; Mukhopadhyay, 2012). Large-scale trough cross-stratification characterizes the core part of the bar, where as small troughs over it accounts for the accretionary part of the Bar (Collinson and Thompson, 1989; Collinson, 1996; Mazumder and Sarkar, 2004). The compound cross strata with both large and small ones oriented in the same direction signify migration of smaller bedforms across the crest and along the gentle downcurrent surface of the larger bedforms, represented by the larger tabular foresets. Such phenomenon is known as downcurrent accretion (Miall and Jones, 2003; Best et al., 2003;

Bridge, 2003). Comparatively larger grain-size and wider trough sets of this facies than the previous facies indicate higher flow-shear resulting from fall of water level in the penultimate stage of channel filling (Harms et al., 1975).

Facies I: Planar laminated sandstone facies

This facies is characterized by coarse- to medium-grained, moderately sorted sandstone bodies having tabular body geometry and internal planar lamination (Fig. 2.3.E). Bases of beds are generally sharp, though undulated. They are discernibly erosional at places. Tops of such beds are less sharp and more often gradational. Definite trend of grain-size change is discernible within these bodies. This facies, though rare in occurrence, generally overlies major erosional surfaces and grades into trough cross-stratified facies vertically. Rarelythey overlie the trough cross-stratified facies also (Fig. 2.2.G).

Interpretation

Such bodies certainly indicate higher flow regime planar beds deposited under shooting tractive current (Cant and Walker, 1978). Position of such bodies over major erosional surfaces attests the presence of shooting flows towards the initiation of channel filling (Bose et al., 2008). Occurrence over trough cross-stratified facies indicates shooting flow due to increasing flow shear resulting from fall of water level in the penultimate stage of channel filling (Harms et al., 1975).

Facies J: Ripple Laminated Facies

This is characterized by internally ripple laminated (Fig 2.3.H) cm-scale bodies made-up ofmedium sand to silt-sized material. Body geometry appears to be broadly lenticular with sharp but non-erosional bases. Such bodies are rare in occurrence, often patchy, but invariably overlie the trough cross-stratified facies G. Grains are moderately sorted, sub-angular to sub-rounded. Rarely, bedding surfaces contain current ripples (Fig 2.3), with few 2 mm height and 5 cm wavelength.

Interpretation

This facies represents product of ripple migration under lower flow-regime condition (Harms and Fahnestock, 1965; Simons et al., 1965). From the extent of textural maturity as well as nature of internal laminations first subfacies appears to be product of unidirectional traction currents. This facies typically marks the terminal period of channel filling. As water depth and velocity within channel decreases, larger dunes, previously moving on the channel floor, are replaced by the smaller scale ripples (Harms et al., 1975).

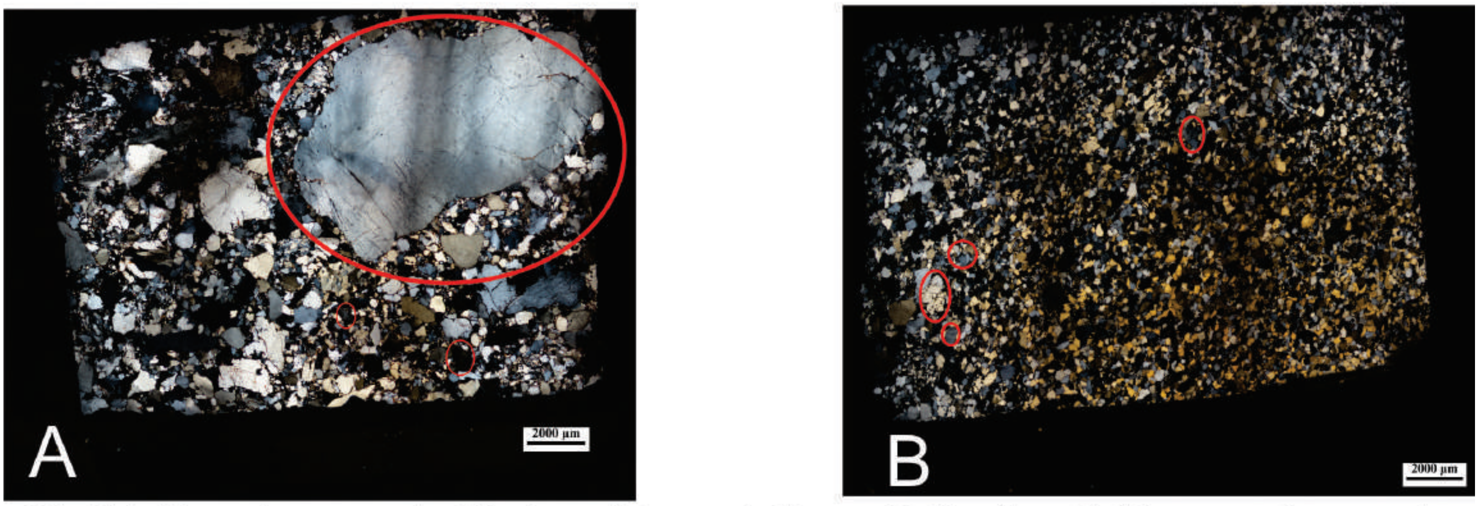


Fig 2.1: Trough cross-stratified sandstone: A. Large Orthoclase Feldspar grains angular in shape, poorly sorted and less matured. B. Relatively well sorted grains with sub angular to sub rounded in shape.

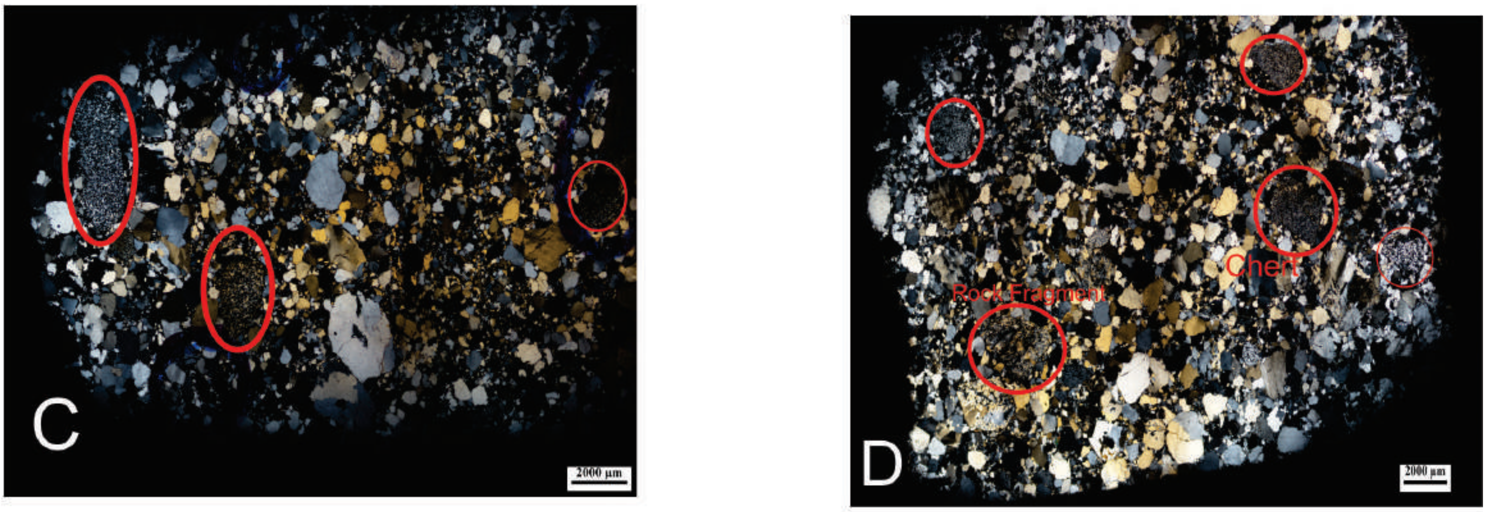


Fig 2.1: Lithic Arenite. C. Highly angular chert body in Lithic Arenite. D. Rock Fragments and chert in lithic arenite.

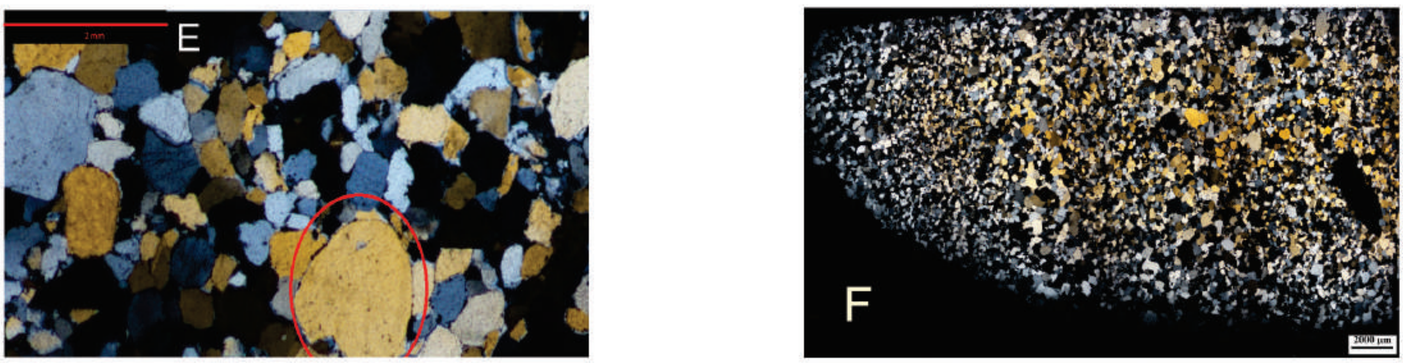


Fig 2.1: Quartz arenite E. Rounded Quartz grain with Broken overgrowth around it. F. Quartz Arenite body with alternate coarser and finer grains with specific zone.

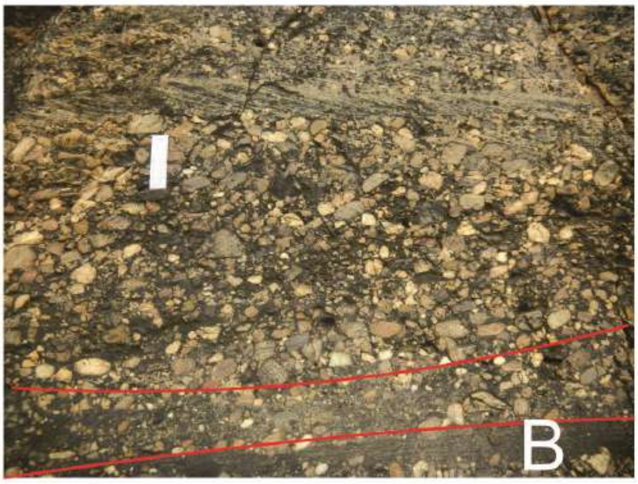


Fig 2.2: Facies Analysis. A) Facies A, Scree conglomerate facies. Showing highly angular clasts wothin the body and some protruding clasts. B) Facies B, Matrix supported massive conglomerate facies with highly angular, haphazardly oriented clast and lensoid geometry. Protrusion of clast in the overlying bed as shown.

Fig 2.2: C) Facies C, Graded conglomerate facies, clast supported character at the base changes into matrix. D) Facies D, Clast supported lenticular conglomerate facies with sub-angular to sub-rounded clasts and lenticular body geometry.

Fig 2.2: Facies E, Inversely graded clast supported facies with angular and densely packed clasts showing lenticular body geometry. Reverse grading shown in the box.

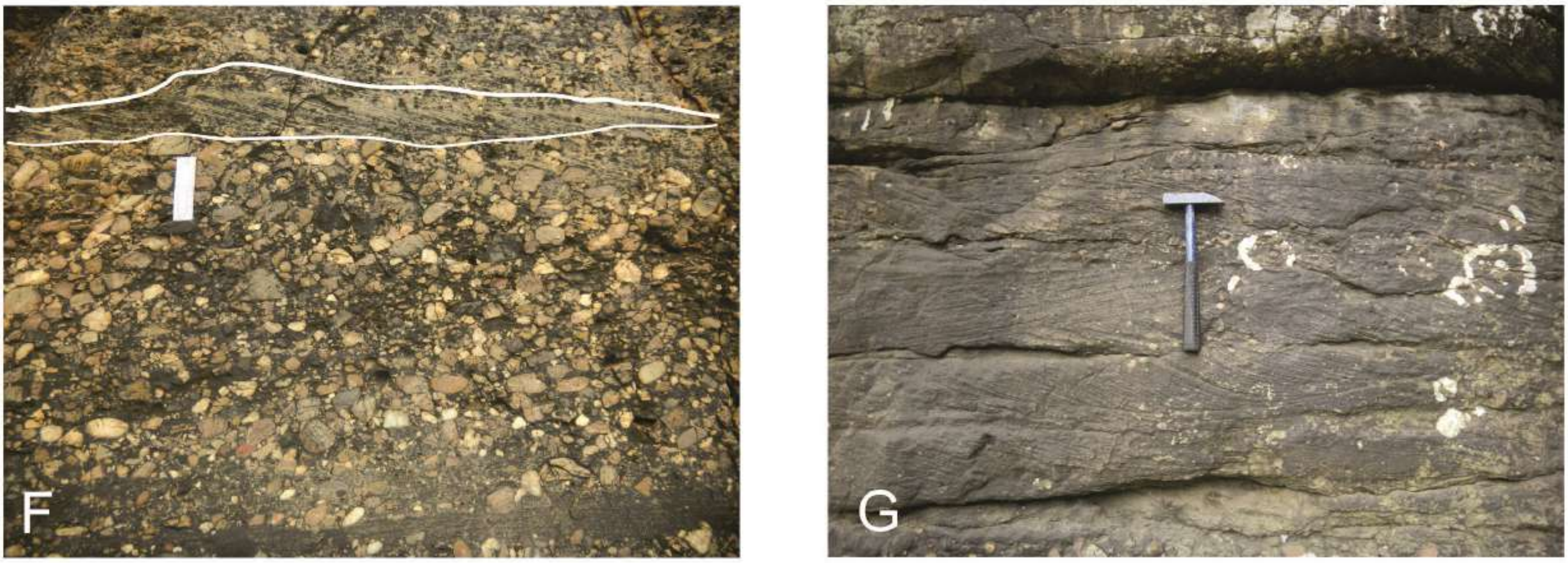


Fig 2.2: F) Facies F, Crudely cross stratified granular sandstone facies, with lenticular body geometry and pebbles are concentrated at the bottom and also along the forsets of cross-strata.G) Facies G, Thoroughly trough cross stratified facies with lensoid geometry and internally trough cross stratified.

Fig 2.2: Scree Conglomerate body with oversized clast supported conglomerate

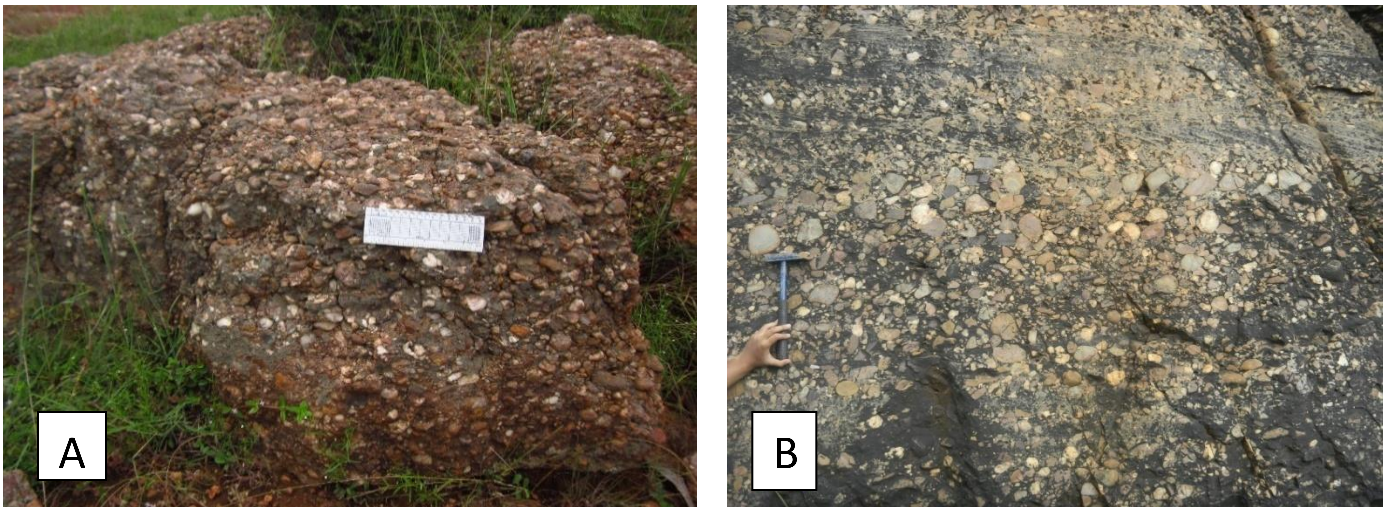


Fig 2.3: A) Facies D, Clast supported lenticular conglomerate facies with sub-angular to sub-rounded clasts and lenticular body geometry. B) Facies F, Crudely cross stratified granular sandstone facies, with lenticular body geometry and pebbles are concentrated at the bottom and also along the forsets of cross-strata.

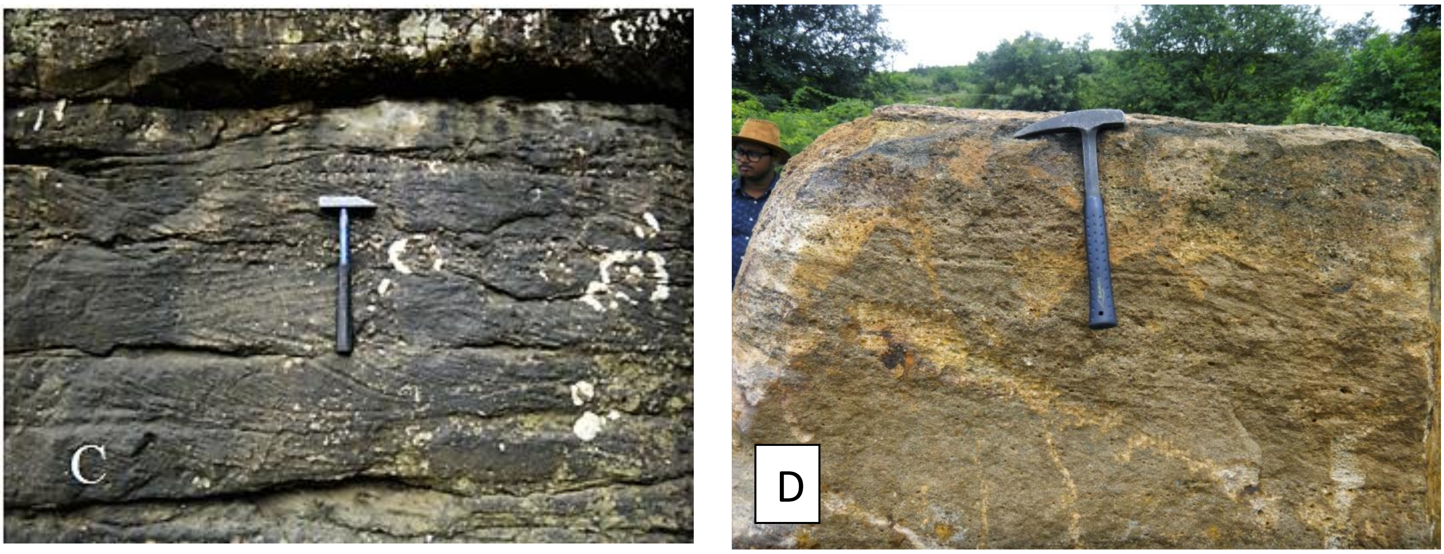


Fig 2.3: C) Facies G, Thoroughly trough cross stratified facies with lensoid geometry and internally trough cross stratified. D) Facies H, Compound cross-stratified facies, in which both the foresets are dipping in the same direction, Down-Current Accretion Element.

CHAPTER 2

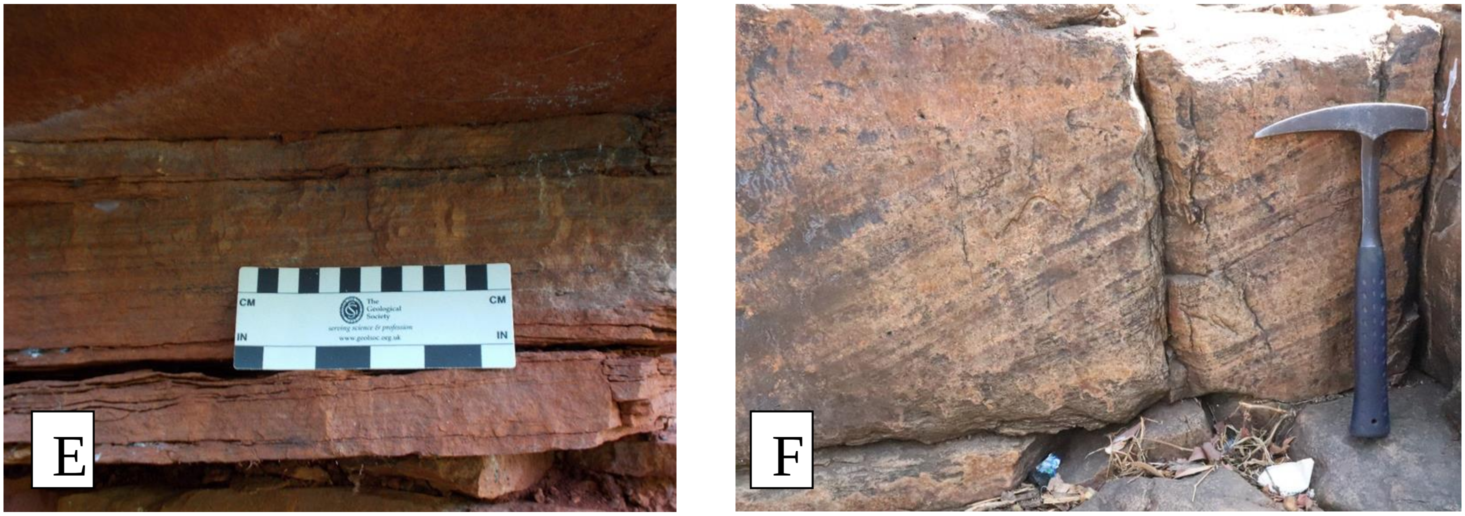


Fig 2.3: E) Facies I, Planar laminated sandstone facies, having tabular body geometry. F) Tabular cross Stratified body with truncated top and Asymptotic bottom indicating Transverse Bar.

Fig 2.3: G) Facies J, Ripple laminated facies, internally current ripple laminated in sectional view. H) Planner laminated Shale by Suspension Fall out indicating Flood Plain Deposit.

CHAPTER 3

Facies Associations

A single sedimentary facies may not indicate a specific depositional environment, as a single facies may be present in different environments. As for example palaeosol facies indicates emergence which can form in fluvial overbank, lake-margin or delta distributary area. Hence, for meaningful depositional environment or palaeogeographic extrapolation grouping of genetically related facies into facies assemblages, depending upon the more sensitive tools, like body geometry, thickness, its position with respect to major erosion surfaces, pebble composition and more importantly, association, is a fundamental prerequisite (Collinson, 1969; Miall, 1980; Hallam, 1981; Walker, 1984; Reading, 1986). Keeping that in mind, this chapter evolves through assimilating all significant distribution of already established depositional dynamics-related facies in time and space, their association and transitions, along with their petrographic properties, with the ultimate aim to group such facies into several associations. These associations differ from each other by the facies present within them, their proportion, transition and body geometry. In other words, a facies, whether authigenic or allogenic, may be a commoner in one association and aberrant in another; some may be exclusive for one association, though perhaps not common in occurrence (Mukhopadhyay, 2012). The combination of the commoners and the exclusive ones within such natural associations provides the most dependable interpretation of palaeogeography.

Facies Associations

The Kerur Formation of Badami Group is bounded by an unconformity below. It starts with Cave temple arenite which is arkosic in nature and gradually transforms into Halgeri Shale which indicates gradual deepening and finally Belikhendi arenite which is entirely marine in nature. This lower part overlies Chitradurga schist belt of Dharwar Craton and in some places over Salgundi conglomerate of Bagalkot Group(Bose et al., 2008; Dey et al., 2009; Patil Pillai & Kale, 2011; Mukhopadhyay, 2012).The work spreaded over about 60 km at the western sector of the basin ranging from Gokak at the north to Godihal towards West.

In the Eastern sector the study area was around Timapur, Torgal and Badami town. The study documents total range of paleogeographic variation, both along and across the depositional dip direction amply through its excellent exposure quality. Hence, a holistic facies association scheme can be coined safely encompassing the variations encountered within the studied stratigraphic interval.

Facies association I

This facies association encompasses all the rudaceous facies varieties (A,B,C,D and E), along with a minor proportion of intervening arenaceous facies G and F bodies. The most dominant facies of this association appears to be facies A and B with subordinate facies D and F. The facies A (Clast supported Breccia) is extended throughout the section in different pulses. Facies B (Matrix supported massive conglomerate) is present in mainly lower part of the succession. It is mainly matrix supported body with protruded clasts at the top part often associated with facies F. Facies C (Graded Conglomerate) is very much limited in occurrence, and restricted within the upper part of the succession only. They often are interbedded with facies B and Facies F. Facies A bodies have bases rather jagged due to the sinking of large clasts beneath the base while resting on a sandy substratum. Facies D (Clast supported conglomerate) often preserved at the top most part of the succession with overlying Facies G (Thoroughly trough cross stratified sandstone). Scarce presence of facies E is observed, almost everywhere associated with facies B bodies. Overall the succession gives a coarsening upward trend.

This association occurs in patches along the basin marginal area only.is the best preserved ones are found in the Gokak area in Northern margin and also in Marihal-Sullebhabi stretch in the western marginof the Western sector of Badami basin.

Interpretation

The presence of both Fluid and Sediment Gravity flow together is quite ambiguous in nature. Both of this flow together indicates a rapid fluctuation in Energy as well as water table. Dominance of sediment gravity flow and coarse sandy fluid gravity flow products indicate deposition in a high gradient paleogeography empirical (Bose et al., 2008; Mukhopadhyay, 2012). Both the presence of Scree and Debris conglomerate indicate a very high energy condition. The highly lenticular shape indicates the facies assemblage is entirely terrestrial in nature. There remains a problem as all depositional mechanisms envisaged in the previous chapter do not have the same value in recognizing the paleogeography. There may be some lack of transparency designating the appropriate depositional condition. Clast supported Sieve conglomerate indicates a percolation of fine sands through the large clasts when the water table going downward due to sharp changes in slope. The graded conglomerate, that is, the sieve facies (C) appears to be the most unambiguous indicator of terrestrial paleogeography (Blair and McPherson, 1994; Collinson, 1996; Mazumder, 2002). Sieve Deposit occurs above the intersection point when the sediment load of the flood is deficient in fine grained sediments. As a result a highly permeable older deposit causes the flow to diminish rapidly as water infiltration occurs. A well sorted, poorly imbricated clast-supported gravel lobe is deposited; clasts may be angular and bodies are strongly lenticular. With burial, the interstices are slowly filled by finer, infiltrating sediment, producing ultimate bimodal fabric that can be sandy and clayey. Crudely laminated sand body with oversized pebble indicates flow through a highly instable channel. The protruding clasts indicate a hillwash deposit. High preservation of matrix supported debris flow conglomerate indicates a high slope that generates the flow from fan apex and extended upto distal Fan. Sieve deposit, on the other hand, extends only upto a short distance. At fan apex flow expands rapidly beyond the channel confinement and the resultant hydraulic jump is likely to induce rapid sedimentation (Leeder, 1999; Allen, 1981; Balance, 1984; Nemec and Muszyanski, 1982; Wells, 1984; Blair and Mcpherson, 1994). As a corollary, the scree and debris flow deposits with greatest bed thickness possibly belong to apex area of the fan. The clast supported conglomerate body at the top part indicates a channel deposit which is generated at the distal part of the slope with unstable banks.

Occurrence of scree within this top part of the fan, on the other hand, necessitated considerable relief generation and thereby implies tectonic uplift of the basement (Bose et al., 2008).Sieve deposits are likely to occur in the area just above the intersection point, hence are recorded only in the upper portion of the fan succession. Lower part of the fan is characterized by products of unchannelized to rapidly avulsive channelized flows alternating with occasional debris flows. Proximal fan facies association includes dominance of sediment gravity flows, with a single large channel cut at the fan apex, showing trough cross-stratified channelized facies. Mid fan is characterized by fewer sediment gravity flows, numerous smaller channels and sieve deposits. Distal fan facies assemblage includes sheet flood deposits along with fewer channels and rare sediment gravity flows.Overall an alluvial fan usually progrades as long as the slope break persist. Ultimate progradation resulted in vertical juxtaposition of coarser proximal fan sediments over finer distal fan ones. Upward thickening and coarsening facies succession thus becomes empirical.

Facies Association II

This facies is entirely made up of F, G, H, I, J with subordinate facies B. The most dominant facies is thoroughly facies G (trough cross stratified sand) and Facies H (Compound cross stratified). Lateral as well as vertical juxtaposition of these two facies characterizes the association; while trough cross stratified bodies are most dominant. Facies I bodies are found in subordinate amount. In lower part of the succession such bodies occupy positions just above major erosional surface, while towards the top, these bodies usually overlies facies G bodies. Facies G bodies occasionally show randomly oriented oversized pebbles, mostly towards lower part of the succession. Wherever present, pebbles or granules tend to concentrate along the erosional bases of the thoroughly trough cross-stratified bodies as well as along set boundaries. Sometimes it is associated with crudely stratified (facies F) bodies, also chiefly towards the lower part of the succession. Facies D bodies are occasionally found to underlie facies G as well as facies F bodies, but their abundance decreases significantly up-the-succession. The top most part is designated by facies I and J, along with omnipresent facies G bodies. Planar laminated bodies often mimic major erosional surfaces. Facies G bodies, all through the succession used to show a more or less steady paleocurrent direction towards . Petrographically, the association is made up of sub-arkosic to sub-lithic arenites, with angular to subangular, poorly sorted grains. Package units of this association, fabricated by different constituting facies arranged in rows, and locally also in columns, are broadly lenticular in geometry and stacked vertically one above another. This imparts the characteristic multistoried look to the succession. Overall the succession shows a fining upward trend.

This association is best developed along the Islampur area in western margin of Badami Basin.

Interpretation

Facies G is formed due to in-channel migration of dunes. Facies H (Compound Cross Strata), on the other hand, indicates barform deposits, basically downcurrent accretionary parts of the longitudinal bars. Although subordinate in occurrence, their presence and lateral juxtaposition with the facies G bodies attests the occurrences of longitudinal bars, occupying mid-channel positions. This indicates a braided stream with relatively high energy condition (Long, 1978; Smith, 1970; Bose et al., 2008). Initially Facies D at the lower part of the succession indicates thalweg deposit. Facies I at the top part of the succession indicates gradual waning of flow. Slope may vary with time or with differing paleogeography. Presence of planar laminated facies over erosional surfaces marks the initiation of flow within channel as shooting flow (Selley, 2000). Oversized pebbles within facies G bodies, as well as rare presences of facies F bodies indicate towards highly fluctuating nature of the flow. The fluctuating nature of the flow is further corroborated by the presence of higher flow regime structures over lower flow regime ones, as documented by the planar laminated facies overlying trough cross-stratified one (Harms et al., 1975; Bose et al., 2008).Occurrences of such bodies above the trough cross stratified bodies pointed towards rapid drawdown of water. Considering all the factors, it can be stated that this facies association represents a braided non-perennial river system, clearly.

Grain size reduction indicates decrease in energy condition as the slope is gradually decreased, owing to aggradation. The overall fining upward nature accords well with the general aggradational nature of the fluvial system (Catuneanu, 2002).Arkosic nature either indicates short transportation and quick dumping of the sediments, or extreme climatic conditions, leading to the preservation of feldspar. Dominance of basement clast as rock fragment within the sandstone bodies further supported the contention of short transportation and quick dumping.

Facies Association 3

This association is more or less similar to that of the previous one, but differs only in some minute aspects, like comparative dominance of different facies and the textural and mineralogical maturity of the constituting sandstone bodies. The association is solely made up dominantly of thoroughly trough cross stratified and compound cross stratified facies, with subordinate ripple laminated facies and rare thalweg conglomerate, restricted only towards the basal portion of the succession. Mutual proportion of compound cross-stratified facies appears to be more than the previous association. Planar laminated facies is entirely absent in this association, along with the crudely cross stratified facies. The association lacks pebbles, and appears to be much more matured, both texturally and minerlogically (Fig 3.4a). The constituting sandstone is quartz arenitic, with moderate sorting and subangular grains (Fig 3.4b). Stacks of packages within this association appear to be more regular, with planar bounding surfaces, lacking the minor undulations, between them. The fining upward trend is also discernible quite clearly.

Interpretation

This association also represents deposition from a braided stream, as lateral as well as vertical juxtaposition of the barforms (facies H) and channel forms (facies G) characterize it (Long, 1978; Smith, 1970; Bose et al., 2008). The mutual dominance of barforms compared to the previous association pointed towards more stabilized channels (Bose et al., 2008). Flow within channel appears to be more stable as well as of comparatively lower energy, as evident from absent of any pebbles. Comparative maturity, both textural and mineralogical, of the sandstone bodies, on the other hand, indicates much more transportation. Overall, the association represents a braided and perennial river system (Bose et al., 2008; Mukhopadhyay, 2012).

Facies Association 4

This facies is composed of Facies I, J with subordinate facies G and very minor facies D. Two subfacies of I (Planner laminated facies) are preserved [I(a)-planner laminated sand, I(b)-Planner laminated shale)]. Two subfacies of facies J (Ripple laminated Facies) are preserved (J(a)- Ripple laminated sand, J(b)- Ripple laminated sand-silt) are also preserved. Facies I(b) is formed as intercalation unit within G. I(a) preserved at the basal part. At the top part facies J(b) is preserved with occasional I(b). Facies I(a) overlies facies G which eventually overlies sometimes very thin layer of D. Alternate I(b) and J(b) facies is observed within short interval. Overall it gives a fining upward sequence.

Interpretation

The presence of I(b) and J(b) indicates a calm and quiet condition. From G to I(a) and I(b) facies is formed due to reduction of energy. This indicates a channel deposit. Facies I(b) indicates flood plain deposit. Shale was formed due to suspension fall out of mud in flood plain. From trough cross stratified to ripple laminated sand there is a gradual waning of flow within the channel. The sand is relatively finer and relatively more mature than facies G. Feldspar content is less which indicates a relatively larger transportation. This facis indicates a meandering river system with prominent flood plains. Fining upward sequence is due to gradual filling of channel.

It was preserved in Honaga area in western margin and Torgal in Eastern margin of Badami basin.

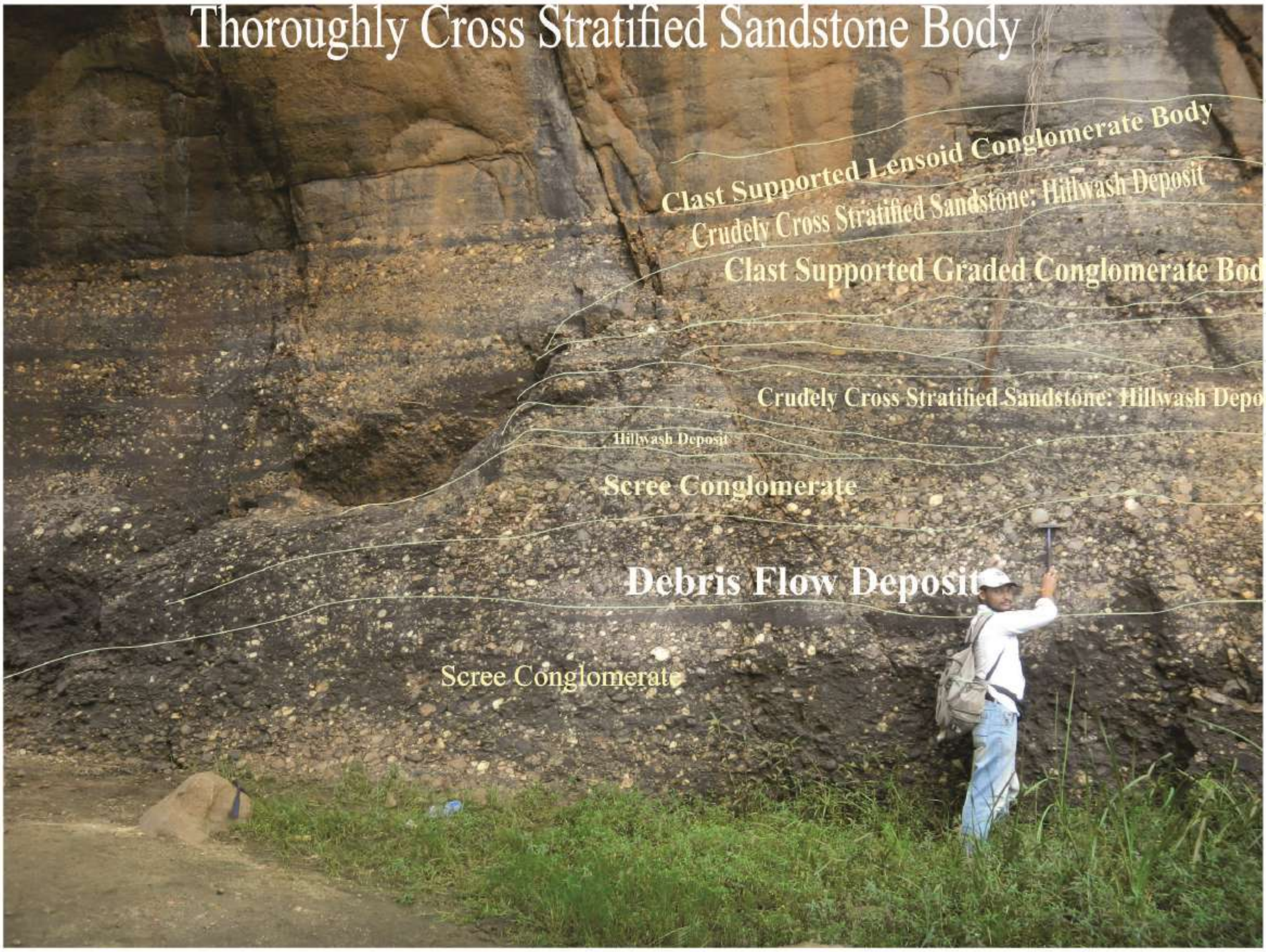


Fig 3.1: Alluvial Fan Deposit at Gokak. From bottom to Top it shows several changes in the characteristic of Conglomerate Body. The Fluvial Body overlies it.

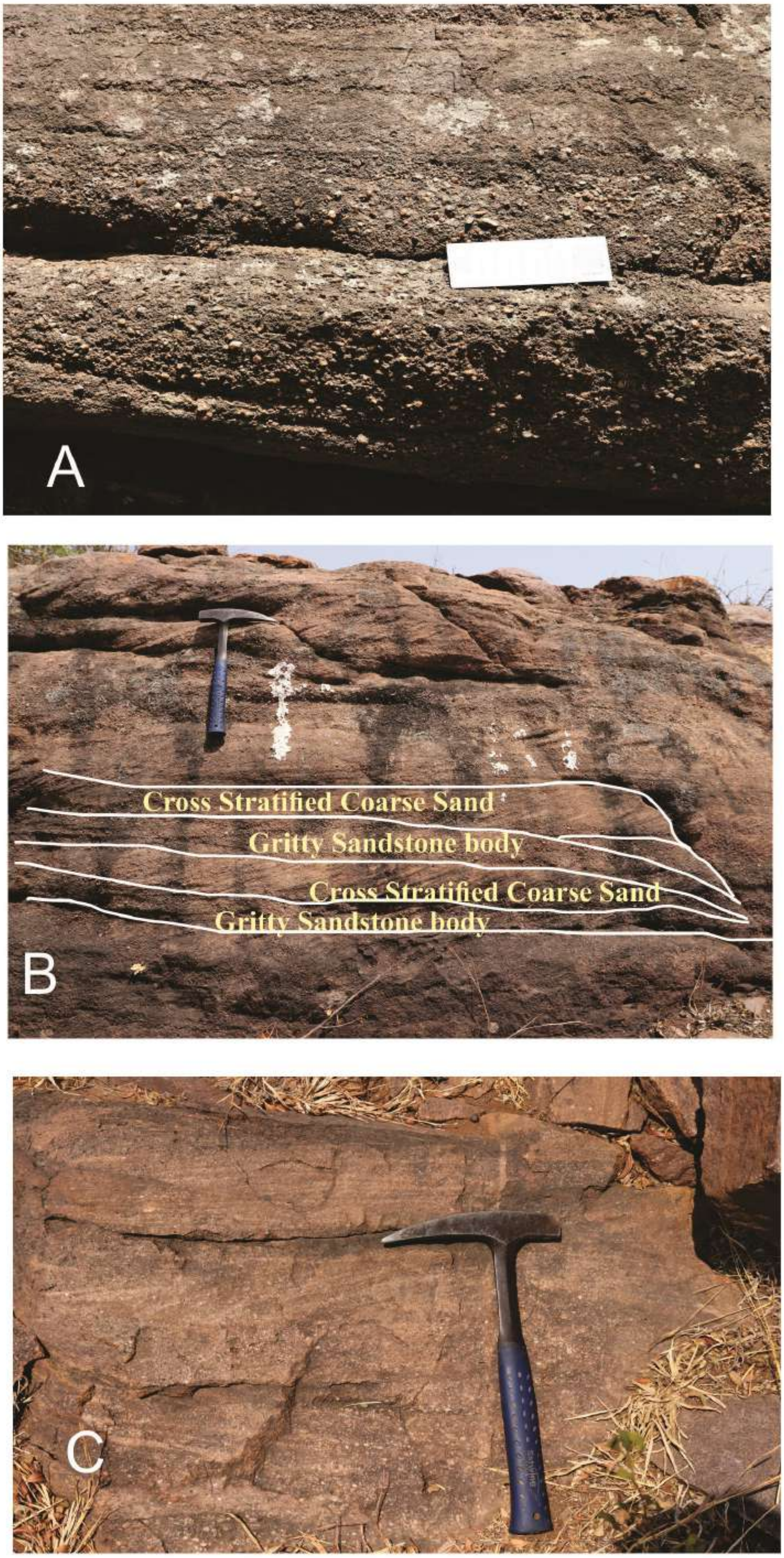


Fig 3.2: Facies Association. A) Crudely cross-stratified body overlain by a coarse sandstone unit. B) Coarse pebbly sandstone becomes showing massive nature at the bottom becomes cross-stratified towards the top. Overall the body shows alternate gritty body and coarse sandstone, C) Trough cross stratified sand overlain by Gritty Sandstone body.

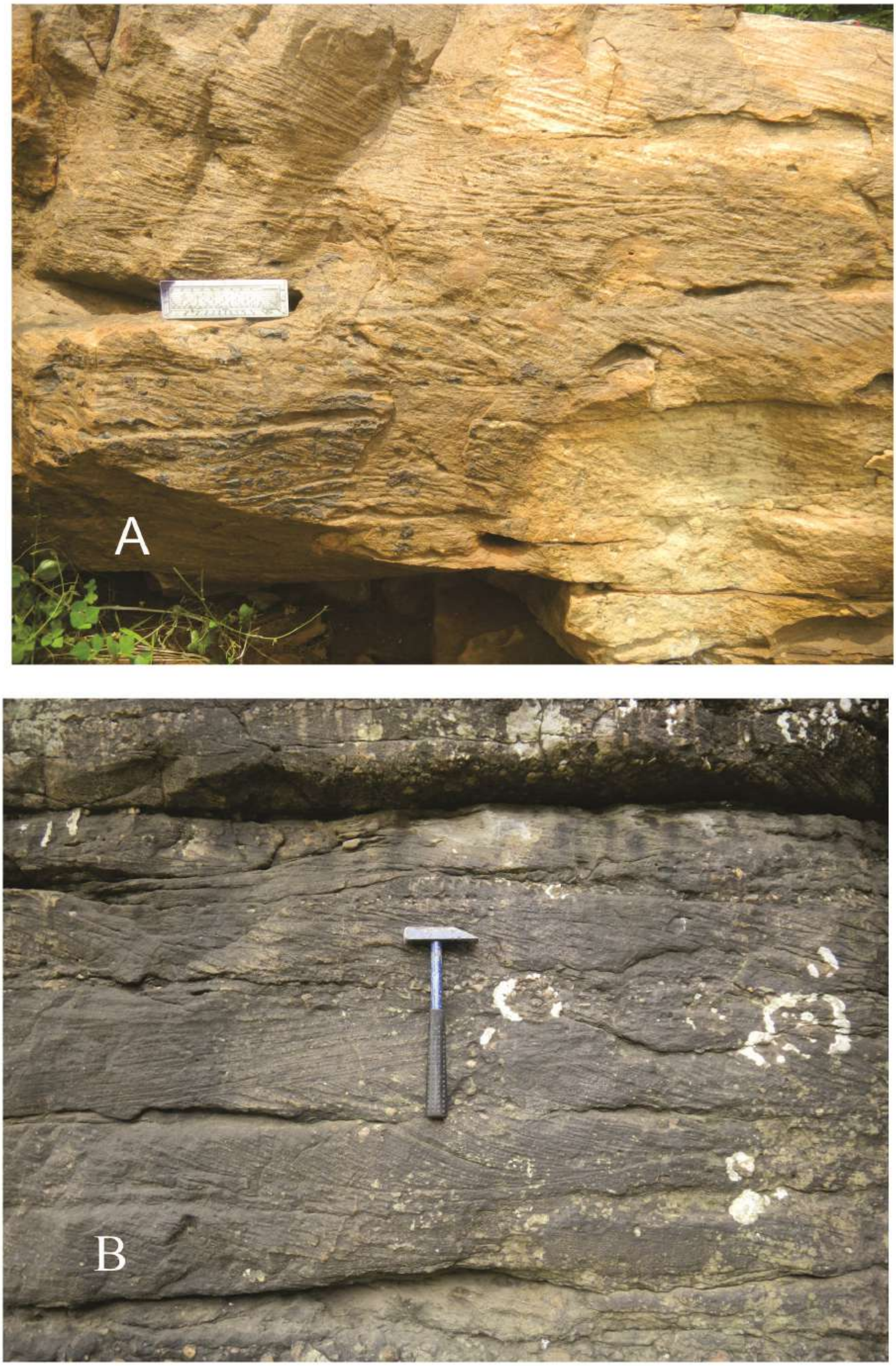


Fig 3.3: A) Medium Sand stone showing trough cross Stratification. B) Medium sandstone body, showing trough cross-stratification in longitudinal section. They show relatively reduced sand grain size as well as no concentration of pebbles within them as in the case of the previous facies.

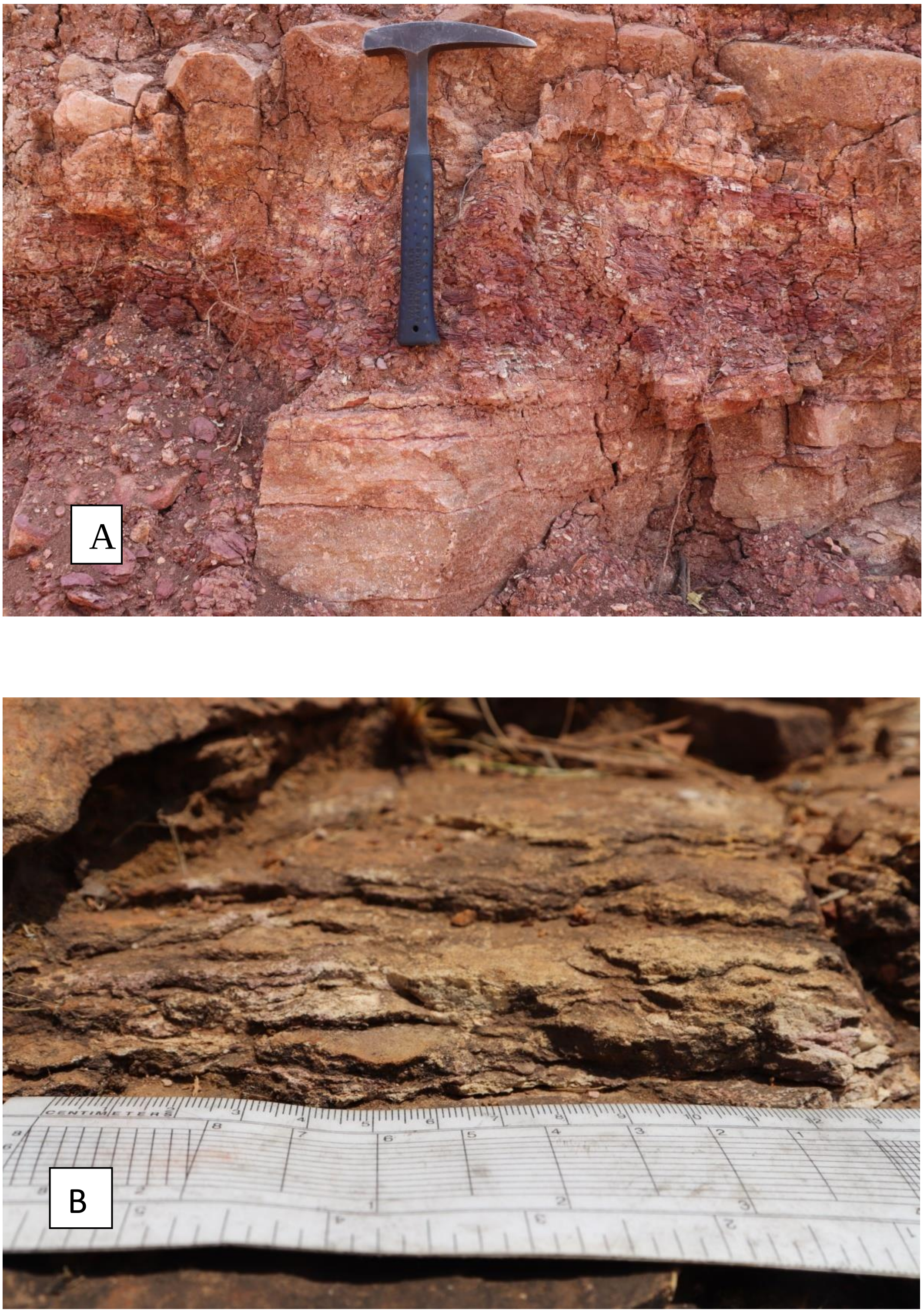


Fig 3.4: A) Planner Laminated Shale indicating flood plain deposition with increasing perennial nature of the channel. B) Ripple lamination in fine sand indicates low energy condition and lower flow regime.

Sequence Architecture

The sequence architectural analysis deals with understanding the pattern of the lateral as well as temporal distribution of different facies and their associations, with the ultimate aim to ascertain any significant knowledge regarding the depositional environment of the concern sedimentary deposit.Vertical profiles are not sufficiently diagnostic for this purpose because they cannot adequately represent three-dimensional variations in composition and geometry (Miall, 1985). The problem is more severe for fluvial depositional systems owing to their higher variabilities, both in spatial and temporal scale, compared to their marine conterparts. The analysis of complex sedimentary systems involves their description, classification and eventual interpretation. To this end sediment depositional settings are characterized and subdivided into hierarchies of genetically related discrete stratigraphic elements, bodies or units. The geometric shapes of these depositional units are defined by their boundaries and collectively they form the building blocks of sedimentary architecture.

- **Unit**: General geologic term that refers to a distinct geologic entity with a lower and upper confining boundary. This unit can be a bed within a large group, forming a bedset.

- **Body**: General geologic term that refers to a mass of sediment with a lower and upper confining boundary.These may be a group of beds or element.

- **Element**: Specific geological term that refers to a distinct body or assemblage of bodies of sediment with lower and upper confining boundaries that are genetically related to each other and were generated in a common depositional milieu.

  The elements of fluvial architecture are: Channels-CH, Gravel bars and bedforms-GB,Sandybedforms-SB, Foreset macro forms- FM, Lateral accretion deposits-LA, Sediment gravity flows-SG, Laminated sand sheets-LS, Overbank fines-OF.

Architectural element is an interpretive characterization of of a sedimentary feature distinguished on the basis of its geometry, scale and facies (Pickeringetal., 1998). The way of description, classification and interpretation of fluvial deposits follows a definite path through step-by-step identification of: (1) facies; (2) facies associations (architectural elements); (3) hierarchies of strata and their bounding surfaces; (4) geometry of sedimentary bodies larger than channelforms (Bridge, 1993).The facies associations and stratal geometries of fluvial deposits have been classified and interpreted in terms of channel and floodplain geometry and modes of channel migration by many workers (e.g. Allen, 1965; Friend, 1983; Miall, 1985a, b, 1992; and many others). As the studied succession is chiefly fluvial in origin, identification of strata-bounding surfaces within the succession becomes indispensible for better correlation as well as understanding regarding the shifts in depositional framework. Recent studies in fluvial architecture extends the premises of architectural elemental analysis (defined by Miall, 1985) to include elements larger than channel-forms, like channel cycles and valley cycles (Miall, 1985, 1988, 1994, 1996, 2006; Bromley, 1991; Eberth and Miall, 1991; Fielding, 1993; Hjellbakk, 1997; Yu et al., 2002; Bridge, 1993, 2003; Miall and Jones, 2003; Best et al., 2003; Gani and Alam, 2004; Long, 2006; Rygel and Gibling, 2006; Gao et al., 2007; Bose et al., 2008). The following section dwells on different ranks of bounding surfaces present within the fluvial succession within the studied interval of Cave Temple Arenite Member of Badami Group following the procedure outlined by Miall (1988, 1992) and presented more explicitly by Holbrook (2001).

Bounding surfaces within studied interval

A top down hierarchical classification of architectural elements is used that often starts at a sedimentary basin scale. This is subdivided downward into a series of broad elements, each in turn is divided downward into a series of comparatively smaller elements ‘the laminae or even the individual sand grain’ (Miall, 1992). This top down classification is used to provide a framework of basin.A hierarchy of architectural elements has been related to Stratal unit of Sequence stratigraphy (Sprague et al., 2002). The general term for a recognizable layer ofsediment or sedimentary rock is a ‘stratum’. The general consensus regarding the assignment of ranks to bounding surfaces are first proposed by Miall (1988), which follows by allotting the zero order to the surfaces bounding the individual laminae and the successively higher denominations for those bounding stratal packages of successively higher genetic orders, such as, 1st order for lamina sets, 2nd order for cosets, 3rd order for bedforms and so on (Miall, 1988; Hjellback, 1997; Miall and Jones, 2003; Holbrook). Bounding Surfaces of lower orders are of small scales and very limited extend. The higher degree boundary surface consist a larger, basin wide regional extend with a prominent change in grain size and sometimes mineralogy.Identifiable autocyclic elements in any fluvial system arechannel deposits. These may only be defined if the concave-up channel scour surface can be defined. Contained within the channel are a wide variety of minor channels and bar complexes. The minor channels may be more readily identifiable than the major ones because of outcrop constraints (Miall, 1985). Channel fills, demarcated by fourth order bounding surfaces, are the smallest of larger than channel form sedimentary packages, which records filling of major channels during channel avulsion and abandonment (Miall, 2014).An individual channel-fill encompasses both the channel-floor and the bar sediments in single or multiple storey (Bridge and Mackey, 1993a, b; Hampson et al., 1999; Gibling, 2006; Miall, 2014). Channel belts, the immediately higher order packages, are comprises of both lateral as well as vertical juxtaposition of several channel-fills, as well as the floodplains corresponding to them. The largest of such genetically related packages are valley fill cycles, demarcated by largest sixth order of bounding surfaces, which are equivalent to basin-wide unconformities. All the sediments deposited by a single river system represent a single valley fill amply. Due to the lack of continuity of the exposure and overall high structural dip of the area, tracing of larger bounding surfaces are challenging within the studied interval. Critical study though identified two sixth order bounding surfaces within the interval, to divide it into three juxtaposed valley fill cycles. The study in this thesis paper mainly concentrated on the characterization of the lower valley cycle. Although, the total distribution is also stated through different synthesized logs and panels.All the cycles may not be present all across the area, but that can be explained by the lack of exposures adequately.

Architectural Pattern

To elaborate the sequence architectural pattern, synthesized sections, formed by combining more than one vertical section, along four different locations, namely Gokak, Karapgatti, Godihal and Islampur (see Fig. 4.1, 4.2, 4.3), were studied in details. Gokak and Godihalis located along the boundary of the basin, northern and western one, respectively. Karabkatti iss located slightly interior of the basin margin, towards south of Gokak. Islampur is located at the interior of the basin. Each section incorporates both strike-wise as well as dip-wise variations in facies distribution, as it is synthesized from more than one measured vertical sections in both along-strike and along-dip directions. Apart from these areas, several areas, namely, are studied to get insight about the lateral continuities of different valley fills, moving successively down-the-slope from the basin margin to the nterior, almost along the paleo-flowdirection (from east to west and north-west broadly) and also across the paleo-strike direction of the basin (from north to south through basin interior), as much as the outcrops permit.

The detailed facies association distribution patterns are described below.

Gokak Area

About 100m stretch along the northern margin of the Badami Basin was covered in the synthesized section along with about 50m down-dip variability. The section overlies the Archean Peninsular Gneiss with an unconformable contact, although no direct contact is discernible in the area. This area only document the lower valley fill, with an overall~150m succession (Fig. 4.1). Three types of facies association isobservedhere. The succession initiates with facies association 1, with a height of about 18m. All the rudaceous as well as arenaceous components of this association is present in this area. The association is pebbly in nature, having oversized pebbles within the arenaceous intervals also. The following part of the succession is arenaceous in nature and can be subdivided into four distinct channel belt cycles. Each channel belt, except the topmost one, initiates with clast supported thalwegconglomeratic bodies and/or gritty to pebbly sandstone bodies, and shows a distinctly fining upward trend. Both the frequencies as well as sizes of the pebbles, decreases from lower to upper channel belts. While lower three channel belts are characterized by the facies association 2, the topmost, almost pebble-free one, is represented by facies association 3.

Karabgatti area

Karabgatti was located at about 2 km southwestfrom the northernmost margin Gokak. The section in this area lies directly over archean basement of Peninsular Gneiss and Schist bodiesbelongingto Chitradurga Schist Belt with an unconformable contact. The area offers the total succession of the Cave Temple Arenite, comprising of all the three valley fillswith an overall 128m height (Fig 4.2). Lower and Upper valley fillis entirely fluvial whereas middle valley fill showsconsists of fluvial to marine transition with an interveningfluvio-Marine transitional unit. Detailed study of the lower valley fill revealed the presence of all the three facies associations in this area.Like the Gokak area, the lower valley fill here also initiates with a ~3m thicklesser developed facies association 1. Characteristically they are almost similar to that of Gokak area, only with less frequent scree bodies, and comparatively finer pebble sizes. The rest of the lower valley fill succession (~40m thick) is chiefly arenaceous in nature, having at least three prominent channel belt cycles. Facies association 2 follows facies association 1 sharply, with pebbly sandstone bodies occupying basal positions of each channel belt and/or channel fill. two distinct channel belts are identified. The topmost channel belt is made up of facies association 3, which is almost entirely pebble-free in nature. at least

Godihal Area

Godihal is located at the westernmost boundary of the basin. The section in this area represents thickest development of the lower valley fill, with about 60m thickness (Fig. 4.3). The basementin this region, showing direct unconformable contact with the studied interval,is consists of a Banded Haematite Quartzite (BHQ) unit of archean age,overlying schistoseunit equivalent to Chitradurga Schist Belt. The succession here lacks facies association 1 and is entirely arenaceous in nature. It starts off with facies association 2, granular in nature with less frequent pebbles. Five prominent channel belts are identified wihin the total succession, among which lower three are represented by facies association 2. The topmost two channel belts are entirely pebble-free and characterized by facies association 3. The successionshows overall fining upward trend.

Apart from these detailed studied areas, several locations, stretching all across the western sector of the Badami Basin, are documented for the study of the paleocurrent-wise lateral variation within the lower valley fill. two panel diagrams are prepared for the purpose, covering and areas (Fig. 4.4). Panel 1 connects Godihal-Kabalapur-Islampur regions. Godihal is at the westernmost boundary of the basin whereas Kabalapur and Islampur located at the interior of the basin.Thickness of Lower fluvial unit is maximum in Godihal and minimum in Kabalapur region which is in between other 2 regions. Thickness of lower fluvial unit is minimum in Kabalapur area and thickness increases in 2 opposite directions.There is an onlap of fluvio-marine transition over lower fluvial unit. Minimum thickness of lower fluvial cycle indicates there might be a basement high in Kabalapur region. So the thickness of lower fluvial unit is less. And then due to gradual subsidence of the basin thickness of the marine bed became greater. Panel 2 (Fig.4.5) connects Marihal-Kabalapur-Islampur region along the palaeocurrent direction towards NW. It shows a greater thickness of lower fluvial unit in Marihal area and thickness decreases towards the basin interior. As the depth of the basin margin is comparatively lower and slope is much high so, the fluvial unit had formed in the basin margin region with a greater thickness. Whereas in the basin interior due to greater depth a marine body is formed during the middle cycle.

Islampur Area

Islampur is located at the NE of Godihal, towards basin interior. The succession in this area is ~60m thick and comprised of the lower and the middle valley fill only. Facies association 1 is also not developed in this are, though direct contact with the basement is not observed. The succession starts off with facies association 2. Owing to the poor quality of the outcrops, only two prominent channel belts, belonging to facies association 2, can be identified in this region, although the total thicknes of the lower valley fill is as high as. Each channel belt starts with a gritty sandstone unit at the base and shows a distinct fining upward trend. The lower channel belt is coarser than the upper one. Overall the lower fluvial unit of this region is different from the other two in terms of very less maturity and larger grain size. The lower valley fill is followed in this area by the more matured, both texturally as well as mineralogically, arenaceous sediments of the middle valley fill. It initiates with a fluvial interval and followed by a transitional marine to marine interval, but that is beyond thwe scope of this thesis work.

Paleogeopraphic Dispositions

Among the three facies associations the alluvial fan association probably represents steepest paleogeography at the base of a slope break, as manifested by the dominance of sediment gravity flows and most importantly scree bodies. Sandstone bodies within fan association also mark deposition from fluidal traction current, but the channels are far more unstable to develop mid-channel bars, as evident from the high energy water discharges within this interval. High slope over an alluvial fan surface, probably resulted the highly unstable discharges (Bose et al., 2008; Mukhoppadhyay, 2012). From the facies association types of fluvial association can be inferred. The first one is due to high slope. In this high energy condition an alluvial fan deposit was generated and that was characterized by matrix-and some clast-supported conglomerates. Development of an alluvial fan demands high energy unstable discharge which is a typical characteristic of an ephemeral river (Bullard, 2007), feeding the alluvial fan. The intervening sandstone units with crude cross stratification indicates traction movement in short-lived channelforms, likely to be designated as hillwashdeposits. In contrast, the fluvial associations,areperhaps deposited over a low gradient plain. Both the associations appear to be braided in nature, though flow durability within them differs, resulting probably from the differing depositional gradient. While facies association 2 shows ample evidences of flow instability, like frequent oversized pebbles, planar laminated shooting flow units occasionalflash flood products (Mukhopadhyay, 2012), the facies association 3 pointed towards more stabilized flows within channel. As the gradient become low potential energy getting lower and stability increases. As a result the highly unstable discharge gradually transfers to more stable braided but to some extent perennial deposit. As a result barforms were preserved there.

Facies association 1, representing alluvial fan environment, are very much restricted in distribution and formed locally, along the high slope area of the basin margin, as expected. In all the other areas, the lower valley fill is entirely made up of facies association 2 and 3, belonging to fluvial association I and II, respectively. The lower valley fill covers a large area from basin margin to interior part. Observing all the fluvial assemblage it can be stated that lower valley fill is made up by lateral and vertical juxtaposition of four to five channel belts(Fig 4.1, 4.2, 4.3). .The 2nd channel belt is the coarsest among all. It is stretched through the entire region and contains a considerable amount of feldspar. The 3rd and 4th is much thin in size and not preserved throughout entire region. In most of the regions these are eroded out and not preserved entirely. 5th channel belt is very rare. Temporally the belts show a fining upward trenddue to gradual filling up. Mineralogically the sandstonebodies are arkosic to subarkosic in nature. Gradual decrease in grain size is present from margin to the interior of the basin. From Gokak to Karabgatti there is a decrease in grain size (Fig. 4.2).The high gradient of the fan fringe prompted development of aephemeral braided system, with lesser amount of transportation. Local development of an alluvial fan indicates its position near the basin margin, where sedimentation started after a considerable gap.

CHAPTER 4

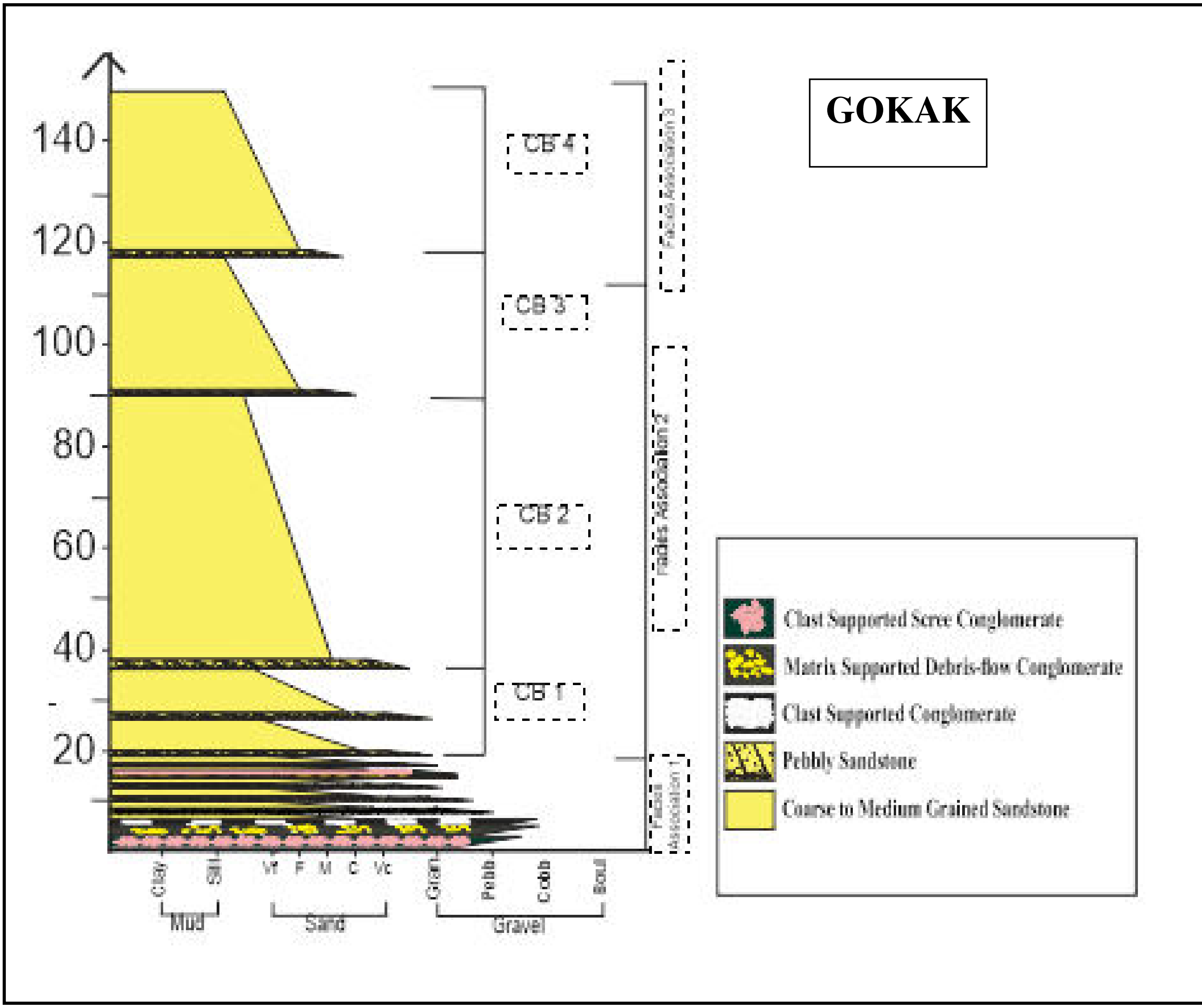


Fig 4.1: Synthetic Section of Gokak area at the northernmost margin of Badami Basin. Starting with a 20 m thick Conglomerate body this area comprises with 4 channel belts within lower valley fill

CHAPTER 4

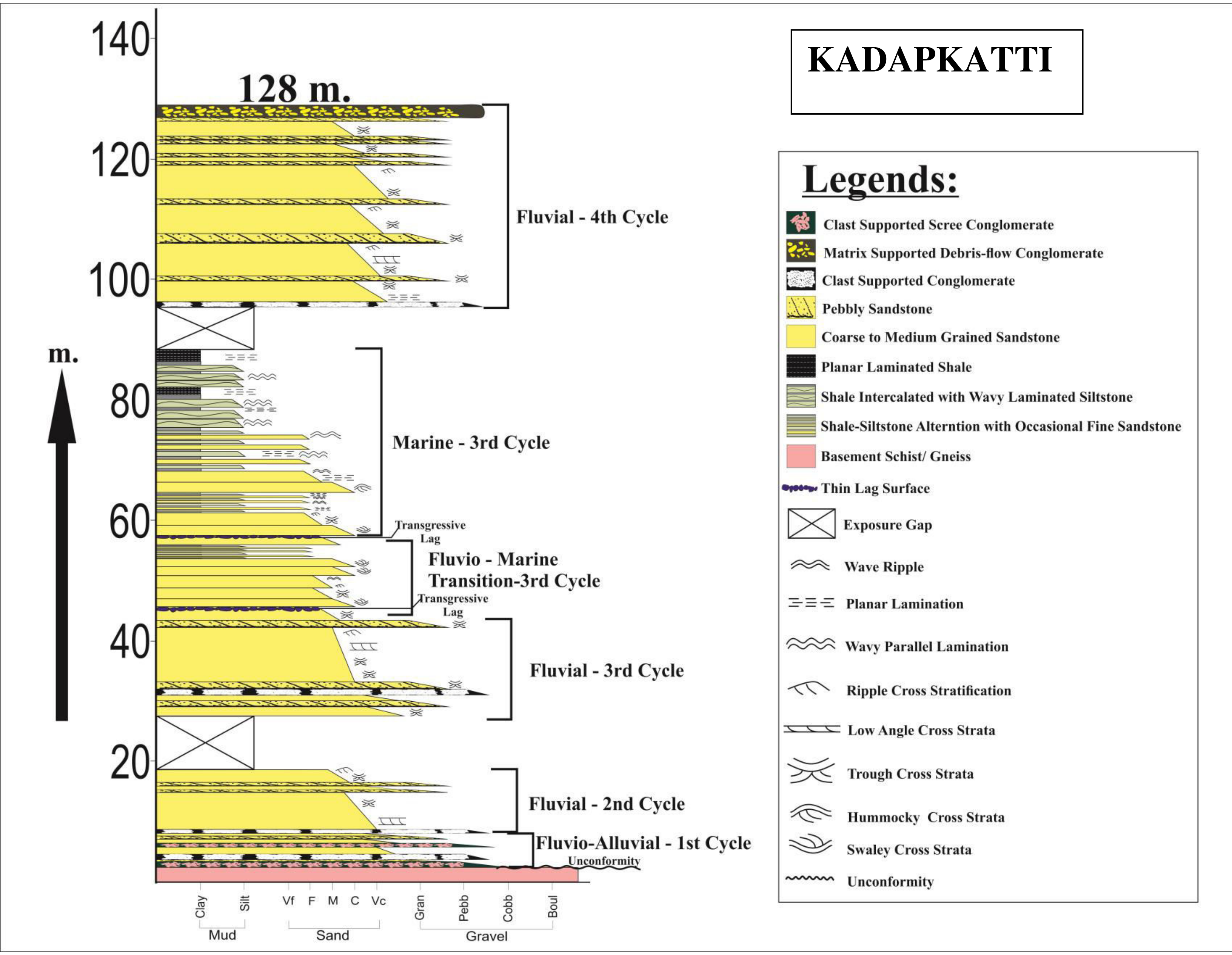


Fig 4.2: Synthetic Section of Kadabkatti area near the northern boundary of the basin; consists of Lower, Middle and Upper Valley fill over Basement. The lower valley fill is about 40 m thick.

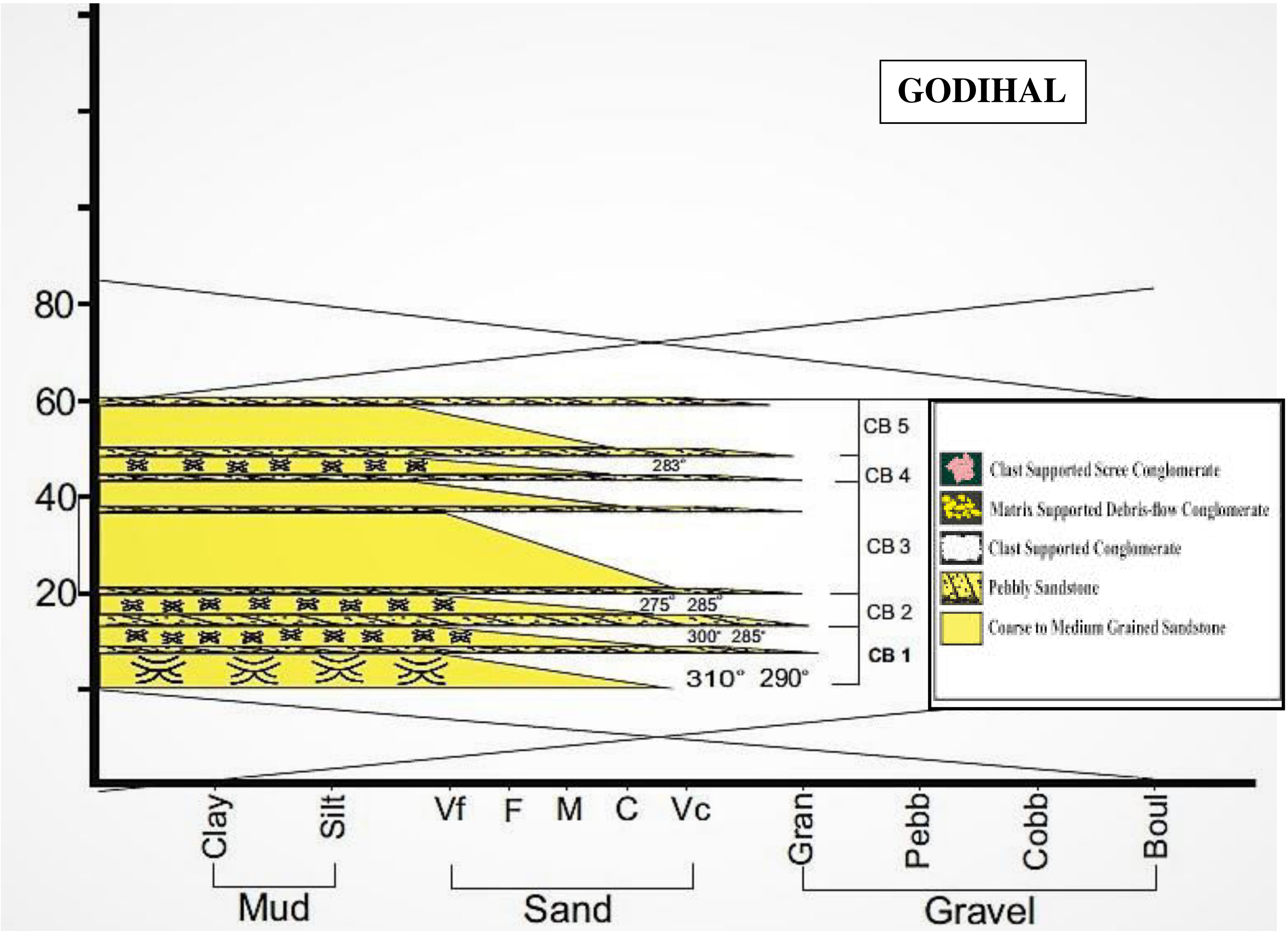


Fig 4.3: Synthetic Section of Godihal area; western region of Badami basin. Consists of 5 channel belts within lower valley fill. Entire area is about 60 m in height.

CHAPTER 4

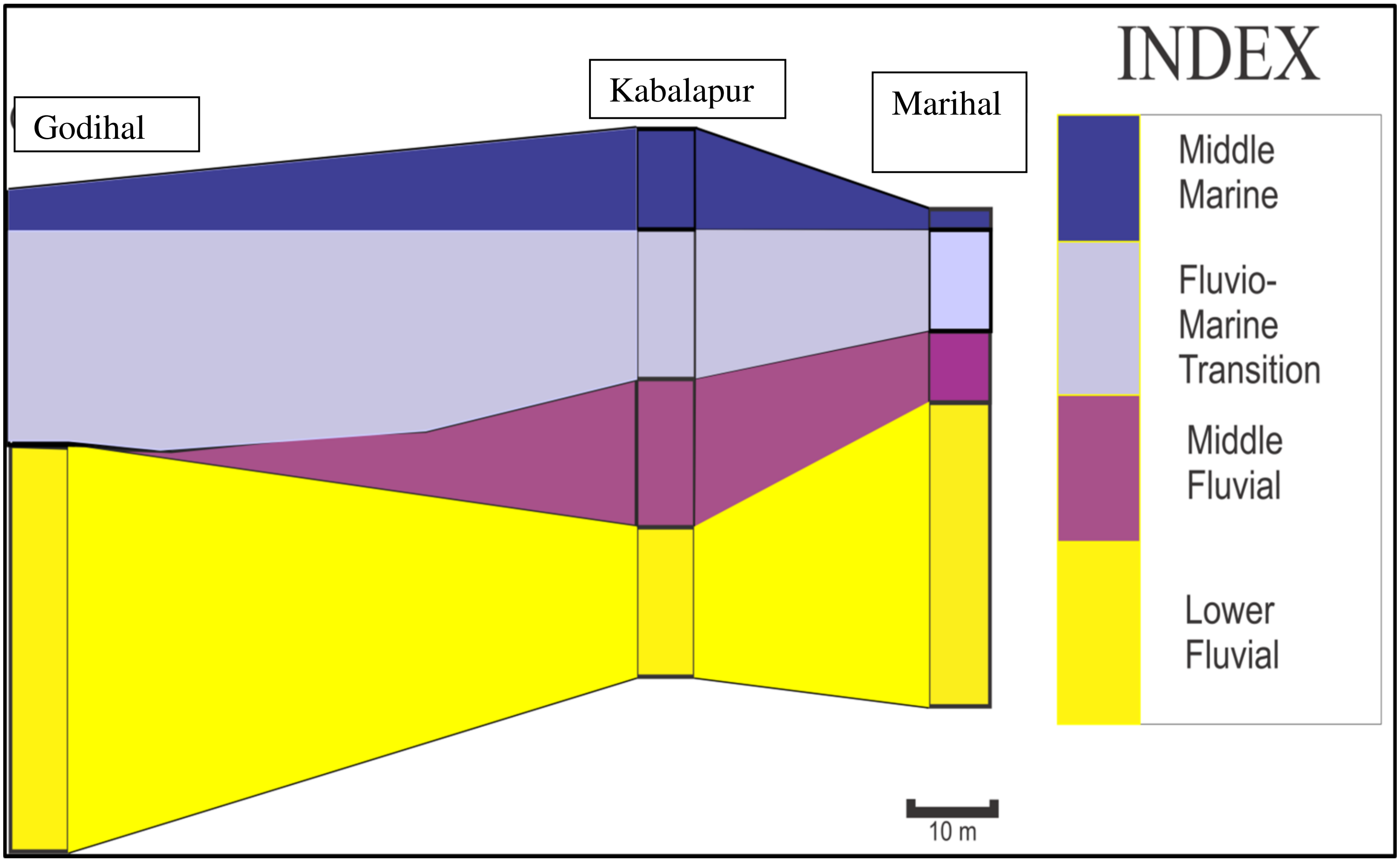


Fig 4.4: Correlation between 3 areas from basin margin to interior. Godihal is at the westernmost margin whereas Islampur is at the interior. Onlap of Fluvio-Marine transition over Lower Fluvial unit is observed. Thickness also varies between different regions.

CHAPTER 4

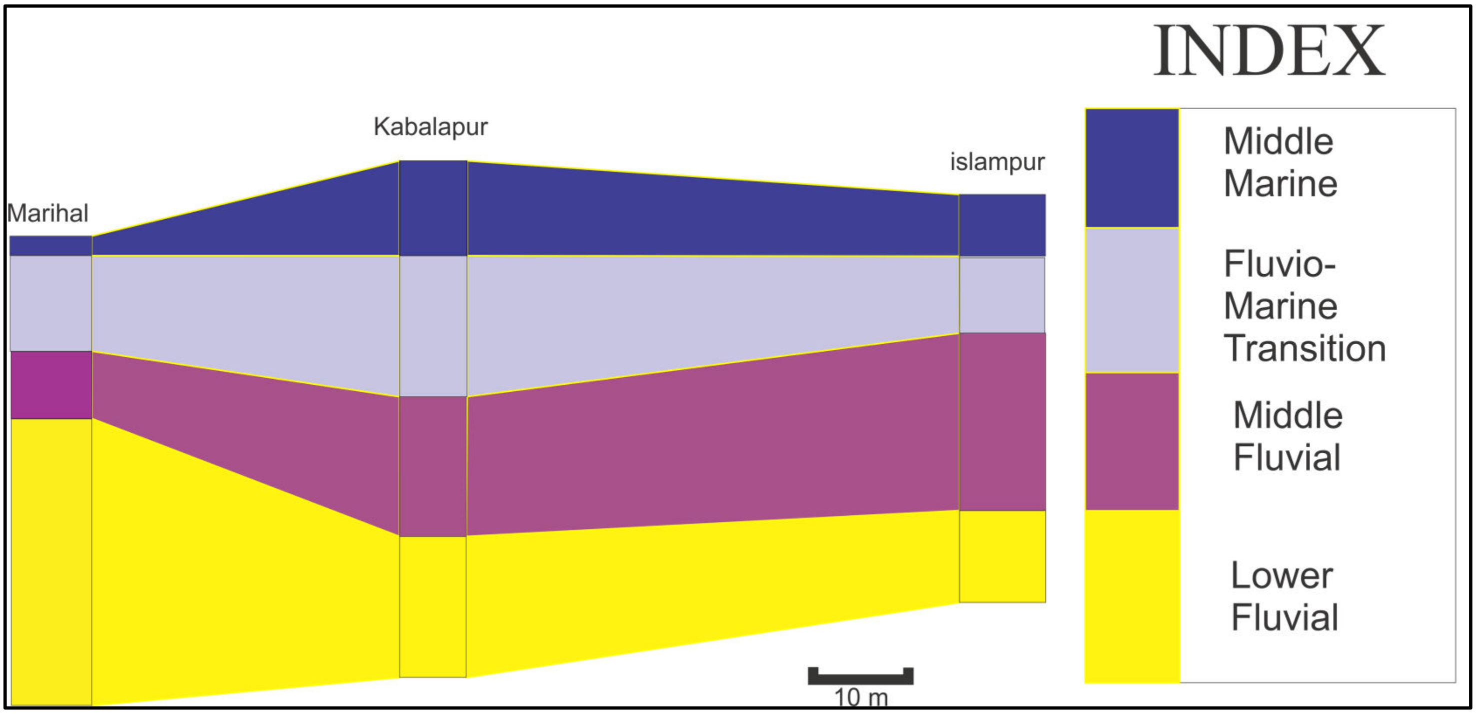


Fig 4.5: Correlation of Marihal- Kabalapur- Islampur. It gives a prominent decrease in thickness of lower fluvial unit from margin to interior

Discussion

Depositional Milieux

State-of-the-art facies analysis and sequence architectural studies within the lower valley fill of the Cave Temple Arenite Member on the western segment of Badami Basin, reveals a lot about the depositional environment and paleogeography of the area as well as their variability in time and space. The coarse sand sized sediments, with poor sorting and angular grains, characterize the studied stretch, with highly lenticular, thoroughly trough cross-stratified bodies, along with some locally developed abundant conglomerate rich portions. Together they represent a terrestrial origin for the studied interval, with traction-current driven fluid-gravity flow as the dominant depositional process for the arenaceous intervals, while local rudaceous portions refer deposition through sediment gravity flows mostly (Miall, 1996; Collinson, 1996; Eriksson et al., 1998). Dominance of trough cross-stratification and compound cross-stratification in all across the studied stretch, interpreted succinctly as channel forms and longitudinal barforms respectively, corroborates the contention further. Position of these barforms in between two channel forms laterally, made their mid-channel nature empirical. Occurrences of large-scale mid-channel longitudinal bars, scarce presence of flood plains (only within the topmost channel belt) and consistent channel flow directions clearly indicates braided nature of the rivers for the studied interval (Cant and Walker, 1978; Mazumder and Sarkar, 2004; Bose et al., 2008). Common occurrences of in-channel ripple laminated units towards top of the channelforms, on the other hand, represents frequent avulsions (Elliot, 1974), a very much common phenomenon for braided streams (Bose et. al., 2001). The braided nature of the studied interval accords well with the general consensus regarding the pre-vegetated Precambrian fluvial systems (Long, 2004), characterized by flashy surface runoff, lower bank stability, frequent avulsions and broad channels with abundant bedload (Schumm, 1968a, b; Martins-Neto, 1994; Sønderholm and Tirsgaard, 1998; Long, 2004). Among the two different fluvial associations, characteristic presence of the oversized pebbles, occasional flash floods and frequent planar laminations within the first association, pointed towards its non-perennial origin (Williams, 1971; Picard and High, 1973; Tunbridge, 1981, 1984; Mader, 1983, 1985; Stear, 1983, 1985; Langford, 1989; Langford and Chan, 1989; Clemmensen and Tirsgaard, 1990; Clemmensen and Dam, 1993; Simpson and Eriksson, 1993; Trewin, 1993; Tirsgaard and Øxnevad, 1998). The textural as well as mineralogical maturity of the constituting sandstone bodies also support lesser transportation and quicker deposition, as expected in channels experiencing rapid drawdown of water. Hence, the ephemeral braided nature of the fluvial association I, becomes empirical. The other fluvial association appears to be perennial, as evidences of flow fluctuations are lacking, indicating a stable and uniform flow within channels. The finding is amply supported by the comparative mineralogical and textural maturity of fluvial association II, indicating longer transport and slow deposition rate. Position of this association towards top of the valley fill, clearly indicates its deposition in low gradient areas, probably resulting from the gradual filling of the valley fill through aggradation. While the deposition of the fluvial association I presumably took place over the newly generated fluvial basin during the initial stages of valley filling. The tectonogenic gradient is undoubtedly high during the initiation of the basin, leading to the deposition of ephemeral fluvial system. With continued aggradation, the depositional gradient decreases gradually, leading to the deposition of more perennial fluvial systems towards later part of the valley filling (Ref.). The rudaceous fan association, on the other hand, develops locally, near the vicinity of the basin margin, where there is a distinct slope break. Dominance of sediment gravity flow products pointed towards steeper depositional gradient undoubtedly. Intervening sandstone bodies are characteristically massive to crudely cross-stratified. Massiveness of the bodies indicates quick dumping on a high slope generated by intermittent emplacement of sediment gravity flow lobes. These fluid gravity flow products unubiquitously indicate deposition from multiple short-lived ephemeral channels, generating intermittent highly sediment-laden flows (Blair and McPherson, 1994). Presence of several scree horizons pointed towards rejuvenance of paleoslope, owing to tectonic disturbances, a common phenomenon in basin marginal areas of intracratonic rift basins (Bose P.K. Sarkar S. Mukhopadhyay S. Saha B. 2008). Localized development of the alluvial fan, on the other hand, indicates point source of sediment supply along the basin-margin.

Petrographic Implication

The lower valley fill, characterized by five vertically juxtaposed channel belts, are typically comprised of texturally and mineralogically immature sandstones, with some local patches of conglomerates along the basal segment. While textural maturity is omnipresent all across the studied stretch, mineralogy varies between considerable ranges. The lower valley fill appears to be arkosic to subarkosic in nature in the western sector, whereas lithic arenite in the eastern sector. The variation can be well accounted by the difference in the immediate provenance, while the eastern sector overlies the Bagalkot Group of metasediments, the western sector is hosted within peninsular gneiss and Chitradurga Schist Belt. Although the finding is interesting enough, due to time constrains this thesis paper deals with the western sector only. Within the range of 40% to 15%, the feldspar content varies spatially as well as temporally, within the lower valley fill. Compositionally feldspar grains are mainly orthoclase (2.1.A), with minor amount of albitic plagioclase feldspar (Fig 2.1). Feldspar grains are comparatively larger in size than the surrounding quartz grains and are angular in shape (Fig 2.1). Some rock fragments, mainly of chert and quartzite, are also found, but in scarce amount.

Plotting the framework elements into the QFR diagram (Fig), revealed the tectonic condition at which it was formed. The bulk composition of Quartz, Feldspar, Lithic Fragments are making a cluster in a region which indicates the rock was formed in Transitional Continental Zone. The transitional origin is favoured by the near vicinity of the sea, to this rift basin. The presence of a marine incursion just on the overlying valley fill supports the contention sufficiently.

Preservation of feldspar is quite a unusual phenomenon by itself. It either requires extreme climatic conditions (Wilkinson and Milliken, 2001) or quick dumping of the sediments after a very short transportation (Petttijohn). Also faster rate of erosion is a prerequisite condition. Faster rate of erosion demands quick relief generation, or in other words, tectonic activity. Hence, arkosic rocks, in majority of the cases are associated with tectonically active basins (Pettijohn). To study the reason behind the presence of high amount of feldspars in the study area systematic sampling is done, with a view to highlight any trends in change of feldspar content, spatially or laterally.

A simple methodology with the following steps are adopted for the purpose-

- Samples were taken from the base of every successive channel belt vertically stacked or laterally juxtaposed in a particular region.
- Within a single channel belts samples were taken from the base, the middle part and the top of a channel belt.
- Polished Thin Sections were prepared from those samples.
- Large images of those samples (A total thin section in a single image) were taken.
- By using **JMVision** software diameter of largest 100 grains were measured. While taking the grain size measurement no mineralogical preferences were taken.
- By using **Petrolite** software the modal abundance of Quartz, Feldspar and Rock Fragments were measured by point counting.
- During this study Quartz, Feldspar, Rock Fragments were again subdivided according to their sizes i.e. Large, Moderate and Fine Quartz, Feldspar and Rock Fragments successively.
- Total no. of grains as well as modal abundances were taken into account during the study.
- Correlate the Feldspar percentage from samples taken from base, middle part and top of a single channel belt a plotting of a graph. (Fig: 5.1)
- Again correlation of Feldspar % from the base of successive channel belt from bottom to top. (Fig: 5.2)
- Correlation of Feldspar content with change of Grain Size (Fig: 5.4).
- Plot the Quartz, Feldspar, Rock Fragment percentages in Q-F-L triangle diagram and analyze the obtained value (Fig 5.5).

Results obtained are represented in series of scatter plot diagrams (Figs 5.1, 5.2, 5.3). Considering all the diagrams a clear trend in change of feldspar content is found, which shows:

- From bottom to middle to top, feldspar content decreases in a linear fashion. Feldspar content is minimum at the top of each channel belt (Fig. 5.1 A & B).
- Among the base of different channel belts feldspar Content also decreases from lower most to uppermost channel belt (Fig. 5.2 A & B).
- Feldspar content also decreases along with the decreasing grain size. Towards the palaeocurrent direction grain size decreases as well as Feldspar content. It gives a negative correlation between Grain size and Feldspar content (Fig.).

As mentioned earlier the preservation of feldspar within sandstone depends upon some critical conditions, namely slope, mostly tectonogenic (Bluth and Kump, 1994) and extreme climatic condition (Wilkinson and Milliken, 2001).Increase of slope eventually results in increase of Feldspar content (Bluth, Kump, 1994). Increase in slope indicates very short transportation which is prerequisite of Feldspar preservation (Arche, 1999). In low energy condition due to longer transportation Feldspars weathered into clay minerals. Feldspar preservation needs rapid burial (Crow, 2008), (Wilkinson, Milliken, 1997). Climate condition, on the other hand, controls feldspar preservation, by retarding the rate of chemical weathering. Feldspar dissolution has a major influence on the cycling of Si, Al, and alkali and alkaline Earth metals in the biosphere; atmospheric CO_2 levels; the composition of natural waters; and soil formation (BrownJr, Chaka 2008). It entirely depends upon the humidity of climate. Humid climate increases the rate of chemical weathering. This increases the rate feldspar decay and transforms it into clay minerals like Kaolinite. Extreme aridity promotes feldspar preservation, as it opposes chemical weathering. In extreme climatic conditions, feldspar can remain stable even after longer transportation. The results obtained from the analysis of feldspar abundance, clearly show that the feldspar content depends upon transportation. In all the diagrams, the amount of feldspar decreases with increasing transportation, as in case of the top of a channel belt, in contrast to the base of the same. The findings clearly indicate that the high feldspar content within the lower valley fill of the Cave Temple Arenite Member in the western sector of the Badami Basin, is not climatically induced, rather has a direct correlation with tectonically derived depositional slope. Enhanced slope facilitated quick dumping after a shorter transportation, and hence promotes preservation of feldspar. Owing to continued aggradation within each channel belt, as well as across channel belt, form bottom to top, the depositional slope decreases gradually, resulting in the decrease in feldspar content.

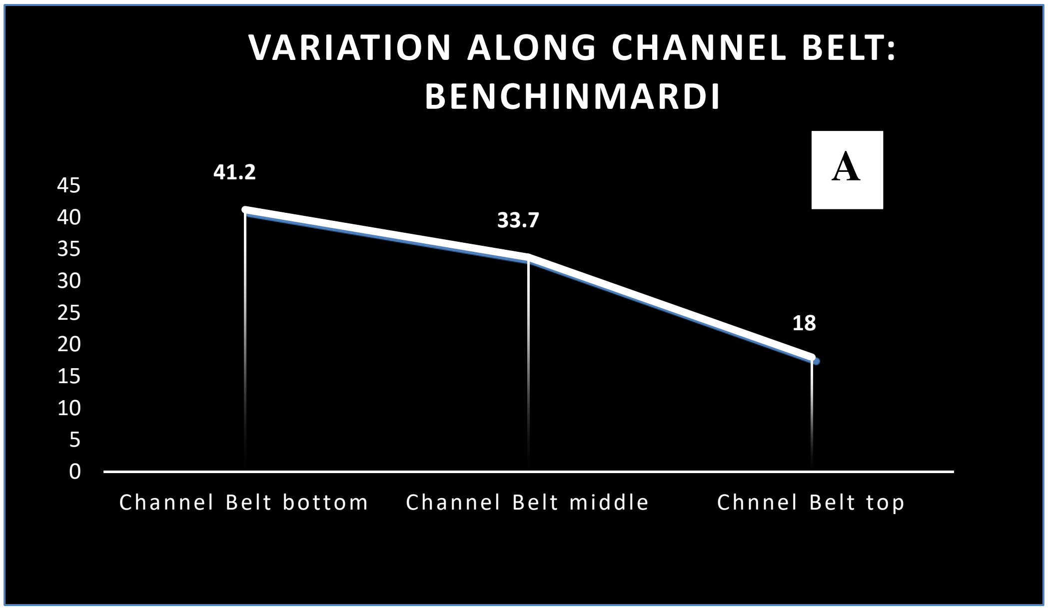
Sequence Architectural Framework

Overlying the Archean Basement, and locally the bagalkot Group of rocks, the multistoried Cave Temple Arenite Member represents prolonged almost entirely fluvial sedimentation in an intracratonic rift basin, the Badami Basin. Tectonics and climate are the two extrabasinal factors, which primarily control the fluvial stratigraphic architecture, interpreted in terms of different orders of bounding surfaces, their distribution and interrelationship (Singh et al., 1993; van Wagoner, 1995; Chamyal et al., 1997; Posamentier and Allen, 1999; Catuneanu and Elango, 2001; Catuneanu, 2003; Raj et al., 2004; Bose et al., 2008). Changes in the level of the standing body of water in which the river debouches may play an important role in this respect also, but only in close vicinity of such body (Posamentier and Allen, 1999; Catuneanu and Elango, 2001; Catuneanu, 2003; Raj et al., 2004; Bose et al., 2008). The effect of both climatic and tectonic variations are likely to produce large-scale variations, whereas base-level fluctuation, caused by smaller scale tectonic as well as climatic variations, results in comparatively smaller variations within a limited exposure. Each major bounding surface, nonetheless, corresponds to a break in sedimentation. The vertical juxtaposition of three valley fills, nonetheless, demands successive creation of accommodation space, and gradual filling of it through fluvial aggradation. Such resurrection of accommodation space clearly depicts tectonic influence. Presence of five channel belts within the lower valley fill, on the other hand, can be equivocally related with both climatic and/or tectonic causes. Although not all the channel belts are identified all across the studied stretch, this deviation can be safely attributed to the paucity of good quality exposures. The abundance of feldspar at the base of each channel belt provides some important clue regarding the regeneration of depositional slope. Hence, channel belts appear to be tectonically induced, all across the studied stretch. The gradual reduction of the feldspar content also pointed towards gradual decrease in depositional slope, owing to fluvial aggradation (Catuneanu, 2006). Hence, tectonics appears to be the prime factor in shaping the sequence architectural pattern in the western sector of Badami Basin, at least up to channel belt scale.

Conclusion

The terrestrial interval at the margin of western Badami basin, overlying an unconformity and underlying the wave imprinted shale and limestone of the uppermost Formation of the Badami Group, is certainly a product of base level lowstand (Posamentier and Vail, 1988; Van Wagoner et al., 1988). Three distinct facies associations, belonging to different paleogeographies of depositions, are laterally as well as vertically juxtaposed together into the lower valley fill, basal among the three distinct valley fills in this sector. While the alluvial fan association is restricted locally , ephemeral to perennial fluvial systems, represented by fluvial association I and II respectively, made up bulk of the valley fill. After the deposition of an alluvial fan during the initiation of basin filling, fluvial sedimentation proceeded, following the general aggradational nature of fluvial deposits, disrupted intermittently by tectonic upliftments. These upliftments resulted in the emplacement of one channel fill over another, leading to the filling of the lower valley fill of the western sector of Badami basin. Rejuvenation of depositional slopes, by these upliftments, led to development of high energy ephemeral river systems in high slope areas, whereas more stable perennial system develops in later stages of basin filling, following gradual aggradation of lower valley fill over intermittent tectonism- generated accommodation space. The fining-upward nature of each valley fill, on the other hand, pointed towards general aggradational nature of fluvial deposits (Catuneanu, 2006). The arkosic to subarkosic nature of the constituent sandstone bodies pointed towards deposition over tectonically generated high slope areas, which facilitate preservation of feldspar by facilitating short transportation and quick dumping of the sediments. The QFR diagram indicates deposition in a tectonically active transitional continental basin, supported by the closeness of sea to this rift basin. Together, the multistoried terrestrial succession in the western part of the Badami basin margin, documents gradual filling of the Basin by fluvial sedimentation frequently disrupted by the tectonic movements leading to rejuvenation of depositional slope.

CHAPTER 5



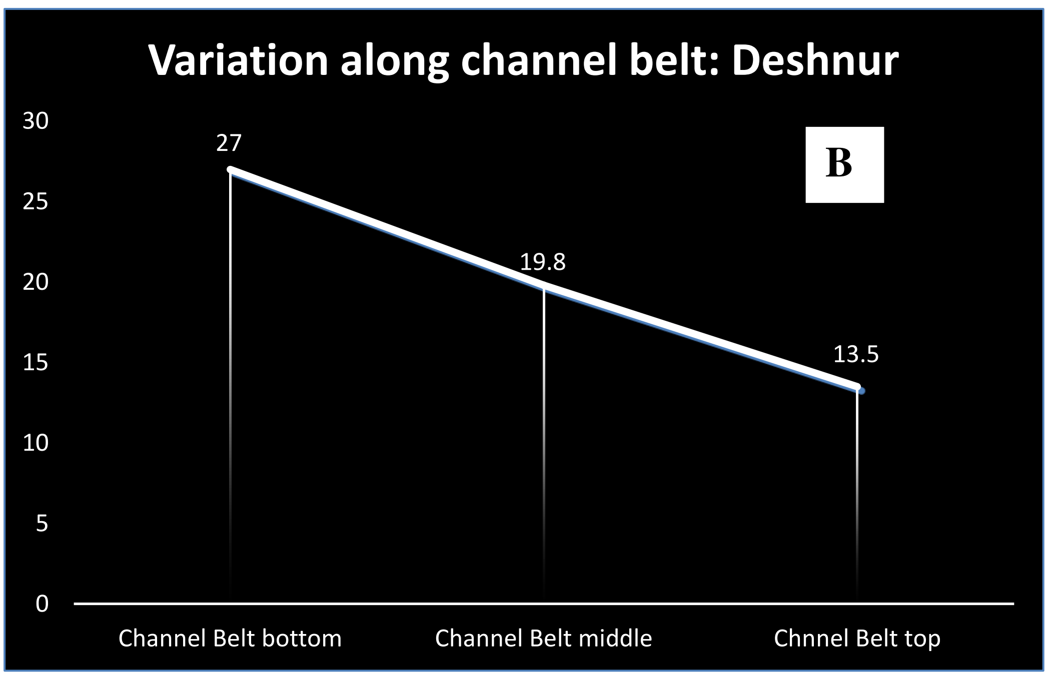
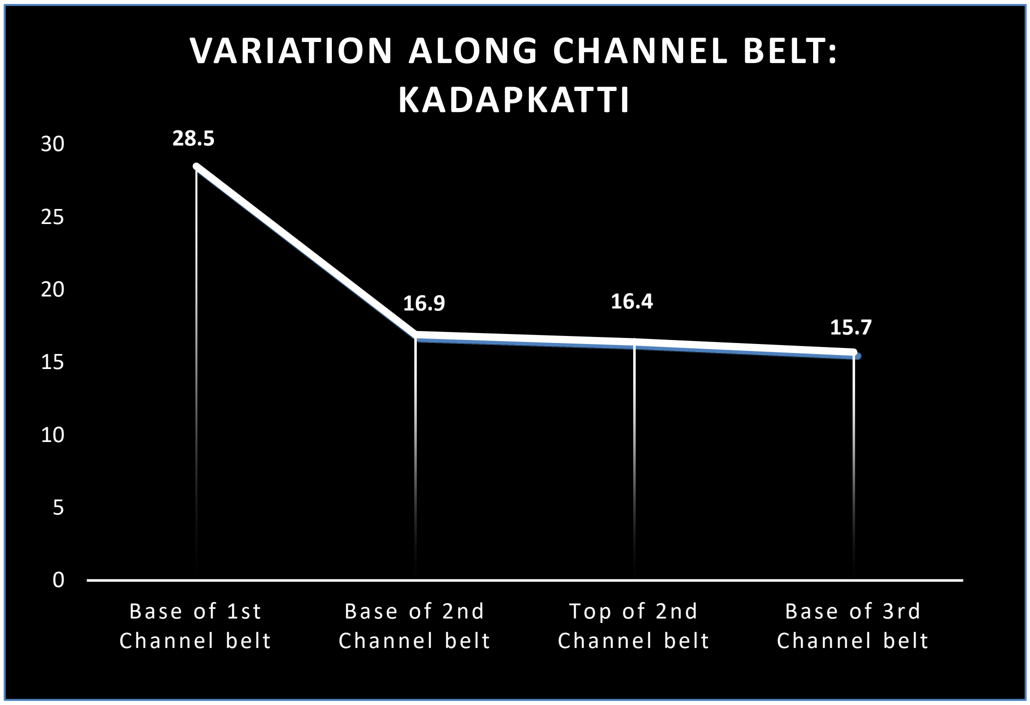


Fig 5.1: Change of Feldspar content within a channel belt. From bottom to top within a channel belt a clear trend of decrease of Feldspar quantity is observed(A and B)

CHAPTER 5



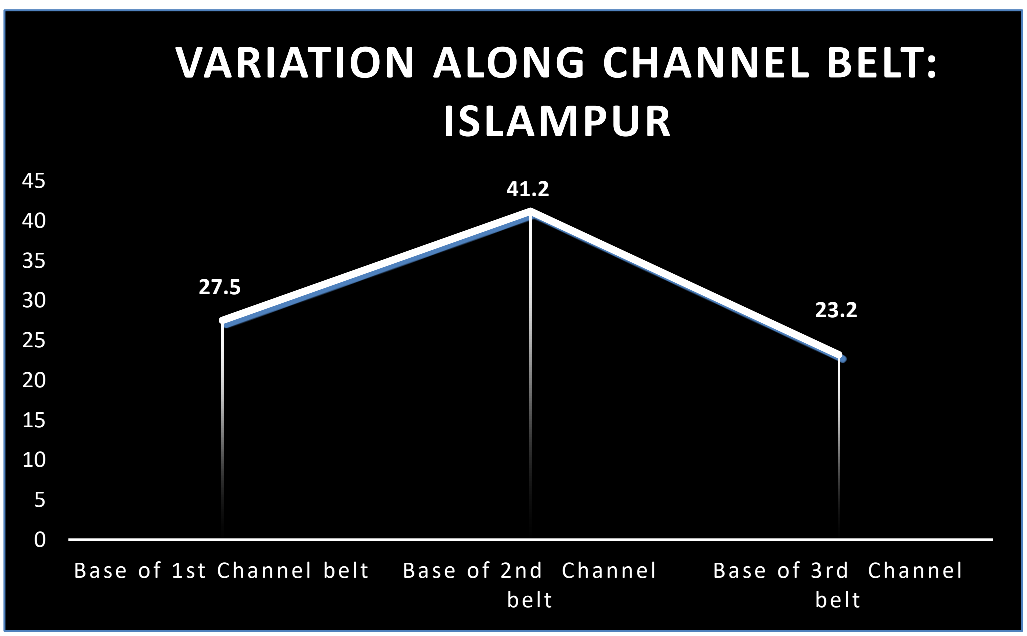


Fig 5.2: Change in Feldspar content among the bases of successive channel belts from bottom to top. Though Feldspar content may increase among the 2 channel belts one over another but overall it shows a gradual decrease.

CHAPTER 5

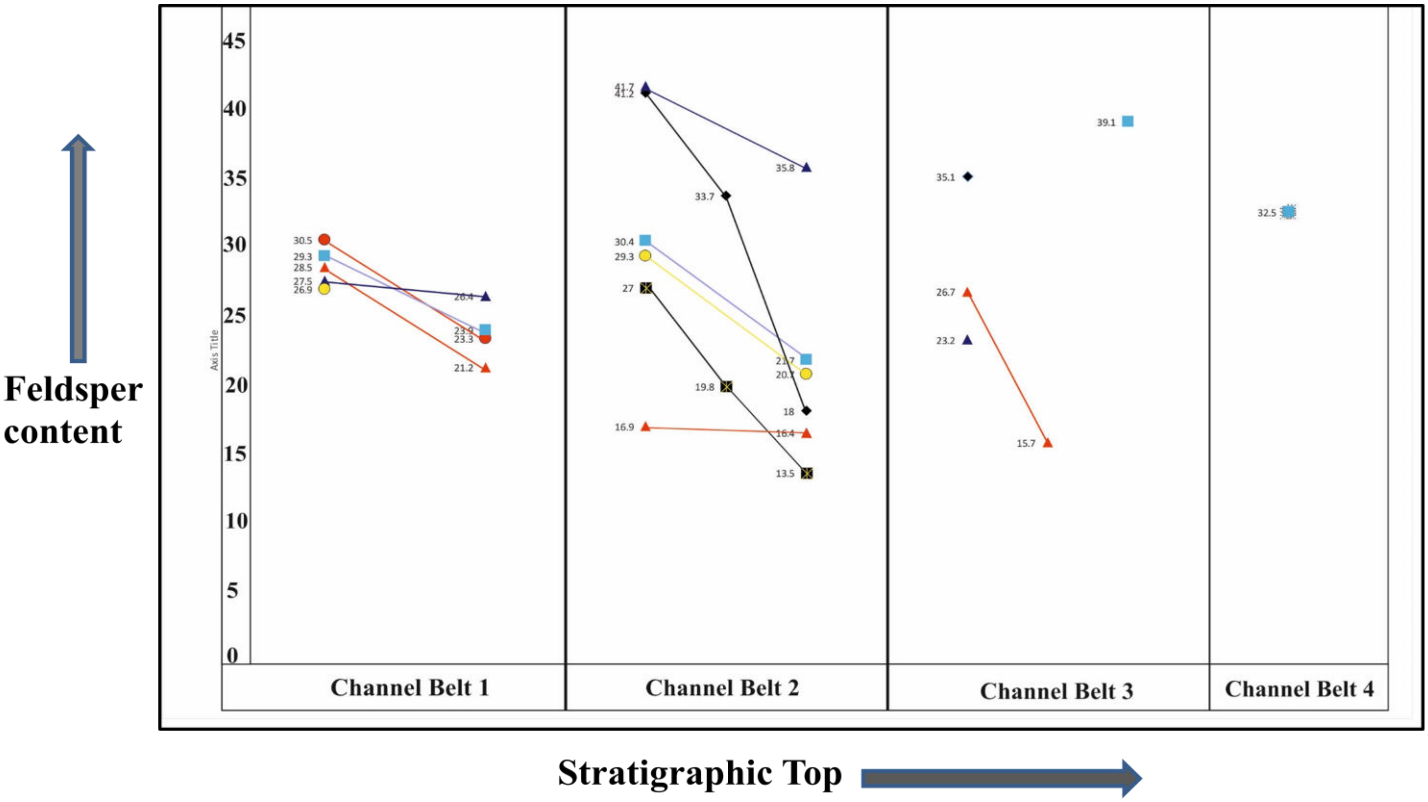


Fig 5.3: Correlation in Feldspar content in different area. In every area it shows a similar negative trend. Both within a channel belt and successive channel belts from bottom to top. X axis shows Stratigraphic top and Y axis shows Feldspar content.

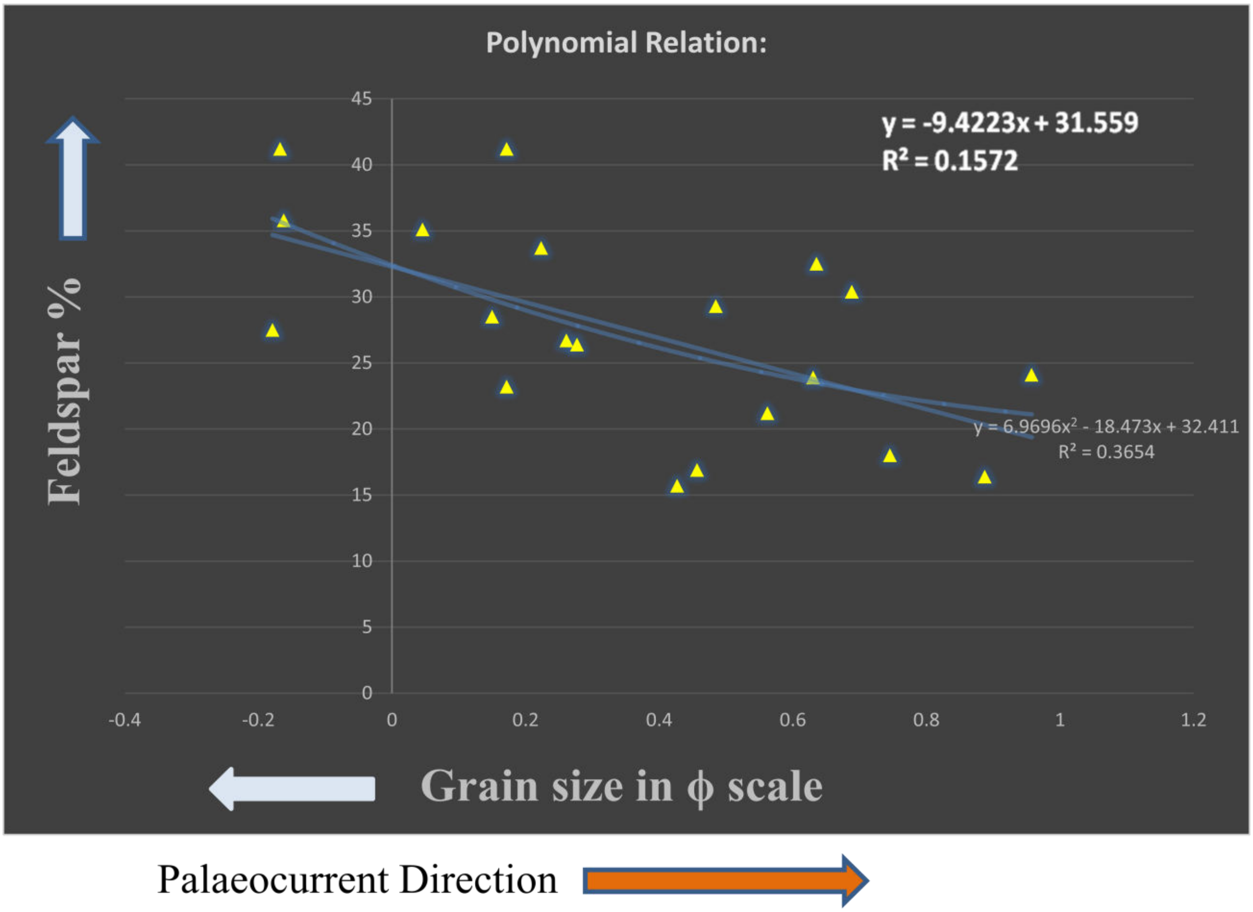
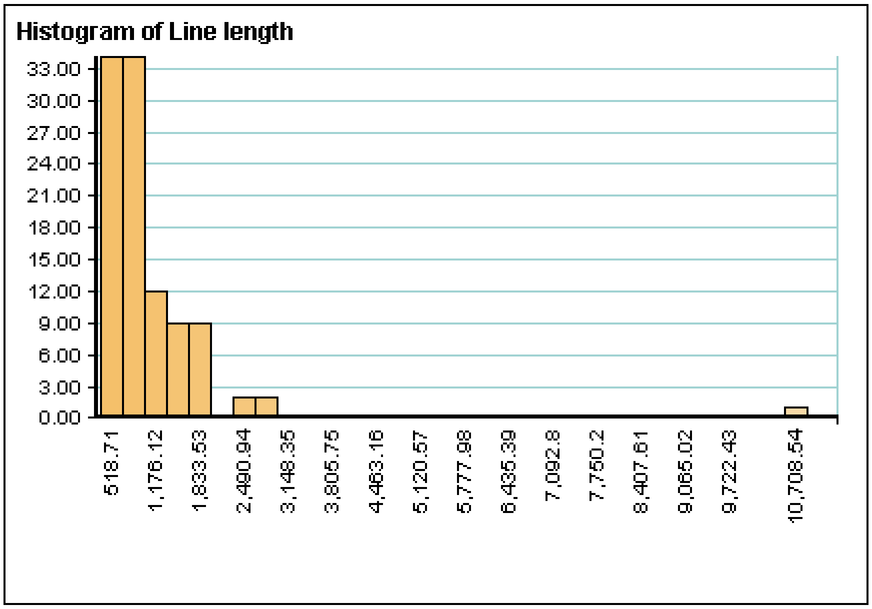


Fig 5.4: Change of Feldspar content with grain Size. As the Grain Size increases Feldspar content also increases. If compared to the Palaeocurrent direction; Feldspar content decreases towards the downcurrent.



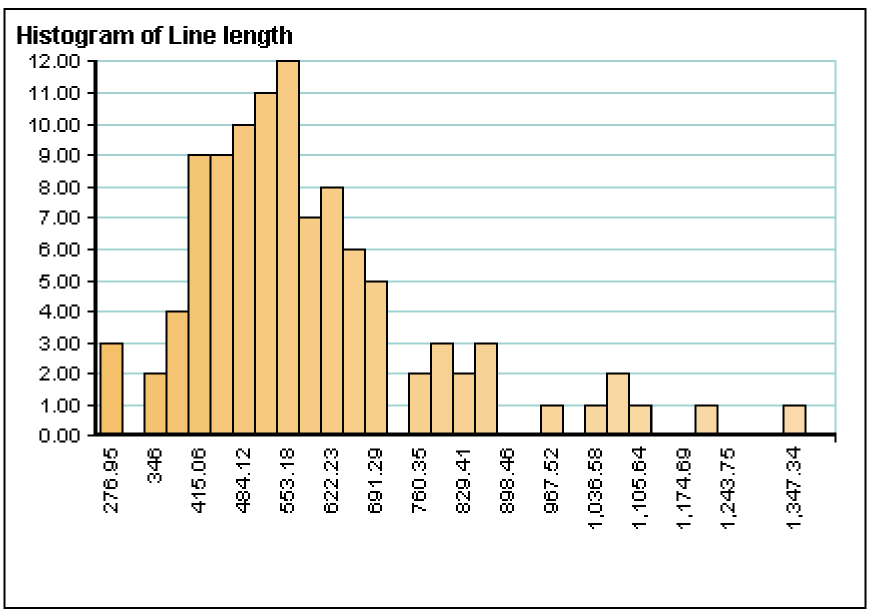


Fig 5.5.1 : Histogram plots for the Sandstone bodies of Benchinmardi area A) BEN 2A, B) BEN 2B

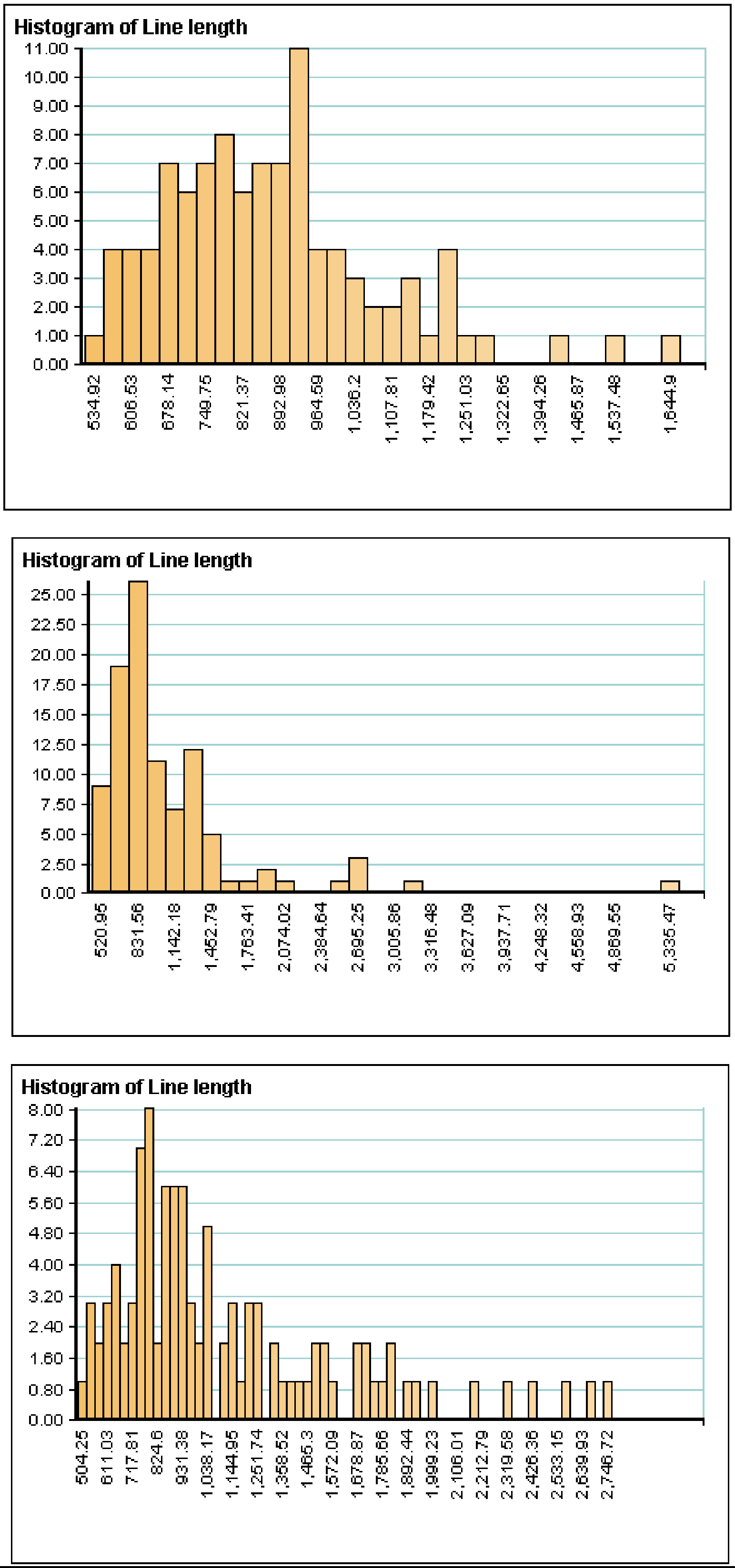
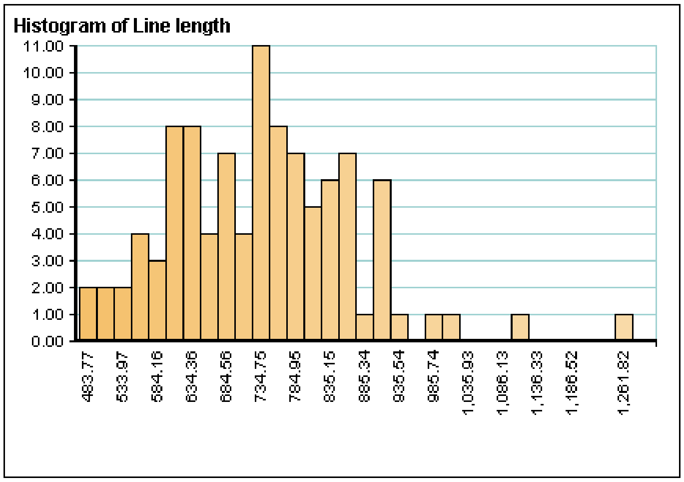
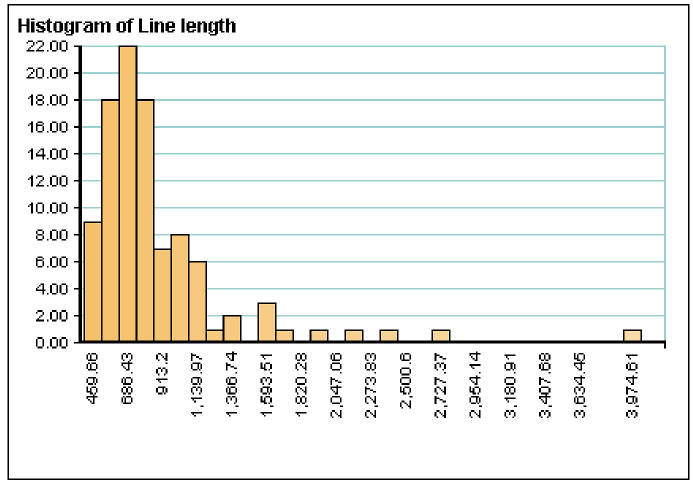
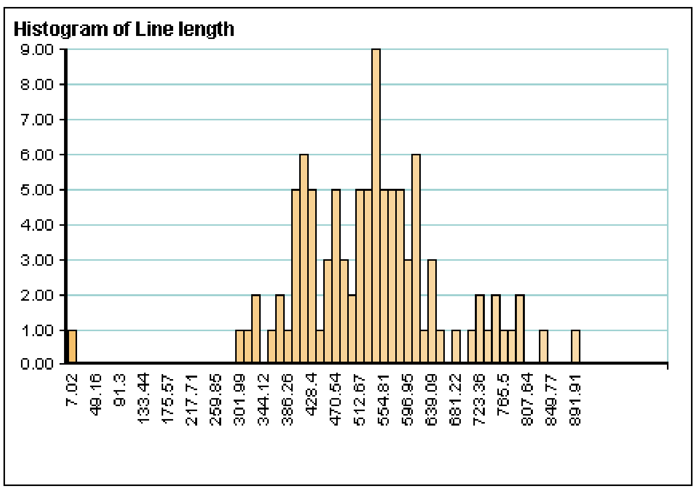


Fig 5.5.2 : Histogram plot for samples of Islampur Area. A) IP 6, B) IP 8, C) IP 10. X axis for Grain Size in micrometer and Y axis is no. of Grains







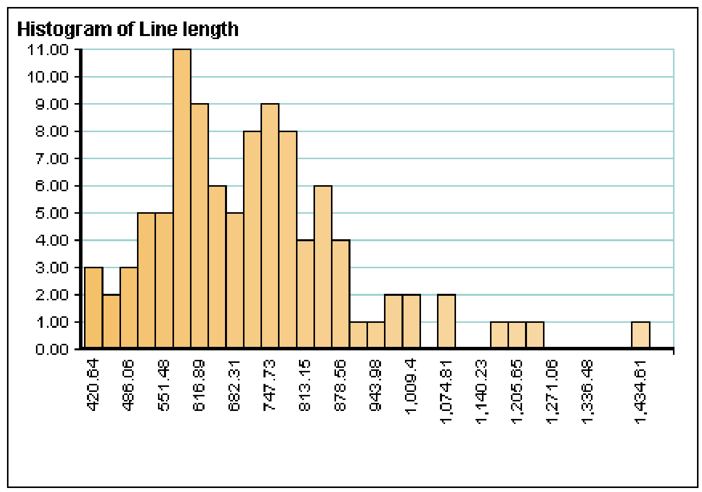
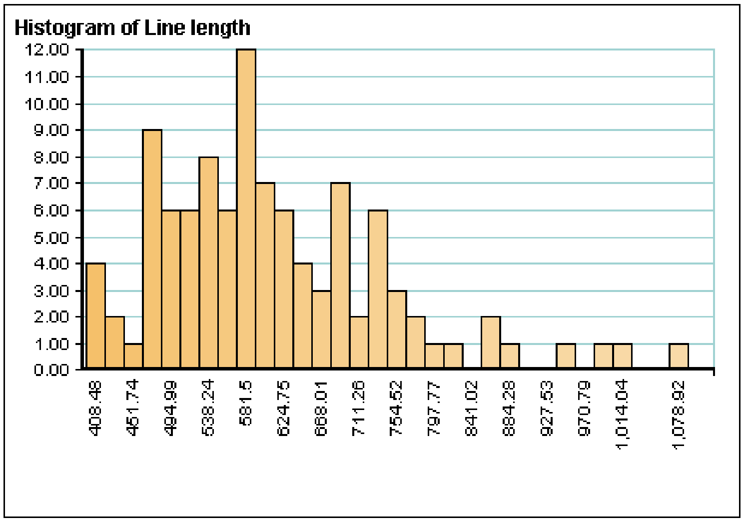
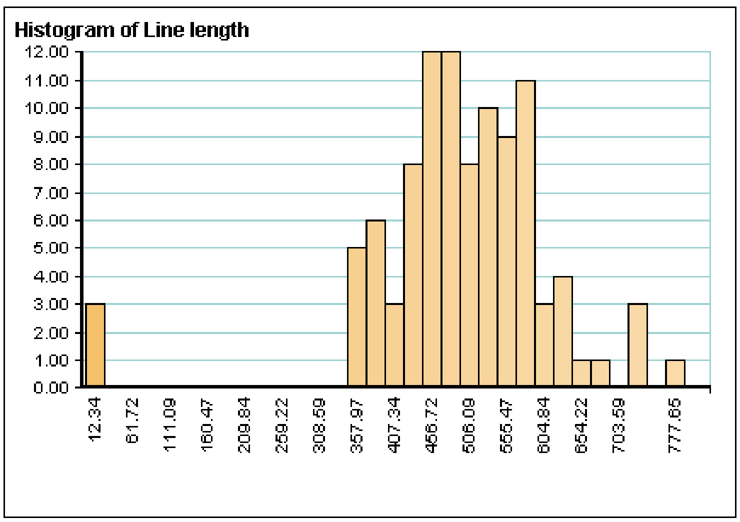


Fig 5.5.3 : Histogram Plots for samples of Kadabkatti area. A) KK 13, B) KK 14, C) KK 15, D) KK 16





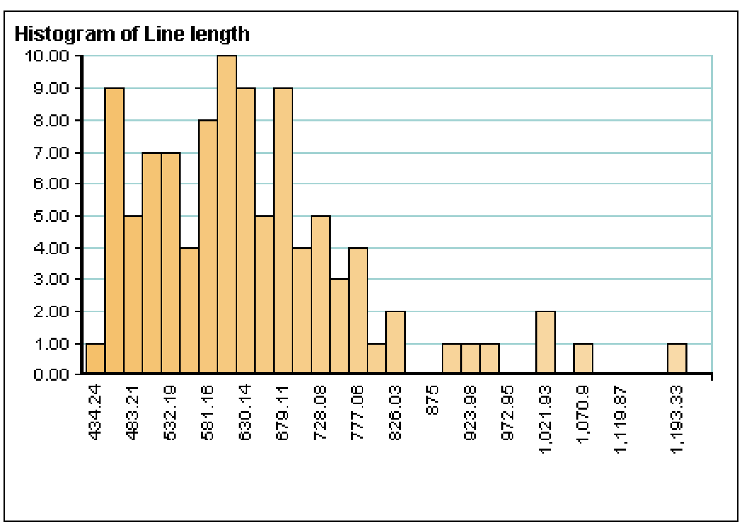


Fig 5.5.4: Histogram plots of grain sizes of lower sandstone near Badami Cave temple. A) BDM 3 B) BDM 6, 3) BDM 7

CHAPTER 5

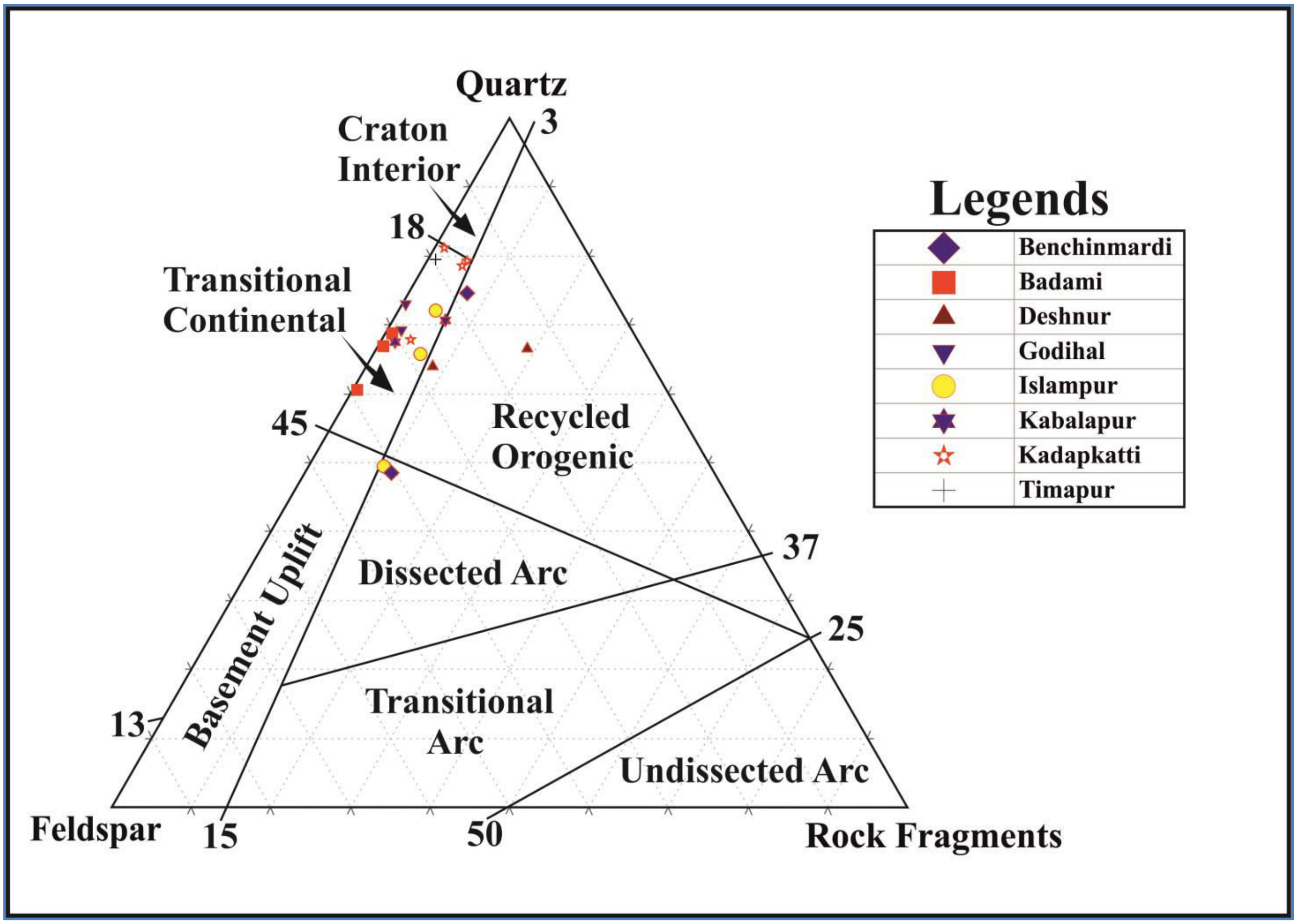


Fig 5.6: Triangular diagram containing Quartz- Feldspar- Rock Fragment in e apex indicating the tectonic set up from which the rock has been formed. The cluster value indicates the provenance of the rock is Transitional Continental. Most likely it might be a rift basin (Dickinson. Et. al., 1983)

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