



Lithofacies and Depositional Environment of the Ferruginous Claystone Member Sediments of Naredi, Kutch, Gujarat, India

KEYWORDS

Sandstone-mudstone; fluvial deposit; palaeoenvironment; process; lithofacies; Naredi; Kutch; India

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ABSTRACT

This paper presents the findings of the sedimentological investigation of the clastic sediments of the upper Ferruginous Claystone Member. The studied outcrops are composed of sandstone facies assemblage dominated by sandstones (Sm, Sh, and Sp) and mud drapes (Fm). Overall medium to coarse grained, moderately to poorly sorted, cross- to horizontally-bedded sandstone, unidirectional current evidence in cross-bedded sandstone, vertical stacking pattern, undefined to coarsening upward trends, negligible bioturbation activity and absence of marine palynofossils suggests fluvial origin in overbank and crevasse splay settings near coastal region during regressive stage of sea level.

INTRODUCTION

The sandstone deposits, belonging to Ferruginous Claystone Member of Naredi Formation, under study are exposed as outcrop sections along a channel, about 1.8 km SSE of the village Naredi (23°39'49":68°40'38", Biswas, 1992), Southwestern Kutch. The first detailed classification of the Tertiary sediments of Kutch was presented by Wynne (1872). Later a more detailed stratigraphic classification of the Tertiary sediments of Kutch has been provided (Biswas, 1992). Biswas (1992) named three members of the Naredi Formation: Gypseous Shale Member (Lower), Assilina Limestone Member (Middle) and Ferruginous Claystone Member (Upper). The age of the Naredi Formation is Late Paleocene to Early Eocene. The Ferruginous Claystone Member is about 15 m thick and consists of grey and brown claystones with layers of gypsum and red ferruginous laminae. However, the thickness of the Naredi Formation is highly variable and all three members do not occur together in the outcrop. Chatteraj et al. (2009) reported mineralogical characteristics of glauconite from shales of the outcrop of the Naredi Formation. Sahay (2009) provided palaeoclimatic and depositional environmental insights into the lignite and shale succession of Panandhro belonging to the lower member of Naredi Formation based on palynology.

The lower (Gypseous Shale Member) and middle (Assilina Limestone Member) members of the Naredi Formation in western Kutch have been studied extensively, but no such specific work has been done on the sandstone succession belonging to upper part (Ferruginous Claystone Member) of the Naredi Formation. The purpose of this article is to document the outcrop characteristics of sandstones and the associated lithological succession and to determine the lithofacies present and to interpret the depositional palaeoenvironment.

METHODOLOGY

In this work sandstone bearing outcrops have been documented and logged where they are exposed along the channel course on parts of the Kakdi River, south of the village of Naredi. The internal structure of the beds was examined during outcrop-based sedimentological field work.

In this study, all of the sedimentary layers were identified and their thicknesses were measured. Lithofacies were classified using Miall's (1978, 1996) and Bordy and Catuaneanu (2001) lithofacies classification method. Architectural elements were defined using Miall's (1985, 1996) scheme of architectural element analysis. The locations of the outcrops are shown in Figure 1. The samples were processed, for palynological study, using standard methods. However no one sample was productive. The thin sections, prepared for palynological study, are in the depository of Department of Geology, Nagpur University.

RESULTS & DISCUSSION

Outcrop 1

Outcrop 1 is composed of sandstone facies assemblages having thickness of 3.69 meters. The sandstones are thin-bedded (5 cm) to very thick-bedded (150 cm) and contain very thin- (2 cm) to thin bedded (8 cm) mudstone drapes between sandstone. The graphic litholog of outcrop 1 is shown in Figure 2.

The lithological sequence exposed at outcrop 1 shows a sequence of upward thickening beds. The thickening beds towards top of the outcrop may indicate progressive deepening of channels and higher accommodation space accommodating more sediments and relatively higher thickness.

Outcrop 2

The outcrop 2 also comprises sandstone facies assemblages having overall thickness of 3.17 meters. The sandstone is medium-bedded (29 cm) to very thick-bedded (129 cm). The sandstone alternates with very thin- (3 cm) to thin-bedded (7 cm) mudstones. The graphic litholog of outcrop 2 is shown in Figure 3.

The thickness of the lithological sequence of the outcrop 2 also shows the overall thickening and coarsening upward sequence. The original depositional structural component of the lower part of this outcrop is altered by the present day surface processes. The lateral extents of lithologies of both outcrops are comparatively more than their thickness which points out towards sheets and tabular types of ge-

ometry.

Facies 1

Massive sandstone (Sm): This facies comprises massive beds of medium to coarse grained sandstone with poor to moderate sorting. At places this massive sandstone contains faint lamination (Fig. 4).

Interpretation. The massive sandstone facies is interpreted to have been deposited by flows that were not related to normal fluvial currents. Cross-stratification is absent, and hence the flow responsible for the deposition of the massive sandstone facies did not maintain traction currents. The possibility of sudden water level falls may be also indicated by the presence of massive beds (Sm). Deposition is interpreted to have taken place during short time intervals through rapid sedimentation. The interpretations made of the massive sandstone facies depositional environments include deposition under upper flow regime conditions, from high concentration currents, and from sediment gravity flows associated with bank and bar collapse (Bordy & Catuneanu, 2001). A massive sandstone facies has not been widely recognized in fluvial deposits, and is not included in the comprehensive lithofacies scheme of Miall (1977). However, a number of workers have described the presence of a largely structureless (massive type) sandstone facies (Bordy & Catuneanu, 2001).

Facies 2

Mudstone (Fm): This lithofacies comprises finely lamination above massive sandstones as mudstone drapes. Desiccation evidences was present (Fig. 4).

Interpretation. Mudstones were deposited during relatively low energy conditions of water flow. Local cyclic flow fluctuations are indicated by the presence of many units of mudstone drapes in between sandstones. Mud drapes suggest that these lithologies were deposited within a river which was not a perennial system with variable discharge. The mud drapes with desiccation cracks argue for non-deposition and subaerial exposure of the channel deposits. This facies may have formed as overbank deposit, abandoned channel, or drape deposits (Miall, 1978, 1996; Bordy & Catuneanu, 2001).

Facies 3

Horizontally stratified sandstone (Sh): This facies comprises horizontally stratified, medium to coarse grained sandstone (Fig. 5).

Interpretation. The horizontally stratified sandstone may have been deposited in the upper flow regime in which abundant sediment is being transported in traction. The upper plane bed flows occurs when the flow velocity is increased above that needed for ripple formation or dune formation. This facies has been interpreted as formed by plane-bed flow (critical flow) (Bordy & Catuneanu, 2001).

Facies 4

Planar cross bedded sandstone (Sp): This lithofacies contains low angle cross bedded sandstone. The cross stratification is in the form of a single set. The grain size is medium to coarse (Fig. 6). The upper and lower bounding surfaces are relatively sharp.

Interpretation. This facies is formed by the migration of straight crested dunes or bars deposited in the lower flow regime (Miall, 1996).

Facies 5

Mudstone (Fm): This lithofacies comprises of very thin to thin bedded mudstone drapes occurring between sandstones. Desiccation evidences are not present.

Interpretation. These mudstones were most probably deposited during the waning flow conditions after sandstone. This facies may have formed as overbank deposit, abandoned channel, or drape deposits (Miall, 1978, 1996; Bordy & Catuneanu, 2001).

Architectural Element Analysis: 5 lithofacies types were identified and classified. These were grouped into facies assemblage and then their architectural elements. The studied outcrops are composed of sandstone facies assemblage dominated by sandstones (Sm, Sh, and Sp) and mud drapes (Fm). The fluvial system under investigation is comprises of sandy bedforms (SB) and overbank fines (OF) architectural elements (Table 1).

Table 1: Architectural elements of the studied sediments

Element	Sym- bol	Principal lithofa- cies assem- blage	Geometry and relation- ship
Sandy bed- forms	SB	Sp, Sh	Lens, sheet blanket, wedge; occurs as channel fills, crevasse splays, minor bars
Over- bank fines	OF	Fm	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

DEPOSITIONAL PALAEOENVIRONMENT

The Ferruginous Claystone Member affiliated studied outcrops lithofacies assemblage, having 3.17 – 3.69 m thick sections, composed of mudstone and sandstone that thicken upward. This assemblage may have formed due to increasing volume of crevasse splay sedimentation during successive flooding (e.g., Willis, 1993; Horton et al. 2001). Sandstones contain massive, horizontal and tabular cross-stratification exhibit relatively higher width to thickness ratio, and are characterized by basal contacts that are non-erosive and on desiccated cracked mudstone. These sandstones are attributed to crevasse-splay deposition. Curved, cracked, elongated mudstone related to desiccation feature shows evidences of an ephemeral fluvial system. Desiccation indicates about arid condition and massive sandstone; deposited by flash flooding event, further points towards an ephemeral fluvial system. Presence of massive sandstone, which has been deposited by rapid sedimentation during flash flooding event, further corroborates the mentioned depositional settings. Absence of plants and plants roots in the sediments also points towards arid condition of the region during the deposition. The depositional palaeo-environmental reconstructions suggest that these sediments were deposited, by a smaller scale ephemeral fluvial system in proximity to shoreline during regressive stage, in crevasse-splay and overbank settings. Similar type of crevasse splay deposit has been observed in the Potoco Formation of late Eocene to Oligocene in the Altiplano plateau, in the form of a common lithofacies assemblage is a 5–10-m-thick section composed of overbank siltstones and crevasse-splay sandstones that coarsen and thicken upward and are overlain by a 1–3-m thick sandstone (Horton et al. 2001).

The environment of deposition of Middle Member, comprising limestones and associated sediments, of Naredi Formation has been interpreted as marine shelf setting. The ferruginous claystone in the upper part indicates re-

gression (Biswas, 1992). The ferruginous claystone member is barren from fossils and so no specific age can be assigned. Our study points out that studied sandstone facies assemblage belonging to the ferruginous claystone member of Naredi Formation were deposited in a fluvial environment, near coastal region, during regressive phase of the sea level in the region.

CONCLUSIONS

The studied outcrop sections of the Ferruginous Claystone Member (Naredi Formation) consist of clastic rocks (sandstones and mudstones). The sedimentology of the studied outcrops is dominated by two main facies assemblages, i.e. sandstones and mudstones. The outcrops comprise of Sm, Fm, Sp, and Sh lithofacies. The depositional palaeo-environmental reconstructions suggest that these sediments were deposited, by ephemeral fluvial systems, in crevasse-splay type of depositional settings.

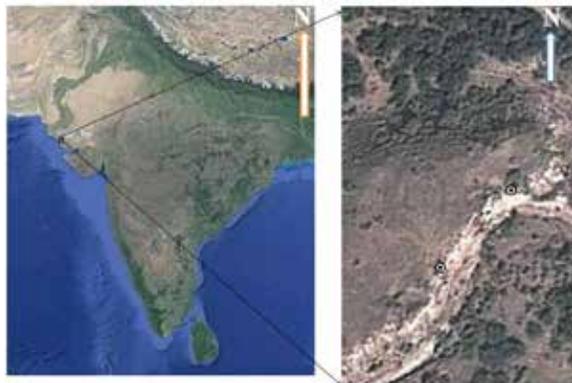


Fig. 1. Satellite imagery of India with location of Kutch showing outcrops 1 and 2. These outcrops are exposed south of the village of Naredi in Kutch. The distance between outcrops 1 and 2 is about 30 meters (Imagery source – Google Earth).

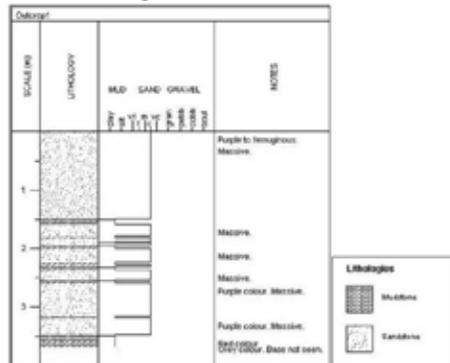


Fig. 2. Litho log of Outcrop 1.

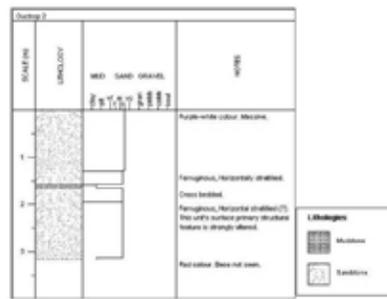


Fig. 3. Litho log of outcrop 2.



Fig. 4. Photograph showing mudstone (Fm) and massive sandstone (Sm) above it. Massive sandstone also has few faint laminations. Curved, cracked, elongated mudstone related to desiccation process.



Fig. 5. Horizontally stratified sandstone (Sh).



Fig. 6. Planar cross-bedded sandstone (Sp). Cross-bedding indicates flow direction towards left of the photograph.

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