Facies and Ichnotaxonomy of Bhuj Formation near Godpar Village, Southwest of Bhuj, Kachchh, Western India

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Abstract—The study area comprises of Bhuj Formation, which is divided into two members that are Lower Member and Upper Member. Lower most bed of the Upper Member of the Bhuj Formation is characterised by highly bioturbated, coarse grained ferruginous sandstone, which marks the boundary between the Lower and Upper Member. Four facies are identified from the study area are Cross Bedded Sandstone Facies (CBSF), Intercalated Siltstone Shale Facies (ISSF), Bioturbated Ferruginous Sandstone Facies (BFSF) and Shale Facies (SF). Common trace fossils found in the study area are Skolithos and Diplocraterion associated with Pholeus and Planolites. Skolithos is most dominant and is represented by four species like S. annulatus, S. ingens, S. linearis and S. verticalis. The lithology, sedimentary structures and the associated trace fossils of the study area indicating the depositional environment ranges from foreshore to middle shoreface zone of shallow silici-clastic Kachchh basin.

Key words: Facies, Ichnotaxonomy, Godpar, Kachchh

I. INTRODUCTION

Kachchh basin is filled over 3000 m thick Mesozoic sediments which are exposed in six disconnected areas that are major uplift zones and forms highlands amidst extensive plain land – (a) Kachchh Mainland (b) Pachcham Island (c) Khadir Island (d) Bela Island (e) Chorar Hills and (f) Wagad [1]. The stratigraphic sequence of the mainland is divided into four formations, formally named as Jhurio, Jumara, Jhuran and Bhuj Formations in ascending order. Age of the Bhuj Formation ranges from Neocomian to Santonian i.e. Lower Cretaceous [2]. The prime objective of the paper is to describe the trace fossils as well as lithofacies and based on these two parameters to deduce the probable environment of deposition of the study area.

II. STRATIGRAPHY OF STUDY AREA

The study area falls in Kachchh Mainland. Godpar is lying 20.1 km southwest of Bhuj city with the coordinates 23°07'03.32''N and 69°32'39.03''E. Bhuj Formation informally divided into two members that are Lower and Upper (Fig. 1). Lower Member of Bhuj Formation is characterised by cyclic repetition of ferruginous or lateritic bands, shales, and sandstones. It consists of medium grain yellowish to brownish sandstone, pink siltstones, and variegated shales. Among the sedimentary structures, cross-stratification is common along with ripple marks and overlapping sequence.

Upper Member of Bhuj Formation is characterised by cyclic repetition of ferruginous sandstones and variegated shales. It consists of pale brown, massive, coarse grained, well sorted sandstone with abundant bioturbation and kaolinitic shale with yellow, pink, grey and brown colour. Ripple marks and structures produced due to differential erosion by wind action are preserved in the sandstones. Few fragmented unidentified plant fossils are present. Trace fossils found in this member are Skolithos and Diplocraterion associated with Pholeus and Planolites.

III. FACES

The discrimination of the facies is based on the area of occurrence, stratigraphic position, distinctive lithologic features such as textures, structures, composition, and colour as well as physical and biogenic sedimentary structures. Stratigraphic section (Fig. 2) measured along Godpar stream, between the village and earthen dam is 16.26 metres.
A. Cross Bedded Sandstone Facies (CBSF)
1) Description
This facies is defined based on coarse grained sandstones, which are characterised by cross-stratification in Lower Member of Bhuj Formation (Fig. 3a). Sandstones are white, buff, yellow to pink in colour, medium to coarse grained, poorly to moderately sorted, friable, current bedded and felspathic.

2) Interpretation
The cross-stratified nature of the facies indicates deposition of the sediments took place in the high energy subtidal environment [4]. It indicates a high, but fluctuating, hydrodynamic regime and high rates of sediment supply. Low bioturbation intensity and ichnodiversity is consistent with a high energy regime [5]. Low and high-angle planar cross-stratification and the overall paucity of bioturbation suggest middle to upper shoreface setting [6].

B. Intercalated Siltstone Shale Facies (ISSF)
1) Description
The facies is developed in Lower Member of Bhuj Formation. It is predominantly argillaceous in nature with thin intercalations of siltstones in the shale sequence (Fig. 3b). The shale beds are thinly laminated with various colours like yellow, grey, pink, yellowish green and even black. Siltstones intercalated with shale are cream, reddish to yellowish in colour, contains minute flakes of mica and calcareous in nature.

2) Interpretation
Dominance of argillaceous material with thin alternate bands of siltstone in the lower part of sequence indicates deposition under low energy conditions and it could be below normal wave base on the shallow marine shelf. In the upper part of the sequence, arenaceous material dominates along with argillaceous material, which indicates deposition in shallower condition and it could be above wave base on an open marine shelf. So, this facies indicates transgression and standstill conditions, which is followed by the regressive condition in the upper part. Silt- and clay-rich inter-beds are formed under lower energy conditions [5] and very slow settling of the suspended fine hemipelagic material deposited below the normal wave base [7].

C. Bioturbated Ferruginous Sandstone Facies (BFSF)
1) Description
This facies is highly bioturbated, which indicates the deposition in the area where waves and current stratification is over shadowed by biological reworking [8]. Such conditions suggest slow to negligible rate of sedimentation. Higher bioturbation intensities reflect longer hiatuses between depositional events [9]. Above characters suggests the foreshore environment of deposition for the facies.

D. Shale Facies (SF)
1) Description
It consists of variegated shale, developed in Upper Member of Bhuj Formation. This facies is argillaceous in nature (Fig. 3d). Thin bands of shale are present in between medium to coarse grained sandstones of BFSF. The shale beds are thinly laminated with various colours like yellow, grey, pink and cream.

2) Interpretation
Dominance of fine grain material suggests low energy environment of deposition. The facies occur in form of thin
bands intercalated with coarse, ferruginous and highly bioturbated sandstones. Fine grain sediments are also deposited in estuarine marshes and inter-distributary bays [10]. The fine grained sediments and the gypsum content suggests a quiet water or low energy conditions of protected environment e.g. lagoon; while the predominant argillites with ferruginous layers, indicates a reducing environment [4]. It suggests a low energy depositional setting protected from tidal/storm currents.

IV. ICHNOTAXONOMY

In all 6 ichnospecies of 3 ichnogenera were identified and described from the study area. In the present study, ichnogenera and ichnospecies are named according to the International Commission on the Zoological Nomenclature (I.C.Z.N.) rules. Sandstones of Upper Member of Bhuj Formation are highly bioturbated, almost occupying entire bed. All the trace fossils of the study area are found from BFSF.

A. Plug Shaped Form

- Ichnogenus: Monocraterion Torell, 1870
- Ichnospecies: Monocraterion isp. (Fig. 4a-c)

1) Description

There are straight cylindrical burrows, perpendicular to the bedding plane. On the bedding plane, they appear as circular to sub-circular outline - funnel shaped, with a prominent central shaft. Many specimens show funnels with raised rims, which may reflect lining to the funnels. The diameter of funnel varies from 2.5-3 cm with the central shaft diameter of 15 mm.

It is considered as dwelling burrow, probably belonging to gregarious, suspension-feeding worm like organism, possibly a polychaete. These are commonly abundant, but never crowded like Skolithos. Funnel obviously constructed by upward migration of animal inhabiting tube. Central shaft considered as the top expression of the vertical tube and the specimens lacking in radiation burrows (tentacles) but presenting funnels are referred to as Monocraterion isp., which is a purely descriptive scheme [16].

B. Spreiten Structure with U-shaped form

- Ichnogenus: Diplocraterion Torell, 1870
- Ichnospecies: Diplocraterion parallelum Richter, 1926 (Fig. 4d)

1) Description

These are fairly straight and uniform U-tubes. Both the tubes are parallel to each other with a rounded base and perpendicular to the bedding plane. The U-tube has moderately developed spreite, which is protrusive. High burrow density at many places indicates sever phase of burrowing. Tube diameter is about 1 cm and almost 5 cm apart from each other.

It is considered as dwelling burrow of suspension feeding animal, probably living in the environment of high wave energy. Complementary ichnologic information indicates that the appearance of Diplocraterion parallelum points to a change from the Cruziana ichnofacies to a mixed Skolithos-Cruziana assemblage, which could be related to increasing energy accompanying a relative shift of the area towards more proximal and shallower depositional settings during a relative sea-level fall. This fall and the concomitant increase energy could have generated higher nutrient contents within the water column, favouring substrate colonization by Diplocraterion trace makers [17].

D. Ichnospecies: Skolithos ingens Howell, 1957 (Fig. 5a and b)

1) Description

Burrows are cylindrical and vertical. The diameter is about 7 to 9 mm and the burrow walls are distinct. Burrows characterized by slight bulges at an irregular interval; which are 3 to 4.5 mm long, and increase in the diameter by 1.5 mm than the main tube.

It is interpreted as dwelling trace – Domichnia. It can be differentiated from the other species of Skolithos by distinct ring-like annulations [11].
E. Ichnospecies: Skolithos linearis Haldeman, 1840 (Fig. 5c-e)
1) Description
These are cylindrical to sub-cylindrical, straight to slightly curved, vertical or steeply inclined burrows, lined, with no ornamentation and burrow tubes are without funnel shaped aperture. It usually occurs in large numbers, but if found isolated, burrow wall is distinct and it appears as the small ring-like projections on the bedding plane. The Length of the burrow in cross-section observed is about 15 cm, while diameter ranges from 0.7 to 2.5 cm. Skolithos linearis most commonly occur in arenaceous sediments and is unique in the preservation of sediment mounds (distribution zone in cross section) associated with it. Although these features are not part of the burrow itself, they reveal some habits of the species which created the burrow.

Various forms are included in this species, from closely crowded, straight burrows (comprising whole rock) to relatively isolated, slightly undulating burrows, but the two extremes were found to intergrade in Swedish occurrences of S. linearis [11]. S. linearis is similar to S. verticalis but differs by the smaller shaft diameter, not crowded and being commonly curved in the case of later. Skolithos represents the dwelling burrow of suspension feeding polychaete or phoroid [12]. It is widely recognized in shallow water intertidal deposits and in floodplain facies [13]. It is common in sandstone deposited under high energy tidal and near shore conditions [14][15].

F. Ichnospecies: Skolithos verticalis Hall, 1843 (Fig. 6a-d)
1) Description
Burrows are cylindrical, straight to curved, vertical to inclined. Diameter is about 8 to 10 mm and length ranges from 10 to 15 cm. Burrow walls are smooth and rarely corrugated. The sediment in the burrows tends to weather out readily, leaving the burrows as holes in the rock. The Skolithos verticalis burrows are generally shorter and smaller, and more commonly inclined and curved than S.linearis, and are never extremely crowded.

It is considered as dwelling burrow and differs from S. linearis by having rough and annulated walls.

V. CONCLUSIONS
The Study area is a part of Kachchh Mainland which comprises rocks of Lower and Upper Member of Bhuj Formation. The Lower Member shows the repetitive development of CBSF and ISSF. CBSF indicates foreshore to upper shoreface environment, while ISSF shows middle shoreface conditions of deposition, which suggests that the depositional environment was fluctuating from foreshore to middle shoreface.

Upper Member of Bhuj Formation consists consecutively by thick BFSF and thin layers of SF. The major part of the member is covered by thick layers of BFSF, which are highly bioturbated and ferruginous. Skolithos are dominating over the Monocraterion and Diplocraterion, which covers the entire bed and even obliterate the physical sedimentary structures. Lithological and ichnological characters suggest that the foreshore environment of deposition of the Upper Member.

Age of the Bhuj Formation ranges from Neocomian to Santonian i.e. Lower Cretaceous [2]. The environment of deposition was fluctuating from foreshore to middle shoreface in the study area during Lower Cretaceous.

REFERENCES
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