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Jurassic shelf sedimentation and sequence stratigraphy of the Surghar Range, Pakistan

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ABSTRACT

In the Surghar Range, facies and biostratigraphical analysis of Jurassic deposits show that the platform development was affected by both the variations in sea-level and the influences of a nearby hinterland. The well exposed shallow marine to intertidal sediments of the Shinawari Formation and the Samana Suk Formation were deposited from the Toarcian to the middle Callovian.

A rise in sea-level during the lower Toarcian submerged the area which was a delta plain before. Shallowing upward cycles and smaller-scale paracycles are characteristic for the marine sequence. Relative sea-level lowstands occurred during the Bajocian, the Bathonian and the Callovian. The lower two coincide with terrigenous influx from the southeast. A lower Callovian hardground is overlain by transgressive middle Callovian open marine limestones. The Jurassic shallow marine platform development ends with another hardground. Drowning of the platform is indicated by the overlying deeper shelf deposits of the Oxfordian - Neocomian Chichali Formation.

INTRODUCTION

Jurassic sediments form a part of a well-exposed rock sequence in the Surghar Range. A variety of clastic and carbonate materials were accumulated on the northern shelf of the Indian plate (Fig. 1). The sediments compose the part of the southernmost tectonic unit of the foreland fold-and-thrust belt of the Himalaya (Duroy et al. 1989).

After the studies of Waagen (1875) and Wynne (1878), Jurassic rocks have been reported to occur in Potwar Plateau. Various names were given to the different strata from top to bottom, "Belemnite Beds" (Wynne, 1878; Gee 1947) or "Chichali Formation" (Danilchik, 1961), "Kioto Limestone" (Cotter, 1933; Gee 1947) or "Samana Suk Limestone" (Davies, 1930) or "Baroch Limestone" (Gee, 1947) and "Variegated Beds or Stage" (Wynne, 1878, Gee 1947) or "Datta Formation" (Danilchik, 1961).

Fatmi (1974) formalized the names of rock units into the Chichali, Samana Suk, Shinawari, Datta and formations (Table 1). Gee (1980) mapped the entire Salt Range. Mensink et al. (1988) proposed the Baroch and Surghar groups combining all the formations. Gee (1989) adopted this grouping, and Fatmi et al. (1990) published a parallel nomenclature. The Jurassic succession comprises the Baroch Group and a part of the Surghar Group. The boundary with the Triassic Musa Khel Group is a discontinuity. The upper boundary of the Baroch Group is a distinct hardground covered by a ferruginous crust. The topmost part of the Baroch Group is separated by another hardground (Makarwal Formation; Mensink et al., 1988). The Surghar Group consists of the Chichali and Lumshiwal formations, which are made up of glauconitic rocks and sandstones, respectively.

BIOSTRATIGRAPHY

Biostratigraphy of the Datta Formation is based on palynological assemblages representing the early Jurassic (Masood and Bhutta, 1985). Determination of ages of the Shinawari and Samana Suk formations is based on ammonoids, foraminifera, and algae. Fatmi et al. (1990) reported the occurrence of *Bouleiceras* cf. *nitecens* Thevenin in the basal part

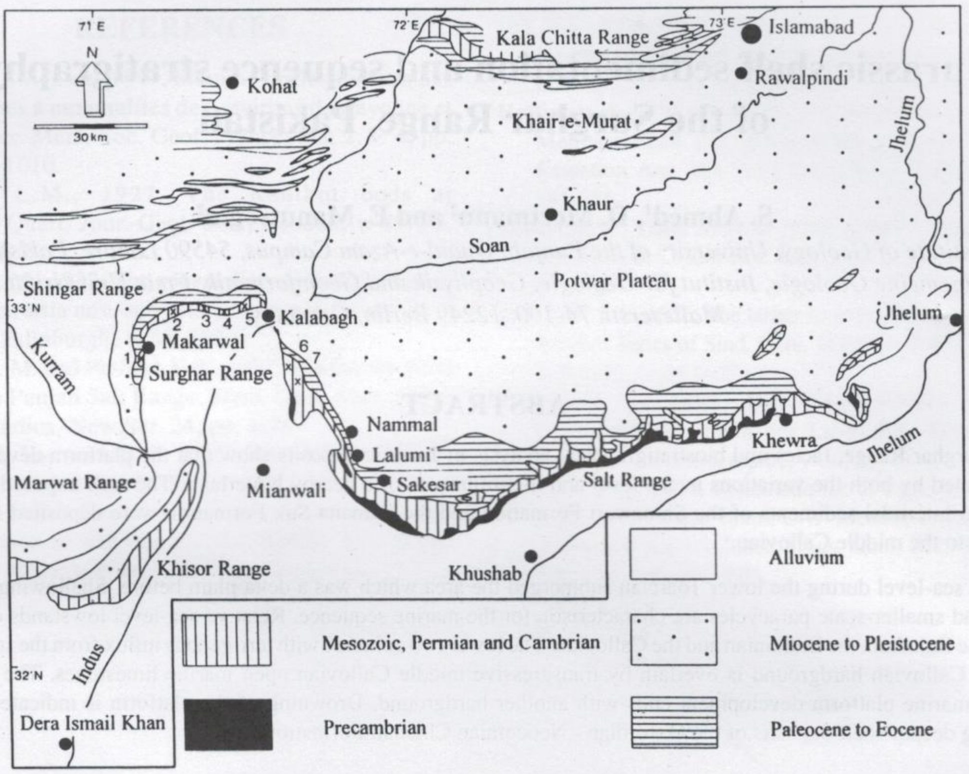


Fig. 1: Simplified geological map of the Salt Range, stretching out between Jhelum and Kalabagh, and the Trans Indus Ranges located between Kalabagh and Dera Ismail Khan (after Gee 1989). The Surghar Range is the northeastern part of the Trans Indus Ranges. Locations of the measured sections are indicated (x). 1 - Miranwal Nala, 2 - Baroch Nala, 3 - Gulakhel, 4 - Narmia, 5 - Chichali Pass, 6 - Daud Khel, 7 - Thatti.

of the Shinawari Formation from Landu Nala, thus indicating the age of lower Toarcian. From the topmost part of the Samana Suk Formation ammonoid Fatmi (1972) and Mensink et al. (1988) described faunas. A fragment of *Macrocephalites* indicates a Lower Callovian age and *Reineckeia anceps* (Reinecke), *Reineckeia* cf. *torulosus* (Spath), *Choffatia* sp., *Hubertoceras* sp., *Obtusicostites* sp., and *Obtusicostites buckmani* Spath indicate the middle Callovian age. The rocks yield a variety of foraminifera and algae assemblages that indicate a Toarcian-Bajocian, Bathonian and Callovian (Dragastan et al. 1993). The most interesting feature is the diachronous nature of the upper Shinawari Formation in the western part of the Surghar Range, presumably all Bajocian, whereas towards the east it is in part Bathonian in age.

The Chichali Formation is rich in ammonoids. The formation represents a presumably condensed section of Upper Oxfordian to Valanginian. The upper part may be the Hauterivian to Barremian (Fatmi, 1972). Köthe (1988) mentioned only an Oxfordian to Tithonian age for the Chichali Formation based on calcareous nannofossils.

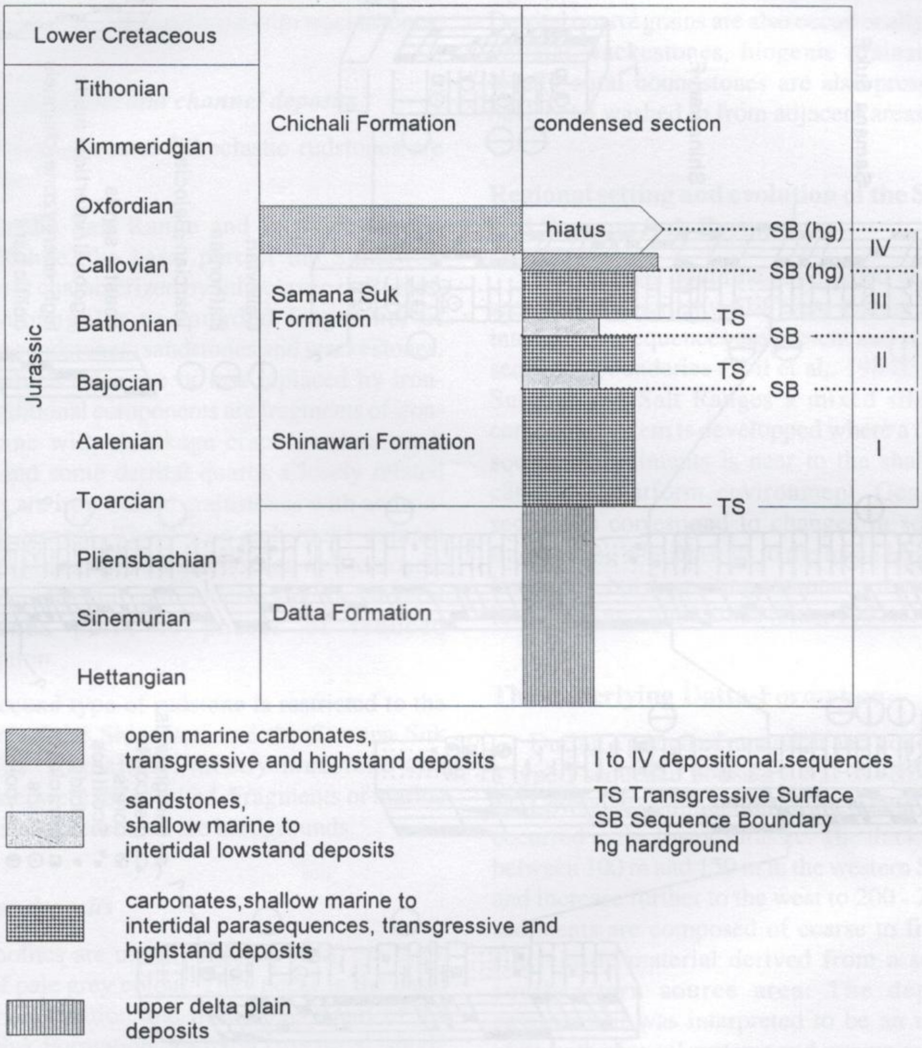
Lithofacies Interpretation

The lithofacies of the Shinawari and Samana Suk formations (Fig. 2) belongs to five depositional environments (Mertmann and Ahmed, 1994).

Coastal sands

Within the Shinawari Formation yellowish-brown beds of siliciclastic material range in thickness from a few centimeters to about 20 m. These parts weather readily in comparison with the carbonates.

Table 1: Depositional sequences of the Jurassic succession in the Surghar Range.



Sandstones and calcareous sandstones are composed mainly of angular to subangular detrital quartz with minor amounts of plagioclase, rock fragments, and trace amounts of zircon, biotite, and heavy minerals. The grain size of quartz varies from coarse silt to medium sand. The cement is calcite. Some beds contain crinoid debris and fragments of molluscs. Finer siltstones are present, and occasionally fine grained conglomerates form the basal fill of small-scale channels. Typical features are ripple crossbedding, flaser bedding, and *Skolithos* burrows. Each sandstone bed forms the upper part of a superimposed shallowing-upward cycle.

Lagoonal and tidal flat deposits

Lagoonal and intertidal muds, usually thin-bedded, are present throughout the section. They overlie shallow marine sediments, and develop subsequently out of shallow marine sediments towards the top of indistinct beds, thus representing part of small-scale shallowing upward cycles.

Typical rock types include mudstones, laminated mudstones-wackestones, some with fenestral fabrics, pelletal grainstones, and wackestones with gastropods, some with foraminifera, algae, ostracods, and shell fragments. Freshwater influence is

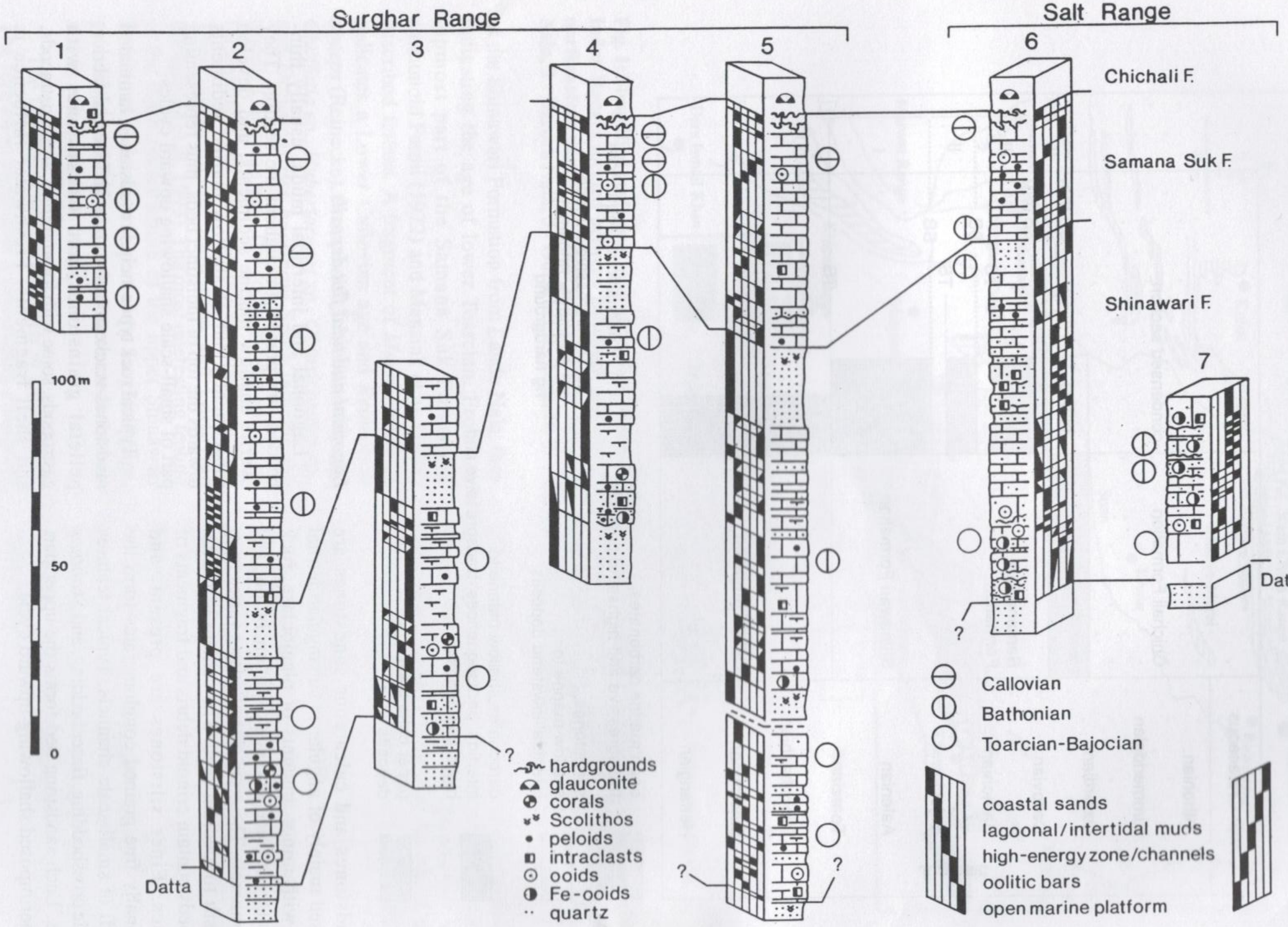


Fig. 2: Measured sections in te Surghar Range and the Salt Range with their facies succession. 1-Miranwal Nala, 2-Baroch Nala, 3-Gulakhel, 4-Narmia, 5-Chichali Pass, 6-Daud Khel, 7-Thatti.

indicated by the presence of charophyte gyrogonites. Several beds with regular mud cracks occur, and dinosaur footprints are associated with wackestones.

High energy coastal and channel deposits

Two types of coarse lithoclastic rudstones are distinguished:

Within the Salt Range and in places in the Surghar Range, the basal part of the Shinawari Formation is characterized by lithoclastic rudstones, rich in subangular to rounded fragments of calcareous sandstones, sandstones and wackestones, some of which are more or less replaced by iron-oxides. Additional components are fragments of iron-crusts, some with shrinkage cracks, coarse shell remains, and some detrital quartz. Closely related rock types are iron-oolitic grainstones with an iron-carbonate cement. These iron-rich rocks contain much detrital quartz and lithoclasts as well as coarse shell fragments and echinoderm debris. Several hardgrounds point to phases of reduced sedimentation.

The second type of rudstone is restricted to the upper part of the Shinawari and the Samana Suk formations. Intraclasts, mostly mudstone and wackestone, were redeposited. Fragments of marine organisms are present, as are hardgrounds.

Oolitic bar deposits

Beds of oolites are usually only up to 20 cm thick and are of pale grey colour. They occur in the basal Shinawari Formation and in the upper part of the Samana Suk Formation. Radially structured, single ooids up to 1 mm in diameter dominate. Only few compound ooids are present. In addition coated grains, bahamites, crinoid debris, shells, foraminifera, and algae occur.

Marine subtidal deposits

A more diverse and richer fauna and flora characterize rocks deposited in open marine subtidal environments. The rocks are also bioturbated. Biogenous wackestones and packstones contain crinoids, brachiopods, mollusc debris, and complete specimens of pelecypods, gastropods, as well as occasional ammonites, bryozoans, foraminifera, algae, pellets, some coated grains, and bahamites. Detrital quartz grains are also occasionally observed. Pelletal wackestones, biogenic grainstones, and locally coral boundstones are also present. Ooids have been washed in from adjacent areas.

Regional setting and evolution of the Shinawari and Samana Suk Formations

The sections could be subdivided according to sequence stratigraphy. Different system tracts with internal parasequences are present and separated by sequence boundaries (Vail et al,. 1984). Within the Surghar and Salt Ranges a mixed siliciclastic - carbonate system is developped where a terrigenous source of sediments is near to the shallow water carbonate platform environment. Generally, the sediments correspond to changes in sea-level by transporting siliciclastics to the basin largely during lowstands, but depositing carbonates during both the lowstands and highstands (Haq, 1991).

The underlying Datta-Formation

During a period of emersion and non-deposition a type I sequence boundary was developed (Table 1). Lowstand sedimention of the Datta Formation occurred in the lower Jurassic. The thickness varies between 100 m and 150 m in the western Salt Range, and increase further to the west to 200 - 230 m. The sediments are composed of coarse to fine grained siliciclastic material derived from a southern to southeastern source area. The depositional environment was interpreted to be an upper delta plain with channel systems and swamp areas in front of the Indian shield (Stoen and Kennedy, 1970).

The Shinawari and Samana Suk Formations

The Shinawari Formation consists of alternating sandstones and limestones. The boundary with the Samana Suk Formation is at the top of the uppermost sandstone bed. The latter formation is almost free of detrital quartz grains. The topmost part of the Samana Suk Formation is characterized by two iron-stained hardgrounds, intensively bored, enclosing about 2-5 m of fossiliferous limestone of an open marine facies indicated by the middle Callovian ammonites, brachiopods, and pelecypods. The upper boundary is the younger hardground, which is overlain directly by the Chichali Formation. Total thicknesses in the Salt Range and Surghar Range vary between 20 m at Lalumi to about 200 m at Baroch Nala, becoming even thicker to the north (Kala Chitta and Hazara more than 350 m), and to the west at Khisor Range possibly more than 450 m (Stoen and Kennedy, 1970; Fatmi, 1974).

The Daud Khel area is considered to represent the typical rock succession of the western Salt Range. Deposition took place in a nearshore high energy environment by wave action. The steady input of coarse quartz material indicates a nearby source area that persisted throughout deposition of the Shinawari Formation. Sedimentation of the Samana Suk Formation started during the Bathonian and lasted into the middle Callovian. Open marine biogenic facies alternate with lagoonal sediments, the latter being dominant below the older hardground.

Conditions of sedimentation in the west of the Indus River allow to distinguish depositional sequences which are characterized by marine influences versus terrigenous input from the hinterland (Table 1).

The sediments representing the transgressive and highstand system tract of the first depositional sequence range in age from the Toarcian presumably to the Bajocian. They overlie a transgressive surface (boundary with the Datta Formation). The initial deepening of the sea documented by reworking during transgression and deposition of ferruginous ooids was followed by small-scale alternations of more open-marine wackestones and grainstones as well as lagoonal limestones. Marls are intercalated. In the Baroch Nala and Gulakhel, small coral patch reefs are present, but are internally completely recrystallized.

The second depositional sequence ranges in age from the Bajocian to the Bathonian. The widespread lower sandstone horizon with abundant *Skolithos* burrows and wavy bedding indicates a shallow-water to intertidal environment. It is interpreted as a lowstand deposit above a sequence boundary. The transgressive surface separates it from transgressive and highstand deposits, again arranged in shallowing upward parasequences. In the eastern Surghar Range, it belongs to the part of the Shinawari Formation whereas in the western Surghar Range it is attributed to the Samana Suk Formation.

A third depositional sequence started again with lowstand sandstones exposing *Skolithos* burrows. In the western Salt Range terrigenous content diminished considerably. The following transgression of the sea led to a thick sequence of lagoonal and shelf limestones. In places oolitic grainstones occur, and reworking occasionally took place. The younger part of the Samana Suk Formation and the entire formation in the eastern Salt Range show small-scale shallowing upward cycles with minor intercalations of oolitic grainstones. This younger part of the section is Bathonian and lower Callovian in age. A terminal hardground is covered with a ferruginous crust and bored by bivalve species.

The following fourth depositional sequence, transgressive and highstand system tract, is of middle Callovian age. Compared to the underlying sediments effects of transgression were much more accentuated. Ammonoid fauna colonized the environment (Bassoullet et al., 1986; Cariou et al., 1985). There is no phase of initial deepening preserved. This immediate increase in water depth was related to a downwarping of the platform. Only up to 5 m of deposits are present, which are covered by another hardground with a ferruginous crust, and again bored. A period of non-deposition lasted from the middle Callovian to the upper Oxfordian. Interpretation of the hardgrounds remains difficult. Einsele (1985) postulated that extensive submarine erosion and long submarine exposure of hardgrounds occurs only if sea level fall is faster than subsidence, (i.e., during regression). But Fursich et al. (1992) interpreted hardgrounds to be tied to phases of relative sea-level rise. Terrigenous sediments are trapped elsewhere, shallow water carbonate shoals may drown and become exposed to open marine currents. Both Callovian hardgrounds may however represent sequence boundaries.

The overlying Chichali Formation

The Chichali Formation is an easily weathered unit, usually of dark green colour. Its thickness ranges up to 60 m. It consists of glauconitic sandstones, siltstones, claystones, and marls arranged in two shallowing upward cycles (Hallam and Maynard, 1987). In the lowermost 10 cm of the Miranwal section, reworked and bored micritic limestone fragments are found. Some phosphoritic and carbonate concretions occur with ammonoids preserved in the center. Belemnites, *Hibolites, Belemnopsis, Duvalia*, and *?Dicoelites* and exogyriform pelecypods are abundant in the basal part, but are also present higher up. In the Surghar Range minable ironstone horizons composed of goethite-glauconite pellets are developed locally. Hallam and Maynard (1987) regarded the sediments as lag deposits that accumulated in never more than a few tens of meters water depth. The Chichali Formation generally represents a "condensed section" within the depositional sequence, which occurs partly at the top of the transgressive system tract and partly within the highstand system tract. It is created by sediment starvation on the outer shelf. During a relatively long time period a basinward depositional environment persisted.

CONCLUSIONS

The largest trend records a general deepening of the sedimentary basin during the Jurassic to the lower Cretaceous. This trend can be correlated with the first/second order long term transgression associated with the breakup of Pangaea and rapid sea floor spreading during the Upper Jurassic/Lower Cretaceous (Einsele, 1992; Vail et al., 1984). Within the Shinawari and the Samana Suk Formations four depositional sequences correspond to third order cycles. Several more sequences are possibly hidden in the Chichali Formation.

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