Physical and biological changes across the Jurassic/Cretaceous Boundary in northwestern Kutch Basin

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In the northwestern part of the Kutch Basin, Lower Cretaceous shales and trigonid-bearing / bioturbated/ barren sandstones, overlie the glauconitic Upper Tithonian *Virgatosphinctes*-bearing "Umia Ammonite Bed" (138±20 Ma). During the lithofacies studies of this sequence, lithology, physical and biogenic sedimentary structures, bed geometry, palaeocurrent and fossil contents were given special attention. Laboratory investigations of heavy minerals, rock fragments and clay minerals revealed two distinct assemblages, one for the lower (Jurassic) and other for the upper (Cretaceous) part of the sequence. Lower part of the sequence is rich in low energy sedimentary structures, biogenic structures of sediment and deposit feeder, heavies and rock fragments of metamorphic province and clay minerals of marine origin. On the other hand, the upper part is rich in high energy sedimentary structures, biogenic structures of suspension feeders, heavies and rock fragments of granitic province and clay minerals of fresh to brackish water origin. These differences are of vital importance in delineating major changes such as shoreline orientation, changing provenance, relative sea level and tectonics during Jurassic/Cretaceous period in northwestern Kutch Basin.

Key-words—Sedimentology, Jurassic, Cretaceous, Kutch Basin, India.

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साराँश

उत्तर-पश्चिमी कच्छ द्रोणी में जुरेसिक/क्रीटेश्यस सीमा पर भौतिक एवं जैविक परिवर्तन

नागेश्वर दूबे एवं बिनय कुमार चटर्जी

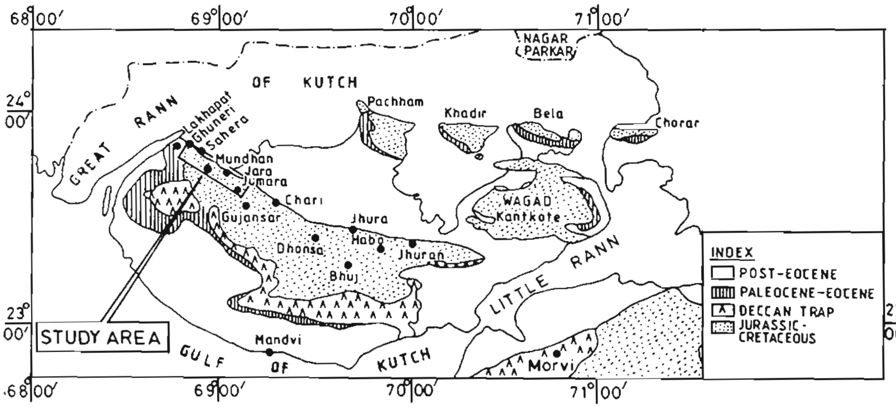
कच्छ द्रोणी के उत्तर-पश्चिमी भाग में अधरि क्रीटेश्यस शैल, ट्राइगोनिड-धारक/जैवजनित संरचना/जीवाश्म विहीन बलुआ पत्थर ग्लॉकॉनाइटी उपरि टिथोनियन *विरगेटोस्फिंक्टीस*-धारक ''उमिया अमोनाइट संस्तर'' (13.8±2.0 करोड़ वर्ष) के ऊपर विद्यमान हैं। इस अनुक्रम के शैल-लक्षणी अध्ययन के समय शैलविज्ञान, भौतिक एवं जैवजनित अवसादी संरचनाओं, संस्तर ज्यामिति, पुराधारा तथा जीवाश्मों की प्रचुरता पर विशेष ध्यान दिया गया है। भारी खनिजों, शैल खण्डों एवं मृदा खनिजों के विश्लेषण से दो विभिन्न समुच्चयों की उपस्थिति व्यक्त हुई है। जिनमें से एक अधरि (जुरेसिक) तथा अन्य उपरि (क्रीटेश्यस) है। अनुक्रम के निचले भाग में अल्पऊर्जा जनित अवसादी संरचनाओं, अवसाद व निक्षेप भोगी जैवजनित संरचनाओं, कायान्तरी प्रदेश के भारी खनिजों एवं शैल खण्डों तथा समुद्री उत्पत्ति के मृत्तिका खनिजों की प्रचुरता है। जबकि ऊपरी भाग में तीव्र ऊर्जा जनित अवसादी संरचनाओं, निलम्बन-भोगी जैव-जनित संरचनाओं, ग्रेनाइट के भारी खनिजों एवं शैल-खण्डों तथा खारे व अलवणीय जल में उत्पन्न मृत्तिका खनिजों की बाहुल्यता है। कच्छ द्रोणी में जूरेसिक-क्रीटेश्यस सीमा पर ये भेद प्रमुख परिवर्तनों जैसे पुरासमुद्ररेखीय सीमा, आनुपातिक समुद्री स्तर एवं विवर्तनिक गतिविधियों के अध्ययन में अत्यन्त महत्वपूर्ण सिद्ध हुए हैं।

WYNNE and Fedden (1872) divided the Mesozoic successions of Kutch Basin (Text-figure1) into a Lower (marine) and Upper (non-marine) unit. Later, Stoliczka (in Waagen, 1875) recognised four units, namely, Patcham, Chari, Katrol and Umia, in ascending order. This classification was followed by Rajnath (1932), Spath (1933) and later workers. Biswas (1977) classified the entire Mesozoic succession of the Kutch Basin into four lithostratigraphic units, i.e., Jhurio, Jumara, Jhuran and Bhuj Formations (Table 1).

A transgression of the epeiric sea produced argillaceous and calcareous, shallow marine, fossiliferous, tabular or sheet-like retrogradational succession (Jhurio, Jumara and partly Jhuran Formations) during Bajocian to Tithonian. This transgressive event reached its acme during Oxfordian, resulting in an aggradational succession of oolitic, fossiliferous hardground of limestone (Dhosa Oolite) in the upper part of Jumara Formation. Finally, major regression of Mesozoic sea produced wedge-shaped unit of coarsening and thickening upward, progradational succession partly Jhuran and Bhuj Formations) during Neocomian to Coniacian/ Turonian.

Table 1—Litho- and chrono-stratigraphical schemes of Mesozoic of Kutch with lithology of various units

WYNNE & FEDDEN (1872)	STOLICZKA in WAAGEN (1875)	RAJNATH (1932)	SPATH (1933)	BISWAS (1971, 77, 81)	PANDEY & DAVE (1993)	LITHOLOGY OF THE STUDY AREA	EPOCH AGE (Ma) SUCCESSION	PERIOD
UPPER (NON - MARINE)	UMIA GROUP	BHUJ SERIES: Palmoxylon beds; Ptilophyllum beds; Zamia beds	UMIA GROUP: Ukra beds	BHUJ FORMATION: UPPER or BHUJ		Thick, coarse, friable sst., with thin glauconitic bands (capped by laterite). Alternating thin, ferruginous, hard sst. & shale, bioturbated sst., coarse friable sst. & shales leaf impression. Sand:Shale= 4:1	CONIACIAN; ---89---; TURONIAN	CRETACEOUS
		UKRA BEDS: Calcareous shales		MIDDLE or UKRA		TRIGONID bearing two/three coquina bands with giant symmetrical ripple; green, glauconitic shale and sst. with fossiliferous bands. Oölitic lst. with wood trunk. Sand:Shale= 1:1	PTIAN-ALBIAN; ---112---	
		UMIA GROUP: Unfossiliferous mainly shales; Barren Sandstone		LOWER or GHUNERI	MUNDHANIAN STAGE	Cyclic repetition of thick, maroom, hard, highly bioturbated sst., coarse, friable, cross-bedded yellow/pink sst., laminated shales (coal, carbonaceous shales & paleosol?) Silty/Sandy shale and argillaceous sandstone, leaf impression + wood. Sand:Shale= 3:1	---120---; PROGRADATIONAL (PS); NEOCOMIAN	
			Barren beds	JHURAN FORMATION: KATESAR		Coarse, friable, greenish-yellow sandstone with abundant sedimentary structures, white gypsyferous shale with TRIGONID bearing thin bands of conglomeratic sandstones Oölitic sst. with leaf impression + wood. Sand:Shale= 2:1		
		TRIGONIA RIDGF Sandstone; Barren sandstone; Three green oolitic bands	TRIGONIA bearing sst.; Green oolitic beds	UPPER		Coarse, friable, cross-bedded sandstone; flaggy sst., shale TRIGONIA RIDGE SANDSTONE (very hard, fossiliferous & hard barren, calcite cemented sst., conglomeritic base); Three green, glauconitic, poorly oolitic, fossiliferous limestone at the base. (VIRGATOSPHINCTES bearing Umia Ammonite Bed) Sand:Shale = 3:1	---138---; TITHONIAN	
	KATROL GROUP	KATROL GROUP: UPPER Mainly shales & sst; MIDDLE Mainly sandstones	KATROL GROUP: Gajansar beds mainly shale; Barren sst.; Upper Katrol	MIDDLE	UMIAIAN	Thickly bedded, coarse, hard, compact, calcitecemented GRYPHAEA bed (Ridge), ferr., fossilliferous sst. silty/sandy shales. Locally coral bearing in JARA DOME, laterally extending and ridge forming. Thick shale beds producing valleys. Sand:Shale = 1:1	---140---; AGGRADATIONAL (AS)	
		LOWER Mainly shale	Middle Katrol; Lower Katrol; Kantcote sst.	LOWER	KATROLIAN	Thick, silty/sandy, poorly gypsiferous, grey-white shale with maroom nodules (sometimes enclosing fossils in their centers). Medium to coarse, hard, compact sandstones. Flaggy sandstone etc. forming small ridges. Sand:Shale = 1:2	KIMMERIDGIAN; ---145---	
	CHARI GROUP	CHARI GROUP: Dhosa Oolite (bed no.1); Atheleta beds (bed no. 1a-3)	CHARI GROUP: Dhosa Oolite; Atheleta beds	JUMARA FORMATION: UPPER	DHOSAIAN	Oolitic, (Dhosa Oölite) richly fossiliferous, glauco. lst. & (conglomeratic, intraformational), olive-green (khaki shale), (gypsiferous, nodule bearing, fossiliferous) & limestones (thick, yellow, fossiliferous, sandy, jointed). Shale predominates, shale > limestone	OXFORDIAN; ---152---	JURASSIC
		Anceps beds (bed no. 4 & 5)		MIDDLE	CHARIAN STAGE	Thick, very hard, highly fossiliferous, jointed, yellow small ridge forming limestone in thick olive green/ khaki shale, gypsiferous, with thin bands of biomicrite highly fossiliferous shale having nodules enclosing either ammonoids or septarian type). Shale predominates, shale > limestone		
		Rehmani beds (bed no.6); Zeilleria zone; Shales & sandstones	Anceps beds; Rehmanni beds	LOWER		Thick, gypsiferous, septarian & concretionary nodules bearing highly fossiliferous shale with thin bands of biomicrite (shell limestone), 'Golden Oölite' bearing fossiliferous limestone at KEERA DOME (East of study area). Shale predominates, shale > limestone	RETROGRADATIONAL (RS)	
LOWER (MARINE)	PATCHAM GROUP	PATCHAM GROUP: Bed no.22 cream coloured limestones; Bed no.22 to 26 and more at PATCHAM Island	Macrocephalus beds	JHURIO FORMATION: UPPER	BADIAN STAGE	Grey-white, thick, pebbly/conglomeratic highly fossiliferous limestone, coral bearing limestone, white calcareous shale (marl), olive green-grey, gypseous shale. Shale > limestone	CALLOVIAN; ---157---; BATHONIAN	
			PATCHAM GROUP: Patcham coral beds; Patcham Shell limestone	MIDDLE		Unexposed in the study area: Thickly bedded, grey-yellow shales alternating with golden oölite		
			Patcham basal bed; Kuar Bet Bed	LOWER		Thin beds of yellow and grey limestones with golden oölite in grey shale	---165---	
GORA DONGAR FORMATION; KALA DONGAR FORMATION (encountered in Banni well no. 2 and Nirona - 1)					PATCHAMIAN; BANNIAN	Mottled clay, claystone, shales, sst. with carb. matter, silty shale, minor limestone, lateritic clay, coarse sst., gravels, kaolinitic clay Sandstones, conglomerates, igneous wash etc.	BAJOCIAN; ---171---; AALENIAN; ---179---	



Text-figure 1—Geological map of the Kutch Basin with study area in northwestern part of Mainland.

Presence of well-preserved ammonites with other fauna facilitates high resolution chronological studies of Jurassic rocks whereas absence of mega index fauna in Cretaceous rocks (except Aptian-Albian, Ukra Member) makes it difficult to mark the base of Cretaceous. Three green, glauconitic, fossiliferous (Tithonian) oölitic, argillaceous limestone bands (1 m, 0.3 m & 0.1 m) alternating with grey, gypsiferous shale bands (1.5 m & 1 m), collectively known as 'Umia Ammonite Bed' mark the Jurassic/Cretaceous transition (Dubey & Chatterjee, 1996). This boundary roughly coincides with the Umiaian and Mundhanian stages of Pandey and Dave (1993). Glauconitic sample of middle band shows a radiometric age of 138 ± 20 Ma (Srivastava *et al.*, 1994). This age roughly coincides with global Jurassic/Cretaceous boundary. Among these three alternating glauconitic bands (1, 2, 3), bed thickness, glauconite and fossil content gradually decrease towards youngest (Figure 1). Occurrence of these glauconitic bands in the western part of the basin is totally facies dependent as they laterally pass into conglomeratic sandstone towards eastern part of the basin (continental side). The absence of glauconitic bands makes it difficult to demarcate the Jurassic/ Cretceous boundary in the central and eastern parts of the basin.

GEOLOGICAL BACKGROUND

Mesozoic sediments in the Kutch Basin directly overlie on Precambrian granitic/syenitic basement with an unconformity (Biswas & Deshpande, 1968).

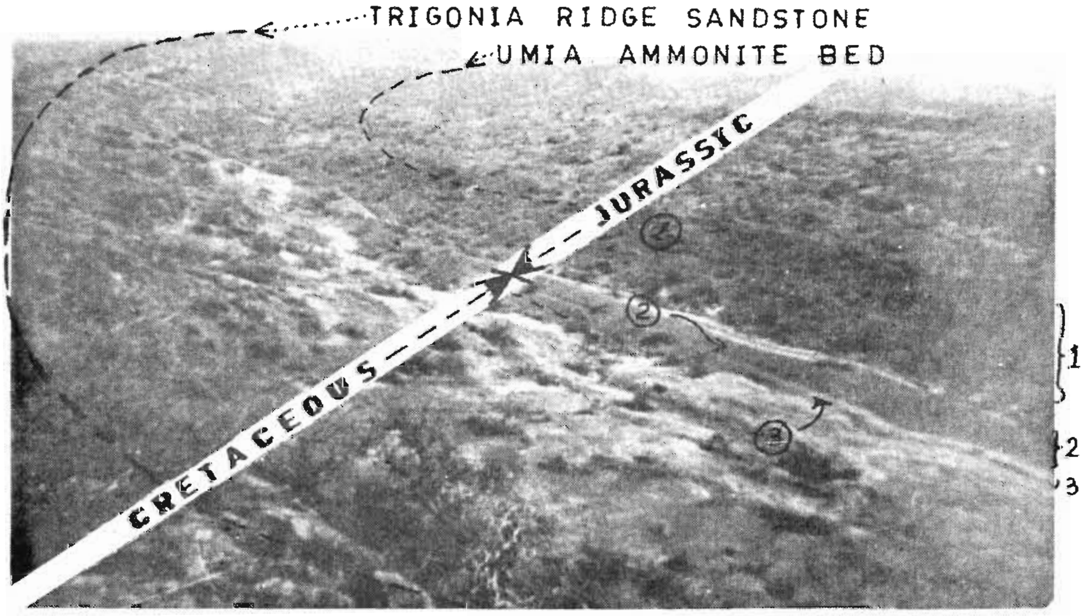
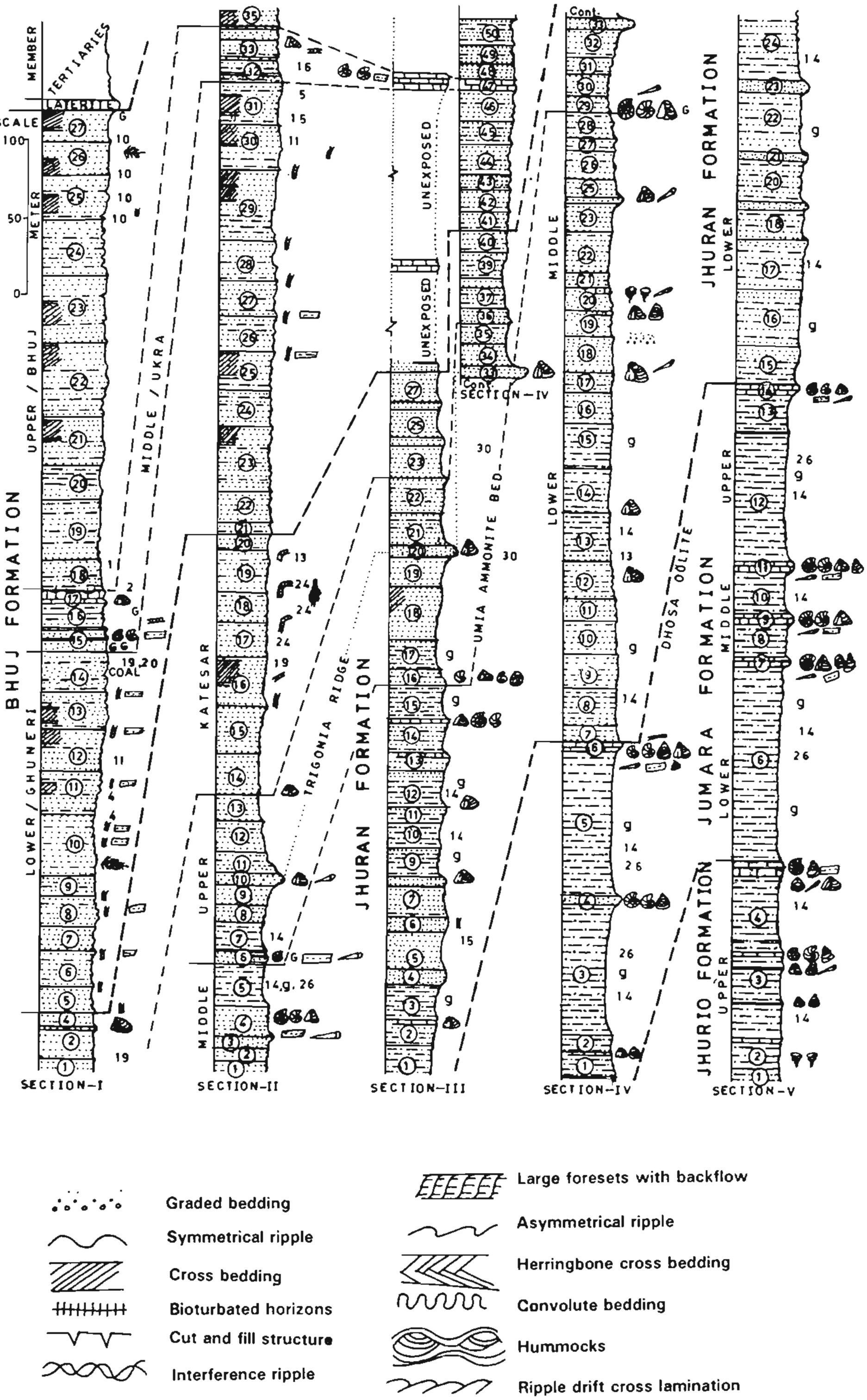


Figure 1—Field photograph showing three green glauconitic bands (1,2 & 3) at the base of Upper Member, Jhuran Formation (≃Umia Ammonite Bed) overlain by "*Trigonia* Ridge Sandstone" in Mundhan Anticline.

Three east-west trending asymmetrical anticlinal ridges, e.g.," the Island belt", Mainland and Katrol-Charwar in the south have domal outcrops with dome centers having oldest rocks and younger rocks near periphery. The study area lies between latitude N23°4' to 23°49' and longitude E68°50' to 69°06' (Text-figure 1). Five domes of the Mainland at Jumara, Jara, Mundhan, Sahera and Ghuneri were examined to get



Text- figure 2—Vertical lithocolumns with occurrence of physical and biological characters. Section I- Ghuneri dome; Section II- Sahera (Katesar) dome; Section III-Mundhan anticline; Section IV-Jara dome and Section V- Jumara dome.

a complete succession deposited during Middle Jurassic to Upper Cretaceous (Text- figure 2). Jurassic/ Cretaceous Boundary could easily be traced in glauconitic outcrops of Jara, Mundhan and Sahera domes. The oldest exposed rock (Bathonian) in present area of study lies in the centre of Jumara dome whereas the youngest (Coniacian/Turonian) occurs on the periphery of Ghuneri dome. Vertical litho-columns for each dome were prepared and sampled at close and regular intervals.

Mundhan Anticline

The Mundhan Anticline has an ideal exposure of Jurassic/Cretaceous rocks. A vertical profile was prepared by taking traverses from anticline center up to Mundhan Village (only bed no.8-21 are shown as sedimentary log in Text-figure 3), measuring more than 503 m of succession with thirty prominent beds. (Text-figure 2). It represents a composite sequence of Middle (bed no. 1 to 15; 265 m thick), Upper (bed no. 16 to 22; 143 m thick) and Katesar Member (bed no. 23 to 27; 75 m thick) of Jhuran Formation. Ghuneri Member, overlying on Jhuran Formation (bed no. 28 and other unexposed beds), followed by Ukra (M2) and Bhuj Members of Bhuj Formation, are well exposed in Sahera and Ghuneri domes, respectively (Dubey, 1992).

Lithologically silty shale, coarse friable sandstone, hard compact bivalve-bearing sandstone, ferruginous cemented well-sorted sandstone, oolitic, glauconitic, argillaceous limestones and olive green (khaki) shales are the main lithology. Tabular cross-bedding, herringbone cross-bedding, flaser and grad-

Table 2– List of common physical sedimentary structures encountered in Jurassic/Cretaceous succession of northwestern Kutch Basin(R= rare, C=common, and A=abundant)

Symbol in Fig. 4			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
AGE PERIOD	FORMATION	MEMBER / Sedimentary structure	Current ripple	Mega wave ripple	Wave-current "	wave ripple with mud drape	Interfer. ripple	Massive beds	Parting lineation	Planar beds & tra-nscurrent lamin.	Reactivation surfaces	Gradded bedding	Planar/tangential (tidal-bundle)	Tabular/trough/swash x-bedding	Ripple drift x-lamination	Flaser/lenticular beds	Herringbone x-bed	Hummocky/swaley x-bed & antidune?	Fining upward	Coarsening upward	Cut & fill stru.	Large channel, in-traformat. congl.	Deformed x-beds	Slumps & slides	Flute mark	Convolute beds	Load cost, pseu-donodules	Septarian nodules	Oriented Shells	Imbricated pebble	Box-work & mud cracks	Conglomerate
CRETACEOUS	BHUJ	UPPER or BHUJ	C	R	C	-	C	A	R	C	A	A	C	C	R	R	R	R	-	C	A	C	C	R	R	R	R	R	R	C	C	C
		MIDDLE or UKRA	-	R	R	R	C	C	R	C	R	C	-	-	R	R	R	C	C	-	R	-	R	-	R	R	R	R	C	R	-	R
		LOWER or GHUNERI	A	R	C	C	R	C	R	C	A	A	A	C	C	A	C	C	-	A	A	C	C	R	R	R	R	C	R	R	R	C
		KATESAR	A	R	A	-	R	C	C	C	A	A	C	C	R	R	C	C	-	A	A	C	C	C	R	C	R	R	R	R	R	A
—138— (Ma)	JHURAN	UPPER	C	R	C	R	R	A	C	C	R	C	R	R	A	C	R	R	-	C	C	R	R	R	C	R	C	R	C	R	A	A
		MIDDLE	R	-	R	R	R	A	C	C	R	C	R	R	A	C	R	R	-	A	C	C	R	R	C	R	C	C	R	R	R	C
		LOWER	R	-	R	-	R	A	C	C	R	R	-	-	A	C	-	-	-	A	R	R	R	-	R	-	C	C	R	R	R	C
JURASSIC	JUMARA	UPPER	-	-	-	-	-	C	C	R	R	R	-	-	C	A	-	-	A	-	-	-	-	-	R	-	C	A	C	-	C	C
		MIDDLE	-	-	-	-	-	C	C	R	R	R	-	-	C	A	-	-	A	-	-	-	-	-	R	-	C	A	R	-	C	C
		LOWER	-	-	-	-	-	C	C	R	-	-	-	-	C	A	-	-	A	-	-	-	-	-	R	-	C	C	C	-	C	C
	JHURIO	UPPER	-	-	-	-	-	C	-	-	-	-	-	-	-	R	-	-	C	-	-	-	-	-	-	-	C	C	-	-	R	R
								BASE NOT EXPOSED																								

ed bedding with load caste structures are common features (Table 2). The Upper Member of Jhuran Formation also includes " *Trigonia* Ridge Sandstone" in the middle. It constitutes three thick, very hard, compact, trigonid-bearing sandstone bands (F) alternating with coarse, rarely fossiliferous sandstone bands, i.e., D (Figure 2). Katesar Member shows conspicuous development of storm-induced low angle hummocks in sandstone and intraformational conglomerate. Vertical to subvertical tubes of meter length and few centimeter diameter are abundant in bioturbated, coarse, friable sandstone of this unit.

Physical changes across Jurassic/Cretaceous Boundary

Middle to Upper Jurassic period is marked by a world-wide sea-level rise reaching its acme during Oxfordian or Kimmeridgian (Vail & Todd, 1981; Hallam *et al.*, 1985), causing major transgression in many parts of the world. Mesozoic Kutch Basin also evolved at the same time as a combined result of eustasy and basinal/ provenance tectonics. In general, Jurassic transgression in the Kutch Basin deposited a retrogradational succession of muddy lithology (shale, limestone, argillaceous sandstone) characterised by fining upward cycles of uniform thickness and sandwitching "Dhosa Oolite" of Oxfordian age. It was deposited during still-stand phase of starved sedimentation, representing aggradational succession.

The beginning of the Cretaceous marks a global sea-level drop followed by gradual sea-level rise. Former is true for the Kutch Basin also, whereas the later was compensated by the uplift of provenance/ basin with high rate of sedimentation, resulting into regression. This deposited wedge-shaped coarser clastics (conglomeratic sandstone, sandy limestone and silty shale) of progradational succession of coarsening and thickening upward cycles.

Sedimentary structures–These commonly include both symmetrical and asymmetrical small and mega ripples, sandwaves, interference ripples, planar and trough cross-stratification, tidal bundles, hummocky cross-lamination, parting lineation, sole marks, herring-bone cross-bedding, flaser and lenticular bedding, large and small tidal channels (Table 2). Jurassic successions are characterised by low energy sedimentary structures like plane laminations, graded beddings, load casts, massive beds, etc., whereas Cretaceous successions are characterised by high energy sedimentary structures.

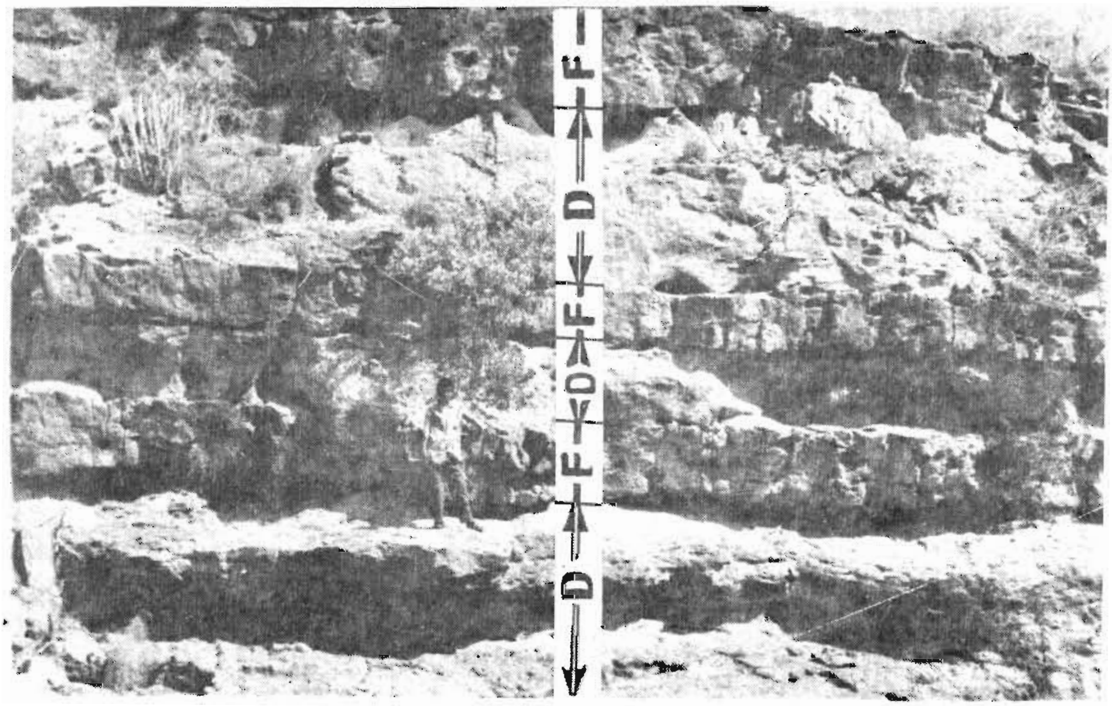


Figure 2—Field photograph showing vertical section of "*Trigonia* Ridge Sandstone" in Mundhan anticline. Distinct bands of hard, highly fossiliferous, granular, calcareous sandstone (F) and coarse, relatively friable, poorly fossiliferous sandstone (D) are alternating.

Bed geometry—Most of the beds deposited during Jurassic are tabular or sheet-like having almost equal thickness, whereas beds deposited during Cretaceous are wedge-shaped (Text- figure 2) generally thicker in offshore direction (West).

Heavy minerals—Both opaque and non-opaque heavies show variation in their abundance (Text-figure 3). Common heavy minerals are garnet, tourmaline, sillimanite, kyanite, monazite, andalusite, staurolite, zircon and rutile. Among the opaque heavies magnetite, ilmenite, leucoxene and hematite are common. There are two distinct assemblages, i.e., heavies of metamorphic affinity dominating in Jurassic, whereas heavies of granitic affinity dominate in Cretaceous.

Lithic/rock fragments—Chert, metaquartzite, quartz-mica schist, granite and silicified oolite are the main rock fragments (Text-figure 3). Similar to heavies, lithic fragments also show two distinct assemblages, i.e., metamorphic and granitic for Jurassic and Cretaceous, respectively.

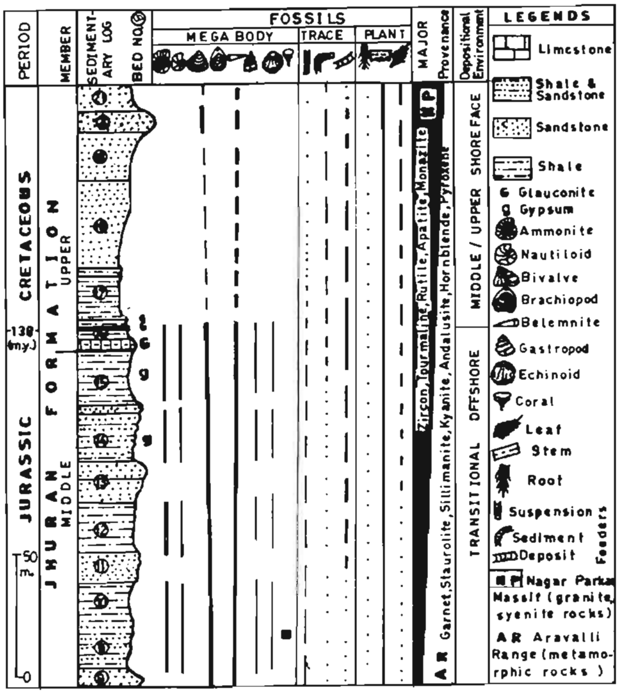
Clay minerals—Kaolinite, illite, chlorite and montmorillonite are the main clay minerals. Illite dominates in Jurassic of marine sediments, whereas kaolinite dominates gradually in Cretaceous indicating fresh to brackish water influence.

Palaeoshoreline—On the basis of palaeocurrent studies a changing scenario of palaeoshoreline emerged as north-south during Jurassic to northwest-southwest during Cretaceous.

Biological changes across Jurassic/ Cretaceous Boundary

The Jurassic succession is highly fossiliferous containing well-preserved cephalopods (ammonites, nautiloides, belemnites, etc.), gastropods, brachiopods, bivalves, echinoderms, corals and fossilised wood (Figure 2). Among the trace fossils, the *Cruziana - Zoophyços* ichnofacies predominates in the Jurassic sediments.

Gradual decrease in fossil content is prominent in Cretaceous part of the sequence, having either poor in body fossils or bioturbated sandstone bands. Bivalves and belemnites are preserved at certain levels only Figure 2. Among the ichnofossils *Skolithos - Arenicolites* ichnofacies predominates. However, the Ukra Member is similar in faunal content to the Jurassic succession, except for younger age and fossil dimensions alongwith *Cruziana - Teredolites* ichnofacies. The Bhuj Member lacks trace and body fossils. Well-preserved leaf-impressions common in this part of the Cretaceous succession. Sometimes wood pieces and root-like axes are also found. Thin coal bands occur at a few levels.



Text-figure 3—Variation of physical and biological characters across the Jurassic/ Cretaceous boundary. Sedimentary log shown in this figure is enlargement of lithocolumn of Mundhan anticline (bed no. 8-21; Section-III, Text-figure 2).

CONCLUSIONS

The Mesozoic sequence in this basin as a whole represents one major cycle of 2nd order (Vail *et al.*, 1977) having several mini-/para-cycles of smaller durations depending on the cumulative effect of sea-level fluctuations, basinal uplift and subsidence. The major transgressive phase commenced as early as pre-Bajocian (Jaitly & Singh, 1983), or Aalenian (Pandey & Dave, 1993) and continued up to Tithonian. During this time interval of more than 40 Ma, Jhurio (≃ Patcham) and Jumara (≃ Chari) and (Lower and Middle members) Jhuran (≃ Katrol) Formations were deposited.

The general regression of sea initiated during Neocomian, resulting into dominantly prograding barrier shoreline environments. During this interval of about 50 Ma, Jhuran (Upper and Katesar members) and Bhuj (≃ Umia) Formations were deposited. On the basis of the present study following differences between the Jurassic and Cretaceous sedimentation patterns have been observed.

1. Jurassic/ Cretaceous boundary lies between middle and upper bands of three green glauconitic bands at the base of Upper Member of Jhuran Formation. This is in accordance with the boundary established on the basis of microfossils (Umiaian/Mund hanian Stage boundary of Pandey & Dave, 1993).
2. Jurassic successions are dominated by carbonates and shales with minor sandstone (retrogradational and aggradational successions), with tabular geometry of uniform thickness, whereas Cretaceous is dominated by sandstones, shales with minor carbonates (progradational succession) of wedge-shaped geometry, thickening in offshore direction (West).
3. Rock/lithic fragments and heavy minerals of metamorphic affinity occur in abundance in the Jurassic as compared to Cretaceous, which contains heavies and lithic fragments of igneous origin.
4. Low energy sedimentary structures are common in the Jurassic, whereas high energy sedimentary structures frequently occur in the Cretaceous part of the sequence.
5. Undulose, polycrystalline, subrounded quartz characterises Jurassic, whereas non-undulose, subangular quartz grains are common in Cretaceous.
6. Amongst the clay minerals illite dominates in Jurassic indicating marine origin, whereas the presence of kaolinite in Cretaceous signifies fresh and brackish water influence.
7. Abundance of mega-, body fossils, including index fauna, characterises the Jurassic, whereas the Cretaceous is poor or sometimes barren in faunal content (except the Ukra Member and few trigonid-bearing thin bands).
8. Small pieces of fossilised wood occur throughout the sequence whereas coal seam, leaf-impressions and large wood trunks are preserved in Cretaceous.
9. Among the ichnofossils, Jurassic is dominated by sediment and deposit feeders whereas Cretaceous sediments are characterised by suspension feeders.
10. North-south palaeoshore line of Jurassic gradually changes to northwest-southwest during Cretaceous.
11. Aravalli range of Rajasthan situated in the east of the basin contributed much more sediments during Jurassic, whereas Nagar Parkar Massive of Pakistan from north and northeastern part contributed much during Cretaceous Period.

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