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Paleoenvironmental Interpretation of Pre-Rift Sediments (Usfan Formation in Haddat ash-Sham) in the Central Red Sea Margin, Jeddah Region, Saudi Arabia

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ABSTRACT. Field work in the Jeddah region beside sedimentological investigation added some information about the depositional history of onshore rift in the central coast of western Saudi Arabia.

The general sedimentary sequences croping out in the central Red Sea coastal area, Jeddah region are subdivided into two major sedimentary phases; pre-rift and syn-rift. The pre-rift sequence (Usfan Formation) essentially of Upper Cretaceous to Early Eocene age unconformably overlies the Precambrian crystalline basement. It is represented by succession of continental fluviatile sandstones and siltstones (Nubia type), grades upward into littoral marine facies (phosphate and carbonate ledge) and supratidal sequence (dolomitic marl and shale with gypsum veins). The pre-rift succession mostly represents a regression of the sea due to uplifting.

Study of heavy and clay minerals in the pre-rift sediments shed light on the paleogeography, paleoclimatology and source rocks. Opaques, tourmaline and rutile with lesser amounts of staurolite, hornblende and epidote indicate an igneous-metamorphic ancient sedimentary province. While kaolinite is the only recorded clay mineral pointing out to an intensive leaching, strong chemical weathering and flat topography.

Introduction

The Cenozoic sediments of the Jeddah region enclose in themselves a catalogue of events and processes. They are the best expression of rift geodynamics where in the early stages of structural evolution and sedimentation in a rift system are recorded. The Tertiary sediments are structurally thrown against the Pre-cambrian basement due to

faulting. It has limited chronological control. Unfortunately no definite age can be referred to most of the Tertiary exposures probably due to the rarity of fossils.

Detailed field work of the sedimentary sequences which outcrop in the central Red Sea coastal plain, near Jeddah region and laboratory investigations carried out on the rock samples collected from these sites will increase our understanding of the basic rifting processes. It will also help in constructing the depositional model of sedimentation in rift basins. Previous studies in this region (Karpoff, 1957a & b; Brown *et al.,* 1962; Al Shanti, 1966; Moltzer and Binda, 1981; Basahel *et al.,* 1982 and Spencer, 1987) also provide valuable scientific informations in this respect.

In the central Red Sea coastal plain, near Jeddah area, the Shumaysi Formation outcrops only along the periphery of the rift, whereas the other parts of the Formation are best developed within certain grabens such as in the Haddat ash Sham village. Pre-rift sequences are represented by Usfan Formation which outcrops only in the Haddat ash Sham area as well as in the Usfan village to the northeast of Jeddah.

Dealing with assigning of the age, Basahel *et al.* (1982) gave Late Cretaceous to Tertiary for Usfan and Shumaysi Formations. However, Beydoun (1988) believed that there was no regional evidence for the presence of Upper Eocene sediments bordering the Red Sea and Gulf of Aden. Either they did not get deposited or were removed by erosion because Arabia was emergent, except for a narrowing seaway between the Mediterranean Sea and the Indian Ocean along the areas of north Syria, north Iraq and parts of SW Iran to western Oman. Hughes and Beydoun (1992), assumed that rifting within the Gulf of Aden took place during the Early Oligocene.

Tectonics and structural setting

The configuraiton of the studied area is mainly affected by the formation of the Red Sea. The Red Sea graben faulting was accompanied by the formation of northwesterly regional block faults, running parallel to the Red Sea causes formation of longitudinal basins subsequently filled with Tertiary sediments (Skipwith, 1973). Local faulting and fracturing took place in both crystalline and sedimentary rocks, while those belonging to the younger tectonic movements are characterised by northeast trending faults that displaced and rejuvenated the former faulting.

Procedures

Field work involved measurements and description of two sections, collecting of about 20 samples and recording of primary sedimentary structures. The studied area lies on the western coast of Saudi Arabia including Haddat ash-Sham and Usfan areas, northeast of Jeddah (Fig. 1). Field investigation was focused on the rock units of the Usfan Formation. The stratigraphic measured section of Usfan Formation in Haddat ash-Sham was constructed (Fig. 2).

Laboratory studies include both sedimentological and lithostratigraphical investigations. These studies make it possible to shed light on the evolution of sediments and sedimentation pattern in the rift basins.

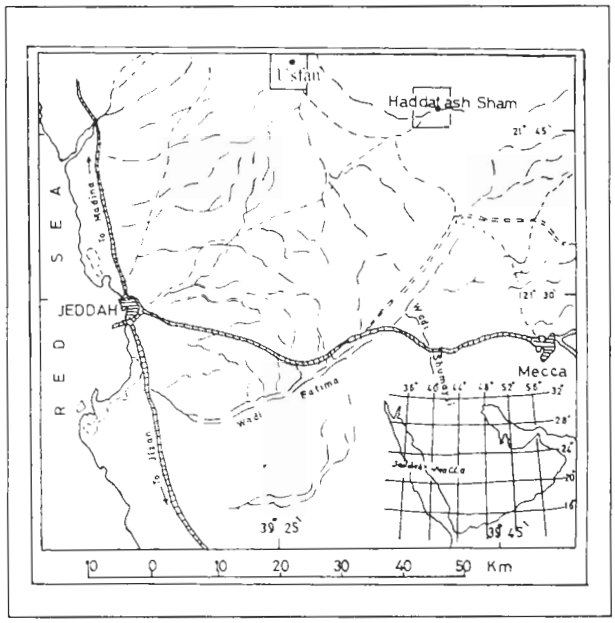

FIG. 1. Key map showing location of the stratigraphic section studied.

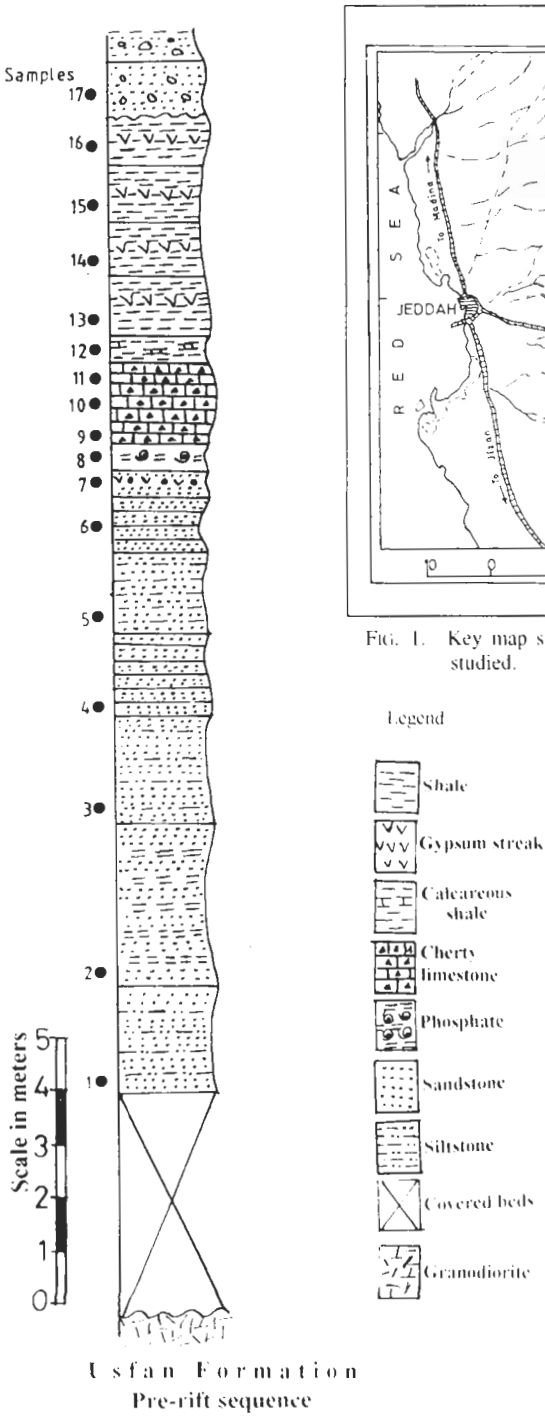

FIG. 2. Stratigraphic measured section of the Usfan Formations (Haddat ash-Sham area).

The heavy minerals fraction has been separated from the light one in the size fraction (D. 125-0.063 mm) using bromoform (S.G. = 2.89). The heavies have been mounted in canada balsam and about 200 mineral grains are counted. The percentages of the non-opaque heavy minerals have been determined.

Clay minerals have been identified by X-ray diffraction method; oriented slides were prepared by the sedimentation technique described by Carver (1971). The paleoclimatic conditions and provenance have been interpreted.

Results and Discussion

Pre-rift sediments

Usfan Formation

The pre-rift sequence is studied in the northeast Jeddah region. It is confined to tectonically depressed area where sediments are restricted to a few small remnants preserved in protected narrow structures.

Usfan rock units (Plates 1 & 2) are formed of fine-grained sandstones (Nubian type), reddish brown and thinly laminated, slightly rippled (Plate 1, Figs. 1 & 2) overlain by 0.5 m thick phosphatic bed, brownish to greenish in colour, slightly arenaceous (Plate 2, Fig. 4) and 1.5 m thick carbonate ledge (Plate 1, Fig. 3) consisting of fossiliferous cherty limestone usually mud dominated and covered by 0.5 m thick of hard dolomitic marly bed with ripple marks on the upper surface (Plate 1, Fig. 4) indicating deposition in a tidal environment. This succusion followed upwards with 5m thick succession of shalty beds, limonitic in colour and thinly lamminated with veins of gypsum (Pate 1, Fig. 5). This succession represents a regression of the sea due to uplifting and formation of a supratidal sequence along the shoreline sedimentation.

The carbonate ledge of Usfan Formation differs in, the two localities at the Haddat ash-Sham area it is 1.5 m thick and appears flat, highly weathered and slightly tilted while at the Usfan area it appears over turned stands like wall with thickness about 4.5 m (Plate 2, Figs. 1, 2, & 3). It extends laterally for hundreds of kilometers till south of Jeddah.

The carbonate ledge has abundant casts, molds, shell remains of brachiopods, gastropods indicating low energy invertebrate accumulation. From the petrographical study of 6 thin sections in some selected samples; 3 different microfacies associations have been recognized; these include calcrudite, calcarenite and calcilutite (Dunham, 1962). They represent deposition under gently to slightly agitated water conditions.

The Usfan succession is overlain unconformably (angular unconformity) by a thick sequence of pebbly sandstone, highly affected with heat flux and forming the lower Shumaysi Formation (Plate 1, Fig. 6).

General outline of the mineralogy of Usfan sediments

Further information can be added from investigation of heavy mineral suite in 6 sandstone samples (Nubia type) under the carbonate ledge of Haddat ash-Sham area. It was

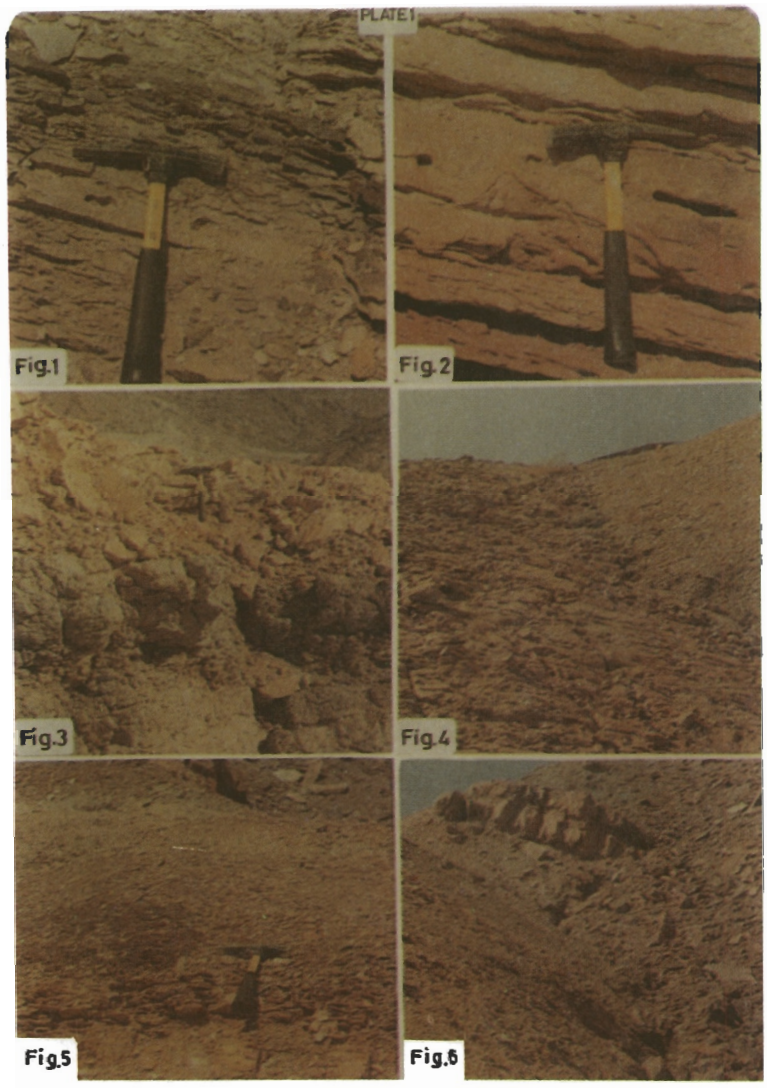

PLATE 1. Usfan Formation (pre-rift sediments) in Haddat ash-Sham area.

FIG. 1. Thinnly bedded, brown sandstone with ferrugineous cement and minor siltstone (Nubian type).

FIG. 2. Ripple laminated, reddish brown sandstone (Nubian type).

FIG. 3. Carbonate ledge, highly weathered, overlying by a hard yellowish dolomitic marly bed.

FIG. 4. Upper surface of the hard marly bed showing ripple marks.

FIG. 5. Thinnly laminated, yellowish to greenish shale intercalated with streaks of gypsum.

FIG. 6. Thick beds of conglomeratic sandstone (Lower Shumaysi with angular unconformity).

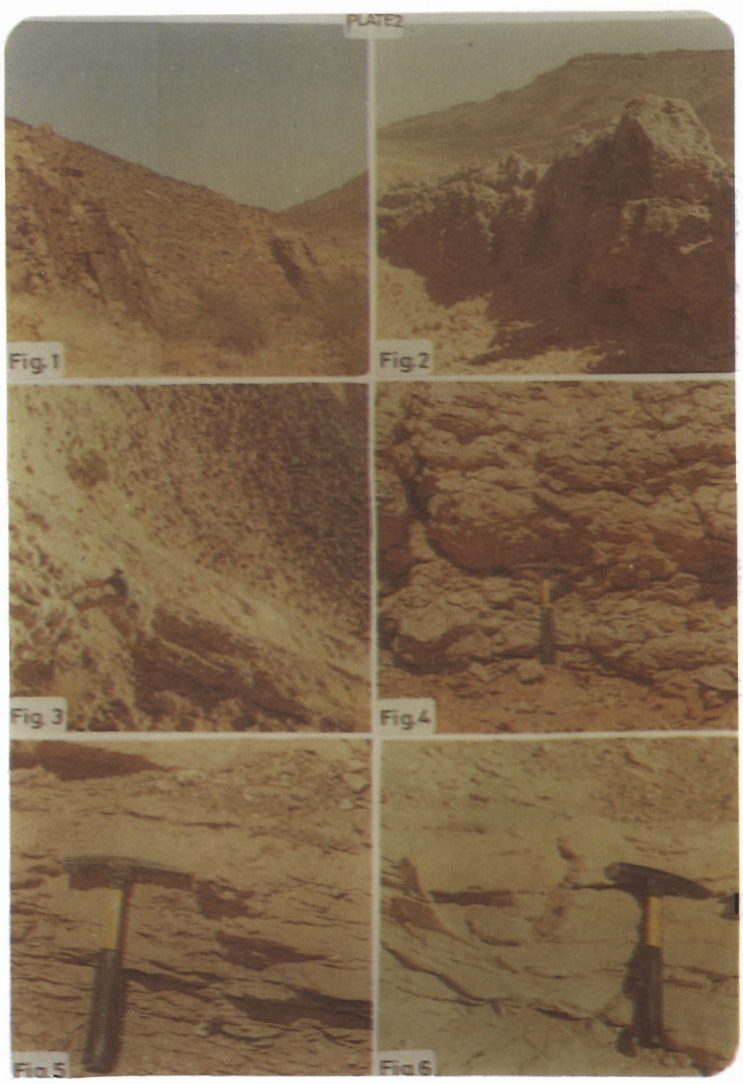

PLATE 2. Usfan Formation (pre-rift sediments) in Usfan area.

FIG. 1. Totally overturned strata of Usfan sequence (Usfan area).

FIG. 2 & 3. Carbonate ledge overturned likes wall stand (Usfan area).

FIG. 4. Phosphatic bed under the carbonate ledge in Haddat ash-Sham area.

FIG. 5. Thinly laminated sandstone with siltstone (Nubian type) in Haddat ash-Sham area.

FIG. 6. Rippled lamination sandstone in Usfan area.

characterised by the dominance of opaque, tourmaline and rutile and minor amounts of staurolite, hornblende, augite, epidote and zircon. They indicate derivation from igneous and metamorphic source rocks of the Jeddah series.

Identification of the clay minerals by X-ray diffraction method in 4 clay fractions separated from the greenish grey shale beds proved the dominance of kaolinite (7A°) in the basal reflection (001). No other clay minerals have been recorded. The predominance of kaolinite indicates a relatively warm climate and long period of strong chemical weathering acting on a terrestrial source with a peneplain topograpy. Such a continental environment encouraged extensive leaching of much weathered rocks.

Continental morphology is determined primary by tectonic activity. Thus tectonic events such as uplift and subsidence and/or rifting seem to be important in the paleoclimatic evolution of clay minerals (Singer, 1984). A continental environment such as a fairly stable uplifted and well-drained peneplained cratonic shelf under a warm climate lead to more intensive leaching and chemical weathering so that kaolinite predominates the clay mineralogy of mud rocks of that period.

Stratigraphic Correlation of Pre-Rift and Syn-Rift Sequence Along the Eastern Red Sea Margin

The sedimentary successions outcroping on the Red Sea margin document the early stages of structural evolution and sedimentation in rift system. Comparison of the sedimentary sequences studied here in the central part of Red Sea coastal plain (Jeddah region, Abou Ouf and Gheith, 1997) with those studied before in the northern part (Midyan region, Purser and Hotzl, 1988) and southern part (Jizan area, Schmidt *et al.,* 1982) allow to establish number of interesting similarities and differences as far as the data permit.

Pre-rift sequence

The onset of Red Sea rifting is dated as Oligocene. On the Arabian side, the Usfan Formation (pre-rift sequence) northeast Jeddah region refers to pre-Oligocene (Upper Cretaceous to Early Eocene) and covered the proterozoic basement metamorphic rocks. It is represented by a succession of continental fluviatile sandstone and siltstone beds, thinnly laminated and overlain by small remnants marine facies of a transgression from the Mediterranean Sea preserved in protected structures. The most complete profile exists in the Azlam through which follows, the old Najed fault trend (Vazquez-Lopez and Motti, 1981).

Throughout the northern parts of the Red Sea and Gulf of Suez, Precambrian basement is overlain by Upper Cretaceous-Paleogene shallow marine clastics and carbonate littoral facies. Pre-rift sediments terminate every where in open marine Eocene carbonate with chert nodules. Along the Egyptian side southward, the fluviatile Nubia Sandstone of Cretaceous age is overlain by the Paleogene phosphatic limestones, which are terminated by Eocene cherty limestone of the Thebes Formation. The disappearance of pre-rift sequence towards south would suggest uplift and erosion prior to the first

stages of syn-rift sedimentation.

In the vicinity of Jeddah, the pre-rift sequence includes both continental and marine faceis. The continental fluviatile Nubian type sandstone grades upward into littoral carbonate ledge, dolomitic marl and greenish yellow laminated shale with veins of gypsum pointing to a shoreline sedimentation. This sequence appears similar to that out cropping out in Wadi Qena (littoral Quseir shales).

Syn-rift sequence

The oldest syn-rift deposits of southwest Arabian are represented by the Jizan Group rocks (Schmidt *et al.*, 1982). They were divided into five formations of Late Oligocene-Early Miocene.

Syn-rift deposits outcropping in the central part, were deposited after strong chemical weathering period for the Precambrian basement rocks and block faulting. Most of the lower Shumaysi Formation appears resemble to the Ayyana Formation (sandstone with conglomerate) in the Jizan Group. The upper Shumaysi Formation already shows synsedimentary extentional tectonics corresponding in their orientation with the later Red Sea rift system. On the basis of new fossil assemblage identification, Abou Ouf and Gheith (1995) assigned the upper Shumaysi Formation to Late Oligocene-Early Miocene age.

Syn-rift deposits (Oligocene-Miocene) on the northern part of the Red Sea are well preserved in the Midyan area (Bayer *et al.*, 1988), where the Midyan sequence represents a generally deeper marine facies.

Analogous with the upper Shumaysi Formation (Jeddah region) is the Baid Formation in the southern part of the Red Sea coastal plain, it consist of laminated varicoloured shales and volcanic tuffs with inorganic precipitated silica in the Jizan Group. It was deposited in lakes in between the eruptive centers. It resembles to the present day rift valley (Jado *et al.*, 1989) and deposited during early rifting. It further points to a low relief source rocks (Voggeneiter and Hotzl, 1989). Based on the fossil assemblage, Schmidt and Hadley (1984) suggested an age of 30-20 Ma for the Baid Formation.

Rare marine sediments are exposed along the southern coastal strip where volcanic rocks are widespread. However, a remnant of marine sandstone in the Midyan region in the most northern part of the Red Sea is preserved. Otherwise, Crossley *et al.* (1992) showed that onset of rifting and flooding by marine waters took place during Late Oligocene in the Gulf of Aden and southern Red Sea. Fully marine conditions had developed throughout the length of the rift system. The northern part, on the other hand, exhibits a largely continental rift at this initial stage which resemble that of the central part of the Red Sea, but continued rifting established marine conditions by the Early Miocene. In Gulf of Aden and the southern part of Red Sea (Thio-1 well) Hughes and Beydoun (1992) found sediments that biostratigraphically dated as Upper Oligocene. The stratigraphic correlation of the Tertiary sequences along the Eastern Red Sea margin is summarised below:

a- Northern Red Sea coastal plain (Midyan ragion)

Miocene	Bad Fm.
	Nutaysh Fm.
Oligocene	Musayr Fm. (Limestone)
	Sharik Fm. (Conglomerate and sandstone)
Precambrian	Basement rocks

b- Central Red Sea coastal plain (Jeddah region)

Late Miocene	Bathan Fm.
Late Oligocene-Early Miocene	Shumaysi Fm.
Up. Cretaceous-Early Eocene	Usfan Fm.
Precambrian	Basement rocks

c- Southern Red Sea coastal plain (Jizan region)

Late-Middle Miocene	Bathan Fm. (Polymictic conglomerate)
Early Miocene	Tihamat Asir Complex (Basaltic dykes and gabbro)
	Damad Fm. (Volcanic flow rocks)
	Liyyah Fm. (Rhyolite-dacite rocks)
Late Oligocene-Early Miocene (Jizan series)	Baid Fm. (Cherty-tuffaceous silt stone)
	Ad Darb Fm. (Volcanic rocks)
	Ayyanah sandstone (Nubian type)
Early Tertiary	Laterite.

Conclusion

Investigation of the exposed Usfan and Shumaysi Formations in the Jeddah area provides me with the depositional history in rift basins. The continental Nubia-type Sandstone beds of Usfan Formation are probably of Upper Cretaceous age, while the overlying phosphatic bed and carbonate ledge may be related to the Upper Cretaceous-Paleocene age. The overlying hard marly bed and thinly laminated shales with veins of gypsum point to shallower environment reaching to a shoreline of essentially Early Eocene age. During Late Eocene the area mostly emerged and suffered folding and erosion due to the abrupt subsiding in sea level and the beginning of tectonic movements associated with the formation of Red Sea and Gulf of Suez. The continental red conglomeratic sandstone beds of the lower Shumaysi Formation were then deposited over the Usfan Formation with angular unconformity.

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تفسيرات البيئـة القديمـة لرواسب قبل الخسف (لمتكون عسفان في هـداة الشام) بالحافـة المركزيـة للبحر الأحمر بمنطقـة جـــدة - المملكة العربية السعودية

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المستخلص . لقد تم إضافة بعض المعلومات عن التاريخ الترسيبي للخسف الشاطئي بوسط الساحل الغربي للمملكة العربية السعودية وذلك من خلال الدراسات الحقلية والمعملية للصخور الرسوبية في منطقة جدة .

إن الترسيب العام المكشوف بوسط المنطقة الساحلية للبحر الأحمر بمنطقة جدة يمكن تقسيمه إلى طورين ترسيبيين هما : قبل الخسف ومتزامن مع الخسف .

تتابع ما قبل الخسف (متكون عسفان) يتراوح عمره من الطباشيري المتأخر إلى الأيوسين المبكر وهو يعتلي قاعدة البريكامبري المتبلور حيث أنه يتكون من الحجر الرملي النوبي والحجر الغريني وهو ذا ترسيب نهري قاري ويتدرج إلى أعلى لسحنة بحرية شاطئية تتكون من حائط الكربونات والفوسفات يليه تتابع فوق مدًى من المارل الدولوميتي والطفل الحاوي على عروق الجبس الذي يمثل بيئة ترسيب الخط الشاطئي .

إن تتابع ما قبل الخسف يعتبر في الغالب ممثلاً لتراجع البحر نتيجة لعملية الرفع . إن دراسة المعادن الثقيلة ومعادن الطين ورواسب ما قبل الخسف ألقت الضوء على الجغرافيا القديمة والمناخ القديم وصخور المصدر . حيث يسود المعادن الثقيلة المعادن المعتمة ، والتورمالين والروتيل وكميات أقل من الشتورليت والأبيدوت والهورنبلند وهي تدل على مصدر لصخور نارية ومتحولة ورسوبية قديمة . بينما وجود معدن الكاؤلينيت كمعدن سائد ووحيد في صخور الطفل يدل على عمليات إذابة وتجوية كيميائية شديدة لبيئة منبسطة طبوغرافيًا .