OCEANOLOGICA ACTA, 1984, N° SP

Structure and evolution of the Mazagan (El Jadida) plateau and escarpment off central Morocco

Mazagan
Continental margin
Seismic
Submersible
Stratigraphy

Mazagan
Marge continentale
Sismique
Submersible
Stratigraphie

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ABSTRACT

The Mazagan (El Jadida) Plateau and Escarpment constitute the seaward extension of the Moroccan Meseta, and offer an excellent example of a starved continental margin bordering the oldest part of the Atlantic Ocean. Sedimentary sequence began at least as long ago as the Triassic. A very dense seismic reflection survey (32 profiles at 1 n. mile spacing) and information from 18 Cyana dives on the Mazagan (El Jadida) plateau and escarpment allow us to construct an isochron map of the depth of the acoustic basement constituted either by Jurassic platform carbonates or by Paleozoic granodiorite to Precambrian (?) crystalline basement, and a detailed structural map.

The carbonate platform is structured in a succession of tilted blocks from the plateau to the foot of the escarpment. This structuration is determined essentially by vertical faults trending N 20, N 90, N 120 and N 160.

During early Cretaceous times, an important phase of vertical structuration is marked by the denudation of the escarpment. Transgressive sediments of late Cretaceous age cover unconformably the carbonate platform along the outer edge of the Mazagan (El Jadida) Plateau. Deformation observed within the sedimentary cover suggests vertical tectonism from late Cretaceous up to the Present. However, these vertical movements were accentuated during Eocene and Miocene times by the tilling of blocks of the faulted carbonate platform and mass wasting events.

Oceanol. Acta, **1984.** Submersible Cyana studies of the Mazagan Escarpment (Moroccan continental margin), CYAMAZ cruise 1982, 59-72.

RÉSUMÉ

Structure et évolution du plateau et de l'escarpement de Mazagan (El Jadida, W Maroc)

Le plateau et l'escarpement de Mazagan (El Jadida) constituent le prolongement vers l'océan du domaine mésétien. Ils représentent un des meilleurs sites d'étude d'une marge continentale effondrée en bordure d'un océan ancien. En effet, l'escarpement de Mazagan borde un domaine océanique où se sont déposées des séries sédimentaires depuis au moins le Trias. Un levé sismique extrêmement dense (une trentaine de profils espacés d'environ 1 mille) et 18 plongées du submersible Cyana sur le plateau et l'escarpement de Mazagan, nous permettent de réaliser une carte isochrone du socle acoustique représentée par la plate-forme carbonatée jurassique ou par le substratum paléozoïque ou précambrien constituant l'ossature du domaine ainsi qu'une carte structurale détaillée. La plate-forme calcaire est découpée en une succession de blocs basculés depuis le plateau jusqu'au pied de l'escarpement. Ce découpage se fait suivant un réseau de cassures dont les directions prédominantes sont N 20, N 90, N 120 et N 160. Au point de vue tectonique, une importante phase de structuration se place au Néocomien terminal, avec pour effet la mise à l'affleurement de l'escarpement. La couverture sédimentaire post-plate-forme ne devient transgressive sur la plate-forme en bordure de l'escarpement qu'à partir du Crétacé supérieur. Les déformations observées dans la couverture sédimentaire nous permettent de conclure à une activité tectonique verticale jusqu'à l'Actuel. En particulier, d'importants mouvements tertiaires (Éocène et Miocène) se manifestent par des surrections de blocs de la plate-forme et des surfaces d'érosion dans la couverture.

Oceanol. Acta, **1984.** Études par le submersible Cyana de l'escarpement de Mazagan (marge continentale marocaine), campagne CYAMAZ 1982, 59-72.

GENERAL FRAMEWORK

The North West African margin is a very good example of a starved passive continental margin bordering the oldest part of the Atlantic Ocean. This margin documents a complex evolution from the first episodes of the Triassic-Liassic intra-continental rifting until the Tertiary tectonic events.

Since the early 1970's, this margin has been very intensively studied by classical geological and geophysical methods, as well as by deep-sea drilling. The most important cruises were conducted by the Lamont Doherty Geological Observatory (Vema cruises 23, 27, 29, 30 and 32), the Bundesanstalt für Geowissenschaften und Rohstoffe (Meteor cruises 25, 39, 46, 53, 67 and Valdivia cruise 79), the Woods Hole Oceanographic Institute (Atlantis II cruises), the Centre National pour l'Exploitation des Océans, now Institut Français de Recherche pour l'Exploitation de la Mer, (Nestlante II and Albatlante cruises) and the IPOD (Glomar Challenger legs 41, 50 and 79 ; Uchupi *et al.*, 1976 ; Lancelot *et al.*, 1977 ; Wissmann, von Rad, 1979 ; Lancelot *et al.*, 1980 ; Hinz *et al.*, 1982 ; Hinz *et al.*, 1982).

Many papers discussing the geology of NW African margin from Senegal to the Strait of Gibraltar describe Triassic-Liassic evaporitic layers dating the initial stages of rifting (Pautot *et al.*, 1970 ; Rona, 1970 ; Van Houten, 1977). These deposits are now covered by very thick sediments emerged in onshore coastal basins or occur as salt diapirs under the abyssal-plain of the offshore Moroccan Basin. Evaporites are also present along the contingent North-East American margin with the same diversity of structural location (Schneider, Johnson, 1970 ; Pautot *et al.*, 1970 ; Bhat *et al.*, 1975 ; Jansa, Wiedmann, 1982 ; Hinz *et al.* 1982).

Another product of previous studies is the documentation of a very important phase of the upper Jurassic carbonate platform construction over the evaporitic or terrigenous layers or over the Pre-Mesozoic substratum (Jansa, Wade, 1975 ; Jansa *et al.*, 1979 ; Renz *et al.*, 1975 ; Schlee *et al.*, 1976 ; Wissmann, von Rad, 1979 ; Hinz *et al.*, 1982).

The further evolution of Western African continental margins is essentially marked by a hiatus during much of the Late Cretaceous. This hiatus has also been described along the North American continental margin (Lancelot *et al.*, 1980 ; Price, 1980 ; Cymor Group, 1981 ; von Rad, Wissmann, 1982 ; Seibold, 1982). It has been explained by a CCD rise, erosion, or non deposition due to large transgressions during the lower Late Cretaceous that invaded the African continent.

During the Tertiary, the North-West African continental margin was affected by a succession of tectonic events marked by uplift, doming, volcanic events and erosional phases (Grunau *et al.*, 1975 ; Lancelot *et al.*, 1977 ; von Rad *et al.*, 1979 ; Seibold, 1982 ; Olivet *et al.*, 1984).

The Mazagan (El Jadida) Plateau and Escarpment are located off the Moroccan Meseta, which is situated between the Atlas and Rif mountain chains. Mesozoic and Cenozoic " Atlantic type " sediments are widely outcropping in Central Morocco, especially in the coastal basins of Safi-El Jadida (Doukkala) and Agadir-Essaouira (Haha or " Atlas Gulf "). This sedimentary cover overlies Paleozoic sediments to Precambrian crystalline basement structured in horsts and grabens by a complex system of Hercynian fractures. NNE-SSW and E-W orientated faults are dominant.

In the coastal Moroccan Meseta, we observe a subhorizontal, relatively thin sedimentary cover in which Triassic, Upper Creataceous and Miocene to Quaternary deposits dominate (Gigout, 1951). In the western " High Atlas ", this cover is folded and continuous from the Upper Triassic to the Turonian (Arambourg, Duffaut, 1960 ; Ambroggi, 1963 ; Société Chérifienne des Pétroles, 1966 ; Michard, 1976 ; Brown, 1980).

The variations of the thickness and facies of the Triassic-Liassic deposits over short distances are the result of synsedimentary tectonic movements creating horsts and grabens due to variations in the rate of subsidence.

The Middle and Upper Jurassic epicontinental deposits are generally transgressive in central Morocco (Reyre, 1966 ; Dillon, Sougy, 1974 ; Michard, 1976 ; Stets, Wurster, 1982). After a widespread Late Jurassic regression, the Cretaceous is marked by an epicontinental stage with a succession of more and more widespread transgressions (Michard, 1976 ; Stets, Wurster, 1982).

The Cenozoic history is dominated by the Atlas and Rif orogenies (Dillon, Sougy, 1974 ; Michard, 1976). From the Middle Eocene, the Moroccan Meseta has emerged except for its northern and western margins.

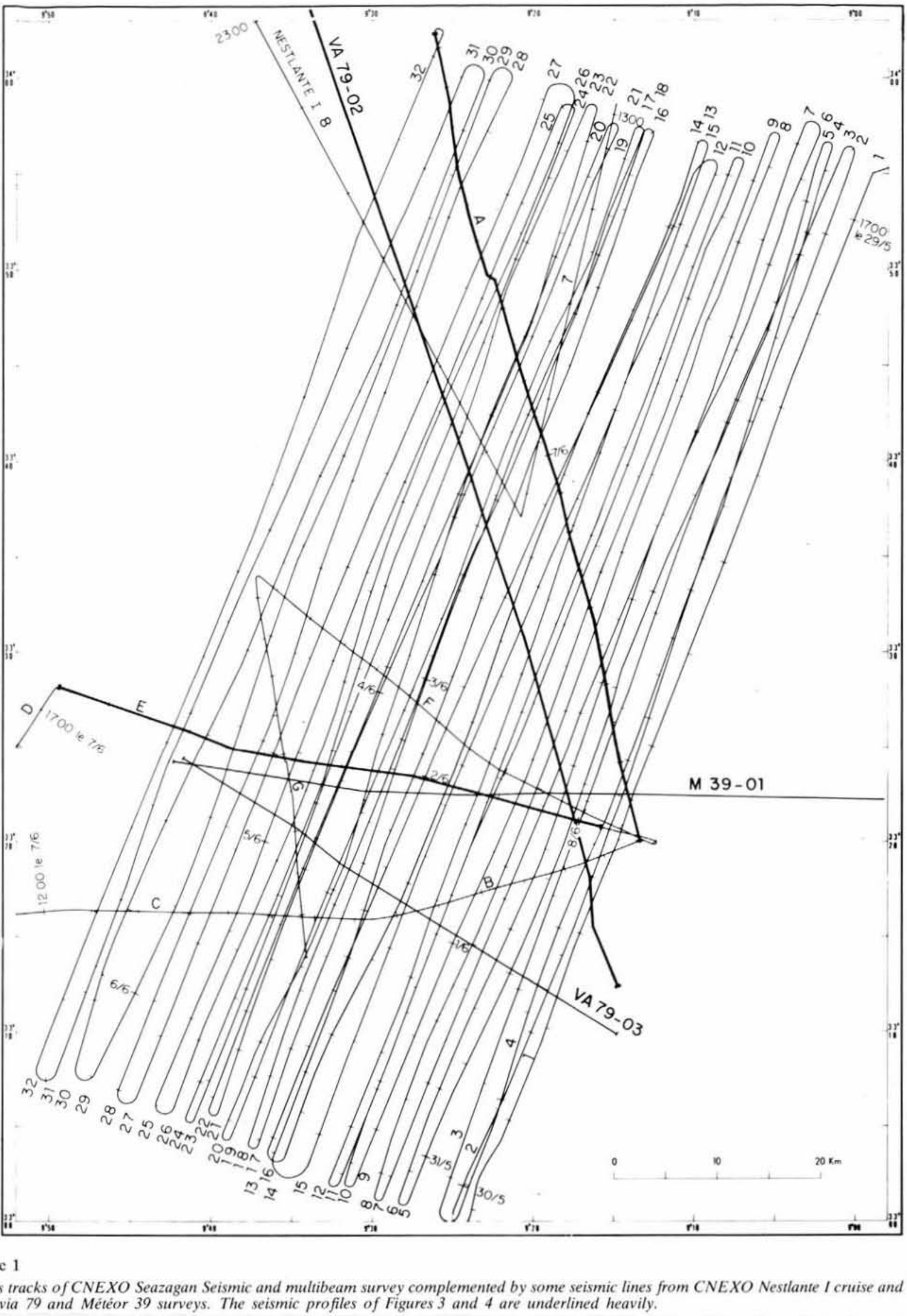

Figure 1

Ship's tracks of CNEXO Seazagan Seismic and multibeam survey complemented by some seismic lines from CNEXO Nestlante I cruise and BGR Valdivia 79 and Météor 39 surveys. The seismic profiles of Figures 3 and 4 are underlined heavily.

The Messinian-Plio-Quaternary tectonics is more intense and transforms the meseta into a large mosaic of horsts and grabens limited by preexisting faults.

The post-Paleozoic tectono-sedimentary evolution of the stable Morocco has constantly been guided by NNE-SSW and E-W Hercynian faults. These faults

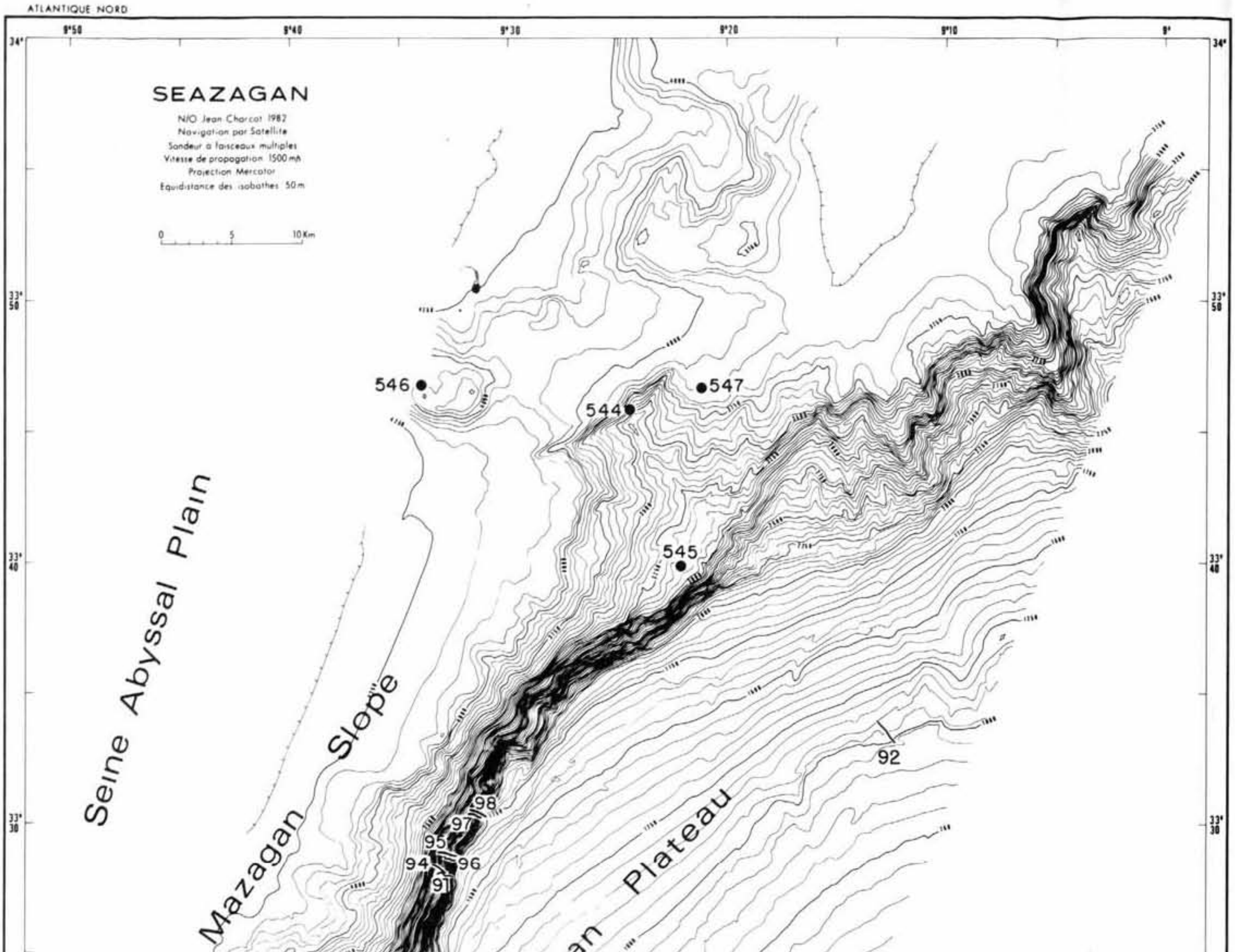

Figure 2

Seabeam bathymetric map of El Jadida plateau and escarpment, with location of CYAMAZ dives and DSDP sites Leg 79.

dissect the substratum and its sediment cover into more or less tilted blocks or rhombic shape (Saadi, 1972 ; Kanes *et al.*, 1973 ; Laville, 1975 ; Michard, 1976 ; Stets, Wurster, 1982).

Since a detailed description of morphological features of the area of Mazagan (El Jadida) Plateau and Escarpment is given in Auzende *et al.* (1984), we present here only the main morphological units (Fig. 2).

The shelf and the plateau proper show a gentle slope towards the northwest from the shore down to about 1 300 m water depth in the southern part and 1 750 m in the northern part.

The Escarpment which borders the Plateau in a crescent shape is the major feature. It is constituted by a succession of narrow steps formed by vertical cliffs. In the southern part, its depth ranges from 1 200 to 2 300 m, and in the northern part from 2 000 to 3 800 m.

At the foot of the escarpment there is a large apron marking the transition between the escarpment and the Seine Abyssal plain. This apron is cut by numerous small canyons running towards the west.

SEISMIC DATA

The geological interpretation of seismic reflection profiles has been correlated with the observations and samples from the CYAMAZ cruise dives. In the deeper zones at the foot of the escarpment, the Deep Sea Drilling results (holes 544, 545, 546 and 547 of Leg 79 — Glomar Challenger — Hinz *et al.*, 1982) have been taken into account. The very close single channel seismic tracks (Seazagan cruise, 1982 ; Fig. 1) supplemented with pre-existing multichannel profiles from the Bundesanstalt für Geowissenschaften und Rohstoffe (Fig. 3) allow us to extend the *in situ* observations and the Deep-Sea Drilling results to the whole Mazagan area.

Schematically, we can distinguish two main seismic units on seismic profiles. The lower one is constituted by the acoustic basement overlain by an upper unit constituted by a well bedded sedimentary cover.

The acoustic basement

Three types of acoustic basements can be distinguished (Fig. 3) :

a) at the foot of the escarpment, a " BM " reflector has been identified as Paleozoic basement with the help of site 544 data (Kreuzer *et al.*, in press). It is constituted by deformed metamorphic granites. The basement is cut by normal faults parallel to the main direction of the northern part of the escarpment. It is difficult to follow this reflector continuously on the seismic profiles because of the westward increasing thickness of the sedimentary cover and the existence of salt layer deformed by diapiric structures.

b) The " BM " reflector disappears under the Mazagan (El Jadida) Plateau. In this area, the top " B " of the Upper Jurassic carbonate platform sampled during the CYAMAZ dives becomes acoustic basement. Only some hyperbolic features located at about 4 seconds two-way travel time might possibly be attributed to Paleozoic basement. In some places, the zone below the " B " reflector becomes seismically opaque.

In the whole eastern part of the plateau, some reflections could be observed under the " B " reflector.

For this phenomenon, which is frequently observed on the edge of the continental shelves, different explanations have been given. It could be a simple lateral facies variation in the sedimentary sequence, linked to different conditions of deposition. They could also result from local diagenetic transformation due to emersion in the initially homogeneous carbonates (Sheridan, 1981). These seismically opaque zones have been also interpreted as reef buildups but so far there is no geological proof of reef building.

c) a third type of acoustic basement of undefined nature was observed on the seismic profiles. It is the S E horst block in very high position located toward the east on profiles A and E. (Fig. 4 *a* and 4 *b*).

Several hypotheses could be proposed concerning the nature of the acoustic basement of this horst. It might be a Paleozoic basement horst emerged until the Late Cretaceous (age of the oldest deposits above this basement). This hypothesis is compatible with land geology, since near El Jadida (about 65 km east of the escarpment) outcropping Precambrian and Paleozoic basement is overlain by Late Cretaceous transgressive sediments (Gigout, 1951). It could also be a remaining high standing block of the Upper Jurassic carbonate platform, which was later uplifted and deformed. It has been also interpreted as a middle to late Cretaceous bioherm (Wissmann, von Rad, 1979 : Hinz *et al.*, 1982). The latter hypothesis, based essentially on seismic interpretation, seems to be excluded, according to Cyamaz (CYAMAZ Group, 1983) and Seazagan data. Several arguments allow us to propose a tectonic interpretation. The outcrop of Paleogene conglomerates with late Cretaceous pebbles in the central Mazagan Plateau (− 1 000 m, Dive 92), the hemipelagic to pelagic facies character of these pebbles and of the whole Cretaceous to Tertiary post-platform sedimentary cover everywhere on the Plateau (*see* below ; and von Rad, this volume) and also the presence of tectonic breccias in the samples and observations of Dive 92 suggest that a middle to upper Cretaceous bioherm can be excluded in this zone and confirm the existence of important fault systems which mark a high central horst already pointed out in Seazagan and BGR seismic profiles.

The post-Jurassic cover

The post-Jurassic sedimentary cover is well bedded and essentially composed of hemipelagic to pelagic sediments (von Rad, this volume ; Hinz *et al.*, 1982). This cover consists of several seismic units separated by unconformities.

1) The first layer (5) partially overlies the Upper Jurassic carbonate platform. Its thickness and seismic facies varies considerably. On profile E, for example (Fig. 4), the oblique internal reflections become progressively attenuated and less clear towards the west. Along the central and southern part of the Mazagan

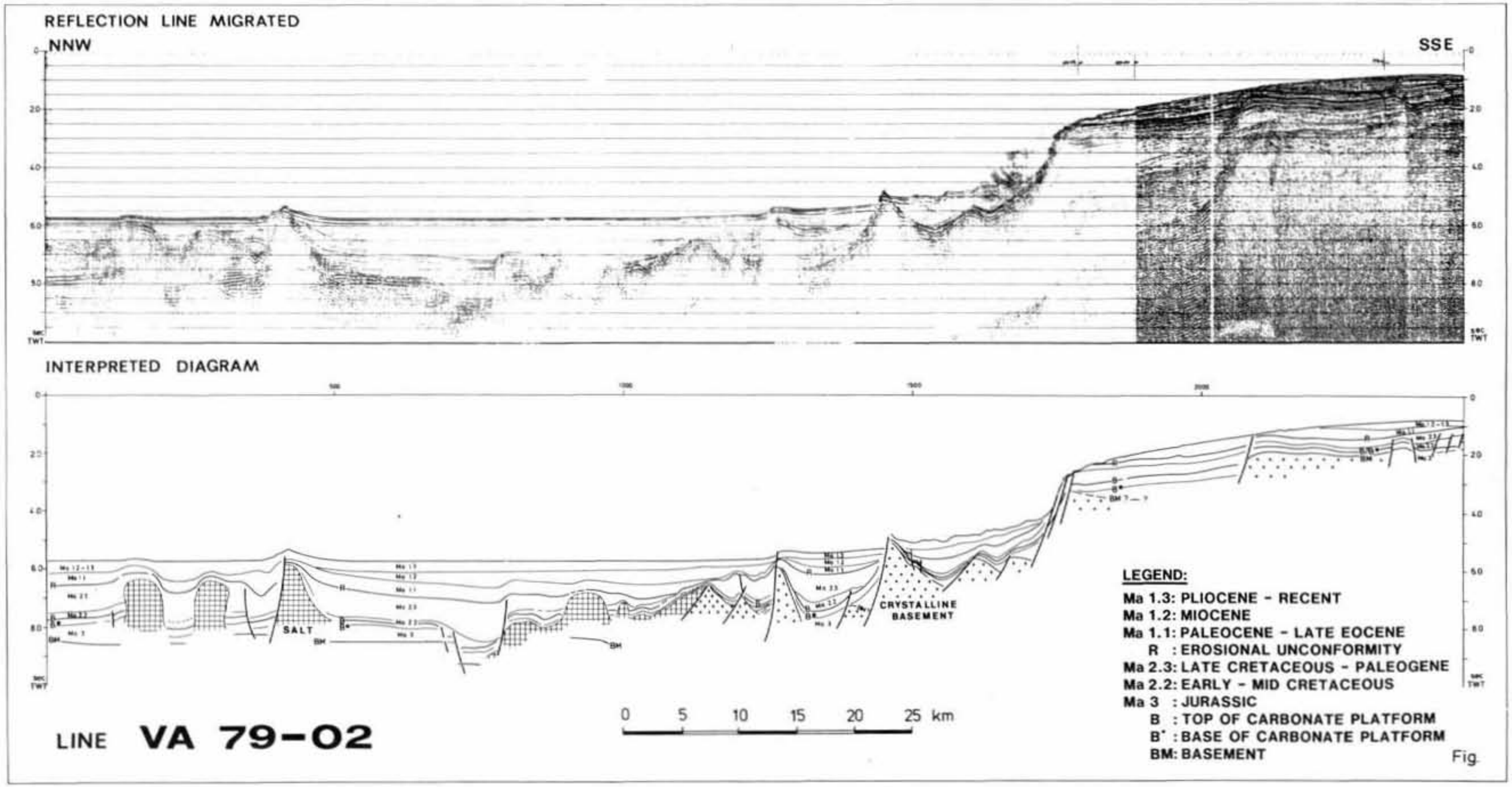

Figure 3

BGR. Valdivia 79-02 multi-channel seismic profile (Hinz et al., 1982) modified interpretation, with projected DSDP sites Leg 79.

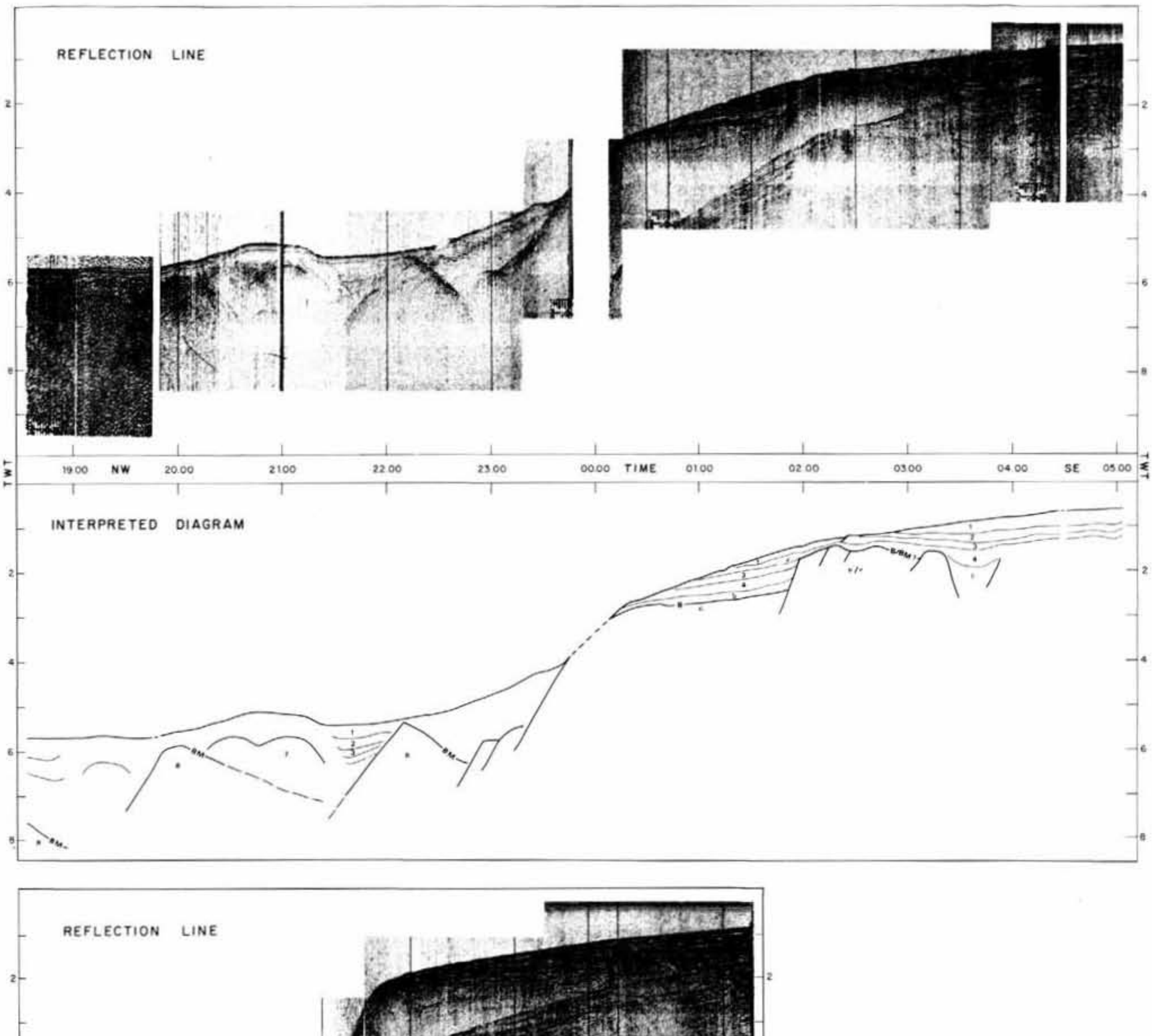

Figure 4

CNEXO Seazagan single-channel seismic profiles A(a) and E(b). (Ruellan, Auzende, 1985) : 1) Miocene, Pliocene and Quaternary ; 2) Oligocene and Early Miocene ; 3) Late Cretaceous and Eocene ; 4) Upper Cretaceous ; 5) Lower Cretaceous basins deposits ; 6) Upper Jurassic to Berriasian carbonate platform ; 7) Triassic-Liassic evaporitic deposits ; 8) Paleozoic and Precambrian basement. B : Top of the Upper Jurassic — Lower Neocomian carbonate platform, BM : Top of the basement.

(El Jadida) Plateau, this layer does not outcrop on the top of the escarpment. However, at the northern part and in the vicinity of El Jadida Canyon, this unit is widely exposed. This layer appears to be deeper water sediment ponded behind topographic highs. On these barriers, which were emerged or nearly emerged during Early Cretaceous time, the sedimentary cover is very thin or absent.

2) This seismic unit is overlain by a transgressive series (4, lower MA 2.3) widely lapping over the top of the escarpment. This succession is the first series transgressing the eastern horst. It is slightly deformed and eroded : it could be interpreted as Upper Cretaceous deposits. In some places, on the edge of the plateau, it directly overlies the carbonate platform.

3) A new unconformity marks the change from this transgressive series to the overlying deposits (3, 2, 1 or Upper MA 2.3, MA 1.1, 1.2 and 1.3). These deposits continue to fill the basins and overlap all fault blocks. They are affected by tectonic deformation and faults that rejuvenate preexisting faults. The lowermost part of this series could be interpreted as uppermost Cretaceous to Eocene. Above it, a thinly bedded sequence tentatively correlated with Oligo-Miocene series presents major thickness variations.

The uppermost layer lies over either Cretaceous, either Paleogene and Lower Miocene separated by an erosional unconformity (*see* synthetis in Fig. 8). El Jadida Canyon. The upper most series is presumably upper Miocene to Plio-Quaternary.

DIVE DATA

The fault observations from Cyana dives allow us to improve on another scale the seismic structural analysis. However, we must discuss the limitations for their interpretation.

The strike and the dip measurements from Cyana are not very precise, because of the observation conditions such as inaccessibility of the outcrops, the limited field of vision, optical deformations by the view from the porthole, camera and cine-camera. Secondly, due to these conditions, the preferredly observed fractures are those which have a direction which is more or less parallel to the course of Cyana. Because the average heading of most Cyamaz dives was about N 90 (*see* Fig. 2) — which is perpendicular to the escarpment — the main consequence is a bias towards faults striking E-W (N 70 to N 90).

On the bathymetric maps of each dive, drawn from available seabeam and dive data, and through the dives observations, the escarpment appears to be made of a succession of dipping, narrow and elongated steps. These steps are covered by soft sediments and limited by very steep and eroded fault scarps. The escarpment results from a major normal fault system. Many joints, weak throws and normal faults (on a dm- to m-scale) dissect the upper Jurassic carbonate platform and the Cretaceous to Quaternary sedimentary cover. The lack of large fault planes can be explained by this great number of small fractures and by the active dissolution and erosion defacing the escarpment. It seems that the fracturation is more developed in the Jurassic carbonate platform than in post-platform sedimentary cover.

In the central Mazagan (El Jadida) Escarpment (dives 91, 93-98) the top of the escarpment is located between 1 750 m (in the south) and 2 000 m (in the North) of water depth. The greatest average slopes ranged from 130 to 150 % (52 to 56 degrees), sometimes more, and are situated in the uppermost part of the escarpment (from the platform edge down to 2 300-2 400 m of water depth). Deeper, the slopes generally do not exceed 70 % (35° ; *see* Auzende *et al.*, this volume).

Many subvertical faults and joints shear and disorganize completely the Jurassic platform and its cover. Those fractures have two main strike directions N 20 and N 90, and three secondary ones N 70, N 110-120 and N 160 (Fig. 5).

The relatively low percentage of the strike direction N 20, compared to N 90 in the frequency diagram (Fig. 5) probably results from the observation conditions discussed before.

In the Southern Mazagan escarpment (Dives 84-90, 101), the edge of the plateau is located between 1 200 m (in the south) and 1 400 m (in the north). Except for a lesser amplitude, we have the same morpho-structural features as in the central Mazagan escarpment. Fractures are organized according to the same main and secondary directions, but we observe an increase of occurrence for the N 150-160 and N 20 fracture direction (normal fault and joints). At the foot of the escarpment, we observe late Aptian to early Albian nanno chalk overlain by Tertiary (middle Miocene) chalk. These mid-Cretaceous sediments probably represent the oldest hemipelagic well-bedded sequence (von Rad, this volume) and show evidence of small gravitative slumping and faulting, with small offset.

Dive 92 is located on the Central Mazagan Plateau slightly sloping northwestward, in a morphologically and tectonically disturbed zone. The well-bedded pelagic sedimentary cover of Late Cretaceous to Paleogene age contains several strips of tectonic breccia and is completely disorganized. This is also proven by the biostratigraphic ages of the Eocene (early-Paleocene samples which become progressively older in an upslope (up-section) direction (Čepek, Hagn, this volume ; von Rad, this volume). According to these observations, we think that vertical tectonic movement, *i.e.* uplift the central horst or subsidence of the outer Mazagan plateau, took place in this zone at least during Cretaceous to Eocene times.

The two dives located in the upper part of the El Jadida Canyon area (Dives 99 and 100) show features of very active dissolution, erosion and mass movement process. The well-bedded post platform sedimentary deposits are down-faulted in three directions : N 10-20, N 90 and N 120 giving generally small southward cliffs. The N 120 orientation, already shown by the morphological and seismic analysis, was not observed very often during these dives due to the limited observation conditions.

In general, our dive observations suggest that the Mazagan Plateau, Canyon and Escarpment, as a whole, were structurally conditioned by two main normal faulting systems striking N 20 and N 90 and

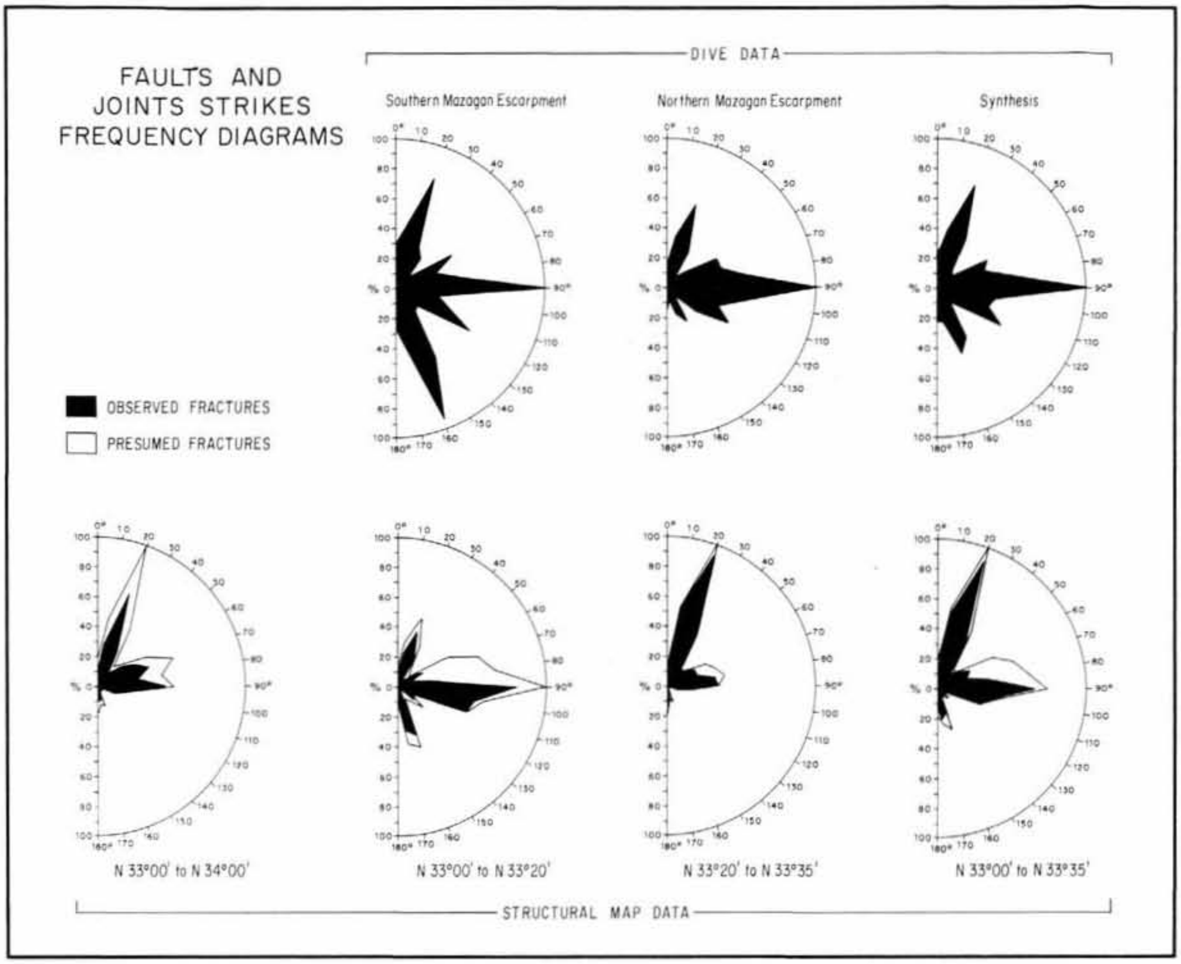

Figure 5

Faults and joints strikes frequency diagrams from CYAMAZ dives data and SEAZAGAN structural map data.

three secondary ones N 70, N 120 and N 160. All the frequency diagrams are consistent with those drawn from the interpretative seismic structural map between latitudes N 33° 00 and N 33° 35 (Fig. 5). Nevertheless, we can see a slight difference of about 10° especially in the secondary directions. We observe a rotation of structural trends from the north to the south. Further north, according to the structural map, it seems that the N 70 secondary strike becomes more abundant and one of the main structural directions, whereas in the southern escarpment, we observed a slightly preferred direction of N 160.

Neither from the structural map nor from the dive data can be established a chronology between these different fault systems. As in the Moroccan Meseta, where we recognized the two same main structural directions inherited from the Hercynian evolution, diving data indicate that all the fault systems were remobilized many times, during the Mesozoic evolution, at least up to the Eocene time. All these facts confirm the seismic interpretation.

ISOCHRONOUS MAP (FIG. 6) AND STRUCTURAL MAP (FIG. 7)

The very dense seismic cover and the eighteen dives on the Mazagan (El Jadida) Plateau and Escarpment allow us to construct an isochron map of the acoustic basement (Fig. 6) representated either by the Upper Jurassic carbonate platform or by the Precambrian to the Paleozoic basement. We also present a detailed structural map (Fig. 7).

At the foot of the escarpment, the Paleozoic acoustic basement is found at a depth of about 5 seconds two-way travel time. It is controlled by a normal faulting system oriented N 10-20 and N 70-80. It is a downwarped and slightly tilted " half-horst ". Further north a new tilted block appears which is also cut by important NE-SW normal faults looking towards north.

In the depressions between these two tilted blocks, sediments ranging from Triassic to Recent were deposited. The Triassic-Liassic deposits are representated by salt deposits which have been affected by diapirism (Wissmann, von Rad, 1979 ; Hinz *et al.*, 1982 ; Ruellan, Auzende, 1985).

Under the Mazagan (El Jadida) Plateau, the central horst is bounded toward the ocean by the Upper Jurassic carbonate platform. On the edge of the plateau this platform creates a small relief, presumably in conformity with a high of the underlying continental basement. The platform is slightly inclined northward where the escarpment feature disappears. The whole Mazagan (El Jadida) Plateau is intensively cut by a complex pattern of normal faults with strike slip faults

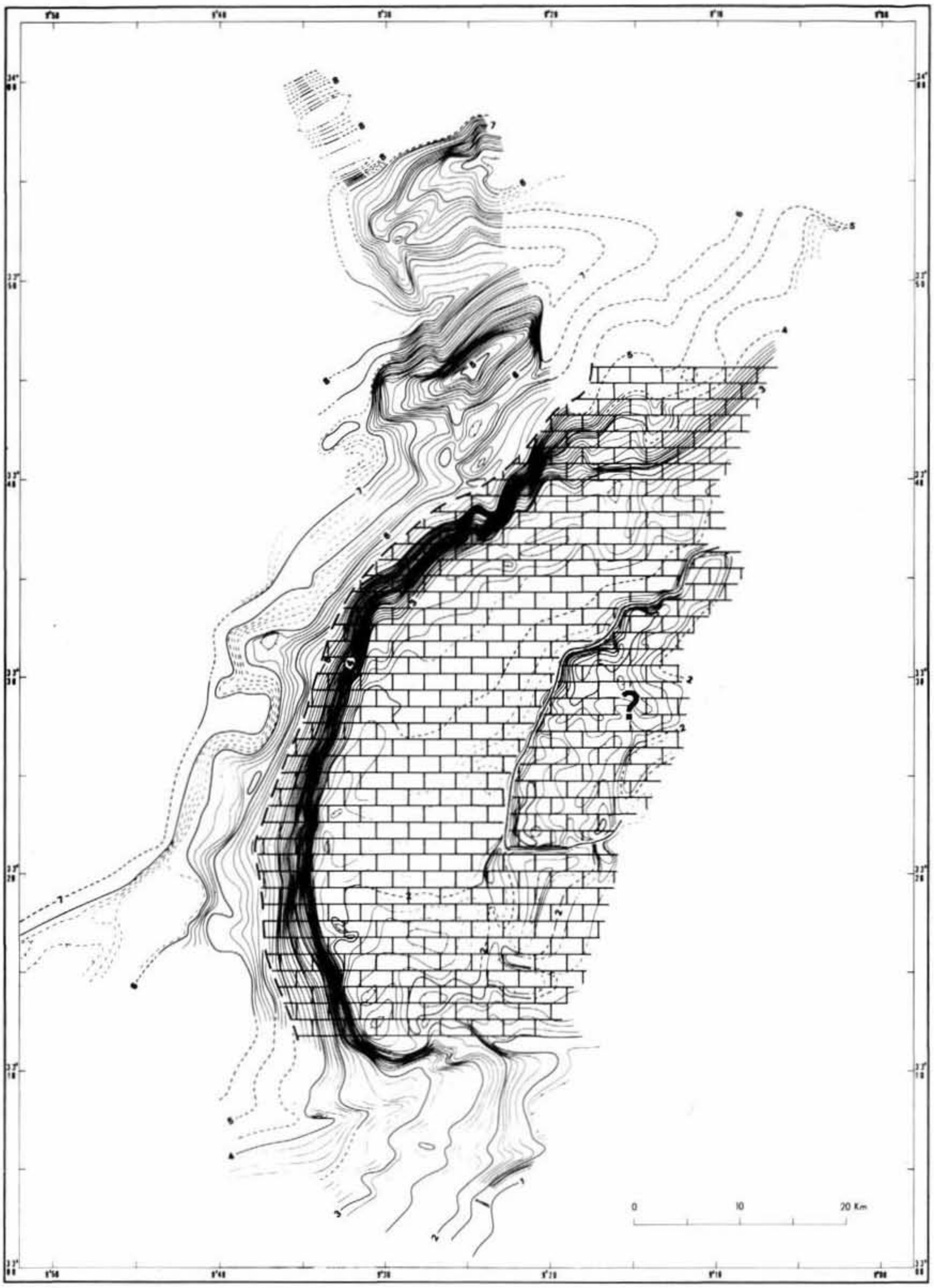

Figure 6

Depth contour to acoustic basement in Sec. TWT below sea level. Under the Mazagan Plateau and along the escarpment, the acoustic basement is the carbonate platform (seismic reflector B) ; elsewhere, it is Paleozoic/Precambrian sialic basement (seismic reflector BM).

in some places. The main directions of fracturation and faulting are N 20, N 60-70, N 90, N 120 and N 160. These directions are principally the Hercynian fractures, widely known from the Moroccan Meseta. Some of them only affect the Paleozoic basement and the platform carbonate. However, most of them were reactivated during the Cretaceous, Tertiary, and probably also during the Quaternary. Some faults affect only the post-Jurassic sedimentary cover, but they are not numerous.

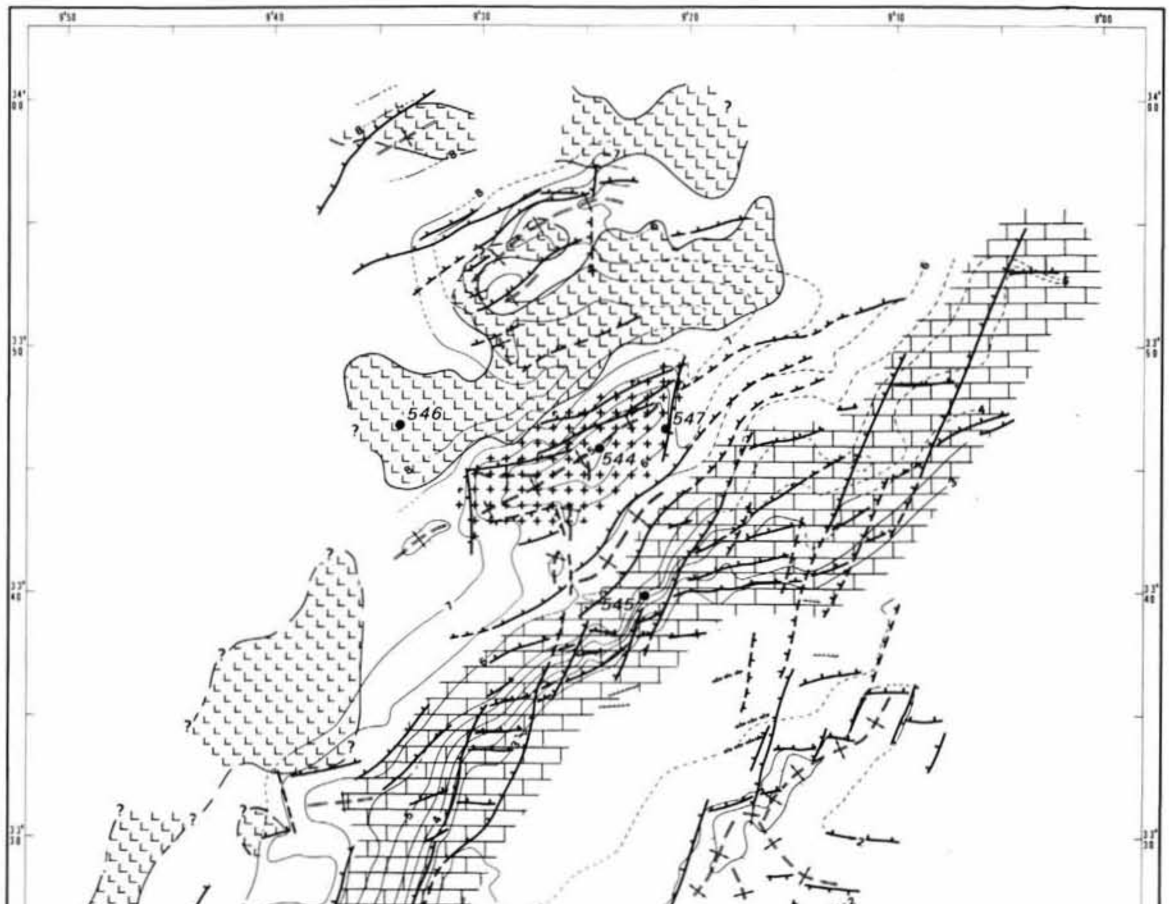

Figure 7

Mazagan structural map : 1) Edge of the Upper Jurassic/Lower Neocomian Carbonate Platform. Generally outcropping or just slightly buried along the escarpment and at the edge of the Mazagan Plateau ; 2) Salt basin with diapirs domes ; 3) Paleozoic crystalline basement very faint overlay ; 4) Isochrons of the acoustic basement. Along the escarpment and under the plateau = top of the Carbonate Platform (seismic reflector B) ; Northwestward of the platform = crystalline continental basement (seismic reflector BM) ; 5) Major normal faults — In dashed line, presumed ; 6) Normal faults only marked in the platform ; 7) Small normal faults marked only in the post-platform sedimentary cover ; 8) Acoustic basement high ; 9) Location of Leg 79 DSDP sites.

DISCUSSION — MODEL OF EVOLUTION

Schematically, the evolution of the Central Moroccan continental margin off El Jadida can be subdivided into five main stages (Fig. 8).

First stage

During the first phases of the intracontinental rifting until the Middle to Upper Liassic, evaporitic layers and carbonates (site 547) were deposited in subsiding epicontinental basins. These basins are located essentially west of the present-day escarpment. In the south, these basins make an indentation into the Atlas gulf. However, some traces of these evaporitic deposits have been reported on the Moroccan Meseta. On the Mazagan (El Jadida) Plateau, some seismic features, essentially located near the main fractures, could be interpreted as small diapirs. In this case, an evaporitic layer would be present between the continental basement and the carbonates of the platform (Ruellan, Auzende, 1985).

Second stage

From Late Jurassic until the lower Neocomian, after a mid-Jurassic tectonic reactivation, a carbonate platform was built up as basement highs. Simultaneously, in deeper areas hemi-pelagic to pelagic sediments were deposited. Towards east, sediments characteri-

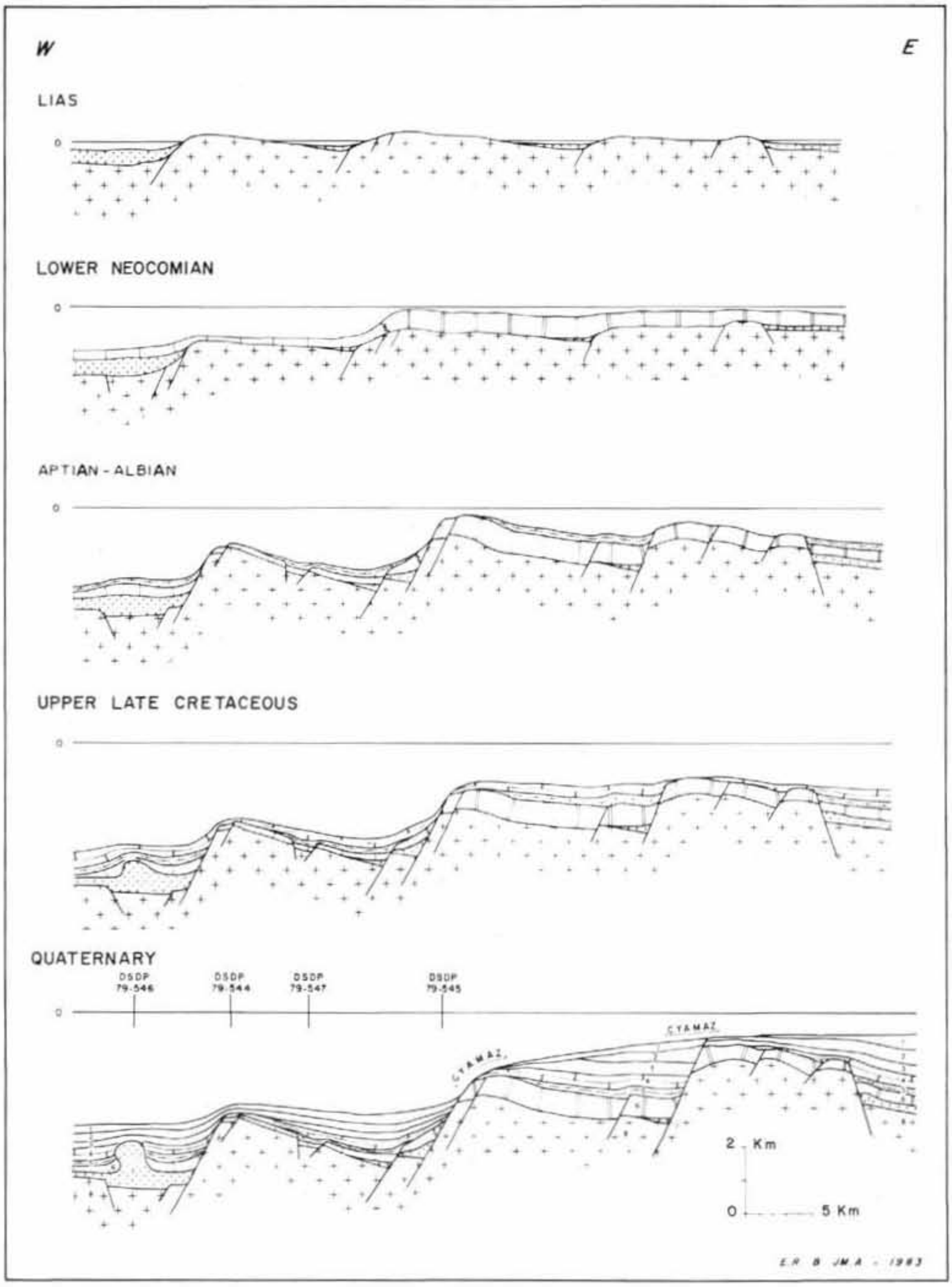

Figure 8

Synthetic sketch of the Mazagan Plateau and Escarpment evolution from the time of the Triassic-Liassic rifting process up to the present.

zing a deeper environment were deposited landwards of the platform carbonates. This difference explains the variation of seismic signal between the seaward edge and the central part of the plateau within the carbonate platform.

Third stage

During the Early Cretaceous, we note a very important phase of vertical structuration of the whole continental margin. The result of this phase is the outcropping of the platform carbonates along the escarpment and the creation of small half-grabens toward the east. In these basins we find a fill of lower to middle Cretaceous sediments.

This major tectonic event along the Moroccan margin which probably began with the late Neocomian may constitute a regional manifestation of the long (about 25 Ma) large scale relative movement reorganization beginning at the time of " J " magnetic anomaly (M 0-M 3, 112-114 Ma) (Olivet *et al.*, 1984). In the Atlantic, the main events are the initial opening north of the Bay of Biscay and the break between continental shields of West Africa and Brazil (Curie *et al.*, 1983 ; Olivet *et al.*, 1984). On a regional scale, we have the abnormal ridge upbuilding of the " J " magnetic anomaly and the change of the Azores-Gibraltar strike-slip plate boundary in a second order frontier, the Iberic plate being welded to Africa in a single movement. The abnormal ridge upbuilding has no definite explanation, but might be correlated with changes of oceanic spreading rates and trends. Thus we have important geodynamic changes at all scales and in all parts of the central Atlantic during this time.

Fourth stage

The upper Cretaceous deposits are widely overlapping. They extend all over the Mazagan (El Jadida) Plateau and also onto part of the Moroccan Meseta. At El Jadida, they overly directly Precambrian or Paleozoic basement. This transgression had its maximum in the Turonian.

Fifth stage

A sedimentary series in which we observe discrete unconformities in the lower Senonian, upper Eocene and middle Miocene has been deposited up to the Present. These unconformities are evidence of ongoing tectonic activity in this area.

In summary, the evolution of the Central Moroccan margin off El Jadida could be divided into two main phases. The first is dominated by the opening of the Atlantic Ocean ; the American and African contingent continental margins had a very similar evolution (salt deposition, carbonate platform buildup).

The second period is more influenced by African events with the Atlas and Rif orogenies. These events are marked by important vertical movements affecting the African margin. During this phase, the African and American margins evolved in a very different manner.

Acknowledgements

We thank U. von Rad, R. Blanchet and G. Wissmann for the helpful review of our manuscript and for the improvement of the English.

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