Outline and results of the CYAMAZ Cruise (Mazagan Escarpment — West-Morocco)

Mazagan escarpment
Moroccan margin
Submersible
Stratigraphy
Tectonics

Escarpement de Mazagan
Marge marocaine
Submersible
Stratigraphie
Tectonique

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ABSTRACT

In September-October 1982, a joint German-French project to explore the Mazagan (El Jadida) Escarpment and Plateau was carried out with the French submersible SP 3000 Cyana. The main purpose of CYAMAZ cruise was to observe and sample the steepest part of the escarpment where previous works suggest that the oldest series (since Jurassic) of the infilling of the Central Atlantic Ocean are outcropping. In this paper we present the main outline and results of the eighteen dives operated during the CYAMAZ cruise. These results essentially concern the stratigraphy and structure of the sedimentary series outcropping along the Mazagan escarpment. The age of the sedimentary sequence ranges from Late Jurassic-Lower Neocomian until Plio-Pleistocene. Late Jurassic-Early Cretaceous sediments constitute the carbonate platform. They are covered with post platform sediments of differents ages and facies. Observations from the submersible allow us to define two main directions of faulting and fracturation, N 20° and N 90°.

Oceanol. Acta, **1984.** Submersible Cyana studies of the Mazagan Escarpment (Moroccan continental margin), CYAMAZ cruise 1982, 5-58.

RÉSUMÉ

Généralités et résultats de la campagne CYAMAZ (escarpement de Mazagan — W. Maroc)

En septembre-octobre 1982, une campagne franco-allemande a eu pour objectif l'exploration, à partir du submersible SP 3000 Cyana, de l'Escarpement et du plateau de Mazagan (El Jadida). Le but principal de la campagne CYAMAZ était d'observer et d'échantillonner la partie la plus abrupte de l'escarpement, où des travaux antérieurs suggèrent que les séries les plus anciennes du remplissage de l'Atlantique central (jusqu'au Jurassique) sont à l'affleurement.
Dans cet article, nous présentons les généralités et les principaux résultats concernant les 18 plongées de la campagne CYAMAZ. Ces résultats ont trait à la stratigraphie et aux événements tectoniques qui affectent les séries affleurantes, le long de l'escarpement. L'âge de la couverture sédimentaire varie de la fin du Jurassique-Néocomien basal jusqu'au Plio-Pléistocène. Les sédiments fini Jurassique-Crétacé basal constituent une plate-forme carbonatée. Ils sont recouverts de séries post-plate-forme d'âge et de faciès variables. Les observations faites à partir du submersible permettent de définir deux directions principales de fracturation, N 20° et N 90°.

Oceanol. Acta, **1984.** Études par le submersible Cyana de l'escarpement de Mazagan (marge continentale marocaine), campagne CYAMAZ 1982, 5-58.

INTRODUCTION

The Mazagan Escarpment and Plateau are located on the north-west african continental margin off Morocco about 200 km south-west of Casablanca (Fig. 1). This area is one of the best examples of an old, starved, passive continental margin. Because the late Jurassic platform carbonates and their Cretaceous-Cenozoic sedimentary cover are well exposed along its steep escarpment, the area provides an excellent opportunity to study the stratigraphy, paleoenvironment and subsidence history of the Moroccan continental margin by direct observations and sampling from a submersible. The Scientific Submersible Committee of CNEXO consequently supported a joint French-German project in this area, using modern tools for the exploration of the seabottom: the multibeam echosounder Seabeam (SEAZAGAN Cruise, September/October 1982). In this paper, we present the objectives and a general overview of the results of the SEAZAGAN and CYAMAZ cruises, CYAMAZ is an acronym for Cyana and the Mazagan Escarpment).

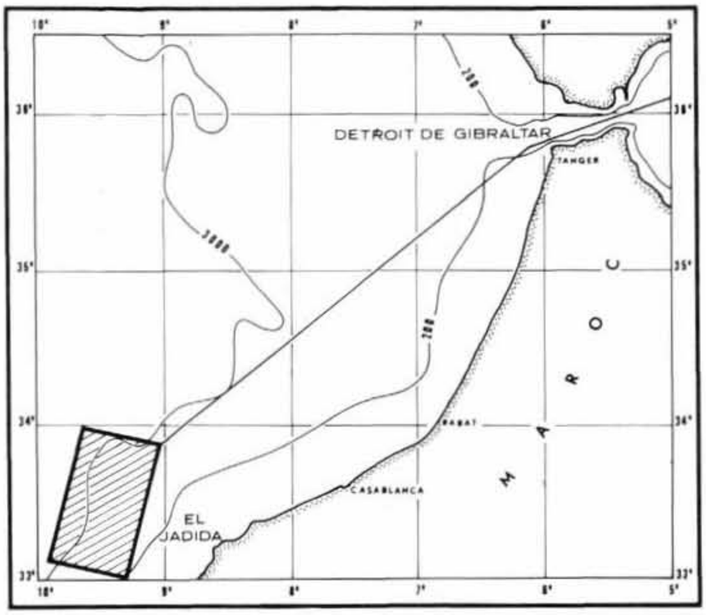

Figure 1
Location of El Jadida site.

PREVIOUS STUDIES IN THE MAZAGAN (EL JADIDA) AREA

The Northwest african continental margin off Morocco is probably one of the best studied passive margins in the world. Many cruises have been carried out in this area.

Different seismic surveys have been conducted during the past 15 years; single-channel seismic lines by Vema, Atlantis and Meteor expeditions (Vema 23, 27, 29, 30, 32 of Lamont Doherty Geological Observatory and Meteor 25, 46 by BGR) have been enhanced by multichannel seismic surveys carried out by the BGR (Meteor 39 and 67, Valdivia 79, IPOD site surveys for legs 50 and 79). Some of these data have been published by Giesel and Seibold (1968), Wissmann and von Rad (1979), Uchupi *et al.* (1976), Hinz *et al.* (1982). During these cruises bathymetry, magnetics, gravimetry and some heat flow measurements were recorded.

Rock sampling by *dredges and piston cores* also provides important information about the geological sequences. Samples of Paleozoic granite, late Jurassic perireefal limestones, Aptian/Albian marls and Eocene glauconitic marls were collected during Vema 30, Meteor 46 and Valdivia 79 cruises. The most spectacular results were the sampling of an ammonite-rich, Oxfordian limestone from the base of the escarpment (Renz *et al.*, 1975) and of Paleozoic granite (Wissmann, von Rad, 1979).

The information given by dredging and coring is, nevertheless, very incomplete because of the discontinuous sampling and its poor localization.

Limited *deep-sea photography* during the *Vema cruise* proved that most of the escarpment is bare of recent sediments and directly accessible to observation and sampling by submersible.

Before the DSDP Leg 79 (Hinz *et al.*, 1982), two deep holes (sites 370/416 — Leg 41 and 50) had been drilled in the deep Moroccan Basin (Lancelot *et al.*, 1977; Lancelot *et al.*, 1980).

The oldest sediments were Tithonian-Kimmeridgian turbidites, considered to represent a deep-sea fan facies below the Jurassic escarpment. During IPOD Leg 79 (Hinz *et al.*, 1982) four sites (544 to 547) were drilled at the foot of the Mazagan Escarpment. The drilled sequence provided important new information about the structure and facies of the carbonate platform (*see* Steiger, Jansa, in press). The CYAMAZ cruise extended the information of the Leg 79 sites from the Mazagan outer high (sites 544/547) and slope (site 545) to the steep escarpment which had a different facies evolution.

SEAZAGAN CRUISE

The CYAMAZ diving cruise was prefaced by a multibeam echosounder bathymetric survey: an uninterrupted coverage of the Mazagan Plateau and Escarpment was carried out during the SEAZAGAN cruise (27 May-10 june 1982) on RV Charcot (Auzende *et al.*, 1983; Auzende *et al.*, 1984). This bathymetric survey was associated with a single-channel seismic survey. 39 lines were covered (Fig. 2) during 8 days. A surface of 3 000 km^2 was covered. On the bathymetric map drawn from this seabeam survey (Fig. 3) we can distinguish three main zones: the Mazagan (El Jadida) Plateau, the Mazagan Escarpment and an apron grading into the abyssal plain.

The Mazagan plateau

The Mazagan plateau, between the 500 m contour and about 1 300 m depth has a very gentle westward slope to the edge of the escarpment. To the northwest, it is perceptibly larger and the " flat " area spreads to the 2 000 m isobath. This plateau is structurally controlled by NE-SW features (*see* Ruellan *et al.*, this

Recent ooze, sandy ooze, ooze with blocks and pebbles.

(N) Tertiary chalk (N : Neogene).

conglomerates or breccias with limestones elements and carbonate matrix.

Breccias with limestone: pebbles components and carbonate matrix.

Well-bedded limestones with a late Cretaceous to Tertiary age.

Late Cretaceous massive limestones with coarse bedding.

Well-bedded limestones / sandstones sequence in the El Jadida Canyon area probably of Cretaceous age.

Well-bedded limestones / sandstones apparently more marly sequence in the El Jadida Canyon area probably of Cretaceous age.

Well-bedded limestones. Late Cretaceous.

Late Aptian / early Albian marls.

Massive to well-bedded limestones.
Age not sure : upper Jurassic to early Aptian ?

well-bedded massive quartz-rich limestones in the El Jadida canyon are:
Early Cretaceous ?

Upper Jurassic to lower Neocomian massive platform carbonates.

Undifferentiated bedded limestone.

Quartz-rich, well-bedded limestones. Age unknown.

Upper Jurassic / lower Neocomian block.
Cretaceous / Tertiary limestone /chalk block.
Undetermined limestone block.
(20) Slope (20°)
Bottom current (observed)
Ripple marks in recent ooze
Small cliff
High amplitude (megaripple or sand wave ?)
Talweg, canyon
Talweg, canyon with evidence of turbidity current
Bioturbation
Recent ooze with mounds
Slump, gravitative sliding
Slump, gravitative sliding (presumed)
Scar
Erosion surface
Tilted mass, mass wasting

Dissolution pocket
Calcite vein
Mn Manganese crust
Y Perforation, burrow
III Y Perforation with Tertiary infilling
F(20) Fault with orientation and dip
Stratification
Slightly reverse fault
Fractures
So Stratification
D Joint
xxxxxxxx Tectonic breccia
Anthropogenic pollution barrel (waste disposal).

Captions of geological maps and geological profiles.

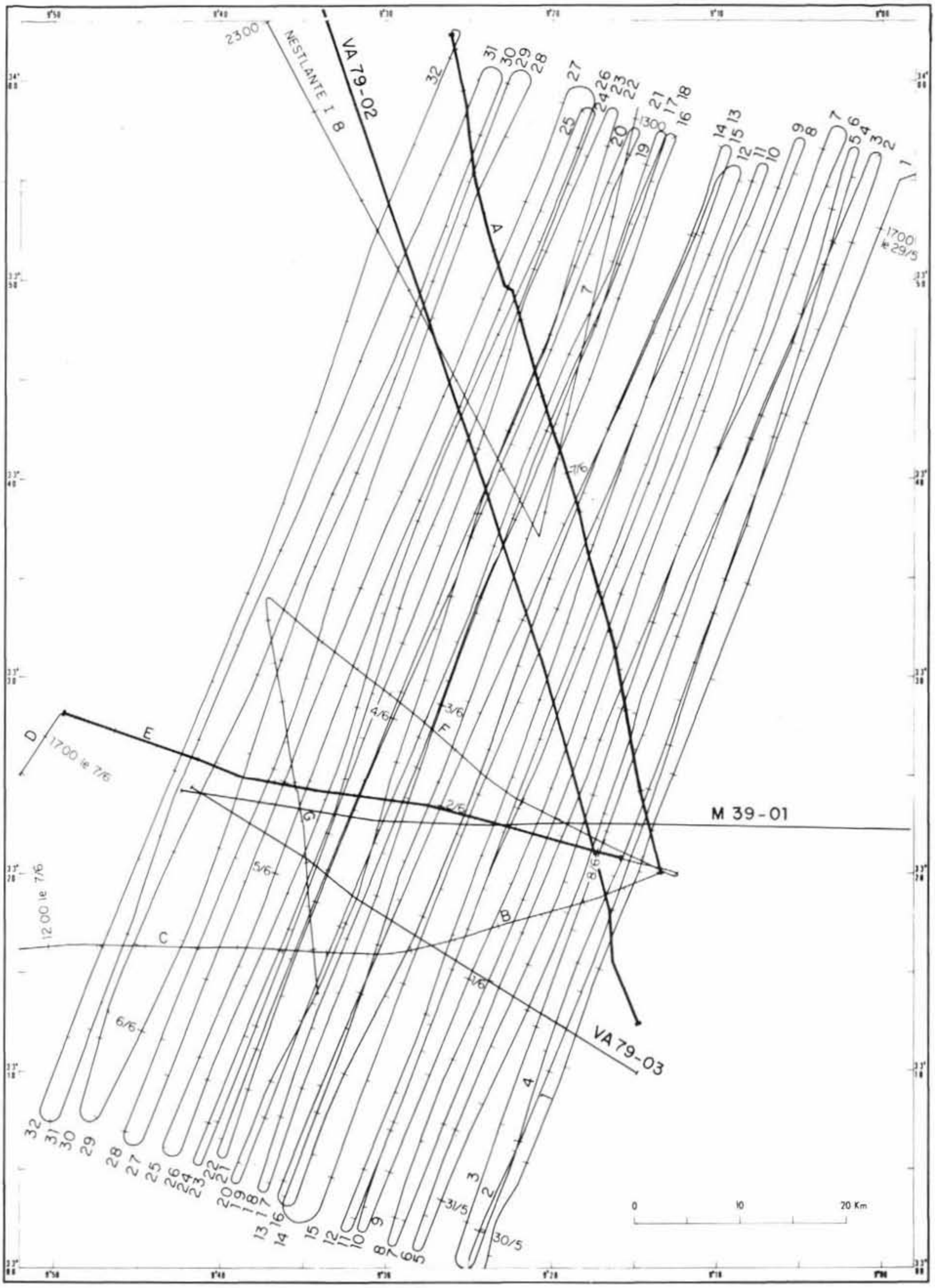

Figure 2
Location map of Seazagan Cruise (Seabeam and single channel seismic profiles).

vol.). In the southern part is a N-S oriented promontory, probably controlled by a high basement. This promontory detaches to the east a small reentrant to the 750 m isobath controlled by NE-SW directions.

The Mazagan escarpment

The Mazagan escarpment shows very steep slopes between 1 300 and 3 000 m in the central and southern

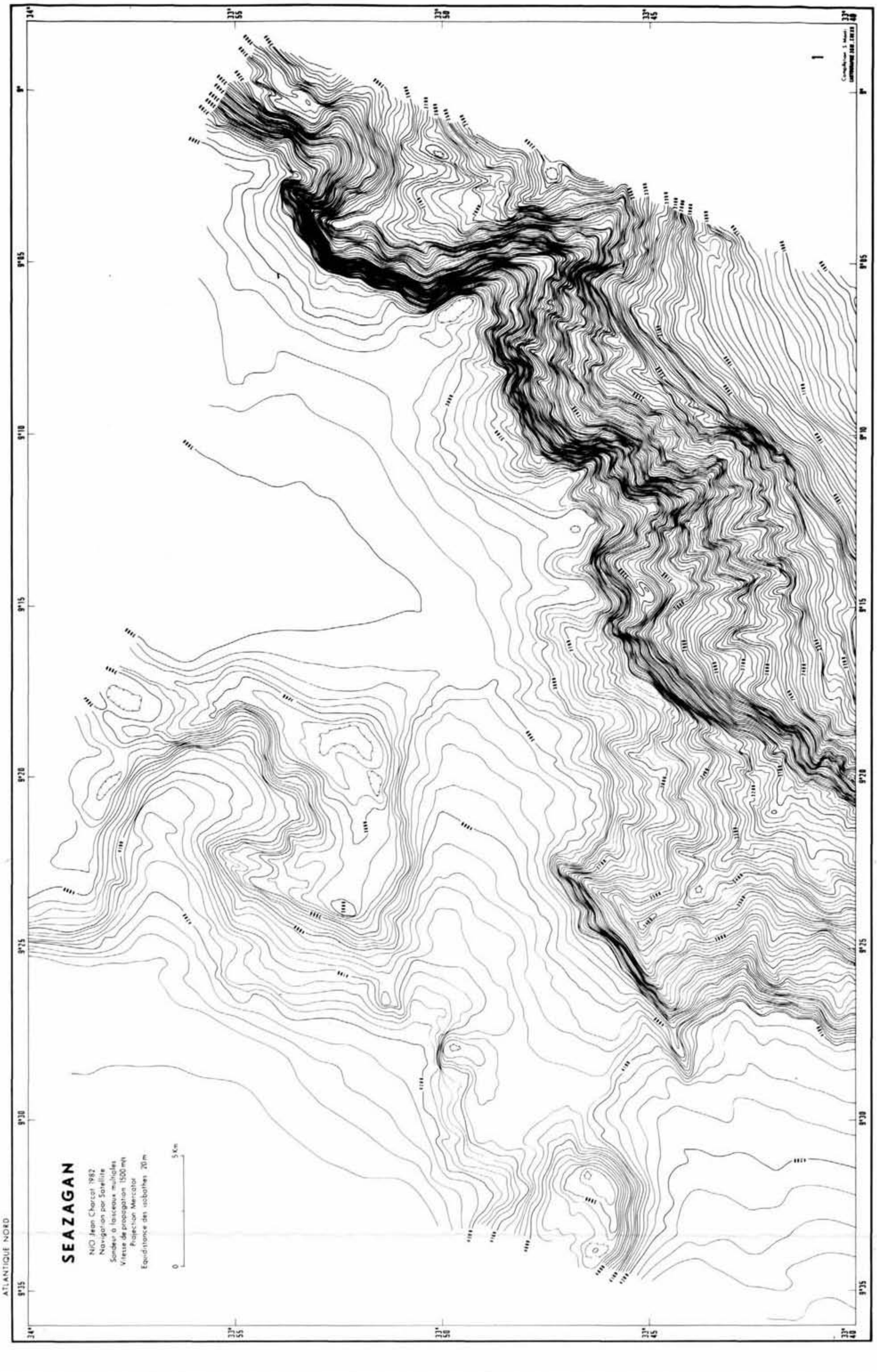

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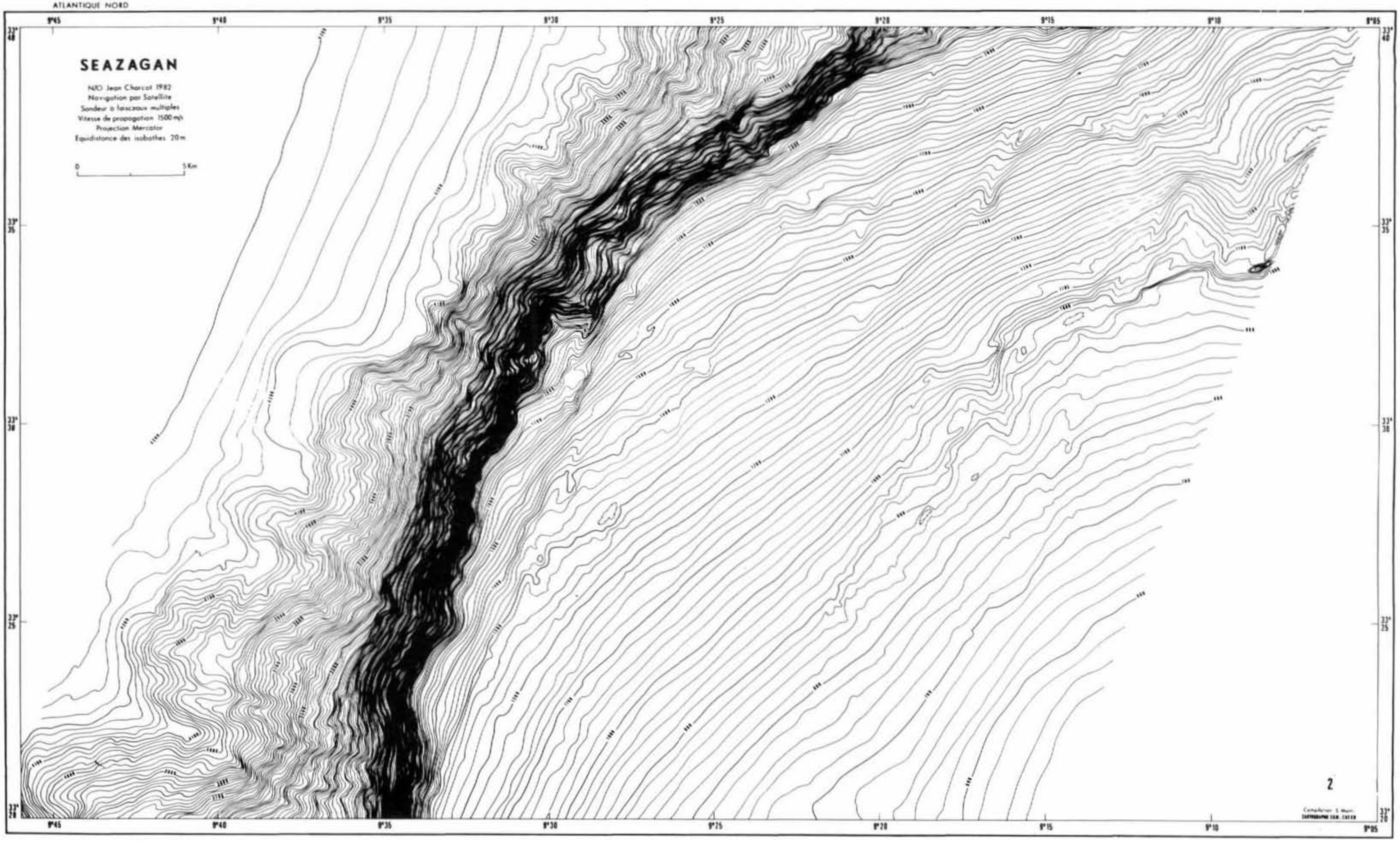
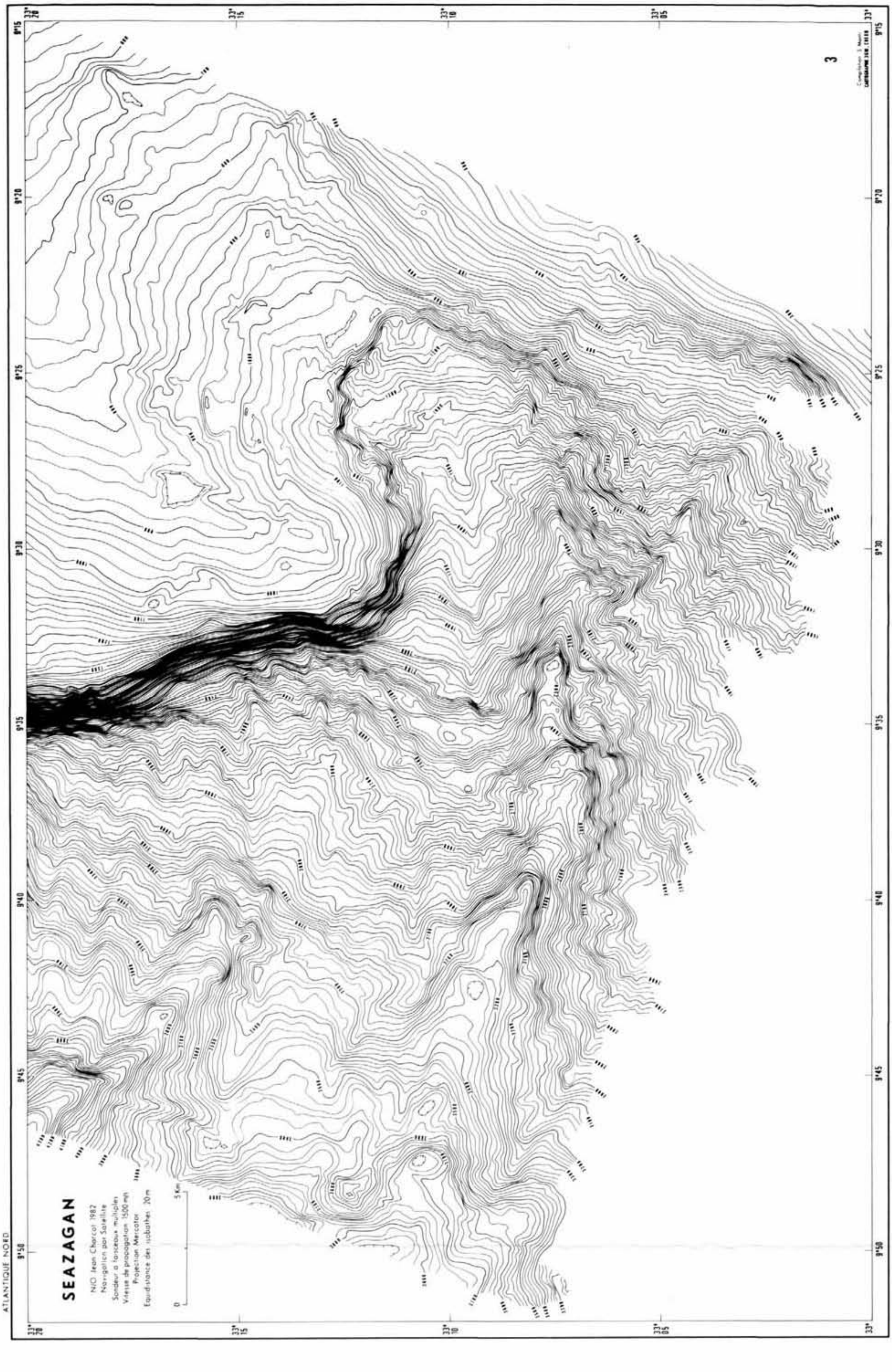
Figure 3 (1-2-3)
Seabeam maps.


ATLANTIQUE NORD
SEAZAGAN
N/O Jean Charcot 1982
Navigation par Satellite
Sondeur à faisceaux multiples
Vitesse de propagation 1500 m/s
Projection Mercator
Equidistance des isobathes 20 m
0
5 Km
2

(2)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SEAZAGAN
N/O Jean Charcot 1982
Navigation par Satellite
Sondeur à faisceaux multiples
Vitesse de propagation 1500 m/s
Projection Mercator
Equidistance des isobathes 20 m
0
5 Km
3

③

parts. On some of these profiles, the average slope is between 45° and 60°. In the south, the main cliff is in most cases between 1 300 and 2 000 m and deeper in the central part. Some steps of variable width appear below, indicating the vast amount of talus making up the apron. Those steps are more accentuated in the southern part of the escarpment between 33°10 and 33°20N.

A broad apron, grading into the Seine Abyssal Plain, lies at the foot of the escarpment, below 3 000 m. The morphology of this apron is similar to that of the talus areas at the foot of other slopes and it is possible to observe some cuts roughly parallel to the lines of highest slopes. The apron is particularly prominent in the south of the area, where it presents a series of WNW-ESE structurally controlled canyons, the most important of which is the El Jadida Canyon. In the north, the apron is also very wide and is broken up by high zones showing erosion of few meters and obviously controlled by faults oriented SW-NE and N-S. The high zone appearing on the north-western edge of the map is much more circular and could be associated with a diapiric structure.

OBJECTIVES OF THE CYAMAZ CRUISE

The Late Jurassic-Early Cretaceous carbonate platform which is normally deeply covered by sediments off the Northwest african margin is weel exposed in the seaward projecting Mazagan Plateau and Escarpment (Renz *et al.*, 1975 ; Wissmann, von Rad, 1979 ; Hinz *et al.*, 1982), offers a unique opportunity to study the early-rift, drift and subsidence .

The main objective of the CYAMAZ cruise was the study of the structure and development of the Mazagan Plateau. The following global or regional objectives had been formulated prior to the cruise :

1) Structuration of the steep escarpment of a carbonate buildup (erosion, rotational block faulting, etc.).

2) Paleoenvironment of the narrow mid-to late Jurassic proto-Atlantic Ocean, " Atlantic " transgression (Oxfordian).

3) Development of a marginal carbonate platform facing the open ocean (evolution, facies model, biostratigraphy) — comparison of high-energy platform margin facies with deeper-water facies of sites 544, 545, 547.

4) Time and causes of rapid drowning of carbonate platform in Early Cretaceous times. Regional versus global (climate, sea level fluctuations) causes. Wealdien-type deltas.

5) Mid-Cretaceous anoxic events.

6) Mid to Late Cretaceous bioherms ?

7) Paleogene paleoenvironment (upwelling, phosphatization).

8) Jurassic, Cretaceous, Tertiary subsidence history.

9) Calibration of important Cretaceous/Paleogene seismic horizons (unconformities).

10) Submarine diagenesis (dolomitization, phosphatization, recrystallization).

11) Biostratigraphical investigations (nannoplankton, foraminifera, algae).

The Seabeam survey allowed us to plan our diving traverses very precisely. The target of the CYAMAZ cruise, of S P 3000, Cyana on R.V. " Le Suroit " (September 15-October 15) was mainly to observe and sample the steepest part of the escarpment where seismic profiles suggest that the oldest sedimentary series are outcropping. For this purpose, eight sections (CZ 84-90, 101) were realized (Fig. 4) in the southern part of the escarpment between 33°10'N and 33°20'N and six others at the central escarpment further north around 33°30'N (CZ 91, 94-98). In addition, three dives were designed to sample and observe the Cretaceous-Tertiary cover. One took place on a small scarp of the Central Mazagan Plateau horst (92), and two south of the Mazagan Plateau in the E1 Jadida Canyon area (99 and 100). A total of 18 dives were made, 130 rock samples collected and more than 6 000 pictures taken (CYAMAZ Group, 1983).

SUMMARY OF THE RESULTS OF CYAMAZ DIVE 84-101

We present here very briefly the objectives and results of all the eighteen CYAMAZ dives. In the Table, we summarize the main logistical data of each dive. For a more detailed description of the lithofacies and age of all CYAMAZ samples *see* von Rad (this vol., Tab. 1-4).

Dive 84 (Fig. 5, 6, 7 ; Plate 1)

Objectives

This first dive of CYAMAZ was planned to make a traverse of the southernmost Mazagan (El Jadida) slope and escarpment from 2 350 to 1 500 m water depth. From the bathymetric and seismic data wa expected outcrops of Jurassic to lower Cretaceous limestones between 2 110 and 1 800 m overlain by younger series.

Main results

The stratigraphic sequence is disturbed by tectonics and draping deposition on the escarpment. The oldest sampled rock is an oolitic ironstone (sample 5) of Early Cretaceous age, but it is sampled near a Maastrichtian/Paleogene limestone breccia (sample 3, 1 243 m) and might be a boulder of this breccia.

At different levels along the escarpment, draping sedimentary covers have been sampled, for example between 2 005 and 1 940 m late Aptian to early Albian quartzose nanno chalk (sample 2) and middle Miocene soft nanno chalk (sample 1 — 2 080-2 036 m).

Two main directions of normal faulting (N 100-120° and N 160-180°) were recognized intersecting the whole escarpment. The recent soft sedimentary cover is wide spread in this area.

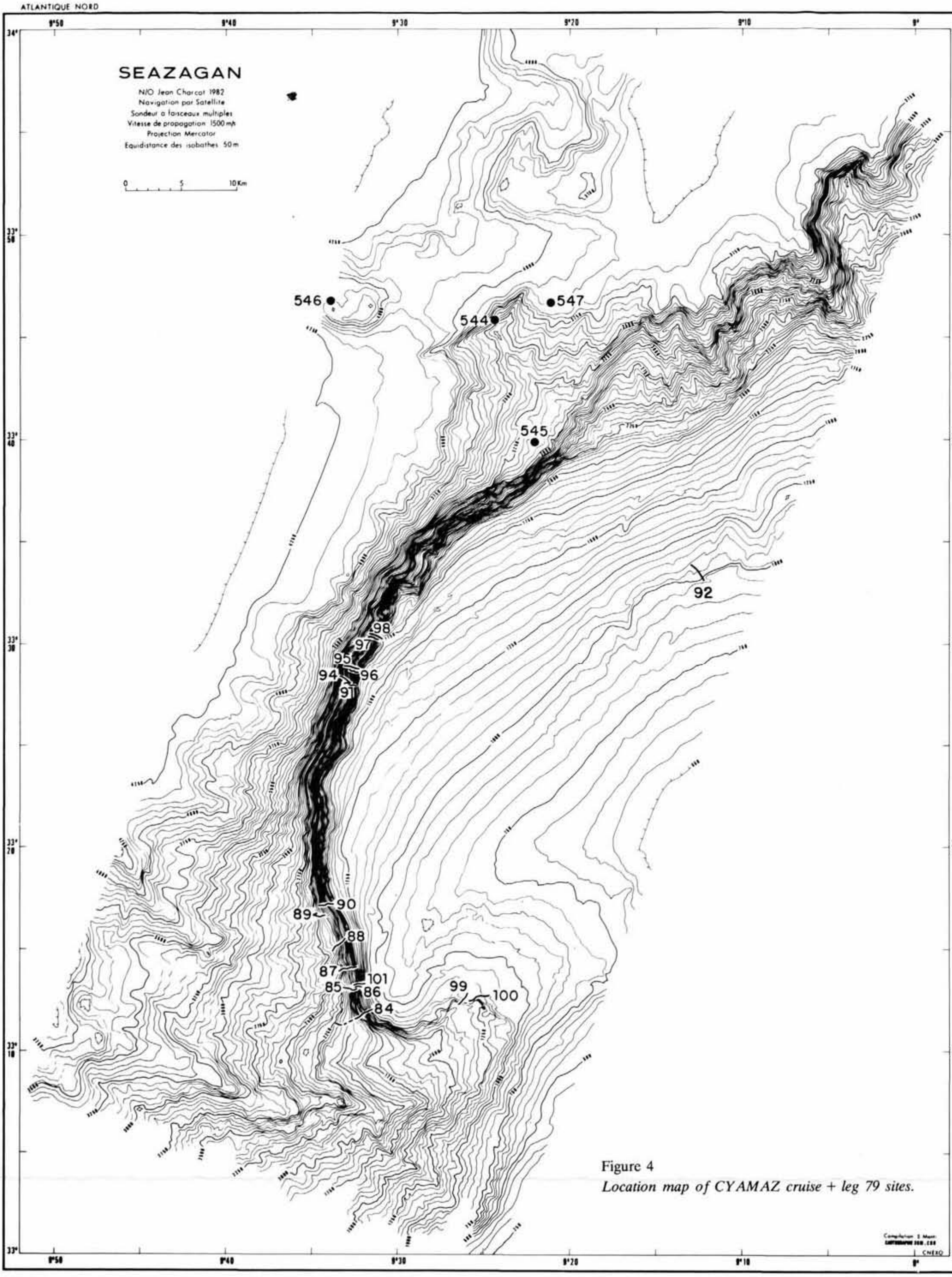


Figure 4
Location map of CYAMAZ cruise + leg 79 sites.

Table
List of dives.

Cyana Dive n°	Date (1982)	Observer	from... to... (total time)	Working time on sea floor (H)	Max.-Min. sea floor depth (m)	Distance (km)	No. of samples	No. of sea floor photos	No. of tapes	Area
84	Sept. 20	von Rad	09:16-16:30	5:10	2 236-1 190	3.8	6	290	2	
85	Sept. 21	Auzende	11:11-16:08	2:44	2 146-1 586	1.5	8	~ 200	1	Southern most
86	Sept. 22	Dostmann	09:15-14:58	4:00	1 817-1 000	1.4	6	178	2	Mazagan
87	Sept. 23	Lancelot	08:53-16:25	5:31	2 335-1 230	2.1	9	~ 420	2	Escarpment
88	Sept. 24	Cousin	10:40-18:16	5:27	2 403-1 378	2.5	9	~ 270	2	Southern
89	Sept. 25	Cepek	09:00-15:04	3:24	2 440-1 953	1.8	4	246	1	Mazagan
90	Sept. 27	ElAsri	09:06-15:37	4:40	2 260-1 400	1.8	3	425	2	Escarpment
91	Sept. 28	v. Rad	09:06-17:32	5:33	3 003-2 035	2.0	8	520	2	Central Mazagan Escarpment
92	Oct. 02	Auzende	16:30-19:55	2:14	1 090- 976	2.0	6	~ 170	1	Central Mazagan
93 *	Oct. 03 *	Steiger	09:16-13:04	1:01	2 412-2 400	0.1		36	1	Plateau
94	Oct. 06	Steiger	09:43-16:08	4:01	2 492-1 809	1.2	8	245	2	Central Mazagan
95	Oct. 07	Biju-Duval	11:36-18:33	3:37	2 978-1 962	1.5	7	364	2	Escarpment
96	Oct. 08	Jaffrezo	11:00-18:25	5:04	2 380-1 766	1.5	11	~ 340	2	Central Maz. Es.
97	Oct. 09	Ruellan	14:48-19:53	2:26	2 420-1 960	0.6	4	~ 670	1	(North of (1))
98	Oct. 10	Cepek	08:50-17:21	5:40	2 943-1 956	2.3	12	~ 630	2	N-slope of El Jadida
99 +	Oct. 11	v. Rad	14:00-18:32	3:04	1 357-1 142	1.2	8	369	1	Cañyon (South M
100	Oct. 12	Auzende	09:22-14:47	4:01	1 331-1 061	2.9	12	450	2	Plateau).
101	Oct. 13	Biju-Duval	09:49-16:59	5:17	1 985-1 195	1.5	9	? 500	2	See above.
			Σ	~ 73		31.7	130	~ 6 300	30	

Premature termination of dive due to : * Technical problems ;
+ Worsening weather conditions.

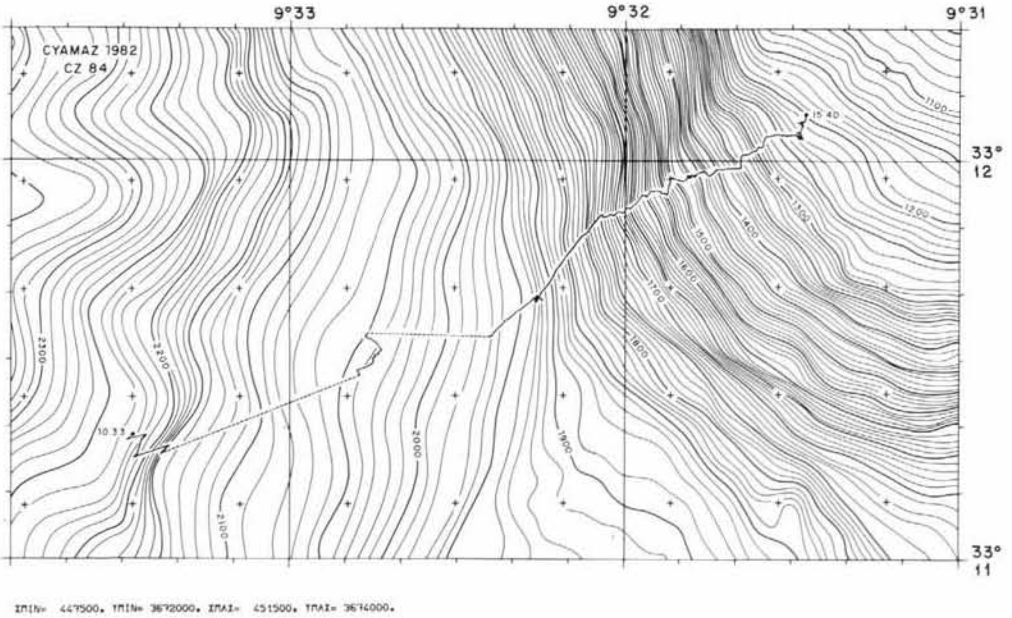


Figure 5 (Dive 84)
Location map.

Dive 85 (Fig. 8, 9, 10 ; Plate 2)

Objectives

The objective of this dive was to explore the lower part of the escarpment between 2 300 and 1 500 m. In this area, the seabeam map and the seismic reflexion profiles suggest that the carbonate platform is outcropping between 2 300 and 1 300 m. The top of the platform and the younger cover was explored, on the same profile, during Dive 86.

Main results

The first part of the dive between 2 150 and 2 120 m ran over a recent sedimentary cover on a gentle slope. The first outcrop at 2 120 m allowed us to sample (sample 1) a neritic bioclastic grainstone of Tithonian age. From this first outcrop toward 2 030 m depth appeared a sequence of carbonate platform outcrops Tithonian to Berriasian in age (sample 4). The limestones of the platform are covered in some places by onlapping soft nanno ooze/chalk of early to late Pliocene in age (samples 2 and 3). Between 2 030 and

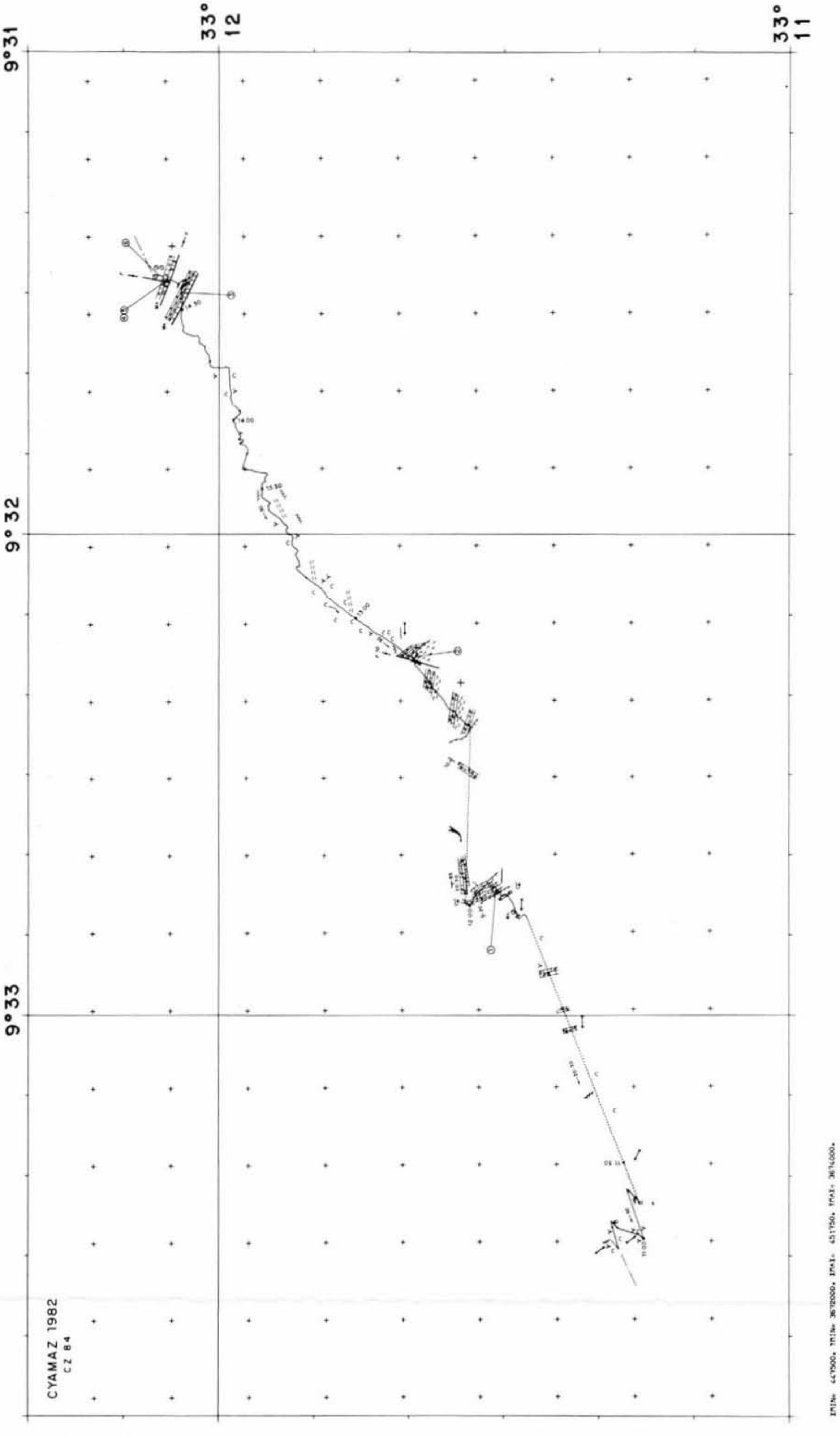


Figure 6 (Dive 84)
Geological map.

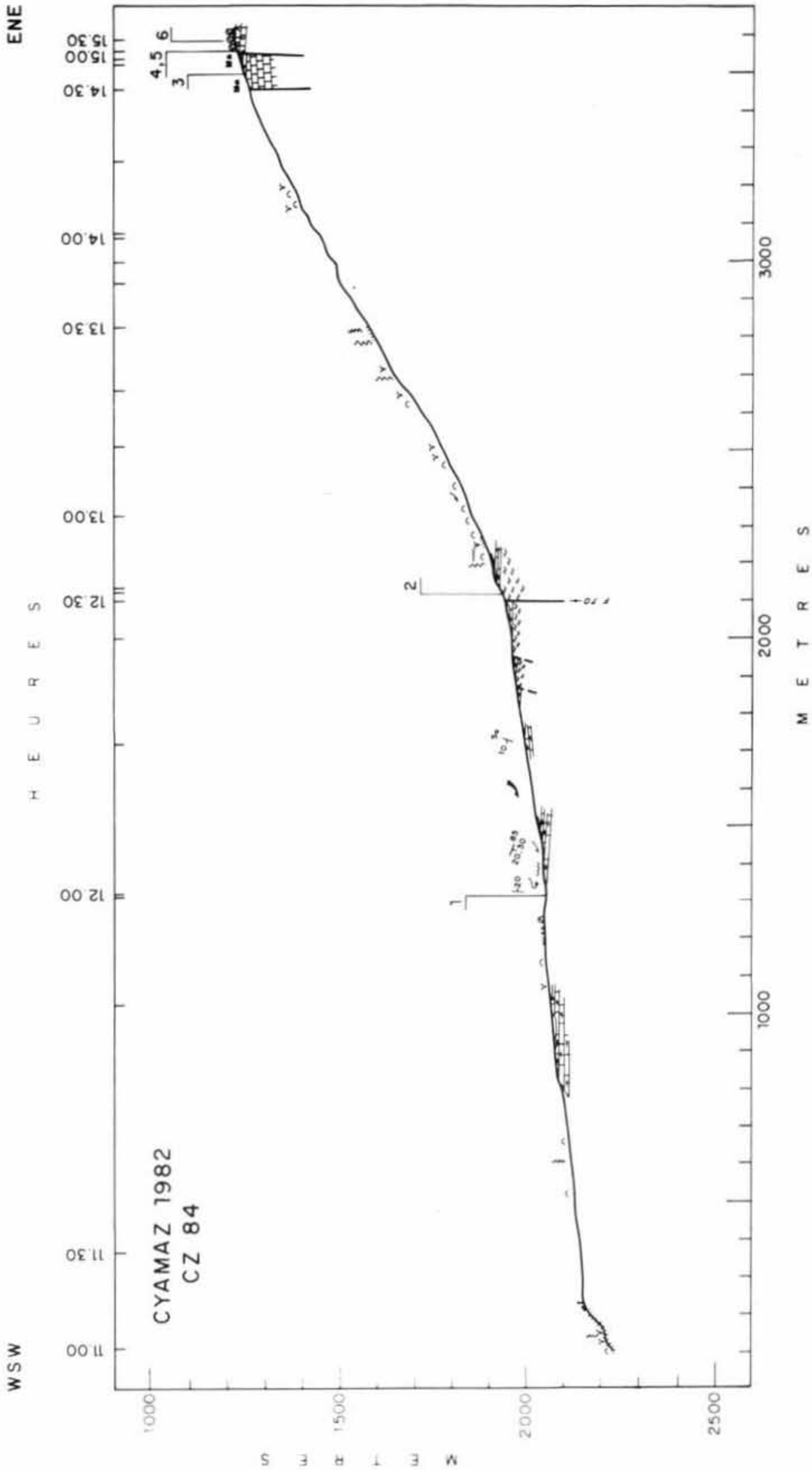
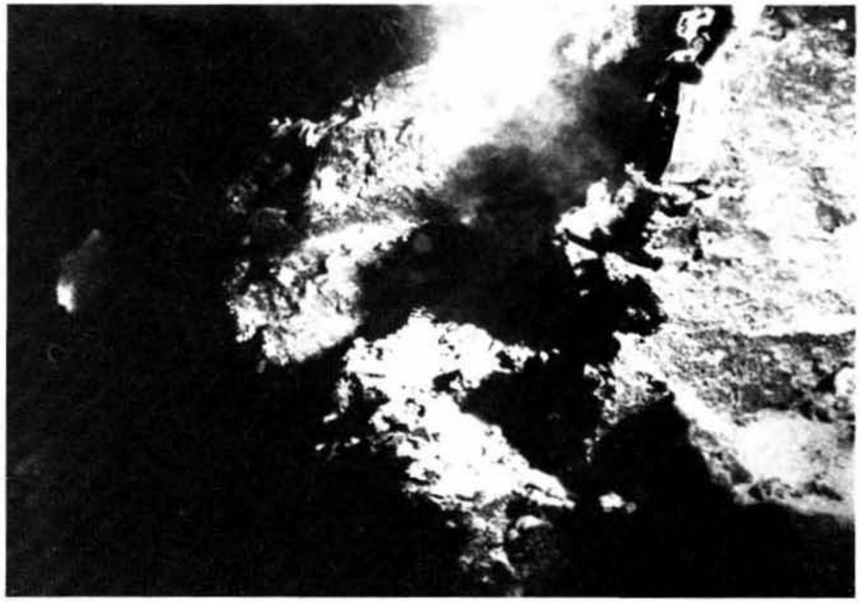


Figure 7 (Dive 84)
Geological profile.

1 800 m, a steep wall, made of sub recent soft sediments forms a cone with alternating spurs and furrows, oriented N 80-100.

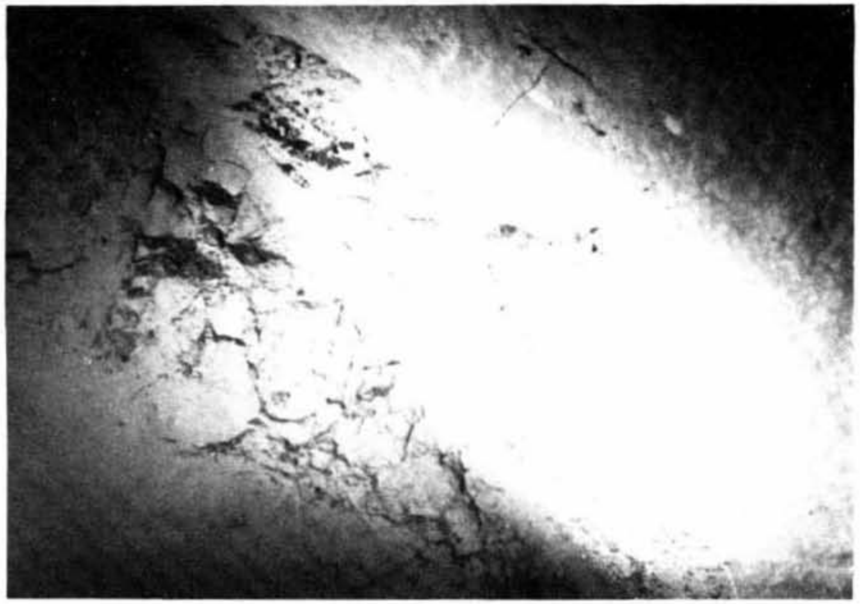
From 1 800 m until the end of the dive (at 1 586 m) the slope is very steep — more than 35° — and made of Late Jurassic to lower Berriasian platform limestone (samples 5, 6, 8). These limestones are cut by N 90 and N 160-180 faults and open fractures.

A



C

B



D

Plate 1

A : cz 84-130 : 1 944 m. Drapping bedded layers on the slope. Fractured Miocene chalk overlying Aptian-Albian marls. Sample cz 84-1 (2 067 m) Middle Miocene. Sample cz 84-2 (1 942 m). Late Aptian — Lower Albian.

B : cz 84-196 : 1 242 m. Post-platform carbonate layers, roughly bedded. Late Cretaceous brecciated limestones with pieces of Late Jurassic Carbonates in late Cretaceous matrix. Sample cz 84-3 (1 242 m).

C : cz 84-215 : 1 237 m. Like picture n° 196. The outcrops are eroded, coated and fractured.

D : cz 84-240 : 1 205 m. Like picture n° 215. Sample cz 84-5 (1 205 m) Cretaceous (?) iron-oolithes chalk.

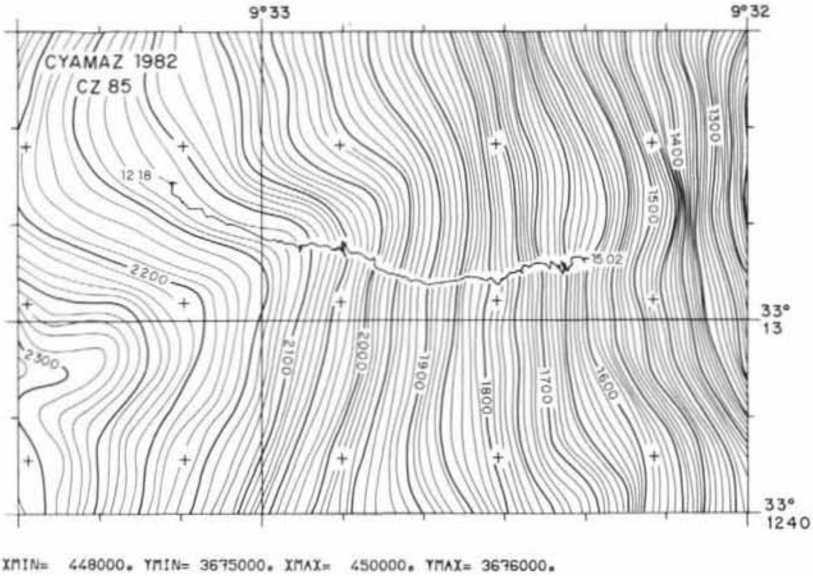


Figure 8 (Dive 85)
Location map.

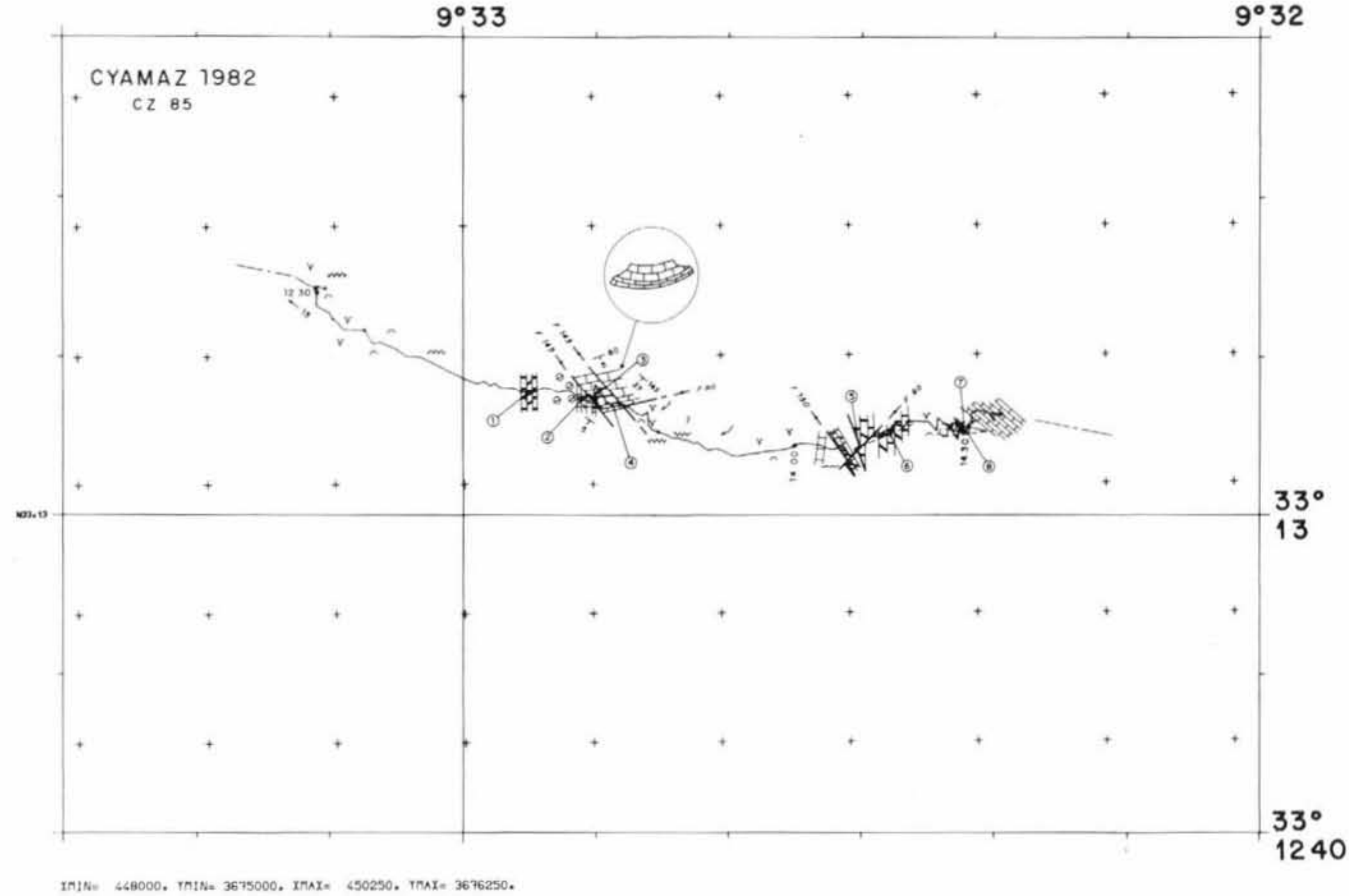


Figure 9 (Dive 85)
Geological map.

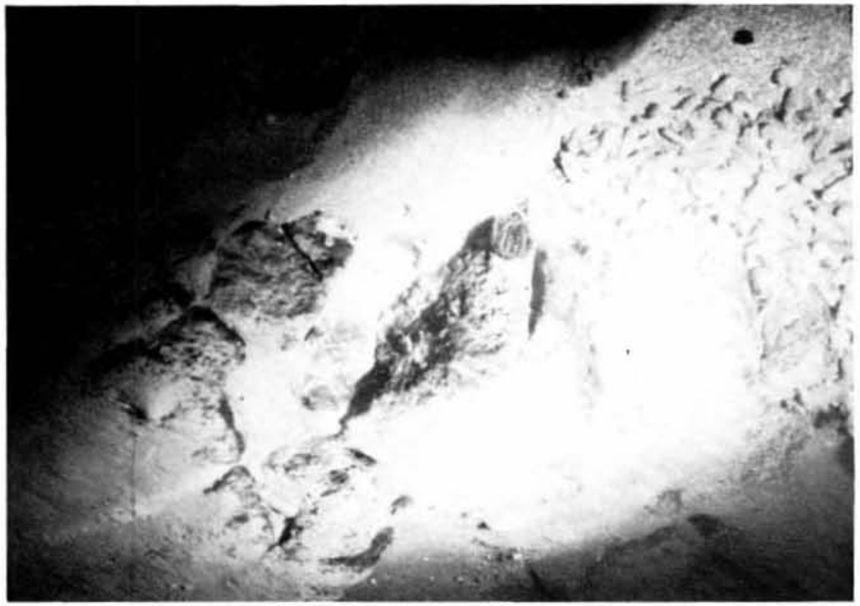
Dive 86 (Fig. 11, 12, 13 ; Plate 3)

Objectives

The objective of this dive was to continue the profile of Dive 85 toward the upper part of the escarpment in order to investigate and sample the contact between the platform and the overlying sedimentary cover.

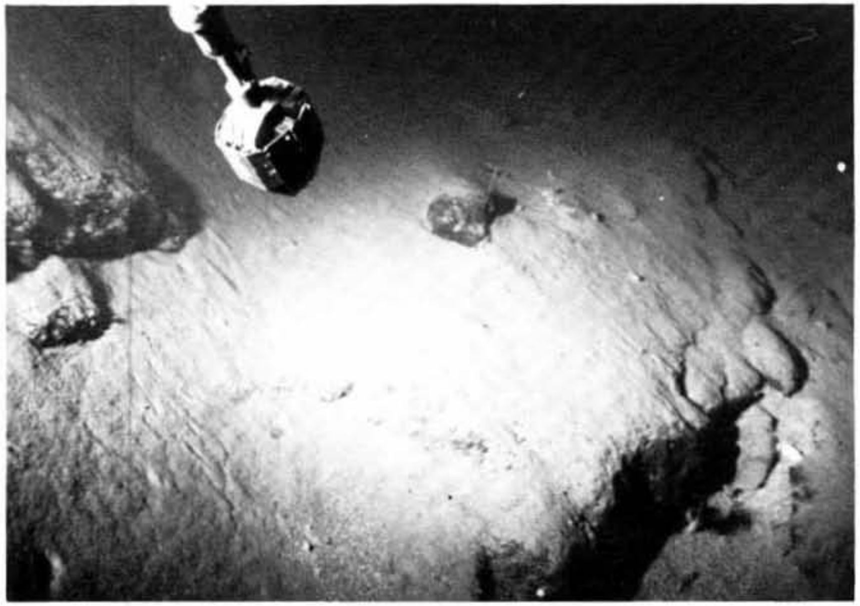
Main results

The first part of the section between 1 800 and 1 695 m consists of a gentle slope covered by recent soft sediments and blocks of limestones. At 1 695 m, the first outcrops of consolidated sediments appear to lap on to the carbonate platform. Sample 1 is a soft nanno ooze of a mixed Late Albian and Middle Miocene age. Between 1 671 and 1 527 m, large outcrops of massive limestones of the carbonate platform are coated by manganese oxides. Sample 4 (1 543 m) is a marly wackestone of Cretaceous age with Jurassic pelsparite clasts. After a zone covered by recent sediments between 1 527 and 1 376 m, the slope becomes steeper and the platform outcrops up to 1 250 m depth. Samples 5 and 6 have been on an



A

C



B

D

Plate 2

A : cz 85-48 : 2 074 m. Late Jurassic platform carbonates outcropping through Tertiary to present day pelagic oozes. Sample cz 85-1 (2 118 m) Tithonian. Sample cz 85-2 (2 070 m) Upper Pliocene.

B : cz 85-59 : 2 066 m. Like picture n° 48. Massive banks faulted and dipping 30° towards the West-South-West. Sample cz 85-3 (2 067 m) — Lower Pliocene. Sample cz 85-4 (2 066 m) — Late Tithonian.

C : cz 85-70 : 2 065 m. Late Jurassic — Lower Neocomian platform carbonates. Massive limestones containing algae.

D : cz 85-181 : 1 685 m. Erosion furrows in the massive carbonates of the Late Jurassic — Lower Neocomian platform. Sample cz 85-6 (1 748 m) Tithonian.

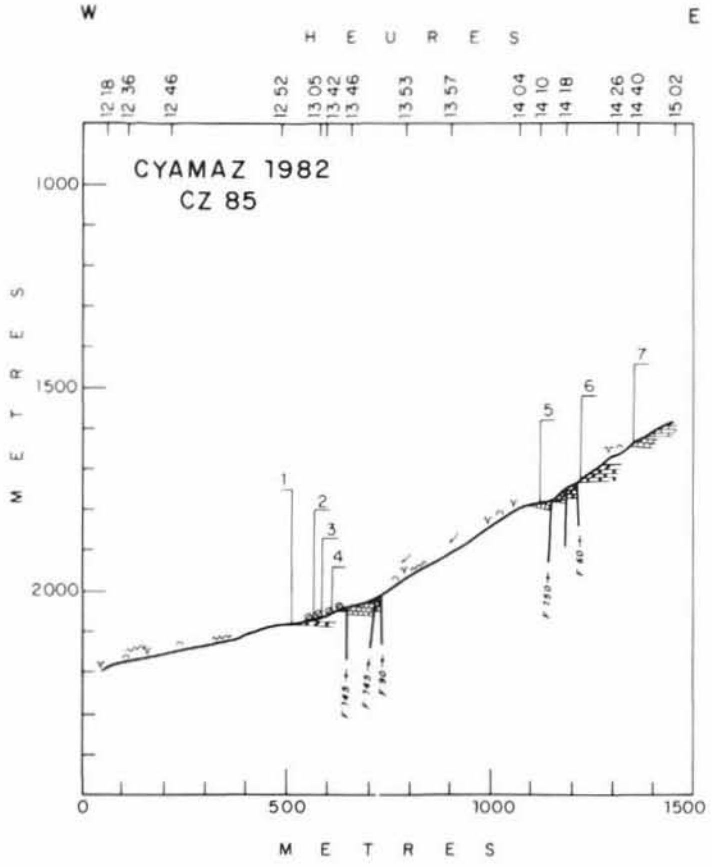


Figure 10 (Dive 85)
Geological profile.

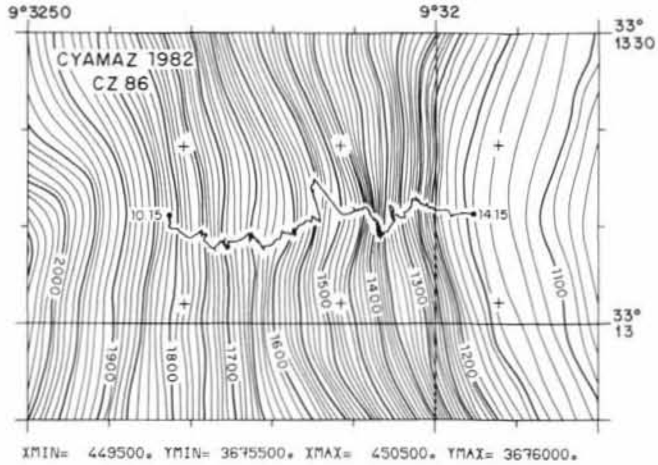


Figure 11 (Dive 86)
Location map.

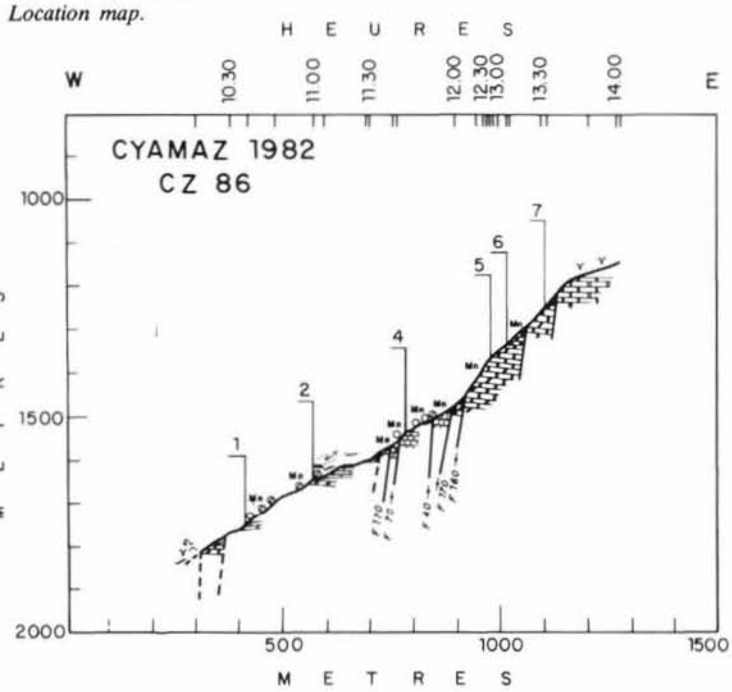


Figure 13 (Dive 86)
Geological profile.

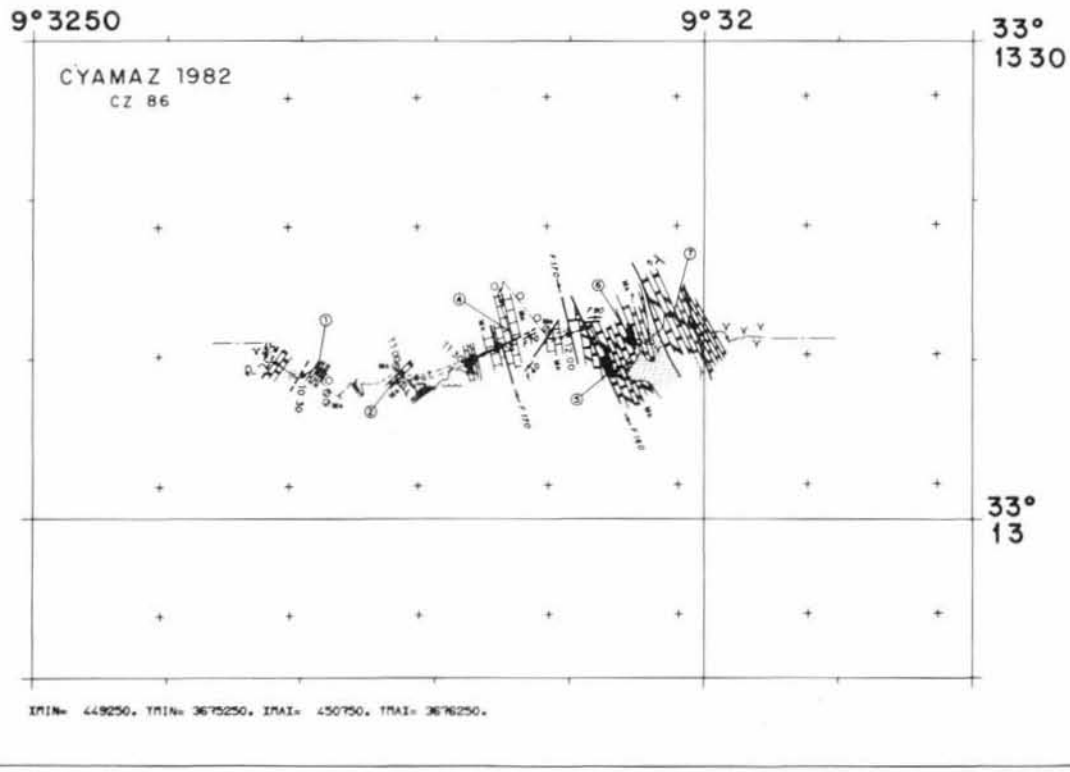
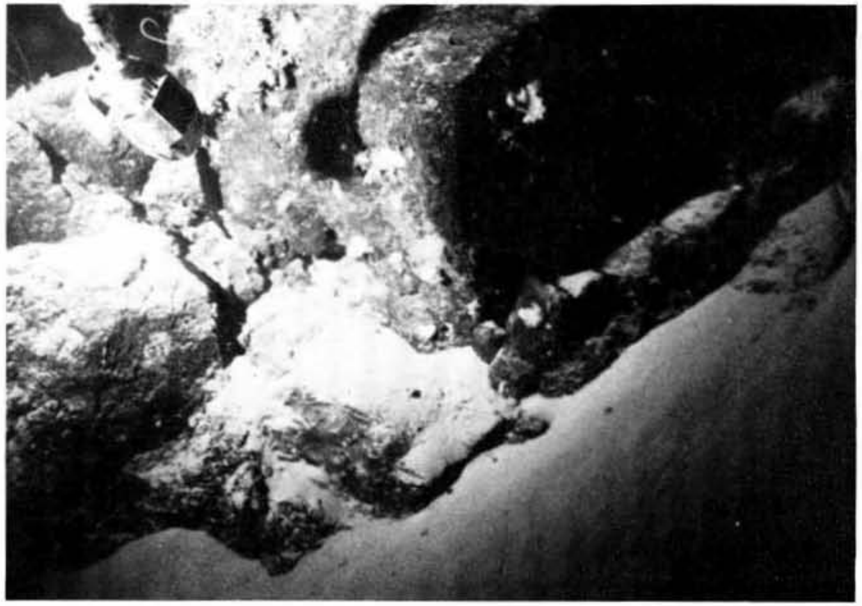


Figure 12 (Dive 86)
Geological map.

A

B

C



D

Plate 3

A : cz 86-78 : 1 543 m. Massive limestones (faulted and coated) of the Late Jurassic platform overlain by marly Cretaceous levels. Sample cz 86-4 — 1 543 m (Cretaceous ?).

B : cz 86-89 : 1 467 m. Talweg cut in tertiary cover by a fault perpendicular to the escarpment. In some places we can see also transverse faulting parallel to the slope.

C : cz 86-133 : 1 325 m. First bedded layers of the post platform cover. They are also eroded and faulted. Sample cz 86-6 (1 325 m). Lower Cretaceous.

D : cz 86-167 : 1 234 m. Massive banks layers outcropping discontinuously through recent deposits. These banks represent the carbonate platform. Sample cz 86-7 (1 234 m) Tithonian.

almost vertical cliff. They are upper Jurassic to Lower Neocomian limestones of very shallow-water facies.

On top of massive carbonates between 1 373 m and the end of the dive (1 210 m), subhorizontal stratified layers appear with alternating massive and conglomeratic beds. Sample 7 (1 234 m) is a micritized intraclastic wakestone of Tithonian to early Neocomian age which is probably the uppermost level of the carbonate platform (Steiger, Cousin, this vol.). In these samples we found burrow fills of Paleogene globigerinid micrite. This part of the Mazagan Escarpment is, like the lower part observed in Dive 85, affected by important fractures and faults, striking mainly N 160-165, N 90 and N 40-50.

Dive 87 (Fig. 14, 15, 16 ; Plate 4)

Objectives

This dive is located in the southern part of the escarpment on a relatively steep profile that let us hope for numerous outcrops between 2 300 and 1 300 m. Indeed, the bathymetry shows the presence of a rather steep slope of about 35° (average) between 2 300 and 1 700 m and of about 60° between 1 700 and 1 300 m. Canyons had been recognized during Dive 85 and had demonstrated that good opportunities exist to find outcrops even in the lower part of the profile.

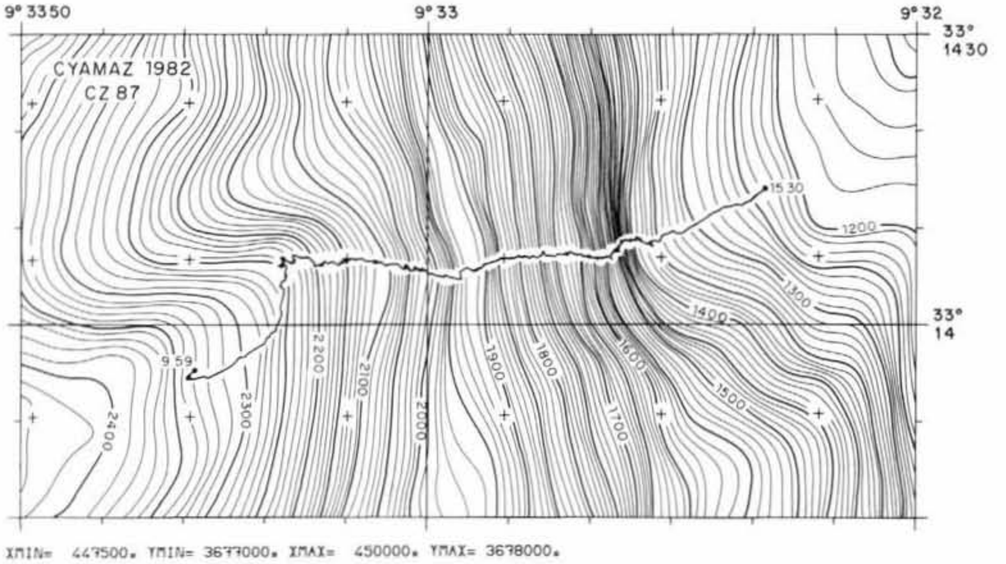


Figure 14 (Dive 87)
Location map.

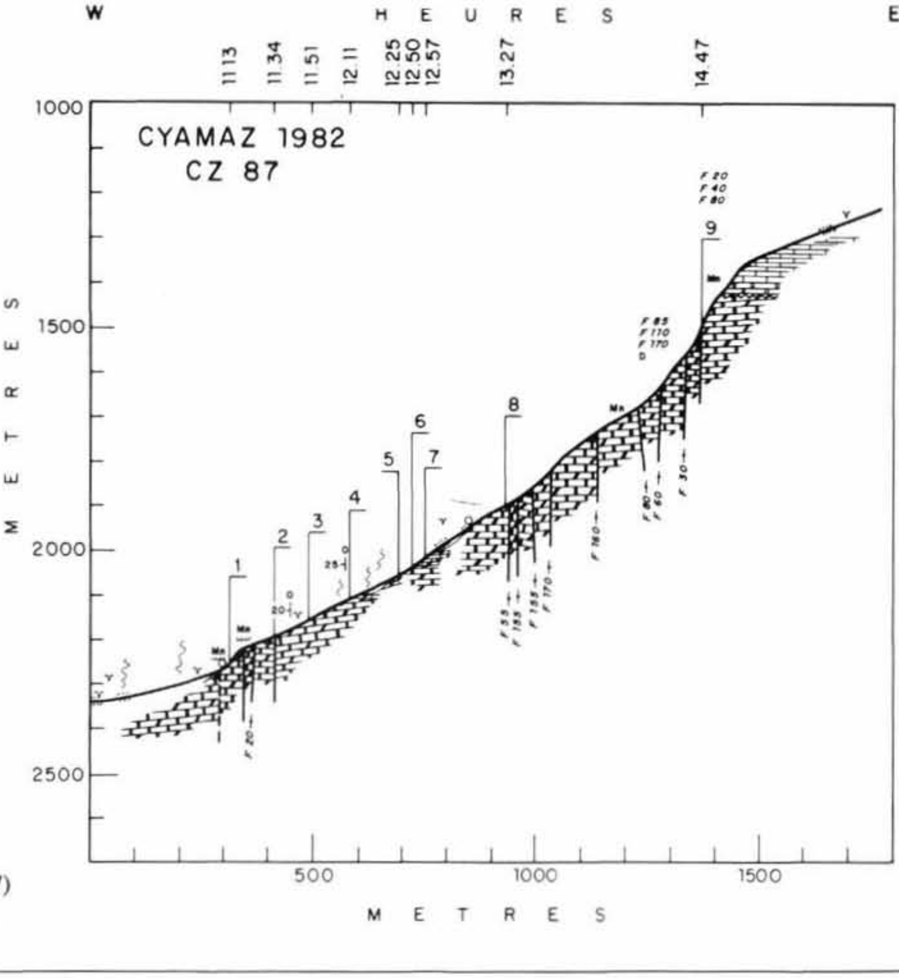


Figure 16 (Dive 87)
Geological profile.

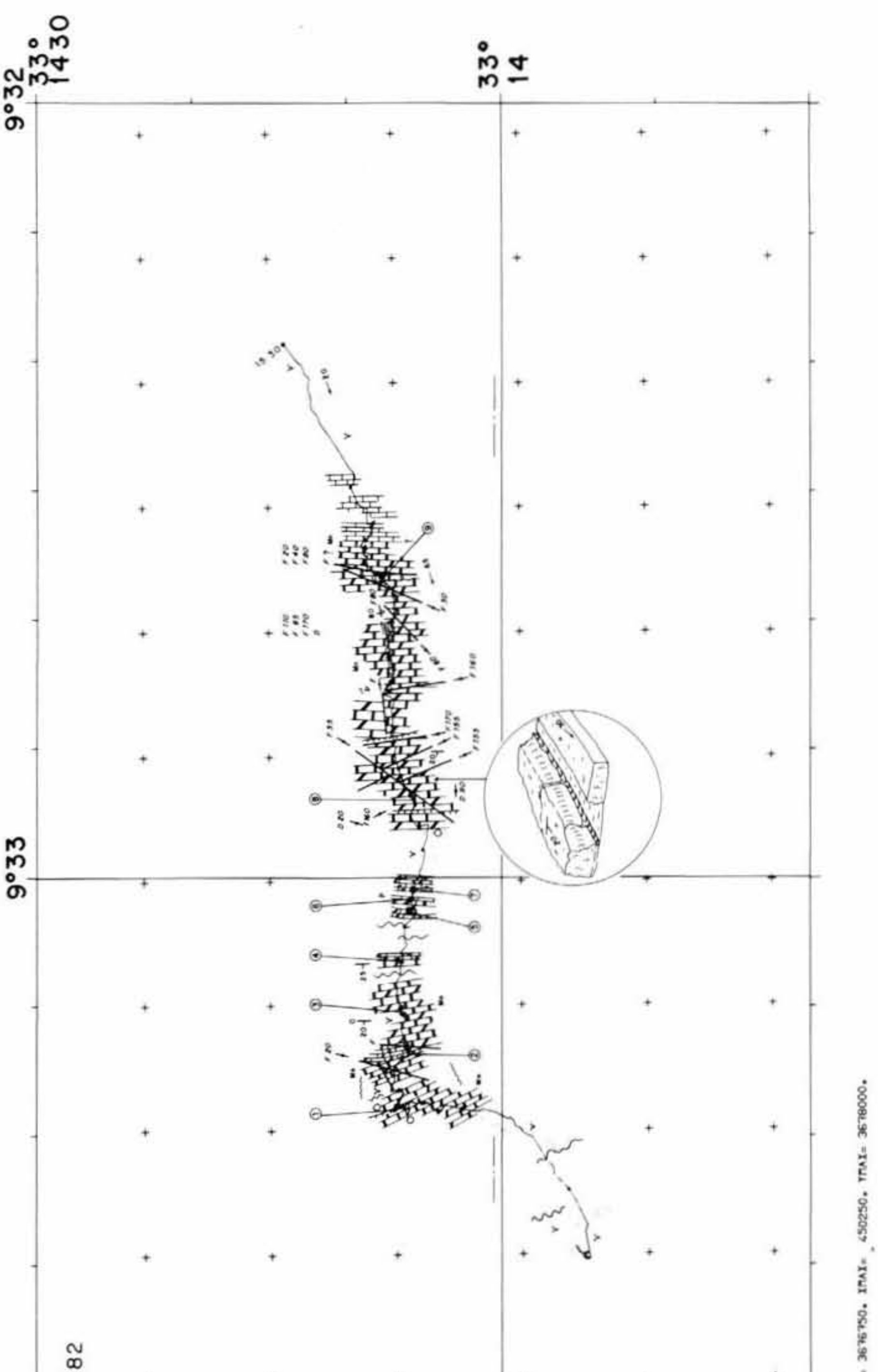


Figure 15 (Dive 87)
Geological map.

Main results

This dive allowed direct observations of outcrops from 2 300 to 1 300 m. Sampling proved to be very difficult because of the hard and homogeneous nature of the limestones that apparently constitute most or all the escarpment. Most samples come from small outcrops. Sampling was concentrated mostly in the lower part of the profile (samples 1 to 8 between 2 245 and 1 914 m). Most samples consist of limestones of Late Jurassic, Tithonian to lower Neocomian age.

In some places (samples 5 — 2 058 m — and 7 — 2 024 m —) there is a thin cover of onlapping lower Pliocene soft sediments. In its most abrupt part, the escarpment is made up of a series of subvertical cliffs with numerous normal faults that exhibit very limited displacement (a few centimeters to a few tens of cm).

A

C

B

D

Plate 4

A : cz 87-114 : 2 232 m. Cliff of massive carbonate platform (Late Jurassic — Lower Neocomian). The carbonates are faulted in many directions. Sample cz 87-1 (2 245 m) Lower Neocomian — Ech. cz 87-2 (2 198 m) Tithonian.

B : cz 87-365 : 1 612 m. Eroded and coated massive carbonates of the Late Jurassic platform.

C : cz 87-512 : 1 407 m. Post platform cover, bedded, eroded and faulted outcropping on the top of the escarpment. Sample cz 87-9 (1 505 m) Upper Cretaceous — Tertiary.

D : cz 87-517 : 1 405 m. Like 512.

These faults strike N 150°-170°. A network of fractures often cuts through these normal faults, oriented at N 50° and N 110°. At 1 505 m, a thin piece of laminated phosphorite (Late Cretaceous ?) (see von Rad, this volume) was sampled (sample 9). Some bedded layers were observed about 50 m below the edge of the upper plateau. The edge of the plateau is marked by a thin (about 25 cm) horizontal layer of hard rock that unfortunately could not be sampled.

Dive 88 (Fig. 17, 18, 19 ; Plate 5)

Objectives

The main objeective was to make a section of the lower part of the escarpment situated north of dive 87. In this area, the Seabeam map shows a N 60° fault cutting the escarpment with an offset of a few tens of metres. The northern part is lower than the southern one Dive 88 was made on the northern part.

From 1 505 m to the end of the dive, a formation of bedded layers appeared with alternating calcareous beds and breccias. Samples 8 and 9 have been dated as late Paleocene and middle to late Eocene. These layers indicate indicate a bathyal depositional environment.

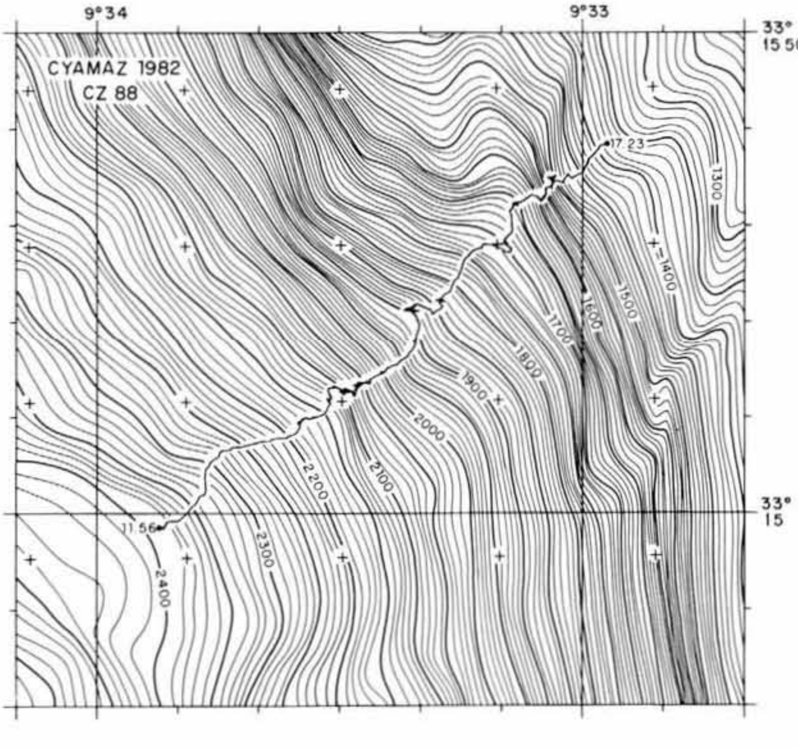
On the whole dive, the main observed directions of fracturation are N-S, associated with N 60° and N 135° in the lower part of the escarpment. In the upper part these directions are associated with N 90°, N 110° and N 160° trending faults.

Dive 89 (Fig. 20, 21, 22 ; Plate 6)

Objectives

The main goal of this dive was to sample outcrops below 2 245 m depth, as previous dives had not reached this depth. The second objective was to try to

Figure 17 (Dive 88)
Location map.



Main results

The dive began at 2 405 m on a steep slope covered with recent sediments. From 2 181 to 1 600 m, the slope is constituted by a succession of limestone cliffs limited by faults. These carbonates are massive and without stratification. Samples 1, 4, 5 and 6 are all Upper Jurassic to lower Neocomian carbonates. They are mainly pelsparites with manganese coating. Sample 3 is a micrite taken in a bedded layer. The age of this micrite is middle to late Oligocene with contamination of Cretaceous. From 1 600 top 1 505 m a major cliff of massive rocks was observed, but could unfortunately not be sampled. This cliff showed intense vertical fracturation and many erosional features.

determine precisely the boundary between the carbonate platform and the bedded layers of the post-platform cover. In the previous dives this contact was not well defined and also the age of the oldest bedded layer was not exactly determined.

Main results

The first part of the dive between 2 509 and 2 244 m ran essentially over soft sediments with a steep slope (15° to 45°), cut by numerous canyons. In one of these canyons, a block of massive pelsparite of Late Jurassic — early Neocomian age was sampled (sample 1). Above 2 244 m, the slope is built up by a succession of outcrops of massive limestones separated

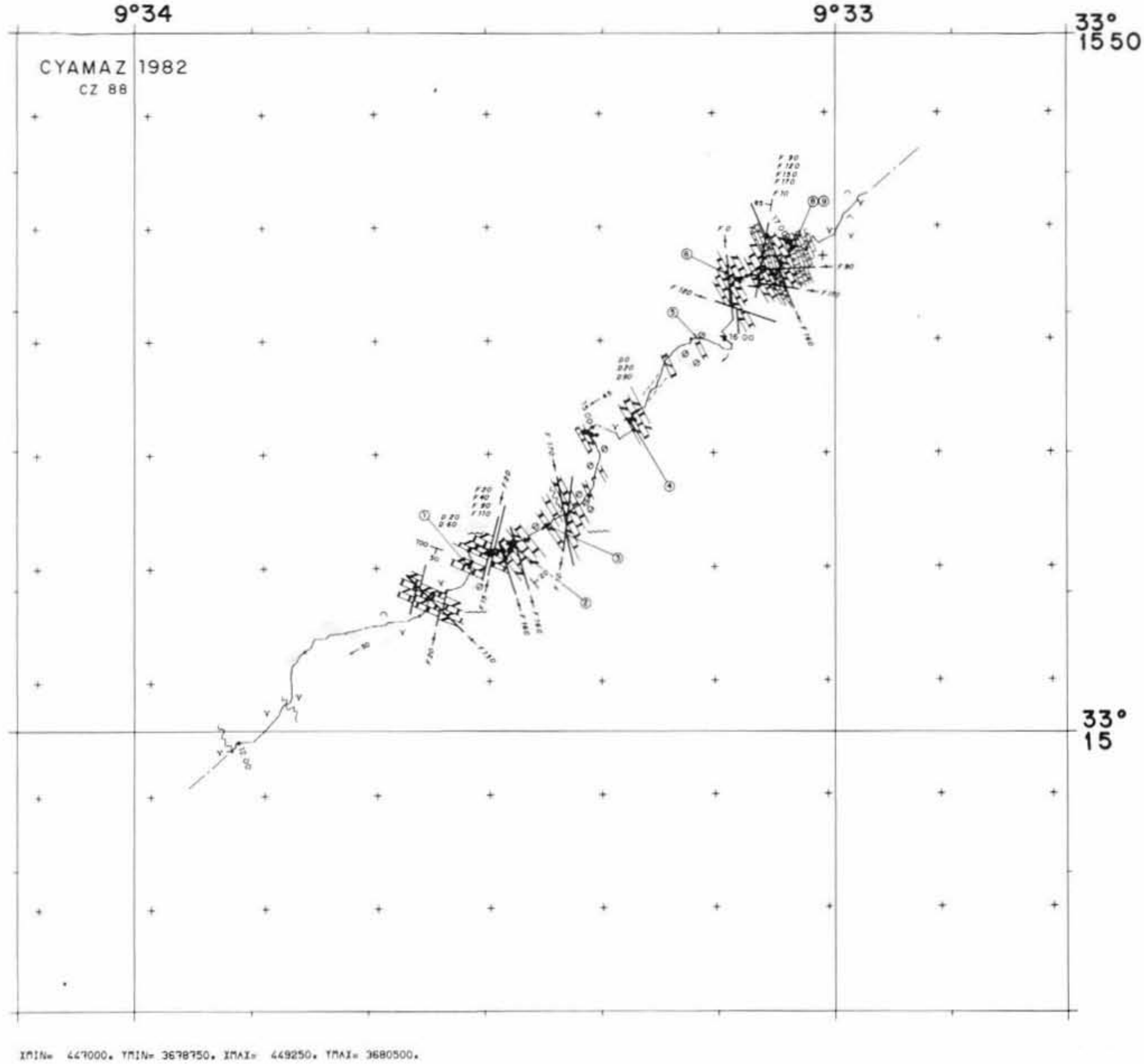


Figure 18 (Dive 88)
Geological map.

by steps and covered by a cover of recent soft sediments. Samples 2 and 4 are limestones of Late Jurassic — early Neocomian age. Sample 3 is a neritic bioclastic grainstone, covered by glauconitic quartz echinoderm packstone of Early Cretaceous age. Seven outcrops of these limestones were counted between 2 244 and 1 953 m. The contact between the platform carbonates and the bedded layers could not be reached, since the dive had to be terminated due to bad weather conditions.

Along the dive, two main directions of faulting which affected the limestone were observed : N 60-70° and N 120°-130°.

Dive 90 (Fig. 23, 24, 25 ; Plate 7)

Objectives

Dive 90 was planned to continue the profile that had to be interrupted during the previous dive. The objective was to explore in detail and sample the contact between the platform carbonate and the bedded post-platform layers. The profile began at 2 268 m.

Main results

The dive started on a relatively steep slope (about 20°) covered with soft sediments. The first outcrop of massive limestones was located at 2 258 m. Outcropping of platform carbonates continues all along the escarpment by a succession of cliffs with different amplitudes. On one step, at 2 195 m, we observed a small outcrop of chalk which was not sampled. Samples 1 and 2 are not significant : one is a manganese crust, the second one is a piece of recent coral. In this dive, we did not sample the platform limestones at all. On the top of the platform beyond 1 741 m, layering appears in the limestones and the steepness of the slope becomes more gentle. Sample 3 is a partly phosphatized dolomicrite of late Turonian to Campanian age with fragments of upper Jurassic pelsparite and oolite.

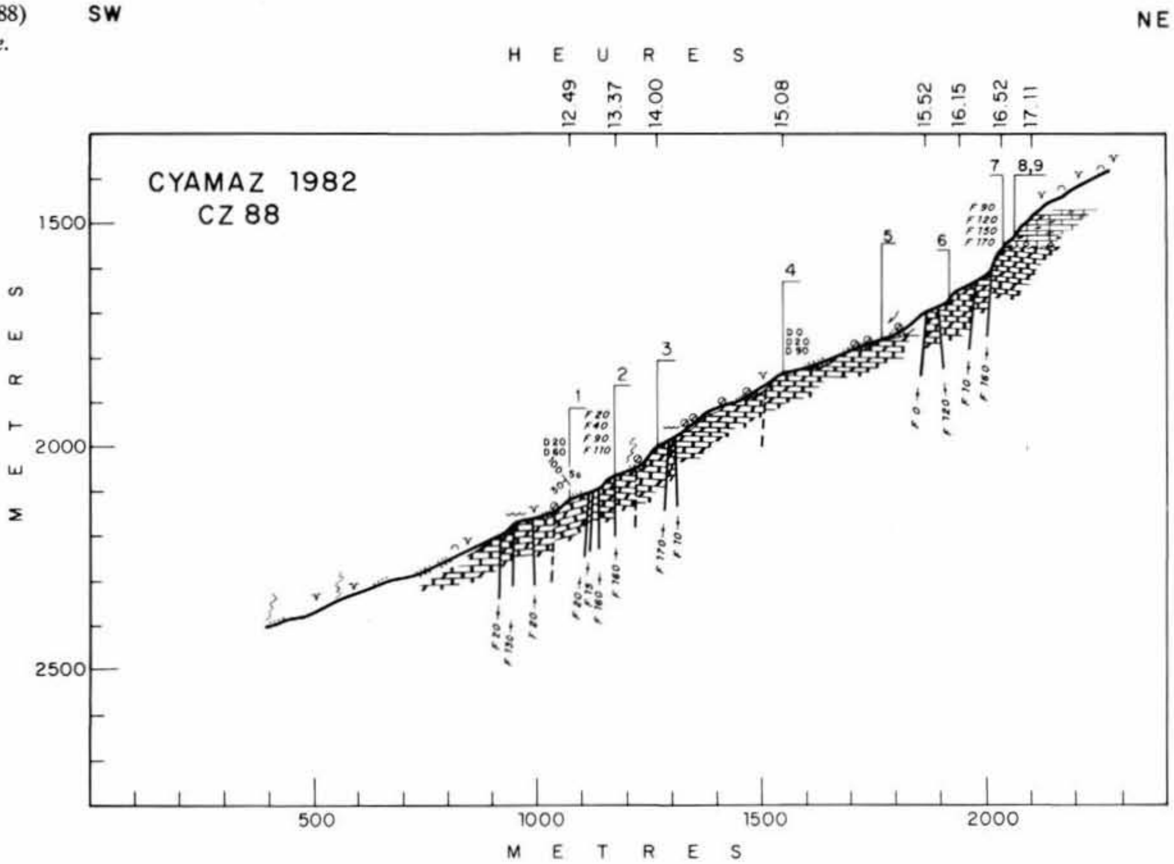
The real contact between the platform and the bedded cover was observed precisely at 1 604 m. The stratification of this cover is clearly horizontal. The edge of the plateau above 1 500 m is covered with soft sediments. The main directions of faulting are the same as the ones, observed in previous dives : N 60°, 90°, 120° and 160°.

Dive 91 (Fig. 26, 27, 28 ; Plate 8)

Objectives

This dive was the first in the area of the central Mazagan escarpment around 33°30N. In this area, the seabeam map shows that the edge of the El Jadida plateau is deeper than in the south, with an average depth of about 1 600 m. In some places, we measured on the Seabeam map a slope of more than 100 %. During Dive 91, we planned to do a section from

Figure 19 (Dive 88)
Geological profile.



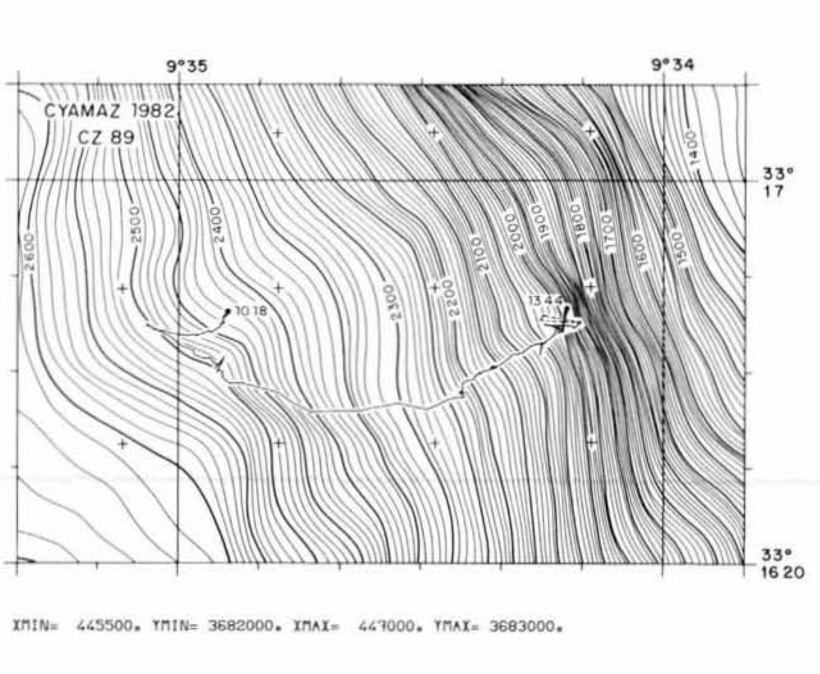
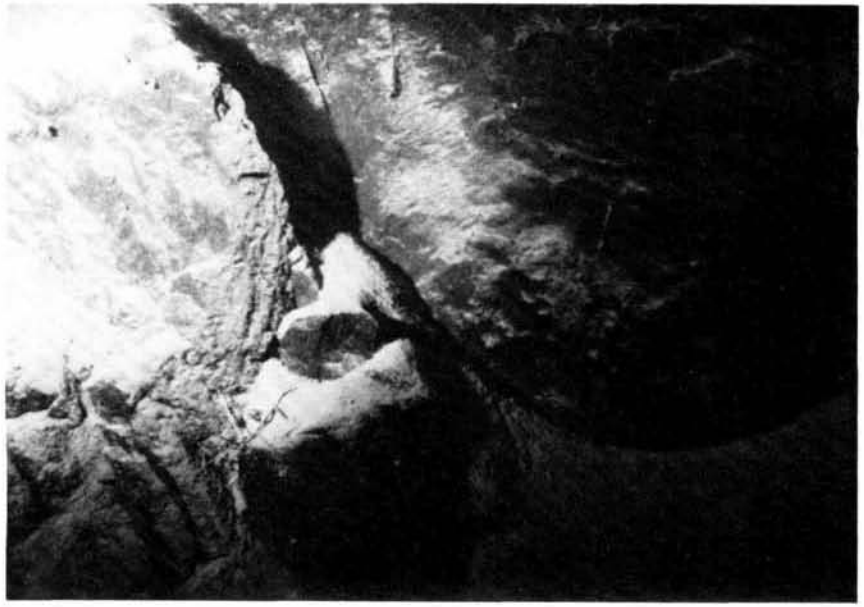


Figure 20 (Dive 89)
Location map.

A



C

B

D

Plate 5

A : cz 88-54 : 2105 m. Massive limestones with rudists of the Jurassic platform. They are sometimes roughly horizontally bedded. Sample cz 88-1 (2 140 m) Kimmeridgian — Tithonian.

B : cz 88-73 : 2 083 m. Small faults (20 to 50 cm) in massive limestones. The main directions of fracturations are N 20-30 and N 160.

C : cz 88-170 : 1 844 m. Limestones of the platform, covered by recent chalky sediments. Sample cz 88-4 (1 842 m). Late Jurassic.

D : cz 88-266 : 1 479 m. Post platform cover, horizontally bedded. Sample cz 88-8 (1 505 m). Upper Paleocene. Sample cz 88-9a (1 505 m) Eocene. Sample cz 88-9b (1 505 m) Upper Jurassic.

A

C

B

D

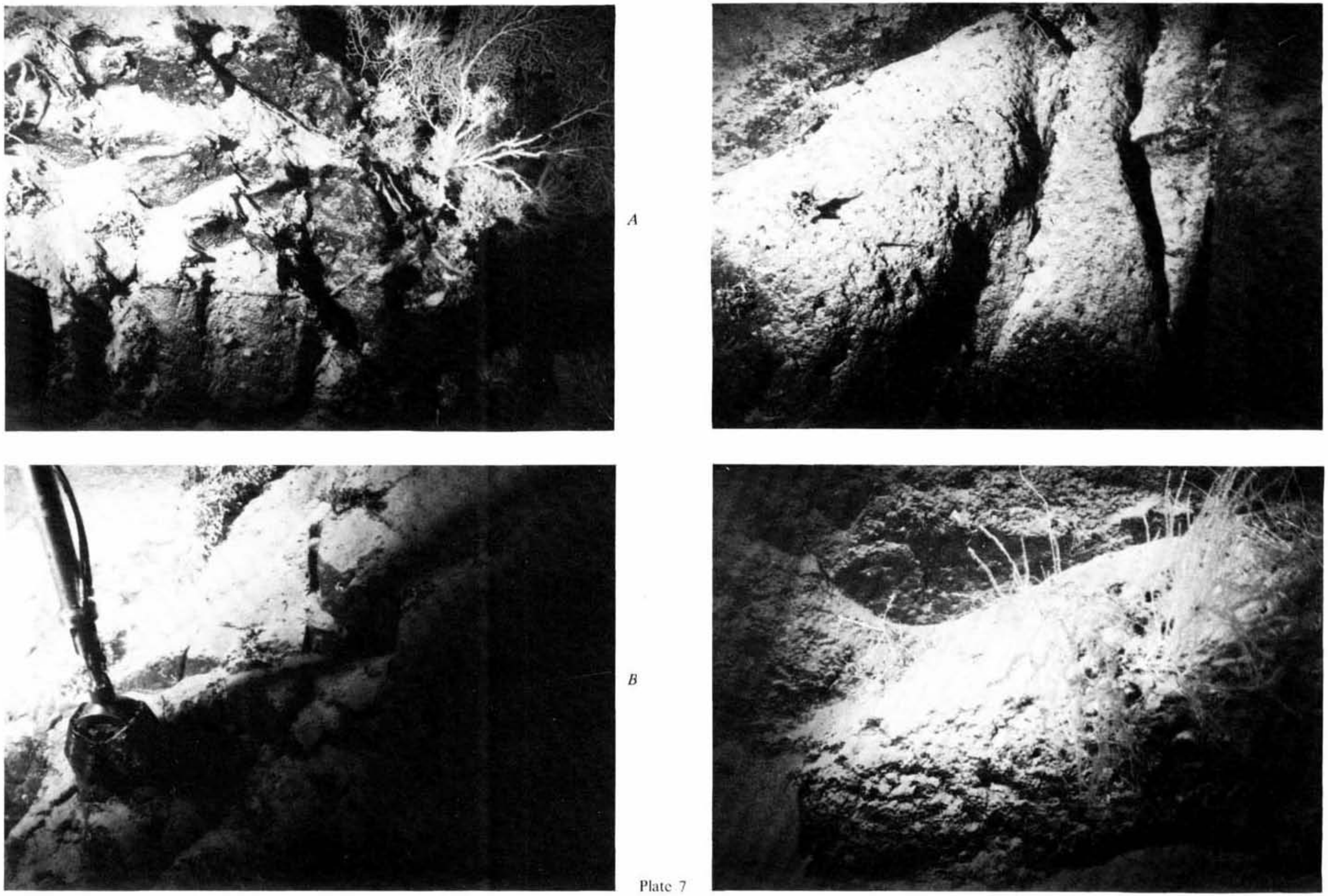
Plate 6

A : cz 89-96 : 2 220 m. Eroded edge of the platform with a fault striking N 60. Sample cz 89-2 (2 237 m). Upper Tithonian.

B : cz 89-143 : 2 159 m. Tilted block of the platform dipping 30° toward the West Sample cz 89-3 (2 160 m) Late Jurassic — Lower Neocomian.

C : cz 89-176 : 2 058 m. Like picture n° 143. The erosion gives rounded blocks covered by recent sediment. Sample cz 89-4 (2 058 m) Late Jurassic.

D : cz 89-232 : 1 999 m. Massive limestones with small fault and diaclases (N 20-30).



A B C D

Plate 7

A : cz 90-84 : 2 048 m. Massive limestones eroded and cut by numerous faults and diaclases. The erosion gives dissolution pockets and rounded blocks.

B : cz 90-299 : 1 926 m. Sub parallel faults N 80-90 cutting the massive limestones.

C : cz 90-377 : 1 829 m. Sampling in the platform. Open fracture N 50-60 in the middle of the picture and fault striking N 120.

D : cz 90-460 : 1 706 m. Post platform cover with horizontal bedding cut by numerous faults. Sample 90-3 (1 733 m) Turonian — Campanian.

A

C

B

D

Plate 8

A : cz 91-152 : 2 804 m. Top of a bank dipping toward the West of the platform limestone covered with recent sediment.
Samples cz 91-1-2-3 (3 002 m ; 2 914 m and 2 804 m) Late Jurassic.

B : cz 91-278 : 2 649 m. Fault N 80 cutting the platform (?). In this area has been sampled the granitoid (in place or not ?). cz 91-5.

C : cz 91-290 : 2 650 m. Sample cz 91-5 (granitoid) handled by CYANA arm.

D : cz 91-397 : 2 359 m. Carbonate platform with chaotic aspect due to numerous faults N 80, N and N 160.

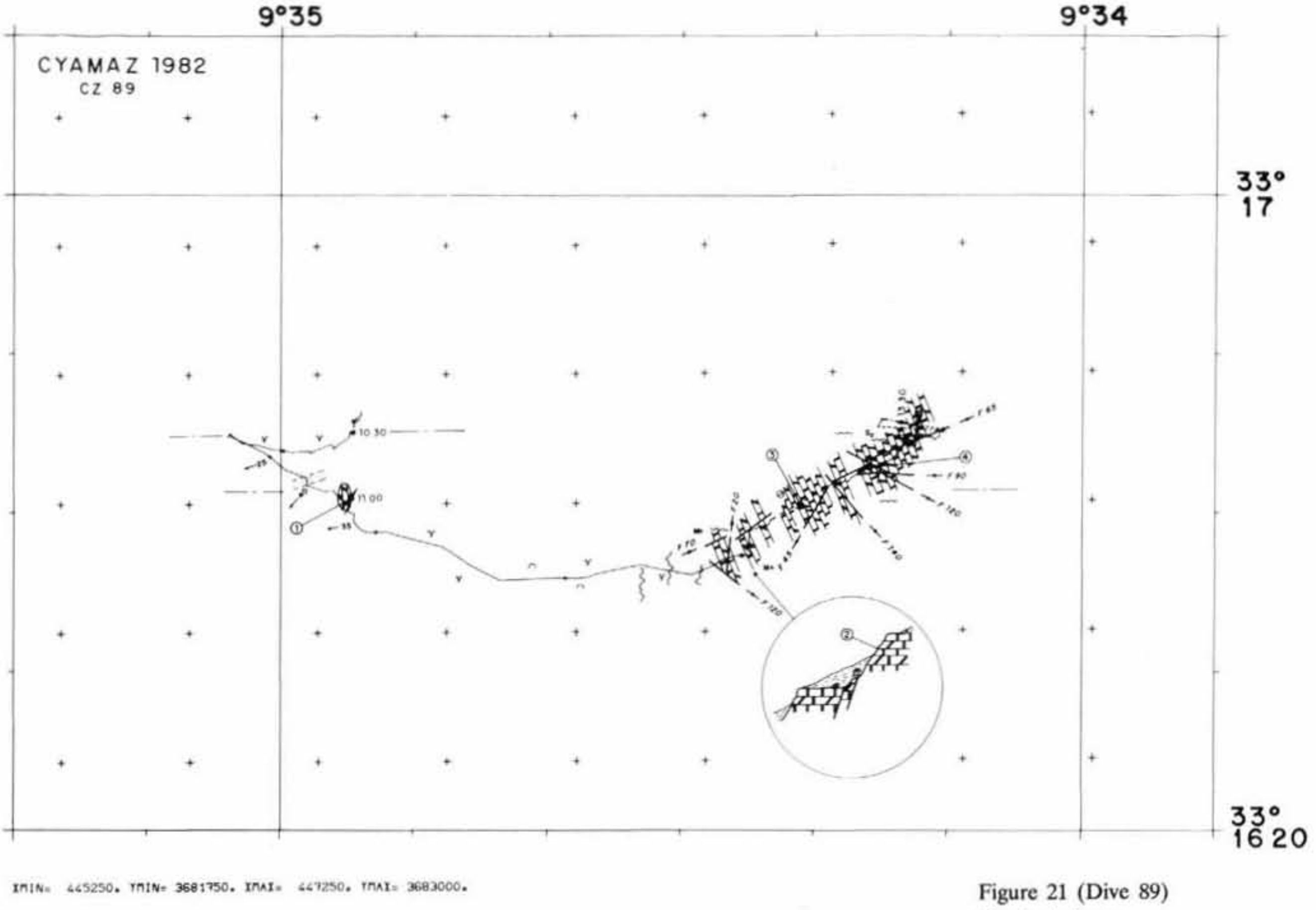


Figure 21 (Dive 89)
Geological map.

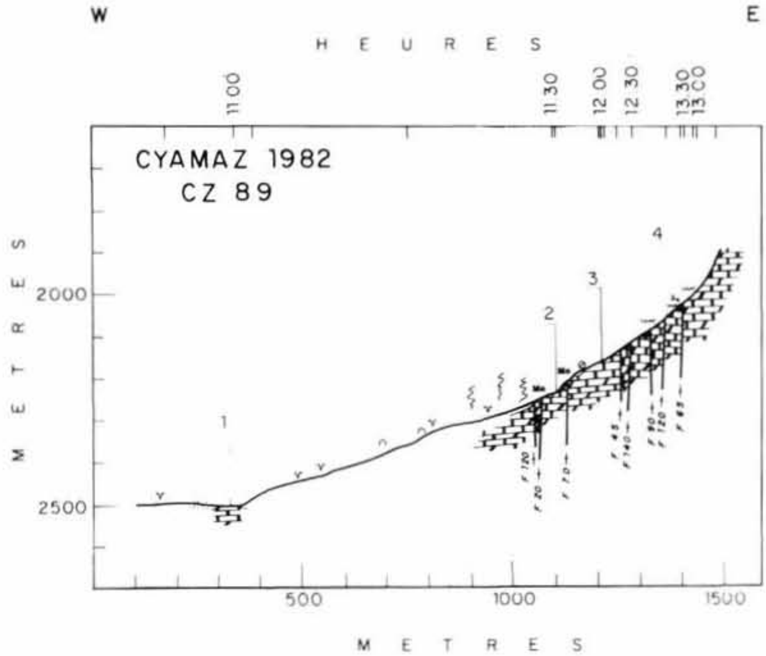


Figure 22 (Dive 89)
Geological profile.

3 000 m (maximum diving limit of Cyana) up to about 1 600 meters, in order to sample the platform and its cover.

Main results

In this dive, Cyana took the deepest sample of the cruise at 3 002 m water depth. This sample 1 is a block of Late Jurassic massive limestone (pelsparite) taken near a discontinuous outcrop. The dive continued in a small canyon where softer looking carbonate rocks crop out. Sample 2 at 2 914 m is a bioclastic grainstone of Tithonian age. For the next hundred m, the slope gradient decreased and the outcrops were covered in many places with soft sediments.

At 2 808 m on a good outcrop, we took a pelsparite (sample 3) of Late Jurassic — early Neocomian age.

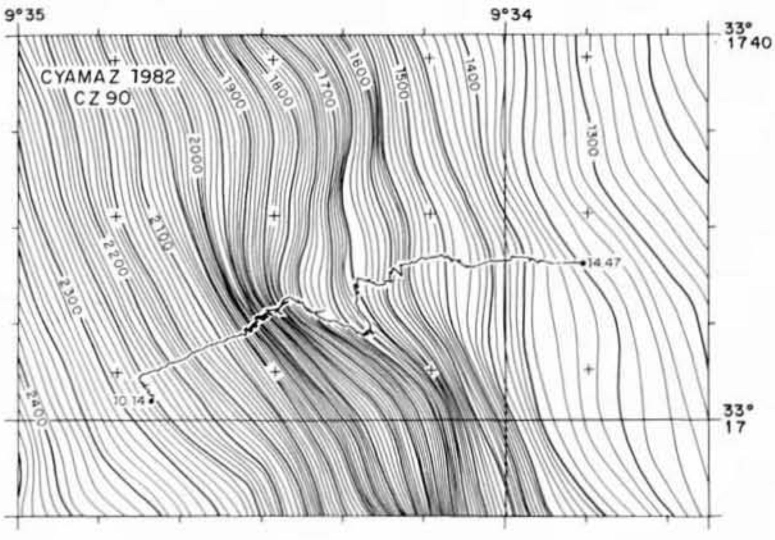
Upslope following the same V shaped canyon, we observed outcrops which have rounded surfaces, but it was very difficult to sample these layers. Sample 4 is a laminated, altered rock of questionable age. At about 2 400 m, the escarpment became very steep and sampling very difficult. Sample 6 at 2 356 m is probably a semi-*in situ* boulder. It is a pelsparite of late Malm age with a fill of late Campanian-Maestrichtian age. In this area, we have the first indication of indistinct bedding. Between 2 336 and 2 219 m appears a large cobble field. The next cliff starts at about 2 207 m with massive limestones of late Jurassic (late Kimmeridgian for Sample 7) and the slope becomes steeper (more than 60°). The last sample (8) taken at the end of the dive (2 038 m) is a Late Cretaceous laminated phosphorite.

The direction of faulting shows two maxima : N 90° and N 150° associated with N 60°, N 110°, N 120° and N 180° directions. The open fractures strike preferentially N 100°-120°.

Dive 92 (Fig. 29, 30, 31 ; Plate 9)

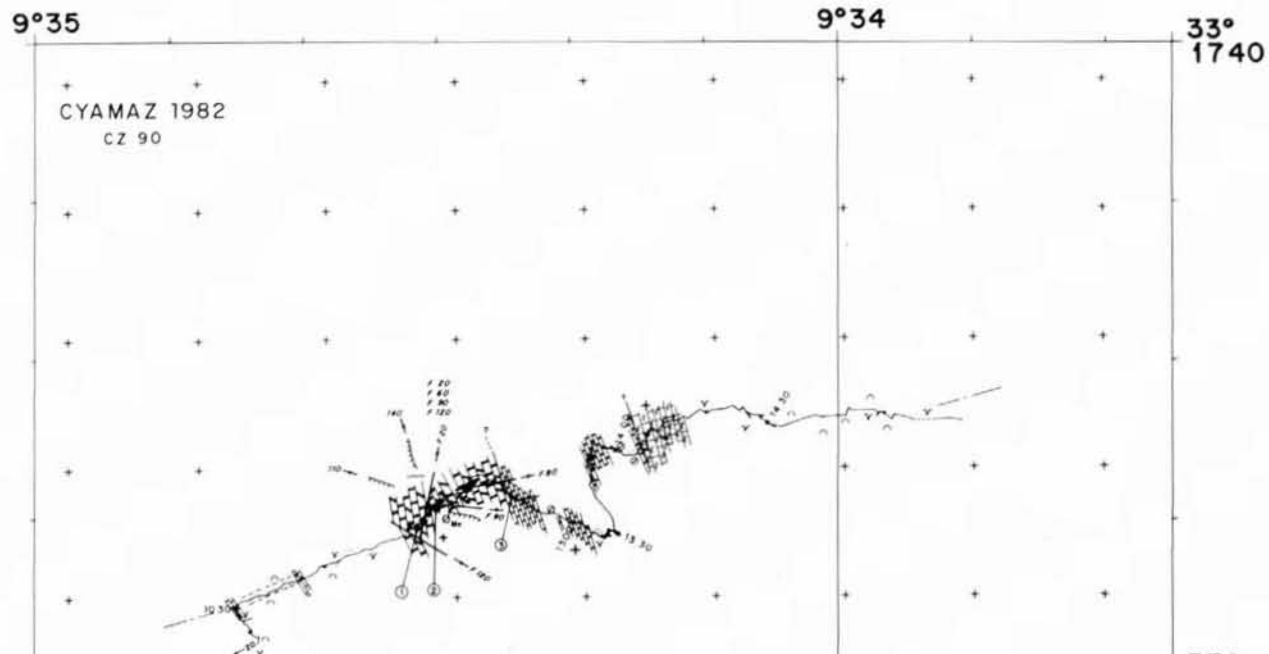
Objectives

The dive was located on the top of the Mazagan (El Jadida) Plateau horst at about 1 000 m water depth.



XMIN= 446000. YMIN= 3683000. XMAX= 447500. YMAX= 3684000.

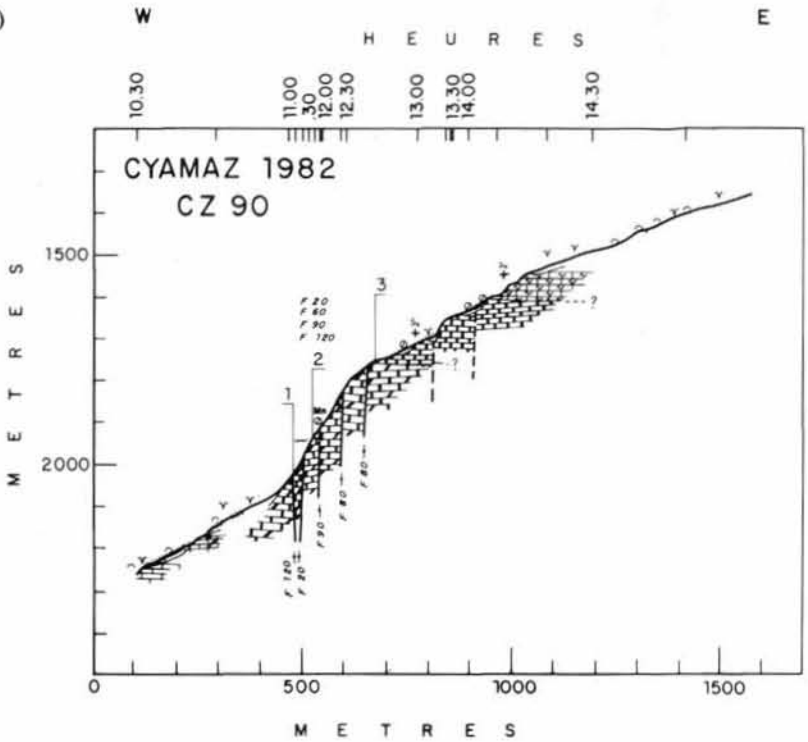
Figure 23 (Dive 90)
Location map.



XMIN= 445750. YMIN= 3682750. XMAX= 447750. YMAX= 3684000.

Figure 24 (Dive 90)
Geological map.

Figure 25 (Dive 90)
Geological profile.



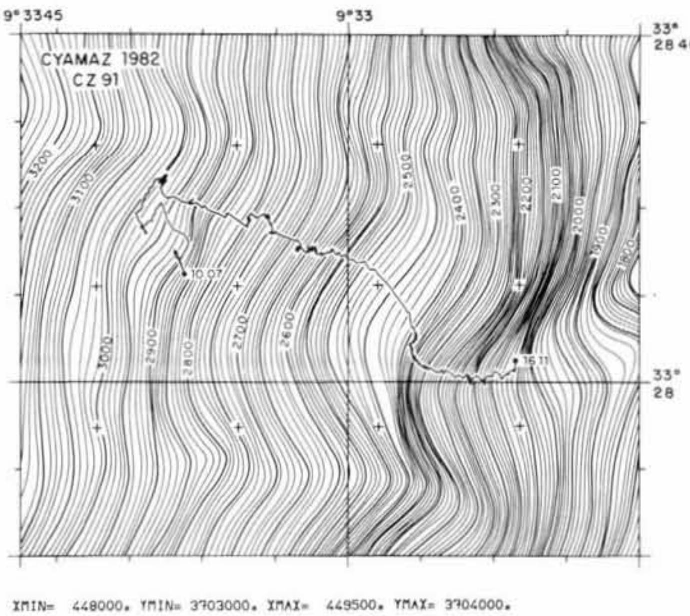


Figure 26 (Dive 91)
Location map.

On the Seabeam map (scale 1 : 10 000) we see an alignment of features striking NE-SW. This alignment is linked with a fault zone. The seismic profiles confirm this interpretation and show that in this area a deep reflector is uplifted by faulting and could reach the surface. The main goal of the dive was to sample this deep layer and to observe and sample the bedded layers overlying this layer.

Main results

The dive began at 1 100 m water depth on a very gentle slope (2° or 3°) covered with soft sediments. On this slope, no outcrop in place was recognized, except for a dolomicritic block corresponding to sample 1 (Early Cretaceous ?). On the top of a small hill culminating at 1 010 m, we observed in many places manganese crusts suggesting that the substratum is not too far from the sediment surface. Towards southeast, a small depression is completely covered with soft sediments. The maximum depth of this depression was 1 050 m.

Between 1 050 and 970 m, we found a small scarp with massive carbonates (sample 2 — middle Eocene) and softer chaotic layers. In some places, these layers are well bedded and constituted by micritic packstone dated between middle and late Paleocene. Samples 3, 4, 5 and 6 were taken in the chaotic zone. The age succession is not representative of the real stratigraphic sequence (*see* Cepek, Hagn, this vol.).

Dive 93

Dive interrupted for technical problems. No results.

Dive 94 (Fig. 32, 33, 34 ; Plate 10)

Objectives

This dive was planned to continue the section started by Dive 91. It should cover the upper part of the escarpment to observe massive carbonates, as well as the contact with the bedded cover. It was planned to

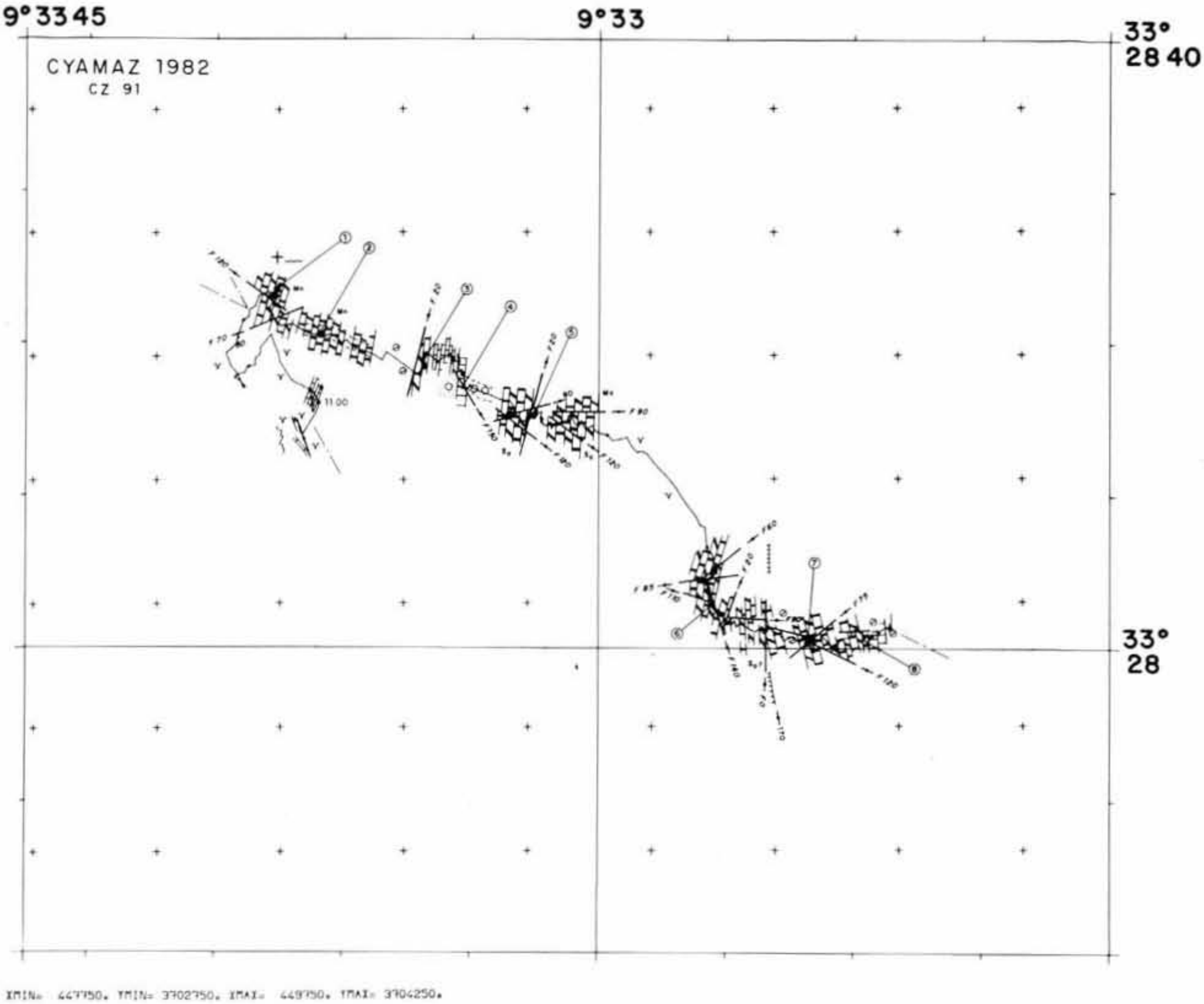


Figure 27 (Dive 91)
Geological map.

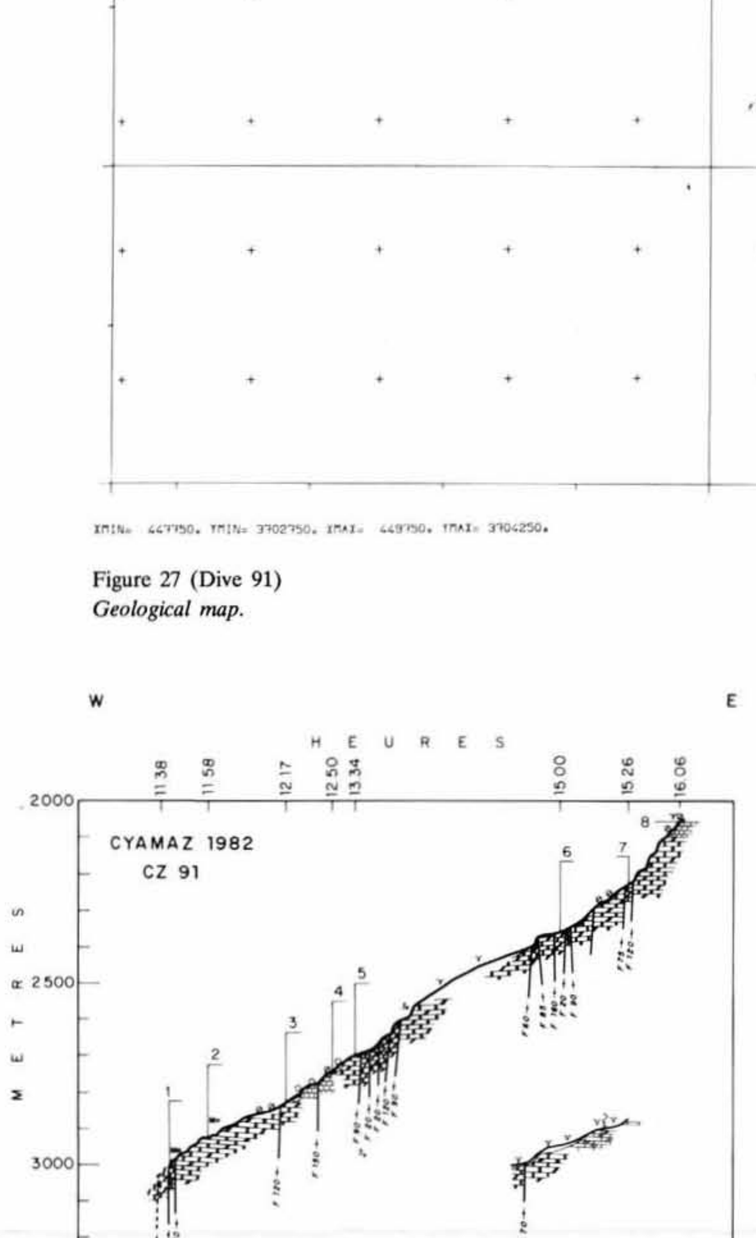


Figure 28 (Dive 91)
Geological profile.

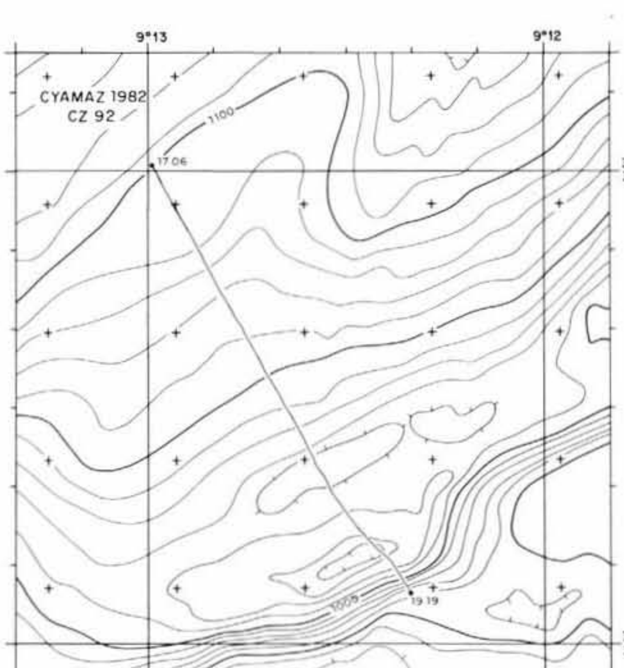


Figure 29 (Dive 92)
Location map.

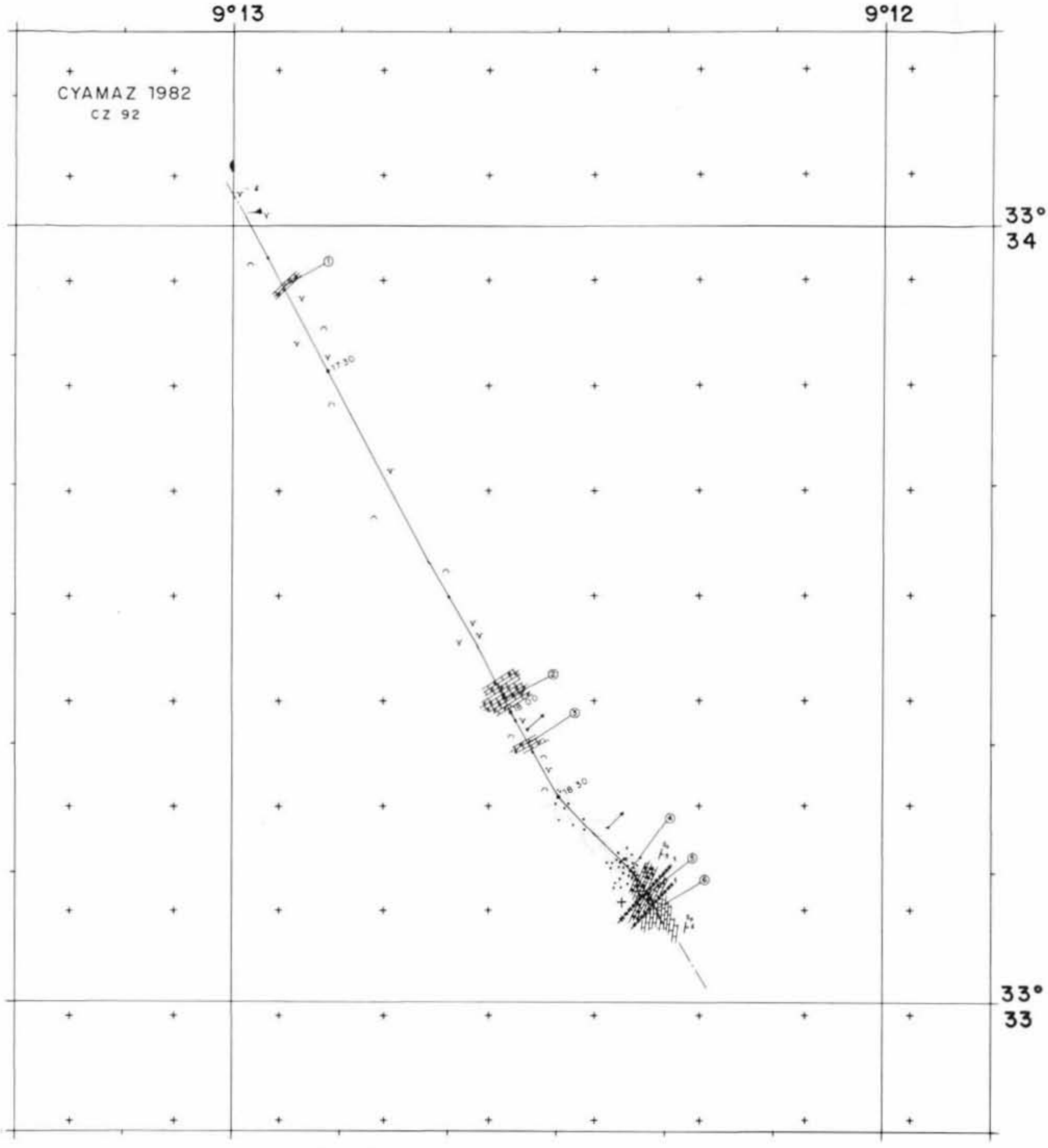


Figure 30 (Dive 92)
Geological map.

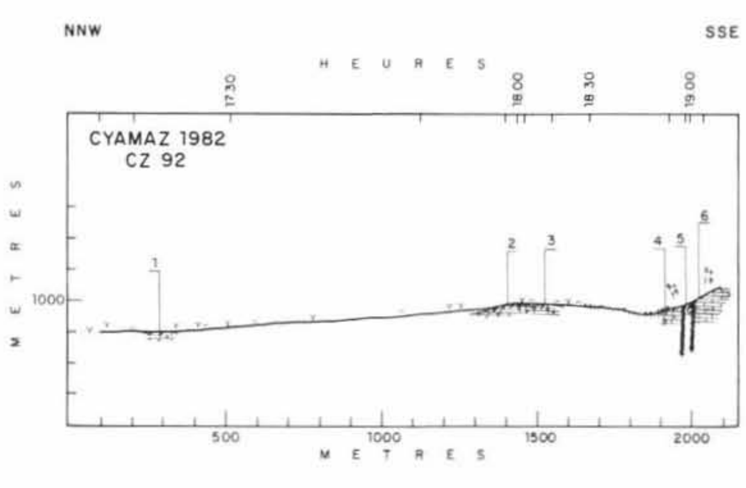


Figure 31 (Dive 92)
Geological profile.

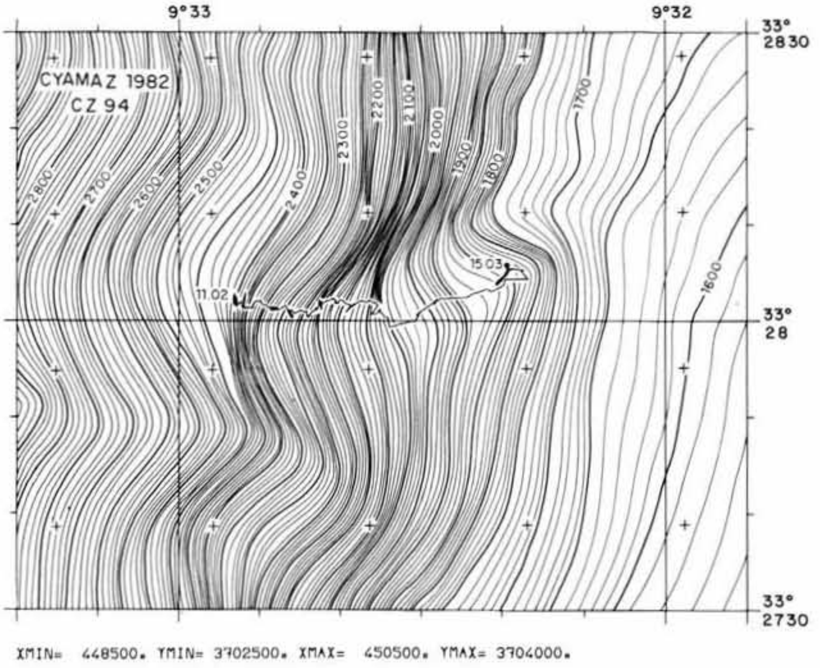


Figure 32 (Dive 94)
Location map.

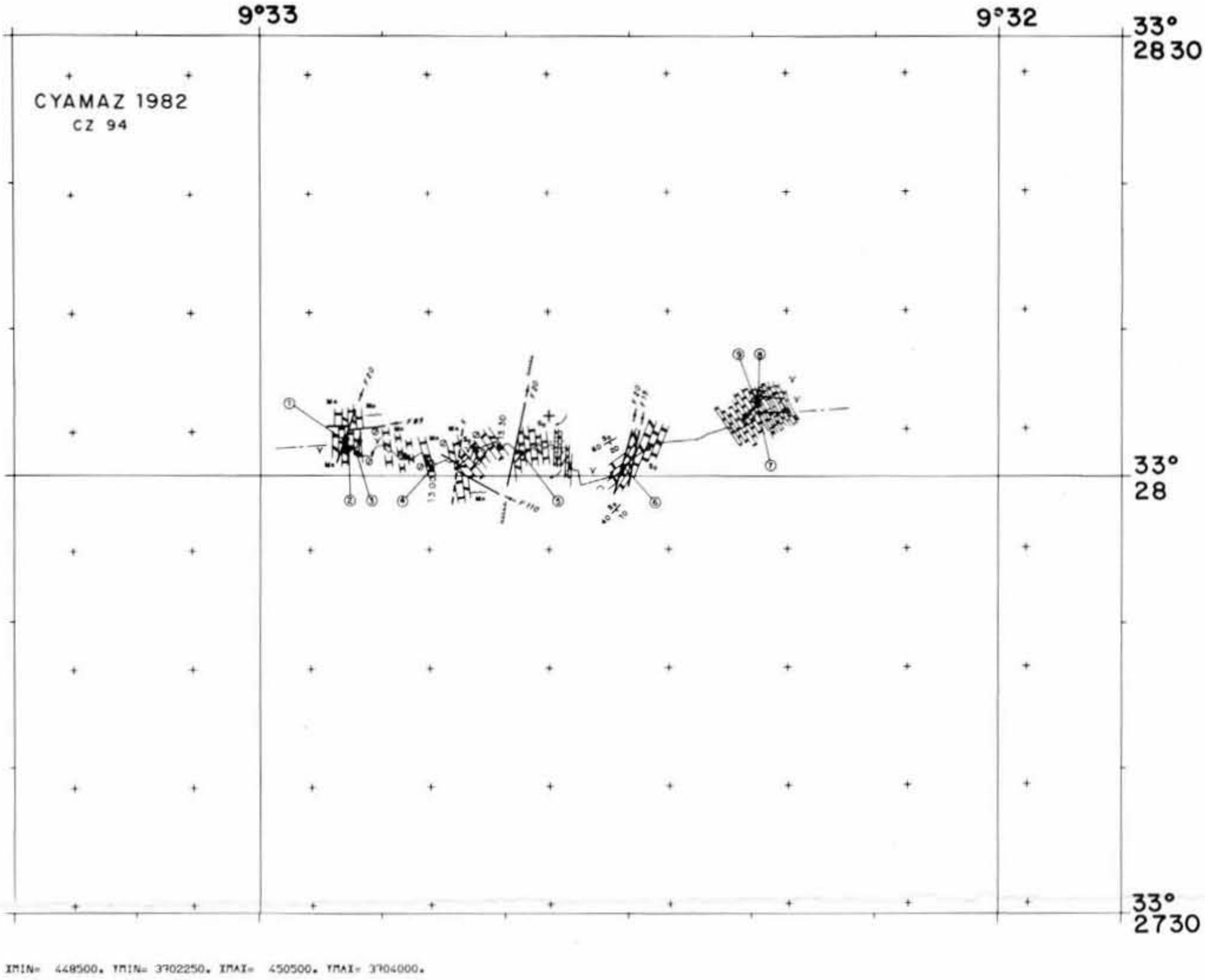


Figure 33 (Dive 94)
Geological map.

A

C

B

D

Plate 9

A : cz 92-91 : 1 032 m. Outcrop in subhorizontal layers of the post platform series. Sample cz 92-4 (1 033 m) Middle Paleocene.

B : cz 92-109 : 1 011 m. Post platform cover gently dipping. This cover is made of slabs coated and fracturated. Sample cz 92-5 (1 011 m) Middle Paleocene.

C : cz 92-130 : 976 m. Horizontal bank of the post platform cover. We can see traces of dissolutions within small faults. Sample cz 92-6 (976 m) Middle Paleocene.

D : cz 92-163 : 973 m. Thinly bedded post platform cover (with traces of erosion, dissolution).

A

C

B

D

Plate 10

A : cz 94-14 : 2 465 m. Intensively faulted N 20-N 40 platform carbonate limestones partially covered with recent sediments.
Sample cz 94-1 (2 465 m) Late Jurassic.

B : cz 94-33 : 2 403 m. Blocks of massive limestones between two faults (one N 20 and the other one N 80). Sample cz 94-2 (2 402 m) Late Jurassic.

C : cz 94-53 : 2 377 m. N 90 to N 100 faults cutting the platform.
Sample cz 94-3 (2 375 m) Tithonian.

D : cz 94-162 : 2 124 m. Rounded, faulted and coated limestones of the carbonate platform.

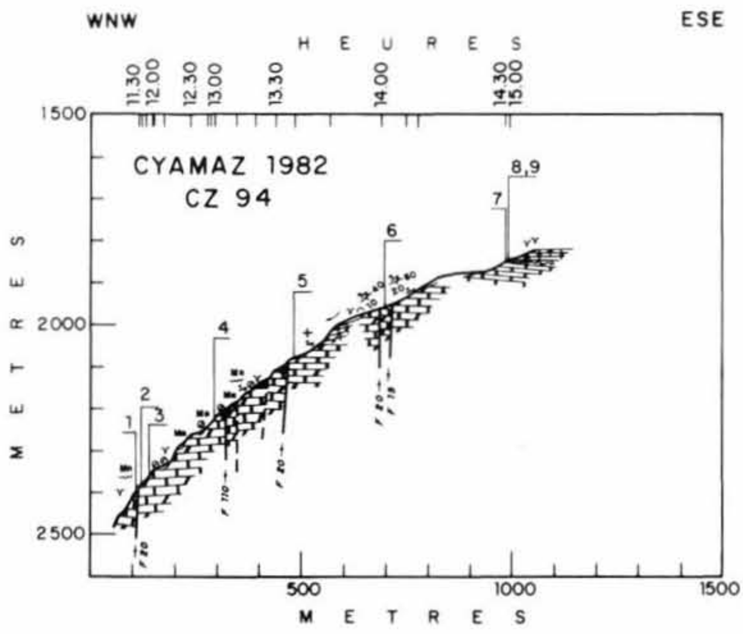


Figure 34 (Dive 94)
Geological profile.

begin diving at 2 500 m water depth to fill the gap of samples from Dive 91.

Main results

The dive started at 2 420 m on a rubble slope thinly covered by recent soft sediments. The lower zone of the escarpment between 2 490 and 2 050 m is characterized by a succession of steps limited by subvertical walls which are oriented N 40° and N 60°. In this zone, four samples (samples 1 to 4) were taken. They are all constituted of platform carbonates and are Late Jurassic — early Neocomian in age. Above the well bedded-sequence, at 1 850 m, conglomerates were found. Two samples 8 and 9 were taken from the conglomerate and show that the matrix surrounding the Jurassic pebbles is a soft calcareous ooze of Valanginian to Aptian age.

Dive 95 (Fig. 35, 36, 37 ; Plate 11)

Objectives

The objective was to start a new diving traverse of the Central Mazagan Escarpment around 1 000 m north of Dives 91 and 94. In this area, a previous cruise of RV Vema had reached Oxfordian marls with many ammonites (Renz *et al.*, 1975) but the depth of dredged sample (3 200 m) is somewhat too deep to be reached by Cyana. Dive 95 was planned to obtain observations and samples from the base of the escarpment and then to reach the base of the main cliff to evaluate the processes which have formed the present topography.

Main results

Between the beginning of the dive at 2 983 m and the end at 2 300 meters the outcrops are more or less continuous and form several small cliffs. Upper Jurassic — lower Neocomian limestones with typical massive morphology crop out in cliffs between 2 957 and 2 951 m, 2 744 and 2 682 m, 2 570 and 2 508 m, 2 420 and 2 391 m. On the top of the platform, these limestones show a rounded morphology and an apparent bedding. During the dive, only two samples (6 and 7) of these limestones were picked up.

More recent, unconsolidated sediments thicken on the moderate slopes where layering parallel to the slope can be observed because of dissection by canyons. They overlie the older rocks of the carbonate platform. The age of these sediments is extremely variable along the escarpment. For example, the samples 1 and 2 (2 972 m) are respectively late Miocene and early Miocene in age. These sediments probably constitute the infilling of a previous topography as marked by some local infilling of open fractures into the Jurassic limestones. These hard limestones are cut by numerous fractures and faults oriented preferentially N 160°, N 120°-110°, N 90°, N 60-70° and N 20°. The directions are the same as observed in previous dives.

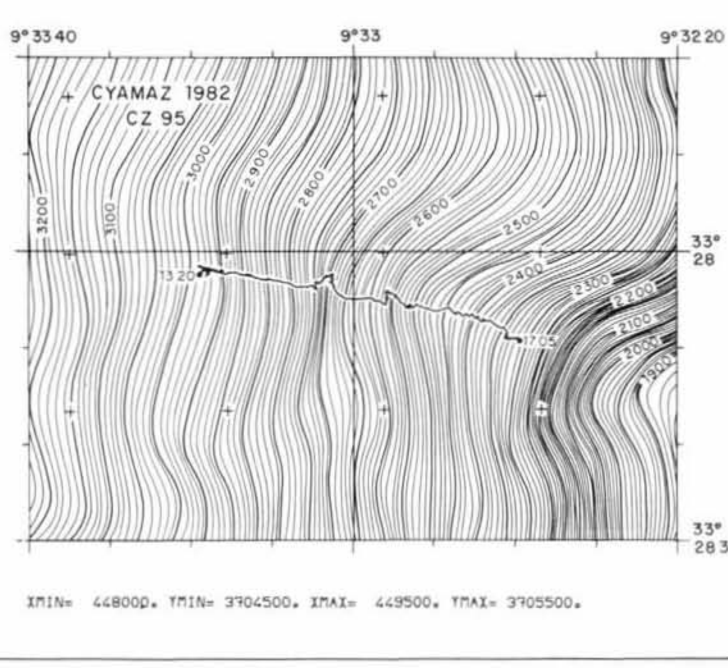


Figure 35 (Dive 95)
Location map.

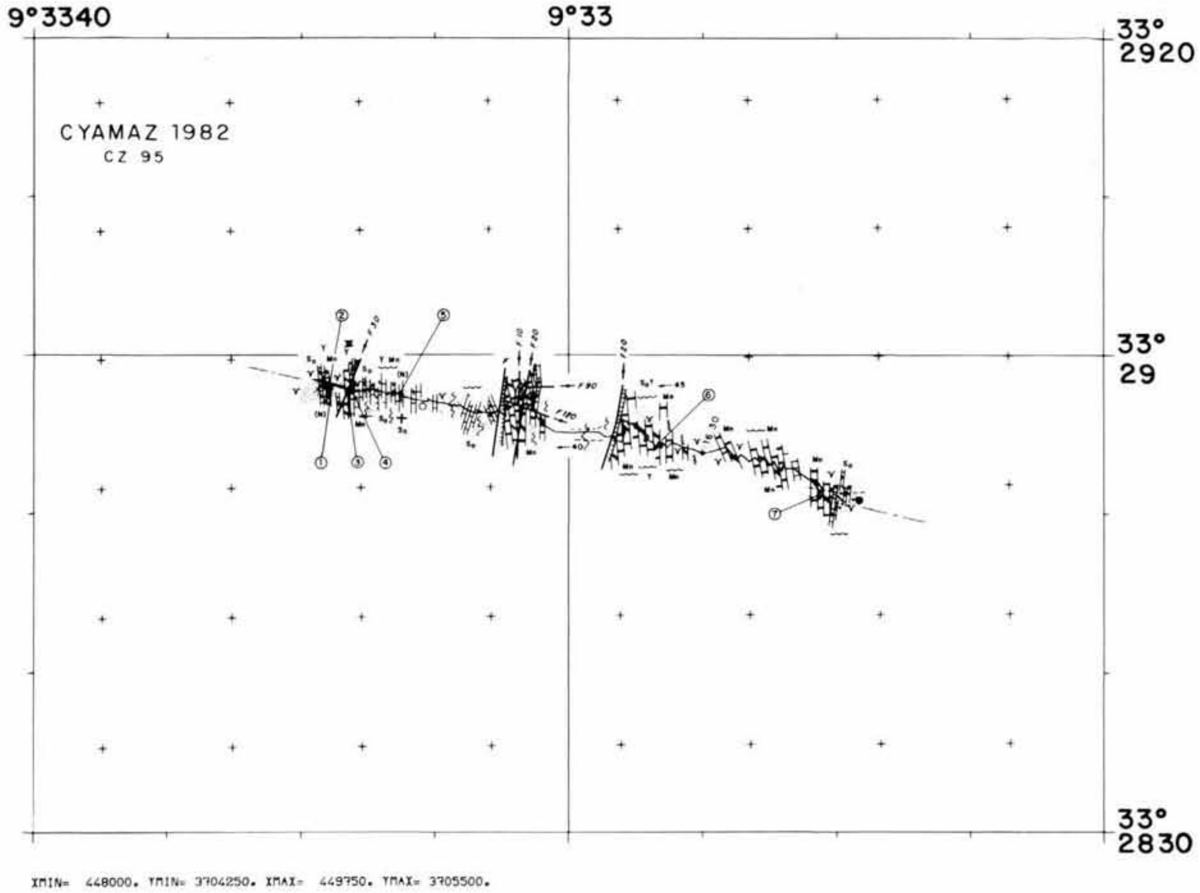


Figure 36 (Dive 95)
Geological map.

Dive 96 (Fig. 38, 39, 40 ; Plate 12)

Objectives

The main objective of the dive was to continue the section initiated during Dive 95 and to observe and sample the upper part of the escarpment between 2 380 and 1 800 m. The objective was to observe the contact between the massive carbonates of the platform and the layered cover of Late Cretaceous to Tertiary age.

Main results

The first part of the dive between 2 383 m and 2 372 m is located on a zone of consolidated screes with intensive fracturation. After these screes, a steep slope is constituted between 2 390 and 2 280 m by recent sediments with sometimes some outcrops of layered sediments (sample 2 : ? Cretaceous phosphorite breccia). Above, the slope is very steep and is made up by massive platform carbonates. These carbonates have been observed and sampled between 2 280 and 1 911 m (samples 4-6-7-9). In some places, the carbonates overlain by softer layers of different ages. For example, sample 5 is a laminated phosphorite of late Campanian-Santonian age included in a breccia, the sample 8 is a lower Cretaceous micrite containing belemnites. The upper part of the platform is masked by recent sediments and we have not

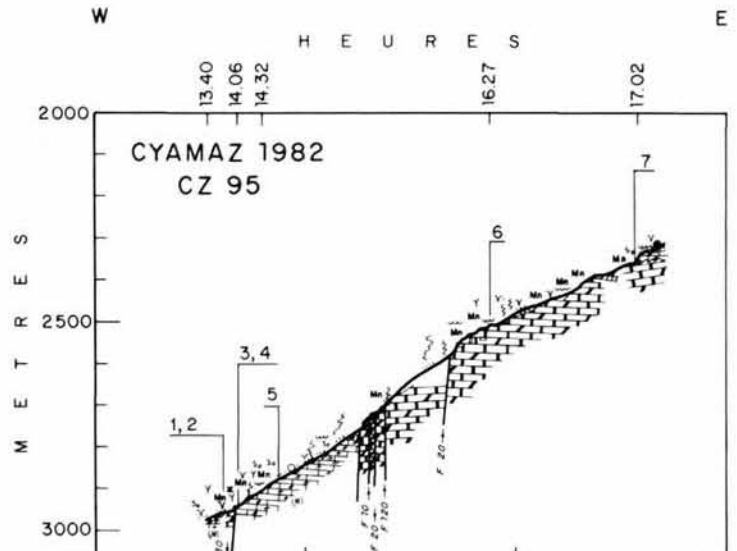
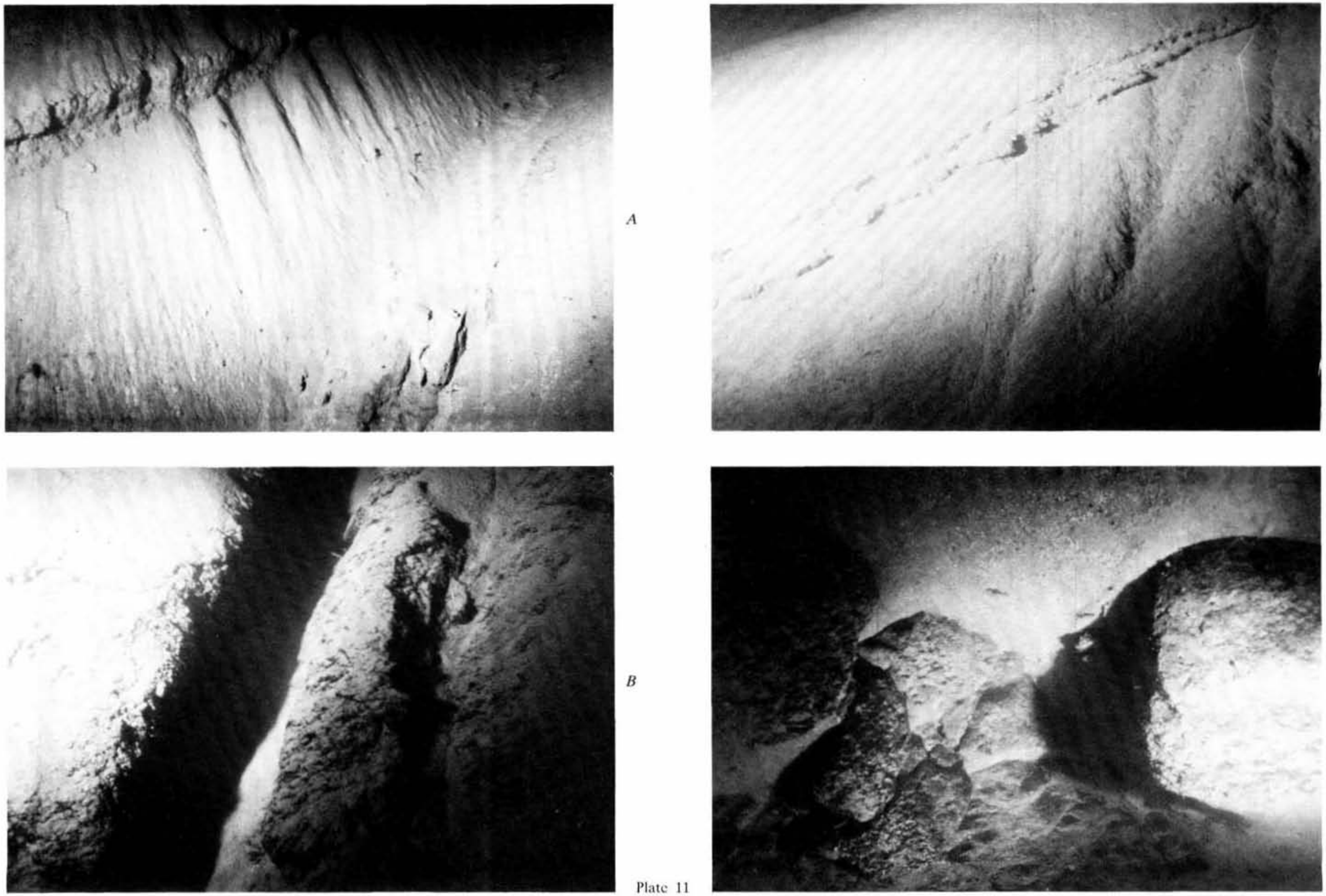


Figure 37 (Dive 95)
Geological profile.

observed the precise contact between the platform and its cover. From 1 842 m until the end of the dive at 1 818 m, the outcrops are essentially characterized by an alternation of hard and soft banks where the erosion is more intense. These layered beds show a



A

C

B

D

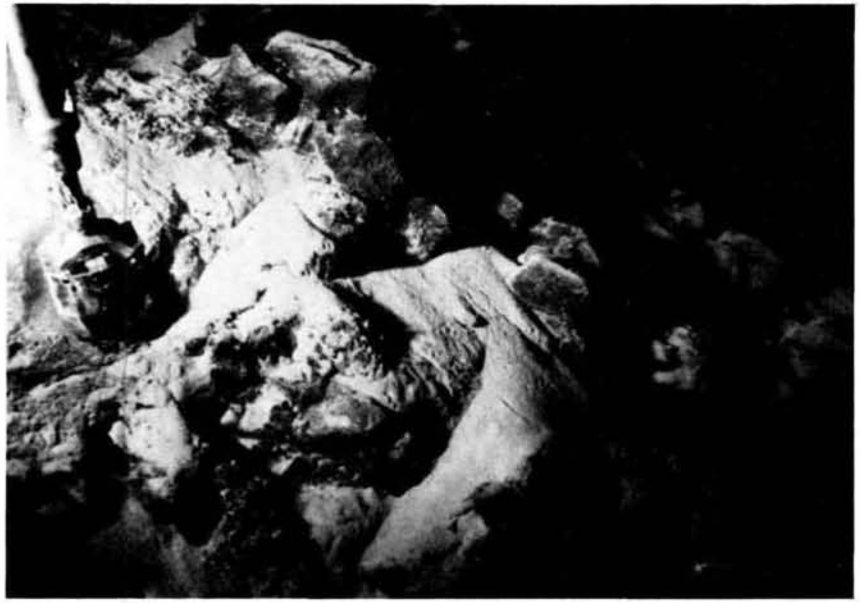
Plate 11

A : cz 95-41 : 2 955 m. Massive limestone coated with manganese. Diaclases N 120 and N 30.

B : cz 95-142 : 2 755 m. Bedded Neogene chalks. In the rear of the picture we can see ridges of recent sediments.

C : cz 95-190 : 2 700 m. Open fracture N 110 in the Jurassic limestones.

D : cz 95-353 : 2 334 m. V shape talweg cut in the bedded tertiary cover (marls).



A

C

B

D

Plate 12

A : cz 96-14 : 2 387 m. Massive limestones of the platform. Very dense network of recently reactivated faults and diaclases (N 10-20, N 90-100). Sample cz 96-1 (2 385 m) Late Jurassic.

B : cz 96-60 : 2 266 m. Recent fault N 120 in eroded massive limestones.

C : cz 96-171 : 2 089 m. Roughly bedded massive limestone of the platform. Sample cz 96-7 (2 088 m) Late Jurassic.

D : cz 96-314 : 1 841 m. Screes in the post platform cover. Sample cz 96-10 (1 842 m) Late Valanginian-Maastrichtian. Sample cz 96-11 (1 818 m) Tertiary.

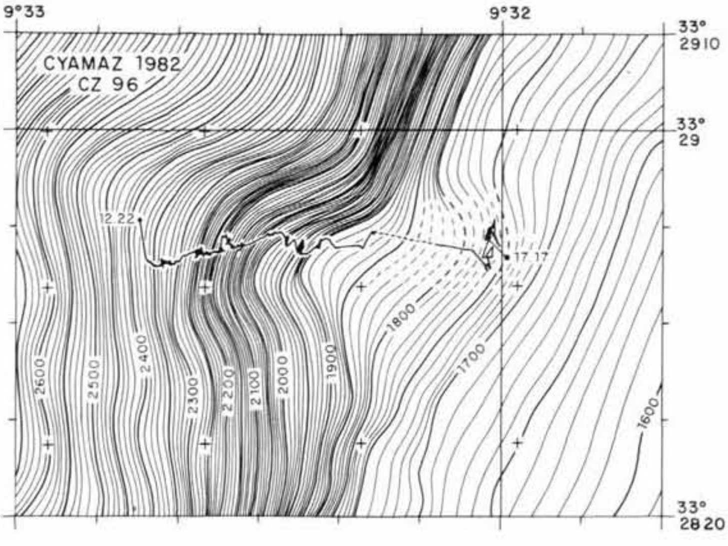


Figure 38 (Dive 96)
Location map.

gentle dipping towards south with an angle of about 5 degrees. Samples 10 and 11 taken in this part of the dive are quartz-rich micrites and phosphorites — probably Cretaceous in age.

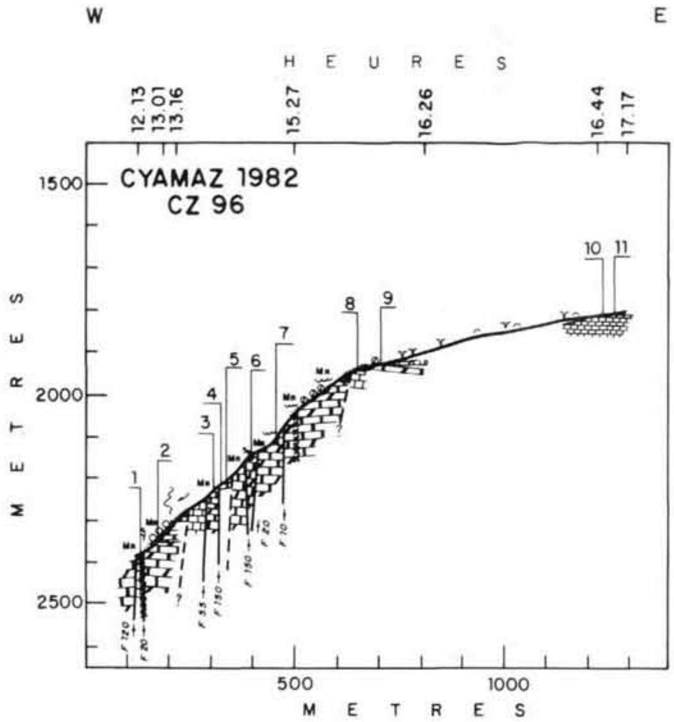


Figure 40 (Dive 96)
Geological profile.

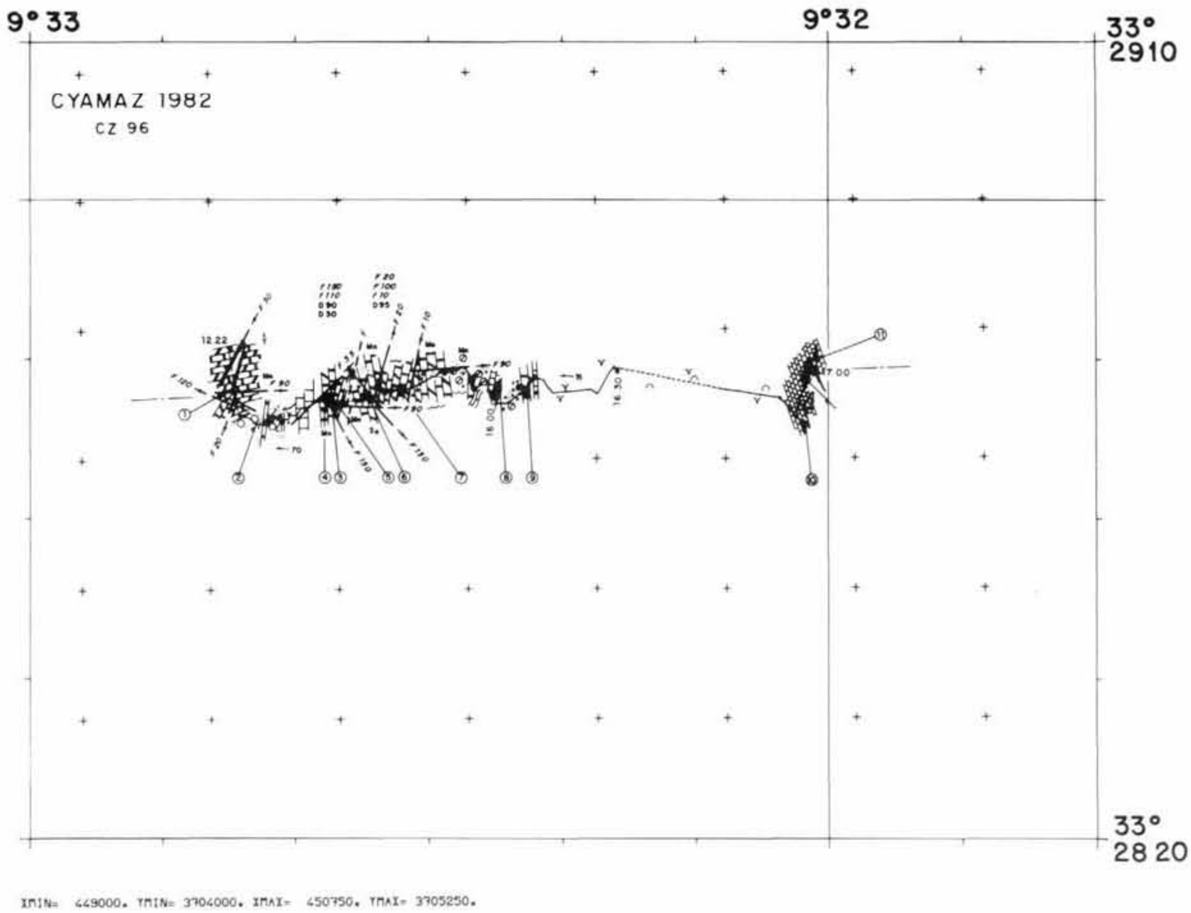


Figure 39 (Dive 96)
Geological map.

Dive 97 (Fig. 41, 42, 43 ; Plate 13)

Objectives

The goal of this dive was to observe and to sample the layered cover overlying the carbonate platform, around 1 900-1 800 m depth. This objective was not completely reached because the dive began at 2 420 m depth, deeper than planned. Also due to the difficulties to progress along the very steep (more than 100 %) slope, the highest level reached at the end of the dive was 1 960 m.

Main results

The dive began at 2 420 m depth on soft sediments with numerous biogenic traces. The slope is cut by small canyons perpendicular to the slope. Above 2 354 m, massive carbonate rocks crop. They are

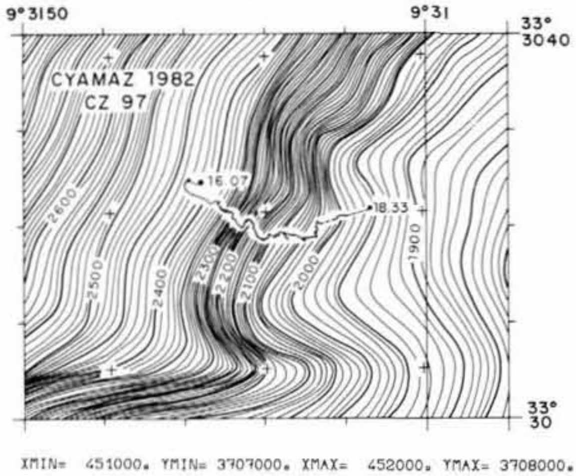


Figure 41 (Dive 97)
Location map.

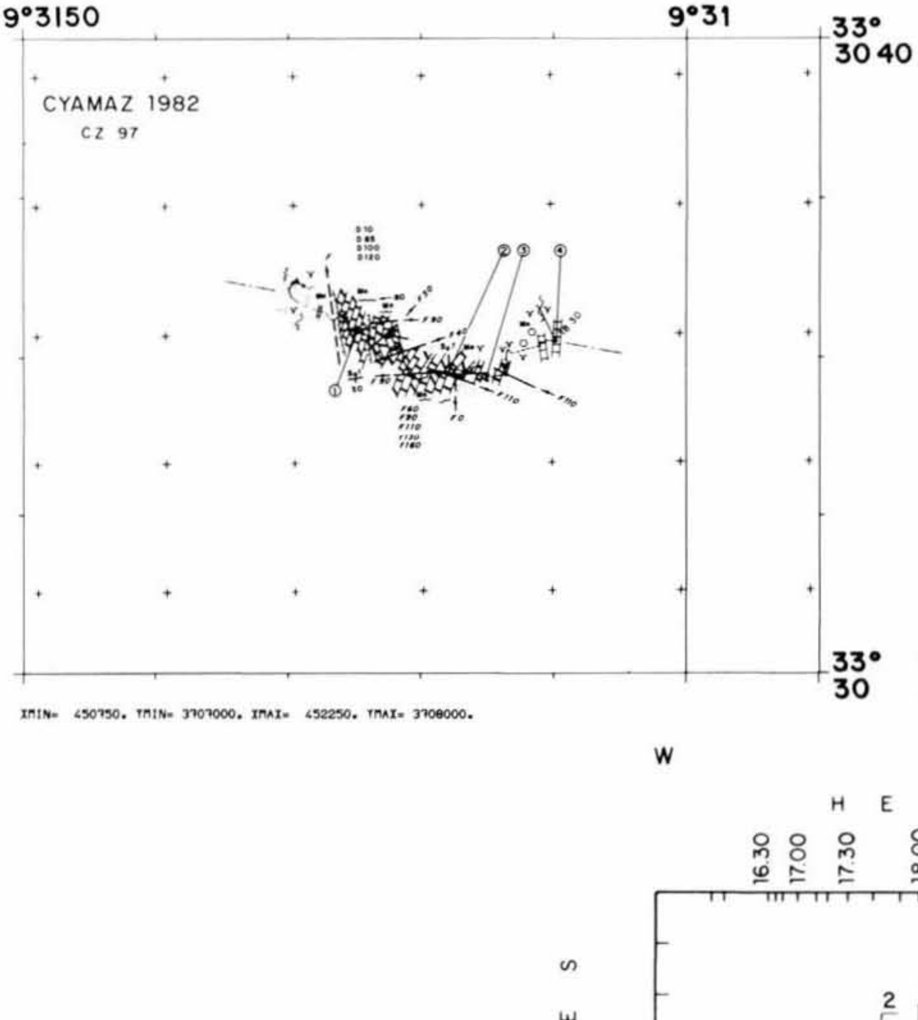


Figure 42 (Dive 97)
Geological map.

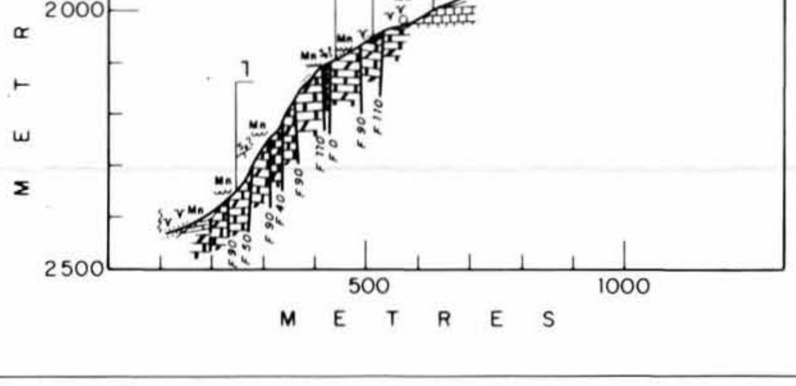
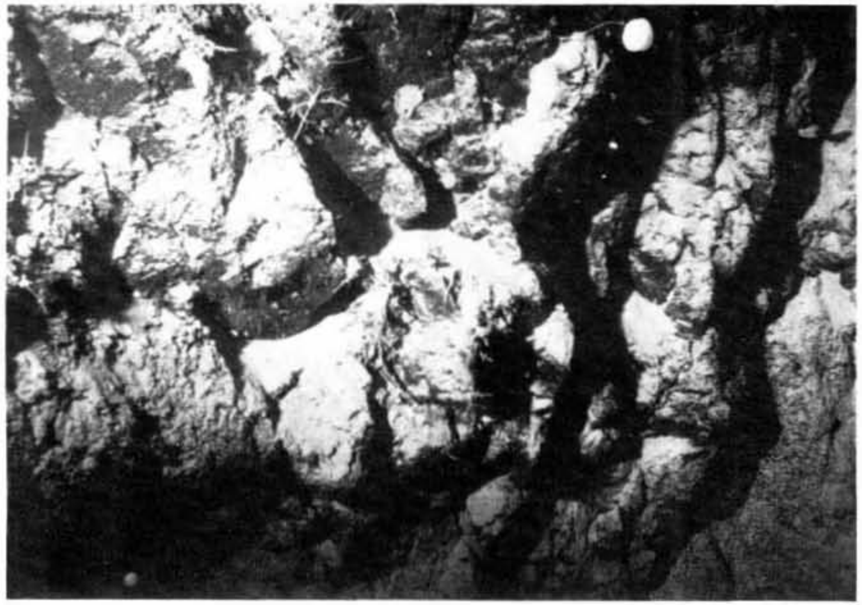


Figure 43 (Dive 97)
Geological profile.



A

C

B

D

Plate 13

A : cz 97-164 : 2 273 m. Massive limestones cut by two normal faults one N 20 and the other one N 120. On the slikenside we can see vertical striation.

B : cz 97-240 : 2 233 m. N 60 and N 110 faults in the limestones of the Late Jurassic.

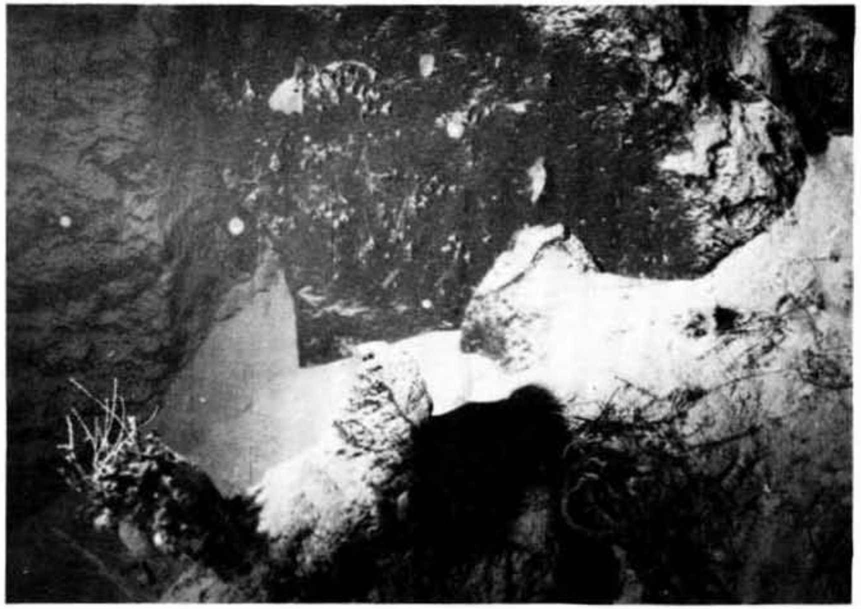
C : cz 97-313 : 2 194 m. Like picture n° 240 — N 150-160 faults and diaclases.

D : cz 97-344 : 2 177 m. Erosional features in the massive limestones (faulted and diaclased) of the platform.

A

C

B



D

Plate 14

A : cz 98-73 : 2 851 m. Well bedded post platform cover dipping towards the West. This cover could probably not be in place but foundered along the slope.

B : cz 98-94 : 2 850 m. Bedded calcareous marls deposited on the slope made by the late Jurassic platform. Sample cz 98-1 (2 862 m) Late Jurassic.
Sample cz 98-2 (2 861 m) and cz 98-3 (2 851 m). Santonian and Campanian.

C : cz 98-104 : 2 850 m. Bedded calcareous marls with erosional features.

D : cz 98-365 : 2 216 m. Massive limestones eroded and fracturated of the Jurassic platform.

eroded into rounded blocks ; numerous faults and fractures were observed. These carbonates are the same as those of the previous dives (sample 1 : Late Jurassic — early Neocomian). No stratifications were observed but some horizontal bedding can sometimes be distinguished within the massive rocks. All along the cliff, many morphological features can be related for the abundance of fractures and faults.

Between 2 170 and 2 000 m depth, the slope becomes more gentle and the soft sediment deposits more frequent. The outcrops are constituted by carbonate platform rocks but it seems that the erosion is more intense than in the lowermost part. From 2 000 to 1 961 m (end of the dive) soft sediments are predominant. The outcrops of the platform carbonates are very sparse. Sample 4 (Berriasian-Barremian) is an echinoderm micrite, probably overlying the platform on a small step.

All along the dive, the carbonates are cut by faults and fractures striking N 60°, N 110° and N 0°-10°.

Dive 98 (Fig. 44, 45, 46 ; Plate 14)

Objectives

The objective of the dive situated further north than the previous dive was to try to sample the outcrops from 3 000 m depth to get older series than the Upper Jurassic rocks which were sampled during the other dives. The second objective was to try to reach the upper edge of the escarpment to observe and sample the contact between the platform and its cover.

Main

Contact with the bottom was made at 2 942 m water depth, on a steep slope (30° to 50°) made up of grey-yellow soft sediments. This sedimentary cover is interrupted by small outcrops (≃ 2 m high) of massive limestomes, encrusted with manganese. This type of outcropping is the same until 2 860 m where sample 1 (Late Jurassic-Lower Neocomian) was taken. Above, the slope becomes steepest and a well bedded cliff constitutes a 12 m high outcrop (samples 2 and 3 : late Santonian - early Campanian). From 2 860 m to 2 294 m, the slope is very steep (60-70°) and made by an alternation of massive limestones outcropping along the cliff with softer sediments lying on the small steps. From this depth until 1 971 m, the slope is constituted by a succession of large steps with alternating steep cliffs (70°-90°) and flat zones, covered with soft sediments. Samples 5, 7 and 9 — taken along the cliffs — are Upper Jurassic carbonates and sample 6 is an Upper Jurassic limestone with a Campanian micrite fill. From 1 971 m to the edge of the plateau, the bottom is built up by soft sediments, boulders and blocks of limestones. The edge of the plateau is made up by belemnite and quartz-bearing Fe-ooid-rich Lower Cretaceous micrites.

Dive 99 (Fig. 47, 48, 49 ; Plate 15)

Objectives

This dive was the first in the area of the southern escarpment of the Mazagan (El Jadida) Plateau. From a water depth of about 1 300 to 1 000 m, there is, on the seabeam map, a steep southward slope down to the northernmost branch of the El Jadida canyon system. The first objective of the dive was to observe and sample the northeastward dipping reflectors outcropping on this scarp and representing the cover of the carbonate platform. The second objective was to try to sample the top of the underlying Jurassic carbonate platform that can be seen on seismic profiles.

Main results

The dive began in the axis of the El Jadida Canyon at 1 360 m, on a flat plain with gravel, pebbles and

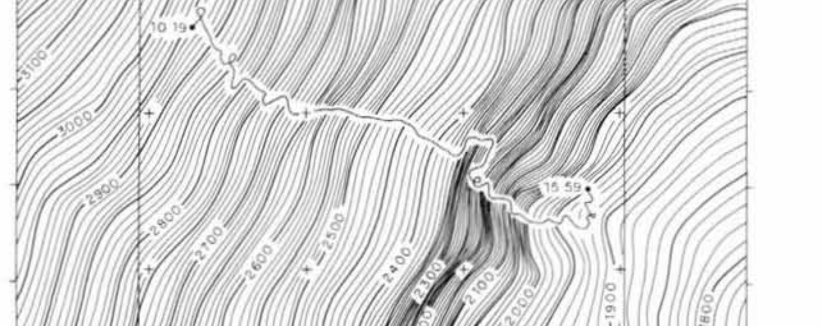


Figure 44 (Dive 98)
Location map.

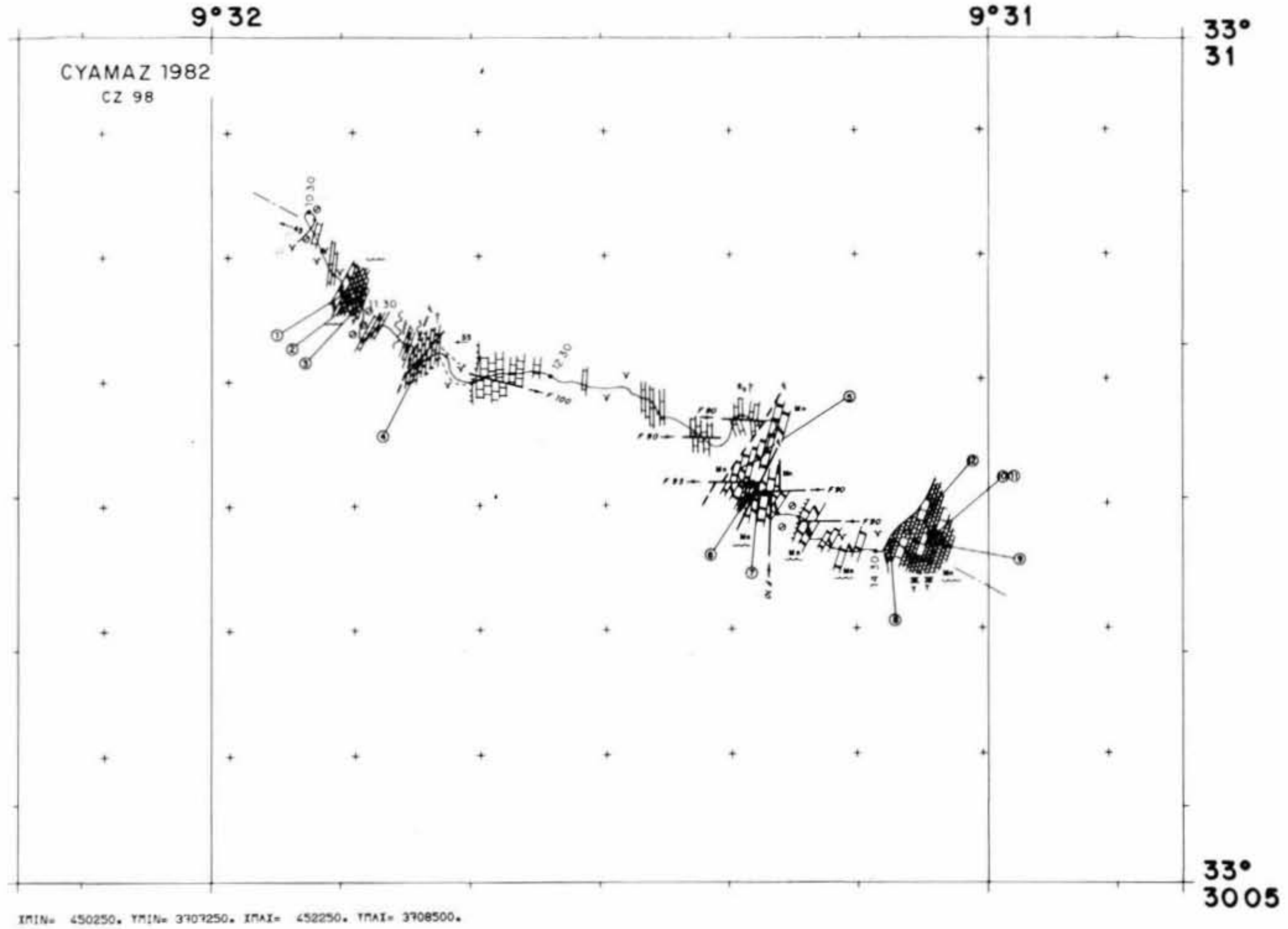


Figure 45 (Dive 98)
Geological map.

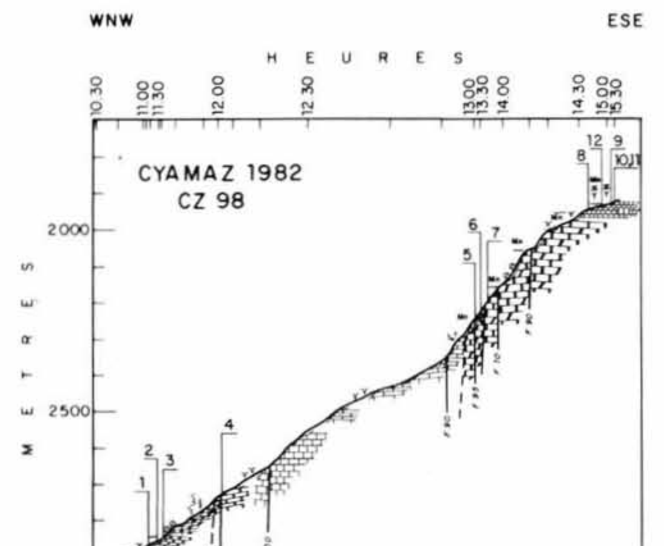


Figure 46 (Dive 98)
Geological profile.

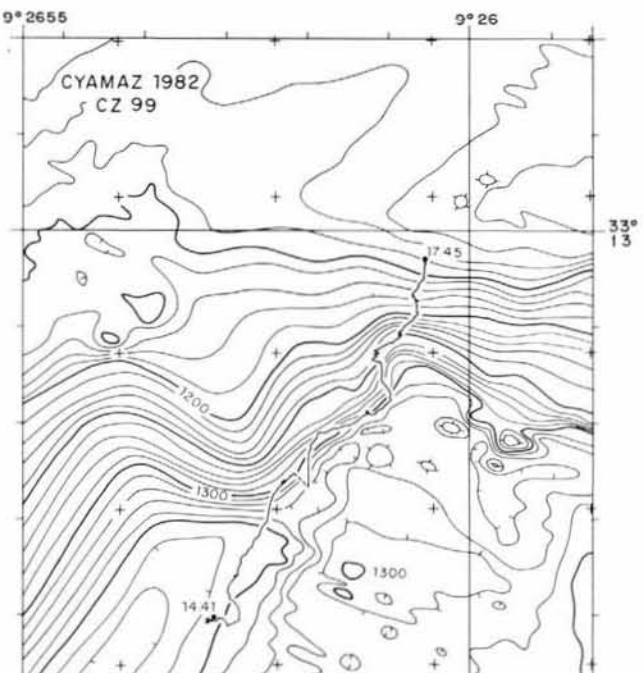


Figure 47 (Dive 99)
Location map.

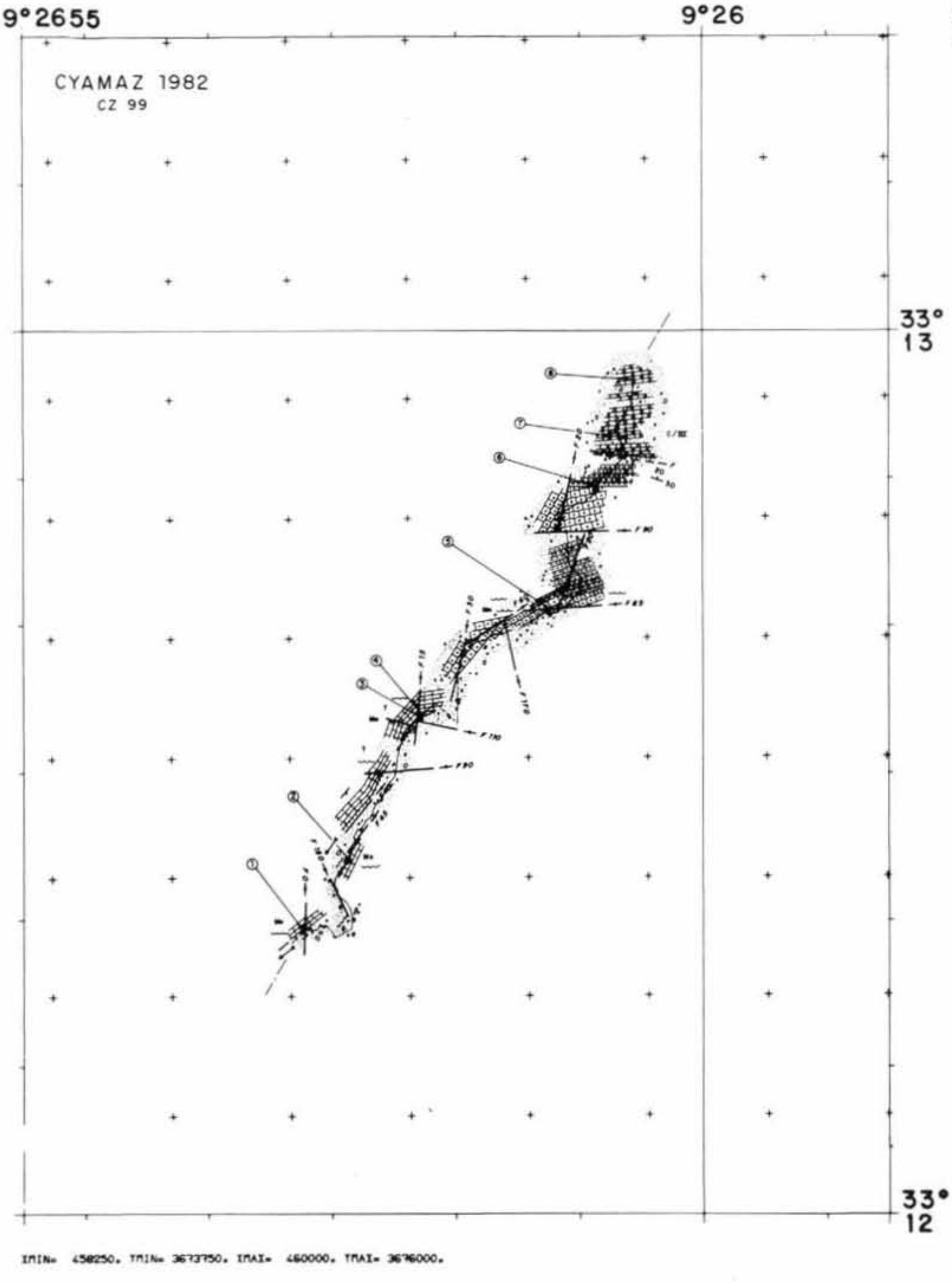


Figure 48 (Dive 99)
Geological map.

boulders (1 to 100 cm diameter). Between 1 355 and 1 297 m, the dive explored the northern wall of the canyon, where well-bedded sandy limestone layers are exposed. The bedding is about N 60-70°/10-30° S.E. A strong superficial dissolution of the calcareous sandstones was observed and produces a karst-like topography. Samples 1 to 5 have been taken from this wall. They are thin (10 cm) to very thick (2 m) bedded, fine to medium grained quartz-bearing echinoderm micrites. Their age is not well defined, but ranges from Berriasian to early Aptian.

The second part of the div . is located northward beyond the canyon along the maximum upslope gradient. In this traverse, numerous conglomeratic beds are exposed on steep escarpments. They were sampled at 1 184 and 1 144 m in samples 7 and 8, and show intraformational phosphorite breccias with laminated glauconitic sand matrix. Their age is also poorly defined (between Aptian — Maestrichtian) probably Late Cretaceous ; *see* von Rad, this vol.).

Dive 100 (Fig. 50, 51, 52 ; Plate 16)

Objectives

The dive is located south of the Mazagan Plateau, where the 1 500 and 1 000 m isobaths constitute a reentrant to the plateau. This area corresponds to the head of El Jadida Canyon. The main objective of the dive was to observe and sample the bedded sedimentary cover of the platform in the axis of the northern branch of the canyon. The goal of the second part of the dive was to observe the east-west escarpment bounding the Mazagan Plateau to the south.

Main results

The dive began in the axis of the El Jadida Canyon at 1 340 m water depth. The bottom of the canyon is formed by a coarse sedimentary cover. On this sedimentary cover lie pebbles, boulders and blocks of extremely variable sizes (cm- to m-scale). Samples 1 to 3 were taken in this area. They are not in place and their ages are not well defined ; they vary between Valanginian and Late Cretaceous.

The second part of the dive runs along the east-west escarpment between 1 200 and 1 050 m. The escarpment is constituted by a succession of steps, about 10 m high. The sedimentary sequence seems to be very homogeneous and shows an alternance of massive banks and softer dm-scale banks. This sequence is completely dissected by a diaclastic system. The main direction of fracturation is N 100°, mainly represented by open fractures (a few cm wide). Samples 8 to 12 were taken in this area. Their age ranges from Early to Late Cretaceous. The dive ended on the top of the escarpment on a large " plateau " made up by a massive bank and cut by small valleys (5 to 10 m deep) oriented N 110.

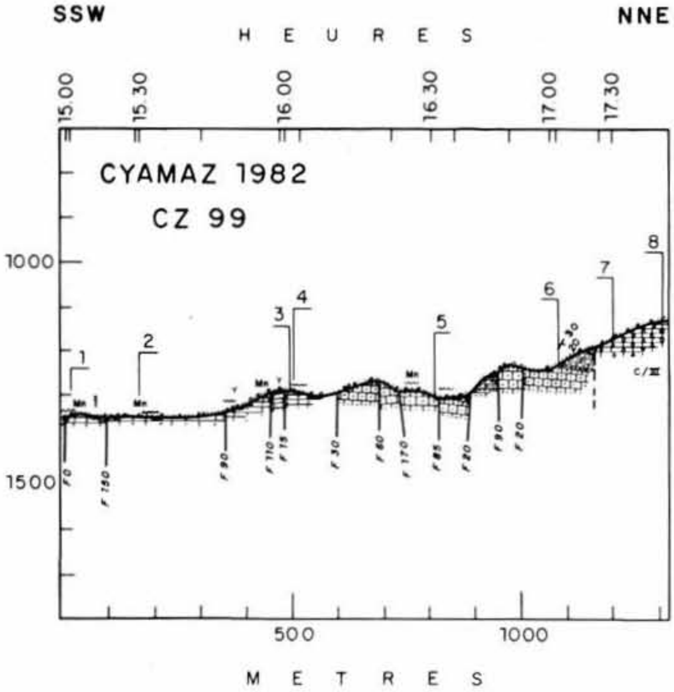
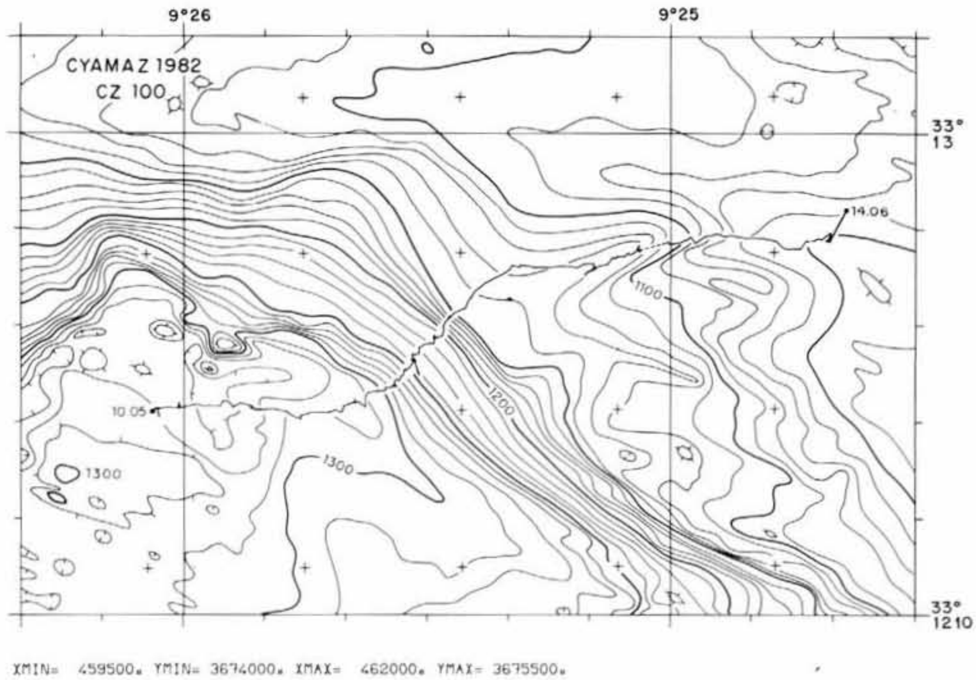


Figure 49 (Dive 99)
Geological profile.

Figure 50 (Dive 100)
Location map.



Dive 101 (Fig. 53, 54, 55 ; Plate 17)

The last Cyamaz dive was located in the southern part of the Mazagan (El Jadida) Escarpment to fill gap in observation and sampling between Dives 88 and 85/86. Once again, the objective was to observe and sample the contact between the carbonate platform and the bedded layers overlying this platform.

Main results

The beginning of the profile in covered with a soft recent sedimentary cover and outcrops are scattered. Sample 1 at 2 003 m corresponds to a small (sub-in place) outcrop of the Upper Jurassic platform. Above this area, between 1 870 and 1 818 m, the slope becomes steeper and a succession of small cliffs shows outcrops without bedding, cut by fractures of variable orientations and open fractures striking mainly N 110.

From 1 660 m, above these massive cliffs, a cover of well bedded layers has been observed. This cover is made by a succession of massive banks (2 to 5 m

A

C

B

D

Plate 15

A : cz 99-17 : 1 360 m. Bottom of the El Jadida Canyon with blocks of sand and gravels. Sample cz 99-1 (1 355 m) Late Jurassic — Cretaceous.

B : cz 99-101 : 1 351 m. Calcareous bedded post platform cover, eroded by currents. The effect of currents can be seen in the recent sedimentary cover. Sample cz 99-2 (1 351 m) Paleocene.

C : cz 99-232 : 1 300 m. Bedded post platform cover cut by diaclases. Sample cz 99-5 (1 299 m) Berriasian — Early Aptian.

D : cz 99-315 : 1 218 m. Thin hard bank eroded by currents and perforated by deep sea animals.

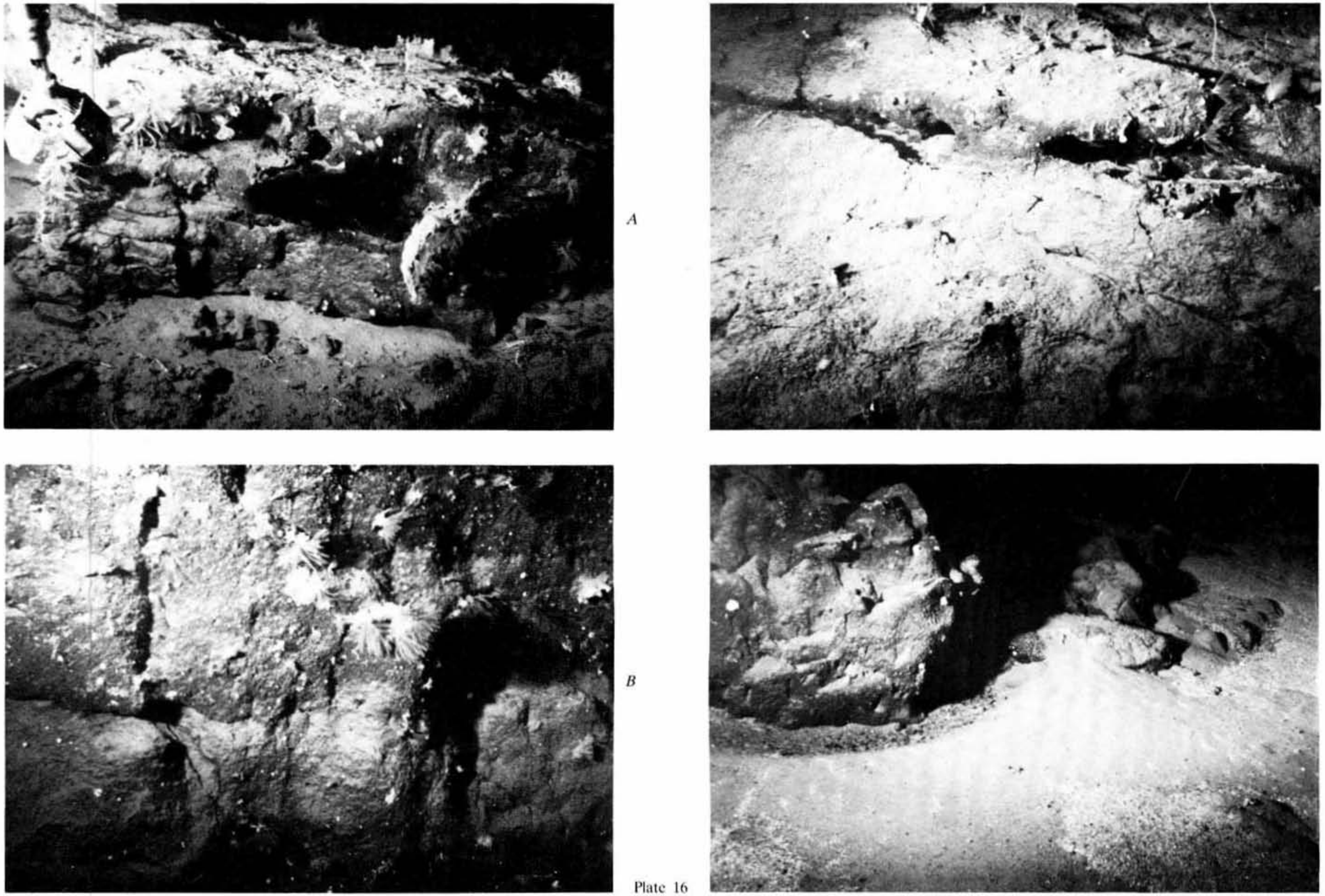


Plate 16

A : cz 100-38 : 1 342 m. Disagregation of calcareous blocks on the bottom of the El Jadida Canyon.

B : cz 100-232 : 1 137 m. Bedded calcareous post platform cover with numerous traces of erosion and dissolution.

C : cz 100-260 : 1 167 m. Like picture n° 232.

D : cz 100-359 : 1 131 m. Like picture n° 232.

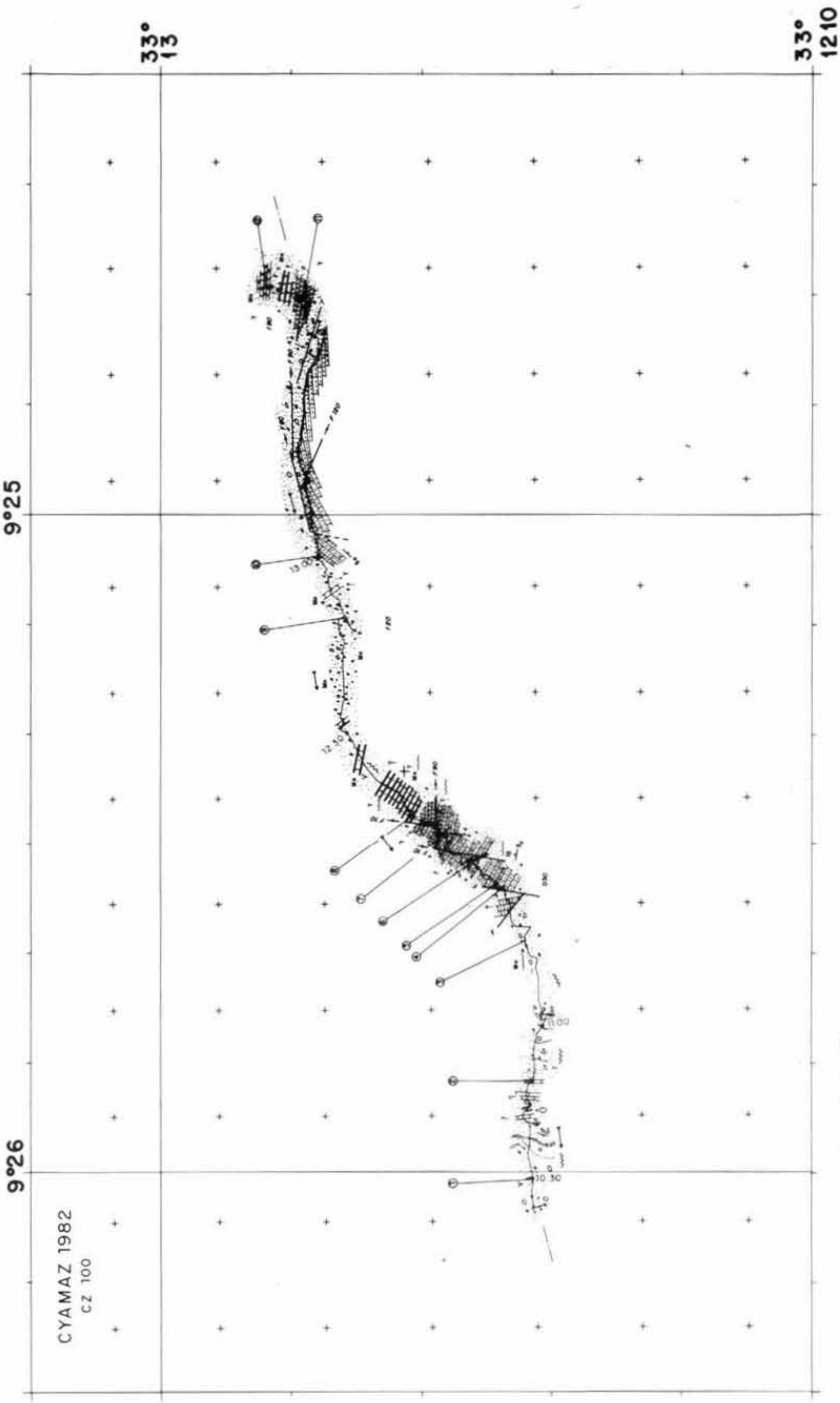


Figure 51 (Dive 100)
Geological map.

thick) and yellow to grey bedded banks. This cover is drapped above the massive platform carbonates. Samples 3 to 6 taken min this area are mainly micrites of (Early) Cretaceous age.

Above this sedimentary cover, between 1 250 and 1 200 m, (end of the dive), the Upper Jurassic — Lower Neocomian carbonates outcrop along a massive cliff, cut by small erosional canyons.

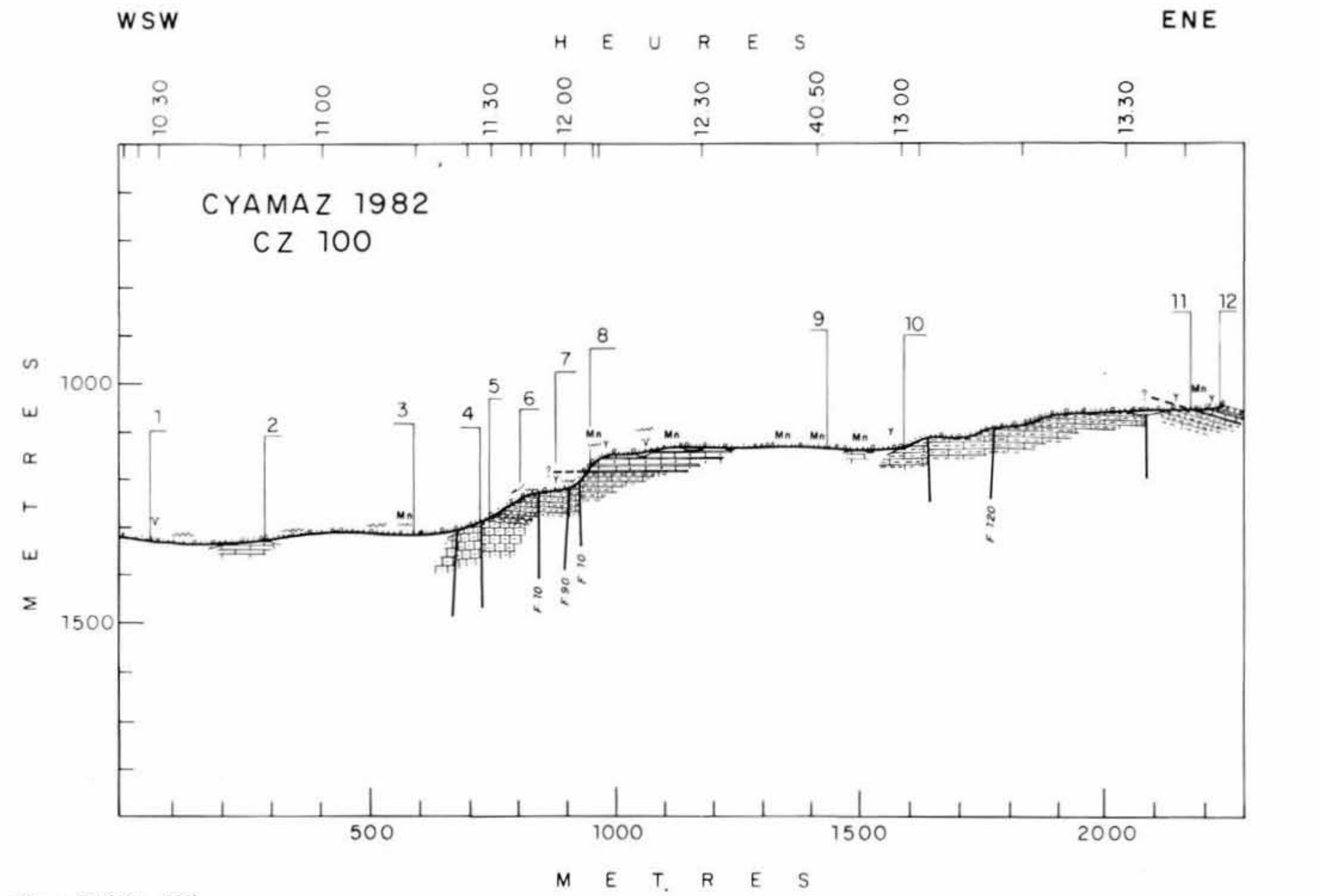


Figure 52 (Dive 100)
Geological profile.

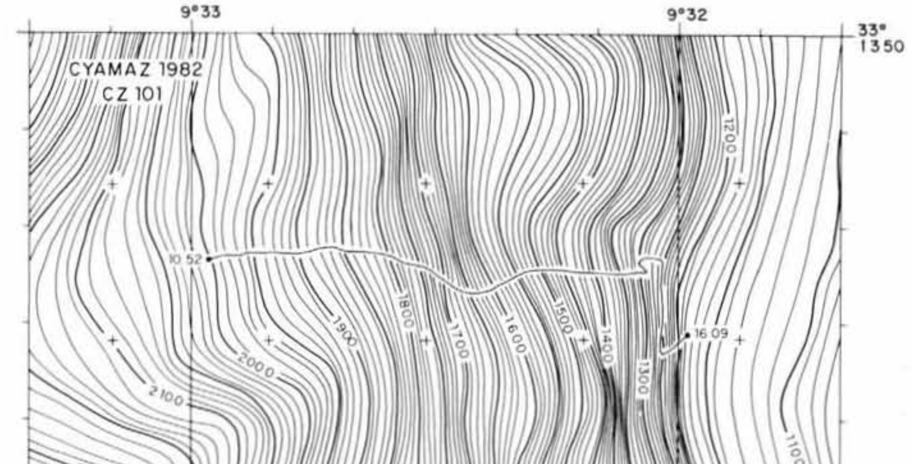


Figure 53 (Dive 101)
Location map.

CONCLUSIONS

The eighteen drives of the Cyamaz cruise allowed to improve considerably our knowledge of the stratigraphy and structure of the Mazagan Plateau and Escarpment. Concerning the stratigraphy, the 130 samples taken give us the possibility to set up a very precise section of the upper levels of the Kimmeridgian-Berriasian carbonated platform. We can note that these platform carbonates do not show any evidence of reef structure. A bedded cover, the age of which varies in relation with the part of the Mazagan Plateau observed, can be seen above the platform. It may appear in the Middle-Cretaceous, as this is the case in the central area of the Escarpment, as well as only in the Tertiary (Paleocene), in the Southern area for

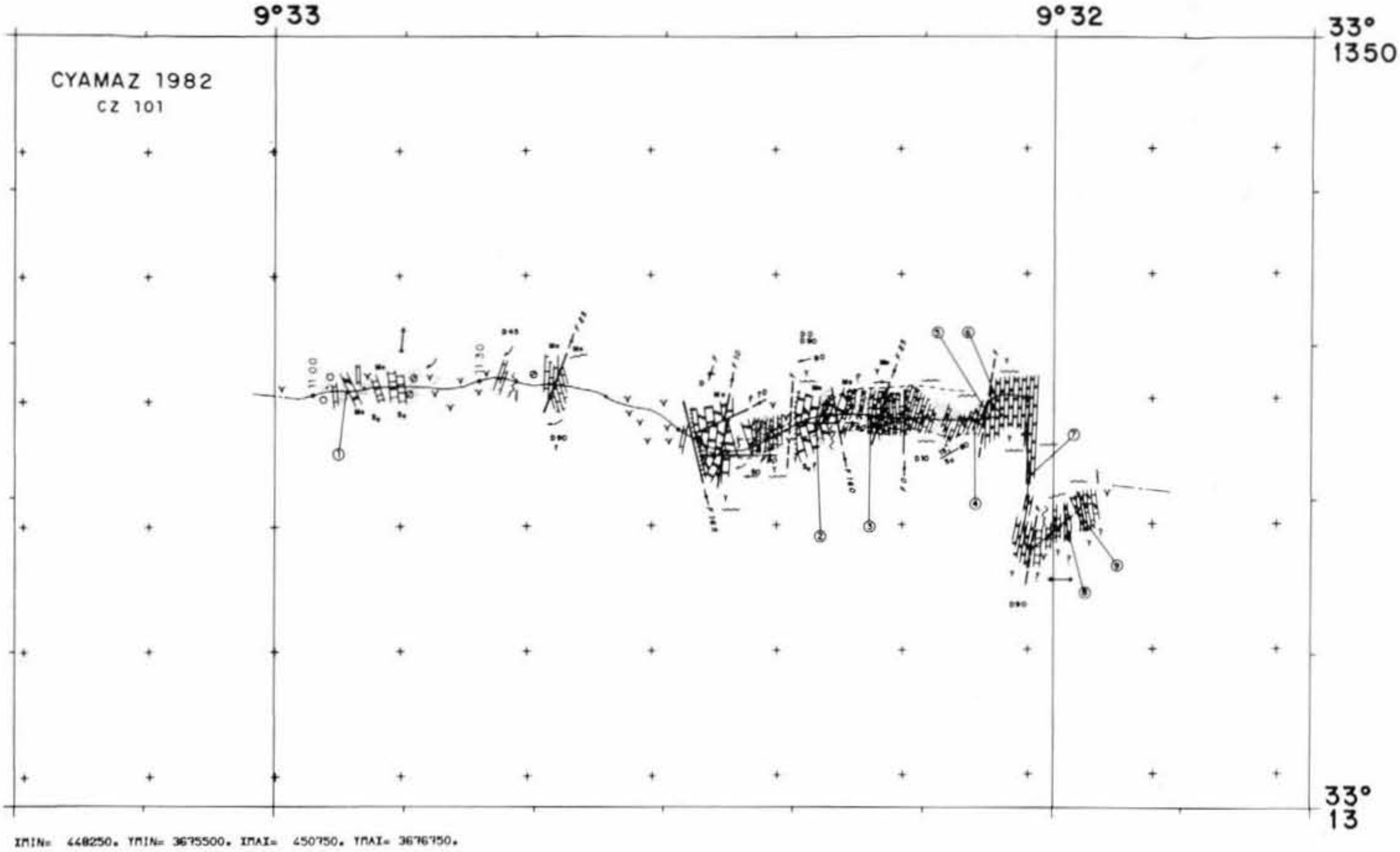


Figure 54 (Dive 101)
Geological map.

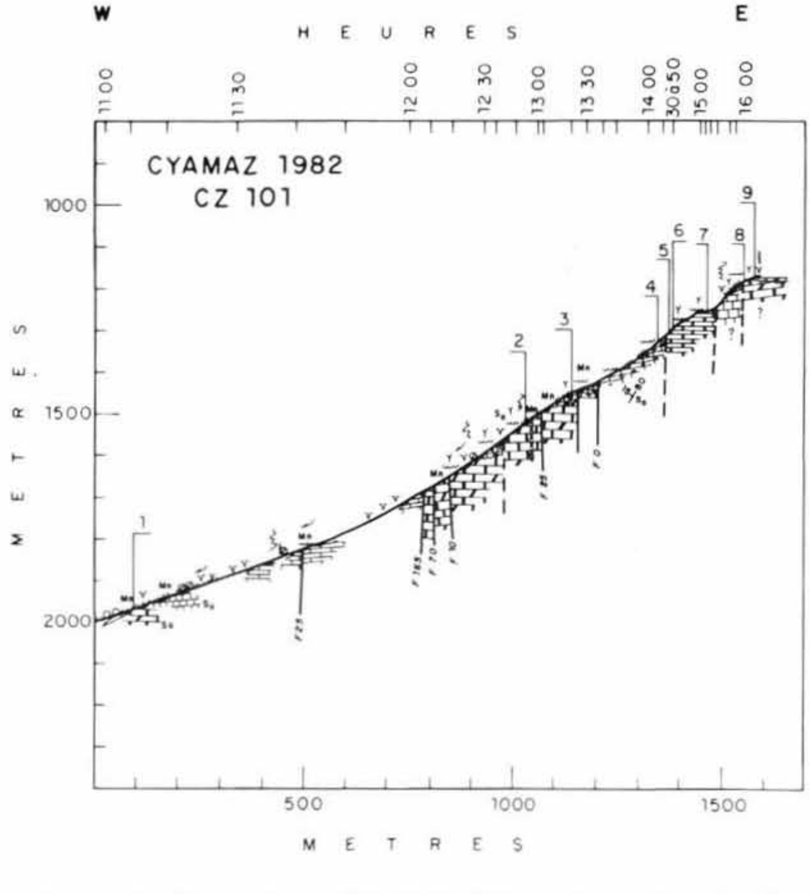


Figure 55 (Dive 101)
Geological profile.

A

C

B

D

Plate 17

A : cz 101-39 : 2 001 m. White massive limestones of the platform, surrounded and partially covered with bioturbated ooze.

B : cz 101-281 : 1 571 m. Barrel on recent sediments.

C : cz 101-439 : 1 285 m. Post platform horizontally bedded banks, eroded and coated. Sample cz 101-6 (1 308 m). Cretaceous (?).

D : cz 101-467 : 1 256 m. Bedded marly calcareous layers surrounded with chalk.

instance. Different age drapping series (from Aptian to Pliocene) were sampled along the Escarpment. The 6 000 pictures taken, although not yet completely evaluated, will give many important informations on the detail of the stratigraphy.

Concerning the structure, the eighteen dives allow us to suggest that the Mazagan Plateau and Escarpment are controlled by two main directions of faulting striking N 20° and N 90°. Three other secondary directions N 70°, N 120° and N 160° have also been recognized. In the South of the Escarpment, the N 160° directions are dominant although the N 70° are dominant in the northern part. With the dive data it is difficult to estimate the chronology of the movements of the faults; nevertheless, we have observed the importance of many small recent faults (few centimettres to metres) that suggest a very strong tertiary reactivation of the Escarpment.

The technical limitations of SP 3 000 Cyana prevented us from reaching older layers than Kimmeridgian. The use of the new submersible Nautile of the IFREMER will hopefully provide, in a next future, the opportunity of exploring, at the foot of the Escarpment, the underlying paleozoic granite and Triassic-Liassic early rift sediments.

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