Chapter 2
The Mauritanian Margin. Bathymetric and Geomorphological Characteristics

José Luis Sanz, Adolfo Maestro and Luis Miguel Agudo

Abstract From 2007 to 2010, four multidisciplinary cruises were carried out on Mauritanian upper and middle slope. Based on the multibeam echosounder swath bathymetry full coverage data, the TOPAS profiles and rock dredges were established for the first time detailed maps of bathymetry and geomorphology. The main morphological features are as follows: (1) >70 canyons and large gullies grouped into 10 different canyon systems, (2) 580 km long cold-water coral mounds ridge at 500 m depth, (3) several pockmark areas, and (4) an isolated seamount of $\sim$200 m high. Based on the distribution of the identified features in Mauritanian slope, three geomorphological provinces were determined as follows: (i) Arguin Province, characterized by the abundance of quite sinuous canyons and the headwalls of three large landslides; (ii) Nouakchott Province, characterized by a few rectilinear canyons and a slope that seems undisturbed in the north, but mostly affected by the headwalls of Mauritania Slide Complex in the south, and (iii) Senegal River Province, characterized by the abundance of canyons and gullies linked to the migration of the mouth of Senegal River.

Keywords Canyon systems · Large submarine landslides · Cold-water coral mounds · Continental margin · Mauritania · Northwest Africa

List of Acronyms

ACUF	Advisory Committee Undersea Features
AHP	African Humid Period
AMW	Arguin Mud Wedge
BdA	Banc d'Arguin
CCLME	Canary Current Large Marine Ecosystem
DTM	Digital Terrain Model

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GEBCO	General Bathymetric Chart of the Oceans
GdA	Gulf d'Arguin
GPS-D	Global Position System-differential
IOC	Intergovernmental Oceanographic Commission
IHO	International Hydrographic Organization
MBES	Multibeam echosounder
MSC	Mauritania Slide Complex
SCUFN	Subcommittee on Undersea Feature Names
TMW	Timiris Mud Wedge
TOC	Total organic matter
TOPAS	Topographic Parametric Sounder
UNE	Una Norma Española

Introduction

Mauritanian continental margin is characterized by prominent slides, slumps, and debris flows, as well as numerous incised canyons and channels that are active since the late Miocene/Pliocene.

The first explorations and studies on Mauritanian continental margin were carried out by Seibold (1972), Seibold and Hinz (1974, 1976), Uchupi et al. (1976), and Jacobi (1976). Jacobi and Hayes (1982, 1992) published the first bathymetric and geomorphological maps of Northwest African margin using the information obtained in previous studies and echosounder 3.5 kHz profiles. Domain (1977, 1980, 1985) published the first sedimentological and geomorphological maps of Mauritanian shelf, and Kidd et al. (1987) obtained images of the continental slope using a GLORIA side-scan sonar. Subsequently, several studies focused on submarine canyon systems and turbiditic processes (Wynn et al. 2000; Krastel et al. 2004, 2005, 2006; Antobreh and Krastel 2006a, b, 2007; Hanebuth and Henrich 2009), submarine landslide complexes (Antobreh et al. 2003; Schulz et al. 2003; Henrich et al. 2008; Förster et al. 2010, 2011; Krastel et al. 2012), sedimentary processes in the continental shelf (Hanebut and Lantzsch 2008; Michel et al. 2009; Michel 2010; Westphal et al. 2012; Klicpera et al. 2015), cold-water corals (Colman et al. 2005; Schulz et al. 2003; Westphal et al. 2007; Eisele et al. 2011, 2014; Freiwald et al. 2012), and fluid vents (Ireland et al. 2011).

The current morphological configuration of Mauritanian margin is the result of a complex interplay of geological processes with climatic changes from Miocene to African Humid Period (AHP). The latter comprises the last deglaciation, causing a rapid sea-level rise that has led to a large increase in the rate of sedimentation of the slope. Therefore, the remobilization of some faults and/or activity of volcanic processes in the adjacent areas of Cape Verde Promontory and off Senegal has led to landslides, the development of large submarine canyon systems; some of them

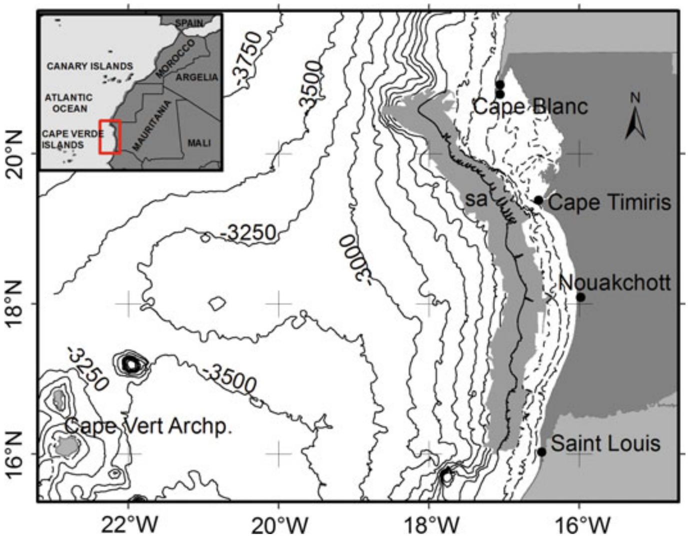

Fig. 2.1 Location of the study area during the *Maurit* surveys

reached the middle of Atlantic. The formation of submarine canyons and current turbidity activity have decreased, but not completely ceased at the present.

Between 2007 and 2010, Spanish Institute of Oceanography (IEO) carried out four *Maurit* surveys on-board R/V *Vizconde de Eza* to evaluate the fishery resources in the upper and middle Mauritanian margins, between Cape Blanc and Senegal border (Fig. 2.1). In addition to the fishing trawling stations, geological and oceanographic information were acquired.

In this chapter, the geophysical and geological results obtained during the *Maurit* surveys are reported. They allowed to conduct a continuous, complete, and precise cartography of the upper and middle Mauritanian continental slope between 110 and 1900 m depth. These maps show the main features of the studied sector, the detailed geometry of the recently discovered canyons and prominent gullies, many of which were unknown until now, the geomorphological characteristics of large landslides; and the shape and size of cold-water coral mounds.

Materials and Methods

During the four *Maurit* cruises, rock and sediment dredges, multibeam echosounder data (EM-300), and high-resolution seismic profiles (TOPAS PS-18) were obtained. The surface covered using the multibeam echosounder was about 31,300 km^2, and it obtained 44 high-resolution seismic profiles close to the coral mounds (Fig. 2.2), 26 rock dredgings on the coral mounds barrier, northern canyons, and seamount (Fig. 2.2), and 68 sediment samples (Fig. 2.3).

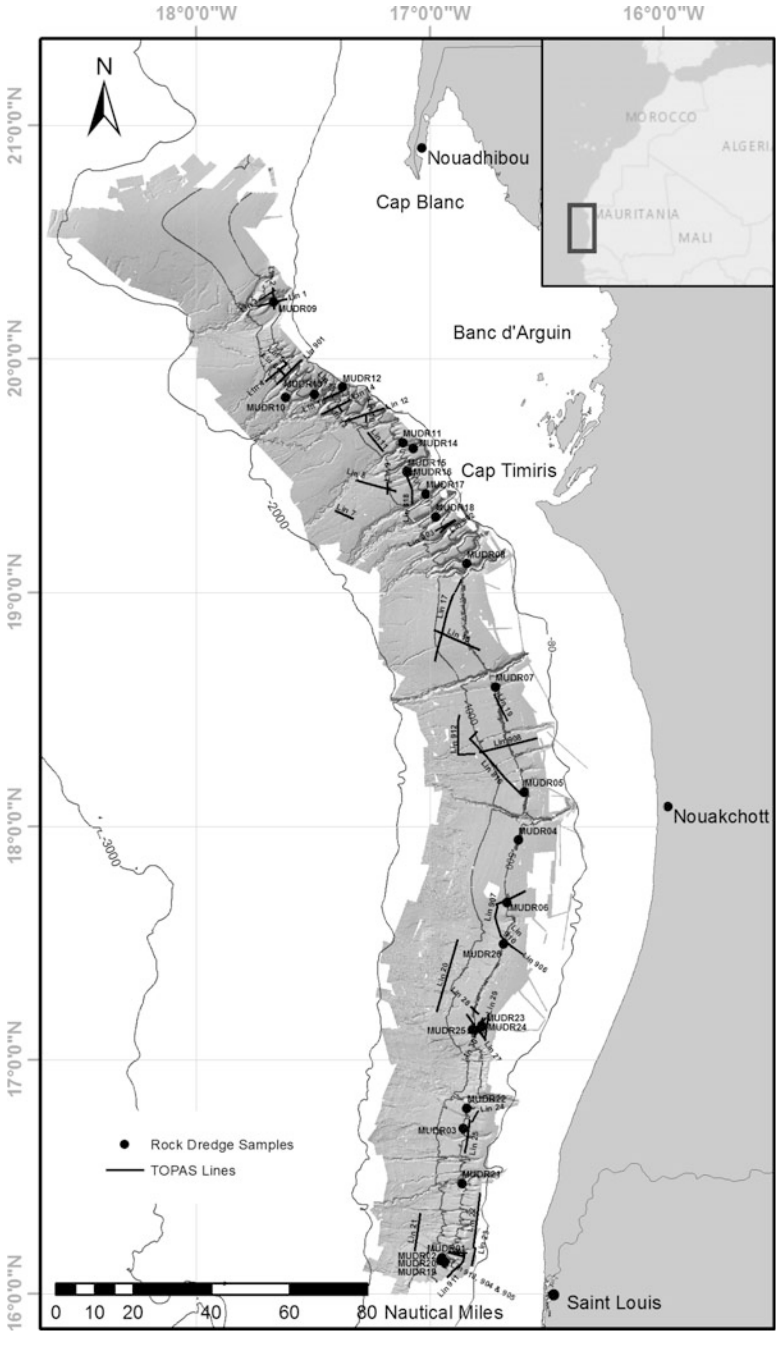

Fig. 2.2 Location of the rock dredgings and high-resolution TOPAS seismic profiles carried out on Mauritanian continental slope during the *Maurit* surveys

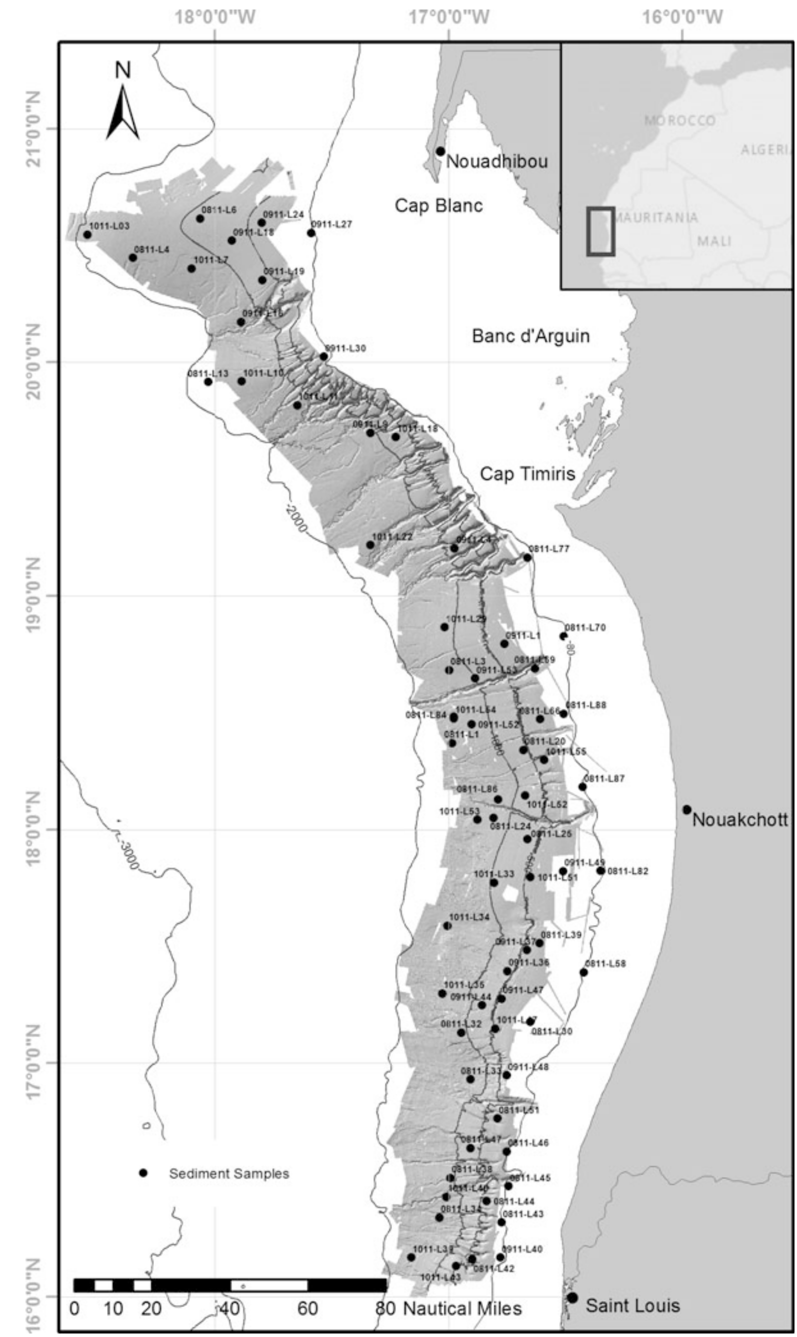

Fig. 2.3 Location of the 68 analyzed sediment samples collected during the four *Maurit* surveys on Mauritanian continental slope

Equipment

The position of the vessel was determined using a GPS-D and Seatex-Simrad Seapath System 200. EM 300 is a high-resolution and high-speed mid-range multibeam echosounder. It provides the bottom information about bathymetry and reflectivity between depths of 20 and 5000 m. Operating at a frequency of 30 kHz, it emits 135 beams per pulse with an angular distance of 1° in reception and transmission, enabling it to cover an angle of 150° and hence a 6.5 times deeper swath. TOPAS PS-18 generates an acoustic emission with a combined basic frequency of 18 kHz and another acoustic emission that varies from 2 to 5 kHz. It was designed to obtain high-resolution subsurface seismic profiles. The under-bottom penetration range depends on the lithology, compaction, grain size, and structure of materials as well as the geomorphology and existence of good mirror surfaces. The MBES and TOPAS data were corrected using the water sound velocity profiles obtained using an Applied Microsystems Plus SV system or CTD stations.

Finally, the sediment samples were obtained using a 40 cm length and 9 cm wide metallic cylinder dredge attached to the trawling gear head.

Methodology

Because of the multidisciplinary nature of the *Maurit* surveys, the trawlings were alternated with other research activities. Prior to the trawling operations, the working area was mapped using MBES and TOPAS. The MBES data were processed immediately using the Neptune software, and the results were downloaded onto GIS using ArcGIS. This immediate preprocessing helped in quality control during the cruises as well as identified possible gaps in the MBES.

Data Processing and Sample Analysis

The MBES data were post-processed in the laboratory using CARIS and Fledermaus softwares to obtain a Digital Terrain Model (DTM) with a resolution of 50 m (Fig. 2.4) and a bathymetric map. The bathymetric data were completed using the data obtained from Domain (1977, 1980) on the continental shelf; Hanebuth and Lantzsch (2008), Michel et al. (2009), and Aleman et al. (2014) on Banc d'Arguin (BdA) zone and GEBCO (2012) on the lower slope. Figure 2.5 shows a synthesis of the bathymetry map compilation of the upper and middle continental slope using 100 m equidistant isobaths.

In most of the dredgings, only coral rubble and/or dead coral were recovered with the exception of the northern area, where some rock samples were collected.

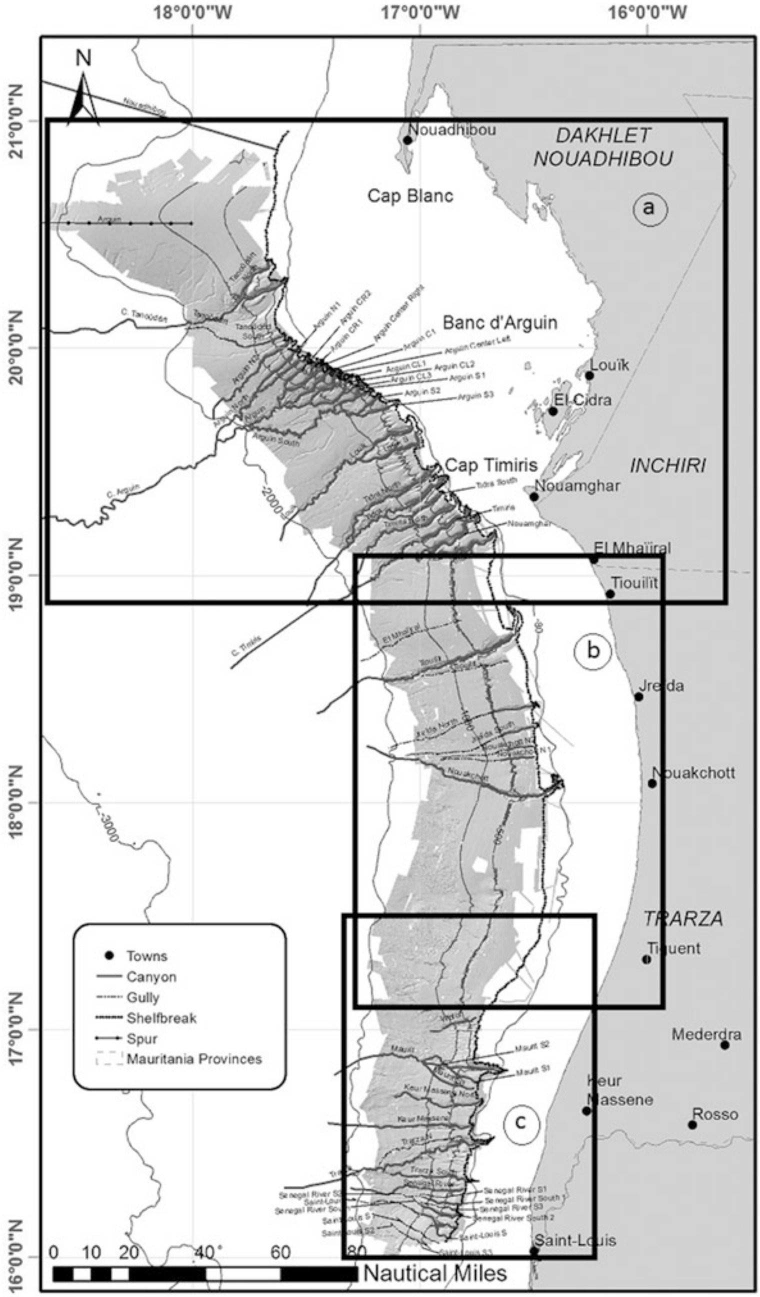

Fig. 2.4 Shaded relief bathymetric map of upper and middle Mauritanian slope and names proposed for canyons and gullies. **a** Limits of Figs. 2.10, 2.11, 2.12, **b** limits of Figs. 2.16, 2.17, and 2.19 and **c** limits of Figs. 2.21, 2.22, 2.23

On the seamount located at the southwest of Nouakchott, carbonate chimney samples were obtained.

The organic matter, carbonate contents, and granulometry of 68 sediment samples were analyzed. The organic matter analysis was performed by the weight loss of a dry sample (105 °C during 24 h) when exposed to high temperatures (550 °C). The difference between the initial and final weights corresponds to the content of total organic matter (TOC) expressed in percentage. The carbonate content was analyzed under UNE 103-200-93, performed by measuring the weight loss of a dry sample (during 48 h) digested with an acid to eliminate all the carbonate contents. The difference in weight before and after the treatment was compared, and the results are expressed in mg/g.

For the granulometric analysis, the gravimetric method was used to screen 100 g sample that was previously dried at 105 °C in a sieve column at the range from 4 mm to 63 μm. The series of graded sieves were 4, 2, 1, 0.5, 0.250, 0.125, and 0.63 mm, presenting the results in percentages. Given the low density of the samples, to build a more complete map of the nature of the seabed of continental shelf and slope, information from other complementary sources was used, such as the information from the rock dredgings, descriptions of the unanalyzed sediments samples from the trawls, and the information provided by previous works (Domain 1977, 1985; Hanebuth and Lantzsch 2008; Michel 2010; Klicpera et al. 2015; CCLME 2015).

To understand the information of all the available sources, a very broad granulometric classification for sediment was defined. This classification was useful from a geological and biological perspective. Consequently, the analyzed sediments were classified according to the Folk triangular diagram depending on the content of gravel, sand and mud. Given the shortage of gravel, the classification is mainly based on the sand/mud ratio.

The hard and rocky bottoms were classified according to the following classes: reef, rock, rocky banks, and sub-outcropping rocks. The distribution and geometry of the last two classes originate from the maps reported by Domain (1977, 1985).

Results

The full coverage of a 31,300 km^2 area of Mauritanian slope using MBES enabled to obtain a detailed bathymetric shaded relief (Fig. 2.4) and a detailed bathymetry of this zone (Fig. 2.6). From this information, a geomorphological map of the upper and middle Mauritanian continental slope between 100 and 1900 m depth was carried out. The main morphological features mapped were >70 canyons and ravines, a 600 km length cold-water coral mounds ridge parallel to the continental shelf, and several landslides including Mauritania Slide Complex (MSC) (Antobreh and Krastel 2006b, 2007). The canyon systems cover about 7950 km^2 (26.5% of the total area explored), the large complex of landslides affects about 9005 km^2 (28.7% of the surface explored) and the instability zones about 2300 km^2 (7.3% of

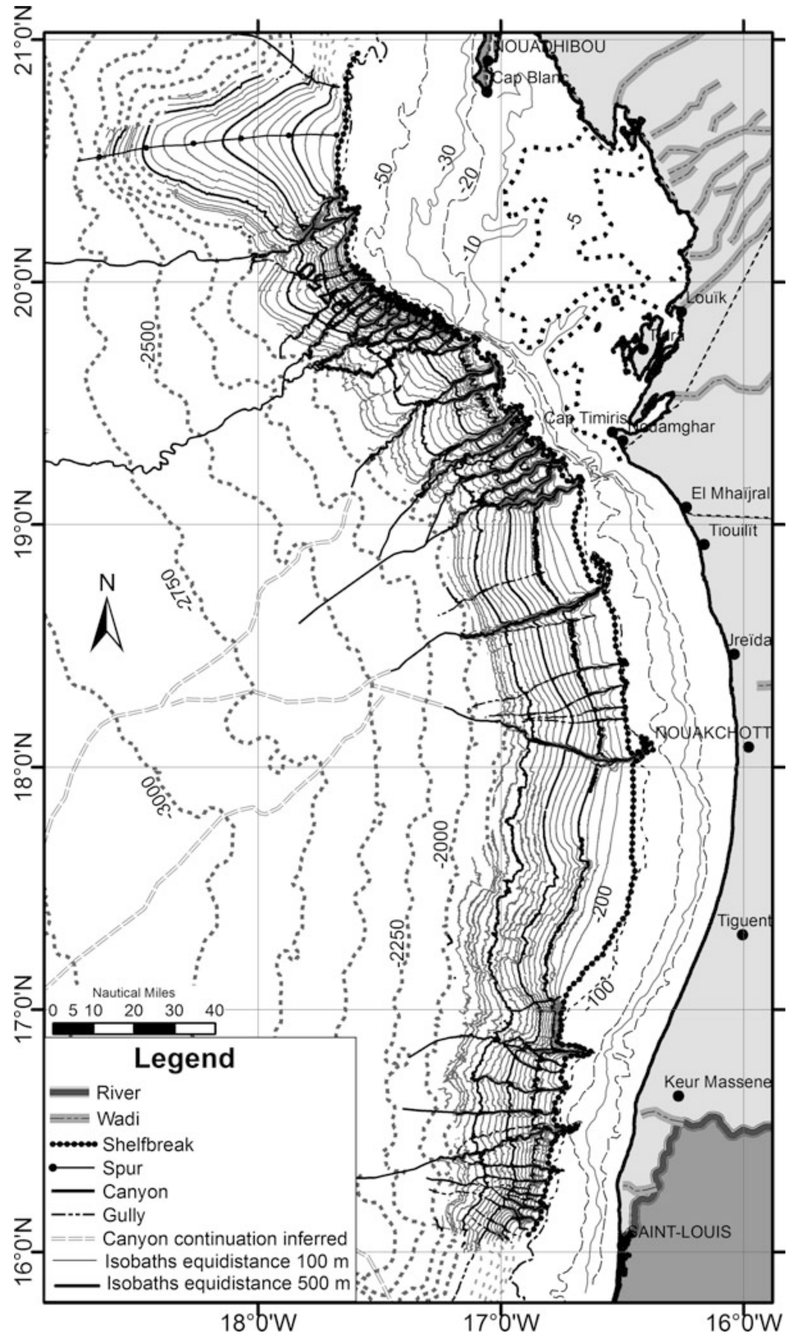

Fig. 2.5 Simplified bathymetric map of Mauritanian upper and middle slopes. Isobaths equidistance 100 m. Shelf isobaths adapted from Domain (1977, 1985), Aleman et al. (2010) and Klicpera et al. (2013). Lower slope isobaths adapted from GEBCO

the surface explored). Furthermore, the main canyons and gullies were named according to the internationally accepted standards of Sub-Committee on Undersea Feature Names (SCUFN) of GEBCO and Advisory Committee Undersea Features (ACUF 2012).

Regarding that, the lists of the names of the recognized international organizations such as GEBCO and ACUF were previously consulted. The names proposed for the canyons and main gullies by us correspond to those of the provinces, cities, and towns closest to the headwaters (Fig. 2.5). Because of the abundance of the features converging on a common axis, the branches that were not possible to associate with the closest city, town, etc. were named after their position with respect to the main canyon (Fig. 2.4). Notably, the canyon named by Krastel et al. (2004) as Timiris Canyon and subsequently referred in the following papers does not correspond to its true name. Indeed, since 1999 (IOC-IHO/GEBCO 1999), it appears under the name of Arguin Canyon as stated on the GEBCO catalog and according to the resolution of the 13th meeting of SCUFN and ACUF. Therefore, its official name will be used, reserving Timiris for the canyon that is close to Cape Timiris.

Bathymetry

In the bathymetric synthesis of the upper and middle continental slope (Fig. 2.5), it is possible to distinguish the geometry of canyons, sedimentary accumulation zones, and areas affected by landslides and scar slides. More detailed maps are presented in the corresponding sections of each geomorphological area.

The Mauritanian shelfbreak is usually located at 120 m depth even though it could be at 50 m depth, because some head canyon incisions affect the shelf between 3 and 15 km off the coast (Fig. 2.5). The width of the continental shelf varies from 60 km in the west of Cape Blanc to 110–120 km between Cape Blanc and Cape Timiris (even reaching 138 km at some places); it then narrows down to 27 km in front of Cape Timiris and gradually broaden to 50 km towards the south. From off Nouakchott to Senegal border, it again reduces to 35–40 km. The inner continental shelf shows a depth of about 5 m, but between Cape Blanc and Cape Timiris, Banc d'Arguin is located with depths of 2–10 m. Below 10 m, the depth of the shelf increases rapidly to reach 120 m in depth (edge of the shelf). The slope gradient of the continental shelf varies from 0.3° to 0.6°, but in some places between Cape Blanc and Cape Timiris increases to 6° (Antobreh and Krastel 2006a) and in front of Senegal River area decreases to 0.2°.

The Mauritanian continental slope seafloor is irregular with frequent and sudden changes in the slope gradient due to the presence of a long mounds ridge, many deep canyons and channels, and large areas affected by landslides (Figs. 2.5, 2.6 and 2.7). Arguin Spur is located in the southwest of Cape Blanc. This feature shows a relatively gentle gradient slope with 0.5°–1.5° between the shelfbreak to 1400 m depth, but deeper on changes from 2° to 5°. The variation in the slope gradient of

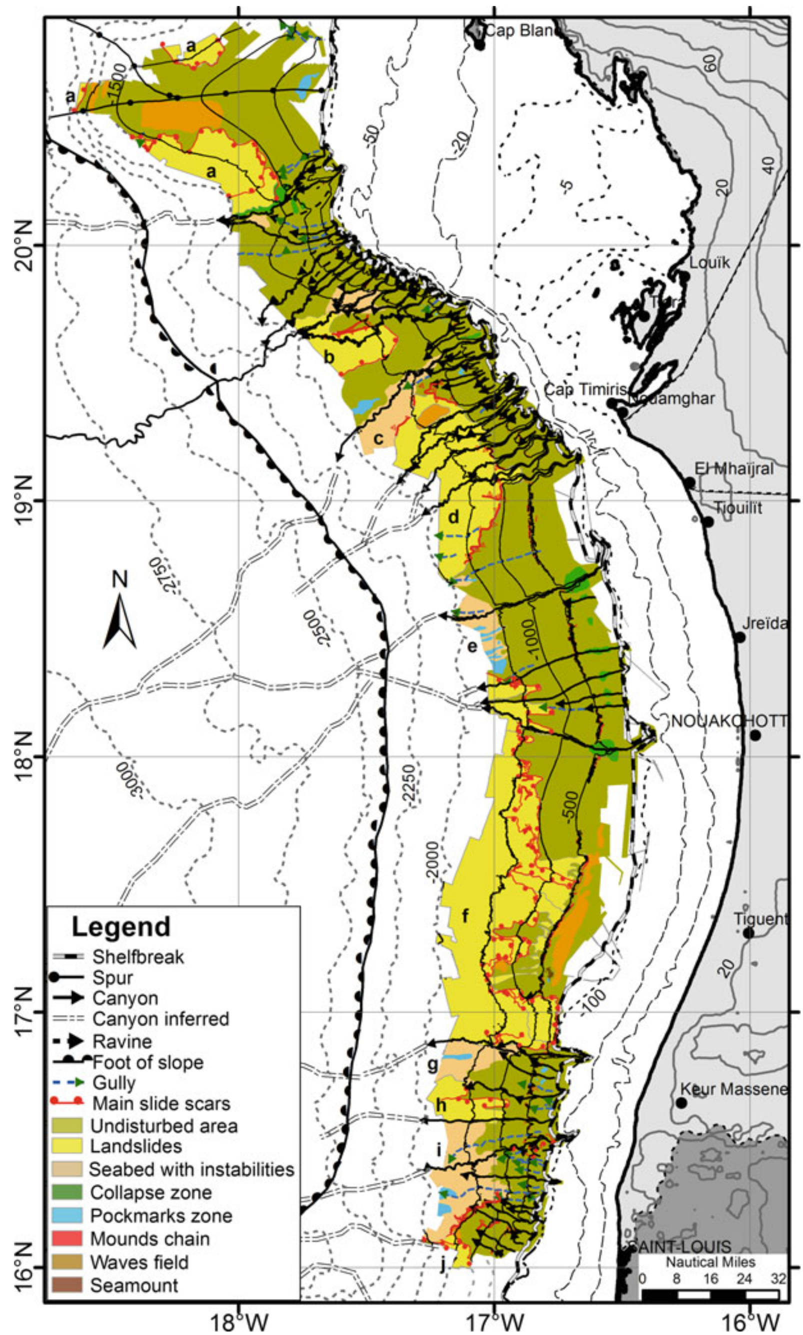

Fig. 2.6 Schematic geomorphological map of Mauritanian upper and middle slope

the continental slope between Arguin Spur and Senegal coast was divided into four sectors that extent subparallel along the slope (Fig. 2.7). The first sector extends between the shelfbreak, and 150–200 m depth shows a gradient of ~0.5°–1°. The second sector is located from 200 m to 450–500 m depth with a gradient of 1°–2°, except in the Arguin and Timiris Canyon area and canyons located in the front of Senegal River, where the gradient varies from 3° to 15°. The third sector extends from 500 to 1200 m in depth, and it shows a gradient from 2° to 3°. The fourth sector is located between 1000 and 1200 m depth until the deepest zones, and it shows a gradient of 1°–2°. This last sector mainly corresponds to landslide areas, as MSC, with slope gradient values reaching 7° (Fig. 2.6). The canyons, ravines, and furrows are deep with very steep walls. The gradients of canyon walls are between 7° and 25°, but sometimes increase to 30°–35°. The valleys and thalwegs are frequently sinuous when crossing the landslide areas, usually from 1000 m depth (Fig. 2.7). A ridge is present at ~500 depth, 580-km long parallel to the slope direction, 100 m high, and 1.7–3 km wide (from 20°14′ 38″N until parallel to Senegal border). This feature shows narrow summits (300–600 m wide) and very steep slopes with gradients of 23°–35° in the upper part that decrease downslope until 12° to 23°. The lower part of this ridge is surrounded by moats of 200–400 m wide and ~50 m deep with gradients of 3°–6° (Figs. 2.5 and 2.7). This structure is a cold-water coral mounds ridge, already partially identified in the upcoming areas (Seibold 1972; Seibold and Hinz 1976; Colman et al. 2005; Ramos et al. 2010). Finally, a small seamount or hill that rises from 350–400 m to 188 m depth with a gradient ranging from 12° to 25° was located in the southern part of the studied zone. The features of this structure are described in detail in a specific chapter (Chap. 15).

Nature of the Seabed

The slope mainly consists of greenish siliciclastic and biogenic sediments, but rocky outcrops are also localized in some areas close to shore and on the slope between 350 and 500 m depth at the top of some wall canyons. Along the slope, a coral mounds barrier is located at ~500 m depth, on average ~100 m high above the bottom. Inside the rock dredges carried out along the slope, mainly close to the barrier, rubbles of dead coral and shells gravel-sized or greater englobed in a matrix of silty sand, all partially lithified, were obtained. Moreover, in the samples MUDR09, MUDR11, and MUDR14 (see location in Fig. 2.2) collected at the edge of Tanoûdêr, Louik, and Louik South canyons, small pieces of calcarenite with altered surfaces and a rich attached fauna were recovered.

Because of the small number of samples analyzed for such a large area as well as its inhomogeneous distribution and possible seasonal variations, only a general scheme about the distribution of carbonates (Fig. 2.8a) and organic matter in the slope (Fig. 2.8b) was obtained. The results of the analysis of 68 sediment samples show that the carbonate content is higher between Cape Blanc and Cape Timiris

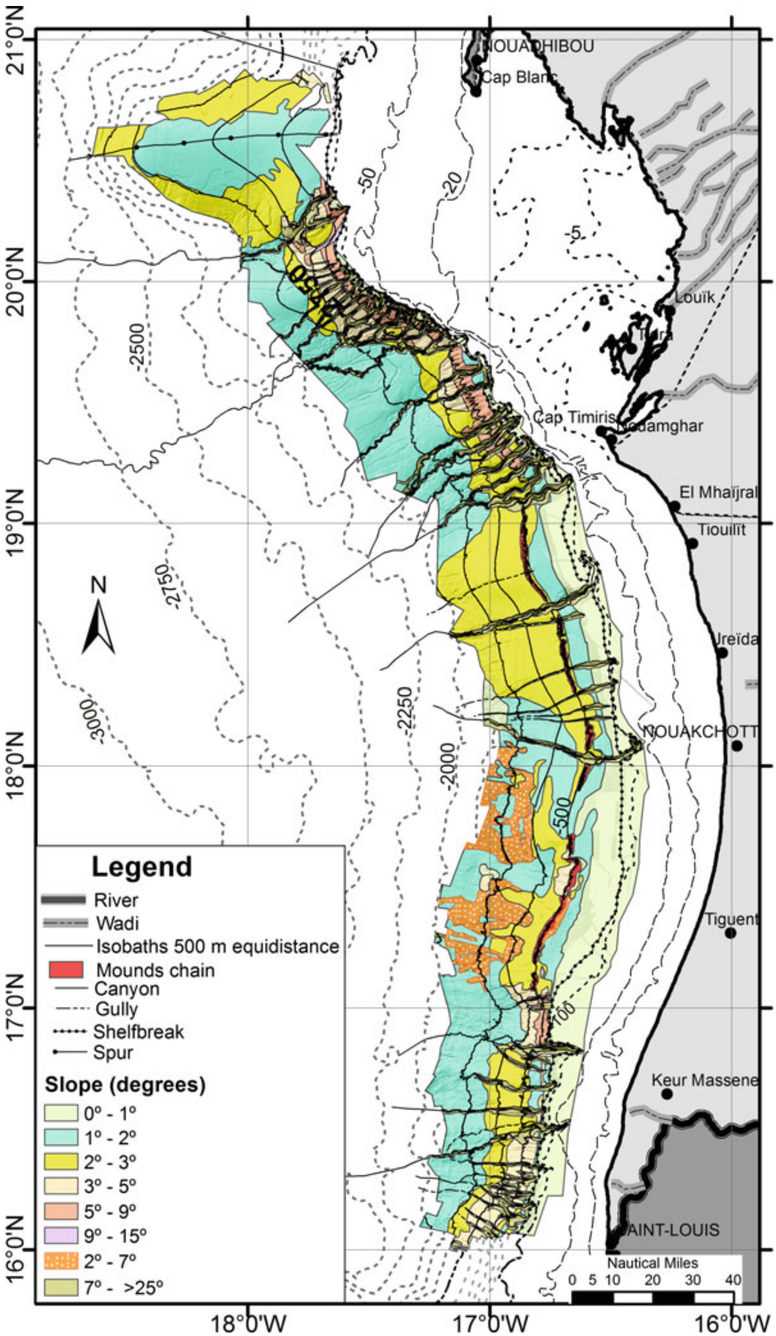

Fig. 2.7 Gradient map of Mauritanian upper and middle slope

(Fig. 2.8a), varying between 25 and 51% of the sample weight and reaching up to 66% in Arguin Spur between 100 and 150 m depth. A notable exception was observed near 16°58′N between Wolof's and Maurit Canyons, near the shelf edge, where the carbonate content reaches 75% close to a small area with similar values described by Domain (1985). The carbonate content in the south of Cape Timiris hardly decreased, ranging between 10–25% and with mean values of ~16%. It even reached lower values, between 6 and 10%, or less in some small areas in front of Senegal River zone (between Keur Massene North and Keur Massene Canyons) or close to Senegal River and Saint Louis Canyon. On the other hand, the content of organic matter expressed as TOC shows a general distribution pattern in two zones parallel to the slope direction: (i) an upper band comprised approximately between 100 and 500 m depth with a content of 3–5% of organic matter and ii) a lower band from 1000 m depth with a percentage of organic matter of 10–15%. However, between Tanoûdêrt Canyon and Arguin Complex Canyon, from 1500 m depth onwards, the organic matter content reaches 15–20% (Fig. 2.8b). Similarly, it should be noted that six areas with organic matter contents varying between 5 and

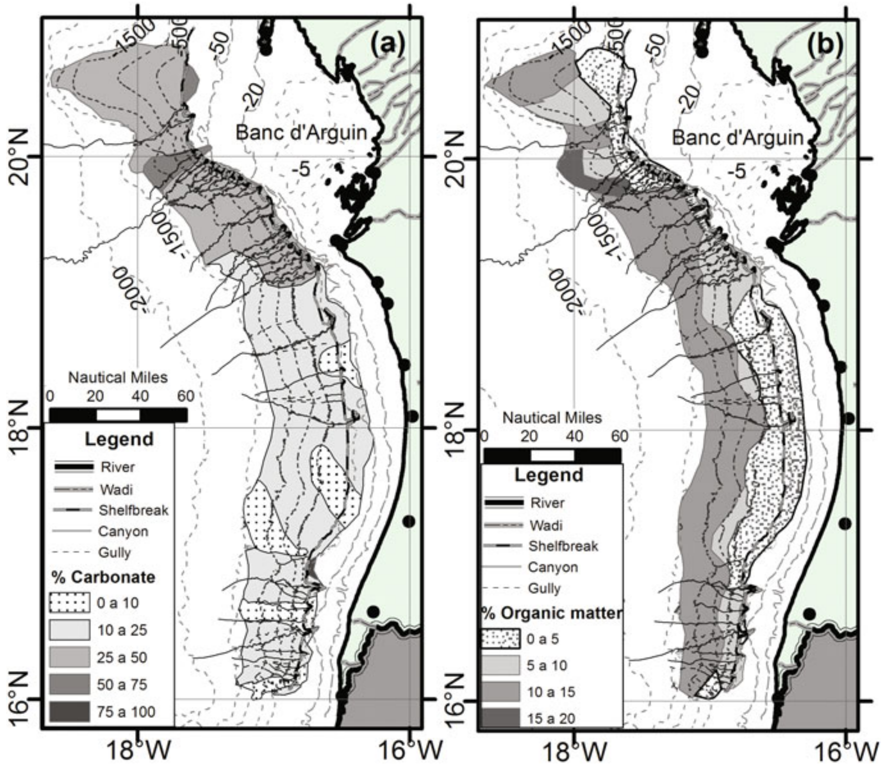

Fig. 2.8 Mauritanian upper and middle slope. Distribution of carbonates **(a)** and distribution of organic matter **(b)**

10% are situated at a range of 100–1400 m depth with an irregular distribution along the slope. These zones are located on the southern slope of Arguin Spur from 500 to 1200 m depth, in the middle zone of Arguin complex canyons between 1000 and 1500 m depth, in Timiris complex canyons and until Mhaïjral Canyon from 100 to 1300 m depth. They are also located between Jreida North and South Canyons from 450 to 700 m depth, from 17°29′N to 17°02′N between 550 and 1200 m depth and a wide area stretching from Maurit Canyon to the actual mouth of Senegal River, from 100 to 1000 m in depth (Fig. 2.8b).

The granulometric analysis of sediment samples showed that these almost exclusively consist of sand and mud in variable proportions and rarely contain gravel. The samples with gravel percentage are very low (<2%), and only in two samples, located in the front of Banc d´Arguin and the mouth of Senegal River, the gravel percentage reached 9%. However, some trawls and rock dredges carried out on the narrow moats surrounding the mounds barrier usually showed 80–95% of coral debris, consisting of coral sands, gravels, and fossil-lithified coral blocks. These deposits cannot be represented at the scale of the synthesis map because of the small size (Fig. 2.9).

The textural composition of the shelf and slope is sand until 500 m depth. Below this depth, the sea bottom mainly consists of sandy mud and muddy sand, but between 18°35′N and 16°35′N, the mud is predominant (Fig. 2.9). Nevertheless, on the shelf off Banc d'Arguin, between 20 m and 80 m depth, close to the heads of the Arguin and Timiris Canyons, two muddy deposits are present (Domain 1977); Hanebuth and Lantzsch (2008) named them as the Arguin Mud Wedge (AMW) and Timiris Mud Wedge (TMW). Similarly, in the Banc d´Arguin, another small depocenter of mud and sandy mud was located, and in the same manner, in the south part of the shelf, the front of the coastal area affected by the activity of Senegal River, a mud belt originated by sediment contribution of river was observed (Domain 1977; Seibold and Fütterer 1982). Moreover, several zones with rocky bottoms were observed (Domain 1977, 1985; Maurin and Bonnet 1969); they are referred on the map as rocky banks and sub-outcropping rocks (Fig. 2.9), located south of the Cape Blanc and Cape Timiris along the continental shelf in front of the present-day sebkhas (Fig. 2.9).

According to Milliman (1977), the AMW and TMW are caused by dust and sand carried by desert storm and the upwelling processes in the north of Cape Blanc, but Hanebuth and Lantzsch (2008) considered that the development of the mud wedges is caused by aeolian activity and its interaction with an abrupt orography.

Geomorphology

The high resolution of bathymetric swaths obtained during *Maurit* surveys allowed to create the first geomorphological map of the upper and middle slope of Mauritanian margin; some of them were partially or even totally unknown (Fig. 2.6).

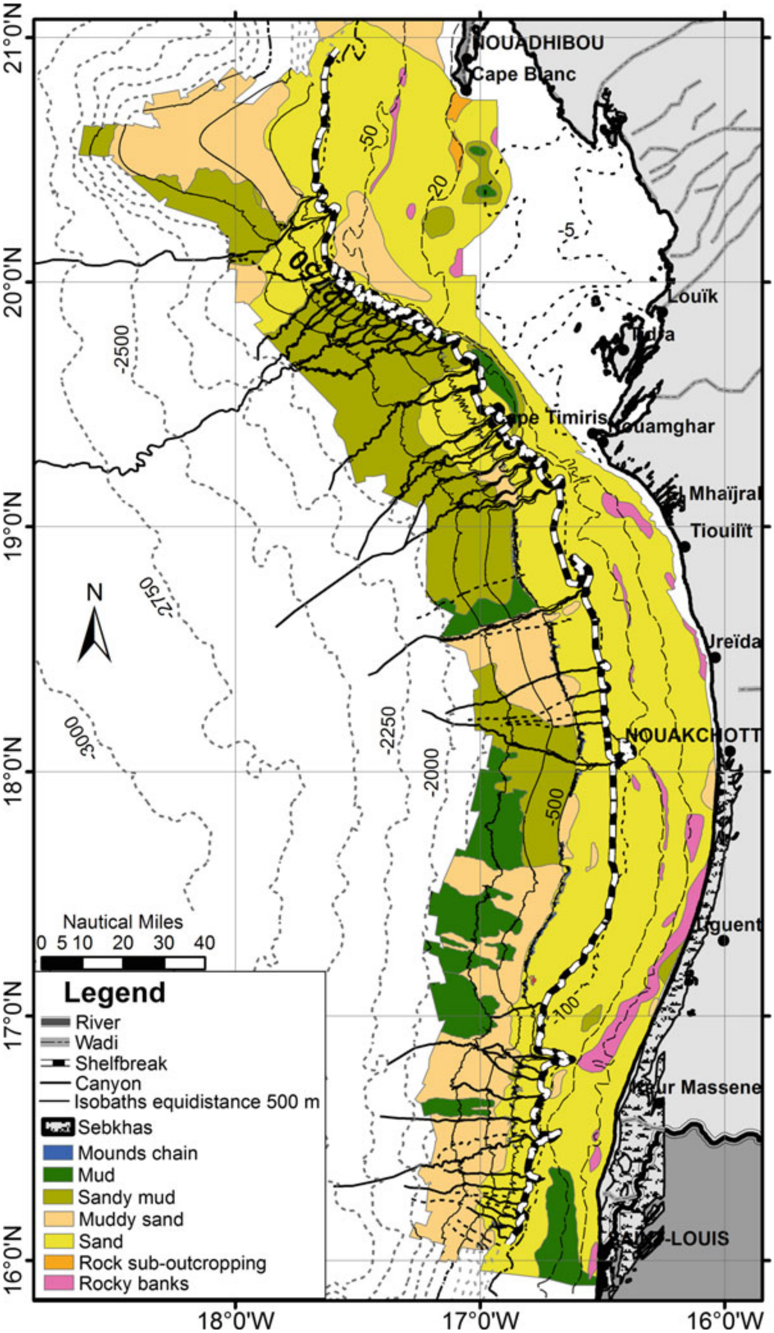

Fig. 2.9 Granulometric distribution of sediments in Mauritanian shelf and continental slope. Shelf information from Domain (1977, 1985) and Klicpera et al. (2015)

The geomorphological map shows the complexity of Mauritanian slope, largely affected by slides and instabilities and cut by a large number of canyons grouped in several large complexes. They incise very deeply both the shelf and slope. Moreover, the mounds barrier existing along the slope, several areas with pock-marks, some large wave fields, and a small seamount have been mapped with a great precision (Fig. 2.6).

Erosional Features

It mapped about 60 submarine canyons, 16 prominent ravines and gullies, as well as other less remarkable channels in detail; most of them formed a part of nine large canyon systems. Some of these canyon systems were subdivided into several small networks; these from the north to the south were named as Tanoûdêrt, Arguin, Louik, Timiris, Tioulit, Nouakchott, Wolof's, Maurit, Keur Massene, and Trarza canyon systems (Figs. 2.4, 2.5, 2.6 and Annexe 2.1).

The canyons are located in the north of the studied area between Cape Blanc and Cape Timiris along the ESE-WNW to ENE-WSW direction, and in the south between the parallel 18°50′N and Senegalese border, where the predominant direction of the canyons are from E-W to ENE-WSW.

In general, the head canyons deeply cut the shelf along a few kilometers. The canyons show a width of 1–3 km, but in some areas, the canyons have widths of 5–7 km. The channel depths range from 100 to 250 m, but sometimes increases to 500–700 m. The wall gradients are ~4°–17° and sometimes show steep slopes of 35° and 55°. Usually the canyons show sinuous thalwegs, mainly from 1000 m depth. The canyons with the largest dimensions, depths, and gradients are located in the northern slope of Mauritania.

Tanoûdêrt Canyon System This system consists of three canyons, four ravines, and six remarkable gullies (Figs. 2.10, 2.11, 2.13 and Annexe 2.1). According to the geometry and direction of channels, a northern zone could be differentiated, where the channels have a NE-SW direction and an arcuate trajectory towards the southeast, as well as a southern zone, where the channels are located along the ENE-WSW direction and an arcuate path towards the south (Figs. 2.11 and 2.12). The main axis of the system is Tanoûdêrt Canyon, receiving Tanoûdêrt North Canyon from the north at 950 m depth and Tanoûdêrt South Canyon from the south at 2100 m depth, further west of the studied zone (Figs. 2.11 and 2.13). Tanoûdêrt Canyon shows a sinuous thalweg of about 900 m depth and terraces from 1600 to 3000 m depth at least. Similarly, the thalweg of Tanoûdêrt South Canyon is sinuous from 1200 m depth.

Arguin Canyon System This system (Figs. 2.10 and 2.11) consists of 18 canyons, four ravines, and two gullies. They have been grouped into three main canyon networks, which converge at over 2000 to 2200 m depth in Arguin Canyon. This canyon continues from Mauritanian margin in the north of Cape Verde promontory until Central Atlantic (Fig. 2.4), reaching a length of ~450 km (Krastel et al. 2006)

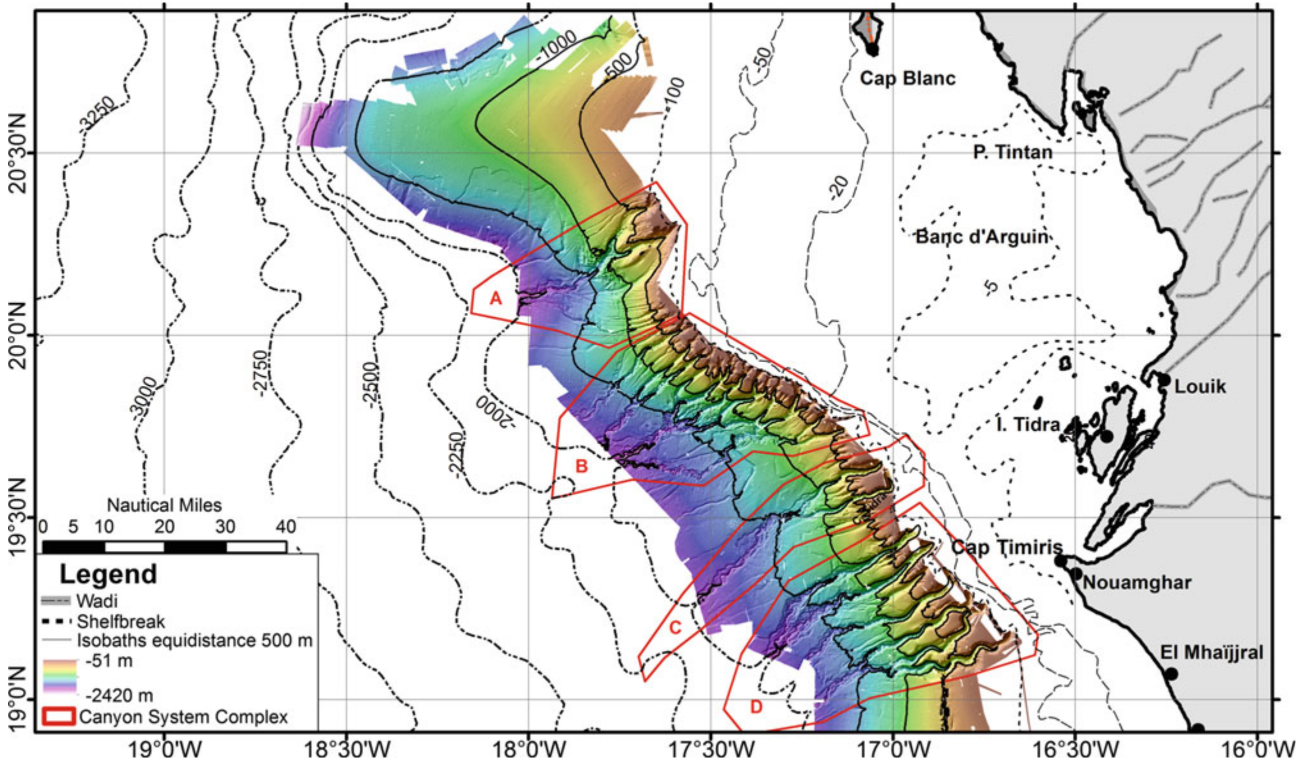

Fig. 2.10 Shaded relief bathymetric map of Mauritanian upper and middle slope between Cape Blanc and Cape Timiris. **a** Tanoûdêrt Canyon System, **b** Arguin Canyon System, **c** Louik Canyon System and **d** Timiris Canyon System

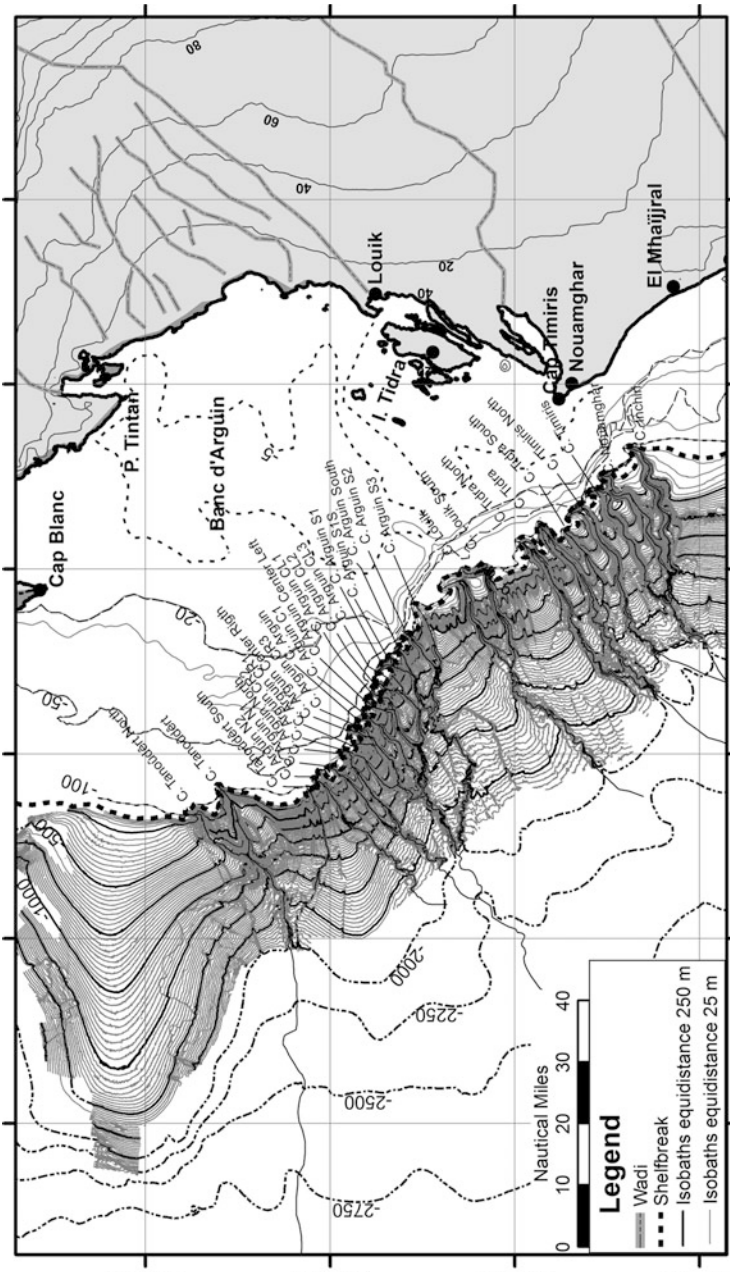

Fig. 2.11 Detailed bathymetric map of Mauritanian upper and middle slope between Cape Blanc and Cape Timiris. Isobath equidistance 25 m

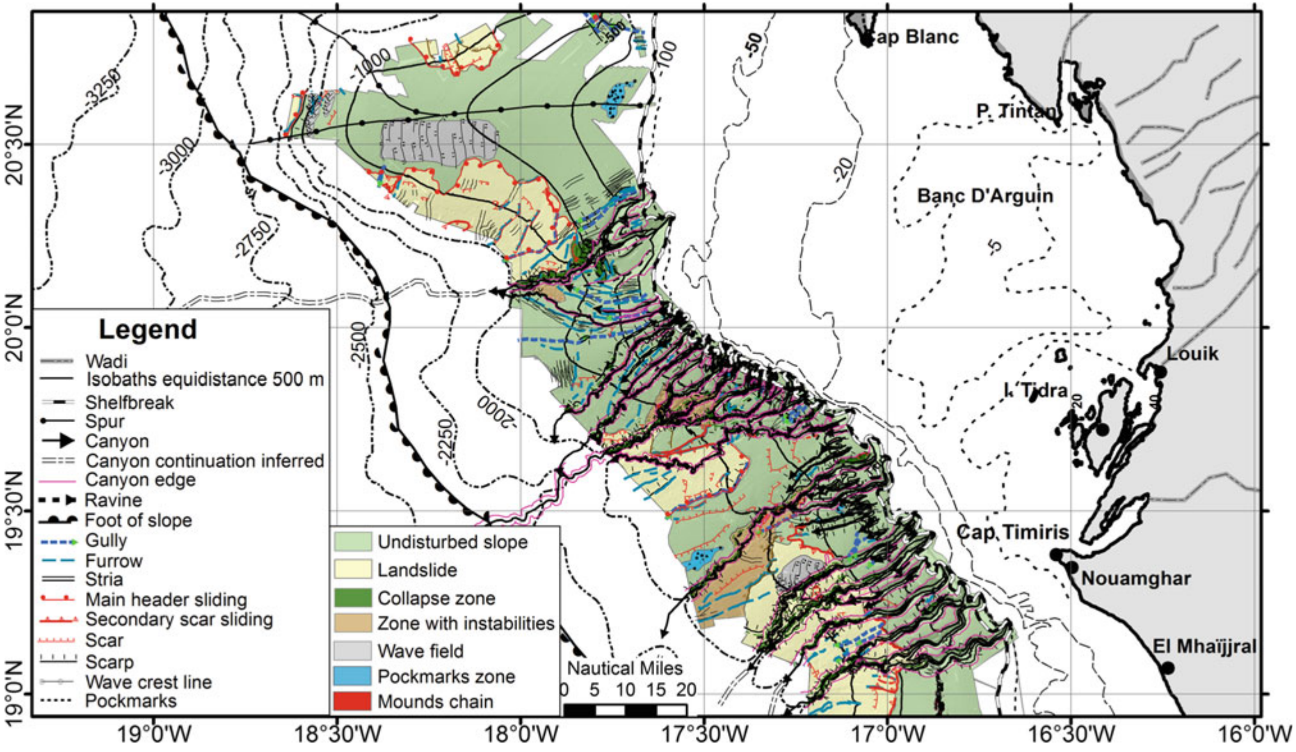

Fig. 2.12 Geomorphological map of Mauritanian upper and middle slope between Cape Blanca and Cape Timiris

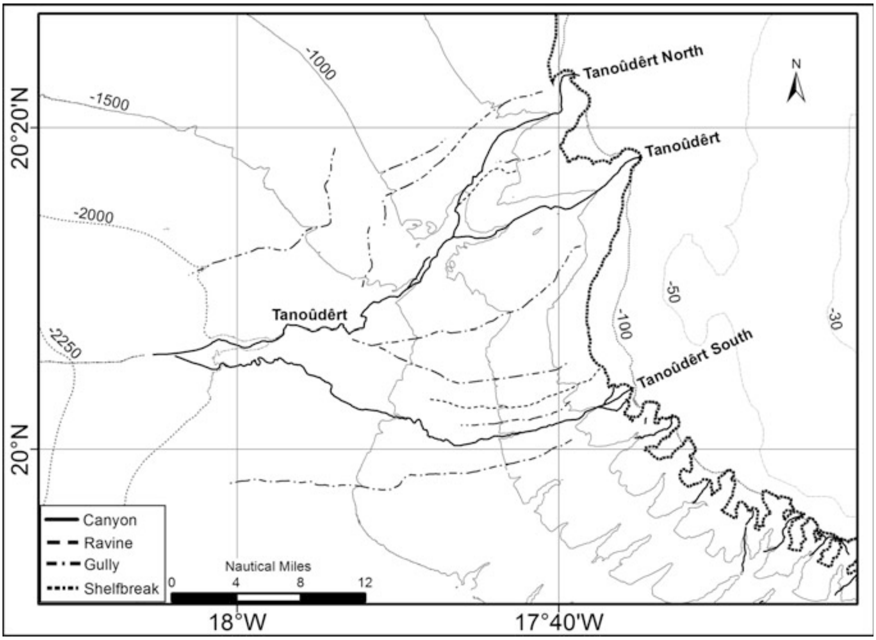

Fig. 2.13 Schematic representation of Tanoûdêrt Canyon System

(Figs. 2.10, 2.12, and 2.14). The main canyon network from the north to the south are as follows (see Annexe 2.1):

(a) *North Network*: It consists of three canyons along the NE-SW direction. The main axis is the Arguin North Canyon, receiving Arguin North 2 Canyon at 1200 m depth and Arguin North 1 Canyon at 2000 m depth, as well as a small ravine (Figs. 2.11, 2.12, and 2.14).
(b) *Central Network*: It consists of 10 canyons that are subdivided into two smaller networks (Figs. 2.10, 2.11 and Annexe 2.1). The main axis is Arguin Canyon, receiving Arguin Center Right Canyon from the north at 1650 m depth and Arguin Center Left Canyon from the south at 1650 m depth (Fig. 2.14). Arguin Center Right Canyon receives Arguin Center Right 1 Canyon from the north at 550 m depth and Arguin Center Right 2 Canyon at ~1300 m depth, whereas in the south side, receives Arguin Center Right 3 Canyon at ~300 m depth (Figs. 2.11, 2.12, and 2.14). Arguin Center Left Canyon receives Arguin Center Left 1 Canyon at 580 m depth and Arguin Left 2 Canyon at ~1575 m depth from the south, previously receiving Arguin Center Left 3 Canyon from the south at 675 m depth (Figs. 2.11, 2.12, and 2.14).

These canyons are separated by small ridges of 20–100 m high and 150–900 m width, constituting small and isolated platforms on the shelf of 4.5–12 km^2 and a

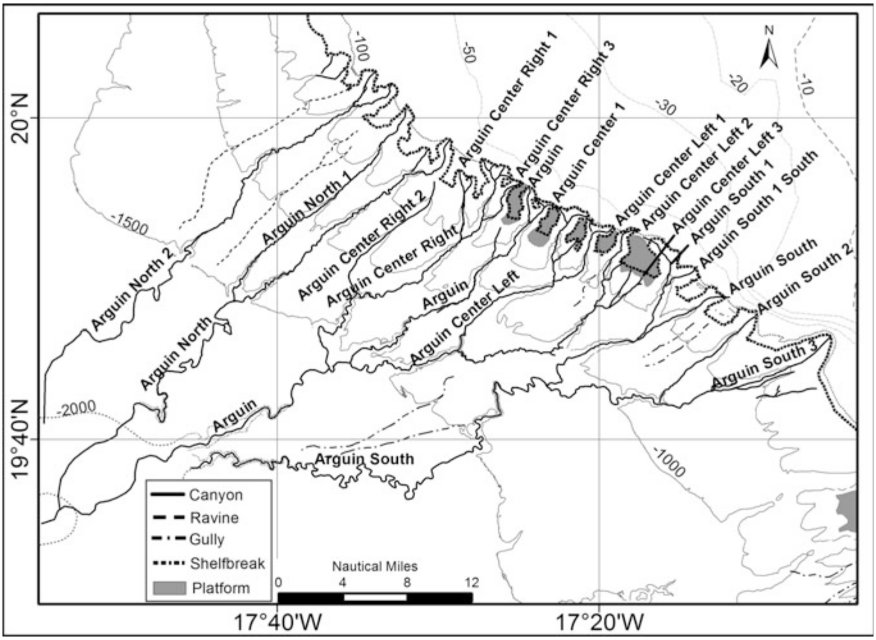

Fig. 2.14 Schematic representation of Arguin Canyon System

succession of valleys aligned in the NE-SW direction. This is observed between Arguin Center Right 3 and Arguin Canyons, Arguin Center 1 and Arguin Center Left Canyons, Arguin Center Left and Arguin Center Left 2 canyons, and Arguin Center Left 2 and Arguin South 1 Canyons (Fig. 2.14). Arguin Center Left 2 and Arguin South Canyons at 1140 m depth are separated by a ridge of 80 m height and 100 m width (Figs. 2.10 and 2.12).

Arguin Canyon at 1600 m depth in the confluence zone with other canyons reaches up 8 km wide, 350 m depth, has terraces and a sinuous thalweg, similar to Arguin Centre Left 2 Canyon (Figs. 2.11, 2.12 and 2.14).

(c) *South Network*: It consists of five canyons (Figs. 2.10, 2.11 and Annexe 2.1). Arguin South Canyon is the main canyon, receiving Arguin South 1 Canyon from the north and Arguin South 3 Canyon from the south (Fig. 2.14). On the other hand, Arguin South 1 Canyon receiving Arguin South 1 South Canyon from the south, and Arguin South 3 Canyon receiving Arguin South 2 Canyon from the north (Fig. 2.14).

These canyons have a general direction, NE-SW, and double-header, except Arguin South Canyon, which has E-W direction and only shows one header. The channel of Arguin South Canyon shows abrupt changes in the direction at about 1200 m depth, where it is displaced 19 km towards the southwest (Figs. 2.4 and 2.12). Arguin South Canyon ends above 2300 m depth in Arguin Canyon.

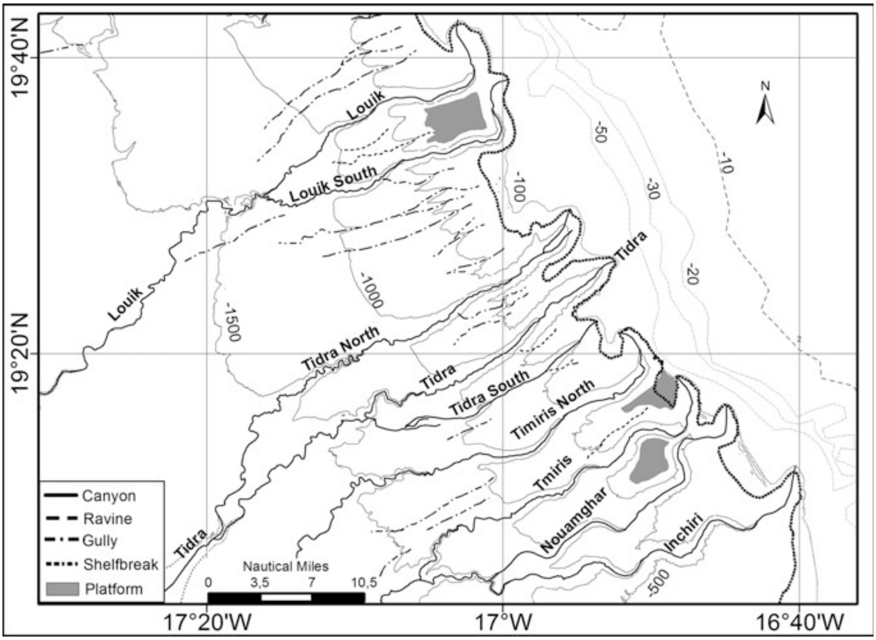

Fig. 2.15 Schematic representation of Louik and Timiris Canyon System

The thalweg and valley of Arguin South and Arguin South 3 Canyons are very sinuous and show terraces from 1000 m and 850 m depth, respectively (Figs. 2.12 and 2.15).

Louik Canyon System This system consists of two canyons along the ENE-WSW direction, Louik and Louik South Canyons. Louik South Canyon converges with Louik Canyon at 1400 m depth (Figs. 2.10, 2.11, 2.15 and Annexe 2.1). Moreover, two gullies are present on the north of Louik Canyon and, three gullies between Louik and Louik South Canyons, and four to the south of Louik South Canyon (Figs. 2.12 and 2.15).

The canyon headers cut the shelf in the NNW-SSE direction along several kilometers. Their valleys are aligned, and they are separated by a small ridge of ~50 m high and 300 m wide. A marginal platform is present between the canyons, isolated from the continental shelf. The marginal platform is located in ~200–500 m depth, with a surface of ~24 km^2 (Fig. 2.15).

Louik Canyon is sinuous from 1400 m depth and shows terraces with strong semicircular crown-back escarps. The valley seems to have been displaced by 4.5 km towards the northwest at 1500 m depth (Figs. 2.11 and 2.12).

Timiris Canyon System This system consists of seven canyons grouped into three networks (Figs. 2.10, 2.15 and Annexe 2.1) besides several gullies and ravines (Figs. 2.11 and 2.12). The main canyon is Timiris Canyon, which receives all the remaining canyons outside the studied area (Fig. 2.4), and it continues to the south of Cape Verde Promontory until Central Atlantic (Fig. 2.1). This system has been grouped in three main canyon networks from the north to the south (see Annexe 2.1):

(a) *The North Network*: It consists of three canyons of NE-SW direction. The main axis is the Tidra Canyon (Figs. 2.10, 2.11, 2.12 and Annexe 2.1), which receives the Tidra North Canyon from the north and the Tidra South Canyon from the south (Fig. 2.15). The Tidra North Canyon Head, consisting of three upstream beginnings, converges with the Tidra Canyon about 1500 m depth and forms a valley with 11 km width.
(b) *The Central Network*: It only consists of the Timiris North Canyon with a NE-SW direction, but whose header cuts deeply the continental shelf along 6.5 km in the NNW-SSE direction (Figs. 2.12, 2.15 and Annexe 2.1).
(c) *South Network*: This network is composed of three canyons along the NE-SW direction. The main axis is Timiris Canyon, which receives Inchiri Canyon from the south. In the same manner, Nouamghar Canyon receives Inchiri Canyon from the north (Figs. 2.12, 2.15 and Annexe 2.1). These canyons deeply cut the shelf along several kilometers.

Timiris and Timiris North Canyon headers are close, and their valleys are aligned in the NW-SE direction. A platform of 16 km^2 and less than 200 m depth is developed between them, partially isolated from the continental shelf (Figs. 2.10 and 2.15). On the other hand, Nouamghar and Timiris Canyons are quite close at 400 m depth, where their valleys are separated by a crest of 180 m height and 850 m width (Figs. 2.10 and 2.12).

Inchiri Canyon lies in the ENE-WSW direction, transverse to the rest of the network canyons, and it has a stepped shape in plain view with displacements of 3.5 km towards the northwest. This zigzagging morphology of the channel in plain view is also observed in Nouamghar Canyon (Fig. 2.12).

Tioulit Canyon System The system is formed by Tioulit Canyon and El-Mhaïjral and Tioulit Gullies, which converge in the canyon from the north and south, respectively, outside the area explored, (Figs. 2.16, 2.17 2.18 and Annexe 2.1). Tioulit Canyon was named by Seibold and Hinz (1976) and Wissmann (1982). The channels lie in the ENE-WSW direction, and this system continues in the south of Cape Verde Archipelago (Fig. 2.4). Tioulit Canyon header cuts the shelf along 17.8 km in the NNW-SSE direction and shows terraces and semicircular scarps from 170 to 400 m depth on the walls (Fig. 2.19). Tioulit Gully shows a small widening with crown cracking scarps from 350 to 450 m depth.

Nouakchott Canyon System The system consists of five canyons and three small gullies (Figs. 2.4, 2.16 and Annexe 2.1). The axis is the Nouakchott Canyon, receiving Jreida North, Jreida South, Nouakchott North 2, Nouakchott North 1, and Nouakchott Canyons in the north (Figs. 2.17 and 2.18). The channels of this system are straight, deep, and narrow, and they converge at 2000 m depth. The channels show a depth between 250 and 500 m, a widening of 2–10 km, with terraces and

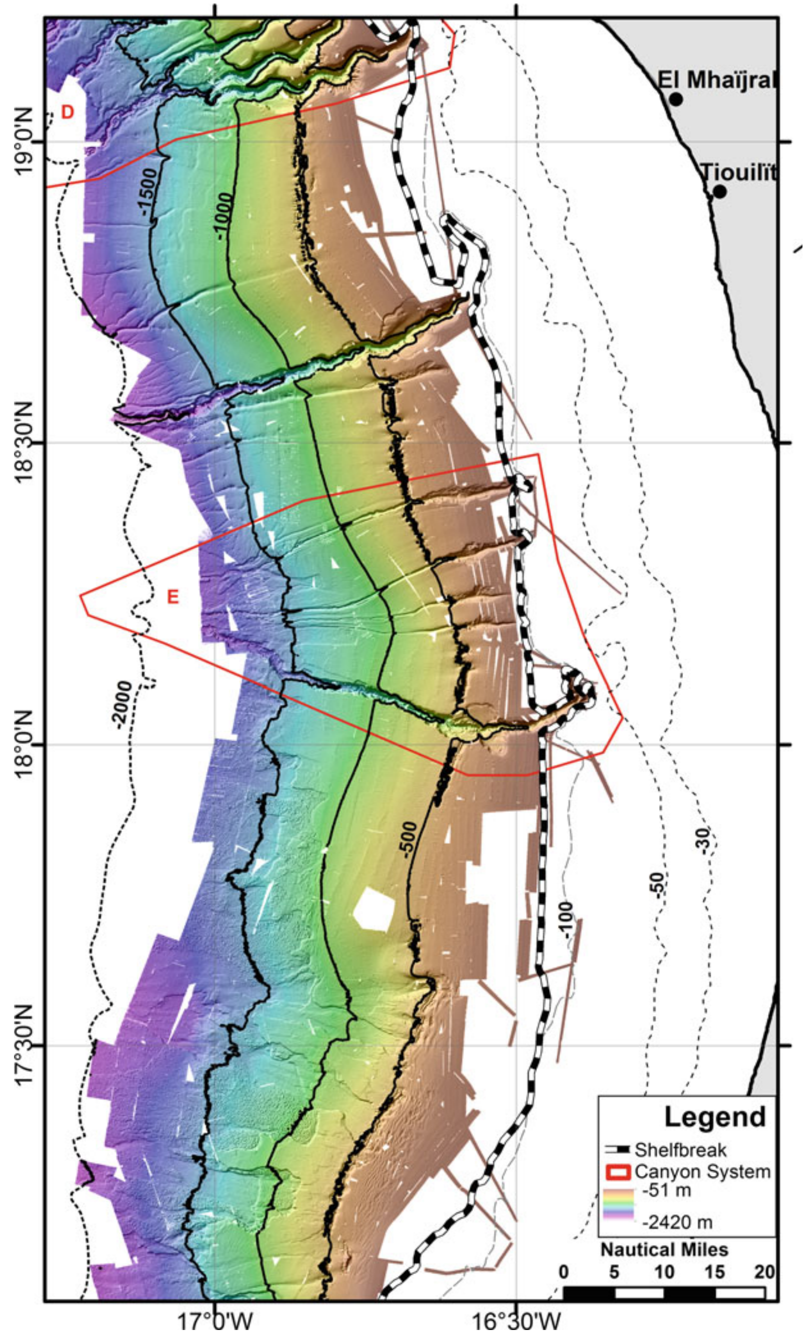

Fig. 2.16 Shaded relief bathymetric map of Mauritanian upper and middle slope between Cape Timiris and 17°06′N latitude. *E* Nouakchott Canyon System

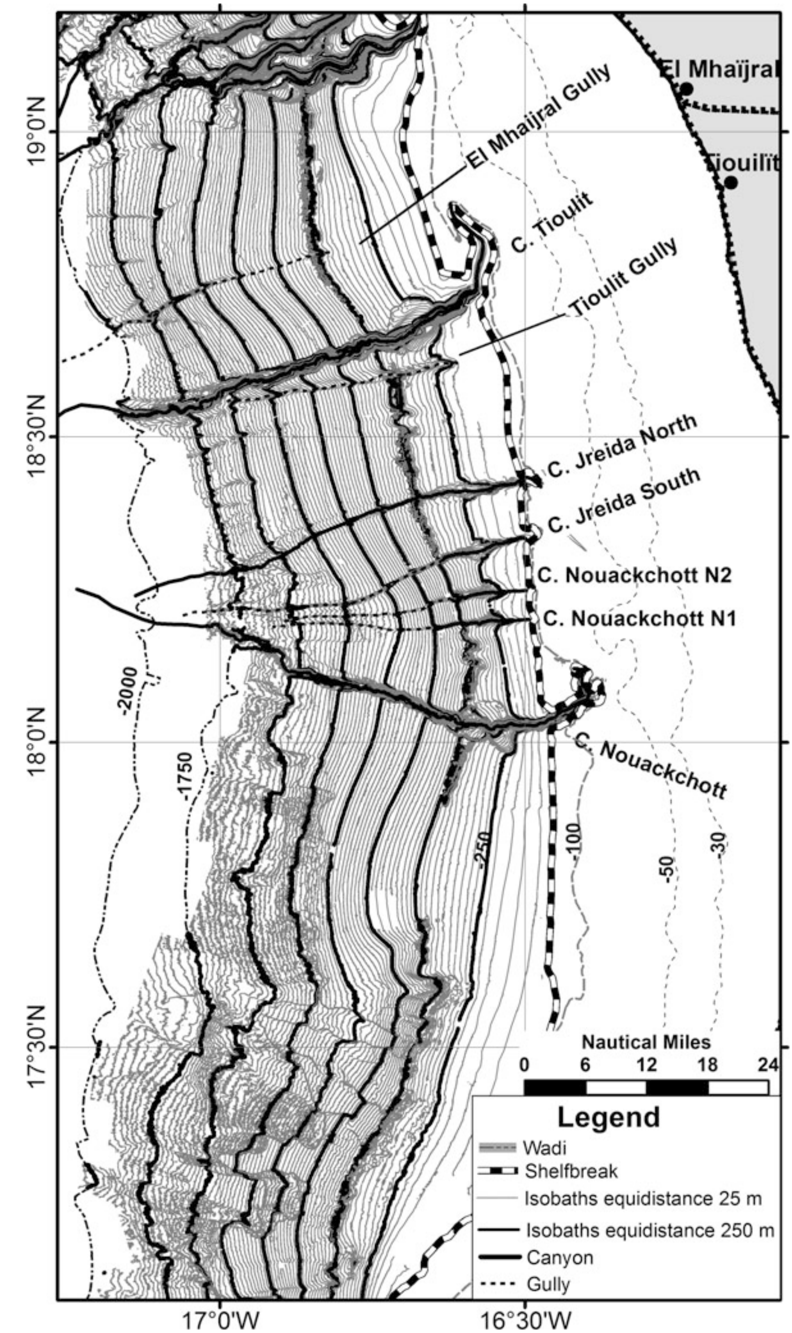

Fig. 2.17 Detailed bathymetric map of Mauritanian upper and middle slope between Cape Timiris and 17°06′N latitude. Equidistance isobath 25 m

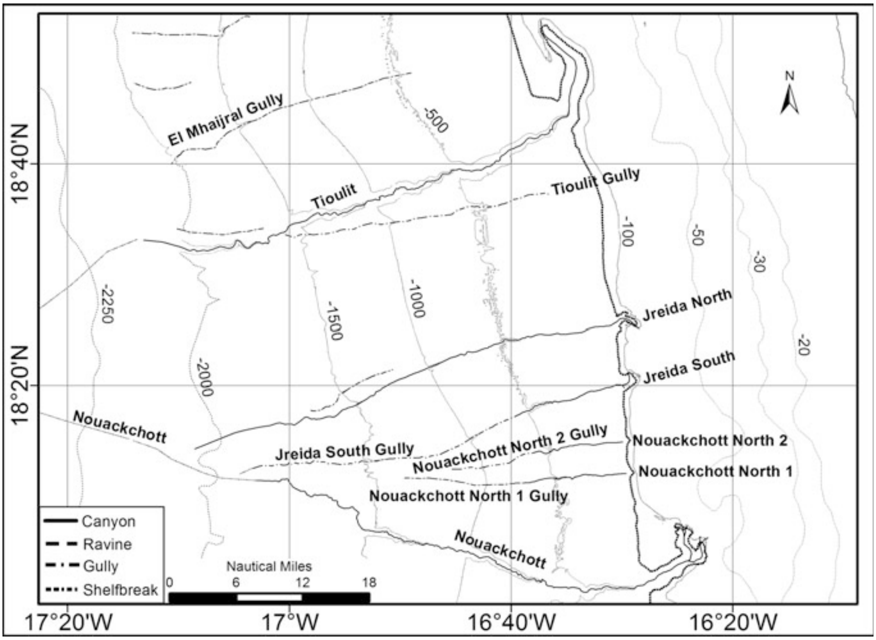

Fig. 2.18 Schematic representation of Tioulit and Nouakchott Canyon Systems

semicircular scarps on the walls. The width significantly decreases from 500 m depth, and some of the canyons become gullies (Figs. 2.17 and 2.19).

Wolof's Canyon lies in the ENE-WSW direction and disappears at ~1500 m depth (Figs. 2.20, 2.21, 2.22 and Annexe 2.1).

Maurit Canyon System This system (Fig. 2.21) consists of four canyons in a general direction, ENE-WSW (Figs. 2.21, 2.22 and Annexe 2.1). Maurit Canyon is the main axis, receiving Maurit South 1 and Maurit South 2 Canyons from the south. In turn, Maurit South 3 Canyon receives Maurit South 2 Canyon from the south (Figs. 2.20 and 2.22).

Maurit Canyon header cuts the shelf deeply along 15 km (Fig. 2.23), and its upper course is aligned with the channel of Maurit South Canyon 2. In ~800 m depth, both are separated by a wall of 100 m height, and Maurit Canyon is displaced by 1.4 km to northwest. The section displaced seems to be bound by Maurit South 1 Canyon (partially aligned with Maurit Canyon) and Maurit South 3 Canyon (Figs. 2.22 and 2.23). The thalwegs of both canyons end 60 m higher than Maurit Canyon.

Keur Massene Canyon System This system (Fig. 2.21) consists of Keur Massene North and Keur Massene Canyons and a few small gullies (Figs. 2.4, 2.20, 2.22 and Annexe 2.1).

Trarza Canyon System This system (Fig. 2.21) consists of numerous gullies and canyons, most of which disappear in the middle slope (Figs. 2.22 and 2.23).

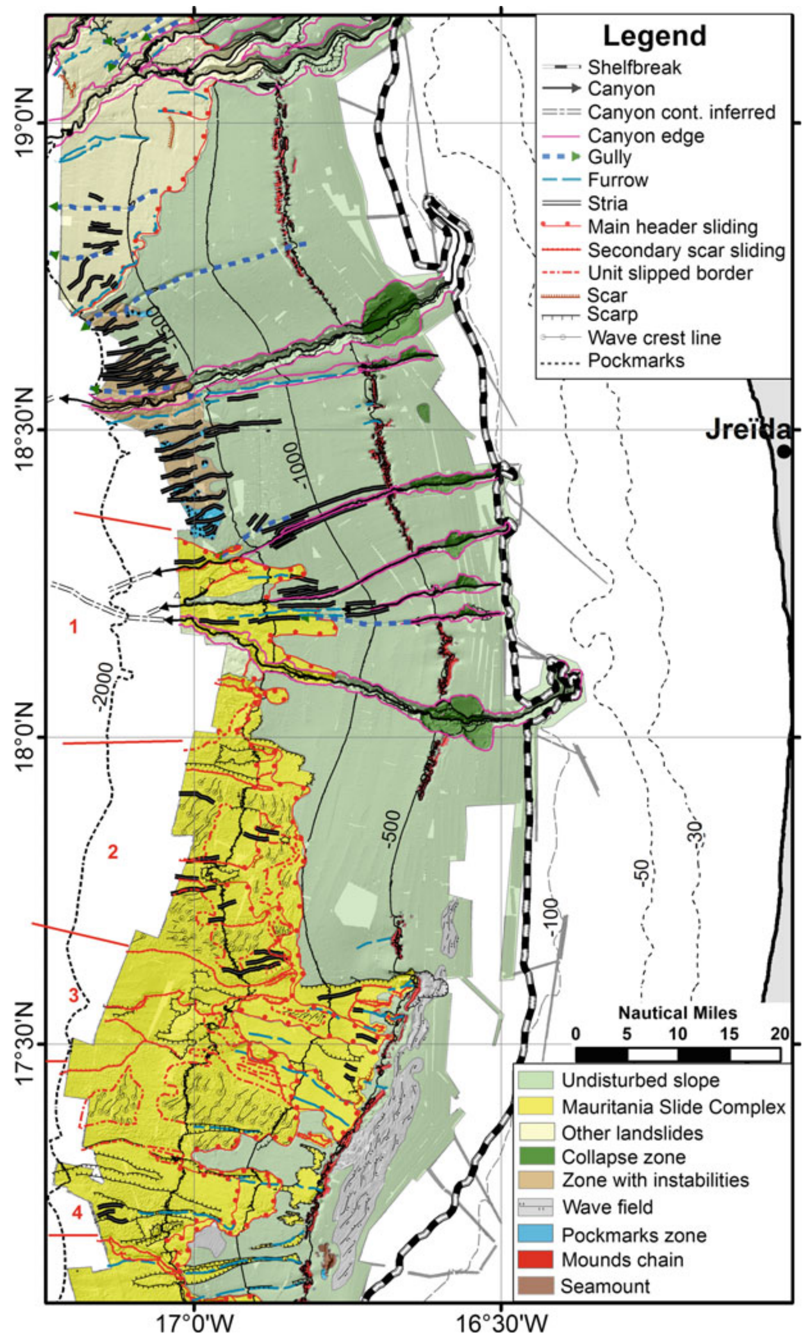

Fig. 2.19 Geomorphological map of Mauritanian upper and middle slope between Cape Timiris and 17°06′N latitude. *1–4* zones differentiated on MSC

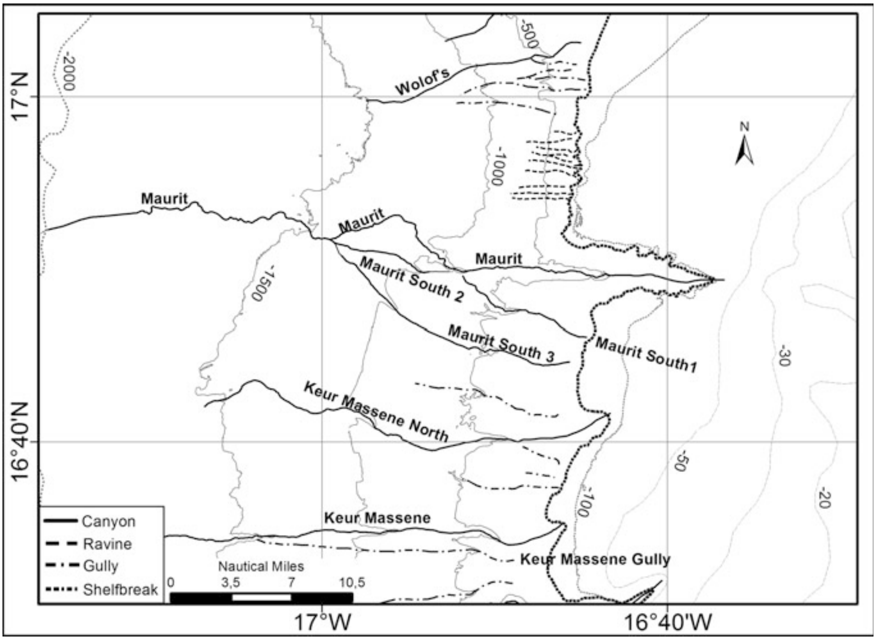

Fig. 2.20 Schematic representation of Wolof's, Maurit and Keur Massene Canyon Systems

They have been grouped into three networks: Trarza, Senegal River, and Saint Louis (Fig. 2.24).

(a) *Trarza Canyon Network*: This network consists of two canyons, five gullies, one of them remarkable, and two ravines (Figs. 2.21, 2.24 and Annexe 2.1). Trarza Canyon is the main axis, receiving Trarza North Gully from the north and a gully, which is, continuation of Trarza South Canyon, from the south (Figs. 2.22 and 2.23). The headers of these canyons are in front of the zone affected by Senegal River mouth migration and cut the shelf deeply along several kilometers (Fig. 2.23). Trarza Canyon shows a general direction, ENE-WSW, transverse to slope. Its channel has been displaced by 5 km towards the northwest close to the head. This channel develops terraces of up to 1.5 km wide from a 700 m depth (Figs. 2.22 and 2.23).

(b) *Senegal River Canyon Network*: This network (Fig. 2.21) consists of three canyons that become gullies of ~1200 m depth and two gullies (Fig. 2.24 and Annexe 2.1). Senegal River Canyon is the main axis, receives Senegal River South 2 Gully (lower course of Senegal River South 1 Canyon) from the south. Senegal River South 1 Canyon receives Senegal River South 1 Gully from the north and Senegal River South 2 Canyon from the south. Finally, Senegal River South 2 Canyon receives Senegal River South 1 Gully from the north (Figs. 2.4, 2.22, and 2.23). Senegal River Canyon channel is displaced southwestward by ~1500 m depth (Figs. 2.22 and 2.23).

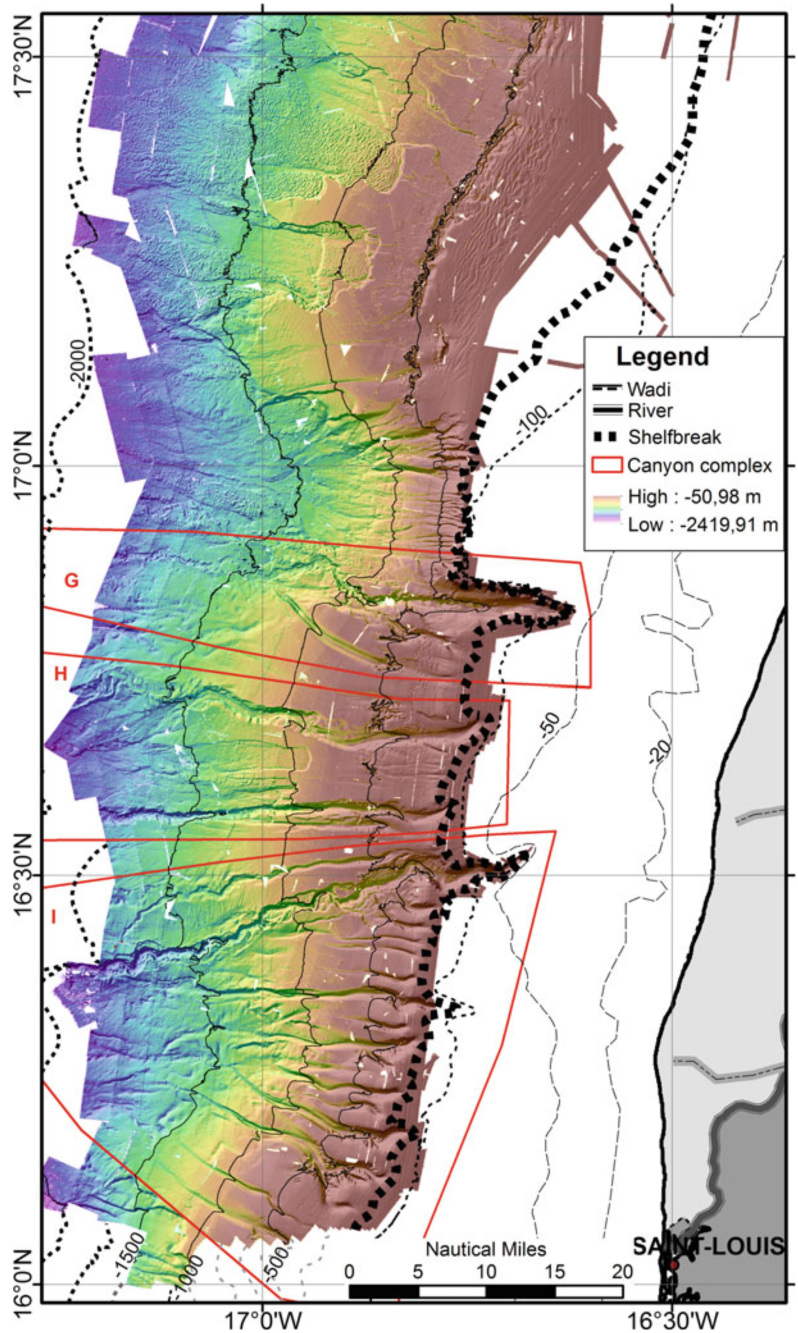

Fig. 2.21 Shaded relief bathymetric maps of Mauritanian upper and middle slopes from 17°25′N latitude to Senegal border. *G* Maurit Canyon System; *H* Keur Massene Canyon System; *I* Trarza Canyon System

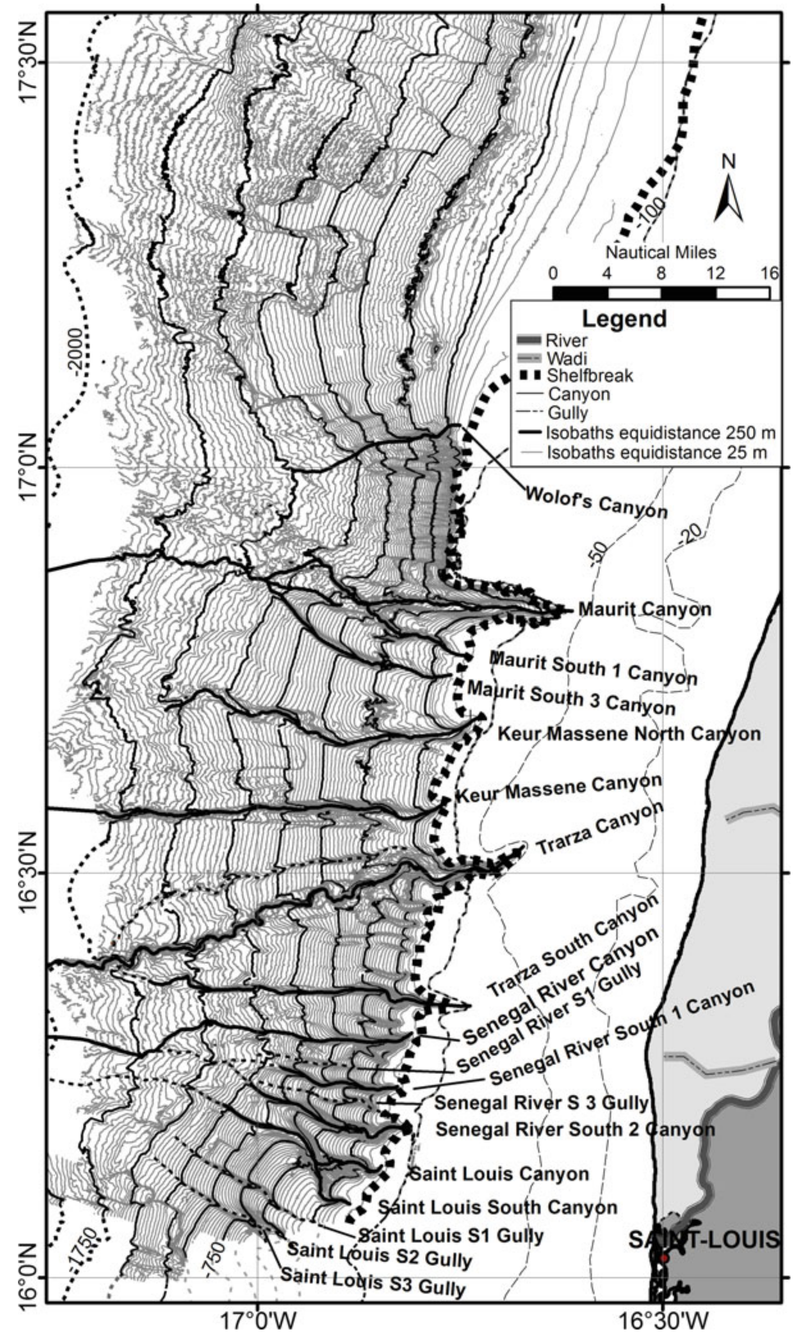

Fig. 2.22 Detailed bathymetric map of Mauritanian upper and middle slope from 17°25′N latitude to Senegal border. Isobath equidistance 25 m

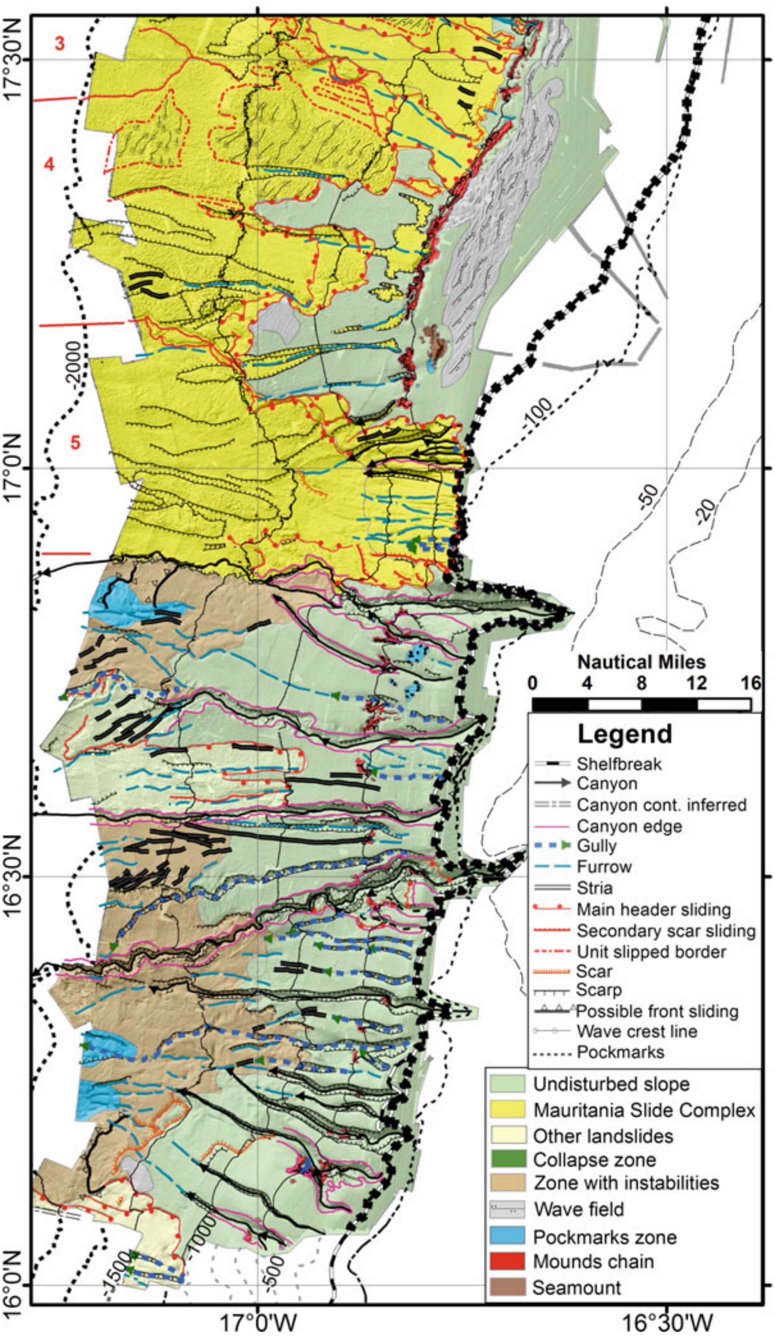

Fig. 2.23 Geomorphological map of Mauritanian upper and middle slope from 17°25′N to Senegal border. *3–5* zones differentiated on MSC

(c) *Saint Louis Canyon Network*: This network (Fig. 2.21) consists of two canyons that by ~1200 m depth become gullies and four gullies that show a general direction, SE-NW (Figs. 2.4, 2.22, 2.24 and Annexe 2.1). The channels become furrows or disappear at ~1400 m depth, and they converge towards the northwestern (Fig. 2.23).

Gravitational Features

Two types of gravitational features have been differentiated in the Mauritania slope, landslides and instability areas. Six large landslides occurred, Cape Blanc Slide Complex, Arguin Slide, Timiris Slide, Mauritania Slide Complex, Keur Massene Slide, and Saint Louis Slide from the north to the south (Fig. 2.6 and Annexe 2.2).

Moreover, four instability zones have been identified. These zones have been established based on the observations of the morphological features of the continental slope, where small scars or semicircular crown scarps, channels, gullies, waves subparallel to the margin direction, among others, were observed, representing the first stages of the seafloor deformation prior to slide. These areas have been named as Louik, Tioulit, Maurit and Trarza instability zones from the north to the south (Fig. 2.6 and Annexe 2.2).

Slide Complex and Landslides

(a) *Cape Blanc Slide Complex*: It has been observed in the scarps in the north, center, and south slopes of Arguin Spur related to the main scar and minor lateral sliding scars of three landslides (a in Fig. 2.6 and Annexe 2.2): Cape Blanc North in the northern slope of Arguin Spur, Cape Blanc Center in the western slope of Arguin Spur, and Cape Blanc South in the southern part of Arguin Spur (Figs. 2.6 and 2.10, 2.11 and 2.12).
(b) *Arguin Landslide*: It is located in the south of Arguin Canyon System (b in Fig. 2.6 and Annexe 2.2). Its morphological characteristic has been modified by erosive processes related to the activity of Arguin and Arguin South Canyons (Figs. 2.6, 2.11, and 2.12).
(c) *Timiris Landslide*: It is crossed and excavated by Timiris Canyon Complex (d in Fig. 2.6 and Annexe 2.2). The slide boundaries are defined by scarps at the north and east, with a small and narrow terrace in the southern (Figs. 2.6, 2.10, 2.12, 2.16, and 2.19).
(d) *Mauritania Slide Complex* (*MSC*): This slide complex, consisting of a large number of superimposed landslides, is bound by Jreïda North and Maurit Canyons at the north and south, respectively (f in Fig. 2.6 and Annexe 2.2).

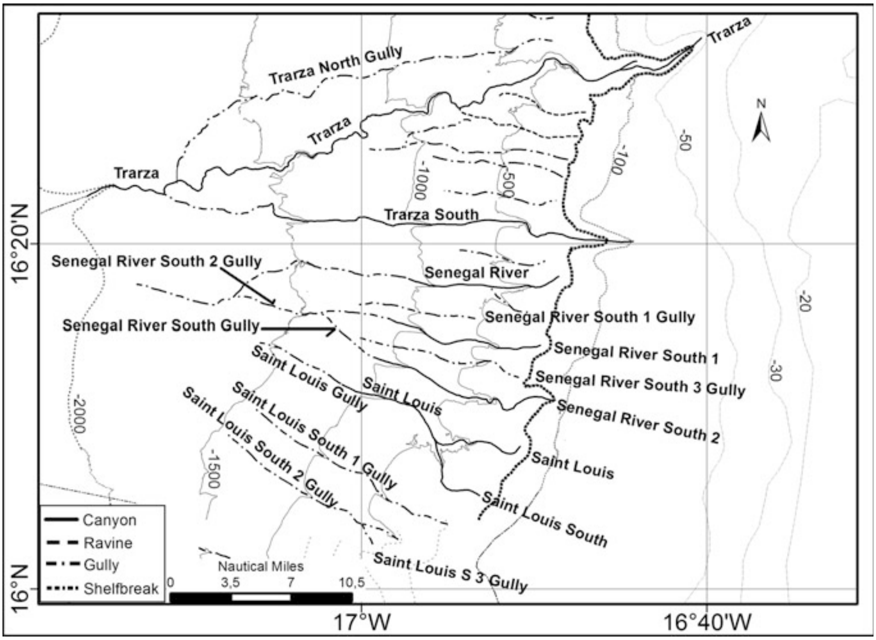

Fig. 2.24 Schematic representation of Trarza Canyon System

It is one of the largest submarine landslides of Northwest Africa continental margin (Figs. 2.6, 2.17, and 2.22), named as MSC by Antobreh and Krastel (2006b).

The upper boundary of MSC has been mapped in the framework of *Maurit* surveys. The head of the slide complex consists of a succession of main scarps, more or less oriented in the N-S and NNE-SSW directions, located from 1500 m depth in the north to 120 m depth in the south (Figs. 2.19, 2.22, 2.23, and 2.25). The main scarps are 30–60 m in height.

The main bodies of MSC are characterized by two types of surface morphologies: (i) surfaces composed by undulations with ridges and cracks and (ii) gentle surfaces. The undulations and ridges consist of aligned crests of 6–15 m in height and 0.5–2 km in length, parallel or subparallel to the slope and separated by transversal cracks, referred as "wave crest lines" in the geomorphological map (Figs. 2.19, 2.23, and 2.25). These morphologies are located in five major zones (Fig. 2.25) covering an area of 556 km^2 ($\sim$16% of MSC surface). These zones show a gradient ranging from 3° to 6° (Fig. 2.7), and they are located at about 15–30 m in height with respect to the adjacent zones. They show a chaotic internal structure in the seismic high-resolution profiles and lithologically consist of mud or muddy. In the deeper areas, within 1600–1700 m depth, these crests are arcuate (Figs. 2.19, 2.23, and 2.25). The zones with gentle surfaces do not show significant reliefs or morphologies, and although they are slightly irregular, the seismic

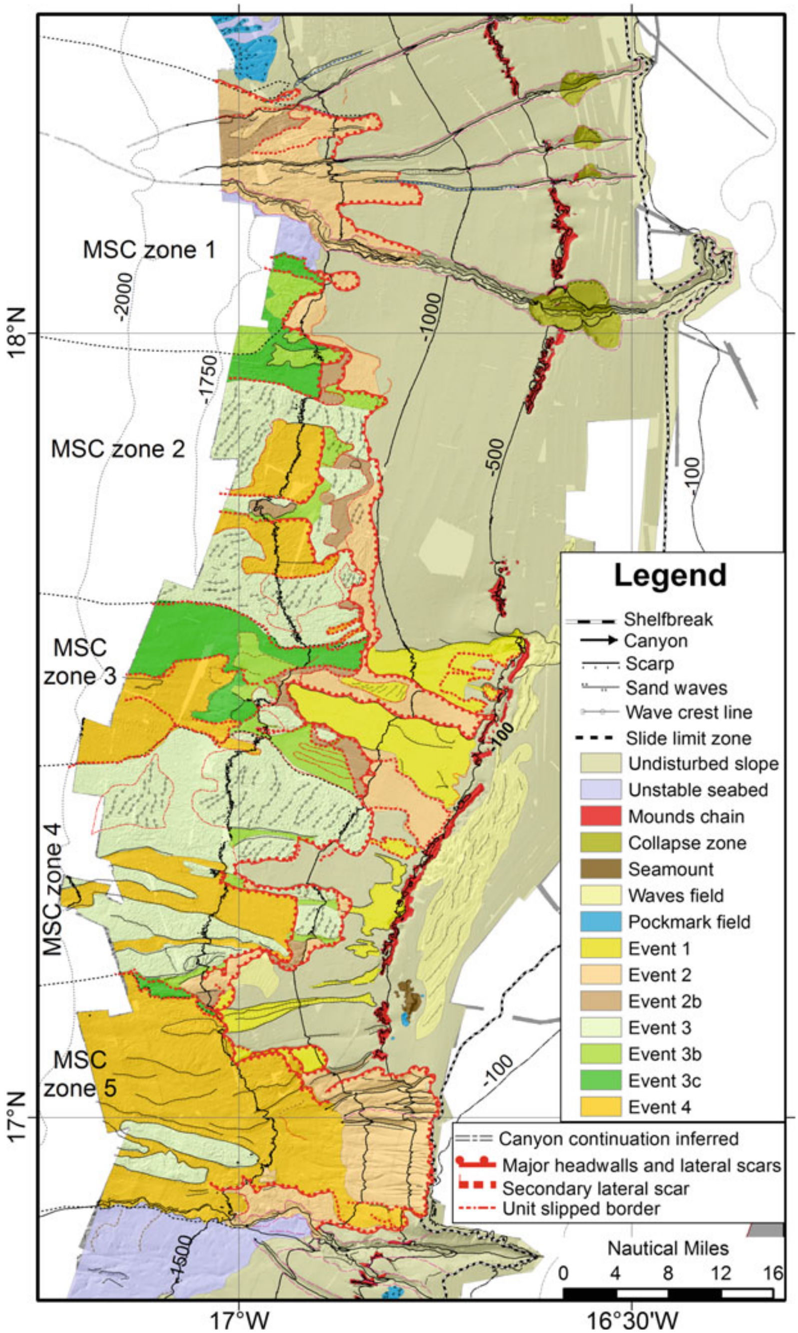

Fig. 2.25 Detailed geomorphological map of MSC

high-resolution profiles (TOPAS) show an internal structure with parallel reflectors. These gentle surfaces have an average gradient of 1.0°–1.7°, mainly corresponding to broad valleys or channels with small furrows of 2–5 m in depth and estriae related to the lateral scarps (Figs. 2.16, 2.19, 2.21, 2.23, and 2.25).

Several large scarps of 20–60 m in height, perpendicular to the slope, were identified, defining five landslide zones that show that with respect to the adjacent areas, different main scarp heights, head slide location, and morphologies affected the main slide body (Fig. 2.25). From the north to the south, the zones are as follows:

– Zone 1 consists of four slides. In the northern sector, between Jreïda North and Nouakchott Canyons, three small landslides are located. The lateral scarps of the slides favored the channelization of Jreida North, Jreida South, and Nouakchott Canyons with excavated thalwegs of 45–130 m in depth (Figs. 2.16, 2.19, 2.25, and Annexe 2.2). In the southern sector the slide, the surface shows a crest surface morphology. The northern and southern sectors are separated by a small area with instabilities.
– Zone 2 consists of one slide (Figs. 2.16, 2.17, 2.19, 2.25, and Annexe 2.2), whose body is higher than the adjacent zones 1 and 3 and a crest surface morphology.
– Zone 3 is a wide valley, 60–200 m deeper than the adjacent zones 2 and 4. The main scar is located close to coral mounds barrier (Figs. 2.16, 2.17, 2.19, 2.25 and Annexe 2.2). The surface morphology is almost exclusively even and smooth.
– Zone 4 shows a convex morphology downslope (Figs. 2.21, 2.23 and 2.25) with three main scarps located in different depths (Annexe 2.2) predominated by the crest surface morphology.
– Zone 5 is a wide valley with a concave profile. The zone is at ~250–300 m lower than the adjacent areas (Annexe 2.2). It has been excavated by several channels extending from the shelfbreak up to 1200 m in depth, and there are no remains of coral mounds barrier at the upper part of the slide (Figs. 2.21, 2.23 and 2.25).

(e) *Keur Massene Slide Complex*: It is located between Keur Massene North and Keur Massene Canyons (h in Fig. 2.6 and Annexe 2.2). In this area, it has been differentiated by several slides with a gradient of 2.0°–2.5°, a smooth surface with furrows and striate in the NE-SW to E-W directions (Figs. 2.21, 2.22 and 2.23).

(f) *Saint Louis Landslide*: This landslide is located at the southern end of Mauritanian slope (j in Fig. 2.6 and Annexe 2.2), and it continues in Senegal slope (Figs. 2.6, 2.21 and 2.23). The surface morphology is smooth without furrows.

Instability Zones

Louik Instability Zone: This zone is a depressed area of ~20–60 m in the adjacent zones, showing an elongated NE-SW shape (c in Fig. 2.6 and Annexe 2.2). It is bound by Louik Canyon in the north and Timiris Landslide in the south (Figs. 2.6, 2.11, and 2.12).

Tioulit Instability Zone: It is bound by Mhaïjral Canyon in the north and Jreida North Canyon in the south (e in Fig. 2.6 and Annexe 2.2). In the eastern part of this instability zone, an area of ~6 km^2 with semicircular crown scarps is located (Figs. 2.16, 2.17, and 2.19), probably the beginning of a small mass flow.

Maurit Instability Zone: This zone (g in Fig. 2.6 and Annexe 2.2) is bound by Maurit Canyon in the north and Keur Massene North Canyon in the south (Figs. 2.21 and 2.23). In the north boundary, the zone is 40 m higher than MSC.

Trarza Instability Zone: This zone (i in Fig. 2.6 and Annexe 2.2) is bound by Keur Massene Canyon in the north and the scarp of Saint Louis Slide in the south (Figs. 2.21 and 2.23).

Wave Fields

Five wave fields were observed along Mauritanian slope:

Arguin Wave Field: Three wave fields are located in Arguin Spur (Figs. 2.10 and 2.12). Two of them are located in the western part of the spur between 1700 and 2000 m depth and cover 14 and 33 km^2, respectively. The crests are oriented NE-SW with 3 m height, 200 m width, and 2 km length. The deepest field has not been mapped entirely; it is possible that it shows a larger area. The other wave field is located in the southern part of the spur between 950 and 1400 m depth, and it has a surface of ~380 km^2. The crests are oriented N-S, subperpendicular to the slope, and they are 6 m in height, 500–650 m in width, and 10 km in length.

Tidra Wave Field: It is located in the north of Tidra North Canyon, between 1175 and 1500 m depth. It has an elongated shape in the NE-SW direction and an extension of ~84 km^2 (Figs. 2.10 and 2.12). The crests are oriented N-S, and they are 5 m high, 400 m wide, and 2–4 km long.

Maurit Upper Wave Field: Two wave fields of 23.5 and 364 km^2 are located between 17°44′N and 17°06′N and at 200–400 m depth, respectively; they have an elongated shape N-S, are parallel to the mounds chain, and have the same length as the two sections of the close mounds barrier (Figs. 2.16, 2.19, 2.21, and 2.23). The waves are oriented NNE-SSW, parallel to slope, 6–10 m in height, 600–700 m in width, and 3–5 km in length. The crest located in the northern zone is smaller than that in the south, and it has a stepped appearance rather than wavy. They do not show an internal structure in the TOPAS profile carried out on a corner of these zones.

Maurit Lower Wave Field: Between 17°12′N and 17°09′N, from 1100–1300 m depth, nearby to a MSC header, there is a wave field of 32 km^2, whose waves are oriented along the NE-SW direction, have an angle of 55° along the slope direction, and are 4–5 m high, 0.6 km wide, and 1.8–3 km long (Fig. 2.19).

Saint Louis Wave Field: Close to Senegal border, between 16°09′N and 16°06′N, from 1400 and 1550 m depth, a wave field of 12.4 km^2 is observed, elongated in the SE-NW direction and close to the instability zone in the upper boundary. The crests show an ENE-WSW direction, with an angle of 30° along the slope direction, 2–4 m height, 200–250 m wide, and 1.5 km long (Fig. 2.23).

Coral Mounds Barrier

Between Tanoûdêrt Canyon and Senegal border, there is an almost continuous mounds barrier with cold-water coral reef—partially identified previously by other authors—which has been mapped completely in detail in the framework of the *Maurit* surveys (Figs. 2.25 and 2.26) (see Chap. 13). This extends from 20°14′ 30″ N (northernmost outcrop) until at least 16°03′N (close to Senegal border) and continues towards Senegal slope. Therefore, in Mauritania slope, the mounds barrier extends along 580 km, but it only shows the greatest continuity between 19° 04′N and 17°54′N, reaching 138 km in length, even though it disappears in a small stretch of 12 km in length, as well as from 17°43′N to 17°04′N, where it is 75 km long (Figs. 2.19 and 2.23). Both in the north and south of the slope, the mounds barrier is cut by numerous canyons, and in some zones, is interrupted by submarine landslides, or it is buried under sedimentary deposits. However, outcrops are present in the canyon walls and interfluves (Figs. 2.25 and 2.26).

The mounds chain is rooted at ~500 m depth, and it is 1.5–3.0 km wide (even though sometimes narrower). Some mounds are 100 m height with very narrow summits (~300–600 m in width) and surrounded by moats of 20–300 m wide and ~50 m deep. In some areas, the barrier shows a double line of summits, separated between 900 and 300 m as well as some branches in the E-W direction (Fig. 2.26).

It is composed of coral debris of different sizes and embedded in a muddy matrix fossilized or in lithification process as observed from the rock dredges. However, in the samples carried out on the edge of canyons, in front of Banc d'Arguin and Senegal River area, live colonies of *Lophelia pertusa* were recovered (see Chap. 14). Freiwald et al. (2012), who performed a ROV profile close to 20°14′ 30″N on the edge of Tanoûdêrt Canyon, found the sea bed covered with old coral fragments and a conical structure consisting of a mixture of coral rubble and silty sands, supporting live colonies of *L. pertusa.* At the same location, the rock dredging MUDR09 (Fig. 2.2) collected pieces of calcarenites with bioturbations, mud, remains of dead corals, and some live corals.

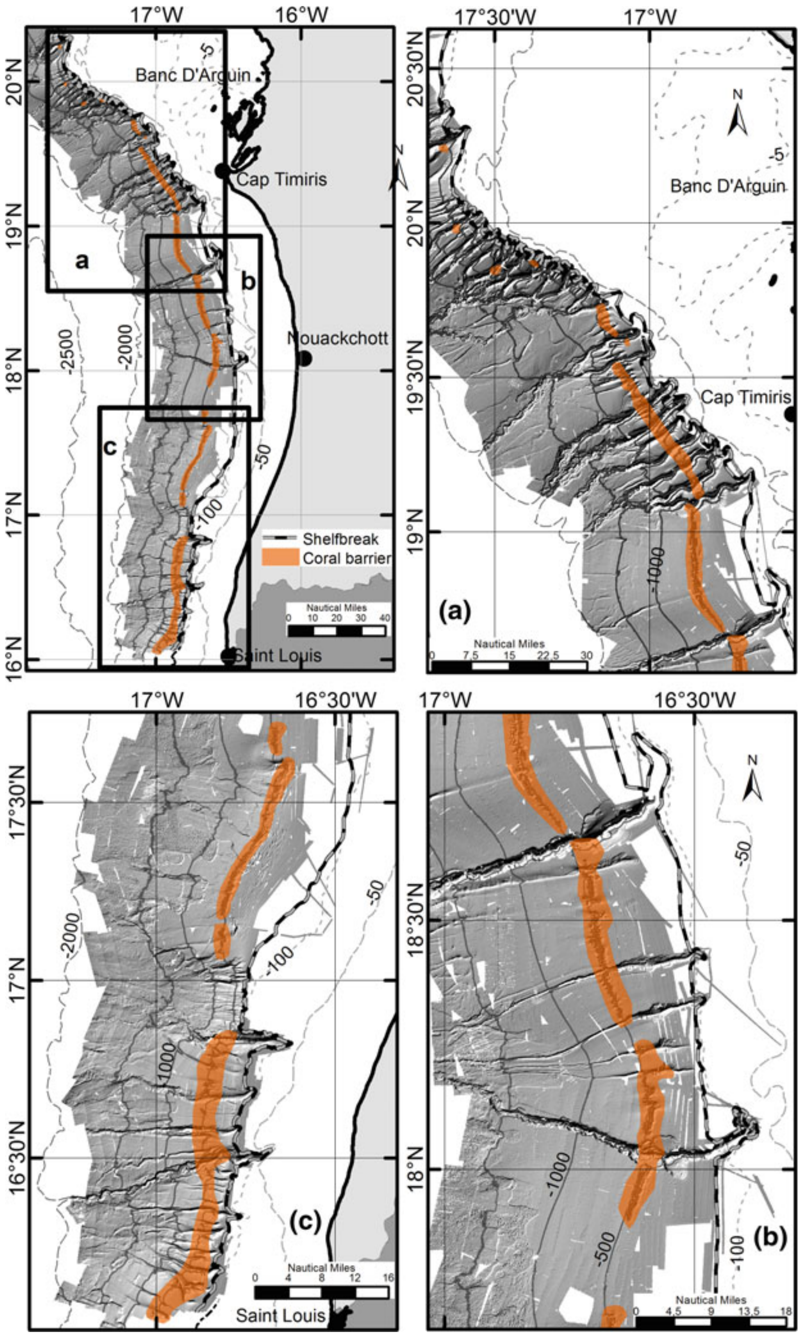

Fig. 2.26 Cold-water coral carbonate mounds barrier. General distribution and detailed maps. Northern zone **(a)**, Central zone **(b)** and Southern zone **(c)**

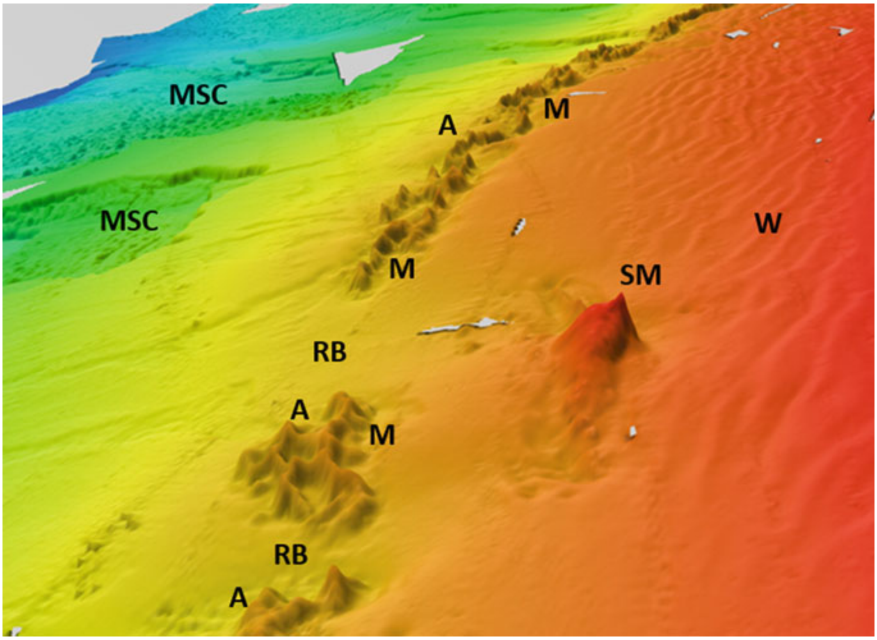

Fig. 2.27 3D image of Mauritanian slope. *A* Mounds barrier. *RB* buried reef, *M* moats, *SM* Wolof's Seamount, *W* waves field, *MSC* higher header (on 120 m depth) of MSC

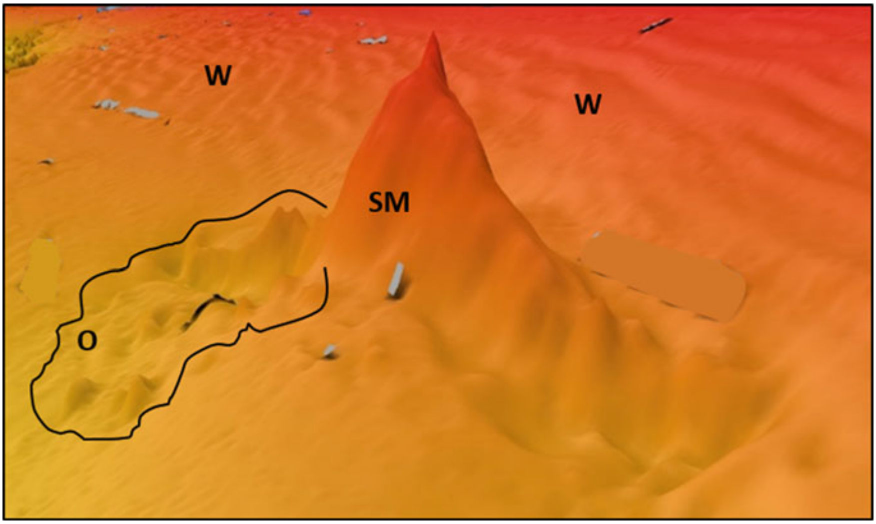

Fig. 2.28 3D image of Wolof's Seamount. *O* Outcrops, *W* waves field

Wolof's Seamount

In the southern part of the studied area, between the coral mounds barrier and shelf edge, at 400 m depth, a small seamount was discovered with a summit at 17°08′ 50″N, 16°46′ 30″W and a minimum depth of 188 m (Fig. 2.27) (see Chap. 15). Its central part is conical, and it extends northward and southward in two ridges, resulting in a slightly curved shape that runs almost parallel to the shelfbreak. The central zone is ~6.3 km long and 1.9 km wide. It is surrounded by a small and discontinuous moat of 200–400 m wide. Moreover, there are small positive reliefs close to the seamount at ~20 m height above the seafloor (Fig. 2.28).

The two rock dredgings carried out over this seamount obtained carbonate chimneys and rock fragments colonized and perforated by tube-dwelling worms. There are no corals. The seamount seems to have no relationship with the coral mounds barrier because its lithology is completely different, and it is also located at ~2.4 km at its east. More details about the characteristics of this feature are discussed in Chap. 15.

Pockmark Fields

In Mauritania slope, several areas have been identified with small circular depressions of ~300–500 m diameter and 10–15 m depth, considered as pockmarks. Nevertheless, it has not been confirmed because, unfortunately, the seismic profiles have not been carried out in any of these areas. These pockmark fields are distributed on two parallel bands along the slope, one of them located at 250–500 m depth (upper band), and the other band is located at 1200 to >1800 m depth (lower band), in which they are associated with furrows perpendicular to the slope (Figs. 2.12, 2.19, and 2.23).

The pockmark fields on the upper band are, from the north to the south, located in: Arguin Spur—a zone of about 46 km^2 between 20°40′N and 20°34′N, from 300 to 350 m depth; in Arguin Canyon System—seven small zones of 0.2–2.8 km^2 between 19°45′N and 19°42′N, from 550 to 700 m; at the south of Louik Canyon System—two zones of 1 km^2 and 6 km^2, respectively, between 19°33′N and 19°29′ N (Fig. 2.12). Similarly, pockmark fields are located from 650 to 800 m depth at the southwest of the Wolof's Seamount—an area ~1.4 km^2 and 400 m depth—and, finally at the south of Maurit Canyon—three zones with surfaces of 5.1, 2.3, and 0.6 km^2, respectively, between 16°47′N and 16°42′N, from 270 to 380 m depth (Figs. 2.19 and 2.23).

Similarly, on the lower band, the pockmarks fields are located at the north of Louik Canyon System—between 19°23′N and 19°20′N, from 1720 to 1875 m in depth, where there is a zone elongation of 61 km^2 perpendicular to slope (Fig. 2.12); at the south of El Mhaïjral Gully—~18°41′N, from 1550 to 1750 m depth, there is a zone of 4.8 km^2 in a furrow; between Tioulit and Jreida North Canyons—from 1500 to 1900 m depth, six zones in the furrows of 8 to14 m depth with surfaces from 2 to 9.6 km^2; at the south of Maurit Canyon—between 16°52′N and 16°48′N, from 1600 m depth, a zone of 56 km^2 with circular depressions widely dispersed (Fig. 2.19); and in Senegal River and Saint Louis Canyons—between 16°19′N and 16°12′N, from 1800 m depth, two zones of 28.5 and 27 km^2 (Fig. 2.23).

Moreover, it was observed that between 18°31′N and 18°29′N at ~1180–1200 m depth, two depressions of ~350–450 m in diameter and a depth of ~15 m are located; that in the center present peaks of 2–6 m in height. Thus, they can correspond to small outcrops of salt diapirs or small mud volcanoes.

Discussion

Development of Canyon Systems

Mauritania margin is characterized by numerous canyons and thalwegs that become sinuous and show terraces from the upper parts of landslides or instability areas (Figs. 2.10, 2.12, 2.16, 2.19, 2.21 and 2.23). This is because the slipped material decreases the gradient of slope; therefore, the turbidity currents that flow through the canyons lose energy. This facilitates the deposit of sedimentary isolated ribbons in the canyons, resulting in sinuous courses (Peakall et al. 2000). However, the sinuous thalwegs are initiated by large turbidity currents and high speeds, as this case in the areas where large rivers flow (Kolla 2007). At the same time, this facilitates the development of terraces, even though they could also result from the collapse on the walls, showing very strong gradients.

The Mauritania Canyon Systems are related to the evolution of two major land drainage systems: One of them is located in the north part and has disappeared (the fluvial networks ends in Gulf d'Arguin). The other system is located in the southern part, still active (Senegal River) . The canyon system of the north is more developed than the south, probably because the river network is more important and Senegal River mouth is migrating to the south.

Origin and Evolution of Mauritania North Canyon Systems

In the hinterland of Gulf d'Arguin (GdA) coast, there are a large number of wadi remnants from some old river networks (Dia 2013). According to Skonieczny et al. (2015), the main remnants correspond to the Tamanrasett River fluvial system, which has been active during the most recent AHP. This seems that 8.7–6.5 ka have resulted in wadi deltas in the inner part of Arguin Basin (Aleman et al. 2014). This is even more closed than today, because the outcrops of rocky bands continue Cape Blanc to the south (Fig. 2.9). During the last 2000 years, the GdA gradually silted, and the marsh areas dried up, transforming into sebkhas (Dia 2013). The present basin bathymetry (Aleman et al. 2010; Hanebuth et al. 2012; Dia 2013; Aleman et al. 2014) shows a series of shoals between Tintan Peninsula and Cape Timiris, the possible remains of deltaic deposits (Aleman et al. 2014). Between the shoals, there are channels that connect the paleo-drainage Tamanrasett network with the canyon systems of shelfbreak. Arguin Canyon Systems may be related to the wadis that end between the Bay of Arguin and Cape Tafarit. Similarly (Fig. 2.29), Louik Canyon System would be associated with the wadis located between Cape Tafarit and Cape Iwik, which seem have prolonged across the depression defined by the isobath by 10 m to the north of Tidra Island (Fig. 2.29).

On the other hand, in the hinterland of GdA, some wadis are not related to the Tamanrasset System and they connect with the other canyon systems off GdA. Tanoûdêrt Canyon System seems to be is related to the wadi that ends at Bay Archiméd (within Lévrier Bay) (Fig. 2.29). Timiris Canyons System seems is related to the wadis of Nouafferd paleoriver that ends in Aouatil Bay, which would have circulated between Tidra Island and the continent, as well as with other paleo rivers that end in Bay of Saint Jean (Fig. 2.29).

Therefore, the origin and evolution of canyon systems off Gulf of Arguin are related to the evolution of old fluvial networks of its hinterland during AHP.

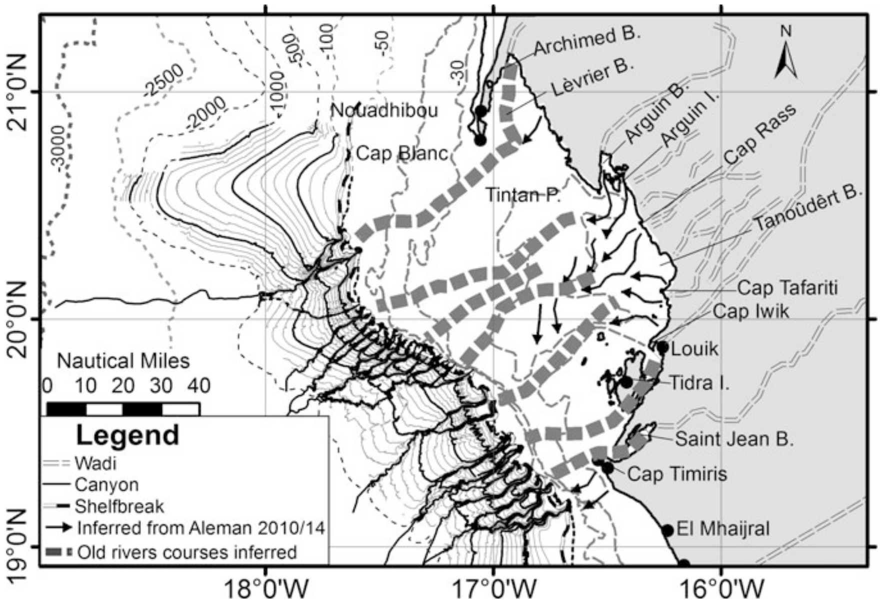

Fig. 2.29 Schematic connection between the paleo-drainage networks of the hinterland coast of Gulf d'Arguin and the current submarine canyon systems

Tectonic Associated to Canyons

The map plan view of canyons shows abrupt changes in the channel direction and other features that suggest their association with faults.

Therefore, some headers of canyon systems in the front of GdA well as those of Tioulit and Nouakchott Canyons excavated long valleys subparallel to shelfbreak; they continue to each other and show a succession of elongated depressions aligned (Figs. 2.11, 2.12, 2.17, and 2.19). This morphology could be related to faults along the NNW-SSE, NW-SE, N-S, or NE-SW direction or weak sedimentary layers parallel to slope, favoring a mass flow according to a fault plane or the beginning of landslides according to a plane parallel to the layers.

Similarly, it is noted that some parts of the courses of Arguin Center Left, Arguin Center Left 2, and Arguin South are aligned in the ENE-WSW direction and almost joined. This indicates the presence of a fault in this direction, contributing to the installation and development of these canyons. Something similar happens with Arguin South, displaced by 19 km downslope to the southwest to Arguin Center Left 2 Canyon, at the same time occupying its course (Figs. 2.11, 2.12, and 2.14). All this indicates that these features are also related to the NE-SW and WNW-ESE faults.

Similarly, the changes in course, almost right angles shown in the plan view of Timiris, Nouamghar, and Inchiri Canyons (Figs. 2.11, 2.12, and 2.14). This could be also reflection of some faults subparallel of NW-SE direction, displacing the course of the canyons.

The abrupt displacement of Maurit Canyon (Fig. 2.22) towards WNW can be attributed to a slide wedge delimited by Maurit South 3 and Maurit South 1 Canyons (Fig. 2.21 and 2.23), associated to the faults in NW-SE direction, but something arched to southwest.

The change in the direction of Trarza Canyon between 100 and 300 m depth as well as its transverse course with regard to the nearest canyons (Figs. 2.21, 2.23, and 2.24) indicates that it is channeled by a fault of ENE-WSW direction that has been displaced on the upper slope by other NW-SE direction.

The poor quality of the existing seismic records has not made it possible to check these relations, which should be done in the future studies.

Characteristic and Evolution of Landslides

The landslides found and mapped show a distribution, morphology, sliding direction, consistent with those reported on lower slope and off margin. This helped in stablishing their continuity (Fig. 2.30).

Cape Blanc Landslide: Wien et al. (2007) considered that Cape Blanc Landslide, mapped by Jacobi and Hayes (1982), did not reach the middle slope. Nevertheless, the distribution and geometry of the three slides located around Arguin Spur as well as the data and information reported by Antobreh et al. (2003)

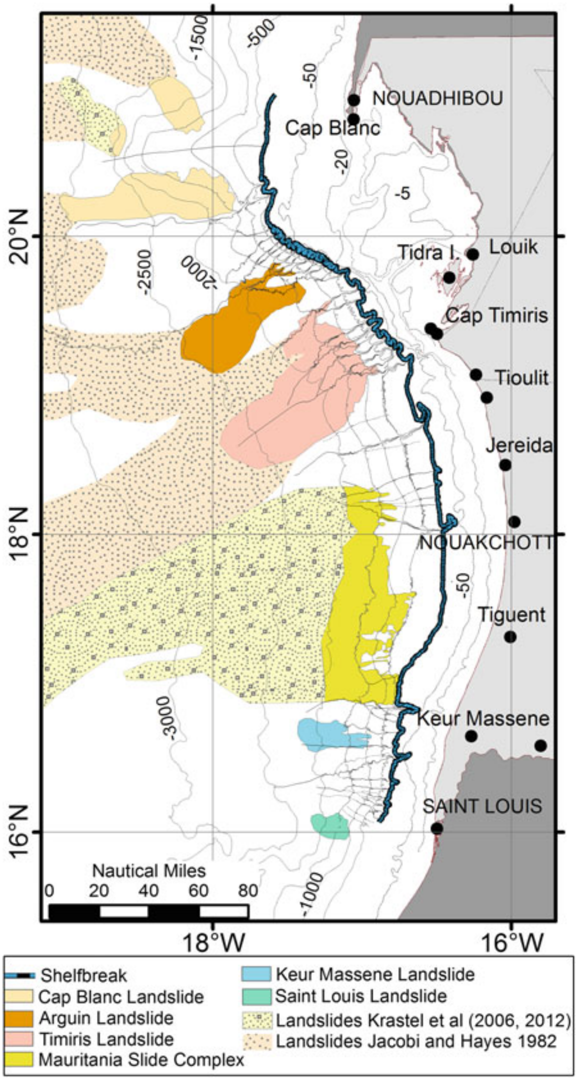

Fig. 2.30 Main landslides on Mauritanian slope. The information about deep zones has been improved using the maps of Jacobi and Hayes (1982) and Krastel et al. (2006, 2012)

and Krastel et al. (2006, 2012) indicate that these are different headwalls of the same Cape Blanc Landslide, which continue towards the west (Fig. 2.30).

Arguin and Timiris Slides: They show a headwall with a strong scarp at the same time with a smooth and gentle surface morphology. By their position, it seems to be the upper part of landslides mapped on at the bottom of the margin by Jacobi and Hayes (1982). These slides continue to west and southwest, respectively, towards central Atlantic (Fig. 2.30).

Mauritania Slide Complex (***MSC***): It was discovered by Seibold and Hinz (1974) and partially mapped by Jacobi (1976) and Jacobi and Hayes (1982) using an echo-character system methodology. Later, Antobreh et al. (2003), Schulz et al. (2003), Krastel et al. (2004, 2005, 2006, 2012), and Antobreh and Krastel (2006b, 2007) explored it in more details and found that it continues towards the west to >3500 m depth, until approximately 16°42′N, 19°46′W, covering an area of 34,000 km^2 (Krastel et al. 2005). Wien et al. (2007), Henrich et al. (2008), and Förster et al. (2010) have proposed age models and possible phases for MSC development.

Antobreh and Krastel (2006b, 2007) reported that MSC is caused by a retrogressive faulting favored by weak unstable layers destabilized by overstepping, growth of diapirs, or pore pressure, and secondly by the seismic activity of the close volcanic Cape Verde Promontory. Nevertheless, Förster et al. (2010) and Förster (2011) found no evidence of this retrogressive faulting; moreover, Henrich et al. (2008) identified the deposit of the youngest landslide—dated at 10.5–10.9 Ka, in the deepest area. The numerous scars perpendicular to the slope and the parallel escarpments seem to confirm this proposal.

However, it could have caused the reactivation of landslides in the upper part of MSC; this would have been stopped by the mounds chain between 17°37′N and 17°19′N (Fig. 2.25), according to the stabilizing effect of hard coral banks and mounds on the landslides proposed by De Mol et al. (2009) and Freiwald et al. (2012). Nevertheless, between 17°04′N and 16°51′N, this retrogressive evolution has destroyed the mounds barrier (Fig. 2.25). In these sites, the headers of two narrow valleys (described as zones 3 and 5) with a smooth morphology are located. They cut the units with the crest morphologies of zones 2 and 4. This indicates that zones 3 and 5 had a remarkable loss of materials due to the most recent landslides.

Regarding the location and mechanism trigger of MSC, it is noted that: (1) the central area of Mauritanian slope is prograding type and has a gentle morphology, indicating that the sedimentary deposits should be rather homogeneous; (2) MSC is bound by Nouakchott Canyon System and Maurit Canyon, which could be related to faults; (3) the rocky banks of the shelf in MSC zone (Fig. 2.9) show a gradually increasing depth towards the southwest, indicating a certain tilting of this possible beach rock barrier in that direction, and (4) MSC is just in front of the volcanic promontory of Cape Verde that had an important seismic and volcanic activity. Therefore, the location and development of MSC can be linked to a tilt towards southwest or movements of a section of the margin delimited by faults perpendicular to the slope, which has also been affected by the seismic and volcanic activity of Cape Verde Promontory and this would have been the mechanism trigger.

Regarding the number of major events that have affected MSC, an agreement has not been reached among the authors who analyzed the sample cores or seismic profiles carried out in this structure. Antobreh et al. (2006) and Wien et al. (2007) propose that at least two major events have taken place, as confirmed by the existence of two types of surface morphologies (with crests and gentle). However, Henrich et al. (2008), Förster et al. (2010), and Förster (2011) proposed three major events, consistent with the features observed in zone 3 (Fig. 2.19). Thus, the headwalls of two tongue-shaped slides that would have been eroded later can be observed close to the mounds barrier, resulting in the adjacent depressed zones, and the third event would be represented by the large scarps observed on 1000–1200 m depth. On the other hand, five major areas of landslides whose headwalls are at different depths have been identified, indicating >3 events (Figs. 2.19, 2.23, and 2.25).

On the other hand, the geomorphology of MSC indicates that at least four significant events with a few small phases occurred in the upper and middle slope (Fig. 2.25). The first event would have created the tongue-shaped deposits of zones 3 and 5, corresponding to one of the two phases reported by Förster et al. (2010). The second event would have eroded these deposits and affected to areas not slipped yet. This event occurred in two phases, indicating the continuity, importance, and parallelism of scarps above the 1000–1200 m depth. The third event would have created the deposits of crest morphologies, covering a large area and cut by small channels and areas with a smooth morphology. This indicates that the occurrence of several phases or adjustments in the event. The more depressed zones with a smooth surface and slabs with small scarps would represent the fourth event, which could be the debris flow tracks. These slides would have cut the oldest deposits and even have reactivated the ancient headwalls, creating a retrogressive evolution that would have destroyed the mounds barrier of zone 5 (Figs. 2.23 and 2.25). These events could be a part or phases of the major events, because they have been explored only in the upper and middle slope and the youngest landslide is deeper (Henrich et al. 2008).

Seepage and Fluid Venting in Mauritania Slope

Along Mauritanian slope, in the bathymetric range of 200 m and 600 m depth, there are pockmark fields, zones with widening in the Tioulit and Nouakchott Canyon Systems that seem to be the result of collapses, and one area near Tioulit Canyon with semicircular scarps resulting from collapses (Figs. 2.12, 2.19, and 2.23). Similarly, in depths >1200 m and in the zones of instabilities, pockmark fields are grouped in furrows (Figs. 2.12, 2.19, and 2.23), in a similar manner to those described on the Norwegian margin by Hovland (2012). He also defined the unit-pockmarks of a diameter of 200 m and from 6 to 10 m depth. In our case, the furrows, the dimensions of the pockmarks, as well as their depth are quite larger.

These morphologies may have originated by the leak of fluids as a result of seepages due to a break in the balance of pore pressures in some zones by overpressurized fluids, as proposed Hovland et al. (2010). Although Colman et al. (2005) did not find the evidence for pore pressure or seepage on Mauritanian margin, later Förster et al. (2010) found evidence for the presence of gas or a high amount of pore water. Davies and Clarke (2010) also located a large zone with methane in stratigraphic traps at the southwest of Cape Timiris. This can be destabilized by pressure changes and facilitate the gas migration and its gradual escape. In fact, they have located 12 gas chimneys that terminate in the pockmarks, indicating gas venting at contemporary seabed. Similarly, Yang et al. (2013) located offshore Mauritania anomalies caused by gas migration, buried at 400–600 m depth. On the other hand, Davies and Clark (2006) reported that the diagenesis of silica during the sediment burial increased the pore pressure and water expulsion. These phenomena facilitate the development of faults; according to Ireland et al. (2011), these can occur on the edges of a large sedimentary package or create circular depressions at the contemporary seabed.

Therefore, it seems that fluid emissions have existed or exist in Mauritania continental slope as in the other zones of Eastern Atlantic margin with these characteristics. The seepage and pore pressure only occurred in certain areas, became intermittent, or had a low intensity and activated when it reached a critical overpressure or a pressure balance break.

Coral Mounds Barrier

Seibold and Hinz (1976) first noticed the mounds barrier of cold-water coral. Later, Colman et al. (2005) indicated the existence of a coral mounds province, at least 190 km long, parallel to the shelfbreak between 17°05′N and 19°00′N. Schulz et al. (2003) detected a series of mounds of 100 m height composed of cold-water corals such as *Lophelia pertusa*, *Madrepora oculata, Dendrophyllia* spp., and *Solenosmilia variabilis*, with some live specimens in the upper part of the mounds at 450–550 m depths. Recently, Ramos et al. (2010) identified this mounds barrier along 405 km, from Cape Timiris to Senegal border. On Tanoûdêrt Canyon, Freiwald et al. (2012) observed a structure composed of coral rubble and silty sands supporting live colonies of *Lophelia pertusa*, as well as a seabed covered with dead coral remains. At the same location, our rock dredging MUDR09 (Fig. 2.2) collected mud, dead and live corals, as well as pieces of calcarenites, which could be the samples of a mounds chain basement as proposed by Hovland (2012). In the other zones of the barrier, live colonies of *Lophelia pertusa* were also observed.

The mounds chain has been studied during the last decade by many authors (Colman et al. 2005; Westphal et al. 2007; Eisele et al. 2011, 2014; Frank et al. 2011; Freiwald et al. 2012), but its origin, evolution, and why it is so large and high have not been concluded yet.

The structure is located in a hydrocarbon basin (Davison 2005) and a similar bathymetric range as the morphologies associated with seepages, as pockmarks fields or collapse zones. Therefore, the origin and development of Mauritanian mounds barrier could related to the seepage of fluids or gas venting, associated with almost every cold-water coral reef in other parts of Atlantic (Hovland 2012).

De Mol et al. (2009) proposed that the landslides create turbulence, which helps to increase the amount of food and thus helps in the development of coral reefs or banks. The recovered live coral colonies were located in the highest part of the mounds chain outcrops; indicating that perhaps only in those areas and this water depth, the suspended sediment is cleaned. This could be the explanation why the mounds chain has not disappeared yet.

The mounds barrier (Fig. 2.26) disappears north of Tanoûdêrt Canyon and south of Nouakchott, where the continental slope is a convex. Probably, it is buried because in these zones, the margin is prograding, stable, and does not have landslides. Something similar happens in the south of Maurit Canyon, where it disappears into the intercanyon areas. On the other hand the barrier continuity is interrupted by submarine canyons (Figs. 2.26a and c), and seems that it has stopped the retrogressive evolution of MSC (Figs. 2.19 and 2.23). Therefore, the mounds barrier origin is older than the development of these features.

More details about the significance and biological implications are discussed in Chap. 13.

Geomorphological Divisions of Mauritanian Slope

In the Mauritania continental slope, three geomorphological provinces, north to south can be distinguished as follows:

Arguin Province

It is located in the northern part of Mauritanian slope and bound by Cape Blanc parallel at the north and Inchiri Canyon at the south (Fig. 2.11). It is characterized by a wide shelf in the Gulf d'Arguin zone and a continental slope cut by numerous canyons (Tanoûdêrt, Arguin, Louik, and Timiris Canyon Systems) and affected by the headwalls of five landslides of rotational type (Figs. 2.10, 2.11, and 2.12). The sediments have a high percentage of carbonates (Fig. 2.8a), possibly because of a high biological activity in Banc d'Arguin zone and the important effect of the upwelling of Cape Blanc.

The abundance of canyons and landslides in this province is related to the activity of large paleo-drainage systems in the coast hinterland of GdA and its evolution during the most recent AHP.

Arguin wave field is located on Arguin Spur, consistent with its shape, and the crest orientation resulted from the activity of a deep current transverse to slope or to the upwelling phenomenon. The wave profile is not well appreciated. Tidra wave field is located on the Timiris landslide, showing an elongated shape subparallel to the canyon, the crests are transverse to slope and dissymmetrical, with a smooth gradient to downslope. Therefore, it seems to be the result of streams that have circulated downslope.

Nouakchott Province

It is bound by Inchiri Canyon at the north and Maurit Canyon at the south (Figs. 2.11, 2.17, 2.22, and 2.23). It is characterized by a shortage of canyons, a concave slope, and the location of the longest and widest section of a cold-water coral mounds barrier (Fig. 2.26a and b) as well as the headwalls of MSC and one small seamount (Fig. 2.25). It consists of two geomorphological subprovinces, whose boundary is the 17°36′N parallel and partially a part of the isobaths of 1000–1300 m depth. The north shows an undisturbed and prograding slope, and the south is almost completely affected by MSC (Figs. 2.16, 2.17, 2.21, and 2.22).

Along the shelf and subparallel to the coast, some rocky banks (Fig. 2.9) that seem to be in front of contemporary sebkhas (old marshes). These could be beach rocks, the remains of ancient coastal lagoon boundaries, according to the model proposed by Aleman et al. (2014) on the Holocene evolution of GdA.

North Subprovince: It is characterized by a slope of convex shaped prograding (Figs. 2.16 and 2.17) with a smooth surface (Fig. 2.7), and that until the 500 m depth shows a bottom sandier than the adjacent areas (Fig. 2.9). Tioulit and Nouakchott Canyons are related to two small paleorivers. This indicates that in this zone, the sediment supply has been mainly eolic with a reduced fluvial contribution. This leads to regular and homogeneous sedimentary deposits, avoiding the existence of weak layers that facilitate landslides.

South Subprovince: It is characterized by a slope with a concave shape, mainly occupied by MSC (Figs. 2.16, 2.17, 2.19, 2.22, 2.23, and 2.25). Other particular features are the presence of a small seamount and two large wave fields that are protected by the mounds barrier.

In this subprovince, Wolof's seamount and two wave fields of different genesis are located (Figs. 2.23 and 2.25). Maurit upper wave field with a crest parallel to isobaths can be classified as 2D sedimentary waves caused by internal waves, as in other areas of the world (Rebesco et al. 2014; Ribo et al. 2016). Maurit lower wave field is located above a headwall of MSC, and the crest direction coincides with one; therefore, the undulations are related to the instabilities caused in the first phase of a mass flow towards NW, rather than by bottom currents.

Senegal River Province

It is bound by Maurit Canyon at the north and the limit of the studied area in the south (Senegal border), which coincides with Senegal River mouth (Figs. 2.22 and 2.23). The slope is cut by numerous canyons and gullies (Maurit, Keur Massene and Trarza Canyon Systems) (Figs. 2.21, 2.22, and 2.23), probably because of a continuous migration southward of Senegal River mouth. This was confirmed by the TOPAS profiles that showed the continuation of some channels under the recent sediments. The gullies dominate the southern part of this province, possibly because they are the first stage of canyon development.

Most of the channels in downslope converge towards the axis of a broad valley, and almost all of them disappear between 1300 and 1500 m depth in the upper limit of an area of instabilities (Figs. 2.21 and 2.23). This indicates that a slow mass wasting is occurring in this area.

Saint Louis wave field is located in the southernmost zone. This has an elongated shape downslope, close to a large scarp, and its waves are subparallel to it. Therefore, the undulations resulted from the instabilities on the slope and the beginning of a mass flow.

Conclusions

For the first time, a complete and detailed bathymetry and geomorphology map covering about 31,300 km^2 of the upper and middle slopes of Mauritanian continental margin was elaborated.

The main geomorphological features identified and mapped are as follows: (1) >70 canyons and channels, unknown until now, grouped in ten canyon systems; (2) a cold-water coral mounds barrier of 100 m height, subparallel to shelfbreak, at $\sim$500 m depth extending 580 km from Tanoûdêrt Canyon to Senegalese border; (3) the upper part of six large slides, including those of MSC; (4) several zones of pockmark fields, and (5) a new 200 m high seamount.

The canyon systems are related to the ancient Tamanrasset fluvial network in the north and Senegal River mouth migration in the south. Most of the canyons are very deep and have abundant courses, sinuous and terraces.

The location and trigger mechanism of MSC could be related to the seismic activity of Cape Verde Promontory. Four major events were differentiated. Therefore, the discrepancies among the studies about the number of events could be the result of the complex structure of MSC, where the data can be changed rather than depending on the place where the sediment cores or seismic profiles have been obtained.

The pockmark fields and collapse zones indicate the presence, either before or now, of seepages and leaks of gas and fluids.

Three geomorphological provinces were differentiated in the Mauritania slope: (1) Arguin Province—largely occupied by submarine canyons and the headers of Cape Blanc, Arguin, and Timiris landslides; (2) Nouakchott Province—scarce of canyons, but mainly affected by MSC, and (3) Senegal River Province—with numerous small and poorly developed canyons, related to Senegal River mouth.

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Annexes

Annexe 2.1 Table of the main features of Mauritanian margin canyons

Canyons System	*Networks*	*Feature*	*Name*	*Latitude N*	*Longitude W*	*Depth Head (m)*	*Depth Distal part (m)*	*Channel Orientation (°)*	*Wall gradient (°)*	*Channel Width (km)*	*Channel Lenght (km)*	*Channel Depth (m)*	*Channel shape plan- view*	*Channel shape cross- section*
Tanoûdêrt System		Gully		20°19'30"	17°46'35"	650	1150	NE- SW	2- 5	0.6	9	25- 45		V
		Gully		20°22'00"	17°41'00"	300	1500	NE- SW	2- 5	0.7	22.5	25- 45		V
		Canyon	Tanoûdêrt North	20°23'00"	17°39'00"	90 aprox	950	E- W / N- S (150 m depth) / NE- SW (400 m depth)	7- 20	3.5	26.8	200- 250		U
		Gully		20°18'32"	17°43'06"	300	900	ENE- WSW	4- 8	0.6	6	35- 50	straight	V
		Gully		20°17'16"	17°42'43"	500	900	NE- SW	4- 11	0.3	8.3	20		V
		Canyon	Tanoûdêrt	20°16'00"	17°35'00"	85 aprox	> 3000	NE- SW / E- W (1650 m depth)	7- 40	7.8 / 3.5 (380 m depth)/1- 1.5 (1250 m depth)	> 191	250- 350 / 100- 150 (1250 m depth)	arcuate sinuous (900 m depth)	U
		Gully		20°12'30"	17°38'40"	500	1700	NE- SW/E NE- WSW (1100 m depth)	4- 8	1.3	30	40- 60	arcuate	U
		Gully		20°05'29"	17°39'25"	400	1650	E- W / SE- NW (1350 m depth)	6- 12	0.5- 0.7	22.5	25- 55	arcuate	V
		Ravine		20°05'00"	17°37'30"	125 aprox	1325	ENE- WSW/E- W (900 m depth)/ESE - WNW (1200 m depth)	8- 18	0.8- 1.2	19.3	60- 80	arcuate	V
		Gully		20°02'55"	17°39'35"	500	1200	ENE- WSW	6- 15	0.2	12	20- 70	straight	V
		Canyon	Tanoûdêrt South	20°04'00"	17°35'00"	85 aprox	2100	NE- SW/SE- NW (1200 m depth)/ ESE- WSW (1825 m depth)	8- 25	0.8- 1	59	250	arcuate sinuous (1200- 1500 and 1700 m depth)	V
		Gully		20°00'40"	17°39'09"	575	>1800	ENE- WSW/E- W (1400 m depth)		0.6- 1	> 38	25- 40		V
Arguin System	Arguin North Network	Ravine		20°02'00"	17°35'46"	130	1425	NE- SW/N NE- SSW (1100 m depth)		0.9	24.5	35- 45		V
		Canyon	Arguin	20°02'57"	17°35'50"	100	1825	NE- SW/N	10- 27	3- 1	54	150- 250	sinuous	U

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
			North 2			aprox	(> 2000)	NE- SSW (800 m depth)/NE - SW (1100 m depth)			(>65.5)		(1450 m depth)	
		Canyon	Arguin North 1	27°00’43”	17°32’12”	80 aprox	1200	NE- SW	7- 25	2.5- 1.5	31.5	400- 200	sinuous (1000 m depth)	V
		Canyon	Arguin North	19°58’37”	17°29’17”	80 aprox	1725 (2250 aprox)	NE- SW	5- 35	2.5- 1.5	66.7 (83 end)	350- 100	meandering (1500 m depth)	V
	Arguin Central Network	Canyon	Arguin Center Right 2	19°56’00	17°30’13”	200	1200	NNE- SSW / NE- SW (350 m depth) / NNW- SSE (1100 m depth)	8- 25	2- 2.5	17			V
		Canyon	Arguin Center Right 1	19°56’45”	17°28’39”	80 aprox	550	N- S	10- 30	2.3	8	200- 250		V
		Canyon	Arguin Center Right	19°56’47”	17°29’34”	75 aprox	1650	NNE- SSW / NE- SW (550 m depth) / ENE- WSW (1050 m depth)	10- 40	2- 3	40	250- 520	meandering (1000 m depth)	
		Canyon	Arguin Center Right 3	19°56’00”	17°24’48”	75 aprox	200	ENE- WSW / NNE- SSW / NE- SW	4- 37	0.9- 1.5	7	80- 250		V- U
		Canyon	Arguin	19°55’40”	17°24’24”	75 aprox	2100 (> 3100)	NNE- SSW / NE- SW (150 m depth) / NNE- SSW (850 m depth) / ENE- WSW (1050 m depth) / NE- SW (1300 m depth)	5- 37	3.5- 1.9 (8)	63 (>300)	400- 250	meandering (1250 m depth) sinuous (1500 m depth)	V

(continued)

Annexe 2.1 (continued)

Canyons System	*Networks*	*Feature*	*Name*	*Latitude N*	*Longitude W*	*Depth Head (m)*	*Depth Distal part (m)*	*Channel Orientation (°)*	*Wall gradient (°)*	*Channel Width (km)*	*Channel Lenght (km)*	*Channel Depth (m)*	*Channel shape plan- view*	*Channel shape cross- section*
		Canyon	Arguin Center 1	19°54'24"	17°22'37"	75 aprox	650	NE- SW	10- 25	1.4	4	180		V
		Canyon	Arguin Center Left	18°55'40"	17°24'23"	75 aprox	1600	E- W / NNE- SSW (200 m depth) / ENE- WSW (750 m depth) / NE- SW (1000 m depth) / ENE- WSW (1300 m depth)	10- 40	2- 2.5	32	360- 540	sinuous (1000 m depth)	U
		Canyon	Arguin Center Left 1	19°53'08"	17°19'01"	75 aprox	580	NE- SW / E- W / NNE- SSW / ENE- WSW	10- 40	1.5- 2.3	10.5	260- 300		U
		Canyon	Arguin Center Left 2	19°53'01"	17°17'27"	75 aprox	1300	NE- SW / E- W (1000 m depth)	7- 40	1.4- 1.8	32	200- 250	sinuous (1000 m depth)	U
		Gully		19°43'47"	17°29'28"	1475	1750	NE- SW	2- 12	0.8- 1.2	20.5	40- 10		V
		Gully		19°40'49"	17°28'35"	1500	1750	ENE- WSW	2- 12	0.8- 1.2	16.5	40- 5	straight	V
		Canyon	Arguin Center Left 3	19°50'02"	17°17'18"	200	675	NE- SW	8- 20	1.2	6	40		V
	Arguin South Network	Canyon	Arguin South 1	19°52'35"	17°17'13"	80 aprox	700	WNW- ESE / NNW- SSE	5- 37	2.8	14.5	350- 400		U
		Canyon	Arguin South- South 1	19°50'44"	17°13'54"	90 aprox	200	ENE- WSW	6- 17	2.3	4.5	170- 270		V
		Canyon	Arguin South	19°49'08"	17°11'56"	60 aprox	2150 aprox	NE- SW / ENE- WSW (700 m depth) / NE- SW (1300 m depth) / ESE- WNW (1625 m depth)	4- 40	1.3- 2.6	99	170- 250	meandering (1050 m depth)	V
		Canyon	Arguin South 2	19°48'01"	17°10'07"	60 aprox	850	NE- SW	5- 35	1.4- 2.2	16	200- 350		U

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
		Canyon	Arguin South 3	19°46'34"	17°05'02"	60 aprox	1250	NE- SW / ENE- WSW	5- 30	1.3- 2.4	40	200- 250	meandering (1000 m depth)	U
Louik System		Canyon	Louik Canyon	19°42'32"	17°03'07"	90 m aprox	> 2250 m	NNW- SSE / NW- SE (120 m depth)/ ENE- WSW (200 m depth) / NE- SW (1000 m depth)	12- 38	4.4- 2.3	96 (until 2000 m depth)	250- 500	meandering (1325 m depth)	U
		Ravine		19°35'08"	17°07'46"	575	1000	NE- SW	6- 14	1.8	7	50- 15		V
		Ravine		19°35'00"	17°04335"	250	1100	NE- SW	6- 20	1	16	120- 20		V
		Canyon	Louik South	19°38'31"	16°59'33"	80 m aprox	1390	ENE- WSW / NNW- SSE (120 m depth) / ENE- WSW (200 m depth) / SE- NW (1200 m depth)	15- 55	2.2- 2.8	43	350- 500	meandering (1000 m depth)	U
		Gullies	5 gullies			260- 300	1200- 1300	NE- SW and ENE- WSW	4- 16	0,8- 1.6	0.9- 23.3	30- 80		V
Timiris System	North Network	Canyon	Tidra North	19°29'57"	16°55'26"	80 m aprox	1825	NNE- SSW / NE- SW / NNE- SSW (1550 m depth)	5- 40	2.5- 4.7	72	700- 400 (1000 m depth)- 250	meandering (1200 m depth)	U- V
		Canyon	Tidra	19°26'11"	16°52'17"	70 m aprox	2250 aprox	NE- SW / SE- NW / ENE- WSW	5- 35	3 /(5.4 - 11.2 some zones)	80 (until 2000 m depth)	700- 340 (1000 m depth)- 200	meandering (800 m depth)	U- V
		Canyon	Tindra South	19°22'18"	16°53'36"	100 m aprox	1400	NE- SW / E- W (1000 m depth) / ESE- WNW	5- 25	3	33	340- 440		U
	Central Network	Canyon	Timiris North	19°21'33"	16°52'10"	80 m aprox	2100 aprox	E- W / NW- SE / NE- SW /	10- 27 (200- 900 m	2.5- 3.5	70 (until 2000 m depth)	520- 350	meandering (1200 m depth)	U

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
								ENE- WSW (1000 m depth) / NE- SW	depth) / 16- 20					
	South Network	Canyon	Timiris	19°18'38"	16°48'21"	80 m aprox	> 2250	NW- SE / NNE- SSW / NW- SE / SW- NE	15- 35	5.7- 2.5	80 (until 2000 m depth)	530- 400 (1000 m depth)- 200 (>1500 m depth)	meandering (1100 m depth)	V
		Canyon	Nouamghar	19°16'35"	16°44'55"	60 m aprox	1400	N- S / E- W / NNW- SSE / NE- SW / NW- SE / NE- SW / NW- SE / NE- SW	2- 39	4- 2.5	45	540- 300		V
		Canyon	Inchiri	19°12'28"	16°40'11"	50 m aprox	1600	ENE- WSW / NE- SW to NW- SE (800 m depth) / E- W	3- 5	4- 2	60	550- 370	meandering (1250 m depth)	U- V
Tioulit System		Gully	El- Mhaïjral	18°48'19"	16°49'06"	420	> 2000	ENE- WSW / E- W (1750 m depth)	6- 15	1 to 1.5 (1100 m depth)	43 (until 2000 m depth)	12 to 60 (1100 m depth)	straight	V
		Canyon	Tioulit	18°53'00"	16°37'18"	90	>2250	N- S / NW- SE / NNE- SSW / ENE- WSW / ESE- WNE (1925 m depth)	7- 15 / 20- 35 (700 to 1100 m depth)	3- 3.9 / 10 (170 to 400 m depth) / 0.4- 0.6 (525 to 2175 m depth)	97 (until 2100 m depth)	500- 350	meandering (500 m depth)	V
		Gully	Tioulit	18°37'20"	16°36'35"	150 aprox	1600	ENE- WSW	1.5 to 3.5 / 9 to 14 (300 to 500 m depth)	2	44	60- 40	straight	V
Nouackchott System		Canyon	Jreida North	18°25'06"	16°28'28"	80	>2000	ENE- WSW / NW- SE	2- 27	0.8 to 1 / 2 to 4 (170 to 350 m depth)	69 (until 1900 m depth)	60- 120		V
		Canyon	Jreida	18°21'20"	16°29'25"	80	600	N- S /	10- 32	1.2 / 2.4	21	170 / 140	straight	V

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
			South					ENE- WSW (140 m depth)		to 4.7 (200 to 325 m depth)		(200 to 325 m depth) / 70 (550 m depth)		
		Gully	Jreida South	18°17'16"	16°39'32"	600	1900	ENE- WSW / E- W (1175 m depth)		0.7	48			
		Canyon	Nouackchott North 2	18°14'58"	16°30'20"	70 aprox	625	E- W	2- 16	1.1 /1.6 to 3.4 (200 to 350 m depth	16	140 (200 to 350 m depth) / 80	straight	V
		Gully	Nouackchott North 2	18°14'00"	16°37'51"	625	1600	ENE- WSW	2- 14	0.7	29	40		V
		Canyon	Nouackchott North 1	18°17'07"	16°29'35"	80 aprox	750	E- W	4- 14	1.5 / 1.7- 3.2 (200- 350 m depth)	18	80 / 140 (200- 350 m depth)	straight	V
		Gully	Nouackchott North 1	18°11'14"	16°38'54"	750	1400	E- W	2- 12	0.9- 0.5	28.5	20		V
		Canyon	Nouackchott	18°07'12"	16°25'12"	70 aprox	>2250	W- E / NNW- SSE to N- S /ENE- WSW / E- W (175 m depth) / ESE- WNW (550 m depth) / SSE- NNW (1500 m depth) / ESE- WNW (1650 m depth)	5- 25 / 10- 39 (550 m depth)	2.2- 2.7 / 3.5- 10 (225- 550 m depth)	97 (until 2000 m depth)	200- 300 / 400 (225- 550 m depth)	sinuous (500 m depth) meandering (1550 m depth)	V
Wolof's System		Canyon	Wolof's	17°03'00"	16°45'00"	140	1510	ENE- WSW / NE- SW (960 m depth) / E- W (1400 m depth) /	11- 21 (wall north) / 4- 13 (wall south)	0.9	24	140		V
Maurit System		Canyon	Maurit	16°49'00"	16°37'00"	50 aprox	> 2250	E- W / SE- NW ENE- WS	4- 12 / 2- 5 (1200 m	2 / 4.5 to 6 (80- 150	83 (until 2000 m depth)	250 / 450 (80- 150 m depth)	sinuous (800- 1175 m and	U

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
								W / SE- NW / NW- SE / E- W	depth)	m depth)			>1525 m depth)	
		Canyon	Maurit South 1	16°46'00"	16°45'36"	140	800	ESE- WNW / E- W / ESE- WNW	4- 14	1.8	16	120		V
		Canyon	Maurit South 2	16°50'00"	16°54'00"	925	1370	ESE- WNW	4- 14	1.1	11	20- 40		V
		Canyon	Maurit South 3	16°44'40"	16°45'23"	125 aprox	1350	ESE- WNW /NW- SE	6- 13	1.2	30	80- 120	arcuate	V
Keur Massene System		Canyon	Keur Massene North	16°41'41"	16°43'29"	125 aprox	1575	NE- SW / ENE- WSW to ESE- WNW	5- 20	2	47	40- 89	arcuate	V
		Canyon	Keur Massene	16°35'22"	16°46'00"	125 aprox	>2000	NE- SW / ESE- WNW / E- W	14- 22	2- 1.5	56 (until 2000 m depth)	70- 210	straight	V
		Gullies	2 gullies			125	325- 550	SE- NW and E- W	2- 8	1- 0.6	5 and 13	20- 10		
		Gully	Keur Massene	16°33'02"	16°49'00"	250	1425	E- W	6- 16	0.9	27	80	straight	V
Trarza System	Trarza Network	Gully	Trarza North	16°32'00"	16°40'00"	325	1700	ESE- WNW / ENE- WSW / NE- SW (1450 m depth)	5- 16	0.9- 1.2	46	80- 10	straight / sinuous (1100- 1450 m depth)	V
		Canyon	Trarza Canyon	16°32'00"	16°40'00"	70	>2500	NE- SW / NW- SE / NE- SW /NW- SE / NE- SW	5- 30 / 10- 20 (350- 800 m depth)	2.2- 3 / 4.5- 8 (350- 800 m depth)	88 (until 2000 m depth	280- 340 / 250 (350- 800 m depth)	meandering (600 m depth)	V
		Canyon	Trarza South Canyon	16°21'00"	16°44'00"	80 aprox	1750	E- W / NNW- SSE (300 m depth) / E- W	6- 21	2.5- 1.3	52	240- 140 - 90		V
		Ravine		16°27'00"	16°46'37"	120	600	ESE- WNW	6- 18	1.5- 1.3	10	160- 100		V
		Ravine		16°26'12"	16°47'20"	120	750	ESE- WNW	4- 16	1.4- 2	13.5	120- 100		V
		Gullies	4 gullies			125- 150	825- 1200	E- W	3- 14	0.6- 1	8- 20- 12 - 11	40- 80		V
	Senegal River	Canyon	Senegal River	16°18'11"	16°48'31"	130	1350 / continue	E- W / NE- SW	6- 30	1.1- 2 / 0.8	23 canyon/25	170 to 120 / 50		V

(continued)

Annexe 2.1 (continued)

Canyons System	Networks	Feature	Name	Latitude N	Longitude W	Depth Head (m)	Depth Distal part (m)	Channel Orientation (°)	Wall gradient (°)	Channel Width (km)	Channel Lenght (km)	Channel Depth (m)	Channel shape plan- view	Channel shape cross- section
	Network						as gully >1925	(1500 m depth) / ESE- WNW (1700 m depth)		(250- 550 m depth)	gully	to 20		
		Gully	Senegal River South 1	16°15’39”	16°51’44”	500	1300	E- W	4- 9	1.2- 1.5	12	120- 50		V
		Canyon	Senegal River South 1	16°14’15”	16°49’38”	130	1200	E- W / ESE- WNW (750 m depth)	6- 20	2.7- 1.7	18	220		V
		Gully	Senegal River South 2	16°15’00”	16°58’00”	1200	1700	ESE- WNW	2- 5	0.9- 1.2	17	5- 20		V
		Gully	Senegal River South 3	16°12’16”	16°50’53”	130		ESE- WNW	2- 20	1.3- 0.5	17.5	80 to 100- 20		V
		Canyon	Senegal River South 2	16°11’00”	16°49’00”	110 aprox	1225	ESE- WNW / SE- NW	5- 25	2- 0.25		160- 290		V
		Gully	Senegal River South	16°14’16”	17°00’23”	1225	1425	SE- NW	4- 16	0.6- 1.1	7	80- 20		
	Sant Louis Network	Canyon	Sant Louis	16°08’00”	16°50’47”	130	1275	NE- SW / E- W / NW- SE / ESE- WNW	10- 21 / 7- 13 (700 m depth) / 5- 12 (1100 m depth)	2.5- 3 / 0.8- 0.3 (1000 m depth)	25.5	140 / 80 to 30 (1000 m depth)		V
		Gully	Sant Louis	16°14’38”	17°00’51”	1275	1575	SE- NW	4- 16	0.8- 1	7.4	50- 15	straight	V
		Canyon	Sant Louis South	16°05’30”	16°53’00”	130	425	SE- NW / E- W / SSE- NNW	4- 16	1- 1.5	9.5	80		U
		Gully	Sant Louis South 1	16°03’42”	16°55’00”	<175	1420	SE- NW	6- 12 / 4- 16 (450- 850 m depth)	0.5 / 0.9 (450- 850 m depth)	>24	35 / 120 (450- 850 m depth)	straight	V
		Gully	Sant Louis South 2	16°02’00”	16°57’00”	<300	1450	SE- NW	4- 16 / 4- 12	1.2- 2.2 / 0.9	>23	150- 80 / 50	straight	V
		Gully	Sant Louis South 3			<400	525	SSE- NNW	6- 8	1.5	>2.5	30- 80		V

(continued)

Annexe 2.2 Table of the main features of Mauritanian margin landslides

Slide Complex/ Landslide/ Instability Zone	*Landslide/ Instabilities Zone name*	*Latitude N*	*Longitude W*	*Head main scarp depth (m)*	*Main scarp height (m)*	*Main scarp direction*	*Slope gradient (°)*	*Slip direction*	*Minor scarps height (m)*	*Landslide type*	*Other features*
Cape Blanc Slide Complex	Cape Blanc North Landslide	20°42'00"	18°03'00"/ 18°15'00"	1250	45- 60	arcuate shape(NW - SE to ENE- WS W)	2- 3	NW	-	flow	furrows transverse undulations
	Cape Blanc Center Landslide	20°27'00"	18°36'00"	2000	100	NNE- SS W	2- 4	WNW	-	flow	furrows
	Cape Blanc South Landslide	20°26'00"/ 20°07'00"	17°50'00"/ 18°06'00"	1100- 1200	40	E- W to NW- SE	2- 3	SW	10- 20	rotational	transverse terraces and scarps
Landslide	Arguin Landslide	19°43'00"/ 19°23'00"	17°36'00"/ 17°25'00"	1300	120	NW- SE to WSW- ES E	1.5- 2.5	WSW	40- 60	rotational	furrows transverse cracks
Instability Zone	Louik Instability Zone	19°31'00"/ 19°17'00"	17°15'00"	1000	20- 60	NE- SW and N- S	1.2- 2	SW	20		furrows (15- 20 m deep) and transverse undulations
Landslide	Timiris Landslide	19°25'00"/ 18°41'00"	17°01'00"	1000- 1100	40- 100	NNW- SS E and NE- SW	1- 2.2	SW	5- 10	rotational	transverse ridges and cracks
Instability Zone	Tioulit Instability Zone	18°42'00"/ 18°21'00"	16°59'00"	1500- 1600	-	NNW- SS E	1.5- 2	WSW	-		furrows
	Tioulit East Instability Zone	18°32'30"/ 18°30'30"	16°37'00"	230- 290	-	N- S	1- 2 (3.5 in the scarp)		-		semicircular scarps
Mauritania Slide Complex	Zone 1 Landslide	18°20'00"/ 17°59'00"	16°47'00"	1270- 1160 - 1150- 150 0	65- 25	N- S and ENE- WS W to E- W	1- 3	SW/W	10- 40	flow	transverse internal scarps (10 to 40 m height) and ridges (6- 10 m height)

(continued)

Annexe 2.2 (continued)

Slide Complex/ Landslide/ Instability Zone	*Landslide/ Instabilities Zone name*	*Latitude N*	*Longitude W*	*Head main scarp depth (m)*	*Main scarp height (m)*	*Main scarp direction*	*Slope gradient (°)*	*Slip direction*	*Minor scarps height (m)*	*Landslide type*	*Other features*
	Zone 2 Landslide	17°59'00"/ 17°38'00"	16°49'00"	1300- 1000	60- 100	N- S and E- W	1.5- 3 (3- 4 1250- 1600 m depth)	WNW	-	flow	transverse ridges (20 m height)
	Zone 3 Landslide	17°38'00"/ 17°26'00"	16°41'00"	500/1000- 1200	20- 60/50	NE- SW and ENE- WSW /SE- NW/ E- W	4- 1.5 to 1.5- 2 (1500 m depth)	WNW/W	40- 50	flow	two slide tongues (toes to 1200 and 1450 m depth)
	Zone 4 Landslide	17°26'00"/ 17°09'00"	16°52'00"	500/850/1100	15- 20/60 - 80/70	NNE- SSW and ESE- WNW	2- 4.5 to 1.5- 2.3 (1600 m depth)	WNW	10- 15	flow	transverse ridges (5- 20 m height) and cracks
	Zone 5 Landslide	17°09'00"/ 16°52'00"	16°45'00"	1500/1250/120	50- 100/ 15- 30	N- S and E- W/ESE - WSW	4- 6 to 2- 3 (1300 m depth)	W/WNW	30- 80	flow	furrows and scarps parallel to slope
Instability Zone	Maurit Instability Zone	16°52'00"/ 16°44'00"	16°50'00"	1000	-	NE- SW	2- 4	WNW	-		depressions and undulations continuous and parallels to slope
Keuer Massene Slide Complex	North Landslide	16°44'00"/ 16°39'00"	17°00'00"	1500- 1600	20- 40	NNW- SSE	1.5- 3.5	SW	20 (1800 m depth)	flow	furrows (NE- SW to E- W)
	South Landslide	16°39'00"/ 16°34'00"	16°57'00"	900- 1000	60	N- S	2- 3	W	25- 50	flow	furrows
Instability Zone	Trarza Instability Zone	16°34'00"/ 16°06'00"	16°56'00"/ 17°00'00"	1000- 1500	30- 50	N- S to NNE- SSW	0.5- 2	W	-		furrows (6- 20 m deep) and undulations
Landslide	Saint Louis Landslide	16°06'00"	17°05'00"	1100- 1000	50- 85	SE- NW and ESE- WNW	3- 3.5	SW	-	rotational	furrows

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