DRADEM campaign - 2016 July - Scientific report

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DRADEM Campaign – July 2016

Scientific report

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1. Working area and objectives

We performed the DRADEM campaign along the northern edge of the Demerara plateau, offshore French Guyana and Suriname (Figure 1).

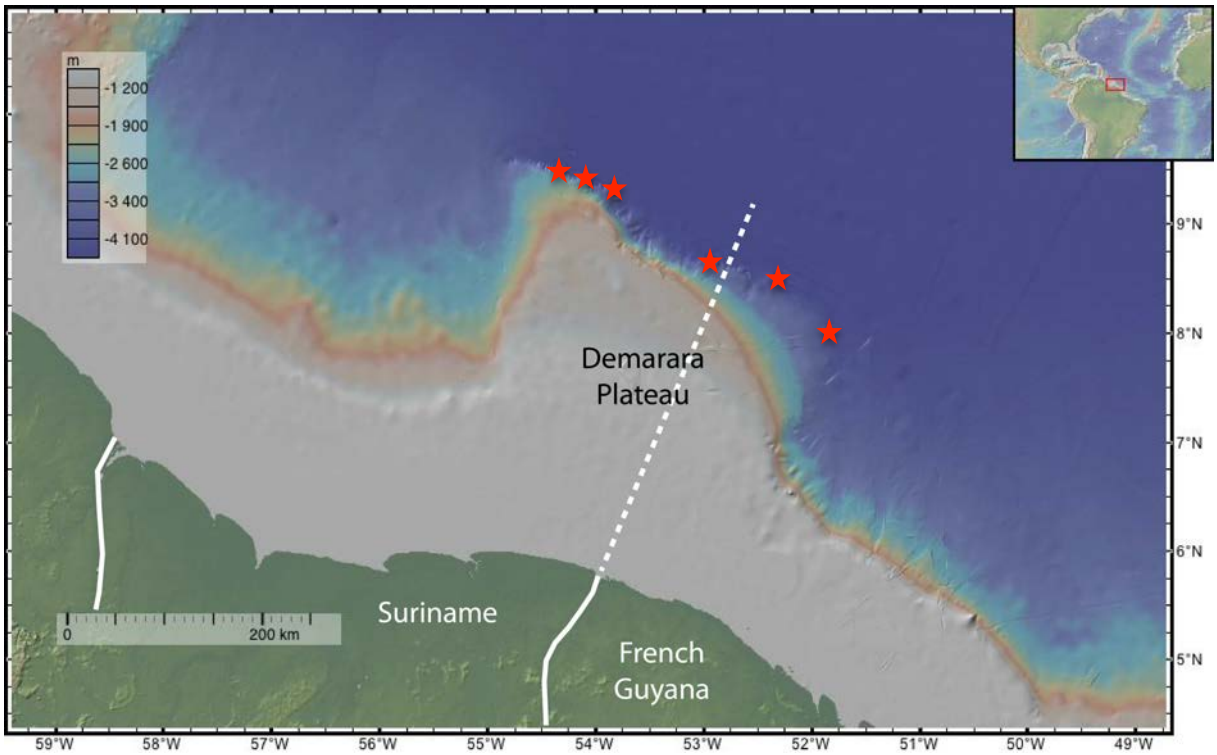

Figure 1: Location of the dredges performed during the DRADEM campaign (red stars) offshore French Guyana and Suriname, on the northern edge of the Demerara plateau.

The objectives of the DRADEM campaign were:

- To map the bathymetry of the continental slope in order to document more precisely its segmentation (Figure 2);

- To sample by dredging the rocks outcropping on the continental slope, on sites where the lack of recent sediments are inferred from previously acquired seismic data (GUYAPLAC -2003 – and IGUANES – 2013 – campaigns; Basile et al., 2013; Loncke et al., 2016). The aim of the dredges was to sample the basement of the Demerara plateau. The older rocks known in the plateau are limestones from the end of Jurassic times, drilled at site Demerara A2-A (Figure 3), and late Jurassic to lower Cretaceous sandstones dredged at the bottom of the continental slope (Fox et al., 1970).

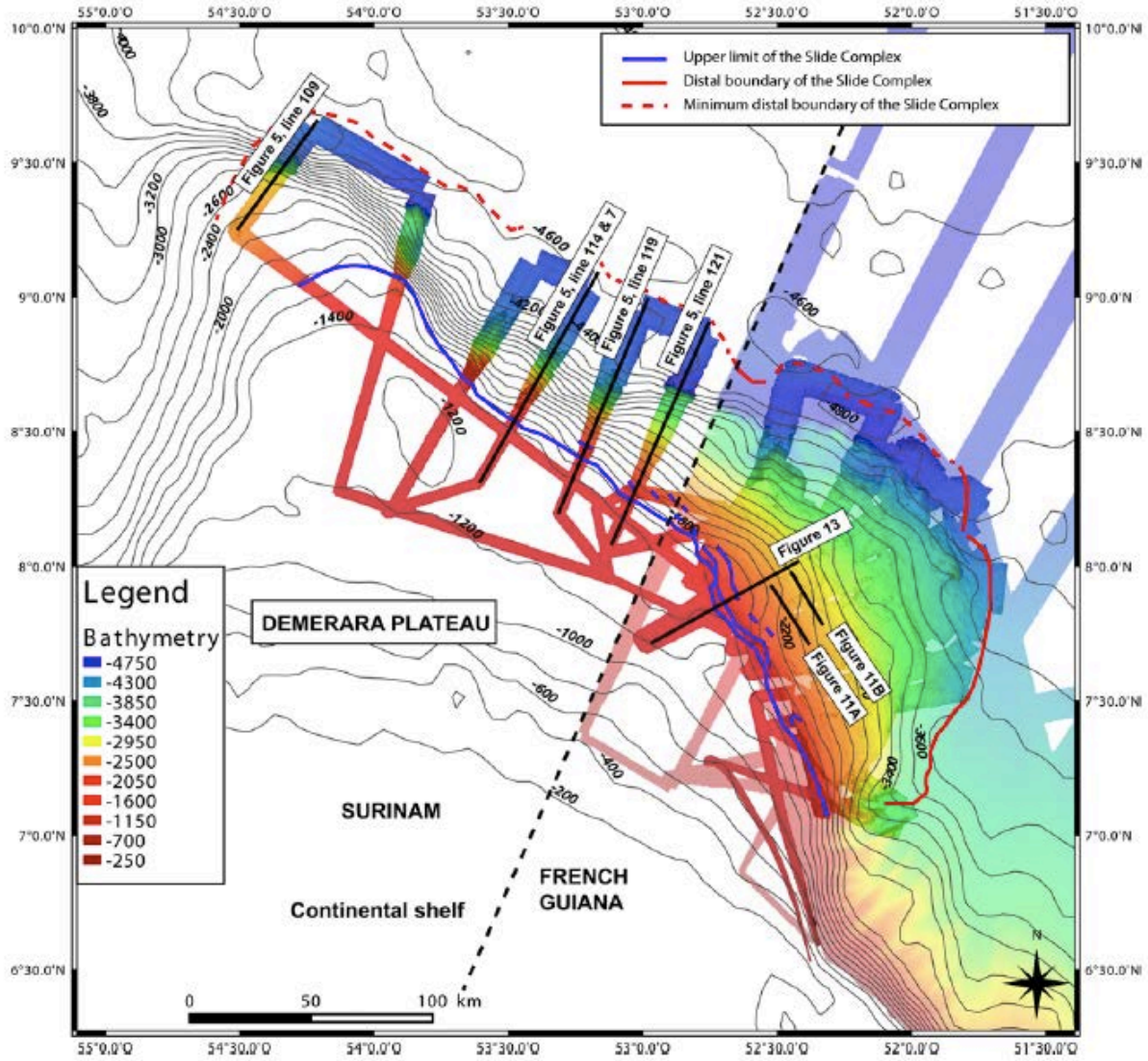

Figure 2: Bathymetry of the Demerara plateau as known before the DRADEM campaign. High-resolution data from IGUANES (dense colours) and GUYAPLAC (light colours); isobaths from Etopo 1 grid (Amante and Eakins, 2009). From Loncke et al., 2016.

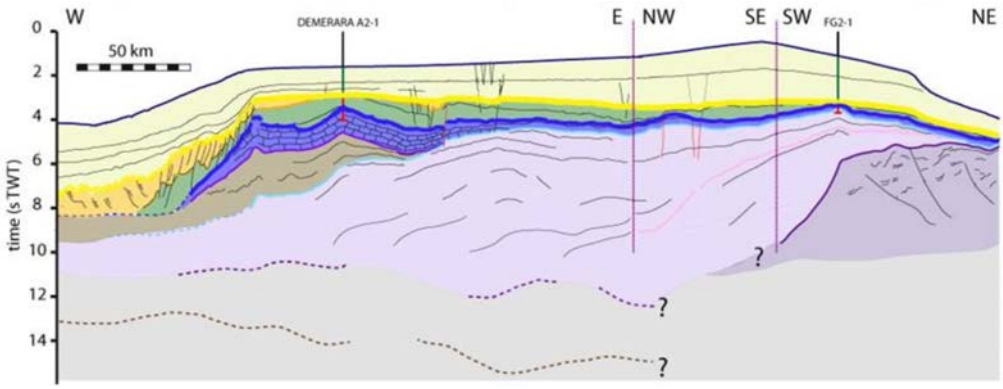

Figure 3: Synthetic East-West section across the Demerara plateau. Light yellow represents the upper Cretaceous to Tertiary sediments, the bold yellow line the upper Albian unconformity, the blue the Jurassic sediments. The underlying units (purple) are stratified, in wedges westward tilted, but their nature and age are unknown. The Moho should be the deepest dotted line. From Mercier de Lépinay, 2016.

Industrial data suggest that the Jurassic limestones overly a very thick stratified unit. It was postulated before the DRADEM campaign that part of this unit (in purple figure 3) might consist in a pile of volcanic sheets, which may outcrop on the northern continental slope.

2. Operations

2. 1 Timing and tracks of the DRADEM campaign

The research vessel Pourquoi Pas? get under way July 10th, 2016 from Pointe à Pitre (Guadeloupe), and came back to the same port July 20th, 2016. Scientific operations were performed in the international waters and the Exclusive Economic Zones (EEZ) of Suriname and French Guyana from July 12th to July 19th. Data acquisition (swath bathymetry, CHIRP, magnetism, gravimetry) started under way at 11°24'N-56°37'W, following a straight line towards the NW corner of the Demerara plateau; coming back, the vessel followed a parallel line slightly shifted eastward in order to increase the bathymetric cover. These two lines crossed the distal part of the Orinoco deep-sea fan (Figure 4).

The main part of the operations was located along the northern continental slope of the Demerara plateau, with a first travel from West to East that mapped the bathymetry up to the northeastern edge.
Before the campaign, we selected six dredging sites labelled A to F. We did not dredged site D as the slope revealed to be not very steep nor rough. We replaced site D by site G, located on a spur at the edge of the plateau (Figure 5).

We labelled the dredges using the site name (A, B …), followed by the serial number (B1, B2, B3 successively). We also named the bathymetric features where the dredges were successful (Figure 5).

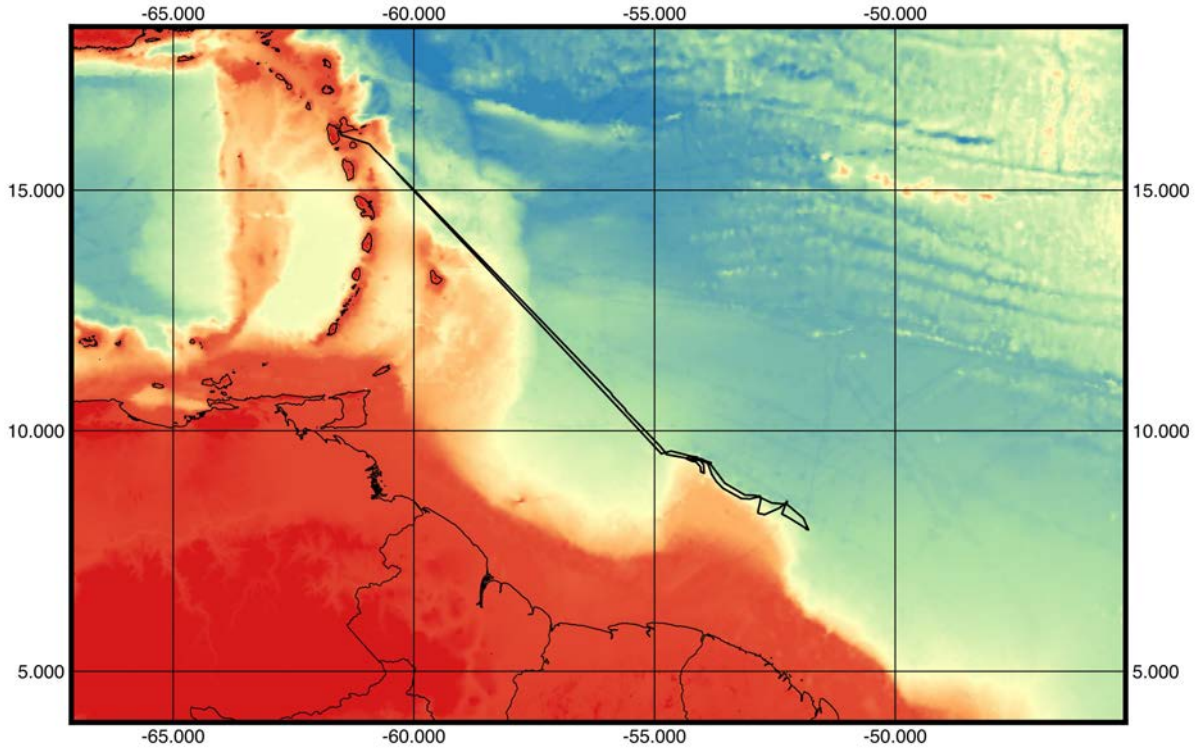

Figure 4: Tracks of the DRADEM campaign.

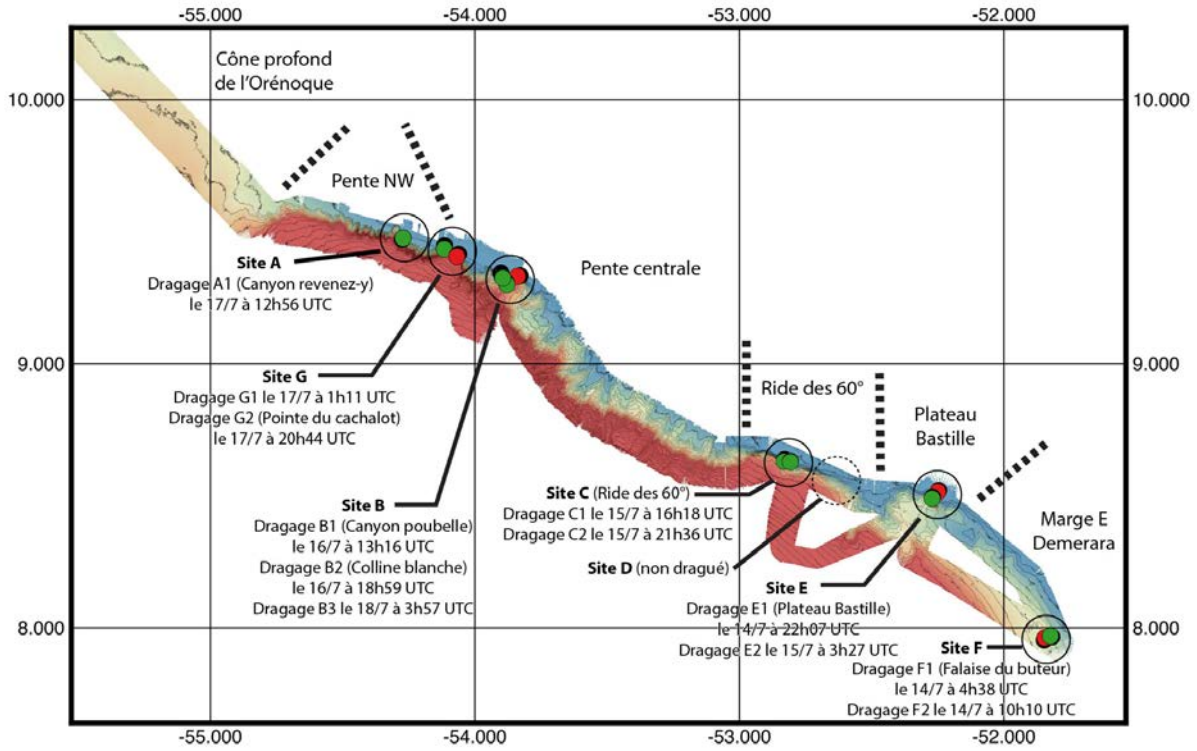

Figure 5: Bathymetric map obtained form DRADEM campaign along the northern slope of the Demerara plateau. Green circles represent the successful dredges, red circles the empty ones. See text for an English version of the toponymy.

The dredges were performed from West to East (F1, F2, E1, E2, C1, C2, B1, B2, G1, A1), the again eastward for the last two (G2, B3) (Figure 5). According to the available transit time between the dredging sites, the tracks were either straight (from site to site), or used to improve the bathymetric mapping.

Two dredging sites are located within the French EEZ: sites E (Bastille plateau) and F (Goleador cliff). The four other sites are within the Suriname EEZ: sites A (Come back canyon), G (Sperm whale spur), B (Waste canyon and White hill) and C (60° ridge).

2.2 Dredging operations

The rock dredge consists in a metallic circle, about one meter in diameter, with teeth and arm in the front part (scraping the sea floor), and a net 1.5 m long in the rear part (Figure 6). The net consists in a wide-mesh metallic net, lined inside by a narrow-mesh nylon net (Figure 7). Two shackles connect the arm to a 15 m-long chain, then to the 125 m-long martyr cable (Figure 8). The chain and the martyr cable are likely to trail on the sea floor during dredging. To put the dredge at sea and on board, the martyr cable is connected to the working winch; during dredging it is connected to the Grand Fond (GF) cable by a swivel. The length and tension of the GF cable are monitored on board.

Figure 6: Dredge on deck at the end of dredging E1

Figure 7: The two nets (inside in nylon, outside metallic) on the deck at the end of dredge E1.

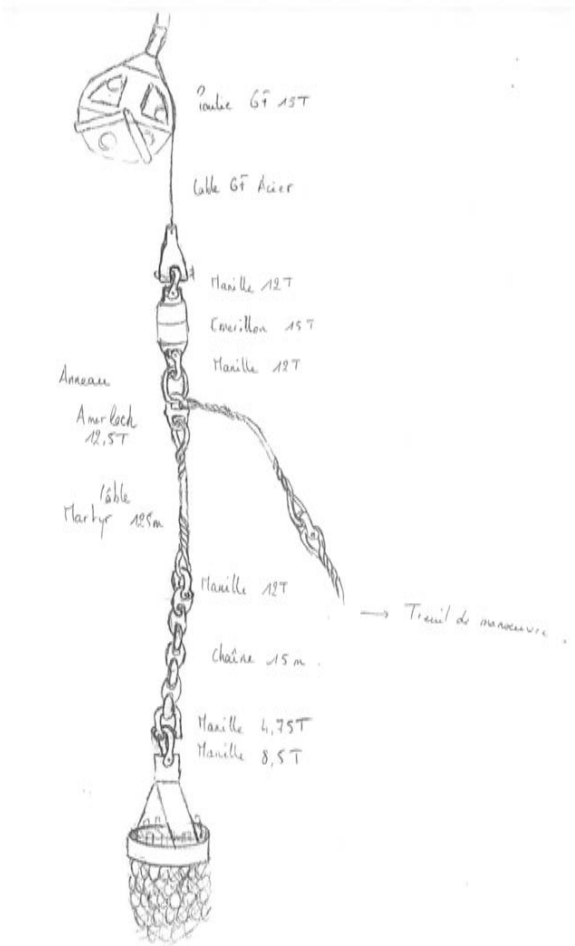

Figure 8: Wiring of the dredge (drawing by Morgane Golain, annotated by Jean Meral). The different parts are not shown at the same scales (cf. figure 9).

Figure 9: Operations to bring back the dredge A1 on deck. From left to right and up to down: 1- the dredge hangs below the swivel (red) and the Grand Fond cable; the cable of the working winch is attached to the shackle below the swivel. 2- the dredge hangs on the working winch, the GF cable and the swivel are going to be removed. 3- the dredge is on deck, and then 4- turned upside-down to be emptied.

At the start of each dredge, the zero for the run out length of the GF cable marks the position of the swivel at level with the rear deck. As the dredge is about 140 m deeper than the swivel, one should add these 140 m to the run out length in order to obtain the total length of the apparatus.
The tension of the GF cable presents a constant offset of 1000 kg. This report refers to the tension peaks as they were measured, without a correction of the offset.
The dredge is sent to water before the vessel reaches the vertical of the starting point of dredging. The dredge is sent down as the vessel advances, typically at 0.5 knots, in order to reach the sea floor at the dredging starting point. This implies that before as during the dredging, the dredge is not at the vertical of the vessel. The vessel advances while heaving the GF cable to allow the dredge to follow the sea floor upslope. During dredging, the cable tension varies with the run out length and the vessel movements. If the dredge hangs the sea floor, the tension increases with the displacement of the vessel and the heaving of the cable, then suddenly decreases when the dredge is free from the sea floor (hopefully by breaking the outcrop).
At the end of the dredging section, the hanging velocity is increased to lift up the dredge. Once on board, the dredge is put upside down on the deck to release the rocks kept in the nets (Figure 9). Then the scientific team cleans and labels the sample, before making a macroscopic description, eventually saw, and archive.

3. Main bathymetric observations

The DRADEM campaign totally mapped the continental slope north of the Demerara plateau. This map confirms the segmentation previously observed during the IGUANES campaign (Loncke et al., 2016), adding some details in the northeastern side. From the bathymetry, one can define four segments on the continental slope, from West to East (Figure 5):

- The NW segment, 80 km-long, where the continental is steep, in average 16° between the slope break at the edge of the plateau (2900 to 3200 deep) and the abyssal plain (4400 m). The slope is regionally linear, but in detail cut by numerous canyons (Figure 12). On the seismic lines, this slope seems to be devoid of recent sediments. The eastern end of this segment is a 13 km-wide plateau northeastward tilted.
- The central segment, which is curved and 145 km-long. The continental slope is not as steep as in the NW segment, in average 5° between the abyssal plain and the edge of the plateau that changes in depth from 2500 m in the eastern and western ends to 1500 m in the central part. The canyons are quite wide, and locally present a staircase morphology (Figure 10). On the seismic lines, the recent sedimentary cover is disturbed by numerous gravitational slides, with the upper scar that defines the morphologic edge of the plateau. The northwestern end of this segment is a small plateau deeper than 3600 m.

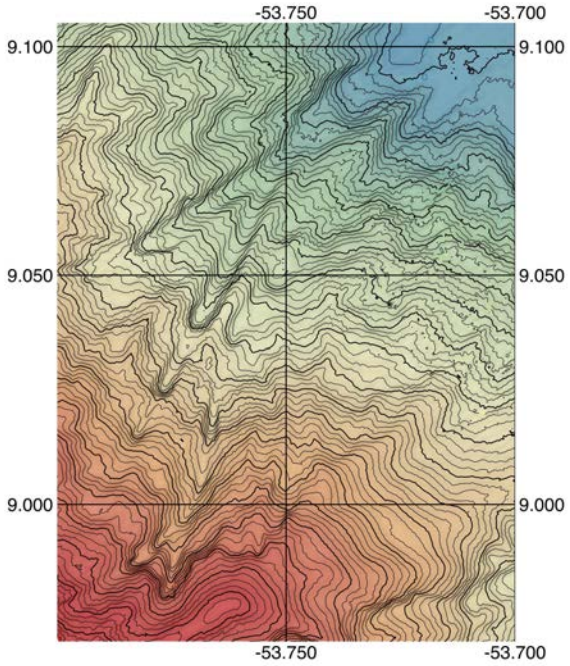

Figure 10: Staircase canyons in the central segment of the continental slope.

- Eastward, a segment consists in an asymmetric ridge (60° ridge), trending WNW-ESE, and rising up to 3400 m deep (Figure 39). This ridge stands up to 200 m above the edge of the Demerara plateau to the south, and 1200 m above the abyssal plain to the south. Northward, the average slope is 40°, locally 60° towards the crest of the ridge. The crest is discontinuous, and locally eroded by hemi-circular slides. Canyons are not well expressed in this segment.
- Finally, the eastern end is characterized by a small plateau (Bastille plateau) which top is almost flat at 3700 m depth, standing 300 to 400 m above the deep part of the Demarara plateau (lower plateau, Basile et al., 2013), and 1000 m above the abyssal

plain (Figure 51). The Bastille plateau trends NW-SE, and is oblique regarding the regional trend of the northern edge of the Demerara plateau.

We observed two bathymetric features we interpret as mud volcanoes. One of them is at the edge of the Demerara plateau, just south of the 60° ridge (Figure 39). It is a circular mound, 100 m high and 800 m in diameter, with a flat summit.
The other feature interpreted as a mud volcano is in the distal part of the deep sea fan of the Orinoco. It is a circular depression with a ring shape, called πr ring. The depression is 70 m deep around a 2 km-wide central part (Figure 11)

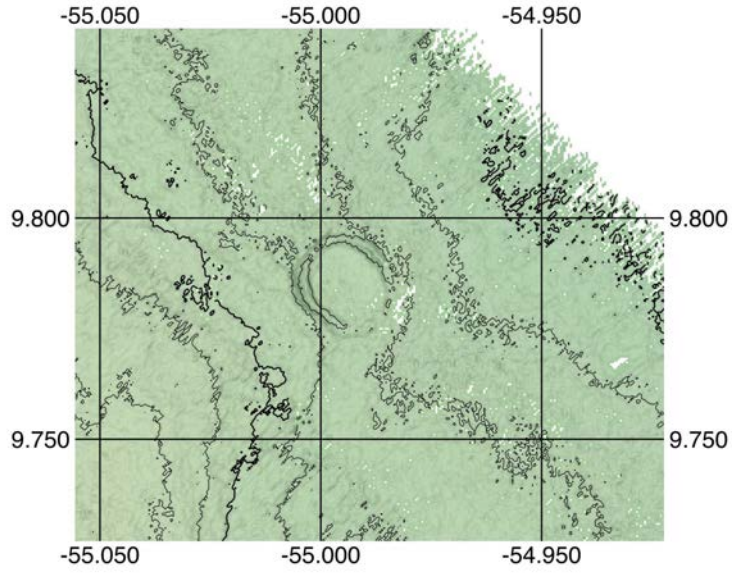

Figure 11: πr ring, depression at 3940 m depth in the distal part of the deep sea fan of the Orinoco

4. Dredges

Dredge results are exposed from West to East (sites A, G, B, C, E, F) instead of following the timing of the campaign (Figure 5). All bathymetric maps are at the same scale, and the dots indicate the location of the boat during dredging. Green dots refer to successful dredges, red dots to empty dredges. Bathymetric sections are drawn according to swath bathymetry following the scheduled dredge; scales are not similar in all sections, but all sections are drawn without vertical exaggeration. The same scale is used to show the tension of the cable for all dredges. The location of the vessel and the tension of the cable come from the CASINO file, where these data are recorded every thirty seconds.

4.1 Site A

Dredge A1 (Come back canyon) (Figure 5)

Location of the vessel (Figure 12) for
Dredge at sea: N 9° 28,76553'; W 54° 16,1401' the 17/7/16 at 11h17 UTC
Dredge at sea floor: N 9° 28,63859'; W 54° 16,22443' the 17/7/16 at 12h56 UTC
Start of dredging: N 9° 28,57038'; W 54° 16,26326' the 17/7/16 at 13h06 UTC
End of dredging: N 9° 28,52263'; W 54° 16,29172' the 17/7/17 at 16h01 UTC

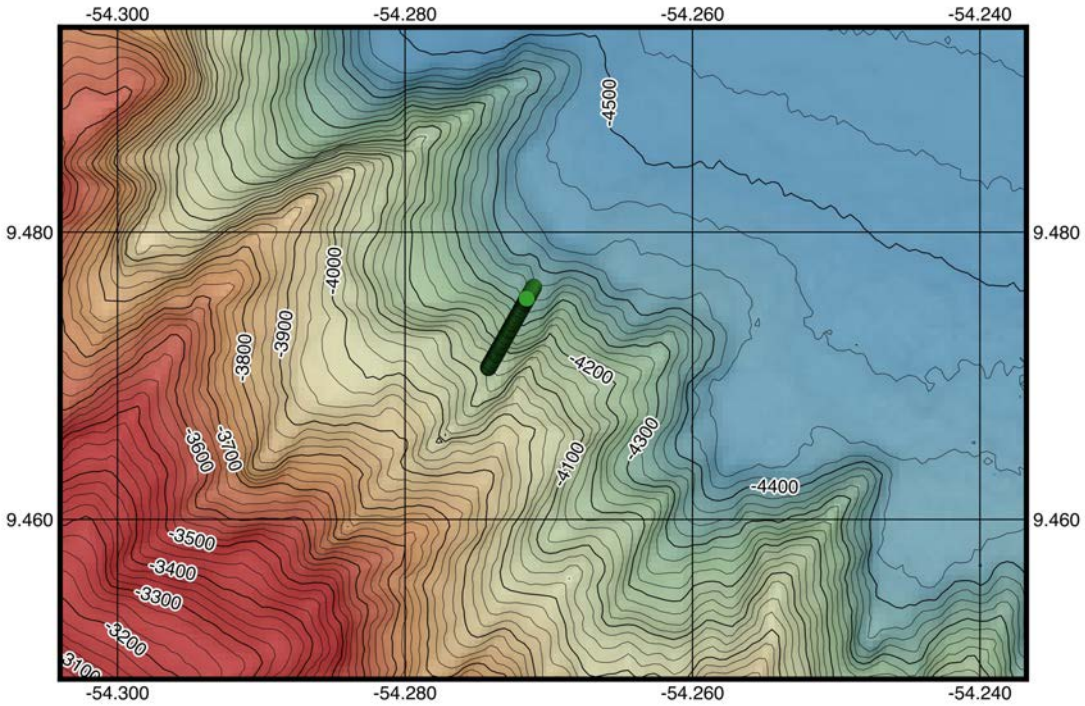

Figure 12: Location of the vessel during A1 dredging.

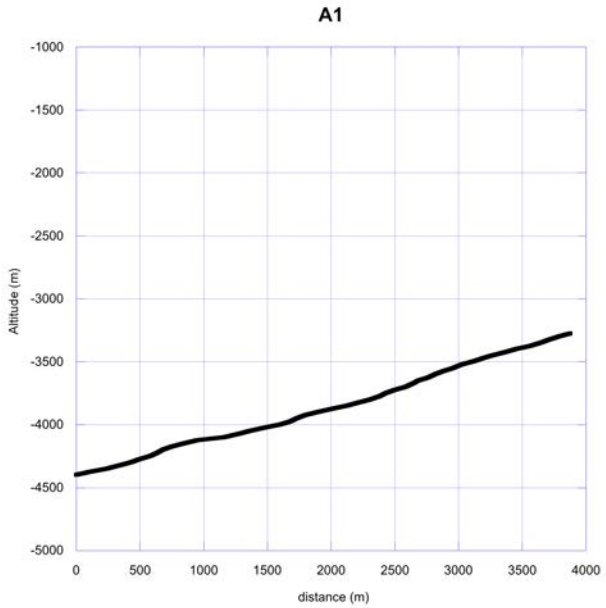

Figure 13: Bathymetric section scheduled for dredging A1.

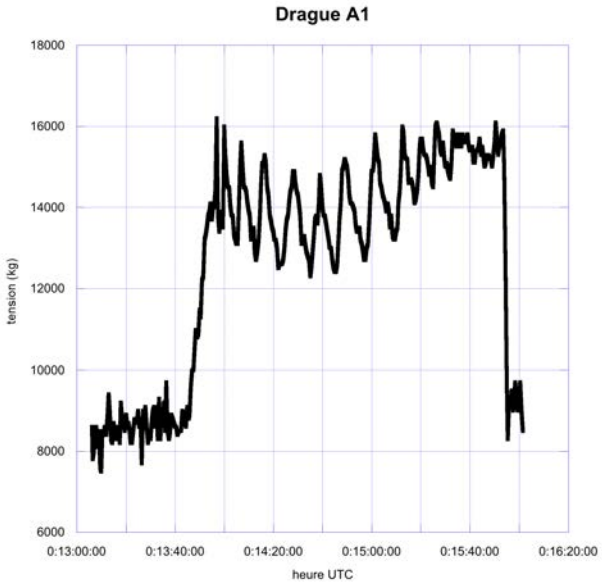

Figure 14: Tension of the cable during dredging A1.

Operations: the A1 dredge was scheduled to follow a canyon across the continental slope (Figures 12 and 13). Close to the start of dredging, the dredge hanged on, without any release of the tension that increases up to 16 tons (Figure 14). The dredge probably gets caught in an outcrop that did not break enough. To release the dredge, the vessel came back to the vertical of the locked dredge, where the tension decreased and the dredge released. The location of the vessel at the end of dredging then fits with the location of the sampling on sea floor, at circa 4350 m depth.

Rocks recovered during A1 dredge were referred as 17 samples labelled DRA-A1-1 to -17. Sample DRA-A1-17 is a bag with 24 pieces. The total recovered mass is 134 kg (Figure 15).

Figure 15: The rocks recovered by A1 dredge.

Rocks consist in yellowish-greenish sandstones. Grains are sub-angular to sub-rounded, well-sorted, currently medium to fine in size, sometimes coarse (DRA-A1-9). Fragments of bivalve shells and oyster shells (DRA-A1-12) are current (Figure 16). Shells and urchins pieces are concentrated in some layers (e.g. DRA-A1-7). Black minerals are common in these sandstones, especially in some layers. Epigenic growth of quartz can be observed around the grains, but the sandstones are not well consolidated, with the exception of some parts that are roughly perpendicular to the bedding (DRA-A1-3). There are also few fine quartz veins (DRA-A1-7). Some bedding are oblique (Figure 16). One can find burrows, soft pebbles (DRA-A1-11), and some shells are infilled by fine sediment. Only few blocks are encrusted (DRA-A1-16).

Figure 16: DRA-A1-3 (oblique bedding, oyster shell)

4.2 Site G

4.2.1 G1 dredge (Figure 5)

Location of the vessel (Figure 17) for
Dredge at sea: N 9° 25,04531'; W 54° 3,52419' the 16/7/16 at 23h23 UTC
Dredge on sea floor: N 9° 25,00201'; W 54° 3,57273' the 17/7/16 at 1h11 UTC
Start of dredging: N 9° 24,91763'; W 54° 3,66777' the 17/7/16 at 1h27 UTC
End of dredging: N 9° 24,31733'; W 54° 4,10485' the 17/7/17 at 3h10 UTC

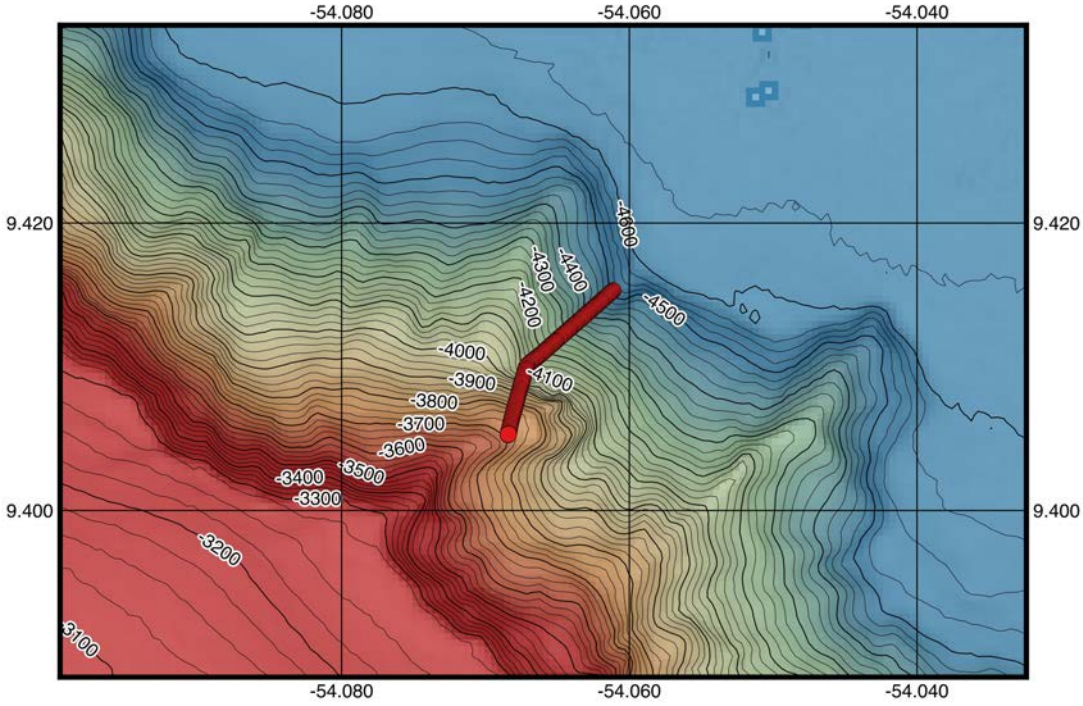

Figure 17: Location of the vessel during G1 dredge.

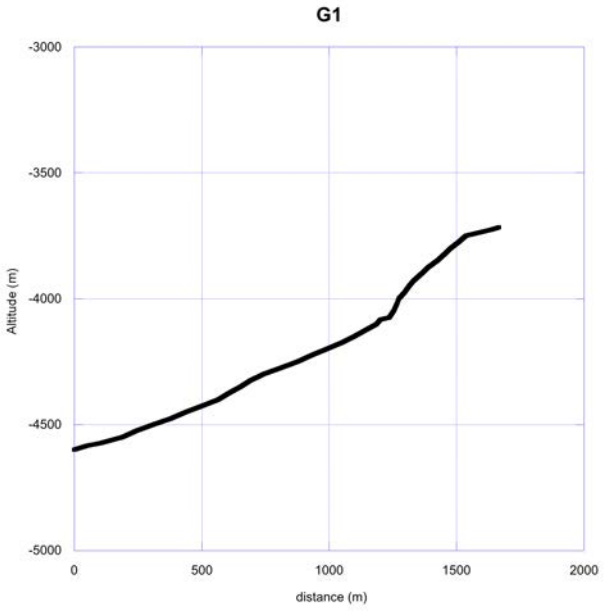

Figure 18: Scheduled bathymetric section for G1 dredge.

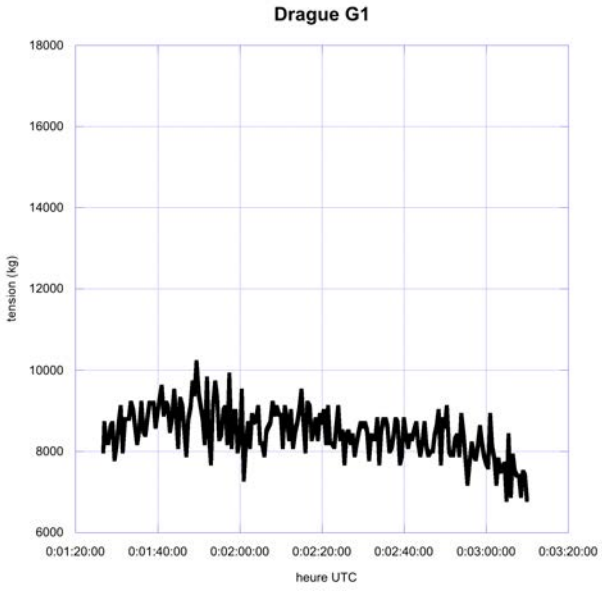

Figure 19: Tension of cable during G1 dredge.

Operations: G1 dredge was scheduled to follow a canyon, then the side of a crest northeast of site G, from 4500 to 3700 m depth (Figures 17 and 18). No hang was recorded during this dredge (Figure 19), and the dredge came back empty.

4.2.2 G2 dredge (Sperm whale spur) (Figure 5)

Location of the vessel (Figure 20) for
Dredge at sea: N 9° 27,01053'; W 54° 7,02407' the 17/7/16 at 18h56 UTC
Dredge on sea floor: N 9° 26,91604'; W 54° 6,87688' the 17/7/16 at 20h44 UTC
Start of dredging: N 9° 26,83808'; W 54° 6,88421' the 17/7/16 at 20h53 UTC
End of dredging: N 9° 26,01799'; W 54° 6,95706' the 17/7/17 at 22h40 UTC

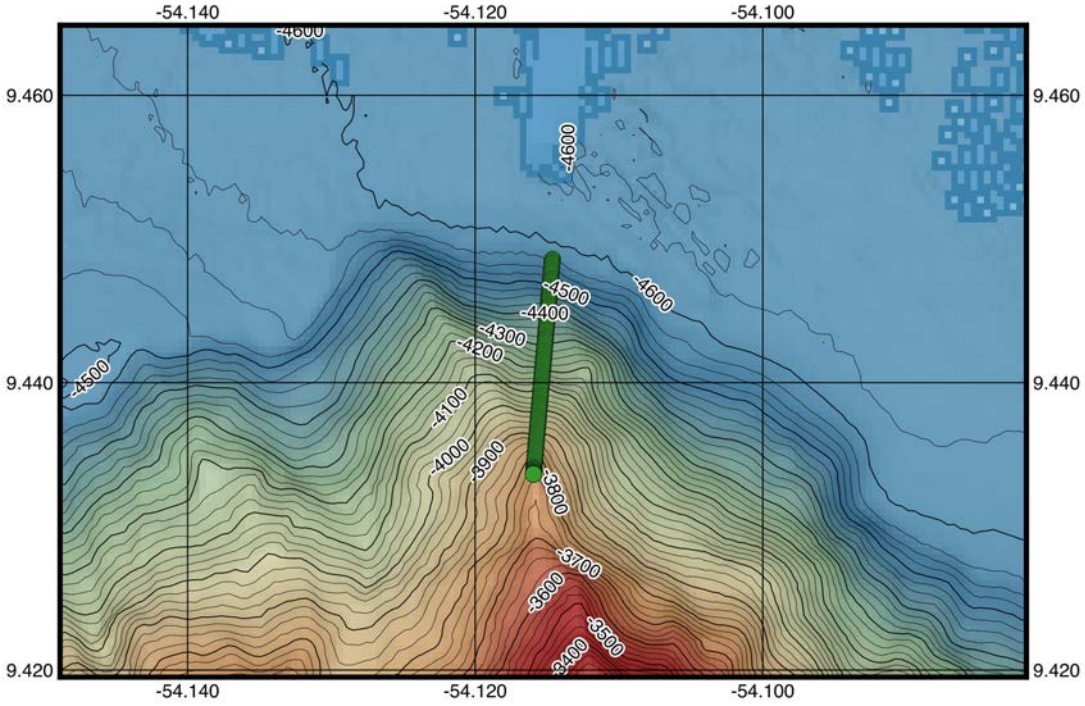

Figure 20: Location of the vessel during G2 dredge.

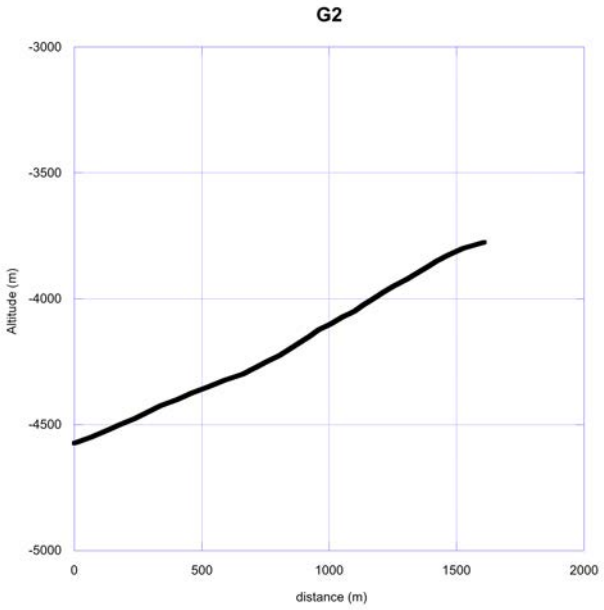

Figure 21: Scheduled bathymetric section for dredge G2.

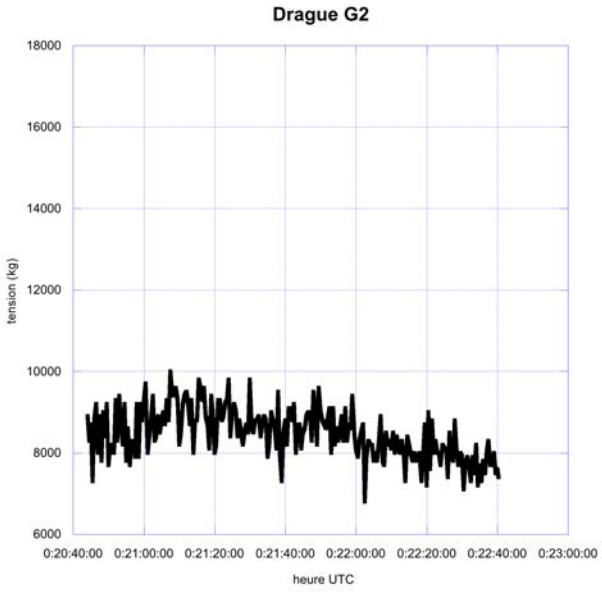

Figure 22: Tension of the cable during dredge G2.

Operations: G2 dredge was scheduled in a triangular facet at the northern end of site G, from 4580 to 3770 m depth (Figures 20 and 21). No hang was recorded during this dredge (Figure 22).

The rocks recovered from dredge G2 are all small. 14 samples were labelled DRA-G2-1 to -14, plus a bag of mud (DRA-G2-15). The recovered mass (excluding mud) is 3.5 kg (Figure 23).

Figure 23: The set of rock recovered by dredge G2.

DRA-G2-14 consists in blocks of hardened mud. All other samples are encrusted on all sides. The thickness of the crust varies from 1 mm to 1 cm in nodules. Some nodules consist in two nodules encrusted together (Figure 24). Inside the nodules, we identified two types of clasts: fine sandstones (DRA-G2-2 (Figure 25), and half of DRA-G2-9 (Figure 24)), sometimes very fine sandstones (DRA-G2-3); and claystones (DRA-G2-1, -5, and half of -9 (Figure 24)).

Figure 24: Section of sample DRA-G2-9. This nodule formed by encrusting two nodules together with several small fragments. The clast in the nodule on the right side is fine sandstone, the clast on the left side is a claystone.

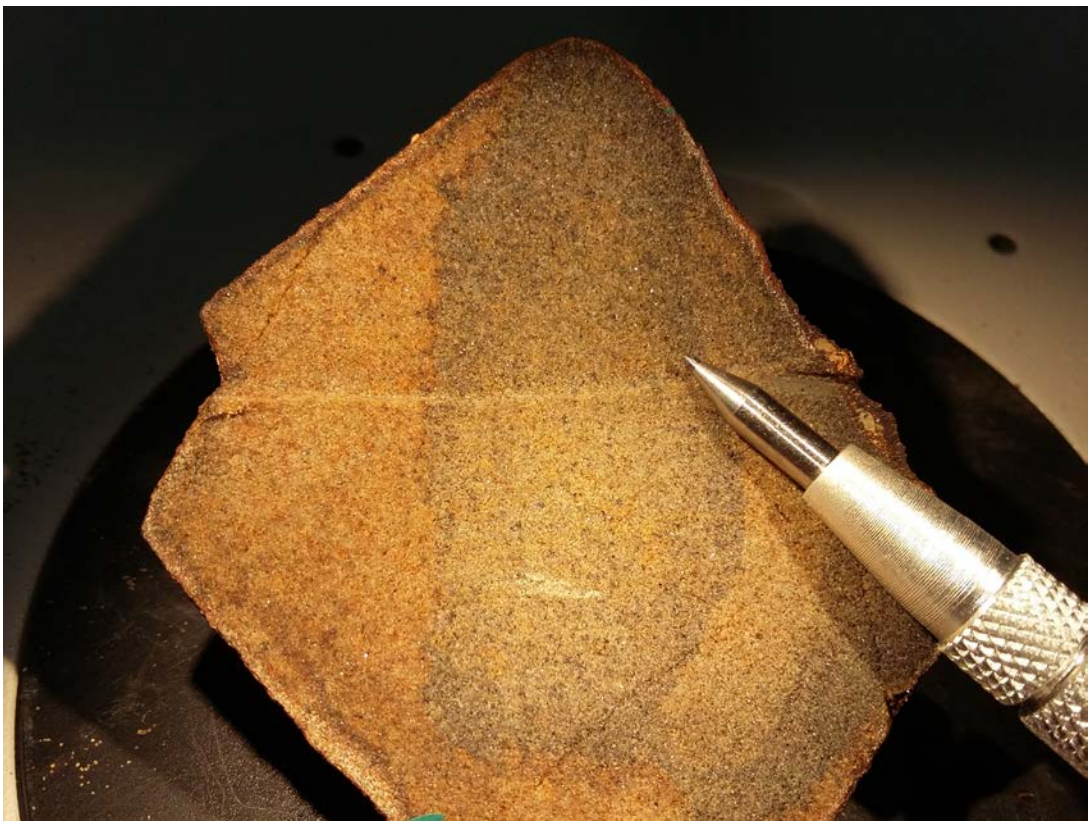

Figure 25: Section of sample DRA-G2-2: fine sandstone.

4.3 Site B

4.3.1 B1 dredge (Waste canyon) (Figure 5)

Location of the vessel (Figure 26) for
Dredge at sea: N 9° 21,35573'; W 53° 54,24244' the 16/7/16 at 11h23 UTC
Start dredging: N 9° 20,65976'; W 53° 54,08468' the 16/7/16 at 13h19 UTC
End dredging: N 9° 19,44138'; W 53° 53,6719' the 16/7/17 at 15h47 UTC

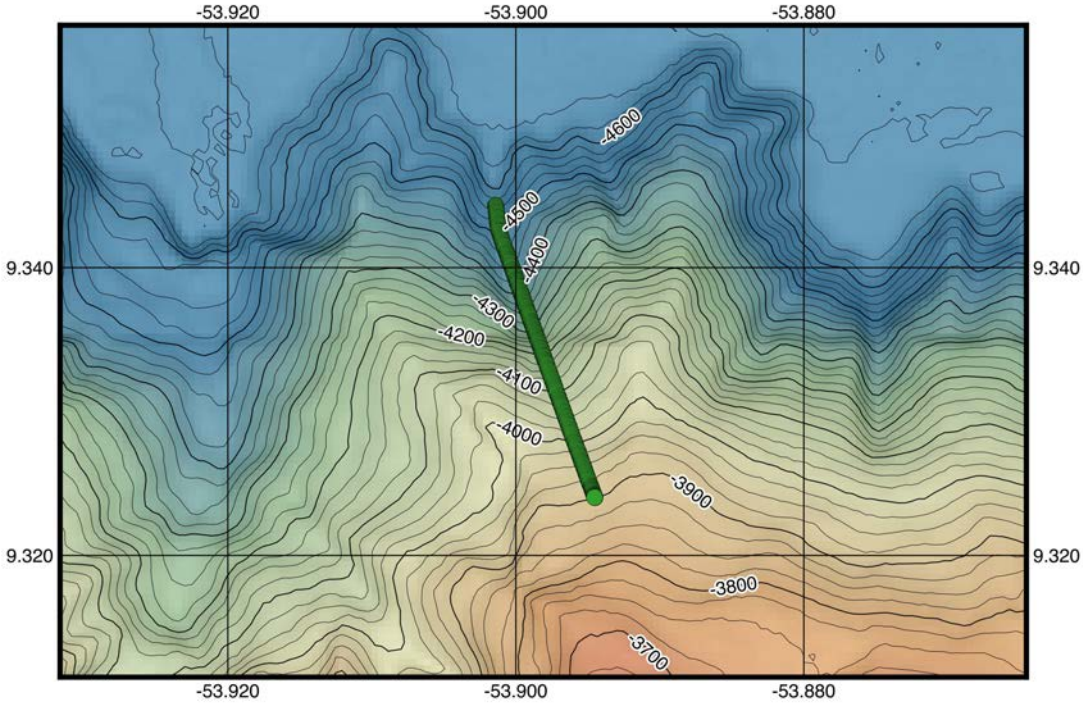

Figure 26: Location of the vessel during B1 dredge.

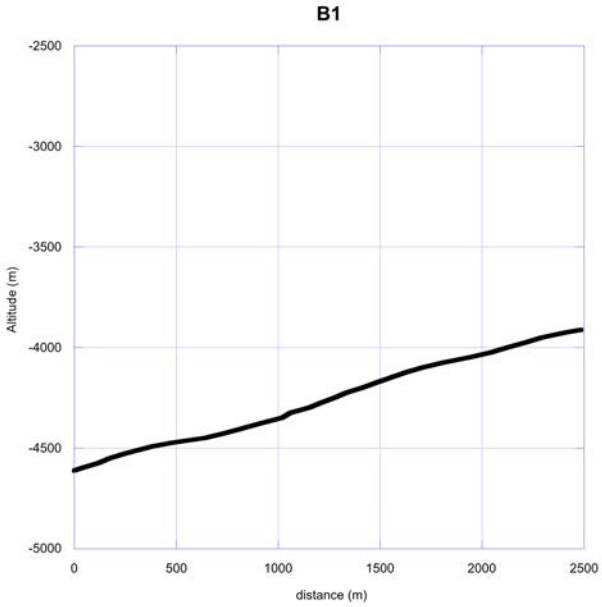

Figure 27: Scheduled bathymetric section for dredge B1.

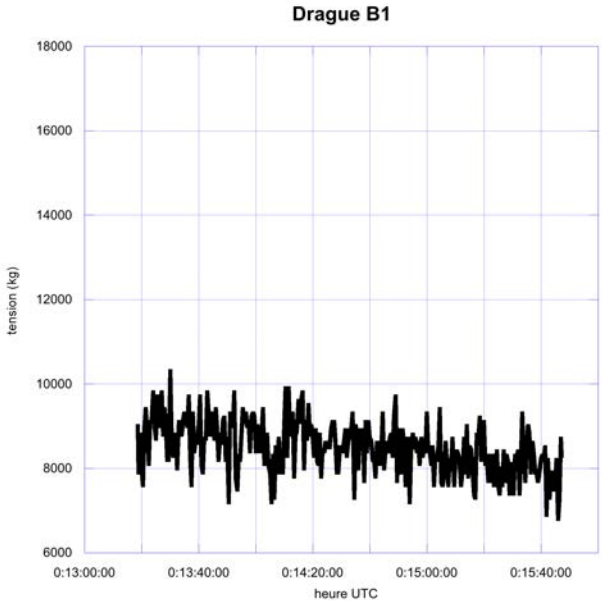

Figure 28: Tension of the cable during dredge B1.

Operations: the B1 dredge was scheduled along a canyon at site B, from 4580 to 3900 m depth (Figures 26 and 27). The aim was to collect the blocks that should have slip in the canyon. No hang was recorded during this dredge (Figure 28).

B1 dredge collected 37 rock pieces, labelled DRA-B1-1 to -37, plus ten mud clasts labelled in bag DRA-B1-38, and mud (DRA-B1-39). The total mass recovered (excluding the mud) is 25.8 kg (Figure 29).

Figure 29: View of all pieces from dredge B1.

Few samples are clay pebbles (DRA-B1-34, -35, -38). All the other rocks from dredge B1 are sandstones, from fine to coarse grain, with frequent plant fragments (DRA-B1-4, -22, 23), especially in the beds with the finest grains. One sample (DRA-B1-25) is finer (mudstone) than the others. Some blocks are graded (DRA-B1-3, -5), with cross-bedding (DRA-B1-2), convolute laminations (DRA-B1-15, -27), ripples (DRA-B1-24), or burrows (DRA-B1-18, -29). Some samples present millimetre-thick veins, probably infilled by quartz (DRA-B1-2, -12).
Three pieces of black crust were recovered (DRA-B1-32). However, the recovered rocks are not encrusted, but frequently exhibit a black patina. In section, the blocks present a peripheral alteration. Sea anemones are fixed on few slates (DRA-B1-36).
The clay pebbles are either grey (DRA-B1-35, with numerous burrows on both sides), light grey (DRA-B1-34), or white (DRA-B1-38). The white clay looks like the rocks recovered upslope in dredge B2.

4.3.2 B2 dredge (White hill) (Figure 5)

Location of the vessel (Figure 30) for
Dredge at sea: N 9° 18,71345'; W 53° 53,02835' the 16/7/16 at 17h32 UTC
Dredge on sea floor: N 9° 18,52837'; W 53° 52,8915' the 16/7/16 at 18h59 UTC
Start dredging: N 9° 18,45623'; W 53° 52,86973' the 16/7/16 at 19h10 UTC
End dredging: N 9° 17,95964'; W 53° 52,72028' the 16/7/17 at 20h21 UTC

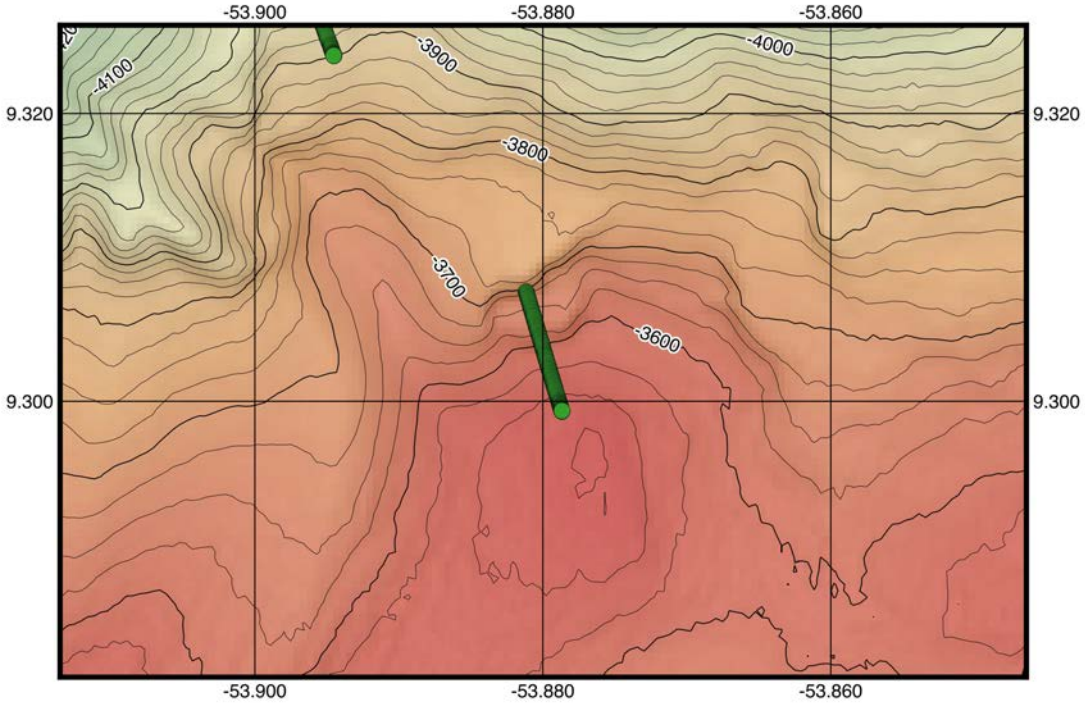

Figure 30: Location of the vessel during B2 dredge.

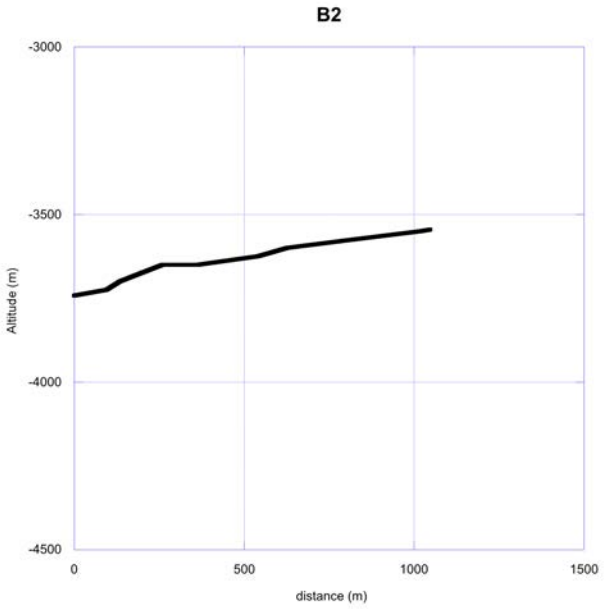

Figure 31: Scheduled bathymetric section for dredge B2.

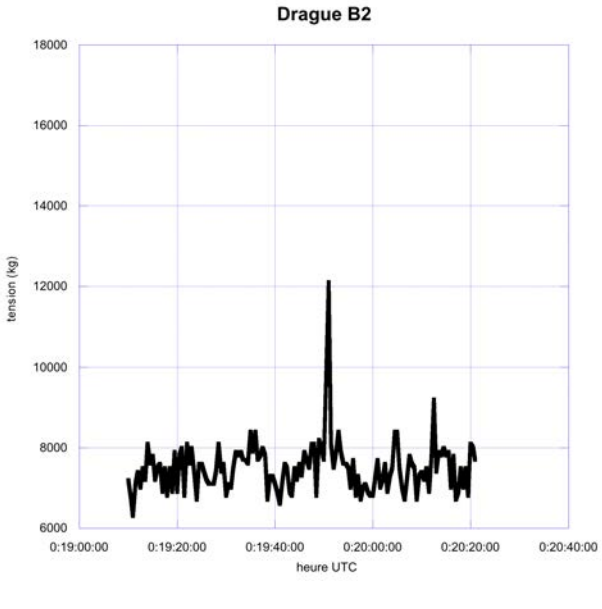

Figure 32: Tension of the cable during dredge B2.

Operations: B2 dredge was scheduled across a small cliff on the crest of site B, from 3700 to 3560 m depth (Figures 30 and 31). A hang with tension higher than 12 tons occurred at 19h50 UTC (Figure 32), probably when the rocks filled the dredge.

Dredge B2 came back full of rocks on deck, including a long block caught in the net (Figure 33). As the rocks were very homogeneous, most were thrown at sea. The kept samples were labelled DRA-B1-1 to -9. The kept mass (excluding mud) is 44 kg.

Figure 33: Pouring dredge B2 on deck.

Dredge B2 was filled by a white clayey mud, slightly indurated, with a bed 20 cm-thick more indurated. Some blocks present a hard ground locally encrusted (Figure 34), which should have been outcropping at the present day sea floor. This hard ground is perforated by numerous thin burrows in the first 5 centimetres, and then by few wide burrows (1 centimetre in diameter) at least 30 centimetres deep (Figure 35). Brown mud infills all the burrows (Figure 35). This brown mud should be the present day sedimentation.

Figure 34: DRA-B2-6a. Encrusted surface.

Figure 35: DRA-B2-3. At the top of the picture the top of the encrusted bed, with the two types of burrows infilled by a brown mud. The thin burrows only occur in the upper part, the wider ones cross cut the whole block.

4.3.3 B3 dredge (Figure 5)

Location of the vessel (Figure 36) for
Dredge at sea: N 9° 20,07817'; W 53° 49,46068' the 18/7/16 at 2h17 UTC
Dredge at sea floor: N 9° 20,01545'; W 53° 49,62053' the 18/7/16 at 3h57 UTC
Start dredging: N 9° 20,00021'; W 53° 49,69007' the 18/7/16 at 4h06 UTC
End dredging: N 9° 19,85906'; W 53° 50,32874' the 18/7/17 at 5h24 UTC

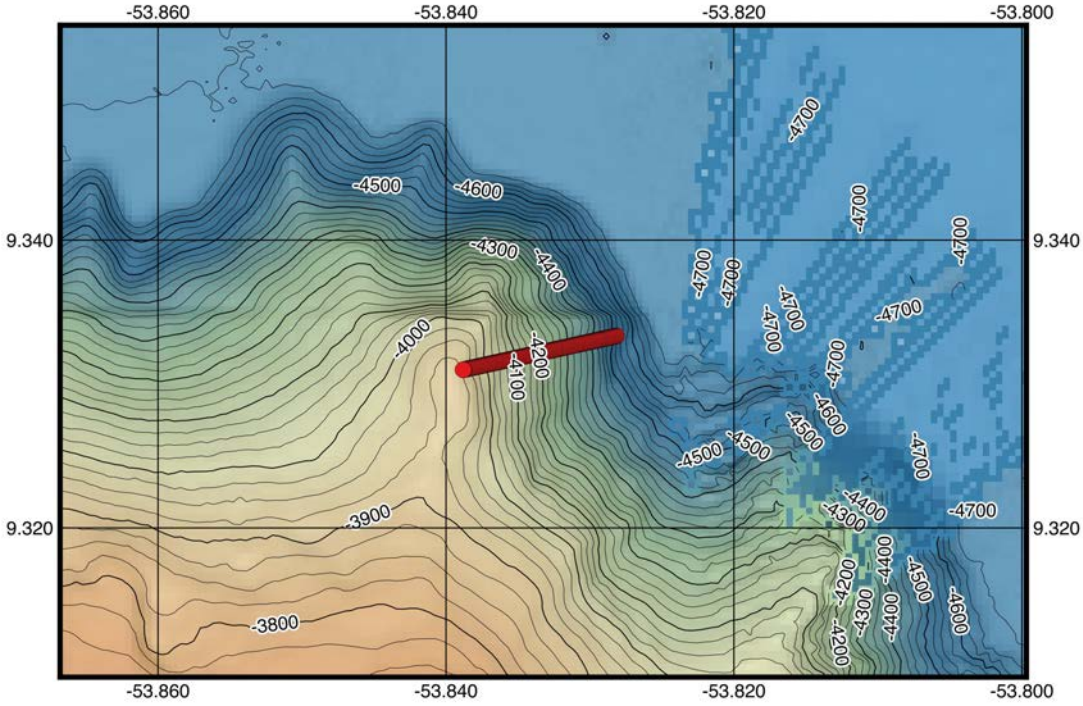

Figure 36: Location of the vessel during B3 dredge.

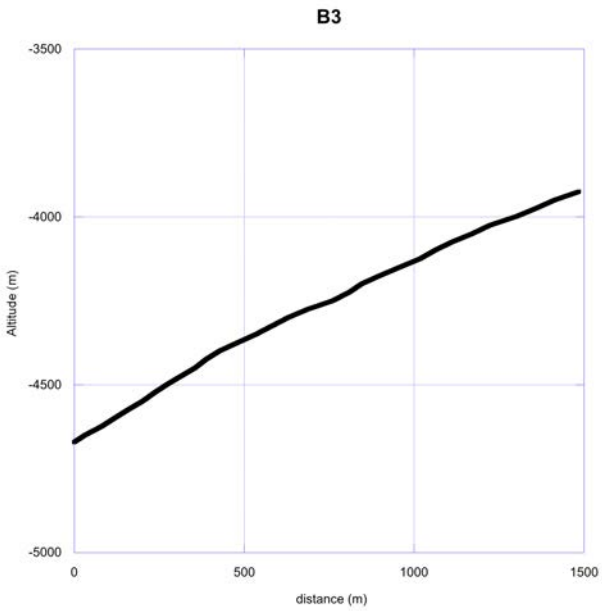

Figure 37: Scheduled bathymetric section for dredge B3.

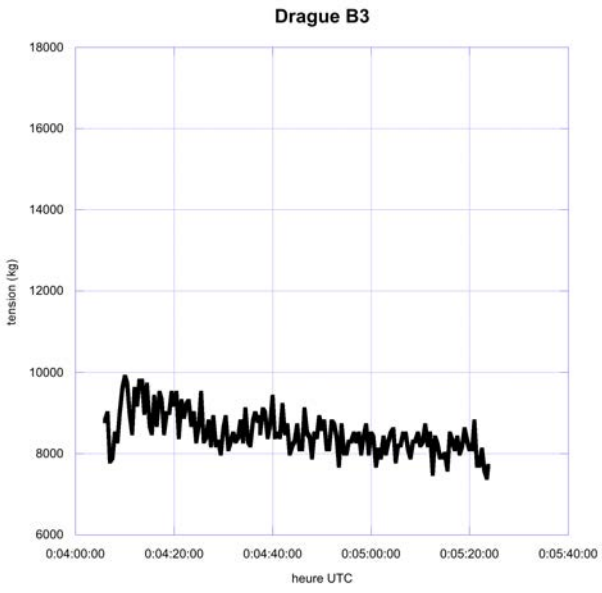

Figure 38: Tension of the cable during dredge B3.

Operations: dredge B3 was located on a planar slope northeast of site B, from 4550 and 3940 m depths (Figures 36 and 37). No hang has been recorded during this dredge (Figure 38), and the dredge came back empty.

4.4 Site C (60° ridge)

4.4.1 C1 dredge (Figure 5)

Location of the vessel (Figure 39) for
Dredge at sea: N 8° 38,0252'; W 52° 48,37761' the 15/7/16 at 14h37 UTC
Dredge on sea floor: N 8° 37,89412'; W 52° 48,40305' the 15/7/16 at 16h18 UTC
Start dredging: N 8° 37,881'; W 52° 48,40595' the 15/7/16 at 16h20 UTC
End dredging: N 8° 37,66829'; W 52° 48, 44579' the 15/7/16 at 17h06 UTC

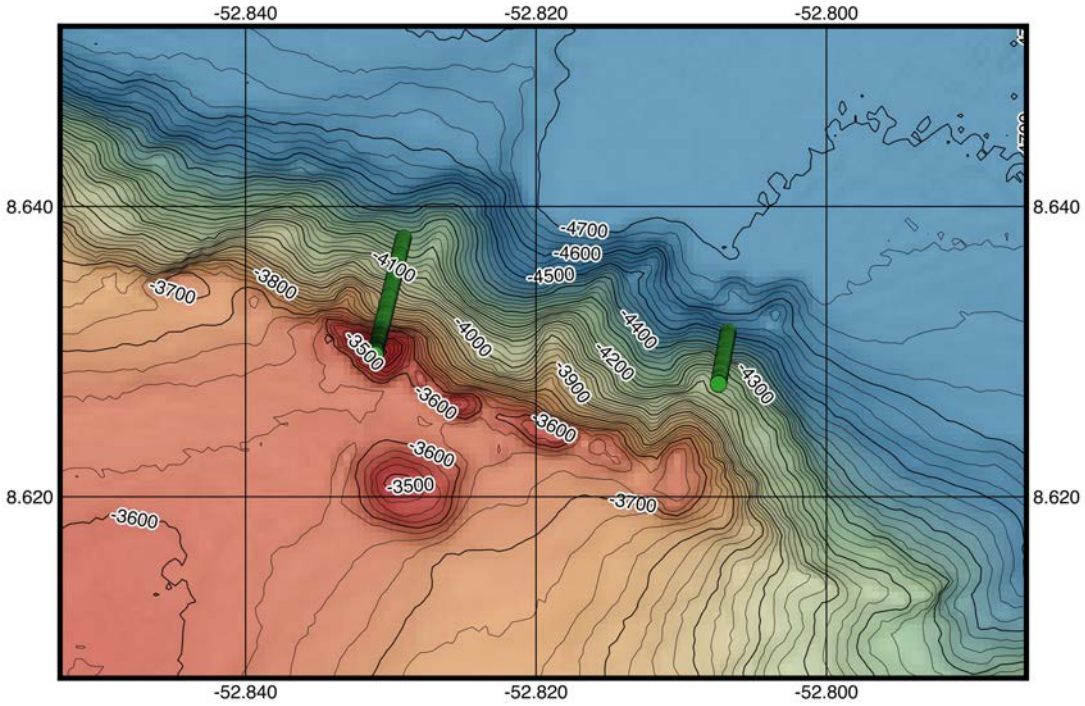

Figure 39: Location of the vessel during dredges C1 (eastward) and C2 (westward).

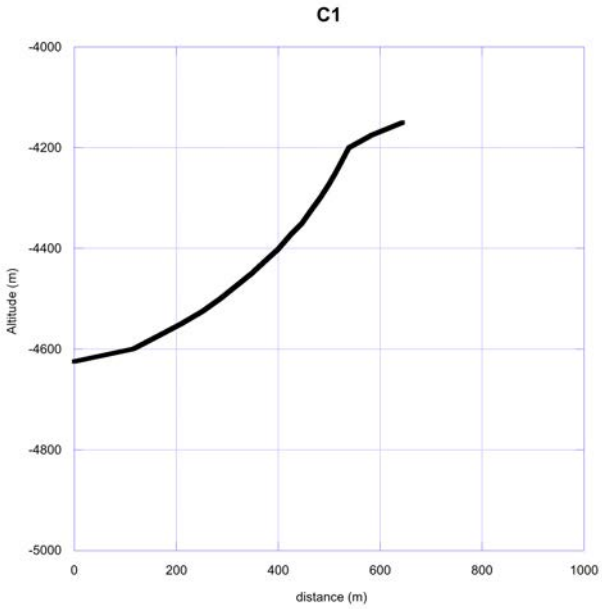

Figure 40: Scheduled bathymetric section for dredge C1.

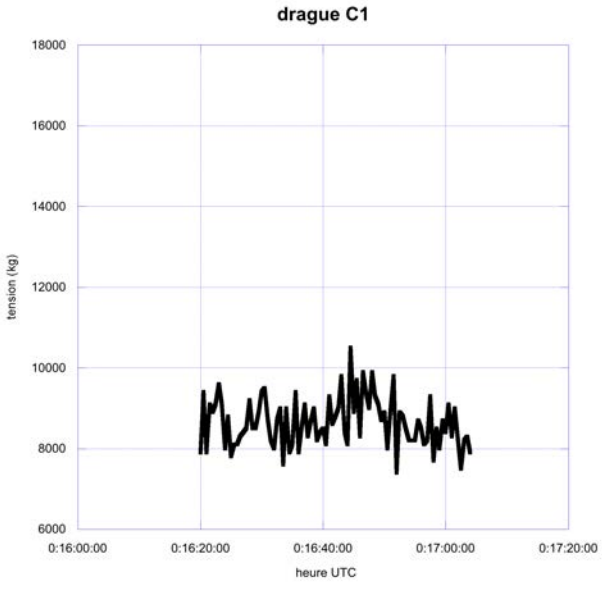

Figure 41: Tension of the cable during dredge C1.

Operations: dredge C1 crossed the lower part of the northern slope of the 60° ridge, from 4540 to 4150 m depths (Figures 39 and 40). No hang was recorded during this dredge (Figure 41).

Dredge C1 brought back 4 pieces of rock, labelled DRA-C1-1 à -4 (Figure 42). 3.4 kg of rocks were recovered.

Figure 42: All samples from dredge C1. DRA-C1-1 is broken in two pieces.

The rocks have a flatten shape that probably represent schistosity, which appear to be oblique by reference to a metamorphic foliation. The rocks have a porphyroblastic texture, with elongated quartz in a matrix made of recrystallized quartz. Locally the texture is mylonitic. Some pyrite can be found in dots and veins, and late epidotes veins cut the foliation.
Samples DRA-C1-2 and -4 have a black patina; DRA-C1-1 is encrusted on two faces, the other two faces are supposed to be on the outcrop side. The crust is thicker on one side (Figure 43). Assuming that the thicker crust is on the upper side, the foliation should dip at 45° and the schistosity should be vertical.

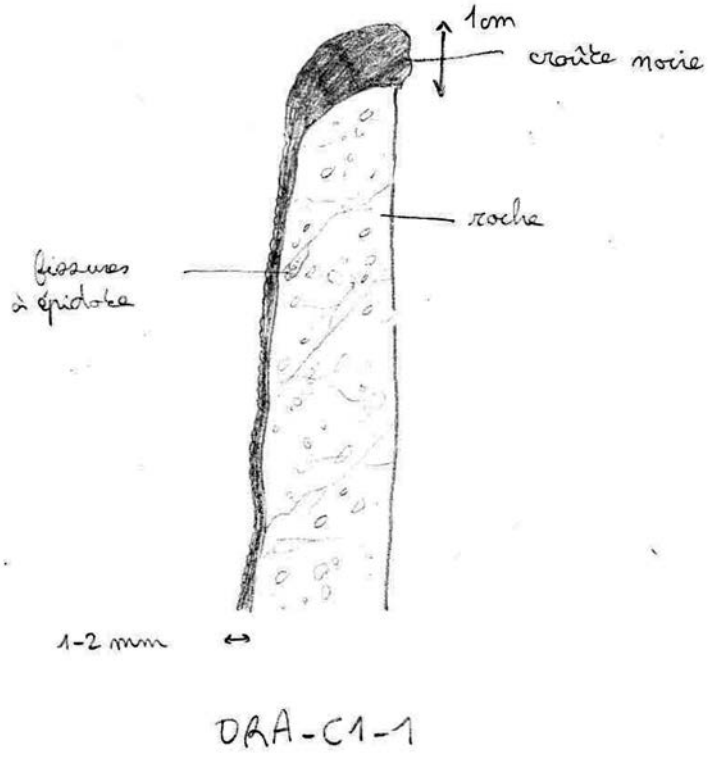

Figure 43: Drawing of a section of sample DRA-C1-1.

4.4.2 C2 dredge (Figure 5)

Location of the vessel (Figure 39) for
Dredge at sea: N 8° 38,82634'; W 52° 49,58501' the 15/7/16 at 18h50 UTC
Dredge on sea floor: N 8° 38,78242'; W 52° 49,59752' the 15/7/16 at 19h56 UTC
Start dredging: N 8° 38,27024'; W 52° 49,74686' the 15/7/16 at 21h36 UTC
End dredging: N 8° 37,7872'; W 52° 49,86528' the 15/7/16 at 22h52 UTC

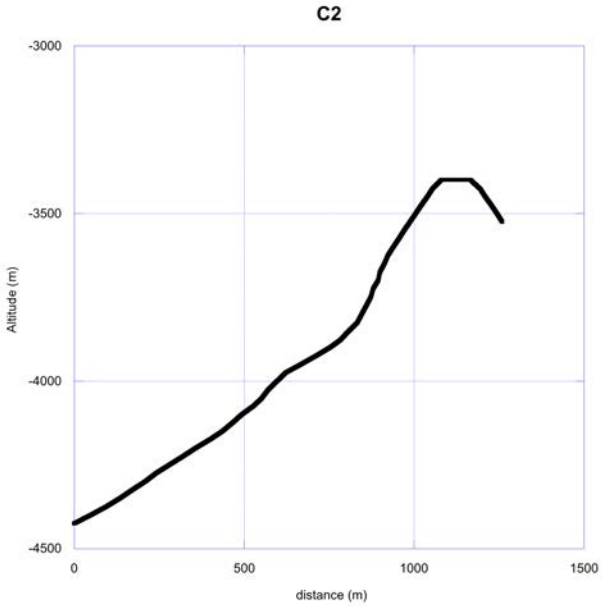

Figure 44: Scheduled bathymetric section for dredge C2.

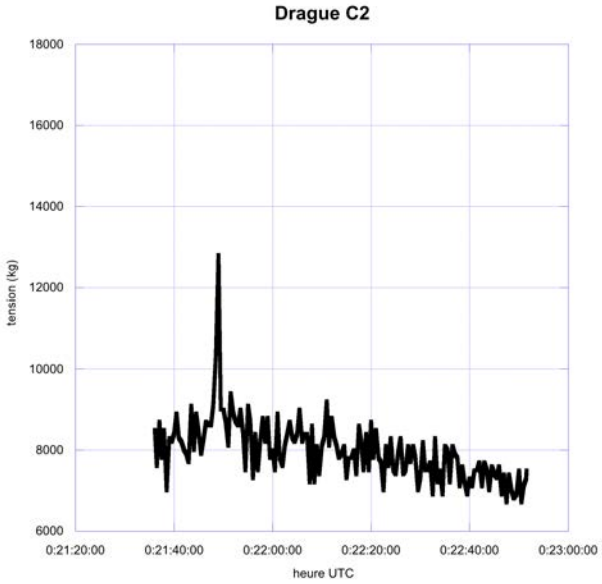

Figure 45: Tension of the cable during dredge C2.

Operations: the C2 dredge crossed the upper part of the northern slope of the 60° ridge, from 4250 m to the crest of the ridge at 3400 m depths (Figures 39 and 44). The dredge hanged on at 21h49, with the tension of the cable increasing higher than 12 tons. This is probably the time when the recovered block (Figure 45) was scrapped of the outcrop.

The C2 dredge recovered a single block, weighting 45 kg. It broke in several pieces when rolling on the deck from the dredge (Figure 46). The main part of the block was labelled DRA-C2-1, with several pieces of rock and crust that can be assembled (Figure 47). DRA-C2-2 represents four pieces of crust we were unable to assemble with the other pieces.

Figure 46: The broken block from C2 dredge on the deck.

They are two types of rocks in the block recovered by dredge C2:
- A greenish metamorphic rock mainly made of finely crystallized quartz, with locally voids that were infilled by secondary quartz (Figure 48). This rock is massive, with some fracture planes (Figure 49).
- A crust, that remains partly fixed on the bedrock. This crust lies on two sides of the block, and is thicker on one side (Figure 47). The base of the crust is laminated and concentric (parallel to the boundary of the bedrock), then columnar and radial outward (perpendicular to the boundary of the bedrock) (Figures 47 and 50). Mud fills he voids between the columns.

Figure 47: Reconstruction of the block DRA-C2-1. A crust follows the block on two sides. The crust is thicker on the right side, which may have been the upper side on the outcrop. There is no crust on two sides of the block, where it should be fixed on the outcrop.

Figure 48: Section of sample DRA-C2-1a.

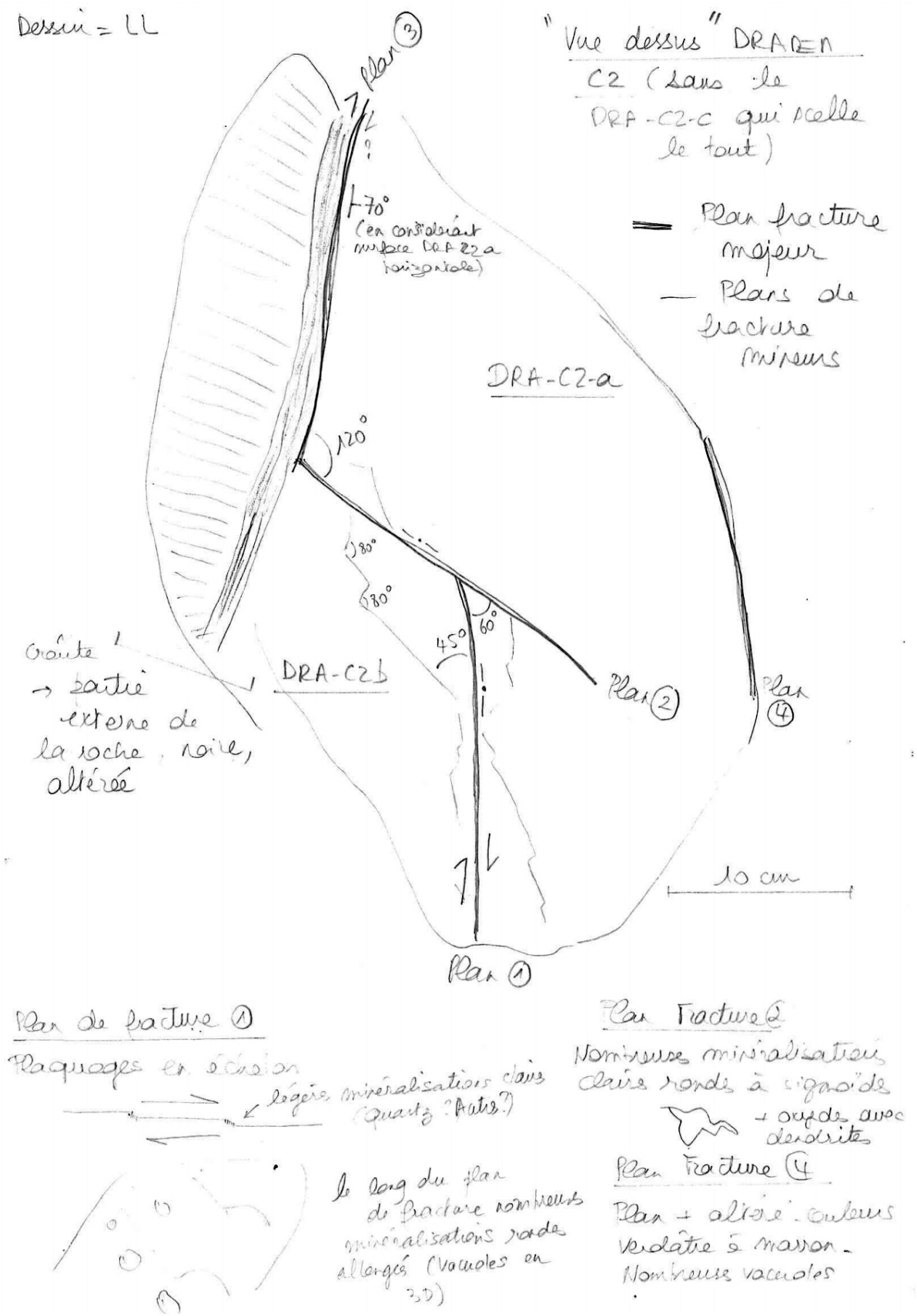

Figure 49: Drawing of pieces DRA-C2-1a and -1b once removed the overlying crust. The sides of the pieces are fracture planes.

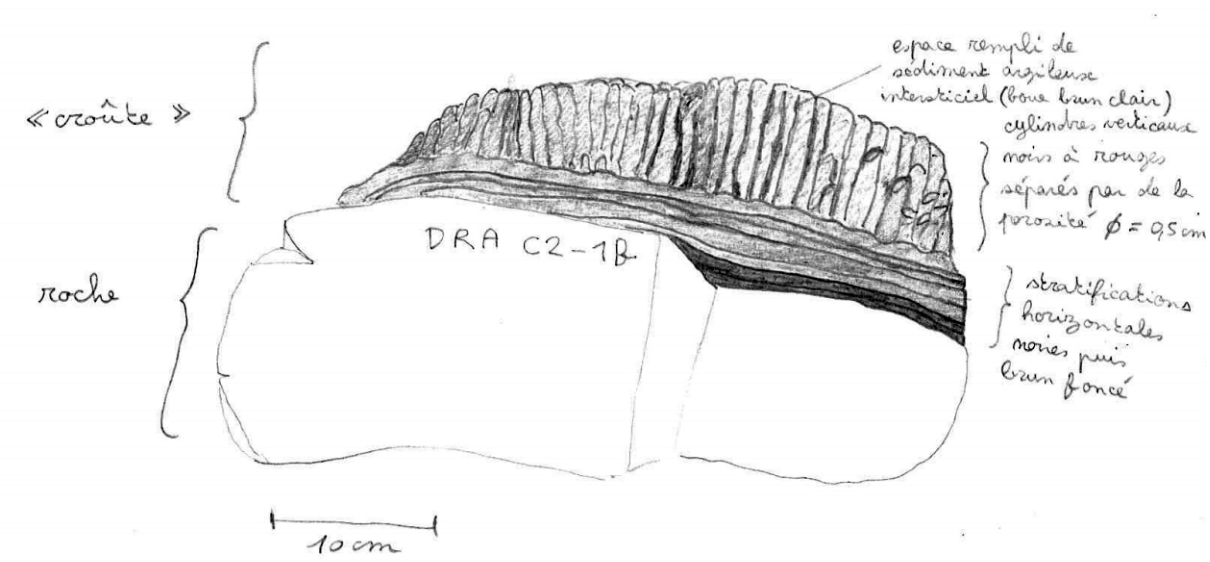

Figure 50: Drawing of sample DRA-C2-1b that includes a piece of the bedrock with its crust. View in the axis of plane 2, perpendicular to the view in figure 49.

4.5 Site E

4.5.1 E1 dredge (Bastille plateau) (Figure 5)

Location of the vessel (Figure 51) for
Dredge at sea: N 8° 29,84531'; W 52° 16,16835' the 14/7/16 at 20h33 UTC
Dredge at sea floor: N 8° 29,76229'; W 52° 16,18838' the 14/7/16 at 22h06 UTC
Start dredging: N 8° 29,75501'; W 52° 16,1903' the 14/7/16 at 22h08 UTC
End dredging: N 8° 29,3505'; W 52° 16,28629' the 14/7/16 at 23h15 UTC

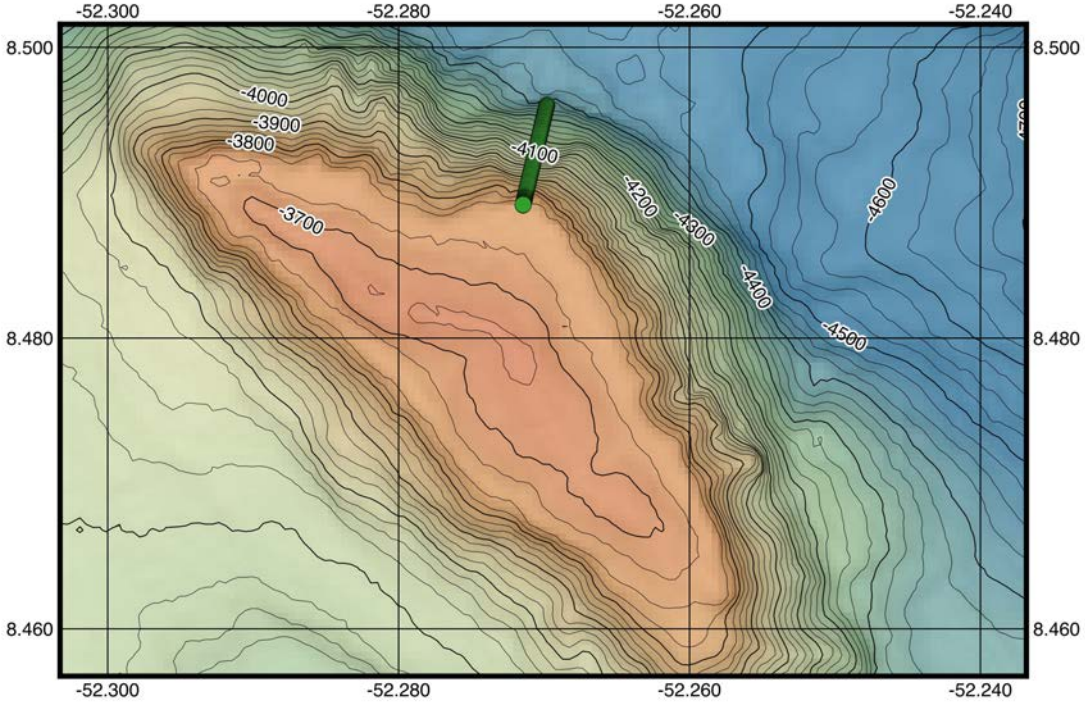

Figure 51: Location of the vessel during E1 dredge.

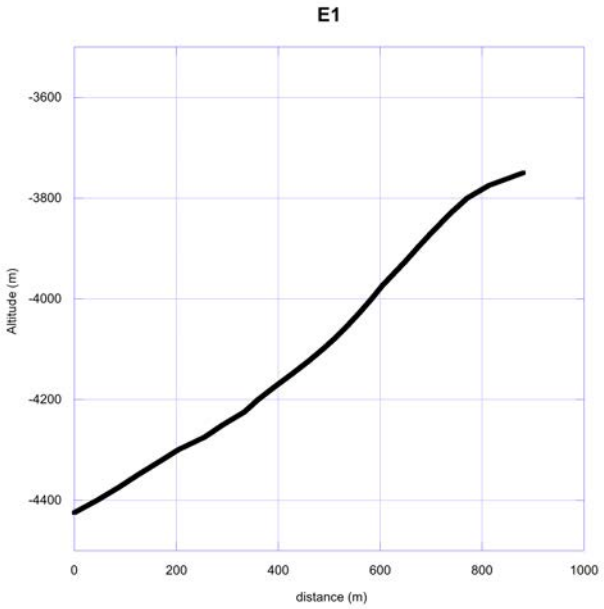

Figure 52: Scheduled bathymetric section for E1 dredge.

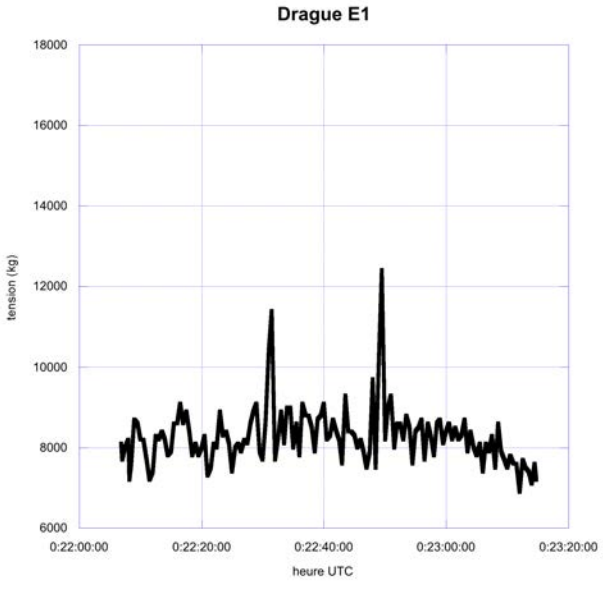

Figure 53: Tension of the cable during E1 dredge.

Operations: the E1 dredge crossed the northern slope of the Bastille plateau, from 4400 up to the flat summit of the plateau at 3740 m depth (Figures 51 and 52). Two hangs with tension increases above 11 and 12 tons were recorded during dredging at 22h31 and 22h49 (Figure 53).

The E1 dredge recovered some 70 pieces of rocks, labelled DRA-E1-1 to -7 for the biggest pieces, DRA-E1-8 for some fifty pieces, and DRA-E1-9 for a ten of pieces (Figure 54). The mass recovered was 39.5 kg.

Figure 54: All the samples recovered by E1 dredge.

We identified three types of rocks:
- Blocks with fresh surfaces, probably broken from the outcrop when the dredge hanged on. These blocks consist in a breccia with a calcareous matrix, where numerous shells or pieces of bivalves are more or less dissolved (DRA-E1-1, -5, -7) (Figures 55 and 56). Lithic clasts inside the breccia are angular, unsorted, either with a micro-granular texture (Figure 57) (with altered feldspars, black minerals, maybe quartz), or sedimentary (red or green claystones). These clasts always appear to have been altered.
- Angular blocks, not encrusted, but with black patina on surface (DRA-E1-9). These blocks have a micro-granular texture, comparable to the one observed in the breccia.
- Nodules (DRA-E1-2, -6), i.e. when cut a clast surrounded by a black laminated crust, from 1 mm to 2 cm in thickness (Figure 58). Only few nodules were cut on board. In the cut nodules, the clasts present the same nature as the clasts in the breccia (micro-granular or claystone), but no matrix was found in a nodule. The clast from the nodule DRA-E1-6 exhibits a polygenic vein, 2 cm thick. Other veins were observed in DRA-E1-9b, -9c, -9d, the last one being polygenic. Some nodules formed by agglomeration of several clasts of various natures (DRA-E1-8b), or encrusted a piece of broken crust

(DRA-E1-8d, -8f). Some millimetre clasts, and sometimes foraminifera can be seen in the lamination of the crust.

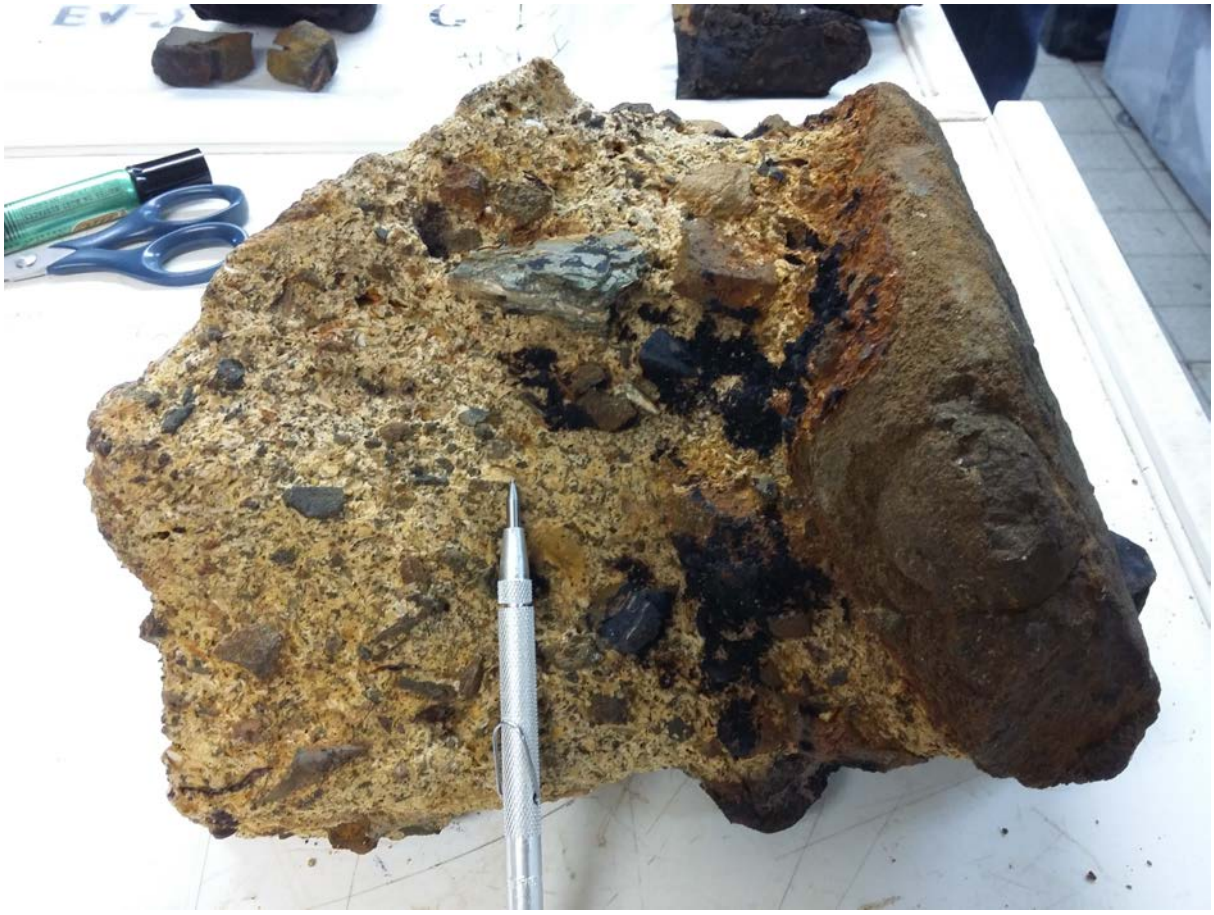

Figure 55: Breccia (DRA-E1-1).

Figure 56: Section in the sedimentary matrix of the breccia (DRA-E1-7).

Figure 57: Section in a micro-granular clast from the breccia (DRA-E1-5).

Figure 58: Sedimentary clast (claystone) in a nodule (DRA-E1-8).

4.5.2 E2 dredge (Figure 5)

Location of the vessel (Figure 59) for
Dredge at sea: N 8° 31,27638'; W 52° 14,74566' the 15/7/16 at 20h33 UTC
Dredge on the sea floor and start dredging: N 8° 31,21828'; W 52° 14,78149' the 15/7/16 at 3h27 UTC
End dredging: N 8° 30,87285'; W 52° 14,99198' the 15/7/16 at 4h36 UTC

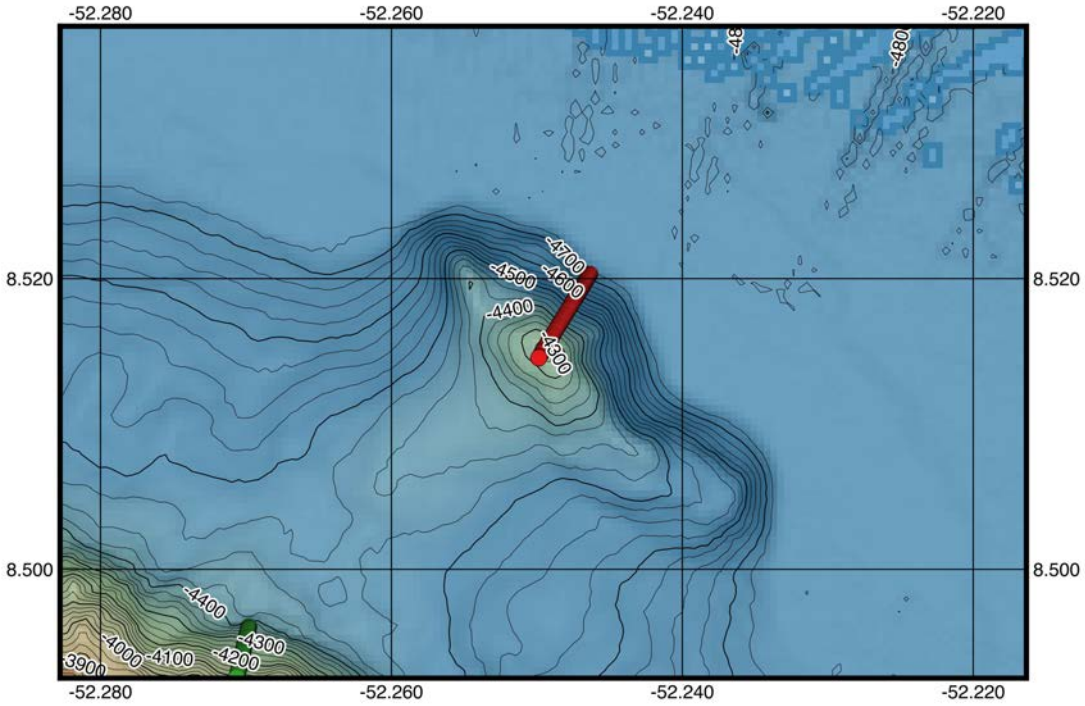

Figure 59: Location of the vessel during E2 dredge.

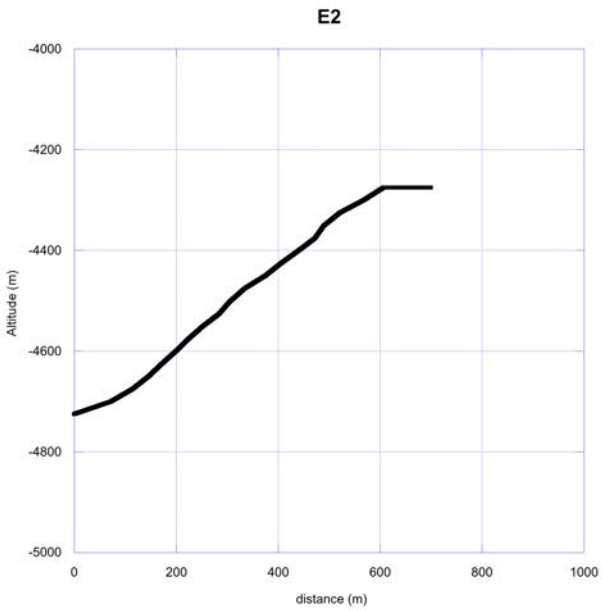

Figure 60: Scheduled bathymetric section for E2 dredge.

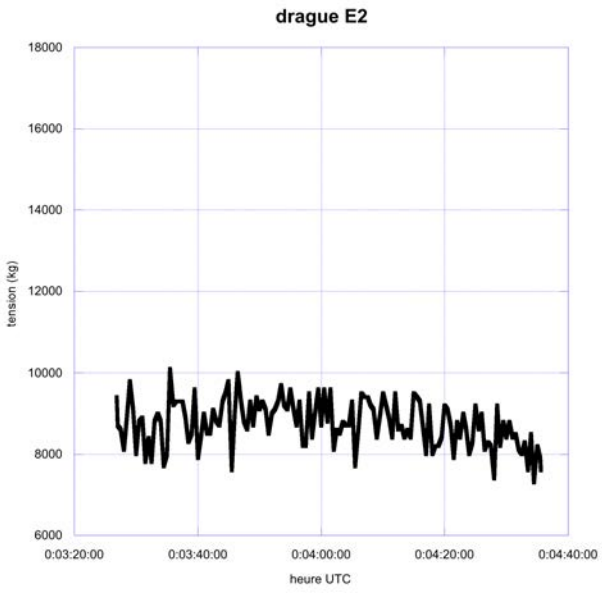

Figure 61: Tension of the cable during E2 dredge.

Operations: the E2 dredge was located on the northeastern slope of a small ridge northeast of the Bastille plateau, from 4700 to 4300 m depths (Figures 59 and 60). No hang was recorded during this dredge (Figure 61), and the dredge came back empty.

4.6 Site F

4.6.1 F1 dredge (Goleador cliff) (Figure 5)

Location of the vessel (Figure 62) for
Dredge at sea: N 7° 57,88517'; W 51° 48,98932' the 14/7/16 at 2h33 UTC
Dredge on sea floor: N 7° 57,93286'; W 51° 49,08385' the 14/7/16 at 4h38 UTC
End dredging: N 7° 58,13161'; W 51° 49,436' the 14/7/16 at 5h54 UTC

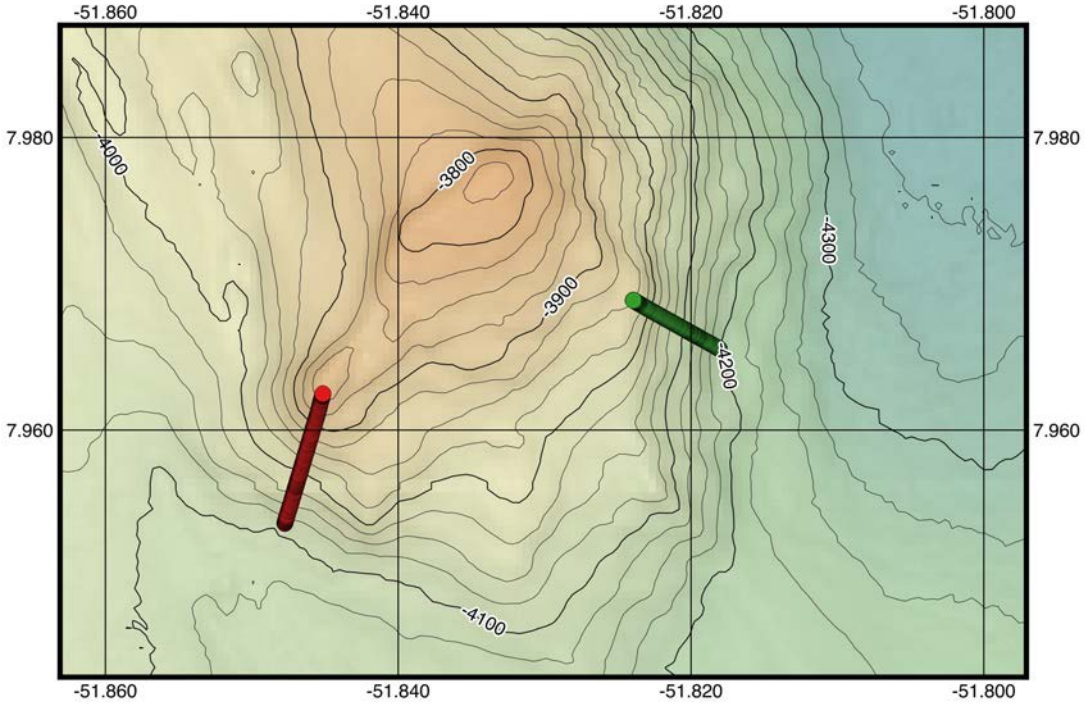

Figure 62: Location of the vessel during dredges F1 (eastward) and F2 (westward).

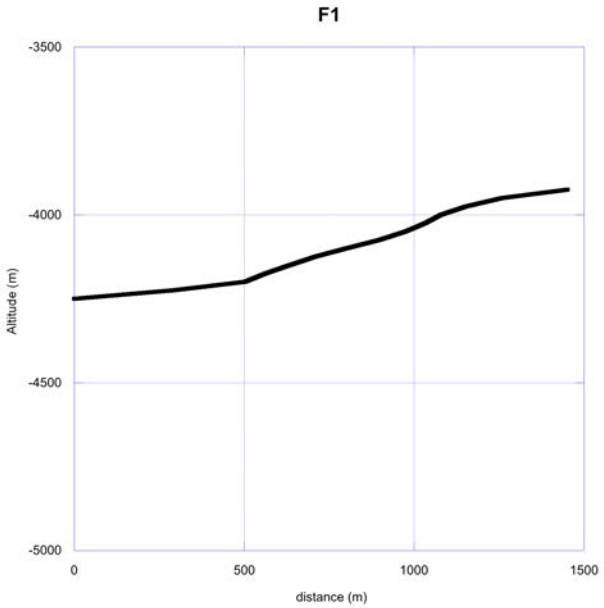

Figure 63: Scheduled bathymetric section for F1 dredge.

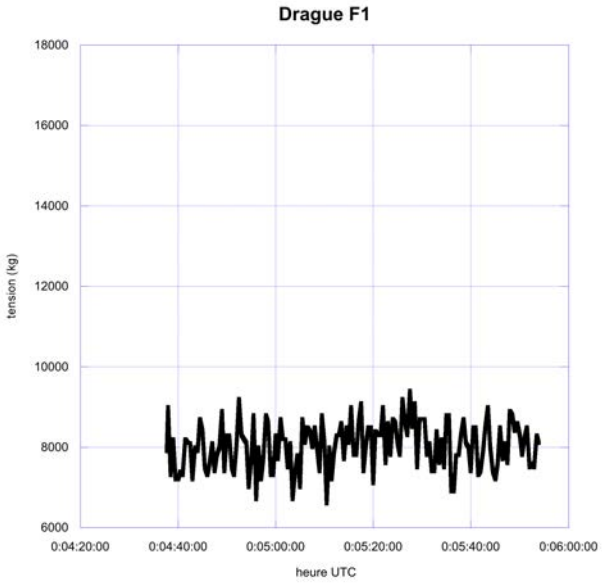

Figure 64: Tension of the cable during F1 dredge.

Operations: F1 dredge was on the eastern slope of site F, from 4200 to 3840 m depths (Figures 62 and 63). No hang was recorded during dredging (Figure 64), but the dredge recovered a massive block and some fragments. F1 dredge recovered a total of 17 rock pieces, labelled DRA-F1-1 to -9, and DRA-F1-10 for 8 pieces that probably broke from the biggest piece DRA-F1-1 (Figure 65). 56.4 kg were recovered.

The biggest piece (DRA-F1-1) has a bowl shape, approximately 35 cm in diameter and 53 kg in weight (Figures 65 and 66). This bowl was too heavy to be displaced easily, and we broke it on board in 9 pieces. All the rocks from dredge F1 consist in coarse sandstone (Figure 66), with angular quartz grains (80% of the grains), and micas, altered minerals (including feldspars), black minerals, and locally a clay matrix around the quartz grains. Because of a peripheral altered corona all around DRA-F1-1, we believe that this bowl was standing on the sea floor, and was not torn away by the dredge, but rolled inside the net.

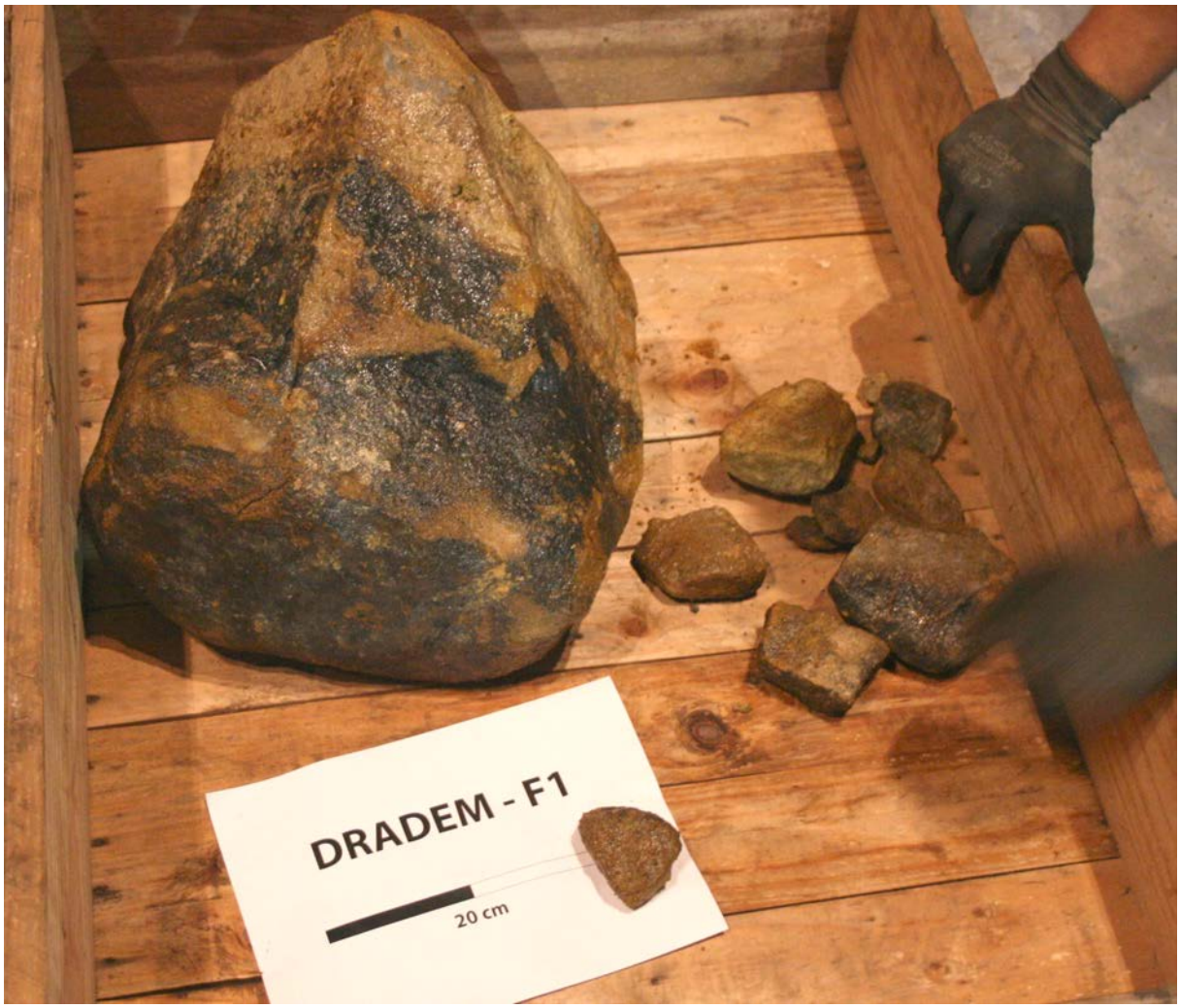

Figure 65: the samples from F1 dredge.

Figure 66: A section (DRA-F1-1b) of block DRA-F1-1.

4.6.2 F2 dredge (Figure 5)

Location of the vessel (Figure 62) for
Dredge at sea: N 7° 57,11273'; W 51° 50,89109' the 14/7/16 at 8h18 UTC
Dredge on sea floor: N 7° 57,21653'; W 51° 50,86498' the 14/7/16 t 10h10 UTC
Start dredging: N 7° 57,23017'; W 51° 50,86108' the 14/7/16 at 10h13 UTC
End dredging: N 7° 57,74869'; W 51° 50,70895' the 14/7/16 at 11h44 UTC

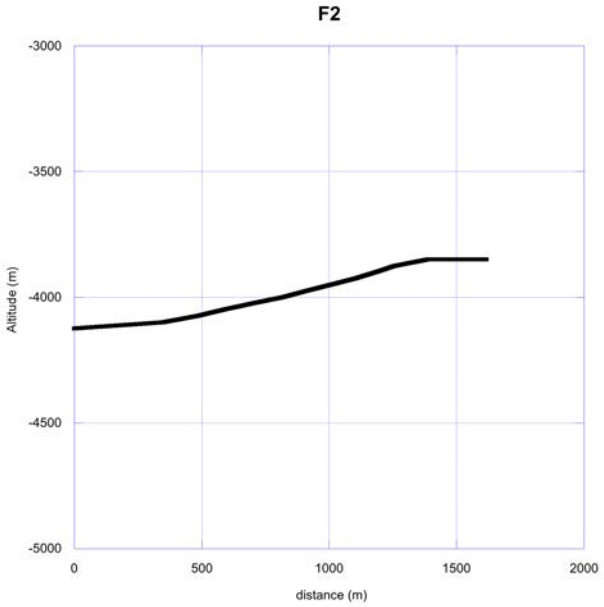

Figure 67: Scheduled bathymetric section for F2 dredge.

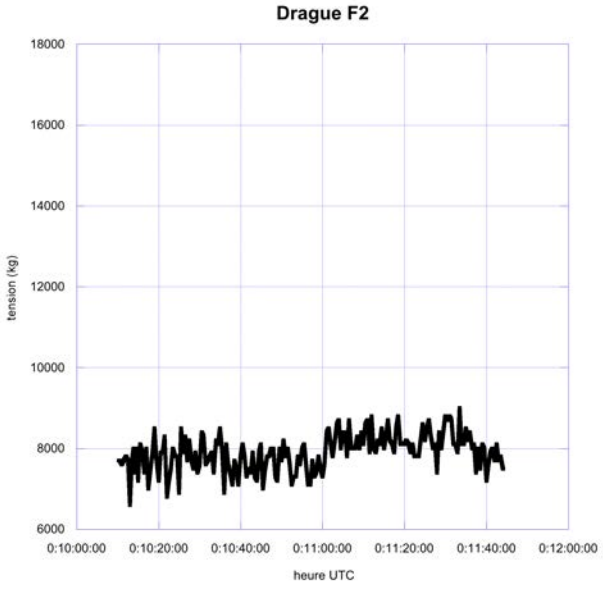

Figure 68: Tension of the cable during F2 dredge.

Operations: F2 dredge was located southwest of site F, from 4100 to 3860 m depths (Figures 62 and 67). No hang was recorded during this dredge (Figure 68), and the dredge came back empty.

4.7 Organisms in the dredges

There were no organisms in the dredges, with the only exception of sea anemones fixed on slates in dredge B1.

5. Synthesis

The occurrence of nodules and of numerous encrusted rocks in the dredges probably indicates that rocks were outcropping on the sea floor, collapsed, and were exposed to seawater during long periods of time. This may confirm the very low sedimentation rates for the recent times, probably because of strong currents in the deep waters (Loncke et al., 2016; Tallobre et al., 2016).

The white clays from B2 dredge, and the similar clayey clasts from the underlying dredge B1, are the only pelagic sediments we recovered. These sediments are probably younger than the upper Albian, which is (as far as we know from the geological history of the Demerara plateau) the more recent time when sediments deposited at shallow depths (Mercier de Lépinay 2016). These pelagic sediments are probably Cainozoic in age, and should be compared to the sediments cored in the same area in Leg ODP 207 drill holes.

With the exception of these clays, all the sedimentary rocks recovered in the dredges are detrital, and formed at shallow water depths (dredges A1, G2, B1, E1, F1), or possibly in aerial setting for F1. These rocks are consequently probably older than the upper Albian. They represent either the erosion of a distant basement, or probably close for the coarse sandstones from dredge F1, and eroded in situ for the clasts in the breccia from dredge E1.

The sedimentary rocks do not appear to have been deformed. But the very steep structure of the 60° ridge is associated with metamorphic rocks, which exhibit foliation and schistosity.

Finally, it is necessary to underline the micro-granular texture of numerous blocks in the breccia of E1 dredge, that indicate the close occurrence, and maybe the outcropping of magmatic rocks we will need to identify.

These samples will be studied in detail, especially for dating purposes. They will be integrated in the history of the Demerara plateau, and may bring crucial information on vertical displacements. Right now one can ask what are the mechanisms that allow the subsidence of sediments deposited at sea level, and sampled at 4000 m depths, in an area where tectonic structures associated to crustal thinning, and especially normal faults, are lacking.

6. Abstract

The DRADEM campaign was performed from July 9th to 21th 2016 on board the Pourquoi Pas?, in the Exclusive Economic Zones of Suriname and French Guyana. This campaign belongs to a program dedicated to geological investigations of the Demerara plateau, following the GUYAPLAC (2003) and IGUANES (2013) campaigns, and before the MARGATS campaign (2016). The aims of the DRADEM campaign were to map the continental slope of the transform margin north of the Demerara plateau, and to dredge the rocks outcropping in the slope.
We completed the bathymetric mapping of the continental slope, including part of the edged of the Demerara plateau. These new bathymetric data confirm the segmentation of the transform margin in three parts with very different morphologies. In addition, two circular structures were interpreted as mud volcanoes, one on the northern edge of the plateau, the other one in the distal part of the Orinoco deep sea fan.
Twelve dredges were performed between 4700 and 3500 m depths. Four from these twelve did not recovered rocks. The eight others brought back variables amounts of rocks, often encrusted, but of various natures: sediments (breccia, coarse sandstones, sandstones with plants debris, sandstones with shells, clayey ooze), micro-granular rocks and metamorphic rocks (including mylonite). The nature of the rocks was determined from macroscopic observation of the rocks, which are currently altered. Of course, these determinations need to be validated and specified by onshore further studies. Anyway, most of these rocks were previously unknown in this area, and they will strongly influence our understanding of the structure and evolution of this margin. They evidence huge vertical displacements that brought back to the surface some of these rocks that formed in a deep setting.

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