5.3.2 Offshore coastal studies - shoreface profile measurements

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5.3.2.1 Introduction

The coastal team of the expedition had continued bathymetric measurements of the shoreface profiles started in 1999. The measurement goal is investigation of the morphology and dynamics of the shoreface in the Arctic seas. In 2002 these measurements were carried out for the first time on the islands of New Siberian Archipelago. The team surveyed 10 coastal sections in the Laptev and East-Siberian seas on the islands Stolbovoy, Belkovsky, Kotelny, Novaya Sibir, Maly Lakhovsky and 1 section on the south coast of Dmitry Laptev Strait (Fig. 5.3.1-1).

The ice complex sediments are wide spread on these islands just as on the continental coast but on the islands the ice complex is based on the bedrock. The bedrock is usually situated near the sea level or above it. On the continental coast the bedrock under the ice complex is absent. Therefore the geological and geocryological conditions of the shoreface evolution on the islands and on the continent differ strongly.

One section composed of ice complex was surveyed on the south coast of the Dmitry Laptev Strait (11 in Fig. 5.3.1-1). The ice complex is underlayed there by a thickness of clayey silts with low ice content and small ice wedges. The top of this thickness in coastal outcrops rises as high as 8.5 m above the sea level. The bedrock was not observed on this coast.

Beside the coasts composed of ice complex, a section composed of weekly lithified low Quaternary and upper Neogenic (Pleocene) sediments with low ice content was surveyed on Novaya Sibir Island (6 in Fig. 5.3.1-1). These sediments do not contain ice wedges and easily undergo erosion by waves and water streams.

Two sections composed of sands with low ice content were surveyed on the south coast of Bunge Land (5 and 8 in Fig. 5.3.1-1). Their composition is identical with the coasts of Arga Island in the Lena River delta, which were surveyed in 1999 and 2001. But there are significant morphological differences. For example, unlike Arga Island, the shore on Bunge Land is aligned, lagoons and barrier islands are absent, wind surges are low.

The lease of the ship «Pavel Bashmakov» from August 14 until September 2 limited the working time of the coastal team. During this time 14 shoreface profiles on 9 sections of the coast were measured (1,3,4,5,6,8,9,10,11 in Fig. 5.3.1-1). Twenty one profiles, including profiles along the tracks of bathymetric measurements, was taken from bathymetric charts to study shoreface dynamics. The scales of charts used are in the range of 1:200 000 - 1:25 000. The charts are based on the measurements carried out 16-43 years ago.

As a whole the data obtained will give a possibility to improve our understanding of the shoreface shape in different geological, geocryological and hydrological conditions and to supplement considerably the data base on the formation of the Arctic shoreface morphology.

5.3.2.2 Methods

The tracks of shoreface profile measurements were chosen using the State Map of Quaternary Formations in the New Siberian Islands Area at the 1:100 000 scale published in 1998, navigation charts at different scale and results of visual survey of the coasts.

The water depth measurements were carried out the same way as in 2001 using a portable echo-sounder from a motor boat. All data were measured every second and stored on a computer. The accuracy of measurements was 1 cm for the water depth. The linear increment of measurements along the track was 2 m at a speed of 5 km/hour. Surface sediments for sedimentological analyses were sampled every 1 m water depth.

Tracks were run along courses chosen beforehand and monitored on a computer display. The standard deviation of the actual azimuth from its mean value during the boat movement was in the range of 4-6 degrees. The maximum short-term deviations reached 20 degrees. A diagram of recorded azimuth fluctuations along the track of the shoreface profile of Bunge Land lower part is presented in Fig. 5.3.2-1 for example. During the recording of this profile the mean value of the azimuth was 155.5° with a standard deviation 4.2°. An inclination of the trend line in Fig. 5.3.2-1 shows a small deviation of the measured track from a strait line.

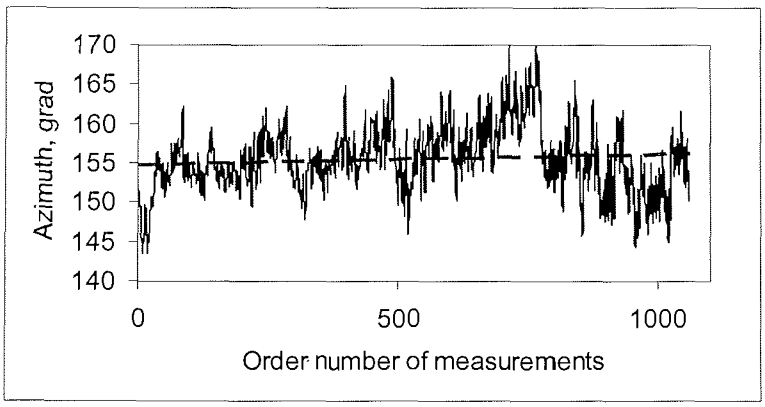

Figure 5.3.2-1: A diagram of measured azimuth fluctuations during the survey of the shoreface profile on the Bunge Land low part.

The horizontal distances between all points of depth measurement and the first point nearest to the shore were calculated for the purpose of drawing complete shoreface profiles. The calculations were made using software kindly provided by Dr. D. Drozdov (Cryosphere Institute, RAS). Another software was used to verify results of calculations with the help of exact geodetic formulas. The divergences of calculations by the use of two kinds of software were negligible.

As it was marked in the previous cruise reports; one of the main tasks of the shoreface morphology investigations is to study the shoreface shape by means of mathematical description. The AISN Corporation software TableCurve 2D v5 will be used for this purpose. The TableCurve presents the widest possibilities for automated processing of the shoreface measurement results, extensive selection of mathematical functions for description of the shoreface shape, and gives a comprehensive statistical evaluation of the function fitness with the actual shoreface shape. But we used a simpler software Grapher v3.01, Golden Software Corporation, with limited possibilities of statistical evaluations for a preliminary presentation of the field work results in this report.

Availability of the shoreface profiles measured in 2002 and bathymetric charts based on the measurement data obtained 16-43 years ago give opportunity to evaluate the shoreface dynamics during these years. Unfortunately the scale of charts and accuracy of field measurements usually are insufficient for assessment of the shore line displacements. However a comparison of the measured shoreface profiles with the same profiles taken from the bathymetric charts permits sometimes to reveal the changes of shoreface shape and corresponding erosion or accretion volumes in the coastal zone.

5.3.2.3 Preliminary results

The shoreface profiles measured in different geological and geocryological conditions in sections 6,8 and 9 (Fig. 5.3.1-1) are considered below for preliminary illustration of field investigations carried out.

Section 6 is situated on the southwest coast of Novaya Sibir Island in the area of "Utyos Derewyannukh Gor" (Wood Mountain Cliff) Cape (75° 0.8′ N., 147° 6.1′ E.). As it was marked above, the coast in this section is composed of weakly lithified sediments of all kinds from clays till rock debris with low ice content. The slopes of seaboard hills as high as 85 m have no vegetation. Their base is cut with steep crumbling cliffs (Fig. 5.3.2-2). In some places the cliffs are plumb, with last year's wave cut niches filled with snow at their base. No large accumulations of thermodenudation products were observed on the beach but recent talus were present everywhere and single destruction blocks of frozen sediments were met. Water streams extensively erode the seaboard slopes above the cliffs. The mouths of some ravines are uplifted for 1-2 m above the beach. These morphological features testify that the sediments composing the coast undergo intensive erosion.

The narrow beach is build by sand with two stripes of gravel with pebbles along the shore. The seawater in the surf zone is very turbid.

One shoreface profile about 3 km long was measured in section 6 (Fig. 5.3.2-3). The doubtless signs of coastal erosion mentioned above caused to anticipate that the shoreface in this section is moulded by waves and has a concave shape. But a flat slope in Fig. 5.3.2-3 stretches up to 6-m depth at 1-km distance from the shore. A strait line fits this part of the shoreface profile with a high coefficient of determination R^2 = 0.9915.

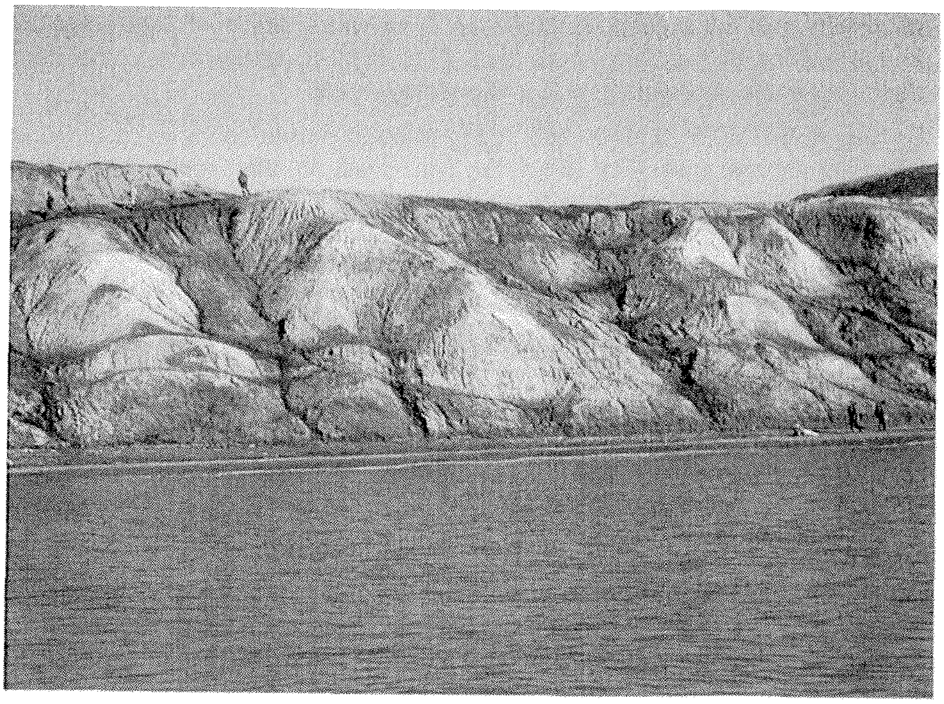

Figure 5.3.2-2. Erosion coast of Novaya Sibir Island in the area of Cape Utyes Derewannykh Gor, section 6.

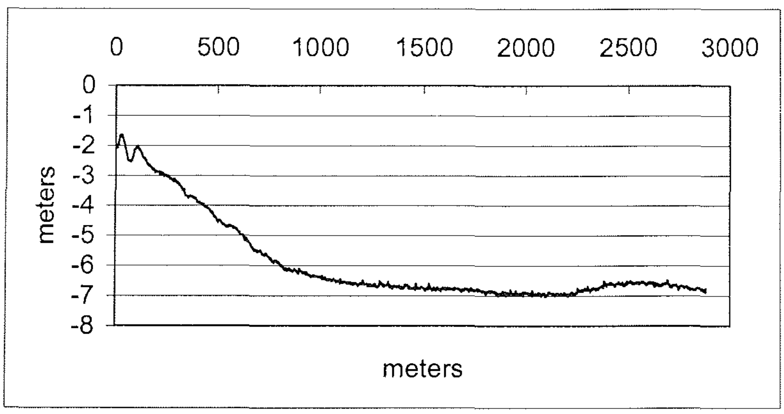

Figure 5.3.2-3. Shoreface profile near the Cape Utyes Derewannykh Gor, Novaya Sibir Island, section 6.

Unfortunately the shoreline location and the coastal shallow profile until 2-m depth were not measured. Extrapolation of the shoreface profile strait trend line in the depth range 2-6 m gives position of the first measurement point (2-m isobath) 340 m from the shoreline. Actually the first point was situated no more than several tens of meters from the shore. It means that the slope of the shoreface part not measured increases in on-shore direction. This peculiarity and existence of two long-shore bars (Fig. 5.3.2-2) testify that in the depth range 0-3 m the shoreface profile is formed by waves.

Section 8 (74° 50,5′ N, 140° 29,2′ E) is situated on the south coast of Bunge Land in its low part (Fig. 5.3.1-1). The coast in this section represents remarkably flat plain, which almost does not rise above the sea level and regularly undergoes flooding for several kilometers up the land. Therefore the shoreline position is very variable and reasonably is shown on the maps with a dotted line.

A long-shore sand bar on the coast about 100 m wide and at most 1 m high was observed on August 25. The surface sand behind the bar to the distance over 2 km from the shore was saturated and semi-liquefied (Fig. 5.3.2-4). Evidently the seaboard area underwent flooding during the storm the previous day.

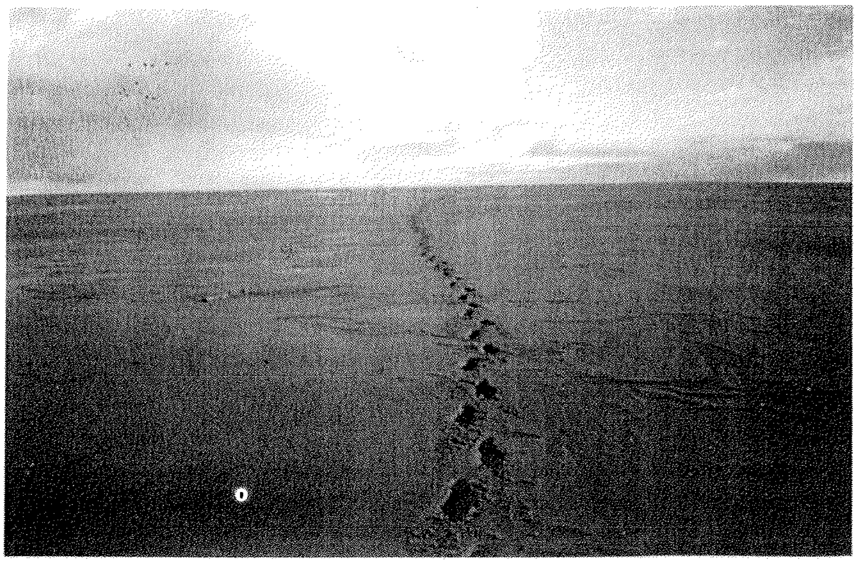

Figure 5.3.2-4. Seaboard surface of the Bunge Land low coast, August 25, 2002, section 8.

One shoreface profile was measured in section 8 (Fig. 5.3.2-5). It was the first time during 4 years of measurements in the Laptev Sea that we met a combined shoreface profile (Inman et al., 1993) consisting of two parts. According to Inmann et al., the lower part called shorerise is formed by shallow waves. The upper part called bar-berm is formed by breaking waves. The both parts follow the formula $\boldsymbol{y = -A \cdot x^k}$ with equal coefficients $\boldsymbol{A}$ and $\boldsymbol{k}$.

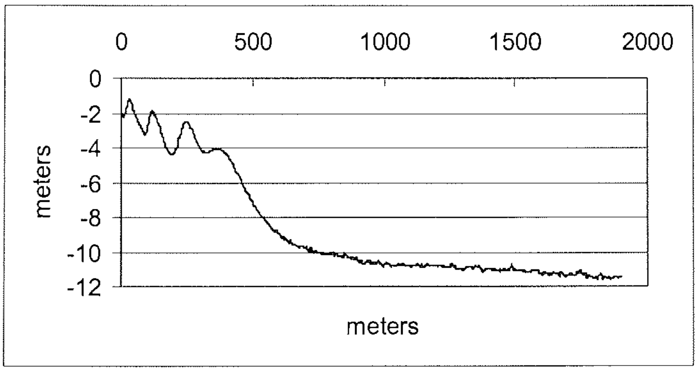

Figure 5.3.2-5. Shoreface profile near Bunge Land low coast, section 8.

The shoreline position on the shoreface profile presented in Fig. 5.3.2-5 was not measured. The water depth measurements were started at a considerable distance from the shore because of very shallow water. Father offshore three underwater long-shore bars as high as 2 m were measured (Fig. 5.3.2-5). A linear extrapolation of the in shore shoreface part gave a position of shoreline at the distance of 73 m from the first point of measurements (***x*** = 0; ***y*** =1.97 m in Fig. 5.3.2-5). The upper part of the shoreface profile with the origin of coordinates at the point ***x*** = -73 m follow equation

$$y = -0.21 \cdot x^{0.49} \qquad (1)$$

with a very low coefficient of determination R^2 = 0.60 (Fig. 5.3.2-6). A low R^2 is no surprise because of the presence of bars about 2 m high. The values of coefficients in equation (1) are in the range usual for Laptev Sea (Are et al., 2002).

A mathematical description of the shoreface lower part in the depth range of 6-10 m is obtained in the form of equation

$$y = -2.93(x-509)^{0.22} \qquad (2)$$

with a rather high R^2 = 0.9924. Equation (2) corresponds to a simple power function

$$y = -2.93 \cdot x^{0.22} \qquad (3)$$

with the origin of coordinates in the point ***x*** = 509 m. The ***A*** values in equations (3) and (1) differ in order of magnitude. It is in disagreement with the above-mentioned statement of Inmann et al. about the equal shape of upper and lower parts of the combined shoreface profile. Furthermore the value ***A*** = 2.93 oversteps substantially the usual limits 0.002-1.38 for the Laptev Sea and 0.19-0.89 for the Beaufort Sea (Are et al, 2002). These discrepancies suggest that the lower part of the shoreface in Fig. 5.3.2-5 is not created by modern hydrodynamics but reflects the geological structure of the sea floor.

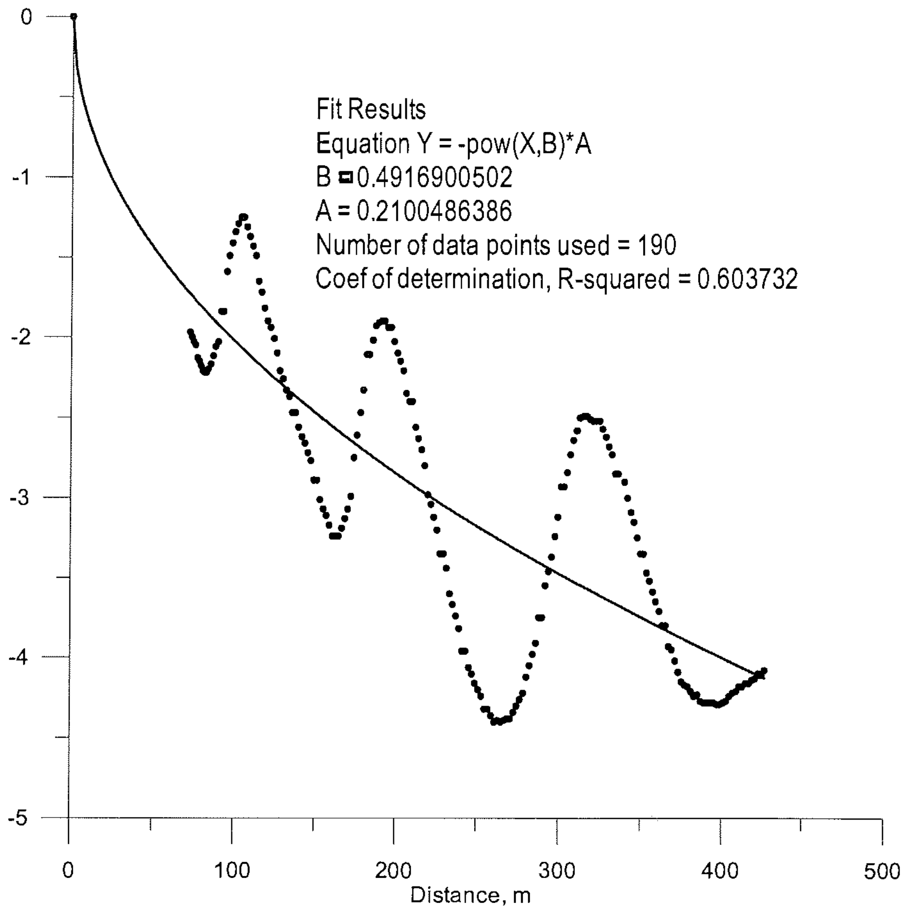

Figure 5.3.2-6. Approximation of the near shore shoreface profile with a simple power function, section 8.

Section 9 (74° 14.6′ N, 140° 19.1′ E) is situated on the north coast of the Maly Lyakhovsky Island. The coast here is composed of ice complex. The coastal bluffs as high as 15 m are sloping. Their vegetated surface is complicated by buydjarakhs. Any signs of coastal erosion are absent (Fig. 5.3.2-7).

Schistose bedrock is exposed on the bottom of water stream mouths. Evidently the bedrock underlies the ice complex on the sea level.

The beach in surf zone is sandy. The seawater is clear. A stripe of poorly rounded gravel is spread along the upper limit of the swash zone. Farther onshore the beach is covered with sand and sparsely scattered gravel. The uppermost part of the beach is steep and composed of gravel, pebbles and single debris. All sediments on the beach are schistose. The signs of sea ice push are present everywhere on the beach in the form of scour craters and gravel pileups. Here and there the driftwood and patches of gravel are spread on bluff slopes up to 2-3 m above the beach upper limit. The mouths of water streams and ravines are damed up with beach sediments.

Figure 5.3.2-7. Stable north coast of the Maly Lyakhovsky Island, section 9.

Two shoreface profiles were measured in section 9. One of them is presented in Fig. 5.3.2-8. Evidently the hydrodynamics is not responsible for the shape of this profile, outside of 3-m isobath. A grab sampler never took a sample of sediments from the sea floor in the range of 3–5 m isobath. Apparently the bedrock, which underlies the ice complex on the shore, is exposed on this part of the sea bottom.

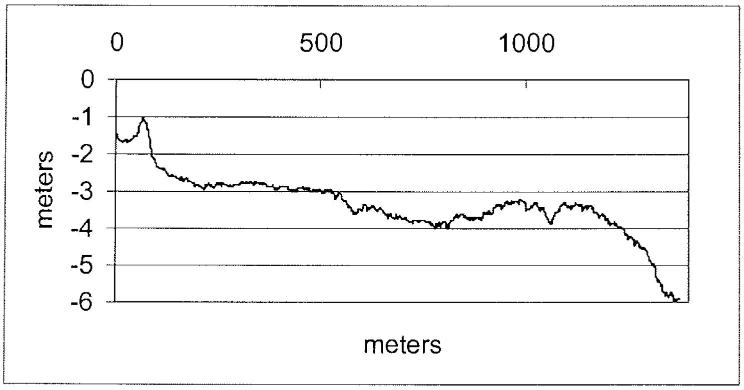

Figure 5.3.2- 8. Shoreface profile near north coast of the Maly Lyakhovsky Island, section 9.

The shoreface relief in the depth range of 1-2 m holds the signs of drift ice impact. It is indicated by the rough surface of the bottom, and asymmetric profile and sharp crest of the underwater long-shore bar, unusual for the sea floor relief created by waves (compare with the bars on the Bunge Land shoreface profile in Fig. 5.3.2-6). It is possible that the long-shore bar in Fig. 5.3.2-8 is formed without any wave impact, only due to the ice push onto the shore. The absence of a long-shore bar on the second shoreface profile, measured 2.7-km west from the first one in the same geological and geocryological conditions, testifies in favour of this assumption.

5.3.2.4 Discussion and conclusions

The shoreface of New Siberian Archipelago islands differs considerably from the shoreface of the Laptev Sea continental coast. The regular concave shape of the shoreface can not be distinguished along some coasts composed of hard bedrock (Stolbovoy and Belkovsky Islands). The shoreface along the coasts, where it can be recognized on profiles visually, is usually several hundred meters wide, and its outer boundary mostly do not reach below 4 m isobath. Along the Laptev Sea continental coasts the shoreface may be several kilometers wide and its outer boundary reaches 5-10 m isobaths.

Two factors may explain these differences: (1) bedrock is widespread below sea level around the New Siberian Islands, (2) decrease of sea roughness in the archipelago area, due to the next factors.

(1) The warming influence of river water in the archipelago area is lesser and correspondingly the open sea period is shorter in comparison with the continental coast areas.

(2) The drift ice remains near the islands during the whole summer and suppresses the waves.

(3) The dimensions of straits between the islands lessen the wave fetch, and vast shallows near the island coasts limit the wave height.

Apparently the decrease of wave energy is so large that even along the sandy coast of Bunge Land the outer boundary of the shoreface does not subside below 4 m isobath (Fig. 5.3.2-5).

Many signs of sea ice impact were observed on the island coasts.

- series of gravel-pebble long-shore ramparts as high as 3 m on the low coasts behind the beach,
- gravel, pebbles and driftwood pushed by the ice from the beach to the coastal slopes as high as 5 m above the beach,
- the mouths of water streams damed by beach material,
- the sediment piles on the beach, created by ice push,
- the pits on the beach scoured around the ice blocks pushed to the beach,
- the stripes of "stamukhi", grounded on the long-shore underwater bars.

All above phenomenon, created by drift ice, do not forward notably coastal erosion. Some of them have a protective impact.

There is no sign of drift ice impact on the sea floor outside of 2-m isobath on all three shoreface profiles presented in this report. The jagged outline of shoreface diagrams is caused probably by vertical movement of the boat with measurement equipment due to sea roughness. A shoreface profile segment 100-m long with measurement points, taken from Fig. 5.3.2-3, is shown on a large scale in Fig. 5.3.2-9 as an example. The distance between adjacent points is about 1.6 m. The standard deviation of measured depths from the mean value equals 4.5 cm. So the sea floor is very plain.

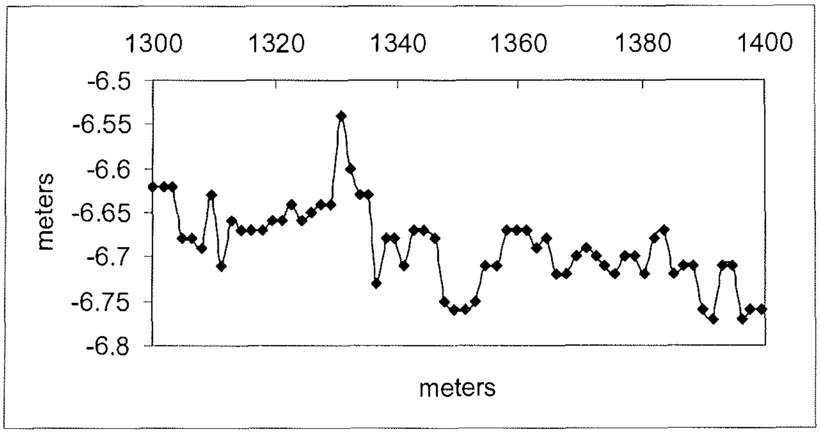

Figure 5.3.2-9. A seafloor profile segment near Cape Utyes Derewannykh Gor, Novaya Sibir Island, section 6.