

4.6.3 ICE WEDGES OF CAPE MAMONTOV KLYK

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4.6.3.1 Introduction

The studies on ice wedges for palaeoclimate reconstruction of winter temperatures started in 1998 and, since then, were applied to different locations in the Laptev Sea region. Among these localities are the Bykovsky Peninsula (Meyer et al. 2002a), Big Lyakhovsky Island (Meyer et al. 2002b), different sites in the Lena Delta (Schirrmeister et al., 2004) and on the New Siberian Islands and Oyagoysky Yar (unpublished yet). In addition to Mamontov Klyk, sampled this year, data from several sites of Taymyr Peninsula can be used, both being located in the western Laptev Sea province representing the westernmost (closest to the Atlantic) sampling sites of all visited regions. The method is based upon the fact that the stable isotopic composition of ice wedges is genetically closely linked with the melting of the seasonal snow cover and hence, well correlated with mean winter temperatures (e.g. Vaikmäe, 1989).

Since ice wedges are predominantly vertically oriented features, they are not limited by sedimentological boundaries. Therefore, ice wedges may penetrate into older sediments (epigenetic ice wedge growth) but also keep up with the sedimentation (syngenetic ice wedge growth). Accordingly, within the same sedimentary unit, ice wedges of different generations may occur. Every ice wedge generation is related to a (new) stable surface. Consequently, the question arises from which sedimentological unit (and hence from which palaeosurface) an ice wedge originates. A detailed description of the outcrop is therefore necessary to gain an understanding of the genesis of the whole section.

During this field season, studies of the ice and water of the Cape Mamontov Klyk area were used for palaeoclimate and palaeoenvironmental interpretation of a terrestrial periglacial locality. These studies will also help to understand the genesis of subsea permafrost ice – to be drilled in the 2004 field campaign – e.g. if subsea ice is of terrestrial origin or refrozen Laptev Sea water. Therefore, the selected samples of all types of ice (recent and paleo ice wedge ice, texture ice, massive ice as well as cavity ice) and water (meteoric water, ground water, surface water) will be analysed for their stable isotope composition as well as for hydrochemistry to understand the regional hydrological and cryolithological regime. In total, 422 samples were taken, among them 226 samples from 28 ice wedges, 24 from ice-sand wedges ("polosatics"), 110 samples of texture ice, 7 of massive ice of unknown origin as well as 7 samples of snow, 5 samples of rain, 22 samples of surface water (e. g. sea water, river water, pond water) and 3 samples of ground water (see Appendix 4-6).

4.6.4.2 The ice wedges in the lower sands (Unit A) and in the sand-peat-complex (Unit B)

Section MAK-IW-1-5, MAK-IW-7 (corresponding to the sediment sub profile Mak-1, see chapter 4.6.2.1)

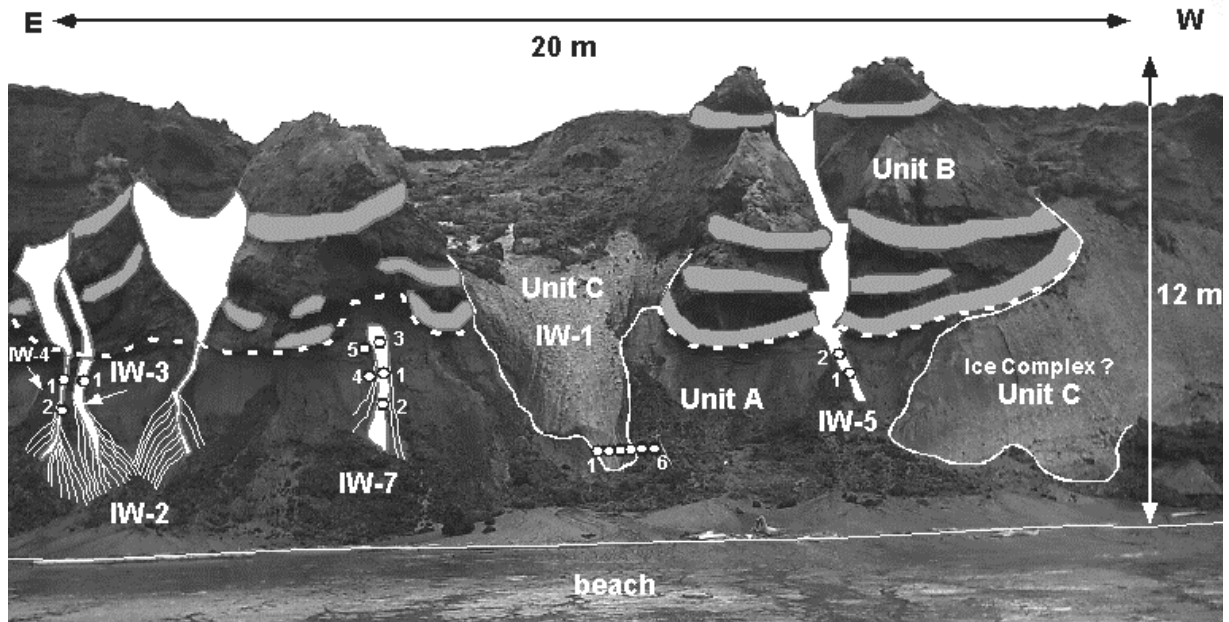


Figure 4.6.3-1: Ice wedges MAK-IW-1 to –IW-5 and MAK-IW-7 with sampling points. MAK-IW-2 is shown in detail in Figure 4.6.3-2.

The section is located at the coast and comprises Unit A (lower sands) in contact with the overlying Unit B (peat-sand complex) (Figure 4.6.3-1). The sands of Unit A contain ice-sand wedges (so called “polosatics”), which are characterised by a vertically-oriented tiger-striped sequence of ice veins and sand veins. These ice-sand wedges are the oldest cryolithological features in the section. Unit B consists of four peat horizons, which were interpreted as stable surfaces (maybe of a floodplain or old branches of a palaeo-river, which were cut from the main river and therefore fell dry and then were subsequently flooded again). Each of these stable surfaces is linked with a generation of ice wedges. These different generations of ice wedges stick one into the other. The older deposits of Unit A and Unit B are dissected by a series of very large ice wedges of Unit C, which were attributed to the Ice Complex.

MAK-IW-1

Description: MAK-IW-1 is a 7-8 m high ice wedge, which is not covered by sediment and where the upper boundary is not visible. The ice wedge shows some syngenetic structures in the upper part such as shoulders at the sides of the ice wedge, one of which seem to be associated with the first peat of Unit B (peat-sand-complex). Especially in the bottom part, the ice wedge is confined by subvertically structured very ice-rich texture ice (“polosatic”-like). The ice wedge

reaches a width of about 3.5 to 4 metres at the top and narrows downwards, where the width does not exceed 0.7 m. The ice is relatively pure and white, with milky appearance containing only small quantities of sediment and organic matter. Vertical oriented ice veins, 1-2 mm wide, are well developed. Additionally, the ice is structured by the high amount of gas bubbles, mostly < 0.5 mm, which are often arranged as "strings of beads". Four samples were taken from this ice wedge, two in the adjacent texture ice. The height of the sampling profile is 1.5 m a.s.l..

Interpretation: Most probably, MAK-IW-1 is an epigenetic ice wedge of the Ice Complex (Unit C) penetrating the lower sands of Unit A. Syngenetic forms associated with the first peat may indicate the onset of ice wedge growth at that time.

MAK-IW-2

Description: MAK-IW-2 is a sequence of ice-sand wedges ("polosatics"). At least three systems and predominant directions of these ice wedges, intersecting with each other could be distinguished, all of them associated with the lower sands of Unit A (Figure 4.6.3-2). However, these systems seem to originate in 0.2 m thin ice wedges originating from Unit B (or *vice versa* have led to the growth of these small ice wedges).

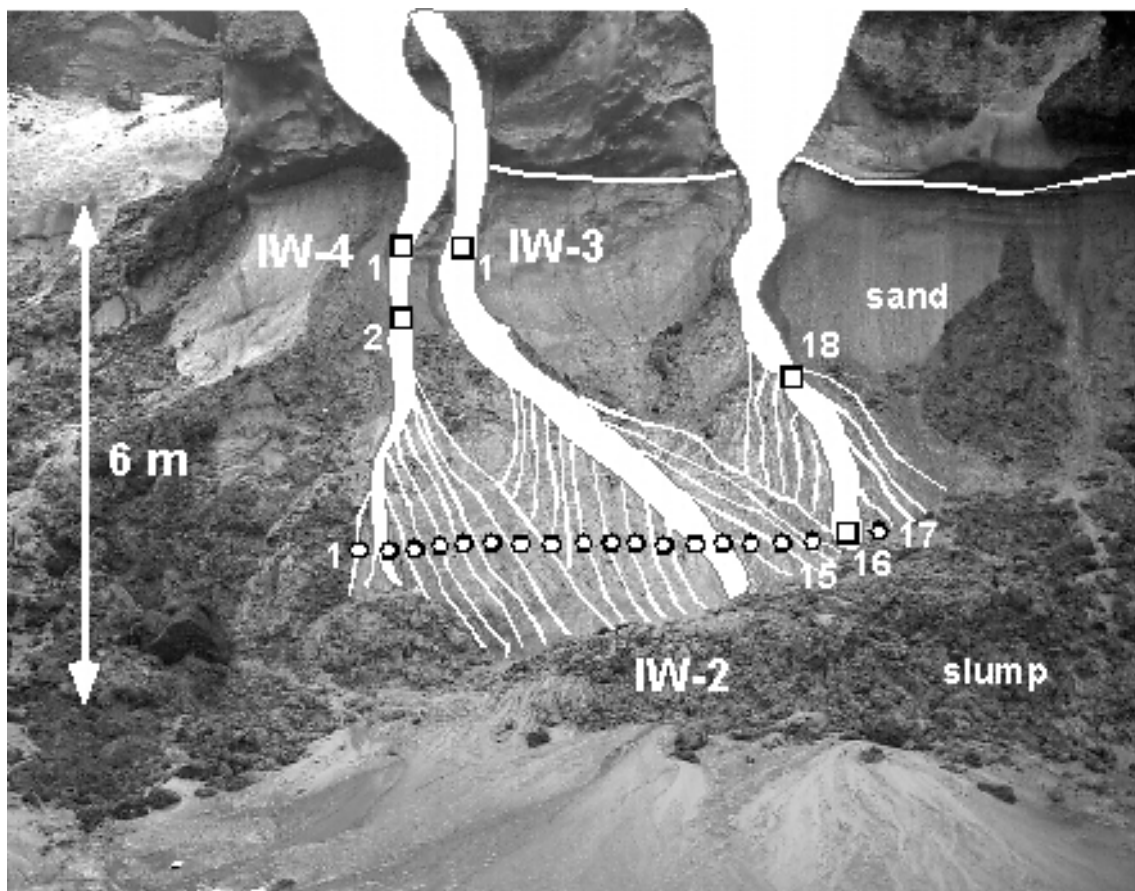


Figure 4.6.3-2: Section MAK-IW-2 with sampling points.

The ice is very pure and transparent and contains no organic matter. Single ice veins are well developed and between 4 and 12 mm (mean 8 mm) thick, interrupted by 1 m thick sediment veins. This leads to a clear subvertical structure of the ice, where eight ice veins were counted for a length of 5 cm. Gas bubbles, mostly < 1 mm, are randomly oriented in the ice. In 20 cm intervals, 17 samples were taken from this system of ice-sand wedges. The height of the sampling profile is 1 m a.s.l..

Interpretation: MAK-IW-2 is composed of different systems of ice-sand veins of the lower sands of Unit A, representing the oldest ice in the outcrop.

MAK-IW-3, IW-4, IW-5, IW-7

Description: All these ice wedges are relatively narrow, about 0.2 m wide, originate in Unit B peats and, in the lower part, are in contact with ice-sand wedges of Unit A. All four ice wedges are similar: consisting of clear, transparent ice in which vertical structures (e.g. ice veins) are recognisable. The mineral content of the ice is rather low. MAK-IW-3 contains small amounts of organic matter within the ice, but MAK-IW-4, IW-5 and IW-7 are characterised by high content of organic matter (plant remains and peat fragments). In general, the gas bubbles in these ice wedges are relatively big (= 2 mm), although smaller bubbles (in sub-mm size) occur. In total, 10 samples were taken by axe from these 4 ice wedges. The height of the sampling is around 5 m a.s.l. for ice wedges IW-3, IW-4, IW-5. Only IW-7 was sampled slightly higher above sea level (5.5 m, 6.0 m, 6.5 m)

Interpretation: MAK-IW-7 is certainly linked with the 1st peat of Unit B, whereas IW-3 and IW-4 originate at least in the 1st peat, maybe in a younger stage (2nd or 3rd peat). MAK-IW-5 is clearly associated with the 2nd peat, thus, representing the second youngest stage of Unit B ice wedges. Since all these ice wedges are relatively small, it can be assumed that they were formed relatively fast and that the stable surface conditions did not persist for a long time. Only ice wedges linked with the 3rd peat reach in some cases widths of about 1.5 m. This leads to the assumption that the stable surface condition associated with the 3rd peat may have lasted longer than the others.

MAK-IW-19 to IW-21

Description and Interpretation: The top of this 2.5 m high outcrop is located at the coast in a height of 7.5 m a.s.l.. Since it is approximately 80 m to the west of outcrop MAK-IW-1 to IW-5, mainly the same sedimentological situation is displayed here. At least four generations of ice wedges of Unit B can be distinguished. MAK-IW-21 is the oldest generation of Unit B ice wedges certainly linked with the first peat horizon. It is marked with an asterisk because it was buried again, when the photograph was taken. One sample was taken by axe from this ice wedge. MAK-IW-20 is the next younger generation of ice wedges within the second peat layer. Here, two samples were taken by axe. At

least, two more generations of Unit B ice wedges were observed: one originating under the third peat, another one originating in the third peat. Both could not be sampled due to difficult outcrop conditions. All these ice wedges are as small as 0.1 to 0.2 m in width and 0.3 m to 1.2 m in height.

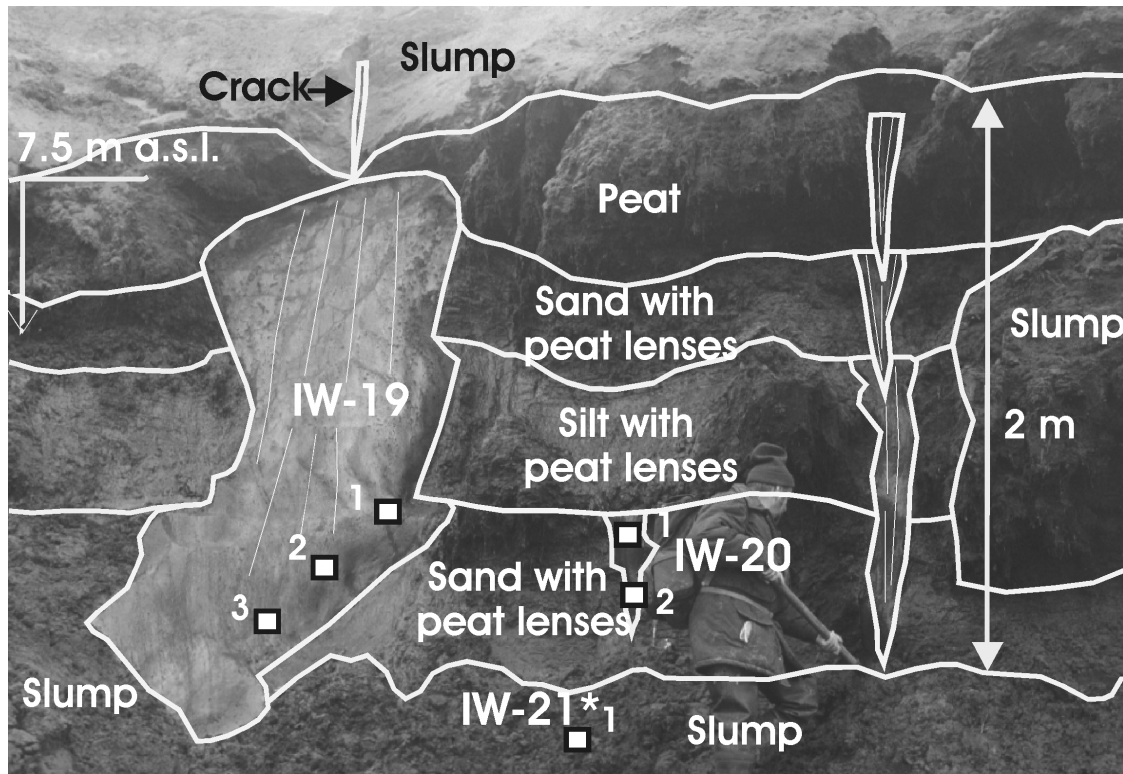


Figure 4.6.3-3: Outcrop MAK-IW-19 to -21 with sampling points

Compared to that, MAK-IW-19 is much bigger in size and at least 2.5 m high and 0.8 m wide (Figure 4.6.3-3). Three samples were retrieved by means of an axe. Similar ice wedges were observed in section MAK-IW-1 to IW-5, where outcrop conditions made sampling impossible. Additionally, MAK-IW-19 is buried by sands of Unit B and located at the same height than the 3rd peat. Therefore, this ice wedge belongs most likely to Unit B and not to the Ice Complex. A small ice vein above ice wedge MAK-IW-19 supports this assumption. The ice wedges of bigger size could signify that during the formation of Unit B, one stable surface might have persisted longer (possibly linked with the growth of the third peat). Possibly, two different types of ice wedges were formed in the same type of deposits.

Section MAK-IW-6 (corresponding to the sediment sub profile Mak-Ovrag, see chapter 4.6.2.3)

Description: At a height of about 13 m a.s.l., two ice wedges (called MAK-IW-6) were sampled in a 7 to 8 m deep thermo-erosional gully (Russian: Ovrag) approximately 100 m S the shoreline and 200 m W of the navigation signal "Cape Mamontov Klyk". Both are about 0.5 m wide and originate in a

sphagnum-rich peat of Unit B, which thickness is about 30-40 cm (Figure 4.6.3-4). The visible thickness of sand lenses enclosing the ice wedges is about 20-40 cm. The ice wedge is characterized by clean, white ice with numerous air bubbles without clear vertical structure. In total, 8 samples were taken from these two ice wedges in 15 cm increments using an ice screw. The height of the sampling profile is 13.5 m a.s.l. for the left ice wedge and slightly lower (13.3 m a.s.l.) for the right ice wedge.

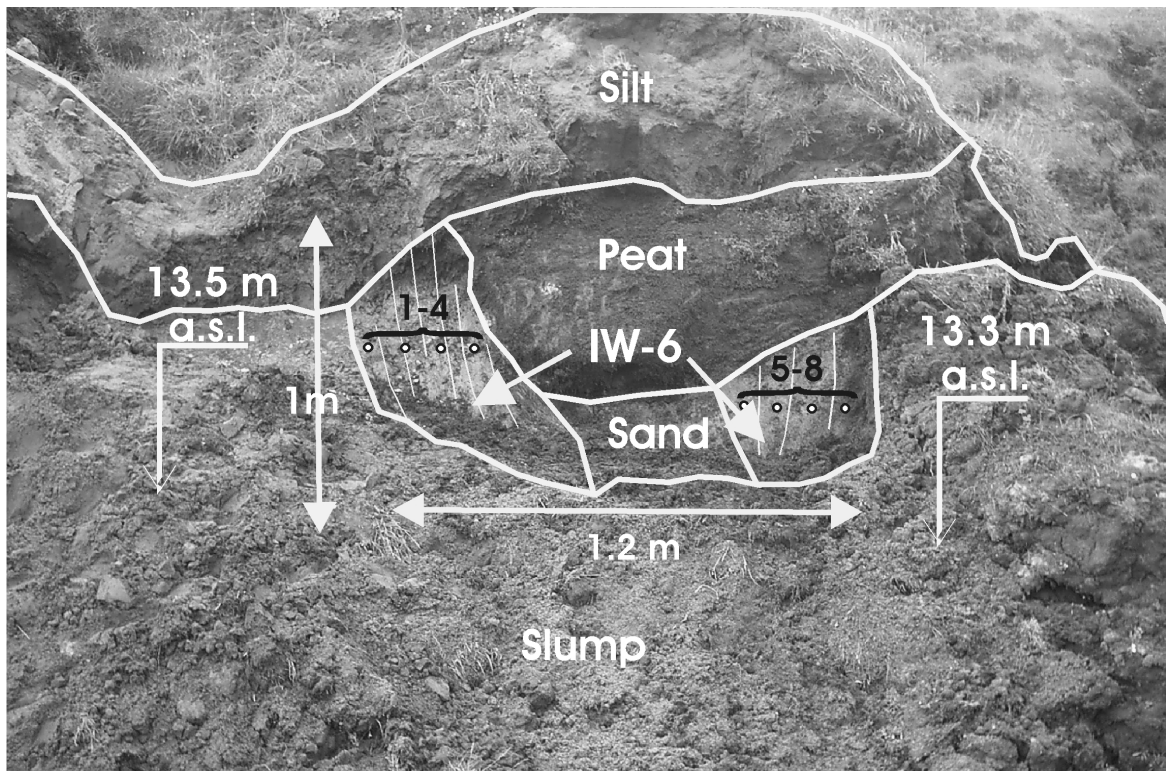


Figure 4.6.3-4: Outcrop MAK-IW-6 with sampling points (see also Figure 4.6.2-1)

Interpretation: Although it is not exactly known to which peat horizon MAK-IW-6 belongs, it is certainly a Unit B ice wedge. With regard to its height above sea level, MAK-IW-6 can most probably be attributed to the 3rd or 4th peat, thus representing a younger stage of genesis than MAK-IW-2 to IW-7.

MAK-IW-8 (corresponding to the sediment sub profile Mak-4, see chapter 4.6.2-1)

Description: At a height of about 12.5 to 13.0 m a.s.l., a 0.3 m wide ice wedge named MAK-IW-8 (see Figure 4.6.2-1 Mak-4) was sampled. Three samples were taken by axe from this ice wedge.

Interpretation: This ice wedge is located in the boundary between Ice Complex and Unit B. It is located below one of the two uppermost peat horizons of Unit B (3rd or 4th peat), most likely the 4th one. Due to the close distance and

approximately same height, it is considered as an equivalent of ice wedge MAK-IW-11.

MAK-IW-9

Description: MAK-IW-9 is a 0.2 wide ice wedge with well-developed vertical orientation (Figure 4.6.3-5). The ice is slightly milky white and transparent with clear subvertical structures. Single ice veins of 2-3 mm in width are common in this ice wedge. Many gas bubbles of different sizes (0.5 – 2 mm) but without predominant orientation occur. The content of mineral particles is medium increasing to the sides of the ice wedge, where single laminae may reach 3 mm of thickness. The organic content is low, nevertheless, numerous lemming coprolithes were found within the ice wedge and sampled for dating (MAK-¹⁴C-2). Three samples were taken from the ice wedge (in 5 cm intervals) and one sample from the adjacent ice-sand wedges.

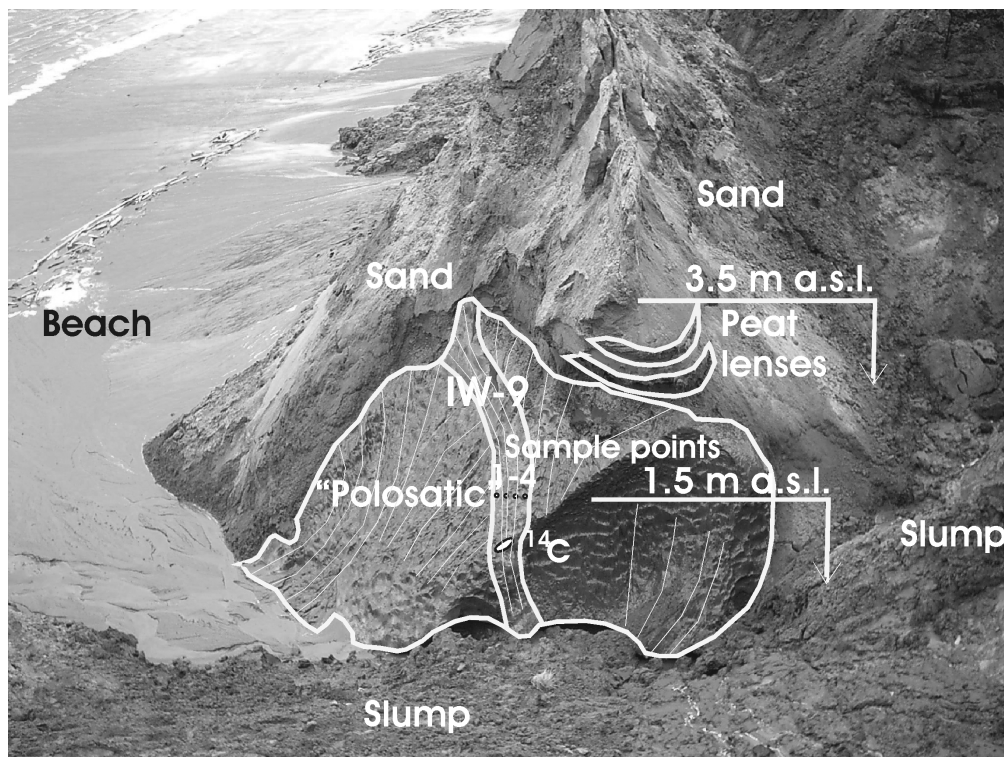


Figure 4.6.3-5: Outcrop MAK-IW-9 with sampling points

Interpretation: Genetically, this ice wedge is enclosed by ice-sand veins, which are in general discordantly cut, except in the lower parts of its landward side. MAK-IW-9 is certainly linked with the first peat horizon, thus belonging to a series of small ice wedges penetrating Unit A from above.

MAK-IW-10 (corresponding to the sediment sub profile Mak-3a, Chapter 4.6.2.1)

Description and Interpretation: Outcrop MAK-IW-10 shows the contact between Unit A and Unit B in detail. Ice-sand wedges of Unit A laterally confine a pair of twinned ice wedges. At the left side, a massive ice body of unknown origin was distinguished from ice wedge ice by the lack of vertical structures within the ice. Sedimentologically, this outcrop belongs to Unit A, nevertheless, the genesis of the ice wedges is related to Unit B. The right ice wedge is certainly linked with the first peat, whereas the left ice wedge most probably can be attributed to the second peat layer. Small ice veins of both ice wedges continue into the overlying sediment layer, where they originate in the peat layers. This may be due to a sudden increase of the sedimentation rate impeding that the ice wedges could keep up with the sedimentation. Four samples were taken from the massive ice body (* two of them approximately 2 m further to the left of Figure 4.6.3-6 and 19 samples from the ice wedges, ice-sand wedges and the small ice veins in the upper part. The height of the outcrop is between 4.7 m and 6.7 m a.s.l..

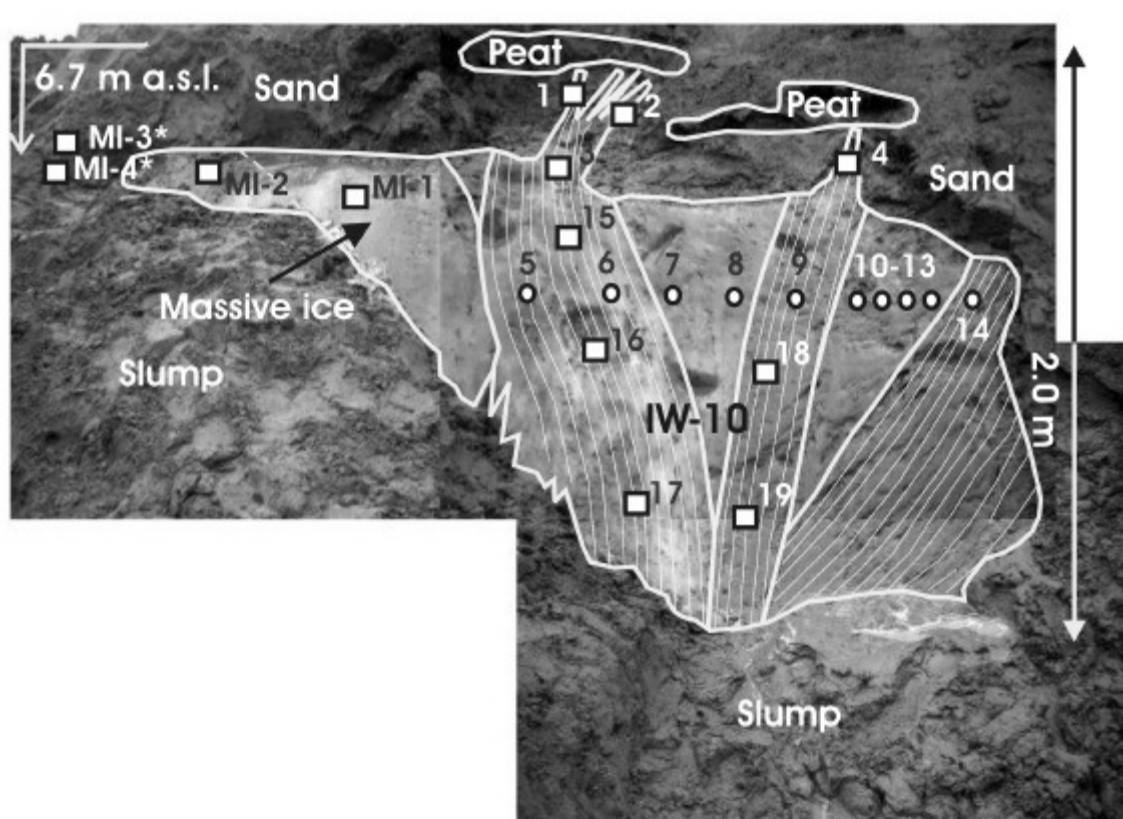


Figure 4.6.3-6: Outcrop MAK-IW-10 with sampling points (see also Figure 4.6.2-1).

MAK-IW-11 (corresponding to the sediment sub profile Mak-3c, chapter 4.6.2.1)

Description: Ice wedge MAK-IW-11 is 0.25 to 0.05 m wide narrowing from above, with vertical structures and transparent ice with brownish colour, due to a relatively high content of mineral particles. Single ice veins of 2-4 mm width are observed. The organic content is rather low, but a stick of 0.5 cm in diameter was found in the ice, in the bottom part of the ice wedge (MAK-¹⁴C-3). At the top, the ice wedge is in contact with a well-developed ice belt of 5-7 cm thickness probably characterising a stable surface. A peat layer, possibly the fourth peat within Unit B, just above the ice belt, supports this assumption. Five samples were taken from the ice wedge and two samples from the ice belts. The ice wedge is located at the top of a thermokarst mound, with a height of 12.9 m a.s.l (Figure 4.6.3-7).

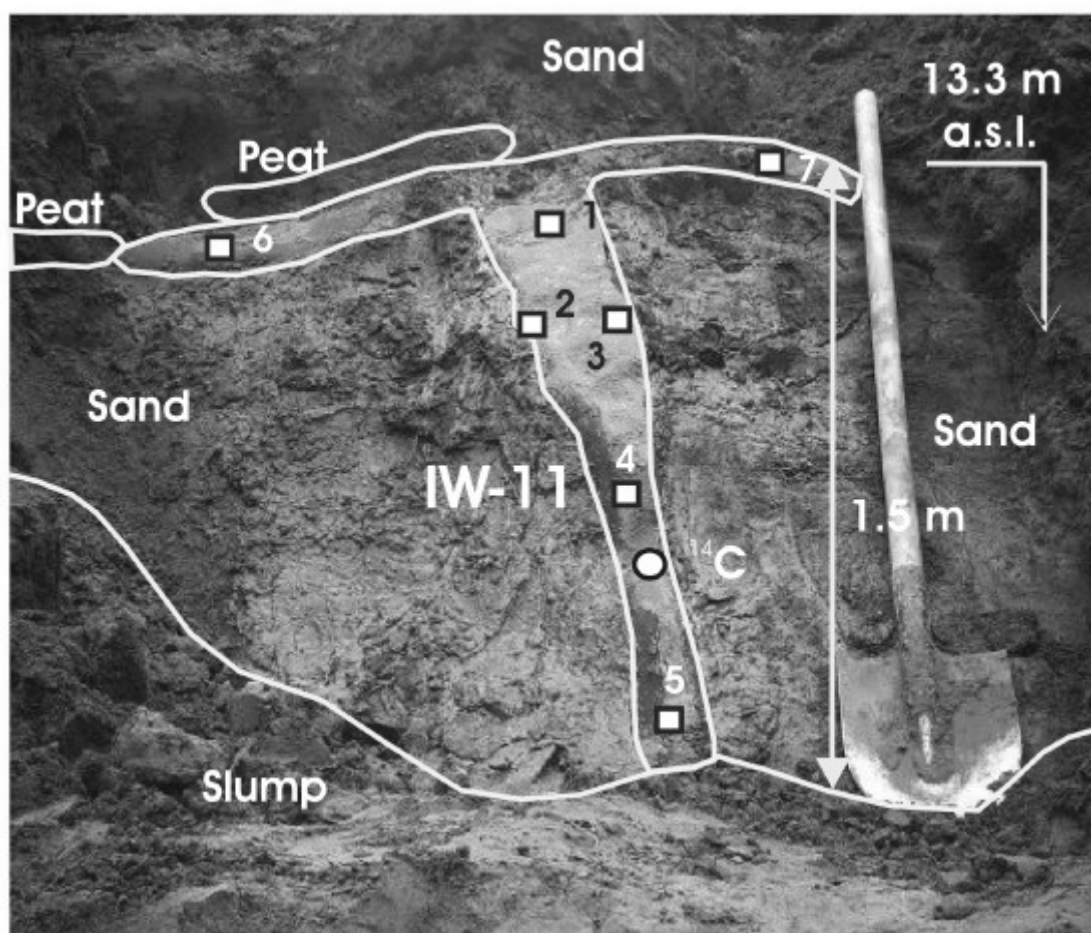


Figure 4.6.3-7: Outcrop MAK-IW-11 with sampling points (see also Figure 4.6.2-1)

Interpretation: Genetically, the ice wedge belongs to the third, or more likely, to the fourth peat of Unit B.

MAK-IW-24, IW-25

Description and Interpretation: MAK-IW-24 and IW-25 are both small ice wedges, 0.1 to 0.15 m wide, which were sampled 100 m to the west of the thermo-erosional ravine (Ovrag) and 50 m from the coast. At this location, a fourth peat horizon could be clearly differentiated and followed for several tens of metres in an estimated height of 10 to 12 m a.s.l., in general forming the tops of thermokarst mounds. The peat is about 0.5 m thick and characterised by a high content of reddish-brown *sphagnum*. Both ice wedges are linked with this fourth peat although in general, ice wedges are rather rare.

4.6.3.3 Ice wedges of the Late Pleistocene Ice Complex (Unit C) and of Holocene deposits (Unit D)

MAK-IW-12

Description: Outcrop MAK-IW-12 comprises a 2.4 m wide ice wedge of the Ice Complex (Figure 4.6.3-8) with transparent grey-yellowish and slightly tiger-striped ice and a moderate content of sediment and a low content of organic matter. Within this ice wedge, a 60 cm wide ice wedge of milky-white ice of a younger generation is observed, most likely associated with the Holocene (?) cover. Single ice veins of 3-5 mm in width are observed in this ice wedge.

From the Ice Complex ice wedge, 26 samples were taken by chain saw in a horizontal sampling transect in 1.5 cm wide slices taken in 10 cm intervals. The ice wedge is situated at the top of the Ice Complex cliff within the second thermocirque between two thermokarst mounds, with a height of the sampling profile of 17 m a.s.l.

Interpretation: Outcrop MAK-IW-12 shows the contact between Unit C (Ice Complex) and Unit D (Holocene cover) at the top of the ice cliff of the Ice Complex.

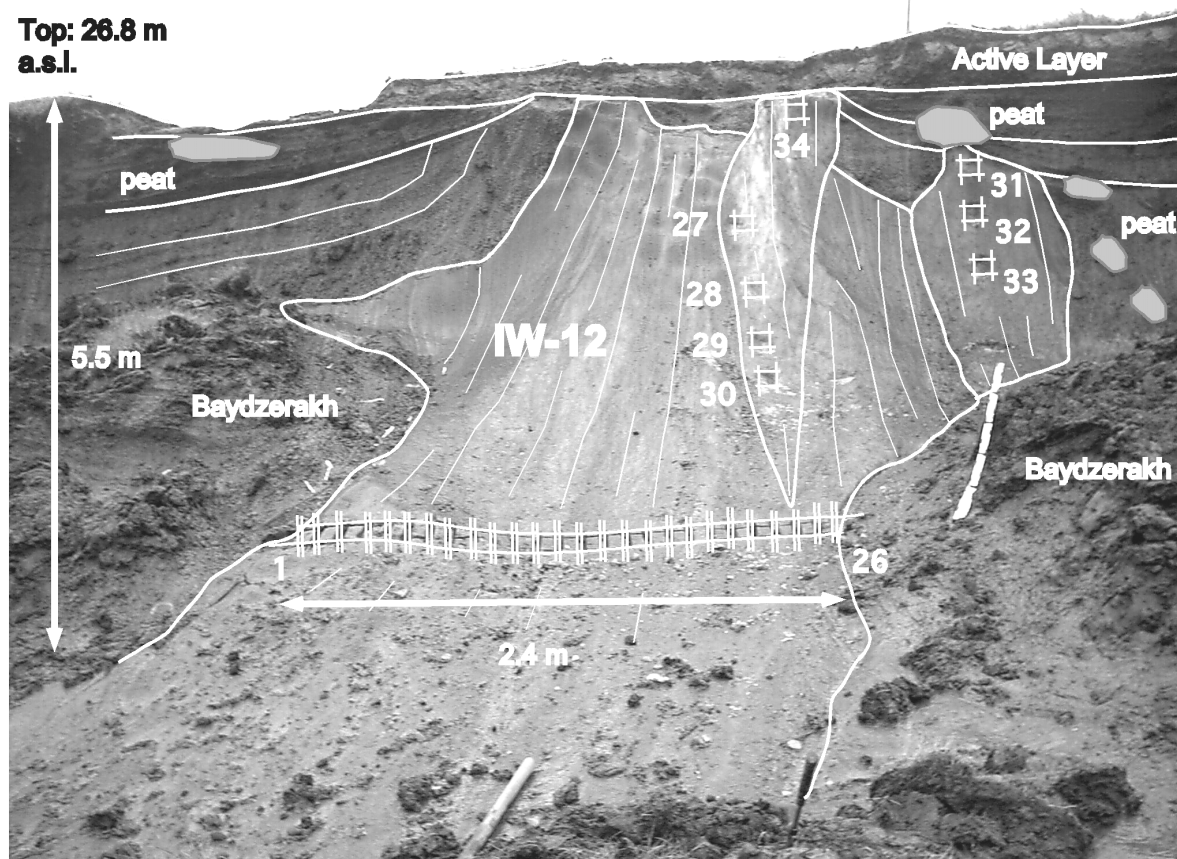


Figure 4.6.3-8: Outcrop MAK-IW-12 with sampling points

MAK-IW-13, -IW-14

Description: The ice wedges MAK-IW-13 and IW-14 are located at the Nuchcha Dzhihle River terrace (Figure 4.6.3-9) within an area of low centre polygons. The sampled outcrop is situated at the shore of the river, which cuts the studied polygon. This changed the drainage conditions and the polygon centre fell dry, whereas the frost cracks in the (former) polygon wall serve as drainage channels. Presently, the polygon walls of the old low centre polygons were lowered, sometimes more than one meter with regard to the former polygon centre, which are plain and characterised by the growth of a secondary generation of high centre polygon ice wedges. MAK-IW-13 is a remnant of an ice wedge in the wall of the former low centre polygon, which was partly eroded. MAK-IW-14 is a younger generation of high centre ice wedges in the middle of the former polygon centre. More detailed observations about the degradation of polygons due to changed drainage conditions can be obtained in Meyer (2003).

MAK-IW-13 is a 1.4 m wide ice wedge with milky, white ice and a medium content of sediment and a high content of organic matter. Well-developed vertical structures such as single, 2-4 mm wide ice veins and oriented gas bubbles are frequent. From this ice wedge, 8 samples were taken by axe in a horizontal sampling transect in 15 cm intervals between the samples. The ice wedges are situated at the western Nuchcha Dzhihle River bank with a height of the sampling profile of 1.5 m a.s.l.

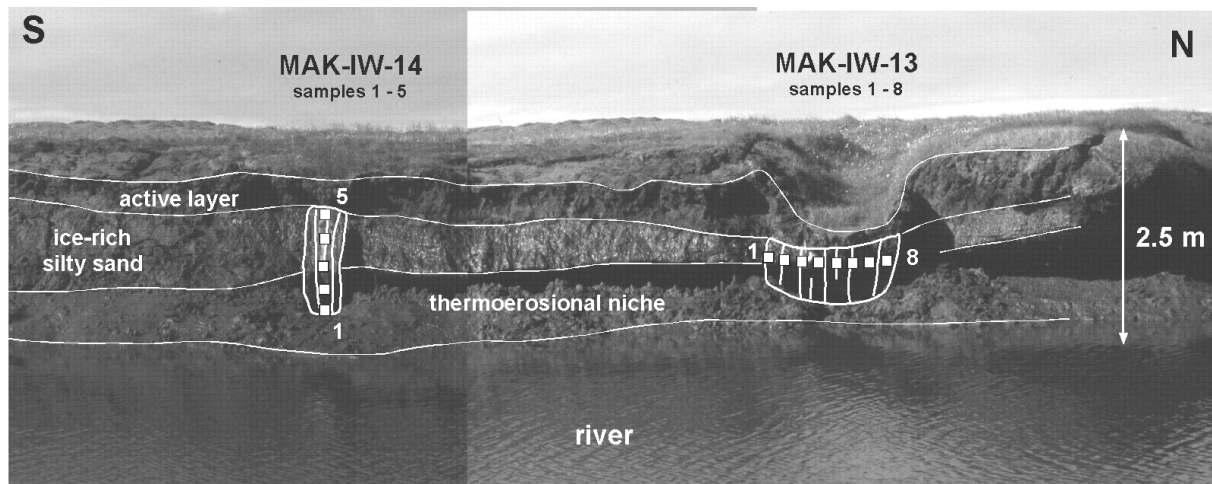


Figure 4.6.3-9: Outcrop MAK-IW-13 and -IW-14 on the Nuchcha Dzhihle River bank with sampling points

Interpretation: Both are Holocene ice wedges. The polygonal landscape and the form of the depression point to the existence of an old (Holocene) alas, which has been destroyed (and maybe also drained) by the erosional forces of the river.

MAK-IW-15

Description: MAK-IW-15 is a 2.5 m wide ice wedge of the Ice Complex (Figure 4.6.3-10) with grey-yellowish transparent ice and a medium content of sediment and of organic matter. Single 1-4 mm wide ice veins are observed. From the ice wedge, 27 samples were taken by chain saw in a horizontal sampling transect in 1.5 cm wide slices with 10 cm intervals between the samples. The first two samples from the left were taken from the ice belts. The ice wedge is situated at the bottom of the steep ice wall within the second thermocirque between two thermokarst mounds, with a height of the sampling profile of 17 m a.s.l.

Interpretation: This is an Ice Complex ice wedge.

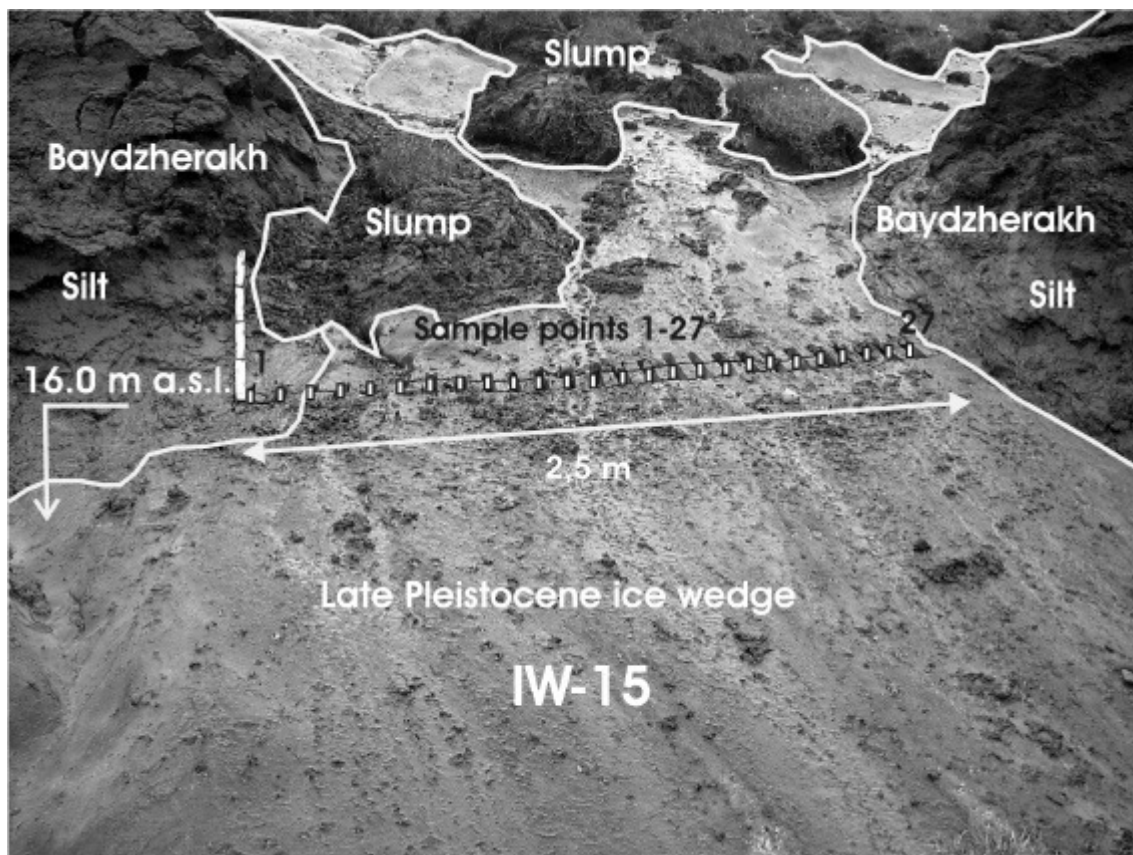


Figure 4.6.3-10: Outcrop MAK-IW-15 with sampling points

MAK-IW-16, IW-23, -MI a

Description: MAK-IW-16 is a 0.2 m wide, milky and white to yellowish ice wedge with clear vertical foliation and low sediment content. At both sides, the ice wedge is limited by subvertical schlieren-like ice-sand-veins. Four samples were taken by axe from this ice wedge. Ten metres to the east, a second ice wedge of the same generation was sampled (MAK-IW-23) and described. MAK-IW-23 is 0.1 m wide and consists of yellowish to brownish transparent ice with high organic content. Vertical structures such as single ice veins are common and well-developed. Here, one sample was taken by axe.

Five metres to the east of MAK-IW-16, a massive ice body (MAK-MI a) of unknown origin was found (Figure 4.6.3-11). The massive ice body is about 1.2 m wide and 0.8 m high and consists of two different types of ice both without preferential internal orientation: a very clear transparent part and a milky-white part rich in gas bubbles. Of both types of ice, one respective sample was taken by means of an axe. The ice wedges and the massive ice body are situated in a height of about 15 m a.s.l. at the top of the section.

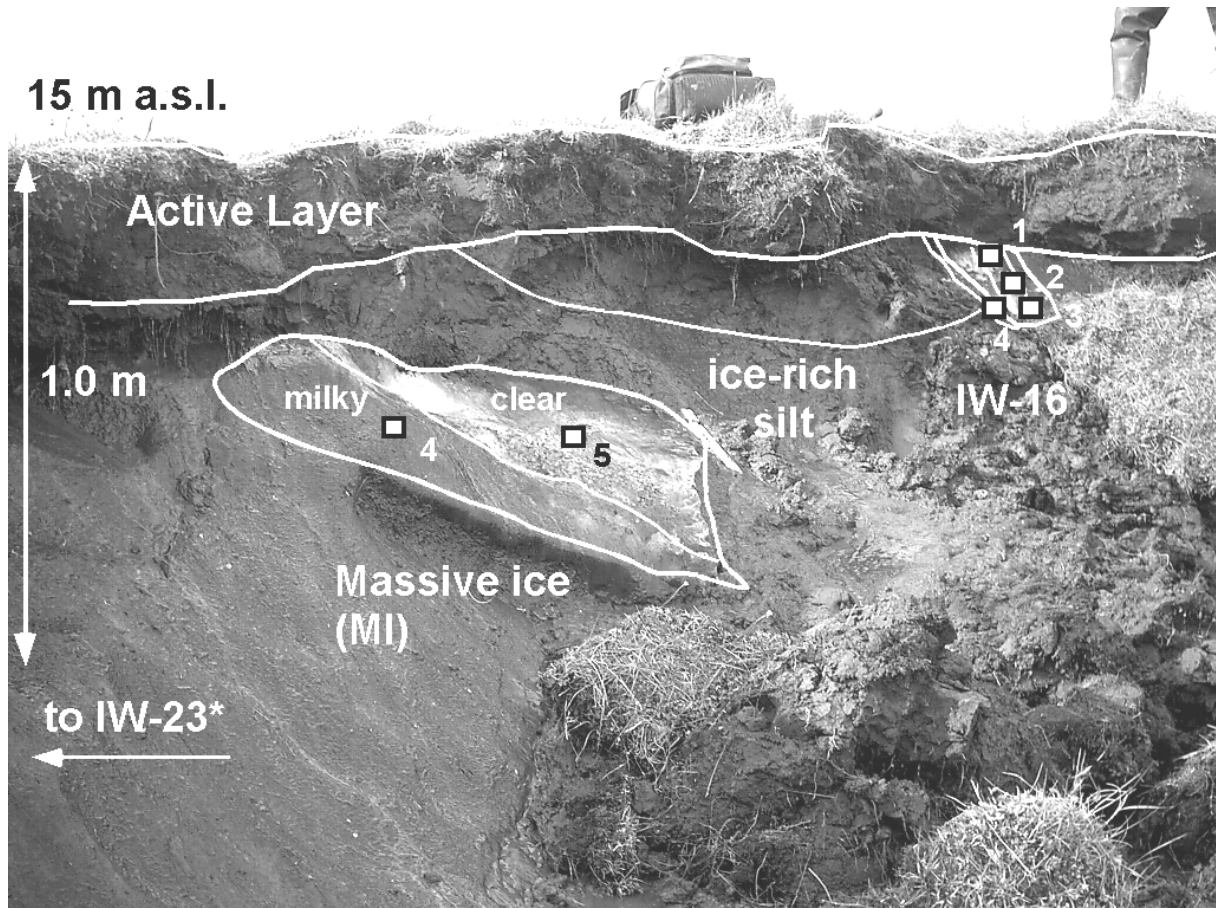


Figure 4.6.3-11: Outcrop MAK-IW-16, IW-23, -MI a with sampling points

Interpretation: The ice wedge MAK-IW-16 and -23 are probably of Holocene age and genetically correlated to the thermo-erosional valley, in which they are located on the western slope. Possibly, they are epigenetic features within older (Ice Complex) deposits. At this place, sediments of the thermo-erosional valley were not found. The massive ice body was interpreted as buried snow patch.

MAK-IW-17

Description: MAK-IW-17 is 3.2 m wide (Figure 4.6.3-12) and shows clear vertical structures, such as single ice veins of 2-4 mm in width, which may intersect each other. The ice is yellowish white to yellowish grey and turbid,

which is certainly related to the high number of very small (< 1 mm) gas bubbles, often oriented as a "string of beads". The content of mineral particles is medium and the organic content is low. On the left side, the ice wedge is in contact with single ice veins (sample MAK-IW-17.0). 33 samples were taken from the ice wedge in 10 cm intervals in horizontal direction by means of an ice screw (\varnothing 15 mm). Samples 1 – 16 were taken from the left, samples 29 to 45 from the right side - samples 17 to 28 are missing. The ice wedge is located at the bottom of the Ice Complex cliff, in a height of 5 m to 5.5 m a.s.l. (slightly rising from the left to the right). On the right side might be the contact to the adjacent ice wedge of the polygon.

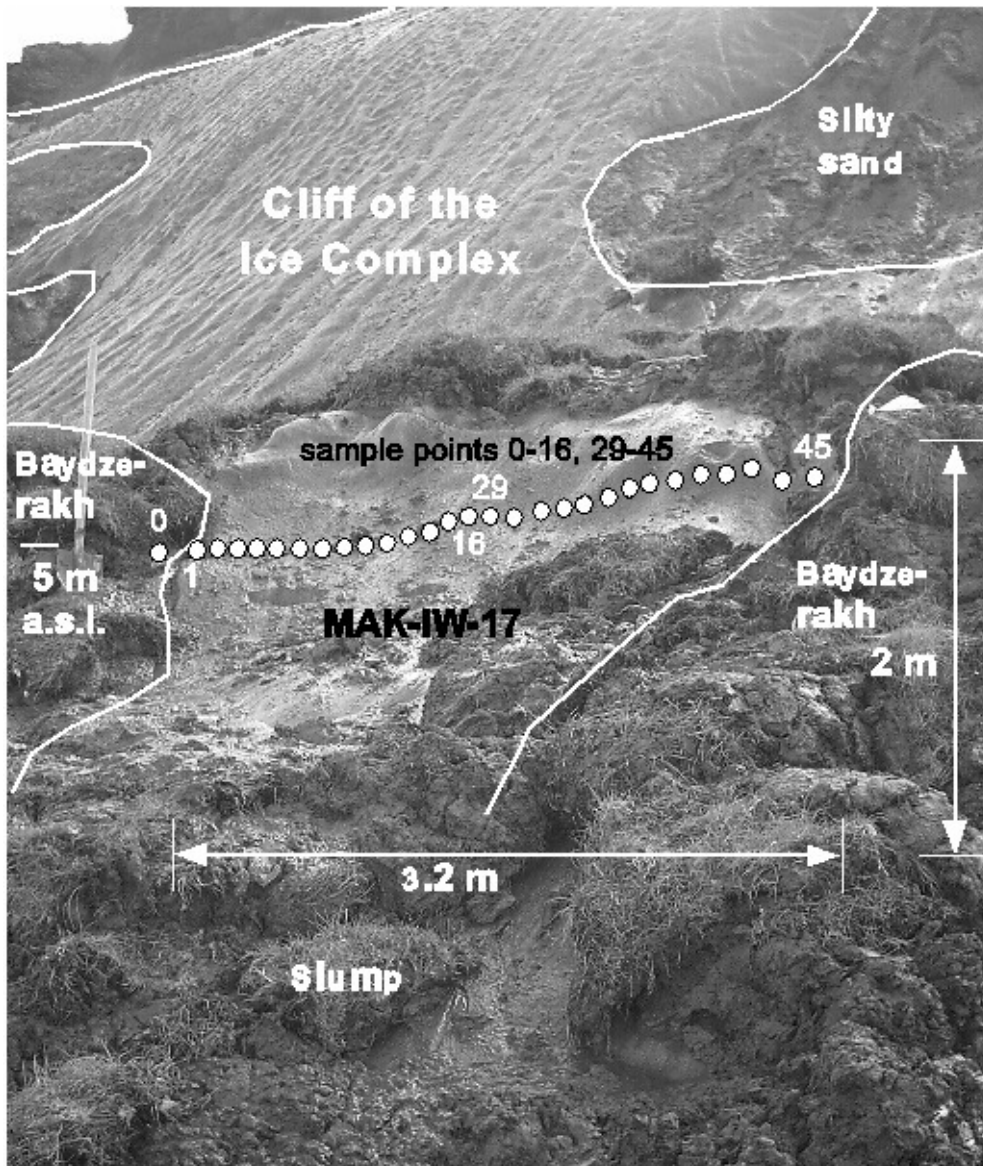


Figure 4.6.3-12: Outcrop MAK-IW-17 with sampling points

Interpretation: The ice wedge MAK-IW-17 belongs to the Ice Complex.

MAK-IW-18 (corresponding to the sediment sub profile Mak-12, Chapter 4.6.2.2)

Description: MAK-IW-18 is 0.6 m wide (Figure 4.6.3-13) and shows a moderate vertical foliation with single ice veins of 2-3 mm in width. The ice wedge is characterised by yellowish to brownish grey and transparent ice, a moderate mineral content and a low organic content. Gas bubbles are small (< 1 mm), spherical, not elongated and oriented along the ice veins. 4 samples were taken from this ice wedge by means of an ice screw (\varnothing 22 mm), again in 10 cm intervals at a height of 1.0 m a.s.l. The ice wedge is located in the second thermo-cirque near the Laptev Sea shore at a height of 1.3 m a.s.l. (top ice wedge).

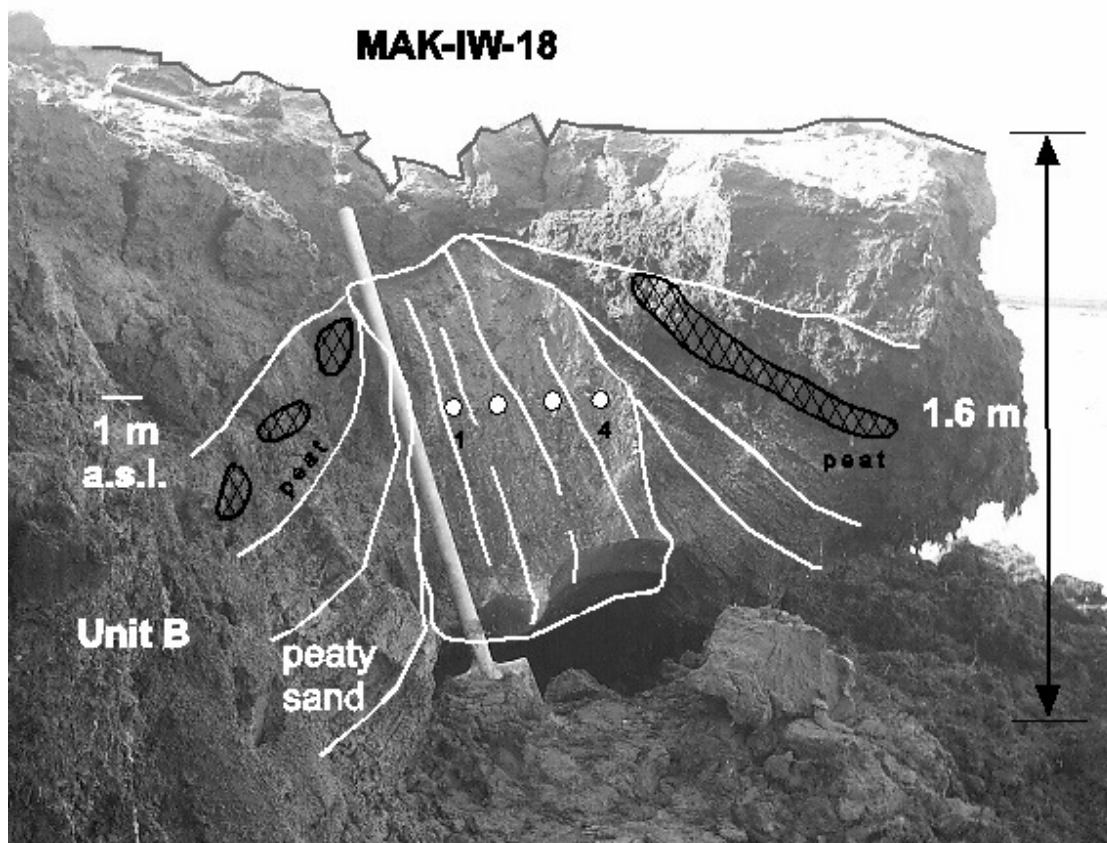


Figure 4.6.3-13: Outcrop MAK-IW-18 with sampling points (see Figure 4.6.2-3)

Interpretation: The ice wedge MAK-IW-18 belongs most likely to the uppermost peat of Unit B, but may also be a small Unit C (Ice Complex) ice wedge penetrating Unit B or a peat-rich part of Unit C. The question whether this section belongs to Unit B or C may be solved during the laboratory analyses.

MAK-IW-22

Description: MAK-IW-22 is a 1 to 1.2 m wide ice wedge and shows a well-developed vertical orientation. Vertical structures may be single ice veins of 2-7 mm in width, with clearly recognisable single ice veins and very small (< 0.5 mm) gas bubbles oriented as a "string of beads". The ice is sometimes milky white, sometimes more transparent. The content of mineral particles is rather low and the organic content is moderate. At the left side, the ice wedge is in contact with sands of Unit A/B. 14 samples were retrieved from the ice wedge by means of an ice screw (\varnothing 15 mm). 11 samples (IW-0 to IW-10) were taken in a height of 3.5 m a.s.l. in a horizontal sampling transect with 10 cm intervals. Samples 11 to 13 were sampled in the upper part by means of an axe. The ice wedge is located at the western flank of a thermo-erosional valley in a height of 3 m to 6.5 m a.s.l. (Figure 4.6.3-14).

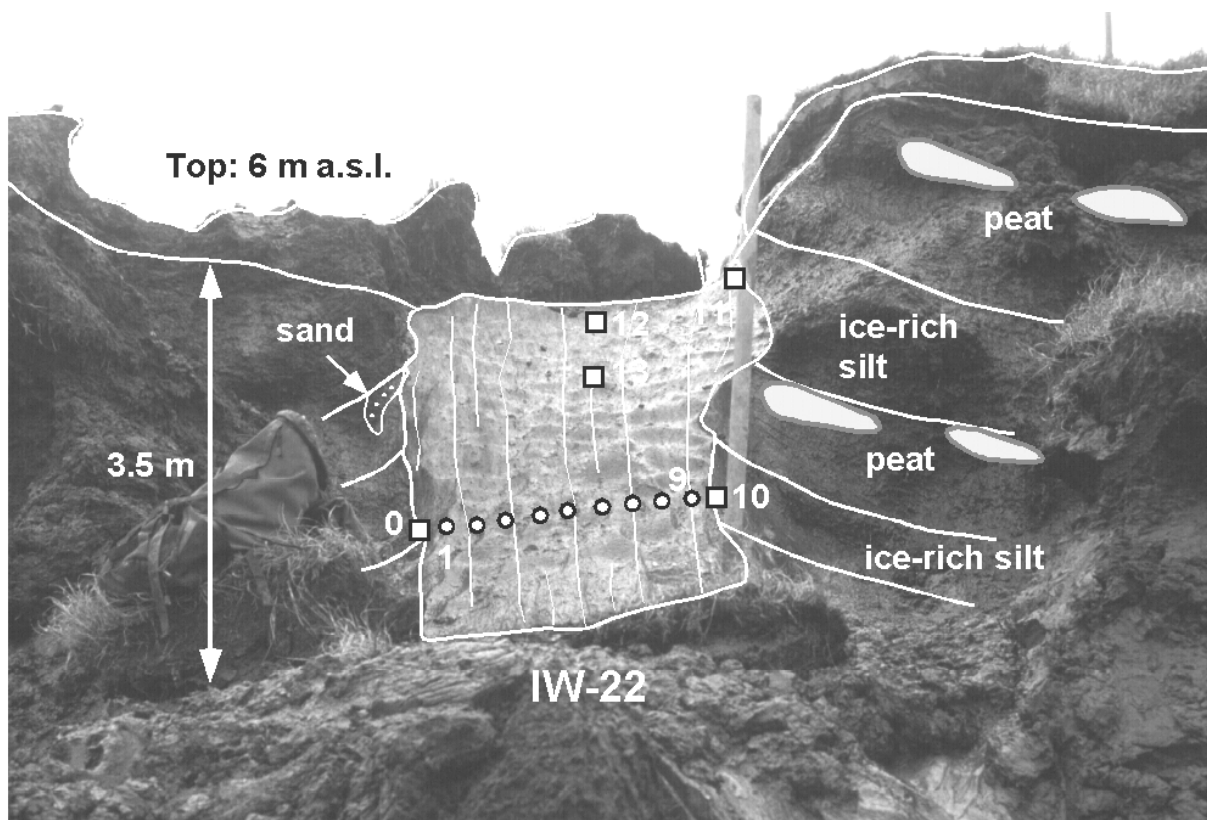


Figure 4.6.3-14: Outcrop MAK-IW-22 with sampling points

Interpretation: The genesis is still a matter of debate, since there are arguments to attribute the ice wedge to the thermo-erosional valley as well as to the Ice Complex. The Ice Complex genesis is supported by: the structure and colour of the ice, the presence of Ice Complex ice wedges 20 m to the west and the sands of Unit A or B, which are observed at the left side of the ice wedge. The size of the ice wedge, the surrounding sediment and the presence of a

thermo-erosional valley are rather favorable for a Holocene genesis within this valley. Stable isotopes will help to solve this problem.

MAK-IW-26

Description: Ice wedge MAK-IW-26 is 1.6 m wide (Figure 4.6.3-15) and was sampled in a horizontal profile in a height of 17.4 m a.s.l.. Six ice blocks, about 12 cm high and 23 to 30 cm wide, were cut by means of the chain saw. The ice was grey to white, tiger-striped with few yellowish ice veins. Single ice veins were about 2 mm wide and fell into (annual) pieces during sampling. The content of mineral particles and of organic matter was moderate. Small ice bubbles (mostly < 0.5 mm) were common, occasionally lengthened up to 4 mm within single ice veins. The right side of the ice wedge is confined by belt-like ice schlieren.

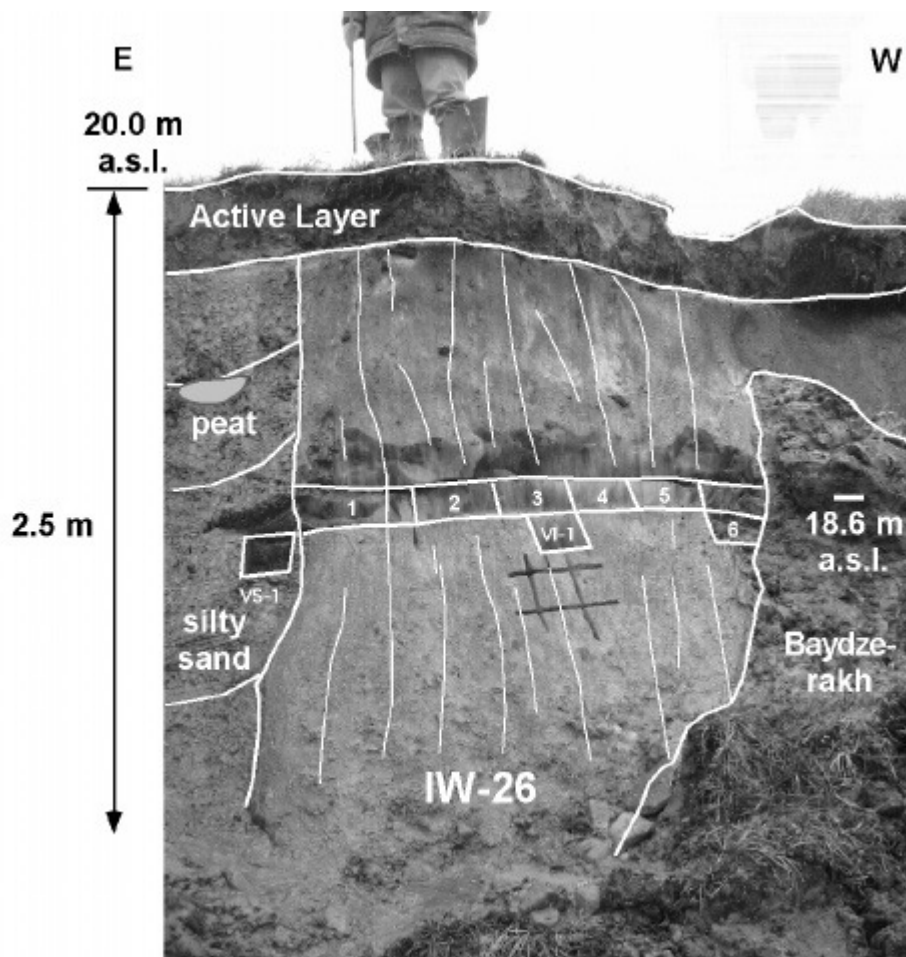


Figure 4.6.3-15: Outcrop MAK-IW-26 with sampling points

Interpretation: This is an ice wedge of the Ice Complex, which is the youngest one of the westernmost profile. The assumed age of the ice wedge is Late Pleistocene.

MAK-IW-27

Description: This ice wedge is 2.4 m wide and about 2.8 m high (Figure 4.6.3-16). Thin slices (about 15 mm wide) were cut by chain saw in 10 cm intervals from a horizontal sampling transect in an absolute height of 19 m a.s.l.. In total, 24 samples were taken. The ice is grey to yellowish-white, with single ice veins of 3 to 4 mm width. However, vertical structures are seldom clearly developed and rather moderately preserved. Gas bubbles are lengthened up to 8 mm in vertical direction. The sediment content within the ice wedge is high, the content of organic matter low. On both sides, the ice wedge is confined by ice-rich silty sands with wood fragments and banded cryostructure. Two additional samples (VI-2 and VS-2) were taken for sediment and ice analyses of the group working on coastal dynamics (see chapter 4.7.2).

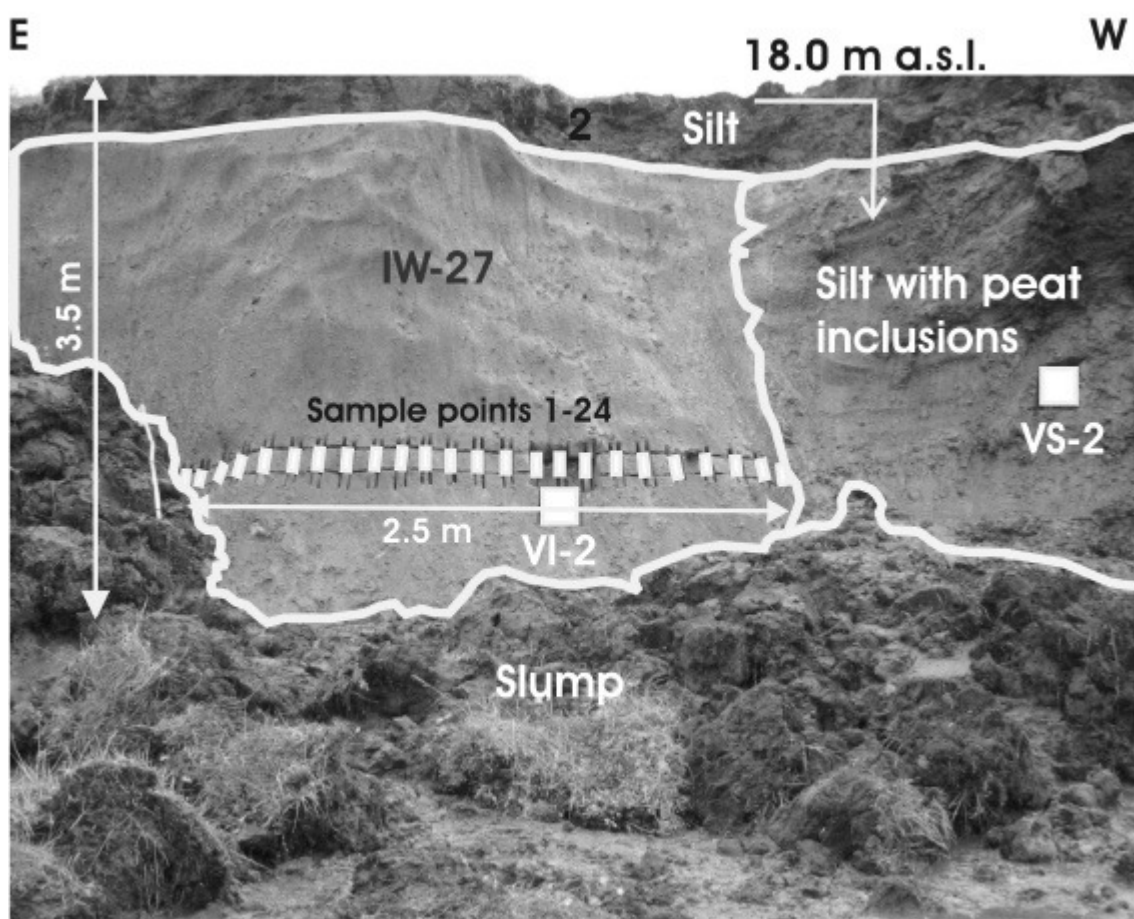


Figure 4.6.3-16: Outcrop MAK-IW-27 with sampling points

Interpretation: This ice wedge belongs to Unit C (Ice Complex).

4.6.3.4 Ground ice of unknown origin

MAK-MI b

A massive ice body (MAK-MI b) was found 20 m west of ice wedge MAK-IW-22 in a height of about 3 to 3.5 m a.s.l. presumably in Holocene log deposits. Ice lenses of massive ice are in contact with ice wedge ice, differing considerably from it. The massive ice body is composed of two different ice lenses: the upper one consists of clean transparent ice with big crystals and only a few gas bubbles, and the lower one of yellowish transparent ice with small crystals and numerous gas bubbles. The size of each of the ice lenses is approximately 0.4 x 1.5 m. Peaty silt with peat lenses encloses both massive ice and ice wedge. Three samples of massive ice and one sample of the ice wedge were taken by axe (Fig. 4.6.3-17).

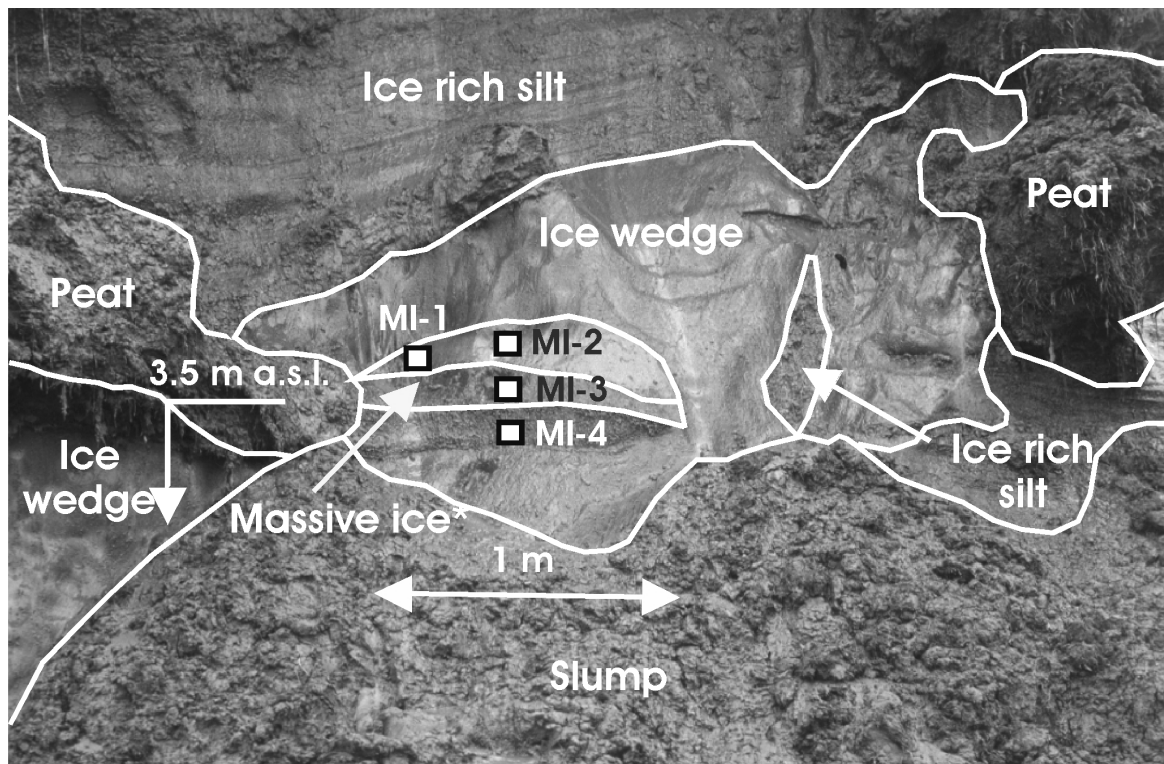


Figure 4.6.3-17: Outcrop MAK-MI b with sampling points

4.6.3.5 Ice wedge section west of the Nuchcha Dzhielle River mouth

MAK-IW-28

Description and Interpretation: This ice wedge is located on the western side of Nuchcha Dzhielle River, approximately 450 m west of the river mouth (Figure 4.6.1-2). The outcrop is a 9.5 m high very steep ice wall being located directly at the Laptev Sea coast. In the lower part, the ice wedge is laterally confined by subvertical ice-sand-wedges of Unit A (Figure 4.6.3-18). It can be clearly seen in this outcrop that these "polosatics" are limited to Unit A and that Ice Complex

ice wedges penetrate the older deposits of Unit A and Unit B. At least three, possibly four peat horizons were observed in Unit B. Unit C (Ice Complex) is only 1.5 to 2 m thick at this locality, which raises the question, whether this ice wedge is only epigenetic to Unit A and B deposits. In that case, this would lead to the assumption, that frost cracking activity during Ice Complex growth may reach depths of 8 m and more.

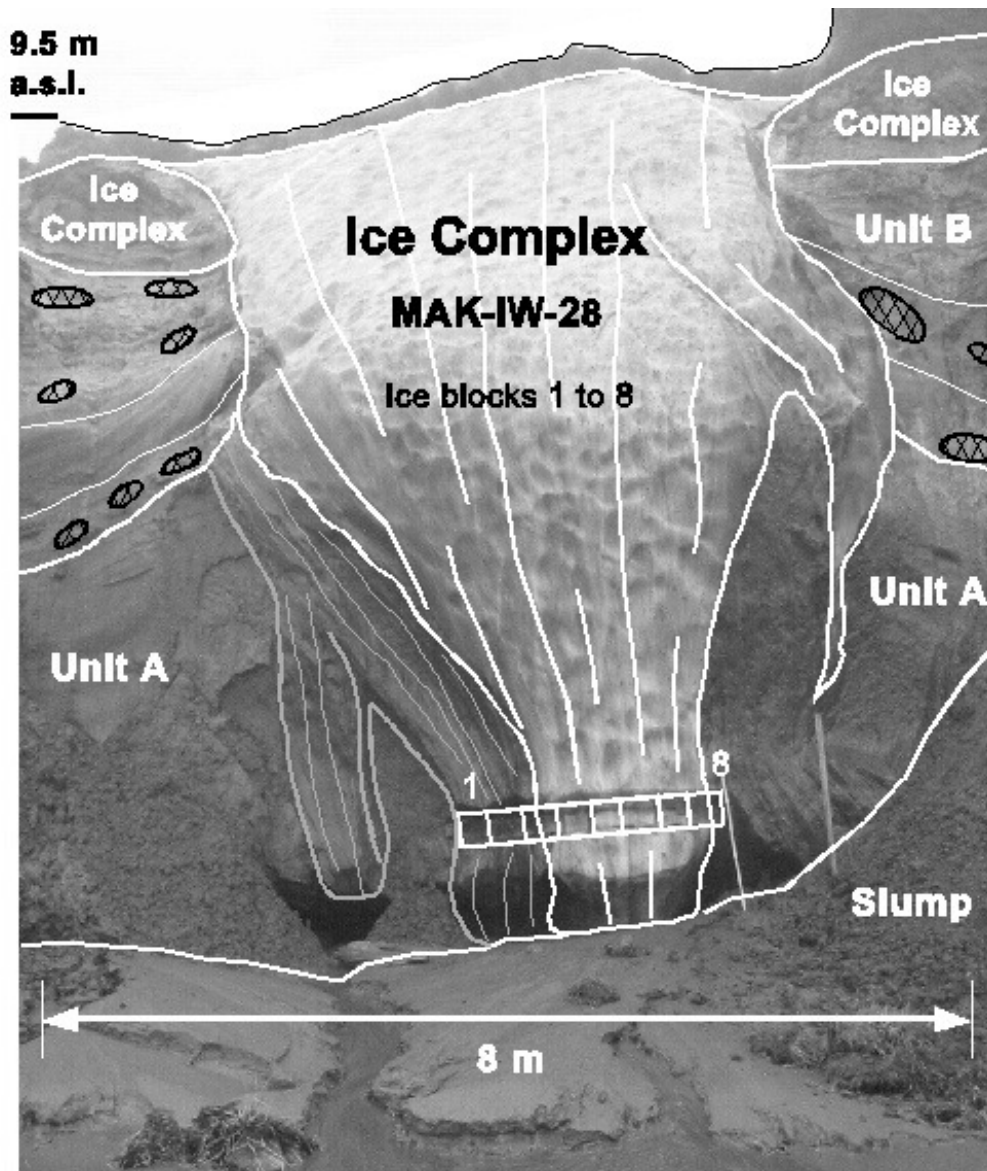


Figure 4.6.3-18: Outcrop MAK-IW-28 with sampling points

The ice of the **ice wedge** is white and milky, and cut perpendicular to the direction of frost cracking with very clear vertical structures. Narrow ice veins of 1-3 mm were observed in the ice wedge, sometimes cutting each other. The contents of organic matter and of sediment particles are both low. Gas bubbles are frequent and in general smaller than 0.5 mm. The **ice-sand-wedges** consist of single 2-8 mm wide ice veins, interrupted by < 1 mm to 2 mm wide sediment veins. The latter consist of ice-rich fine-grained sand to silt. The ice veins

originate in the adjacent ice wedge. Ice-sand veins are confined to Unit A and are cut by the first peat of Unit B.

Eight ice blocks (about 25 cm in length) were sampled by chain saw in a height of 1.5 m a.s.l.. This results in a 1.98 m long horizontal sampling profile, which includes the contact between ice-sand-wedge and Ice Complex ice wedge. Samples 1 to 3 were taken from ice sand-wedge and samples 3 to 8 from the ice wedge.

4.6.3.6 General interpretation of the sampled profile

The observation of other sampling sites such as the Bykovsky Peninsula, Oyagoysky Yar and the Big Lyakhovsky Island were confirmed during this field campaign. The Ice Complex is a Late Pleistocene formation with big syngenetic ice wedges and very ice-rich silty to sandy sediment. However, the ice wedges of Mamontov Klyk reach widths about 2.5 m, maximum 4 m, thus do not attain the dimension of their equivalents at the sampling sites mentioned above. This may point to less favourable conditions (e.g. lower water supply, higher sediment accumulation, less frequent frost cracking activity). Like at other locations, Big Lyakhovsky Island or Kurugnakh, the Ice Complex of Mamontov Klyk is underlain by a sandy facies, which may be linked to fluvial activity (at least for Kurugnakh and Mamontov Klyk). Like on Big Lyakhovsky Island, ice-sand wedges ("polosatic") occur within these sands pointing to a rather fast deposition of sediments and to the concurrency of water and sediment supply. Again, the Ice Complex is destroyed by Holocene sedimentary processes (especially by thermo-erosion in flat valleys (logs). A peculiarity is a Holocene cover above the MAK Ice Complex with a new generation of (presumably Holocene) ice wedges, which was not observed in Bykovsky Peninsula. Remarkable is the high number of massive ice bodies of unknown origin (not formed by frost cracking) which were observed and sampled in the section.