The Expeditions Amery Oasis, East Antarctica, in 2001/02 and Taylor Valley, Southern Victoria Land, in 2002

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Acknowledgements

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Abstract

In the context of long-term studies to the climate and environmental histories of ice-free coastal regions (oases) of Antarctica an Australian-German expedition to the Amery Oasis, Northern Prince Charles Mountains, and an American-German expedition to the Taylor Valley, southern Victoria Land, were carried out during the austral summers 2001/2002 and 2002/2003, respectively. The project is based on earlier Russian-German expeditions to the Schirmacher and Untersee Oasis (1991/1992 and 1994/1995), the Bunger Oasis (1993/1994), and an Australian-German expedition to the Windmill Islands (1998/1999). The overall goal of the studies is to understand the reactions of the environment at the margins of the Antarctic ice sheet on past global climate variabilities, and to develop scenarios for their future reactions on climate changes. The German and American contribution to the project, which is targeted on the reconstruction of the climate and environmental history, is based on studies of sediments from existing lakes as a natural climate archive, whereas the Australian cooperation partners focus their work on geomorphological studies.

The Amery Oasis and the Taylor Valley are of special significance within these long-term studies. According to previous studies, the Amery Oasis could already have existed during the Last Glacial Maximum. The location of the oasis provides a unique opportunity to reconstruct the history of the Lambert Glacier/Amery Ice Shelf system, which drains about 9% of the area of the Antarctic ice shield today. A comparable long lasting ice-free history is also proposed for the Taylor Valley in the southern Victoria Land. During the Last Glacial Maximum the valley outlet was presumably blocked by the northward advanced iceshelf, which dammed up the proglacial Lake Washburn at least in the lower valley. The today existing lakes are supposed to be remnants of this proglacial lake.

During the Amery Oasis expedition 2001/2002 sediments were recovered from three different lakes in three different regions with a total amount of about 20 m. The basis of the limnic sediments was reached in all three lakes. The postglacial sediments of Lake Terrasovoje, a ca. 1.5 km^2 and 31 m deep lake in the northern part of the study area, were mainly composed of algae mats and moss layers. The high content of organic matter in the sediments enables to establish a reliable chronology by radiocarbon dating, and to reconstruct the regional climate history by past changes in lake bioproductivity. The sediments of Radok Lake, recovered from three different locations within the lake, may give information about late Quaternary movements of the ice masses in the western catchment of the Lambert Glacier/Amery Ice Shelf. The sediments of Beaver Lake, which is hydraulically connected with the ocean underneath the Stagnant and Charybdis Glacier, are of special interest, because they probably document changes in the relative sea-level history. These changes are probably indicated in subaquatic terraces along a bathymetric profile in the western part of the lake.

During the Taylor Valley expedition from october to december 2002 a total sum of about 33 m of sediment was recovered from three different lakes along the valley. At Lake Hoare and at both east and west lobes from Lake Bonney, the maximum core length was about 3 m. The core from East Lobe Bonney was almost exclusively formed by salt cristals, whereas the sediments from the other lakes in Taylor Valley mainly consisted of coarse-grained terrigenous matter. However, interspersed layers of organic matter in the top sediments of Lake Fryxell, and several horizons composed of relatively fine-grained sediments in the deeper parts enabled to obtain an almost 10 m long core from this lake. According to the calculated sedimentation rate from former expeditions to Lake Fryxell, the lower part of this core might consist of the proglacial Lake Washburn sediments.

Zusammenfassung

Im Rahmen der langfristig angelegten Untersuchungen zur Klima- und Umweltgeschichte eisfreier Küstenregionen (Oasen) der Antarktis fanden in der Südsommern 2001/2002 und 2002/2003 eine australisch-deutsche Expedition zur Amery-Oase, nördliche Prince-Charles-Berge, und eine amerikanisch-deutsche Expedition in das Taylor Valley, südliches Victoria Land, statt. Die Arbeiten bauen auf russisch-deutsche Untersuchungen in den Oasen Schirmacher, Untersee (1991/1992 und 1994/1995) und Bunger (1993/1994), sowie australisch-deutsche Untersuchungen in der Windmill-Oase (1998/1999) auf. Übergeordnetes Ziel der Untersuchungen ist es, die Reaktionen der Umwelt am Rande des antarktischen Inlandeises auf vergangene globale Klimaveränderungen zu studieren, um Prognosen für deren Entwicklung im Zuge zukünftiger Klimaveränderungen zu erstellen. Dabei werden für die Rekonstruktion der Klima- und Umweltgeschichte von deutscher und amerikanischer Seite besonders die Sedimente am Grund heute existierender Seen als natürliches Archiv genutzt, während die australischen Kooperationspartner vor allem geomorphologische Untersuchungen durchführen.
Die Amery-Oase und das Taylor Valley sind im Kontext des langfristigen Forschungsvorhabens von besonderer Bedeutung. Nach geomorphologischen Untersuchungsergebnissen könnte die Amery-Oase bereits während des Letzten Glazialen Maximums existiert haben. Ihre Lage bietet einzigartige Möglichkeiten zur Rekonstruktion der Geschichte des Lambert-Gletschers/Amery-Schelfeis Systems, über das heute etwa 9% des antarktischen Inlandeises entwässern. Eine vergleichbar alte, eisfreie Geschichte wird für das Taylor Valley im südlichen Victoria Land angenommen. Während des Letzten Glazialen Maximums war der Ausgang des Tales wahrscheinlich durch das nordwärts vorgerückte Schelfeis blockiert, was zur Aufstauung des proglazialen Lake Washburn zumindest im unteren Talabschnitt führte. Die heute im Tal existierenden Seen werden als Überbleibsel des glazialen Sees angesehen.

Auf der Expedition Amery-Oase 2001/2002 wurden aus drei Seen in drei verschiedenen Regionen der Oase insgesamt ca. 20 m Sedimente gewonnen. Bei allen drei Seen wurde die Basis der limnischen Sedimente erreicht. Im Terrasovoje, einem ca. 1,5 km^2 großen, bis 31 m tiefen See am Nordrand der Oase, wurden organisch reiche postglaziale Sedimente angetroffen, die gut datierbar sein dürften und über Schwankungen in der Bioproduktion die regionale Klimaentwicklung seit dem Eisrückzug widerspiegeln könnten. Aus der Bearbeitung der Sedimente des Radok-Sees werden vor allem neue Erkenntnisse zu spätquartären Bewegungen der Eismassen im westlichen Einzugsgebiet des Lambert-Gletschers erwartet. Die Sedimentkerne vom Beaver-See, der unter dem Stagnant- und Charybdis-Gletscher eine hydraulische Verbindung zum Ozean aufweist, sind schließlich von besonderer Bedeutung. In ihnen könnten Schwankungen des relativen Meeresspiegels dokumentiert sein, die sich in hangnormalen bathymetrischen Profilen in Form von subaquatischen Terrassen andeuten.
Während der Expedition ins Taylor Valley von Oktober bis Dezember 2002 wurden insgesamt 33 m Sediment aus drei verschiedenen Seen entlang des Tales gewonnen. Im Hoare-See und im Ost- und Westbecken des Bonney-Sees betrug die maximal erzielte Kernlänge jeweils 3 m. Der Sedimentkern aus dem Ostbecken des Bonney-Sees wurde fast ausschließlich aus Salzkristallen gebildet, während sich die Sedimente der anderen Seen im Taylor Valley vornehmlich aus grobkörnigem terrigenem Material zusammensetzten. Aus dem Fryxell-See konnte ein fast 10 m langer Kern erbohrt werden, da dort die Seesedimente neben gröberen klastischem Material auch aus organischen Horizonten im oberen Bereich und relativ feinkörnigen Sedimenten in den tieferen Bereichen zusammengesetzt waren. Nach der von früheren Expeditionen kalkulierten Sedimentationsrate im Fryxell-See könnte sich der untere Teil des auf der Expedition 2002 gewonnenen Kerns aus den proglazialen Lake Washburn Sedimenten zusammensetzen.

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1.1. Introduction and aims

1.1.1. Present knowledge

Approximately 97% of the Antarctic continent is covered by ice today. These ice masses form about 90% of the global continental ice volume. Changes in the extent and the volume of the Antarctic ice sheet may significantly modify the global water circulation patterns and may have a direct impact on the global sea level. Additionally, these changes influence the albedo, and atmospheric and oceanic circulation patterns, consequently affecting the global heat budget (Ingólfsson & Hjort 1999).
The changes in the size of the Antarctic ice sheet during the glacial and interglacial cycles seemed to be well understood for a long period. Marine geological investigations, mainly carried out at the continental shelf and slope, revealed that the ice sheet advanced to the continental margin during a glacial period and retreated far onto the shelf during an interglacial period (e.g., Anderson et al. 1979, Ehrmann et al. 1992, Grobe & Mackensen 1992, Melles & Kuhn 1993, Gersonde & Zielinski 2000). However, information about small scale changes of the ice sheet during glacials and interglacials was rare due to a poor time resolution or gaps in most of the marine sediment archives. Therefore, little information exists about the impact of stadials and interstadials during the Weichselian on the size of the Antarctic ice sheet (e.g., Behre & Lade 1986, Daansgard et al. 1993, Andrews 1998).
According to more recent investigations, primarily using terrestrial sediments from ice free coastal regions (oases) in East Antarctica, the glacial history at least during the last glacial-interglacial cycle was much more complicated than expected so far. These investigations revealed that particularly the East Antarctic region contains major uncertainties for the modelling of the Antarctic contribution to the global sea level rise (Bentley 1999).

1.1.1.1. Last Glacial Maximum

After the first investigations it was generally assumed that large areas of the continental shelves of Antarctica were ice covered during the Late Weichselian. However, the lack of Late Weichselian moraines in the Prydz Bay and at the George V coast (Fig. 1.1) led Hambrey et al. (1989) and Domack et al. (1991a) to the conclusion that these shelf areas were, in contrast to the common assumption, ice free during the Last Glacial Maximum (LGM). A thinner ice cover than previously assumed was also reconstructed for the Bunger Oasis by Colhoun & Adamson (1992) and for the Larsemann Hills by Gillieson (1991). The thicknesses of the ice cover in these regions were calculated from the isostatic rebound, being documented in the ages and altitudes of fossilized terraces of

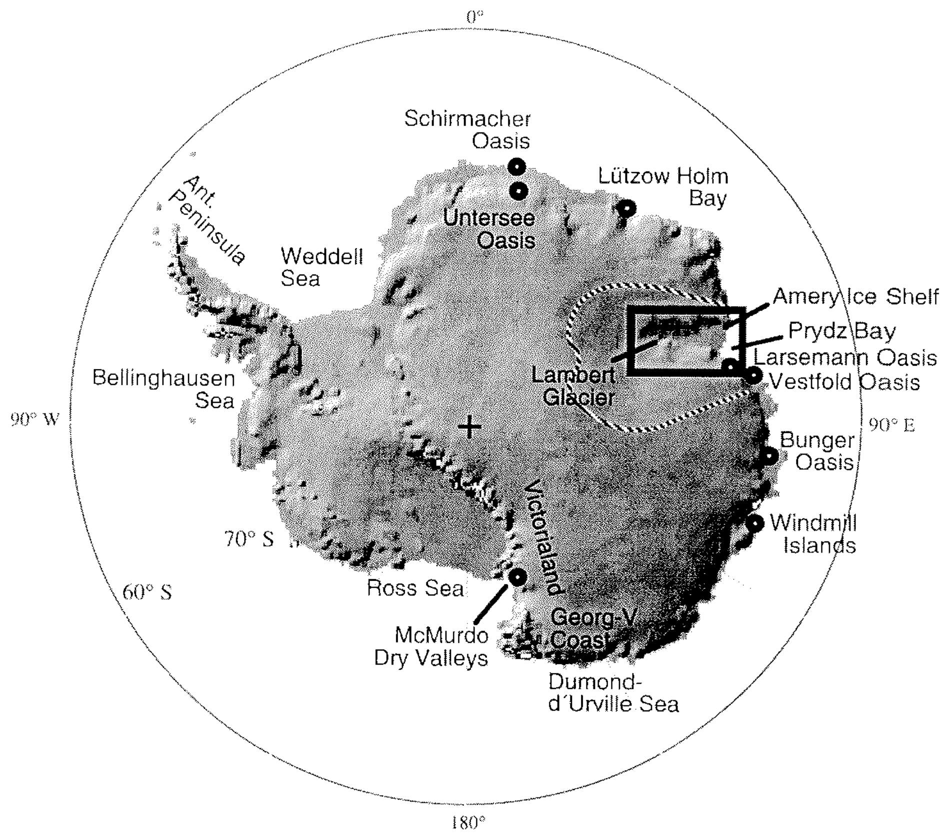


Fig. 1.1: Overview map of Antarctica showing regions mentioned in the text. The draining system of the Lambert Glacier in East Antarctica covers an area of about 9% (dashed line) of the total Antarctic ice shield. The frame indicates the position of the satellite image shown in Fig. 1.2.

Holocene age. The calculated ice thicknesses of 155 - 400 m during the LGM in the Bunger Oasis, and 200-500 m in the Larsemann Hills are distinctly lower than the formerly assumed 1000 m of ice cover in both regions. Similar observations were made in the Amery Oasis. According to Adamson et al. (1997) the lack of shoreline terraces above the present sea level suggests that the ice cover of the Amery Oasis during the LGM was similar or even thinner than today. This interpretion is confirmed by geomorphological investigations of Hambrey & McKelvey (2000), particularly carried out on moraine structures in the Amery Oasis.

Ice free areas during the LGM may also have persisted at the Lützow Holm Bay, in the Vestfold Oasis, the Untersee Oasis and the Larsemann Hills. These interpretions, made by Yoshida (1983), Zhang et al. (1983), Hiller et al. (1988), and Burgess et al. (1994, 1997), are based on Middle and Late Weichselian radiocarbon (^{14}C) ages of marine fossils, bird excrements (mumyio) and terrestrial mosses (Tab. 1.1). Radiocarbon and Uran/Thorium ($^{234}U/^{230}Th$) datings on lake sediments indicate ice free areas during the

LGM also in the Dry Valleys (Clayton-Greene et al. 1988). Similar reconstructions have been made by OSL datings on lake sediments and cosmogenic isotope datings on exposed rocks from the Bunger Hills (Gore et al., unpubl.; Zwartz & Stone, unpubl.).

Tab. 1.1: Examples for maximum ages of pre- and postglacial sediments from ice free coastal areas, and of postglacial sediments from the Antarctic continental shelf (for locations see Fig. 1.1).

^{14}C-age [B.P.]	material	region	reference
a) preglacial ages from ice free coastal areas			
25000	terrestrial mosses	Larsemann Oasis	Burgess et al. (1994, 1997)
30500 [1)]	marine carbonate shells	coast of Lützow Holm Bay	Yoshida (1983)
23000	autigeneous limnic carbonate	Dry Valleys	Clayton-Greene et al. (1988)
32900 [2)]	mumyio	Untersee Oasis	Hiller et al. (1988)
b) postglacial ages from the continental shelf			
9500 [1)]	marine carbonate shells	Lazarev Sea	Gingele et al. (1997)
13000 [1)]	marine carbonate shells	Ross Sea	Denton et al. (1989)
10700 [1)]	marine organic carbon	Prydz Bay	Domack et al. (1991a)
12400 [1)]	marine carbonate shells	Bellingshausen Sea	Pope & Anderson (1992)
11000 [1)]	marine carbonate shells	Weddell Sea	Melles (1991)
c) postglacial ages from ice free coastal areas			
9500	limnic organic carbon	Larsemann Oasis	Gillieson (1991)
9100 [1)]	marine carbonate shells	coast of Lützow Holm Bay	Yoshida (1983)
12000 [2)]	Penguin-Guano	coast of Victoria Land	Baroni & Orombelli (1994a)
9500	limnic organic carbon	Bunger Oasis	Melles et al. (1994, 1997)
9500 [1)]	mumyio	Bunger Oasis	Verkulich & Hiller (1994)
8400	limnic organic carbon	Vestfold Oasis	Fulford-Smith & Sikes (1996)
8600 [1)]	marine carbonate shells	Vestfold Oasis	Fitzsimons & Domack (1993)
10000	terrestrial mosses	James Ross I. (Ant. Penin.)	Ingólfsson et al. (1992)
8700	limnic organic carbon	Hope Bay (Ant. Penin.)	Zale & Karlén (1989)
8000	limnic organic carbon	King Georg I. (Ant. Penin.)	Mäusbacher et al. (1989)
6650	limnic organic carbon	Schirmacher Oasis	Schwab (1998)

[1)] corrected by the regional ´Antarctic marine reservoir effect´ (AMRE)

[2)] AMRE of 1000 years assumed

Ant. Penin. = Antarctic Peninsula

1.1.1.2. Postglacial ice retreat

The postglacial ice retreat from the continental shelf started at about 16 000 B.P. with the global temperature increase and sea level rise (Johnsen et al. 1972). Both melting and calving, the latter primarily induced by destabilisation due to the rising sea level, led to a rapid retreat of the ice margin southwards (e.g., Domack 1982, Anderson et al.

1983). For example, facies changes in the sediments of the Weddell Sea indicated an ice retreat between 14 000-13 000 B.P. (Melles 1991).

The existing ^{14}C ages of sediments from the continental shelf (Tab. 1.1) can only be interpreted as minimum ages of the ice retreat, because the dated sediment horizons do not overlay the basal tills or glacial erosion discordancies directly. In general, they are separated by sediments of uncertain ages and with only small amounts of organic matter. Hence, although the oldest ^{14}C ages comprise a period between 13 000 and 9500 B.P., regional differences in the onset of ice retreat may not be figured out.

The coastal ice free regions of Antarctica provide a higher diversity of biogenic materials, which enable radiocarbon dating. These include marine carbonate shells from recent marine basins or old shoreline terraces, organic carbon from marine and limnic sediments, terrestrial mosses, penguin guano, and snow petrel excrements (mumyio). The ^{14}C datings on these materials provide, as the datings on the sediments from the continental shelves, only minimum ages for the onset of the glacial retreat. They characterize the beginning of bioproduction and accumulation of organic matter, probably with a great delay to the deglaciation. This seems to be indicated in regions where no or only minor glaciation since the Middle Weichselian is assumed by the ages of fossils or other dated materials (Tab. 1.1).

1.1.1.3. Holocene glacier movements

The knowledge about Holocene ice advances and retreats on the Antarctic continental shelf is relatively unsufficient today. The facies successions of shelf sediments from the southern Weddell Sea (Fig. 1.1) indicate a stepwise ice retreat without any intermediate advances until 4000 B.P. at least (Melles 1991). It is likely that the ice in the eastern Weddell Sea reached its present position at ca. 10 000 B.P., and has remained more or less stable (Grobe 1986). Conversely, Holocene advances of glacier tongues and ice shelves onto the shelf areas of the Georg-V coast, the Dumond-d'Urville Sea, and the Prydz Bay (Fig. 1.1) were reconstructed by Domack et al. (1991b), all occurring between 7000-4000 B.P. These ice advances were explained by a warmer climate, which would have reduced the sea-ice cover, and thus led to higher evaporation over the sea and a higher precipitation rate in the accumulation areas of the ice sheets and glaciers.

A more detailed knowledge exists about the Holocene glacier retreats and advances in the coastal ice free regions of Antarctica. There, the limits of glacier movements are well reconstructed using geomorphological methods. The ages of these movements or stillstands are, however, often unprecise (Tab. 1.2). Maximum ages of glacier advances, for example, may be derived from ^{14}C datings on biogenic matter, which only could have been produced during periods of glacier absense (e.g., Baroni & Orombelli 1994b), or which have been incorporated into the ice during a glacier advance and later deposited in a moraine (Colhoun & Adamson 1992). Minimum ages of glacial retreats, in contrast, may be derived from ^{14}C datings on autochthonous biogenic matter, as for example marine carbonate shells (e.g., Baroni & Orombelli 1994b) or organic matter in limnic sediments (e.g., Björck et al. 1996), which overlay the moraines of a glacier advance. Additional information may be received from the ages of facies changes in proglacial marine basins and lakes in the Antarctic coastal regions (e.g., Melles et al. 1997).

Tab. 1.2: Examples of radiocarbon dated Holocene ice advances and retreats in coastal regions of Antarctica (for location of the regions see Fig. 1.1)

^{14}C-age [B.P.]	data basis	region	reference
a) Holocene ice advances			
ca. 7000 [1)]	glac., marine, lacustr. sedim.	James Ross I. (Ant. Penin.)	Ingólfsson et al. (1992)
6000-5000 [1)]	glac. and glaciomarine sedim.	James Ross I. (Ant. Penin.)	Rabassa (1987)
< 6200 [1)]	glacial sediments	Bunger Oasis	Colhoun & Adamson (1992)
6000-5000 [1)]	marine and limn. sediments	Bunger Oasis	Melles et al. (1997)
< 5000 [1)]	glacial sedim., marine terraces	Victoria Land	Baroni & Orombelli (1994b)
4200-3000	limnic sediments	James Ross I. (Ant. Penin.)	Björck et al. (1996)
< 4000 [1)]	marine terraces, lichens	Budd Coast	Goodwin (1996)
< 400 [1)]	glacial sediments	Bunger Oasis	Colhoun & Adamson (1992)
b) Holocene ice retreats			
7500-5000 [1)]	marine terraces	Victoria Land	Baroni & Orombelli (1994b)
6000-5000 [1)]	glac., marine, lacustr. sedim.	James Ross I. (Ant. Penin.)	Ingólfsson et al. (1992)
>5000	limnic sediments	James Ross I. (Ant. Penin.)	Björck et al. (1996)
3000-1200	limnic sediments	James Ross I. (Ant. Penin.)	Björck et al. (1996)
> 2000 [1)]	glacial sedim., marine terraces	Victoria Land	Baroni & Orombelli (1994b)

[1)] corrected by the regional 'Antarctic marine reservoir effect' (AMRE)
Ant. Penin. = Antarctic Peninsula

A circum-Antarctic comparison of relatively well dated ice movements on the continental shelf (Domack et al. 1991b) and inland reveals a poor time consistancy, even partly contrary ice movements at the same period. For example, numerous ice advances are reported between 7000 and 4000 B.P. (e.g., Rabassa 1987, Domack et al. 1991b), but ice retreats have also been reconstructed during the same period (e.g., Ingólfsson et al. 1992, Baroni & Orombelli 1994b). Because these discrepancies may hardly be explained by dating faults, they have to be caused by regional differences.

1.1.1.4. Late Quaternary climate and sea level changes

Today, little is known about the reasons for the Holocene ice movements in Antarctica. The ice movements were explained by regional temperature and precipitation changes, which have a direct impact on the increase and the decrease of the ice masses (e.g., Domack et al. 1991b, Björck et al. 1996), and also in the context of marine

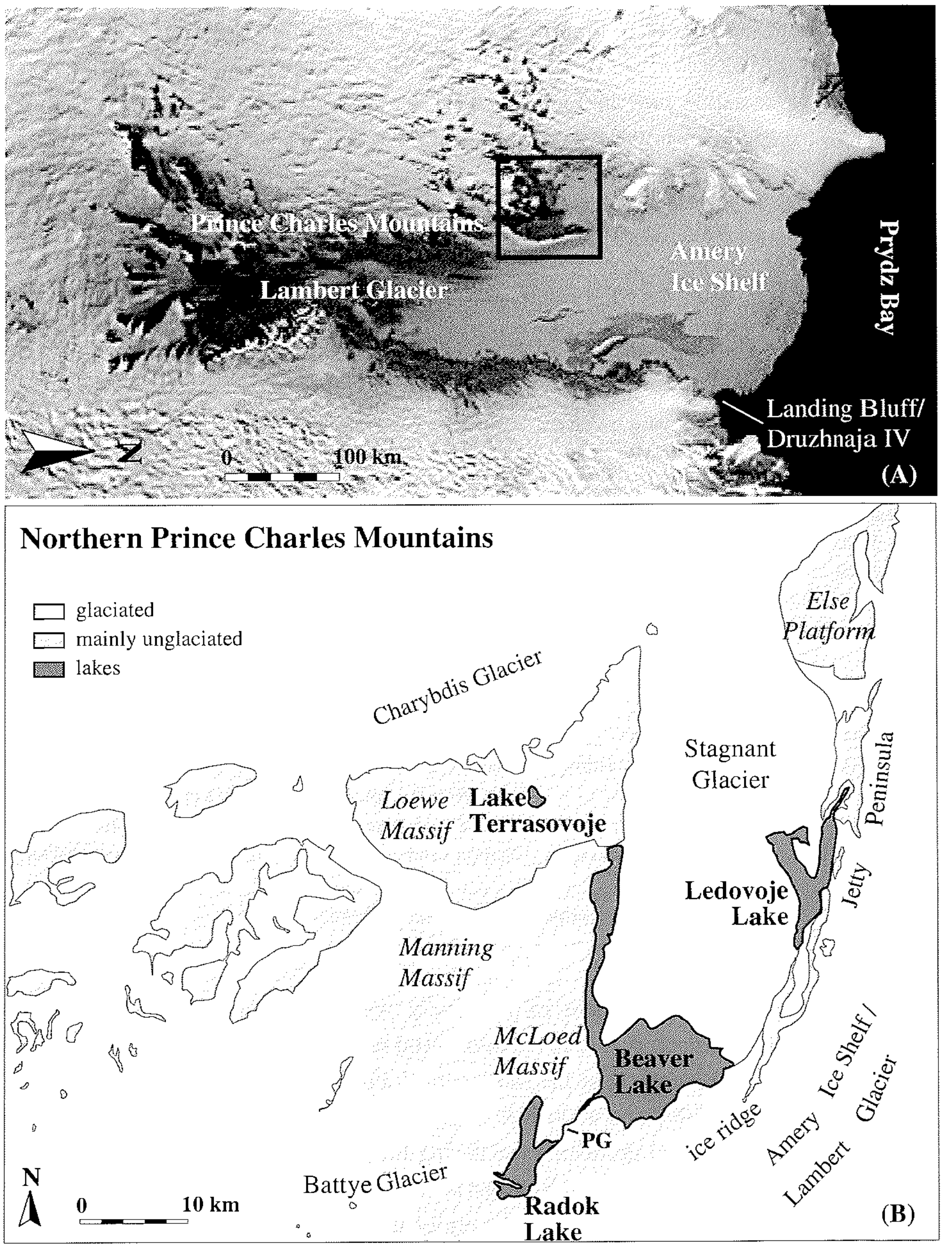


Fig. 1.2: (A) Satellite image of the Lambert Glacier / Amery Ice Shelf region. The black rectangle indicates the limits of the map shown in (B), containing most of the Northern Prince Charles Mountains, respectively the Amery Oasis and Jetty Peninsula. Note that (B) is anticlockwise rotated by 90°. PG = Pagodroma Gorge.

transgressions and regressions that affect the calving intensity at the ice margins (e.g., Ingólfsson et al. 1992, Melles et al. 1997).

The large scale climate changes of Antarctica within the last 420 000 years are best documented in the ice cores of the Antarctic ice shield (e.g., Johnsen et al. 1972, Lorius et al. 1985, Mayewski et al. 1996, Petit et al. 1999). These can not yet explain regional climate changes at the more coastal regions, where longer ice cores have not been recovered so far.

The existing knowledge of the postglacial climate history of the coastal regions is mainly based on the investigations of local terrestrial, limnic and marine sediment sequences. A comparison between the sediment sequences from different regions indicates, however, a large asynchroneity in the climate history. The Holocene temperature maximum in the Untersee Oasis, for example, is recorded to have occurred before 7000 B.P. (Schwab 1998), that of the Bunger Oasis was reconstructed for the period between 4700 and 2000 B.P. (Melles et al. 1997), probably corresponding to the Middle to Late Holocene climate optimum in the Windmill Islands (Cremer et al. 2001). A comparison between the well dated climate history in the Bunger Oasis and those documented in the closest ice cores inland reveals no significant correlations (Kulbe 1997, Kulbe et al. 2001).

The Holocene changes of the relative sea level in the coastal regions of Antarctica are the result of the global sea level changes and the isostatic rebound of the continent, which strongly depend on the glacial history. The reconstructed sea level changes at the East Antarctic coast indicate large regional differences, corresponding to the obviously inconsistent glacial histories of these regions. For example, highest relative sea levels were recorded at about 6200 B.P. in the Vestfold Oasis with ca. 9 m a.s.l. (Zwartz et al. 1998, Roberts & McMinn 1998, Roberts et al. 1999, Roberts & McMinn 1999), at ca. 7700 B.P. in the Bunger Oasis with 7-8 m a.s.l. (Colhoun & Adamson 1992), and at ca. 7000 B.P. at the Windmill Islands with 32 m a.s.l. (Goodwin & Zweck 2000; Fig. 1.1). According to Adamson et al. 1997, no indication for a sea level higher during the Holocene than today was found in the Amery Oasis (Fig. 1.1).

1.1.2. Significance of the Amery Oasis

The drainage system of the Lambert Glacier/Amery Ice Shelf covers an area of ca. 1×10^6 km^2, which is approximately 9% of the area of the total Antarctic ice shield (Higham et al. 1997, Hambrey & McKelvey 2000). The Amery Oasis is located at the western margin of this drainage system (Fig. 1.2), and was first sighted in the middle of the 1950´s. It consists of several ice free massifs, and is the largest ice free region in the Prince Charles Mountains (Fig. 1.2). The Amery Oasis is the furthest inland located oasis of its size in central East Antarctica, located ca. 250 km from the coast. It is separated by a 200 m high and ice covered ridge from the Lambert Glacier/Amery Ice Shelf system (Adamson et al. 1997). The main morphological feature of the Amery Oasis is a hugh southwards trending valley, which is at the most part occupied by the Stagnant Glacier, itself being a branch of the Charybdis Glacier (Fig. 1.2). At the

Stagnant Glacier, itself being a branch of the Charybdis Glacier (Fig. 1.2). At the eastern margin of the Stagnant Glacier lies the Ledovoje Lake, and at the southern margin the Beaver Lake, the largest known Antarctic lake. Although both lakes are located some 250 km from the ocean, observations have shown that they are tidal, and are therefore connected with the ocean underneath the Amery Ice Shelf. Due to their marine connection, these lakes are called epishelf lakes. Several fresh water lakes are located particularly to the west and northwest of Beaver Lake in the ice free massifs.
The lack of Holocene raised marine terraces and beaches in the Amery Oasis indicates that an isostatic rebound of the land masses during the last ca. 10 000 years has not taken place. This implies that the glaciation during the LGM was of a similar extent or even less than today (Adamson et al. 1997). The occurrence of marine fossils and the lack of erosional features in the Amery Oasis suggest that the Lambert Glacier has not transgressed the ridge at the eastern margin of the oasis since at least the Pliocene (Adamson et al. 1997).
Geomorphological investigations and the study of sediment sequences from the lakes and epishelf lakes in the Amery Oasis may provide a large potential to reconstruct changes in the volume and extent of the local ice masses, and will help to better understand their interactions with the local and regional sea level and climate changes.

1.1.3. Aims of the expedition 2001/2002

The expedition to the Amery Oasis during the austral summer 2001/2002 is an important contribution to the Australian-German research project "Palaeoenvironments of the Antarctic coast, from 50°E to 120°E", which is funded since 1998 by the ´Antarctic Science and Advisory Committee´ (ASAC). The aim of this project is to discover the reasons for regional differences in the Late Quaternary glacial history of East Antarctica. Available data to the climatic and environmental history of the coastal region between 50 and 120°E were collected, and completed by new geomorphological and palaeolimnological field and laboratory work. From the differences and the similarities between the glacial histories, depending on the regional climatic and environmental histories, regularities for the reaction of the East Antarctic ice margins on climate and sea level changes shall be considered.

The expedition 2001/2002 to the mostly unexplored Amery Oasis is intended to provide answers to the following questions:

(1) What was the glacial history of the Amery Oasis during the Late Pleistocene and Holocene?
(2) Were the glacial movements during these periods affected by local climate and sea level changes?

(3) What are the differences in the glacial, climate and sea level histories between the Amery Oasis and other coastal regions of Antarctica, and which causalities do they have?

To answer these questions, limnological and sedimentological sampling, as a part of the project, were carried out on several lakes from the Amery Oasis by the German expedition members during the austral summer 2001/2002. The geoscientific analyses of samples and data, as well as a comparison to the geomorphological results obtained by Australian colleagues may provide a detailed picture of the glacial and environmental history of this region, its differences and similarities to other East Antarctic regions, and its causalities in dependence to climate and sea level changes.

1.2. Amery Oasis 2001/2002 season

1.2.1. Itinerary

The MV „Polar Bird" left Hobart in the evening of 12. November 2001 in destination to Davis Station at the coast of East Antarctica. The weather and sea conditions while crossing the Southern Ocean were rather normal for the time of year, and also the ice conditions approaching the Antarctic continent did not cause a major delay in the voyage schedule. Arrival at the Davis Station was in the morning of 1. December, when the MV „Polar Bird" was fastened at the ice edge, ca. 3 km in front of the station. During the following three days most of the field training was conducted in the surrounding of the station. Davis Station was left in the morning of 4. December in destitation to Sansom Island, which is located in the Prydz Bay and where a fuel depot for helicopter operations into the Prince Charles Mountains and to the Amery Ice shelf is installed. Due to increasing sea ice cover the voyage of the MV „Polar Bird" was stopped, however, about 100 km in front of Sansom Island. Therefore, the seven members of Amery Oasis expedition 2001/2002 were evacuated on 7. and 8. December by aboard stationated helicopters from the MV „Polar Bird" to the Russian summer station Druzhnaja IV, which is located on Landing Bluff, a small island next to Sansom Island.

A first attempt of four expedition members to fly already in the evening of 8. December into the study area, the Northern Prince Charles Mountains, was foiled by increasing cloud cover towards the south of the Amery Ice shelf. During the following days, ongoing snow showers and cloud cover over the ice shelf avoided a further attempt to fly into the Amery Oasis region. However, in the late evening hours of 12. December a short period of cloudless conditions allowed a group of five expedition members equipped with their most important personal gear to reach Lake Terrasovoje in the northern Amery Oasis. Because of a renewed weather deterioration, no helicopter operations could have been carried out during the next days. The rest of the expedition members and most of the scientific gear was flown to Lake Terrasovoje on 20. and 21. December. Sedimentological and limnological field work at the lake lasted until 1. January 2002. Snowfall and strong winds again prevented during the following days a helicopter transfer of the German expedition members and their coring equipment to the next location, Radok Lake, ca. 40 km to the south.

Radok Lake was reached on 9. January, after spending one night at the Beaver Lake camp, a summer base with five apple huts ca. 8 km to the east of Radok Lake. A first camp was build on the lake ice in the northeastern branch of Radok Lake, with the coring location close by. Field work at this location lasted until 15. January, before a pre-site survey was carried out in the northern branch of the lake on 16. January. During the following two days, the camp and scientific equipment were moved into the northern branch, using a Quad and two sledges. The sedimentological and limnological programme in this part of Radok Lake was finished on 23. January, but a permanent

programme in this part of Radok Lake was finished on 23. January, but a permanent cloud cover over the Amery Ice shelf avoided any helicopter operations to move the camp again. Therefore, a small scientific programme was carried out in the southern part of Radok Lake, before the German expedition members and their personal and scientific gear were moved with Quads and sledges by the urgently needed assistance of the Australian collegues between 31. January and 3. February to the Beaver Lake camp. After finishing the scientific programme at Beaver Lake, all members of the Amery Oasis 2001/2002 expedition were flown along with their gear in the morning of 13. February back from the camp to the Davis Station.
The RSV „Aurora Australis“, which was scheduled for the return to Hobart, left Davis Station on 20. February. After a short stop at the Mawson Station on 25. February the RSV „Aurora Australis“ went back to Tasmania and reached Hobart on 8. March 2002.

1.2.2. Meteorological field observations

Meteorological observations were made at different locations in the Northern Prince Charles Mountains during the expedition (Tab. 1.3). Local effects may have had a great influence on the wind direction, wind speed, and some other meteorological parameters. However, barometric pressure, after correction for the altitude, and cloud cover should be valid for almost the whole region. Thus, the meteorological field observations may give an overview of the weather development during the season 2001/2002.

Tab. 1.3: Meteorological field observations taken at different locations in the Northern Prince Charles Mountains during the season 2001/2002.

date	time	location	alt. m a.s.l.	temp. °C	press. hpa	wind dir.	wind knts	cloud cover (1) total	l	m	h	remarks
09.12.	1900	Druzhna. IV	50	-2	958(2)	E	30-35	8	8	-	-	
10.12.	1900	Druzhna. IV	50	-1	973(2)	E	30-35	8	8	-	-	
11.12.	1100	Druzhna. IV	50	-2	989(2)	NE	15-17	7	2	2	7	
12.12.	2345	Terrasovoje	150	-4	950(3)	-	0	2	-	-	2	
13.12.	0800	Terrasovoje	150	-9	948(3)	v	3-7	7	-	-	7	
13.12.	1900	Terrasovoje	150	-5	973(3)	S	30-35	8	-	-	-	
14.12.	0900	Terrasovoje	150	-3	973(3)	SW	20-25	8	8	-	-	
14.12.	1900	Terrasovoje	150	+1	978(3)	S	15-17	7	7	-	-	
15.12.	0800	Terrasovoje	150	0	985(3)	SW	15-18	8	8	-	-	
15.12.	1820	Terrasovoje	150	0	992(3)	S	8-10	8	8	-	-	snow
16.12.	0840	Terrasovoje	150	+2	988(3)	SE	8-10	8	-	8	-	snow
17.12.	0730	Terrasovoje	150	0	976(3)	S	5	8	8	-	-	
17.12.	1900	Terrasovoje	150	+1	976(3)	SW	3-7	8	-	-	-	
18.12.	0900	Terrasovoje	150	-1	978(3)	E	8-10	8	8	-	-	snow
18.12.	1900	Terrasovoje	150	0	980(3)	S	7-10	8	8	-	-	snow
19.12.	0900	Terrasovoje	150	-1	989(3)	S	5	8	-	8	-	

Tab. 1.3 continued

19.12.	1900	Terrasovoje	150	+2	992[3]	S	10	8	8	-	-	
20.12.	0845	Beaver	20	+1	996[3]	v	0-3	3	-	1	2	
21.12.	0900	Beaver	20	-1	994[2]	SW	20	8	-	-	8	
21.12.	0900	Terrasovoje	150	-1	983[2]	v	0-3	5	-	-	5	
21.12.	1900	Beaver	20	+2	986[3]	SW	18	7	-	-	7	
22.12.	0900	Beaver	20	+1	994[3]	v	0-3	8	8	-	-	snow
22.12.	1830	Beaver	20	-3	994[3]	SW	17	8	8	-	-	snow
23.12.	0900	Beaver	20	0	982[3]	SW	15-20	8	8	-	-	
23.12.	2015	Beaver	20	+5	988[3]	SE	3-5	8	8	-	-	snow
24.12.	0900	Beaver	20	-1	992[3]	SW	3-5	8	8	-	-	snow
24.12.	1830	Beaver	20	+9	989[3]	v	0-3	7	7	-	-	
25.12.	0900	Beaver	20	-2	981[3]	SW	3	7	2	2	5	
25.12.	1900	Beaver	20	-2	982[3]	SW	3	7	3	5	4	
26.12.	0900	Beaver	20	-3	984[3]	SW	7-10	8	-	4	8	
26.12.	1900	Beaver	20	+2	984[3]	SW	3-5	8	2	6	4	
28.12.	0900	Terrasovoje	150	-3	985[3]	SW	20	8	8	-	-	
28.12.	1900	Terrasovoje	150	0	998[3]	SW	20-25	7	2	-	5	
29.12.	0740	Terrasovoje	150	-3	985[3]	SW	30	8	-	-	-	
29.12.	1450	Terrasovoje	150	-3	982[3]	SW	20-25	8	-	-	-	
30.12.	0800	Terrasovoje	150	-2	-	SW	15-20	8	8	-	-	
30.12.	1845	Terrasovoje	150	-1	1005[3]	S	25-30	2	1	-	1	
31.12.	0800	Terrasovoje	150	-1	979[3]	SW	15-20	1	-	-	1	
31.12.	1200	Terrasovoje	150	+4	981[3]	S	5-10	4	-	1	4	
01.01.	0800	Terrasovoje	150	0	980[3]	S	25	7	-	2	7	
01.01.	1900	Terrasovoje	150	+1	986[3]	S	10-12	7	2	5	5	
02.01.	1130	Terrasovoje	150	-1	994[3]	S	15-20	7	3	7	7	
02.01.	1840	Terrasovoje	150	+2	-	S	5-10	3	1	-	3	
03.01.	1130	Terrasovoje	150	+2	992[3]	SW	15	1	1	1	1	
03.01.	1845	Terrasovoje	150	0	987[3]	S	20	1	-	-	1	
04.01.	0845	Terrasovoje	150	-2	988[3]	S	15	7	-	7	-	
04.01.	1900	Terrasovoje	150	-1	990[3]	S	20	7	-	7	-	
05.01.	0845	Terrasovoje	150	-1	975[4]	SW	10	5	-	3	1	
05.01.	1900	Terrasovoje	150	+1	977[4]	SW	10	5	-	3	1	
06.01.	0845	Terrasovoje	150	-1	969[4]	SW	15	7	-	5	4	
06.01.	1900	Terrasovoje	150	+1	973[4]	SW	15-20	8	8	-	-	
07.01.	0915	Terrasovoje	150	-1	988[3]	SW	15	7	-	4	6	
07.01.	1915	Terrasovoje	150	+4	977[4]	-	0	1	-	-	1	
08.01.	0800	Terrasovoje	150	-1	988[4]	-	-	1	-	-	1	
08.01.	1600	Beaver	20	+1	998[4]	SW	12	0	-	-	-	
09.01.	0900	Beaver	20	-1	995[4]	S	25	1	-	1	-	
09.01.	1900	Beaver	20	-1	991[4]	SW	10-20	1	-	1	-	
10.01.	0900	Radok	10	-	-	S	5	1	-	-	1	
10.01.	1900	Radok[5]	10	+2	-	S	5	2	-	1	1	
11.01.	0900	Radok[5]	10	+2	992	SW	5-10	3	-	3	-	
11.01.	1900	Radok[5]	10	+4	977	S	5	5	-	5	-	
12.01.	0900	Radok[5]	10	0	990	NO	5	8	-	-	-	
13.01.	0900	Radok[5]	10	-2	989	E	5	6	-	-	6	
13.01.	1900	Radok[5]	10	+2	-	SW	10-12	2	-	-	2	

Tab. 1.3 continued

14.01.	0900	Radok(5)	10	-1	984	SW	15-20	1	-	-	1
14.01.	1900	Radok(5)	10	0	980	SW	15	1	-	-	1
15.01.	0900	Radok(5)	10	-1	987	SW	20-25	1	-	-	1
15.01.	1900	Radok(5)	10	-	-	SW	15	1	-	-	1
16.01.	0900	Radok(5)	10	+1	990	SW	20	1	-	-	1
16.01.	1900	Radok(5)	10	-	-	SW	15	0	-	-	-
17.01.	0900	Radok(5)	10	-8	986	SW	10	1	-	-	1
17.01.	1900	Radok(5)	10	+4	993	S	8-10	3	-	3	-
18.01.	0900	Radok(5)	10	+2	992	SW	12-15	7	-	7	-
18.01.	1900	Radok(5)	10	+5	985	SW	12-15	0	-	-	-
19.01.	0900	Radok(5)	10	-5	975	SW	25-30	0	-	-	-
19.01.	1900	Radok(5)	10	+5	977	S	0-3	0	-	-	-
20.01.	0900	Radok(5)	10	-1	980	S	10-12	8	8	-	-
20.01.	1900	Radok(5)	10	0	-	SW	10-12	0	-	-	-
21.01.	0900	Radok(5)	10	-2	987	SW	12-15	2	-	1	1
21.01.	1900	Radok	10	-	-	SW	10-12	1	-	1	-
22.01.	0900	Radok	10	-	-	S	15-20	0	-	-	-
22.01.	1900	Radok	10	-	-	SW	12	1	-	1	-
23.01.	0900	Radok	10	-	-	SW	10	0	-	-	-
23.01.	1900	Radok	10	-	-	SW	8-10	0	-	-	-
24.01.	0900	Radok	10	-	-	S	20-25	0	-	-	-
24.01.	1900	Radok	10	-	-	S	10	0	-	-	-
25.01.	0900	Radok	10	-	-	S	18	0	-	-	-
25.01.	1900	Radok	10	-	-	SW	10	1	-	1	-
26.01.	0900	Radok	10	-	-	SW	18	5	1	3	3
26.01.	1900	Radok	10	-	-	SW	10-12	3	-	-	3
27.01.	0900	Radok(6)	10	-1	972	SW	18	3	-	1	2
27.01.	1900	Radok(6)	10	0	974	S	8	1	-	-	1
28.01.	0900	Radok(6)	10	-3	975	SW	20	0	-	-	-
28.01.	1900	Radok(6)	10	-2	977	SW	6-10	0	-	-	-
29.01.	0900	Radok(6)	10	-4	981	SW	10-12	7	7	-	-
29.01.	1900	Radok(6)	10	0	984	SW	10-12	7	7	-	-
30.01.	0900	Radok(6)	10	-4	986	S	8-10	2	-	2	-
30.01.	1900	Radok	10	+3	-	SW	0-3	6	-	6	-
31.01.	0800	Radok(6)	10	-5	984	SW	12	5	-	5	-
31.01.	1900	Beaver	20	-	-	S	15	7	1	7	-
01.02.	0930	Beaver	20	-1	989(3)	S	20-25	1	-	1	1
01.02.	1900	Beaver	20	-3	990(3)	SW	20-25	4	-	-	4
02.02.	0830	Beaver	20	-3	991(3)	SW	20-30	7	-	2	7
02.02.	1830	Beaver	20	-1	995(3)	SW	20	8	8	-	-
03.02.	0830	Beaver	20	-5	980(3)	S	35-40	7	1	3	5
03.02.	1830	Beaver	20	-3	978(3)	SW	30	1	-	1	-
04.02.	0830	Beaver	20	-4	980(3)	SW	30	7	6	1	-
05.02.	0840	Beaver	20	-2	981(3)	S	25-30	1	-	1	-
05.02.	1930	Beaver	20	0	982(3)	S	15-20	0	-	-	-
06.02.	0900	Beaver	20	-3	985(3)	SW	15-20	1	-	1	-
06.02.	1915	Beaver	20	-4	986(2)	SW	10-15	1	1	1	-
07.02.	0900	Beaver	20	-7	991(2)	SW	15-20	2	1	2	-

Tab. 1.3 continued

07.02.	1900	Beaver	20	-6	986(2)	SW	10-20	7	2	5	3
08.02.	0830	Beaver	20	-8	975(2)	SW	25-35	7	-	-	7
08.02.	1900	Beaver	20	-5	969(2)	SW	25-30	1	-	-	1
09.02.	0830	Beaver	20	-8	970(2)	SW	10-15	3	-	3	1
09.02.	1900	Beaver	20	-6	970(2)	N	5-10	7	1	6	-
10.02.	0830	Beaver	20	-10	978(2)	W	5-10	5	2	5	-
10.02.	1630	Beaver	20	0	976(2)	N	5-10	3	2	3	1
11.02.	0830	Beaver	20	-5	978(2)	SW	-	2	-	2	-
11.02.	1900	Beaver	20	-1	979(2)	SW	15	6	-	6	-
12.02.	0830	Beaver	20	-7	982(2)	SW	15-25	0	-	-	-
12.02.	1900	Beaver	20	-5	983(2)	SW	20-25	0	-	-	-
13.02.	0600	Beaver	20	-9	993(2)	SW	15-20	1	-	1	-

(1) cloud cover in octas, l = low, m = medium, h = high
(2) measured by a Thommen altimeter
(3) measured by a Kestrel hand weather station
(4) measured by a Casio watch
(5) temperature and pressure measured (with a Kestrel) at Lake Terrasovoje
(6) pressure measured (with a Kestrel) at Lake Terrasovoje

Due to the lack of a permanent weather station in the Northern Prince Charles Mountains, the meteorological field observations made during the season 2001/2002 may hardly be compared to a long-term climatic trend from this region. The closest long-term climate observations were made at the Davis Station, some 400 km away at the East Antarctic coast. Due to the large distance between the Northern Prince Charles Mountains and the Davis Station, regional anomalies certainly affect the data records.

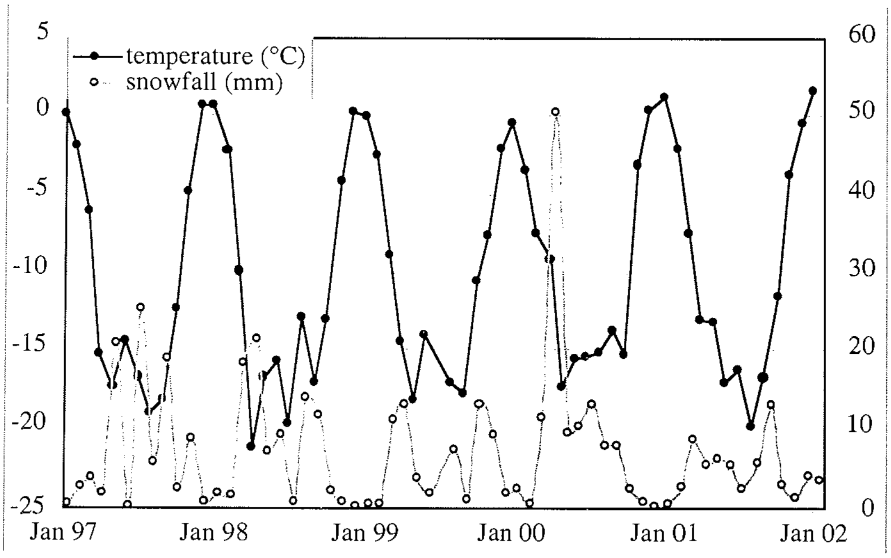


Fig. 1.3: Monthly average temperatures and total snowfall in the years 1997 to 2002 at Davis Station.

At Davis, a series of slightly cooler summers during the seasons 1997/1998, 1998/1999, and 1999/2000 was apparently followed by warmer summers in 2000/2001 and 2001/2002 (Fig. 1.3). However, longer lasting distinct anomalies of the monthly average temperatures or the total snowfall are not recorded during the past five years.

1.3. Studied lakes

1.3.1. Lake Terrasovoje

Lake Terrasovoje is an oval shaped lake between the Loewe Massif to the west and the entrance of the Stagnant Glacier to the east (Fig. 1.2). The maximum length of the lake is 2 km in northwest to southeast direction, the maximum width measures 1.3 km in southwest to northeast direction (Fig. 1.4). The catchment area of Lake Terrasovoje is approximately 25 km^2, and characterized by several moraine ridges particularly to the east of the lake. The lake is mainly fed by meltwater from the surrounding slopes during the summer, however a major inlet is lacking. The outlet is in the northwestern corner of Lake Terrasovoje and leads into a lateral tongue of the Charybdis Glacier that passes the Amery Oasis and the Loewe Massif to the north.

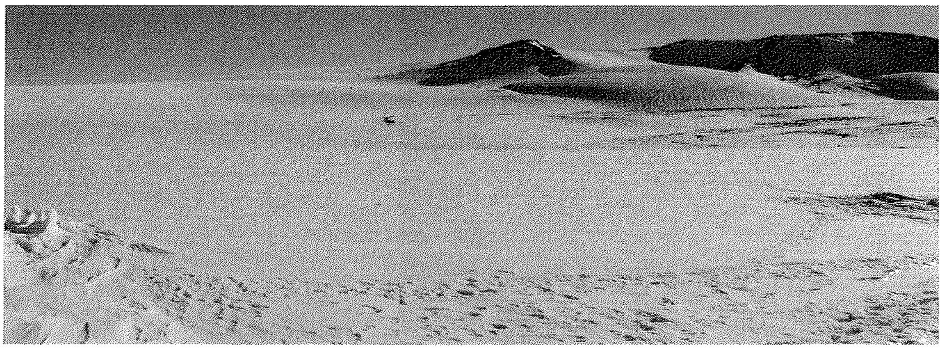


Fig. 1.4: Photograph of the thick snow-covered Lake Terrasovoje with view from the northern shoreline.

1.3.2. Radok Lake

Radok Lake has a maximum water depth of 362 m (Wand et al. 1987), and is the deepest known lake in Antarctica. It is located to the south of the McLeod Massif at an altitude of 7 m a.s.l. The length axis of the lake in southwest to northeast direction spans almost 10 km in total, whilst the cross axis of the lake measures 3 km in the southern half (Fig. 1.5). The northern part of the lake is split into a 5 km long and up to 1.4 km wide northern branch and a 2.5 km long northeastern branch with a maximum width of 1 km. At the southwestern corner the Battye Glacier enters into Radok Lake forming a floating ice tongue. The lake is mainly fed by the glacier and meltwater supply from the surrounding slopes during summer. Major meltwater inflows were observed in the northern branch and at the northeastern branch close to the outflow. The outflow of Radok Lake at the end of this branch has formed a 7 km long and deep incised valley, the Pagodroma Gorge (Fig. 1.2). This Gorge has been formed by an once-vigorous, but now vanished, river that leads into the Beaver Lake.

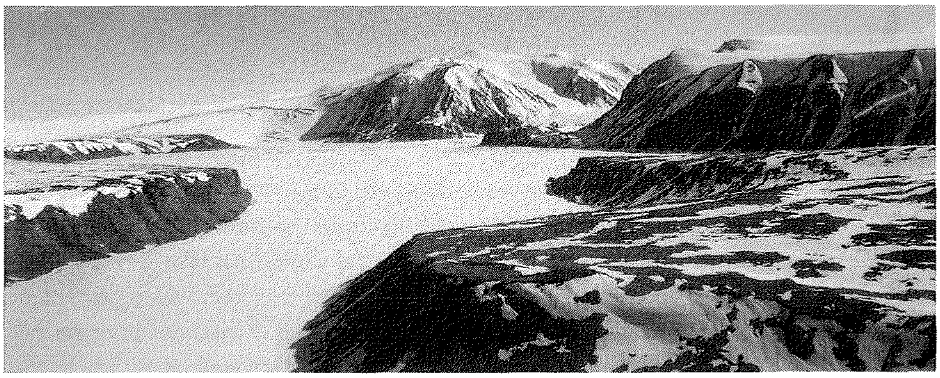


Fig. 1.5: Obligue photograph of Radok Lake. In front is the northeastern branch of Radok Lake, the entrance of the Battye glacier is in the center, and the northern branch is indicated in the right half of the photograph.

1.3.3. Beaver Lake

The Beaver Lake is the largest known lake in Antarctica, located some 250 km from the ocean. It has an irregular shape, characterized by the margins of the Stagnant Glacier tongue. The total north to south expansion measures about 30 km, the maximum width is about 12 km in the southern half of the lake (Figs. 1.2 and 1.6). Observations carried out already in 1958 have shown that Beaver Lake, despite its distance from the Antarctic coast, is tidal, and is therefore connected directly with the ocean underneath the Stagnant Glacier and the Amery Ice Shelf. In general, these tidal lakes are called epishelf lakes. The combination of salt water supply from the ocean and melt water supply from glaciers and snow creates a stratification of Beaver Lake, which is indicated in temperature, salinity, and isotopic profiles along the water body (Wand et al. 1987, Laybourne-Parry et al. 2001).

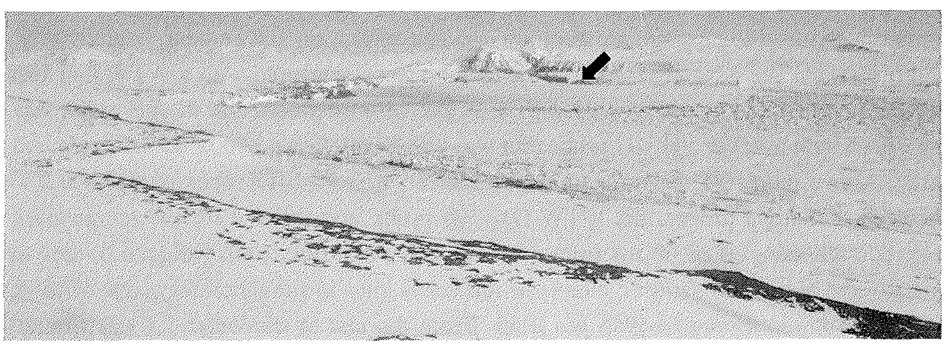


Fig. 1.6: Obligue photograph of Beaver Lake with view from the northeast. The Stagnant Glacier enters from the right side. The black arrow indicate the entrance of the Pagodroma Gorge.

1.4. Methods

1.4.1. Bathymetric measurements

A reliable bathymetry and/or seismic investigations are the basis for obtaining suitable coring locations, with more or less calm sedimentation conditions and minimal influences from the surrounding subaquatic and subaerial slopes. All lakes investigated during the Amery expedition 2001/2002 were completely ice covered, which prevented a seismic survey. Therefore, bathymetric measurements were carried out prior to the sediment coring using an echosounder through holes in the ice covered lakes. The holes through the ice were drilled with a Jiffy driller in distances between 100 and 150 m along profiles across the lakes. For the bathymetric measurements, the transmitter of the echosounder was placed directly underneath the lake ice. The water depth at each location then was calculated by adding the average ice thickness of each lake to the value recorded by the echosounder. The information obtained from these measurements was supplemented at Radok and Beaver Lakes by single spot measurements of the water depth from previous studies (Adamson et al. 1997). Wherever the information density of the single spot measurements was high enough, bathymetric maps of the lakes or parts of their basins were created.

1.4.2. Water sampling and measurements

Water sampling and measurements occurred at the same locations, where the sediment coring was conducted. Samples were taken from different depths along the water column using an water sampler (UWITEC corp.) that is released by a short uplift in a certain depth and contains 2 l of water.
Once at the surface the sampled water was split into several aliquots. About 800 ml was immediately used to measure temperature, oxygen saturation and content, conductivity, and pH value. The oxygen saturation and content were measured with a WTW Oxi 196 probe, the conductivity was recorded by a WTW LF 197 probe, and the pH value was measured with a WTW PH 197 probe that was combined with a Sentix 80 electrode. All three probes indicated the temperature, however, due to differences of up to 0.2°C between the single probes, the WTW Oxi 196 probe was utilized for the temperature record. Two samples of 60 ml from each horizon were filled into Nalgene bottles to analyze the anion and cation contents of the water later in the laboratory, one of them first was filtered through a 0.45 μm filter. From the rest of the water 1 l was filtered through a 0.45 μm filtre in order to determinate the diatoms and their abundances in the different water horizons. The filter then was dried and stored in a plastic container. A 5 μm plankton net was finally pulled throughout the water column from the bottom to the surface to get an overview of the diatom assemblage. The content of the net was filled

into two plastic bottles. To one of these bottles alcohol was added to about 30% in order to prevent grazing by zooplankton, which had been observed in some of the samples.

1.4.3. Sediment coring

Sediment coring was carried out using two different coring systems. A gravity corer (UWITEC corp.) was employed to obtain undisturbed surface sediments. The gravity corer is equipped with a PVC liner of 6 cm diameter and 60 cm long. It can be loaded optionally with two weights of ca. 5 kg each. The penetration of the gravity corer into the sediment depends on its release above the sediment surface and the amount of weights used, it commonly ranges between 20 and 40 cm. However, very soft and unconsolidated sediments may fill the complete liner, which is not desirable because of the loss of the undisturbed surface sediments. When the corer is pulled out of the sediment, a ball that is fixed on a rubber band closes the basis of the liner and thus catches the sediment. Once at the lake surface, the ball was replaced by a plastic lid. Attention was payed that the sediment surface was horizontally embedded in the liner and that the superstanding water was clear. At cores that passed these criteria the sediment surface was stabilized with a sponge, before the liner was cut at the top of the sponge and closed with a second lid.

A piston corer (UWITEC corp.) was used to obtain deeper sediments. The piston corer is handled via a tripod, which is mounted on a floating platform or, optionally, on wooden boards on the lake or sea ice. Each leg of the tripod carries a winch with a steel rope. One of the ropes is attached to the tube of the piston corer, the second controls the release of the piston, and the third moves a hammer along a metal tube subaquatically up and down (Fig. 1.7). The piston corer consists of a 3.3 m long metal tube, which is loaded with a 3 m long PVC liner of 6 cm diameter. It has a rubber cuff and a piston at its base, as long as the piston is not released. The piston gets released, when its controlling steel rope is fixed at a certain depth, and the rest of the corer is hammered deeper into the water or sediment. Then, the PVC liner incorporates the piston and slides 3 m downwards into the sediment until the piston reaches the upper end of the liner and corer tube (Fig. 1.7). There, the piston displaces water from a hollow. This water is conducted downwards to the lower end of the corer, where it closes the rubber cuff. Thus, the sediment is fixed in the PVC liner during the recovery.

When starting the coring process, the piston of the corer is generally released ca. 50 cm above the sediment surface in the water body. This enables the recovery of a sediment sequence reaching from the sediment surface to about 2.5 m depth (Fig. 1.7). Deeper sediments can be obtained by overlapping of several of these 3 m segments. Therefore, at the next step, the corer tube with the not released piston is hammered 2 m into the sediment, before the piston controlling steel rope gets fastened. Subsequently, a sequence from 2 to 5 m sediment depth may be recovered by hammering the coring tube

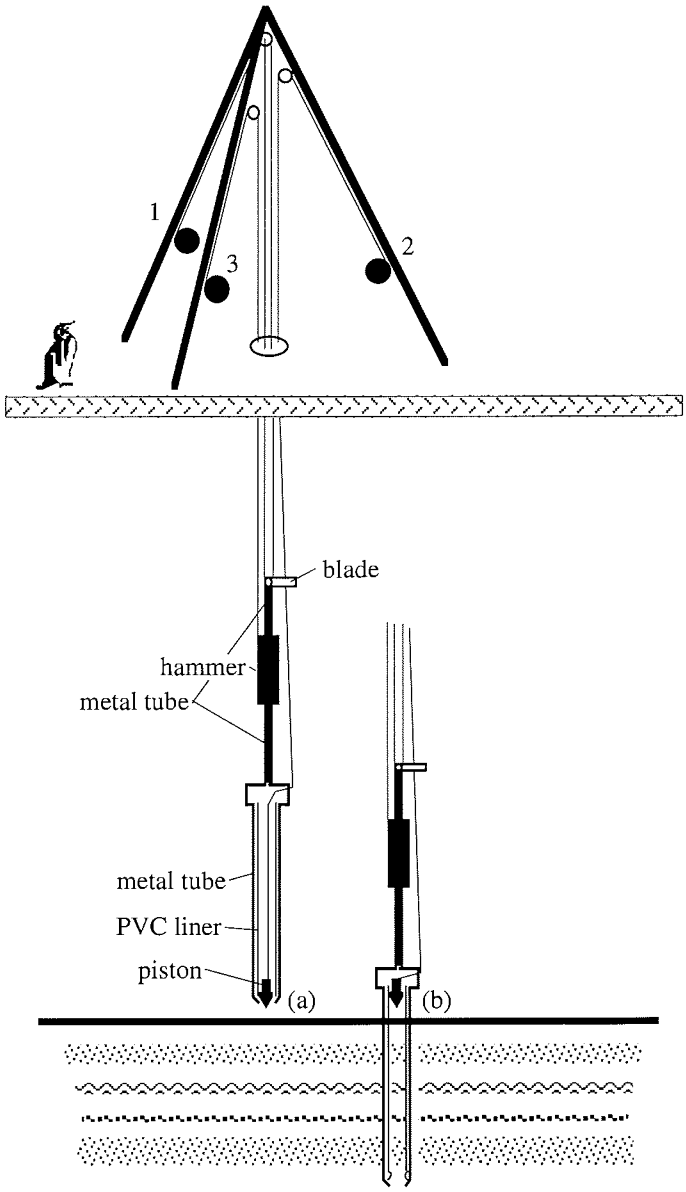


Fig. 1.7: Sketch of the piston corer system and a coring process. The coring process is controlled by three winches, one for the metal tube of the piston corer (1), a second for the piston (2), and a third for the hammer that drives the corer down into the sediment (3). The metal blade at the upper end of the hammer tube prevents twisting of the ropes. At a surface coring process the piston is released ca. 50 cm above the sediment surface (a), before the coring tube is hammered into the sediment (b).

along the piston another 3 m into the sediment. This procedure is repeated until there is no further penetration of the corer tube into the sediment. The penetration of the corer tube can be stopped, for example, by massif sand layers, too coarse or too consolidated

sediments. An overconsolidated diamicton, often forming the base of lacustrine sediments in Arctic and Antarctic regions will generally stop the coring process.
The sediment cores recovered with the piston corer were split into pieces of up to 1 m length for an easier transport and stored, together with the gravity cores, in thermo boxes to prevent freezing. A bottle with warm water was added to the thermo boxes during the nights, when neccessary.

1.5. Samples and results

1.5.1. Lake Terrasovoje

1.5.1.1. Bathymetry

The bathymetric measurements at Lake Terrasovoje were performed between 16. and 21. December 2001. The lake was covered with 3 to 3.5 m of ice and 20-40 cm of snow during this period. When the water depth at each location was calculated, an average ice thickness of 3 m was added to the value recorded by the echosounder (Tab. 1.4).

Tab. 1.4: Locations and water depths of single spot bathymetric measurements at Lake Terrasovoje.

Lake Terrasovoje	site no.	latitude	longitude	water depth
Profile 1, 332°	P01	S 70°33.777	E 068°02.299	3 m
	P02	S 70°33.702	E 068°02.167	5 m
	P03	S 70°33.630	E 068°02.075	7 m
	P04	S 70°33.557	E 068°01.957	9 m
	P05	S 70°33.483	E 068°01.844	14 m
	P06	S 70°33.409	E 068°01.737	23 m
	P07	S 70°33.335	E 068°01.619	31 m
	P08	S 70°33.266	E 068°01.501	30 m
	P09	S 70°33.198	E 068°01.385	22 m
	P10	S 70°33.126	E 068°01.265	13 m
	P11	S 70°33.061	E 068°01.155	8 m
	P12	S 70°32.978	E 068°01.027	6 m
	P13	S 70°32.937	E 068°00.943	3 m
Profile 2, 242°	P01	S 70°33.045	E 068°01.692	6 m
	P02	S 70°33.082	E 068°01.467	12 m
	P03	S 70°33.160	E 068°01.029	8 m
Profile 3, 242°	P01	S 70°33.477	E 068°00.743	6 m
	P02	S 70°33.437	E 068°00.968	8 m
	P03	S 70°33.399	E 068°01.197	16 m
	P04	S 70°33.364	E 068°01.381	30 m
	P05	S 70°33.284	E 068°01.812	19 m
	P06	S 70°33.243	E 068°01.016	8 m
Profile 4, 242°	P01	S 70°33.444	E 068°02.598	10 m
	P02	S 70°33.483	E 068°02.378	12 m
	P03	S 70°33.520	E 068°02.161	10 m
	P04	S 70°33.597	E 068°01.735	10 m
	P05	S 70°33.636	E 068°01.523	8 m
	P06	S 70°33.674	E 068°01.313	7 m

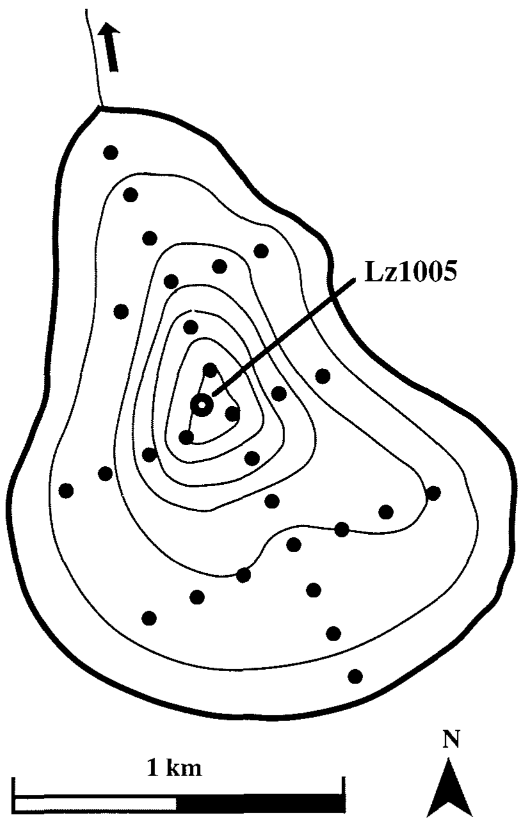


Fig. 1.8: Bathymetry of Lake Terrasovoje. The contour lines are given in 5 m intervals, and the black dots mark the locations of the single spot measurements. The open cicle indicate the coring location Lz1005, which also corresponds to the location of the water profile.

According to observations made by helicopter pilots, who have operated in the Northern Prince Charles Mountains for several years, such a thick ice and snow cover on Lake Terrasovoje as occurred during the 2001/2002 season is unusual. The lake has even been known to completely melt out during the austral summer. However, the air temperatures during the season 2001/2002 were often below the freezing point (see chapter 1.2.), and snow fall and drifting snow led to a 70 cm thick snow cover on the lake ice in late December 2001. Climate conditions during the last few years have probably additionally influenced the thick ice and snow cover on Lake Terrasovoje. A couple of relatively cold summers and intense snow fall may have supported an annual accumulation of ice and snow in the study area. This, however, is not recorded during recent years at the Davis Station located ca. 400 km away (see chapter 1.2.). When Lake Terrasovoje was left the season 2001/2002 by a field party at the end of January, it was still ice covered, and no major melting or thinning of the ice had been observed during the season. It is very unlikely that the lake would have melted out, even partially, later

in the season. Instead, it would probably take a warmer and dryer summer to completely melt the ice cover of the lake.
The bathymetric map of Lake Terrasovoje, based on the single spot measurements, shows a rather simple basin structure with the maximum water depth of about 31 m in the center of the lake (Fig. 1.8). The subaquatic slopes to the west and east are slightly steeper than those to the north and south, reflecting the elongated shape of the lake.

1.5.1.2. Water profile

The measurements of temperature, conductivity, pH value, oxygen content and oxygen saturation were carried out on 28. December 2001. The water body of Lake Terrasovoje showed a slight stratification (Tab. 1.5, Fig. 1.9). It is likely that the upper 7 m of the water body were influenced by the ice cover, indicated in a relatively low conductivity and temperature. The maximum bioproductivity seems to have occurred in a horizon between 7 and 20 m water depth, where the oxygen content and saturation are at their maximum values.

Tab. 1.5: Water profile and sample depths at the center of Lake Terrasovoje, where the maximum water depth was measured. The location corresponds to the coring site Lz1005 shown in Fig. 1.8.

sample no.	water depth (m)	cond. (mS/cm)	pH	temp. (°C)	O_2 (mg/l)	O_2 (%)
T1	4	1.08	8.23	1.1	10.4	78
T2	7	1.30	8.28	2.2	12.2	89
T3	10	1.48	8.27	4.2	13.0	103
T4	13	1.45	8.17	4.3	12.7	102
T5	16	1.46	8.17	4.4	12.5	100
T6	19	1.47	8.13	4.5	11.9	96
T7	22	1.48	8.13	4.4	12.0	94
T8	25	1.48	8.07	4.4	11.4	93
T9	28	1.48	7.99	4.4	10.9	86
T10	30	1.50	7.78	4.4	9.7	76
T11	31	1.59	7.81	4.5	6,2	50

Such horizons of bioproductivity, situated underneath a relatively thick ice and snow cover, are also found in many other lakes in polar regions. Below 20 m water depth in Lake Terrasovoje a weak decrease of the pH value, the oxygen content and saturation occurred downwards to the sediment surface. The bottom waters of the lake were still oxygen saturated to about 50%, which indicates that biogenic matter is only slightly reduced and decomposed within the water column. The sharp drop of the oxygen content in the lowest meter of the water column, however, suggests that the reduction and decomposition of the biogenic matter commence soon after its sedimentation. The

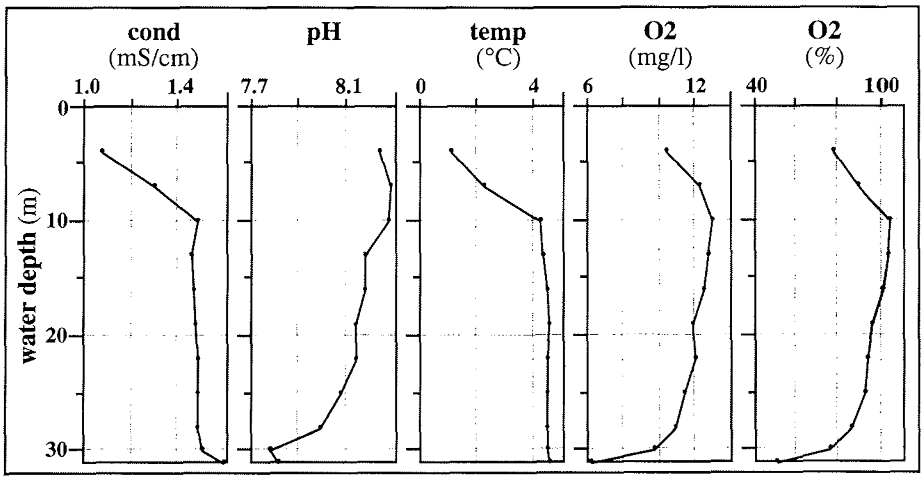


Fig. 1.9: Water profile from Lake Terrasovoje, taken at the coring location Lz1005 (see Fig. 1.8).

conductivity in Lake Terrsovoje is relatively high in comparison to other fresh water lakes. This may be explained by enhanced evaporation of lake water, which is promoted by the large surface in relation to the low water depth of the lake.

Water and plankton samples were taken at the same location and from the same horizons as shown in Tab. 1.5. Sporadically, red coloured crustacea (*Boeckella* spec.; J. Gibson, pers. commun.) have been observed to occur in the samples, particularly in those from directly underneath the lake ice. They were cought by the plankton net, which was pulled throughout the whole water column in order to obtain the diatom assemblage of Lake Terrasovoje.

1.5.1.3. Sediment samples

Sediment coring at Lake Terrasovoje started on 25. December in its deepest part with the employment of the gravity corer (Lz1004, Tab. 1.6). After a successful recovering of three gravity cores from this location, the coring process was continued from the 29. to the 31. December with the gravity and the piston corer at a new location (Lz1005, Tab. 1.6) close by (ca. 30 m), thus providing still undisturbed surface sediments.

During the first two attempts at the coring location Lz1004 the gravity corer was released too far from the sediment surface or too heavily loaded. Therefore, the recovered sediments completely filled the PVC liner, with a loss of the uppermost centimeters. These sediments, however, could have been correlated to those recovered at the third attempt, when the PVC liner was filled with 42 cm of sediment and 18 cm of clear water on top of it. The sediment surface consisted of a thin and dark layer of algae flakes, as the deeper sediments were also almost exclusively formed by very soft organic matter. The organic matter was composed of very fine laminated green algae mats, which were partly deformed and interspersed with moss layers of up to several centimeter thickness.

A very similar structure was shown at the gravity core from the location Lz1005 (Tab. 1.6). The uppermost piston core from this location (Lz1005-2) had ca. 35 cm superstanding water on top of the sediments, which is a clear indicator for a release of the piston in the water column. As the sediments obtained with the gravity corer, the top sediments of the piston core Lz1005 were composed of green algae mats and interspersed moss layers. When core Lz1005-2 was split into the three segments a colour change from green and dark green to black at a depth of about 1 m, and a strong smell of H_2S was noticed. The proportion of clastic matter remained low in the upper two meters. At about 3 m sediment depth, the colour changed again to grey and ochre sediments, and some coarse grains were observed. The coarse fraction increased downwards, leading to a stiff and consolidated diamicton in 4 m sediment depth. This diamicton, containing gravel of various sizes, avoided a further penetration of the piston corer into the sediment at a depth of 552 cm.

Tab. 1.6: Sediment cores from the center of Lake Terrasovoje, where the maximum water depth was measured. For locations see Fig. 1.8.

core no.	latitude	longitude	water depth	type	penetration
Lz1004-1	S 70°33.321	E 068°01.490	30.5 m	gravity corer	5-65 cm
Lz1004-2	S 70°33.321	E 068°01.490	30.5 m	gravity corer	1-55.5 cm
Lz1004-3	S 70°33.321	E 068°01.490	30.5 m	gravity corer	0-42 cm
Lz1005-1	S 70°33.324	E 068°01.540	30.5 m	gravity corer	0-49 cm
Lz1005-2	S 70°33.324	E 068°01.540	30.5 m	piston corer	0-266 cm
Lz1005-3	S 70°33.324	E 068°01.540	30.5 m	piston corer	216-498 cm
Lz1005-4	S 70°33.324	E 068°01.540	30.5 m	piston corer	466-552 cm

The sediments of Lake Terrasovoje likely provide, due to their high proportion of appearently undisturbed organic matter, a reliable climate history of the Northern Prince Charles Mountains. The fine lamination of the algae mats, visible at least in the upper meter, seems to derive from the annual bioproduction in the lake. Assuming a sedimentation rate of about 1 mm per year for the uppermost 3 m of the sediments, based on the lamination of the algae mats in a submillimeter range and the few interspersed moss layers of up to 3 cm thickness, the climate history stored in the sediments of Lake Terrasovoje may span at least the last several thousand years. Additional information comes from the diamicton at the base of the core. It is likely that the diamicton derives from the last glaciation or deglaciation of the area and indicates the onset of ice free conditions in the lake depression.

1.5.2. Radok Lake

1.5.2.1. Bathymetry

The bathymetric measurements at Radok Lake were carried out on 10. and 11. January 2002 in the northeastern branch, and on 19. and 20. January 2002 in the northern branch of the lake. The ice cover on the lake was at all sites between 3 and 4 m, partly with up to 60 cm snow on top of it. The water depth at each location was calculated adding an average value of 3 m to that recorded by the echosounder. The complete list of the single spot measurements is shown in Tab. 1.7.

Tab. 1.7: Locations and water depths of the single spot bathymetric measurements taken along profiles at Radok Lake. The profiles 1-5 are from the northeastern branch, profiles 6 and 7 lay in the northern branch of the lake.

Radok Lake	site no.	latitude	longitude	water depth
Profile 1, 133°	P01	S 70°51.066	E 068°01.146	4 m
	P02	S 70°51.101	E 068°01.265	31 m
	P03	S 70°51.134	E 068°01.376	83 m
	P04	S 70°51.180	E 068°01.511	116 m
	P05	S 70°51.215	E 068°01.625	157 m
	P06	S 70°51.251	E 068°01.730	167 m
	P07	S 70°51.293	E 068°01.859	132 m
	P08	S 70°51.327	E 068°01.970	85 m
	P09	S 70°51.364	E 068°02.086	29 m
Profile 2, 313°	P01	S 70°51.189	E 068°02.686	20 m
	P02	S 70°51.150	E 068°02.567	82 m
	P03	S 70°51.112	E 068°02.440	119 m
	P04	S 70°51.075	E 068°02.332	127 m
	P05	S 70°51.036	E 068°02.210	123 m
	P06	S 70°50.998	E 068°02.087	107 m
	P07	S 70°50.963	E 068°01.973	74 m
	P08	S 70°50.926	E 068°01.842	24 m
Profile 3, 150°	P01	S 70°50.742	E 068°02.686	11 m
	P02	S 70°50.791	E 068°02.522	31 m
	P03	S 70°50.838	E 068°02.599	61 m
	P04	S 70°50.881	E 068°02.681	78 m
	P05	S 70°50.930	E 068°02.763	99 m
	P06	S 70°50.977	E 068°02.848	103 m
	P07	S 70°51.021	E 068°02.931	92 m
	P08	S 70°51.069	E 068°03.012	53 m

Tab. 1.7 continued

Profile 4, 340°	P01	S 70°51.032	E 068°03.683	8 m
	P02	S 70°50.979	E 068°03.625	50 m
	P03	S 70°50.928	E 068°03.569	65 m
	P04	S 70°50.882	E 068°03.508	66 m
	P05	S 70°50.828	E 068°03.453	39 m
	P06	S 70°50.778	E 068°03.407	5 m
Profile 5, 160°	P01	S 70°50.710	E 068°04.023	21 m
	P02	S 70°50.756	E 068°04.074	41 m
	P03	S 70°50.816	E 068°04.135	36 m
	P04	S 70°50.867	E 068°04.197	22 m
Profile 6, 110°	P01	S 70°48.963	E 068°00.017	28 m
	P02	S 70°48.984	E 068°00.171	56 m
	P03	S 70°48.999	E 068°00.324	81 m
	P04	S 70°49.018	E 068°00.476	96 m
	P05	S 70°49.037	E 068°00.629	105 m
	P06	S 70°49.056	E 068°00.788	108 m
	P07	S 70°49.073	E 068°00.939	110 m
	P08	S 70°49.092	E 068°01.096	106 m
	P09	S 70°49.110	E 068°01.252	106 m
	P10	S 70°49.128	E 068°01.402	92 m
	P11	S 70°49.145	E 068°01.552	57 m
Profile 7, 110°	P01	S 70°48.740	E 068°00.559	20 m
	P02	S 70°48.759	E 068°00.718	34 m
	P03	S 70°48.778	E 068°00.868	53 m
	P04	S 70°48.797	E 068°01.020	62 m
	P05	S 70°48.815	E 068°01.181	65 m
	P06	S 70°48.835	E 068°01.330	64 m
	P07	S 70°48.853	E 068°01.487	57 m
	P08	S 70°48.871	E 068°01.638	56 m
	P09	S 70°48.889	E 068°01.790	43 m
single spots		S 70°50.798	E 068°02.558	38 m
		S 70°48.905	E 068°00.891	72 m
		S 70°48.923	E 068°01.042	79 m
		S 70°48.934	E 068°01.036	81 m
		S 70°48.937	E 068°01.247	75 m
	*	S 70°52.830	E 067°58.303	357 m

* measured with a mechanical counter

Based on these measurements, and those carried out during former expeditions (Adamson et al. 1997), bathymetric maps were constructed for the northeastern and the northern branch of the lake (Fig. 1.10).

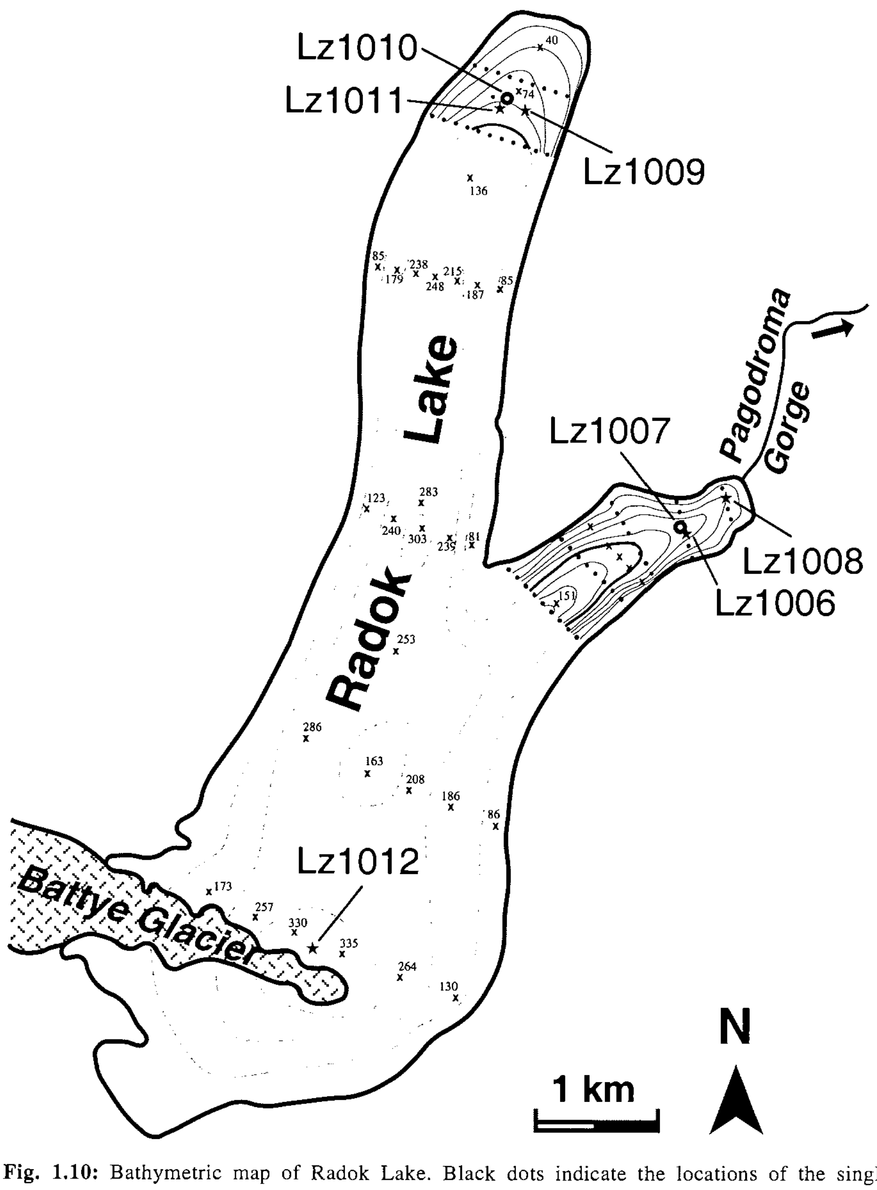


Fig. 1.10: Bathymetric map of Radok Lake. Black dots indicate the locations of the single spot measurements carried out during the season 2001/2002, black crosses indicate those of earlier expeditions with their related water depths (Adamson et al. 1997). Continuous contour lines are given in 20 m intervals, dashed lines in 100 m intervals. Open circles mark the piston coring locations, asterics indicate gravity core locations. Water profiles were taken at the coring locations Lz1007 and Lz1012.

The bathymetry of the northeastern branch shows an elongated basin, gradually deepening towards the southwest and with relatively steep lateral slopes. These subaquatic slopes are the extensions of subaerial exposed cliffs at the southeastern shore, and steep slopes and cliffs towards the northwest, leading to a plateau at about 200 m a.s.l. between the northeastern and the northern branch of Radok Lake (Fig. 1.2). The tip of the northern branch of Radok Lake is formed as an elongated basin as well. However, the subaquatic slopes in this part of the lake are, even if the exposed slopes to the west and east are partly steeper and higher than those surrounding the northeastern branch, more gently inclined. During the field season in 2001/2002 bathymetric measurements were not carried out in the southern part of the northern branch and towards the floating tongue of the Battye Glacier. According to previous investigations, the bathymetry in this part of Radok Lake seems to be more complicated, probably with submerged ridges and sub-basins (Fig. 1.10). A single spot measurement close to the front of the Battye Glacier tongue revealed a water depth of 357 m (Tab. 1.7, Fig. 1.10), probably in the proximity of the deepest measured location of 362 m (Wand et al. 1987).

1.5.2.2. Water profiles

A water profile, including conductivity, pH value, temperature, oxygen content and saturation, was measured at the coring location Lz1007 (Fig. 1.10) on 14. January.

Tab. 1.8: Water profile and sample depths from the northeastern branch of Radok Lake. The location corresponds to the coring site Lz1007 shown in Fig. 1.10.

sample no.	water depth (m)	cond. (μS/cm)	pH	temp. (°C)	O_2 (mg/l)	O_2 (%)
R1	4	15.0	5.43	0.7	12.6	91
R2	7	157.3	7.47	1.0	13.3	97
R3	10	159.2	7.78	1.1	12.7	91
R4	15	158.0	7.87	1.1	12.9	94
R5	20	160.4	7.85	1.1	12.6	91
R6	25	159.7	7.81	1.1	12.3	90
R7	30	156.5	7.79	1.1	12.0	87
R8	35	157.6	7.84	1.1	12.0	87
R9	40	156.0	7.68	1.4	12.0	86
R10	45	157.0	7.68	1.4	11.9	87
R11	50	157.7	7.58	1.4	11.9	88
R12	55	157.9	7.64	1.5	11.8	87
R13	60	158.2	7.73	1.4	11.8	85
R14	65	157.0	7.59	1.5	11.4	86
R15	70	156.5	7.61	1.5	11.4	86
R16	73	158.0	7.51	1.6	11.5	87

Relatively warm temperatures in mid January 2002 (see chapter 1.2.) caused a mixture of wet snow and meltwater superstanding on the ice of Radok Lake, particularly during the afternoon and evening hours. The influence of meltwater on the water profil is clearly visible in the uppermost water sample at 4 m depth of Radok Lake (Tab. 1.8, Fig. 1.11). This sample from directly underneath the lake ice is, as shown in the extremely low conductivity and pH value, a mixture of lake water and meltwater from the snow on top of the lake ice, draining through the ice hole into the water body. Two slight maxima of the oxygen content and saturation within the upper 15 m of the water column probably indicate horizons of weakly increased bioproduction. However, the lack of a distinct stratification, an oxygen saturation of more than 80% and a temperature of 1.6°C in the bottom water indicate that the water body of Radok Lake is completely mixed. The relatively low temperature of the bottom water is probably caused by a continuous stream of cold bottom water flowing into the deeper part of the lake.

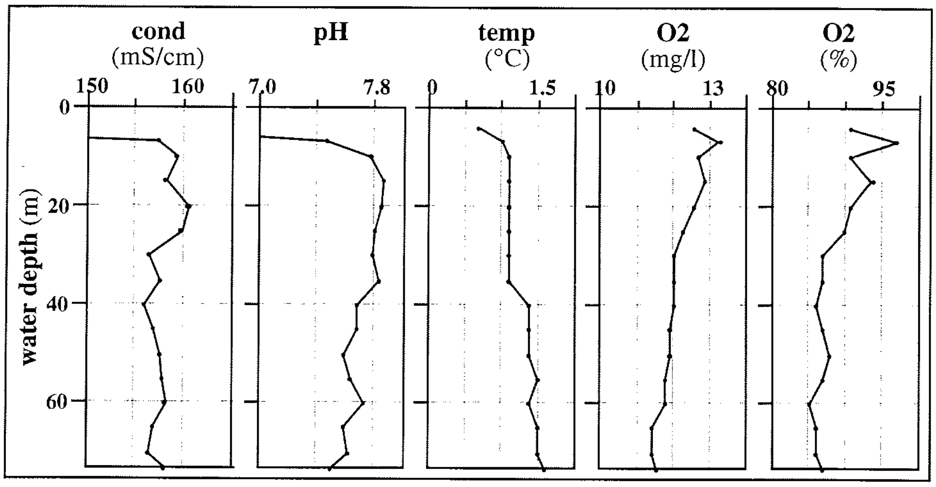


Fig. 1.11: Water profile from the northeastern branch of Radok Lake, taken at the coring location Lz1007 (see Fig. 1.10).

The complete mixing of the water body of Radok Lake is confirmed by a second water profile, taken on 27. and 28. January in front of the Battye Glacier tongue, where Radok Lake has its deepest basin. At this location, the water is also oxygen saturated to the sediment surface (Tab. 1.9, Fig. 1.12). The influence of the surface melt is lacking, because the temperatures decreased during the second half of January (see chapter 1.2.) and there was no snow cover on the lake ice in the vicinity of the drilled ice hole. The temperatures throughout the whole water column at this location are lower than those measured in the profile from the northeastern branch of Radok Lake. This is probably due to the cooling effect of the glacier tongue. The bottom water sample originates from the superstanding water in the PVC liner of a gravity core taken at this location. This sample is probably affected by sediment-water interactions, because it shows the only distinct shift within the profile.

Tab. 1.9: Water profile and sample depths from the deepest part of Radok Lake, where a maximum water depth of 357 m was measured. The exact location is shown in Fig. 1.10.

sample no.	water depth (m)	cond. (μS/cm)	pH	temp. (°C)	O_2 (mg/l)	O_2 (%)
RD1	5	161.5	7.84	0.4	13.5	96
RD2	10	164.3	7.76	0.4	13.7	99
RD3	30	162.8	7.79	0.4	13.9	101
RD4	60	164.5	7.73	0.4	13.9	101
RD5	100	164.7	7.74	0.4	13.3	95
RD6	150	162.8	7.82	0.5	13.6	98
RD7	200	162.0	7.83	0.6	13.9	100
RD8	250	161.0	7.79	0.8	14.1	102
RD9	300	161.0	7.84	0.8	13.9	101
RD10	330	161.3	7.81	0.8	13.7	100
RD11	350	162.5	7.73	0.9	13.5	98
RD12	357	164.0	8.25	0.4	14.2	102

Water samples for cation and anion analyses were taken from the northeastern branch, at the same location and from the same water depths as listed in Tab. 1.8. Filter samples from these horizons and a plankton sample from the whole water column are used for the determination of the diatom assemblages of Radok Lake. Red coloured crustacea were common in some of these samples.

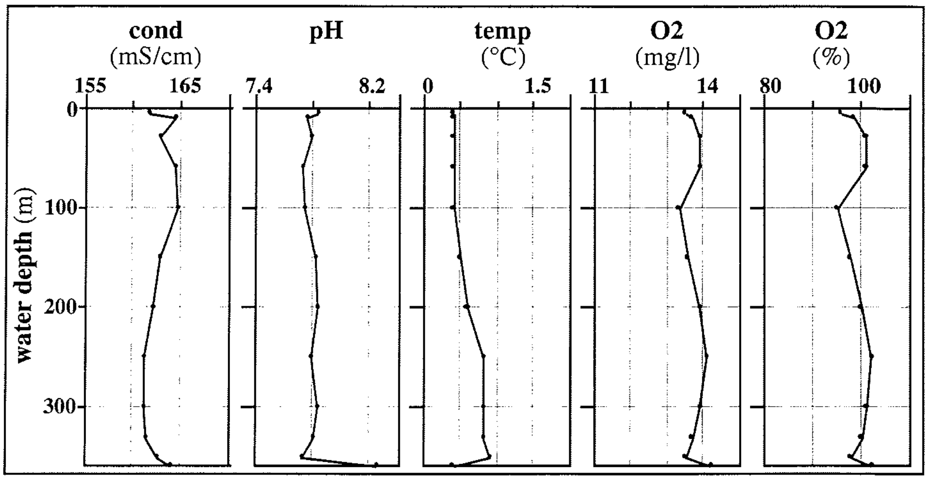


Fig. 1.12: Water profile from the location in front of the Battye Glacier tongue. The bottom water sample derives from the superstanding water of a gravity core taken at this location (see Fig. 1.10).

1.5.2.3. Sediment samples

Based on the bathymetric measurements carried out in the northeastern branch of Radok Lake, a coring location was placed, where the subaquatic slopes were comparatively gently inclined, thus promising relatively calm sedimentation conditions. The sediment coring commenced by the use of the gravity corer on 12. January 2002. Three gravity cores of up to about 30 cm length (Lz1006) were recovered from 66 m water depth (Tab. 1.10, Fig. 1.10). They all showed a thin cover of water mosses growing on the sediment surface, with clear superstanding water on top of it. With the exception of these mosses, organic matter could not be detected in the sediments. The sediments were of brownish colour and comprised mainly silt and clay layers with a few interspersed sand horizons. Some dark particles were dispersed in the sediments, likely originating from extensive coal layers exposed in the catchment area of Radok Lake.

Tab. 1.10: Sediment cores from Radok Lake. For locations see Fig. 1.10.

core no.	latitude	longitude	water depth	type	penetration
Lz1006-1	S 70°50.882	E 068°01.490	66 m	gravity corer	0-25.5 cm
Lz1006-2	S 70°50.882	E 068°01.490	66 m	gravity corer	0-25.5 cm
Lz1006-3	S 70°50.882	E 068°01.490	66 m	gravity corer	0-30.5 cm
Lz1007-1	S 70°50.895	E 068°03.510	74 m	gravity corer	0-30.5 cm
Lz1007-2	S 70°50.895	E 068°03.510	74 m	piston corer	10-205 cm
Lz1008-1	S 70°50.756	E 068°04.074	41 m	gravity corer	0-21.5 cm
Lz1009-1	S 70°48.937	E 068°01.247	75 m	gravity corer	0-21 cm
Lz1010-1	S 70°48.923	E 068°01.042	79 m	gravity corer	0-20.5 cm
Lz1010-2	S 70°48.923	E 068°01.042	79 m	piston corer	0-257 cm
Lz1010-3	S 70°48.923	E 068°01.042	79 m	piston corer	207-483 cm
Lz1010-4	S 70°48.923	E 068°01.042	79 m	piston corer	433-592 cm
Lz1011-1	S 70°48.934	E 068°01.036	81 m	gravity corer	0-28.5 cm
Lz1012-1	S 70°52.830	E 067°58.303	357 m	gravity corer	0-25.5 cm

Another gravity core close by was taken two days later at the location Lz1007 (Tab. 1.10, Fig. 1.10). It showed a similar structure and was also covered with growing water mosses at its surface. The coring continued on 15. January with the use of the piston corer at the same location. The penetration of the corer into the sediment was very slow from about 2 m sediment depth onwards. The recovering of the sediment core revealed that the base of the sediments was formed by massif gravel and sand layers, only slightly decreasing in grain size upwards. The gravel and sand layers avoided a further penetration of the corer. The top meter of the PVC liner was filled with water. The water likely entered the system due to a vacuum, which was created by the fastened piston and the downwards hammered corer tube.

Sediments of such a structure are not useful for climate reconstructions. Therefore, another attempt to find a more suitable coring location was carried out with a gravity corer in a shallower area of the northeastern branch (Lz1008, Tab. 1.10). The sediments at this location, however, were of similar structure and allowed no deeper penetration of the gravity corer.

Subsequently, camp and coring site were moved to the northern branch of Radok Lake. Although the surrounding slopes were partly steeper and higher than in the northeastern branch, the lake basin was broader in this part, thus suggesting another possible coring location. A first gravity core (Lz1009) from the northern branch of Radok Lake was taken on 16. January, without having detailed bathymetric information. The sediment core was, similar to those recovered in the northeastern branch, of brownish colour and covered with growing water mosses. However, it was composed of finer grain sizes.

Based on the bathymetric measurements carried out in the northern branch during the following days, a new coring location (Lz1010) was placed in a distance of ca. 200 m to Lz1009. The coring process at this new location commenced on 21. January. A gravity core (Lz1010-1) from this location, and another core (Lz1011) from a location next to it (25 m) consisted of mainly silt and clay, had a brownish colour and water mosses growing on the sediment surface. A piston core recovered within the next two days was composed of three segments (Lz1010-2 to Lz1010-4, Tab. 1.10), partly overlapping each other by ca. 50 cm. The top sediments of this core were silimar to those in the gravity core. Downwards, an increase of grain sizes was observed along with a decrease of the water content and a colour change towards a dark brown. Unrounded gravel grains appeared first in a depth of about 300 cm, increasing in size and number with increasing sediment depth. The wide range of particle sizes from mud and sand to gravel, a stiff consistency, and a low water content stopped the penetration of the corer at a depth of 592 cm.

For a better comparison of the surface sediments, another gravity core (Lz1012) was taken on 29. January in front of the Battye Glacier tongue (Fig. 1.10), where a water depth of 357 m was measured. The sediments from this location were formed by silt and sand layers of brownish colour, and had no vegetation cover. The coarse grain sizes of this core probably are due to the close distance to the glacier, being one of the major sources of terrestrial material for Radok Lake.

The sediments of Radok Lake may hardly be used to reconstruct a long and detailed climate history of the Northern Prince Charles Mountains. A radiocarbon dating of the sediments in order to obtain a reliable chronology is difficult because of the obviously low content of organic matter and the presence of coal particles in the sediment. Additionally, the sediments seem to be affected by mass movement processes, even in the northern branch, where the longer sediment sequence was recovered. However, a comparison of the sediments from the different locations, as from the northeastern and the northern branch, and the sediments in front of the Battye Glacier tongue, may provide good information about the origin of sediment supply to Radok Lake. The transition from a diamicton at the base to more fine grained sediments at the top in both the northern and northeastern branch may also give information about the last deglaciation of the lake.

1.5.3. Beaver Lake

1.5.3.1. Bathymetry

The bathymetric measurements at Beaver Lake started on 4. February along a single profile from the western shoreline towards the center of the lake in a northeastern direction (Tab. 1.11, Fig. 1.13). The adjacent slopes at the western shoreline were only

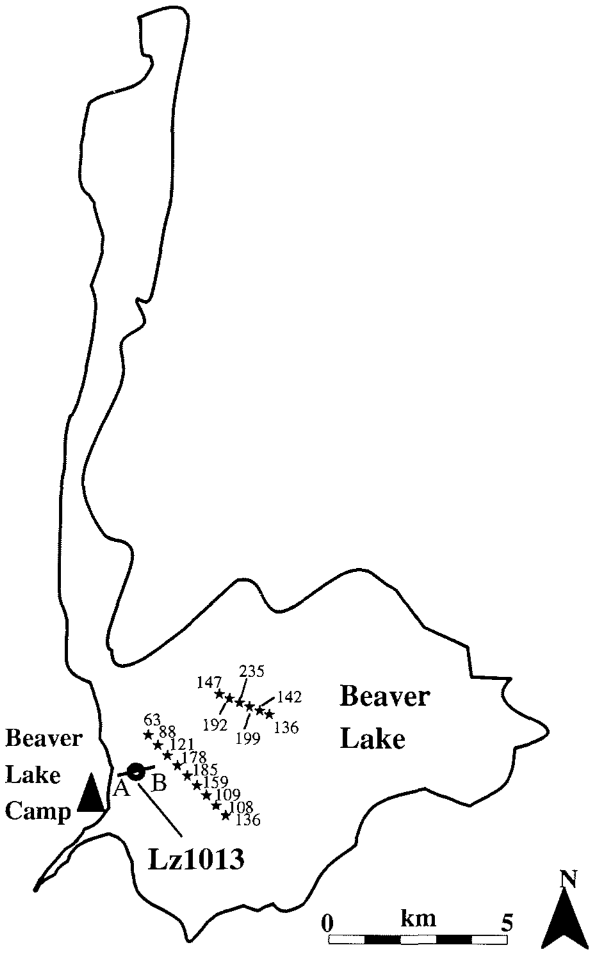


Fig. 1.13: Map of Beaver Lake. The black line (A-B) indicates the location of the bathymetric profile, the open dot indicates the coring position Lz1013. Black asterics mark locations of earlier bathymetric measurements with their related water depths (Adamson et al. 1997).

gently inclined, suggesting more or less calm subaquatic sedimentation conditions at this side of the lake. The ice thickness at Beaver Lake was averaged to 3 m, and this value was added to that recorded by the echosounder for obtaining the water depth. Like the other studied lakes, Beaver Lake, although cooled by the Stagnant Glacier, has been known to melt out completely during summer. This has probably been due to a succession of relatively warm and dry summers during the previous years.
Because the remaining time at Beaver Lake during the field season 2001/2002 was very short, the selection of a coring location was based on this profile and on bathymetric information from earlier expeditions (Adamson et al. 1997). However, after finishing the coring programme, the bathymetric measurements along this profile were intensified on 9. and 11. February in order to obtain information about the occurrence of subaquatic terraces. Two terraces were found at water depths of about 35 and 56 m (Fig. 1.14). Further towards the northeast, the inclination of the subaquatic slope rapidly increases. The profile ends at the water depth of about 140 m in a subaquatic valley. This valley likely corresponds to the submerged prolonging of the Pagodroma Gorge, which is known to occur in the more southwestern part of Beaver Lake (Adamson et al. 1997).

Tab. 1.11: Locations and water depths measured along a profile at Beaver Lake. The bathymetric measurements at locations marked with a letter were conducted after the sediment coring.

Beaver Lake	site no.	latitude	longitude	water depth
Profile 1, 075°	P01	S 70°47.736	E 068°11.122	18 m
	P01a	S 70°47.739	E 068°11.172	25 m
	P01b	S 70°47.737	E 068°11.221	29 m
	P01c	S 70°47.741	E 068°11.268	32 m
	P01d	S 70°47.743	E 068°11.320	34 m
	P02	S 70°47.743	E 068°11.367	35 m
	P02a	S 70°47.745	E 068°11.405	35 m
	P02b	S 70°47,744	E 068°11.464	36 m
	P02c	S 70°47.745	E 068°11.519	39 m
	P02d	S 70°47.747	E 068°11.563	42 m
	P03	S 70°47.748	E 068°11.615	45 m
	P03a	S 70°47.751	E 068°11.695	48 m
	P03b	S 70°47.756	E 068°11.774	50 m
	P04	S 70°47.756	E 068°11.860	54 m
	P04a	S 70°47.761	E 068°11.934	56 m
	P04b	S 70°47.764	E 068°12.024	57 m
	P05	S 70°47.764	E 068°12.102	58 m
	P05a	S 70°47.769	E 068°12.184	61 m
	P05b	S 70°47.773	E 068°12.260	67 m
	P06	S 70°47.768	E 068°12.351	71 m
	P07	S 70°47.779	E 068°12.596	85 m
	P08	S 70°47.783	E 068°12.834	139 m

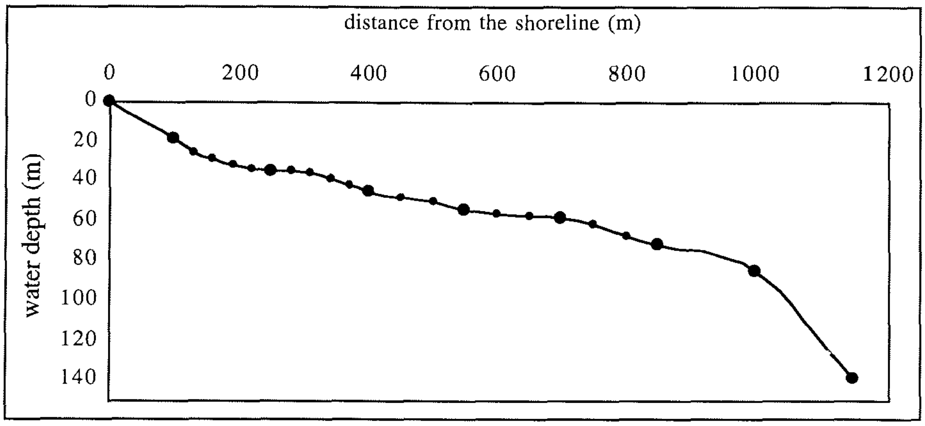


Fig. 1.14: Bathymetric profile of Beaver Lake. Two terraces are observed in water depths of ca. 35 and 56 m. For location of the profile see Fig. 5.6. The heavy dots indicate locations measured on 4. February, the small dots are from later investigations.

1.5.3.2. Water profile

A water profile, including temperature, conductivity, pH value, and oxygen content and saturation, was measured at the coring location Lz1013 on 8. February (Tab. 1.12, Fig. 1.15). The water body indicated a distinct stratification. The top 3 m underneath the lake ice were formed by a mixture of saline water from the marine connection underneath the glacier ice and fresh water likely originating from the melt of the lake and glacier ice,

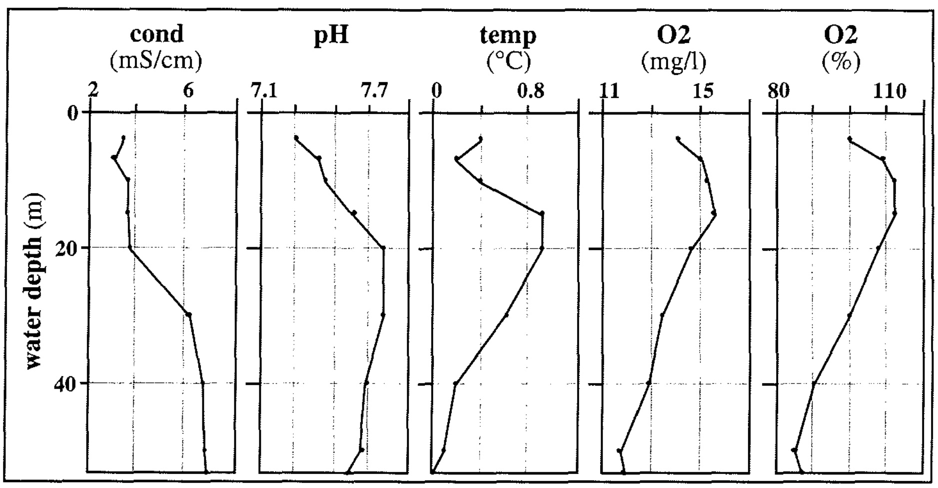


Fig. 1.15: Water profile from the coring location Lz1013 (see Fig. 1.13) at Beaver Lake.

and from the inflow of the Pagodroma Gorge. The so formed water was characterized by its conductivity, typical for brackish conditions, low pH values and temperatures. The maximum oxygen saturation and content between 7-20 m water depth correlate with a distinct increase of the pH value and temperature, and probably correspond to a horizon of slightly enhanced bioproductivity. However, according to a previous study, Beaver Lake is an ultra-oligotrophic lake, in which the bioproductivity is strongly limited by low organic carbon concentrations and low temperatures (Laybourn-Parry et al. 2001). At the day of measurements in summer 2001/2002 the conductivity distinctly increased to more saline conditions between 20-30 m water depth. At the same horizon temperature, oxygen content and saturation decreased to values similar to the topmost water horizons. Below 30 m water depth the drop of the oxygen content and saturation indicated a slight decomposition of the organic matter produced in the water column. The bottom water at a depth of 53 m, however, remained oxygen saturated to 87%.

The measurements carried out during the 2001/2002 field season confirm earlier results of a distinct stratification of Beaver Lake (Wand et al. 1987, Laybourn-Parry et al. 2001). According to these studies, a slight decrease of the water temperatures below 55 m depth coincided with an increase in salinity. It is likely that the oxygen content and saturation decrease coincidently, as a result of ongoing decomposition of the organic matter.

Tab. 1.12: Water profile and sample depths from Beaver Lake. The location corresponds to the coring location Lz1013, shown in Fig. 1.13.

sample no.	water depth (m)	cond. (μS/cm)	pH	temp. (°C)	O_2 (mg/l)	O_2 (%)
B1	5	3.43	7.29	0.4	14.0	100
B2	7	3.09	7.42	0.2	15.0	109
B3	10	3.60	7.45	0.4	15.3	112
B4	15	3.65	7.60	0.9	15.5	112
B5	20	3.74	7.77	0.9	14.1	108
B6	30	6.20	7.77	0.6	13.4	100
B7	40	6.75	7.68	0.2	12.8	90
B8	50	6.84	7.65	0.1	11.7	85
B9	53	6.91	7.58	0.0	11.9	87

Water samples for cation and anion analyses, as well as filter samples for the analyses of the diatom assemblages were taken during the field season 2001/2002 from different horizons along the water column. Their depths corresponded to those measured with the probes (Tab. 1.12). A plankton sample, taken with a net throughout the complete water column, is for obtaining an overview of the existing diatom assemblage of Beaver Lake. Crustacea were not observed in the lake water.

1.5.3.3. Sediment samples

Sediment coring at Beaver Lake was carried out on 5. and 7. February 2002 on a terrace at about 54 m water depth (Fig, 1. 13, Tab. 1.13). A gravity corer penetrated up to 31 cm into the sediment, and was composed of ochre to brown silt and clay layers and several intermediate thin and dark brown horizons of similar grain sizes. The superstanding water in the PVC liner was clear.

Tab. 1.13: Sediment cores from Beaver Lake. For location see Fig. 1.13.

core no.	latitude	longitude	water depth	type	penetration
Lz1013-1	S 70°47.756	E 068°11.860	54 m	gravity corer	0-31 cm
Lz1013-2	S 70°47.756	E 068°11.860	54 m	piston corer	5-86 cm

Because Beaver Lake is a tidal lake, special attention was payed to the release of the piston at the coring process. The water depth, in which the piston should have been released 50 cm above the sediment surface, was calculated by a mark, set onto the piston controlling steel rope during the gravity coring process, and a tide table of Beaver Lake, provided for the first half of February (Tab. 1.14).

Tab. 1.14: Tide table for Beaver Lake, provided by the University of Tasmania.

date	high tide		low tide		date	high tide		low tide	
	time(1)	m(2)	time(1)	m(2)		time(1)	m(2)	time(1)	m(2)
05.02	0128	1.30			10.02			0501	0.70
	1424	1.79	2103	0.84		2106	1.86		
06.02	0145	1.15	0712	0.63	11.02	1328	1.29	0454	0.64
	1454	1.98	2245	0.97		2154	1.91	1608	1.21
07.02	0145	1.03	0708	0.64	12.02	1234	1.24	0509	0.59
	1526	1.92				2232	1.93	1634	1.03
08.02			0707	0.67	13.02	1150	1.27	0531	0.56
	1627	1.80				2305	1.89	1653	0.88
09.02			0649	0.71	14.02	1143	1.35	0554	0.57
	1950	1.78				2329	1.80	1710	0.78

(1) local time

(2) meters above the local spring low tide averaged over several years

The corer, however, already hit the sediment surface at the calculated depth, and was consequently placed 1 m higher before the piston was released. Nevertheless, the penetration of the corer into the sediment was stopped at about 1 m depth. When the sediment core was recovered, the base of the corer was filled with a diamicton of dark brownish colour. The diamicton was mainly composed of silt and sand, and depleted in its water content. The top sediments were similar to those observed in the gravity corer. The dry consistancy of the sediments directly underneath the topmost surface sediments suggests that they were overconsolidated, likely by an overlaying glacier. Assuming a sedimentation rate of about 1 mm per year for the uppermost 30 cm of soft and water enriched sediments, deglaciation of Beaver Lake to the present margins may have started only a couple of centuries ago. Another possible explanation for the lack of a long lacustrine sediment sequence is probably the water depth at the coring location. Assuming that the global Holocene sea-level rise of about 120 m was not or only to a minor part accompanied by an isostatic rebound of the Amery Oasis after the LGM (Adamson et al. 1997), the coring location would have become submerged just a couple of thousand years ago. A low isostatic uplift rate for the region seems to be confirmed by the lack of saline bottom waters at Radok Lake, located only 7 m a.s.l. and connected with the Beaver Lake via the Pagodroma Gorge.

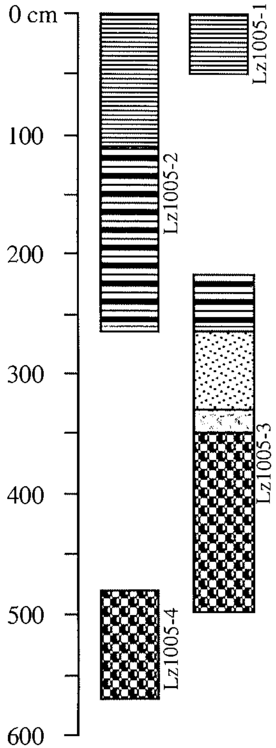
1.6. Sediment core descriptions

All of the piston cores and most of the gravity cores obtained during the Amery expedition 2001/2002 were opened after their arrival in the laboratory. For core opening, the PVC liners were lengthwise scratched on two opposite sites by the use of an electrical saw, and then fully cut by a knife in order to avoid a contamination of the sediment with PVC splines. Subsequently, the cores were divided into two halves with a fishing line, or, depending on the texture, with two metal blades.
Immediately after opening of the cores, a photographic documentation and a sediment description were carried out, before one half was stored as an archive for future work and the other half was split into subsamples. Figs. 1.16 to 1.20 give a simplified overview of the core descriptions. Whenever possible, the depths of the core segments are already correlated according to optically corresponding horizons. This explains differences between the core depths in Figs. 1.16-1.20 and the field depths listed in Tab. 1.6, 1.10, and 1.13.

Legend for Figs. 1.16-1.20

laminated algae mats, greenish	mainly fine sand, not laminated
laminated algae mats, black	sand, graded bedding
laminated clay	coarse sand
mainly clay, dark grey to black	coarse sand with pebbles
fine laminated clay and silt	pebbles and granules
clay and silt, not laminated	calcareous diamicton
mainly fine sand, laminated	diamicton

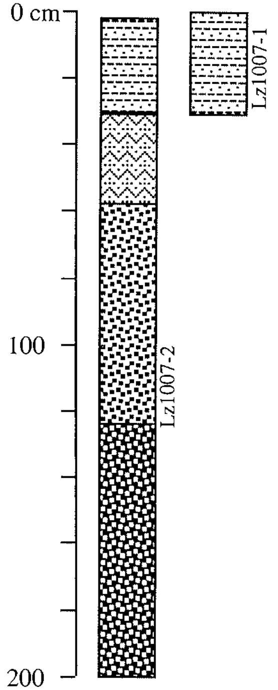
Lake Terrasovoje
Lz1005-1/2/3/4



colour	texture	structure	remarks
greenish to dark olive grey, moss layers dark reddish brown	algae mats with interspersed moss layers	fine laminated, thickness of moss layers up to 30 mm	lamination, partly crumbly structure, smell of H_2S
black	algae mats	fine laminated	strong smell of H_2S
greenish to dark olive grey	algae mats	fine laminated	strong smell of H_2S
greyish	mainly fine sand, no organic material	no fabric recognizable	sharp transition, sporadic occurrence of gravel
grey matrix, carbonate white to olive	calcareous diamicton	no fabric recognizable	
olive to dark olive grey	diamicton	upwards fining	gravel partly rounded, increasing occurrence of granules and pebbles, particularly at the base

Fig. 1.16: Graphical core description of core Lz1005 from Lake Terrasovoje

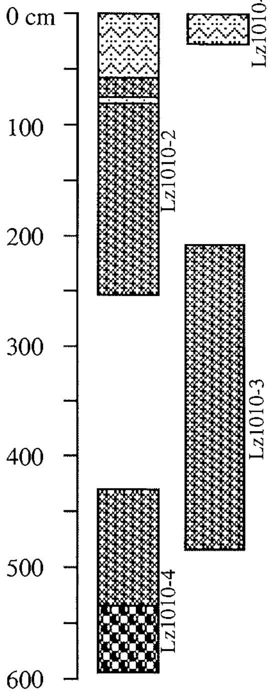
Radok Lake
NE-branch
Lz1007-1/2



colour	texture	structure	remarks
dark greyish brown to dark yellowish brown	mainly fine sand	fine laminated, partly upward fining	several turbidity layers, sporadic occurrence of small dropstones
dark greyish brown to very dark grey	mainly clay and silt with layers of fine sand	well laminated	
dark greyish brown	mainly coarse to very coarse sand, sporadic occurrence of granules and pebbles	no fabric recognizable	fragments of coal
dark greyish brown	mainly coarse to very coarse sand, increased amount of granules and pebbles	no fabric recognizable	fragments of coal

Fig. 1.17: Graphical core description of core Lz1007 from Radok Lake

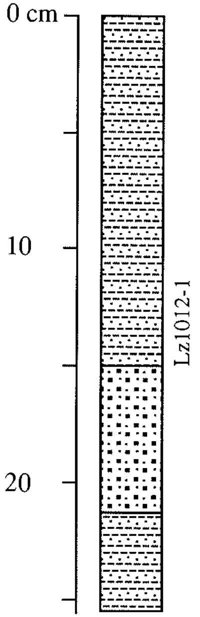
Radok Lake
N-branch
Lz1010-1/2/3/4



colour	texture	structure	remarks
dark greyish brown to olive brown	mainly clay and silt, partly fine sand	fine laminated	occurrence of turbidity layers
bown to very dark grey	mainly clay and silt, partly fine sand, 5 cm layer of clay between 68-72 cm	no fabric recognizable, weak lamination at the base	coal particles, dropstones, stiff consistence
bown to very dark grey	diamicton	no fabric recognizable	increasing amount of clasts, stiff consistence

Fig. 1.18: Graphical core description of core Lz1010 from Radok Lake

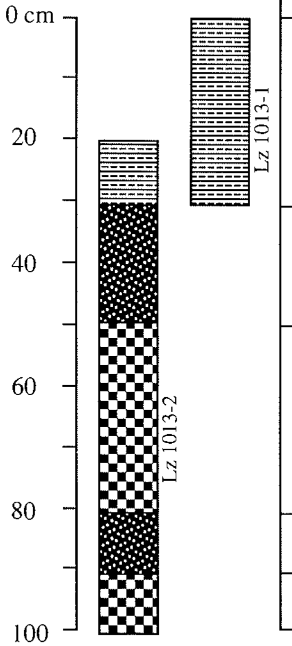
Radok Lake
Battye Glacier
Lz1012-1



colour	texture	structure	remarks
dark greyish brown	mainly sand	upward fining	soft consistence and micas throughout the core
brown to light olive brown	sand with layers of clay and silt	well laminated	
very dark grey	coarse to fine sand	graded bedding, upward fining	
brown to light olive brown	mainly sand	laminated	

Fig. 1.19: Graphical core description of core Lz1012 from Radok Lake

Beaver Lake
Lz1013-1/2



colour	texture	structure	remarks
light olive brown	mainly clay	laminated	no organic material
very dark grey to black	mainly clay with layers of sandstone clasts	no fabric recognizable	many coal fragments
light olive yellow to olive yellow	pebbles and granules of sandstone	no fabric recognizable	angular to subangular fragments of sandstone
black	mainly clay	no lamination recognizable	layers of micas
olive brown to yellowish brown	pebbles and granules of sandstone	ungraded bedding	angular to subangular fragments of sandstone

Fig. 1.20: Graphical core description of core Lz1013 from Beaver Lake

2. The American-German expedition Taylor Valley 2002

2.1. Introduction and aims

2.1.1. Present knowledge

The circum-Antarctic reconstruction of ice free regions during the LGM and ice advances and retreats during the Holocene shows a rather complicated picture with partly contrary ice movements in different regions during the same period (see chapter 1.1.).

The Dry Valleys in the southern Victoria Land (Fig. 1.1) are one of the regions supposed to have been ice-free already during the LGM. This is indicated by sediments of proglacial lakes in the different valleys (Clayton-Greene et al. 1988, Hall & Denton 2000). In Taylor Valley the proglacial Lake Washburn occupied at least most of the lower valley during the LGM, when the Ross Ice Shelf was blocking the eastern end of the valley (Stuiver et al. 1981, Hall & Denton 2000). The lake deposits along the sides of the valley give valuable information about climatic and environmental changes of the region and about the extent of the West Antarctic Ice Sheet (WAIS). However, the information ends, according to radiocarbon datings on organic matter that is preserved in fossil deltas and ancient shore lines, at ca. 8700 B.P. (Hall & Denton 2000).

From 8700 B.P. the reconstruction of the climatic and environmental history of the region is based on isotopic records from ice cores, evidences from geomorphic features, marine records, and the occurrence of penguin colonies along the coast. However, the climatic and environmental history indicated in these records is not consistent.

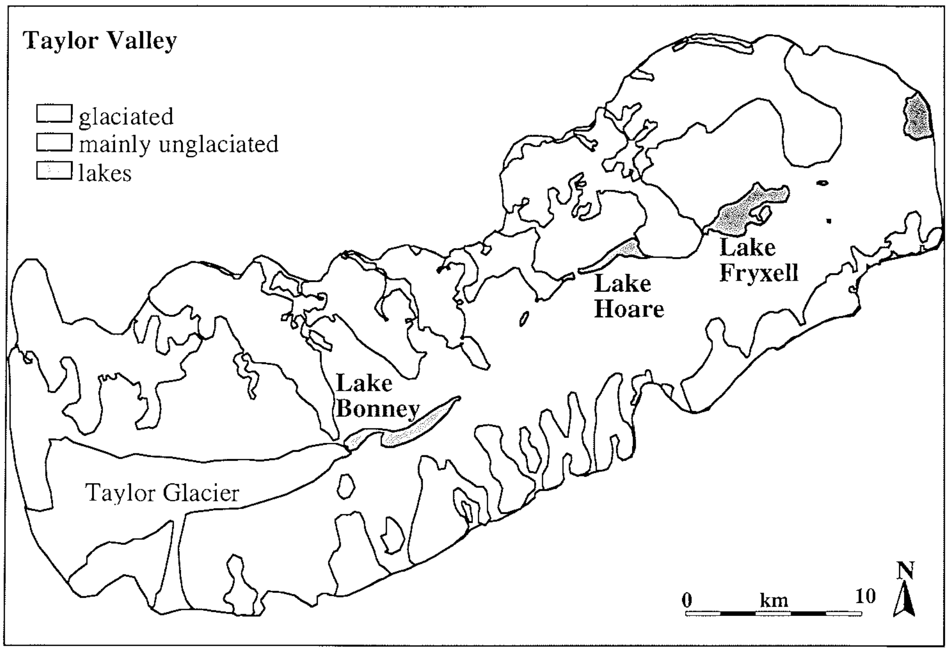
Warmer periods are indicated in the isotopic record from Taylor Dome (Steig et al. 1998). For example, a warm period around 6000 B.P. is probably related to a retreat of the WAIS past Ross Island at 7400 B.P. (Licht et al. 1996). Between 4000-3000 B.P. warmer temperatures and more open water in the Ross Sea are suggested by penguin remains (Baroni & Orombelli 1994a). A maximum advance of Taylor Glacier was observed between 3500 and 2500 B.P. (Higgins et al. 2000). Advances of glaciers in Antarctica are in general related to warmer temperatures and a higher moisture supply, however, the reaction time of glaciers is highly dependent on the location and the size of the catchment areas. A warmer period during the last 1000 years is indicated in ice core records (Masson et al. 2000), in marine records (Leventer et al. 1993), and in moraine records (Baroni & Orombelli 1994b).

In contrast, colder periods are indicated from 4000-1000 B.P. in ice core records (Masson et al. 2000), and after 3000 B.P. in marine records (Cunningham et al. 1999) as well as in the disappearance of penguin colonies (Baroni & Orombelli 1994a). Several lake studies in the Dry Valleys suggest that a cold and dry period ended at around 1200-1000 B.P. (e.g., Wilson 1964, Lyons et al. 1998). A Little Ice Age event

has been observed in marine records from the Ross Sea (e.g., Leventer et al. 1993) and in moraine records onshore (Baroni & Orombelli 1994b).
The climatic and the environmental history during most of the Holocene hence is not well known. A more detailed information can be obtained by investigation of the sediments from the existing lakes in Taylor Valley.

2.1.2. Significance of the lakes in Taylor Valley

The Taylor Valley, as part of the Dry Valleys in the southern Victoria Land, was first explored at the beginning of the last century. During this period a few expeditions, the most famous amongst led by Scott and Shackleton, investigated the region around Ross Bay in order to find a suitable access to the central ice sheet and to the south pole. The lakes in Taylor Valley were first visited by Scott in 1903 and Taylor in 1911.
The lakes in Taylor Valley today are closed-basin lakes with a perennial ice cover. Several studies indicate that the lake levels and the thicknesses of their ice cover vary with climatic changes of the past decades (Chinn 1993, Fountain et al. 1999, Doran et al. 2002). The lakes have been suggested to be remnants of the much larger proglacial



Lake Washburn that existed already during the LGM (Hall & Denton 2000). Because

Fig. 2.1: Map of Taylor Valley in the Dry Valleys, indicating the three largest lakes along the valley. The water indicated at the eastern end of the valley belongs to the New Harbour bay and is part of the Ross Sea.

the youngest palaeolake deposits above the recent lake shorelines have an age of 8000-9000 years B.P., lake level fluctuations since that time have to be near or below the present level of lakes in Taylor Valley. Thus, the more recent history of the valley is likely stored in the bottom sediments of the today existing lakes.

The largest lakes in Taylor Valley are Lake Fryxell, Lake Hoare, and Lake Bonney with its east and west lobe (Fig. 2.1). These lakes are since about one decade part of the Long Term Ecological Research (LTER) programme. This project concentrates on the investigation of modern physical and biogeochemical processes in the lakes, and the links between climate changes and their impact on the lakes and their environments. The hydrology of the lakes in Taylor Valley varies from entirely freshwater (Lake Hoare) to brackish (Lake Fryxell) to hypersaline (Lake Bonney). Sediment cores, some of them already obtained during earlier expeditions, recovered so far only the surface sediments up to about 1 m depth (Doran et al. 1999, Hendy 2000). Most of the cores indicate very slow sedimentation rates and rather differing sediment compositions. The surface sediments recovered from Lake Fryxell are composed of fine laminated microbial and algae mats with interspersed calcareous layers in a submillimeter range. These horizons alternate with up to two decimeter thick horizons of sand. Aragonite has been dated to about 10 410 B.P. in a depth of 64 cm, and to about 21 000 B.P. in a depth of 87 cm (Hendy 2000). Although the absolute ages of both datings are questionable, because a hard water effect due to the occurrence of carbonate and a reservoir effect due to the permanent ice cover and the influence of glacial meltwater can be assumed, they confirm a very slow sedimentation rate.

The sediments of Lake Hoare, in contrast, are more composed of sand and gravel with only few interspersed organic layers. The lake is supposed to have been dried out at around 1200 B.P., before an advance of the Canada Glacier, which separates the basins of the lakes Fryxell and Hoare, dammed up the existing Lake Hoare (Lyons et al. 1999). A ca. 40 cm long surface sediment core was dated to about 2400 B.P. at the base (Doran et al. 1999). Deeper sediments were not recovered so far.

The surface sediments of Lake Bonney are, in contrast to the sediments of the other lakes in the Taylor Valley, dominated by salt cristals, particularly in its eastern lobe. Uran/Thorium ($^{234}U/^{230}Th$) dating of gypsum-aragonite horizons suggest that the oldest yet recovered surface sediments are less than 5000 years old. Limestone deposits in the surrounding of Lake Bonney indicate that the lake may have existed already 100 000 to 300 000 years (Hendy et al. 1977, Lyons et al. 1999).

The old ages of the lakes Bonney and Fryxell are confirmed by isotopic and geochemical analyses of the lake waters. Because both lakes belong to density-stratified lake types, the bottom waters of the lakes are not in exchange with the surface waters. Therefore, the bottom waters of the lakes may indicate the ages of the lakes. For example, $\partial^{18}O$, ∂D, and chloride profiles from Lake Bonney suggest that the bottom water has an age of about 8000 B.P. (Doran et al. 1999). In contrast, the relatively young age of the today existing Lake Hoare is confirmed by only few dissolved salts, which suggests that the lake has been accumulating salts for a short time (Doran et al. 1999, Hendy 2000).

2.1.3. Aims of the expedition 2002

Because the hydrology of the lakes in Taylor Valley is relatively well known from former studies, the expedition in 2002 focussed on the recovery of lake sediments from the lakes Fryxell, Hoare, and Bonney. The study of the recovered lake sediments is intended to solve the following four key questions:

(1) How sensitively do Dry Valley lake sediments record Holocene environmental and climate variability?
(2) What is the palaeoclimatic variability in the Dry Valleys on a century and millenial scale throughout the Holocene? Especially, is the 1200 B.P. evaporite event unique, or are there other such events in the record?
(3) Does a mid-Holocene (7000 to 5000 B.P.) climate shift occur in the Dry Valleys as documented elsewhere in the polar regions?
(4) Is there evidence in the Dry Valley lake record of the 15 000 year Holocene periodicities recently recognized in the Taylor Dome record?

2.1.4. Itinerary of the expedition Taylor Valley 2002

Most of the expedition members flew from Christchurch, New Zealand, to the McMurdo Station, Antarctica, on 21. October 2002. The days at McMurdo Station were characterized by the preparation of the equipment for the field season and the participation on a two days field training.
On 28. October the field party and their equipment were flown by helicopter from the McMurdo Station to the Lake Hoare camp in central Taylor Valley. The field work at Lake Hoare took about one week. The weather conditions were relatively good during this period. Coring was finished on 02. November. Then, two days were spend with packing of the equipment, when flight conditions were unsuitable. The transfer to Lake Fryxell took place on 05. November, supported by helicopter transport of most of the expedition members and their equipment. Simultaneously, a small party of three expedition members walked over to Lake Fryxell around the mouth of Canada Glacier, which separates Lakes Fryxell and Hoare. Coring at Lake Fryxell lasted about 8 days. Due to the progressive summer season, the weather during the coring period was rather favourable, with relatively warm and calm days. Snow fall and bad visibility during the following two days avoided, however, a transfer from Lake Fryxell to Lake Bonney. Therefore, Lake Bonney camp was reached not before 15. November. Whilst the camp

at Lake Bonney is located at its eastern lobe, coring started in the western lobe, about 200 m in front of Taylor Glacier. Catabatic winds during the first days and the consistency of the sediments made coring at West Lobe Bonney very difficult. After completing the coring at West Lobe Bonney, the equipment was moved by helicopter, Skidoo, All Terrain Vehicle, and sledge to East Lobe Bonney on 19. November. The weather conditions improved during the following days, and coring at East Lobe Bonney was finished on 23. November. On 25. November, the last expedition members left Taylor Valley in destination to McMurdo Station. Return from McMurdo Station to Christchurch took place between 26. November and mid December, depending on the different jobs of the expedition members.

2.2. Studied lakes and coring modifications

2.2.1. Lake Hoare

Lake Hoare is a southwest-northeast, along the Taylor Valley oriented closed-basin lake of about 7 km length and up to 2.5 km width. The maximum width is measured at the northeastern end of the lake, where the tongue of the Canada Glacier forms a natural barrier (Figs. 2.1 and 2.2). The lake consists of several sub-basins, the deepest with about 34 m in the northeastern part of the lake. At the coring location within this basin a water depth of 32.6 m was measured by leadline (Fig. 2.3).

Fig. 2.2: Photograph from Lake Hoare towards northeastern direction, where the Canada Glacier forms a natural barrier (entering from the left side). The ice surface ist extremely rough and partly covered with sediment.

The 1.8 km^2 lake area is perennially ice covered and has a very rough surface in its central part (Fig. 2.2). Along the shoreline, a broad band of moat is formed during summer, creating a more planar ice surface of up to several tenths of meters width. At the end of October 2002, the ice thickness in the central part of the lake was measured to be 4.3 m from the bottom to the top and 4.0 m from the bottom to the water surface. Sediments of various grain sizes up to the size of big boulders are deposited all over the lake ice. Particularly sand and silt, mostly of eolian origin, are incorporated into the ice, forming lenses or pockets (Squyres et al. 1991).

Lake Hoare, located at an elevation of 73 m a.s.l., is surrounded by steep and up to 2000 m high mountains of the Asgard Range to the north, and by slightly less inclined slopes of the Kukri Hills of similar elevation to the south. Meltwater feds the lake during

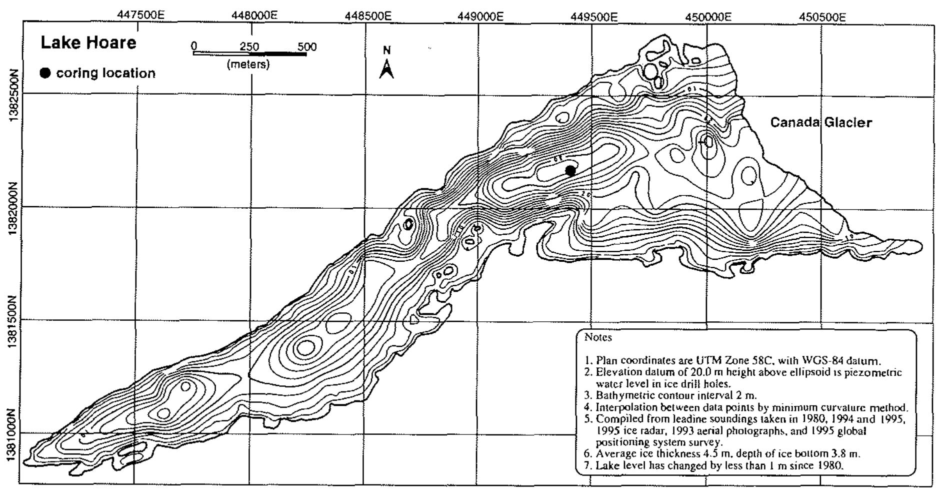


Fig. 2.3: Bathymetric map of Lake Hoare. The black dot in the northeastern part of the lake indicates the coring location.

summer, particularly along the Canada Glacier, where a creek bed has been formed by the temporary streaming Andersen Creek.

The origin of Lake Hoare is uncertain, however, the lake is supposed to have been dried out at around 1200 B.P. (Spaulding et al. 1997, Doran et al. 1999), before the Canada Glacier readvanced and dammed up the water body existing today. The young age of Lake Hoare would also explain the relatively low solute concentrations in comparison to other lakes in the Taylor Valley. Despite the low solute concentrations, a chemocline is formed in a water depth of between 10 to 15 m as a result of the perennial lake ice cover, which prevents mixing and leads to anaerobic bottom waters.

2.2.2. Lake Fryxell

Lake Fryxell is located at the downvalley side of Canada Glacier (Figs. 2.1 and 2.4). The irregular shape of the lake measures about 9 km in length and 2.2 km in width. Even though a few islands rise above lake level, the bathymetry of Lake Fryxell is rather simple, with a maximum depth of almost 20 m in the central part of the lake. The water depth at the coring location was 18.3 m (Fig. 2.5).

As Lake Hoare, Lake Fryxell is perennially ice covered, and a moat is formed along the shoreline during summer. However, the ice surface is smoother and less covered with sediments, likely because the Canada Glacier blocks the downvalley blowing catabatics, and eolian transported clastics are trapped in front of it. During the expedition in 2002, the ice thickness was 5.45 m from the bottom to the top and 4.7 m from the bottom to

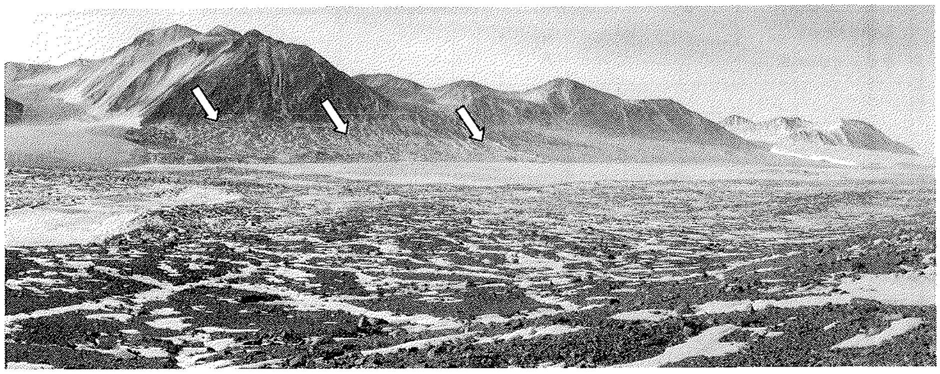


Fig. 2.4: Photograph of Lake Fryxell, taken from the south. At the left corner is the Canada Glacier. Proglacial Lake Washburn shorelines are indicated by arrows.

the water surface. A similar ice thickness was also observed in earlier studies (Howes et al. 1992). The permanent ice cover in the central part of the lake leads to a density stratified water body, with aerobic conditions in the upper 5-9 m and an amictic and anaerobic monimolimnion below (Howes et al. 1992). The salinity of the lake in general is brackish and increases gradually from the top of the water column to the sediment surface. The temperature in the water column has a maximum of about 3.3°C in 10 m depth, and decreases to 2.5°C at the bottom.

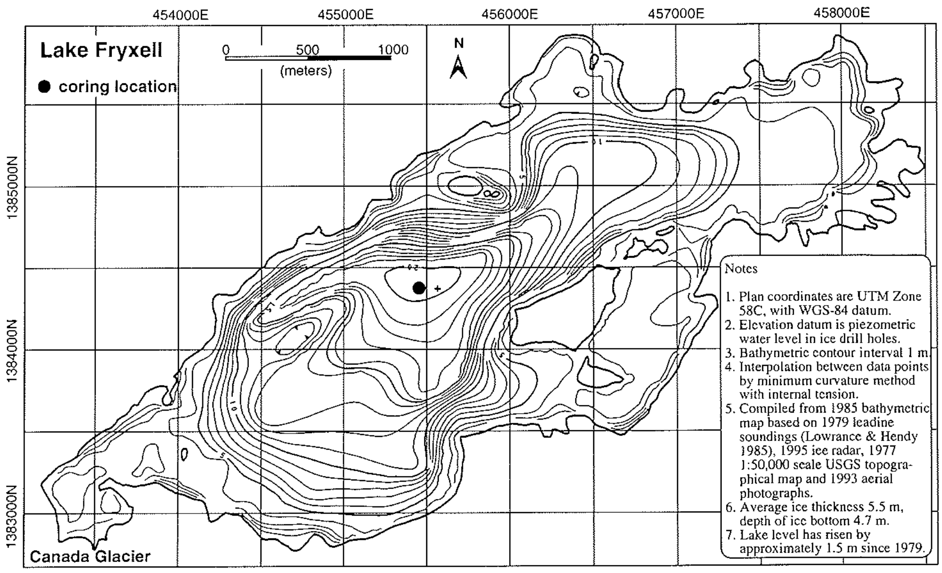


Fig. 2.5: Bathymetric map of Lake Fryxell. The black dot in the center of the lake indicates the coring location.

Lake Fryxell is supposed to be a remnant of proglacial Lake Washburn. Fossil shorelines of Lake Washburn are visible on the slopes above the present lake level of 18 m a.s.l. (Fig. 2.4). Today, Lake Fryxell is fed by several meltwater streams during summer, mainly coming down from the glacier tongues in the catchment. Steep slopes of the Asgard Range to the north and less inclined slopes of the Kukri Hills to the south form a relatively broad u-shaped valley in this part. The surrounding mountains are, in comparison to Lake Hoare, much lower.

2.2.3. Lake Bonney

Lake Bonney consists of two up to 800 m wide basins, the ca. 2 km long west lobe and the ca. 5 km long east lobe (Figs. 2.1 and 2.6). Both lobes, elevated at ca. 60 m a.s.l., are separated by a ca. 50 m wide and 12 m deep sill to the north of the Bonney Riegel. The bathymetry of both east and west lobe is relatively simple, with maximum water depths of 38 and 39 m, respectively (Fig. 2.7).

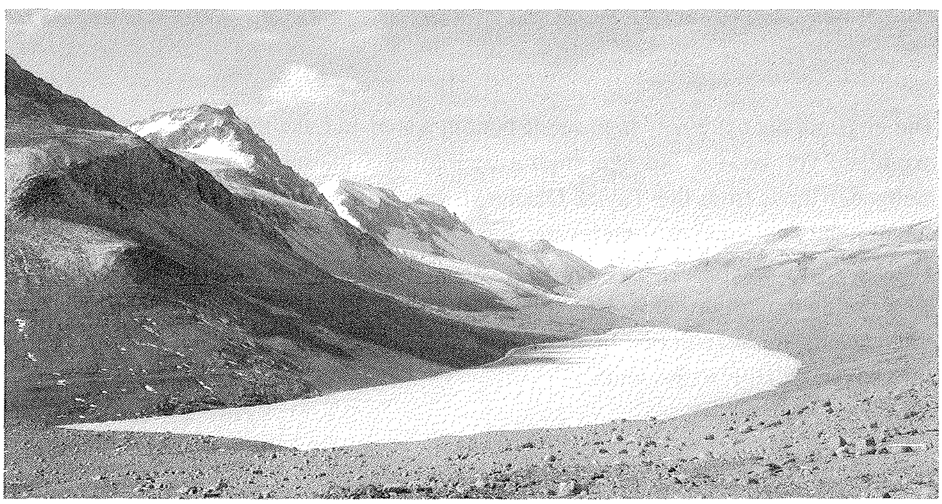


Fig. 2.6: Photograph from Bonney Riegel towards the eastern lobe of Lake Bonney.

The surface on the perennially ice-covered lobes is relatively smooth, with only few sediments on it. A band of moat is formed during summer along the shoreline. Measurements of the ice thicknesses resulted in 3.9 m over all and 3.5 m from the ice bottom to the water surface in the west lobe. In the east lobe, a total thickness of 4.9 m from the bottom to the top of the ice and 4.3 m from the bottom to the water surface were measured. The permanent ice cover and the presumed old age of Lake Bonney cause an anaerobic and hypersaline monimolimnion below 20 m water depth.

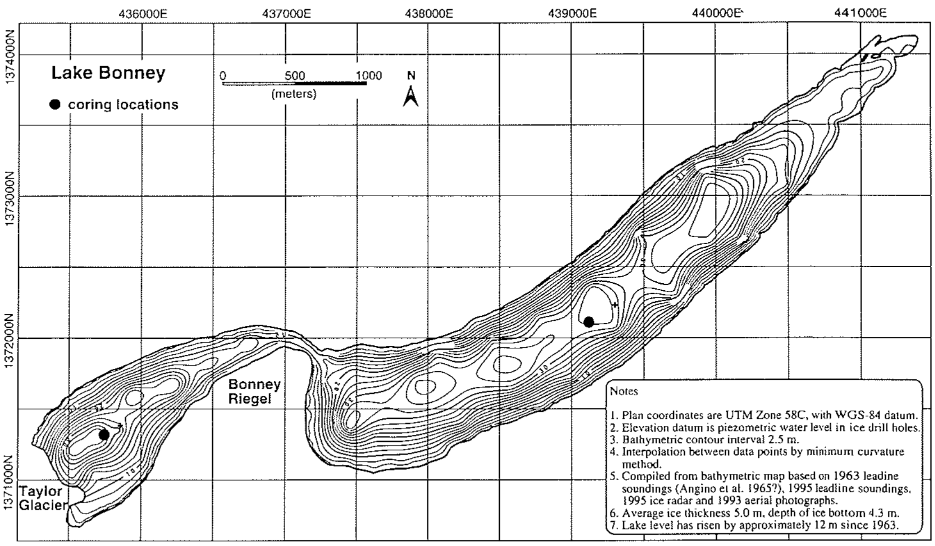


Fig. 2.7: Bathymetric map of Lake Bonney. The black dots indicates the coring locations in west and east lobe.

The origin of the extremely high saline bottom waters in Lake Bonney is not completely explained yet. A very old age, high evaporation, a marine transgression and saline meltwater input from the Taylor Glacier, revealed at the so-called bloodfalls, are in discussion. The summerly meltwater input from the surrounding glaciers, of which Taylor Glacier determines the west end of Lake Bonney, leads to an increase of the lake level during the last decades. The slopes in the vicinity of Lake Bonney are rather steep and reach maximum altitudes of about 2200 m in the Asgard Range to the north and 200 m in the Kukri Hills to the south.

2.2.4. Modifications of the coring procedure

Several modifications of the coring equipment and the coring procedure (see chapter 1.4.) were carried out during the Taylor Valley expedition 2002 in order to meet the special requirements of the environment. Because of ongoing studies in the lakes Hoare, Fryxell, and Bonney as part of the LTER programme, an essential precondition for the coring of sediments was the avoidance of any mixing or contamination of the water column, for example even with sediment from the bottom of the relative lakes.

At Lake Bonney, the coring tube was filled with saline water from the monimolimnion to ensure that the piston of the piston corer releases at the subzero bottom-water temperatures. During the coring process the saline water was then progressively released back into the monimolimnion of the lake.

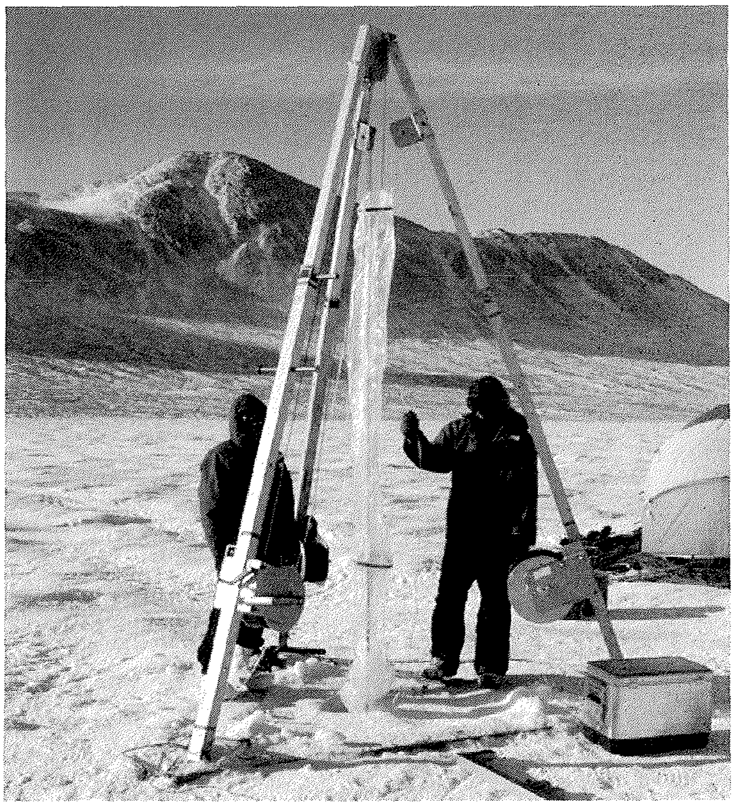


Fig. 2.8: Coring tripod on Lake Fryxell. In the center is the tubular film visible, which coates the subaquatic coring equipment to the lake bottom.

In order to catch sediment, which might have been raised during the coring process or lost during the uplift of the gravity and piston corer, the whole subaquatic coring equipment was coated by a tubular film. The tubular film had the length of the water column and was strengthened by metal rings (Fig. 2.8). To control its correct position and its successful use a subaquatic camera was used. The camera also was employed to ensure that the piston of the corer was released immediately above the sediment surface (1-2 cm), when coring the uppermost segment. Thus, the lowermost tip of the coring tube reached a depth of almost 3 m at this attempt, and the superstanding water on top of the sediment surface was minimized in order to avoid disturbances.

High amounts of coarse grained sediments in all lakes and high salinities in the sediments of Fryxell and Bonney necessitated a special procedure to prevent disturbance of the internal sediment structures in the cores by flushing water. Sediment cores of all lakes were, once recovered from the water columns, immediately frozen. The freezing was performed while keeping the cores vertically placed in lake ice holes. Because of the extremely high amount of salt in the sediments of Lake Bonney, the use of dry ice for core freezing even was required. The dry ice was carefully placed around the coring tube for about 4 hours. Then, the core was removed from the ice hole, and the PVC tube was extracted from the coring tube, after melting the water between the metal and PVC tube. The splitting of the cores into several segments and the transport of the segments were also carried out while keeping the sediments frozen.

2.3. Samples and results

2.3.1. Lake Hoare

Coring at Lake Hoare was relatively complicated due to a high proportion of coarse grained terrigenous matter in the sediment. The origin of the coarse grains is still under discussion and not yet completely understood. On the lake ice, bolders of up to several meters in diameter are observed. Their present location, particularly on the old ice in the center of the lake, can be explained with lake level fluctuations, mass movement processes from the surrounding slopes, and/or a sorting of grains through the ice by freezing, melting and refreezing processes. Additionally, the ice is partly covered with eolian transported silt and sand. The finer particles of the coarse fraction are obviously trapped in pockets or lenses into the lake ice, and probably melt through the ice with time.

The top 5 cm sediments at the bottom of Lake Hoare were composed of coarse clastic matter and fluffy organic matter, with a slight smell of H_2S. Single layers of organic matter also occurred in sediment depths of up to about 1 m, however, a downcore increase of the proportion of terrigenous clastic matter was observed through the PVC liner. Along with the increase of the proportion of terrigenous matter, the grain sizes became coarser to mainly sand and gravel. Penetration of the sediment with the piston corer stopped in a depth of almost 3 m because of too coarse sediments (Tab. 2.1). When pulling the 3 m long coring tube out of the sediment, the friction was extremely high until the tube passed the lower 1 to 1.5 m of sediment. Probably a horizon composed of predominantly coarse and unrounded clastic matter in a depth of about 1.7 m collapsed during the coring process and, thus, avoided an easy recovery of the core.

Although the piston of the corer was released less than 1-2 cm above the sediment surface at the begin of the coring process (see chapter 2.2.4.), the water column between the piston and the sediment surface measured up to several decimeters, when the cores were recovered (Tab. 2.1). This can be explained by a collapse of the internal clastic and coarse sediments, lacking on binding material, or by an entry of water from the top of the corer, when the penetration of the corer was hampered by gravel or single rocks.

Tab. 2.1: Sediment cores from Lake Hoare, where the maximum water depth was measured. For location see Fig. 2.3.

core no.	latitude	longitude	water depth	type	penetration
Lz1020-1	S 77°37.726	E 162°52.934	32.6 m	gravity corer	0-10 cm
Lz1020-2	S 77°37.726	E 162°52.934	32.6 m	piston corer	10-182 cm
Lz1020-3	S 77°37.726	E 162°52.934	32.6 m	piston corer	0-204 cm
Lz1020-4	S 77°37.726	E 162°52.934	32.6 m	piston corer	0-233 cm

2.3.2. Lake Fryxell

A gravity core (Lz1021-11) from the deepest part of Lake Fryxell revealed after opening in the field that the top 32 cm sediments are composed of fine laminated organic and carbonate layers and irregularly interspersed horizons of coarse sand without any internal structure (Fig. 2.9). The organic matter was mainly formed by algae and microbial mats, while the light carbonate layers are thought to be the result of calcite and aragonite rain due to depletion of CO_2 when photosynthesis during summer takes place (Hendy 2000). A colour change of the organic matter from black and dark olive in the top 8 cm towards light grey and light olive in the deeper sediments likely indicates a change in the redox conditions.

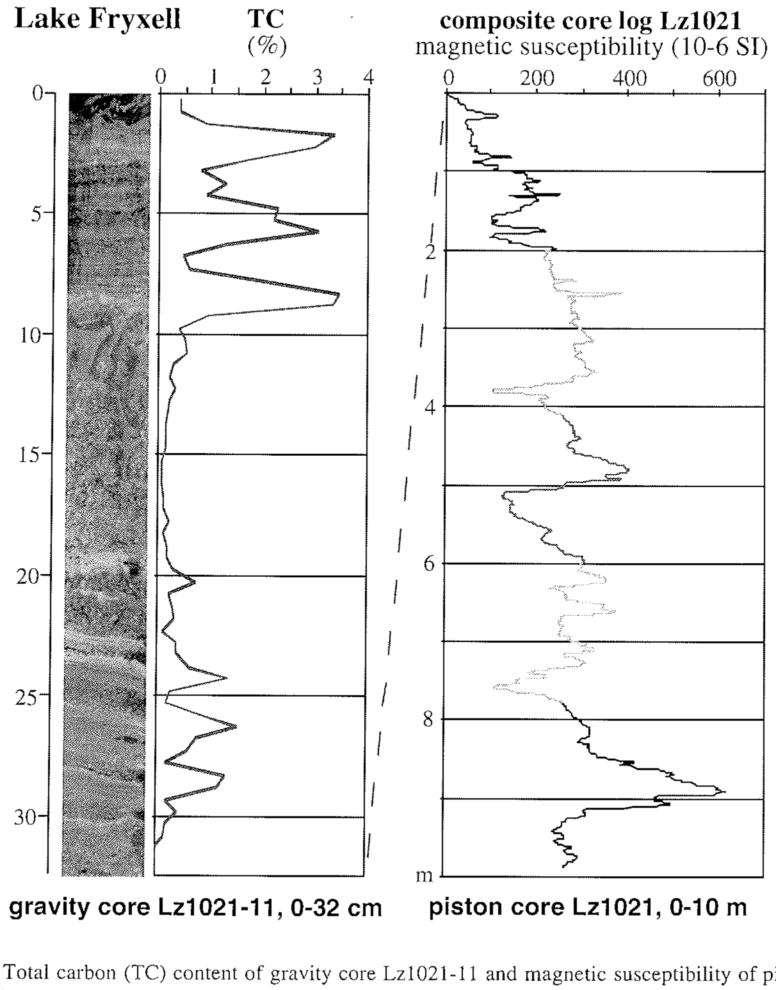


Fig. 2.9: Total carbon (TC) content of gravity core Lz1021-11 and magnetic susceptibility of piston core Lz1021, indicating high fluctuations throughout the cores (data Doran unpubl.). Peaks of TC content can be correlated to fine laminated organic and carbonate layers.

Additional horizons of organic matter were observed through the closed PVC liner of the uppermost piston core Lz1021-2 in sediment depths of about 80-90 cm and 105 cm, respectively. In the deeper parts of this core and in the underlaying piston cores organic layers were not visible. The sediments at the top and the base of the piston cores, and where the piston cores were split into single segments, consisted of greyish terrigenous matter with varying grain sizes from mud to sand. A clear trend in grain-size composition with increasing depth was not recognizable. This is also reflected in fluctuations of the magnetic susceptibility of core Lz1021, except that lowest values are measured at the top, and a maximum is recorded in about 9 m depth (Fig. 2.9). At a sediment depth of about 10 m coarse sand avoided a further penetration of the piston corer into the sediment. The results from the field campaign in 2002 are in a contradiction to the observations of earlier coring campaigns carried out during the years 1982, 1985 and 1989 at Lake Fryxell. The cores recovered during these expeditions were thought to contain the complete lake history because of a basal diamicton in a depth of about 1 m (Hendy 2000). Core Lz1021 from the expedition in 2002 suggests, in contrast, that the lake history is much older than previously assumed.
As already observed at the sediment cores from Lake Hoare, there were up to several decimeters of water between the piston and the sediment surface in the PVC lines after recovering and freezing of the cores from Lake Fryxell, probably due to a collapse of the internal clastic matter or suck of water from the top of the corer. Because it is hard to discover, where the superstanding water comes from, the penetration of the sediment was calculated from the release of the piston in a certain depth and excluding the superstanding water. Therefore, the tip of the corer likely will have reached deeper horizons during each coring process than shown in Tab. 2.2.

Tab. 2.2: Sediment cores from Lake Fryxell, where the maximum water depth was measured. For coring location see Fig. 2.5.

core no.	latitude	longitude	water depth	type	penetration
Lz1021-1	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-33 cm
Lz1021-2	S 77°36.629	E 163°08.390	18.3 m	piston corer	0-274 cm
Lz1021-3	S 77°36.629	E 163°08.390	18.3 m	piston corer	0-219 cm
Lz1021-4	S 77°36.629	E 163°08.390	18.3 m	piston corer	150-421 cm
Lz1021-5	S 77°36.629	E 163°08.390	18.3 m	piston corer	320-572 cm
Lz1021-6	S 77°36.629	E 163°08.390	18.3 m	piston corer	500-780 cm
Lz1021-7	S 77°36.629	E 163°08.390	18.3 m	piston corer	700-954 cm
Lz1021-8	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-32 cm
Lz1021-9	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-36 cm
Lz1021-10	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-27 cm
Lz1021-11	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-30 cm
Lz1021-12	S 77°36.629	E 163°08.390	18.3 m	gravity corer	0-37 cm

2.3.2. Lake Bonney

Sediment cores were recovered from Lake Bonney in its western lobe close to the front of Taylor Glacier and in the central part of the eastern lobe. At both locations a maximum water depth of almost 40 m was measured.

Tab. 2.3: Sediment cores from West Lobe and East Lobe Bonney. For coring locations see Fig. 2.7.

core no.	latitude	longitude	water depth	type	penetration
Lz1022-1	S 77°43.279	E 162°17.479	38.7 m	gravity corer	0-25 cm
Lz1022-2	S 77°43.279	E 162°17.479	38.7 m	gravity corer	0-27 cm
Lz1022-3	S 77°43.279	E 162°17.479	38.7 m	gravity corer	0-24 cm
Lz1022-4	S 77°43.279	E 162°17.479	38.7 m	piston corer	0-300 cm
Lz1022-5	S 77°43.279	E 162°17.479	38.7 m	piston corer	0-275 cm
Lz1022-6	S 77°43.279	E 162°17.479	38.7 m	gravity corer	0-34 cm
Lz1022-7	S 77°43.279	E 162°17.479	38.7 m	gravity corer	0-37 cm
Lz1023-1	S 77°42.892	E 162°26.216	38.3 m	piston corer	0-259 cm

The cores from West Lobe Bonney (WLB) were characterized by a yellowish brown colour and the lack of organic matter. The sediment composition changed from predominantly clay and silt with single, interspersed layers of sand (5 cm and 20 cm) at the top to coarse sand and gravel in a depth of about 3 m (Tab. 2.3). These coarse sediments avoided a further penetration of the corer into the sediment. In the upper part of the core, a lamination of the sediment was partly indicated by small layers of calcite

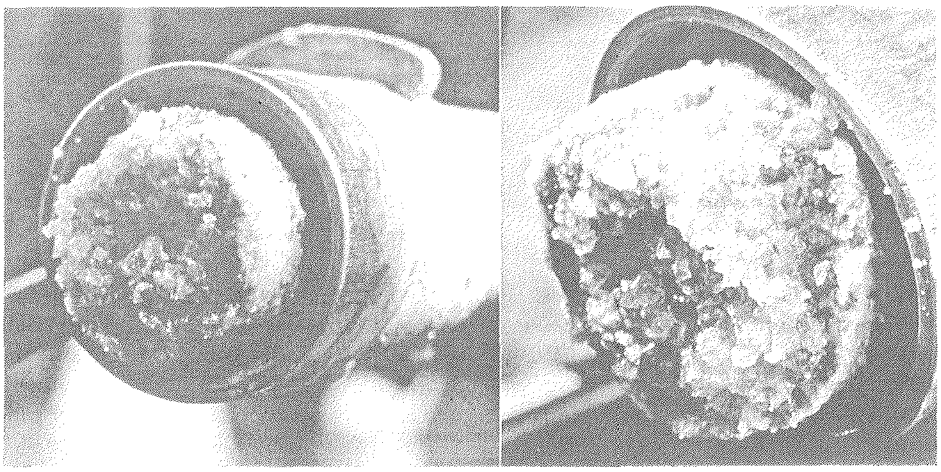


Fig. 2.10: Photographs of core Lz1023. The base at a sediment depth of about 2.5 m is formed by salt cristals, likely halite.

and/or salt crusts. When splitting the unfrozen cores at the surface, the sediment structure became very unstable, and sediment appeared being dissolved, as it is typical for the occurrence of metastable cristals such as mirabilite (Na_2SO_4 * 10 H_2O), ikaite ($CaCO_3$ * 6 H_2O) or methane hydrates. To prevent a destabilisation of the sediment at the surface, the cores were frozen by the use of dry ice (see chapter 2.2.4.).

At East Lobe Bonney (ELB) the sediment surface was formed by a salt crust. The occurrence of a salt layer of unknown thickness at the top of the sediments was already observed in earlier studies (e.g., Hendy 2000). When coring in ELB, the salt crust avoided any penetration of the gravity corer into the sediment. Using the piston corer, the penetration into the sediment was very slow, but successful. Noteworthy was an uplift of the piston by about 30 cm during the coring process, which probably is due to overpressure of water in different sediment horizons. This also would explain several cracks throughout the core. The base of the core was almost exclusively formed by cristals of salt, likely halite (Fig. 2.10). The overall length of the piston core Lz1023 recovered from ELB measured 259 cm (Tab. 2.3).

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