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HOLOCENE RAISED BEACHES IN THE LÜTZOW-HOLM BAY REGION, EAST ANTARCTICA

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Abstract: Geomorphological investigations of raised beaches were conducted in the Lützow-Holm Bay region to interpret the age and elevations of Holocene marine limits in relation to the glacial history of ice-free coastal regions around Antarctica. Prior to the Holocene, it is inferred, based on the recent data, that the incursion of the sea took place between 35000 and 40000 yr BP. Holocene raised beach deposits developed most extensively below 20 m asl in the Lützow-Holm Bay region and there was a significant correlation between their elevations and ages. A high sea level stand appears to have occurred between 4000 to 5000 yr BP in this region. Above 25 m asl, the Holocene marine limits can not be reliably determined in this region. This is accordant with other Antarctic regions where the maximum heights of raised beaches have not been identified above 30 m asl. Together, the age and elevation characteristics of these raised beaches suggest that there has been minimal Antarctic ice-sheet expansion since the Last Glacial Maximum.

Key words: Antarctica, Lützow-Holm Bay, raised beach, Holocene limit, radiocarbon dates

1. Introduction

Raised beaches and emerged marine deposits are important subjects for estimating sea level, ice advance and environmental change in the polar regions. Holocene raised beaches are common around Antarctica and have been widely studied since the beginning of the century. The present authors have studied the coastal geomorphology with special reference to Holocene raised beaches in the Lützow-Holm Bay region on the basis of recent field work as well as a review of previous work. The purpose of this paper is to clarify the Holocene glacial history in this region on the basis of Holocene marine limits and radiocarbon dates. Comparison and correlation of raised beaches in other ice-free areas of Antarctica also is discussed.

Research on Cenozoic glacial fluctuations started in the Ross Sea area. NICHOLS (1968) reported the distribution and characteristics of coastal topography in this area.

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Glacial history during late-Wisconsin and early Holocene has been investigated by DENTON *et al.* (1975), STUIVER *et al.* (1981) and DENTON *et al.* (1989) in the Ross Embayment. BARONI and OROMBELLI (1991) constructed a relative sea-level curve, judging from Holocene raised beaches at Terra Nova Bay.

In East Antarctica, the glacial history based on the beach chronology has been carried out by ADAMSON and PICKARD (1983, 1986) and ZHANG *et al.* (1983) at the Vestfold Hills. PICKARD (1985) examined the Holocene marine fossils in detail. ADAMSON and COLHOUN (1992) and COLHOUN and ADAMSON (1992) discussed a glacial history of the Bunger Hills from glacial landform and dating of the marine deposit. COLHOUN *et al.* (1992) recognized the relation between the ice sheet fluctuation and sea level change on the basis of raised beaches in East Antarctica. They concluded that Antarctic ice did not expand so greatly during the Last Glacial Maximum as supposed by the CLIMAP model and that it scarcely contributed to the postglacial sea level rise.

In West Antarctica, studies on raised beach and Late Quaternary glaciation have been developed in the Antarctic Peninsula and the surrounding islands. CLAPPERTON and SUGDEN (1982) investigated glacial history and ice shelf fluctuation in the George VI Sound and Alexander Island. Raised beaches and coastal platforms were examined in the South Shetland Islands by JOHN and SUGDEN (1971) and BARSCH and MÄUSBACHER (1986). MARTINEZ *et al.* (1992) also mentioned raised marine features in the Livingston Island. CLAPPERTON (1990) summarized a tentative correlation of Late Quaternary glaciation among the Falkland Islands, South Georgia, South Orkney and South Shetland Islands and Antarctic Peninsula. He recognized the occurrence of the Neoglaciation and the Little Ice Age. Previously studied areas mentioned above are shown in Fig. 1.

Radiocarbon dates of fossil deposits have been obtained, since they were effective for interpreting the ages of raised beaches. STUIVER and BRAZIUNAS (1985) compiled isotopic dates from Antarctica. However, radiocarbon dating of marine fossils around Antarctica is problematic because of the reservoir effect which is associated with meltwater from the ice sheet and upwelling of deep water. In fact, living marine species can be more than 1000 years dated older than their actual age. Corrected radiocarbon ages have been discussed by many authors (RAFTER, 1961; OMOTO, 1983; ADAMSON and PICKARD, 1986).

In the Lüzow-Holm Bay region, the first investigation on raised beaches and marine deposits was done by YOSHIKAWA and TOYA (1957) in Ongul Islands and the Langhovde ice-free area. MEGURO *et al.* (1964) dated fossil marine organisms sampled from the beach deposits on the East Ongul Island, and obtained radiocarbon dates from 3800 to older than 30000 yr BP. YOSHIDA (1970) discovered the emerged marine deposit in the Skarvsnes area and the Prince Olav Coast, and concluded tentatively that they were formed by postglacial transgression. FUJIWARA (1973) conducted a detailed geomorphological study on raised beaches in the East Ongul Island where five steps of beaches were divided into three groups. Ages of these groups were assigned to older than 30000, between 20000 and 25000, and between 3000 and 6000 yr BP in age, respectively, based on previously reported data. MORIWAKI (1974, 1976) added the radiocarbon dates of fossil shells and suggested that ages of marine fossils contained in raised beaches around Lüzow-Holm Bay could be divided into two groups; postglacial

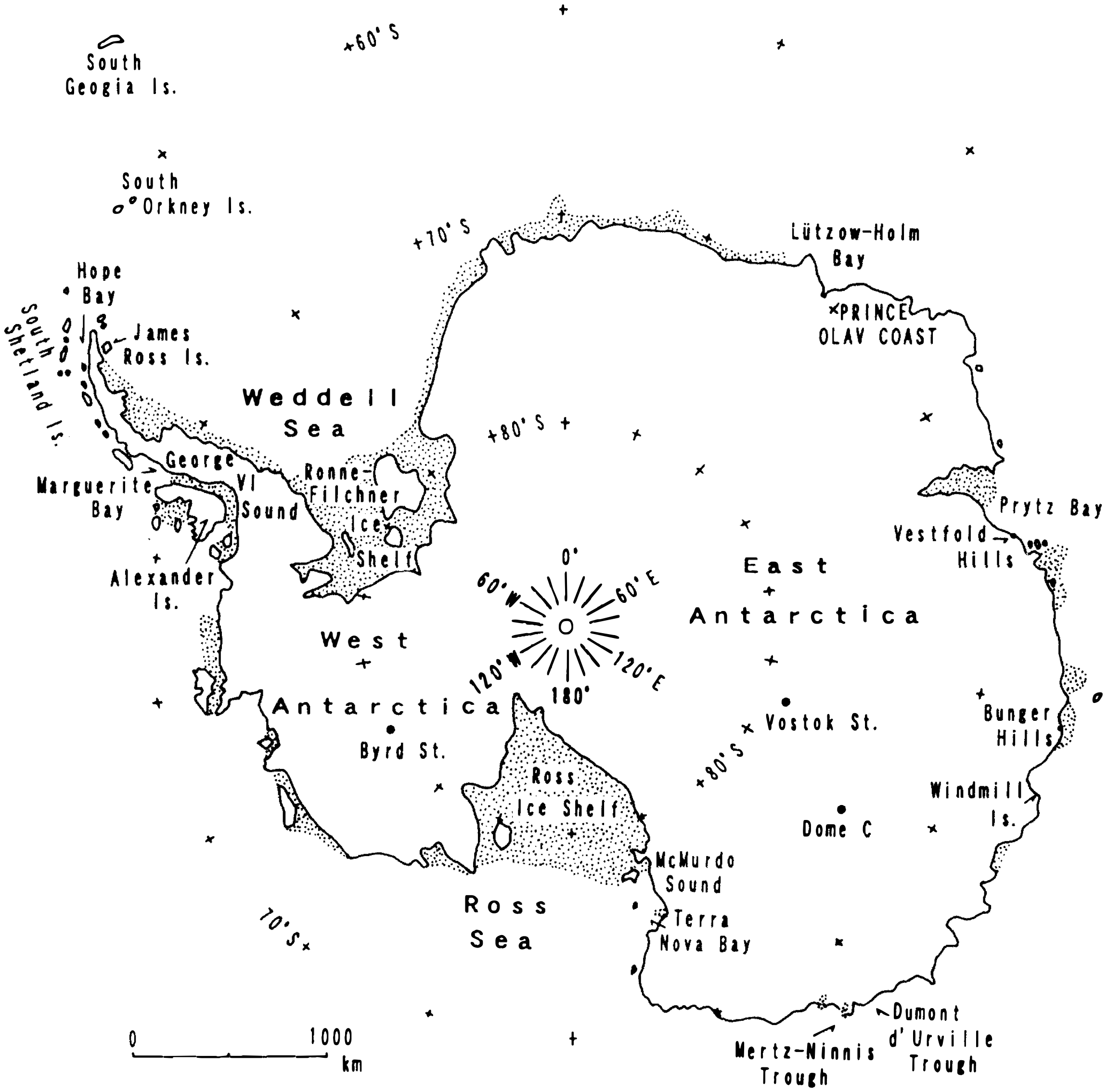


Fig. 1. Map of Antarctica showing the location of the main ice-free areas.

and older than 20 Ka. NOGAMI (1977) collected many samples of marine fossils and dated their radiocarbon ages. Succeedingly, OMOTO (1977) studied the geomorphic development of the Sôya Coast. He identified stepped topography up to 39 m asl as raised beaches and distinguished many steps on the slopes. In addition to the previous ones, he provided considerable radiocarbon dates. He also drew an eustatic curve in which the Ongul Islands were *ca.* 100 m in depth during the time prior to postglacial emergence judging from results of UCHIO's analysis (1966) on foraminifera species in the beach deposits. YOSHIDA (1983) summarized the characteristics of raised marine features and the glacial history in the Prince Olav Coast. He concluded that the higher sites of raised beaches were formed around 6000 yr BP and that the older aged fossils were reworked ones with postglacial beach deposits.

2. Location and Outline of Landforms of Lützow-Holm Bay

Lützow-Holm Bay (69–70°S, 35–40°E) is a large embayment in the eastern part of Queen Maud Land, East Antarctica (Fig. 2). It is bounded by the Prince Harald and Prince Olav Coasts. The Shirase Glacier pours into the head of this bay and draws a conspicuous topographic boundary between both coasts. A group of islands, headlands and inlets forms a major ice-free area. The bedrocks are composed of gneissic and granitic rocks. The landforms are strongly controlled by lithology and geological structures. Each ice-free area is small in expansion; even the largest Skarvsnes area is 61 km^2. Bedrock surfaces have a lower undulating topography, mostly less than 300 m asl; Mt. Heitô at the Langhovde area is the highest peak, about 500 m asl. These surfaces were entirely covered by as ice sheet during the glacial maximum stage and subjected to erosion, as evidenced by scattered erratic boulders and glacial striations in every locality. The traces of glaciation are rather fresh and well-preserved in the southern part of Lützow-Holm Bay in comparison with those in the northern part. Previous glacial flows inferred from glacial striations were SE–NW and/or E–W trending in this region (YOSHIDA, 1983).

3. Characteristics of Landform and Description of Raised Beaches

Features of raised beaches of the Ongul Islands, Langhovde, Skarvsnes and Skallen areas can be examined where field investigations have been conducted. The index maps of the Langhovde and Skarvsnes areas are drawn in Figs. 3 and 4, respectively, and

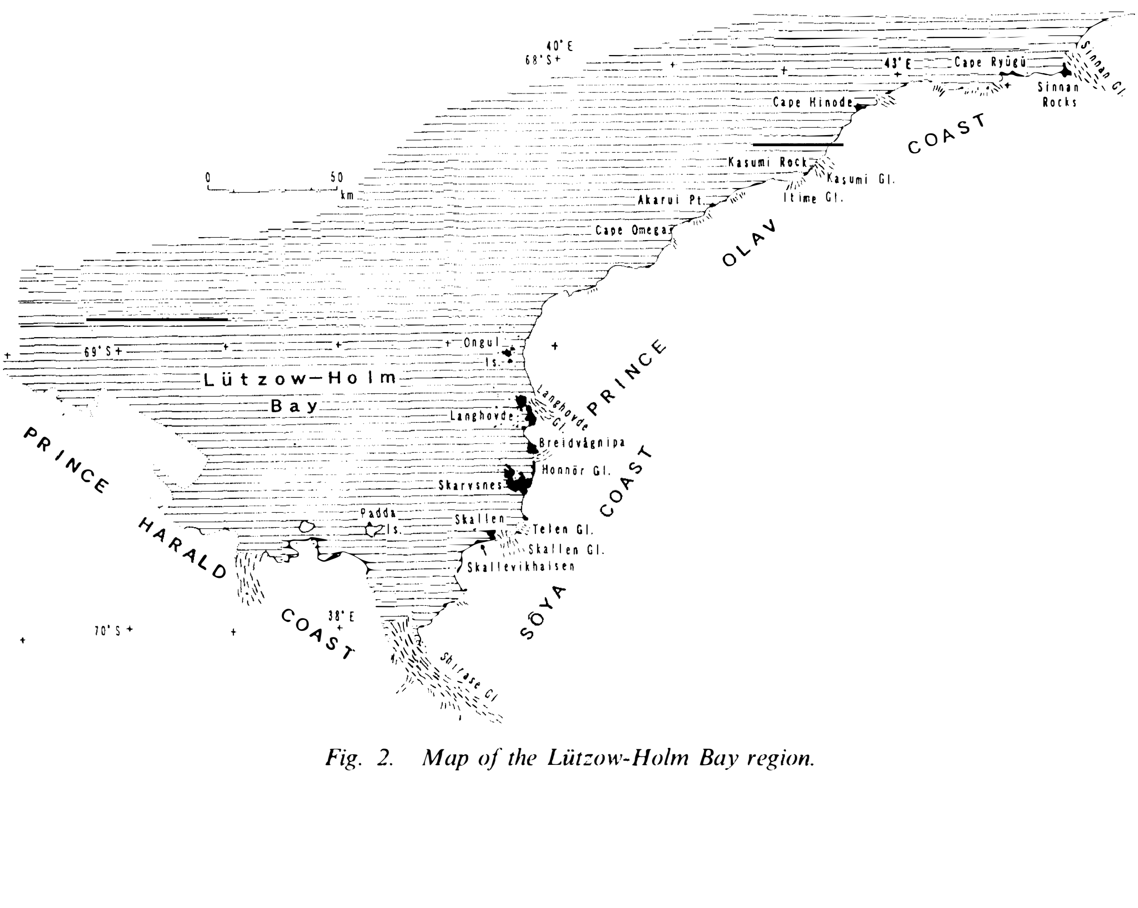


Fig. 2. Map of the Lützow-Holm Bay region.

the cross profiles of raised beaches are in Figs. 5a to 5c. Altitudes of the raised beaches were measured by using a hand level with an error of $\pm$ 1 m.

3.1. Ongul Islands

The Ongul Islands are located in the northern part of Lützow-Holm Bay 5 to 10 km away from the continent, separated by the Ongul Strait, where a drowned deep glacial trough is found. Larger islands among them are West and East Ongul Islands. These islands show low-lying hilly features below 50 m asl without conspicuous cliffs. On East Ongul Island, beaches are well recognized at Mizukumi Stream near the Syowa Station. The alteration caused by construction works prevented us from conducting a detailed study. Other raised beaches developed at the Kai-no-hama and Kitamihama Beaches in the western part of the island. Beaches neighbor each other without any interrupting bedrock. They extend up to 15 m asl exhibiting terrace-like surfaces bearing four steps of low ridges. Beach deposits are composed of coarse sand with gravel and occasional bedrock. Fossils of pelecypods, mainly *Laternula elliptica* and *Adamussium colbecki*, are often found in beach deposits. Around the Lake Ô-ike in the West Ongul Island, similar raised beaches occur at almost the same level. The highest altitude of reliable beach deposits with dated materials was about 16 m asl in the northern part of East Ongul Island (YOSHIDA, 1983), although OMOTO (1977) identified the raised beaches and step topography up to 22 m asl.

3.2. Langhovde area

The Langhovde area is located 20 to 30 km south of the Ongul Islands, with an area of 50 km^2, and is the second largest ice-free area in this region. Its eastern side is cut by the Langhovde Glacier that is flowing northward. A deep glacial trough, Naka-no-tani Valley, divides this area into two parts; the northern and the southern Langhovde areas. A geomorphological map of Langhovde has been completed by HIRAKAWA *et al.* (1984).

The landform of the northern part is characterized by undulating hilly land with jutting peaks. Three peaks of Mt. Tyôtô with steep cliffs rise about 250 to 300 m from surrounding hilly land and appear as giant roches moutonnées (KOAZE, 1964). The bedrock surface of this area has been weathered so strongly that a series of granitic dikes rise at maximum 2 m high out of the neighboring surface of gneissic bedrocks. Rather arid conditions prevail in the northern part of the Langhovde, where conical drifts of eolian sand and evaporated salt crystals of NaCl which probably originated from wind-transported sea water frequently occur.

Hyper-saline Lake Zakuro is another conspicuous feature of the northern Langhovde. Its level is about 6 m below the present sea level and surrounded by the raised beaches whose maximum altitude is about 12 m asl to the west of Lake Zakuro. Since the lowest saddle between this lake and the eastern Ko-minato Inlet stands at 6 m asl and is covered with marine deposits, this lake had unquestionably been joined to the sea and detached from the sea due to the local uplift during the succeeding period. In fact, the beach deposit contains abundant fossil shells, *Laternula elliptica* and *Adamussium colbecki*. Valves of *Laternula* as large as 15 cm in length are found mostly in growth position. These would be the largest known Quaternary mollusc samples.

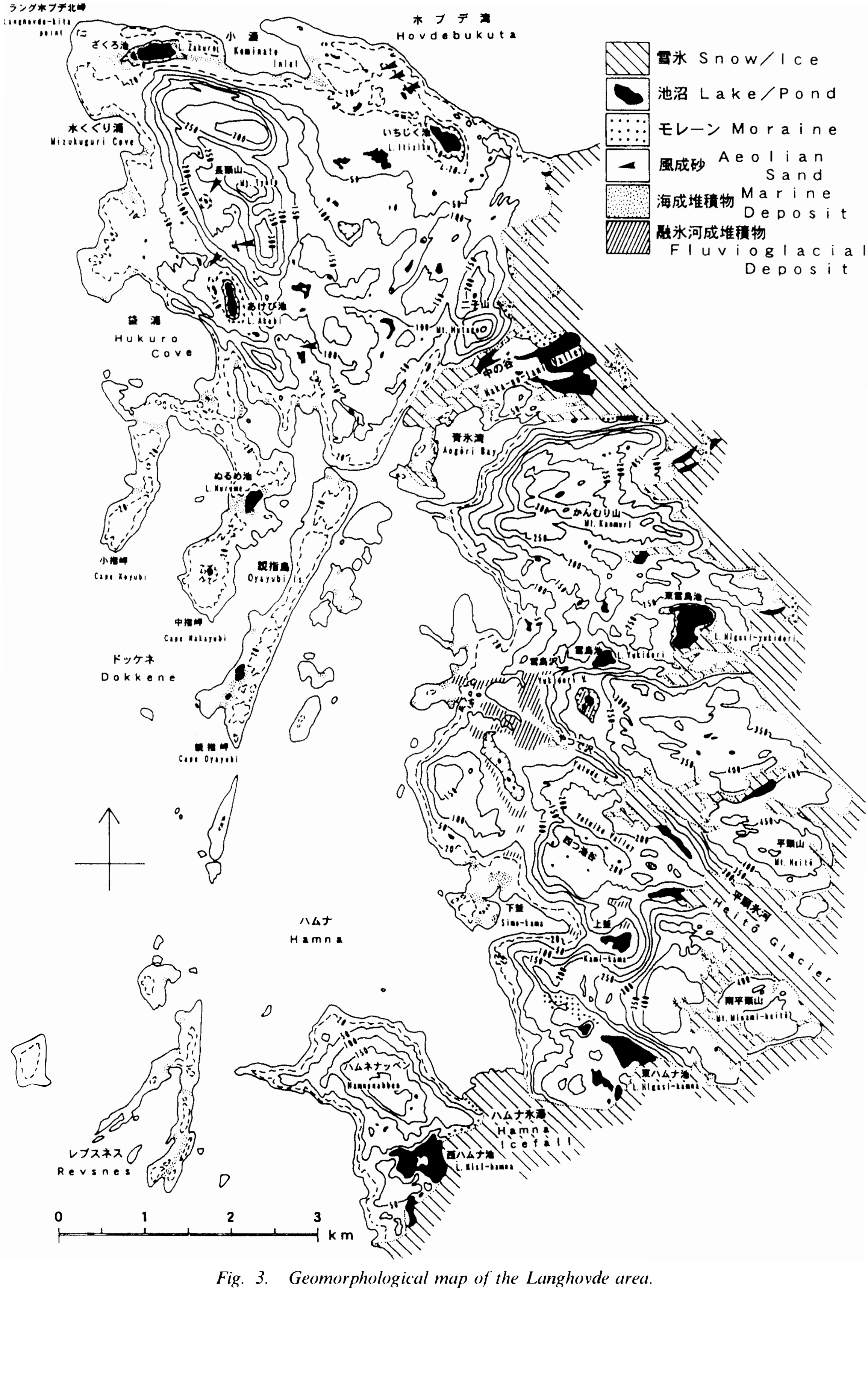


Fig. 3. Geomorphological map of the Langhovde area.

Raised beaches can be traced up to 10 m asl around the Lake Zakuro and the Ko-minato Inlet. On the southern coast of the Mizukuguri Cove, a raised marine feature was recognized at the site of about 20 m asl, where plenty of rounded boulders occupy the higher part of the area and make a marine-boulder pavement. The Lake Itiziku also is hyper saline, at a level of 14 m below the present sea level, and almost dry. The lowest saddle between this lake and the present sea stands about 20 m asl near the eastern coast of Ko-minato Inlet. There is no evidence of marine work around Lake Itiziku

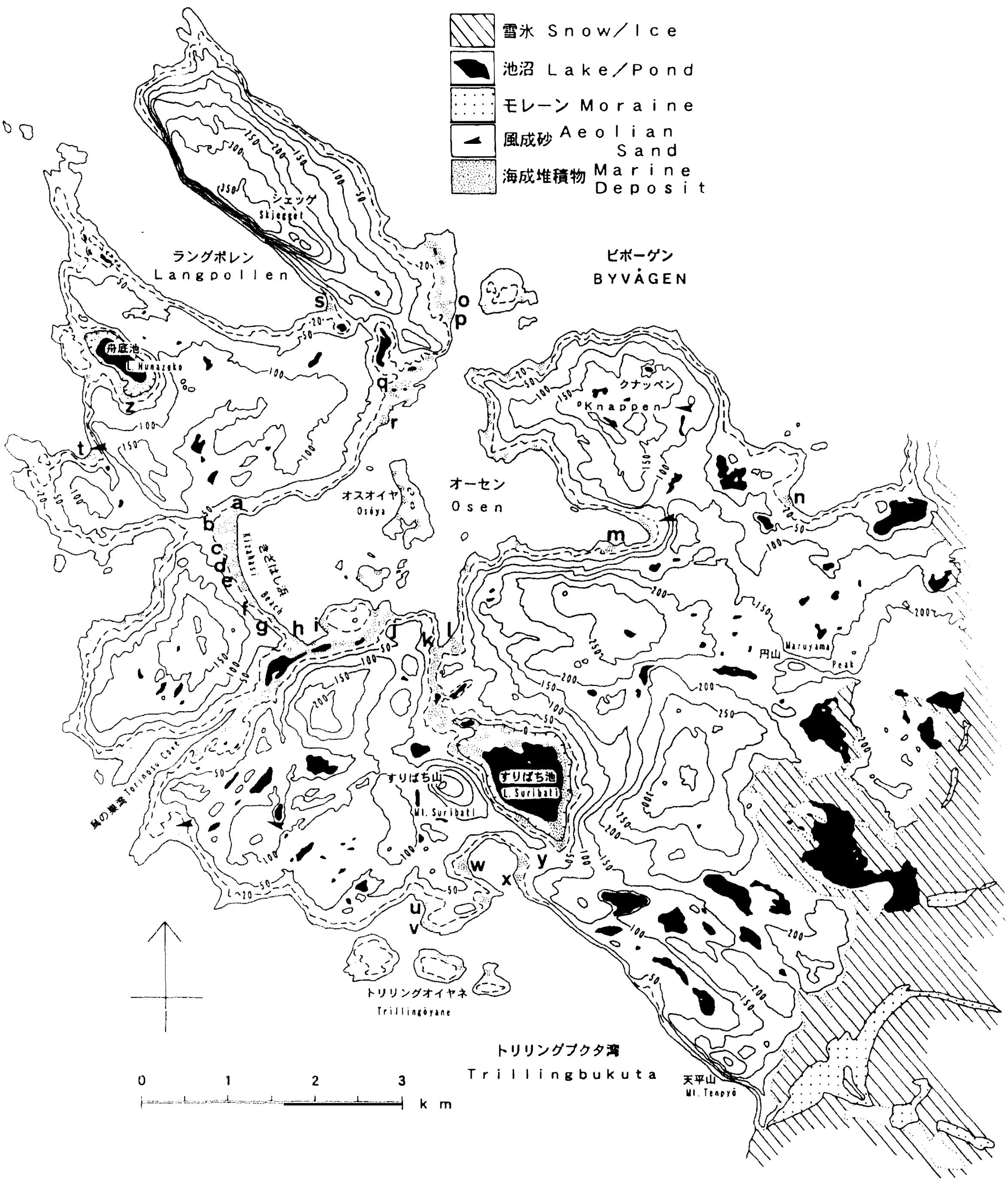


Fig. 4. Geomorphological map of the Skarvsnes area.

which suggests that the previous sea level never exceeded 20 m in this area.

In the southern Langhovde, the bedrock topography is characterized by several steps accompanied with relatively flat surfaces, where rather deep depressions and narrow linear valleys develop along a joint system of bedrock. The southern part of the Langhovde area is rather humid compared with the arid northern part. Widespread meltwater plains covered with fluvioglacial deposits develop along the lower reaches of the Yukidori and Yatude Valleys, in particular at the confluence of the two valleys. A narrow levee of fluvioglacial deposits extending horizontally was discovered on an upper slope of a circular depression (Lake Minami-Yukidori, a provisionally named) between the Yukidori and Yatude Valleys.

Raised beaches are found at the mouth of Yatude Valley and around the coast of a small cove, Simo-kama. Beach deposits exist below 10 m asl, forming three steps of beach ridges, where valves of *Laternula* are discovered in places. Another set of smoothed terrace-like surfaces are found at the slightly higher level above these raised beaches at the mouths of Yukidori and Yatude Valleys. These terraces reach 22 m asl in the Yukidori Valley, 17 m in the northern mouth and 10 m in the southern mouth of the Yatude Valley. These sites are composed of considerably coarse gravel with boulders. However, slightly laminated sand beds within the bottom layer reveal that they are a fan-delta affected by large quantities of meltwater which is correlated with the fluvioglacial deposits occurring in the Yukidori and Yatude Valleys. The margins of this fan-delta are poorly extended and are demarcated by steep scarps without any interruption. The level of this fan-delta is certainly associated with the postglacial higher sea level. The poor extension and linear terrace scarps suggest that this delta was formed by a rapid rise and the succeeding rapid descent of sea level. A similar higher terrace is located at the lower reaches of Yotuike Valley to the north of Simo-kama Cove, where it stands at a level of about 25 m asl. However, since it is composed of coarser materials and the terrace surface is buried with angular blocks, it remains unsolved whether this level around Simo-kama was directly associated with the former sea level.

3.3. Skarvsnes area

The Skarvsnes area is the largest ice-free area in the Lützow-Holm Bay region. Quarried surfaces and rounded peaks with glaciated troughs and precipitous cliffs trending E–W and SE–NW prevail in this area. However, the linear arrangement of topography is not as remarkable as in the Langhovde area. Most of the area is lower than 300 m asl; the Skjegget, at 400 m high is the highest peak truncated by a glaciated perpendicular cliff in the southwestern face. A conformity of summit levels is recognized at 100 to 150 m and 200 to 250 m asl, respectively.

Two hyper-saline lakes which had been a part of the sea stand in basins below sea level. Lake Hunazoko is located in the northwestern part of this area and stands at about 23 m below the sea level. The lowest threshold between this lake and the sea is at 1.5 m asl in the northwestern margin of this basin. Lake Suribati, whose level is at 32 m below the sea level, is situated in the central part of this area. At the northwestern end of this basin the threshold is lower than 15 m asl where a shallow valley covered with beach sand containing marine fossils gently declines and joins to Osen Bay. Continuous narrow levees of beach deposits are situated horizontally on the upper

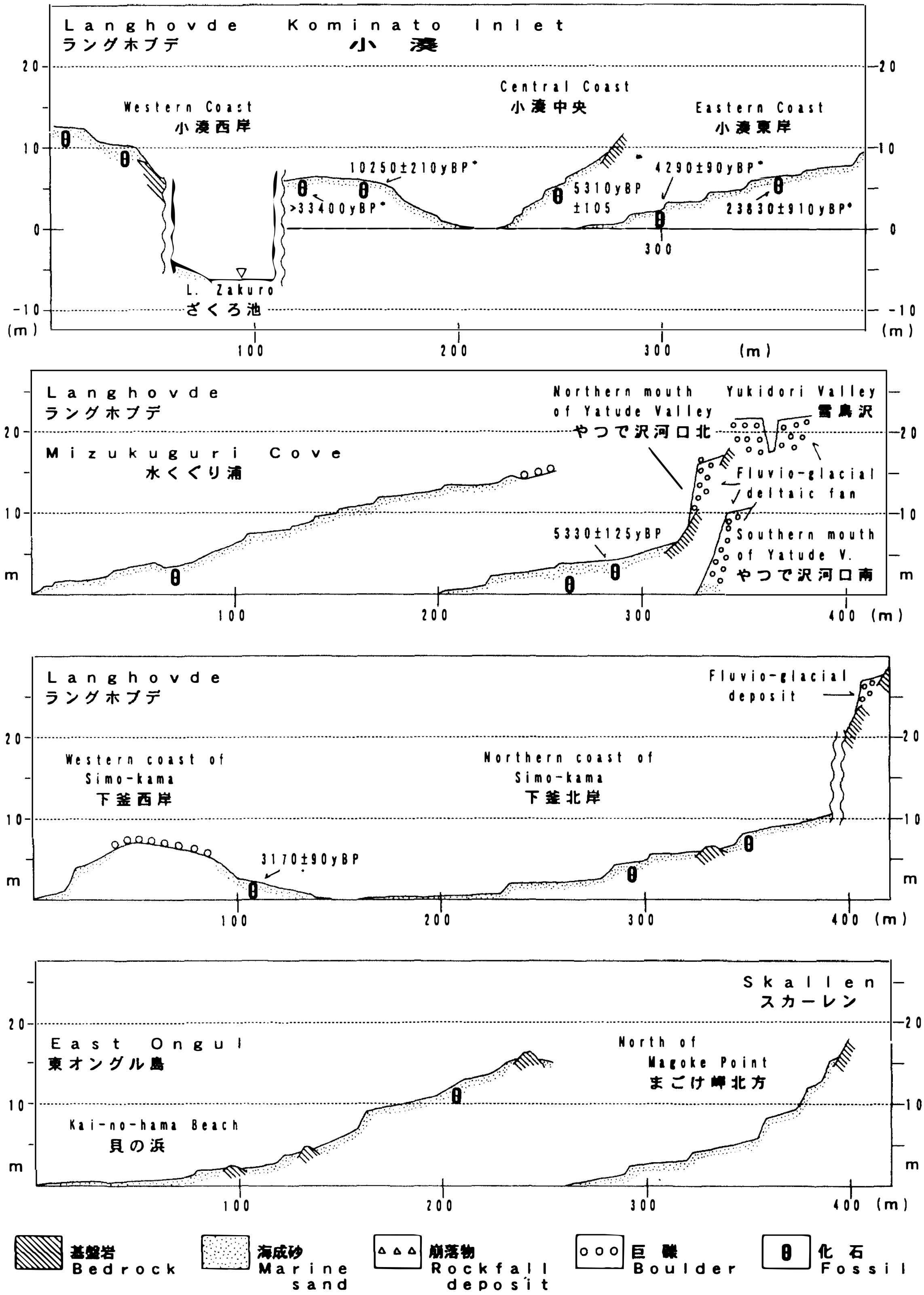


Fig. 5a. Cross profiles of the raised beaches —1—. Langhovde, Ongul Islands and Skallen area.

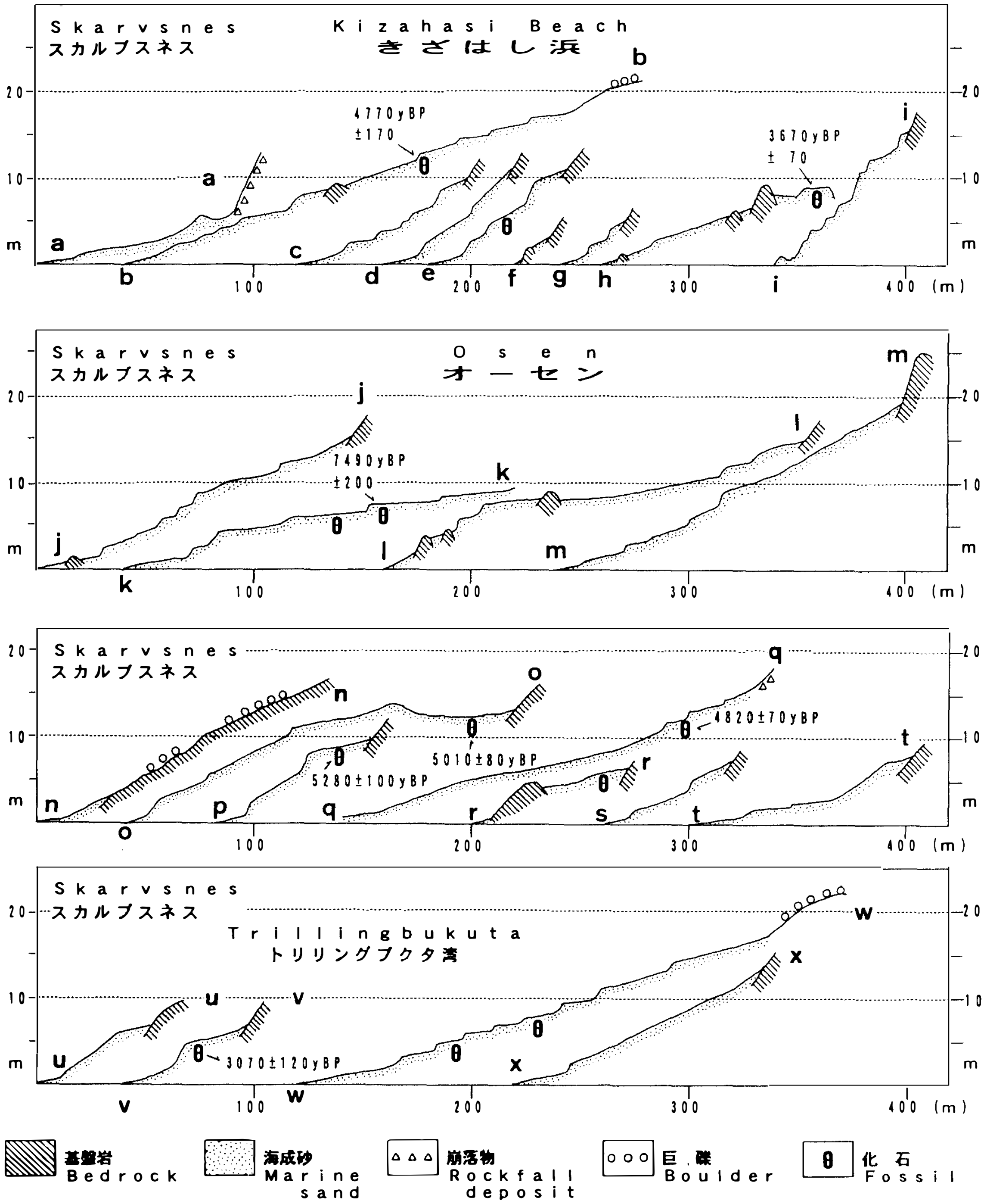


Fig. 5b. Cross profiles of the raised beaches —2—. Skarvsnes area.

slopes of both lake basins in particular around 15 m asl. On the other hand, the saddle between the Lake Suribati basin and Trillingbukta, the nearest sea, is about 35 m asl and does not show any evidence of marine work, suggesting that the former relative marine limit would be below 35 m asl.

Other Holocene raised beaches are found along the shoreline of Osen Bay, and are especially well developed at Kizahasi Beach. The marine deposits reach up to 22 m

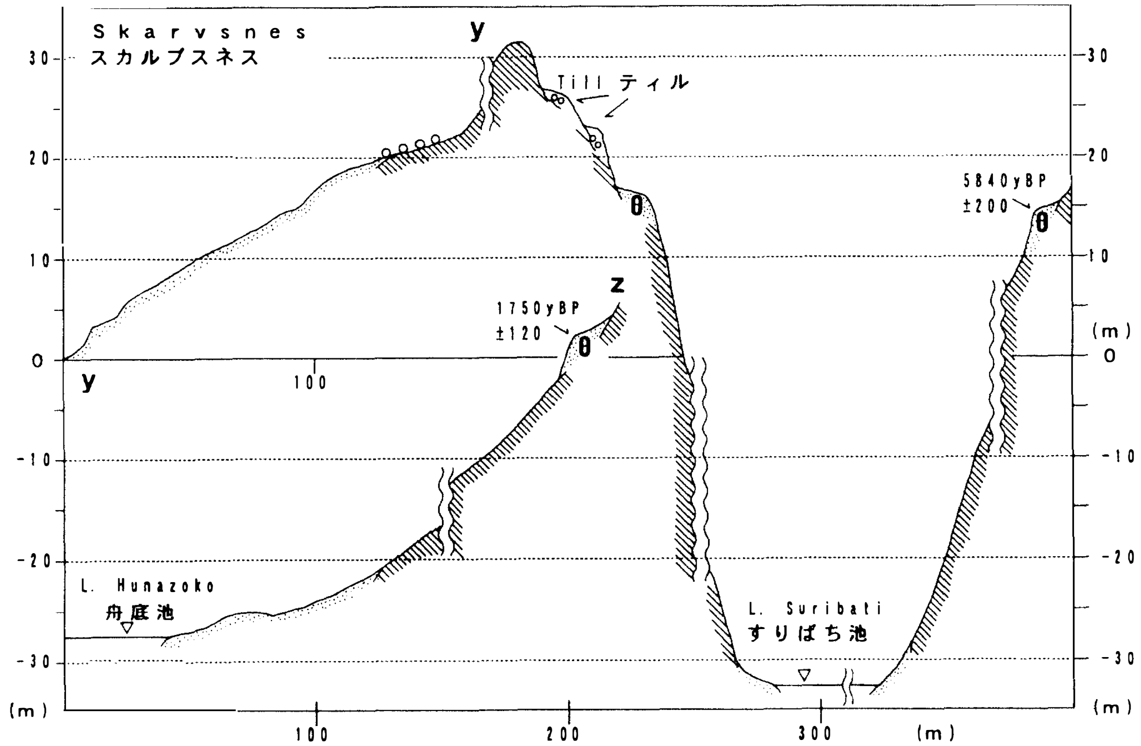


Fig. 5c. Cross profiles of the raised beaches —3—. Skarvsnes area.

asl at this beach. Kizahasi Beach, which means "staircase beach," is characterized by well-marked stepped or berm-like topography on the beach surface. Nine steps are distinguishable below 15.5 m asl. Each step is rather small and low, having 20 to 100 cm in relative height, and extends along a present strandline. Comparatively conspicuous steps are recognized at 2–3 m and 7–10 m asl, respectively. The former step is apparently formed by current sea-ice push. The low bank-like ridges composed of angular gravel occur on several steps of beaches and they are estimated to have the same origin. Beach deposits are composed of relatively fine materials, mainly coarse sand which is coverd by a veneer of flattened gravel. A bluish clay to fine-sand layer which slightly declines toward the sea is sometimes embedded in this deposit. Marine fossils such as molluscan shells are found only in this layer. The valves of *Laternula elliptica* in growth position are commonly found. Fossils of worm tubes only have been discovered around the shoreline of Osen Bay and the basin of Lake Suribati.

The maximum height of the raised beach is 23 m asl in the locality south of Knappen, Osen Bay. An emerged beach stands at relatively higher position in the coast facing to the southern Trillingbukta, where the maximum height is 22 m asl. Rounded boulders occupy the higher sites in both beaches and form marine-boulder pavements.

At the end of the Torinosu Cove, raised beaches border a narrow and linear valley which stretches toward northeastern Osen Bay with a threshold below 5 m asl. It is clearly defined that this valley was once drowned completely and formed a strait connecting the Torinosu Cove with Osen Bay. During this stage the northwestern part of Skarvsnes became an island separated from the southeastern peninsula.

Himomusi Lake (a tentative place-name) southeast of the Skjegget peak occupies a small basin whose lowest threshold to the sea is about 20 m asl and has no outlet streams. No evidence of marine work has been found in this basin in spite of its rather low threshold elevation. From the above facts, it is inferred that the Holocene shorelines in the Skarvsnes area are below 23 m asl.

3.4. Skallen area

The Skallen area is a small ice-free peninsula extending from south to north. It shows an undulating hilly topography without any conspicuous peaks. The maximum elevation reaches 186 m asl. Glacial striations, grooves and polished faces are remarkably preserved on the smoothed bedrock surfaces. The stoss-and-lee topography is found in most slopes. Close to the eastern coast, a floating tongue of an outlet glacier, the Skallen Glacier, is flowing toward north. The freshness of glaciated features suggests that ice sheet retreat occurred considerably later than in the Langhovde and Skarvsnes areas.

Raised beaches are recognized along the eastern coast, but hardly found on the western coast. A raised beach similar to those of other ice-free areas is located northwestward of the Magoke Point, where 5 steps accompanied with low and narrow ridges can be recognized below 12 m asl. Beach deposits consist of coarse sand, but molluscan shells have not yet been discovered in the higher part. Recently, IGARASHI *et al.* (1993) collected shell fragments at the site below 5 m asl.

Around Osiage Beach, meaning "pushed-up beach," a continuous terrace like a wall is distributed along the coast line with an altitude of 8 to 10 m. It consists of unsorted fresh boulders with sand and clay which would have derived from morainic materials. However, a small amount of shell fragments are embedded at places in this deposit. It seems either that the neighboring Skallen Glacier once pushed out the marine deposit and formed it as a moraine ridge or that the glacier deformed the pre-existing raised beach during its extending or stagnant stage. This means that the lateral margin of the Skallen Glacier retreated east- to southeastward by 200 to 500 m recently. A similar aspect of ice retreat is observed at Kasumi Rock in the middle Prince Olav Coast, where low ridges of lateral moraines stretch along the western coast 50 to 100 m far from the lateral margin of the Itime Glacier.

Along the strandline of Osiage Beach, unconsolidated deposits make two or three banks 20 to 40 m high above this coast. These banks are composed of gravel and boulders, but rarely mixed with fine materials. Because marine features were never observed, the banks are certainly lateral moraines formed by the Skallen Glacier. OMOTO (1977) described the beaches rising up to 32.3 m high, but these deposits may safely be identified as the above mentioned lateral moraines.

4. Dates of Raised Beaches

4.1. Radiocarbon dates from the Lützow-Hólm Bay region

Many radiocarbon ages of organic materials sampled from raised beaches in this region have been obtained (Appendix 3). The ages used in the present paper are uncorrected. Most of the samples were collected from the Ongul Islands, the Langhovde, and the Skarvsnes areas. *Laternula elliptica* is the most common species throughout the region and occupies about a half of the samples. Radiocarbon dates may be classified into two age groups; one is postglacial age between 1000 and 10000 yr BP and the other is between 22000 and 34000 yr BP or more. The younger group comprises about 80% of the total samples. Approximately 50% of the older group were obtained from fragments of shells, sampled mainly in the Ongul Islands and the northern Langhovde. No samples were dated between 10000 and 20000 yr BP, except one sampled near Ko-minato Inlet which was dated 10250±210 yr BP. Dates were based mainly on mixtures of shells, because a considerable amount of shell samples was needed for former conventional ^{14}C dating method. Therefore, it appears that 10250 yr BP date and 20000–30000 yr BP dates were derived from samples of the mixture of both younger and older shells. Particularly this seems to be ascertained by the recent result as is described below.

Regarding the older age group, the level of the sampling site was not necessarily higher than that of the younger group. The older samples sometimes have been found in almost the same or closely neighboring position as the younger samples. Neither distinctive gaps in topography nor unconformities can be distinguished in the deposits between both groups. At present, it is difficult to give a clear answer to the reason that the older age group occurs among the raised beaches at the same level as those of the younger age group. But, the following interpretations are suggested: (i) Some kind of error during the assay of radiocarbon dating due to the low volume of samples, especially in the case of small fragments; (ii) The older-aged species have been reworked and mixed within the younger deposit as pointed out by YOSHIDA (1983); and (iii) Original raised beaches were formed before the Last Glacial Age, and reemerged after the period of succeeding submergence as supposed by OMOTO (1977). The recent study of IGARASHI *et al.* (1993 and personal communication) by AMS ^{14}C method indicated that two age groups of Holocene (younger than 9000 yr BP) and 30000 or younger than 40000 yr BP were clearly recognized. The present authors suggest that a transgression took place in Antarctic coastal areas about 35000 to 40000 yr BP.

Concerning the younger, or Holocene group, a significant correlation is statistically recognized between the elevations and dates of the fossils; the correlation coefficient is 0.664 in the case of 50 samples obtained from raised beaches higher than sea level. The relation between radiocarbon ages and sampling altitudes of the Holocene raised beaches is drawn in Fig. 6, though the field survey revealed that the higher raised beach does not yield the older fossils in each spot. The following facts can be pointed out with regard to the Holocene samples: (i) Two thirds of the samples are dated between 3000 to 6000 yr BP; (ii) Dates from worm tubes, between 5500 and 8500 yr BP, appear slightly older in comparison with the sampling altitudes of other species; (iii) Ages prior to 6500 yr BP are rarely found in the Ongul Islands and Langhovde area; (iv) Marine species sampled from the localities higher than 10 m asl always are older than 4800 yr BP; and (v) There are no dates later than 5000 yr BP around Lake Suribati. This fact suggests that Lake Suribati was detached from the sea before 5000 yr BP. The separation of Lake Hunazoko seems to have occurred before 2000 yr BP.

Most of the dated organic remains occurred *in situ*, especially the *Laternula elliptica*, which may have been caused by rapid emergence or sudden dilution with abundant fresh water derived from ice sheet melting. In the case of *Laternula elliptica* at Skarvsnes, samples between 5000 and 6000 yr BP occur at almost the same level as those between

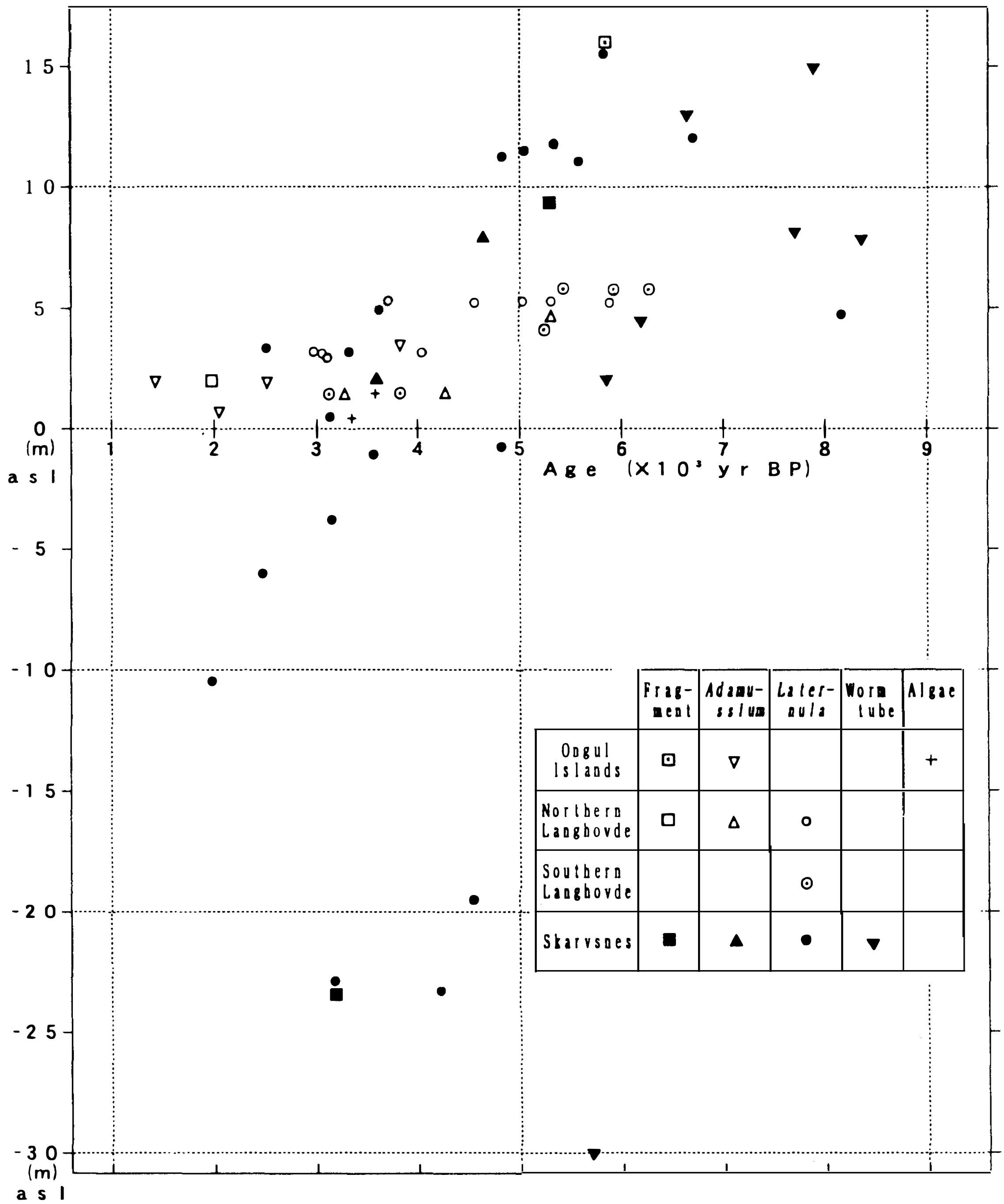


Fig. 6. The relationship between radiocarbon ages and sampling altitudes of the Holocene raised beaches in the Lützow-Holm Bay region.

6500 and 7500 yr BP. The highest elevations in which the organic remains have been dated are different in each ice-free area; 16 m asl at East Ongul Island, 6 m at northern Langhovde, 5.5 m at southern Langhovde and 15.5 m at Skarvsnes. These elevations have ages which are concentrated around 5000 to 6300 yr BP, with the exception of the 10250 yr BP date at the Ko-minato Inlet. Those elevations imply that the sea level during 5000 to 6300 yr BP had been standing in the higher position than during 7000 yr BP, assuming that the species lived at nearly the same depth throughout this period. This suggests that the rising speed of sea level exceeded the continuous isostatic rebound at that time.

Regarding the reservoir effect, many modern radiocabon dates have been obtained. ADAMSON and PICKARD (1983) reported 950 to 1300 yr BP for modern shells in the Vestfold Hills. STUIVER *et al.* (1976) obtained 850 to 1400 yr BP from modern molluscan shells in the McMurdo Sound region. Some examinations have been carried out for the pre-bomb species, mainly penguins or seals, and a reservoir correction between 750 to 1300 yr has been adopted in the Antarctic marine organisms (HARKNESS, 1979; STUIVER *et al.*, 1981; MABIN, 1985, 1986; WHITEHOUSE *et al.*, 1988; GORDON and HARKNESS, 1992).

YOSHIDA and MORIWAKI (1979) analyzed the living marine organisms and dated them for 860 to 1190 yr BP (with an average of 1120 yr BP) based on fish, sea urchins, starfish and sea snails from Lützow-Holm Bay. Modern radiocarbon dates in this region are shown in Appendix 4. A corrected age of 1120 yr proposed by YOSHIDA and MORIWAKI (1979) seems quite reasonable in the Lützow-Holm Bay region, though 1400 yr obtained from the more precise examination for correction has recently been provided by BERKMAN (this volume) based on pre-bomb mollusc samples. A correction age of 1100 yr was adopted in this area for the sake of comparing the glacial history with those of the other Antarctic regions. Using this correction it is suggested that the postglacial sea level occurred 4000 to 5000 yr BP (corrected age) at its maximum stage in the Lützow-Holm Bay region.

4.2. Radiocarbon dates from the other regions of Antarctica

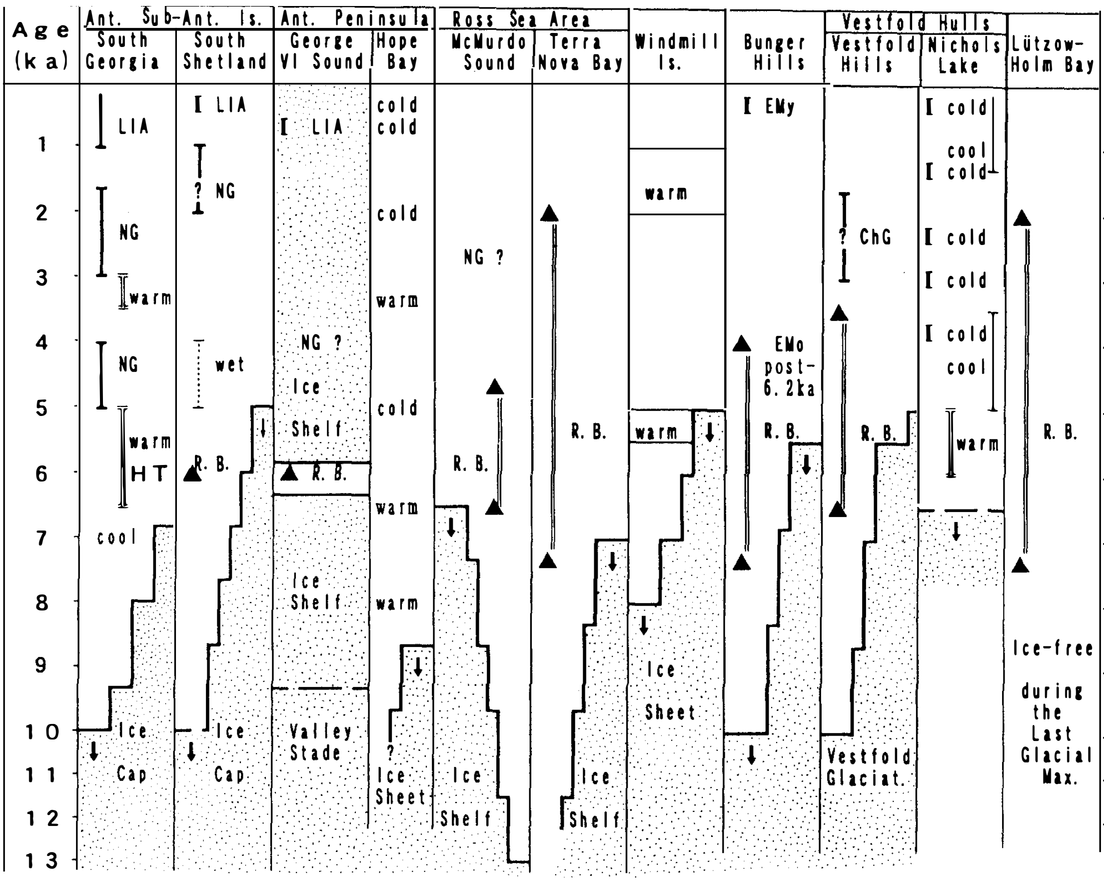
Radiocarbon dates from the other regions of Antarctica are drawn in Appendix 5. Although the dates vary in places and by organic species, most of them situate in the range between 4000 and 8000 yr BP as suggested by BERKMAN (1992). Dates for penguin remains at Terra Nova Bay and whale bones at South Shetland Islands have a wider distribution. The dates obtained from the highest sampling elevations in each region seem to be confined to the same age range; 5600 yr BP sampled at 6.0 m high in the Vestfold Hills, 5480 yr BP at 5–7 m in the Bunger Hills, 4370 yr BP at 22 m in the Terra Nova Bay and 5650 yr BP at 13 m in the McMurdo Sound. These values are concordant with those obtained from the Lützow-Holm Bay region. This fact suggests that the Holocene higher sea level occurred between 4400 and 6000 yr BP in the Antarctic region.

5. Holocene Marine Limit

In Lützow-Holm Bay , maximum heights of reliable marine deposits are recognized between 23 m asl in the Skarvsnes and 12 m at the Skallen. On the other hand, raised beaches beyond 30 m asl have been reported from the eastern areas of Prince Olav Coast, where beaches show the feature of ice-pushed ridges or marine-boulder pavements. Positive evidence of higher Holocene marine deposits have not yet been discovered. Therefore, the reliable Holocene marine limit is thought to be between 20 and 25 m high in this region.

The highest elevations and some aspects of the raised beaches observed in Antarctic regions are listed in Appendix 6. Elevations vary between locations and range from 10 to 54 m asl. The highest beach was discovered at the point of 54 m asl in the South Shetland Islands (JOHN and SUGDEN, 1971), and JOHN (1972) estimated that this beach was formed *ca.* 10000 yr BP on the King George Island. However, BARSCH and MÄUSBACHER (1986) who re-examined the planation surfacc and strandline disagreed with the JOHN's view and concluded that Holocene beaches never exceeded 20 m asl in the South Shetland Islands. Therefore, the reliable heights of Holocene raised beaches exceeding 35 m asl have not yet been discovered throughout the Antarctic. It is noteworthy that raised beaches beyond 30 m high provide somewhat erosional or gravelly feature such as wave-washed benches or ice-pushed ridges. Some of them have not yet been confirmed whether they were formed during the Holocene or in an older period. It may safely be said that the reliable Holocene beach deposits are up to 30 m asl. It is notable that most of the highest level of beach deposits is located between 20 and 30 m asl throughout the Antarctic ice-free areas.

Another remark is that small stepped-topography is found commonly on the surface of raised beaches. Although they might have been formed in relation to relative short standstills of sea level, it is rather difficult to identify them with those of the other localities because the numbers and levels of steps are quite different at each site. Sea-ice push may have been responsible, in part, for the formation of these steps since low and



LIA: Little Ice Age NG: Neoglacial HT : Hypsithermal ▲: ^{14}C dating R. B. : Raised beach
EMy: younger Edisto Moraine EMo: older Edisto Moraine ChG: Chelnock Glaciation

narrow ridges have often been distributed on the beach surfaces.

6. Discussion on Holocene Glacial History

The glacial history in the Antarctic region has been interpreted from deep sea cores, lake and terrestrial sediments cores, ice cores and the geomorphology of ice-free areas, using a variety of dating methods. A correlative synthesis on Cenozoic glacial history has been attempted by MORIWAKI *et al.* (1992b). On the basis of raised beaches and landforms of Antarctic ice-free areas, the Holocene glacial history in the Lützow-Holm Bay region can be described as follows;

Fig. 7 (opposite). Schematic correlation of Late-Glacial and Holocene glacial history among Antarctic ice-free regions. Compiled from sources below.

Region	Dating materials and (method)	Reservoir correction	References
South Georgia Is.	lake bottom core and slope deposit (^{14}C and sediment rate)	850 yr	CLAPPERTON *et al.* (1989)
King George Is. (S. Shetland Is.)	lake bottom core; (^{14}C)	750 yr	MÄUSBACHER *et al.* (1989)
George VI Sound and Alexander Is.	marine fossil; (^{14}C)	750 yr	CLAPPERTON and SUGDEN (1982)
Hope Bay and James Ross Is.	lake bottom sediment; (^{14}C and sediment rate)	2100 yr	ZALE and KARLÉN (1989)
McMurdo Sound	marine fossil and algae on moraine (^{14}C)	no correction	STUIVER *et al.* (1981) DENTON *et al.* (1989)
Terra Nova Bay	marine fossil and penguin remains (^{14}C)	$\Delta R = 779 \pm 60$ yr	BARONI and OROMBELLI (1991)
Windmill Is.	penguin remain and lake bottom core; (^{14}C)	1090 yr	GOODWIN (1993)
Bunger Hills	marine fossil and lake bottom sediment (^{14}C)	1300 yr	BOLSHIYANOV *et al.* (1991) COLHOUN and ADAMSON (1992)
Vestfold Hills	marine fossil and algae (^{14}C)	1300 yr	ADAMSON and PICKARD (1986)
	lake bottom core (^{14}C and sediment rate)	1300 yr	BRONGE (1992)
Lützow-Holm Bay	marine fossil (^{14}C)	1100 yr	present study

(i) Ice sheet had retreated from the main areas such as the Ongul Island, Langhovde and Skarvsnes during the stage prior to 30000 yr BP, although it was delayed in the southern part of this region.
(ii) A transgression probably occurred between 35000 and 40000 yr BP and marine organisms of an older-aged group were deposited during this interval.
(iii) Raised beaches have been developing during the Holocene due to local isostatic rebound.
(iv) These Holocene raised beaches have rarely been subjected to ice sheet erosion. No evidence of remarkable advance or retreat of the ice sheet has been recognized except a minor advance of small outlet glaciers such as Skallen Glacier.

Among the ice-free areas of Antarctic regions, a schematic correlation of Holocene glacial history was compiled in Fig. 7. The retreat of the ice sheet started mostly around 10000 yr BP and was completed between 6000 and 5000 yr BP (corrected age). It is inferred that a warmer climate and/or higher stand of sea level occurred during the stage which was concentrated between 4000 and 5000 yr BP (corrected age), though the adopted correction ages vary slightly between places in the Antarctic.

On the other hand, the information provided from examination on ice cores or marine cores gives a little different glacial regime. Ice cores from Dome C and Vostok Station suggests that the climatic optimum occurred between 10000 and 8000 yr BP, and that a rather cool condition between 5000 and 7000 yr BP succeeded (LORIUS *et al.*, 1979; JOUZEL *et al.*, 1987; BARNOLA *et al.*, 1987). Data from marine bottom sediments also gave a similar result (DOMACK *et al.* 1991). But, analysis of ice cores from Byrd Station (EPSTEIN *et al.*, 1970) and Ross Sea Ice (GOOTES and STUIVER, 1986) shows an opposite result in which the climatic optimum occurred around 6000 yr BP and warm episode between 10000 and 7000 was not recognized. The latter view is concordant with the results from Antarctic ice-free areas. Some conflicting results probably depend on the dating methods or age correction.

Concerning the Holocene marine limit, the maximum level 20 to 30 m asl is quite common in Antarctic ice-free areas, although they resulted mainly by regional isostatic rebound. This fact seems to imply that all of the ice-free areas have an identical isostatic effect. The value of rebound is about one tenth in comparison with that in the Laurentide, where the ice sheet has expanded 3000 to 4000 m in thickness during the Last Glacial Maximum (FULTON, 1989). This supports the idea that the ice sheets have not so deeply covered the present ice-free areas in Antarctica as suggested by COLHOUN *et al.* (1992). However, the thick ice sheet which occupied the vast areas close to the coast also may be responsible for a small amounts of uplift of the ice-free areas. In fact, the fluctuation of the ice sheet surface was assumed to be minimal in the inland area after the late Pleistocene; level of glacially scoured bedrock surface dated 36000 yr BP is exposed lower than 5 m high above the present ice surface in the Sør Rondane Mountains (MORIWAKI *et al.*, 1992a). Only some outlet glaciers were possibly sensitive to the climatic and eustatic changes in Antarctica.

7. Summary

The results from Holocene raised beaches and their dates are summarized as follows;

(1) The ice sheet retreated from the main areas during the period prior to 35000 yr BP in the Lützow-Holm Bay region. No significant advance or retreat of the ice sheet has been recognized since this period, except a minor advance of some small outlet glaciers.

(2) Raised beaches have been formed throughout the Holocene age in this region. Stepped topography on beach surfaces was formed by the interaction of the sea and regional isostatic uplift which continued without any distinct breaks. As a result of this uplift, Lakes Suribati and Hunazoko at Skarvsnes area were detached from the sea before 4000 and 1000 yr BP (corrected by 1100 yr), respectively.

(3) Raised beach deposits developed most extensively between 15 and 20 m asl in this region and a significant correlation ($r=0.664$) can be recognized between the elevations of raised beaches and their ages.

(4) The reliable Holocene marine limit rarely exceeds 25 m asl in this region, although some marine features such as marine boulders or wave action have been observed in slightly higher positions.

(5) The higher sea level noted along the Sôya Coast probably correlated with the postglacial high sea level stand which occurred between 4000 and 5000 yr BP (corrected age). This event may be correlated with the other regions of Antarctica, where the high sea level or warmer episode occurred during the period between 4000 and 5000 yr BP (corrected age).

(6) The Holocene marine limit, about 25 m asl of this region is similar to those obtained from the other regions of Antarctica, where the maximum elevations of raised beaches appear commonly between 20 to 30 m asl.

(7) The Holocene marine limit, which is a reflection of the regional isostatic rebound, suggests that the ice sheet was not thickly covering the present ice-free areas in Antarctica during the Last Glacial Maximum. However, still existing ice sheets close to the coast may also be resposible for small amount of uplift. It may be necessary to conduct detailed investigations on the crustal conditions by geophysical experiments to assess this conclusion.

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Appendix 3. Inventory of radiocarbon dates from the Lützow-Holm Bay region.
(All radiocarbon dates are uncorrected, though all samples are subject to reservoir effects.)

Locality	Altitude (m)	Age (yr BP) uncorrected	Sample	References
—Prince Olav Coast—				
Akarui Point	10	7730 ± 110 (GaK-5839)	fragment (*L.e.*)	MORIWAKI, 1976
—Lützow-Holm Bay—				
-Ongul Islands-				
Kitami Beach	7–8	31200^{+2500}_{-1900} (GaK- 289)	foraminifera	MEGURO *et al.*, 1964
North of East Ongul Is.	16	5850 ± 100 (GaK-2032)	fragment	YOSHIDA, 1970
Mizukumi Stream	12	30700 ± 2000 (GaK-2033)	fragment	YOSHIDA, 1970
Kitami Beach	12	34000^{+3000}_{-2000} (GaK- 286)	fragment	MEGURO *et al.*, 1964
Kai-no-hama Beach	9–10	22800 ± 1000 (GaK-288)	fragment	MEGURO *et al.*, 1964
Kitami Beach	7–8	25400 ± 1200 (GaK-285)	fragment	MEGURO *et al.*, 1964
Kitami Beach	5–6	> 30000 (GaK- ?)	fragment	MEGURO *et al.*, 1964
Kai-no-hama Beach	3–4	29500^{+2400}_{-1800} (GaK- 287)	fragment	MEGURO *et al.*, 1964
Kai-no-hama Beach	3–4	3840 ± 110 (GaK- ?)	*Adamussium*	MEGURO *et al.*, 1964
Nisi-no-seto Strait	3.5	25840 ± 2450 (GaK-6372)	*Adamussium*	NOGAMI, 1977 (pers. commu.)
East Ongul Is.	2	2510 ± 110 (N-925)	*Adamussium*	OMOTO *et al.*, 1974
Do. (same with N-925)	2	1450 ± 110 (TH-021)	*Adamussium*	OMOTO *et al.*, 1974
East Ongul Is.	0.8	2040 ± 90 (GaK- ?)	*Adamussium*	YOSHIDA, 1983
Ô-ike, West Ongul Is.	2.5	> 31510 (GaK-6382)	*Laternula*	NOGAMI, 1977 (pers. commu.)
East Ongul Is.	1.5	3540 ± 90 (GaK- ?)	marine algae	YOSHIDA, 1973
East Ongul Is.	0.5	3340 ± 90 (GaK- ?)	marine algae	YOSHIDA, 1973
-Langhovde-				
Oyayubi Is.	2	2000 ± 220 (GaK- ?)	fragment	YOSHIDA, 1983
West of Ko-minato Inlet	6	10250 ± 210 (GaK-4150)	*Adamussium*	MORIWAKI, 1974
South of Ko-minato Inlet	4.7	5310 ± 105 (N-2603)	*Adamussium*	HAYASHI, 1976 (unpublished)
East of Ko-minato Inlet	1.5	4290 ± 90 (GaK-4151)	*Adamussium*	MORIWAKI, 1974
Do. (same with GaK-4151)	1.5	3305 ± 130 (TH-044)	*Adamussium*	OMOTO, 1976
North of Lake Zakuro	−4.6	> 33200 (GaK-6375)	*Adamussium*	NOGAMI, 1977 (pers. commu.)

North of Lake Zakuro	−3.4	>31700	(GaK-6376)	*Laternula*	Nogami, 1977 (pers. commu.)
West of Ko-minato Inlet	6	>33400	(GaK-4149)	*Laternula*	Moriwaki, 1974
Northeast of Ko-minato Inlet	5	@ 5330 ± 80	(NUTA-2993)	*Laternula*	present study
Do. (same with NUTA-2993)	5	@ 5930 ± 90	(NUTA-2994)	*Laternula*	present study
Do. (same with NUTA-2993)	5	@ 5030 ± 90	(NUTA-2995)	*Laternula*	present study
East of Ko-minato Inlet	5–6	23830 ± 910	(GaK-4148)	*Laternula*	Moriwaki, 1974
East of Ko-minato Inlet	3	@ 3100 ± 70	(NUTA-2996)	*Laternula*	present study
Do. (same with NUTA-2996)	3	@ 3000 ± 70	(NUTA-2997)	*Laternula*	present study
Do. (same with NUTA-2996)	3	@ 4020 ± 70	(NUTA-3024)	*Laternula*	present study
Ko-minato Inlet	3	3120 ± 110	(TH-186)	*Laternula*	Omoto, 1978
North of Cape Koyubi	5.5	3730 ± 220	(GaK-6388)	*Laternula*	Nogami, 1977 (pers. commu.)
West of Ko-minato Inlet	5.1	4570 ± 120	(GaK-6374)	*Laternula*	Nogami, 1977
Mouth of Yatude Valley	4	5330 ± 125	(N-2605)	*Laternula*	Hirakawa *et al.*, 1984
North of Simo-kama	5.5	@ 6290 ± 60	(NUTA-2984)	*Laternula*	present study
Do. (same with NUTA-2984)	5.5	@ 5990 ± 70	(NUTA-2985)	*Laternula*	present study
Do. (same with NUTA-2984)	5.5	@ 5450 ± 70	(NUTA-2986)	*Laternula*	present study
North of Simo-kama	1.5	3840 ± 90	(GaK-4850)	*Laternula*	Ishikawa, 1974
West of Simo-kama	1.5	3170 ± 95	(N-2604)	*Laternula*	Hayashi, 1976 (unpublished)
-Skarvsnes-					
Lake Suribati	−32	5230 ± 155	(TH-053)	mummy seal bone	Omoto, 1977
Lake Suribati	15	7830 ± 280	(GaK-5837)	tube	Yoshida, 1983
South of Lake Suribati	13.0	6630 ± 230	(GaK-6373)	tube	Nogami, 1977 (pers. commu.)
Southernmost of Osen	8.0	7680 ± 250	(GaK-6369)	tube	Nogami, 1977 (pers. commu.)
Mouth of Suribati valley	7.8	8370 ± 270	(GaK-5833)	tube	Yoshida, 1983
West of Lake Suribati	4.5	6180 ± 260	(GaK-6371)	tube	Nogami, 1977 (pers. commu.)
Lake Suribati	0–6	6090 ± 90	(GaK-5840)	tube	Moriwaki, 1976
West of Lake Suribati	2.0	5870 ± 210	(GaK-6370)	tube	Nogami, 1977 (pers. commu.)
Lake Suribati	−30	5640 ± 130	(GaK-2038)	tube	Yoshida, 1970
Northwest of Osen	9.3	5280 ± 100	(N-2606)	fragment	Hayashi, 1976 (unpublished)
Lake Hunazoko	8	31600^{+2800}_{-2100}	(GaK-2036)	fragment	Yoshida, 1970
Lake Hunazoko	−23	3200 ± 130	(TH-051)	fragment	Omoto, 1977
North of Kizahasi Beach	8	4700 ± 100	(GaK-2034)	*Adamussium*	Yoshida, 1970
North of Kizahasi Beach	1.8	3600 ± 100	(GaK-2035)	*Adamussium*	Yoshida, 1970

Appendix 3 (continued).

Locality	Altitude (m)	Age (yr BP) uncorrected	Sample	References
North of Kizahasi Beach	15.5	5860± 170 (GaK-6392)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Near Lake Suribati	14	7450± 135 (N-926)	*Laternula*	OMOTO, 1977
Near Lake Suribati	14	6020± 175 (TH-020)	*Laternula*	OMOTO *et al.*, 1974
North of Kizahasi Beach	12.0	6700± 180 (GaK-6391)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Southeast of Skjegget	11.7	5370± 160 (GaK-6389)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Northwest of Osen	11.5	5010± 80 (N-2607)	*Laternula*	HAYASHI, 1976 (unpublished)
Northwest of Osen	11.1	4820± 70 (N-2608)	*Laternula*	HAYASHI, 1976 (unpublished)
North of Kizahasi Beach	4.7	8130± 200 (GaK-6390)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Kizahasi Beach	11	5580± 180 (GaK-5835)	*Laternula*	YOSHIDA, 1983
Northwest of Lake Oyako	5	3670± 70 (N-2609)	*Laternula*	HAYASHI, 1976 (unpublished)
Southernmost of Osen	6	4430± 90 (GaK-5841)	*Laternula*	YOSHIDA, 1983
Southwest of Lake Hunazoko	3.3	2540±160 (GaK-5834)	*Laternula*	YOSHIDA, 1983
Trillingbukta	3.1	3370± 120 (GaK-5836)	*Laternula*	YOSHIDA, 1983
Torinosu Cove	0.5	3180± 250 (GaK-2039)	*Laternula*	YOSHIDA, 1970
Lake Hunazoko	−1	4830± 150 (TH-054)	*Laternula*	OMOTO, 1977
Southeast of Lake Hunazoko	−1.4	3530± 130 (GaK-6380)	*Laternula*	NOGAMI, 1977 (pers. commu.)
West of Lake Hunazoko	−3.8	3120± 110 (GaK-6384)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Southeast of Lake Hunazoko	−6.0	2510± 110 (GaK-6379)	*Laternula*	NOGAMI, 1977 (pers. commu.)
West of Lake Hunazoko	−10.4	2000± 120 (GaK-6383)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Southeast of Lake Hunazoko	−19.6	4540± 360 (GaK-6378)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Southeast of Lake Hunazoko	−22.8	3200± 130 (GaK-6377)	*Laternula*	NOGAMI, 1977 (pers. commu.)
Lake Hunazoko	−23	4190± 100 (GaK-2037)	*Laternula*	YOSHIDA, 1970

Adamussium: *Adamussium colbecki*; *Laternula* (*L.e.*): *Laternula elliptica*; tube: tube of Polychaeta or *Serpula narconensis* (Surpuloid tube); foraminifera: tests of foraminifera; fragment: fragments of molluscan shell

@: AMS dating

Lake Zakuro is a saline lake and lake level is about 6 m below sea level.

Lake Suribati is a saline lake and lake level is about 32 m below sea level.

Lake Hunazoko is a saline lake and lake level is about 23 m below sea level.

Appendix 4. Inventory of modern radiocarbon dates from the Lützow-Holm Bay region.

Locality	Altitude (m)	Age (yr BP) uncorrected		Sample	References
Naka-no-tani V., Langhovde	—	modern	(GaK-6381)	moss	NOGAMI, 1977 (pers. comm.)
Cape Koyubi, Langhovde	—	* 1210±110	(GaK-6385)	piece of penguin egg	NOGAMI, 1977 (pers. comm.)
Cape Koyubi, Langhovde	0	490± 80	(GaK-6386)	algae (freshwater ?)	NOGAMI, 1977 (pers. comm.)
West Ongul Is.	<8	* 930± 90	(GaK-5832)	*Adamussium*	MORIWAKI, 1976
Cape Koyubi, Langhovde	1.4	* 1030±100	(GaK-6387)	*Laternula* with dried flesh	NOGAMI, 1977 (pers. comm.)
Ungane Is.	0	* 1455±110	(TH-052)	seal skin (died in 1973.2)	OMOTO, 1983
Sea, 80 km NW to Ungane Is.	−10	* 880±115	(N-860)	sea water	OMOTO, 1972
Ongul Strait	−10	* 2860±125	(N-858)	sea water	OMOTO, 1972
Skallen	−0.5	278± 19	(N-859)	lake water	OMOTO, 1972
Skallen	−0.5	253± 19	(N-861)	lake water	OMOTO, 1972
East Ongul Is.	10	487± 17	(N-922)	CO_2 in air	OMOTO, 1972
East Ongul Is.	10	315± 45	(N-923)	CO_2 in air	OMOTO, 1972
Sea bottom near East Ongul	−9	* 150± 80	(GaK-3666)	living sea urchin (shell)	YOSHIDA, 1973
Sea bottom near East Ongul	−17～−35	* 1190± 90	(GaK-6789a)	*Neoliuccinum eatoni* (flesh)	YOSHIDA and MORIWAKI, 1979
Do. (same with GaK-6789a)	Do.	* 1300±900	(GaK-6789b)	*Do.* (shell)	YOSHIDA and MORIWAKI, 1979
Sea bottom near East Ongul	−92	* 1070±9 0	(GaK-6790a)	*Ophionotus victoriae* (flesh)	YOSHIDA and MORIWAKI, 1979
Do. (same with GaK-6790a)	−92	* 1210±100	(GaK-6790b)	*Do.* (shell)	YOSHIDA and MORIWAKI, 1979
Sea bottom near East Ongul	−17	* 1160±110	(GaK-6791a)	*Sterechinus neumayeri* (flesh)	YOSHIDA and MORIWAKI, 1979
Do. (same with GaK-6791a)	−17	* 860±110	(GaK-6791b)	*Do.* (shell)	YOSHIDA and MORIWAKI, 1979
Sea bottom near E. Ongul Is.	−15	* 1160±110	(GaK-6792)	*Trematomus berunacchi*	YOSHIDA and MORIWAKI, 1979
Sea bottom near E. Ongul Is.	−500	* 1010±110	(GaK-6793)	*Zoarcidae* sp.	YOSHIDA and MORIWAKI, 1979

Adamussium: Adamussium colbecki; Laternula: Laternula elliptica

*: marine materials.

Appendix 5. Inventory of radiocarbon dates from raised beaches in Antarctica other than in the Lützow-Holm Bay region.

Locality	Altitude (m)	Age (yr BP) uncorrected	Sample	References/Notes
—Vestfold Hills—				
Eastern end of Watts Lake[(1)]	?	7680±120 (SUA-1828A)	tube	Adamson and Pickard, 1983
Eastern end of Watts Lake	<2.6	6150± 95 (Beta-4764)	tube	Adamson and Pickard, 1983
Between Club and Deep Lakes	2.6	5340± 90 (SUA-1237)	tube	Pickard and Adamson, 1983b
Watts Lake	?	6100±108 (ZDL-70)	shells	Zhang *et al.*, 1983
Eastern end of Watts Lake	?	6500±105 (Beta-4765)	*Limatura hodgsoni*	Adamson and Pickard, 1983
Eastern end of Watts Lake	<0	7305±130 (Beta-4768)	*Adamussium*	Adamson and Pickard, 1983
Do. (sieved from SUA-1828A)	?	7380±250 (SUA-1828B)	marine algae	Adamson and Pickard, 1983
Eastern end of Watts Lake	?	8260±110 (SUA-1410)	marine algae	Pickard and Adamson, 1983a
			revised from 8700±100 yr BP of Zhang *et al.* (1983)	
Lebed' Lake[(2)]	?	6452±160 (Beta-4763)	marine algal mud	Adamson and Pickard, 1983
Calender Lake[(3)]	?	5677± 94 (ZDL-81)	marine algae	Adamson and Pickard, 1983
Eastern end of Watts Lake	?	4760±190 (SUA-1824)	marine algae	Adamson and Pickard, 1983
Southern side of Ellis Fjord	0–5	6225±85 (Beta-4761)	marine organics	Adamson and Pickard, 1983
Dingle Lake	6.0	5600± 77 (ZDL-79)	*Laternula*	Zhang *et al.*, 1983
Lebed' Lake	5.5	7590± 80 (SUA-2026)	*Laternula*	Pickard, 1985
Deep Lake	4.0	6632±118 (ZDL-80)	*Laternula*	Zhang *et al.*, 1983
Partizan Is.	3.0	7370± 95 (Beta-4767)	*Laternula*	Adamson and Pickard, 1983
Triple Lake	3	6141± 90 (ZDL-78)	*Laternula*	Zhang *et al.*, 1983
Mud Lake	3	3500± 86 (ZDL-69)	*Laternula*	Zhang *et al.*, 1983
Mud Lake	3	3325±103 (ZDL-66)	*Laternula*	Zhang *et al.*, 1983
East of Laternula Lake[(4)] (upper)	3 ?	3270± 90 (ANU-1009)	*Laternula*	Adamson and Pickard, 1983
Do. (lowermost part)	3 ?	3470± 80 (ANU-1010)	*Laternula*	Adamson and Pickard, 1983
Lake Stinear	2.6	4710± 70 (ANU-1011)	*Laternula*	Adamson and Pickard, 1983
Do. (same loc. with ANU-1011)	2.6	5440±110 (SUA-1239)	*Laternula*	Pickard and Adamson, 1983b
Eastern end of Watts Lake	2.4	5795± 85 (Beta-4766)	*Laternula*	Adamson and Pickard, 1983
Lichen Valley	2.0	6910±150 (SUA-2027)	*Laternula*	Pickard, 1985
Between sea and Mud Lake	2	2410± 90 (SUA-1411)	*Laternula*	Pickard and Adamson, 1983b
Calender Lake	1.8	6850±160 (SUA-2030)	*Laternula*	Pickard and Seppelt, 1984

—Bunger Hills—					
Thomas Is. marine terrace	5–7	5480 ± 40	(LU-2292)	*Laternula*	Bolshiyanov *et al.*, 1991
North of Krylatyy Peninsula	5.2	6250 ± 140	(Beta15832)	*Laternula*	Colhoun and Adamson, 1992 (mxh 8.6 m)
Elliptica Lake, Thomas Is.	4	5630 ± 90	(Beta15830)	*Laternula*	Do. (mxh 10.5 m)
Ice Axe Bay, Kapakon Inlet	3–3.5	6900 ± 120	(Beta15829)	*Laternula*	Do. (mxh 8 m)
North Coast Bay, Thomas Is.	3	4960 ± 120	(Beta17526)	fragment (*L.e.*)	Do. (mxh 6.9 m)
Head of Edisto Inl. Thomas Is.	2.8	8950 ± 490	(Beta15828)	fragment (*L.e.*)	Do. (mxh 6.8 m)
Geo Bay, Thomas Is.	2.6	6010 ± 100	(Beta17525)	fragment (*L.e.*)	Do. (mxh 6 m)
Ostrovnaya Bay, Kapakon Inlet	2.2	6500 ± 130	(Beta17527)	fragment (*L.e.*)	Do. (mxh 8.5 m)
Shchel Inlet	2	6880 ± 160	(Beta15831)	fragment (*L.e.*)	Do. (mxh 3 m)
Charnockite Peninsula	1.3	6210 ± 100	(Beta17524)	fragment (*L.e.*)	Do. (mxh 7 m)
—Windmill Islands—					
Vanderford Gl. Windmill Is.	23	6040 ± 250	(M-1052)	marine algae(5)	Cameron and Goldthwait, 1961
Holl pond A, Holl Is. (core)	28	8160 ± 300	(ANU-6401)	gravelly mud algae	Goodwin, 1993 depth 25–30 cm
Bailey Peninsula	26–33	4380 ± 250	(ANU-6403)	penguin skul	Goodwin, 1993 depth 20 cm
—Ross Sea area—					
-Terra Nova Bay-					
Icarus Camp	25	4495 ± 135	(GX-12755)	penguin bone	Baroni and Orombelli, 1991
Gondowana Station	15	4615 ± 85	(GX-13620)	penguin guano	Baroni and Orombelli, 1991
Terra Nova Station	18	5770 ± 60	(GX-12760)	penguin guano	Baroni and Orombelli, 1991
N. Adelie Cove (not beach)	52	6855 ± 195	(GX-13621)	penguin guano	Baroni and Orombelli, 1991
N. Adelie Cove (not beach)	39	7065 ± 250	(GX-14098)	penguin guano	Baroni and Orombelli, 1991
Adelie Cove	7.95	CA 1690 ± 45	(NZ-7035A)	penguin bone	Whitehouse *et al.*, 1988
Adelie Cove	7.85	CA 766 ± 68	(NZ-6920A)	penguin bone	Whitehouse *et al.*, 1988
Adelie Cove	5.82	CA 691 ± 76	(NZ-6919A)	penguin bone	Whitehouse *et al.*, 1988
Adelie Cove	4.15	CA 1330 ± 80	(NZ-6997A)	penguin bone	Whitehouse *et al.*, 1988
Adelie Cove	4.00	CA 3400 ± 280	(NZ-6906A)	penguin bone	Whitehouse *et al.*, 1988
Adelie Cove	3.33	CA 900 ± 330	(NZ-6932A)	peng. flesh & bone	Whitehouse *et al.*, 1988
Evans Cove	22.74	CA 1440 ± 60	(NZ-7037A)	penguin bone, flesh and feather	Whitehouse *et al.*, 1988
Evans Cove	11.09	CA 520 ± 43	(NZ-6963A)	Do.	Whitehouse *et al.*, 1988
Evans Cove	14.5	4360 ± 175	(GX-14068)	fragment	Baroni and Orombelli, 1991
Evans Cove	10.5	4885 ± 155	(GX-14067)	fragment	Baroni and Orombelli, 1991
Evans Cove	8	3235 ± 155	(GX-14065)	fragment	Baroni and Orombelli, 1991

Appendix 5 (continued).

Locality	Altitude (m)	Age (yr BP) uncorrected	Sample	References/Notes
Evans Cove	8	3335± 90 (GX-13628)	fragment	BARONI and OROMBELLI, 1991
Evans Cove	3.5	2395± 60 (GX-13626)	fragment	BARONI and OROMBELLI, 1991
Evans Cove	22	4370±170 (GX-14077)	Cirripedia	BARONIand OROMBELLI, 1991
Evans Cove	18.5	4485±300 (GX-14619)	Cirripedia	BARONI and OROMBELLI, 1991
Evans Cove	8	2710±135 (GX-14101)	Cirripedia	BARONI and OROMBELLI, 1991
Evans Cove	6.5	3545±150 (GX-14073)	Cirripedia	BARONI and OROMBELLI, 1991
Evans Cove	6	3010±150 (GX-14073)	Cirripedia	BARONI and OROMBELLI, 1991
Evans Cove	14.5	7505±230 (GX-14069)	Pelecypods	BARONI and OROMBELLI, 1991
Evans Cove	12.5	7480±260 (GX-14070)	Pelecypods	BARONI and OROMBELLI, 1991
Evans Cove	10.5	6915±230 (GX-14066)	Pelecypods	BARONI and OROMBELLI, 1991
Evans Cove	10.5	6620±190 (GX-14825)	*Adamussium*	BARONI and OROMBELLI, 1991
Evans Cove	9.5	6765±355 (GX-14824)	*Adamussium*	BARONI and OROMBELLI, 1991
Evans Cove	9	6815± 90 (GX-13627)	*Adamussium*	BARONI and OROMBELLI, 1991
Evans Cove	12.5	6890±100 (GX-14628)	*Laternula*	BARONI and OROMBELLI, 1991
Evans Cove	10.5	6645± 95 (GX-14627)	*Laternula*	BARONI and OROMBELLI, 1991
Evans Cove	9	6935±100 (GX-14823)	*Laternula*	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 5–9 cm	20.7	3010±220 (GX-13613)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 32–34 cm	6.2	3340± 85 (GX-13616)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is.	14	3675± 90 (GX-13617)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is.	14	4190± 80 (GX-12757)	penguin remain	BARONI and OROMBELLI, 1991
Inexpressible Is.	26	4930±85 (GX-12758)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is.	20.7	5315±100 (GX-13609)	penguin remain	BARONI and OROMBELLI, 1991
Inexpressible Is. dep. 9–11.5 cm	20.7	5360± 90 (GX-13608)	penguin remain	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 5–12 cm	19.7	5440± 85 (GX-13610)	penguin remain	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 20–25 cm	19.7	5530±100 (GX-13611)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 20–25 cm	20.7	5945±340 (GX-13614)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 35–40 cm	19.7	6235± 110 (GX-13612)	penguin guano	BARONI and OROMBELLI, 1991
Inexpressible Is. depth 35–40 cm	20.7	6335±110 (GX-13615)	penguin guano	BARONI and OROMBELLI, 1991
-McMurdo Sound-				
Marble Point	13	CC 4450±150 (L-594)	Elephant seal	OLSON and BROECKER, 1961
			(In case of usual standard = 5650±150) ht 9.5 m ?	

South River	ht 6.0	6430± 70	(QL-72)	*Adamussium*	STUIVER *et al.*, 1981
South River	ht 4.5	6350± 60	(QL-96)	*Adamussium*	STUIVER *et al.*, 1981
South River	ht 4.0	6120± 50	(QL-1042)	*Adamussium*	STUIVER *et al.*, 1981
Mouth of Taylor Valley	0.8	4360±110	(GaK- ?)	*Adamussium*	YOSHIDA, 1983
Explorers Cove	ht 8.1	5400± 60	(QL-163)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 7.5	5800± 70	(QL-138)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 5.7	6050± 70	(QL-137)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 5.3	5970± 70	(QL-162)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 5.0	5240± 40	(QL-139)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 4.5	6150± 80	(QL-157)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 4.2	5860± 70	(QL-158)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 3.3	5630± 60	(QL-154)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 2.9	4620± 60	(QL-165)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 2.2	5090± 50	(QL-156)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 1.9	5350± 70	(QL-159)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove (delta-like)	ht 1.7	5500± 70	(QL-161)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 1.4	5200± 60	(QL-153)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 1.0	5310± 60	(QL-155)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove (delta-like)	ht 0.5	5770± 50	(QL-160)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove	ht 0.5	5760± 60	(QL-164)	*Adamussium*	STUIVER *et al.*, 1976
Explorers Cove (DVDP)	−21.1−−22.1	6670±200	(QL-191)	*Adamussium*	STUIVER *et al.*, 1981
—Islands in Ross Sea—					
Franklin Is. (top)	13+	1750±70	(QL-170)	penguin remains	STUIVER *et al.*, 1981
Franklin Is. (middle)	13+	3150± 70	(QL-169)	penguin remains	STUIVER *et al.*, 1981
Franklin Is. (lowermost)	13+	5340± 70	(QL-141)	penguin remains	STUIVER *et al.*, 1981
Cape Bird, Ross Is.	—	CC 7070±180	(NZ-5590)	penguin remains	SPEIR and COWLING, 1984
—Antarctic Peninsula—					
Two Step Cliffs, George VI Sound	?	6930± 60	(SRR-1500)	*Bathylasma corolliforme* (outer fraction) in moraine	CLAPPERTON and SUGDEN, 1982 CLAPPERTON and SUGDEN, 1982
Do. (same with above sample)	?	7250±250	(SRR-1500)	Do. (inner fract.)	CLAPPERTON and SUGDEN, 1982
—South Shetland Is.—					
South Beach, Livingston Is.	4.5	1025± 80	(I-7869)	Whalebone on beach	CURL, 1980 (CA=85±80)
South Beach, Livingston Is.	7.6	2530± 85	(I-7870)	Whalebone on beach	CURL, 1980 (CA=1590±85)
Start Point, Livingston Is.	1.8	4905±100	(I-7872)	Whalebone on bench	CURL, 1980 (CA=3965±100)

Appendix 5 (continued).

Locality	Altitude (m)	Age (yr BP) uncorrected	Sample	References/Notes
South Beach, Livingston Is.	3	1056±130 (Birm-50)	Whalebone	SUGDEN and JOHN, 1973
Bayers Penin. Livingston Is.	10.3	2823±40 (SRR-1086)	Buried whalebone	HANSOM, 1979 depth 30cm
Bayers Penin. Livingston Is.	10.1	3121± 35 (SRR-1087)	Buried whalebone	HANSOM, 1979 depth 40cm
Barton Penin. King George Is.	6–7	1390±140 (Birm-224)	Whalebone on beach	SUGDEN and JOHN, 1973
Barton Penin. King George Is.	5.2	1440± 55 (MB-2:DIC-373)	Whalebone on beach	CURL, 1980 (CA=550±55)
Barton Penin. King George Is.	2	1210±55 (MB-4:DIC-369)	Whalebone on beach	CURL, 1980 (CA=270±55)
King George Is. raised beach	18	6650± 90 (—)	penguin bone	BARSCH and MÄUSBACHER, 1986
Do.	18	6560± 55 (—)	penguin bone	BARSCH and MÄUSBACHER, 1986
King George Is. lowest beach		1650± 50 (—)	marine organics	BARSCH and MÄUSBACHER, 1986
Kiteschsee (level=16m asl), King George Is.	core	6950±195 (HD11162-10997)	marine organic mud (195cm deep from bottom)	MÄUSBACHER *et al.*, 1989
—South Georgia Is.—				
Will Point, Royal Bay	8	2369± 40 (SRR-520)	unidentif. animal	HARKINSS, 1979

Radiocarbon dates are uncorrected ones in case of without notes, although all the samples are marine materials subject to reservoir effects.

Laternula (L.e.): *Laternula elliptica*; *Adamussium*: *Adamussium colbecki;* CA: corrected by 1091 yr; CC: corrected age; mxh: maximum height of raised beach; ht: leveled from high-tide mark.

(1): Lake level is 5.8 m below sea level in Watts Lake.

(2): Lake level is 20 m below sea level in Lebed' Lake.

(3): Lake level is 2.5 m below sea level in Calender Lake.

(4): Lake level is 1.0 m below sea level in Laternula Lake.

(5): *Archaeolithothamnion*.

Appendix 6. Inventory of elevations and features of raised beaches.

Locality	Altitude (m asl)	Remarks *containing fossil, **do. (fragment)	References
—Prince Olav Coast—			
Sinnan Rocks	Max. 31	ice-pushed ridge with pitted beach	Yoshida, 1970
Cape Hinode	Max. 35	marine-boulder pavement ?	Moriwaki, 1976
Kasumi Rock	Max. 6	beach sand with boulder **	present study
Akarui Point	Max. 10	beach sand with gravel **	Moriwaki, 1976
—Lützow-Holm Bay—			
-Ongul Is.-			
North of East Ongul Is.	Max. 16	beach sand *	Yoshida, 1983
Kai-no-hama Beach, E. Ongul		beach sand * (4 steps below 15 m asl)	present study
Mizukumi Stream, E. Ongul Is.		beach sand * (5 steps below 14 m asl)	Fujiwara, 1973
West Ongul Is.	Max. 15	gravelly sand *	Yoshida, 1983
-Langhovde-			
Ko-minato Inlet	Max. 10	sand * (6 steps below 9 m asl)	present study
West of Lake Zakuro	Max. 12	beach sand *	present study
Mizukuguri Cove	Max. 20	marine-boulder pavement **	Yoshida, 1983
Mizukuguri Cove		9 steps below 14 asl **	present study
Mouth of Yukidori Valley	22	fluvioglacial fan-delta	present study
North, mouth of Yatude Valley	17	fluvioglacial fan-delta	present study
South, mouth of Yatude Valley	10	fluvioglacial fan-delta	present study
Northern coast of Simo-kama	Max. 10	beach sand with boulder *	present study
North of Simo-kama	*ca.* 25	fluvioglacial fan-delta ?	present study
-Skarvsnes-			
Lake Hunazoko	Max. 14	beach sand with gravel *	present study
Lake Suribati	Max. 16	gravelly sand *	Yoshida, 1983
Kizahasi Beach	Max. 22	beach sand *(9 steps below 15.5 m asl)	present study
Southeast of Osen	Max. 23	marine-boulders with beach sand	present study
Trillingbukta	Max. 22	sand with boulder * (9 steps below 20 m)	present study
-Other area-			
Breidvågnipa	Max. 10	rounded boulder	present study
N. of Magoke Point, Skallen	Max. 12	sand (5 steps below 12 m asl)	present study
Skallevikhalsen	*ca.* 23	fluvioglacial deltaic fan ** ?	Yoshida, 1970

Appendix 6 (continued).

Locality	Altitude (m asl)	Remarks *containing fossil, **do. (fragment)	References
—Vestfold Hills—			
Near Heidemann Bay	*ca.* 11		Adamson and Pickard, 1986
Watts Lake	15	*ca.* 6000 yr BP	Zhang *et al.*, 1983
—Bunger Hills—			
Elliptica Lake, Thomas Is.	*ca.* 10.5	(ahwm) highest marine limit =(7.5±1 m above modern marine limit)	Colhoun and Adamson, 1992
Fish Tail Bay	7–9	*ca.* 6000 yr BP *	Rozycki, 1961
Fish Tail Bay		15 ridges below 9.4 m asl	Adamson and Colhoun, 1992
—Windmill Islands—			
North of Clark Peninsula	26.7±0.5	beach	Goodwin, 1993
Dewart Is.	29.0±1.3	beach	Goodwin, 1993
Bailey Peninsula	29.5±0.5	ice-pushed ridge	Goodwin, 1993
Shirley Is.	29.3±0.5	beach	Løken, '59 (after Goodwin, '93)
Mitchell Peninsula	28.1±1.0	wave-washed bedrock	Løken, '59 (after Goodwin, '93)
Warrington Is.	27.5±1.0	beach	Løken, '59 (after Goodwin, '93)
Midgeley Is.	28.1±1.0	beach	Løken, '59 (after Goodwin, '93)
Robinson Ridge	28.5±1.0	beach	Løken, '59 (after Goodwin, '93)
Ford Is.	28.9±1.0	wave-washed bedrock	Løken, '59 (after Goodwin, '93)
Nelly Is.	29.0±1.3	vave-washed bedrock	Hollin, '58 (after Goodwin, '93)
Holl Is.	31.5±1.5	vave-washed bedrock	Hollin, '58 (after Goodwin, '93)
Herring Is.	32.0±1.0	beach	Hollin, '58 (after Goodwin, '93)
Browning Peninsula	31.3±1.0	wave-washed bedrock	Hollin, '58 (after Goodwin, '93)
—Ross Sea area—			
Ross Sea	23	*ca.* 2,000 yr BP *	Lingle and Clark, 1979
Franklin Is.	Max. 18	"7 m beaches" are well preserved	Denton *et al.*, 1975
Beaufort Is.	Max. 9.9	"3.1 m beaches" are best developed	Stuiver *et al.*, 1981
South of Cape Bird, Ross Is.	9.5	(ahtm) well preserved	Stuiver *et al.*, 1981
-Terra Nova Bay-			
Terra Nova Bay	Max. 23		Priestley, 1923
Campbell Glacier Tongue	Max. 30.5	(ahtm) well preserved	Stuiver *et al.*, 1981

Northern Foothills	Min. 12	(ahtm) partly covered with rock glacier	Stuiver *et al.*, 1981
Hells Gate, Inexpressible Is.	Max. 30	(ahtm) well preserved	Stuiver *et al.*, 1981
Evans Cove, Inexpressible Is.	Max. 30.5	(ahtm) well preserved	Stuiver *et al.*, 1981
Inexpressible Is.	Max. 30.5		Denton *et al.*, 1975
Gondowana Station		more than 12 ridges below 30 m asl	Baroni and Orombelli, 1991
-McMurdo Sound-			
McMurdo Sound	8.1	*ca.* 5,400 yr BP *	Stuiver *et al.*, 1976
Granite Harbour	Max. 15		Taylor, 1922
Gneiss Point	Max. 20	5 steps below 18 m	Nichols, 1968
Granite Harbour	Max. 19	wave-washed bedrock	Nichols, 1968
Cape Roberts	Max. 20	beach ridges (4 steps below 16 m asl)	Nichols, 1968
Dunlop Is.	Max. 20	beach ridges	Nichols, 1968
Spike Cape	Max. 17	beach ridges (5 steps below 17 m asl)	Nichols, 1968
Wright Glacier	Max. 17	pitted beach	Nichols, 1968
Scheuren River	Max. 20	5 steps below 20 m asl	Nichols, 1968
Surko River	Max. 19	more than 5 steps below 19 m asl	Nichols, 1968
Marble Point	Max. 20	more than 10 steps below 13 m asl	Nichols, 1968
South River	Max. 14	more than 5 steps below 14 m asl	Nichols, 1968
Cape Bernacchi	Max. 12	boulders	Nichols, 1968
Broad Delta Bay	Max. 3	rounded boulder	Nichols, 1968
—Antarctic Peninsula—			
James Ross Is.	Max. 24	beach	Bibby, 1965
Red Rock Ridge, Marguerite Bay	Max. 33.5	coarse boulder beach	Nichols, 1960
Neny Is., Marguerite Bay	Max. 23	beach	John and Sugden, 1971
Jenny Is., Marguerite Bay	Max. 24.5	beach "18 beaches" are best developed	John and Sugden, 1971
—South Shetland Is.—			
Livingston Is.	Max. 18.6	*ca.* 6000 yr BP	Maritinz *et al.*, 1992
Livingston Is.	18.6–12	8 steps below 18.6 m asl (Upper group)	Martinez *et al.*, 1992
Livingston Is.	8–2.8	6 steps below 6.7 m asl (Intermed. gr.)	Martinez *et al.*, 1992
Livingston Is.	<2	1–3 steps below 2 m asl(Lower group)	Martinez *et al.*, 1992
King George Is.	Max. 54	*ca.* 10000 yr BP	John, 1972
Barton Penin., King George Is.	54	Post-glacial max.(cobbles and sand)	John and Sugden, 1971
Fildes Penin., King George Is.	25–45	marine platform older than 85000 yr BP	Barsch and Mäusbacher, 1986
Fildes Penin., King George Is.	*ca.* 24	*Laternula* U/TH ages = 84,000 ± 6500 (HD-1085), 86000 ± 15000 (HD-1086) and 85000 ± 6000 (HD-1107) yr BP	Barsch and Mäusbacher, 1986

Appendix 6 (continued).

Locality	Altitude (m asl)	Remarks *containing fossil, **do. (fragment)	References
King George Is.	Max. 20	*ca.* 6000 yr BP	Mäusbacher *et al.*, 1989
Fildes Penin., King George Is.	15–20	strandline, *ca.* 6000 yr BP	Barsch and Mäusbacher, 1986
Fildes Penin., King George Is.	4–6	strandline, *ca.* 1000 yr BP	Barsch and Mäusbacher, 1986
South Shetland Is.	17–20	well develop and common "18.5 m beach"	John and Sugden, 1971
Edward Penin. Robert Is.		10 steps with 5 ridges below 19.7 m asl	John and Sugden, 1971
Fildes Penin. King George Is.		9 steps below 17.3 m asl	John and Sugden, 1971
South Shetland Is.	5–7.5	continuous and common "6 m beach"	John and Sugden, 1971
—Laurentide—			
Baffin Island	Max. 168	Holocene marine limit	Fulton, 1989
Cumberland Penin., Baffin Is.	−20∼−40	Holocene submergence	Fulton, 1989
Southampton Is.	Max. 190	Holocene highest shoreline in North. Canada	Fulton, 1989
Central Keewatin, NW Territ.	Max. 187	*ca.* 8300 yr BP	Fulton, 1989
SW. of James Bay, Ontario	Max. 182	Holocene marine limit	Fulton, 1989
North of Ottawa, Quebec	Max. 274	Holocene highest marine limit in Laurentide	Fulton, 1989
—Greenland—			
East Greenland	130	Holocene marine limit	Fulton, 1989
West Greenland	140	Holocene marine affected by Laurentide Ice	Fulton, 1989
North Greenland	120–150	Holocene marine limit	Fulton, 1989
NW, S. and SE. Greenland	<20	Holocene marine limit	Fulton, 1989

asl: above sea level; ahwm: above high-water mark; ahtm: above high-tide mark.