Geological-geomorphological analysis and ^{14}C dating of submoraine organogenic deposits within the Renardbreen outer margin, Wedel Jarlsberg Land, Spitsbergen

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Amazing organogenic deposits were encountered within the terminal moraine zone of Renardbreen, north-western part of Wedel Jarlsberg Land. Pollen analyses and ^{14}C dating locate the deposits at the Middle Late Subatlantic transition. The position of these deposits indicates possible glacial advances 3,500–2,000 years BP and during the Little Ice Age, respectively. Remnants of human activity at least as old as the 9th century were also found within organogenic deposits.

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During geological-geomorphological exploration of the north-western part of Wedel Jarlsberg Land in 1986 (while attending the first UMCS – University of Lublin Scientific Expedition), the authors focused on an interesting profile of submoraine organogenic deposits situated within the zone of Renardbreen terminal moraines lying on raised marine terraces 0–6 m a.s.l. (Fig. 1). Ten samples for pollen analysis and three for ^{14}C dating from organogenic deposits were collected.

Renardbreen is the largest glacier in this part of Wedel Jarlsberg Land. A small part of the glacier terminates directly in the sea and forms an about 15 m high ice cliff in Josephbukta (part of Recherchefjorden). The outer margin of the glacier shows a typical young glacial relief (Fig. 2). The largest part of the surface is occupied by sandurs (two generations at least) with plenty outflows and lakes as well as ground moraine passing into the fluted moraine (Merta 1989) close to the glacier's snout. There are other glacial forms, including kames, eskers and roches moutonnées. The outer margin of the glacier is composed of morainic hills, 30 m high, 1.0–1.5 km from the present Renardbreen snout (Figs. 1, 2).

Position of the organogenic deposits and their characteristics

The arch of the Renardbreen terminal moraines displays a composite structure. There are two chains of domes separated by a narrow depression (Figs. 2, 3). The outer domes are composed of stones derived from the basement rocks, extensively weathered, mixed with gravel-till material. The variable relief of the dome tops is related to the melting of an ice core. Inner domes, of similar size to outer domes, are characterized by ice cores. Blocky rubble, a main component of these domes, is slightly weathered.

There were organogenic deposits within the small depression between moraine chains. These deposits, situated at a level of c. 1.0–1.5 m a.s.l., have been cropped out due to marine abrasion. Deposits overlying the organogenic sediment sequence belong to the inner moraine. Thus, it may be assumed that the organogenic deposits lie on a ground moraine associated with the outer chain domes.

The organogenic peat-like deposits are brown to dark brown with sandy admixture and clay intercalations with single gravel particles. At 1.12–1.14 and 1.23–1.28 m a.s.l. there are light-gray silt laminae with a large amount of moss pedicles (Fig. 3). These laminae are slightly postdepositionally deformed. The authors discovered pieces of charcoal, woolen web and pottery as well as remnants of animal fur, hair and bones within the examined organogenic deposits. Detailed investigations of these relics (Dzierżek et al. this volume) have resulted in strong evidence for human activity through the formation of the deposits.

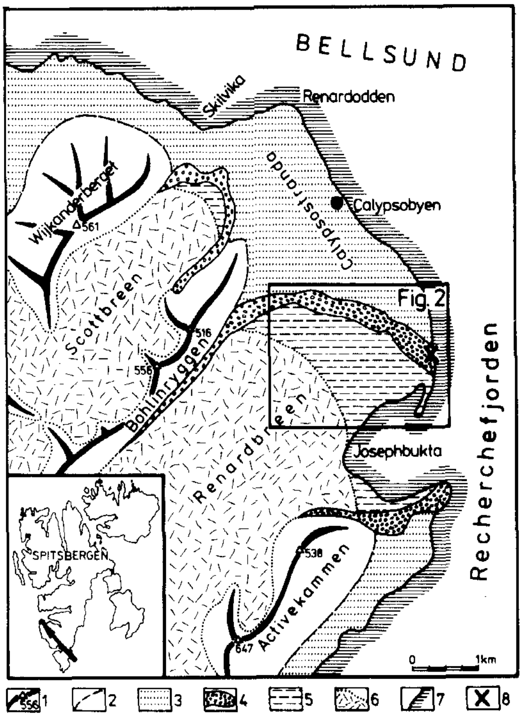

Fig. 1. Geomorphological sketch of the western outline of Recherchefjorden. 1. Main ranges and peaks; 2. Zone of slope deposits extention; 3. Coastal plain; 4. Lateral and terminal moraines; 5. Young glacial deposits; 6. Glaciers; 7. Shoreline; 8. Locality of organogenic deposits.

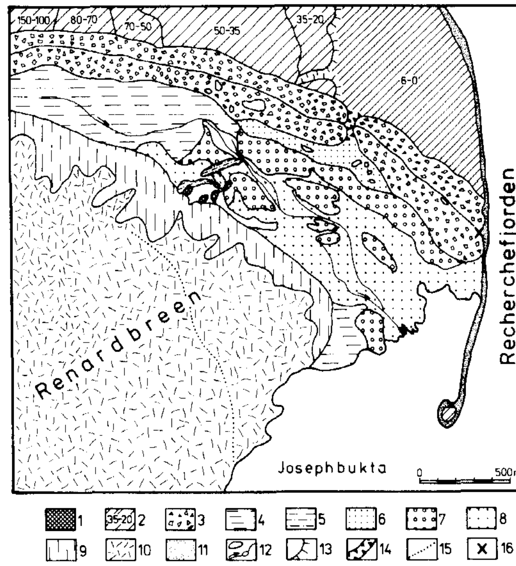

Fig. 2. Geological map of the Renardbreen outer margin (after Szczęsny et al. 1989, modified). 1. Bedrock exposure; 2. Beach terraces at marked height. a.s.l.; 3. Rocky blocks, boulders, gravels and sands of the terminal moraine; 4. Boulders, gravels, sands and tills of the ground moraine; 5. Sandy and gravelly eskers; 6. Sandy kames and kame terraces; 7. Gravels and sands of the older sandur; 8. Gravels, sands and silts of the younger sandur; 9. Tills, sands and gravels of the ablational moraine; 10. Glacial ice; 11. Beach sands and gravels; 12. Lakes and extramarginal rivers; 13. Steep edges; 14. Meltwater channel; 15. Terminal extent of Renardbreen in 1986; 16. Locality of the organogenic deposits.

The question of age of the youngest marine terrace (0–6 m a.s.l.) and the Renardbreen terminal moraines

In the western outline of Recherchefjorden seven marine terraces have been identified. These are at 0–6 m, 20–35 m, 35–50 m, 50–70 m, 70–80 m, 100–150 m and 150–180 m a.s.l. (Szczęsny et al. 1989; Nitychoruk et al. 1989). ^{14}C dating of the mollusk fragments from the upper part of the terrace (20–35 m a.s.l. in the vicinity of Renardodden) resulted in ages of 8,150 ± 70 years BP and 9,930 ± 70 years BP (Troitsky et al. 1979). Similar results 10,310 ± 200 years BP (29 m a.s.l.) and 9,400 ± 120 years BP (10 m a.s.l.) have been presented by Salvigsen (1977) for mollusk shells and a whale bone, respectively, from Calypsostranda. These values are in accordance with results (10,240 ± 70 to 8,910 ± 110 years BP) by Landvik et al. (1987) for the whalebones and bivalve (*Hiatella* sp., *Mya* sp.) fragments on the similar terraces in the northern part of Bellsund. Landvik et al. (1987) determined the age of the lowermost terraces (Beach Level A–11.1 m a.s.l.) to less than 6,180 ± 180 years BP. The youngest age is 4,490 ± 50 years BP for the whalebones at the level 7 m a.s.l.

In the light of those data it may be assumed that the age of the lowermost terace of Recherchefjorden is less than 5,000 years.

For sure, the Renardbreen inner chain of terminal moraine domes was accumulated on the emerged terrace, so the moraine must be younger than 5,000–4,000 years BP. Two younger glacial advances on Spitsbergen have been postulated – 3,500–2,000 years BP and Little Ice Age, respectively (Baranowski 1977; André 1986). The formation of the inner moraine chain was finished by the beginning of the 20th century, because the Renardbreen front extended to that chain in 1936 (visible in topographical map 1 : 1,000,000). Thus, the outer chains of the moraine domes formation could be related to the older (3,500–2,000 years

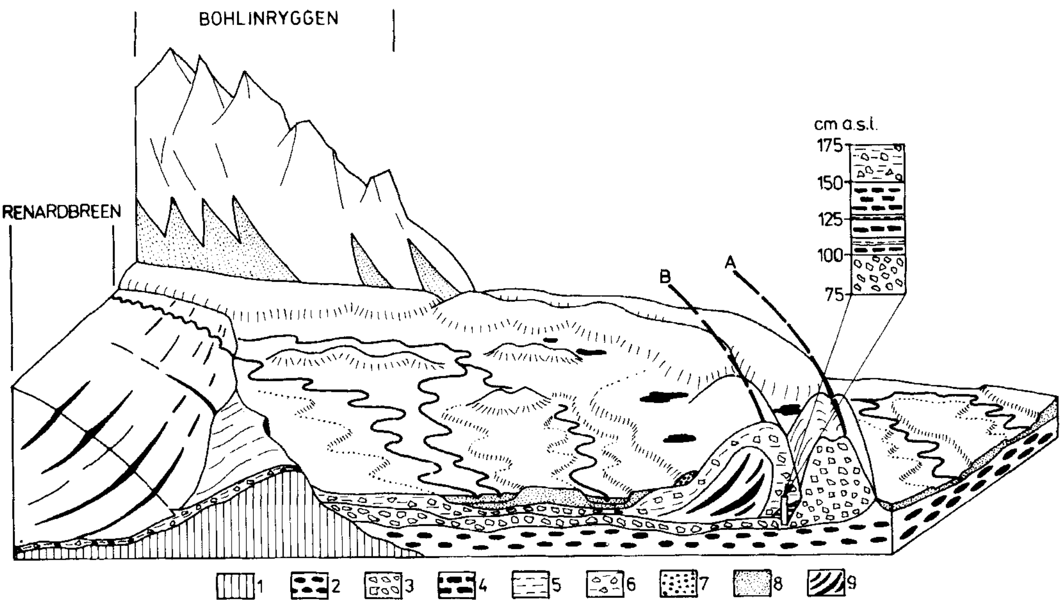

Fig. 3. Block diagram of the Renardbreen outer margin. 1. Bedrock; 2. Terrace deposits 0–6 m a.s.l.; 3. Older moraine deposits; 4. Organogenic deposits; 5. Silts; 6. Younger moraine deposits; 7. Kames; 8. Extra and intramarginal sandurs; 9. Glacial ice and dead ice; A. Glacial advance 3,500–2,000 years BP; B. Little Ice Age.

BP) advance of the glacier. Moreover, the inner moraines formation should be related to the youngest cooling, beginning at about 500 years BP (Szupryczyński 1968).

Radiocarbon dating

Radiocarbon dating of three samples taken from organogenic deposits (peaty part) carried out by Professor M. F. Pazdur in the ^{14}C Laboratory of the Silesian Technical University (Gliwice) gave the following results:

no. samp.	m above sea level	^{14}C age years BP
Gd–4,323	1.40–1.43	660 + 80
Gd–2,911	1.23–1.26	1,130 ± 80
Gd–4,321	1.05–1.10	1,040 ± 80

Each sample examined in the ^{14}C Laboratory was directly prepared according to the standard procedure (Pazdur 1982; Gloslar & Pazdur 1985). All macroscopic remnants of drift wood and fragments of contemporary plants were removed.

Detailed mapping of Quaternary cover in that region excludes accumulation of old carbon within examined organogenic deposits.

Pollen analysis

The section of the organogenic deposits was sampled continuously, for pollen analysis. Samples were taken at 0.025 m intervals in the upper part of the section and at 0.12 m intervals in the lowermost part. In sample preparation the flotation with CdJ and KJ was applied and acetolysis was carried out (cf. Wasylikowa 1973). *Lycopodium clavatum* spores were finally added for determination of the pollen concentration in the sediment (Stockmarr 1971).

Almost all pollen spectra are dominated by *Gramineae* (Fig. 4). *Betula* cf. *nana*, *Caryophyllaceae* (*Cerastium/Stellaria* type), *Cruciferae*, *Saxifragaceae* (*Saxifraga granulata* type), *Rosaceae* (*Potentilla* type among others) and *Compositae tubuliflorae* have also been indicated. *Saxifraga granulata* type (Verbeek-Reuvers 1977) includes nine genera – four of them (*Saxifraga caespitosa*, *S. cernua*, *S. hirculus* and *S. rivularis*) presently occurring on Spitsbergen. Pollen of *Pinus* and *Myrica* coming from far away regions were also identified. This phenomenon had often been noted from pollen spectra of different age on Spitsbergen (Środoń 1960, 1968; Fabiszewski 1975) and in Greenland (Funder 1978, 1979;

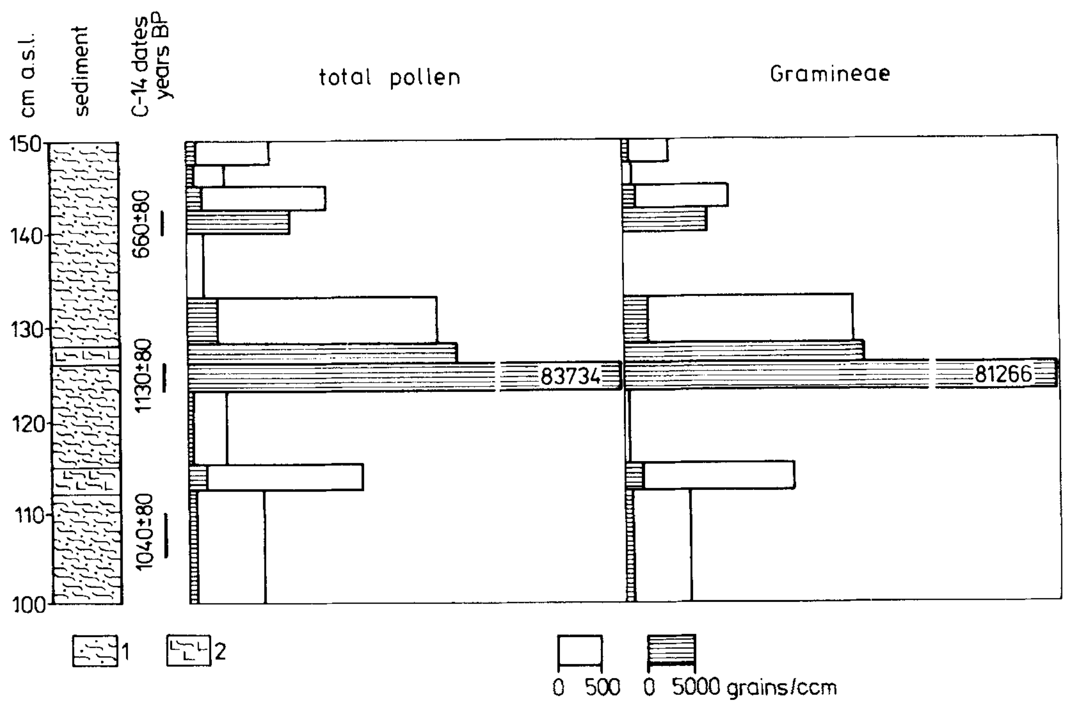

Fig. 4. Complete pollen diagram based on quantity of pollen grains within 1 cm^3 of organogenic deposits. 1. Peat (Tb^4 3Ga 1G+); 2. Silt (Ag3 $Tb^0$1).

Funder & Abrahamsen 1988) as well as within the Canadian Arctic (Ritchie & Lichti-Federovich 1967; Andrews et al. 1979; Hyvärinen 1985). Amazingly, there has been found spores of *Humulus/Cannabis* type strongly suggesting activity of human invaders at that time (Dzierżek et al. this volume).

Pollen concentration in particular layers of the analysed section was sharply irregular (Fig. 4). The higher values were reached at level 1.24–1.28 m a.s.l. (29×10^3–83×10^3 grains per cm^3). *Gramineae* were most abundant here. Otherwise, at the level 1.26–1.28 m a.s.l. *Cruciferae* were also abundant.

Several causes could be responsible for such irregularities. Decrease in sedimentation rate (assumed as 0.03 m in 100 years at the level 1.24–1.42 m a.s.l.) would be a good explanation. Another explanation would be compaction of organogenic deposits due to the load of overlying till. It may also be assumed that the peaks of pollen concentration reflect a vivid development of plant cover at the time. Funder (1979) came to the conclusion that the low beginning pollen concentration in Greenland was caused by long distance transport of grains. Thus, the rapid concentration increase should indicate the invasion of flora on new land. The latter seems to the authors to be the best explanation. Thus, the pollen concentration in the examined deposits is related to environmental conditions, and may indicate a climatic optimum between glacial advances 3,500–2,000 years BP and the Little Ice Age (1,130 ± 80 years BP). A climatic optimum prior to the Little Ice Age noted in the Canadian Arctic was of a similar age (1,000–800 years BP – Andrews et al. 1979, 1,500–1,000 years BP – Miller 1973, 1975), whereas cessation of flora development was determined to about 600 years BP (Nichols 1969, 1974, 1975).

Obtained results suggest a slightly different image of the plant community from the present one, although all the taxons encountered in examined deposits are observed on Spitsbergen nowadays. The raised marine terraces of southern Bellsund are presently dominated by *Salix polaris* and *Saxifraga oppositifolia* (Rzętkowska 1987). There were no evidence of those taxons in the investigated sediments, which is amazing especially in the case of *Salix*, as this occurs in great amounts in other ancient deposits from Spitsbergen, and has been represented by spores

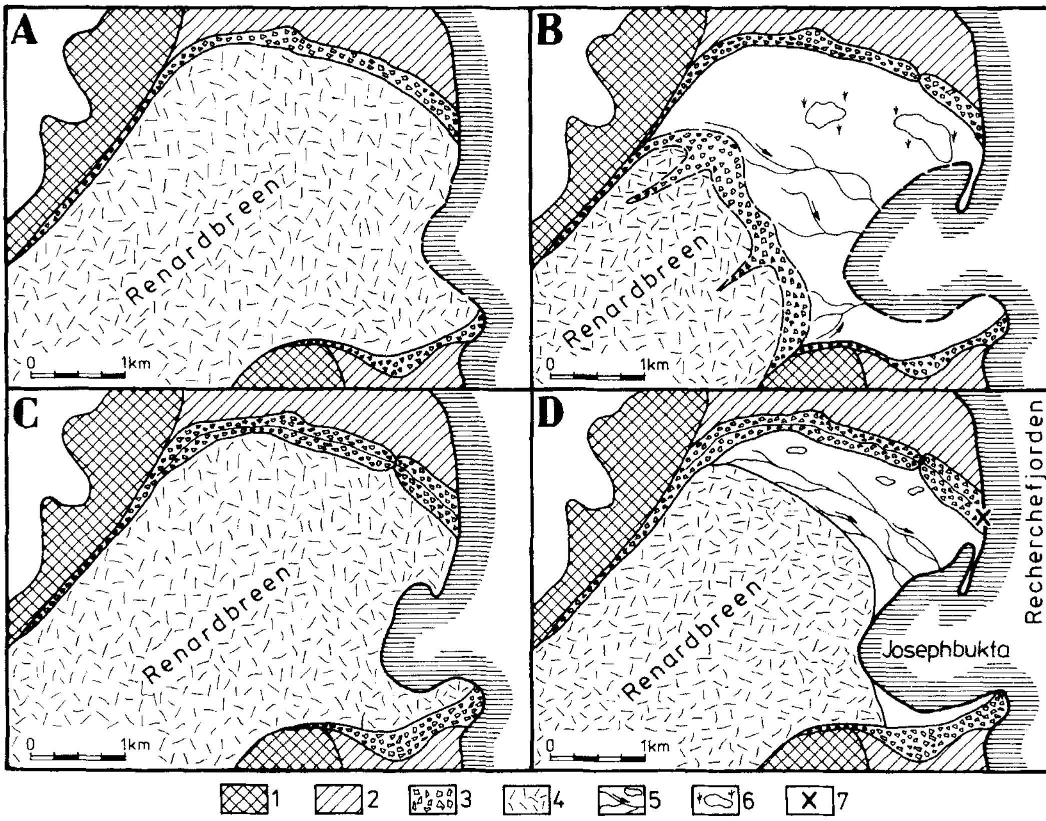

Fig. 5. Development of terminal moraines and outer margin of the Renardbreen-a-scheme. A. Glacial advances 3,500–2,000 years BP; B. Climatic optimum between the Middle and Late Subatlantic; C. Little Ice Age; D. Recent. 1. Mountain ranges; 2. Marine terraces, nondivided; 3. Terminal moraines; 4. Glacial ice; 5. Rivers and lakes; 6. Peat bogs; 7. Locality of the organogenic deposits.

of *Salix arctica*, *S. glauca* and *S. herbacea*. On the other hand, grasses so abundant in examined deposits, being a component of moss-grass peat bogs, are now rather seldom observed in the Renardbreen region. Thus, low diversity, grass dominance and absence of willow are all characteristic for the polar deserts (Funder & Abrahamsen 1988). Such deserts, recently occurring in the southern part of Spitsbergen, belong to the *Papaver dahlianum* zone (Brattbakk 1986). It may be suggested that the climatic optimum prior to the Little Ice Age was somewhat cooler than recent times.

Note on Holocene palaeogeography of the Renardbreen terminal moraine zone

Marine terraces with organogenic deposits were formed due to the glacioisostatic uplift during the Holocene climatic optimum, i.e. on Spitsbergen from 7,000 to 3,500 years BP (Baranowski 1977).

An advance of Renardbreen probably took place during the period 3,500–2,000 years BP (Baranowski 1977; André 1986). The maximum extent of this advance is outlined by the outer chain of moraine domes (Figs. 1, 5A).

The Middle/Late Subatlantic transition (Mangerud et al. 1974) was marked by a warming episode related to the Renardbreen glacier snout retreat (Fig. 5B). Behind the neoglacial moraine chain, in the vicinity of glacial lakes, the peat bog plant communities were developed (the remnants of these plants became investigated organogenic deposits). The organogenic deposition in these peat bogs was periodically interrupted by silt sedimentation with moss relics due to extensive glacial outflows. Absence of diatoms in the silt (Marciniak pers. comm.) excluded sea transgressions at the time (cf. Blake et al. 1965).

Climatic optimum at 1,130 ± 80 years BP is in accordance with the sediment layer of the highest amount of pollen grains. Since that time, up to at least the 14th century, human activity had developed there (Dzierżek et al. this volume).

During the Little Ice Age, Renardbreen and other Spitsbergen glaciers advanced (cf. Baranowski 1977; Lindner et al. 1983), essentially changing the older landscape (Marks 1983; Michalska 1968). Renardbreen had reached at least the moraine chains of 3,500–2,000 years BP transgression (Fig. 5C) at that time. The organogenic deposits were, therefore, covered and slightly deformed.

The Renardbreen front head has retreated about 1.5 km since the beginning of the 20th century (Fig. 5D). In comparison to adjacent terraces and valleys the marginal zone of Renardbreen has an exceptionally poor vegetation cover.

Concluding remarks

1. Detailed studies of submoraine organogenic deposits resulted in the environmental reconstruction of the Renardbreen terminal moraines zone during the Late Holocene.

2. Radiocarbon dating (from 1,130 ± 80 to 660 ± 80 years BP) determined the period of organic deposits development on the Middle/Late Subatlantic transition.

3. The geological position of the organogenic deposits solved the question of the Renardbreen terminal moraines. The outer chain of moraines was probably connected with glacial advances 3,500–2,000 years BP, whereas the inner chain of moraines was formed during the period of cooling called the Little Ice Age.

4. Pollen analyses indicate a warming between 2,000 years BP and the Little Ice Age, allowing development of grass-moss communities. The climatic optimum was about 1,100 years BP.

5. Existence of hair, pieces of wooden coal, pottery fragments, wooden chips, animal fur fragments, whalebone fragments, pieces of web and pollen of *Cannabis/Humulus* type within organogenic deposits strongly suggest the earliest human activity marked on Spitsbergen (Dzierżek et al. this volume).

6. The authors' data could be a base for studies on the other Spitsbergen glacier terminal moraines.

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