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First thermoluminescence datings of Pleistocene sediments from Sörkapp Land, Spitsbergen

ABSTRACT: Thermoluminescence datings of glacial and marine sediments from Sörkapp Land, southern Spitsbergen enabled to limit the Late and Middle Pleistocene glacial events in this area. Sediments of raised beaches at 15—18, 30—38 and 42—56 m a.s.l. in Breinesflya were TL dated for 63, 68 and 87 ka respectively. Four other dates from Lisbetdalen, Slaklidalen and Sergeijevskardet proved two glacial advances during the Sörkapp Land (=Würm) Glaciation, named the Lisbetdalen Stage (47 and 41 ka) and the Slaklidalen Stage (28 and 22 ka). Glacial sediments on slopes of Gavrilovfjellet and Strupryggen were dated for 141 and 217 ka respectively. These dates prove the glaciers of the Wedel Jarlsberg Land (=Riss) Glaciation occupied a considerably larger area in southern Spitsbergen than the glaciers of the following Sörkapp Land Glaciation.

Key words: Arctic, Spitsbergen, Quaternary chronostratigraphy

Introduction

The paper presents results of the first thermoluminescence datings of Pleistocene sediments from Sörkapp Land, southern Spitsbergen. Samples of these sediments were collected in 1985 by R. Szczęsny who took part in the Spitsbergen scientific expedition organized by the Jagiellonian University of Cracow. The samples come from the previously known to the

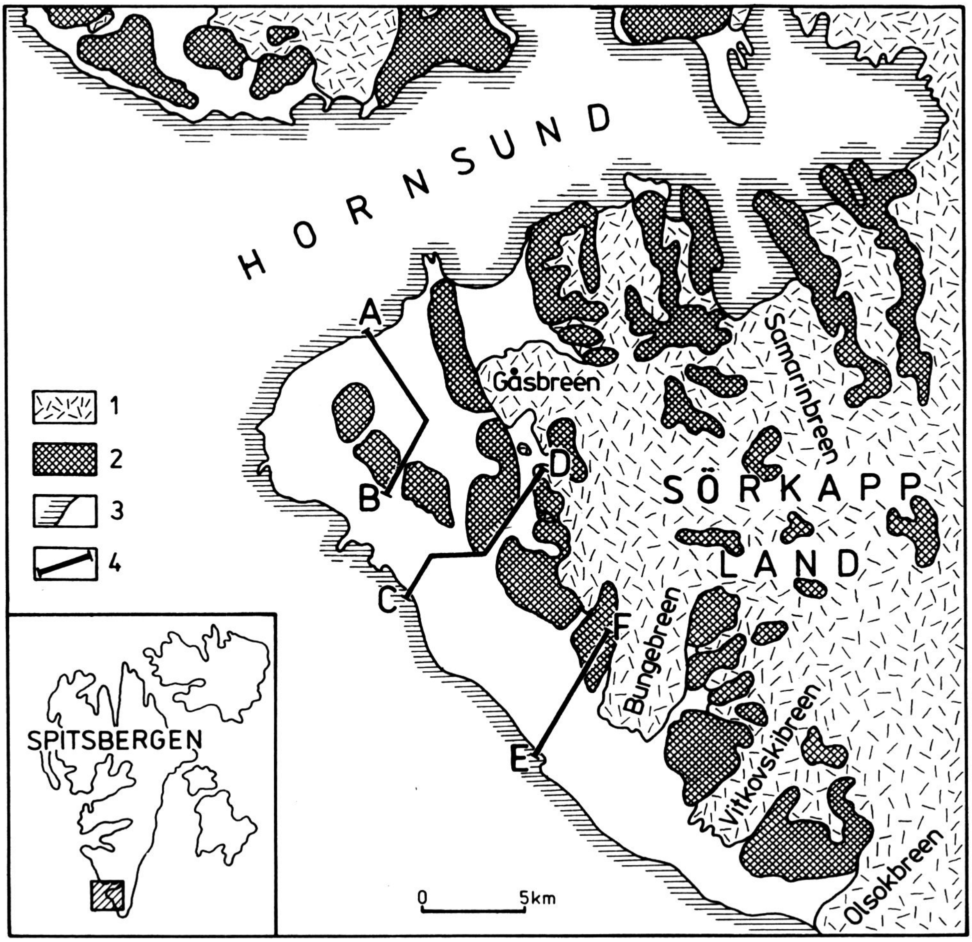

Fig. 1. Location sketch of northwestern Sörkapp Land in southern Spitsbergen: 1 — glaciers, 2 — mountain massifs, 3 — coastline, 4 — geologic section (see also Figs 2 and 3)

authors sites with marine (3 samples) and glacial (6 samples) sediments, located in the representative geologic sections from this area (Fig. 1).

Thermoluminescence analysis was done in the Thermoluminescence Laboratory, Institute of the Earth Sciences of the M. Curie-Skłodowska University of Lublin (Table 1). The dates supply with significant changes in the authors' previous opinions on stratigraphic location of some Pleistocene sediments in this area (*cf.* Kłysz and Lindner 1981a, b, c; 1982, 1983a, b; Lindner, Marks and Ostaficzuk 1984, 1986; Lindner, Marks and Pękala 1984, 1986). The changes result in general in finding the dated sediments much older and refer them all to the Pleistocene. On the other hand, received thermoluminescence datings support the authors' earlier opinions to define the last Pleistocene glaciation in southern Spitsbergen

Table 1

Thermoluminescence (TL) datings of deposits from the Sörkapp Land, southern Spitsbergen

Location	Age (ka TL)	Laboratory dating no.	Dated deposits
Sergeijevskardet	41 ±6	Lub-1130	till
Lisbetdalen	47 ±7	Lub-1131	glacial sand
Lisbetdalen	22 ±3	Lub-1132	glacial sand
Breinesflya	63 ±9	Lub-1133	marine shingle
Breinesflya	88 ± 13	Lub-1134	marine shingle
Breinesflya	87 ± 13	Lub-1135	marine shingle
Gavrilovfjellet	141 +21	Lub-1136	till
Slaklidalen	28 +4	Lub-1137	till
Stupryggen	217 ±32	Lub-1138	till

as the Sörkapp Land Glaciation and its correlation with the Vistulian (Würm) Glaciation in Europe (Lindner, Marks and Pękala 1983, 1984, 1986). These data enable also an attempt of a chronostratigraphic correlation of the main Pleistocene stages in Sörkapp Land and in the previously described area to the north of Hornsund (*cf.* Lindner, Marks and Pękala 1986).

Method

Theoretical foundations of the applied thermoluminescence method are not much different from the ones, accepted in other laboratories (Aitken 1981, Wintle and Huntley 1982). A thermoluminescence (TL) age of Quaternary sediments is calculated from the ratio of measured natural thermoluminescence (geologic dose ED) converted to definite units of ionized radiation absorbed by analyzed sample (Butrym 1985).

Dated samples are firstly properly prepared. Washing on sieves makes grains of 50—56 μm in diameter be selected for TL measurements. A choice of this grain size is supported by numerous experiments that proved the TL curves, received from grains of this size, to be more homogeneous for an analyzed sediment than curves from larger grains. Selected grains are then cleaned in the ultrasonic disintegrator. Carbonate, ferruginous, manganese, etc. dirts are removed from grain surfaces at a working frequency of 22 kHz and vibration amplitude of 2 m/s. Organic matter and less resistant minerals get also disintegrated. A time of ultrasonic action on samples is chosen by experiments and is equal 8—15 minutes what depends on degree of grain contamination. In result of ultrasonic cleaning a distinct increase in thermoluminoscence intensity of quartz and feldspar grains is noted. After another wash with distilled water, a sample is dried in a room temperature and in a shady place.

Measurements of geologic dose (ED) by thermoluminescence method are done for polymineral samples, partly enriched in quartz and feldspars due to ultrasonic disintegration. Thermoluminescence of samples and dosimeters is done with a laboratory counter — TL analyser (model 770 A), constructed in the Institute of Nuclear Physics, Cracow. This instrument has a very sensitive photographic multiplier (type 9789 QA, EMI made) that enables a measuring of doses below 1 mrad. Heating of 2 mg sample is done in microwave stove in inactive gas (argon) at a linear rise of temperature and with experimental speed of 4°C/s. Stability of the working instrument is secured by cooling of a photomultiplier with a flow ultrathermostat.

Graphic presentation of the TL analysis is filled by the recorder XY (type D-8, made by Riken Denshi Co., Ltd). Obtained TL curves are used to define a right peak and a temperature at which it occurs. Height of the peak of TL curve is proportional to the thermoluminescence effect, dependent on a dose of ionic radiation that has been absorbed by mineral grains. Precise measurements of peak heights are done with a use of a milivoltmeter with numerical reading (type 245 AC/DC, UNIPAM made) that records peak values of a current. A peak in the temperature interval of 230—280°C is of particular significance in TL datings of the used grain size of 50—56 μm. It constitutes a specific feature for quartz and feldspar and its temperature depends on size of grains of these minerals.

A geologic dose (ED) is estimated by comparison of a peak height on the natural curve of sample thermoluminescence with a corresponding peak of TL curve, received for the same sample after extra and artificial radiation. Every measurement is repeated at least ten times and mean value is calculated to define a dependency of the peak height from the doses of *e.g.* 10, 12 and 15 krads. In the case of a nonlinear dependency of the TL effect from a radiation dose, measuring of the natural TL is based on artificially induced peak of temperature of about 180°C. Height of this peak enables to define trends i speed of TL rise in a linear dependence from the dose.

The annual dose of absorbed ionized radiation is measured with TL dosimeters, type MTS-N (LiF, Mg, Ti), produced in the Institute of Nuclear Physics of Cracow. Dosimetric measurements are done in a laboratory, after 9 dosimeters are put for 3 month inside each sample with a natural grain size content and 1—2 kg in weight. Then a mean annual dose is calculated. In the same time the same method is used to estimate the background radiation in a laboratory. Experiments proved that doses measured for the same samples just in a room and in a lead-protected chamber

(4 cm thick layer of Pb) are much similar and do not go beyond the measuring error. A dependence of the measured dose from the sample weight was also noted in the weight interval of 1 to 3 kg and found to be insignificant; the noted variation does not exceed 4%.

An evaluation of the TL age of a sample is received from the quotient of a geologic dose in rads (or grays) and of an annual dose in rads a year (or grays a year). The age calculated in this way comprises an error, an exact value of which cannot be easily defined. Only the error that results from inaccuracy of measuring instruments, dispersed readings of dosimeters and accuracy in finding the dose of artificial radiation is to be calculated. This error does not exceed usually 15% of the evaluated age of a sample.

TL datings can comprise also an irrational error that results from type and origin of analyzed material. Foundations of the TL method say that mineral grains of analyzed sediment have lost their primary TL properties due to transport (ultraviolet radiation, friction, disintegration). Analyses of the material that has been transported at short distances (and such sediments are frequently analyzed in Spitsbergen), indicate a considerable variation of the TL effect. It proves then that a very ancient material (from the bedrock) was mixed with the one that gained once again its TL properties already in the analyzed deposit. Separation of the "ancient" and "fresh" thermoluminescence is in general possible as TL curves have different shapes in each case. Therefore, only the youngest dates received for an analyzed sample can define a probable age of deposition. Earlier dates seem to be referred rather to the time when a weathering waste was formed. But a reliability of such dates is small as some of them go beyond the limits of the TL method.

A certain irrational error in TL measurements is caused by the analyses of polymineral samples. Occasionally a too small content of quartz and feldspars in samples can influence the final dating result. A type and conditions of deposition of Quaternary sediments in Spitsbergen make the received TL dates be considered as approximate and not as absolute ones. For this reason they are presented as the TL age of analyzed sediments.

Key areas

Lisbetdalen Region

Previous geomorphologic and geologic investigations of Libestdalen, Kulmstranda and slopes of surrounding mountain massifs of Hohenlohefjellet (614 m a.s.l.), Sergeijevfjellet (437 m a.sl.), Lidfjellet (531 m a.s.l.), Savitsjotoppen (464 m a.s.l.) and Kovalevskifjellet (640 m a.s.l.), separated by passes of Hohenloheskardet and Sergeijevskardet as well as Liddalen and Kovalevskidalen, enabled to distinguish here a rich complex of Quaternary marine, glacial and slope landforms and sediments (Kłysz and Lindner 1981a, b, 1983a; Stankowski 1981, 1982, 1983; Andrzejewski *et al.* 1983; Karczewski *et al.* 1984; Lindner, Marks and Pękala 1984; Ziaja 1985, 1986).

Marine features of this area comprise six raised beaches (Fig. 2) cut in a bedrock composed of glacigenic deposits. The latter include a till, ascribed to the Sörkapp Land = Würm Glaciation (Kłysz and Lindner 1981a, b, 1983a; Lindner, Marks and Pękala 1984), locally replaced by a rubble of Carboniferous sandstones, forming a so-called exaration moraine (*cf.* Kłysz and Lindner 1981a). The highest beach (80—100 m a.s.l.) is preserved only to the west from the Lisbetelva gorge. In the south it is delimited by a distinct edge, formed during a primary locking by a glacial snout that occupied mid and upstream parts of the Lisbetdalen. Three successive lower marine beaches (56—75, 30—38 and 20—28 m a.s.l.) are probably

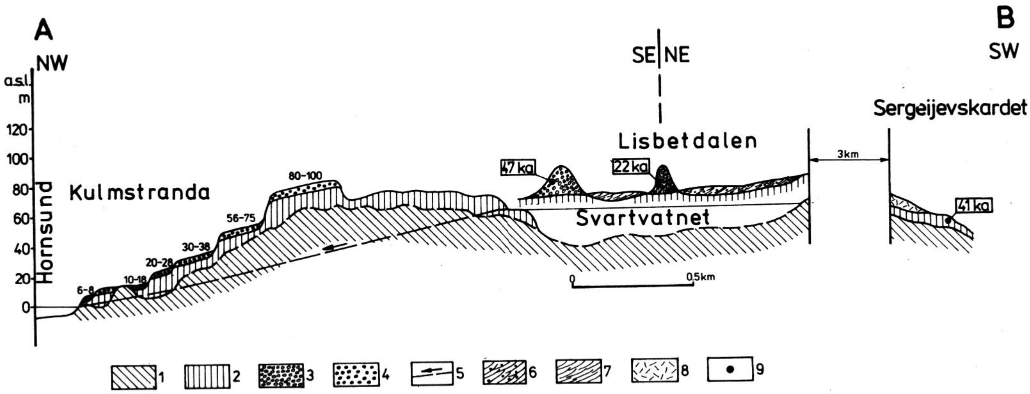

Fig. 2. Schematic geologic section A—B across the Lisbetdalen and Kulmstranda area after Kłysz and Lindner (1981a, modified): 1 — bedrock, 2 — till, 3 — gravels and sands of lateral moraines, 4 — marine shingle (beach altitudes in metres a.s.l.), 5 — bed of Lisbetelva, 6 — outwash gravels and sands, 7 — talus sands, 8 — solifluction mantle, 9 — sites of TL datings

corresponding with the Sörkapp Land Glaciation whereas a development of the lowest beaches (10—18 and 6—8 m a.s.l.) should be referred to the Holocene.

Glacial landforms and sediments of mid and upstream parts of the Lisbetdalen, on slopes of surrounding mountain massifs and within valleys and passes have been previously connected with valley and pass glaciers, present at the end of the Sörkapp Land Glaciation and in the Holocene (Kłysz and Lindner 1981a, b; 1983a; Lindner, Marks and Pękala 1984). Collected samples of these deposits were TL dated for 47±7 ka (Lub-1131), 41±6 ka (Lub-1130) and 22±3 ka (Lub-1132). Such date speaks for their older age and reference to the Sörkap Land Glaciation only. Glaciers of the latter were here younger than the up-valley rock ledges, connected by Stankowski (1981, 1982, 1983) with the Late Pleistocene abrasion by sea.

Lateral moraines formed by glaciers of the Sörkapp Land Glaciation in the Lisbetdalen, dated for 47 and 22 ka, are treated on the geomorphologic map of the Hornsund Region (Karczewski *et al.* 1984) as subslope nival moraines, notwithstanding the opinion of the ones who worked in this area (P. Kłysz and L. Lindner). TL dates prove these moraines to delimit the two successive glacial stages during the mentioned glaciation. The older stage, named by the authors the Lisbetdalen Stage (*cf.* Fig. 4), corresponds with the last but one phase of the Sörkapp Land Glaciation (*cf.* Lindner, Marks and Pękala 1983, 1984, 1986). A deposition of till in the Sergeijevskardet area (TL dated for 41 ± 6 ka, Lub-1130) should be also connected with the same period (Figs. 2, 4). The younger stage corresponds with the last phase of the Sörkapp Land Glaciation (*cf.* Lindner, Marks and Pękala 1983, 1984, 1986). The name Slaklidalen Stage is proposed for this interval, based on new data from the Slaklidalen area (*cf.* Fig. 4).

All these facts suggest that glacial sediments at the raised marine beaches in Kulmstranda are not to be still correlated with the middle Sörkapp Land Glaciation. They seem to represent the older part of this glaciation or even the Wedel Jarlsberg Land = Riss Glaciation (*cf.* Lindner, Marks and Pękala 1983, 1984, 1986).

Slaklidalen Region

This area is composed of the Slaklidalen, surrounded by mountain massifs of Gavrilovfjellet (598 m a.s.l.), Brevassfjellet (585 m a.s.l.), Gråkallen (716 m a.sl.) and Wiederfjellet (754 m a.s.l.), and the central part of the seashore (Breinesflya). The upstream part of the Slaklidalen is occupied by the Gråkall Glacier (Gråkallbreen), with its firn field common with the Bunge Glacier (Bungebreen) and Wieder Glacier (Wiederbreen). On the southeastern slope of the Slaklidalen there are three relic glacierets, the largest one of which has been already transformed into a rock glacier (Lindner and Marks 1985).

Previous geomorphologic and geologic investigations (Andrzejewski *et al.* 1983; Kłysz and Lindner 1983a, b; Lindner, Marks and Ostaficzuk 1986; Ostaficzuk, Lindner and Marks 1986), allowed to distinguish in the Slaklidalen several systems of terminal moraines of varying age (Fig. 3), accompanied by tills, cirques, trimlines, two outwash levels (Fig. 3) and various slope sediments and features.

In the Breinesflya the carried investigations formed the basis to dinstinguish seven marine beaches (Fig. 3), underlain by pre-Quaternary rocks composed of Cambro-Ordovician quartzites, Carboniferous sandstones as well as Triassic siltstones and shales (Flood, Nagy and Winsnes 1971). The bedrock is locally covered by a till, previously ascribed to the Sörkapp Land Glaciation (Kłysz and Lindner 1983a, b; Lindner, Marks and Ostaficzuk 1986). Marine beaches are cut by younger outwash trains running from the Slaklidalen. Four higher marine beaches of this area (42—56, 30—38, 28—30 and

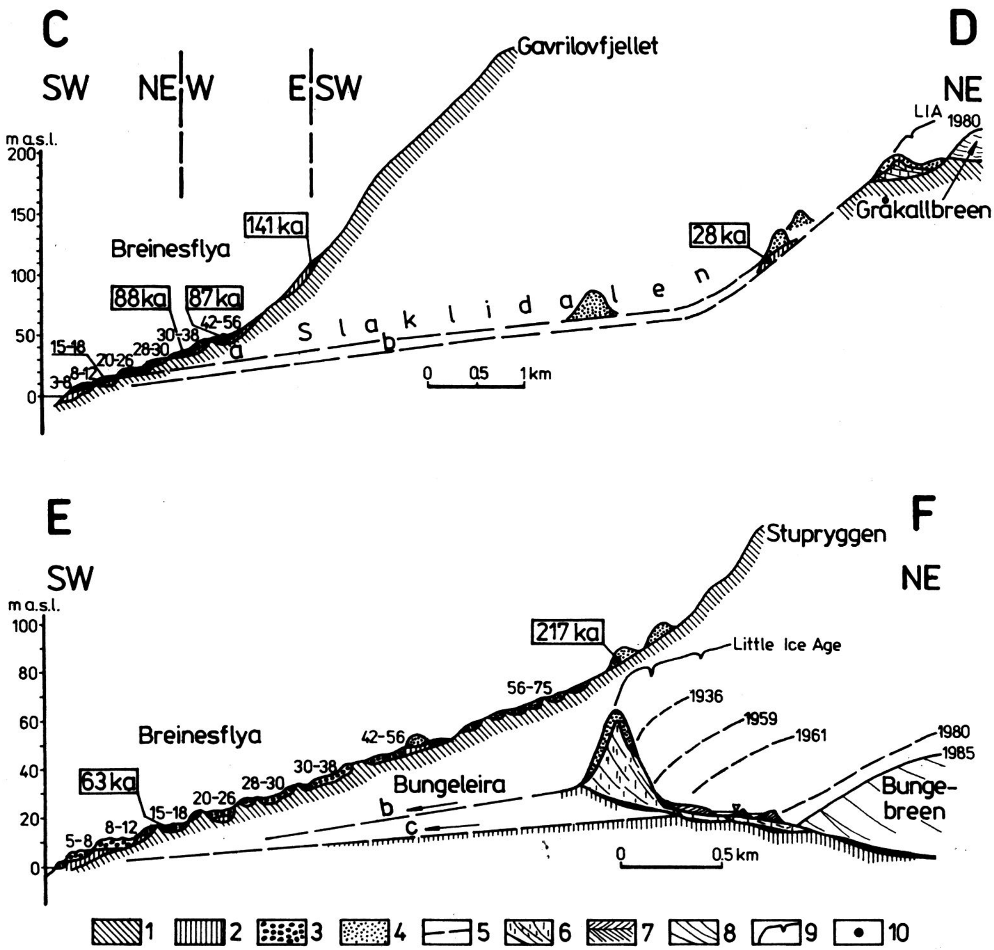

Fig. 3. Schematic geologic sections Breinesflya-Slaklidalen-Gråkallbreen (C—D) and Breinesflya-Stupryggen (E—F) after Lindner, Marks and Ostaficzuk (1986, modified) 1 — bedrock, 2 — till, 3 — marine shingle (beach altitudes in metres a.s.l.), 4 — gravels and sands of terminal and lateral moraines, 5 — outwash levels of varying age (a, b, c), 6 — buried glacial ice, 7 — sands and gravels of intramorainal outwash, 8 — compact glacial ice, 9 — glacier extents (LIA — Little Ice Age), 10 — sites of TL datings

20—26 m a.s.l.) were previously connected with the Sörkapp Land Glaciation and three lower ones (15—18, 8—12 and 3—8 m a.s.l.) with the Holocene (Lindner, Marks and Ostaficzuk 1986).

Four samples of Quaternary glacial and marine sediments collected in this area for TL datings (Table 1) result in certain changes in stratigraphic conclusions. Glacial sediments in the upstream part of the Slaklidalen (Fig. 3) were TL dated for 28 ± 4 ka (Lub-1137) whereas similar deposits on a slope of Gavrilofjellet by the Slaklidalen outlet (Fig. 3) for as much as 141 ± 21 ka (Lub-1136). The younger date refers the age of dated glacial sediments to the late Sörkapp Land Glaciation, named by the authors the Slaklidalen Stage (Fig. 4). The older date defines the age of glacial deposits at the Slaklidalen outlet for the younger part of the Wedel Jarlsberg Land Glaciation (Fig. 4). A larger extent of glaciers in that time is therefore proved if compared with previous suggestions (*cf.* Kłysz and Lindner 1983a, b; Lindner, Marks and Ostaficzuk 1986).

TL age of marine sediments in the Breinesflya (Fig. 3) was found similar to the previously suggested one, resulting from a paleogeomorphologic analysis that located their deposition during the Sörkapp Land Glaciation (*cf.* Lindner, Marks and Ostaficzuk 1986). A certain surprise was only made by TL ages of the beach 42—56 m a.s.l. (87 ± 13 ka, Lub-1135) and the beach 30—38 m a.s.l. (88 ± 13 ka, Lub-1134), and is not based on the resersed values (what can be easily explained if the method error is taken into account) but on the reference of their development during the earlier stage of this glaciation (*cf.* Fig. 4).

Forefield of the Bunge Glacier

This area comprises southern slopes of the Stupryggen mountain massif (636 m a.s.l.), southern part of the seashore Breinesflya and the morainal part of the Bunge Glacier with its extramorainal outwash plain in Bungeleira (Fig. 3). Quite a lot geomorphologic and geologic works have been carried here (Jewtuchowicz 1962, 1965; Kłysz and Lindner 1982; Ostaficzuk, Lindner and Marks 1982; Andrzejewski *et al.* 1983; Lindner, Marks and Ostaficzuk 1984, 1986; Lindner, Marks and Szczęsny 1985, 1986; Lindner and Kłysz 1987; Szczęsny 1986).

These works enabled to find on slopes of the Stupryggen and in the Breinisflya 8 raised marine beaches, developed on a bedrock composed of clastic and carbonate sediments of the Upper Hecla Hoek Formation and locally, of Triassic siltstone-shale facies (*cf.* Flood, Nagy and Winsnes 1971). The bedrock is covered by a less or more continuous mantle of glacial sediments, composed of a till and several series of ancient lateral and terminal moraines of the Bunge Glacier. Five higher raised beaches (56—75, 42—56, 30—38, 28—30 and 20—26 m a.s.l.) were previously connected with the Sörkapp Land Glaciation and three lower beaches (15—18, 8—12 and 5—8 m a.s.l.) with the Holocene (Kłysz and Lindner 1982; Lindner, Marks and Ostaficzuk 1986).

A new TL dating of the highest found glacial sediments in this area (Fig. 3) defines their age for 217±32 ka (Lub-1138) *i.e.* for the Wedel Jarlsberg Land Glaciation (Fig. 4). They are therefore considered to be older than in previous opinions, ascribing them to the last glaciation (*cf.* Kłysz and Lindner 1982; Lindner, Marks and Ostaficzuk 1986). Sediments of the marine beach 15—18 m a.sl. were found older too as TL dated for 63±9 ka

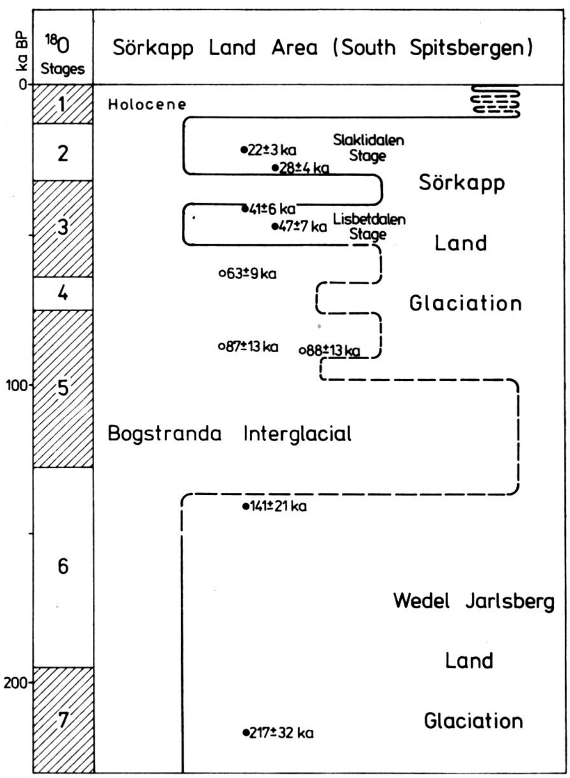

Fig. 4. Chronostratigraphic subdivision of the Quaternary of the Sörkapp Land, southern Spitsbergen: marked is location of glacial (black dots) and marine (circles) sediments dated by TL method

(Lub-1133). This date refers them to the middle part of the Sörkapp Land Glaciation (Fig. 4) and supports the previous opinion of the authors on a significance of young tectonic phenomena in this area and improper hypsometric criterion applied frequently in age correlation of marine terraces (Lindner, Marks and Szczęsny 1985, 1986). All these data indicate also a more limited extent of glaciers of the last glaciation in southern Spitsbergen if compared with the previous opinions (*cf.* Kłysz and Lindner 1981, 1983a, b; Lindner, Marks and Pękala 1983; Lindner, Marks and Ostaficzuk 1986).

Final remarks

The presented TL datings allow to draw the chronostratigraphic conclusions for the northwestern Sörkapp Land. Dates for raised marine beaches 15—18 m a.s.l. (63 ka), 30—38 m a.s.l. (88 ka) and 42—56 m a.s.l. (87 ka) prove their development during the middle and late Sörkapp Land Glaciation (*cf.* Lindner, Marks and Pękala 1983, 1984, 1986). In turn a location of these marine beaches against tills in the Sergeijevskardet and upstream part of the Slaklidalen (dated for 41 and 28 ka respectively) as well as of ancient lateral moraines in the Lisbetdalen (dated for 47 and 22 ka), indicates that glaciers of southern Spitsbergen did not form vast ice caps during the Sörkapp Land Glaciation but advanced within the mountain valleys only and transfluenced the mountain passes. Therefore, this part of Spitsbergen was occupied by a valley glaciation.

On the other hand an occurrence of the older till on a slope of the Gavrilovfjellet (141 ka) and of ancient lateral moraines on a slope of the Stupryggen (217 ka) proves that during the younger part of the Wedel Jarlsberg Land Glaciation (*cf.* Lindner, Marks and Pękala 1983, 1984, 1986) the glaciers of the northwestern Sörkapp Land occupied a considerably larger area, advancing outside the mountain valleys.

Slope features of mountain massifs around the Lisbetdalen and the Slaklidalen could therefore develop already during the younger part of the Sörkapp Land Glaciation, at first on nunataks and afterwards on larger and larger areas exposed successively from under a glacial ice. Such features could obviously develop during the Holocene until the present.

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Streszczenie

W artykule przedstawiono pierwsze oznaczenia wieku TL osadów plejstoceńskich z Sörkapp Land w południowym Spitsbergenie (fig. 1, tab. 1) wraz z omówieniem stosowanej metodyki datowań. Pobrano 9 próbek ze znanych wcześniej autorom profili osadów morskich i lodowcowych (fig. 2—3) co umożliwiło określenie wieku transgresji lodowców w tym rejonie w czasie zlodowaceń Sörkapp Land (= Würm) i Wedel Jarlsberg Land (= Riss). Osady tarasów morskich 15—18, 30—38 i 42—56 m n.p.m. datowano odpowiednio na 63±9 ka, 88±13 ka i 87±13 ka. Datowania czterech próbek osadów lodowcowych udowodniły występowanie dwóch transgresji lodowców w młodszej części zlodowacenia Sörkapp Land. Starszą, określoną datami 47±7 ka i 41±6 ka, nazwano fazą Lisbetdalen (fig. 4) zaś młodsza, wyznaczona przez daty 28±4 ka i 22±3 ka, została nazwana przez autorów fazą Slaklidalen (fig. 4). Osady lodowcowe na zboczach Gavrilovfjellet i Stupryggen datowano odpowiednio na 141±21 ka i 217±32 ka, a więc na młodszą część zlodowacenia Wedel Jarlsberg Land. Daty te dowodzą znacznie większego rozprzestrzenienia lodowców południowego Spitsbergenu w owym czasie niż w okresie późniejszego zlodowacenia Sörkapp Land.

Wymienione oznaczenia TL osadów plejstoceńskich Sörkapp Land wnoszą wiele istotnych zmian do wcześniejszych poglądów autorów (*por.* Kłysz i Lindner 1981a, b, c, 1982, 1983a, b; Lindner, Marks i Ostaficzuk 1984, 1986; Lindner, Marks i Pękala 1984). Zmiany te polegają przede wszystkim na znacznym postarzeniu datowanych osadów. Jednocześnie możliwa się staje próba korelacji chronostratygraficznej głównych faz rozwoju i zaniku lodowców na obszarze Sörkapp Land i na wcześniej opracowanym obszarze Wedel Jarlsberg Land (Lindner, Marks i Pękala 1986).

Praca została wykonana w ramach CPBP 03.03. B.7.