Polarforschung 62 (1): 57–65, 1992 (erschienen 1993)

Mitteilungen / Notes

Micromorphological Observations on Till Samples from the Shackleton Range and North Victoria Land, Antarctica

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Summary: In a study of the micromorphological properties of glacial sediments, we have taken the opportunity to look at a small number of samples from North Victoria Land and Shackleton Range, Antarctica. Because micromorphological knowledge of Antarctic sediments and soils is very limited, we accepted the small number of samples. Thin section analyses focussed on characterizing the samples by means of textural and structural composition plus plasmic fabrics. In addition post depositional features such as silt and clay illuviation and precipitation of iron and carbonates were studied. The five samples show a very strongly developed structure which relates to the periglacial, rather than the glacial environment. This structure is best described as a pebble structure, consisting of rounded aggregates which exhibit a strong plasmic fabric, i.e. an internal orientation of fines. The latter is known as a latti-skelsepic plasmic fabric which is caused by rotational movement. All samples show evidence of translocation of material, be it clay, silt, $CaCO_3$ or iron (hydr)oxides, indicating that (percolating) water and dispersion of clay play an important role in these sediments/soils. Especially the amount of illuviated clay is larger than expected. This provides important clues for landscape development.

Zusammenfassung: Für die Untersuchung mikromorphologischer Eigenschaften glazialer Ablagerungen konnte eine Anzahl von Grundmoränenproben aus Nord-Viktoria-Land und der Shackleton Range in Antarktika bearbeitet werden. Die Mikromorphologie antarktischer Sedimente und Böden ist nur rudimentär bekannt, so daß auch die geringe Probenzahl die Kenntnis stark erweitert. Dünnschliffuntersuchungen konzentrierten sich auf die Charakterisierung der Proben nach Textur und Struktur, einschließlich des Plasmagefüges. Zusätzlich wurden postsedimentäre Erscheinungen wie Schluff- und Tonverlagerung sowie Eisen- und Carbonatausfällungen untersucht. Die fünf Proben zeigen ein Gefüge, das mehr mit periglazialen als mit glazialen Verhältnissen übereinstimmt. Dieses Gefüge läßt sich als Aggregatstruktur beschreiben, aufgebaut aus runden Aggregaten mit einem starken Plasmagefüge, d.h. eine starke Orientierung von Feinmaterial mit lattiseptischem Gefüge, das durch Rotationsbewegungen entstannden ist. Alle Proben zeigen Anzeichen von Schluff-, Carbonat- und Eisen(hydr)oxid- Umlagerung, Hinweise dafür, daß perkolierendes Bodenwasser und Dispergierung von Ton in diesen Sedimenten/Böden eine wichtige Rolle spielen. Insbesondere der Umfang der Tonverlagerung ist größer als erwartet; dieses gibt wichtige Anhaltspunkte für die Landschaftsentwicklung.

INTRODUCTION

Over the past ten years we have run a project to establish the micromorphological characteristics of glacial deposits, more in particular of tills (VAN DER MEER et al 1983, VAN DER MEER 1987, 1993). As the aim of the project is to obtain more insight into the genesis of tills, samples from a wide range of glacial environments and glaciated areas are needed. Up to now the results of studies on glacigenic material from a variety of - mainly temperate - places have been published (e.g. VAN DER MEER 1987, 1990, VAN DER MEER & LABAN 1990, RAPPOL et al, 1989, LAGERLUND & VAN DER MEER, 1990). It is felt, that within such a project, samples from the Antarctic as representing the very cold environment, cannot be missed.

In this paper we will describe and discuss the micromorphological characteristics of five till samples from North Victoria Land and Shackleton Range, Antarctica (Fig. 1). The restricted surface of the available thin sections makes quantification unrealistic and thus we have concentrated on a qualitative description. Apart from some samples mentioned by KUBIËNA (1971) our samples are the first thin sections from the Antarctic continent to be published. An extensive search of the pedologic and sedimentologic literature provided no other examples. As it is difficult and time-consuming to obtain additional samples we do not want to postpone publication. This paper should be considered as a first step in the micromorphological study of Antarctic tills.

METHODOLOGY

For the present study we have used samples collected on the Nansen Ice Shelf (Fig. 1) by the third author during the 1989 GANOVEX IV expedition and in the Shackleton Range (Figs. 1 and 2) during the German Expedition 1987/1988 to that range. Not in order to compare them to each other, but because they were available and the samples come from far apart places. The samples consisted of loose till blocks, forming part of larger bulk samples. In size the elongated blocks range from 5-10 cm long and 3-5 cm wide.

After air-drying the samples were impregnated with an unsaturated polyester resin (Synolite, type 544-A-3), using monostyrene as thinner, cobaltoctate as accelerator and cyclonox as catalyser. After hardening the samples were cut, mounted on glass and then ground and polished to a thickness of about 20 µm. The thin sections, one from each block, were studied at low (6.3 - 32 x) magnification under a „Wild Photo Makroskop M400".

Although the samples were studied primarily from a sedimentological point of view, the description of the thin sections follows the terminology developed in pedology (BREWER, 1976

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Manuscript received 16 June 1993; accepted 28 July 1993.

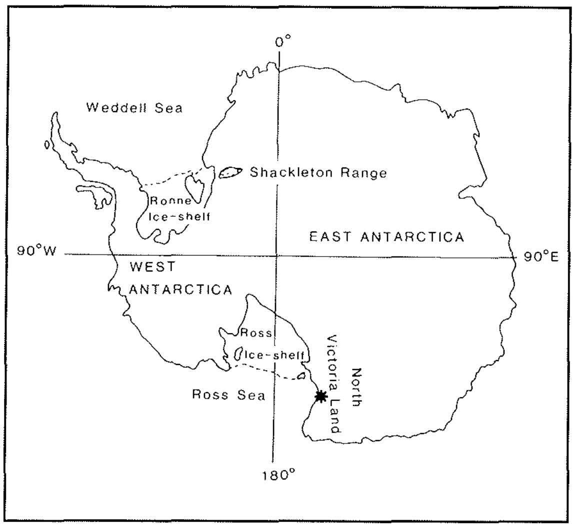


Fig. 1: General location map of Antarctica, showing position of the Shackleton Range and North Victoria Land. The asterix indicates the Nansen Ice Shelf in North Victoria Land.

Abb. 1: Übersicht über die Antarktis mit Lage von Nord-Victoria-Land und der Shackleton Range. Der Stern bezeichnet die Lage des Nansen-Schelfeis in Nord-Victoria-Land.

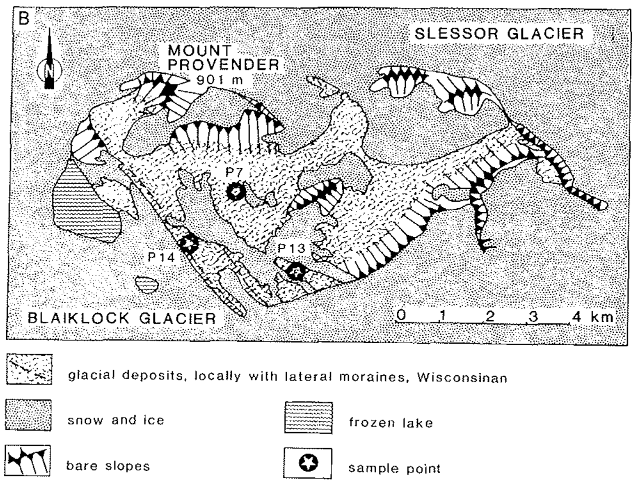


Fig. 2: Detailed location map of Shackleton Range with sampling localities (for overview see Fig. 1).

Abb. 2: Detailkarte der Shackleton Range mit Lage der Probenpunkte (Übersicht siehe Abb. 1).

BULLOCK et al 1985). The reasons for this have been outlined before (VAN DER MEER 1987, 1993).

FIELD SITES

Four samples were collected at three sites in the neighbourhood of Mt. Provender, a 901 m high mountain in the NW part of the Shackleton Range (Fig. 2). This mountain top is located along the Slessor Glacier, which is a tributary to the Filchner Ice-shelf. An ice- and snow-free valley extends S and SE of Mt. Provender. This valley is surrounded by mountains and glaciers and only opens up to the Blaiklock Glacier in the west. The valley bottom is covered by glacigenic deposits, which range from scattered erratics, through a continuous cover of erratics to tills that are several metres thick. The samples were collected from the latter. Samples P14A + B were collected in the nonfrozen part of the face of a snow-filled gelifluction gully (Fig. 3). The face itself is 1.2 to 1.4 m high. Long-axis clast fabric analyses below the sampling depth resulted in a NNW-SSE orientation. This orientation is more or less parallel to the slope and is probably a reliable indicator of ice-movement in this area. This glacigenic material must have been deposited in the geologically recent past, because at the surface there are numerous easy-to-weather erratics (on the Antarctic scale; see CAMPBELL & CLARIDGE 1987), which, moreover, still carry striae. Comparison with data on the Ross Drift (DENTON & HUGHES 1981, CHINN et al 1989) in the coastal areas of North Victoria Land revealed that the Mt. Provender material must be of the same age (Höfle unpubl. data).

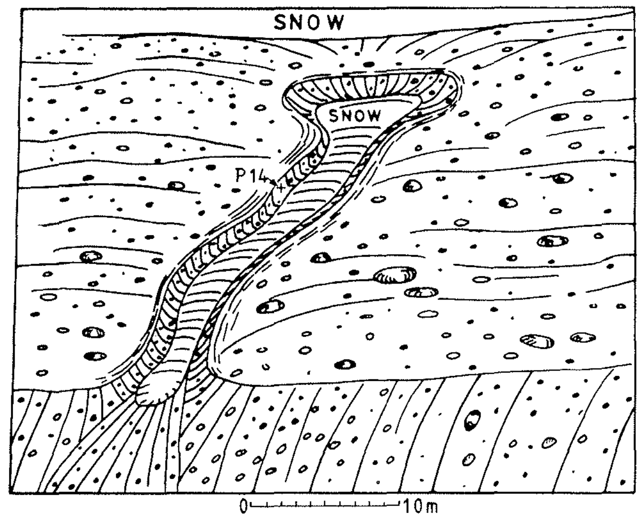


Fig. 3: Sketch showing surroundings of sampling locality P14.

Abb. 3: Schemazeichnung der Umgebung des Probenpunktes P14.

During the Wisconsin both the Ross and the Filchner Ice-shelves expanded up to 600 km to the North, as a response to sea-level lowering. This extension caused thickening of the shelf ice and consequently blocking of the tributary glaciers. In the end this led to thickening of the latter as well. As the Slessor and Blaiklock Glaciers are located only 10 km from the Filchner Ice-shelf, the (proven) thickening of the glaciers at Mt. Provender amounted to more than 300 m. The thickening in turn caused deposition of tills, which are known as the Blaiklock Drift.

Texturally the tills are typical diamictons with grain size ranging from loamy sand to sandy clay loam. Samples were collected from the more silty and clayey tills in the western part of the Mt. Provender area (Fig. 2). X-ray analyses of five separate (bulk) samples from the eastern part of the distribution area of the Blaiklock Drift showed quartz, muscovite/illite and chlorite as main components, with feldspars and calcite as additional minerals.

The fifth sample (thin section Mi.316) was collected on a „medial moraine" on Inexpressible Island on the Nansen Ice-shelf

(Terra Nova Bay, North Victoria Land; Fig. 1). Actually the sampling site is an approximately 80 cm high ridge consisting of material that has apparently been squeezed up through a crevasse, as there is no other source. Particulars on the samples are given in Table 1.

DESCRIPTION

In describing thin sections the observed features can be grouped under several headings: texture, structure, plasmic fabric, and postdepositional changes (VAN DER MEER 1987). We list our observations following these headings (Tab. 2).

sample number	thin section	sampling depth (cm)	height above sea level	comments
Inexpressible Island, Nansen Shelf				
—	Mi.316	surface		„medial moraine“
Mt. Provender, Shackleton Range				
P7B	Mi.312	10-20	490 m	till
P13B	Mi.313	10-15	395 m	till
P14A	Mi.314	60-70	≈ 350 m	gelifluctedtill
P14B	Mi.315	70-80	≈ 350 m	gelifluctedtill

Tab. 1: Origin and particulars of samples.

Tab. 1: Herkunft der Proben und allgemeine Daten.

	texture[1]				structure[3]				plasmic fabric[4]					postdepositional[5]					
thin section	size	shape[2]	distri-bution	compo-sition	pores	compound peb	compound par	compound lin	Sk	La	Om	Bi	Un	calc is	calc det	arg is	arg pap	sil	Fe
Mi.312	< 1 cm	R	even	sandstone siltstone shale limestone	compound packing voids	X	X	–	X	X	–	–	–	X	–	X	–	–	–
	100 µm	R-A		quartz															
Mi.313	< 1 cm	SA-A	uneven	sandstone siltstone limestone crystalline	compound packing voids + channels	X	–	–	X	X	–	X	–	X	X	–	–	X	–
	< 300 µm	SA		quartz															
Mi.314	< 6 mm	R-SA	uneven	sandstone siltstone Limestone	(mammilated) vughs	(X)	–	X	(X)	(X)	X	–	–	X	X	X	X	–	X
	< 300 µm	R-A		quartz															
Mi.315	< 1,5 cm	R-SA	uneven	sandstone limestone crystalline	craze planes + mammilated pores	X	X	–	X	–	–	–	–	X	–	X	?	X	X
	< 1000 µm	R-SA		quartz															
Mi.316	< 1 cm	R-SA	even	sandstone crystalline	planes	X	–	X	X	X	–	–	X	–	–	X	–	X	–
	> 100 µm	WR-A		quartz															

Tab. 2: Summary of micromorphological observations. [1] entries for texture are differentiated for gravel and material <2 mm, [2] WR = well rounded, R = rounded, SSA = sub-angular, A = angular; [3] peb = pebble structure, par = parallel structure, lin = linear structure; [4] Sk = skelsepic, La = lattisepic, Bi = bimasepic, Om = omnisepic, Un = unistrial plasmic fabric; [5] calc = calcitan, is = in situ, det = detached, arg = argillan, pap = papule.

Tab. 2: Zusammenfassung der mikromorphologischen Beobachtungen. [1] Angaben für Korngrößen sind differenziert nach Kies und Material <2 mm; [2] WR = gut gerundet, R = gerundet, SA = sub-angular, A = eckig; [3] peb = Bröckchengefüge, par = Parallelgefüge, lin = Lineargefüge; [4] Plasmagefüge: Sk = skelsepic, La = lattisepic, Bi = bimasepic, Om = omnisepic, Un = unistrial; [5] calc = Calcitfällungen, is *in situ*, det = losgelöst, arg = Tonhäutchen, pap = Knötchen.

All the samples are characterised by a wide variety of grain sizes. Because of the actual size of the samples (max. 5 x 9 cm), large gravel particles and stones are not represented and thus cannot be used for comparison. However, gravel particles up to 1.5 cm are present. Differences in size between individual skeleton particles within the matrix are better suited for inter sample comparison (Figs. 4A through to 8A). It is then clear that the samples are all different. The dominant size of the skeleton particles in these samples usually starts at about 100 μm (Tab. 2). In sample Mi.312 (Fig. 4) this is actually the dominant grain size, while in the other samples larger grains are equally well represented. Sample Mi.315 (Fig. 7) shows the greatest variety in grain size in that not only the gravel particles reach up to 1.5 cm, but also sand grains up to 1 mm are distinctly present.

The shape of the gravel particles ranges from sub-angular to rounded (Tab. 2), the latter being dominant. In smaller grains the range may be the same, but it is quite obvious that sub-angular grains are more common.

Compositionally there is not much variety since most of the smaller grains consist of quartz, while the gravel particles in every sample are dominated by sand- and siltstones, except Mi.315 where siltstone is absent. Limestone is only absent in sample Mi.316, while crystalline rock types are present in three samples (Tab. 2).

The areal distribution of skeleton grains is uneven in most thin sections, which implies that also the distribution of the fine matrix or plasma is uneven. Only sample Mi.312 (Fig. 4) seems to show an even distribution of coarse and fine grained material.

The structure of the samples relates to the organisation of primary particles into larger units, separated by planes of weakness. In this sense the most obvious structure in these samples is the arrangement of oval to rounded pebbles (or in micromorphological terms nodules, BREWER 1976, 266-282), mainly consisting of fine matrix material (Tab. 2) The term pebbles is used in a descriptive sense in analogy to „clay pebble" (VAN DER MEER 1987). The size of these pebbles never exceeds 7 mm, and is usually several mm smaller. Although Figure 4C might give the impression that the partly welded pebbles (0.6-2 mm in diameter) are related to fecal pellets, this is not the case given the large variation in size and the absence of soil fauna.

The pebbles themselves are delineated by (almost) continuous pores, which can only be described as compound packing voids. Only sample Mi.314 (Fig. 6) does not obviously show this pebble structure. However, it does give the impression of welded or condensed pebbles (Fig. 6C). The pores in this sample must be described as vughs, partly of a mammillated nature (example in Fig. 8C), which suggests the former occurrence of vesicles. Partly it may also be the result of the still surviving remnants of compound packing voids, partly rounded due to the shape of the surrounding pebbles. Also sample Mi.316 occasionally gives the impression of welded, at least flattened pebbles (Fig. 8D).

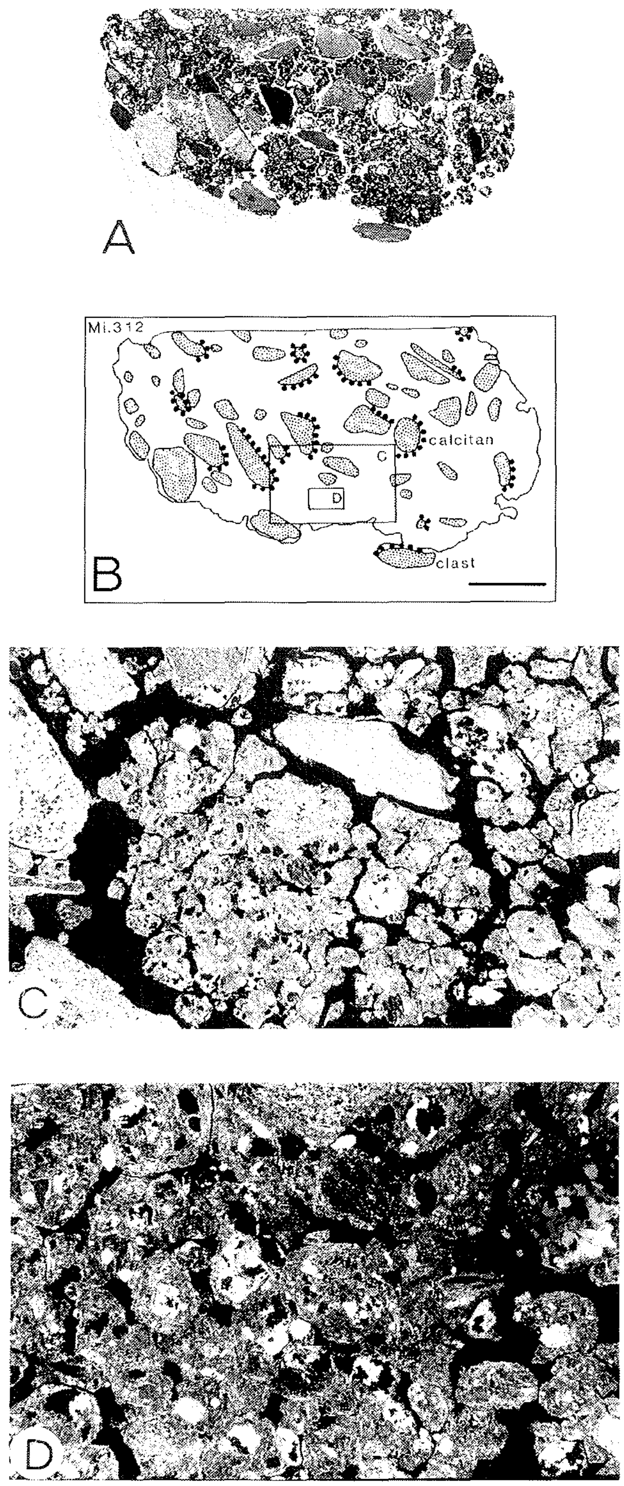
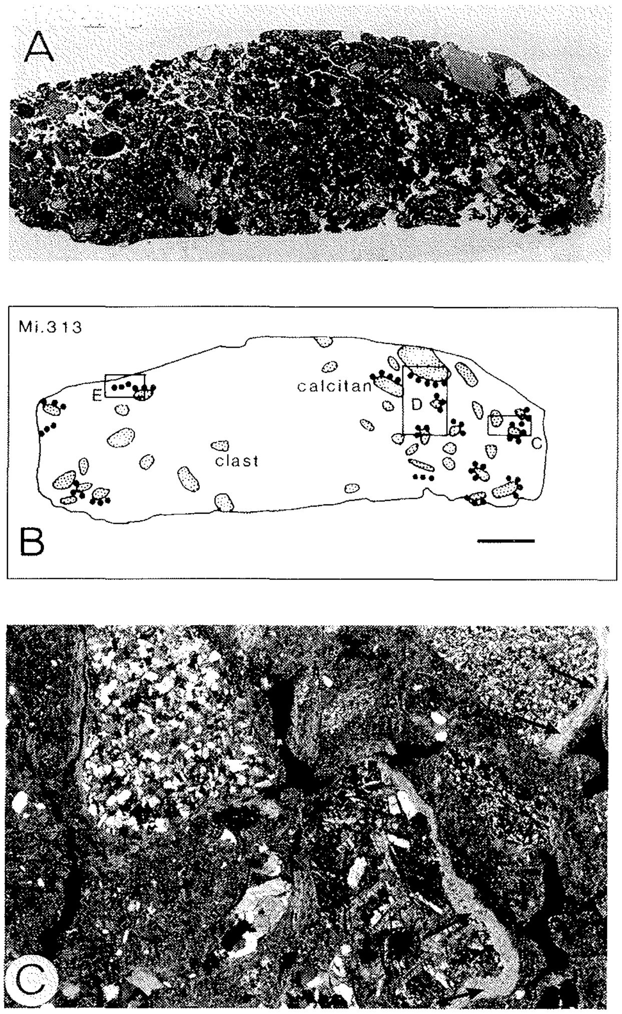


Fig. 4: Sample Mi.312. (**A**) Whole thin section, seen in plane light. (**B**) Sketch of thin section, dotted lines represent calcitans; rectangles show position of figures (C) and (D), bar indicates 1 cm. (**C**) Detail (width of view is 18 mm) of pebble structure, cross-polarised light. (**D**) Detail (width of view is 5.1 mm) of figure (C), showing latti-skelsepic plasmic fabric; cross-polarised light; voids are black.

Abb. 4: Probe Mi.312. (**A**) Dünnschliff in einfach polarisiertem Licht. (**B**) Schemazeichnung des Dünnschliffs; punktierte Linien zeigen Calcitfällungen; Rechtecke verweisen auf Abbildung (C) und (D); Maßstab ist 1 cm. (**C**) Ausschnitt (Bildbreite 18 mm) der Aggregatstruktur, mit gekreuzten Nicols. (**D**) Ausschnitt (Bildbreite 5,1 mm) von Abb. C mit lattisepischem Plasmagefüge; gekreuzte Nicols, Hohlräume erscheinen schwarz.



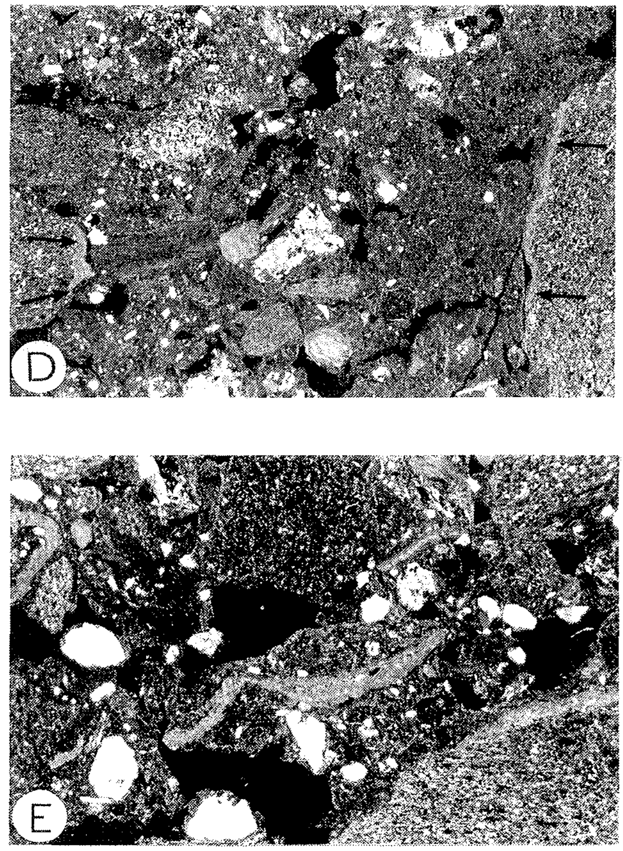


Fig. 5: Sample Mi.313. (**A**) Whole thin section, seen in plane light. (**B**) Sketch of thin section, dotted lines represent calcitans; rectangles show position of figures (C), (D) and (E); bar indicates 1 cm. (**C**) Detail (width of view is 5.1 mm) showing calcitans (arrows) on gravel particles; cross-polarised light. (**D**) Detail (width of view is 11.2 mm) showing calcitans (arrows) on opposed faces of gravel particles; cross-polarised light. (**E**) Detail (width of view is 8 mm) showing detached calcitan in centre and calcitans on gravel particles; cross-polarised light.

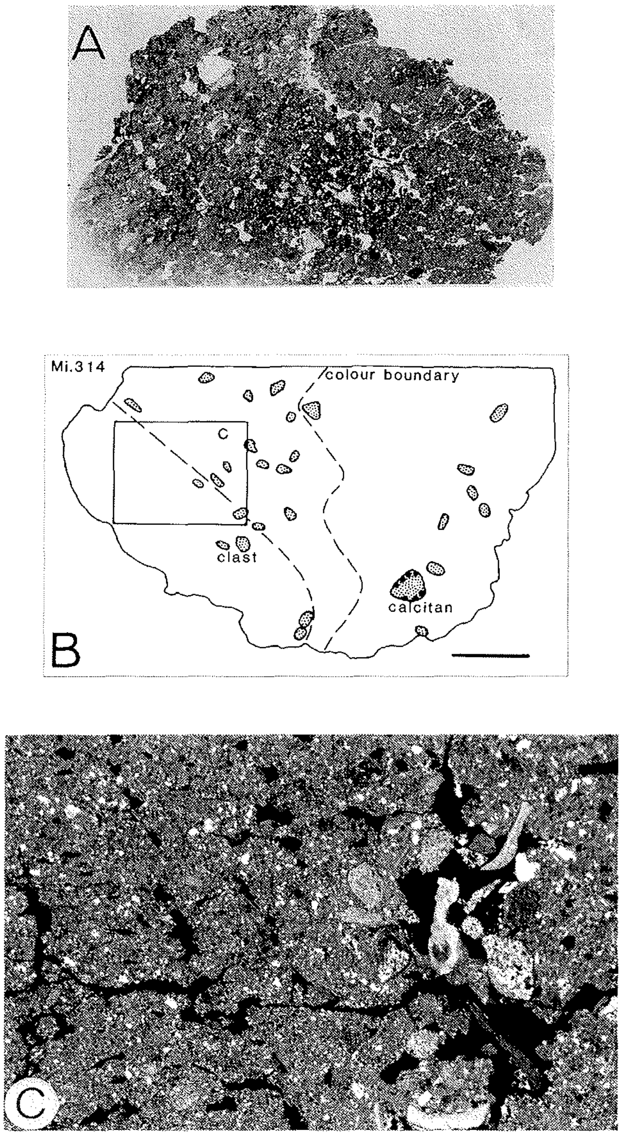
Abb. 5: Probe Mi.313. (**A**) Dünnschliff in einfach polarisiertem Licht. (**B**) Schemazeichnung des Dünnschliffs; punktierte Linien zeigen Calcitfällungen; Rechtecke verweisen auf Abbildungen (C), (D) und (E); Maßstab ist 1 cm. (**C**) Ausschnitt (Bildbreite 5,1 mm) mit Calcitfällungen (Pfeile) auf Kiespartikeln; gekreuzte Nicols. (**D**) Ausschnitt (Bildbreite 11,2 mm) mit Calcitfällungen (Pfeile) auf einander gegenüberliegenden Kiesoberflächen. (**E**) Ausschnitt (Bildbreite 8 mm) mit losgelösten Calcitfällungen im Zentrum und auf Kiespartikeln; gekreuzte Nicols.

Although the pebble structure is very obvious in four of the samples, it does not mean that it is the only structure (Tab. 2) that can be discerned. Two of the samples (Mi.312 and Mi.315) show clear enough evidence for a lining up of (silt) particles parallel to the surface of larger grains, indicating a mutual relation (VAN DER MEER 1993). Two other samples (Mi.314 and Mi.316) locally show a linear, subparallel pattern in the distribution of skeleton grains.

Altogether the structure of the Antarctic samples is very clear; in the micromorphological literature on tills there are to be found few other examples of such a strong arrangement of primary particles.

The next group of features relates to the presence and expression of oriented domains, which refers to small clusters of aligned clay particles. Because of this alignment the clusters show clear interference colours (often referred to as birefringence, BREWER 1976) when viewed under cross-polarised light. In the arrangement of such domains as well as their relation to the larger skeleton grains (the plasmic fabric) a number of fixed patterns can be recognised (BREWER 1976). The most common pattern in the five samples under consideration is the skelsepic plasmic fabric (Tab. 2; Fig. 4D). This pattern, in which the clay domains are oriented parallel to the surface of skeleton grains, is found in all samples and very strongly expressed in four out of the five. The exception is Mi.314, the sample that did not show a clear pebble structure. On the other hand this was the only sample to show a (strongly developed) omnisepic plasmic fabric, which means that all the plasma shows clear interference colours in a random, complex striated orientation pattern. In almost all the samples, the skelsepic plasmic fabric is associated with an equally strong development of a lattisepic plasmic fabric. Actually the term should be latti-skelsepic plasmic fabric (Fig. 4D), because the orientation parallel to skeleton grains is more obvious than the closely associated lattice pattern.

Two of the five samples show, besides the plasmic fabrics described above, still another type of fabric. Sample Mi.313 shows a well developed bimasepic plasmic fabric, indicating that there are striated orientation patterns which cut each other under a



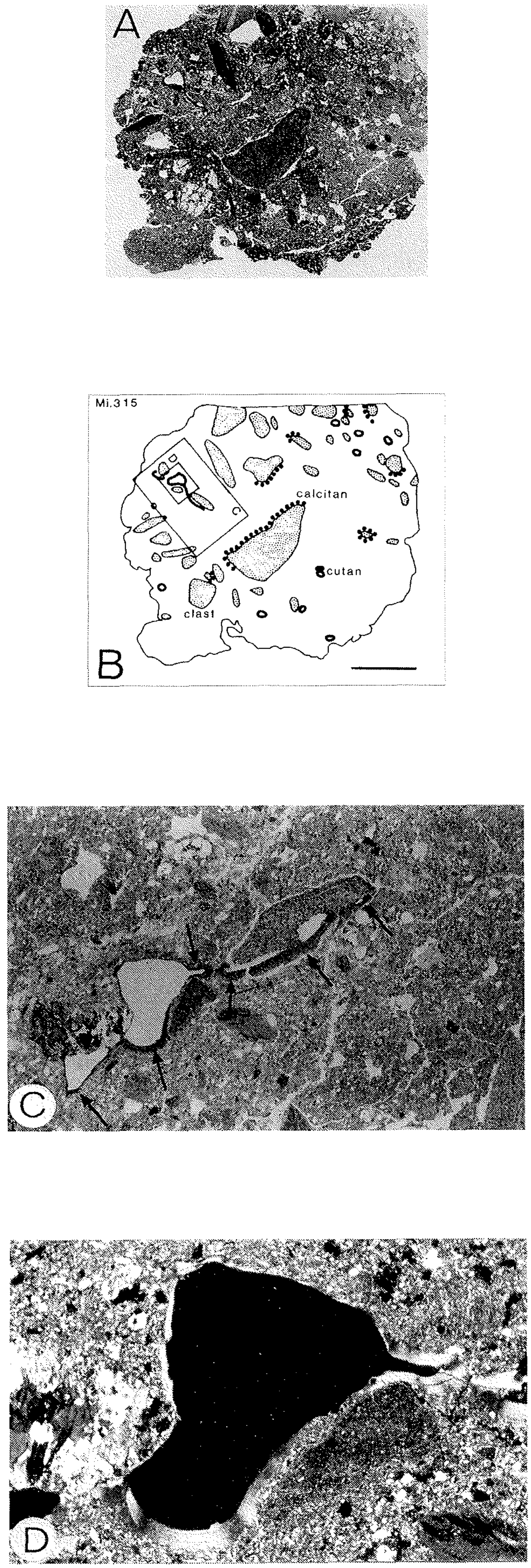


Fig. 6: Sample Mi.314. (**A**) Whole thin section, seen in plane light. (**B**) Sketch of thin section, dotted line represents calcitan; rectangle shows position of figure (C); bar indicates 1 cm. (**C**) Detail (width of view is 18 mm) showing suggested welded pattern of pebbles, notice detached calcitans; cross-polarised light; voids in black.

Abb. 6: Probe Mi.314. (**A**) Dünnschliff in einfach polarisiertem Licht. (B) Schemazeichnung; punktierte Linien zeigen Calcitfällungen; Rechteck verweist auf Abb. (C), Maßstab 1 cm. (**C**) Ausschnitt (Bildbreite 18 mm) mit vermutlich verschmolzenen Aggregatstrukturen; losgelöste Calcitfällungen; gekreuzte Nicols, Hohlräume erscheinen schwarz.

Fig. 7: Sample Mi.315. (**A**) Whole thin section, seen in plane light. (**B**) Sketch of thin section, dotted lines represent calcitans, heavy lines cutans; rectangles show position of figures (C) and (D); bar indicates 1cm. (**C**) Detail (width of view is 18 mm) showing ferri-argillans in pores and underneath gravel particle (arrows); plane-polarised light. (**D**) Detail (width of view is 5.6 mm) of figure (C) showing clear interference in ferri-argillan, note laminated nature of the argillan; cross-polarised light.

Abb. 7: Probe Mi.315. (**A**) Dünnschliff in einfach polarisiertem Licht. (**B**) Schemazeichnung, punktierte Linien zeigen Calcitfällungen, fette Linien Tonhäutchen; Rechtecke verweisen auf Abbildungen (C) und (D); Maßstab 1 cm. (**C**) Ausschnitt (Bildbreite 18 mm) mit Tonhäutchen in Hohlräumen und unter Kiespartikeln (Pfeile); einfach polarisiertes Licht. (**D**) Ausschnitt (Bildbreite 5,6 mm) von Abb. (C) mit deutlicher Interferenz in laminierten Tonhäutchen, gekreuzte Nicols.

small angle. On the other hand sample Mi.316 exhibits such patterns in one direction only, a fabric that can be described as masepic (unistrial), reflecting shear.

The final group of observations relates to postdepositional changes. Such features are widespread in these samples, and they all concern the relocation of material (Tab. 2).

With the exception of sample Mi.316 the samples show clear evidence of the translocation of carbonates. Many of the gravel particles bear a discontinuous coating (calcitan) of secondary $CaCO_3$ (Figs. 4B, 5B-D, 6B) originally formed as pendents (BULLOCK et al 1985, 99-100). In two samples (Mi.312, Fig. 4B and Mi.315, Fig. 7B) these occur throughout the sample, while in Mi.313 (Fig. 5B) it is only found in the extreme ends of the sample. Sample Mi.314 (Fig. 6B) displays only one particle, which has a calcitan on two sides. In this sense it is different from the other coatings, because usually these are restricted to one side of the gravel particles only. It is very clear that the discontinuous coatings do not systematically occur on the same side of the gravel particles, i.e. it is no longer possible to use it for discerning top from bottom. Apparently the calcitans are not attached very strongly to the gravel particles either, because three of the samples show also detached coatings (Fig. 5E).

Most surprising in these samples is the occurrence of illuviated clay in the shape of clay cutans or ferri-argillans (Figs. 7C and D). Argillans are well known from temperate latitudes, where they are related to the translocation of clay after dispersion by humic acids in (mainly decalcified) soils. And although it is not completely unknown from the dry and cold environment of Antarctica (MACNAMARA 1969), the amount of clay illuviation in our samples is astonishing.

Only sample Mi.314 does not show any argillans, while it is a rather weak feature in sample Mi.312. The remaining three samples show well developed, continuous and sometimes laminated (illuviated) argillans. Sample Mi.314 (and possibly Mi.315) also contain reworked and broken argillans, which are known as papules, and which have been incorporated in the pebbles.

Samples Mi.313 and Mi.315 and to a lesser extent also Mi.316, demonstrate that translocation was not restricted to the finest grain size only. All three show evidence of the mechanical translocation of silt by meltwater. In sample Mi.315 this happened in close association with the clay illuviation, while in Mi.313 silt has accumulated on top of some calcitans.

Finally samples Mi.314 and Mi.315 show the presence of precipitates of iron (Fe-nodules). In sample Mi.315 small Fe-specks display either diffuse or sharp boundaries. The latter may indicate redistribution of Fe-impregnated material.

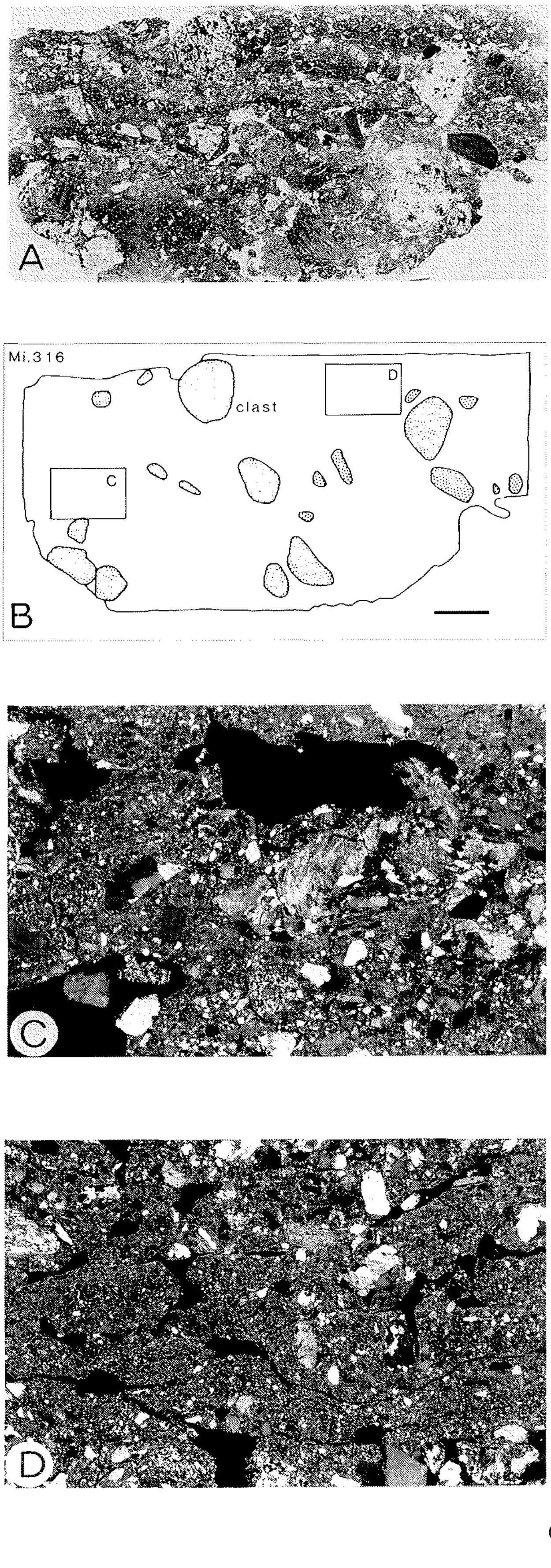


Fig. 8: Sample Mi.316. **(A)** Whole thin section, seen in plane light. **(B)** Sketch of thin section; rectangles show position of figures (C) and (D); bar indicates 1 cm. **(C)** Detail (width of view is 11.2 mm) showing mammillated vughs; cross-polarised light; voids in black. **(D)** Detail (width of view is 11.2 mm) showing flattened nature of pebbles in this sample; cross-polarised light.

Abb. 8: Probe Mi.316. **(A)** Dünnschliff in einfach polarisiertem Licht. **(B)** Schemazeichnung; Rechtecke verweisen auf Abb. (C) und (D); Maßstab 1 cm. **(C)** Ausschnitt (Bildbreite 11,2 mm) mit warzigen Höhlungen; gekreuzte Nicols; Hohlräume erscheinen schwarz. **(D)** Ausschnitt (Bildbreite 11,2 mm) mit abgeflachten Aggregatstrukturen; gekreuzte Nicols.

DISCUSSION

When we want to discuss the genesis of the samples under consideration we may first look at their properties described under texture. The variety of grain sizes and lithologies indicate that they are diamictons. As diamictons can originate in a multitude of ways (e.g. by slump) it is the glacial setting of the samples which indicates that these diamictons must be regarded as tills.

The pebble structure as described here, has been found before in a weaker form in tills in temperate areas. In those instances the pebbles have been interpreted as a primary feature of tills, caused by subglacial movement in a deformable bed (VAN DER MEER 1987, 1993, unpubl. data). However, in the samples from the Antarctic there are observations which point to a different origin, i.e. the occurrence of postdepositional changes like calcitans and argillans.

It should be noted that the occurrence of clay and carbonate translocation is not exclusively a postdepositional process. Subglacial deposition of carbonates on bedrock has been described from a number of localities (AHARON 1988 cum lit.), while illuviation of clay has also been interpreted as a subglacial process (MENZIES 1986). According to KUBIËNA (1971) carbonate needles (not observed in these samples) occurred between 30 and 70 cm in soils in South Victoria Land. The fact that the carbonate coatings do not systematically occur on the same side of gravel particles (CAMPBELL & CLARIDGE 1987, p. 264), but instead show different orientations, demonstrates that the gravel particles have experienced movement subsequent to the formation of the calcitans. Thus, even if the calcitans had been formed subglacially the subsequent movement of the gravel particles, also demonstrated by the detached calcitans, implies that the observed structure of the samples is a postdepositional feature. This is further substantiated by the observations on argillaceous papules (broken, detached and redeposited argillans) and sharply bounded Fe-nodules, in combination with the pebbles.

Thus there is very strong evidence for postdepositional disturbance of the sediments, which are then most likely to be of a periglacial nature. This is in accordance with micromorphological observations by VAN VLIET-LANOË (1985) and VAN VLIET-LANOË & COUTARD (1984), who described a gelifluction fabric consisting of well-rounded aggregates with a silty cap on several faces. The origin of this structure is attributed to rotational movement of temporarily supersaturated material, associated with large displacements as can be observed in gelifluction lobes (VAN VLIET-LANOË 1985) and VAN VLIET-LANOË & COUTARD (1984). We have to assume then that such conditions do occur in the Shackleton Range and on the Nansen Shelf. Samples Mi.314 and Mi.315 were collected in a gully in a gelifluction lobe (Tab. 1), but Table 2 demonstrates that the upper sample (Mi.314) does not display the expected pebble structure (although there is the suggestion of welded pebbles). This sample does contain mammillated vughs, possibly indicating the former presence of vesicles, as well as detached calcitans and (argillaceous) papules. These, in combination with the absence of a clear structure, are exactly the features described by VAN VLIET-LANOË (1985, p.141) as being indicative of mudflow. Thus samples Mi.314 and Mi.315 can be interpreted as indicating a mudflow deposit (Mi.314) overlying a geliflucted till (Mi.315). This could also explain the difference in incorporated lithologies (Tab. 2). This is not contradicted by the clast fabric (see above), because this was measured below the sampling depth of the thin sections. The implication of all these observations is that, except for the texture, none can be regarded as a primary feature of the tills under consideration. The presence of a pebble structure in tills can be the result of periglacial activity, the difference with primary (subglacial) pebble structures in tills lies in the nature of the planes of weakness or pores. As a primary feature of tills these display a less continuous pattern (VAN DER MEER 1987, 1993) and cannot - as in the Antarctic samples - be described as compound packing voids. As in a deformable bed there is limited space for the till to dilate, especially so in comparison to periglacial processes occurring at or near the surface, the primary pebble structure in tills is much more compact. This difference enables dilferentiation between analogous structures.

The development of the plasmic fabrics in the samples from the Antarctic is much stronger than any observed in tills before. Several hundred thin sections of tills from most glaciated areas in Western Europe, including Spitsbergen, as well as from Argentina, do not demonstrate this strong development. And this includes samples that have demonstrably been influenced by (postdepositional) periglacial activity (VAN DER MEER 1987, 1993). We must thus conclude that the periglacial environment in (North Victoria Land) Antarctica are such that through the development of a strong stress field they produce a very strong reorientation of clays. It is most obvious to look for non-incidental freeze/thaw and/or wetting/drying processes as the primary sources for such a stress field.

The observed plasmic fabrics demonstrate that rotation has been more important than planar movement. The prominent latti-skelsepic fabrics must be ascribed to rotational (circular to ellipsoidal) movement (JIM 1990), since the clay-mineralogical analyses shows the absence of swelling clays (LAFEBER 1964, VAN DER MEER 1993). On the other hand, the much less prominent masepic (unistrial) and bimasepic plasmic fabrics are related to shear-induced planar movements (VAN DER MEER 1987, 1993, unpubl. data).

All this leaves us with the presence of the illuviation argillans. These clearly indicate that percolating water, the carrier of the clay, is not uncommon in surficial sediments in this part of the Antarctic. The fact that the clays do go in dispersion relatively easily can be caused by the high dielectric property of (snow) meltwater (VAN VLIET-LANOË 1985, p. 131) as well as by the presence of salts, as is common in soils in the Transantarctic Mountains (CAMPBELL & CLARIDGE 1987 p. 256). Also KUMAI et al (1976) identified with energy dispersion X-ray analysis (EDAX) various chloride minerals on the surface of clay platelets in moraines of Beacon and Lower Wright Valleys of South Victoria land. They explained the presence of chloride as the result of sea spray and wind, chloride acting as nuclei of snow crystals. The chloride minerals were left on the soil after sublimation of the snow. Similarly KUBIËNA (1971) detected sodium chloride crystals in thin sections from Wright Valley. MACNAMARA (1969) explained the origin of illuviation cutans in soils in Enderby Land as caused by spring meltwaters descending through and supersaturating the zone immediately above the frost table. On the other hand KUBIËNA (1971) mentioned that polygenetic soils were characterised by the inclusion of mud „dating from older and warmer geologic periods", by which he meant the formation of clay drapings on sand grains.

As the number of papules is fairly small, the presence of largely undisturbed argillans seems to imply that the argillans are younger than the pebble structure. If this is the case it would have consequences for the occurrence of freeze/thaw cycles with gelifluction (causing the pebble structure) as opposed to percolating water (causing argillans). We feel however, that for such deductions the number of samples as well as the size of the samples is too small and must await further studies.

CONCLUSIONS

Gelifluction of till on the gently sloping nunataks in the Shackleton Range as well as of medial moraine material on the Nansen Shelf leads to a very strong development of a pebble structure, or a gelifluction fabric *sensu* VAN VLIET-LANOË (1985) and VAN VLIET-LANOË & COUTARD (1984).

This pebble structure is associated with a very strong development of the plasmic fabric. The fabric is usually but not exclusively of the latti-skelsepic type, which is associated with a rotational movement of sediment particles and aggregates (e.g. JIM 1990).

Rotational movement of the particles is also evidenced by the position of calcitans on gravel particles. Such calcitans form at the base of a particle (CAMPBELL & CLARIDGE 1987) and are now found in all directions.

Clay illuviation both in sediments on nunataks and in medial moraine sediments on Nansen Shelf is common, suggesting that downward movement of water carrying dispersed clay during some time of the year (spring and/or summer) is an important process.

The micromorphological observations indicate that the structure of the sediments under observation is completely of a periglacial nature, which has superseded the original (glacial) structure. They furthermore demonstrate the successive occurrence of ascending or descending water (carbonate crusts), saturated conditions (pebble structure and plasmic fabric) and percolating water (illuviation cutans). The consequence must be that the areas where the samples were collected may have experienced distinct phases of differing (micro-?) climatic conditions and associated landscape development.

The amount of relocation as observed in the samples considered here indicates that the material from which they were taken can also be considered as soils (*sensu* CAMPBELL & CLARIDGE 1987) and no longer as primary sediments.

ACKNOWLEDGEMENTS

The authors would like to thank Cees Zeegers for making the thin sections, Frans Bakker for preparing the ilustrations and the X-ray Laboratory of the Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, for providing clay mineralogical data.

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