Heavy minerals in sandur deposits from the forefield of the Scott Glacier, Wedel Jarlsberg Land, Spitsbergen

ABSTRACT: Heavy minerals in sandur deposits from the forefield of the Scott Glacier present a very poor set (mainly zircon, tourmaline and rutile), concentrated exclusively in the finest fractions – less than 0.1 mm. They are very strongly crumbled and sharp-edged. These characteristics are specific for contemporary sandur deposits and considerably different from past sandur deposits, e.g. the Pleistocene ones in northeastern Poland. Presence of amphiboles in a detrital fan proves additional source of material and different transport.

Key words: Arctica, Spitsbergen, heavy minerals, sandur deposits.

Introduction

This paper continues presentation of the results of studies of sandur deposits in the southern Bellsund region of Spitsbergen (Chlebowski 1991). It concerns sandur deposits in the forefield of the Scott Glacier (Fig. 1).

The first study of heavy minerals from sandur deposits in the forefield of the Renard Glacier suggested considerable depletion of these minerals and also, that some regularities could be defined by the most resistant components. These regularities could result from mineralogical components, specific for contemporary sandur deposits, which make possible distinguish them from the Pleistocene counterparts (Chlebowski 1991). The present study of sandur deposits is based on zones distinguished at the 1:10 000 map (Szczęsny et al. 1989) in the forefield of the Scott Glacier. It allows for several generalizations and provides more arguments to the previous suggestions (cf. Chlebowski 1991).
The samples were collected in the same way as in the case of deposits in the forefield of the Renard Glacier (Chlebowski 1991) during the 3rd Polar Expedition organized by the Maria Curie-Skłodowska University in Lublin in 1988.

Description of the forefield of the Scott Glacier

In the forefield of the Scott Glacier there are deposits of extramorainal sandurs, distinguished on the photogeological map of glacier forefields in the Bellsund region (Szczęsny et al. 1989). They are located similarly as in the case of the Renard Glacier, i.e. in forefield of the terminal moraine in front of the glacier snout. The sandur deposits form a relatively narrow strip; they fill a valley train with steep slopes, cut perpendicularly into the raised marine beaches. Meltwater streams coming out of the glacier, flow down this valley directly into a sea. At the present beach close to the inlet to the fiord, there is an extended conical alluvial rampart, composed of redeposited sandur and beach deposits.

Just as in the case of the forefield of the Renard Glacier (cf. Chlebowski 1991), in this very area there is also a very intensive supply of weathering waste from mountain massifs that surround the glacier. These massifs are composed of the Precambrian metamorphic rocks (Flood et al. 1971). Weathering waste of these rocks (tillites, quartzites, phyllites and dolomites) is the major material of the terminal moraine of the Scott Glacier. This moraine has been intensively washed out by meltwaters, flowing into the glacier forefield where deposition occurred in the aforementioned valley.

The supply and transport of material are also enhanced by streams flowing down from high terraces, and making flow dynamics and local material transport grow substantially. The flow is very impetuous and a transport route is very short. Glacial waters, enhanced by numerous meltwater streams, intensively drag and roll a rock material. In practice, this material is deposited without any sorting in forefield of the terminal moraine. The water flow and the transport of dragged rock material are particularly impetuous during intensive glacial ablation in short melt seasons. In turn, in seasonal and also daily periods with varying temperature, the water which fills all fissures and cracks freezes fast, leading to intensive disintegration of rock material. Quantity and type of clastic material i.e. size and sharp-edged nature of rock fragments transported over very short distances, indicate the higher than standard transport capacities of fast flowing proglacial rivers (Klimek 1972). In fact, large volume of water flowing out a glacier snout carries both the material washed out from moraine ramparts at the glacier front and weathering mountain slopes, and the melted out from ice and washed out from terrace deposits. This material is distinctly angular and non-sorted; moreover, the finest fractions are washed out and transported over a short distance, out of the mainstream of the flowing water, to be deposited at point-bar ridges behind and between rock fragments, where flow dynamics and
transport force drop significantly. The fine-grained fractions of clastic material come from the transported material, which is crushed due to turbulence of the flowing water and seasonally, is subjected to frost disintegration.

As a result of very intensive disintegration and crumbling of rock blocks and pieces, a set of heavy minerals is commonly deposited in the finest fractions. Due to their specific gravity they reach occasionally distinct concentrations in ridges behind obstacles i.e. sheltered by larger rock fragments that form partly a thick-fragmented sandur material.

Mineralogical studies of the finest fractions of sandur deposits in which there are agglomerations of heavy minerals were carried through not only to identify them but above all, to determine their morphological features. In fact, composition of the heavy minerals fractions and their morphological features seem to be the most peculiar for deposits, formed by fast and short transport in a dynamic meltwater environment in front of a glacier.

Composition and characteristics of heavy minerals

Analyses of heavy minerals were performed on fractions below 0.1 mm (mainly 0.1–0.05 mm), recognized as the most relevant for a set of heavy minerals in different environments with deposition of fine-grained sands and silts (Chlebowski and Lindner 1976, Chlebowski 1991). The larger fractions present in contemporary sandur deposits either contain no heavy minerals at all or they are single, completely accidental grains of these minerals only.

Assemblage of heavy minerals (Table 1) is characteristic for metamorphic rocks and resembles mineral composition of sandurs deposits in forefield of the Renard Glacier (Chlebowski 1991). The Renard and Scott Glaciers are separated from each other by the same mountain ridge built of metamorphic rocks which are a common source of a weathering waste for lateral and terminal moraines of these

<table>
<thead>
<tr>
<th>No.</th>
<th>Fraction [mm]</th>
<th>Transparent heavy minerals (in %)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Zircon</td>
</tr>
<tr>
<td>1</td>
<td>0.1–0.05</td>
<td>89.9</td>
</tr>
<tr>
<td>2</td>
<td>0.1–0.05</td>
<td>90.5</td>
</tr>
<tr>
<td>3</td>
<td>0.1–0.05</td>
<td>81.7</td>
</tr>
<tr>
<td>4</td>
<td>0.1–0.05</td>
<td>94.8</td>
</tr>
<tr>
<td>5</td>
<td>0.1–0.05</td>
<td>95.8</td>
</tr>
<tr>
<td>6</td>
<td>0.1–0.05</td>
<td>89.6</td>
</tr>
</tbody>
</table>

Samples 1–5 were collected from extramorainal sandur deposits, and sample 6 – from alluvial fan deposits.
glaciers. The finest sand and silt fractions with sets of heavy minerals are derived from rocks of the surrounding mountain massifs and their weathering waste. Zircon predominates in all examined samples (nos 1–5), collected from sandur deposits. It is followed by rutile, tourmaline and epidotes. In turn pyroxenes, staurolite, chlorite and amphiboles occur in scant or trace amounts, except for the sample 6 which is very rich in amphiboles.

The set of heavy minerals in the sample 6 is slightly different than in the other samples. This sample was collected from deposits of an alluvial fan that encloses the sandur from a sea. The fan deposits indicate substantial impact of a fine clastic material from the weathering waste of other rocks, especially the Tertiary clastic rocks which build the first sea terrace, located directly at the shore of the Bellsund Fiord (a steep shore in Fig. 1).
Fig. 2. Bellsund, steep shore built of the Tertiary sandstones with tors and rock ridges formed by intensive corrosion (A) and with accumulation of ample weathering waste at feet of tors (B).
Due to intensive weathering as well as corrosion and deflation phenomena caused by strong winds in a periglacial zone, picturesque sandstone tors and very ample weathering waste of these rocks have emerged (Fig. 2). The author’s unpublished data confirm that substantial amount of zircon, rutile and partly chloritized amphiboles occurs in mineral composition of these sandstones and their weathering waste. The weathering waste material which comes from sandstone rocks exposed at the shore, is transported both by undulation and rolling of material on the seashore and by intensive aeolian activity. Hence, in the granulometric and mineral composition of the alluvial fan (sample 6) there is a mixture of material coming from two different alimentation sources. Large content of amphiboles in the sample from the alluvial fan, in contrast to a simultaneous lack of this material in the other examined samples, indicates that the fine clastic material is derived from another source and that this mineral was transported in a different way. Most probably, the aeolian transport could play a leading role in this case as is indicated by location of the fan, leeward of the intensively weathering Tertiary sandstones (Fig. 2).

The essential problem is preservation of individual minerals and their morphological features, because they reflect glacier forefield environment that is specific if its dynamics is concerned.

Carrying the material washed out from the bedrock, melted out from a glacier ice and captured from the moraines, the waters flowing from under the glacier gain very high dynamics and transport force over a short distance (about 2–3 km between a glacier snout and a seashore with altitude about 100–120 m lower). In such environment, even following a very short transport, numerous mineral components are eliminated due to lower resistance to mechanical crushing, breaking and crumbling, i.e. the ones with a good cleavage and a poor hardness. Due to natural selection, components which are not fissile and are very hard (zircon, rutile and tourmaline) become richer. In the environment with very high dynamics, these minerals crumble but do not disappear from deposits; on the contrary, they occur in the finest fractions. Hence, very numerous fragments of rods, prisms and face edges of zircon, rutile and tourmaline can be found in the examined samples. The increasing content of zircon is to be observed over a relatively short distance between the samples 1 and 5 (Table 1). It could have been caused both by secondary pulverization of larger grains and additional supply of fine-grained material by waters flowing down from the sea terraces. In turn, large content of amphiboles (which are characterized by very good cleavage) in the sample 6, suggests another origin and transport of this mineral.

Morphological features and behaviour of individual components of the heavy mineral fractions make it possible specify the environment with sandur deposits in glacier forefields in Spitsbergen. Observations of sandur deposits of the Scott Glacier in the Bellsund region permit some diagnostic features to be defined. The latter would make it possible identify the present sandur formations in glacier forefields. In addition to texture of the coarse clastic material, which could have been transformed by contemporary processes, mineralogy and morphology of mineral com-
ponents in the finest fractions, particularly the ones of the heavy minerals, seem to be essential. Due to dynamics of the turbulent glacial waters, which transport much material to glacier forefields, a mineral composition of this fraction is strongly depleted. The latter is indicated by elimination of minerals which are less resistant to dynamic factors of physical weathering and by a very strong crumbling of the remaining material.

Conclusions

1. Heavy minerals in sandur deposits of the forefield of the Scott Glacier concentrate exclusively in the finest fractions i.e. less than 0.1 mm.

2. Composition of the set of heavy minerals in the examined sandur deposits is extremely poor, consisting of a few (4–5) components which are characterized by great hardness and no cleavage, or which are hardly fissile. These components are zircon, rutile, tourmaline and trace epidotes.

3. Glacial water environment where the finest clastic fractions containing heavy minerals were transported and deposited, is indicated by very high dynamics and intensive transport. The transported coarse clastic material is intensively crushed and disintegrated; this applies above all to the very hard components. As a result, they concentrate in the finest fractions (less than 0.1 mm) whereas less resistant components are eliminated.

4. Full analogy can be found in terms of both the composition of the set of heavy minerals and the morphological features of individual mineral components between the sandur deposits in the forefields of the Renard Glacier (cf. Chlebowski 1991) and the Scott Glacier.

5. The impoverished set of heavy minerals and their morphological features i.e. extremely angular shape acquired during crumbling of larger mineral grains, may be diagnostic features for the contemporary sandur deposits in glacier forefields in Spitsbergen. These features make contemporary sandur deposits different from the Pleistocene ones. The latter are characterized, among others by a very rich inventory of the heavy mineral fractions and a very good roundness of these components. Despite a similarity of the sedimentary environments, a mineralogical differentiation is due to derivation of the Pleistocene sandurs from moraine and glacier systems, which were considerably different in their lithology and mineralogy. These features are also a diagnostic indicator of a very dynamic glacial water environment.

References

Streszczenie

Badaniom mineralogicznym poddano osady sandru zewnętrznego występujące na przedpolu lodowca Scotta w rejonie południowego Bellsundu na Spitsbergenie (fig. 1). Zbadano skład przez-roczystych minerałów ciężkich (tab. 1) stwierdzając, że występują one wyłącznie we frakcjach drobniejszych od 0,1 mm. Skład zespołu minerałów ciężkich jest wybitnie ubogi i ogranicza się do kilku składników jak cyrkon, turmalin, rutyl i Epidot. Dominują składniki najbardziej odporną na wietrzenie fizyczne (głównie cyrkon i turmalin) o dużej twardości, które w burzliwym środowisku wodnolodowcowym o dużej dynamice ulegają rozkruszeniu na drobne ostrokrawędziste fragmenty. Ubogi skład zespołu minerałów ciężkich oraz ich drobnoziarnistość i ostrokrawędzistość są najbardziej istotnymi cechami, które mogą określać wskaźnik mineralogicznyc, charakteryzujący współczesne osady sandrowe tworzące się na przedpolach lodowców na Spitsbergenie. Prawdopodobieństwo tę sygnalizowano wcześniej dla osadów sandrowych na przedpolu lodowca Renarda (Chlebowski 1991), a obecnie potwierdzono ją w analogicznych osadach na przedpolu lodowca Scotta. Uznano również, że określony wskaźnik mineralogiczny pozwala jednocześnie odróżniać współczesne osady sandrowe od ich odpowiedników plejstoceńskich, które charakteryzują się bardzo bogatym zespołem minerałów ciężkich oraz bardzo dobrym stopniem obtoczenia ziarn.

Obecność w osadzie minerałów bardzo słabo odpornych na wietrzenie mechaniczne, jak np. amfiboli (próbka nr 6), świadczy że w strefie stożka aluwialnego zamykającego osady sandrowe od strony morza zaznacza się wpływ dodatkowego źródła zasilania w materiał detrytyczny. Nieodległym obszarem alimentacyjnym był tu wysoki brzeg zbudowany z detrytycznych skał zbudowanych z takie minerały jak cyrkon, rutyl i amfibole. Intensywna działalność korazyjno-deflacyjna doprowadziła do powstania wietrzeniowych skałek typu grzybów i gzymsów skalnych (fig. 2A) oraz nagromadzenia dużych ilości zwietrzeliny u ich podnóża (fig. 2B), natomiast bardzo aktywna działalność eliciczna spowodowała wywiewanie i nagromadzanie w osadach wspomnianego stożka aluwialnego m.in. takich składników jak amfibole.