Sediment budgets for two glacier forefields (Pasterze & Obersulzbachkees, Hohe Tauern, Austria) - conceptual approach & first results

Martin Geilhausen, Jan-Christoph Otto, Lothar Schrott

Summary

Within the national park Hohe Tauern studies are carried out in the glacier forefields of Pasterze and Obersulzbachkees in order to establish sediment budgets. The sediment budget approach provides a useful mean to quantify sediment storages and transfer processes within a landscape. In glacier forefields, sediment budget studies are of specific scientific interest due to high sediment availability and rapid reworking. The linkage of sediment storage volumes with present-day sediment transfer rates can contribute to i) an understanding of previous landscape development and ii) to the prediction of future topographic evolution. The conceptual approach, aims and objectives of a recently started research project and preliminary results from the Pasterze are presented. The glacier forefield represents a typical composition of glacial, gravitational and glacifluvial landforms and processes. The glacial melt water stream is the dominant path of sediment output.

Keywords

Sediment budget, Glacier forefields, Sediment routing, Sediment thickness, Hohe Tauern.

Introduction & Aims

Retreating alpine glaciers expose landscapes with partly unconsolidated, loose and potentially unstable landforms (e.g. moraine slopes), which are not in equilibrium with changing environmental conditions and therefore susceptible to a rapid topographic modification. In this regard, sediment budget studies on relative short time scales within glacier forefields are of specific scientific interest. The sediment budget approach helps to identify and quantify sediment sources, storages and transfer processes. Furthermore, coupling and decoupling of system components is regarded. Linking sediment storage volumes with present-day sediment transfer rates can contribute to both, an understanding of previous landscape development and the prediction of future topographic evolution.

In this paper we present preliminary results of a research project on sediment budgets for two glacier forefields. The aims of the project are:

1. to integrate present day fluxes and temporarily stored sediments,
2. to compare glacier and sediment dynamics,
3. to describe the sediment routing system and
4. to validate the conceptual model of paraglacial landscape adjustment.

This requires high resolution data on sediment transfer and storage in proglacial areas with rapidly changing sediment budget conditions.

Study Sites

Both study sites are located in the national park Hohe Tauern, Austria (Fig. 1). The selection of the study sites was influenced by the availability of long term data sets on glacier retreat and hydrological (e.g. discharge) conditions (Seeland, 1880; Richter, 1883; Rudel, 1911; Paschinger, 1948; Paschinger, 1969; Patzelt, 1973; Slupetzky, 1993; Wakonigg & Lieb, 1996; Nicolussi & Patzelt, 2001). Both glaciers are listed by the WGMS. An overview of the study site characteristics is given in table 1. Data on catchment size and glacier area represent the real surface area and are calculated using digital elevation data. This is a crucial consideration as the planimetric area underestimates the real catchment size in steep alpine basins.

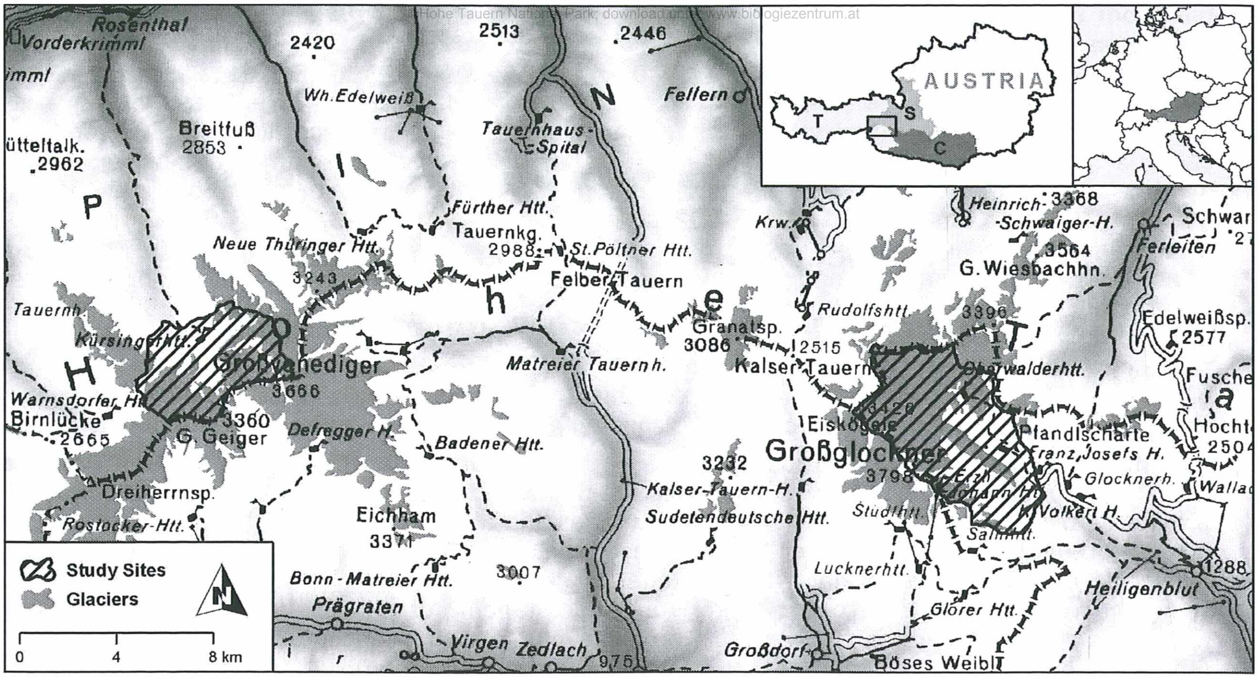

Figure 1: Location of the study sites in Austria (insets, provincial codes S: Salzburg, T: Tyrol and C: Carinthia) and the Hohe Tauern range (base maps: topographic map of Austria 1:500 000 and SRTM data, glaciers: Corine 2000 data)

Table1: Study site characteristics (* after WGMS, 2008; RY: reference year; SY: survey year)

	Obersulzbachkees	**Pasterze**
Altitudinal range	1975 - 3656 m a.s.l.	1980 - 3789 m a.s.l.
Catchment size:	22.4 km²	38.6 km²
Glacier area (2007):	11 km²	21 km²
First RY*	1871	1879
First SY*	1815	1880
Oberservations*	89	124
Lithology:	metamorphic rocks	
	mainly tonalite and gneisses	mainly prasinite, amphibolite, calcareous mica schists & gneisses
Geomorphic processes:	glacial, gravitational and glacifluvial processes	
Storage / sink elements	valley fills, debris-/talus-/avalanche cones, debris/till covered slopes	

Methodological approach

The methodical approach includes orthophoto-interpretation and detailed geomorphological field mapping to identify sediment storages and sediment transfer processes. Data on sediment thickness and the internal structures of sediment bodies will be achieved by a combination of field geophysics, in particular ground penetrating radar (GPR), refraction seismic tomography (RST) and electrical resistivity tomography (ERT). The total sediment volume stored in the forefields will be modelled by means of GIS techniques using morphometric and geophysical data complementary. Present day sediment fluxes will be monitored by hydrological methods (valley bottom, measurement of discharge, bed, suspended and solute load) and repeated terrestrial laser scanning (valley bottom and slopes). An overview of the methodological approach including the data basis, the subsequent data processing and objectives is shown in Fig. 2.

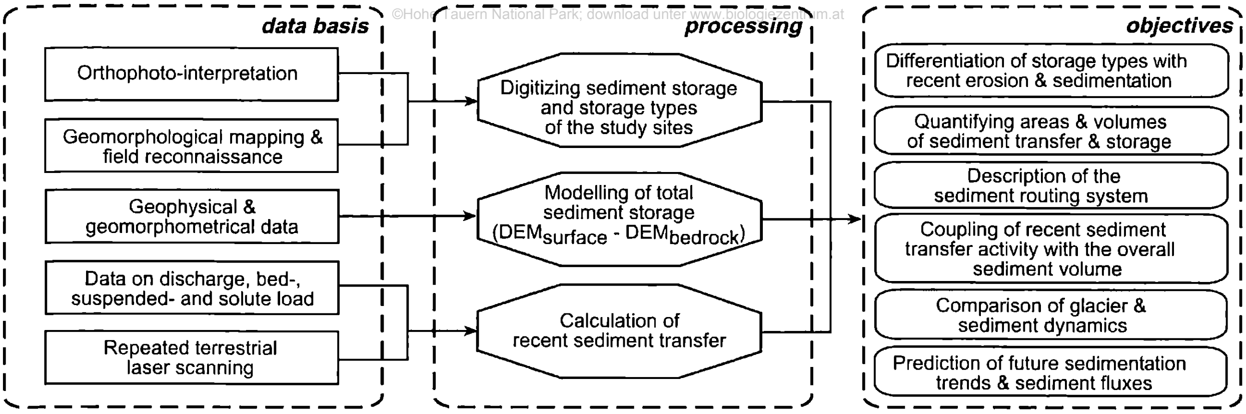

Figure 2: Flowchart of data basis, processing and objectives

Preliminary results (study site Pasterze)

Geomorphological situation

A simplified geomorphological map covers the lower part of the glacier forefield between the glacier snout and the outlet of the sandur (Fig. 3). Further mapping customized for sediment budgets will be carried out in 2009 covering the entire catchment. The catchment area excludes the hydropower reservoir (Margaritze) below the glacier.

Bedrock, glacial debris and blockfields are sediment sources on the slopes and active processes involve debris flows, avalanches, rock falls and rill erosion. In addition solifluction and landslides occur on the north facing slope. Sediments are partly reworked but also transferred to the valley floor. Affiliated to the glacier, the valley floor is characterised by gravel, variable channel patterns and small scale topographic modification. The subsequent almost round sandur is dominated by fine grained sediments. The sandur is a former lake that has been exposed by retreat of the Pasterze since the late 1950s and completely filled up by continuous glacifluvial sedimentation. The current size of the sandur is appr. 12,000 m^2, mean sediment thickness of the sandur area is 6.15 m, delivered by geophysical surveys. This results in a calculated volume of 785,700 m^3 and mass of 1,571,400 t of sediments. To avoid high sediment input rates to the Margaritze water reservoir, the outlet of the sandur was twice dammed artificially which consequently caused high sedimentation rates.

Qualitative sediment flux model & sediment availability

The study site is roughly divided into three subsystems: (1) the slope subsystem, (2) the glacier subsystem and (3) the glacier forefield subsystem (Fig. 4). Each subsystem represents a unique set of sediment sources, transfer processes, regulators and sediment storages and creates output of material and energy that will enter one of the subsequent subsystems (CHORLEY & KENNEDY, 1971). Subsystem connectivity is provided by processes (e.g. rock fall) and influenced by regulators (e.g. slope angle). Within the subsystems, growth, persistence or degradation of sediment storages mainly depends on the processes. The spatial distribution of debris has been digitized on the basis of digital orthophotos (year 2007) and joined with the subsystems.

Current sediment fluxes in the glacier forefield

The glacial meltwater stream is the dominant path of sediment transfer through the system. Preliminary measurements of suspended load indicated that the suspended sediment budget seems to be balanced even though a specific sedimentation pattern could be revealed. During periods of decreasing discharge suspended sediment input into the sandur appear to exceed output, whereas increasing discharge causes higher sediment output. In contrast, the slope processes seem to play a negligible role for sediment output of the forefield system. The valley floor receives material through avalanches and debris flows, which remains in the valley floor and is currently not coupled to the meltwater stream. From the current observations we assume that no significant clastic output (bed load) occurs at the outlet of the forefield system, which therefore appears to be partially closed.

Discussion and perspectives

First results indicate the dynamic sedimentary situation at the Pasterze that will be linked and compared to the glacier fluctuation in the next step. Future work will mainly focus on the quantification of sediments stored in the catchment and the measurement of present day sediment transfer. By linking these recent transfer rates with both, the available sediment and the sediment routing network, we aim to predict the future sedimentary evolution.

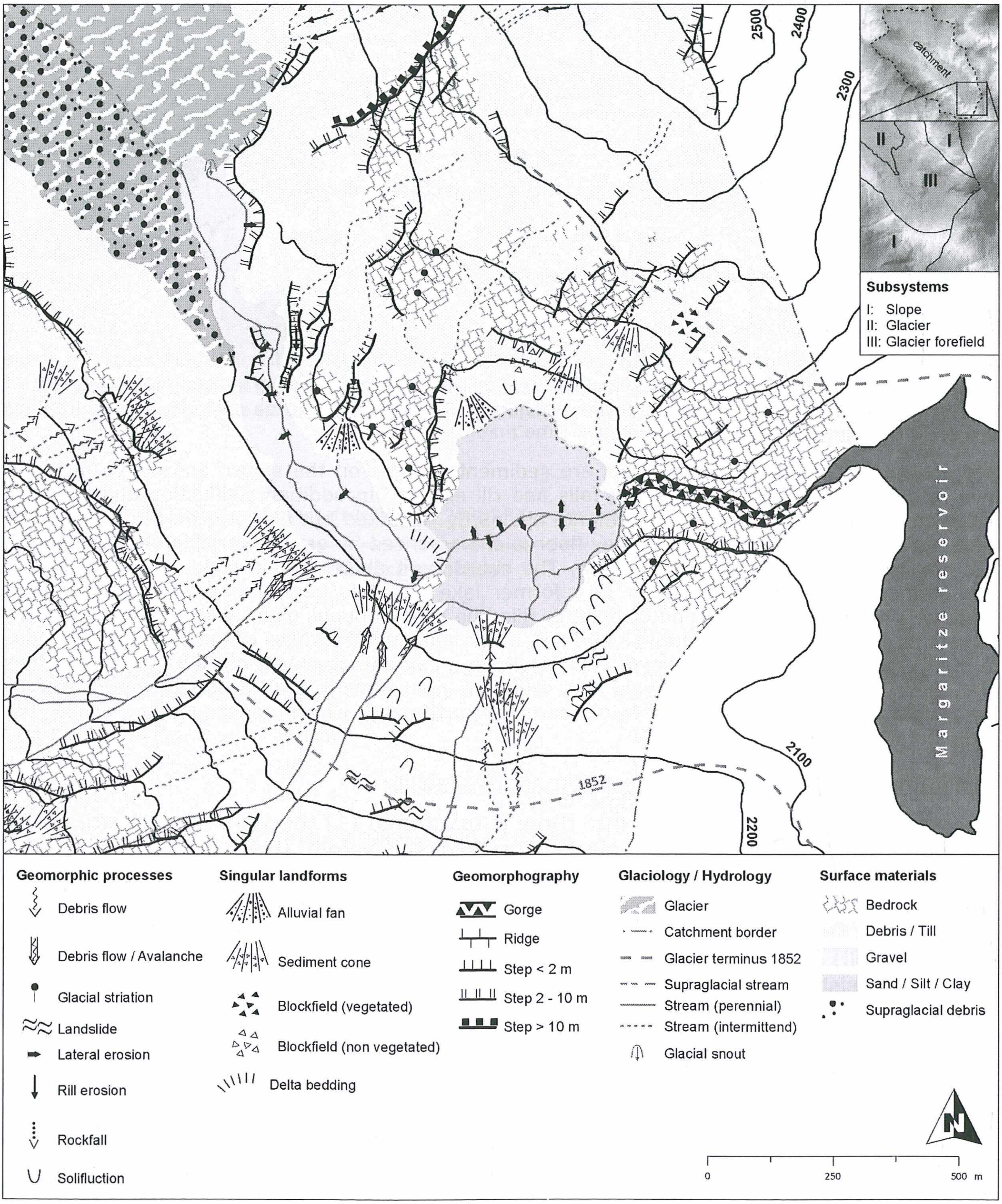

Figure 3: Simplified geomorphological map of the forefield of Pasterze glacier, data on geomorphic process domains, slope angles and curvature are not presented

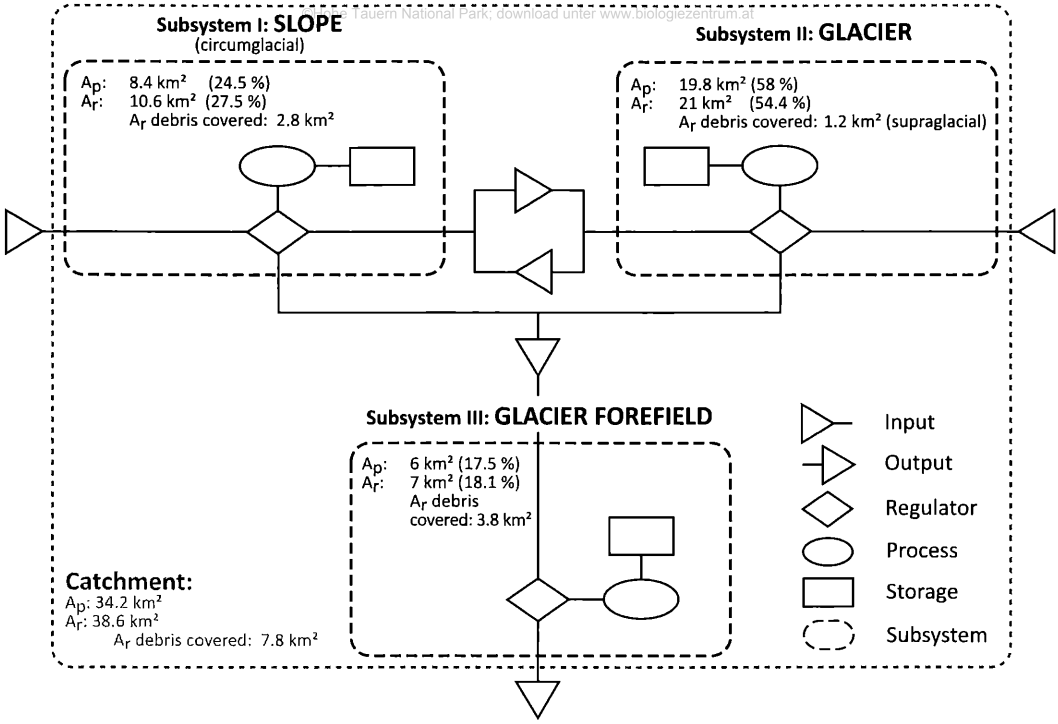

Figure 4: Qualitative sediment flux model of the forefield of Pasterze glacier. Spatial extent of the catchment and subsystems is depicted in planimetric (Ap) and real surface area (Ar), the percentage of debris cover also represents real surface areas

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Contact

Dipl. Geogr. Martin Geilhausen
martin.geilhausen@sbg.ac.at

Research Group 'Geomorphology and Environmental Systems'
Department of Geography and Geology
University of Salzburg
Hellbrunnerstr. 34
5020 Salzburg
Austria