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Investigation on and Modelling of Material Properties of Periglacial Layers (Tharandt Forest, Saxony, Germany)

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4 Text-Figures, 1 Table

Deutschland
Sachsen
Geomorphologie
Periglazial
Bodenanalyse

Contents

Untersuchung und Modellierung von Materialeigenschaften periglazialer Ablagerungen (Tharandter Wald, Sachsen, Deutschland)

Zusammenfassung

Periglaziale Ablagerungen bedecken weite Teile der Mittelgebirge von Mitteleuropa. Sie haben großen Einfluss auf Standorteigenschaften, indem sie den Standort vom Einfluss des anstehenden Gesteins entkoppeln. Bei Dresden, Sachsen, wurden 40 Bodenprofile makroskopisch und mikroskopisch beschrieben sowie röntgendiffraktometrisch und granulometrisch untersucht. Es wird ein Modellansatz vorgestellt, mit dem der reliefgesteuerte Massenversatz am Hang für einzelne Lagen vorhergesagt werden kann.

Abstract

Periglacial layers cover large areas of Central European low mountain ranges and have great impact on the landscape by decoupling site properties from bedrock influence. Near Dresden, Saxony, 40 soil profiles were investigated by macroscopic, microscopic, X-ray diffraction and granulometric analyses. A model is introduced to predict topography-controlled material displacement due to solifluction-like processes for separate layers.

1. Introduction

Periglacial layers cover large areas of Central European low mountain ranges. They have significant impacts on soil and site properties (SCHOLTEN, 2003), water flow patterns (KLEBER & SCHELLENBERGER, 1999) or matter fluxes (KLEBER et al., 1998). By periglacial layers the first decimetres of soil are, at least partly, decoupled from local bedrock influence. Allochthonous and parautochthonous material is added according to the topographical position and further

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contributes to modify site properties. It is thus necessary to determine changes in sediment properties due to the development of periglacial layers and gain information on lateral composition patterns of these features.

2. Study Area

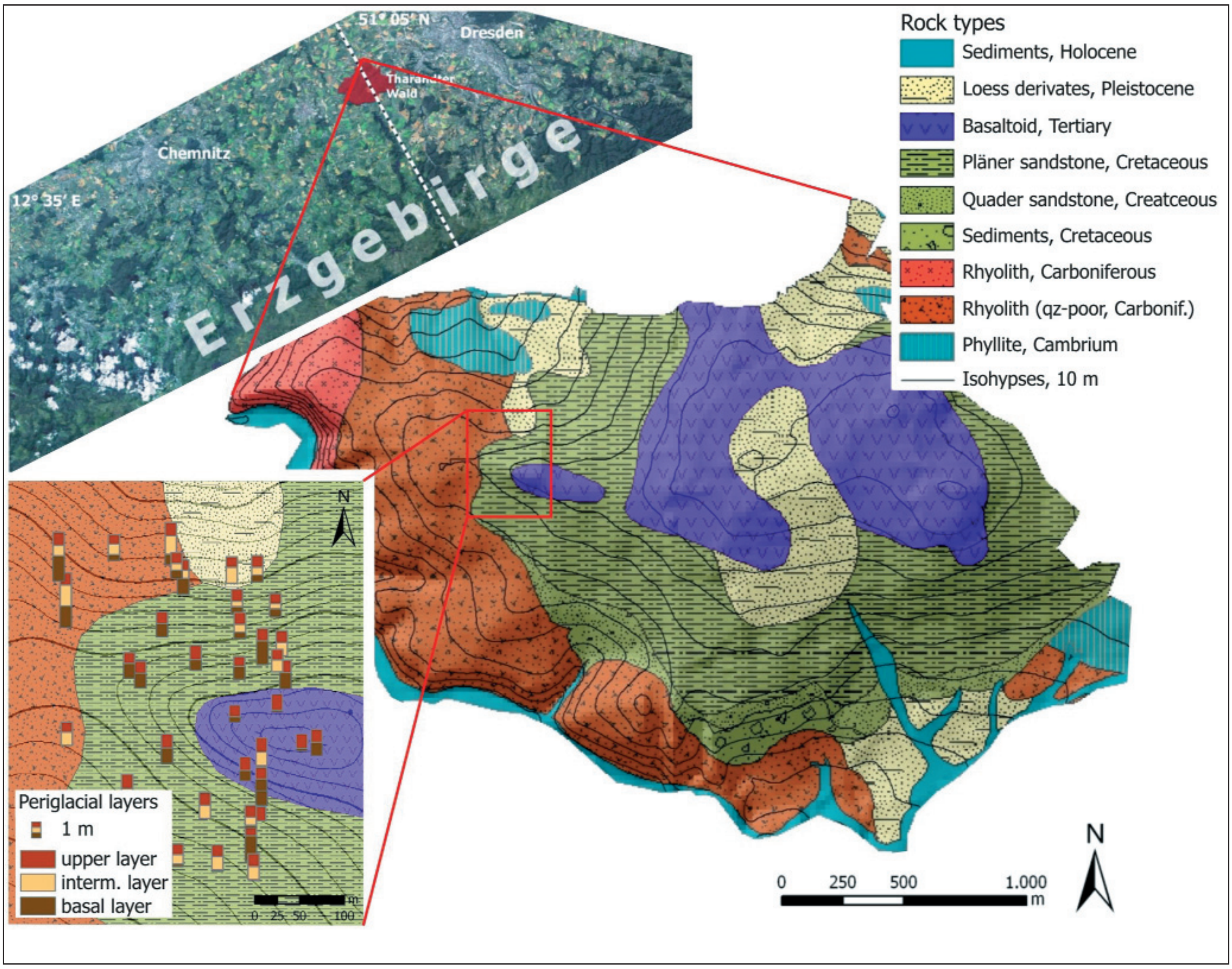
Northern Tharandter Wald, approximately 20 km southwest of Dresden, Saxony, Germany, is regarded as foothill of the eastern Erzgebirge and descends into the northerly lying Sächsisches Lösshügelland, dominated by aeolian sediments. In its northern part, the Landberg area, the complex geological history of Saxony is manifested in different rock types getting increasingly younger with height and ranging from Palaeozoic, Variscian gneisses and rhyoliths over Mesozoic sequences of sand stones up to Tertiary basaltoidic lava flows and Quaternary loess derivates (see Text-Fig. 1). On top of these rock types palaeosols were developed eventually and some surfaces show remnants of such formations. During Pleistocene the first decimetres of sediment were reworked by periglacial processes and resulted in certain patterns of periglacial layers.

Fiedler & Schmiedel (1962, 1963), Fiedler & Brückner (1984) and Fiedler et al. (1994) have investigated such formations in the Tharandter Wald in respect to altered site properties, cryoturbation features and periglacial layers in combination with palaeosols. Within the Landberg area a small basaltoidic outcrop with underlying sandstone and rhyolith were chosen for detailed studies. This Buchhübel area served for sampling and model validation.

3. Field and Laboratory Work Approaches

We described 40 soil profiles (soil pits and soil auger holes) to designate their composition of periglacial layers. Soil properties were described, basically following AG Boden (1994, 2005). Layers were identified in the field by detecting abrupt changes in pedological parameters, breaks in grain size, differing composition of rock fragments and the qualitative influence of aeolian material. Samples were taken from each layer and horizon.

Laboratory investigation included detailed macroscopic soil description. Microscopic observation of aliquots of the gathered material yielded derived, qualitative indicators of sediment rework due to weathering, soil formation and anthropogenic impact. Further, X-ray diffraction analyses of both soil and bedrock samples were done to qualify the sample's mineralogical composition. Especially the phyllosilicate content as indicator of weathering and soil forming processes was concerned, following the techniques described by Moore & Reynolds (1997) and Jasmund & Lagaly (1993). Evaluations of grain size indices were used to support field derived layer boundaries and explain the significances of different sediment sources (as described in



Text-Fig. 1.
Location of the study site with geological setting and investigated soil profiles.
Image and DEM data source: GLCF 2007, simplified geological map after Sauer & Beck (1891).

and applied by FOLK [1980], THALHEIM [1988] and TUCKER [1996]).

4. Model Approach for Material Properties

Material properties of periglacial layers strongly depend on rock types in the specific catchment area of a site, and the site's topographic setting as processes of cryoclastic, cryoturbation, gelifluction and solifluction, respectively, mobilises and dislocates material downslope according to relief controlled paths (SEMMEL, 1985; SELBY, 1993; JAESCHE, 1999; RITTER, 2002). For accordant layers the implementation of aeolian sediment has to be considered (SEMMEL, 1985; THALHEIM, 1988; KLEBER, 1992). SCHOLTEN (2003) and BEHRENS (2003) introduce several statistical relationships between rock types, topography and periglacial layers.

A GIS-based model was set up to describe material distribution due to solifluction processes. A multiple flow direction algorithm (FREEMAN, 1991; OLAYA, 2004) for surface runoff was modified to provide gravity controlled downslope distribution patterns for each rock type, present in the study area (see Text-Fig. 2). A pre-processed DEM with 20 m grid size was used. Petrographical data came from digitised geological maps. Subsequent combination of individual distribution patterns yielded a two dimensional map with potential sedimentpetrographical units of periglacial layers. For the accordant layers aeolian sediment incorporation was added.

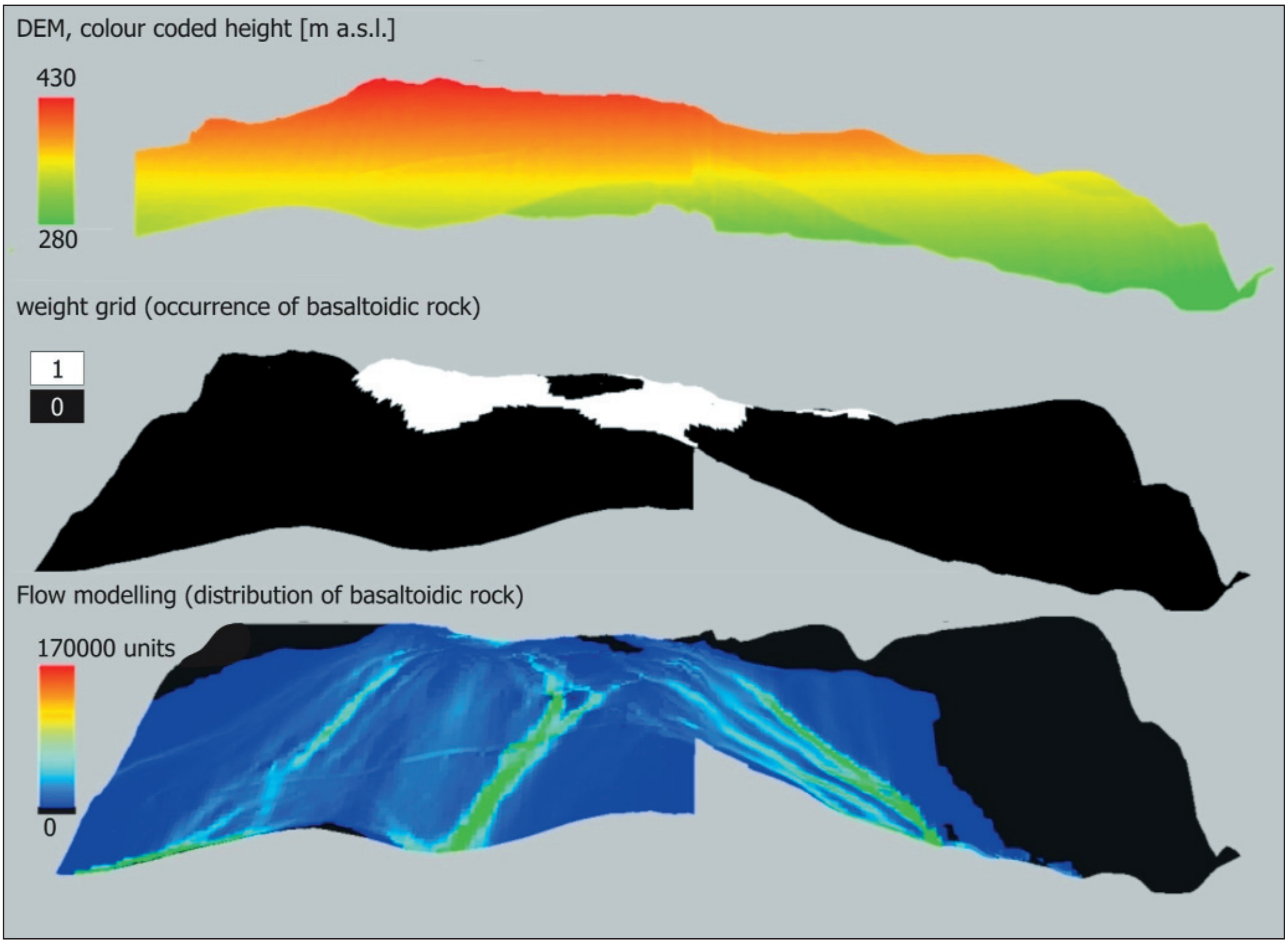
5. Results of Field and Laboratory Work

From all investigated soil profiles relationships between parent rock types, topography, periglacial layers and soil types are systematically consistent. Three major soil types occur at the study site with shallow Braunerden in top positions and steep slopes; leading over to Pseudogleye that cover gentle slopes. Parabraunerden were only detected at two profiles although transitions between all three types occur.

Soil types are closely bounded to the developed periglacial layers, by two-layer profiles (upper layer and basal layer) allowing only Braunerden and three-layer profiles (upper layer, intermediate layer and basal layer) providing potential for Pseudogleye and Parabraunerden. Table 1 summarises thickness values for the investigated layers.

Table 1.
Descriptive statistical parameters concerning thickness values of periglacial layers at investigated profiles (units are cm).

Layer (number of profiles)	Minimal value	Maximal value	Mean value	Standard deviation
Upper layer (40)	36	61	46,62	5,94
Intermediate layer (22)	20	80	41,50	15,49
Upper + intermediate layer (40)	38	126	69,45	22,86
Basal layer (31)	6	150	46,68	30,83



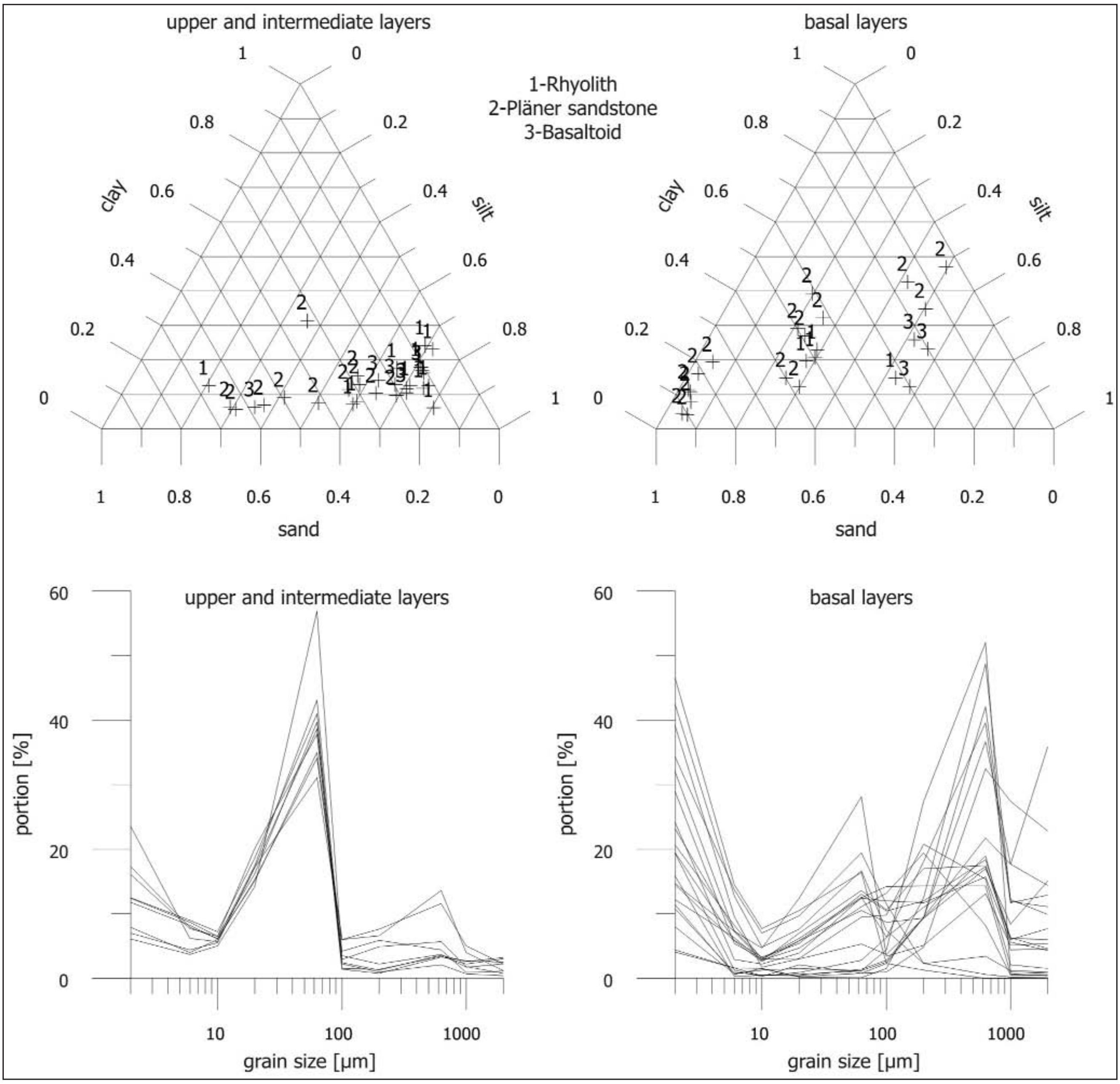
Text-Fig. 2.
Model approach to describe topography-controlled downslope displacement of individual rock types.
A modified flow distribution model (FREEMAN, 1991; OLAYA, 2004) uses digital elevation model data and weight grids representing initial locations of rock types to create solifluidal-like patterns of material redistribution.

Microscopic analyses revealed descriptions of rock fragments, mineral grains, concretions and cementations of different appearance as well as charcoal fragments and hollow spheres of quartz grains indurated by manganese oxides. All these features were used to indicate autochthonous and parautochthonous material in specific layers, to qualify pedological overprints and weathering alteration of parent material, and to evaluate anthropogenic disturbances of the profiles.

Grain size measurements (TACHIVA, 1996) and derived sedimentpetrographical parameters were not only used to affirm field-derived layer boundaries but also to describe relations of distinct layers to different parent rock types. Thus it is possible to address sediment alteration due to admixture of aeolian material and to quantify the range of sediment properties of profiles developed on specific parent rock types (see Text-Fig. 3).

X-ray diffraction analyses highlight quartz as ubiquitous mineral, regardless of parent rock type and periglacial layer. Traces of weathered and dislocated basaltic material reoccur as augite and, more infrequent, haematite. Nepheline and olivine are not present except for layers at sites directly upon basaltoidic bedrock.

Regarding clay minerals, chlorites are very abundant (85 % of all samples exhibit this mineral type), showing clearer signals in layers and horizons altered by strong pedogenesis. Kaolinite and muscovite/illite are even more abundant by occurring in 90 % of all samples, making them improper for distinguishing layers. Expandable 2:1 phyllosilicates and mixed-layer minerals were identified only sporadically and seem to be restricted to basaltoidic bedrock material.



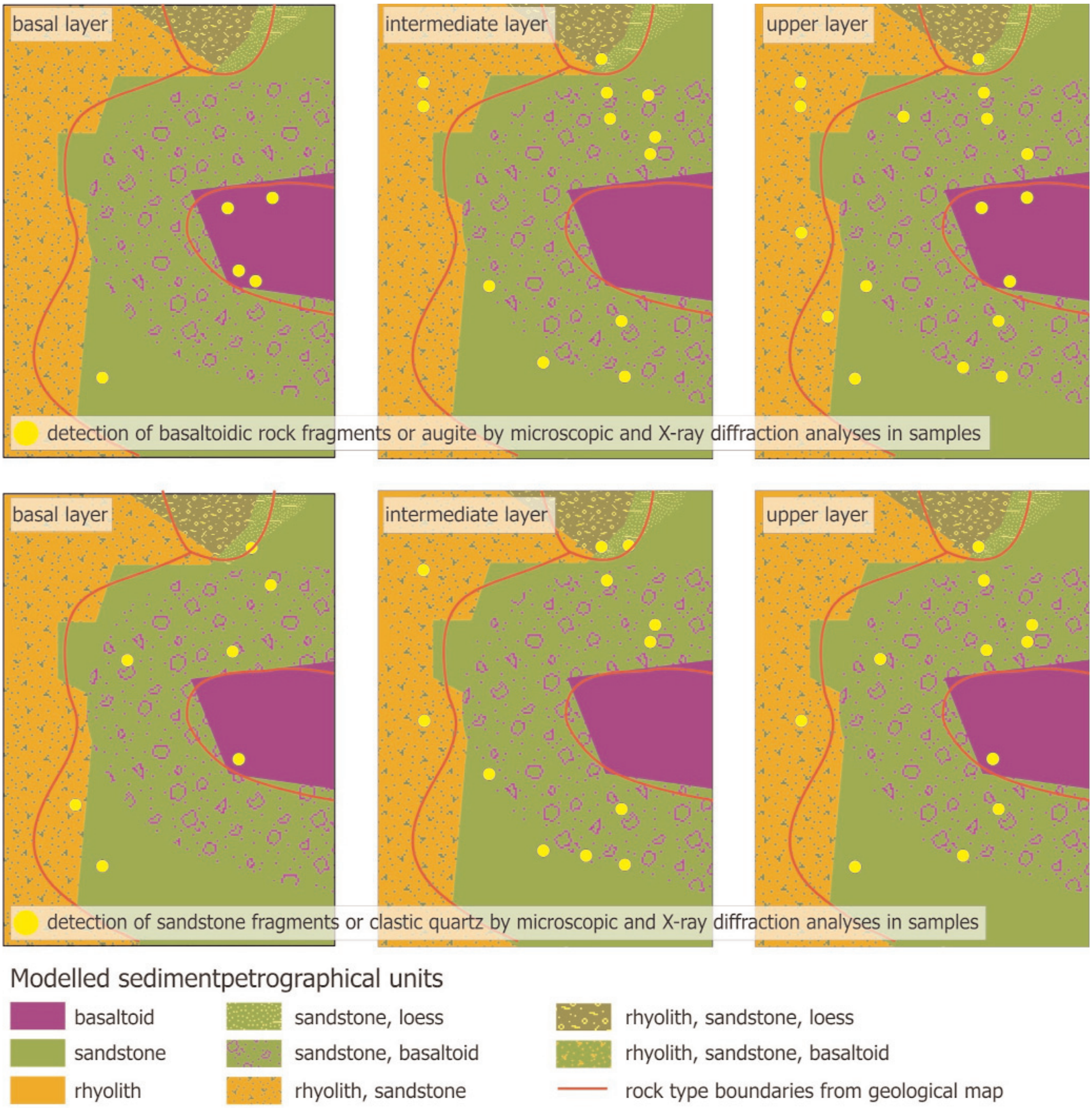
Text-Fig. 3.
Comparison of grain size fractions of samples from distinct periglacial layers with respect to bedrock material.
The loess-influenced upper and intermediate layers show no clear relationship to parent rock type but are dominated by grain sizes between 30 and 80 µm while basal layers can be grouped by their parent rock material and have a much more irregular grain size distribution. Original measurements of some granulometries are taken from TACHIVA (1996).

6. Modelling Results

The modelling of solifluidal material redistribution resulted in a vector dataset with 48 sedimentpetrographical units for the entire study area. A smaller section is presented in Text-Fig. 4 together with validation. In general the model predicts a downslope movement of sediment. Due to topography control original distribution areas of material are widened. There were also mixture areas created, including up to 4 different rock types. The shape of these mixture areas is determined by flow patterns, in turn controlled by relief properties. For instance, a plateau 200 m west of Buchhübel prevents mixing of rhyolith and sandstone material by solifluidal movement. Validation (see Text-Fig. 4) of the predicted distribution areas was done using results of microscopic and X-ray diffraction analyses. For each layer and sample the indices of the according rock types were plotted against the modelled sedimentpetrographical units. In many cases the distribution patterns could be confirmed, although the distance of material displacement is not questionable.

7. Conclusions and Further Discussions

Field derived results have been verified by laboratory methods. The layers and their boundaries could always be traced, even though not by one unique technique. Microscopic parameters in combination with X-ray diffraction analyses approved to be confident and proper methods to distinguish material properties of periglacial layers, especially regarding implementation of allochthonous material.



Text-Fig. 4.
Results and validation of topography-controlled material redistribution.
Eight sedimentpetrographical units were modelled and show, besides admixed rock types, the broadened appearance of initial materials beyond the original boundaries. For all periglacial layers separately, mineralogical parameters indicative for distinct rock types, allow validation of modelled patterns.

Changes in the composition of periglacial layers were found laterally and vertically, i. e. generally due to the influence of aeolian material as well as the differentiation of upper and intermediate layer. Transition of a rock type boundary alters the properties of periglacial layers by implementation of different material. But vice versa, periglacial layers change site properties determined by bedrock. Pedological overprint of the sediment could be displayed frequently by different methods. For instance, chlorites (2:2 phyllosilicates) were identified mainly in the upper soil but are virtually absent in lower parts and may thus resemble pedologic alteration of sediment.

The introduced model approach highlights these areas that experienced material modification due to periglacial processes and the derived sedimentpetrographical units qualify the mixed rock types. However, exact data about distances and paths of solifluidal sediment displacement are not addressable. As SAUER (2002) and SCHOLTEN (2003) point out, there is a strong dependence of solifluction intensity on sediment properties. Further, it is virtually impossible to quantify displacement rates because of possibly multiple solifluction periods of indeterminable durations. Further detailed profile investigation following the modelled unit boundaries need to be stressed. To securely identify rocks dislocated by solifluction, soil pits need to be dug and measurements of rock alignments have to be carried out.

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