Internationales Symposion
INTERPRAEVENT 1996 – GARMISCH-PARTENKIRCHEN
Tagungspublikation, Band 5, Seite 243 – 253

GEOMORPHOLOGICAL / GEOTECHNICAL MAPPING OF THE VERSETTLA-GARFRESCHEN SLOPE

for forest road alignment

GEOMORPHOLOGISCHE / GEOTECHNISCHE KARTIERUNG DES VERSETTLA-GARFRESHA HANGES

für Forstweg-Anlage

by J.Rupke & A.C.Seijmonsbergen

Abstract. The Versettla-Garfrescha slope is situated opposite to the village of Gortipohl on the SW bank of the river Ill in the Montafon region of Vorarlberg, Austria (see Fig.1). The area surveyed measures approximately 4.3 km^2. The height difference is approximately 970 m. The Versettla slope carries forest that has been virtually without normal exploitation or management in modern times. As a consequence of the absence of forest roads large stands become too old; risk of toppling and consequent destruction of potential wood production slopes become immanent. Moreover, the policy of preventing avalanche risk building up, necessitates sound forest management. Considering the length of the slope from the river to the water divide, the best solution would be the construction of three forest roads at approximately equal height intervals. Hence, we are confronted with the following questions:

Which road alignments can be selected representing minimum costs; maximum safety during construction and use; minimum maintenance problems; minimum loss of forest due to cutting?

As slope behaviour is controlled by a complex of geological qualities, post-glacial geomorphological developments and slope processes, it was decided to carry out a 1:6.000 geomorphological/geotechnical survey with emphasis on factors as material, form and process and hydrology that combine and lead to slope instability. A slope hazard zonation map was constructed from these data. This served to select forest road alignments reckoning with slope failure risk.

Zusammenfassung. Der Versettla-Garfreschahang befindet sich an der Schattenseite, dem Dorfe Gortipohl gegenüber, südwestlich des Ill, in der Region Montafon, Vorarl-berg, Österreich (sehe Fig. 1). Das untersuchte Gebiet ist nahezu 4,3 km^3 gross. Der Hohenunterschied zwischen Wasserscheide und Talebene beträgt ungefähr 970 M. Der Versettlahang ist bewaldet; die Forstpflege oder sonstige Betreuung hat seit Jahrzehnten viele Mangel aufgezeigt. Infolge dieser mangelhaften Pflege und der Abwesenheit von Forstwegen sind viele Bestände überreif gewachsen. Windwurfgefahr, resultierend in Erosion von potenziellen, holzproduzierenden, bewaldeten, vor Lawinen schutzenden Hängen, macht eine richtige Forstpflege notwendig. Die Distanz zwischen Flussebene und Wasserscheide ist gross; daher würde der Bau von drei Forstwegen mit gleichen zwischenabständen die beste Lösung bieten. Daher werden wir folgende Fragen gegenübersgestellt: *Welche Trasseführung, mit minimum an Kosten, mit maximaler Sicherheit während der Konstruktion und während des Gebrauchs, mit minimaler Pflege und minimalem Verlust von Bäumen, wird als Optimum gewählt?* Da das Verhalten eines Hanges bestimmt wird von einem Komplex geologischer, postglazial-geomorphologischer Entwicklungen und Hangprozessen, wurde eine geomorphologisch/geotechnische Aufnahme 1:6.000 gemacht. Akzent wurde dabei gelegt auf die Faktore: Material, Form Prozess, und auf die Hydrologie, welche zusammen die Hangstabilität bestimmen. Eine Stabilitäts-Zonierungskarte wurde aus diesen Daten konstruiert. Diese karte wurde dann als Grundlage für eine optimierte Trasseführung verwendet

1) General geology and geomorphology

The Versettla slope appears in the geological map 169 Partenen Ost, scale 1:25.000. (GBA, WIEN 1984). The area belongs to the Silvretta nappe, containing non-sedimentary series overlying sedimentary formations of the RÄTIKON outcropping to the N.

The hardrock exposures belong in majority to the Hornblende Gneiss and Amphibolite Formation. The geological and mineralogical diversity is restricted to plagioclase amphibolite with large amounts of hornblende and up to 5 vol.% of quartz and epidote containing amphibolite (<5 Vol.% of garnet). The parent material must have been of sedimentary origin before the regional metamorphosis; in most of the area the original Quartz-controlled bedding planes are easily recognized. The bedding planes over the whole of the area are constantly dipping to the N and NE at angles between approximately 22° and 42°. Cleavage planes are well-developed in the intercalated mica-series, in the rocks of high Qz-content they are not developed. The non-lithified materials building the Quaternary deposition cover the major part of the slopes,that have been affected/oversteepened by glacial scour to altitudes of 1800m.

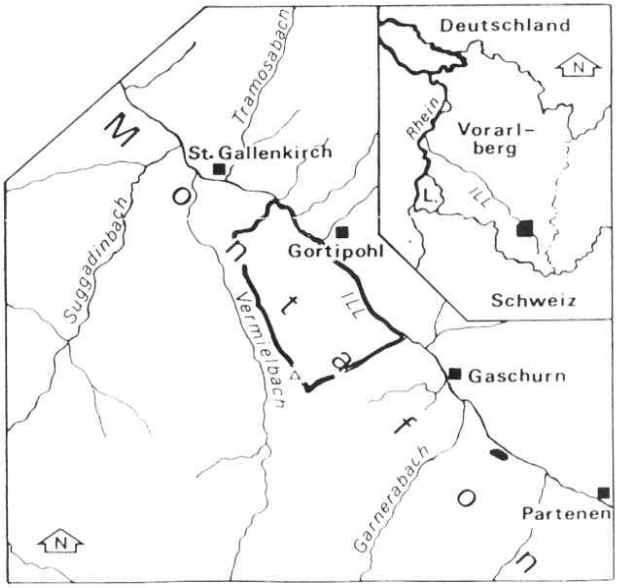


Fig.1
Location of the study area in Vorarlberg, Austria.

Abb.1
Lage des Untersuchungsgebietes in Vorarlberg, Österreich

2) Slope development and slope instability factors

The instable character of the Versettla terrain is caused by several factors; we will mention these factors briefly.

The geological factors include:

- original sedimentary bedding planes, acting as gliding surfaces, form a risk, especially when the geological dip angle is parallel or less steep than the local terrain slope.
- folding and metamorphism of rock series will often lead to the development of minute folds and shear planes at various angles to the sedimentary bedding planes.

The fine grained micaceous sections often develop shallow sheets (1-2m) of material creeping or sliding parallel to the slope. Destruction of root systems may accelerate this process. A fragment of the geomorphological map (original: scale 1:5.000) has been presented in Fig. 2.

The geomorphological factors to be mentioned are:

- The effect of oversteepening due to glacial erosion and subsequent glacial erosion.
- The process of weathering under which material decomposes physically and chemically, due to temperature changes and dissolution. The result is cracking of the material under freezing; more important is the change of minerals to clay minerals and lowering of the rock shear strength.
- Special attention has been given to the phenomenon of tensional fissuring. In large areas the slope is in general parallel to the geological dip direction of the geological bedding. When this leads to a situation of (near)failure or slow failure (under natural conditions) we find the rock surface broken up by a network of tensional fissures leading to a uneven blocky terrain without soil cover.
- large units of rock slumping nature we have found mainly in the upper half of the slope; these occur especially under the water divide GANTA KOPF-WEISSPLATTE. They are bordered by long-trending tensional fissures.

Fig.2 / Abb.2

Fragment of the geomorphological map of the Versettla-Garfrescha slope.

Ausschnitt der Geomorphologische Karte des Versettla-Garfrescha Hanges.

Important legend units / Wichtige Legende Einheiten:

slope symbol / Hangsymbol

fissure (large) / Zugriss (gross)

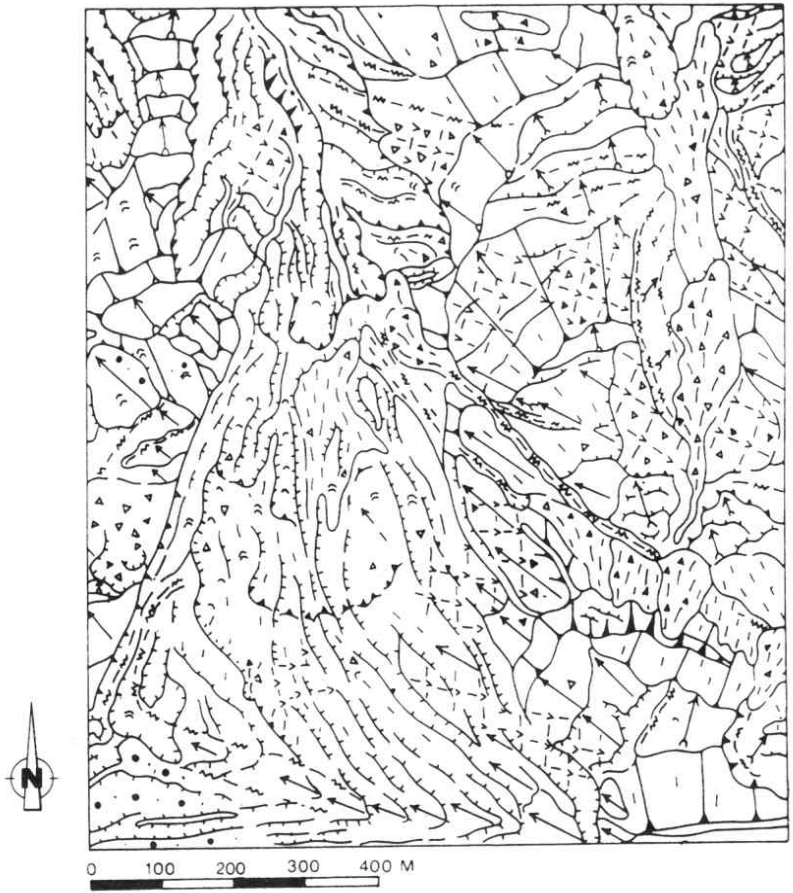
disintegrated terrain / zerrissenes Terrain

Steep cliff (a) with rockfall- and scree material (b) and slumps (c) / Steilkante (a) mit Schutt- Blockhalde (b) Sackungen (c)

dipslope terrain / Gelände mit hangparallelle Schichtneigung

scree / rockfall
Hang- Blockschutt

moraines
Moränen



- In certain stretches avalanches and other gravity processes have created long corridors of blocky slope waste. These intersect the contours at right angles and are - apart from the avalanche risk - in continuous creeping motion. They are main contributors to fan deposition at the foot of the Versettla slope. In these bodies deep throughflow will be expected.

The hydrological factors are complex but of major importance:
A first subdivision could be made into surficial and subsurface hydrology. Surficial hydrological features have been documented on the 1:10.000 geomorphological map; such as (intermittent) drainage lines, springs, wet areas etc. Only below approximately 1100 m. altitude (i.e. a zone appr. 100m above the valley floor) several springs and corresponding drainage lines can be distinghuished. Therefore it must be concluded that internal (deep) drainage in the area is controlling hydrological conditions.
The alluvial fans that accumulated on the valley floor are restricted in size and volume. This is in contrast to the northern slopes where huge alluvial fans have been deposited. These are fed by streams that drain small catchments in which surficial drainage prevails. These fan systems forced the river Ill to flow directly in front of the southern valley slope; undercutting of the southern slope and promoting instability is the result.
On the geomorphological map two elements are important for the hydrology:

1) SSW-NNE running linear tension systems; in some cases they bridge a height of more that 700 m and can be traced for more than 2 km;
2) Slope segments that are disrupted by tensional fissuring; they have been indicated by a zig-zag symbol on the geomorphological map.

It can be assumed that deep-reaching disintegration of the rock mass took place along these major fissure lines and the slope segments mentioned under 2). Deep groundwater will preferentially follow these disrupted zones. For instance, deeper groundwater has therefore the possibility to cross the contourlines obliquely along the major fissure lines in the subsurface. Areas that at the surface show as local waterdivides can therefore be crossed by

groundwater flow. In a number of cases the linear systems are linked with subareas mapped as 'zerrissenes Terrain'. If this knowledge is combined with data on the geological dip of the rock-mass and the topographical gradients, areas with special hazard can be recognized.

A special mass movement phenomenon can be found near the divide, between the Ganta Kopf and the Weissplatte. Linear tensional systems cross the divide into the Vermiel valley. The divide has been lowered by sliding blocks towards either side thus creating a so-called 'twin-divide'.

3) Stereographic Projections

At seven locations in the Versettla area stereographic projections have been made (Fig.3). Discontinuity planes and geological dips were measured and entered into a lower hemisphere equatorial equal angle projection (Wulff net). Various types of discontinuities have been differentiated: open triangles for joints/cleavage planes and black triangles for the geological dip. Double black triangles were used to indicate the local terrain angle. In the figure 3, some measurements have been presented. The aim of the measurements was to recognize those joint sets that are of main importance for slope stability in the area, especially the near-parrallel and less steep discontinuities with respect to the surface gradient. In the field it was observed that most scree

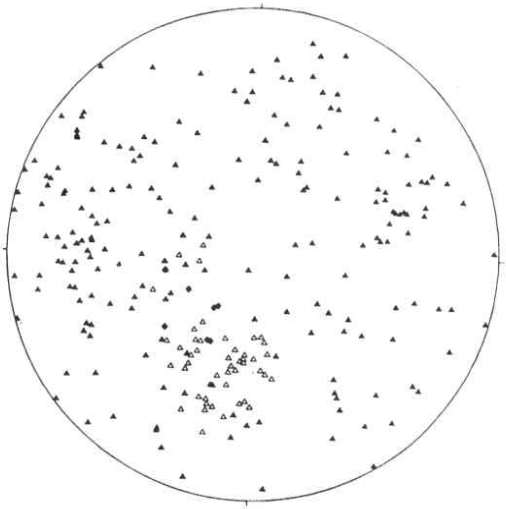


Fig.3./Abb.3 Stereographic plot of geological data. Stereographische Projektion von geologischen Daten (Wulff Netz)

fragments have the shape of small parallellograms. This shape is found back in the general geomorphological outline; it is thought that this is caused by a number of joint systems in combination with the dip of the geological strata. The stereographical projection shows that four concentrations of discontinuity planes occur. The bedding plane is almost identical to the terrain gradient; range between 43°-55°. In combination with two other joint sets, poles in W and NW, typical paralellograms are produced during disintegration. The scree or blocksize is also depending on joint spacing and layering thickness; this was not measured. A combination of bedding planes with two other favourable sets of joints (more or less perpendicular to the bedding plane and crossing at approximately 70 ° with each other) can thus potentially lead to planar failures. This fact was used in the Geomorphological-Geological Hazard classification as a major distinction in the hazard degree.

4) Geotechnical analysis; the hazard zonation map

Boundaries of more or less homogeneous areas can be depicted on the basis of the geomorphological map. Since the aim of this study is to give a slope stability appraisal for forest road routing, the Geomorphological-Geological Hazard classification only contains information that is relevant for this purpose.

In figure 4 the area is subdivided into 4 main classes: The letter code A) depicts the most important areas: those areas where the geological dip is approximately equal to the surface gradient: planar failures may occur. A further subdivision is made into A1 and A2. A1 indicates subareas less endangered by these type of failures, A2 indicates highly endangered subareas. In the field the rock mass underlying the A2 areas showed severe signs of disintegration. Often exfiltration of water was observed; bare and fresh rock surfaces are common. A2 on the geomorphological map is a combination of dipslope arrows with 'zerrissenes Terrain' and/or scree symbols. It was also decided to indicate the steeper scarps exceeding 40° in

Fig.2 / Abb.2

Fragment of the geomorphological map of the Versettla-Garfrescha slope.

Ausschnitt der Geomorphologische Karte des Versettla-Garfrescha Hanges.

Important legend units / Wichtige Legende Einheiten:

slope symbol / Hangsymbol

fissure (large) / Zugriss (gross)

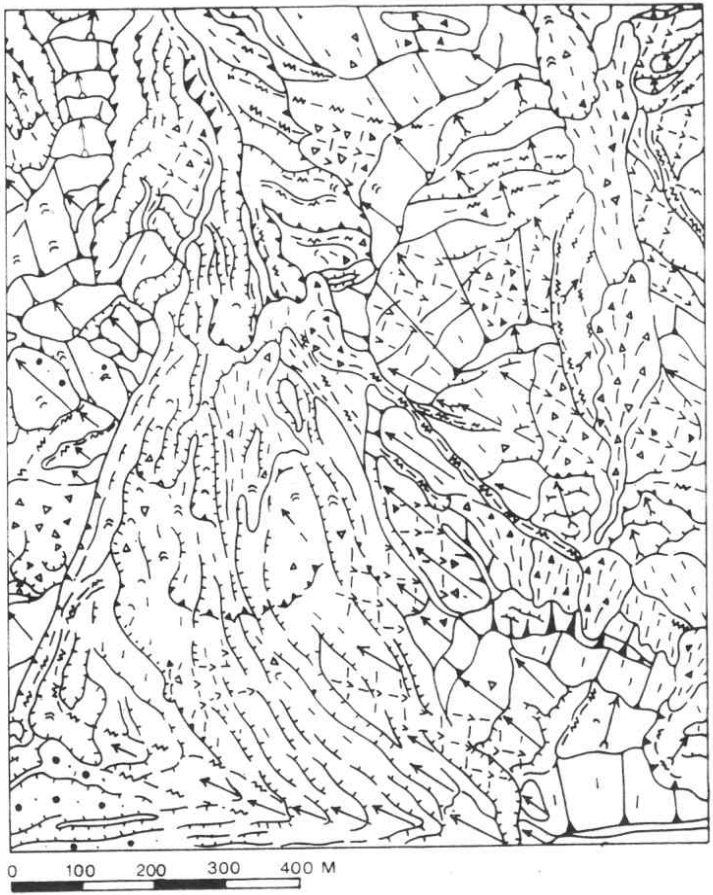
disintegrated terrain / zerrissenes Terrain

Steep cliff (a) with rockfall- and scree material (b) and slumps (c) / Steilkante (a) mit Schutt- Blockhalde (b) Sackungen (c)

dipslope terrain / Gelände mit hangparallelle Schichtneigung

scree / rockfall
Hang- Blockschutt

moraines
Moränen



this map. These breaks in slope are natural boundaries and can better be avoided by the construction of forest roads; this will save costs significantly.

5) Forest road alignments

Three initially planned forest road alignments have been indicated (see alignment in fig. 4, dashed). The precise location of these roads is mainly based on forest economical considerations. Possible instable areas are mainly judged according to the state of the vegetation cover by foresters. The gradient of the road has also been taken into account. Through detailed geomorphological mapping and subsequent appraisal of the natural hazards in the area, the initially proposed road sections could be evaluated in detail with respect to the substratum and the problems expected in construction and maintenance due to the instability expected. Based on the Geomorphological-Geological Hazard Classification it was possible to indicate alternative routes for the originally proposed forest road alignments (see fig.4, dotted lines). To avoid the dangerous A2 subareas that would be crossed by the original upper road section an alternative route for the upper road has been projected for approx. 650 m along the original route. The areas located in the lower half of Qdr.C2 and the upper half of Qdr.C2 (in the full scale map) can better be entered from a more reliable route via the central road. This central road has only slightly been altered along the first 550 m with respect to the initially proposed alignment. Upslope areas can fairly easily be reached with a few wide bends to approx. 1600 m, although there is even the possibillity for an extra take-off to the west to reach the eastern section of the upper road. The maximum length of the lower road cannot exceed approx 750 m. Two alternatives are given: the upper alternative follows the initial section, the lower (slightly saver) route almost runs parallel 50 m lower. A possibility for a road to reach the C4 and C5 (central area) quadrangles is also indicated; a connection with existing roads east of the study area could then be made.

6) Conclusions, construction problems, recommendations

The hazard zonation map (and geomorphological maps) clearly indicate\delimit high risk areas and localities for construction work, which must be avoided when building forest roads. These maps are the main guides when evaluating slope conditions. The problem of disposal of rock waste produced during excavation may be minimized. Certain geomorphological units may receive this material without aggravating slope instability or destruction of healthy forest. We must note that the present investigation served as a first detailed appraisal of the slope processes active in the Versettla terrain. They allow a good interpretation of conditions in the slope material and a zonation of hazards. Still, the scale is limited; therfore it must be stressed here that an optimal alignment, avoiding risks as much as possible, needs discussion and possible further work in the field at a scale of site investigation (1:1000-1:2000), for those particular problematic subareas that cannot be avoided in the freshly selected alignments.

NOTE: As the full value of this research can be understood while having the complete maps at one's disposal, interested parties may contact us.

Dr. J.Rupke — applied geomorphology - geology

Dr. A.C.Seijmonsbergen — remote sensing & applied geomorphology

Alpine Geomorphology Research Group
University of Amsterdam
Nieuwe Prinsengracht 130
1018 VZ Amsterdam
The Netherlands