Europe Inside – Out. Young Geographers explore their notions of Europe. What is this construct built of? Where is the border? Is there a border? All participants had their challenges, being confronted with different ideas and notions. During one week 180 young Europeans participated in several workshops to find out more - more about their own notions and about the notions of their fellows.

XVIII. EGEA Annual Congress 2006:

Europe – Inside Out.
Acting as a young European in a globalised world

Massmovements in the Salzkammergut

natural hazards caused by geology and anthropogene influence

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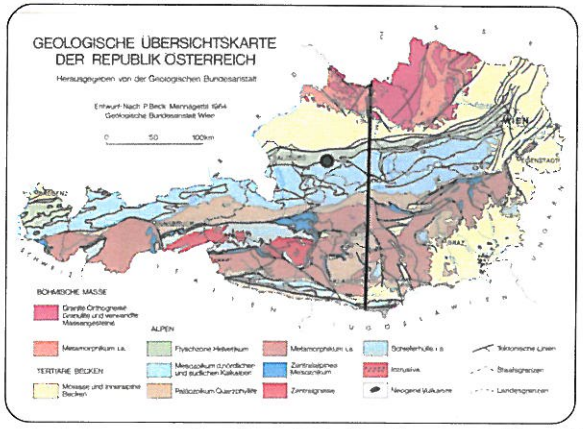

Figure 1:
Geological map of Austria with the position of the focused mass-movement areas (black marker). (Source: Geologische Bundesanstalt, Wien)

Introduction

The areas of the Gschliefgraben on the eastern shore of lake Traunsee near Gmunden, the Zwerchwand east of Bad Goisern, the Plassen west of Hallstatt (all three areas in Upper Austria) and the Sandling in the Styrian Ausseerland are home of some of the most impressive landslide processes in Austria (Fig. 1). Their extraordinary tectonic position, their lithology between the Ultrahelvetic or the Hallstätter Zone and the Northern Calcareous Alps as well as their morphological overprint caused by the ice-age glaciers made them to special examples of Applied Geology, Engineering- and Environmental Geology. Because the disintegration of mechanically brittle and rigid reacting cap-rocks into huge blocks and boulders resting atop of a mechanically weak reacting basement is a widespread phenomenon of slope instability there. This special geotechnical constellation results in toppling of high rock-towers and block sliding, rock-avalanches (Fig. 2) as well as debris streams in the weak sequence, which have been triggered by the first mentioned phenomenon. The reconstruction of their pre-quaternary and quaternary geology as well as their paleo-geography provides not only the opportunity for understanding natural factors and parameters for the genesis of mass-movement-systems but also the recognition of involved anthropogene influences as triggers for natural catastrophes: these are the salt mining as well as the connected de-forestation for salt production and the construction of ships for the salt-transport.

The Gschliefgraben on the eastern shore of lake Traunsee near Gmunden, Upper Austria

A tectonic window of Ultrahelvetic rocks overthrusted by the Flysch Nappe is exposed in front of the border of the Northern Calcareous Alps (Mt. Traunstein, 1691m) in the so called Gschliefgraben, east of Lake Traunsee, district Gmunden (Upper Austria). There the rock series mainly consist of dark grey, partly variegated marls ("Buntmergelserie"),

which are highly susceptible to water saturation, forming huge streams of earth-, mud- and debris down the valley. Those glacier-like massmovements (velocity: 20m/yr) have destroyed forests, cultivated land and farm houses for centuries, f. i. in the years 1660, 1734, 1825 and 1910. Debris flows along the main creeks within the Gschliefgraben have made serious problems during thunderstorms until present times, f. i. in the years 1897, 1899, 1947, 1955, 1977, 1987 (Fig. 3a, b). Additionally rock avalanches are also well known from the overthrusted Triassic limestone of the Calcareous Alps, adjacent to the Gschliefgraben. They have occurred f. i. in the

Figure 2:
The tremendous mountain collapse of the Bischofsmütze in October 1993 in the Salzkammergut dislocated 150.000m3 of rock material within a few seconds. (Source: own)

years 1730, 1884, 1891, 1967 and 1990. The deposited rock material has periodically formed debris flows with high velocity during summer season with high precipitation. The whole landslide affected area has a size of more than 5 km2.

An actual research project of the Austrian Academy of Science in the Gschliefgraben from 2004-2007

New geologic mapping of this geomorphologic highly active area serves as a base information for the interpretation of 2d-multi-electrode-geo-electric measurements (steel electrodes in a distance of 10m) with the STING/SWIFT system (by AGI) along selected cross sections (project leader: Univ. Prof. Dr. Karl Millahn, University of Leoben/Styria). As a result of these studies it can be show that a correlation of data of the engineering geologic field mapping and the geo-electric measurements has proofed as a helpful tool for the interpretation of actual shallow sedimentation processes (up to 100m of depth) within the massmovement area of the Gschliefgraben, such as i) movement horizons, ii) consolidation and compaction of transported material, iii) detection of moisture as well as iv) distribution of solid rock from mass movement sediments.

The Zwerchwand-rockavalanches and the Stambach-earth stream west of Bad Goisern, Upper Austria

The Zwerchwand (1341m) east of Bad Goisern is a 1km long and 80m high rock wall composed of Jurassic limestone which is underlain by Haselgebirge, a mixture of clay, gypsum and salt of the Permoskyth. The area at the foot of this rock wall is covered by huge blocks and boulders which have collapsed in October 1978 (60.000km3), in February 1980 (40.000km3) and in March 1981 (30.000km3). These rockavalanches triggered another massmovement by mobilizing the pore water in the subsurface. In February 1982 this earth-, mud- and debris stream with a total volume of 14 Mill. m3 started to moved along the so called Stambach valley with velocities of 5m/day endangering the village of Bad Goisern. After intense mitigation measures

such as drainage of the moving masses this stream could be stopped several month later.

The Sandling-rockavalanches and the Michlhallbach-earth stream in the Ausseerland, Styria

The Sandling mountain (1717m), composed of Jurassic limestone cliffs, has been divided to blocks by the salt diapirism (=migration of salt caused by pressure and temperature) of the underlying Haselgebirge. Especially during spring time, when water of the snow melt is flowing to its joint system, the movement in the subsurface is increasing, separating these blocks more and more. So the massmovement along the S-flank of the Sanding mountain has enlarged to a volume of more than 50 Mill. m3 during the Holocene. Additionally rock collapses and rockavalanches have shaped this mountain in historical times. Archaeological excavations document a catastrophe that must have occurred in the 5th century A. D. A rock tower, the Uh-sinning Kira (= tremendous cry), is the silent witness of a rockavalanche in 1546 which destroyed the ancient salt mine of Michlhallbach. After an initial rock collapse in 1765, 6-9 Mill. m3 of rockavalanche material dislocated in 1920. This massmovement not only destroyed the Alp meadow on the foot of the mountain (Fig. 4a) but also triggered the debris stream of Michlhallbach which ended up in a 4km long devastated area after one month (Fig. 4b).

Figures 3a, 3b:
Debris flows caused by cloud breaks in summer buried a house in 1955 at the foot of Mt. Traunstein (upper) and destroyed the camping ground in the vicinity of the Gschliefgraben in 1987 (belower). (Source: own)

The Plassen-massmovement and rockavalanches in Hallstatt, Upper Austria

Since the salt mine at Hallstatt west of the same named village on foot of the Plassen mountain (1954m) is an archaeologically well documented site, we have known about catastrophic massmovements in this area since prehistoric times. The whole mountain, composed of Jurassic limestone and again underlain by a huge salt diapir of the Haselgebirge, is moving towards the lake Hallstättersee. This movement with a volume of 60 Mill. m3 causes other landslides. 9 large rock failures (from 1652 to 1985) and 12 large debris flows and debris streams (from 1709 to 1968) occurred in historical times. Additionally 42 earthquakes were registered from 1348 to 1994. Collapses such as the one from the Rote Wand (=red wall) of the Steinbergkogel with a volume of 800m3 in October 1981, or the one from the Roten Kögele with a volume of 30.000 m3 in December 1985, buried roads and made serious problems to cultivated land.

Predesign, destabilizing factors, triggers and systems of the mass-movements

Engineering geologic investigations and hazard mapping in the past and at present times confirm a direct relation of these geomorphologic activities in the massmovement areas with the geotectonic history and neo-tectonic movements. Acting as preparatory causal factors and triggers of the periodically occurring intense massmovements, climatic conditions and the infiltration of water after snow melt have played an important role too. The precipitation f. i. in the Gschliefgraben, close to the northern border of the Alps is as high as 2500mm/year and can be as high as 200mm/day. Also the vegetation (flat root plates) and deforestation linked with salt mining have had effects on the degradation of the terrain. So far we can say that the disasterous chronology is as follows: tectonics -> seismicity -> rock loosening and weakening of rock strength -> rock avalanches and high precipitation -> mobilization of earth-, mud- and debris streams -> torrent activity -> debris flows. This complex system of massmovements in the Salzkammergut is called "hard on soft rocks".

Figures 4a & 4b: The Sandling rockavalanche in 1920 (left side) triggered the debris stream along the Michlhall-bach (right side), which reached velocities of 50m/hour. (Source:own)

Stabilizing inputs, mitigation measures and monitoring

Diverging opinions of local people and the authorities concerning the right mitigation measures have produced sociologic and economic conflicts not only in the past; since the late eighties of the 20th century new hazard-zone-maps have been the reason for various discussions especially about land use. In areas where local people could not cope with these natural hazard problems by simple solutions, active measures in torrent and avalanche control organized by the technical engineers of die.wildbachverbauung have been done. Geologic research has given the basic information for geo-biologic measures and technical constructions as stabilizing input against these extraordinary phenomena. Technical constructions, drainage systems as well as stabilizing input in forest techniques have partly solved different problems during the past 100 years. Unfortunately there is still a lack solving problems on the knowledge of the internal mechanism of the sliding areas for preventing new catastrophes. Also modern monitoring and warning systems are still missing although measurements (f. i. with extensometers) have already been done.

Areas for basic research and teaching students

All mentioned circumstances make the areas of massmovements in the Salzkammergut to ideal testing and investigation areas concerning massmovements and their impact on cultural history. Due to all facts and the exceptional positions of these landslide areas they also serve as perfect study objects for university training courses in geology and physical geography. During excursions not only students but also their teachers come to new perceptions – these scientific findings are the product of the contact with the phenomenon in the field and can be discussed instantaneously. That is why this paper should also serve as an excursion guide for those who are interested in this topic (Fig. 5).

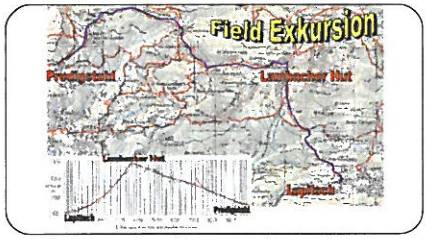

Figure 5: Route of the excursion, crossing the massmovement areas of Sandling and Zwerchwand from Lupitsch via Lambacher Hut to Predigstuhl. (own depiction)

Erkudok© - a center of geoscientific research and the documentation of massmovements

Gmunden, capital of the same named district in Upper Austria, is the home of Erkudok©, an Institute founded for the geoscientific research and the documentation of the cultural historic evolution in the Salzkammergut. This Institute is a division of the museum of this town, which was founded in 1907. Creating popular scientific pathways, exhibition halls in the museum, producing publications as well as ensuring field guidances for scholars and students give this Institute a leading role in public relation of geosciences in Austria. Local and international research work concerning the topic „mountain hazards, massmovements and landsliding" led to a cooperation of this Institute with the University of Leoben in Styria (Department of Applied Geosciences and Geophysics) and the University of Salzburg (Department of Geography and Geology). This project could act as a visionary idea for other regions and different subjects or scientific disciplines.

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Field-Excursion

A geological experience

Excursion "Massmovements in the Salzkammergut"

There are different reasons, why the excursion day during the Annual Congress 2006 in Bad Aussee - as well as every excursion during conferences and congresses - was an important part of the whole event:

The excursions included the surroundings of the meeting place, the Ausseer Land, into the programme. The participants not only get to know the guesthouse and the view from it, but also become acquainted with the area with the aid of on-site experiences. The location of the event becomes an inherent part of the congress week and an unforgettable frame for the participants.

Furthermore, the participants have the possibility to get to know each other. Excursions have deep impacts on group dynamics. Friendships are formed, continued, cultivated and revived. There is time to talk and to exchange thoughts.

Last but not least excursions offer the best possibility to make scientific topics and theory concrete. Thus science gets more understandable and memorable. Excursions are the best way to bridge the gap between theory and practice.

Especially in the last point, the excursion "Massmovements in the Salzkammergut" was outstanding. This excursion

was linked to the lecture "Massmovements in the Salzkammergut" by Dr Johannes T. Weidinger, which he held on Monday during the lecture session of the congress. We were very lucky, that Dr Weidinger, who had great experience in the field of research of landslides all over the world, also agreed to act as a scientific leader of an excursion.

After his lecture it took only a short time until more than 20 interested participants signed in for the excursion "Massmovements in the Salzkammergut". Elisabeth Maierbeck from EGEA München and Philipp Sartorius from EGEA Wien escorted the excursion group as organisational tutors. Dr Weidinger led the excursion group to geologically interesting places and to locations especially affected by massmovements in the region of Bad Goisern and Lupitsch. He already mentioned these places during his lecture on Monday in the guesthouse in front of an interested audience. During the hike Dr Weidinger gave some small lectures about the geological features in the Salzkammergut to ensure the scientific demand underlying this excursion.

Figure 1: The excursion group at the Zwerchwand (Source: own)

This excursion was an intermediate hiking tour. The group started at 8:30h a.m. at the guesthouse. The entrance of the hike was located in Oberlupitsch, about 5km next to Bad Aussee and on an altitude of 864m above sea level. The tour led towards the mountain Sandling (1.717m). We were tangent to the mountain about 300m below the summit and reached the highest altitude of our tour at the Lambacher Hütte (1.432m). Then our tour led in the direction of the mountain Zwerchwand, which we reached after our lunch break. After about 6 hours, exhausted and satisfied, we arrived at the meeting point close to Bad Goisern, where we were picked up.

Already during the first hour of the trip, the possibility arose to repeat the basics of the topic "massmovements" in the form and spectacular shape of a rock. Massmovements means the relocation of rock masses due to gravitation. There are four different basic types of movements: slides, toppling, rock falls and debris flows. Often combinations of these basic types appear, which are abstracted in the term "landslides". Landslides can occur fast and immediate or slow and constant.

When we were tangent to the mountain Sandling, we had a free view of another impressive landslide. At this place, the topic massmovements as natural hazards was taken up. Landslides and massmovements can demolish and destroy houses, infrastructure and cultural landscape and they can be danger to life. Facing a dangerous landslide, the participants realized that it is essential to research for strategies of hazard mitigation, especially for villages close to endangered areas.

After lunch break we reached the Zwerchwand, which is an instable rock wall. Several major rock falls occurred three decades ago, the last one in 1983. The wall is constantly observed, and measurements show that the mountain is moving and that it's merely a matter of time until the next rock fall will occur. On closer inspection of the rock wall the top layer consists of inflexible limestone, the subsoil of permian Haselgebirge, which is mobile and weak. This different consistency of the ground layers causes the movement.

Thanks to Dr Weidinger and to all participants for this marvellous hiking experience!