Final Report of Mini-Proposal

BLOSSOM

Bathymetry at Lake Ohrid for Subaquatic Slide Overview Mapping

Katja Lindhorst

General information:

Mini-Proposal within the framework of the Integrated School of Ocean Scienes (ISOS) for financial support during a field campaign at Lake Ohrid (Macedonia/Albania)

Applicants:

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Topic:

Detailed mapping of a major sub-aquatic slide in the southwestern part of ancient Lake Ohrid by means of multibeam and sediment echosounder data in order to describe, characterize, and quantify lacustrine slides in comparison to mass movements along continental margins.

Report and funding period:

February to November 2009

Work report and Results

Initial questions and objectives

Previous investigation with high resolution seismic suggest that Lake Ohrid host several large mass wasting events, one of them covering an area over more than 25 km². Only high resolution seismic and multibeam data provides essential information of slope morphology, surface topography, and expansion of such failure events (Locat and Sanfaçon 2000).

Specific goals of the multibeam survey are:

- to obtain a detailed map of the slope area to reconstruct the environment before failure occurred in order to investigate where the slide has been initiated
- to map pathways of sediment transport into the basin, along slope area and within the slide deposits
- to characterize topographic features such as slope angle, the occurrence of gullies or other erosive features along the escarpment to investigate whether erosion is a ongoing process
- to image the depositional part of the slide in the central basin in order to reveal total cover area and run-out distance for estimating the kinematic energy of the failure
- to evaluate surface and internal structures of the slide to understand sediment transport and deposition processes
- to reveal whether the sliding event was superimposed by some minor events occurring after the major failure indicating that the area was unstable over a long period
- to discover a mechanism for stopping the run-out of this particular slide
- to recognize tectonic features such as faults which are most likely connected to slope failure as the Ohrid basin is in general a tectonically active region.

For a profound characterization of the slide a simultaneously operating sediment echosounder system allows us to map the upper most lacustrine sediment down to ~30m beneath the lake floor. Such data are crucial to estimate the volume of the failure event and its internal structure. These slide parameters such as geometry, structure, volume, and origin can then be used to improve models of tsunami generation, which might be triggered by such failure events (Weiss 2008).

Development of investigations

In order to successfully carry out an acoustic survey several preparation steps have been undertaken. The field campaign was scheduled for September 2009 for several reasons. First of all, the weather conditions during this time period around Lake Ohrid seemed to be most favorable as observed for several years at the weather station at Ohrid Airport. For successful operation, the lake must be calm as the multibeam device is very sensitive for strong movements although compensated by a motion sensor. Another reason was the availability of the operating systems and co-workers. Finally, it turned out that such a field campaign needs at least 6 month for preparation.

Preparation phase

Preparation steps included purchasing of material, team building, customs handling, and time management. Both measurement instruments (multibeam, sediment echosounder) came in boxes with additional supply for each system. The sediment echosounder was kindly provided by the University of Cologne, our partner within the ICDP project SCOPSCO (Scientific Collaboration on Past Speciation Condition in Ohrid). A generator for electricity on the research vessel and raw material for the holder construction was organized prior to the field campaign.

The team of BLOSSOM consists of three people: i) Katja Lindhorst, PhD student at IFM-Geomar as main applicant of Mini-Proposal BLOSSOM, ii) Matthias Grün and Stephanie Kurschat (Kiel University), enthusiastic students actively participating in the field campaign.

The field campaign started with the transport of materials via a VW Bus with a small trailer over a distance of 2300km to Ohrid in Macedonia. Sebastian Krastel, advisor of Katja Lindhorst who is experienced in scientific project management, participated at the field campaign for one week during installation phase. Engineer Norman Lindhorst was responsible for the holder construction of the multibeam transducer system, attended the campaign throughout the first week. A specialist for the multibeam device, Wilhelm Weinrebe (IFM-Geomar), installed and calibrated the system. Finally, Zoran Brdadovski (Hydrological Institute in Ohrid) was responsible for the functionality of the vessel and catering on board. Several additional people in Kiel as well as in Ohrid provided great support for the project.

A major step within preparation phase was custom handling. The procedure includes a proposal of a so called CARNET A.T.A, comparable with a passport for materials. A CARNET A.T.A. can always be used for a limited time span (maximum a year) within non EU countries in order to operate the system and subsequently re-import to Germany. A timetable for activities at Lake Ohrid was the last important point of the preparation phase.

Field campaign

After completion of all preparations we started on September 17th, 2009 around 2pm at the IFM-Geomar. The route ran through the Czech Republic, Slovakia, Hungary, and Serbia to arrive in Macedonia. After picking up Norman Lindhorst at Skopje airport we finally arrived in Ohrid on Saturday 19th, 2009 around 11pm.

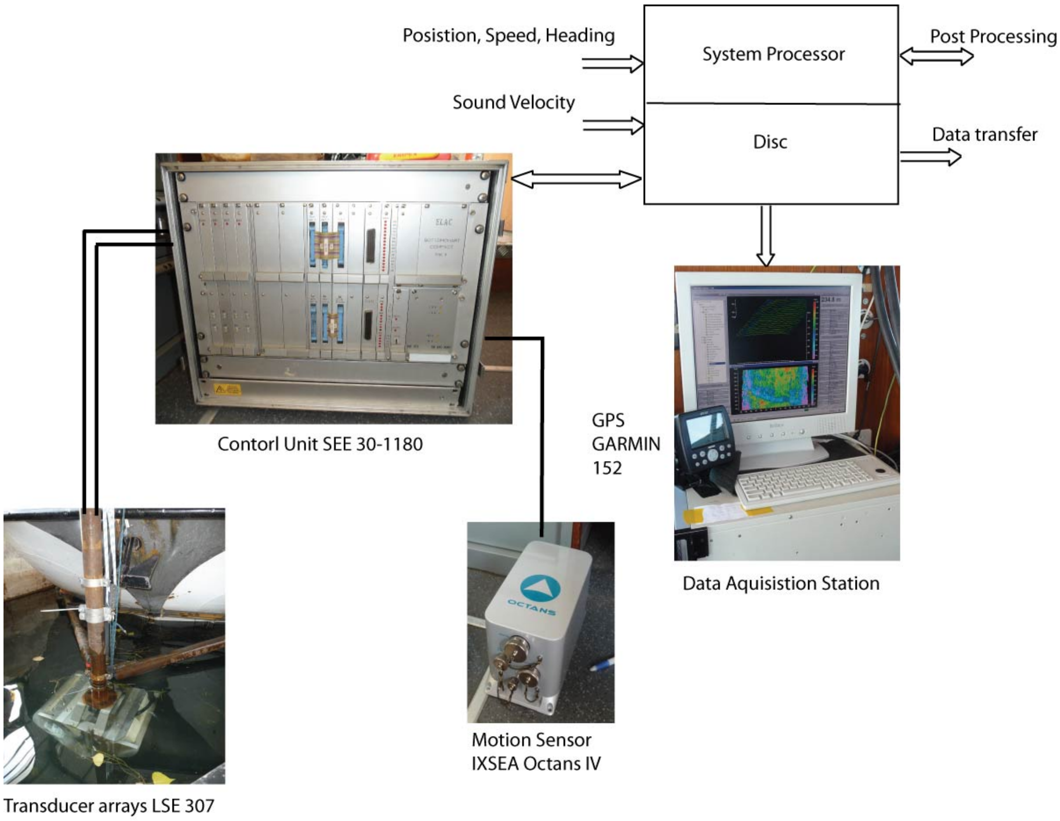

Figure 1: Schematically view of the multibeam configuration as used during the BLOSSOM campaign on Lake Ohrid

During the first days we concentrated on building up the holder construction for the transducer, the set up the sediment echosounder as well as the acquisition systems. Due to the fact of that the motion sensor for ship movement compensation was missing we started surveying the lake with the sediment echosounder. Unfortunately, the motion sensor we were planning to install was not available because of some damage on a former cruise right before our field campaign. A spare system could be organized quickly but needed some additional custom handling in Germany. Subsequently we had to face one week of delay in arrival of Wilhelm Weinrebe what led to a significant change in our original schedule. The actual multibeam survey started on Thursday, October 1st 2009 with. One consequence of this change in schedule was that Wilhelm Weinrebe who could only stay for a shorter time at Lake Ohrid the transducer calibration had to be done in one day. Nevertheless, we manage to survey the lake from 2nd to 10th October 2009 with multibeam and sediment echosounder and mapped almost the entire lake in depth greater than 80m. The survey was a great success although we have to admit that next time one additional day with the multibeam specialist would have been necessary in order to minimize beginner's mistake. For example we only collected four sound profiles within the entire lake not knowing that this would not be enough and therefore the data needs additional processing.

Presentation of results and ongoing work

The work followed by the acoustic survey in Ohrid included processing of all sediment echosounder profiles and subsequently loading them to interpretation software The Kingdom Suite 8.2. For the purpose of a conference that was held in November 2009 in Austin Texas entitled Submarine Mass Movements and their Consequences, the multibeam data were processed with focus on the southwestern part were we observed a major submarine sliding event with nicely visible head scarps and sidewalls. A poster showing a detailed bathymetric map and the internal structure of two events was presented in Austin.

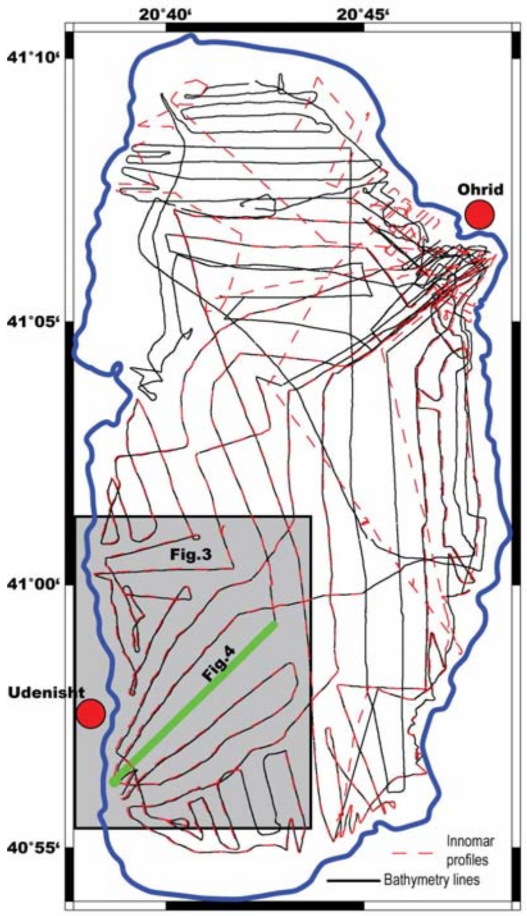

Figure 2: Photographs of multibeam transducer during operation (top) and a side view of the Macedonian research vessel showing the holder construction in front as well as the sediment echosounder device along the side (bottom). Map of seismic and multibeam lines (right)

At the time of the final report, processing of the data is still in progress. However, we are planning to present results and first interpretation of the data at the DGG held in Bochum in March 2010. A publication of final interpretation of multibeam data and hence a quantitative description of the Udenisht slide will be submitted not later than July 2010 in form of a master thesis by Matthias Grün. In addition the bathymetric map of the slide in the southwestern part of Lake Ohrid, which was the main focus of this project, will be integral part of a manuscript published in a peer-reviewed journal not later than spring 2011.

Results and possible subsequent investigations

The hydro-acoustic survey at Lake Ohrid was carried out from September 17th to October 14th 2009. A cruise track map showing all bathymetric lines and sediment echosounder profiles is shown in Figure 2. Within Ohrid Bay we even manage to image the lake floor as shallow as 20m due to the fact that the bay is located close to Hangar of the vessel and therefore passed twice a day.. Furthermore, our data of high resolution sediment echosounder contributes to the overall dataset that has been collected since 2004. By now a dense grid of seismic lines with ~100m spacing separating single profiles is available. A setup of the system is shown in Figure 1.

The main goal of the Project BLOSSOM was the quantitative description of the Udenisht mass movement event (named after a small village in Albania where the slide most likely originated). Hence we will focus our description of preliminary results on that area. Figure 3 presents a first image of preprocessed bathymetric data of the southwestern part of Lake Ohrid. Artifacts caused by an erroneous sound profile are still visible within the outer beams of some profiles. However, the Udenisht slide area is nicely imaged on the picture.

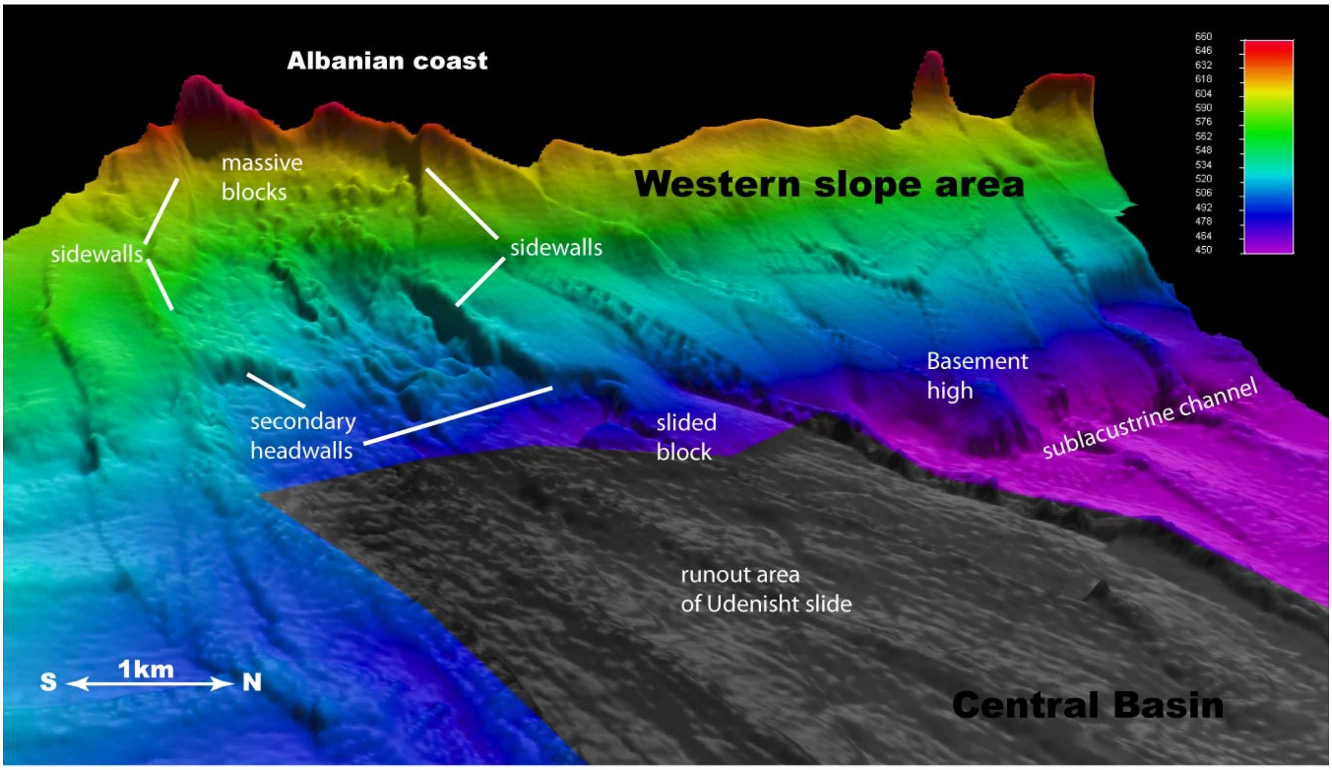

Figure 3: Bathymetric map of the southwestern part of Lake Ohrid showing the Udenisht slide (see text for details).

A first morphological analysis shows that the slide covers an area of about 27km² (about 10% of the area of entire lake). Udenisht slide complex is bounded by clearly visible sidewalls within the upslope part. Several massive blocks with diameter of up to 150m (Figure 3) can be seen on the steep inclined lake floor. The runout area marked in grey was most likely during the mass movement as material got reworked and transported towards the center of the basin. A cross section of the area shows a huge transparent body in seismic data underlying the lake surface, which represents slide deposits (Figure 4). A more detailed study of this particular area will be one aspect within the master thesis of Matthias Grün. By investigating travel distances and type of material he will be able to give an estimation of the transport energy of the mass movement event. Within the lower part of Udenisht slide a block with a length of 450m has been identified. As a first interpretation, such blocks were broken up of the sidewalls within a second phase while the slide area got reactivate. This indicates that the slope in the southwestern part of Lake Ohrid is still instable.

Additionally, further to the north a basement high is apparent that has a diameter of 1km and heights of about 70m. Furthermore, an incised channel marks the intersection of the western slope area with the deep central basin of Lake Ohrid.

Internal architecture of Udenisht slide can be studied by means of sediment echosounder data. An example of a seismic line shot across the slide from central basin towards upslope area is shown in Figure 4. Sediments on the eastern side of the profile are well stratified hence indicating that they are unaffected by the major sliding event. In contrast, a huge transparent body representing reworked material is imaged in the central part of the profile.

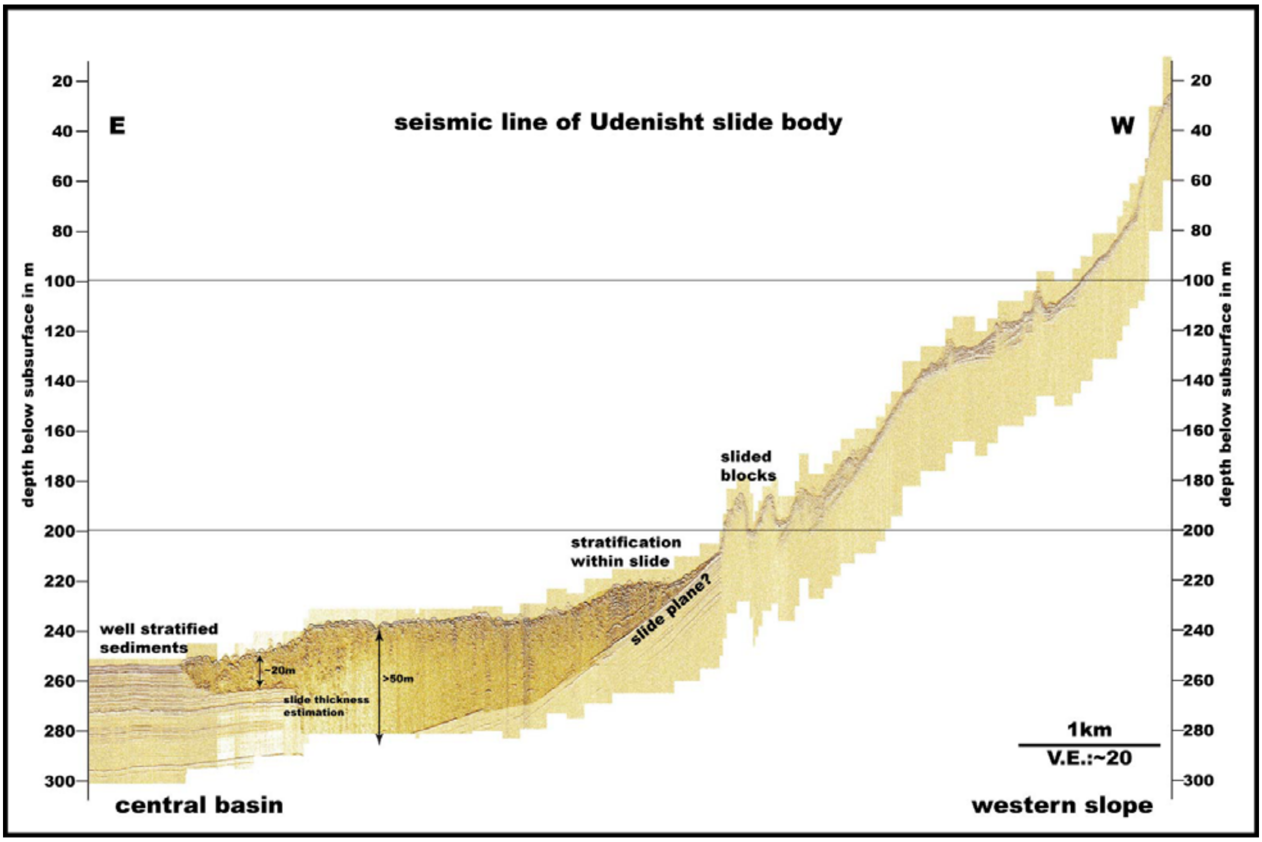

Figure 4: Seismic section across Udenisht slide showing internal structures of the Mass movement event (see text for detailed description).

A first estimation of slide thickness is more than 50m in some parts but a thinning towards the central basin has been observed (Figure 4). Some internal stratification within the transparent unit is preserved in an upslope part. Additionally, three blocks are marked in the seismic section (Figure 4). A possible glide plane, characterized by a prominent reflector has been identified. Further interpretation of the data will shed light on possible trigger mechanism, energy content of the slide, and the origin. Our hope is to answer scientific questions such as whether the slide was a single or multi phase event, why are slides occurring along the western slope of Lake Ohrid but are absent along the eastern part, and whether it is possible that the Udenisht slide initiated tsunami.

Summary

Lake Ohrid on the Balkan Peninsula is the oldest lake in Europe (3-5 Ma) and host an outstanding degree of endemic species and biodiversity. The Ohrid area is still a tectonically active area with several larger Earthquakes in recent time. Earthquakes can be trigger mechanism for submarine mass movements as present in the southwestern part of Lake Ohrid. Our study investigated a major slide in Lake Ohrid (Udenisht slide) by means of hydro-acoustic methods in order to gain a better understanding of such massive failure events that have been described not only in lakes but along continental margins (Gardner et al. 2000; Keefer 2002; Krastel et al. 2001; Strasser et al. 2007). The Udenisht slide covers an area of 27 sqkm and reaches thickness of more than 50m. Preliminary results of morphological analyses show that the slide most likely

originated on the Albanian land in vicinity of the small village Udenisht. Massive blocks on the upslope part could be identified in contrast to finer material that traveled further basinward. A detailed study of this data available in summer 2010 will allow quantifying the sliding event in terms of its energetic regime, trigger mechanism, and phases of sliding hence providing input parameter for a tsunami model.

Acknowledgement

Special thanks to Marion Liebetrau for her support in many aspects. I gratefully acknowledge the assistance during field work, especially the excellence Macedonian style catering on board provided by Zoran Brdarovski together with his colleagues from the Hydrobiological Institute in Ohrid. I also thank Bernd Wagner and Hendrik Vogel from the University of Cologne for providing the sediment echosounder and for many fruitful discussions in Ohrid. I would like to acknowledge Wilhelm Weinrebe who was an indispensible help throughout the entire project. I am very grateful to Sebastian Krastel for his confidence in my work and being a supportive advisor whenever needed. Special thanks also go to Norman Lindhorst who made the operation of the multibeam possible by constructing a special holder assembly in almost no time. Thanks to my student assistant workers Stephanie Koch and Matthias Grün for their work and interest in the project.

Cited References

Gardner J., Mayer L. and Hughs Clarke J. (**2000)**. *Morphology and processes in Lake Tahoe (California-Nevada)*. Bulletin of the Geological Society of America 112: 736-746.

Keefer D. (**2002)**. Investigating landslides caused by earthquakes–A historical review. Surveys in Geophysics 23: 473-510.

Krastel S., Schmincke H., Jacobs C., Rihm R., Le Bas T. and Alibes B. (**2001)**. *Submarine landslides around the Canary Islands.* Journal of Geophysical Research 106.

Locat J. and Sanfaçon R. (**2000)**. Multibeam surveys: A major tool for Geosciences.

Strasser M., Stegmann S., Bussmann F., Anselmetti F., Rick B. and Kopf A. (**2007)**. *Quantifying subaqueous slope stability during seismic shaking: Lake Lucerne as model for ocean margins.* Marine Geology 240: 77-97.

Weiss R. (**2008)**. Sediment grains moved by passing tsunami waves: Tsunami deposits in deep water. Marine Geology 250: 251-257.