

## ABSTRACT

From 1991 to 1994 slopes of the lakes "Starnberger See" and "Tegernsee" were mapped with respect to subaquatic mass movements using geophysical methods like echo sounders, sidescan sonar and subbottom profiling equipment. The combination of precise laser navigation with sidescan sonar and subbottom profiling techniques allowed to record the typical surface conditions of mass movements simultaneously with the stratification of the subbottom. Only very steep slopes limited both practical exercise and interpretation of records. Mapping by scuba diving and coring to determine the sedimentological and physical properties of the sediments completed the geophysical records.

These investigations seemed to be necessary because subaquatic mass movements hold an important potential risk for pipelines for gas, electricity, communication or sewage, which are increasingly installed on lake bottoms. The aim of this mapping of recent and fossil mass movements was their characterization with respect to their size, the involved material, as well as the type and the time of movement. The two lakes were chosen for these investigations because of their very different orographic, geological and hydrological background. Therefore it was expected to determine also different geological, tectonic, climatic or anthropological factors as possible reasons for the movements.

The mapping shows that the different types of sedimentation between the lakes "Starnberger See" and "Tegernsee" affect the number as well as the type of mass movement. In the lake "Starnberger See" recent slides are of minor importance. The main type of movement found in this lake is sediment creeping which is affecting wide areas of the slopes. Due to the small catchment area autochthon sedimentation is dominant. These holocene sediments with high carbonate contents show high water contents even in greater depth of the sediment sequence. A "Thixotropic" behavior is the result of water contents higher than those found for the liquid limits. This seems to be the reason for the slow creeping movements. In contrast the late glacial sediments dominated by allochthon material show water contents below that of the liquid limit. This seems to be the reason that these processes are restricted to the holocene sequence. Beside the gravity forces additional triggers may be important for this type of movement.

Fossil slides were found in three areas of lake "Starnberger See". While the slide at "Seeleiten" is characterized by several phases of activity, the others - south of Seeleiten and near Tutzing - were single events. According to pollen analyses and  $^{14}\text{C}$ -dating the main period of mass movement at the site of Seeleiten was during the Younger Atlantic and a second period occurred at the end of the Subboreal. Simultaneous lake level fluctuations seem to have triggered these slides. The relative position in the subbottom profiling records indicates also a holocene age for most of the other slides found in lake "Starnberger See".

The surface mapping of lake "Tegernsee" by sidescan sonar show no indications for creeping processes. In contrast to lake "Starnberger See" there is also a significant difference in mechanisms and reasons leading to mass movements. Rotational and translational slides are the dominant types of mass movement in the delta areas of lake Tegernsee. Due to the big catchment area with high relief energy deltas are well developed and the overall sedimentation is highly influenced by the allochthon input. This is supported by the tributary with highly erodible "Flysch" deposits combined with different types of landslides in this area.

During high flood events the sediment input into the lake is done by high density turbidity currents. As a result current lineations are formed on top of the delta as well as in the adjacent profundal areas and even on lower parts of the opposite slope. The distributional pattern and the shape of these surface structures can serve as a model for high flood sediment transport in deltas with coarse grained sediments. With respect to the mass movements such events with extremely high sedimentation rates in a short time period may lead to an increasing overburden stress and finally a failure of the sediment in the deltas of this lake.

In areas not influenced by delta sedimentation, sediment movements of smaller scale and with small depth of the rupture surface have been found. High productivity of natural gas due to high contents of organic matter is influencing the stability. Migration of this gas is responsible for weakening the sediment structure and for building surfaces of rupture leading to an increased instability of the slope sediments. In comparison with sediment slides of the delta type these slides triggered by the release of gas are in general smaller and affect only the higher parts of the sediment sequence. At lake Tegernsee the human impact was found to be an additional factor for triggering subaquatic slides.

In both cases, Starnberger See and Tegernsee, smaller mass movements are already stopping at the slope. In contrast the big mass movements move along the steeper slopes and finally stop at the transition to the flat profundal areas. Turbidity currents triggered by these mass movements but also high density turbidity currents during high flood events move over long distances even upslope on the opposite side of the lake.

Compared to known mass movements in other lakes, lake Starnberger See and Lake Tegernsee can act as model cases for most mass movement types, for their transport and trigger mechanisms and finally for the potential risk.