Geophysical Research Abstracts,
Vol. 10, EGU2008-A-00145, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-00145
EGU General Assembly 2008

Breakdown mechanisms in gypsum caves of southern Italy, and the related effects at the surface

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Direct mapping and examination of breakdown structures in caves may provide a unique opportunity to: i) verify the likely relationships between sites affected by breakdown processes and their geologic features (bedding, fractures, weathering, etc.), ii) identify different stages in the development of breakdown mechanisms, iii) study the relationships between surface and underground settings, and iv) evaluate the effects at the surface of what is occurring underground. The latter point also allows for an evaluation of the overall gravity-related hazard. Geological, morphological and speleological researches have been recently carried out in Calabria (Southern Italy), one of the most landslide-prone areas in the Mediterranean basin. Different types of slope movements affect the outcropping rocks, due to the combined action of a number of causal factors, either predisposing (abundance of weathered materials, rugged topography, high relief energy, and active tectonic uplift), or triggering (heavy rainfall, moderate to strong seismic shocks, and anthropogenic action). Due to the presence of several karst areas, further instability phenomena in the region are represented by development of sinkholes and subsidence. This study deals with analysis of instability phenomena in the Upper Miocene to Pleistocene deposits of the evaporite karst in the Crotone Basin, which includes several renowned caves as the system Grave Grubbo - Vallone Cufalo (the second longest Italian gypsum cave, with a length over 2,800 m). Peculiarity of the local environment allowed to observe and analyze instability phenomena both at the surface (through field surveys and interpretation of aerial photos) and underground (by means of caving explorations). The hilly landscape in the study

area is carved in the easily-erodible Miocene and Pliocene terrains, with deep fluvial incisions breaking the rounded hilly landforms. At the surface, the transition between a landscape of clear fluvial origin and the typical karst is commonly to be found, at the contact between soluble rocks and impervious, not soluble, clayey terrains. Both solution- and collapse-sinkholes are present (the latter being more spectacular), with vertical walls, and big heaps of rocks at the bottom. Solution-sinkholes with smooth slopes are often modified by man for agricultural practices. This may result in development of widespread linear and areal erosion, and in the development of badlands. Within the underground karst systems, breakdown deposits are to be found, together with alluvial sediments left after flood passages. Rock falls deposits, with blocks of even great size, characterize the largest chambers and caverns, produced by breakdown processes. The erosive s.l. processes acting in shaping the caves are favoured by the high solubility and low resistance of gypsum, and by the alternation of prolonged dry periods with severe flash floods. The abundance of allogenic materials further causes mechanical erosion, thus promoting evolution of the cave through instability processes. The effect of human activities on the environment has also to be taken into account: man has in fact strongly been changing the landscape in the last decades, aiming at gaining land for agriculture, but often inducing severe land degradation and increase in erosion. The swallow holes in the area have often been modified to: i) facilitate the underground drainage and avoid the surface runoff in the cultivated fields, and, at the same time, ii) slow down the passage of water, in order to have available the amount needed for agricultural practices. The two actions are in some way contrasting, and it is not easy to reach the correct balance between the two; too often they result in an increase in erosion, in the diversion of the natural surface runoff, and in loss of vegetation, thus promoting slope instability processes along the borders of dolines and valleys.