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Assessment of cover-collapse sinkholes in southwest Sardinia (Italy)

F. Ardau (1), R. Balia (1), M. Bianco (1), S. Cinus (2), **J. De Waele** (3) and M. Farris (2)

(1) Dipartimento di Ingegneria del Territorio, University of Cagliari, Cagliari, Italy, (2) Regione Autonoma della Sardegna, Soil Protection Division, Cagliari, Italy, (3) Dipartimento di Scienze della Terra, University of Cagliari, Cagliari, Italy (geoam@unica.it / Fax: +39 070-282236)

In recent years the southwestern part of Sardinia has been afflicted by several cover collapse sinkholes, especially during or immediately after heavy rain periods. These phenomena didn't cause serious damage up to now, but just due to the fact that they occurred in scarcely dense populated areas; however in 1998 one rather big sinkhole occurred only 50 m from the railway that connects Cagliari, the capital of Sardinia, to the towns of Iglesias and Carbonia. Actually, beyond the serious danger for people, these events could damage some important infrastructures such as railways, roads and buildings, with significant economical impact.

The study area is characterised by the outcropping of the Variscan basement related to the South European Hercynian chain. The Palaeozoic sequence ranges in age from Early Cambrian to Lower Carboniferous, is variously metamorphosed and can be subdivided in two sedimentary cycles, the Caledonian (Lower Cambrian-Lower Ordovician) and the Hercynian one (Upper Ordovician-Lower Carboniferous) divided by a sedimentary gap as testified by the Sardinian unconformity. Main outcropping rock types are metasandstones, metadolostones, metalimestones, shales and metconglomerates. Besides the local deposition of some marine sediments during Mesozoic and Early Tertiary, during Eocene-Oligocene structural lowlands were filled in with a fluvial-lacustrine continental sedimentary sequence known as Cixerri Formation reaching thicknesses of more than 150 meters.

The main structures in the Palaeozoic basement reflect the regional directions of the

Caledonian and Hercynian tectonic phases with important E-W folds related to the Sardinian phase and narrow N-S folds corresponding to the Hercynian phases.

The Cambrian carbonatic rocks have been involved in several karstic cycles since Upper Cambrian, and constitute the most important aquifer of the region, confined by the impervious sandstones at the bottom and by the shales at the top.

The study of the cover collapse sinkholes in Southwest Sardinia is of primary importance in order to analyse their spatial and temporal distribution and to relate them with the local geological and structural condition. The most sensible areas for sinkhole development seem to be located close to Cambrian carbonatic outcrops where limestones and dolostones are covered with a more or less thick (0-30 m) mattress of continental Cixerri Formation sediments.

Most of the cover collapse sinkholes observed in the epikarstic zone are of secondary origin, related to the transport of sediment (ravelling) in existing tectonically controlled major karren and/or karstic tunnels, and are generally triggered by the oscillation of the water table; moreover, they form in areas of high infiltration rates, where downward erosion of covering sediment into pre-existing karstic voids is enhanced. This means that collapses prevalently occur in low areas (valleys and low plains) covering the epikarstic zone, often close to little streams where concentrated water flows during heavy rains. The presence of pumping stations or drainage systems can trigger collapsing, while high construction density enhances concentrated infiltration and turbulent flow.

Cover collapse sinkholes in Southwest Sardinia always seem to be related to well determined climatic conditions and confined to specific geological, tectonic and morphological situations. Most of the events studied in this work have been triggered by human activities, especially water table lowering by the exploitation of the karstic aquifer or by mining activities.

The application of geophysical techniques proved to be very useful and promising. The near- surface geological and structural model of the already cited area where one sinkhole occurred close to the railway was realized by means of a combination of gravity and seismic refraction/reflection methods, integrated with six boreholes and geotechnical aswell as hydrogeological measurements. Presently the geophysical work is concentrated on gravity profiles, prevalently crossing the N-S oriented Hercynian structures. Two of these profiles, carried out along the railway lines, show the very close relationship between some of the sinkholes at issue and the above mentioned regional structures, and provide a highly detailed information on the hazard of new cover collapse sinkholes.

Summing up, the historical analysis of the phenomena, the geological knowledge of the Iglesiente-Sulcis area and the results of the geophysical researches can allow to determine the most probable areas where cover collapse sinkholes can occur in the future. Beyond this, construction and settlement should be avoided in the areas that already have been interested by collapsing phenomena in order to prevent human losses and material damage in the future**.**