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Seismic surface-wave prospecting methods for sinkhole hazard assessment along the Dead Sea shoreline

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The Dead Sea's coastal areas have been dramatically hit by sinkholes occurrences since around 1990 and there is an obvious potential for further collapse beneath main highways, agricultural lands and other populated places. The sinkhole hazard in this area threatens human lives and compromise future economic developments. The understanding of such phenomenon is consequently of great importance in the development of protective solutions. Several geological and geophysical studies tend to show that evaporite karsts, caused by slow salt dissolution, are linked to the mechanism of sinkhole formation along both Israel and Jordan shorelines. The continuous drop of the Dead Sea level, at a rate of 1m/yr during the past decade, is generally proposed as the main triggering factor. The water table lowering induces the desaturation of shallow sediments overlying buried cavities in 10 to 30 meters thick salt layers, at depths from 25 to 50 meters. Both the timing and location of sinkholes suggest that: (1) the salt weakens as result of increasing fresh water circulation, thus enhancing the karstification process; (2) sinkholes appear to be related to the decompaction of the sediments above karstified zones. The location, depth, thickness and weakening of salt layers along the Dead Sea shorelines, as well as the thickness and mechanical properties of the upper sedimentary deposits, are thus considered as controlling factors of this ongoing process.

Pressure-wave seismic methods are typically used to study sinkhole developments in this area. P-wave refraction and reflection methods are very useful to delineate the salt layers and to determine the thickness of overlying sediments. But the knowledge of shear-wave velocities (Vs) should add valuable insights on their mechanical properties, more particularly when the groundwater level plays an important role in the process. However, from a practical point of view, the measurement of Vs remains delicate because of well-known shear waves generation and picking issues in shear-wave refraction seismic methods. As an alternative, indirect estimation of Vs can then be proposed thanks to surface-wave dispersion measurements and inversion, an emerging seismic prospecting method for near-surface engineering and environment applications.

Surface-wave prospecting methods have thus been proposed to address the sinkholes development processes along the Dead Sea shorelines. Two approaches have been used: (1) Vs mapping has been performed to discriminate soft and hard zones within salt layers, after calibration of inverted Vs near boreholes. Preliminarily, soft zones, associated with karstified salt, were characterized by Vs values lower than 1000 m/s, whereas hard zones presented values greater than 1400 m/s (will be specified during following studies); (2) roll along acquisition and dispersion stacking has been performed to achieve multi-modal dispersion measurements along linear profiles. Inverted pseudo-2D Vs sections presented low Vs anomalies in the vicinity of existing sinkholes and made it possible to detect loose sediment associated with potential sinkholes occurrences.

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