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Subsidence susceptibility zonation based on the analysis of paleokarst exposures in a high-speed railway built on a salt-bearing evaporite karst (Ebro Valley, NE Spain)

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The Ebro Valley in the central sector of the Ebro Tertiary Basin (NE Spain) is probably the area in Europe where the sinkhole hazard due to evaporite dissolution has a higher socio-economic impact. Here, the generation of sinkholes is related to the karstification of the several hundred meters thick, halite and glauberite-bearing Zaragoza Gypsum Formation. This bedrock, with a subhorizontal structure and affected by subvertical joints, is extensively mantled by alluvial deposits (terraces, mantled pediments, valley fills and alluvial fans). Locally, the terrace and pediment deposits show thickenings in excess of 60 m filling dissolution-induced basins generated by synsedimentary subsidence. Some of the most significant detrimental effects of the sinkhole hazard in the area include the demolishment of buildings, the abandonment of irrigation structures and the occurrence of collapse sinkholes in communication routes leading in one case to the derailment of a train. The high-speed Madrid-Lérida railway runs along 75 km on the Zaragoza Gypsum Formation and carries more than 2 million passengers per year. Before its inauguration in 2003, a controversial debate arose about the safety of this highly vulnerable infrastructure devoid of any protective engineering measure capable of spanning sinkholes. Even a slight settlement might cause the derailment of the train running at more than 300 km/h. A 35 km long stretch located between the Valdespartera karstic Depression and the Ginel River valley has been surveyed. Five different types of sections have been differentiated: A) Railway on bedrock (4 km). B) Railway on hectometre-long karstic depressions (6.5 km). The available exposures indicate that these large depressions, underlain by strongly karstified bedrock, are due to collapse and sagging subsidence mechanisms resulting from interstratal karstification. C) Railway on infilled valleys (4 km). D) Railway entrenched in thickened terrace and pediment alluvium (5 km). E) Railway entrenched in evaporitic bedrock (13 km). A

methodology for the elaboration of a subsidence susceptibility zonation is proposed for sections D and E based on the analysis of the dissolution and subsidence features exposed in the railway cuttings. These features are present in more than 35% of sections D and E and include air-filled dissolutional conduits, alluvium-filled conduits (suffosion), breccia pipes, stratiform breccias and sagging structures. The location, size and density of the paleokarst structures allow us to establish zones with different degrees of susceptibility and to identify especially hazardous locations where the application of protective measures should be of top priority. This zonation is based on the hypothesis that the areas affected by subsidence in the past (karstified areas) have a higher subsidence potential than the sectors that do not show any evidence of karstification or subsidence. This assumption is supported by the fact that sinkholes frequently result from the natural or human-induced reactivation of pre-existing karst features.