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New insight into unstable hillslopes hydrology from hydrogeochemical modelling.

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In the black marl outcrops of the French South Alps, sub surface flow conditions are considered as the main triggering factor for initiation and reactivation of landslides. The problem is traditionally addressed in term of hydrological processes (how does percolation to the water table occur?) but in some cases the origin of water is also in question. Direct rainfall is generally assumed as the only water source for groundwater recharge in shallow hillslope aquifers. The bedrock is also supposed impervious and continuous. Yet the geological environment of the study area is very complex owing to the geological history of this alpine sector. The autochthonous callovo-oxfordian black marl bedrock is highly tectonized (Maquaire et al., 2003) and may be affected by large, possibly draining discontinuities. A deep water inflow at the slip surface may at least locally result in increase the pore pressure and decrease the effective shearing resistance of the landslide material.
In the active slow-moving landslide of Super-Sauze (Malet and Maquaire, 2003), this question has been addressed using hydrochemical investigations. The groundwater was sampled during five field campaigns uniformly spread out over the year from a network of boreholes. Water chemistry data were completed by geochemical and mineralogical analyses of the marl material. The major hydro-geochemical processes over area proved (1) mixing processes, (2) pyrite alteration, (3) dissolution/precipitation of carbonates and (4) cations exchange (de Montety et al., 2007). A geochemical modelling was carried out using the model Phreeqc (Parkhurst and Appelo, version 2.15, 2008) to check how suitable was observed water chemistry with the reservoir characteristics. The modelling exercise was based on a kinetics approach of soil-water interactions. The model simulates the rock alteration by the dissolution of the primary minerals and the precipitation of new phases. Initial parameters were obtained from geochemical and mineralogical analyses or from the literature (kinetics constants). The simulations showed that pH, sulphate and calcium concentrations in groundwater could be reproduced from reasonable assumptions. However, the observed high concentrations in magnesium and sodium were not correctly simulated by the model. Furthermore, a particular anomaly in the Na+ concentration was observed in the most active part of the landslide. Lastly, isotopic investigation showed that groundwater 3H content in this sector was significantly lower than groundwater content in the other parts of the landslide and lower than the mean rainwater content. This result showed that the mean groundwater age in the active part was probably higher than elsewhere in the landslide. All these arguments led us to conclude that groundwater was locally recharged with saline waters from areas outside the watershed, coming up through the bedrock using major discontinuities. This assumption is in agreement with the geological context.

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