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Hydrogeology characterization of roto-translational slides in flysch rock masses

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The hydrogeological characteristics of roto-traslational slides in flysch are complex, due to the inherent anisotropy and heterogeneity of such rock masses.

The paper deals with the hydrogeological characterization of a reactivated roto-translational slide affecting Cretaceous flysch, located in the Northern Apennines of Italy. In situ permeability and pumping test, continuous monitoring of groundwater levels, hydrochemical and isotope analyses, and finally uranine tracers were the adopted prospecting methods.

The landslide sector classified as rock slide extends for about 0.5 km2 and is characterized by a marked active sliding surface at 40 m depth. Borehole cores showed an upper 10-20 m landslide layer made of clayey debris, and a lower 20 m landslide layer made of highly fractured sandstone-rich flysch. Below sliding surface the flysch is much less fractured and it is overlying a clayey mélange.

The hydraulic conductivity of both layers of the rock slide body was estimated with more than ten borehole permeability tests and by 5 slug-tests in open-pipe piezometers. Results highlighted a variability of permeability at different depths and locations, between 10-6 to 10-8 m/s, linked to fracturing of rock masses and to clay fraction.

Groundwater levels were monitored for more than 3 years by means of transducers in 5 standpipe piezometers, fissured above or below the sliding surface. Results showed that two overlaying aquifers exist at the slope scale: an unconfined one, in the fractured flysch of the rock slide; a confined one, in the undisturbed flysch below sliding surface. Pore pressure in the unconfined aquifer is controlled by rainfall, with fluctuation of several meters occurring hours or days from onset of precipitation. On the contrary, pore pressure in the confined aquifer shows little response to precipitation events, has fluctuations of few meters related to seasonal trends, and maintains pressure head higher than that in the unconfined one. This makes it a relevant factor for the stability of the slide.

Storage coefficient of 10-3 and Trasmissivity of 1E-5 m2/s were estimated for the unconfined aquifer with a pumping test carried out with several control piezometers.

The geochemical characterization obtained by sampling and lab analysis highlighted two groundwater types in the landslide area. One shallow, directly connected with rainfall, that can be classified as cold (13° C) and Ca-carbonate, rich with low electric conductivity (800 µS/cm). The second consists of deep-fluids, rich in Na-sulfate, characterized by the mixing between the two extreme hydrotypes Na-bicarbonate waters and Ca-sulfate waters. This deep-fluids are characterized by cold temperature (13° C) and high salinity, over 4000 µS/cm.

The tracer test between the undisturbed rock mass in the crown zone and the 12 control points in the landslide body (at different depths) indicates that there is no connection between the two parts. Even assuming the failing of the test for high dilution/dispersion, considering the high quantity of uranine injected and its conservative behavior in such flysch rocks, it can be reasonably argued that there's no significant groundwater exchange between the two domains.

The results obtained in Ca' Lita show a high complexity of the groundwater flow due to high heterogeneity and anisotropy of the hydraulic characteristics inside the deposits of the rock slide and in the underlying fractured bedrock. Moreover, the hydrogeological study has individuated a rising of deep fluids in the landslide area, which can have a negative effect on the stability of the whole slope. The research results will be the basis of numerical groundwater flow models of the slope and will be also used to design and implement deep drainage systems for risk mitigation purposes.