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Using a combination of radiogenic and stable isotopes coupled with hydrogeochemistry, limnometrics and meteorological data in hydrological research of complex underground mine-pit lake systems: The case of Cueva de la Mora

J. Sánchez-España (1), M. Diez Ercilla (1), F. Pérez Cerdán (2), and I. Yusta (3)

(1) Unidad de Mineralogía e Hidrogeoquímica Ambiental (UMHA), Instituto Geológico y Minero de España (IGME), Ríos Rosas, 23, 28003 Madrid, Spain (j.sanchez@igme.es), (2) Dpto. Infraestructura Geocientífica y Servicios, Área de Cartografía Geocientífica, Instituto Geológico y Minero de España (IGME), c/Calera 1, 28760 Tres Cantos, Madrid, Spain, (3) Unidad de Mineralogía e Hidrogeoquímica Ambiental (UMHA), Departamento de Mineralogía y Petrología, Universidad del País Vasco (UPV/EHU), Apdo. 644, E-48080 Bilbao, Spain

This study presents a combination of radiogenic and stable isotopes (3H, 2H and 18O on pit lake water, and 34S on dissolved sulfate) coupled with bathymetric, meteorological and limnometric investigations, and detailed hydrogeochemical studies to decipher the flooding history and hydrological dynamics of a meromictic and deeply stratified pit lake in SW Spain. The application of these combined techniques has been specially succesful considering the complexity of the studied system, which includes a substantial number of horizontal galleries, shafts and large rooms physically connected to the pit lake. Specific conductance and temperature profiles have depicted a physical structure of the water body which includes four monimolimnetic layers of increasing density with depth. This internal configuration includes m-scale layers separated by sharp transional zones and is rarely observed in natural, fresh water bodies and most other pit lakes. The tritium abundance of the different layers indicate that the deepest water consists in strongly acidified and metal-laden meteoric water infiltrated in the mine system soon after the mine closure in 1971-72. Oxygen and hydrogen isotope ratios of the different layers reflect a sharp stratification with increasing evaporative influence towards the lake surface. The combination of tritium data with the oxygen and hydrogen isotope composition of the different layers suggests a model of pit lake formation with an initial stage of flooding (with entrance of highly metal- and sulfate-loaded mine drainage from the underlying mine galleries) that deeply determined the physical structure and meromictic nature of the lake. After reaching the present water level and morphology, the stagnant, anoxic part of pit lake seems to have remained chemically and isotopically unmodified during its 40 year-old history. Although the pit lake receives significant water input during autumn and winter (which in turn provoke significant volumetric increases), all parameters analyzed during this study (3H, 18O, 2H, 34S, T, Sp and SO42- concentration) suggest that this volume increase is basically provoked by the inflow of direct precipitation, runoff and subsurface flow at near-surface conditions, with very little or no input of groundwater at depth. It is hypothesized that a deep groundwater inflow to the lake bottom is not permitted by the extremely high density gradient existing between the lake monimolimnion in one hand, and the local groundwaters of the area in the other hand.