Investigating the provenance of thermal groundwater using compositional multivariate statistical analysis: a hydrogeochemical study from Ireland

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The geothermal energy of thermal groundwater is currently being exploited for district-scale heating in many locations world-wide. The chemical compositions of these thermal waters reflect the provenance and hydrothermal circulation patterns of the groundwater, which are controlled by recharge, rock type and geological structure. Exploring the provenance of these waters using multivariate statistical analysis (MSA) techniques increases our understanding of the hydrothermal circulation systems, and provides a reliable tool for assessing these resources.

Hydrochemical data from thermal springs situated in the Carboniferous Dublin Basin in east-central Ireland were explored using MSA, including hierarchical cluster analysis (HCA) and principal component analysis (PCA), to investigate the source aquifers of the thermal groundwaters. To take into account the compositional nature of the hydrochemical data, compositional data analysis (CoDa) techniques were used to process the data prior to the MSA.

The results of the MSA were examined alongside detailed time-lapse temperature measurements from several of the springs, and indicate the influence of three important hydrogeological processes on the hydrochemistry of the thermal waters: 1) increased salinity due to evaporite dissolution and increased water-rock-interaction; 2) dissolution of carbonates; and 3) dissolution of metal sulfides and oxides associated with mineral deposits. The use of MSA within the CoDa framework identified subtle temporal variations in the hydrochemistry of the thermal springs, which could not be identified with more traditional graphing methods (e.g., Piper diagrams), or with a standard statistical approach. The MSA was successful in distinguishing different geological settings and different annual behaviours within the group of springs. This study demonstrates the usefulness of the application of MSA within the CoDa framework in order to better understand the underlying controlling processes governing the hydrochemistry of a group of thermal springs in a low-enthalpy setting.