

Geochemical approaches to evaluate groundwater flow system stability: implications of research at Sellafield, UK and Aspo Sweden

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Groundwater flow will affect the movement of radionuclides from any future deep geological waste repository. To assess the safety of such a repository it will be important to evaluate the extent to which the surrounding groundwater flow system has been stable. Investigations at Sellafield in northwest England and at Aspo in eastern Sweden, have demonstrated that geochemical information can improve our understanding of groundwater flow patterns and their stability.

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Geochemical constraints on flow-system stability may be either quantitative (e.g. data for the radioactive isotopes ^{36}Cl and ^{14}C may indicate the timing of past water flow) or qualitative (e.g. the presence of pyrite may support any suggestion that deep groundwaters have remained reducing). Sequences of mineral precipitates can also constrain the geochemical evolution of a groundwater system. This quantitative or qualitative information can be used to develop and/or support conceptual models for past groundwater flow (e.g. indicate general flow directions, sources of water etc). Alternatively, this information can be used to constrain numerical groundwater flow models, designed to scope the sensitivity of the flow system to varying conditions. Two important aspects of this second approach are: 1. the use of geochemistry to define the initial numerical model, for example by suggesting boundary conditions; and 2. the application of geochemistry to test model output. Different kinds of chemical information can be used to suggest boundary conditions and to test model output. For example, chemical data for groundwaters may suggest boundary conditions, while mineral distributions might suggest past groundwater distributions, that can be compared with the simulation.

These approaches were adopted at Sellafield. The value of halide chemistry (notably variations in Br and Cl) to deduce the origins of groundwater salinity and mixing relationships was demonstrated. Most of the groundwaters' Cl was attributed to sedimentary halite dissolution to the west of the investigated area. It was concluded that variations in Cl concentrations within the area were caused dominantly by Cl-enriched water from the west mixing with more recently recharged, fresh groundwaters originating to the east. These water sources were used to set boundaries for groundwater flow models, using computer codes such as SUTRA. Computer simulations were adjusted until they matched the observed variations in groundwater Cl. The general consistency between the flow models and variations in water Cl concentrations was supported by isotopic data such as ^{36}Cl , $^{34}\text{S}/^{32}\text{S}$, $^{87}\text{Sr}/^{86}\text{Sr}$, and by the distributions of minerals, notably Fe/Mn-oxyhydroxides, pyrite, calcite and anhydrite. The mineralogical data suggest that the present deep groundwaters have been distributed similarly to the present for a long time, possibly from the Tertiary.

In contrast to Sellafield, variations in groundwater chemistry at Aspo are due to mixing between at least 4 different waters, each with a different Cl concentration. A particular groundwater Cl concentration at Aspo can be explained by several alternative mixing schemes. This limits the use of variations in Cl concentrations alone to constrain groundwater flow models. However, multivariate statistical techniques may distinguish, for a range of solutes, chemical variations due to mixing, from variations due to water/rock reactions. The mixing-related variations may be valuable constraints on groundwater flow models, enabling the effects of fracture zones on groundwater flow to be constrained.

In Japan, a focus of basic research concerned with radioactive waste disposal has been the stability of chemical conditions deep underground. Compared to programmes in many other countries, there has been less use of geochemical information to constrain the stability of groundwater flow systems. It is suggested that in future such an application of geochemistry may become more important in Japan.