CRUSTAL-SCALE HYDROGEOLOGY -- AN EMERGING PARADIGM

EDITOR'S MESSAGE

by

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During the past decade, hydrogeologists working in academia and governmental agencies have come to appreciate that active and ancient groundwater flow systems are not restricted to the upper few kilometers of the Earth's crust. Supporting evidence for this emerging paradigm of crustal-scale hydrogeology is based on observations derived from field, laboratory, and modeling studies of 1) the formation of excess pore pressures in compacting sedimentary basins; 2) infiltration-driven metamorphism; 3) heat-flow anomalies; 4) preservation of bacterial communities at remarkable depths (>2 km); and 5) the chemical alteration of deeply buried sediments. It is now clear that two types of long-distance fluid migration are possible: vertical pore-water movement through crystalline rocks to depths greater than 6 km, and lateral groundwater movement through sedimentary basins over hundreds of km. Paleohydrologists emphasize that various driving mechanisms of fluid motion are active in the Earth's crust on geologic time scales that are not typically considered in water-quality and water-supply investigations (e.g., thermal- and compaction-driven flow). This realization has also forced hydrologists to think hard about the coupled nature of thermal, mechanical, biogeochemical, and hydrologic processes.

Why is this area of research so exciting and vital? Much of the work described above is having profound implications on how geologists explore for energy and mineral deposits. For example, mathematical modeling and isotopic age-dating studies indicate that the formation of the world-class lead-zinc ore deposits in the mid-continent, USA, probably occurred during a period of "continental-scale" fluid migration associated with the formation of the Appalachian and Ouachita Mountains, hundreds of millions of years ago. These mountain-building events elevated regional water tables, thereby driving warm, saline brines across the continent hundreds of kilometers. As these mountain belts were eroded, the regional flow systems diminished. Active continental-scale flow systems are well documented today within the Great Artesian Basin, Australia. Here, meteoric fluids that recharge coastal regions of northeastern Australia migrate more than 1,000 km before discharging. Recent fluid-inclusion data suggest that the occurrence of petroleum reservoirs in discharge areas of the Basin, in the southwestern part, is probably not coincidental.

Environmental scientists working on nuclear waste isolation are also benefiting from paleohydrologic studies. State-of-the-art models of coupled groundwater flow and reactive chemical mass transport have been successfully used to describe the formation of world-class Proterozoic-age uranium ore deposits in Australia. These models have provided an important test of the mathematical descriptions of reactive transport processes, which must soon be used in models to predict the fate over the next 10,000 years of nuclear waste that is proposed to be stored in a repository in Nevada, USA.

Unfortunately, because much of this work involves significant new concepts rather than incremental improvements on what is currently being done, governmental agencies appear not to realize the potential benefits of this research, and support is meager at best. Increased funding could be used to expand the continental and marine drilling programs of deep (>2 km) scientific boreholes and to support the development of fully coupled models of hydrologic, thermal, geochemical, and mechanical processes. Such work would expand our knowledge of basic hydrologic properties of crustal rocks and help water-resource planners constrain deep and shallow components of recharge within sedimentary basins, a critical issue for many urban areas in the arid southwestern part of the United States.