Evaluation of Radiogenic Helium-4 in the Fruitland Formation, and Implications for Regional Hydrogeology, San Juan Basin, Colorado

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Abstract. The Fruitland Formation is part of a deep, confined groundwater system in the San Juan Basin that consists of interbedded clastics and coal lenses, and is the source of large scale coal-bed methane production. Permeability is generally relatively low except for coal seams, whose permeability is enhanced by the presence of cleats (densely spaced, orthogonal fracture sets). As such, flow primarily occurs in the coal seams. The distribution of radiogenic helium-4 ($^4He_{rad}$) has been assessed in order to determine groundwater velocities through the system. $^4He_{rad}$ is an excellent tracer of physical transport because it is extremely geochemically conservative. Also, $^4He_{rad}$ is a decay product in the uranium-238, uranium-235, and thorium-232 decay series, so concentrations in the saturated zone are directly proportional with time. Assuming an advection dominated system (plug flow), apparent groundwater ages have been calculated with $^4He_{rad}$ concentrations and the accumulation rate. Calculated $^4He_{rad}$ apparent ages range from 13.8 to 53.5 My in areas ranging from 5 to 30 km from the recharge zone, and are in good agreement with iodine-129 (^{129}I) derived ages. These ages are the same order of magnitude as the depositional age of the Fruitland (70 My), and suggest that the groundwater velocity in the Fruitland is less than 8.0×10^{-4} meters/year, essentially stagnant. However, groundwater flow through coal cleats may complicate the transport of the tracers such that a simple plug flow model does not accurately represent the system. In fractured porous media, there is potential for matrix diffusion effects to mask relatively younger isotopic signatures in fractures with relatively older signatures from the undisturbed matrix. Therefore, migration of groundwater through coal cleats may be significantly faster than indicated by the calculated apparent ages. A two-region, discrete fracture transport model has been utilized to evaluate the significance of the matrix diffusion process and determine implications for regional groundwater velocity. The modeling analysis includes $^4He_{rad}$ and ^{129}I, whose differing diffusion coefficients and radiogenic pathways allow for unambiguous results.

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