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Noble and Ignoble Gases in the Missoula Valley Aquifer

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Abstract

Water from the Missoula Valley aquifer was analyzed for tritium, noble gases (3He, 4He) and chlorofluorocarbons (CFCs) in an attempt to age date and trace ground water flow. Wells were sampled along lines of ground-water flow and where possible, at nested well pairs to evaluate vertical relationships.

Tritium (3H), the radioactive isotope of hydrogen, is produced naturally in the upper atmosphere and decays to the noble gas helium-3 (3He). By determining the amount of 3H and tritiogenic helium-3 (3He-trit) in a ground-water sample, a 3H/3He age can be calculated by applying the radioactive decay law. Successful application of the method requires that 3He-trit be distinguished from atmospheric helium-3 (3He-atm). The 3He-atm in water results from equilibrium solubility of He from the atmosphere and from air that is trapped below a rising water table (excess air). The 3H/3He dating in the Missoula Valley aquifer was hindered by the relatively young age of most of the sampled water which led to low 3He-trit concentrations and significant uncertainty in the 3H/3He ages. In several samples the 3He-trit component was overwhelmed by the 3He-atm component, i.e there simply had not been enough time to generate significant amounts of tritiogenic 3He. The 3H/3He age dates ranged from 0 to 4.6 years. In general ages increased along flow path, however there were anomalies.

Helium-4 (4He) can also be used as a tracer of ground-water flow. The general concept is that certain minerals release internally-produced, terrigenic helium-4 (4He-terr) into ground water (e.g. by U and Th decay); the longer ground water is in contact with these minerals the greater the 4He-terr concentration in the water. Measured 4He-terr concentrations in the Missoula Valley aquifer were surprisingly high and generally decreased along flow path. The 4He-terr concentrations were significantly larger than can be explained by U and Th decay and the counterintuitive distribution (decreasing rather than increasing concentrations along flow path) defies conventional interpretation. Possible explanations may include a very localized source of 4He-terr within or near the base of the aquifer, or localized diffusion of 4He-terr from crustal or mantle sources.

Virtually all the ground water sampled (10 out of 12 wells) for CFCs contained concentrations in excess of air-water solubility, rendering it unsuitable for age dating. However the results suggest that CFCs may be valuable qualitative tracers of recent recharge in parts of the Missoula Valley aquifer. The areal distribution of CFC-12 shows concentrations generally increasing down flow path, however, the highest CFC-12 concentrations were detected immediately downgradient from areas of high septic-tank density, suggesting that CFC-12 may be an indicator of septic effluent.