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USE OF ISOTOPES TO ASSESS GROUNDWATER AGES AND SOURCES IN EASTERN MONTANA

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Isotopic methods were used to assess groundwater ages and sources in east-central Montana. The investigation focused on aquifers in the Fox Hills, Hell Creek and Fort Union Formations; as well as sands and gravels associated with the Yellowstone and Missouri rivers. Groundwater from the deep, regionally extensive and confined Fox Hills–lower Hell Creek aquifer was sampled for carbon-14 (^{14}C), carbon-13 (^{13}C), tritium, deuterium (δD), and oxygen-18 ($\delta^{18}O$), along two transects that follow regional flow paths: 1) a southern transect, which included a line of five wells from the Cedar Creek anticline southeast of Baker, MT, to the Yellowstone River near Terry, MT; and 2) a northern transect, which included four wells along a line from Circle, MT, to Sidney, MT, near the confluence of the Yellowstone and Missouri rivers. Of the nine samples, only four had detectable levels of ^{14}C activity. The results ranged from 1.45 to 8.34 percent modern carbon (PMC) yielding uncorrected ages in excess of 20,000 years. The water with the highest PMC content (youngest water) was obtained from a well near the Cedar Creek anticline where the aquifer is exposed at the surface. In each transect, samples from wells located farthest downgradient—close to presumed discharge areas—contained detectable ^{14}C activity, while samples from wells immediately upgradient contained no detectable ^{14}C activity suggesting a possible mixing of relatively younger water with old water at the discharge areas. The δD and $\delta^{18}O$ values from all nine samples plot along the meteoric water line; however, the results from each transect plot in separate groups. Samples from the southern transect are isotopically lighter than the northern transect, suggesting different recharge areas or a change in recharge conditions. Tritium was detected in only one of the ten samples from the Fox Hills–lower Hell Creek aquifer; the one detection occurred in an area where the aquifer is unconfined and exposed at the surface.

Groundwater from the shallow, generally unconfined Fort Union, upper Hell Creek, and sand and gravel aquifers was sampled for tritium. Tritium was detected in 17 of the 27 samples; the concentrations ranged from 5.5 to 49.8 tritium units. Although the groundwater chemistry from the shallow aquifers is variable, the Ca+Mg/Na ratio and the frequency of tritium and nitrate detection appear to be related. Groundwater that has a Ca+Mg/Na ratio greater than one is more likely to be post-1953 water and have detectable levels of nitrate. Of the 17 samples with detectable tritium (post-1953 water), 16 had a Ca+Mg/Na ratio greater than one, and 15 had detectable nitrate levels; the concentrations ranged from 0.25 to 44.4 mg/L nitrate as N. Only 4 of the 10 samples with no detectable tritium (pre-1953 water) had a Ca+Mg/Na ratio greater than one, and only 2 had detectable nitrate levels. This association between the Ca+Mg/Na ratio, tritium, and nitrate suggests that in this hydrogeological setting the chemical signature of groundwater may be used to assess groundwater age and the potential for contamination.