OSMRE National Technology Transfer Team (NTTT), **Applied Science Fact Sheet***
U.S. Department of the Interior, OFFICE OF SURFACE MINING RECLAMATION AND ENFORCEMENT

Developing an isotopic fingerprint of acid mine drainage to identify underground controls on groundwater flow paths

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Project Description and Objectives:

Abandoned underground coal mines in central Montana are producing acid mine drainage that may be infiltrating by gravity into the underlying Madison Limestone, a major source of drinking water in the region. This study used stable isotopes of dissolved sulfate, in combination with groundwater chemistry, to evaluate contamination of the Madison Aquifer beneath—and downgradient of—points of acid mine discharge.

Applicability to Mining and Reclamation:

The quality of domestic and municipal well water is threatened by acid mine drainage (AMD) from nearby active or abandoned mining operations (Fig. 1). However, a simple water-quality analysis may give an ambiguous answer as to whether a given water supply has been negatively impacted by AMD. Depending on the geologic setting, the stable isotope composition of dissolved SO_4^{2-} ion released from the oxidation of pyrite in coal will be distinct from SO_4^{2-} in background groundwater. If so, then stable isotopes provide a potentially valuable tool for screening of wells for AMD contamination.

Methodology:

Water samples were collected from domestic water wells, groundwater monitoring wells, AMD seeps and drains, and selected surface water bodies in the Stockett–Sand Coulee–Belt area, as well as a set of domestic wells in a new subdivision located about 8 km downgradient of the historic coal-mining centers. Each of the major drinking-water aquifers in the region was tested. Each sample was analyzed for a full suite of field parameters, major cations and anions, and major/trace metals, as well as the isotopic compositions of O and H in water, and S and O in dissolved sulfate. Several sites were sampled multiple times during the study to test for seasonal variations.

Figure 1. Acid mine drainage (Kates Coulee) near the former coal-mining town of Sand Coulee, Montana.

Results and Findings:

A few of the findings of this study include the following:

1. Acid drainage from the abandoned coal mines in central Montana contains very high concentrations of sulfate, iron, aluminum, and manganese, as well as elevated cadmium, copper, nickel, and zinc.
2. Background concentrations of sulfate in the Madison Aquifer are very low near

Continued on Back >

groundwater recharge areas, but increase as groundwater flows northward and dissolves gypsum in the formation.

3. Dissolved sulfate in the coal AMD is strongly depleted in its S- and O-isotope signature (meaning that it has very low concentrations of the lighter stable isotopes), whereas sulfate derived from dissolution of gypsum in the Madison Limestone is strongly enriched (high concentrations of the heavier isotopes).
4. Stable isotope cross-plots for O and S in sulfate show evidence of AMD contamination for some domestic wells in the historic mining districts (Fig. 2), as well as potentially 8 km downgradient (north) of the mining centers. This indicates regional AMD contamination of the Madison Aquifer, which has likely been going on for nearly a century.
5. Despite the isotopic evidence of AMD contamination, the water quality of most of the domestic wells is very good. This underscores the ability of the Madison Limestone to buffer water chemistry.

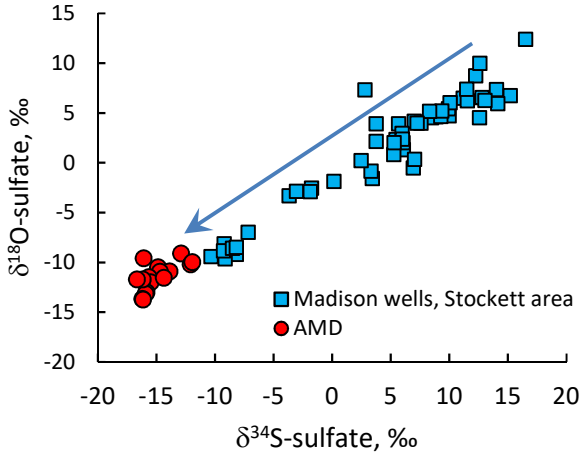

Figure 2. A plot of the O- vs. S-isotope composition of dissolved sulfate for all samples collected in a subregion shows an apparent mixing trend between background sulfate from the Madison Aquifer (upper right) and sulfate from acid mine drainage (lower left).

Highlights:

Stable isotopic composition of dissolved sulfate can be an effective tool for monitoring contamination of groundwater (and surface water) from acidic drainage associated with abandoned coal mines. Contamination into the Madison aquifer probably occurs in many ways. As the AMD flows across the ground surface, it naturally infiltrates into the underlying formations and aquifers, including the fractured outcrops of the Madison Limestone (Fig. 3).

Figure 3. At times surface water flows directly over fractured limestone outcrops.

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