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FINGERPRINTING OF GROUND WATER
BY ICP-MS

PROGRESS REPORT
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SAMPLE ANALYSIS

Analysis of waters collected from springs in the Spring Mountains was completed during this quarter.

DATA REDUCTION

Data for the Ash Meadows and Death Valley sixth sampling is undergoing final review and will be available in November 1995. Data from the spring mountain samplings is also in final review and will be available in December 1995.

DATA ANALYSIS

We are currently analyzing the data from Ash Meadows, Death Valley and Pahranaagat springs, a number of wells and springs on the Nevada Test Site and several Amargosa Valley wells using principal component analysis and of rare earth element normalization patterns. An analysis using rare earth elements to evaluate ground water mixing is listed below.

Mixing of groundwater in south-central Nevada using the rare earth elements

Understanding the groundwater flow regime in south-central Nevada and the Death Valley region of California is of particular concern for both the Nevada Test Site and Yucca Mountain region because of the potential of contamination of the regional groundwater with radionuclides. The general region of study is shown in Figure 1. Previous investigations indicated that groundwater in the region is recharged in the north and subsequently flows towards the south, eventually discharging partially to the Muddy River system as well as within Ash Meadows National Wildlife Refuge and Death Valley National Park (Figure 1). For example, deuterium analysis of Ash Meadows groundwater indicates that between 30 - 35% originates in the Pahranaagat Valley to the northeast (Figure 1) whereas the remaining 60 - 65% represents groundwaters recharged in the local Spring Mountains. Previous investigators have also argued based on the Na^+ concentrations of the Ash Meadows groundwaters, that up to 5% of this water originated as recharge waters in the felsic volcanic rocks of the Nevada Test Site.

We have examined the previous conclusions concerning the groundwater flow regime using the rare earth elements (REE). Figure 2 is a shale-normalized REE plot for the two proposed end member groundwaters, i.e., Spring Mountain and Pahranaagat Valley groundwater, the average Ash Meadows groundwater, and the result of mixing 65% Spring Mountain groundwater with 35% Pahranaagat Valley groundwater. In general, we see that the heavy REEs (HREEs) (i.e., Gd - Lu), for a groundwater mixture of these proportions, closely resembles the Ash Meadows groundwater. A major depletion is, however, recorded for the light REEs (LREEs) (i.e., La - Eu) in this mixture. If, on the other hand, a small percentage of groundwater from the perched aquifers of the Nevada Test Site is added to this mixture, a much closer fit to the Ash Meadows data is obtained (Figure 3). These results suggest that although the Ash Meadows groundwaters are most likely a mixture of Spring Mountain and Pahranaagat Valley groundwater as discussed by previous investigators, there must also be a small component of groundwater from the perched aquifers of the Nevada Test Site that contributes to the discharge of the Ash Meadows springs in order for these waters to acquire their REE signature.

We have also examined the origins of the groundwater obtained from Army Well #1. Previous investigations have suggested that this groundwater is likely representative of Spring Mountain groundwater. However, upon inspection of the REE patterns for Army Well groundwater and Spring Mountain groundwater we see that the Army Well groundwaters have typically lower REE concentrations and a much flatter pattern than the Spring Mountain groundwaters. Applying our mixing model, we see that the best fit for the Army Well data is a mixture of groundwaters from the Spring Mountains, the Pahranaagat Valley, and the Nevada Test Site in the percentages of 4.98, 94.67, and 0.35 %, respectively. Consequently, based on the REEs, the Army Well groundwater is composed primarily of Pahranaagat Valley groundwaters with just under a 5% contribution from the Spring Mountains, and a very small, although significant, contribution from the perched aquifers of the Nevada Test Site. Without the Nevada Test Site groundwater contribution, the generally flat pattern for the LREEs of the Army Well groundwaters cannot be reproduced by mixing only Spring Mountain and Pahranaagat Valley groundwaters.

Finally, we have examined the origin of the groundwaters that discharge from the springs in the Furnace Creek region of Death Valley National Park. Previous investigators have argued that these groundwaters result from through-flow of groundwaters from the Amargosa Desert to the north of Furnace Creek. Our REE analyses, however, do not support an unequivocal Amargosa Desert

origin for the Furnace Creek groundwaters. Instead, the REEs indicate that groundwater from Ash Meadows contributes more significantly to the Furnace Creek groundwaters. Mixing calculations for the Ash Meadows and Amargosa Desert groundwater, using the respective REE patterns for these end member groundwaters, indicates that the Furnace Creek groundwater can be most closely reproduced by mixing between 75 to 85% Ash Meadows groundwaters with 15 to 25% Amargosa Desert groundwaters (Figure 4). Consequently, Ash Meadows groundwater contributes the majority of groundwater to the springs at Furnace Creek in Death Valley. Moreover, the Furnace Creek groundwaters can be more closely approximated by adding a small fraction of perched groundwater from the Nevada Test Site. Figure 5 shows the results of mixing 64.7% Ash Meadows groundwater, 34.8% Amargosa Desert groundwater, and 0.5% Nevada Test Site water.

The importance of this work is clear in that mixing calculations using the REE concentrations in groundwaters results in similar conclusions as determined using stable isotopes and major elements such as Na^+ . The advantage of employing the REEs in groundwater mixing and origin studies is their direct relation to the different rock types of which the aquifers are composed. Stable isotopes, such as deuterium, although conservative in groundwater systems, rely on characteristic of the source precipitation and recharge elevation. Dissolved REEs in groundwater come directly from the rocks through which the groundwater flows and, because different rocks have different REE signatures, groundwaters originating in different aquifers will have different signatures. This is clearly evident in our studies where in almost every case, LREE enriched groundwaters from the perched aquifers of the Nevada Test Site which occur in LREE enriched felsic volcanic rocks, must contribute to the LREE depleted groundwaters characteristic of the regional carbonate aquifer (i.e., Spring Mountain and Pahranaagat Valley) in order to produce groundwaters with the approximately flat patterns of both Ash Meadows and the Furnace Creek groundwater of Death Valley. In the past we had to call upon both stable isotopes, strontium isotopes, as well as the major ion concentrations (e.g., Na^+) to investigate groundwater mixing and sources. Our work indicates that the REE are a new and powerful tool for investigation groundwater flow. Moreover, new analytical equipment such as the ICP-MS is making REE analysis almost routine.

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Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6