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STRONTIUM ISOTOPES IN CARBONATE DEPOSITS AT CRATER FLAT, NEVADA

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ABSTRACT

Strontium isotope studies of carbonates from soils, veins, eolian dust and Paleozoic basement sampled near Crater Flat, southwest of Yucca Mountain, provide evidence for the origins of these materials. Vein and soil carbonates have nearly identical ranges of $^{87}Sr/^{86}Sr$, and eolian material has $^{87}Sr/^{86}Sr$ ratios at the lower end of the pedogenic range. The average $^{87}Sr/^{86}Sr$ of Paleozoic basement from Black Marble Hill is similar to the $^{87}Sr/^{86}Sr$ in the eolian dust, perhaps indicating a local source for this material. Possible spring deposits have generally higher $^{87}Sr/^{86}Sr$ than the other carbonates. These data are compared with similar data from areas east of Yucca Mountain.

INTRODUCTION

Yucca Mountain in southern Nevada has been selected by the United States Congress for evaluation as a possible site for the development of a nuclear

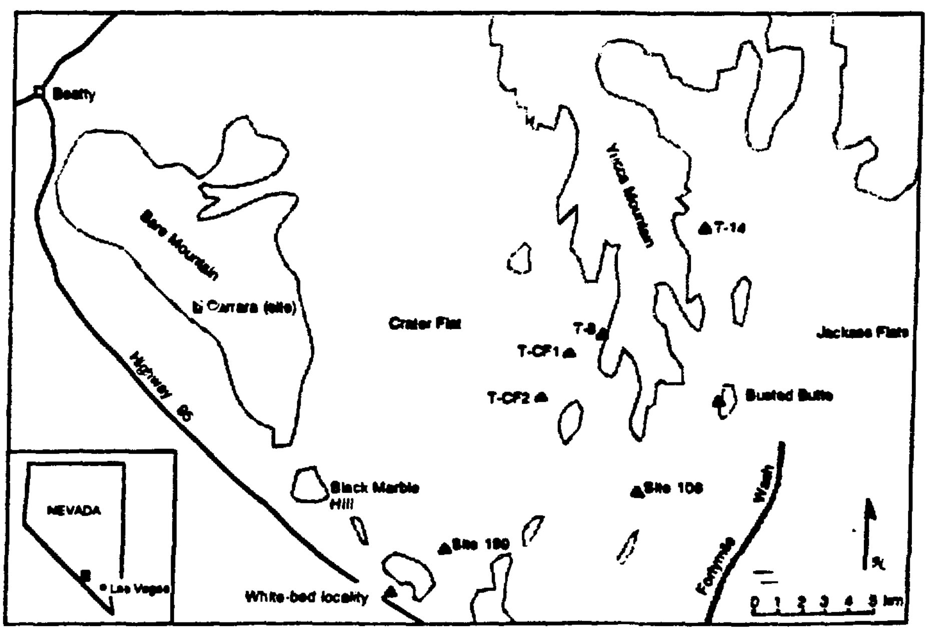

Figure 1. Map of the Yucca Mountain area showing localities discussed in text. Upland areas are outlined in gray.

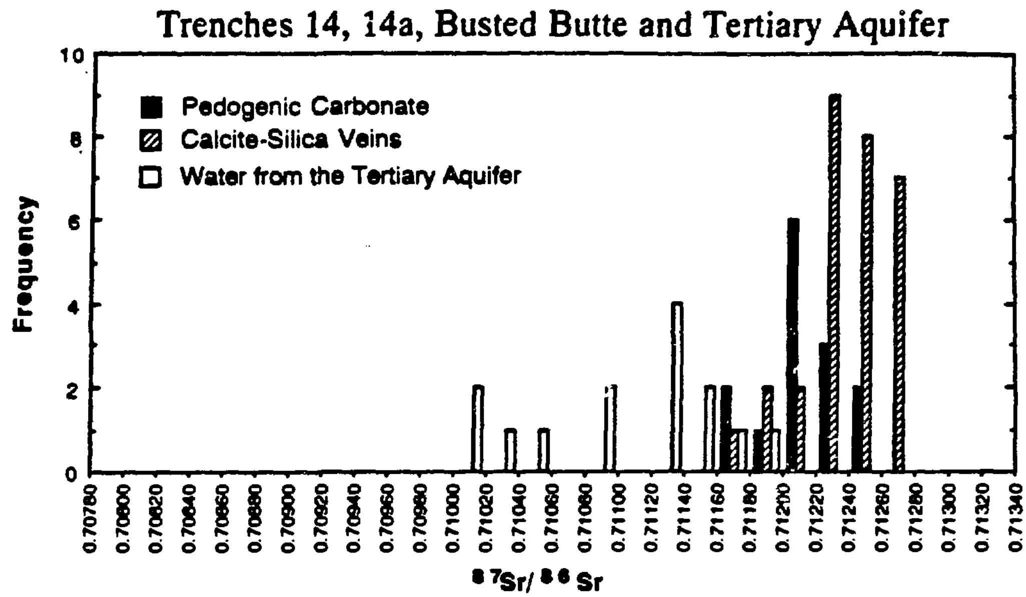

Figure 2. Histogram of strontium isotope ratios of pedogenic carbonate and calcite-silica veins from areas east of Yucca Mountain, and those of the Tertiary aquifer water.

waste repository. A major hydrologic question involved in evaluating the suitability of Yucca Mountain is the stability of the water table during the Quaternary[1]. A key to the history of possible water-table fluctuations is the presence of calcium carbonate deposits that have formed from either ascending ground water or descending surface water. By determining the ages and modes of origin of these deposits near Yucca Mountain, an assessment of past water-table fluctuations may be made.

To constrain the origin of some of these hydrogenic deposits in the area surrounding Yucca Mountain, strontium isotope analyses of various carbonate materials south and west of the site (Fig. 1) have been obtained. These materials include possible ancient spring deposits, pedogenic calcretes and rhizoliths, vertical veins along faults and fractures, Paleozoic basement, and eolian dust. In this paper, we refer to the calcretes and rhizoliths as pedogenic carbonate and the veins as a separate entity although all of these carbonates may share a common origin. The objectives of this research include the determination of the origin of the carbonate accumulations along faults and their relation to possible ancient spring deposits in the area. The strontium isotope data are one aspect of a larger study that aims to determine the origins and ages of all of the carbonate deposits.

STRONTIUM ISOTOPE SYSTEMATICS

Strontium is either a minor or trace element in almost all naturally occurring calcium carbonates; it is typically present at concentrations of 100 to 1000 parts per million. Natural strontium varies in its isotopic composition due to the radioactive decay of rubidium-87 to strontium-87 with a half-life of 48.8 Ga. Rocks vary in the amount of radiogenic strontium-87 due to differences in their ages and Rb/Sr ratios and due to inheritance of radiogenic strontium from their source materials. Secondary minerals precipitated from water will retain the isotopic composition of the water from which they were precipitated provided that their Rb/Sr ratio is low. Carbonates have very low Rb/Sr ratios and therefore are good recorders of the $^{87}Sr/^{86}Sr$ ratio in the source waters. Ground waters vary in $^{87}Sr/^{86}Sr$ due to variations in the geology of their recharge areas and due to interactions with the aquifers through which they flow.

ANALYTICAL TECHNIQUE

Carbonate is removed from admixed silicate material by dissolution in a weak solution of hydrochloric or acetic acid. The supernatant is then decanted, dried and redissolved in hydrochloric acid prior to introduction onto an ion exchange column. Strontium is eluted from the column in hydrochloric acid, dried, and then loaded onto filament material with phosphoric acid. Mass spectrometric analysis of the strontium emitted from the filament are obtained by sequentially measuring ^{88}Sr, ^{87}Sr, and ^{86}Sr ion beams. To correct for fractionation of the sample, the $^{87}Sr/^{86}Sr$ ratio is normalized to an $^{86}Sr/^{88}Sr$ ratio of 0.1194. The $^{87}Sr/^{86}Sr$ values reported here are precise to better than 0.007% and are on a scale where modern seawater has an $^{87}Sr/^{86}Sr$ of 0.70919, as determined by repeated measurements of the USGS standard EN-1. Data are presented in histograms in Figures 2-5.

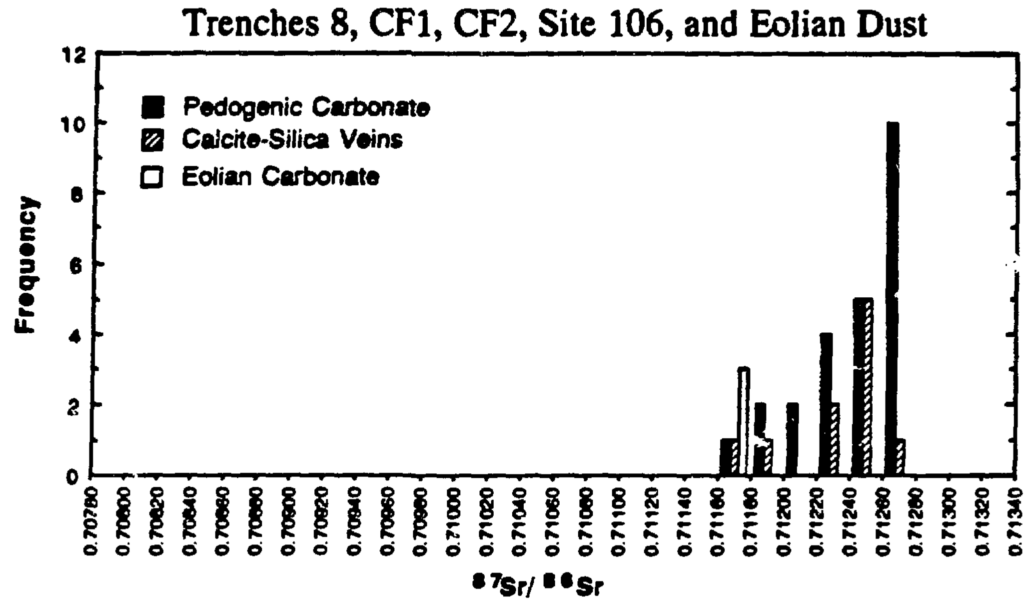

Figure 3. Histogram of strontium isotope ratios of pedogenic carbonate and calcite-silica veins from areas south and west of Yucca Mountain, and those of eolian carbonate.

PREVIOUS WORK

Prior to this study, strontium-isotope analyses of pedogenic and vein carbonate from areas just east of Yucca Mountain (trench 14, trench 14a, Busted Butte) were completed[2]. These data, summarized in Figure 2, show the similarity of $^{87}Sr/^{86}Sr$ in these materials. Also, water samples from the Tertiary aquifer were analyzed[3]; these samples have mostly lower $^{87}Sr/^{86}Sr$ ratios (Fig. 2) indicating that the carbonate was not deposited from these waters.

SAMPLES

Pedogenic calcretes were collected from the walls of bulldozed trenches in Crater Flat; trench 8 is located on the Solitario Canyon Fault and trenches CF1 and CF2 are on the Windy Wash Fault (Fig. 1). One rhizolith (carbonate-cemented root cast) from trench 8 was also sampled. These trenches were originally dug to determine possible Quaternary movement along these faults. Near-vertical veins of carbonate and opaline silica are exposed in the trenches along the main faults and subsidiary fractures. The veins and calcretes were sampled primarily by drilling into cleaned trench-wall surfaces and collecting the resulting powder. Near-surface calcretes exposed at the south end of Yucca Mountain (site 106, Fig. 1) have been reported as a spring deposit with an U-series age of 78 ± 5 ka[4], but the deposit is probably a thick pedogenic K horizon (E.T. Taylor, oral communication, 1989). Hydrogenic deposits of possible spring origin were sampled at two sites. The first deposit, at the south end of Crater Flat (site 199, Fig. 1), is also reported as a spring deposit with an age of ~30 ka[4], but the deposit is mapped as a lacustrine deposit of Pleistocene (?) and Pliocene age with local subaqueous spring discharge deposits[5]. The second deposit, informally called the white-bed locality, located along highway 95 southwest of Crater Flat, is mapped as a lacustrine deposit without evidence of spring discharge. To examine the carbonate component of wind-blown dust one sample of the uppermost fine soil was collected near trench CF2 and two samples of eolian silt from man-made structures at Carrara (ghost town northwest of Crater Flat) were collected and analyzed. Paleozoic carbonate rocks exposed at Black Marble Hill were collected to compare the local exposed basement with the other carbonate materials. Also, a traverse through the Spring Mountains (100 km southeast of Yucca Mountain) provided samples of similar Paleozoic carbonates farther away from Crater Flat.

RESULTS

Nine samples of pedogenic carbonate from the three trenches in Crater Flat have an average $^{87}Sr/^{86}Sr$ of 0.71216 with a standard deviation of 0.00028. This value is essentially identical with the average value of 0.71218 obtained on pedogenic carbonate sampled at trenches 14 and 14a and at Busted Butte on the east side of Yucca Mountain[2]. This agreement is notable because of the availability of disparate source materials as outlined below. Ten-samples of vein carbonate accumulations along faults and fractures in the three trenches in Crater Flat yield an average $^{87}Sr/^{86}Sr$ of 0.71233 (standard deviation of 0.00031). This value is slightly lower than the average obtained on the calcite-silica veins from the areas east of Yucca Mountain (0.71239) but the difference is not statistically signifi-

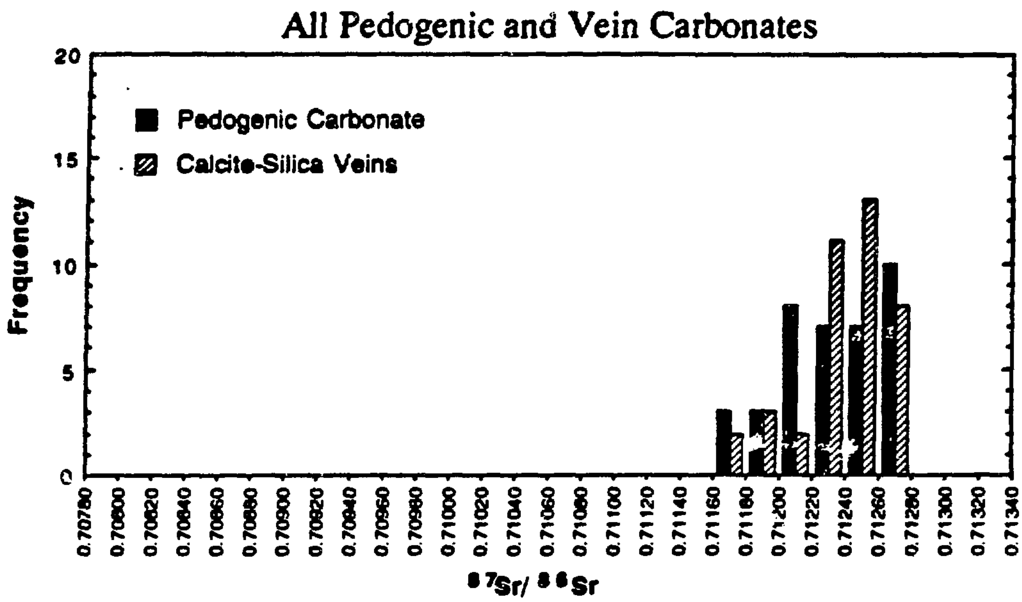

Figure 4. Histogram of strontium isotope ratios of pedogenic carbonate and calcite-silica veins from the Yucca Mountain area.

cant. Overall, the calcite-silica veins contain carbonate with slightly higher $^{87}Sr/^{86}Sr$ ratios than the pedogenic samples; however, examination of histograms of these data (Fig. 2 and 3) show the rather similar nature of the pedogenic and vein carbonates when compared to other materials analyzed. The range of $^{87}Sr/^{86}Sr$ for a given sample set may be more meaningful for comparison because the arithmetic means could be slightly biased by the particular sampling scheme (i.e., many samples from a single vein, etc.). Also, 15 samples of pedogenic carbonate from site 106 at the south end of Yucca Mountain yield an average $^{87}Sr/^{86}Sr$ of 0.71255 (standard deviation of 0.00017) which shows that there are pedogenic carbonates in the region with slightly higher $^{87}Sr/^{86}Sr$ ratios than those exposed near the faults. The average of all 37 analyses of pedogenic carbonates in the vicinity of Yucca Mountain is 0.71233 (standard deviation of 0.00028), essentially identical to that of the 39 samples of vein carbonate ($^{87}Sr/^{86}Sr$ of 0.71238, standard deviation of 0.00026; Fig. 4).

These data suggest a similar mode of origin for the veins and pedogenic carbonates, including the large veins previously studied at trench 14[2]. Water from the Tertiary aquifer in the immediate vicinity of Yucca Mountain could not have been involved in the generation of these deposits because its $^{87}Sr/^{86}Sr$ averages 0.71104 with a standard deviation of 0.00058[3] (Fig. 2).

The three samples representing wind-blown silt form a tight grouping with an average $^{87}Sr/^{86}Sr$ of 0.71166 and a standard deviation of 0.00004, comparable to the precision of a single analysis. This value is about equal to the lowest values obtained on the pedogenic and vein carbonates in Crater Flat (Fig. 3), suggesting that the eolian carbonate is one end-member of the materials that contribute strontium and calcium to the pedogenic carbonates. The probable end-member for the high $^{87}Sr/^{86}Sr$ end would be the Tertiary volcanic rocks, some of which carry strontium with $^{87}Sr/^{86}Sr$ values as high as 0.7202[3]. This scenario requires chemical weathering of the volcanic detritus to release strontium into the local soil. We note that models for the formation of calcic soils[6] do not take into account this source for the calcium. The $^{87}Sr/^{86}Sr$ of the carbonate component in the wind-blown silt is similar to the average $^{87}Sr/^{86}Sr$ of nine samples of Paleozoic carbonate (Bonanza King Dolomite) sampled from Black Marble Hill on the west side of Crater Flat (0.71156, S.D. = 0.00058). The Paleozoic carbonate has a higher Sr isotope ratio than expected, which must be due to pervasive alteration (i.e., influx of strontium with a higher $^{87}Sr/^{86}Sr$ ratio) after original deposition (perhaps associated with Tertiary tectonism). A suite of Paleozoic limestone samples from the Spring Mountains yields an average $^{87}Sr/^{86}Sr$ of 0.70848 (S.D. = 0.00042, N = 11), consistent with their Early Paleozoic age[7] (Fig. 5).

The two hydrogenic deposits sampled near Crater Flat have Sr isotopic compositions that are distinct from the pedogenic samples discussed above. Four samples from a possible tufa mound at site 199 (Fig. 1) in the southern reaches of Crater Flat yield an average $^{87}Sr/^{86}Sr$ of 0.71309 (S.D. = 0.00013), significantly higher than both the pedogenic carbonates and the nearby Paleozoic basement. Possible sources for the radiogenic strontium include the Tertiary volcanic

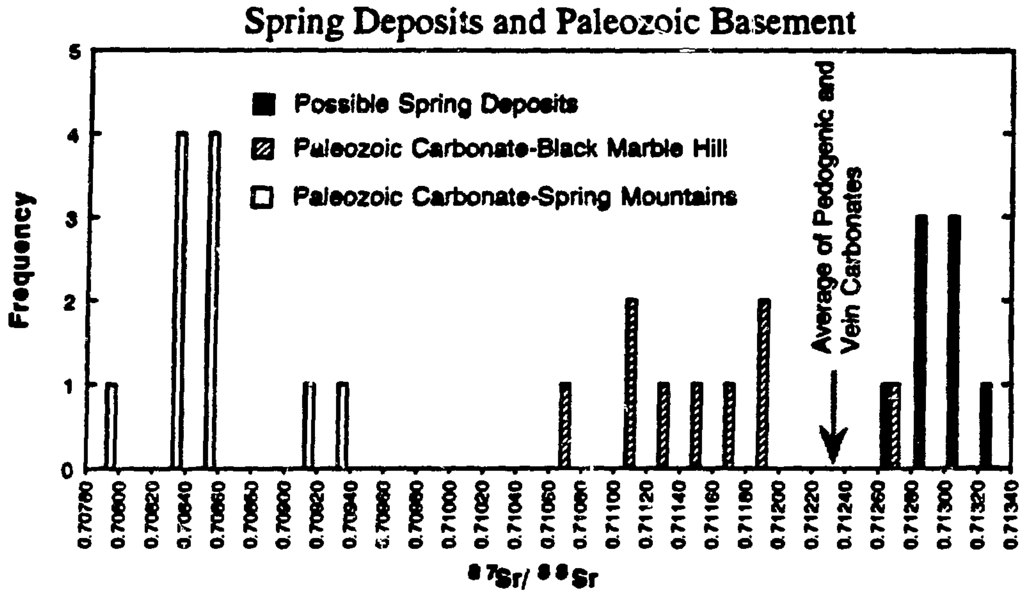

Figure 5. Histogram of strontium isotope ratios of possible spring deposits and Paleozoic basement from Black Marble Hill and the Spring Mountains. Gray arrow shows the average $^{87}Sr/^{86}Sr$ of pedogenic and vein carbonate from Fig. 4.

rocks and breccia underlying the carbonate at Black Marble Hill ($^{87}Sr/^{86}Sr = 0.71897$). Four samples of carbonate from marsh deposits near highway 95 have an average $^{87}Sr/^{86}Sr$ of 0.71288 with a standard deviation of 0.00011. Three more samples from a similar deposit (white-bed locality) about 3 km northwest along highway 95 yield an average $^{87}Sr/^{86}Sr$ of 0.71289, indicating a similar origin for these two deposits (Fig. 5). These deposits have higher $^{87}Sr/^{86}Sr$ ratios than the pedogenic carbonates or the regional aquifers and thus pose a question regarding the source of the waters that precipitated these carbonates.

CONCLUSIONS

Strontium isotope data obtained on carbonate deposits in the vicinity of Crater Flat amplify conclusions based on similar data from the east side of Yucca Mountain including trench 14 and Busted Butte[2]. The very similar range of $^{87}Sr/^{86}Sr$ in the pedogenic calcretes and rhizoliths and in the carbonate veins support a common source of strontium in these materials. Furthermore, the distinctions in $^{87}Sr/^{86}Sr$ between these materials and ground water from the Tertiary aquifer strongly suggest that the calcite-silica veins did not form from ascending ground water. Finally, eolian carbonate derived from locally exposed Paleozoic basement may provide a portion of the strontium in the pedogenic carbonates, if some Sr is released from weathering of the volcanic rocks.

These conclusions indicate that the carbonate accumulations and veins along faults in the vicinity of Yucca Mountain are most likely the result of downward-percolating surface water rather than being causally related to a rise of the local water table. Thus, the presence of these features does not indicate a much higher water table in the recent past. The small number of strontium analyses obtained on possible spring discharge deposits suggests a large range of $^{87}Sr/^{86}Sr$ in these deposits that will help to correlate them with specific subsurface waters in the region.

ACKNOWLEDGEMENT

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