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Progress Report: Studies on the origins of soil and fault-related mineralogy in the vicinity of Yucca Mountain.

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I. Introduction

Studies of soil and fault-related samples around Yucca Mountain, particularly in relation to faults exposed in trenches, were begun in late September at the request of NNWSI Management. Concern was expressed that some of the mineral deposits associated with faults may be the products of deep-seated springs. Any future activity of deep-seated springs could compromise a repository at Yucca Mountain by providing aqueous transport of waste upward to the surface.

The mineralogy of these soil and fault-related samples is being studied with four possible origins in mind:

(1) The deposits may be pedogenic, reflecting only local dissolution and reprecipitation of material from the soil zone. This would be a local, low-temperature origin.

(2) The deposits may have formed from a low-temperature spring. Such springs could be either perched or deep-seated.

(3) The deposits may have formed from a high-temperature spring, with a deep-seated origin.

(4) The deposits may include material that originated from early high-temperature alteration along with early faulting soon after tuff emplacement.

More than one of these hypotheses may be necessary to explain the full variety of minerals found in these faults, in the altered tuff cut by the faults, and in the nearby soils.

This is a multi-disciplinary study because of the large variety of data relevant to the resolution of an origin for these deposits. Also for this reason, the studies are spread jointly between researchers at LANL and in the USGS. At this time, J. O'Neil of the USGS is analyzing oxygen and carbon isotopes in samples from this collection.

No active springs of deep-seated origin have been observed at Yucca Mountain or vicinity. However, spring deposits of 30,000 yr age occur in southern Crater Flat, and a 78,000-yr old spring deposit may occur at the southern end of Yucca Mountain (Szabo et al., 1981). It is certainly possible that other springs may have occurred with activity so old or rare as not to have been observed in surface mapping. Such springs could be recognized by study of mineral deposits or alteration in trenches. The descriptions below concentrate on what is at present our best known suite of samples, from Trench 14 on the eastern side of Yucca Mountain.

II. Field relations

Trench 14 was excavated across a north-south trending fault on the west side of Exile Hill. From east to west, the trench exposes volcanic bedrock, bedrock with overlying alluvial cover, and alluvium. There is considerable calcite and silica accumulation within the alluvium. Several fault traces are exposed at the east end and central part of the trench; faults and associated fractures are coated with carbonate and silica.

Preliminary study suggests that there is a close textural and mineralogical similarity between the pedogenic material in weathered alluvium and the material deposited along faults within the weathered alluvium. Pedogenic calcite is transported in soils by downward-moving surface water and deposited from solution. Continuing deposition and recrystallization force the non-carbonate soil particles apart, leading to the formation of laminated, nearly pure carbonate horizons (ref. Birkeland, 1974). For carbonate deposition in a fracture, however, the geometry and permeability of the depositional environment are different. In addition, because tectonic fractures can conduct water well below the root zone, carbonate deposition may be less affected by plant CO_2 in such fractures than in the soil horizons. Nevertheless, the basic depositional processes are much the same. The material deposited along fractures may be nonpedogenic mainly in the sense that it transgresses soil horizons. The apparent greater abundance of coarse sparry calcite in fractured tuff and in caliche near the fault, compared to horizontal K-horizon caliche, may result from locally increased permeability along fractures and from possible fluid composition differences. Lattman and Simonberg (1971) showed that infiltration of rainwater into carbonate alluvium in southern Nevada was sufficient to cause local solution and reprecipitation of fine-grained carbonate as sparry cement to depths of more than 10 ft (3 m). Therefore, no additional source of water (e.g., a spring) is required to account for the sparry calcite. It is in this pedogenic association that sepiolite is also found.

In contrast, the altered tuff also contains drusy quartz that could be the product of moderate temperature hydrothermal alteration. If this is true (see fluid inclusion studies, below), it would be important to establish the time of alteration and the relationship, if any, between alteration and fluid movement along faults. Further field study will determine the distribution of alteration within tuff and its relationship to the exposed faults.

III. Mineralogy

X-ray diffraction analysis of bulk samples of both soil- and fault-filling materials revealed the presence of major calcite and minor amorphous silica or opal CT. However, the 10% HCl-insoluble residue of the carbonate rocks contained major sepiolite and/or opal CT and lesser amounts of palygorskite(?) and quartz. The presence of sepiolite and palygorskite, magnesium silicates with chain-like structures, is noteworthy because these minerals are thought to form at low temperatures. These two minerals are very common in calcic soils, pedogenic calcretes, and other surficial carbonates, such as paludal or lacustrine deposits, in the semiarid southwestern U.S. In fact, their presence in calcic horizons of the surficial deposits of the NTS area has been noted by Jones (1983).

Lacking strong evidence for a hydrothermal origin for the deposits in Trench 14, we suggest that these deposits represent low-temperature pedogenic calcretes, similar to those documented in the NTS area. Khoury et al. (1982) showed that these Mg-silicates can form under ambient conditions simply through the evaporation of surface water equilibrated with atmospheric CO_2.

IV. Fluid inclusions

Multiple thin sections through soil and fault-filling samples have shown no fluid inclusions large enough to analyze for temperature of homogenization. The largest inclusions found are less than 2 μm in size, or occur as fracture-related secondary inclusions in opaline silica. However the intergrowth of these carbonate-rich samples with sepiolite is strong evidence of low-temperature origin. Moreover, although the inclusions found are very small, examination at high magniication reveals no bubbles that would be expected from formation at higher temperatures.

The drusy quartz crystals that occur in altered tuff also are poor in large inclusions, but the small inclusions which occur in abundance contain visible bubbles. The largest inclusion found so far (8 µm) yielded a homogenization temperature of 145°C. Further serial sections are being obtained to confirm this temperature. This preliminary datum plus the textural evidence for early growth of the drusy quartz suggest that some form of hydrothermal event preceded the calcite - opal CT - sepiolite - palygorskite (?) - amorphous silica crystallization along the fault.

V. Isotopic studies

Samples of pedogenic K-horizon carbonate, of fault-filling carbonate, and of amorphous silica from one of the trenched faults are being analyzed for carbon and oxygen isotopes by J. O'Neil of the USGS. A sample of the early-formed drusy quartz from altered tuff along the fault will also be analyzed. These data will be compared with those compiled for Yucca Mountain drill-hole carbonates by Scott et al. (1984). Analysis of the drusy quartz will be particularly useful for comparison with the high temperature (145°C) so far indicated by fluid inclusion studies, and may help to distinguish between a high-temperature spring origin or an origin during early high-temperature tuff alteration.

VI. Preliminary interpretations and future work

Of the four possible interpretations for the origin of fault-related minerals stated in the introduction, none can yet be explicitly ruled out. We can however state that more than one episode of alteration is recorded in these samples. An early episode of high-temperature quartz growth (either during early cooling of the tuff or by high-temperature spring activity) was

followed by an episode of low-temperature sepiolite-carbonate-silica-palygorskite (?) alteration (through either pedogenic or low-temperature spring activity). The problem remains of uniquely determining whether or not spring activity was involved in either the high-temperature or low-temperature stages of alteration. Our preliminary data lead us to suggest that a combined field and laboratory study will provide the answers to these questions by (1) comparing the formation conditions, including direct or indirect radiometric dating if possible, of early drusy quartz in Yucca Mountain faults with the formation conditions of similar silica alteration that occurs elsewhere at Yucca Mountain, and by (2) comparing the later low-temperature alteration in the faults with the known spring deposit at Crater Flat and with the suspected spring deposits of southern Yucca Mountain. Trench CF-2, CF-3 ?
CF-1,

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