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Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

July 17, 1985
TWS-ESS-1-7/85-20

TO: Donald L. Vieth, Director
Waste Management Project Office
US Department of Energy
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Las Vegas, Nevada 89114-4100

Through: Don Oakley
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William Dudley
MS 418
US Geological Survey
Box 25046
Denver Federal Center
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From: D. Vaniman (LANL), J. Downey (USGS), D. Bish (LANL), J. O'Neil (USGS), S. Levy (LANL)

Contact: Dave Vaniman
MS J978
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IMPACT OF FAULT-RELATED MINERAL DEPOSITS ON SITE CHARACTERIZATION AT YUCCA MOUNTAIN: STUDIES AS OF JULY, 1985

Dear Don;

During our discussion of fault-related mineral deposits on June 27-28, it was decided that a summary of our knowledge of their origins be provided by the end of July. Although many questions remain open and can only be answered through the research program outlined by Joe Downey for the TPOs on June 27, we know enough at this time to show that the most recent and abundant of these deposits need not be viewed with alarm as evidence for hot-spring activity. There is still a viable possibility that the older, drusy quartz that occurs in faults around Yucca Mountain might be a product of hot-spring deposition (ref. Vaniman et al., 1984), but this question can not be answered at this time. This high-temperature quartz is very different from the calcite - silica - sepiolite deposited after it within the faults. For these later deposits we can answer the following questions.

(1) Are the fault-related calcite - silica - sepiolite deposits a result of high-temperature spring activity?

Calcite and silica from the fault exposed in Trench 14, along the eastern flank of Yucca Mountain, have the following $\delta^{18}O$ and $\delta^{13}C$ per-mil isotopic compositions referenced to Standard Mean Ocean Water (SMOW) and the Pee Dee Belemnite (PDB) respectively (O'Neil, 1984 and 1985):

	$\delta^{18}O$(SMOW)	$\delta^{13}C$(PDB)
T14-FB calcite	19.6	-5.3
T14-3a-w calcite	20.3	-7.5
T14-Fa amorphous silica	27.2	n.a.

From the high $\delta^{18}O$ values and the large difference in $\delta^{18}O$ between calcite and silica in this assemblage, it is certain that these materials formed at or near surface temperatures (O'Neil, 1984 and 1985). This rules out a high-temperature spring origin for this assemblage.

It is instructive to compare the isotopic composition of the Trench 14 fault-related calcite with that of soil-zone calcite collected from one of the sand ramps skirting Fran Ridge, just east of Yucca Mountain (O'Neil, 1984):

	$\delta^{18}O$(SMOW)	δ^{13}(PDB)
FR6 calcite	19.8	-7.0

Isotopically, there is no basis for assuming that there is any difference between soil-zone calcite of the sand ramps (FR6) and calcite deposited within the fault at Trench 14 (T14-FB, T14-3a-w).

(2) On the basis of mineral assemblage, is there any reason to assume a different origin for soil-zone deposits and the fault-related calcite - silica - sepiolite deposits?

If we compare the soil-zone mineralogy of the sand ramps around Yucca Mountain with the calcite - silica - sepiolite mineralogy that occurs near the surface within faults, are there any significant differences? Figure 1 compares the x-ray diffraction patterns of silica-bearing deposits from the sand ramp at Fran Ridge (FR6) with fault-related calcite - silica - sepiolite deposits within the fault exposed in Trench 17 (TR17). Both patterns are very similar, showing assemblages dominated by calcite and opal CT (opal with cristobalite- and tridymite-type structure) with lesser quartz and sepiolite. After treatment with HCl and separation of the <2μm size fraction, both types of localities can be shown to contain very similar opal CT and sepiolite patterns. Seams of amorphous silica have also been found in Trench 14, but this material is closely related to the opaline deposits and its occurrence may well be controlled by near-surface flowage in open fractures.

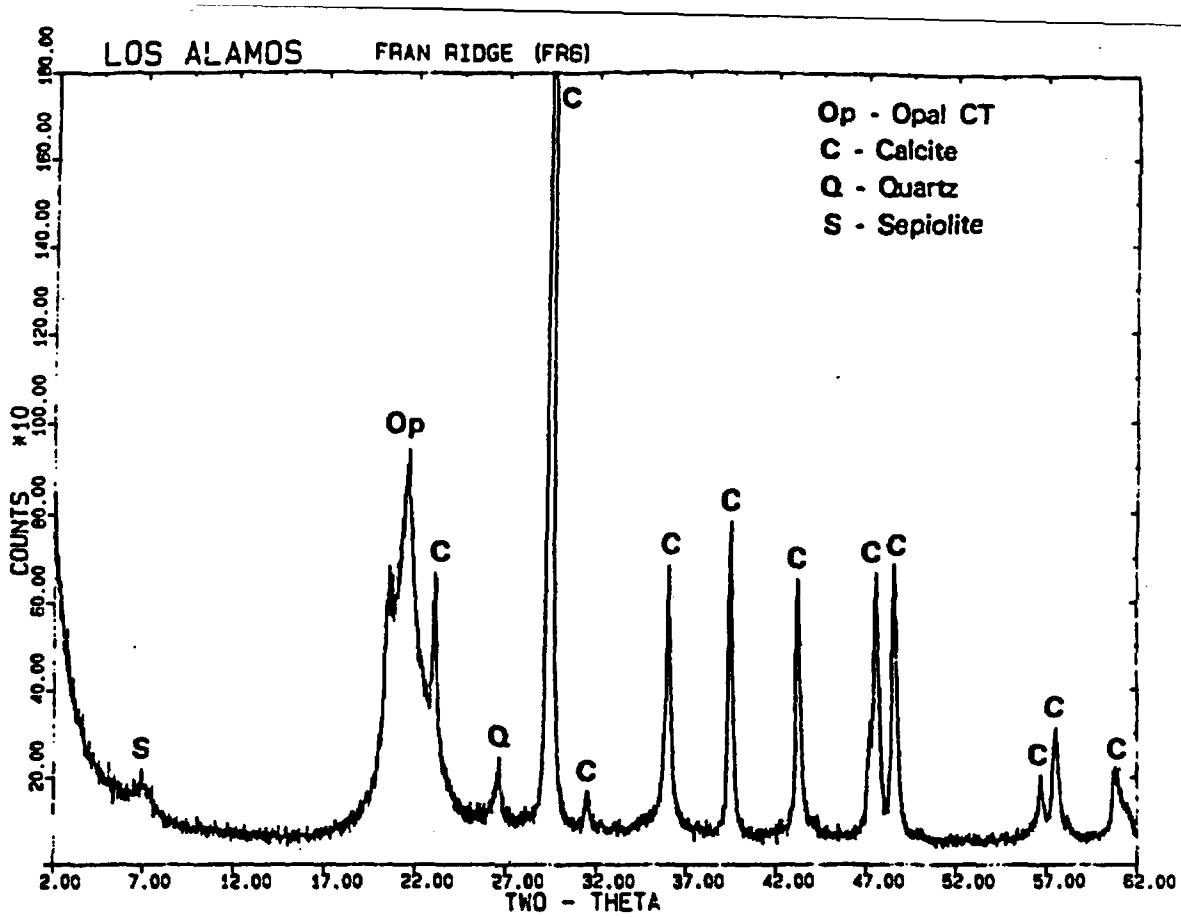
Based on the directly comparable mineralogy of sand-ramp and fault-related samples, there is no reason to assume an origin for the fault-related minerals that would be significantly different from the soil-zone origin of similar sand-ramp minerals. It is quite possible that local saturation may have occurred within some faults, but to date we have found no evidence that would require a deep-seated spring origin for the calcite - silica - sepiolite deposits that occur within faults at Yucca Mountain.

References

O'Neil, J.R. (1984), letter of Dec. 19 to D. Vaniman (attached)

O'Neil, J.R. (1985), letter of April 29 to S. Levy (attached)

Vaniman, D., D. Bish, and S. Levy (1984), progress report of Nov. 30, TWS-ESS-1-11/84-22 (attached)


LOS ALAMOS
FRAN RIDGE (FR6)
Op - Opal CT
C - Calcite
Q - Quartz
S - Sepiolite
COUNTS ×10
TWO - THETA
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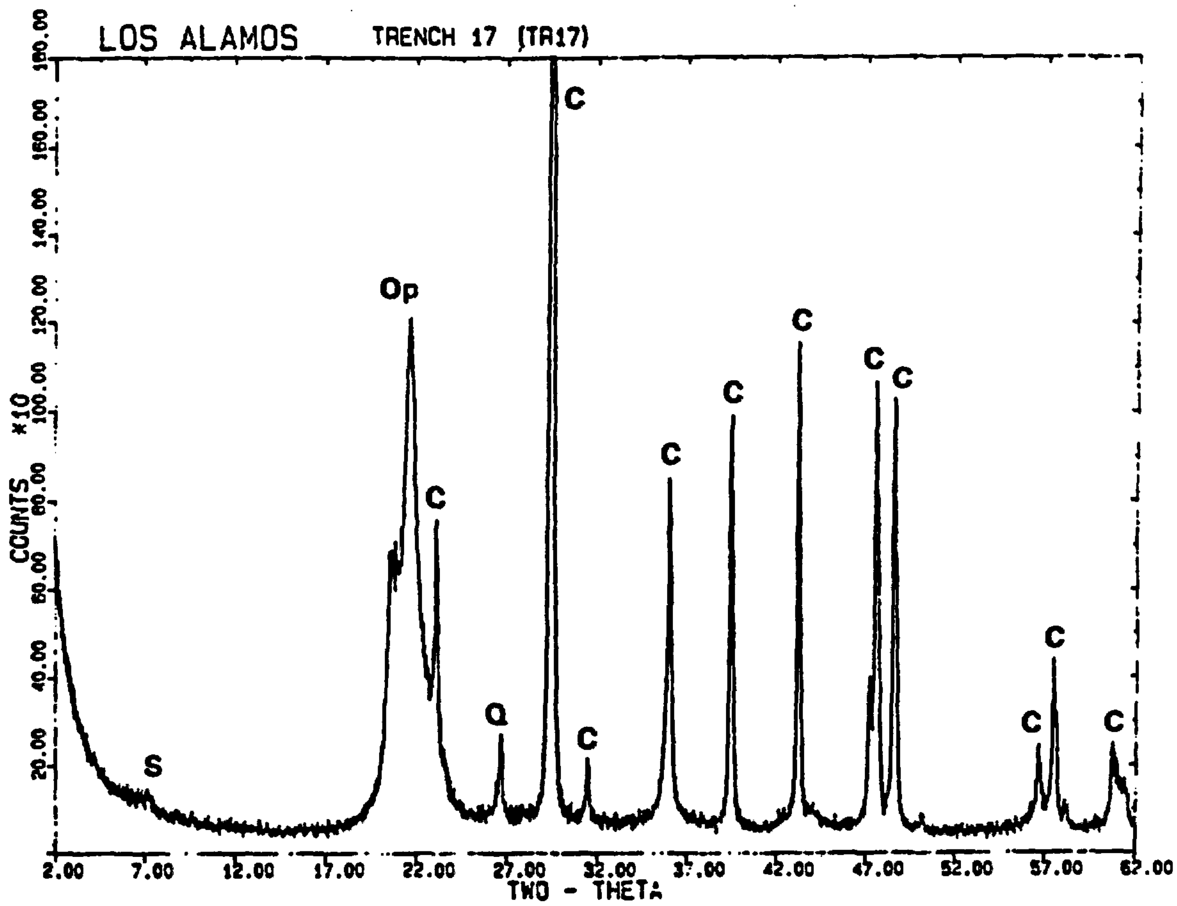
LOS ALAMOS
TRENCH 17 (TR17)
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United States Department of the Interior

GEOLOGICAL SURVEY

Branch of Isotope Geology (MS 937)
345 Middlefield Road
Menlo Park, California 94025
U.S.A.

December 19, 1984

Dr. David Vaniman
Los Alamos National Laboratory
Los Alamos, New Mexico 878545

Dear Dave:

Given below are the stable isotope analyses of the three samples from Yucca Mountain, Nevada that you sent to us recently.

Sample	^{18}O (SMOW)	^{13}C (PDB)
T14-FA amorphous silica	27.2	
T14-FB calcite	19.6	-5.3
FR6 calcite	19.8	-7.0

From the high ^{18}O values and the large ^{18}O fractionation of 10.0 between silica and calcite, it is certain that these minerals formed at very low temperature. A typical ^{18}O value of ground water in this region is -13.0‰ From this I calculate a temperature of formation of about 15°C. The hot springs suggestion is effectively ruled-out by the isotope data.

Sincerely yours,

James R. O'Neil

cc: W. Dudly
R. Zartman

United States Department of the Interior

GEOLOGICAL SURVEY

Branch of Isotope Geology (MS 937)
345 Middlefield Road
Menlo Park, California 94025
U.S.A.

April 29, 1985

Dr. Schon S. Levy
ESS-1 Geology and Geochemistry
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Dear Schon:

The stable isotope analyses and oxygen isotope "temperatures" of the most recent suite of samples you sent are given in the table.

Sample	Description	$\delta^{18}O$ (SMOW)	$\delta^{13}C$ (PDB)	T(°C)	T*(°C)
TR-14-3a-q	drusy quartz	22.1		145	50
TR-14-3a-w	calcite in WR	20.3	-7.5	90	5
YF-4-q	drusy quartz	17.8		190	70
YW-4-q	botryoidal quartz	13.1		255	100
VH-2-3545-q	quartz fracture filling	13.0		225	100
VH-2-3565-q	quartz fracture filling (impure)	11.9		--	

Temperatures given in the first T column were calculated assuming that the filling temperature of 145°C is a correct temperature of formation for quartz in TR-14-3a-q and that the other minerals were precipitated from a fluid with the same isotopic composition. Using the quartz-water fractionation curve of Bottinga and Javoy (1973) this fluid would have had a $\delta^{18}O$ value of + 2.0 °/oo. Such a value, if correct, would be characteristic of a formation water or brine that may have originated as ocean water ($\delta^{18}O$ = 0 °/oo). If the fractionation curve of Clayton et al (1972) is used, a water with an unusually high $\delta^{18}O$ value of +5.3 °/oo is implied. My initial reaction is that such waters were not involved in the growth of this quartz and that there is something wrong with the filling-temperature measurements. I can check this possibly by crushing the quartz and analyzing the deuterium content of the fluid inclsions. Under "normal" circumstances where ground water of meteoric origin is involved in the growth of these minerals, a high $\delta^{18}O$ value such as 22.1 implies that the quartz formed at relatively low temperatues.

In general, the lower the temperature, the larger the fractionation factor and the higher is the $\delta^{18}O$ value of a mineral. Igneous quartz has typical $\delta^{18}O$ values of ~7 to 10, medium-rank metamorphic quartz has $\delta^{18}O$ values of ~12 to 18, and low-temperature quartz has higher values up to +36 for authigenic quartz forming on the ocean floor.

The temperatures given in the second T* column were calculated with the Bottinga-Javoy equation assuming a $\delta^{18}O$ value of -13.0 °/oo for local ground water. If this value were shifted to higher (more positive) values by exchange with ^{18}O-rich wall rocks before quartz was deposited in the fissures (and this is likely), the temperatures would be higher but much closer to those in the second column than to those in the first.

In any event, if similar waters were involved in the formation of the various samples of quartz, a variety of formation temperatures is implied. The relative temperatures are more meaningful than the absolute temperatures. The amorphous silica sent in the first batch has a very high $\delta^{18}O$ value of 27.2 °/oo and I am certain that it was formed at or near suface temperatures from ground water.

If I get further involved in extracting fluid inclusions to check this all out, I shall need some financial support. Please call me if you need further explanations of the limitations of the isotopic data and how they were manipulated.

Regards,

James R. O'Neil

cc: J. Rosholt
D. Vaniman

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

D. Vaniman, D. Bish, and S. Levy

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

Trenc.. 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 magnilcation 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 um) 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.

References

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