LA-UR 91-4035

LA-UR--91-4035

DE92 005058

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TITLE: Natural Gels in the Yucca Mountain Area, Nevada, USA

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SUBMITTED TO: Applied Clay Science

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FORM NO 836 R4
ST NO 2629 5/81

Natural gels in the Yucca Mountain area, Nevada, USA

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ABSTRACT

Relict gels at Yucca Mountain include pore- and fracture-fillings of silica and zeolite related to diagenetic and hydrothermal alteration of vitric tuffs. Water-rich free gels in fractures at Rainier Mesa consist of smectite with or without silica-rich gel fragments. Gels are being studied for their potential role in transport of radionuclides from a nuclear-waste repository.

INTRODUCTION

Yucca Mountain, in southwestern Nevada, USA, is being studied as a potential site for an underground high-level nuclear waste repository (Fig. 1). The possibility of aqueous radionuclide transport from a repository to the accessible environment will be an important issue in evaluating the site. Gels and colloids -- either naturally-occurring or produced by interaction of repository contents with ground water -- might participate in radionuclide transport or retardation. Yucca Mountain water contains about 2.7×10^{-5} g/l of particles smaller than 10 μm, not enough to make an important contribution to radionuclide transport relative to transport in solution. However, a particulate content of about 10^{-2} g/l or greater could account for at least 10% of the transport for some radionuclides (Ogard, 1987).

Gel studies at Yucca Mountain apply to concentrations of colloidal material within the rocks. Materials of potential interest include both gels that are still liquid-rich and former gels that have solidified and crystallized. Studies of relict gels help answer questions about the nature, abundance, and distribution of gels; they also provide evidence of origin and transport. This information has a potential use as a natural analog for alteration conditions in a geologic waste-repository environment that might lead to the formation of new gels and colloids.

SAMPLE COLLECTION AND ANALYSIS

Materials studied include cores and sidewall samples from drill holes at Yucca Mountain. Individual samples are identified by abbreviated drill-hole designation and depth in meters. This paper highlights examples of altered tuffs containing relict gels.

Two semi-transparent fluid gel samples were collected by other investigators from tunnel exposures at Rainier Mesa. No determinations of water or solid content were made at the time of collection. Sample U12t.02 Sta 19+24, hereafter referred to as sample U12t, was collected in 1971 from a fracture at a drift location that is no longer accessible (Levy et al., 1986). The material had the consistency of a gel when collected and was dried at room temperature. Sample MIEC-2, with the consistency of a paste, was collected from a fracture in tunnel U12n in 1988. Yucca Mountain and Rainier Mesa samples were studied in thin section by petrographic microscope and by x-ray diffraction, scanning electron microscopy, and electron microprobe analysis. Iron in microprobe analyses is rendered as ferric iron.

GEOLOGIC SETTING

Yucca Mountain is a thick accumulation of Miocene silicic ash-flow tuffs (Byers et al., 1976; Carr, 1988). Most pyroclastic units retained enough heat after deposition to develop densely-welded, devitrified interiors in which the original glass particles were consolidated and crystallized to a high-temperature assemblage of feldspars and silica minerals. The upper and lower margins of the units remained vitric (glassy). Thinner, bedded tuffs between the main ash flows also remained vitric and nonwelded. In the middle and lower units of the pyroclastic section, most glassy tuffs have been diagenetically altered to zeolite-dominated hydrous-mineral assemblages (Broxton et al, 1987).

The candidate host rock for repository construction is within the densely-welded, devitrified central portion of the 300-m thick Topopah Spring Member of the Paintbrush Tuff. A basal vitrophyre (densely welded but still glassy) underlies the candidate host rock and would be the natural glass-bearing unit closest to a waste repository.

The static water level (SWL) is about 730 m below the crest of the mountain, 200 to 400 m below the candidate host rock (Waddell et al., 1984). The SWL may have reached its highest level and receded downward more than 11 myr ago; since then, it may have been no more than about 60 m above its present position (Levy, 1991). A generalized boundary between low-lying, diagenetically-altered zeolitic tuffs and unaltered vitric tuffs at higher elevations is taken as an approximation to the former high stand of the SWL.

Rainier Mesa is 40 km NE of Yucca Mountain and also consists of Miocene ash-flow and bedded tuffs. About 400 m below the surface are bedded tuffs extensively altered to zeolites, clays, and silica. Local recharge into the

mesa maintains saturated conditions and active zeolitic alteration in the tuffs. A large tunnel complex has been mined in this interval, 300 m above the regional static water level.

RELICT GELS AT YUCCA MOUNTAIN

Gels of Diagenetic Origin

Free water-rich gels have not yet been found at Yucca Mountain. The most common examples of former gels are microscopic geopetal deposits in pores of the zeolitized nonwelded tuffs. The term "geopetal" refers to the gravitational settling of colloidal particles in water-filled pores. A typical deposit is shown in Fig. 2a. Pores containing deposits are either primary voids, such as vesicles, or secondary cavities created by dissolution of glass pyroclasts. Most of the pores containing relict gel deposits are less than 1 mm across. The deposits contain silica of variable crystallinity and heulandite-clinoptilolite. Planar layering is characteristic of many deposits. Layers within silica deposits are distinguished by color, by variations in incipient birefringence related to differences in crystallinity, or by differences in granularity. Zeolite and silica are commonly in separate layers with the zeolite lowermost. Some gel deposits crystallized as aggregates of mixed 3- to 5-μm cristobalite and heulandite-clinoptilolite crystals (H-5 584.3 m).

Another variety of relict gel fills only primary pores and is a major cementing constituent in certain well-sorted bedded tuffs that originally contained little or no fine-grained ash. Heulandite-clinoptilolite and opal, in variable proportions, are the main constituents (Fig. 2b). Internal

layering is absent, but in a few incompletely-filled pores the free upper surface of the deposit is planar. The infilling of virtually all primary porosity, but only primary porosity, by gel in this kind of tuff indicates that the gel constituents were externally derived and transported into the bedded tuff by moving water before the tuff itself began to be altered.

Gels of Hydrothermal Origin

The transition zone between Topopah Spring devitrified tuff and underlying vitrophyre is an interval of partly devitrified vitrophyre, between 3 and 30 m thick, in which devitrification is localized around fractures. The outermost margins of devitrified fracture borders and adjacent vitrophyre also contain hydrous minerals plus dissolution cavities in the glass (Levy, 1984). Former gels in the transition zone are of special interest because they are products of alteration conditions that may be a natural analog to a repository environment. Alteration accompanied the cooling of the pyroclastic deposit and lasted about 10^2 yr. The local temperature range was 40 to 100°C or higher (Levy and O'Neil, 1989). Water moved downward along fractures in the cooling tuff to the transition zone between the central, hotter part of the tuff where glass devitrification prevailed and the underlying, cooler vitrophyre where glass dissolution and hydrous-mineral precipitation dominated. In the transition zone, domains of devitrification and dissolution are discontinuous and intermingled on both a macroscopic and microscopic scale.

The chief hydrous products of glass alteration are smectite and heulandite-clinoptilolite. Smectite and small amounts of extremely fine-grained heulandite-clinoptilolite commonly crystallized at

glass-dissolution sites as spherical aggregates, 2 to 50 μm across, adhering to each other. Perhaps because of this growth habit, there is little evidence of free smectite gels. Smectite fracture fillings that might have crystallized from gels transported into the fractures are volumetrically less abundant.

The most abundant gels crystallized to heulandite-clinoptilolite, silica, and zeolite-silica mixtures (Fig. 2c; Table I). Silica products include opal, chalcedony, and cristobalite, locally in combination with each other. Additional minor gel products include hematite, manganese minerals, and other zeolites. Fractures and dissolution pores are filled with layered and nonlayered accumulations of former colloidal particles. One example has been found (VH-1 516.3 m) of a nonlayered gel fracture filling that crystallized first Ca-K-rich heulandite-clinoptilolite (molecular Si:Al = 3.67) and then Na-K-rich clinoptilolite (Si:Al = 5.14). Relict colloidal accumulations also fill dissolution cavities in altered vitrophyre and primary and secondary pores in moderately-welded tuffs below the vitrophyre.

FLUID GELS FROM RAINIER MESA TUNNELS

Sample U12t is the dried residue of a smectite-water gel with fragments of zeolitic wall rock and silica-rich gels. Analyses of silica-rich gels and smectite are shown in Table I. Low analysis totals for the silica-rich gels reflect both the high water content and low density of the gel products. The smectite dried as a laminated coating binding the granular material. Sample MIEC-2, which contained only a few large wall-rock fragments when collected, revealed a well-crystallized smectite without admixture of other material.

Silica-rich gel fragment textures in U12t are massive, spongy, granular,

or faintly fibrous. Gel fragments underwent both fracturing and plastic deformation (Fig. 2d). Small cavities in the gel contain submicron crystals of barite, Cu and Fe sulfates or sulfides, probable zeolites, and silica.

CONCLUSIONS

Genesis and deposition of gels at Yucca Mountain were associated with diagenetic and hydrothermal alteration of volcanic glass. The principal gel products in both environments were heulandite-clinoptilolite and silica. Even within individual samples, there is considerable variation in the texture and crystallinity of the products. In both Yucca Mountain and Rainier Mesa materials, Al-rich gel products (clays and zeolites) have attained a completely crystalline state, whereas much of the silica is only partly ordered.

With the heat generated by a potential nuclear-waste repository in devitrified Topopah Spring tuff, recharge water from major precipitation events or reflux water concentrated by the repository thermal regime may be sufficient to cause renewed local alteration of glass in the underlying vitrophyre, colloid transport, and gel formation. Moderately-welded tuff below the vitrophyre may act as a trap for downward-moving gels or colloids.

ACKNOWLEDGMENT

This work was supported by the Yucca Mountain Site Characterization Project Office as part of the Civilian Radioactive Waste Management Program. This Project is managed by the U.S. Department of Energy. Review comments by D. Vaniman and J. Thomassin are also appreciated.

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TABLE I:
Electron microprobe analyses of gels and related materials

	Drill Hole 25a#1 395.3 m, Yucca Mountain				Rainier Mesa, U12t		
	Glass	Smectite	Gel product*	Heul.-clino.	Silica-rich gels		Smectite
Weight %							
SiO_2	72.0	53.6	58.7	64.6	20.8	85.8	57.5
TiO_2	0.09	0.18	0.00	0.00	0.00	0.08	0.22
Al_2O_3	11.7	26.9	10.1	12.3	3.18	2.27	24.2
Fe_2O_3	0.8	1.5	0.4	0.00	0.14	0.16	3.7
MnO	0.00	0.00	0.00	0.00	0.00	0.00	0.23
MgO	<0.03	0.74	0.35	0.58	0.00	0.00	1.15
CaO	0.40	3.18	3.45	4.60	0.36	0.18	0.63
Na_2O	3.44	0.34	0.44	0.37	0.42	0.47	0.54
K_2O	4.69	0.24	0.51	0.92	0.45	0.66	3.00
Total	93.1	86.7	74.0	83.4	25.4	89.6	91.2

*probable mixture of heulandite-clinoptilolite with silica

Figure Captions

FIG. 1: Location map.

FIG. 2: (a) layered silica geopetal filling in dissolved-shard cavity, G-1 660.2 m, plane-polarized light, 0.1-mm bar. (b) primary pore between two phenocrysts contains elongate <0.02-mm clinoptilolite crystals surrounded by clear opal, H-5 584.3 m, plane-polarized light, 0.05-mm bar. c) layered and non-layered zeolite-silica fracture fillings in altered vitrophyre, 25a#1 395.3 m, plane-polarized light, 0.1-mm bar. d) silica-rich gel fragment with white silica particles outlining relict fractures, surrounded by laminated dried smectite, secondary electron image, 50-μm bar.

Data sources:

Notebook TWS-ESS-1-10/82/19, pages 127, 160, 163-183, 224, 229; electron microprobe printout record TWS-EES-1-2-91-2, and photomicrograph record TWS-EES-1-2-91-8.

Data reported in this paper were not generated under an approved software quality-assurance program.

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