UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE & MATERIALS
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December 18, 2007

MEMORANDUM TO: ACNW&M Members

FROM: Antonio F. Dias, Chief **/RA/**
Nuclear Waste & Material Branch, ACRS/ACNW&M

SUBJECT: TRANSMITTAL OF TRIP REPORT BY ACNW&M STAFF ON THE OCTOBER 2007 GEOLOGICAL SOCIETY OF AMERICA MEETING

Enclosed is the trip report by Senior Staff Scientist Neil Coleman regarding his attendance at the Geological Society of America scientific conference; where he also gave a presentation. The conference was held in Denver, CO from October 28-31, 2007.

Enclosure: As stated

cc w/att:
F. Gillespie
S. Jones
ACNW&M Staff

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Trip Report - Attendance at the 2007 Geological Society of America (GSA) Annual Meeting & Exposition, Denver, Colorado

Neil Coleman, ACNW&M Senior Staff Scientist

During October 28-31, 2007 I attended the GSA meeting in Denver, CO. I also participated in a pre-conference field trip on Saturday, October 27th. I gave a talk on Sunday, October 28th titled "Reduced Likelihood of Volcanic Disruption of a Geologic Repository at Yucca Mountain." ACNW&M consultant Bruce Marsh (Johns Hopkins University) co-authored this presentation and the meeting abstract. This talk updated the probability estimates that were published in a 2004 paper in Geophysical Research Letters (Coleman, Marsh, and Abramson, doi:10.1029/2004GL021032) using new data from the drilling and dating of suspected buried basalts near Yucca Mountain. The new data reduce the number of possible buried post-Miocene basalts near the site.

My other focus at this meeting was to gather information that would help support current interests and planned activities of the ACNW&M. To that end I attended presentations on topics such as seismicity, uranium in-situ leach groundwater issues, fluvial erosion, landslides and catastrophic failure of dams, Pleistocene climate change at Yucca Mountain, regional groundwater response to climate change, and volcanism at Yucca Mountain. Additional details about each of these topics are given below. Information about fluvial erosion will be especially helpful in planning a working group meeting in 2008 on erosion models that have potential application to the long-term stability of decommissioning and low-level waste sites.

Volcanism at Yucca Mountain

F. Perry (Los Alamos National Laboratory) gave a talk titled "Tectonically controlled, time-predictable basaltic volcanism from a lithospheric mantle source, Southwestern Nevada Volcanic Field, USA." Understanding the evolution of basaltic volcanic fields is critical to understanding basaltic magmatism and volcanic risk assessment. Volcanological, geochemical, and time-volume characteristics of the Plio-Pleistocene part of the Southwestern Nevada Volcanic Field (SNVF) suggest it is an extremely low volume-flux end member of basaltic volcanic fields. The SNVF has produced 17 volcanoes of dominantly trachybasaltic composition over the past 5 Myr with a total volume of slightly less than 6 km^3. Eruptive volumes decreased after the Pliocene. Major element data suggest that most of the magmas underwent similar degrees of fractionation during ascent, and trace element compositions show a decrease in the degree of partial melting of the lithospheric mantle source since ~3 Ma. Isotopic data support an interpretation in which magmas ascended quickly from their source regions with little interaction with crustal rocks. Relationships between age and cumulative erupted volume indicate that the repose interval between eruptive episodes is determined by the volumes of prior episodes and, since ~3 Ma, an average eruption rate of ~0.5 km^3/Myr. It appears the volcanic field is time-predictable. These features support a model where magmatism is a passive result of regional tectonic strain. Partial melt resides in pockets of lithospheric mantle that are enriched in hydrous minerals. Slow deformation focuses melt, occasionally resulting in sufficiently high melt pressure to drive dikes upward and feed eruptions. Larger source volumes result in larger eruptive volumes and wider dikes that relieve more strain in the crust than smaller volume events, and therefore are followed by longer repose intervals required for recovery of crustal stresses. The data suggest that time-predictability may be a fundamental property of tectonically controlled basaltic fields, where melt accumulation and ascent are controlled by tectonic strain rate. This behavior contrasts with magmatically controlled fields where the magma flux is high enough to overwhelm local tectonic strain, eruptions are primarily caused by processes that build pressure in reservoirs, and the systems are more likely to be volume-predictable.

Fluvial Erosion

The Committee is hosting a working group on erosion as it applies to decommissioning and waste disposal sites. Several presentations at this meeting were of special interest because they described rapid erosion and landform evolution in regions were the surface geologic units are young and unconsolidated, having been deposited during Pleistocene glaciations.

One of these presentations was titled "Sediment loading in the Le Sueur River, Minnesota River Watershed," by S. Day, A. Johnson, K. Gran, L. Perg, and C. Jennings (2007). They are studying sediment influxes to the Le Sueur River in central Minnesota using field work, analyses of DEMs, and historical aerial photographs. High sediment loads in the Minnesota River have led to declining water quality in Lake Pepin. There is an increased desire to understand sediment sources in the Minnesota River. Influx from the Le Sueur River is a primary contributor of these sediments.

The Minnesota River is deeply incised, with tributaries cutting down through unconsolidated glacial and alluvial sediments. Potential sources of sediment include high bluffs along the lower Le Sueur, ravines and gullies, floodplains and terraces, and upland agricultural fields. To investigate erosion rates over a longer span of time, the study areas are being compared with aerial photographs dating back to 1938. The photos are referenced using ArcGIS by correlating common points in each photo. To find the meander migration rates we are using an ArcGIS add-in that calculates the meander migration based on the center lines of both the modern and historic channels. The average meander migration rate for the portion of the LeSueur River within Blue Earth County is 0.22 m/yr with a maximum meander migration rate of 2.4 m/yr (Day et al. 2007). This rate does not account for any downstream translation of the meanders.

To better understand source contributions, Day et al. (2007) are using ground-based (side scanning) LiDAR to survey bluffs and banks along the channel to estimate retreat rates. These surveys will be repeated and compared each year of the study to calculate volume of sediment lost per year. Day et al. (2007) report there are at least two types of bluffs. One group consists of over-consolidated tills or bedrock. It is hypothesized that these bluffs break apart in large blocks that are subsequently broken down and transported in the river. The other bluff type is poorly consolidated till and alluvium that slumps into the river. The more consolidated material forms steep slopes, while the looser material forms gentle slopes.

Areas of exposed bluffs, banks, and ravines are being determined from high-resolution airborne LiDAR data, which reveals much greater topographic detail than aerial photography in the basin. The LiDAR was flown in 2006 for all of Blue Earth County MN. The data are also being used to estimate floodplain and terrace areas along three branches of the Le Sueur River for use in a floodplain exchange model. Preliminary investigations show long-term migration rates as high as 3.23 m/yr for isolated meander bends and bluff retreat rates up to 0.43 m/yr (Day et al., 2007).

A sediment gauging network has been established at eight sites within the Le Sueur River basin. Sediment gauging eventually will be combined with source contribution data to create a sediment routing model. This work will contribute to a broader understanding of how sediment moves throughout the river network.

Future work will include cosmogenic radionuclide sediment fingerprinting to quantify exposure history and sediment mixing from different sources throughout the basin. For example, ratios can be used to quantify the relative activity of bluff surfaces and identify ravines that are funneling upland sediment versus ravines producing sediment from incision. Day et al. (2007) will also conduct repeat surveys of the channel bed and the ravines to have an additional test for the amount of erosion taking place in these environments. Experimental models of ravine development will be used to better understand the effects of different size and length of rainfall events. These experiments will also model the impacts of tile drainage and ditching on ravine growth. Finally, computer modeling will close the sediment budget. This will include a sediment routing model coupled with a rainfall model. The meander migration rate and bluff retreat rate for the model will be calibrated using aerial photography and ground based LiDAR (Day et al., 2007).

C. Wittkop (Minnesota State University) gave a talk titled “Geomorphic response to rapid fluvial change: The 2006 Suncook River Avulsion, Epsom, New Hampshire.” In May of 2006, 100-year floods triggered a local avulsion (i.e., rapid migration of a river channel) in the Suncook River of southeastern New Hampshire. In less than 24 hours, a 2.4-km-long reach of the channel was abandoned and bypassed, and 0.8-km of new channel incised through wetlands and glacial lake sediments not previously mapped as floodplain. Analysis of digital elevation models, air photos, GPS data, ground surveys, and eyewitness accounts were used to assess the conditions surrounding the channel migration and its aftermath. A confluence of natural and human factors triggered the event. Near the capture point, the pre-existing channel made a 180-degree turn into a reach impounded by a small dam and floored by resistant bedrock. In contrast, the new channel crosses wetlands and unconsolidated glacial lake sediments. Sand and gravel mining in glacial deposits compromised a low ridge that acted as a natural levee and once prevented the Suncook from taking a direct route through the area now occupied by the new channel. Aggregate mining extended the 100-year floodplain and allowed floodwaters to form a knickpoint, which rapidly migrated upstream through unconsolidated sediments and captured the Suncook channel. The channel migration shortened the course of the Suncook by 0.8-km, consolidated flow from two channels into one, and increased local gradient by as much as 50%. These changes drive ongoing rapid incision at the site, with over 3-m documented at the capture point since May 2006. Incision created ephemeral landforms such as terraces and lateral bars, and introduced as much as 100,000 m^3 of sediment to the river. Significant aggradation occurred downstream of the new channel, and floodplains were locally covered with a sand sheet up to 1-m thick. The channel migration exacerbated flooding in the Spring of 2007 and led to channel instability downstream. Continued study of this natural experiment in channel migration will yield further insights about the dynamics of channel migration, rapid fluvial incision, and sedimentation. Meantime, the migration and dynamic fluvial response pose a unique challenge to river management and restoration.

Uranium in-situ leach groundwater issues

V. McLemore (New Mexico Bureau of Geology and Mineral Resources) gave a talk titled “Geologic controls of uranium recovery of Grants uranium deposits, New Mexico.” She reported that New Mexico ranks 2nd in uranium reserves in the U. S., which amounts to 15 million tons of ore at 0.28% U_3O_8 (84 million lbs U_3O_8) at \$30/lb. The most important host rock in the state is sandstone in the Morrison Formation (Jurassic) in the Grants district. More than 340 million pounds of U_3O_8 have been produced from these deposits during 1948-2002, accounting for 97% of the total production in New Mexico and more than 30% of the total production in the U.S. Sandstone uranium deposits are defined as epigenetic concentrations of uranium in fluvial, lacustrine, and deltaic sandstones. Three types of sandstone uranium deposits are recognized in the Grants district: primary tabular (primary, trend, blanket, black-band), redistributed (roll-front, post-fault, secondary, fault-related, stack), and remnant deposits. Uranium recovery methods from the different deposit types are controlled by differences in mineralogy and chemistry. Primary tabular, redistributed, and remnant sandstone deposits are amenable to conventional recovery methods (i.e. milling). Redistributed deposits can be recovered by in-situ methods. Two stages of redistributed deposits could exist in the Grants district—Cretaceous age (redistributed primary roll fronts or redistributed deposits during Cretaceous) and Tertiary age (redistributed from primary and Cretaceous roll fronts).

A. Miller (Colorado School of Mines) gave a talk titled “Upscaling of uranium (VI) transport in contaminated soil and groundwater.” He commented that, with few exceptions, mathematical models of sorbing contaminants have invoked distribution coefficients (e.g., K_d values) to account for contaminant solid-solution partitioning. However, distribution coefficients are conditional, ‘non-chemical' parameters that do not allow for variations in system chemistry. Alternatively, reactive transport models (RTMs) couple chemistry with water flow models. This coupling allows for the incorporation of the explicit chemical behavior of target contaminants in transport simulations. A major problem for RTMs is how to extrapolate information collected at the lab scale up to the field scale. Miller reported on experiments that are taking place at intermediate scales. Approximately 3 m^3 of U-contaminated aquifer sediments were collected from the Naturita UMTRA site in southwestern Colorado. Two intermediate scale tanks were constructed and filled with size sorted aquifer material. The larger tank was filled in a homogenous fashion using only the <2 mm size fraction. For the smaller tank, the <2 mm fraction was re-sieved into 0-0.25mm and 0.25-2mm and these two fractions were packed in a heterogeneous fashion. Bulkhead fittings were installed through the side of the tank wall to allow for spatial measurements of pressure head, as well as withdrawal of water samples to determine pH, $[U(VI)]_{aq}$, $[Ca(II)]_{aq}$, and alkalinity.

Uranium distribution in the tank varied with pH, alkalinity, dissolved calcium and the rate of release of U from the different particle size categories and the nature of the heterogeneity distribution. In the larger tank, effluent uranium concentrations ranged from 7.26μM at early time points, and decreased to ~1.5μM as the tank began to exhibit tailing behavior. For the aquifer material and ground water composition under study, it is suspected that the major control on both pH and alkalinity is the dissolution/precipitation of calcite. Modeling is underway using the code CRUNCH to simulate the intermediate-scale tank behavior based on the experimental data of U desorption at the lab scale.

Pleistocene climate change at the proposed Yucca Mountain site

J. Paces (USGS) gave a talk titled “Pleistocene climate variation identified by ion-microprobe dating of vadose-zone opal, Yucca Mountain, Nevada, USA.” The opal provides continuous records spanning 100,000-yr time scales that can be used to evaluate hydrologic responses to climate change at Yucca Mountain, Nevada. The site likely will experience numerous climate cycles before radioactivity in disposed waste decays to background levels (>1 m.y.). Secondary coatings of calcite and opal in the ~500-m-thick vadose zone preserve a record of water percolating through fractures and seeping into cavities. Opal contains high U concentrations (5 to 500 μg/g) and high ratios of U/Th, allowing U-series dating using the USGS/Stanford ion microprobe. Resulting analyses for 25-μm-diameter spots traversing the outermost 1 mm layer of opal grains indicate that: (1) both $^{230}Th/U$ ages for layers younger than 300 ka and model $^{234}U/^{238}U$ ages for layers between 300 and 1,500 ka increase with microstratigraphic depth, (2) multiple analyses of texturally synchronous layers yield identical ages, and (3) analyses of opal older than 1,500 ka have $^{234}U/^{238}U$ and $^{230}Th/^{238}U$ ratios in radioactive secular equilibrium. Age profiles across individual grains indicate that opal growth rates were extremely slow (0.1 to 2 μm/k.y.) and, at the depth of the potential repository, remarkably constant over the last 300 to 400 k.y., despite substantial differences in infiltration rates at the surface during glacial and interglacial climates.

The age determinations were used to calibrate cathodoluminescence (CL) images of opal that reveal distinct growth layering caused by oscillatory variations in U concentration. Relative intensities of U-rich (bright CL) and U-poor (dim CL) layers were quantified from digital images. The age-calibrated CL profiles indicate that U-rich layers correlate with interglacial periodicity (orbital eccentricity), whereas U-rich layers are more frequent in opal older than 600 ka, reflecting increased influence of 40-k.y. obliquity variations. Opal data indicate that percolation deep in the vadose zone responded to climate cycles. However, the uniformity of growth rates indicates that hydrogeologic processes effectively buffered seepage at the potential repository horizon from climate-induced changes.

Regional groundwater response to climate change

F. Schwartz (Ohio State University) gave a talk titled "Transient readjustment of regional-scale flow systems due to climate change." He began his talk by commenting that, historically, the main reason for transient analysis of groundwater flow systems has been to account for adjustments due to groundwater withdrawals. Temporal variability in infiltration and recharge rates is not often considered in basin-scale flow models and instead constant, long-term average rates are used. There is growing awareness of the variability of climate over different time scales, and the concomitant influence of these changes on recharge. Schwartz focused on the impacts caused by the variability in rainfall since the last interglacial (LIG) period on groundwater flow in a major segment of the Death Valley Flow System that passes through Yucca Mountain. Aspects of this flow system include the long time scale over which infiltration to the system has changed (tens of thousands of years), the thickness of the unsaturated zone, and the large physical extent of the flow system (many tens-of-kilometers). A numerical analysis was performed using a dual-porosity, dual-permeability model of variably-saturated flow developed for a two-dimensional cross-section 40 km long. The hydrostratigraphic framework captures the key aquifers and aquitards in the upper 2000 m. Estimated paleo-infiltration rates were derived from a fully-coupled global climate model that extends from the last interglacial period (approximately 125 ka BP) to present. The analysis included simulating the migration of an ideal tracer and the calculation of mean groundwater ages. The flow model results suggest a relatively large time constant, because the system requires a very long time period to re-equilibrate following an adjustment to the recharge rate. This result has important implications for the conceptualization and simulation of regional-scale flow systems.

Rock Chemistry at Yucca Mountain

Z. Peterman (USGS) gave a talk titled "Refined geochemistry of the Paintbrush Group tuffs at Yucca Mountain, Nevada." The Miocene Paintbrush Group (Tp) at Yucca Mountain, Nevada, includes two devitrified, densely welded, regionally extensive pyroclastic flow deposits, the upper Tiva Canyon Tuff (Tpc) and the lower Topopah Spring Tuff (Tpt). Each unit is composed of an upper quartz latite member and an underlying, thicker rhyolite member. These densely welded units are enclosed within nonwelded vitric units. Chemical and mineralogical zonation in the Tpc and Tpt has been attributed to an eruptive inversion of a stratified magma chamber or to mixing of separate magmas prior to eruption. Progressive changes in rare-earth element (REE) patterns are consistent with fractional crystallization in the magma chamber. Strontium and neodymium isotopic variations have been used by other workers to support the hypothesis of concomitant assimilation of country rock. Concentrations of halogens, bound water, and ferrous iron, typically not available in earlier analyses, differ between welded and vitric units. Samples from the nonwelded vitric units between Tpc and Tpt average 499±78 (SE_{MEAN}) ppm Cl, 982±91 ppm F, and 3.94±0.14 weight percent H_2O+ (bound water in contrast to moisture or H_2O-). Samples of the welded Tpt contain only 85±12 ppm Cl, 71±19 ppm F, and 0.81±0.05 weight percent H_2O+. Iron is strongly oxidized in the welded tuffs with Fe_2O_3/Total Fe as Fe_2O_3 ranging from 0.96 in the rhyolite to 0.98 in the quartz latite. This ratio is highly variable (0.75 to 0.98) in the nonwelded vitric units, and the smaller values may be primary magmatic ratios. Substantial differences in the halogen and H_2O+ contents between the densely welded and nonwelded vitric units of Tp are attributed to degassing that occurred during welding and devitrification, as shown by vapor-phase corrosion along cooling fractures and in lithophysae. These data show that complete chemical analyses of rocks add considerable value to petrogenetic studies, especially in determining the effects of post-depositional processes such as degassing associated with devitrification, crystallization, and welding.

Seismicity

R. Wheeler (USGS) gave a talk titled "Largest likely earthquake, central and eastern U. S." Most seismic-hazard assessments require an estimate of M(max), the moment magnitude (M) of the biggest earthquake thought possible in a given region. M(max) affects the USGS national seismic-hazard maps, which impact building codes, and also hazard assessments for critical structures such as nuclear power plants. In most of the central and eastern United States (CEUS), long intervals between large historical earthquakes preclude observation of M(max). One way to estimate CEUS M(max) is to include global geologic analogs of the CEUS to increase the likelihood that their combined historical earthquake records capture M(max). This strategy is reasonable because geologic controls on the size of a CEUS earthquake rupture, and therefore on CEUS M(max), remain unclear. Thus, there is no evidence against the assumption that CEUS M(max) is regionally constant and the same as in the analogs. The global analog dataset indicates that the CEUS can be divided into two large regions with different M(max): a central craton, and an extended margin of Phanerozoic rifts, passive margins, and orogens that rim the central craton on the east and south. Two histograms of M of the largest earthquakes in the CEUS and its analogs contain 17 values from craton analogs and 30 values from the extended margin and its analogs. Both histograms have tall peaks at M 6.6-6.7, whose values come from CEUS geologic analogs in diverse continents and plate settings. The peaks suggest that M(max) is unlikely to be less than M 6.6-6.7 anywhere in the CEUS. The high-M tails of the histograms indicate that M(max) is probably larger. Outliers are 7.5 in cratons and 7.8 in extended margins. Overall, M(max) for the craton is taken as M 6.6-7.2, with a preferred value of M 7.0, and for the extended margin as M 7.1-7.7, with a preferred value of M 7.5. These values are used in the June, 2007 draft of the updated USGS national seismic-hazard maps.

Catastrophic Flooding

J. O'Connor (USGS) gave a talk titled "Floods from natural dam failures." Breached dams of rock debris have produced many of the largest floods in Earth's history. Two broad classes of natural impoundments are (1) valley-blocking accumulations of mass movements, glacier ice, and volcaniclastic debris, and (2) closed basins rimmed by moraines, tectonic depressions, and calderas and craters formed during volcanic eruptions. Each type is restricted to particular geologic and geographic environments, making their incidence non-uniform in time and space. Floods from breached natural dams and basins result from rapid enlargement of outlets. Erosion is commonly triggered not only by overtopping, but also by piping or mass movements within the natural dam or basin divide as the impounded water level rises. Events such as large waves caused by mass movements or ice avalanches, and upstream meteorologic or dam-break floods, can trigger outlet erosion.

The peak discharge and hydrograph of a flood from breached rock dams depends on the impounded volume, breach geometry, and breach erosion rate. For impounded lakes that are large with respect to final breach depth, like most tectonic and volcanic basins as well as ice- and volcanic-dammed lakes, the peak discharge is mainly a function of final breach geometry. These floods typically last longer and attenuate less rapidly than those from smaller impoundments. For impoundments of smaller volume relative to final breach depth, such as most moraine-rimmed lakes and landslide and constructed dams, peak discharge is a nearly linear function of breach erosion rate. Floods from natural dam failures are geomorphically important because their high flows achieve shear stresses and stream powers orders of magnitude greater than meteorologic floods. Such flows can exceed critical thresholds for eroding bedrock and can transport boulders with diameters of many meters, thus forming some of the most spectacular landscapes on Earth.