June 6, 2006

MEMORANDUM TO: ACNW Members

FROM: Michael Snodderly, Chief ***/RA/***
Technical Support Branch, ACRS/ACNW

SUBJECT: TRIP REPORT ON DEVILS HOLE WORKSHOP, INTERNATIONAL HIGH LEVEL WASTE MANAGEMENT CONFERENCE, AND FIELD TRIP BY THE EXPERT PANEL ON PROBABILISTIC VOLCANIC HAZARD ASSESSMENT BY ACNW STAFF NEIL COLEMAN

Neil Coleman (ACNW Senior Staff Scientist) attended and gave two presentations at the Devils Hole Workshop in Death Valley during April 26-28, 2006. Dr. Ruth Weiner (ACNW member), Dr. Antonio Dias (ACNW Team Leader), and Neil Coleman then attended portions of the International High Level Waste Management Conference in Las Vegas (May 1-4, 2006). During May 2-4, 2006, Dr. William Hinze (ACNW Member) and Neil Coleman attended the field trip by the Expert Panel on Probabilistic Volcanic Hazard Assessment. The joint report for all three of these trips is attached. The ACNW plans to continue monitoring the progress of the expert elicitation on probabilistic volcanic hazard analysis at Yucca Mountain. The next meeting of the expert panel is tentatively scheduled for the last week of September, 2006.

If you have any questions please contact Neil Coleman at 301-415-7656.

Attachments: As stated

cc w/att:
J. Larkins
A. Thadani
ACNW Staff
B. Sosa
S. Jones

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DATE	06/06/2006		06/06/2006		06/06/2006	

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Probabilistic Volcanic Hazard Analysis Update (PVHA – U)

Field Trip to Southern Nevada

Volcanic Event Definition and History of Volcanism in the Yucca Mountain Region May 2-4, 2006

Member William Hinze and ACNW Senior Staff Scientist Neil Coleman participated as observers during the 3-day PVHA-U field trip to investigate volcanic activity in the Yucca Mountain region. The PVHA-U expert elicitation panel has been tasked with updating the 1996 PVHA analysis of the probability of volcanism at Yucca Mountain. Several workshops have been conducted since the new panel was assembled, and this field trip was an opportunity for the experts to examine volcanic features of Pliocene and Pleistocene age in the Yucca Mountain region. The overall purpose of the field trip was to explore the characteristics of intrusive and extrusive volcanic events by examining examples of these features in the Yucca Mountain region. Seven photographs from this field trip are provided in PDF format as Attachment 1.

Key questions addressed by the field trip were "How do the characteristics of volcanic and intrusive features change through geologic time? What is the relationship between faults and dikes or fissures in the region? What is the role of topography in determining volcano location vs. other possible mechanisms such as mantle source characteristics or critical structure? None of these questions were answered explicitly, but were the subject of investigation at the volcanic rock outcrops and extensive discussions. Examination of Miocene and Pliocene volcanic systems shows differences between Quaternary volcanic systems and older systems in terms of volume, feeder dike characteristics, number of vents, and vent spacing. Also, preliminary modeling by DOE shows that surface topography and pre-existing faults can have an impact on the location and orientation of intrusive dikes at shallow crustal levels.

Day 1 - On May 2nd the panelists gathered for technical briefings that had been prepared in response to panel member requests. A notebook of information, maps, photos, and papers had been assembled for distribution to the experts and other attendees. This information will soon be made available and distributed in CD format by the event organizers. The briefings consisted of a summary of analog volcanic centers, a summary of the influence of geologic structure on dike propagation, and an overview of drilling results and aeromagnetic survey interpretations. The notebook includes a 20 page summary by Perry et al. titled "Preliminary Results and Interpretations of a High-Resolution Aeromagnetic Survey and Drilling Program to Investigate Buried Volcanic Features near Yucca Mountain." A PDF of this summary and associated maps is included as Attachment 2 to this trip report.

The following table summarizes results of the exploratory drilling to determine the origin of strategic magnetic anomalies observed in the recent high-resolution survey. As shown, four of the seven boreholes penetrated basalt. Only in one case, anomaly "Q," was an unexpected basalt encountered. Age determinations for all drilled basalts are expected by mid-2006. Only one has been tentatively dated. The basalt of anomaly "Q" has a preliminary age of 10.2 Ma (Miocene), which is consistent with its location and depth of burial.

Summary information for completed PVHA drill holes						
Anomaly	Drillhole	Location	Magnetic Source	Predicted Source	Depth to Basalt (m)	Basalt Thickness
A	USW VA-1	Crater Flat	Basalt (basanite)	Basalt	148	62
Q	USW VA-4a	Crater Flat	Basalt	Tuff	141	>22
JF-5	UE-25 VA-10	Jackass Flats	Basalt	Basalt	77	>17
JF-6	UE-25 VA-11	Jackass Flats	Likely tuff	Unknown	n/a	n/a
I	USW VA-5	Amargosa Desert	Tuff	Tuff	n/a	n/a
O	USW VA-3	Amargosa Desert	Tuff	Tuff	n/a	n/a
G	USW VA-2	Amargosa Desert	Basalt	Basalt	119	31

After the technical briefings the group traveled to the Nevada Test Site for badging in Mercury. Then we drove to the crest of Yucca Mountain and then north along the spine of the ridge to a location near the Solitario Canyon basalt dike. This traverse required the use of 4 x 4 vehicles. Participants hiked down into the canyon to view the basaltic dike exposures, which were isolated and few. This ancient dike intruded several segments of the Solitario Canyon fault approximately 10-12 Ma ago (Miocene time). We did not take photographs here because the NTS security did not allow cameras to be transported onto the Yucca Mountain site. Figure 1 shows a segment of the dike that was obtained during an NRC field trip in 2004. The group then traveled via Mercury to a hotel in Amargosa Valley, where the group was assembled for an evening presentation by Edward Gaffney (DOE contractor) on the modeled effects of topography on basaltic dike propagation.

Day 2 - On May 3rd the group traveled to the Nellis Air Force Range access road north of Beatty, Nevada to view the basalts of Sleeping Butte and Thirsty Mesa. The purpose of this stop was to discuss the topographic setting of volcanos and the differences in Pliocene versus Pleistocene eruptive styles. Cameras were not permitted on the range itself, however a distant image of the cone of Little Black Peak is provided as Figure 2. These basalts have been dated at ~320 Myr (middle Pleistocene).

We then drove to Crater Flat (Figure 3) to observe 3.7 million-year-old Pliocene basaltic dikes and the remnants of two vents (volcanic conduits). This area required 4 x 4 vehicles for access. The discussions at this locality focused on the characteristics of Miocene and Pliocene eruptive and intrusive characteristics and the impact on the interpretation of Pleistocene igneous plumbing systems. Figure 4 was taken from the summit of a Pliocene volcanic conduit, looking northward toward a Pliocene dike complex and another volcanic vent. Figure 5 is a closer view of the remnant of a Pliocene volcanic vent. Figure 6 was taken on top of a conduit and shows

agglomerate (foreground) formed by the material that ultimately plugged the vent at the end of the summit eruption.

Near the end of the day we visited the quarrying operation at the Lathrop Wells volcanic cone where vesicular basaltic tephra is mined, washed, and transported for commercial sale. The technical discussion here focused on the evolution of the eruption style. A key observation was made that there is no evidence for additional fissures or vents at this site other than the summit (main) vent. All volcanic products vented from the area of the main cone. The group then walked out onto the lava flows south of the tephra cone and mining facilities. We viewed a large mass of broken basalt that had formerly been part of the cone but had been rafted away from the cone on the top of a lava flow. Neil Coleman (ACNW staff) traversed the easternmost lava flow from its terminus northward over a distance of 600 m, collecting rock samples for examination by an ACNW consultant. Additional material that was rafted away from the tephra cone is shown in Figure 7. The cone appears in the distance behind the "raft." The "raft" is located on the easternmost lava flow.

Day 3 - The group traveled to Mercury for badging, then proceeded to the Paiute Ridge intrusive complex on the Nevada Test Site, east of Yucca Flat. This drive to a remote area again required the use of a 4 x 4 vehicle. The volcanic rocks of Paiute Ridge represent an intrusive complex. The discussions focused on dike/fault relationships and the formation of conduits. We then drove to the Yucca Mountain Sample Management Facility in Jackass Flats to view drill-core samples of basalts obtained during the recent drilling. We then listened to a discussion of igneous/volcanic event definitions, an overview of preliminary observations, and conclusions. The group was not permitted to take cameras onto the Nevada Test Site so no pictures are available for this day.

ACNW Observations

Some surprises were found in the magnetic anomaly drilling results. The anomaly at Q was expected to be caused by faulted tuffs, but a basalt was found with a minimum thickness of 22 m. Additionally, the mafic material sampled by drilling anomaly A has been tentatively identified as basanite, which is an extrusive rock composed of feldspathoidal olivine basalt. This material is unusual for the Yucca Mountain region. Possible interpretations of the volcanic rocks are that the basanite represents a mafic intrusive body or that the borehole directly intersected a buried volcanic conduit at depth. Given the depth to basalt at anomaly A (148 m), it is likely to have a Miocene age.

Although the ages of the four basalts penetrated by the drilling are still being determined, there is no evidence at this time of the existence of Pliocene or Quaternary basalts east of Yucca Mountain in Jackass Flats, north of Amargosa Valley.

The high-resolution aeromagnetic survey (see Attachment 2, p. 11) has provided new significant information regarding the structure of the Yucca Mountain region, and the distribution of volcanic rocks.

At the 80,000 year old Lathrop Wells volcano, all volcanic products vented from the area of the main cone. There is no evidence for additional fissures or vents in the vicinity.

Counts of tuff xenoliths in the basalts at Lathrop Wells suggest a mean volume fraction that corresponds to a 22-m-wide conduit. The maximum volume fraction would suggest a maximum conduit diameter of 64 m.

Much discussion ensued among the expert elicitation panelists regarding the source region in the upper mantle for the magmas that produced the Pleistocene cones and basalt flows near Yucca Mountain and the role of pre-existing geologic structures.

A primary observation from the 2004 aeromagnetic survey is the close association between Pleistocene volcanoes and faults interpreted from the aeromagnetic data. This association was also interpreted from earlier high-resolution ground magnetic surveys (Connor et al., 2000). Analog field studies at eroded centers have also demonstrated that nearly all dikes ocupy normal faults, indicating capture of dikes by faults in the shallow crust.

Discussions indicated that the panel's assessments may extend out to consideration of a million year period. It is unclear why this is being considered because the draft final EPA standards specify that DOE use the performance assessment for the first 10,000 years for the period reaching to peak dose.

Currently, the only known buried post-Miocene basalt is at anomaly B in the northern Amargosa Desert. Elsewhere the post-Miocene basalts have experienced only partial burial along their periphery.

IHLWM Meeting (May 1-4, 2006)
Las Vegas, NV

Member Ruth Weiner, ACNW Team Leader Antonio Dias, and ACNW Senior Staff Scientist Neil Coleman participated in this meeting in Las Vegas. This meeting was sponsored by American Nuclear Society, University of Nevada, Las Vegas, and the U. S. Department of Energy, in addition to numerous professional and technical societies, national laboratories, commercial and federal organizations throughout the world. The theme of this meeting was "Global Progress Toward Safe Disposal." The opening plenary began at 8:30 am on May 1, 2006. This plenary was chaired by Daniel Bullen (Exponent) and Budhi Sagar. (CNWRA). The speakers included Jack Strosnider *(Director, Office of Nuclear Material Safety and Safeguards, NRC),* Elizabeth Cotsworth *(Director, Office of Radiation and Indoor Air, EPA),* Eric Knox *(Associate Director for System Operations and External Relations, DOE), and* Harold McFarlane *(President-elect, ANS)*. Cotsworth mainly discussed the EPA high-level waste standards for Yucca Mountain. EPA plans to publish a response to public comments by the end of 2006. Leon Reiter (US Nuclear Waste Technical Review Board, technical staff member, retired) asked a question about EPA's use of median values for projected doses vs. mean values, noting that the National Academies had recommended use of the mean. Cotsworth commented that EPA considered the mean values to be too susceptible to outliers. However, the question of mean vs. median values was still to be resolved because the final standards have not yet been published.

Following the plenary were the following technical sessions: Status of International Programs; Techniques for Site Characterization; DOE Science and Technology Program on Natural Barriers; Waste Handling, Storage, and Emplacement; Waste Package Corrosion; Unsaturated Flow and Transport; and Regulatory Development. Additional technical sessions followed on May 2-3.

On the last day of the conference (May 4th), Dr. Antonio Dias participated in a field trip to the Yucca Mountain repository site. During the bus trip to the site, many of the human-related, ecological and weather-related factors appropriate to the region were described. We were first

taken to see the tunnel boring machine, which is now decommissioned. DOE is planning to purchase at least two more of these machines in order to complete the tunnels for the repository. After that, we went to the top of the mountain, where some of the nearby local mountains and extinct volcanos, including Lathrop wells, and the margin of the Timber Mountain caldera were identified. Also discussed was the role of erosion (wind & water) upon the local mountains and terrain. After that we went into the main tunnel, where in the 2nd alcove we were given a lecture on the geological research that was carried on in order to characterize the site.

Summaries of selected presentations are provided below on topics of interest to the ACNW:

Saturated Zone Plumes in Volcanic Rock: Implications for Yucca Mountain (Kelkar et al.) This paper presented a literature survey of the occurrences of radionuclide plumes in saturated, fractured rocks. Three sites, Idaho National laboratory, Hanford, and Oak Ridge are discussed in detail. Results of a modeling study were also presented showing that the length to width ratio of a plume starting within the repository footprint at Yucca Mountain decreases from about 20:1 for the base case to about 4:1 for a higher value of transverse dispersivity, indicating enhanced lateral spreading of the plume. Due to the definition of regulatory requirements, this lateral spreading does not directly impact breakthrough curves at the 18 km compliance boundary, however it increases the potential that a plume will encounter reducing conditions, thus significantly retarding the transport of sorbing radionuclides.

Natural Analogs for Future Volcanism in the Yucca Mountain Region (Morrissey and Apted). The Electric Power Research Institute's (EPRI) total system performance assessment (TSPA) of the extrusive-release and intrusive-release scenarios depend strongly on identifying natural analogs for a potential future eruption. The two release scenarios require estimates of parameters such as number of dikes, dike length and widths, conduit diameter and extent, number of conduits, and volume and duration of each eruption stage, that characterize the expected eruption. To obtain a range of values for characteristic properties representative of a future eruption, natural analogs are needed. This work presented criteria for selecting natural analogs for a possible future eruption in the Yucca Mountain region. Proposed analogs such as Paricutin, Grants Ridge, Tolbachik, and Longuimay are not appropriate because they do not meet at least two criteria. Use of such analogs should be restricted to understanding processes associated with an igneous event but not to quantify a characteristic property. Analogs such as Basalt Ridge, Paiute Ridge, Boulder Dam dikes, and Red Cones in California fit the criteria. Field observations of eruptive characteristics at these analogs may reduce the uncertainty associated the intrusive and extrusive scenario.

Benchmarking RADTRAN Loss of Shielding Model for a SNF Cask (Boyd, Worthy, Osborn, and Weiner). The RADTRAN Loss of Shielding (LOS) Model was benchmarked using MicroShield 6.20®. This analysis considers an intact spent fuel truck cask as well as a set of damaged truck casks. Ratios of dose rates are calculated for casks with a loss of lead shielding to those of intact casks, and are then compared to ratios generated by the LOS model. LOS Model results were considered verified if two main constraints were satisfied. First, the dose rate profiles for both the LOS and MicroShield 6.20® calculations must have the same general shape and behavior. Additionally, the largest factor difference between any two points of the dose rate profiles may not exceed an order of magnitude. Reasonable agreement is shown for large- fraction LOS scenarios; however the differences in results are not satisfactory for cases with small fractions of slump.

Uranium-Series Constraints on Subrepository Water Flow at Yucca Mountain, Nevada

(Neymark, Paces, Chipera, and Vaniman). Mineral abundances and whole-rock chemical and uranium-series isotopic compositions were measured in unfractured and rubble core samples from borehole USW SD-9 in the same layers of variably zeolitized tuffs that underlie the proposed repository at Yucca Mountain. Uranium concentrations and isotopic compositions also were measured in pore water from core samples from the same rock units and rock leachates representing loosely bound U adsorbed on mineral surfaces or contained in readily soluble secondary minerals. The chemical and isotopic data were used to evaluate differences in water-rock interaction between fractured and unfractured rock and between fracture surfaces and rock matrix. Samples of unfractured and rubble (fragments about 1 centimeter) core and material from fracture surfaces show similar amounts of uranium-series disequilibrium, recording a complex history of sorption and loss of uranium over the past 1 million years. The data indicate that fractures in zeolitized tuffs may not have had greater amounts of water-rock interaction than the rock matrix. The data also show that rock matrix from subrepository units is capable of scavenging uranium with elevated uranium-234/uranium-238 from percolating water and that retardation of radionuclides and dose reduction may be greater than currently credited to this aspect of the natural barrier. Uranium concentrations of pore water and the rock leachates are used to estimate long-term in situ uranium partition coefficient values greater than 7 milliliters per gram.

Conceptual Models of Expected Events Associated with an Igneous Event at Yucca Mountain Repository (Morrissey, Apted, and Kozak). EPRI's calculation of a probability weighted, mean annual dose to an individual living at the compliance location arising from a hypothetical igneous events at Yucca Mountain requires two different scenarios, one for an extrusive (surface eruption) event and another for an extrusive (subsurface) event. A conceptual model for each release scenario is presented based on field and theoretical evidence. Each model is described in terms of fluid flow regimes along with specific assumptions, models and data to be used in the respective scenarios. Conceptual models are also necessary for identifying disruptive events associated with the interaction of either an intrusive or extrusive igneous event with the proposed repository.

Field Investigation of the Drift Shadow (Su, Kneafsey, Ghezzehei, Cook, and Marshall). In a study being conducted by Livermore-Berkeley National Laboratories, they have identified a nearby old coal mine (in the 1800's) that was later also used as a sandstone mine (from 1922 to 1945), which led to two separate overlying drifts being excavated. This offers the perfect site for exploring the drift shadow phenomena (migration of moisture around underground openings in the vadose zone). The research effort will match experimental data against analytical modeling data. Analysis of collected cores for passive tests are currently underway. Also underway are the calibrating and testing of the instrumentation for the active tests. They expect to start working on collected data by August, 2006.

Consequences Associated with Igneous Activity at Yucca Mountain (Kozak, Apted, and Morrissey). EPRI has undertaken an independent assessment of the consequences of igneous activity on the proposed repository at Yucca Mountain. The DOE and NRC have focused considerable attention on the probability of occurrence of an igneous event, and current estimates of the probability of a volcanic eruption through the proposed repository are just high enough that dose consequences must be estimated. To date, both DOE and NRC have treated the consequences in a conservative manner. The EPRI project team has undertaken analyses directed at evaluating the reasonably expected consequences of an igneous event, in keeping with the stated philosophy of 40 CFR 197. Both extrusive and intrusive scenario variants have been evaluated, with the conclusion that there is reasonable expectation that igneous activity will not lead to consequential releases from Yucca Mountain. Mechanical analysis of the

impacted waste package indicates that the waste package could get dented but remains unbreached. Recent evaluation indicates possible tearing near the sides of the waste container, the consequences of which may be investigated by EPRI.

Impact of Quaternary Climate on Seepage at Yucca Mountain, Nevada (Whelan, Paces, and, Neymark, Schmitt, and Grove). Uranium-series ages, oxygen-isotopic compositions, and uranium contents were determined in outer growth layers of opal and calcite from 0.5- to 3-centimeter-thick mineral coatings hosted by lithophysal cavities in the unsaturated zone at Yucca Mountain, Nevada, the proposed site of a permanent repository for high-level radioactive waste. Micrometer-scale growth layering in the minerals was imaged using a cathodoluminescence detector on a scanning electron microscope. Determinations of the chemistry, ages, and delta oxygen-18 ($\delta^{18}O$) values of the growth layers were conducted by electron microprobe analysis and secondary ion mass spectrometry techniques at spatial resolutions of 2 to about 20 micrometers (μm) and 25 to 40 μm, respectively. Growth rates for the last 300 thousand years (k.y.) calculated from about 300 new high-resolution uranium-series ages range from approximately 0.5 to 1.5 μm/k.y. for 1- to 3-centimeter-thick coatings, whereas coatings less than about 1-centimeter-thick have growth rates less than 0.5 μm/k.y. At repository depth, correlations of uranium concentration and $\delta^{18}O$ values with regional climate records indicate that unsaturated zone percolation and seepage water chemistries have responded to climate change during the last several hundred thousand years.

Proposed Amendments to the Environmental Radiation Protection Standards for Yucca Mountain, Nevada (Raymond Clark). The EPA proposed amendments to its radiation protection standards for the potential repository at Yucca Mountain, NV on 22 August 2005. The original standards are found in Part 197 of Title 40 of the CFR. The Energy Policy Act of 1992 directed, and gave the authority to, EPA to take this action based on input from the National Academy of Sciences (NAS). The final original standards were published in the *Federal Register* (66 FR 32073) on 13 June 2001. In July 2004, a Federal court remanded part of the standards to EPA for reconsideration. The 40 CFR Part 197 standards, as issued in 2001, have four major parts: (1) individual-protection during storage activities; (2) individual-protection following closure of the repository; (3) human-intrusion; and (4) ground-water protection. The storage standard is 150 microSv (15 mrem) annual committed effective dose equivalent (CEDE) to any member of the general public. The disposal standards are: (1) 150 microSv (15 mrem) annual CEDE for the reasonably maximally exposed individual (RMEI) for 10,000 years after disposal; (2) 150 microSv (15 mrem) annual CEDE received by the RMEI within 10,000 years after disposal as a result of human intrusion; and (3) the levels of radionuclides in the ground water cannot cause annual individual doses to exceed: (1) 40 microSv (4 mrem) per year from beta and gamma emitters or (2) 5 picocuries per liter (pCi/L) of radium-226 and -228 or 15 pCi/L of gross alpha activity. There were also requirements related to the post-10,000-year period, the basis of compliance judgments, and performance assessments. EPA's proposed amendments would retain the individual-protection standard established in the 2001 standards, up to 10,000 years. In addition, the compliance period for the individual-protection and human-intrusion standards would be increased to 1 million years and the annual CEDE limit between 10,000 and 1 million years would be 3.5 mSv (350 mrem). There are also proposed requirements for the way performance assessments will be conducted. Finally, the dose calculation methodology would be updated to an ICRP 60 and 72 basis instead of ICRP 26 and 30. The comment period on the proposed amendments ended 21 November 2005. The Agency is analyzing the comments and will publish its responses when issuing the final standards. The proposed standards and the support documents are available at http://www.epa.gov/radiation/yucca/index.html. The docket containing all of the comments is under Docket ID EPA-HQ-OAR-2005-0083 at: http://www.regulations.gov.

Devils Hole Workshop (April 26-28, 2006)
Furnace Creek, Death Valley, California

The Devils Hole Workshop was conducted at the National Park Service auditorium at Furnace Creek in Death Valley, California. This meeting provides overviews of the hydrology, geology, and aquatic biology conditions in the region that includes Death Valley, the Amargosa Desert, and the Nevada Test Site. Neil Coleman (ACNW Senior Staff Scientist) attended and gave two presentations, an oral talk and poster presentation titled "NUREG-1710 Series: History of Water Development in the Amargosa Desert Area." Copies of two NUREG reports were provided in CD format to meeting attendees and additional copies have been emailed to those who requested them. Attendees have also requested copies of the third NUREG in this series.

Abstracts from this meeting are provided as Attachment 3 in PDF format. Technical presentations and abstracts relevant to Yucca Mountain included the following:

> Regional vs. local groundwater conditions in the Yucca Mountain region - T. Buqo
>
> A novel installation for long-term monitoring of hydrologic and geochemical conditions at NC-EWDP-24-PB - B. Freifeld
>
> Photography tour of surface hydrologic features in the Death Valley area - Abe Van Luik (DOE)
>
> Vapor transport, performance assessment, and design - J. Walton
>
> Specific discharge and groundwater velocities estimated from flowing electrical conductivity logs in the Crater Flat Tuff - B. Freifeld
>
> Groundwater modeling simulations in the Amargosa Desert using the Death Valley regional flow model - W. Belcher
>
> Evaluation of groundwater pumping effects in the Death Valley regional model using regional-scale and locally refined grids - S. Mehl
>
> Death Valley National Park springs: A geochemical investigation - M. King
>
> The Lower Carbonate Aquifer as a barrier to radionuclide transport - M. King

Observations

Abe Van Luik presented a photographic tour of the Amargosa River region during the wet spring of 2005. Most striking was his photograph of the Badwater area of Death Valley. Compare Figure 9, which shows the salt flats at Badwater in a typical year, with Figures 10 and 11. Figure 10 shows that a large lake had formed in central Death Valley in early March of 2005. This was in response to wet spring weather that caused surface flow in the Amargosa River and the Mohave Rivers, both of which flow into the southern end of Death Valley. These photos make it easy to imagine how climate change, with an increase in precipitation and a lowering of temperatures during pluvial episodes, could generate long-lived lakes in this basin.

Figure 11 shows that with high evaporation rates in the present climate the 2005 lake had already begun to recede less than three weeks after it formed.

John Walton (University of Texas at El Paso) gave a talk on vapor transport at Yucca Mountain. He and his co-workers analyzed hypothetical moisture flow in the disposal drifts of a high-level nuclear waste repository at Yucca Mountain. They have concluded that the predominant direction of vapor migration during the thermal period would be into the drifts rather than into the surrounding rock. Previous models by other workers have indicated the opposite - that vapor would migrate within the rock away from the heat sources (waste containers).

Michael King (The Hydrodynamics Group) gave a talk about a geochemical investigation of the springs of Death Valley National Park. Water samples were collected from over 40 springs in the park and subsequently analyzed. Small springs in the mountains around Death Valley have major ion signatures that show consistency within each mountain range. In the Furnace Creek area, local recharge is less than 10% of the spring discharge, providing further evidence that the large springs at Furnace Creek discharge from the regional carbonate aquifer.

Harrill et al. gave a poster presentation on water levels in Devils Hole. This information is being used in research regarding the endangered Devils Hole Pupfish. Continuous water level monitoring began in 1962. Photographs taken in 1937 and 1947 verify that the water levels in those years were 0.35 m higher than today. There was no discernable water-level trend between 1937 and 1962, therefore the reduction in water level has happened since 1962.

A sobering note from this workshop was the status of the Devils Hole Pupfish. Once numbering in the hundreds, the individuals in Devils Hole are now down to 38 at the latest count. The drop in the water level has reduced the size of the breeding area for the fish, and a recent flood washed debris into Devils Hole, disturbing the environment. Unless ongoing research efforts are successful, we may soon witness the extinction of this species. Some of the pupfish have been transported to refuge areas so that separate populations would exist, eliminating the chance that a single catastrophe at one location could eliminate the population. Unfortunately, one of the refuge populations has inadvertently become hybridized with another species of pupfish.

Field Trip to Selected Locations in Death Valley

On Friday, April 28th the workshop organizers led a field trip into northern Death Valley. Figures 12-18 of Attachment 1 are photos from this field trip. We first made a road stop at a series of Pleistocene gravel bars that were hundreds of meters long. The top of one of these gravel bars is shown in Figure 12. These bars were formed either by lakeshore processes when a paleolake existed in Death Valley or they were generated by spillover floods into the valley from paleolake areas to the north. The location we visited was ideal because a road-cut had been built through the center of the largest bar, permitting a stratigraphic view of its cross-section.

We then visited the inactive Keane Wonder Mine (Figures 13-16) where we examined rocks of the Proterozoic Pahrump Group and also Paleozoic carbonates. These rocks represent the base of the stratigraphic section in the Death Valley area, where metamorphosed units of the Pahrump Group overlie crystalline basement rocks. The Keane Wonder mine produced about a million dollars of gold in the early 1900's. Much of the Death Valley region was prospected and mined for gold during this period but only a few areas such as Rhyolite to the east, Skidoo to the west and this site produced much gold. The mill sits on high grade metamorphic rock

derived from the lower member of the Crystal Spring formation. These rocks were probably metamorphosed twice: First and most intensely during the Cretaceous and to a lesser degree during the Tertiary. From the mill site there was a very good view of central Death Valley. Figure 14 shows the pipeline that conducted water from a spring to the mining operation. Figure 15 shows the phreatophyte colonies around the spring area. A surface shaft (Figure 16) had been built by the former miners to control and capture the spring discharge. A strong odor from hydrogen sulfide gas was being emitted from the surface opening to the spring.

After departing the mine area we traveled to Monarch Canyon, which required 4 x 4 vehicle access. This canyon contains some of the oldest rocks exposed in the Death Valley region, including Proterozoic rocks. We hiked down the canyon past old mine workings to a phreatophyte area (Figure 17), beyond which was a small waterfall. The field trip was closed out with two roadside stops in Grapvine Canyon, one being a visit to Paleozoic carbonate exposures near Scotty's Castle, and the other to a sequence of volcanic tuffs (Figure 18).