Diggin' Deep

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Inside...

Diggin' Deep is a publication of the USDA Forest Service Minerals & Geology Management Program

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Thunder Basing National Grassland Coal Bid Nets $298 Million for 2,838-Acre Lease

Bruce Ramsey, M&GM-CNO Deputy Director

On 5/11/2011, the BLM announced that it accepted a $298 million bonus bid for a 2,828 acre lease involving the Thunder Basin National Grassland. The West Antelope II North Coal Tract contains an estimated 350.3 million tons of mineable coal. A royalty payment of 12.5 percent of the value of the coal produced by strip mining could generate another $400 to $500 million during the life of the mine in payments to the Federal treasure of which 50% is returned to the State of Wyoming. In 2010, nearly 400 million tons of federal coal was mined in Wyoming, resulting in coal royalties of over $598 million.

Announcement: 2011 National Groundwater Training - Canceled

Chris Carlson, M&GM-CNO, National Groundwater Program Leader/ Groundwater Team Lead

Due to the 20% travel reductions instituted by the agency for FY11 and subsequent agency travel stand-down, M&GM and WFW have decided to cancel the 2011 National Groundwater Training offered through the Geology and Minerals Training Office and scheduled for Sisters, OR, in July. We will be looking for opportunities to offer the course again as soon as possible.

Announcement: Showcase the Work & Research Conducted on NFs and Grasslands - Submit Abstracts for the 2011 National GSA Meeting

Chris Carlson, M&GM-CNO, National Groundwater Program Leader/ Groundwater Team Lead

This coming October, the Forest Service will again be sponsoring a technical program session at the 2011 Geological Society of America - National Conference. We hope to have a wide range of topics for the session to highlight all the neat work and research being conducted on YOUR National Forests and Grasslands. This is a great opportunity to share the interesting and innovative work you do with your professional colleagues. You'll find all the information you need to get started on the GSA technical program webpage. Don't be shy; you can do it!

Technical program information - find this entry to submit your abstract for the session! DEADLINE is July 26, 2011.

Session T91. Geology in the National Forests and Grasslands: Stewardship, Education, and Research; *Sponsors:* GSA Geology and Society Division; GSA Hydrogeology Division; GSA Quaternary Geology and Geomorphology Division; USDA Forest Service; GSA Environmental and Engineering Geology Division; *Session Chairs:* Michael A. Crump, Christopher P. Carlson; *Categories:* Hydrogeology; Geomorphology; Geoscience Education.

This session will explore aspects of geological science conducted on National Forests and Grasslands. Topics include paleontology, cave and karst geology, engineering geology and natural-hazard mitigation, hydrogeology, interpretive and recreational geology, geo-ecology, and more.

Announcement: Annual New Mexico Geological Society Fall Field Conference

Gina Rone, Idaho Panhandle NF, Forest Soil Scientist

The annual New Mexico Geological Society Fall field conference is located this year in the southern Tusas Mountains and Ojo Caliente in northern NM and will be held from September 28-October 1. Registration usually starts in August.

Additional information is available at the web site: http://nmgs.nmt.edu/ffc/home.html

Coronado National Forest March, 2011 Rosemont Copper Project Paleontological Survey

Beverley Everson, Coronado National Forest, Forest Geologist

A paleontological survey was completed for the proposed Rosemont Copper Project area on the Coronado National Forest in March 2011, with the assistance of CNO Paleontologist Mike Fracasso, Santa Fe National Forest Geologist Larry Gore, and Region 2 North Zone Paleontologist Barbara Beasley. The survey was done to comply with direction and policy set forth in our agency's 2005 Washington Office Paleontological Training Guide and with pertinent statute and regulation. Notably, the survey was responsive to the analysis of impacts to surface resources required by the National Environmental Policy Act (NEPA), for significant ground disturbing activities such as the proposed copper mining operation.

Plant fragments in the Mt. Fagan Rhyolite megabreccia

Geologic units that were the focus of the survey were identified in a classification report completed earlier in the year by paleontologists with the Coronado's third party NEPA consultant, SWCA Environmental Consultants. The consulting paleontologists also assisted in the survey, and will be writing a report on the survey findings which will be utilized in the effects analysis of the Rosemont Copper Project Environmental Impact Statement.

The proposed operation, including part of the open pit, the plant, tailings, waste rock and heap leach facilities, would cover approximately 3,700 acres of Forest Service System lands. Although most of the ore deposit is associated with metamorphosed, fossil-barren Paleozoic limestones and related sedimentary rocks, the project area also includes Paleozoic, Mesozoic and Cenozoic strata that were classified as having a moderate to high potential for vertebrate fossils, including various types of dinosaurs and Miocene to Pleistocene mammals. The potential for rare fossils in these formations was determined based on the occurrence of fossils in the same formations elsewhere in Southeastern Arizona.

As an introduction to the area geology and paleontology, the survey team visited fossil localities about two miles east of the project area, including a site in the Cretaceous Shellenberger Canyon Formation and a Pleistocene site in cienega (spring) deposited sediments. Vertebrate fossils found at the Shellenberger Canyon Formation site include dinosaur (titanosaurid sauropod and nodosaurid ankylosaur), crocodilian and turtle remains (McCord, Robert. D and David D. Gillette, 2005, Cretaceous Vertebrates of Arizona. *In*: McCord, Robert D., editor, Vertebrate Paleontology of Arizona, Mesa Southwest Museum Bulletin No. 11, pp. 94-103). The Pleistocene site that the crew visited was discovered during survey work for a proposal for mining of the Rosemont ore deposit in the 1970s. Disarticulated bone and teeth fragments found at the site include camel (*Camelops* sp.), mastodon (*Mammut* sp.), horse (*Equus* sp.), bison (cf. *B. antiquus*), and other mammals (Huckell, Bruce B., 1980, The Anamax-Rosemont Testing Project, Arizona

Rugose coral in the Mississippian Escabrosa Limestone

State Museum, University of Arizona, and personal communication with Bill Gillespie). Thanks go to Dr. Robert McCord of the Arizona Natural History Museum for taking the group to the Cretaceous site, and to Bill Gillespie, Coronado National Forest Archeologist and Pleistocene paleontologist, for introducing the crew to the Pleistocene site. Rosemont Copper Company Geologist Jeff Cornoyer spent a day with us in the field to help familiarize everyone with the project area project area geology, and his assistance was also greatly appreciated.

The surveying resulted in no vertebrate fossil finds; however, unidentifiable plant material was found in clasts in megabreccia of the Cretaceous Mt. Fagan Rhyolite and coral and other invertebrate fossils were found in Paleozoic outcrops and in float. I would like to personally thank Barb, Larry and Mike for their willingness to assist with the survey and for their help in the development and review of a scope of work for the surveying. In spite of the cactus, catclaw Acacia, prolific shindagger Agave, rattlesnakes and way too much barren Gila Conglomerate, they all say that they would be willing to help the Coronado on other projects!

Geology in the Classroom

Leslie Vaculik, M&GM--CNO, & Joe Gurrieri, M&GM--CNO, Hydrogeologist

If you can't get the kids into the woods, take the geology to the kids. GRHSM staff members presented fossils, rocks, and minerals to various classrooms this spring.

R1 Stay-in-School, Jazmond Knox, helps kindergarten students sort fossils

Several Missoula, Montana, kindergarten teachers have developed a 3 to 4 week dinosaur themed learning module. The students read about dinosaurs; add and subtract dinosaurs; and do art and science projects about dinosaurs. As part of the module, Leslie Vaculik provides a talk about dinosaur digging and fossils. The presentation includes video clips of the Vaculik family on a Little Missouri NG dig and examples of various fossils. The students test their skills as junior paleontologists by sorting fossil fragments and petrified wood from various common rocks. An extra benefit of inviting a Forest Service speaker is every student gets to take home a Forest Service Fabulous Fossil poster and Smokey Bear pencil.

Meanwhile, on the evening of April 14, parents throughout Evergreen, Colorado were shocked when their 2nd graders refused to brush their teeth shouting "no, I'm not brushing my teeth with rocks"! Joe Gurrieri had done it again. Earlier in the day he visited his daughter's second grade class to tell them about rocks and earth science. In addition to identifying rocks for the class and breaking open geodes,

Toilet paper time

Joe amazing kids with stories about rocks. Here he shows a rock that is really made out of foam rubber. He subsequently threw it at a kid in the front row to screams of delight from the other students.

Joe tells the students that many of the items they use every day are made out of rocks including tooth paste. Another highlight is the unrolling of The Toilet Paper Timeline which shows some major events in Earth's history (one sheet = 2 million years). While the students were interested in how far apart the major events took place and how short a time humans have been around, they were really amazed at the sheer length of an unrolled roll of toilet paper.

The Earth's Changing Climate, 6th Graders, B-25 Bombers and Bivalves

Bruce A. Schumacher, Region 2 South Zone Paleontologist

Recently, the Cretaceous Greenhorn Limestone on the Comanche National Grassland in southeastern Colorado has been receiving attention. In April 2011, approximately ninety 6th grade students visited a classic exposure of this rhythmically bedded limestone and marl sequence. The students were instructed as to the ethics of casual collecting of fossils, and basic taxonomy by identifying the various types of mollusk fossils present (clams, oysters, ammonite impressions). The real assignment of the day was talking cycles in nature and

climate change. Students learned how to identify basic rock types and the cyclical nature of the bedding. The earth's cyclically alternating climate of 87 million years ago was examined by measuring the thickness of limestone/marl couplets, and using simple math combined with concepts of absolute age dating the students calculated the length of time for each cycle (alternating arid/wet periods). Students found that climate cycles ranged from about 28,000 years to 64,000 years in duration.

Nearly seventy years earlier, a nearby area of the Comanche Grassland was utilized during World War II as a training area for B-25 bomber crews. Intense drought this year has made many of the historic bomb craters visible. In some places the high explosive ordinance welled up underlying Greenhorn Limestone layers as an ejecta berm surrounding the crater. In May a small colony of rudistid bivalves was discovered around one such crater. Rudists are a group of coral-like marine bivalves that arose in the Jurassic and became prolific reef builders in tropical waters during the

Cretaceous. On some tropical shelves, rudist reefs can be hundreds of meters thick and are highly favored oil traps due to their high porosity. Although somewhat better known in younger Cretaceous rocks such as the Niobrara Formation, occurrences of rudistid bivalves in rocks of Greenhorn age are exceedingly rare, especially at mid-latitude locations

such as in Colorado. This discovery marks only the seventh such stratigraphic occurrence of rudist bivalves in the United States (Cobban, W.A., Skelton, P.W. and Kennedy, W.J. 1991. Occurrence of the rudistid *Durania cornupastoris* (Des Moulins, 1826) in the Upper Cretaceous Greenhorn Limestone in Colorado. U.S. Geological Survey Bulletin 1985-D: 1-8).

Paleontology Passport in Time (PIT) Project, Late Cretaceous Lance Formation, Thunder Basin National Grassland, September 20-24, 2010

Mike Fracasso, M&GM--CNO, Paleontologist

Thirty unsuspecting volunteers allowed themselves to be led by FS paleontologists Mike Fracasso & Barb Beasley in late September in performing a paleontological survey and collection effort covering nearly 5 sections of Late Cretaceous Lance Formation badland exposures in the Alkali Divide Paleontological Special Interest Area on the Thunder Basin National Grassland (TBNG), Wyoming. Despite the logistical difficulties keeping track of a large number of volunteers in the badlands (you've heard of cat-herding?!), we were able to keep them all within the FS boundaries, while under scrutiny by a binocular-equipped abutting landowner and grazing permittee (and yes, we did provide appropriate advance notice of the project area and scheduling). The Lance Fm is a dinosaur-bearing, fluvial-dominated terrestrial unit deposited at the end of the Cretaceous Period. The end-Cretaceous mass extinction event is represented in the Lance and correlative Hell Creek Formation elsewhere regionally, and dinosaurs that have been found in the project site and surrounding areas include the iconic *Tyrannosaurus*, *Triceratops*, *Edmontosaurus* (duckbill), and an unidentified ankylosaur (think armored VW bug). Microfossil sites have also been documented in and near the project area, which have produced concentrations of tiny specimens of invertebrates, fish, amphibians, crocodilians, turtles, dinosaurs, and mammals.

Above: Assuming the pose at a microfossil site; Left, *Tyrannosaurus* tooth tip found at site. Photos by John Wise, Douglas Ranger District

Museum-quality "trophy" specimens were elusive, although *Triceratops* frill fragments, probable *Edmontosaurus* limb fragments, turtle shell fragments, and unidentified isolated dinosaur vertebrae were commonly found. Lance faunas, much like recent terrestrial vertebrate communities, appear to have been herbivore-dominated. Microfossil accumulations were prevalent, and produced fragmentary turtle shells, gar scales, and the occasional crocodilian scute and freshwater gastropod (snail) shell. Noteworthy finds included a very small, complete raptor claw, several ankylosaur or pachycephalosaur (dome-headed dinos) teeth, and a sizeable portion of the business end of a tyrannosaur tooth. One small exposure contained associated freshwater bivalves, gastropods, unidentified dinosaur bone chunks, a tooth fragment, and a possible *Metasequoia* cone. It seems to be a paleontological cliché that the best specimens and most promising collection localities are found on the last field day—and this PIT project was true-to-form! We located promising microfossil sites and potential excavation sites containing near-complete probable edmontosaur bones, as well as some associated ankylosaur bony armor plates on the last day! Looks like a future PIT project needs to be scheduled…

Mike & Barb express thanks to the Medicine Bow-Routt NFs & TBNG Supervisor's Office for financial support of this project. The Douglas Ranger District of the TBNG also provided much-appreciated field vehicles and other logistical support, including grazing permittee and abutting landowner notifications, and a good number of District employees who helped set up and tear down the project base camp (yes, we camped out—no motels allowed!)

Skeletons of the Flying Reptile *Pteranodon* Added to the Bismarck Airport Fossil Exhibit

Transmitted by Larry Melvin, Dakota Prairie Grasslands, Minerals Program Manger; authored by John W. Hoganson, North Dakota Geological Survey, State Paleontologist

North Dakota's fossil record has provided us with great insight into the community of animals that lived during the Late Cretaceous about 66 million years ago. At that time, most of western North Dakota was a delta, and to the east oceanic conditions still persisted. The climate was warm and humid and forests covered much of the delta. This delta provided habitats for some of the most unusual and interesting animals that have ever lived in the State, including dinosaurs. Remains of about 14 kinds of dinosaurs have been recovered from the Hell Creek Formation in North Dakota including *Triceratops*, *Edmontosaurus* (duck-billed dinosaur), and *Tyrannosaurus rex*. Crocodiles, lizards, turtles, fish, birds, mammals, and many other animals lived with the dinosaurs. Many species of invertebrate animals, fish, mosasaurs (huge marine lizards), and seabirds inhabited the ocean east of the delta. Dinosaurs were the dominant life form on land and mosasaurs and sharks dominated the marine waters.

But what about the animals that spent much of their lives in the sky? Bird fossils are uncommon because their bones are generally hollow and thin and are not often preserved. We do know that birds lived during the Late Cretaceous in North Dakota, but we know very little about them. The largest flying animals that lived at this time were pterosaurs, flying reptiles. Pterosaurs were not dinosaurs but were their contemporaries and dominated the air as dinosaurs did the land. More than two hundred million years ago during the Triassic Period, pterosaurs were the first vertebrate animals to develop the capacity of sustained flight with control over steering and direction. The wing membrane in pterosaurs was stretched over a single extremely long finger referred to as the "wing finger." The other three fingers terminated in powerful, sharp, curved claws used for climbing rock ledges or perhaps trees. Pterosaur bodies were lightly built, and their wing bones, like those of birds, were hollow with extremely thin walls. Because of this, pterosaur fossils are also scarce. They were probably fairly helpless on land, but they had webbed feet and likely could swim. It is believed that at least some pterosaurs had hair and fur and were probably warm-blooded. They ranged worldwide and, like dinosaurs and mosasaurs, became extinct at the end of the Cretaceous about 65 million years ago.

Like dinosaurs, there were many species of pterosaurs. Fossils of one of these pterosaurs, *Pteranodon*, have been recovered from the Hell Creek Formation. *Pteranodon* ("toothless flyer") was gigantic. Though its body was quite small, weighing only about thirty-five pounds (15 kg), its wingspan was more than twenty feet (6 m). *Pteranodon* was a powerful flyer who also could glide and soar effortlessly on rising air thermals over great distances and for long periods of time. It had a long, thin bone crest at the back of its head that was possibly used for sexual display or functioned as a stabilizer for its long head during flight. The crest could also have served as a counterweight to the animal's long beak. Unlike many pterosaurs, *Pteranodon* did not have teeth. A fish eater, it lived along the coast of the ocean that covered eastern North Dakota at the end of the Cretaceous Period. Although not closely related to birds, it led a life style similar to that of the modern-day albatross, which has a ten-foot (3 m) wingspan and spends most of its life soaring over marine waters preying on fish.

In 2009, a fossil exhibit was created for display at the Bismarck Airport (see Hoganson, 2009, *North Dakota Department of Mineral Resources Geo News* July issue). That display features a *Triceratops* skull and other fossils recovered from the Little Missouri National Grassland in North Dakota administered by the USDA Forest Service-Dakota Prairie Grasslands. The Dakota Prairie Grasslands administrators were enthusiastic about exhibiting fossils found on the Little Missouri National Grassland and provided funding to construct the display case and the graphics. While that exhibit was being installed, Greg Haug, manager of the Bismarck Airport, and John Hoganson discussed the possibility of suspending casts of *Pteranodon* from the ceiling over the display case to enhance the exhibit. It was decided that adding flying reptiles would be an exciting addition. For those of you who have not been to the Bismarck

Airport it is a beautiful facility and the 40 foot high ceiling is painted as a blue sky with clouds. When Greg and others designed the building they installed hooks in the ceiling with the thought that display objects could be suspended. The Dakota Prairie Grasslands was approached about the plan. Again, they endorsed the idea and provided funds for three skeletal casts of *Pteranodon* for the display. The exhibit was completed in May 2011.

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Forest Service Prevails in Karuk Tribe of California v. Forest Service, et al (9th Circuit Court)

Mike Doran, M&GM--CNO, Senior Mining Geologist

In a major win for the Forest Service, the Ninth Circuit Court of Appeals ruled that the determination that a Plan of Operation is not required (decision made by Klamath National Forest District Ranger) does not constitute an agency action subject to the Endangered Species Act. If a District Ranger does not require a PoO, then the mining operation may proceed and is not subject to NEPA or ESA. In this particular case the operators and the District Ranger worked together to develop acceptable Notices of Intent.

The 36 CFR 228, Subpart A regulations describe when a NOI and a PoO are required. A NOI is required when the proposed operations might cause significant disturbance of surface resources (228.4(a)). A PoO is required when the proposed operations will likely cause a significant disturbance of surface resources (228.4(a) (3)). It is not possible to develop a universal definition of "significant disturbance". Due to the great variability of NFS ecosystems, identical operations could cause a significant disturbance in one highly sensitive location and not cause a significant disturbance in another less sensitive location.

The phrase "will likely cause significant disturbance of surface resources" means that, based on past experience, direct evidence, or sound scientific projection, the District Ranger reasonably expects the proposed operations would result in impacts which more probably than not need to be avoided or ameliorated by means such as reclamation, bonding, timing restrictions, and other mitigation measures to minimize adverse environmental impacts on NFS resources. (See Clarification as to When a Notice of Intent to Operate and/or a Plan of Operations is Needed for Locatable Mineral Operations on NFS Lands, Federal Register, Vol. 70, No. 107, June 6, 2005)

The requirement for prior submission of a NOI alerts the Forest Service that an operator proposes to conduct mining operations which the operator believes might, but are not likely to, cause significant disturbance of NFS surface resources and gives the Forest Service the opportunity to determine whether the agency agrees with that assessment such that the Forest service will not exercise its discretion to regulate those mining operations. (U. S. Forest Service, Notice of Intent Instructions; 36 CFR 228.4(a) - Locatable Minerals.

http://www.fs.fed.us/geology/NOI_instructions.doc).

Well-Known Author Takes Geology Tour of Kaibab National Forest

Transmitted by Jessica Lopez Pearce, Kaibab NF Williams and Tusayan Ranger Districts, Geologist; authored by Jacqueline C. Banks, Kaibab National Forest, PAO

Well-known author and geologist Wayne Ranney recently participated in a geology tour of the Williams Ranger District of Kaibab National Forest. In fact, Ranney helped lead the earth science discovery tour by teaming with Kaibab National Forest geologist Jessica Lopez Pearce to explain geologic features at six locations across the district.

Looking over the Johnson Crater

The goal of the field trip was to provide Forest Service resource specialists with a more in-depth understanding of the geology of the local area – information that might prove valuable when planning projects or doing field work.

The group started their tour at Summit Mountain, which is located about 8 miles southeast of Williams. From this high point, Ranney and Lopez Pearce explained the evolution of the Colorado Plateau, Basin and Range, and the San Francisco Volcanic Field. Ranney provided a description of the ancient Mogollon Highlands, which once stood like an Andean-type mountain range across the southwestern border of the Colorado Plateau approximately 100 million years ago. These long-gone mountains have been replaced by the Arizona Transition Zone and the Basin and Range Province, which are now visible in the area.

Kaibab National Forest resource specialists expressed particular interest in the presence of local faults, like the nearby Mesa Butte fault. Local faults like Mesa Butte are reminders that there is always the possibility of an earthquake on the Williams Ranger District.

Next, the group stopped along the southern boundary of the Williams district in Grindstone Wash. Participants observed the various sedimentary rock layers of the Coconino Plateau including the Toroweap Formation, Coconino Sandstone, Hermit Formation, and Schnebly Hill Formation. Ranney provided insight into the unique depositional environments of each rock layer and showed beautiful illustrations of paleogeographic reconstructions from a book he coauthored with Ron Blakey, titled Ancient Landscapes of the Colorado Plateau.

The next stop was a sandstone quarry near Ash Fork, at which tour participants discovered many fossilized reptile tracks within the Coconino Sandstone. Ranney described how the Coconino Sandstone was deposited in a 275-million-year-old desert environment containing a large sand dune sea, or erg. A short drive through the sandstone quarries provided participants an opportunity to see more three-dimensional examples of the ancient sand dunes.

Vertebrate fossil tracks in the Coconino Sandstone

"It was fascinating to discover that our beautiful pine forest was once a harsh desert complete with sand dunes," said Roger Joos, a Kaibab National Forest wildlife biologist. "And, it was really awesome to understand the processes that created what are now our flagstone quarries. The coolest part for me was to learn exactly how the fossilized tracks that we often find in flagstone were formed and preserved."

As the tour headed south on Forest Road 6, participants were able to see volcanic features in the San Francisco Volcanic Field including a dike, or vertical lava intrusion, and several lava flows. The trip concluded with a stop at Johnson Crater, a geological oddity, where Ranney and Lopez Pearce discussed the possible ways this collapse structure was formed.

"I had no idea that we had so many geological treasures out there," said Mark Thibodeau, visitor information specialist on the Williams Ranger District. "Now that I am more educated, I can pass that information along to our visitors so that they can enjoy the district even more and have a better experience during their time here."

To view photos of the Williams Ranger District geology field tour, please visit http://www.flickr.com/photos/kaibabnationalforest/sets/72157626793688861/. To learn more about Wayne Ranney, please visit his website at www.wayneranney.com. For geology information about the Kaibab National Forest, please contact Jessica Lopez Pearce at jlopezpearce@fs.fed.us.

San Jacinto District (San Bernardino NF) Reclaims Historic Mine

Raj Daniel, San Bernardino National Forest, Minerals Administrator

The District's many years of attempting to clean up the Gold Shot Mine site finally came to fruition with funding made available from the Central National Operations (CNO) of the FS Minerals & Geology Management program and from the Region 5 Abandoned Mine Land program, administered by Maggie Baker (M&GM, CNO). Laurie Rosenthal (District Ranger) delegated the arduous task to her staff, Heidi Hoggan (Special Use--Mineral Administrator) and Dustin Bryant (District Archeologist) to remove the trash accumulated over the decades, preserve the historical mining equipment at the site and close unsafe mine shafts using foam plugs. Several historical and environmental societies were pleased with the outcome and several

Historic cabin preserved

Historic Straub Rotary Stamp Mill (year 1900) "Anywhere a mule can go" Straub Manufacturing Co., Oakland, CA

articles were published in the local media commending the Ranger's decision.

The Gold Shot Mine was located on or about 1918, and no production records have been maintained by the State of California. This remote site has served as a haven to many transients who were storing and using controlled substances in the cabins and trailers. The mine is located near Butterfly Peak, in southern California.

Access to this mine was landlocked with a private land owner. The District Ranger and her staff did the negotiations with the land owner who provided the access to remove trash and preserve the historic rotary stamp mill which happens to be one of the few left in the State.

The Abandoned Mine cleanup crew from Tahoe NF lead by Mary Rosellen helped clean up the site along with our volunteer retirees Louis Nuno and Don Ogden.

Earthquakes and Groundwater

Troy Thompson, R9, Regional Hydrogeologist

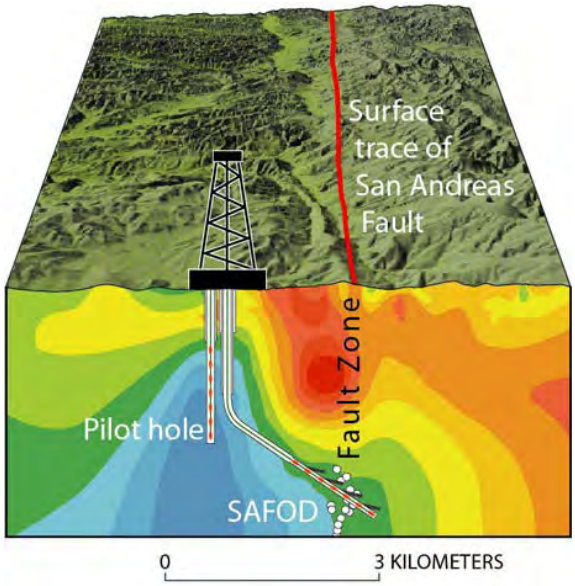
Editor's Note: This article was previously published in the Wisconsin Ground Water Association newsletter. Please contact Troy for complete citations to referenced publications

The passive link between groundwater and earthquakes is not new and is well documented. The Chinese noticed centuries ago that water levels in wells can vary in association with earthquake activity, and used this behaviour with some success to anticipate earthquakes. More recent research in the United States has attempted to use monitoring of groundwater levels in wells to help predict eartquake activity (Moyle, 1980). In addition, it is known that earthquakes such as the 2004 Indonesian quake can cause measurable changes groundwater levels in places thousands of miles from the epicenter (USGS, 2005). The 1983 Borah Peak earthquake in southeastern Idaho caused groundwater located near its epicenter to erupt as much as 25 feet into the air (CGER, 1992). It has been suggested that an earthquake could similarly cause groundwater to rise towards the ground surface and flood the proposed Yucca Mountain radioactive waste repository, although this potential threat is not generally accepted as likely as the repository would be located approximately 1,000 feet above the water table.

However, within the past 50 year researchers have noted that groundwater can play a direct role in earthquake occurrence and earthquake related damage. Research on earthquake mechanisms indicates that groundwater likely plays a significant role in many earthquakes, including most if not all large earthquakes. Furthermore, groundwater can magnify the damaging effects of groundwater. This article briefly surveys the role of groundwater in earthquake disasters.

Fault Slip and Earthquake Generation

Most people are familiar with the standard model of fault-related earthquake generation: two bodies of rock lock against each other along a fault as the result of frictional resistance until opposing shear stresses on either side of the fault build to the point where they overcome the frictional resistance resulting in a sudden slip along the fault and an earthquake. However, following the recognition of thin-skinned thrust zones exhibiting movements over tens of miles, it became apparent that this model of fault slip was incomplete.



Planned drilling scheme for the San Andreas Fault Observatory at Depth Source: Lovett, 2006

Calculations of slip along a thrust fault based on dry frictional conditions showed that such faulting should not occur as only a maximum of 6 miles of slip offset could be accommodated before the crush strength of the upper plate rocks would be exceeded.

In a classic paper, Hubbert and Rubey (1959) showed how the presence of water could resolve this problem. They calculated that high fluid pressure along the fault plane could sufficiently reduce the effective normal stress on the fault plane to overcome frictional resistance to lateral sliding. The reduction in effective normal stress is potentially so great that one geologist has joked that the problem is not getting thrust faults moving, but getting them to stop.

This explanation has subsequently been extended to explain how slip occurs on other faults, such as the San Andreas fault (Preuss, 1998). The potential role of fluids in controlling the behavior of the San Andreas fault has been of particular interest given the threats posed by this fault, as well as some apparently paradoxical conditions associated with the fault. The amount of shear stress causing movement along the fault is considerably less than it should be given the magnitude of the compressional stresses exerted on the fault. Furthermore, frictional heating along the fault should lead to higher geothermal temperatures along the fault than have been observed. It has been proposed that presence of fluids along the fault zone could in effect lubricate the fault reducing its strength and associated frictional heating.

Two different models of the source and role of these fluids have been proposed (Preuss, 1998). One model, called the Byerlee-Sleep and Blanpied model, or "closed box" model, proposes that local crustal fluids, such as groundwater, are drawn into the fault zone due to fault rupture, become trapped by mineralization, become overpressured by stress buildup, and then facilitate the occurrence of the next rupture. The other model, called the Rice model, proposes that fluids from the mantle are forced up under pressure and focused into the fault zone. Preliminary analyses of gases along the fault zone indicate the Rice model is at least partially correct. To test hypotheses concerning the role of fluids in slip on the fault, a project called the San Andreas Fault Observatory at Depth (SAFOD) was started in 2005 to drill deep into the fault zone, collect samples, and place instruments at depth to monitor fault behavior (Earthscope, 2006).

The role of fluids in the slip of subduction zones and the generation of earthquakes, such as the 2004 Sumatra earthquake, are also being examined (NSF, 2006). Potential effects include overpressuring along the fault and effects on rock mechanics due to fluid alteration of minerals.

Research is also focusing on the complex interactions between fluids, magma, and faulting in volcanic zones (Templeton and Dreger, 2004).

The role of fluids in earthquake generation has led to the recognition that human activities have had affects on seismic activity, at least at small scales (University of Texas, 2001). Minor seismicity has been recorded in connection with the impounding of water behind dams and fluid injections from wells at various places around the world. However, it is unlikely these types of activities would lead to a damaging earthquake as such earthquakes occur at depths that are unlikely to be affected by the hydrodynamic stresses created by these activities.

Groundwater and Earthquake Effects

Groundwater can also play a significant role in how earthquakes affect the ground surface when an earthquake occurs. The most well known effect is liquefaction. During the shaking cause by an earthquake, certain types of fluid saturated sediments can lose their structure and become liquefied. This phenomenon led to increased structural damage in the Marina district of San Francisco during the 1989 earthquake. However, this fact seems to have had little effect on local property values. Various projects are underway in different earthquake-prone areas, such as the Los Angeles Basin (Hillhouse, et. al., 2002), to map areas susceptible to groundwater related earthquake damage.

Liquefaction effects from the 1933 Long Beach earthquake. Source: Hillhouse, et. al., 2002.

Increased earthquake damage has also been observed in areas without liquefaction, but with shallow groundwater, such as during the 1994 Park Ridge earthquake in California (USGS, 1996).

In spite of all the research to-date, there still remains a lot to learn about the relationship between groundwater and earthquakes.

Mine Portal Closure, Railroad and Barren Forks, Stearns Ranger District, Daniel Boone National Forest - Protection of Bat Habitat and Public Safety

Transmitted by Tom Buchta, M&GM--CNO, AML Program Leader; authored by George Chalfant, Tennessee Valley Authority Contractor

During the week of May 22, 2011, a mine portal closure Team, comprised of Jeff Gabardi[1/] (Mining Engineer and certified mineral examiner), Jason Ringenberg[1/], and Kurran Kelly of the Sawtooth National Forest, Twin Falls, Idaho, Region 4; John Lane, Shane Ferguson, Tim Stephens and George Chalfant, Tennessee Valley Authority (TVA) Contractors, closed six underground coal mine openings. They first reviewed the Job Hazard Analysis prepared for this project, and National Protocol[2/] for protecting bats from spread of White-nose Syndrome (WNS) disease, before assembling personal gear, steel materials and miscellaneous supplies to use on the closure project. During previous prep work, air was monitored at each mine opening for harmful or toxic/hazardous gases and none were detected.

Steel was loaded on a utility trailer and moved to a field location selected to serve as a base from which to mobilize vehicles, and equipment, supplies, and transfer of steel to two Utility vehicles (UTV's) provided by TVA for transport to each mine opening planned for closure. Steel closures, conforming to National Guidelines developed by BAT Conservation International, for protecting bat habitat, were constructed as closures of six deep or underground coal mine openings, commonly referred to either as mine adits or portals. These mines, accessed by openings planned for closure, were operational in the late 1800's to the mid-1930's by the Barren Fork Coal Company. In all but two of these mine openings, there are remnant stone wall closures constructed during the WPA era (***W***ork ***P***rogress ***A***dministration, a public unemployment relief program started in 1935 during the depression), in the late 1930's to early 1940's. Unfortunately, since that time vandals have broken down these walls, possibly to mine 'house coal' for home use during the depression, but each closure was placed so as to protect these unique and historically significant archeological resources. At each mine opening, the Team performed additional finishing prep (e.g. removal of gob/waste rock) and installed both stulls (wooden mine roof supports from posts cut by chainsaw on-site) and steel screw jacks to provide temporary roof support for safety of those working in a mine opening. Each stull installed inside a remnant stone wall was not removed.

Jeff Gabardi (in front); left to right--Kurran Kelly, Shane Ferguson, John Lane, George Chalfant, and Jason Ringenberg

A chop saw was used to custom cut steel to desired dimensions at each mine opening. A MIG welder (MIG=***m***etal ***i***nert ***g***as), using flux core wire (a mixture of carbon and argon combined as a flux core wire) combined with heat from electrodes powered by a 6500 watt Honda generator, was used for welding. Two inch square steel tubing was first welded to #8 (3/4 inch diameter) rebar, anchored in holes drilled into competent sandstone rock or solid coal along each rib or abutment, and the mine roof to form a frame for the full mine closure. Anchorage to the mine floor was limited given presence of gob (waste rock) and soft shale. Inside each piece of square tubing, prior to welding to the rebar or other cross members, a ¾-inch hot rolled round steel bar was inserted into the square tubing to prevent vandals from successfully cutting through the square tubing and gaining access into the respective mine in the future. The initial framework was completed with horizontal cross-members providing a 5 ¾ "± 1/16 "spacing to accommodate bat access/egress, as per Bat Conservation International guidelines. All steel tube openings were capped with welded plate steel to protect the rolling rod inside the square tubing from being held by vice-grips, pliers, etc., if someone tries to cut through the tubing with a hacksaw or sawzall (reciprocating saw). In addition, capping prevents collection of damp debris (i.e. acid shale) within the tubing, to reduce corrosion of the steel tubing, and hence extend life of the closure.

Jason had lead responsibilities for designing and constructing each mine closure; including the welding. Kurran was in charge of cutting the steel, delivering it to Jason, and assisting Jason as he did the welding. Kurran was assisted by other team members at various times, but Tim, John and Shane operated the UTV's for the Team used for moving steel and miscellaneous supplies (welder, chop saw, stulls, steel screw jacks, etc.).

Jeff, as certified mineral examiner, gave clearance for working beneath each mine face-up or underground, and provided overall project leadership.

The Team first installed stulls (6"-7" diameter posts cut on site for best fit), with boards as a base and top plate with wedges, behind a remnant stone walls. In addition, steel screw roof jacks were installed outside the selected gate alignment as needed and specified by Jeff. These closures weren't difficult to install, but anchorage on either rib or abutment was not as favorable as desired in some instances; competent rock, nor solid coal may not have been available. But, Jason did a fantastic job considering these limitations. Mine drainage at five of the mine openings provided sloppy working conditions.

When the Team completed their work, they returned to the District work center to wash the UTV's. Equipment and personal gear were detoxed by washing with disinfectant soap and or wiped down with disinfectant wipes before storing in the work center shop or vehicles.

In conclusion, this project went very smoothly without any incidents that may have jeopardized personal safety and damaged our equipment, etc. Some of us were a little scratched up from moving supplies through green brier to Mine #38, and some had a few bruises and sore muscles, but the team got along fantastically with one another, even during some inclement weather. The District was very supportive of our every need, providing two utility trailers for moving steel and supplies; without which this project would've been much more difficult and costly.

Jeff supported the Job Hazard Analysis (JHA) we prepared for this project. He also said that when this kind of work is done, always make sure a Qualified Certified Mineral Examiner/Qualified Safety Lead (QCME/QSL) is on site, as we did with this project to be compliant with the Forest Service Safety Handbook. In addition, Jeff believes a good supporting rule of thumb is "don't go underground unless the QCME/QSL goes first, and only go underground at their invitation".

Note remnant stone wall behind the newly installed steel gate closure

All the closures are solid, professional, and should provide protection from further vandalism of the historically significant stone walls constructed in the late 1930's to early 1940's (prior to 1943 when the WPA program was discontinued). The closures will also provide protection to bat habitat and public safety.

1/ Jeff Gabardi and Jason Ringenberg have had extensive experience (multi-state) with mine closures. Jeff has facilitated the closure of 2,000 to 3,000 underground workings since 1992, but Jason has had lead responsibility for physically closing over 1,500 underground mines by backfilling, foam plugging, and/or gating in the past 10 years; collectively between them a tremendous amount of expertise in closing mines.

2/ U.S. Fish and Wildlife Service protocol.

TRANSITIONS

M&GM CNO Introduces New Geologist

Ryan Cole, M&GM-CNO, Geologist

Hello, my name is Ryan Cole, and I recently began my career as a Geologist with the Forest Service on May 19th. I am assigned to the WO/Office of Leasable Resources under Barry Burkhardt and Bob Fujimoto, in the now "non-vacant" geothermal position.

Prior to my collegiate career I served in the 1st Battalion, 75th Ranger Regiment of the US Army from 2000-2004, where I served four combat tours in Afghanistan, and one in Iraq. For three years, prior to coming to the Forest Service, I worked at the US Geological Survey Oregon Water Science Center as a Hydrologic Technician in a STEP appointment, while completing a B.S. in Geology at Portland State University. I am currently finishing an M.S. in Geology, also at PSU. My interests in geology range from hydrogeology to environmental geology, chemical hydrogeology, and engineering geology. I am, however, very excited and eager to learn about geothermal energy and resources, and am looking forward to working with the experienced and

knowledgeable team of scientists within all the programs of M&GM.

I feel very privileged to work for an agency that seeks to conserve some of the resources that I myself consistently enjoy. In my free time, I like to play in NFS lands whether kayaking the Little White Salmon, backpacking near Mt. Adams, climbing on Mt. Hood, or mountain biking in the Gifford Pinchot.

Memorial: Stories of Buster

Compiled by Ruth Seeger (R6, Area Mining Geologist) & Mike Burnside (retired WO M&G, R1 Assistant Director, Locatables)

On March 1, 2011, Buster LaMoure passed away in Salmon, Idaho. **Buster is someone to remember.** He was Director of M&GM in Region 1 from 1978-1983 and the national Director from 1984-1989. He was one of a kind. To honor him, we collaborated to pull together a few stories important to us and which you may enjoy. ***Cheers to you Buster!***

Some biographical info: Sometime after 1970, Buster and his family moved to Livingston, Bozeman and Billings, MT with Buster's Forest Service career. They moved to Springfield, Va., in 1976 when Buster worked for Howard Banta from 1976-1978 as Banta was the first full-time WO M&G Director. Previously, M&G was combined with various other staff groups. Buster moved his family back to Missoula, in 1978 and he became the R1 M&G Director and served from 1978 to 1983. The family remained in Missoula while Buster returned to Virginia in 1984 for a second stint in the WO, this time as the Director, M&GM until retiring in 1989. Upon retirement, he returned to Missoula, and later Salmon, ID.

When Buster and I were undergraduates in geology in 1969, we went to geology field camp together for half the summer at Univ. of Indiana's field camp in SW Montana on the north end of the Tobacco Root Mountains. The field terrain was fairly steep and not easy to get around. The professors were concerned about Buster being able to do the field work. They worried about the condition of Buster's leg, (his knee was stiff and that leg was shorter than the other so that he walked with a pronounced limp). Buster replied that actually, it gave him an advantage: 1) it was much easier to side-hill with one leg shorter than the other, although he could only do it in one direction; and 2) he seldom got lost since with one leg shorter, he tended to go in a circle and come back to where he started!

In 1994 or thereabouts, during the height of the controversy over the New World Project when Region 1 was trying mightily to satisfy environmental groups and EPA (one and the same) and get a draft EIS out, we had a meeting with some of them in the local bar (the Miner's Saloon, of course). The discussion had hardly gotten started with a particularly annoying and anti-USFS environmental representative in attendance, when Buster paused to light up a cigarette. Being his usual thoughtful self and wanting to share, he exhaled some smoke her direction. She was out of there like a shot! We thought the meeting highly successful. --**Mike Burnside; Retired Region 1 Locatables; Asst. Director, WO M&G**

I am trying hard to remember something that could be printed in something other than "National Lampoon"! Buster did so much for the Minerals and Geology Program in Region 1 and eventually the entire Forest Service...I don't think that people in the minerals program today realize what Buster did to bring the Minerals Program to the status that it has today.

I spent quite a few days with Buster on some controversial projects...like the New World Mine near Yellowstone National Park...and he definitely supported (emphatically!) the Forest Service's role in administering controversial mining proposals. He was a real advocate for the FS mineral professionals on the ground to be involved in the technical review and decisions regarding complex, controversial mining proposals. He was 100% supportive of our decisions on the ground and he did his best to deflect the political fallout of those decisions. **--Sherm Sollid; Retired Forest Minerals Geologist/Staff; Gallatin NF; Region 1**

My favorite anecdote of time spent with Buster was his trip to Butte around 1989, with some visiting Australians. The Aussies were on a tour of mines in the Western US on NFS lands learning about our approach and our responsibilities under the 228A regs. They stopped in Butte to establish a "sister city" relationship between Kalgoorlie and Butte….and to tour the Pegasus Beal Mountain Mine. I welcomed the group at the Butte airport with some cold champagne...and Buster joked about the funding being good on the Deerlodge that year! The next day we took them

on a short field trip - including the Beal Mountain mine and a visit to the 90 foot tall statue of "Our Lady of the Rockies". Merrill Davis, the District Ranger back then, was there - along with Dan Avery and Liz McFarland. We gave them a tour of the statue and a typical All-American picnic lunch of fried chicken, pie and beer…and we ate it right there under the Lady's skirt (made out of sheet metal for those of you who haven't been to Butte yet). It seemed to suit them. Merrill was great that day....he was one of the most down to earth Rangers I've ever worked with....and he and Buster and Dave Fredley and the Australians all got along well. Merrill was telling them what a District Ranger had to do, needed to do, should do. I'll remember Buster sitting up there on the mountain listening to the Ranger tell the foreign visitors how to successfully manage a mine on public lands; what cooperation can accomplish. Buster seemed proud of the way things turned out....and of course, the pie & beer helped! Their visit culminated with the leaders of Butte throwing the visitors a "welcome to Butte" party where they forged their Kalgoorlie/Butte sister-city friendships. That was a good night for the Forest Service and our M&G program. **--Ruth Seeger; Area Mining Geologist; Western OR/Southwestern WA Minerals Zone; Region 6**

The Golden Age of the Minerals and Geology Program was when Buster was Director. Buster was a leader, a strong leader. It took a strong leader to help the biologically-oriented Forest Service recognize the agency's responsibilities to manage mineral and geologic resources on more than 190 million acres of federal land. Buster showed what strong leadership can achieve even when faced with such a Mission Impossible task. Tom Collins; Minerals & Geology Program Manager; George Washington & Jefferson NFs

Buster invested heavily in newer employees. I was one of many people that benefited from that when he was the Regional Director of M&G in Region 1. He was constantly placing newer employees on project teams, pairing them up with more senior mentors, detailing them from one Forest to another, arranging training, and providing encouragement. He had his entire direct staff actively involved in this cultivation process. At the time, you could have found pieces of this mode at any number of Forest Service offices, but you would have to look long and hard before finding another office that did so much of it. And you would have had to look just as long to find an office that had as much laughter. **--Steve Marshall, Assistant Director, Cooperative Forestry; WO-FS**

I remember his first day on the job in Rosslyn. He came into the office and immediately told us to find the building manager and have the name on the directory changed ASAP – he was <u>not</u> Bronson LaMoure!

There was no beige, grey, or ecru in Buster's management style and philosophy. It was black and white- get rocks in the box and oil and gas in the pipeline. His goal was simple and direct. Follow the law and policy that Congress gave to the Forest Service and the country. To Buster being the M&GM Director was not just filling a position – it was a passion. As a Director he was certainly different than the "apple polishers." Many of the WO Directors used their positions as stepping stones to jobs with greater responsibility and which exceeded their ability. They would take on meaningless task forces and committees to create irrelevant products now dusty and long forgotten. Not Buster. His job was to allow his staff to use their experience and creativity to implement the National Minerals Policy enacted into law by Congress.

Buster had a nickname – "Bulldozer." We would tell Buster he needed to wheel to the right and he would lower the blade and with black smoke coming out of the diesel engine move obstacles out of the way for us. Most of the time those obstacles were other staff directors, OGC, and groups such as the Sierra Club and National Wildlife Federation. What made his job easier for all of us was that he had the confidence of Max Peterson and Dale Robertson. He always gave them good advice and never played games with them. He could be very blunt in that advice. And they appreciated that.

Buster knew that creativity and initiative required changing the mindset and personnel in the WO. Frankly, before Buster came to Washington few of us in the field could even name the WO staff. That was true. So he brought in Sam, Steve, Bruce, Bob, Stormin' Norman, Nancy – and with stalwarts like Tom King and others on the staff, and turned us loose.

You may not know that Buster lived in my home for 4 years. So M&G management was a 24/7 experience. We would talk over issues long into the night or pour over statutes and case law. But we would also sit on the back porch, drink some beer and BS. Sometimes Newman would drop over and we would cook steaks and have a great time. I lived on a lake in Virginia and Buster and I would go out in the boat and fish. Buster was not a real good fisherman. He just didn't have the "feel." If he had his way he would have fished with dynamite.

One day Buster and my 10 year old son were "home alone" (Oh my God!). Peter had to develop some kind of experiment for school, so he decided to determine the temperature at which oil would start to boil. Buster was helping. The experiment was a success. They learned that oil, when heated sufficiently on the stove, will not boil before explosively igniting…and they learned that to save the house from burning down it was necessary to carry the flaming pot of oil out of the kitchen while at the same time seriously burning both (of Buster's) arms.

Buster had big strong hands. I remember a couple of times after coming out of surgery and just waking up Buster would be there holding my limp hand in his, and ask if I was doing ok.

One last thing – Buster never did learn how to tuck in his shirt tail. **--Dave Fredley; Retired Assistant Director; WO M&G**

I remember Buster for his strong support of the Minerals Program. He wasn't afraid to lead, nor to speak out in support of minerals being an important part of the Forest Service and Multiple Use. His lasting gift was assembling a strong and expert team who knew and understood mineral management in the Forest Service, allowing them to work and then supporting them. These are the marks of a leader. **--Nils Johnson, Director; Legislative & Regulatory Affairs; Holland & Hart; Washington, D.C.**

Probably my favorite Buster story was when Buster was the Custer Forest Geologist, and I was a newly hired District Geologist on the Little Missouri National Grasslands. Buster came out to the District to help mentor me. I had just gotten married, and Buster asked me how that was going. I told him Kathy and I could not agree on how to spend money. After a long pause Buster said "For me and Pat, I found a long time ago it best to give Pat all the money and let her take care of the finances". I can only imagine what was going through Buster's mind, but it was the fatherly way Buster said it that made me take his advice, and 37 years later that is still how the Ramsey household gets along. **--Bruce Ramsey; Deputy Director; WO M&G**

Cheers to you Buster! Thanks for dropping the blade, clearing the path and helping us enjoy the journey together. You are missed.

Memorial: Bob Porter

John C. Nichols, Ouachita National Forest, Geologist

In 1994 the Forest Service started sending me to set up an exhibit and outreach at the Tucson Gem and Mineral Society Show in the Convention Center. I first met Bob Porter in 1996 when he contacted me to see if he could help with arranging Coronado NF Sabino Canyon Volunteers to help me staff the exhibit over the 4 days of the show. Bob and I immediately took to one another. In the early years I also brought my young daughters to help staff the exhibit and for the learning experience the show offered. Then as they grew and could not come, my wife started coming to help. Over the years my family came to know and love Bob. His quiet and unassuming manner, his love of the pursuit of knowledge, his care and compassion for my family as well as his own and his many friends left a great and positive mark on us. Bob was a dedicated academic and naturalist with a true gift for reaching folks of all ages. He was a graduate of Princeton, served with distinction in terrible battle conditions as an officer in the Pacific theater in WWII, became a professor at Princeton, and a Dean at Yale where he retired. He moved to Tucson in 1986 and became active with the Coronado National Forest Sabino Canyon located on the edge of the city. He developed the Volunteer Naturalist program into a strong group of highly dedicated, knowledgeable and trained volunteers serving the public and the Forest. Bob loved to help and support the Minerals exhibit at the Tucson Show. At 89 years old, Bob Porter, friend and mentor, passed away peacefully in the presence of his family on May 4, 2011. I am glad to have had one more show with him this past February. He remained active and still drove his own vehicle, and I recall his looking forward to participating again at the exhibit for the 2012 TGMS Show. Well, he will be there with us, in memory, and we will carry on in honor of him with the Sabino Canyon minerals and geology hands on display he always brought to the exhibit. Bob's knowledge of the natural world, including geology, was boundless. His greatest gift was in being able to make it real and understandable to children, young people, and adults alike. That gift will be missed. But the example he left those of us who knew him will carry on...

John Nichols, Jonathan Dufek, Nancy Nichols, Heidi Schewell, and Bob Porter at the TGMS Exhibit in 2005