102

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 27 1987

MEMORANDUM FOR: Ronald L. Ballard, Branch Chief
Technical Review Branch
Division of High-Level Waste Management
Office of Nuclear Material Safety and Safeguards

FROM: Keith I. McConnell
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SUBJECT: REPORT DESCRIBING ACTIVITIES ASSOCIATED WITH THE MARCH 23 THROUGH MARCH 26, 1987, VISIT TO THE DEATH VALLEY AND BARE MOUNTAIN AREAS

PURPOSE OF TRIP:

The tectonic stability of the Yucca Mountain site is one of the Key Issues for determining the site's suitability as a repository for high-level nuclear waste. Specifically, factors related to the site's ability to successfully fulfill the performance objectives are largely tied to tectonic issues. However, tectonic issues in the Yucca Mountain area, namely the presence or absence of detachment faults, the age of most recent movement of many faults, and the association between volcanism and faulting (i.e., Lathrop Wells cone) are largely unresolved and all tectonic issues may never be completely resolved. To help decipher the tectonic history of the Yucca Mountain area, geologists at the USGS are investigating areas near Yucca Mountain that may have formed in an analogous tectonic environment.

The Death Valley region, approximately 25 km to the west of Yucca Mountain, has been the subject of detailed study for many years and may provide insight into tectonics at Yucca Mountain. Several tectonic models under study by the USGS and the State of Nevada imply that faulting and volcanism near Yucca Mountain may be developing under a similar tectonic framework as faults and basaltic volcanism observed in Death Valley. Therefore, the detailed history of faulting worked out for the Death Valley region over the past thirty years may provide a great deal of understanding of the tectonic stability of the Yucca Mountain site.

Faulting in Death Valley may also have a direct impact on the Yucca Mountain site. The DOE has suggested that some study should be given to possible impacts to the repository from a number of large earthquakes (M = 7 or greater) located on the long normal and strike-slip faults present in Death Valley (SAIC, 1985, p. 2-10).

AREA OF TRIP

The field trip attended on this visit presented an overview of Tertiary and Quaternary tectonics along the eastern margin of Death Valley (approximately 25 km west of Yucca Mountain) and extended eastward to the Bare Mountain area (approximately 15 km west of Yucca Mountain).

FIELD TRIP LEADERS:

Lauren Wright (Penn State University)
Bennie Troxel (University of California-Davis)
Mike Carr (U.S. Geological Survey)

NOTE: The On-Site Representative's office in Las Vegas was a significant factor in facilitating my participation in this field trip. The On-Site Representative's office provided support in gaining motel reservations in the small town of Pahrump, near the field trip starting point, and in providing a four-wheel drive vehicle, required for access to many of the stops on this trip. Participation in this field trip would have been a great deal more difficult without the help of the On-Site Representative's office in Las Vegas.

DAILY ACTIVITIES:

March 23, 1987 - Resting Spring Range-Black Mountains

This day began near Tecopa Hot Springs where the age and origin of Pleistocene lake beds near Tecopa and Shoshone were described. The lakebeds near Tecopa display only minor evidence of deformation following their deposition while lakebeds of similar age in Death Valley are highly deformed. As will be discussed more thoroughly later, this suggests that in this area most of the Quaternary deformation has occurred west of the southern Furnace Creek and Sheephead fault system.

The Sheephead fault zone, interpreted by Wright and Troxel to be a major zone of right-lateral, strike-slip displacement with latest movement prior to 3 m.y.a., was also visited this day. Wright and Troxel have speculated that the Sheephead and the southern Furnace Creek faults are connected by a zone of steeply dipping, spoon-shaped normal faults and are part of the same fault system. Movement on this fault system occurred prior to the Quaternary Period. The area between the two major faults containing numerous normal faults is interpreted to have developed as a rhombochasm.

The proposed mechanism of formation for the Sheephead fault, southern Furnace Creek fault, and the intervening rhombochasm is similar to the "wrench" tectonic model proposed by some geologists for the Yucca Mountain area. In the Yucca Mountain area, the zone between the southeastern end of the Walker Lane and the northwestern end of the Las Vegas Valley strike-slip fault zones may also be a rhombochasm. In both the Yucca Mountain and Death Valley cases, the zone between the major strike-slip faults (i.e. the Sheephead and Furnace Creek, faults in Death Valley and the Walker Lane and Las Vegas Valley faults near Yucca) represents a zone of major extension.

Several additional features of the Sheephead fault system that might have relevance to the Yucca Mountain area are that the Sheephead fault flattens with depth and listric normal faults in the zone of greatest extension bend into the plane of the Sheephead fault. A similar interpretation has been developed for detachments and north-trending normal faults at Yucca Mountain by the USGS (Scott, 1986).

March 24, 1987 - Death Valley-Furnace Creek

This day began in southern Death Valley near Shoreline Butte and continued northward to Furnace Creek. We were west of the southern Furnace Creek-Sheephead fault system in the Confidence Hills, in an area where Quaternary deformation is common. Ash beds in the Confidence Hills show evidence of two fault related fold events. Faulting is related to movement along the southern Death Valley fault zone. Anticlines formed during the first fold event parallel the trend of the southern Death Valley fault for the most part. The second folding episode produced folds with axes slightly oblique to the southern Death Valley fault zone. The age of both folding events has a lower limit of 1.5 m.y. based on an isotopically dated basalt at the top of the sequence.

Further north in Death Valley (Stop 10) we observed a .69 m.y. old cinder cone on the east side of the highway. This cone is cut by the rangefront fault in this area. West of the Highway is another .69 m.y old cinder cone that has been offset by a right-lateral strike-slip fault. Investigations related to the COCORP project (de Voogd and others, 1986) have indicated that this cone is underlain (approximately 15 km) by a magma chamber and that an east-west trending fault has provided access to the surface for basaltic magma. This relationship between magma chamber, faulting and volcanism may be analogous to the Lathrop Wells cone south of Yucca Mountain. Of interest is the differnce in age between the cone in Death Valley (690,000 yrs) and the Lathrop Wells cone (approx. 20,000 years).

Continuing north in Death Valley (stop 11, attachment 1), we observed a low angle fault separating alluvium and bedrock (i.e., a rangefront fault). This fault does not extend into mountain front, but does steepen as you approach the mountain front. Troxel indicated that this fault may represent a detachment fault reactivated by movement along the rangefront. Some of the normal faults associated with this structure do not become listric as they approach the main fault but sole into the main fault. This suggests that all normal faults associated with detachments do not necessarily have to display a listric style. At this stop two periods of wrench-tectonics or rhombochasm formation were defined in more detail. The first episode occurred approximately 9 m.y.a. and is represented by movement along the southern Furnace Creek and Sheephead faults and the separation of the Panamint Mountains westward from the Black

Mountains. The second episode of rhombochasm formation began approximately 4 m.y.a. along the northern Furnace Creek and southern Death Valley fault zone resulting in the present day form and seismicity of Death Valley.

In the Mormon Point area (Stop 12, attachment 1), we returned to a stop visited on a previous trip (see NNWSI Field Trip, February, 1987). At this locality, good examples of listric normal faults are observed above and soling into a low-angle fault separating Precambrian carbonate from overlying Quaternary alluvium. [Scott (1986) has suggested a similar relationship exists at Yucca Mountain where normal faults (e.g., Bow Ridge, Solitario Canyon, Windy Wash) are interpreted to be listric and sole into a detachment under Yucca Mountain.] At Morman Point, Troxel indicated that the low-angle fault could possibly represent an exhumed turtleback structure with subsequent Quaternary movement reactivated by the rangefront fault. High-angle faults associated with the rangefront are visible at the entrance to the canyon. A basic question about this type of structure is whether the rangefront fault reactivated the detachment or do deep detachment structures activate rangefront faults? The same question can be applied to the Bare Mountain fault on the west side of Crater Flat.

At Copper Canyon (Stop 13) we stopped for an overview of the Copper Canyon turtleback. A turtleback is both a geomorphic and structural feature. The geomorphic form of turtlebacks bear a resemblance to a turtle's carapace, but the feature also denotes a fault surface separating metamorphosed basement rocks from more highly deformed cover rocks, in this case Tertiary volcanics. Basement rocks in turtlebacks generally are in the crestal areas of northwest-trending anticlinal structures.

We then moved on to Zabriskie Point (Stop 14) in Furnace Creek where 7000' of sediments are deposited in the earlier of the two rhombochasm events mentioned previously. Clastic sediments here are largely in the Artist Drive, Furnace Creek and Funeral Formations with the Furnace Creek Formation dated by the presence of the 5.15 m.y. old Furnace Creek Basalt. Spring related carbonate veins present in the Furnace Creek area and visited in several previous site visits (e.g., NNWSI Field Trip, February, 1987), cut through sediments in the Furnace Creek Formation.

March 25, 1987 - Boundary Canyon-Keane Wonder faults

This day started with an overview of the Boundary Canyon fault near Monarch Canyon. Generally, the Boundary Canyon fault is interpreted to be a middle Miocene detachment surface with low grade Stirling Quartzite and Tertiary volcanics in the upper plate and higher grade Johnnie Formation and Stirling Quartzite in the lower plate. Unpublished Ar^{40}/Ar^{39} ages indicate that Mesozoic metamorphic ages near the fault zone have been retrogressed to younger Tertiary ages. A similar relationship is observed in the Bullfrog Hills where Mesozoic metamorphic ages in Precambrian rocks have been altered to mid-Tertiary ages. Warren Hamilton (USGS) believes that the Keane Wonder fault and Boundary Canyon fault are the same fault thus making the Keane Wonder fault part of the detachment system. Lauren Wright and Bennie Troxel interpret the Keane Wonder fault to be a right-lateral strike-slip fault and do not believe the Keane Wonder connects with the Boundary Canyon fault. Folding in upper plate rocks of the Boundary Canyon fault is believed to be Tertiary in age because Tertiary rocks are locally folded.

The Boundary Canyon fault is marked by a thin carbonate unit that coincides with and is intensely deformed by faulting. Isoclinal folds are common in the carbonate. A question developed regarding the origin of the fabric in the carbonate basically revolving around whether the fabric was a Mesozoic feature reactivated by Tertiary tectonics or whether the fabric is Tertiary in age.

Later in the day we stopped near the Keane Wonder mine in Death Valley. More discussion ensued over the nature of the Keane Wonder fault. Mapping in the area does not appear to justify extending the Keane Wonder northwestward into the Grapevine Mountains and connecting it with Boundary Canyon fault. Also, normal faults are mapped into the Keane Wonder fault while they appear to truncate abruptly against the Boundary Canyon fault.

Also in the afternoon, we visited an exposure in Boundary Canyon of the Boundary Canyon fault. Here the fault is denoted by a highly brecciated carbonate and Stirling Quartzite in the hanging wall and Johnnie Formation in the footwall.

The final stop of the day was at Daylight Pass where Titus Canyon Formation (oldest Tertiary unit in this area) overlies Zabriskie Quartzite apparently in conformable contact.

March 26, 1987 - Bullfrog Hills-Bare Mountain

This day started in the Bullfrog Hills just west of the Bullfrog mine. An exposure in an abandoned railroad cut displays Precambrian rocks in the core of an arched detachment. Faulted Tertiary volcanic and sedimentary rocks surround these exposures. Unpublished Ar^{40}/Ar^{39} ages from amphibolites give Mesozoic ages while muscovite and biotite ages are Tertiary.

In the Bullfrog Hills area, the detachment fault separates similar stratigraphic units (i.e., Tertiary from Paleozoic rocks) as the Boundary Canyon fault separates to west (see above). Carr (USGS) equates the two faults (i.e., Boundary Canyon and Bullfrog Hills detachment) and extends this surface further to the east connecting them with the Fluorspar Canyon fault. Two detachment surfaces are present in Bullfrog Hills; one separates Precambrian rocks from Tertiary and Paleozoic rocks and a second detachment surface separates Paleozoic rocks from the Tertiary rocks. Both surfaces are interpreted to have moved concurrently with isolated blocks of Paleozoic rocks caught up in the fault movement as "horses." Carr believes that the Paleozoic rocks were left behind when the Grapevine mountains moved westward to their present location from a position on the western side of Bare Mountain.

Extension along the Bullfrog detachment is greater than 100% and could be as great as 300%. The Thristy Canyon tuff (7.5 m.y.) is involved in the detachment faulting indicating that faulting continued to occur after 7.5 m.y.a. Paleozoic and Precambrian rocks representing core areas (e.g., Bare Mountain) rise isostatically as Tertiary rocks slump into basins.

All rocks of the Tertiary sequence in the Bullfrog Hills show evidence of hydrothermal alteration associated with gold mineralization in this area. This suggests that at this time there is no upper age limit on the hydrothermal event.

Prior to leaving the Bullfrog Hills, a discussion of the nature of the Beatty fault(?) took place. Various theories have been proposed for the scarp-like feature exposed south of Beatty along the Amargosa River. Carr indicated that trenching and shallow refraction studies showed no evidence of faulting along this feature. However, recent investigations (USGS) have shown that to the north in Oasis Valley a fault with Quaternary movement is present. Indications are that if the fault in Oasis Valley was extended southward, it would connect with the Beatty feature. The USGS considers the nature of the Beatty feature an open question.

We next travelled to Fluorspar Canyon to observe the Flurospar Canyon fault, part of Carr's detachment system. At this stop it was indicated that there were exposures of a 100 m.y. old granite intrusion in the Paleozoics at the west end of the Canyon. Mafic intrusives are also present at this locality. Carr believes that the Fluorspar Canyon fault is a partially reactivated thrust fault. Rocks as young as 10-11 m.y old have been affected by the Fluorspar Canyon detachment. As stated previously, Carr also believes that the Fluorspar Canyon detachment is part of the detachment system exposed in the Bullfrog Hills. However, it is unclear what happens to the lower of the two detachment surfaces seen in the Bullfrog Hills which separates Precambrian rocks from Paleozoic and Tertiary rocks (the Fluorspar Canyon fault separates Paleozoics from Tertiary rocks). A suggestion was made that the lower detachment could turn southward along the west side of Bare Mountain. Carr also believes that the breakaway of the detachment occurred along the Fluorspar Canyon fault and he would not extend deformation related to this event any further east. Thus, development of the Fluorspar Canyon detachment is believed to be older than the Holocene faulting proposed for the Bare Mountain fault. Carr also interprets faulting on the east side of Bare Mountain as a response to deeper detachments.

We then travelled to the east side of Bare Mountain where the discussion involved the nature of the Bare Mountain fault and tectonics of the Crater Flat area. Only parts of the Bare Mountain fault have been active in the Holocene, others being relatively quiet since mid-Pleistocene. Fans along the east side of Bare Mountain get younger to the south suggesting that faulting gets younger to the south. All slickensides in Quaternary material display pure normal movement. This is in contrast to later movements along the Windy Wash fault to the east which are believed to involve some strike-slip movement (Whitney and others, 1986).

A discussion of faulting near Yucca Mountain also developed. Scott (USGS) indicated that offset of the Bishop Ash along the Paintbrush Canyon fault at Busted Butte was 4 m. Also, approximately 10-30 m of Quaternary left-lateral offset is interpreted to have occurred along the Stagecoach Road fault. Scott indicated that one breakaway occurred along the Windy Wash fault and another along the Yucca Wash-Stagecoach road fault, with both connected to a detachment surface beneath Yucca Mountain. The westward extent of the detachment under Crater Flats was, in Scott's interpretation, uncertain because Crater Flats is interpreted as a spreading center.

Carr indicated that faults at Yucca Mountain are antithetic to faults dipping to east at Bare Mountain. The Bare Mountain fault where it shows Holocene movement dips approximately 60°, therefore, he beleives that this rules the Bare Mountain fault out as being a detachment surface. Carr also extends the rangefront fault into the mountain front and sees Quaternary movement both in and out of the range.

Two small scarps denote the Bare Mountain fault. One occurs at the entrance to Tarantula Canyon and another was at the location now covered by the heap leach pad at the Sterling gold mine.

Carr indicated that much of the sequence at the Sterling mine was overturned and that the folded and thrust faulted Paleozoic rocks are cut by normal faults along which they slumped eastward toward Crater Flats. The exposures east of Steve's Pass (see NNWSI Field Trip, February, 1987) may fall into this category.

The final stop was in a trench at the rangefront which contained evidence for Holocene movement along the Bare Mountain fault. Middle to late Pleistocene soil (Q2 a or b; 150,000) has been faulted but it is difficult to tell whether uppermost (Holocene) soil has been faulted, indicating that evidence for Holocene faulting at this location is somewhat equivocal.

SIGNATURE	DATE

Keith I. McConnell

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