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MEMORANDUM FOR: Philip S. Justus, Acting Chief
Geotechnical Branch
Division of Waste Management

FROM: Michael E. Blackford
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Geotechnical Branch, DWM

SUBJECT: GEOLOGY FIELD TRIP/MEETING: HLW TUFF SITE (YUCCA MOUNTAIN (NNWSI)) NEVADA

From Sunday, February 22, 1987, through Saturday, February 28, 1987, I attended a meeting and field trip to observe and discuss modes of faulting and other tectonic aspects present in the vicinity of the Yucca Mountain potential HLW repository site. In addition, the field trip included visits to other sites in the western Basin and Range where modes of tectonism, possibly analogous to the Yucca Mountain site, were observed. This report should be considered to be a preliminary report limited to my descriptions of the stops. A more complete report shall be submitted jointly by the attendees. A chronological summary of the stops follows:

Sunday, February 22. NRC personnel, Rus Purcell from LLNL, and three persons from SAIC representing the DOE gathered at the On-site Representative's office in Las Vegas, Nevada prior to travel to the Mercury camp on the Nevada Test Site (NTS). Because of delayed flights from the east coast, our departure was postponed until the early evening and LLNL presentations by McKague and Purcell were rescheduled for the following evening. We arrived at the NTS at 9:00 o'clock.

Monday, February 23. Today's travel was within the eastern portion of the NTS from Mercury camp to the Climax stock. The first stop was on an abandoned portion of the Mercury Highway a short distance north of Mercury camp where the basal Tertiary formation, the Horse Springs formation, unconformably overlies the Paleozoic Eureka quartzite. McKague pointed out minor faulting in the Horse Springs formation at this site. At a second stop, further along this stretch of abandoned highway, we attempted, unsuccessfully, to locate isoclinal folding near the Tertiary-Paleozoic contact. This stop was near the Rock Valley fault system. The third stop was made on Mine Mountain. McKague indicated that the outcrops at this stop were Devonian in age and that they had been thrust over the reddish outcrops and float rock seen at lower elevations along a low angle fault called the Mine Mountain Thrust. The mining activity at this site had concentrated on mineralization near the fault contact. McKague also indicated the general trend of the Mine Mountain Fault, the strike-slip fault that extends from here southwestward into Jackass Flat. We proceeded north from Mine Mountain into Yucca Flat to a brief stop near the southern terminus of the surface rupture on the Carpetbag fault that occurred at the time of the Carpetbag nuclear test. McKague explained that the activity of this fault was unrecognized prior

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to the test. The surface rupture extended northward from this stop roughly 6 to 7 kilometers. The rupture extended about equally north and south of the the Carpetbag ground zero along a trend about one kilometer west of ground zero. A second stop was made further north on the fault at a point where the vertical displacement, east side down, was in excess of one meter. McKague indicated that an antithetical fault, defining the east side of a broad graben, was located about 0.5 kilometers to the east, however we did not attempt to observe this rupture. We had lunch at the Area 12 Camp during which heavy snow showers began to blanket the northern part of the NTS. Following lunch, on the way to the Climax stock, we paused briefly at a point where the road passed very near the scarp of the Yucca fault. McKague's description is essentially covered in the field trip guide handout. The snowfall obscured the possibility of following the trace of the scarp northward as we proceeded to the trenches along the Boundary fault at the Climax stock. We stopped at one of the more northerly of the several trenches across the Boundary fault. Here the more competent granitic rock appeared to be faulted against less competent material ranging to alluvium. Infilling of presumably carbonate material was present in the fault strands. At this point the snow drove us out of the field and we returned to Mercury for McKague and Purcell's presentations on NTS geology and desert geomorphology.

Tuesday, February 24. Today's activities concentrated on the extreme eastern portion of the Amargosa desert and the western part of Jackass Flat. We were joined by persons from the State of Nevada and from the University of Nevada, Reno. The first stop was at a wash south of the old stagecoach road southwest of Busted Butte and south Yucca Mountain. This wash, which drains in a westerly direction into the Amargosa desert, apparently is offset in a left-lateral sense by a north trending fault. This fault had been mapped by Swadley and has been identified as Ramelli's fault number 7. The fault is said to trend into the Stagecoach Road fault a kilometer or so north of the stop, however, air photos seem to indicate that the fault may actually continue northward along the trend of faults on the west side of Yucca Mountain. The Stagecoach Road fault, which has not been mapped east of Busted Butte, trends southwest into the Amargosa desert. This fault is along the general alignment of a projection of the Mine Mountain fault, although there is a hiatus of mapped faulting across Jackass Flat. The next stop was at Trench 14 on the west side of Exile Hill east of Yucca Mountain. This trench straddles the Bow Ridge fault and exhibits the spectacular veins which have been the subject of much discussion in recent years among parties interested in their impact on the siting of a HLW repository under Yucca Mountain. Peterson from the State of Nevada offered that the veins could be pedogenic with the vein material derived from leachate carried in by horizontal as well as vertical groundwater flow. As infilling progressed the vein material may have wedged the ground mass aside. The last stop was on the west slope of Busted Butte where we examined sand-rich sediments, called sand ramps by the USGS. These have been cited as analogs of the possible pedogenic deposition observed in Trench 14. The slope is deeply eroded into a series of spur ridges and gullies. In the gullies a former caliche layer is exposed. This layer has a slope considerably steeper than the present grade of the spur ridges. In some places a second caliche layer, subparallel to the present spur ridge grade, is also exposed. At least two fault strands can be identified by nearly vertical infillings exposed from near the spines of the spur ridges down into the gullies. Walking upslope along the bottom of the gullies, the first bedrock one encounters typically appears to be a tuff breccia cemented by wide calcic veins.

Wednesday, February 25. About an inch of snow coated the vehicles this morning when we prepared to leave Mercury to observe faults in Crater Flat and the northern portion of the Amargosa Desert. Heavy snows in Crater Flat limited visibility to the extent that much of Yucca Mountain was not seen until the afternoon. The first stop was along Highway 95 opposite the Lathrop Wells volcanic cone. McKague gave an explanation of the development of the cone generally along the line of the explanation given in the field trip guide handout. A second stop was made at trenches CF2, CF2.5, and CF3 on the east side of Crater Flat just northwest of a westerly lobe of Yucca Mountain. The fault exposed in these trenches is believed to have a strike-slip sense of movement as evidenced by a "flower-like" splaying of the near-vertical fault trace as it approaches the surface. These splays may represent the third dimension of mole track structures often seen along the surface ruptures of strike-slip faults. The sense of movement on this fault is believed to be right-lateral. The last stop on the east side of Crater Flat was at an exposure of a strand of the Solitario Canyon fault in the cutbank of a northerly draining wash along the road leading to the south end of Yucca Mountain. The fault intersects the cutbank at a low angle and is well exposed. The site may be a good place to add a trench across the Solitario Canyon fault. The next stop was on the west side of Crater Flat on a splay of the Bare Mountain fault. The discussion in the field trip guide adequately covers this stop. This stop was also a repeater point for the USGS seismic network. Apparently data from three other stations in the network is received here and mixed with data from a local seismometer. These four stations are then transmitted elsewhere. The local seismometer appears to be located in a partially buried canister vault most likely seated on bedrock. The last stop of the day was at a trench on the west side of Bare Mountain about a mile south of the Amargosa Narrows south of Beatty. This trench was dug to try to intersect a possible fault that may have caused a high scarp on this face of Bare Mountain. Bedded sand, silts and gravels exposed in the trench could represent various meanders of the Amargosa river through time. Since the trench does not extend far enough east into the scarp it does not confirm or deny the existence of a tectonic scarp. The scarp may just represent the eastern limit of Amargosa meanders.

Thursday, February 26. Today we continued to observe examples of the faulted contact between altered Paleozoic rock and Tertiary rock near Beatty and Goldfield. The first stop was at the site of Bullfrog, which is just inside the Death Valley National Monument boundary about ten kilometers west of Beatty and a few of kilometers west of Rhyolite. The site was the location of intense mining early in this century that exploited the rich mineralized zone near the fault. A low angle fault was observed in a cut on the southeast face of this southern lobe of the Bullfrog Hills. The USGS has proposed, at times, that this may be the western extent of a large detachment fault system that extends eastward to Jackass Flat. A brief stop was made at some low hills just south of Bullfrog. These hills are an exposure of the Precambrian core complex, some of the oldest rock in the region. From here we proceeded to a stop on the north side of Flourspar Canyon Road a couple of kilometers east of Highway 95 southeast of Beatty. Although a definite fault trace was not observed, an fault trending east-west was assumed to pass through a saddle here separating the Paleozoic rock to the north from a small hill of sheared Tertiary volcanics, which was the site of several prospects. Slickensides indicating predominately dip-slip motion were observed on several of the east-west trending shear planes in outcrops on the southeast side of the small hill. We proceeded north to Goldfield where we met the operators of an open-pit gold mining operation northeast of Goldfield. This mine, and several of the mines in the Goldfield area, exploit the mineral-rich fault zone bounding the region's caldera-like volcanic center. The fault was observed in the open pit. Brightly colored altered rocks at this stop indicated the presence of significant amounts of sulphur at the time of alteration.

Friday, February 27. The first stop on this day was at the Mizpah mine on the north side of Tonopah. The present Mizpah mine is an open-pit which again is an example of exploitation of the mineralized faulted contact between Tertiary volcanics and older altered sedimentary rock. Mining in the Tonopah area followed this contact as it plunged off to the west with some of the westernmost mines having shafts extending 2400 feet down to the mineralized zone. Since some of these mines were below the watertable, it would be interesting to try to find out how they responded to the larger earthquakes that have occurred in the vicinity since the mines were developed. The episode of volcanism began here about 20 mya with mineralization occurring about 18 mya. About 16 mya renewed dacitic volcanic activity tended to segment the mineralized zone. From Tonopah we continued northwestward to Mina and then eastward into Monte Cristo Valley to observe the remains of fault scarps that formed there nearly 55 years ago as the result of the December 1932 Cedar Mountain earthquake. A series of low en echelon scarps had formed on the up-fan sides of low hills a few kilometers north of the valley playa. These scarps are now degraded to small ripple on the otherwise smooth hillslope. The amplitude of the degraded scarp at this stop is approximately 30 centimeters. The State of Nevada has trenched across the fault here revealing a series of interbedded fine and coarse detrital sediments, typical of a fan, interrupted by the fault which is marked by a resistant infilling that has preserved subhorizontal slickensides with a rake of about 10 degrees. The fault splays into a "flower structure" near the surface. From this stop we returned to Mina and proceded south through Fish Lake Valley and the communities of Dyer and Oasis. From the highway in Fish Lake Valley we observed the northern extension of the Death Valley fault along the west side of the valley. North of Dyer the fault appeared to cut a broad fan with a prominent scarp. Between Dyer and Oasis the fault was marked by an alignment of faceted spurs and uplifted fans into which new fans are being cut.

Saturday, February 28. Today the field trip concentrated on tectonic and sedimentation features in Death Valley and east and south of Death Valley. The first brief stop was at the Death Valley Museum at Furnace Creek to get an overview of the formation and sedimentation of Death Valley. From Furnace Creek we proceeded to the eastern boundary of the monument were we observed prominent veins cutting through the loosely consolidated sediments on the north side of the Furnace Creek Wash. In a cliff overlooking the stop the veins appear to terminate at a horizontal boundary and then continue upward from this boundary to the top of the cliff. The boundary could possibly be a fault or a resistant bed that impeded the upward movement of the vein material causing it to flow horizontally until it found new vertical paths. The veins outcropping near the road appeared to be calcic in nature and were one to two meters in width. From here we returned to the valley and proceeded south from junction of the eastside road and Highway 190 about one kilometer to an exposure of the Artist's View fault. The fault trends generally north-south about ten to twenty meters east of the road and more or less parallel to it. The scarp is up to a meter in height. The fault is difficult to trace north or south from this point, but to the south it may trend southeastward into the Black Mountains. The next stop was at Badwater where McKague described a possible mechanism for the development of the turtleback structures observed here and on to the south. The turtlebacks, of which three have been identified between here and Morman Point about 16 kilometers to the south, appear to be wedges of the basement rock a few kilometers in length parallel to the trend of the valley that have broken loose from the main body and have slumped into the valley. These bodies tend to contain small faults that trend listrically into the main detachment surface along which slumping takes place. As we left this stop to observe the turtleback at Morman Point, McKague pointed out the presence of graben-like structures in the fan margins which may be the result of compensation by the underlying old lake sediments to the increased detrital load. It would be interesting to know if these grabens formed coseismically and could be considered to be an example of paleo-lateral spreading. At Morman Point we examined the features of a turtleback exposed in a narrow canyon that is part of the drainage of the Black Mountains into Death Valley. We viewed the first hundred or so meters of this canyon from where it empties onto a fan that is part of the east bajada of southern Death Valley, back to a dry falls that limited further exploration. Near the entrance to the canyon relatively close spaced faults that dipped steeply toward the valley were observed. Farther into the canyon the faults were less closely spaced and dipped more gently. At the dry falls a fault, assumed to be the detachment of the turtleback, was exposed. Although this fault apparently dipped northward, slickensides indicated the motion on the fault to be westward toward the valley. The last stop in Death Valley was opposite Jubilee Mountain at the southern end of the valley. Here we observed lake stands of the former Pleistocene Lake Manly. This lake, which was one of several interconnected Pleistocene lakes in this part of the Basin and Range. These lakes, including Lake Manly, possibly drained to the south to the Colorado River. As drier climatic conditions developed, these lakes dried up leaving traces of old beaches or shorelines when they stood at a particular elevation for a number of years. These strands are well exposed on the flanks of Jubilee Mountain. To the west of Jubilee Mountain, on the valley floor there is a cinder cone that straddles a fault. Movement on this fault, subsequent to development of the cone, has shifted one side of the cone left-laterally with respect to the other side of the cone about one-half of the diameter of the cone. We left Death Valley and proceeded to Shoshone which is situated within the basin of the former Lake Tecopa. At a stop a few kilometers south of Shoshone we stopped among lake deposits having a distinctly greenish color. McKague explained that the lake deposits graded from a fresh glass near the sources of fresh water flowing into the lake at its northern end, through a zeolitzed zone at intermediate depths, to zone rich in K-feldspar in the deepest part of the lake at its southern end. This stop was in the zeolitized zone. From here continued on to Tecopa, which is situated near the deepest part of former Lake Tecopa. At Tecopa we examined tufa mounds of low relief in an area dotted with many springs. From here we returned to Las Vegas to conclude the field trip.

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