RESPONSES TO NRC COMMENTS ON THE MOAB FAULT, UTAH

Prepared for

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26 May 1994

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May 26, 1994

Mr. Bruce Hassinger
Canonie Environmental Services Corporation
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Subject: **Responses to NRC Comments on the Moab Fault, Utah**

Dear Bruce:

We are pleased to submit to you our written responses to the U.S. Nuclear Regulatory Commission's technical comments regarding the earthquake and surface faulting potential of the Moab fault and its implications to Atlas Corporation's Uranium Mill Tailings site. The evaluation of these issues was performed by Susan Olig and myself. We were aided by discussions with Michael Ross, Bill Mulvey, and Gary Christenson of the Utah Geological Survey (UGS) and we very much appreciate their assistance. Our thanks also to Lee Allison, Director of the UGS.

Our thanks for this opportunity to assist you in this very interesting study. Please call me if you have any questions or require further assistance.

Regards,
WOODWARD-CLYDE FEDERAL SERVICES

Ivan G. Wong

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Vice-President and Manager
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RESPONSE TO NRC COMMENTS ON THE MOAB FAULT

In a Request for Information transmitted to Atlas Corporation, dated 29 November 1993, from the U.S. Nuclear Regulatory Commission (NRC), the following two issues were raised relevant to the Atlas Uranium Mill Tailings site in Moab, Utah:

ISSUE 1: "There is evidence that a fault runs under the disposal site. Evaluate the extent of faulting under the disposal site and determine if there is capability for surface rupture."

ISSUE 2: "Evaluate the seismic potential for faults adjacent to the site, including the potential for fault movement due to salt dissolution."

The following discussion addresses these two issues. To a large extent, our interpretations are based on site characterization studies which were performed for a proposed underground nuclear waste repository for the U.S. Department of Energy from 1978 to 1987 (Woodward-Clyde Consultants, 1982; 1984).

LOCAL FAULTING

On the geologic map of the Arches National Park and vicinity, Doelling (1985) of the Utah Geological Survey (UGS) shows a concealed section of a northwest-striking, northeast-dipping normal fault, which extends from a point 1.6 km northwest of the Atlas tailings pile to the southwest for a distance of 5 km (Figure 1). He suggests this fault is one of two traces of the Moab fault and that it extends beneath the tailings pile. Doelling (1985) also shows the other parallel trace of the Moab fault concealed, located a few hundred meters to the southwest, and not traversing the tailings pile. In cross-section, Doelling (1985) portrays the Moab fault as juxtaposing, in the near-surface, Pennsylvanian rocks (principally salt of the Paradox Formation) capped by Permian Cutler Formation on the west against Jurassic and Triassic rocks such as the Entrada and Morrison sandstone on the east (Figure 2). The fault exhibits a total displacement of about 790 m near the Colorado River (Yeats, 1961).

The closest exposure of the Moab fault, 1.6 km northwest of the tailings pile, occurs in the Entrada sandstone. No direct evidence for southeastward continuation of the fault exists in

Source: Doelling, 1985

Project No. SK9407	Moab Uranium Mill Tailings Site	GEOLOGIC MAP OF THE ATLAS MILL TAILINGS SITE	Figure 1
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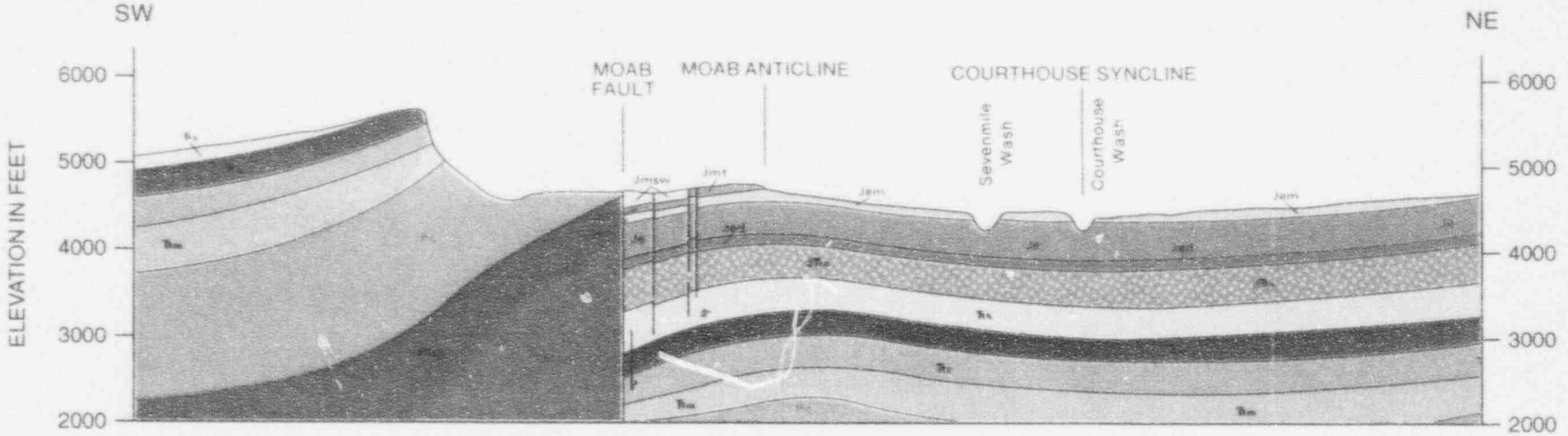

EXPLANATION

TRk	Kayenta Formation	Jmsw	Salt Wash Member of Morrison Formation
TRw	Wingate Sandstone	Jmt	Tidwell Member of Morrison Formation
TRc	Chinle Formation	Jem	Moab Tongue of Entrada Sandstone
TRm	Moenkopi Formation	Je	"Slıckrock" or Main Body of Entrada Sandstone
Pc	Cutler Formation	Jed	Dewey Bridge Member of Entrada Sandstone
IPhp	Pennsylvanian rocks	JTRn	Navajo Sandstone
IPpg	Paradox Formation		

Source: Doelling 1985

Project No. SK9407	Moab Uranium Mill Tailings Site	GEOLOGIC CROSS-SECTION THROUGH THE MOAB FAULT	Figure 2
Woodward-Clyde Federal Services			

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the Quaternary alluvial deposits that apparently bury the fault along the west side of the northern Moab Valley and at the tailings pile (Figure 1). The Moab fault is observed, however, along strike in bedrock 6 km southeast of the tailings pile and about 2 km south of Moab (Doelling, 1993). Doelling (1985) apparently extended the fault to the southeast beneath the tailings pile assuming the Moab fault is continuous through this area and connects the two bedrock faults observed to the north and south. This interpretation need not be the case, as the exact location of any faults is concealed beneath Quaternary sediments. Elsewhere, a complex geometry with multiple strands and steps is observed along the Moab fault and this is also probably the case along this concealed section. Thus, no definitive evidence exists for a fault located beneath the tailings pile. However, a buried fault or deformation zone may exist somewhere in this location, although its absence in Quaternary deposits suggests that it does not pose a surface faulting hazard to the site based on NRC criteria for a "capable" fault (see following discussion).

Less than [illegible] km to the north of the tailings pile, a series of relatively short northwest-striking faults, dipping both northeast and southwest, apparently offset Navajo sandstone of Triassic/Jurassic age. Doelling (1985) did not extend these faults to the southeast into the Quaternary alluvium in Moab Valley (Figure 1). These faults probably represent tensional features over the crest of the Moab anticline which have undergone displacement due to dissolution of the underlying salt of the Paradox Formation (Doelling, 1985).

AGE OF FAULTING

Based on recently revised NRC criteria (10 CFR Part 100 dated 20 October 1992), a fault is classified as being "capable" if it has undergone tectonic movement at least once in the past 50,000 years or multiple movements in the past 500,000 years. Hecker (1993) summarizes indirect evidence which suggests that the most recent movement along the Moab fault occurred sometime during the late Quaternary. However, during recent detailed (1:24,000) mapping of Quaternary deposits along the fault, William Mulvey (UGS, personal communication, 1994) observed no direct evidence for Quaternary (last 1.6 million years) displacement along the Moab fault. Specifically, alluvial deposits of Bull Lake age (~130,000-200,000 years) do not appear to be offset by the fault. In addition, given the absence of any observed seismicity associated with the fault (Wong and Humphrey, 1989), we do not consider the Moab fault to be a capable fault based on NRC criteria.

The evidence cited by Hecker (1993) for late Quaternary activity on the Moab fault is indirect, based on geomorphic and stratigraphic relations that indicate a lowering of base level in Moab and Spanish Valleys occurring during the late Quaternary. This change in base level is not necessarily tectonically controlled, and in fact, could be due to subsidence related to salt dissolution and/or migration under Moab Valley. The evidence for late Quaternary subsidence in Moab and Spanish Valleys is discussed in the section on "Potential for Dissolution and Related Subsidence."

Piling of late-Pleistocene to early Holocene sediments along Bartlett Wash near the northern end of the Moab fault was suggested to be possible evidence for recent displacement along the fault (Hecker, 1993). However, in a recent reconnaissance of the Bartlett Wash area, Mulvey (UGS, personal communication, 1994) found a clear exposure of the Moab fault offsetting Entrada sandstone but not Quaternary deposits and evidence that pileing of late-Quaternary fine-grained sediments on the upthrown side of the fault is probably controlled by conditions unrelated to faulting.

EARTHQUAKE AND SURFACE FAULTING POTENTIAL

In her summary description, Hecker (1993) states that the Moab fault may be similar to the Lisbon fault, located to the southeast, in that it is probably related to salt dissolution with a possible tectonic component. The down-to-the-east displacement observed along the Moab fault is likely due to subsidence of Moab and Spanish Valleys from dissolution of the underlying salt (Hite, 1978). Large relative displacements are displayed along the Moab fault north of Moab which could be interpreted as surface expressions of major down-to-the-east faults that extend beneath the Paradox Formation. Other segments of the fault and large portions of the Lisbon fault, however, show no such displacements. Such large displacements can alternatively be interpreted as occurring in areas of locally extensive collapse due to salt dissolution (Woodward-Clyde Consultants, 1982; 1984).

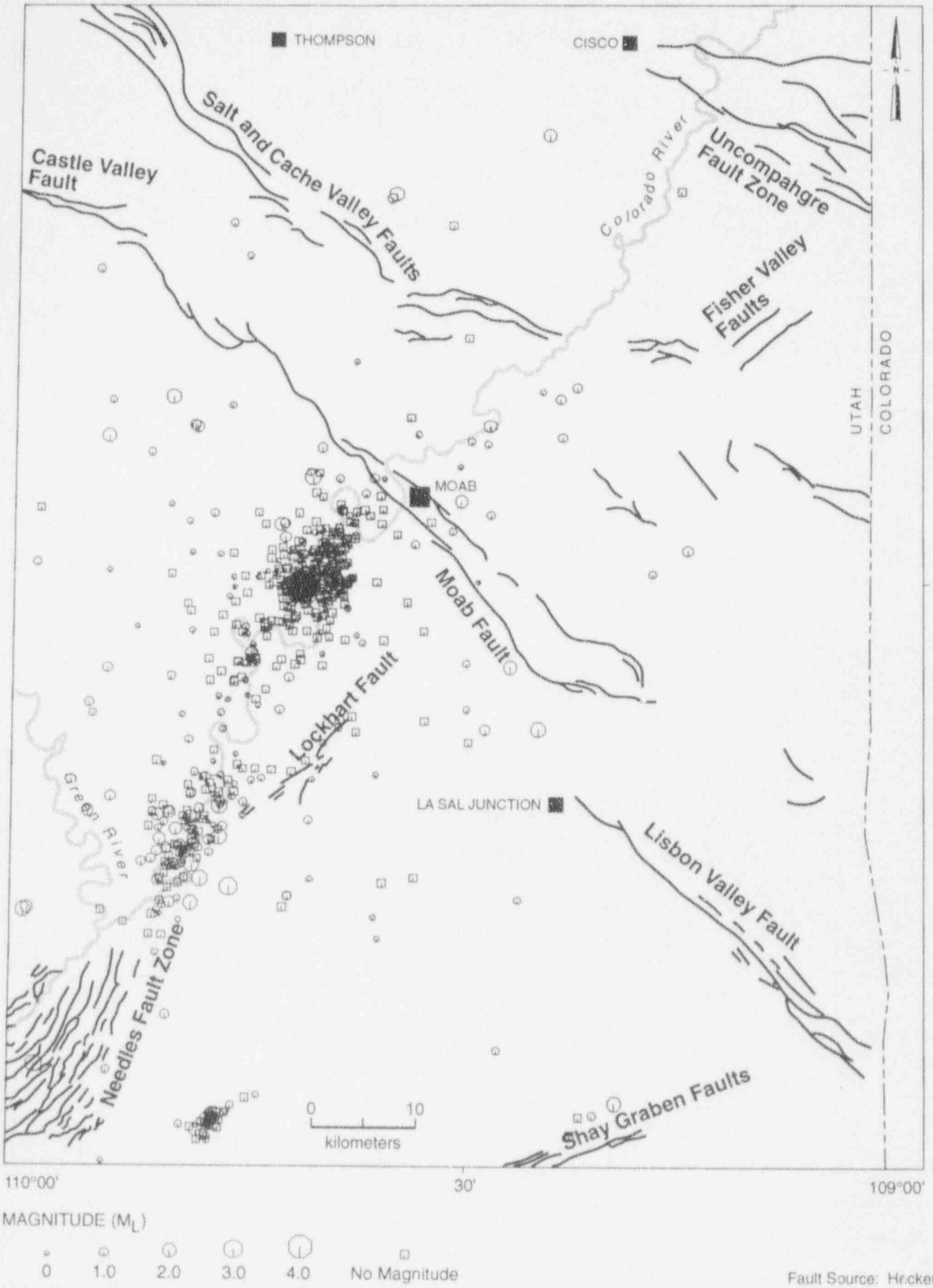
Recent discussions with UGS staff about their unpublished mapping indicate their findings are consistent with our interpretations of the Moab fault. Earlier studies suggested that the Moab fault may extend below the salt, offsetting pre-Paradox Formation strata (Shoemaker et al., 1958). In contrast, we interpret the Moab fault as a structure which developed primarily from salt dissolution and migration although movement along the fault has also probably been in partial response to broad regional tectonic stresses (Woodward-Clyde Consultants, 1982; 1984). We also believe the fault is confined to the Paradox Formation and overlying strata. Based on borehole data, Hite (1978) suggested that the analogous Lisbon Valley fault to the southeast does not penetrate through the salt (Figure 3). Pre-Paradox faults may exist beneath the salt (Figure 3), but no evidence exists that these faults are continuous with faults, such as the Moab fault, observed at the surface.

Recent studies by the UGS also suggest the Moab fault does not penetrate beneath the salt based on seismic data (M. Ross, UGS, personal communication, 1994). According to Ross, a seismic profile near the visitors center at Arches National Park shows the Moab fault becoming listric near the top of the Paradox Formation at a depth of about 914 m (3,000 ft) where it soles out within the salt. Other seismic profiles to the north along the Moab fault also show the fault dying out within the Paradox Formation (M. Ross, UGS, personal communication, 1994).

If the Moab fault is indeed a shallow fault, its seismogenic potential will be negligible as it will not be subjected to significant tectonic stresses which are largely occurring at depth beneath the top few kilometers of the upper crust. Deformation along the fault will most likely be aseismic due to the plastic nature of salt. Although strata along the fault zone overlying the salt are likely to deform in a brittle manner in response to movement of the underlying salt, the strata are thin and deformation will be seismogenically insignificant.

In a detailed microseismic survey of the Cane Creek potash solution mine southwest of Moab in 1984, several hundred microearthquakes of Richter magnitude (M_L) < 2 were recorded (Wong et al., 1989) (Figure 4). At the time, the mine was undergoing a major brine extraction and refilling and, as a result, the ground surface over the mine subsided about 10 cm. The observed maximum rate of subsidence was 19 cm/yr. The large majority of microearthquakes were observed to occur in the shallow brittle strata overlying the Paradox Formation in response to the ongoing subsidence, suggesting that any deformation within the salt was largely aseismic (Wong et al., 1989).

Consistent with our observation that the Moab fault is not a seismic source, a dense seismographic network operated in the Paradox Basin from 1979 to 1987 revealed no microearthquakes (M_L < 1) which could be definitely associated with the Moab fault (Wong



Fault Source: Hecker (1993)

Project No. SK9407	Moab Uranium Mill Tailings Site	SEISMICITY, 1979-1993 AND LATE QUATERNARY FAULTS OF THE NORTHERN PARADOX BASIN	Figure 4
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and Humphrey, 1989) (Figure 4). Additionally, no earthquakes from 1987 through September 1993 have been recorded by the University of Utah Seismographic Stations which locate in the vicinity of the Moab fault. Similarly, no microearthquakes have been observed in the vicinity of the Lisbon fault. Earthquake focal mechanisms, however, indicate a tectonic stress field characterized by an approximate northeast-southwest-trending minimum principal stress which would be consistent with normal slip on a northwest-striking fault. Thus, salt deformation along the Moab fault could be aided by tectonic stresses acting on the fault within the top kilometer or two of the crust.

In summary, we believe the Moab fault is not a capable fault, is not seismogenic, and does not pose a hazard to the Atlas tailings pile from strong ground shaking and earthquake-related surface faulting because: (1) detailed mapping of surficial deposits along the fault show no evidence for offset of Quaternary deposits or soils along the fault; (2) detailed microearthquake studies in the area show no association or concentration of seismicity along the fault; and (3) the characteristics of deformation both at the surface and in the subsurface suggests deformation is related to non-tectonic processes such as salt dissolution and/or migration beneath Moab Valley.

Based on the seismological and geologic studies performed as part of the DOE repository site characterization program, no known capable fault has been identified in the vicinity of the tailings pile. The nearest potentially capable faults are those associated with the Shay graben more than 50 km south of Moab (Wong and Humphrey, 1989) (Figure 4). Microearthquakes are concentrated along a northeast-trending zone aligned along the Colorado River from about Moab to the confluence with the Green River (Figure 4). The source of this seismicity is probably a zone of Precambrian basement faults which underlie the river. The largest event observed in this zone has been a M_L 3.3 near the Cane Creek potash mine (Wong and Humphrey, 1989) (Figure 4). It is highly unlikely that a large earthquake could be generated within this zone.

POTENTIAL FOR DISSOLUTION AND RELATED SUBSIDENCE

Mulvey (UGS, unpublished mapping, 1994) found multiple lines of evidence recorded in the Quaternary deposits for a lowering of base level probably caused by subsidence associated with salt dissolution beneath Spanish and Moab Valleys including: (1) active fans with incision of older fans and younger fans being deposited farther down the valley; (2) Pinedale age strath terraces along Mill Creek; and (3) map patterns showing alluvial fan deposits progressively getting younger to the northwest, toward the Colorado River. These relations suggest subsidence has continued into the latest Pleistocene and probably into the Holocene (W.E. Mulvey, UGS, personal communication, 1994). However, all of this evidence is south of the Colorado River in the vicinity of a perennial stream, Mill Creek, that flows into the Colorado River. There is no evidence for late Quaternary subsidence north of the Colorado River in the vicinity of the tailings pile. This apparent lack of subsidence could be related to the lack of any perennial streams flowing into the river in this area.

Rates of subsidence or dissolution are not well-constrained but are certainly influenced by climate. Thus, rates have probably slowed down since the time of Pinedale glaciation (roughly 15,000 to 25,000 years ago) due to a drier climate. A hypothesized decrease in the subsidence rates during the Holocene is also consistent with evidence for Holocene aggradation such as the Moab marsh deposits (W.E. Mulvey, UGS, personal communication, 1994). Thus, the potential for subsidence related to salt dissolution at the tailings pile appears lower than in latest Pleistocene time.

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