Appendix A

Guidebook for an Informal Field Trip to Western Rock Valley

TECTONIC EVOLUTION OF THE YUCCA MOUNTAIN REGION: ROLE OF THE LAS VEGAS VALLEY SHEAR ZONE

Thomas H. Anderson, Ann L. Vander Schrier and Danielle L. Deemer
Department of Geology and Planetary Science, University of Pittsburgh, Pittsburgh, PA 15260

Abstract

Kinematic analysis of regional fault systems and field studies (mainly west of Mercury, NV) provides insight into the tectonic history of Yucca Mountain. Our results support the previously offered interpretation of the Yucca Mountain region as a pull-apart basin filled with volcanic units erupted through thinned crust. The boundaries of the southern part of the pull-apart basin coincide with major faults (Kawich Greenwater rift or Gravity fault, Rt. 95/Carrara and Bare Mountain) that may have accommodated multiple episodes of crustal extension during Tertiary time. These major fault structures have the potential to influence and possibly control the transmission of water from the proposed repository into Amargosa Valley. Tens of km of right-lateral displacement along the Las Vegas Valley Shear Zone (LVVSZ) was accommodated by formation of a pull-apart basin at a northward releasing step along Forty Mile Wash. East of Forty Mile Wash, the trace of the LVVSZ trends westerly (roughly between Lathrop Wells and Mercury) probably along a pre-existing structure. Upright folds record Transpression along this left-step constraining bend with local vertical limbs in layers of the rocks of Pavits Spring (17+ to 14 Ma) that crop out south of Little Skull Mountain. Tuff of the Crater Flat Group (~14 Ma) that directly overlies folded beds of Pavits Spring records eruption during deformation. Gentle folds and Irregular bed geometries that have been mapped in units as young as the Timber Mountain Group are evidence that contraction continued contemporaneously with volcanism until 11 Ma. Contraction recorded by folds is not evident in units younger than 11 Ma suggesting cessation of transpression related to strike-slip movement along the LVVSZ. Subsequent development of north-striking normal faults commonly linked by northwest-striking right-lateral strike-slip faults (e.g., Yucca Wash; Sever Wash) and complementary Northeast-striking left-lateral strike-slip faults (e.g., Mine Mountain; Rock Valley) records the transition to pure shear accompanied by local north-south contraction. Normal faults at releasing steps along the Rock Valley Fault that break across west-trending transpressional folds in the Specter Range reveal the relative ages of simple and pure shear deformation.

INTRODUCTION

The area of study is located in the western Rock Valley, which is within the Nevada Test Site (NTS) area 25, south of Little Skull Mountain. Lauffer-Aho's (2000) study of structural relationships and kinematic analysis of fault patterns at Yucca Mountain and the surrounding region reveals fault systems that bound basins containing aquifers. These basins act as compartments in which groundwater may collect. Structural analysis, complemented by stratigraphic considerations and a brief field study, led Lauffer and Anderson (2000) to conclude that crust of the Yucca Mountain region records two episodes of extension characterized by pull-apart basins. The episodes are different ages (~25 to 15 Ma and ~15 to 10 Ma). Basins of the older episode trend northwest, and basins of the younger (Basin and Range) episode trend north-south. Most

of the thrusts in this region are due to Mesozoic contraction. However Specter Range thrust, the principle thrust of Specter Range and vicinity, may be Tertiary in age or a Mesozoic structure reactivated during Tertiary time. Recognition of these fault systems and the strata that fill the basins helps to improve understanding of both the regional structural history and regional groundwater flow. This knowledge will help constrain the number and locations of pathways along which fluids may move away from the repository and test areas.

PURPOSE

This study focuses upon an investigation of structural and stratigraphic relations among Tertiary rock units east of Yucca Mountain in the region of Skull Mountain and Little Skull Mountain. In this area the Tertiary section is exposed among outcrops standing above an alluviated floor. An over arching objective of this work is to:

- Unravel the stratigraphic and structural history of Tertiary rocks near Mercury
- Demonstrate correlations between formations on opposite sides of the Gravity Fault
- Demonstrate the profound differences between the structural evolution of Tertiary rocks near Mercury and correlative rocks at Yucca Mountain

Working Hypothesis

Folds in Pavits Spring beds formed in response to transpression at a left-step restraining bend west of Mercury, Nevada. Contraction resulted in uplift and inversion of Early Miocene strata. Deformation occurred after accumulation of Pavits Spring beds and during accumulation of younger Miocene volcanic units. The volcanic units that underlie Yucca Mountain formed within a pull-apart basin concurrent with displacement along the LVVSZ between approximately 15 and 10 Ma

PRELIMINARY STRATIGRAPHIC OVERVIEW

Stratigraphic sections that illustrate the rock formations at fourteen locations were constructed. Each column includes the name and location of the section, elevation of the ground surface above the section, depths below surface for entire span of section, names and abbreviations for each rock formation, ages of rock formations (if known), and locations for any known unconformities, faults, or detachments. The sections were then incorporated into diagrams that show the stratigraphic conditions of the study area at five different times: beginning of the Tertiary period, end of the early Miocene epoch, end of the late Miocene epoch, at 11.6 Ma, and present day. Further correlations between the individual sections were made after analyzing the evolution diagrams for the purpose of determining a rough estimate of the locations and extent of early and late Miocene basins, regional unconformities, and local unconformities.

Three main observations in regard to the region's stratigraphy and geologic structure have been made: 1.) A regional unconformity that marks the beginning of the Tertiary period, is shown in every section. 2.) Early to late Miocene strata that crop out

in the east-west region from Little Skull Mountain; Striped Hills Quadrangle to North of Mercury Ridge; Mercury Quadrangle reveal the presence of Miocene basin. 3.) A second unconformity occurs at 11.6 Ma, and is distinct in every section east of Hampel Wash; Camp Desert Rock Quadrangle. This unconformity, and the other lower units, record breaks in deposition in the volcanic sedimentary sequence.

It is possible that the unconformities have originated from movement along the Las Vegas Shear Zone (LVSZ), which was active as a right-lateral strike-slip by 12 Ma. South of Mercury, the LVSZ steps west (left), forming a restraining bend. Movement along this left-step restraining bend caused transpression to occur, resulting in uplift and inversion of sediments. Subsequently, these events caused folding and faulting, and led to substantial erosion of Miocene basin deposits. In places, the uplift brought Paleozoic rocks (Antelope Valley, Pogonip, Carrara, Bonanza King) to the surface. North of Lathrop Wells, the LVVSZ's strike-slip strain was partitioned abruptly into a pull-apart basin along the north striking Gravity fault. Crater Flat and Yucca Mountain occupy the area that accommodated extension during transtension.

Several stratigraphic sections southeast and east of the southwestern Nevada volcanic field show early Miocene clastic rocks that must have accumulated in an early Miocene continental basin. Two areas of outcrops occur: 1) The larger, informally designated "Mercury Basin", is approximately 35 km long and 12 km wide extending east from the western edge of Skull Mountain to the western edge of the Ranger Mountains. 2) A smaller, 10 km by 6 km Early Miocene basin, "Little Mercury Basin", adjoins Mercury Basin on the west, and encompasses the Little Skull Mountain region.

Outcrops of Oligocene-Miocene Horse Spring Formation and Miocene Rocks of Pavits Springs are the major units that distinguish former basins. These rocks provide evidence of probable older extension. The basins were deepest near the Camp Desert Rock area, approximately 700 meters deep as indicated by the thickness of the uplifted, exposed Tertiary strata. They shallow both to the east and west where the basin boundaries are inferred. Folds and dipping beds record contraction that may be related to basin inversion as proposed by Cole and Cashman (1999).

Near the latitude of Las Vegas, Horse Spring Formation consists of four members. The lowest, Rainbow Gardens Member, accumulated between 26-18 Ma and has been correlated with the Amargosa Valley Formation found exposed in other parts of the Central Great Basin (Cemen et al., 1999). This member includes clastic sedimentary rocks of varied grain sizes, from conglomerate to claystone, as well as numerous interbeds of carbonate, evaporite, and chert. Conglomerate generally occurs at the base, and carbonate beds are most abundant in the uppermost parts. The Thumb Member overlies the Rainbow Gardens Member, and was deposited between 17.2-13.5 Ma. It is mainly clastic, comprised of conglomerate, breccia, sandstone, and siltstone, but gypsum and carbonate may crop out at some localities. The overlying Bitter Ridge Limestone Member that accumulated between 13.5-13 Ma is mainly, light-brown, yellow, and pale-pink crystalline limestone. The uppermost member of the Horse Spring Formation is the Lovell Wash Member that accumulated between 13-11.9 Ma, is composed mainly of white limestone and dolomite, gray and white claystone, gray and brown tuff, tuffaceous

sandstone and arenaceous tuff (Bohannon, 1984). The Horse Spring Formation within the Mercury Basin corresponds loosely with the formations occurring near Las Vegas. It is composed of conglomerate in the basal part that contains thin interbeds of fine ash-rich sediment that may be calcareous. The coarse basal units are overlain by argillaceous limestone with lenses of conglomerate and bedded tuff (potassium-argon dated at 29.3 =/- 0.9Ma). Within the Mercury Basins, the Horse Springs Formation lies unconformably over Cambrian and Devonian rock formations.

The members of the Rocks of Pavits Spring are not as well defined. This formation accumulated between 18.3-15.8 Ma and is comprised of conglomerate and conglomeratic sandstone, sandstone and zeolitic tuff, ash flow-tuff, interbedded limestone, tuffaceous claystone, siltstone, and sandstone, siltstone and sandstone, and limestone and tuff.

MAGNETIC ANOMALIES

Offsets of magnetic rocks along faults may create magnetic anomalies where magnetic rocks are juxtaposed against less magnetic units. Through conducting an aeromagnetic survey of the Amargosa Desert and surrounding areas, these magnetic fields or anomalies have been detected.

Rocks beneath the southwest Nevada volcanic field (SWNVF) produce magnetic anomalies with high amplitude and short wavelengths. These anomalies are attributed to the Paleozoic Eleana Formation and Precambrian rocks, such as the Wood Canyon Formation, that are magnetic. The alluvial deposits and alluvium-filled basins that cover most of the surveyed area are relatively nonmagnetic, thus anomalies detected over the alluvium are likely to have originated from volcanic or other magnetic rocks at depth.

Three major magnetic lineations trending easterly across the volcanic field may indicate the presence of faulted magnetic rocks. The strongest anomaly (X1) corresponds to the southern margin of the SWNVF. Additionally, most of the north- to northeast-striking lineaments to the north terminate at this lineament. X2 and X3 are postulated to record faults that displace Eleana Formation, Precambrian basement rocks, or Cretaceous-Tertiary intrusions such as the Wahmonie granodiorite. X2 and X3 discontinuities do not disrupt the north- to northeast- striking lineaments, thus they are older than the overlying volcanic material (Blakely, 2000). We speculate that X1 merges with X2 and extends eastward as does X3. X2 may coincide with the northern margin of the postulated early Miocene basins, identified as Mercury Basin and Little Mercury Basin. A major left-step in the Las Vegas Valley Shear Zone (LVVSZ) corresponds with the southern margin of these extensional basins (prior to transpression). The X2 lineament may have been a pre-Cenozoic fault reactivated in the Miocene Epoch.