
# Nye County Local and Regional Structural Geology Annual Report for Fiscal Year 2002

NWRPO-2003-02

*Prepared for*
Nye County Department of Natural Resources and Federal Facilities,
Nuclear Waste Repository Project Office, Grant No. DE-FC28-02RW12163

*Prepared by*
Thomas H. Anderson
University of Pittsburg

February 2004

This report was prepared by the Nye County Department of Natural Resources and Federal Facilities, Nuclear Waste Repository Project Office, pursuant to a Cooperative Agreement funded by the U.S. Department of Energy, and neither Nye County nor any of its contractors or subcontractors nor the U.S. Department of Energy, nor any person acting on behalf of either, assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Department of Energy or Nye County. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Department of Energy.

## CONTENTS



## FIGURES

## APPENDICES



## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| km | kilometer |
| $km^2$ | square kilometer |
| LVVSZ | Las Vegas Valley shear zone |
| Ma | million years ago |
| NWRPO | Nuclear Waste Repository Project Office |
| RVF | Rock Valley Fault |

## 1.0 INTRODUCTION

This annual report summarizes the continuation of studies of local and regional structural geology in Nye County conducted from April 2002 through March 2003 (fiscal year 2002) as part of the Nuclear Waste Repository Project Office (NWRPO) Independent Scientific Investigation Program. During this time, structures were studied to identify and delineate those with the greatest potential to influence groundwater flow paths toward Amargosa Valley, especially from the proposed Yucca Mountain high-level nuclear radioactive waste repository and/or the Yucca and Frenchman Flat nuclear bomb test areas. Field studies and structural analysis focused on the Las Vegas Valley shear zone (LVVSZ), a major, regional, right-lateral strike slip fault along which several tens of kilometers (km) of displacement are postulated to have occurred. The LVVSZ is postulated to bend westward south of Mercury, Nevada, and extend westward to link to the Yucca Mountain area, where a northward bend in the fault led to the formation of a structural (i.e., pull-apart) basin. This co-genetic system of faults has the potential to exert important, if not principal, control on groundwater flow. Estimates of offset along the shear zone range from 40 to 74 km. Barnes and others (1982) report 40 to 64 km of offset, based on the Ross and Longwell (1964) study of Ordovician stratigraphy. Fleck (1970) estimated 74 km of displacement, based on an offset of isopach data for the Precambrian Stirling Quartzite, 30 km of which is attributed to strike-slip movement and the remaining from oroflexural bending (Barnes et al., 1982).

The trace of the LVVSZ has not been delineated north of Mercury (Barnes et al., 1982). Burchfiel (1965) shows an inferred extension that bends to the west in the direction of the Highway 95 Fault, a major fault that forms the southern boundary of the volcanic rocks of the proposed repository site. The Highway 95 Fault is an important structure, as indicated by field studies of ancient spring deposits near its trace and the juxtaposition of different lithologies across the fault, as indicated by data from Nye County Early Warning Drilling Program wells.

INTENTIONALLY LEFT BLANK

# 2.0 STRUCTURAL INVESTIGATION OF THE WESTERN ROCK VALLEY AND SPECTER RANGE REGION

## 2.1 Activities and Products

Activities performed during fiscal year 2002 included field mapping and reconnaissance, coupled with performing a structural analysis of pre-existing maps, guiding a field trip, and participating in three conferences involving the preparation and presentation of two posters and two lectures.

### 2.1.1 Field Mapping and Reconnaissance

Near the end of 2001, mapping along Jackass Flats Road between Skull Mountain and the Specter Range (Figure 1) revealed previously unrecognized folds in Miocene rocks of Pavits Spring and underlying, older, early Miocene rocks of Winapi Wash that lithologically resemble carbonate units of Horse Springs, as described by Bohannon (1984) (Figure 2).

In 2002, field mapping was extended south to include a portion the Specter Range (Figure 3). Fieldwork performed during 2002 included the following tasks:

- Gathering structural data from rocks along the contact between supposed early Miocene beds (i.e., Horse Spring equivalents) and underlying Cambrian strata.
- Gaining familiarity with Paleozoic formations and the structures they contain within the Specter Range.
- Establishing structural relationships between the Striped Hills and nearby rock bodies within Little Skull Mountain and the Specter Range.

Map analysis and field data interpretation included the following results:

- Recognition and characterization of structures interpreted to relate to displacement along the LVVSZ.
- The formation of a model for the deformation co-genetic with faulting along the LVVSZ in the region of study.
- Development of the history of deformation during post-early Miocene displacement along the LVVSZ.
- Delineation of fault zones within rocks that may be especially porous and permeable.

### 2.1.2 Field Trip

A field trip and brief field guide were prepared with the goal of familiarizing the NWRPO team with rocks and geological field relations along Jackass Flats Road in the southwestern part of the Nevada Test Site (Appendix A). Fifteen participants attended the trip on May 31, 2002, after attending a Devil's Hole workshop in Pahrump, Nevada.

### 2.1.3 Scientific Outreach

Presentations were made at three public meetings, including a regional technical workshop and two national meetings of scientific societies. These presentations are described in Appendices B and C.

## 2.2 Results from Field Studies

Rocks within the region between Skull Mountain and Highway 95, along the southern margin of the Specter Range, record ductile and brittle structures that could be attributed to contraction along a constraining bend of the LVVSZ during Miocene time. Structures such as folds, stratigraphic detachments, brecciation, and thrust, left-lateral strike-slip, and normal faults may be attributed to transpression at the constraining bend.

### 2.2.1 Folds

East-trending folds recorded in rocks of Pavits Spring and Winapi Wash and probable older units are shown on Figure 2. Figure 4 is a working cross section of Miocene strata exposed in western Rock Valley west of the north-trending segment of Jackass Flats Road south of Skull Mountain. The schematic section illustrates the asymmetry of some of the folds, some of which are interpreted to be almost contemporaneous with deposition. Sargent and Stewart (1971) and Maldonado (1985) mapped some folds in Tertiary strata in the region but did not attribute them to the transpressional contraction that inverted Tertiary strata exposed northeast of Mercury and westward along the axis of Rock Valley. These Tertiary beds overlie lower Paleozoic strata with a gentle angular unconformity, as revealed in exposures north of Mercury. In contrast, several km west, where Jackass Flats Road bends north, northeast of the Striped Hills, steep dips are recorded locally by carbonate beds that generally occur low in sections of early Miocene strata (Figure 5). The strike and dip of these steeply upturned Tertiary strata, similar to those of Cambrian beds east of the Striped Hills, are interpreted as an indication that tilting of the Tertiary and Paleozoic sections was likely co-genetic. It is speculated that the rocks of the Striped Hills were emplaced as a hanging wall onto Paleozoic strata in Mesozoic time, as inferred by the map in Sargent and Stewart (1971). It is believed that, during Tertiary contraction, the detached Paleozoic strata in the hanging wall were peeled up from the underlying thrust and folded along with the overlying Tertiary beds. The steeply dipping strata of the folded hanging wall also crop out in hills northeast of the main body of the Striped Hills, although within a few km they disappear beneath Miocene beds.

Gentle folds and irregular bed geometries that have been mapped in units as young as the Timber Mountain Group by Maldonado (1985) are evidence that contraction continued contemporaneously with volcanism until about 10 million years ago (Ma). Contraction recorded by folds is not evident in units younger than 10 Ma, suggesting a cessation of transpression related to strike-slip movement along the LVVSZ.

### 2.2.2 Stratigraphic Detachments

Detachments along layering in the Cambrian carbonate strata have been mapped in the northeastern portion of Specter Range, as shown on Figures 6 and 7 (Sargent and Stewart, 1971). The detachments occur principally along gently dipping bedding planes within the Bonanza King

formation. It is proposed that the detachments may have formed as the northern Spring Mountains block moved northward against the southern flank of the Tertiary basin. Sediments in the basin were folded, and the basin uplifted (i.e., inverted). Southward-directed detachments (Sargent and Stewart, 1971) and the Specter Range thrust (Burchfiel, 1965) record the southern part of an inferred positive flower structure above the zone of strong contraction along the constraining bend of the LVVSZ.

### 2.2.3 Brecciation

Extensive brecciation also characterizes the detached beds of the Bonanza King formation and locally other units in the northeastern portion of Specter Range throughout an area of approximately 20 square kilometers ($km^2$) (Figure 7). This extensive brecciation among the detached competent carbonate strata records brittle deformation associated with low confining pressure stemming from the shallow depth of the units at the time of deformation.

### 2.2.4 Thrust Faults

A major thrust occurs in the Specter Range. The Specter Range thrust strikes east-northeast and places Cambrian strata onto Siluro-Devonian formations (Figure 6) (Sargent and Stewart, 1971). According to mapping by Sargent and Stewart (1971), the Specter Range thrust has a minimum heave of approximately 1.5 km. Steeply dipping Cambrian beds record folding in a klippe of the hanging wall. It is postulated that thrusts, similarly oriented, in the northern Spring Mountains record Tertiary contraction (Abolins, 1999). The westerly trend of the outcrop trace of the Specter Range thrust is parallel to the trends of folds in Tertiary strata and indicates its probable age or reactivation of a Mesozoic structure during Tertiary contraction.

### 2.2.5 Left-Lateral Strike-Slip Faults

Five faults that strike northeasterly and record left-lateral separation of formation contacts are present within the Specter Range (Figure 6). These faults cut the shallow detachments that are inferred to have formed during contraction of brittle, shallow carbonate strata of the Bonanza King Formation and some steeper faults in the hanging wall of the Specter Range thrust. Based on the crosscutting relations, these left-lateral faults may be among the latest fault structures associated with simple shear deformation along the LVVSZ. The left-lateral strike-slip faults may be interpreted as escape faults that record the effects of late contraction during which the hanging wall began to splinter and extrude southwestward . Displacements of 100 to 750 m along individual faults are estimated, based on offsets of truncated faults and stratigraphic contacts interpreted from the map of Sargent and Stewart (1971).

### 2.2.6 Rock Valley Fault and Associated Normal Faults

The northeast-striking Rock Valley Fault (RVF) set (Figure 7), is postulated to accommodate approximately 4 km (O'Leary, 2000) of left-lateral displacement (Figure 8) although much of its inferred trace is concealed. The RVF may cut and displace the LVVSZ constraining bend. The development of the RVF may indicate the initiation of northeast-striking, left-lateral, strike-slip faults that signal the transition from simple to pure shear strain among rocks within the region.

### 2.2.7 Mesozoic Features

Few Mesozoic features are recognized within the region of study. A Mesozoic thrust is inferred (Sargent and Stewart, 1971) to coincide with the trace of the southern part of the RVF (Figure 7). The basis for this inferred thrust is the presence of Cambro-Ordovician carbonate strata exposed in the Striped Hills, interpreted by Sargent and Stewart (1971) to have been emplaced onto correlative strata in the westernmost Specter Range. Abolins (1999) documents folds south of Highway 95 with northerly trending fold hinges. These fold hinges are recorded by strata in the footwall beneath the inferred Mesozoic thrust, which suggests eastward-directed transport consistent with northerly trending outcrop traces of regional Mesozoic thrusts.

The trace of the Mesozoic thrust inferred by Sargent and Stewart (1971) does not trend northerly. The northeasterly trend of the trace of the thrust, parallel to the trend of the inferred southwest extension of the RVF, probably reflects the effects of two episodes of Tertiary deformation imposed upon the Mesozoic structure: 1) contraction, during which the strata of the Striped Hills, composing the hanging wall of the thrust, were tilted steeply along with the lowest units of the rocks of Pavits Spring and 2) truncation by the RVF followed by uplift and erosion so that the inferred trace of the older fault parallels the younger one.

### 2.2.8 Development of the Crater Flat Basin Pull-Apart

Near Lathrop Wells, the LVVSZ is postulated to step to the right (i.e., north) along Fortymile Wash, where faults such as the Gravity and Forty Mile Wash Faults are inferred (Figure 8). The right-step formed a releasing (i.e., transtensional) bend resulting in the formation of a pull-apart basin that coincides with Crater Flat Basin. In simple terms, the development occurred as follows:

- During basin opening, Bare Mountain, bounded on the east by Bare Mountain Fault, moved northwestward relative to Calico Hills, which are bounded on the west by the Gravity Fault, or a similar fault.
- As the Bare Mountain mass moved away from Calico Hills, a right-lateral fault propagated northwestward from the former western terminus of the LVVSZ, near Lathrop Wells. This fault corresponds with the Highway 95 Fault.
- A similar right-lateral strike-slip fault that is assumed to bound the pull-apart basin on its northeast margin is probably buried by volcanic rocks of the Southwest Nevada volcanic field, which erupted through crust thinned during basin opening.

### 2.2.9 Development of Complementary Strike-Slip Fault Sets

After the cessation of strike-slip activity along the LVVSZ, pure shear strain is recorded by normal and complementary strike-slip faults. North-striking normal faults that formed during this event cut volcanic units within the pull-apart (Figure 8), as well as detachments and thrusts within the Specter Range. In addition, as mentioned previously, displacement along the RVF offsets the LVVSZ.

## 3.0 LAS VEGAS VALLEY SHEAR ZONE STRUCTURAL INTERPRETATIONS

The following interpretations are based on both the fieldwork and map analysis described in Section 2.0 and previous work conducted by Lauffer (2000) in the vicinity of Yucca Mountain:

- The LVVSZ bends west near Mercury and is linked to the Highway 95 Fault by means of a left (i.e., constraining) step between Mercury and Lathrop Wells.
- Tens of km of right-lateral displacement along the LVVSZ between Mercury and Lathrop Wells is recorded by folds in Miocene strata (i.e., approximately 25 to 10 Ma). The folds accommodated transpression along a left-step (i.e., constraining) bend in the LVVSZ. The zone, characterized by east-oriented contractional structures, extends tens of km north and south of the inferred principal fault trace.
- Eruption of the volcanic rocks between approximately 16 and 10 Ma that form Crater Flat Basin and Yucca Mountain, and the subsequent development of calderas composing the Southwest Nevada volcanic field occurred contemporaneously with transpression along the LVVSZ to the east.
- Eruption of volcanic rocks and the formation of calderas within Crater Flat Basin are postulated to have formed within a releasing bend of the LVVSZ, when magmatism occurred through thinned crust between approximately 16 and 10 Ma, contemporaneous with displacement along the LVVSZ. The releasing bend is west of, but adjacent to, the constraining step.
- The Highway 95 Fault is part of a regional structure that was probably active during, or possibly before, the early Miocene.
- The Highway 95 Fault between Bare Mountain and Lathrop Wells that forms the southern margin of the Yucca Mountain pull-apart basin accommodated right-lateral slip between approximately 16 and 10 Ma.
- Faulting and strong brittle deformation in carbonate rocks along the restraining bend of the LVVSZ, coupled with subsequent strike-slip faulting along the RVF that transects the restraining bend, have created an unusually porous and permeable body of rock that intervenes along part of the groundwater flow path from Yucca and Frenchman Flats to Amargosa Valley.

The following sequence of youngest to oldest deformation in the western Rock Valley-Specter Range region is proposed:

- Left-lateral displacement along RVF and normal displacements along unnamed north-northeasterly striking faults at releasing steps in the Specter Range.
- Simple LVVSZ transpressional structures:
  - Left-lateral strike-slip faults.
  - Bedding parallel detachments, folds, and thrusts, including the Specter Range thrust.
  - Steep tilting of Paleozoic strata exposed in the Striped Hills and smaller hills to the northeast.

  - Folds in Miocene strata south of Skull and Little Skull Mountain.
- Mesozoic thrust (i.e., north-trending fold hinges in the footwall south of the region of study).

## 4.0 PLANS FOR FUTURE WORK: PRODUCTION OF A PALINSPASTIC MAP

Based on the work described in this report, construction has begun on a palinspastic map of the study area that will show restored deformation in the region, from most-recent features (i.e., Rock Valley) to oldest recorded features (i.e., Mesozoic contraction). These features are shown on Figures 7 and 8. Restoration of the stages of deformation is based on map analysis, field investigation, and previous work conducted in the region by other researchers. The offset of the left-lateral RVF is estimated to be approximately 4 km, based on O'Leary (2000). Left-lateral offset along escape faults associated with the latest stage of simple shear deformation from the LVVSZ will be restored between 40 and 74 km, in addition to tens of km of displacement along the LVVSZ as determined by the best matching piercing points. Restoration of offset along the Mesozoic thrust is difficult because piercing points are unrecognized. As a result, restoration of this deformational stage will be more regional in context.

INTENTIONALLY LEFT BLANK

## 5.0 REFERENCES

Abolins, M.J. 1999. *The Kwichup Spring Thrust in the Northwestern Spring Mountains, Nevada: Implications for Large-Magnitude Extension and the Structure of the Cordilleran Thrust Belt*. Pasadena, California, California Institute of Technology. 143 pp.

Barnes, H., E.B. Ekren, R.L. Cleaves, and D.C. Hedlund. 1982. *Geologic and Tectonic Maps of the Mercury Quadrangle, Nye and Clark Counties, Nevada.* U.S. Geologic Survey I-1197 1:24,000.

Bohannon, R. G., 1984, *Nonmarine sedimentary rocks of Tertiary age in the Lake Mead region, southeastern Nevada and northwestern Arizona.* U. S. Geological Survey Professional Paper 1259, 72 p.

Burchfiel, B.C. 1965. *Structural Geology of the Specter Range Quadrangle, Nevada, and its Regional Significance.* Geological Society of America Bulletin, 76, pp. 175-191.

Cornwall, H.R. 1967. *Preliminary Geologic Map of Southern Nye County, Nye County, Nevada.* U.S. Geological Survey, Open-File Report 67-68.

Fleck, R.J. 1970. *Age and Possible Origin of the Las Vegas Valley Shear Zone, Clark and Nye Counties, Nevada*, [abs.]: Geological Society of America Abstract with Programs, v. 2, no. 5, p. 333.

Lauffer-Aho, Sharon R. 2000. *Fault sets, systems and basins, Yucca Mountain region, Nevada: A geographic information systems-based kinematic analysis.* University of Pittsburgh, Pittsburgh, PA, M.S. thesis (unpublished), 101 p.

Maldonado, F. 1985. *Geologic Map of the Jackass Flats Area.* U.S. Geologic Survey I-1519 1:48,000.

O'Leary, D.W. 2000. *Tectonic Significance of the Rock Valley Fault Zone, Nevada Test Site*. U.S. Geologic Survey Digital Data Series. 13 pp.

Ross, R.J. and C.R. Longwell. 1964. *Paleotectonic Significance of Ordovician Sections South of the Las Vegas Shear Zone, p. C-88-C-93 In*: Ross, R. J., Jr., *Middle and Lower Ordovician Formations in southernmost Nevada and adjacent California.* U.S. Geological Survey Bulletin 1180-C, 101 pp.

Sargent, K.A. and J.H. Stewart. 1971. *Geologic Map of the Specter Range NW Quadrangle Nye County, Nevada.* U.S. Geologic Survey GQ-884 1:24,000.

INTENTIONALLY LEFT BLANK