

MEMORANDUM FOR: Ronald L. Ballard, Chief
 Technical Review Branch
 Division of High-Level Waste Management

FROM: Michael E. Blackford
 Geology/Geophysics Section
 Technical Review Branch, DHLWM

SUBJECT: MEETING REPORT ON "LATE CENOZOIC EVOLUTION OF THE SOUTHERN
 GREAT BASIN: A WORKSHOP"

The subject workshop was held in Reno, Nevada on the campus of the University of Nevada from Monday, November 9, 1987 through Tuesday, November 10, 1987. The workshop was followed by a field trip to various sites in central Nevada where examples of geologic phenomena discussed in the workshop could be observed. The NRC staff attending the meeting were Keith McConnell and myself. This memorandum shall discuss the presentations at workshop on Monday and Tuesday. A report, prepared by Keith McConnell, describing the field trip that took place during the remainder of the week following the meeting, is included as Attachment B.

The workshop was given in a set of nine thematic blocks as indicated in the annotated agenda found in Attachment A. Each block was followed by a period of discussion of the presentations made in in a particular block. Abstracts of some of the presentations were available at the meeting, however proceedings of the meeting together with transcripts of discussions were to be published as an open file report by the Nevada Bureau of Mines and Geology in early 1988. The available abstracts are included in Attachment C.

MB
 Michael E. Blackford
 Geology/Geophysics Section
 Technical Review Branch, DHLWM

Enclosures:
 As stated

cc: P. Justus
 K. McConnell
 C. Abrams

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ATTACHMENT A
Late Cenozoic Evolution of the Southern Great Basin:
A Workshop

Theme: Great Basin Extension: The Geology

Lauren Wright Wrench faulting and normal faulting in the Cenozoic structural framework of the Death Valley region.

Wright's presentation discussed faulting in the Chaos region between the Furnace Creek and Sheephead faults.

Brian Wernicke Neogene extensional tectonism in the Basin and Range province at the latitude of Las Vegas, Nevada.

A palinospatic reconstruction of the terrane between the Sierra Nevada on the west and the Colorado plateau on the east by Wernicke yielded a total opening, in a direction bearing N80W, of 260 kilometers in 15 million years. At this latitude the opening appears to be divided into two regions separated by a central stable region. The western region has opened 65 kilometers while the eastern region has opened 55 kilometers. The average rate of opening would be 17 mm/yr for the total opening.

Bennie Troxel Evidence for right slip along the south Death Valley fault zone.

Investigations of outwash gravels by Troxel from the Avawatz, Owlshhead, and Panamint mountains yields offsets of 24 and 35 kilometers. These offsets could either be synchronous or consequent in which case the total offset would range between 35 and 59 kilometers.

Gary Axen Magnitude and style of Miocene upper crustal extension in the southern Nevada area.

Axen proposed that the extension observed in the eastern region (see Wernicke above) is accommodated by movement on the Morman Peak, Tule Springs, and Castle Cliffs detachment faults. Upthrusting of the western edge of the Colorado plateau is post-Miocene tectonic activity due to denudation and isostatic rebound.

Wanda Taylor and Style and timing of Cenozoic extension in the Dry
John Bartley Lake Valley area, southeast Nevada.

Taylor identified four episodes of tectonism over the last 31 million years which has resulted in a west-dipping detachment known as the Highland-Bristol fault. To the west of the outcrop of the

Highland-Bristol fault are the Ely Springs and Dry Lake Valley faults which dip steeply and may either cut or sole into the Highland-Bristol fault.

Bob Scott Regional tectonic interpretation of the evolution of Cenozoic extensional detachment terranes between the Funeral Mountains and the Calico Hills based on structural and paleomagnetic evidence.

Scott's interpretation of the extensional terranes indicates: a 30 degree rotation of the southern end of Yucca Mountain, uplift of Bare Mountain approximately 11 million years ago, doming of the detachment under Crater Flat extending under Bullfrog Hills, and progressively younger deformation to the west.

Theme: Great Basin Extension: Seismic Reflection and Refraction

T.M. Brocher, Seismic refraction studies in the Great Basin: A
J. McCarthy, review of USGS efforts.
W.D. Mooney,
R.D. Catchings,
E.L. Geist,
C. Jarchow and
W.S. Holbrook

Four crustal studies using seismic methods were discussed: COCORP lines in Death Valley, refraction in the Yucca Mountain vicinity, PACE lines between California and Arizona to study the Basin and Range-Colorado Plateau relationship, and PASSCAL lines in north central Nevada.

Laura Serpa Doming of the lower crust beneath an extensional orogen.

Serpa's interpretation of COCORP lines from Death Valley to the western Mohave indicates the presence of lower crustal doming accompanied by thinning of the crust both toward the Sierra Nevada and toward the Spring mountains.

Theme: Quarternary Faulting in the Walker Lane and Adjacent Region

Jack Stewart Tectonics of the Walker Lane belt, western Great Basin.

Stewart divides the Walker Lane belt into 9 subregions: 3 right lateral, 3 left lateral, and 2 stable subregions. A ninth subregion is an area located in the Coaldale-Excelsior mountains vicinity with structures crosscutting the general trend of the Walker Lane belt.

Marith Reheis and Jay Noller New perspectives on Quaternary faulting in the southern Walker Lane, Nevada.

Review of remote sensing data covering the southern Walker Lane has revealed several newly identified faults, many cutting Quaternary sediments.

Tom Sawyer Late Holocene surface faulting along the northern Death Valley-Furnace Creek fault zone, Fish Lake Valley, California-Nevada.

Stratigraphic relationships in 2 trenches on the DV-FCFZ indicate recurrence intervals on the order of 700 to 1000 years. The trenches are located on the outwash fans of Liedy and Indian Creeks. The following are dates for 3 events observed in each of the trenches:

	Marble Ck.	Indian Ck.
	ypb	ypb
Event 1	140-210	160-230
Event 2	960-1230	970-1210
Event 3	1670-2170	1670-2170

John Bell, Craig dePolo, and Alan Ramelli The 1932 Cedar Mountain earthquake, and its relation to Yucca Mountain.

The 1932 Cedar Mountain earthquake was a mostly right lateral strike-slip event with surface rupture occurring in the Stewart and Monte Cristo valleys within the Walker Lane belt. Its magnitude was 7 1/4. Similarities between the tectonic settings of the site of the Cedar Mountain earthquake and the Yucca Mountain vicinity are similar stress regimes, focal mechanisms, possible conuate relationships between structural trends, and the occurrence of flower structures associated with faults exposed in trenches.

Ron Bruhn Deformation in the Dixie Valley area, west central Nevada.

Bruhn discussed the rheological history of fault rupture using Dixie Valley as a model. The region underwent a period of high fracturing with low shear followed by a period of low fracturing with a high rate of shear. Evidence for this sequence lies in an interpretation of the presence of phyllonites and asperities along the faults.

Bob Smith Paradox and paradigm of normal faulting earthquakes deep vs shallow, listric vs planar, big vs really big.

Seismic reflection data indicate the presence of listric faults that become nearly horizontal a few kilometers below the surface while

evidence from large normal earthquakes seem to occur on planar deep seated faults. Rheological considerations indicate that a narrow seismogenic zone should exist at depths ranging from 4 to 7 kilometers yet large earthquakes nucleate at depths of 10 to 16 kilometers.

Theme: Stress, Faulting, and Rotations

Virgil Frizzell and Application of a refined method for determining
Mary Lou Zoback principal stress orientations in southern Nevada.

Frizzell discussed their studies of Hampel Wash of fault striations; strike-slip striae exhibit bimodal distribution.

Larry Anderson USBR seismotectonic studies in the Lake Mead area

Anderson compared both ends of the Walker Lane- the Pyramid fault in the north with the faults of the Boulder and Gregg basins in the south.

John Geissman, General paleomagnetic applications to late Cenozoic
Mark Hudson, Jim tectonics in the Basin and Range.
Callian, Jim,
Falls, and Steve
Harland

A general review of geomagnetic investigations in the Basin and Range indicates that there has been a pervasive decrease in the counter-clockwise rotation with time to the extent that some clockwise rotation is present.

Theme: Seismicity of the Southern Great Basin

Al Rogers and Characteristics of seismicity in the southern Great
Steve Harmsen Basin of Nevada-California

Rogers presented the general information available in his, or his staff's, open file reports on SGB seismicity. He noted a lack of correlation with geologic structures and a bimodal depth distribution with a null at about 3 to 4 kilometers.

Keith Priestley The 1987 Edgecombe, New Zealand earthquake: A
moderate normal faulting event

Priestley believes this event may be similar to the type of event that might be expected to occur in the Yucca Mountain vicinity. The earthquake, which was accompanied by extensive surface faulting, had a magnitude of 6.3. Accelerations as high as .3g were recorded at a

reservoir 20 kilometers from the epicenter but only 7 kilometers from the nearest surface rupture.

Kenneth Smith, Earthquake clustering in the Mina, Nevada region July
William Walter, and August 1987.
Raul Castro,
Rasool Anoshehpour,
and Keith Priestley

Smith, and others, investigated a tight, 3 kilometer in diameter, cluster of earthquakes that occurred just south of Mina, Nevada and concluded that it is a possible analog to similar clusters that have occurred in Round Valley and Chalfant Valley, California.

Theme: Thermal and Flexural Character of the Crust: Implications

Richard Blakely Estimation and tectonic implications of the
Curie-temperature isotherm of Nevada.

Blakely demonstrated that the Battle Mountain heat flow high and the Eureka low follow the trend of the Nevada seismic belt.

Terry Wallace, The role of preconditioned crust and flexural
Clem Chase, isostasy in the development of Basin and Range
Karen Demsey, and terrain.
Phillip Pearthree

As a hypothesis for the origin of the Basin and Range, Wallace discussed the possibility of an initial upward flexure of a plate compensating for the presence of a buoyant body beneath it, followed by rupture and more rapid uplift. He cited the Sierras as a late stage of this hypothesis.

Theme: Geomorphology, Dating, and Paleoclimates.

John Dohrenwend Rates and patterns of piedmont evolution in the
southwest Basin and Range.

Dohrenwend described several instances in the Basin and Range where erosion and deposition appear to be in balance- surfaces where ancient soils are juxtaposed with recent channels.

John Whitney Dating the Beatty scarp: A comparison of Quaternary
dating techniques.

This talk was not presented.

Emily Taylor Late Quaternary paleoclimate studies- geologic and questions problems.

Taylor presented a review of techniques that are being used to reconstruct the paleoclimate in the Yucca Mountain vicinity including measuring modern climate, modelling carbonate deposits, and coring lake sediments, playas, and marshes.

Theme: Volcanic and Hydrothermal Character of the Southern Great Basin

Eugene Smith Evolution of calc-alkaline igneous rocks during mid-Miocene extension in the Lake Mead area, Nevada and Arizona.

Gene Smith presented a geochemical analysis of the degree of mixing and fractionation of mineralogical elements of igneous rocks derived from plutons in the Lake Mead study area. Using the abundance of tantalum in various mineral suites as an example he demonstrated that relatively low mixing took place during the formation of the Eldorado, Boulder City, and McCulloch plutons and relatively high mixing occurred in the Hoover Dam, Wilson Ridge, and River Mountain plutons.

Mac Roy Jackson, Don Noble, Steve Weiss, and Larry Larson Timber Mountain magmato-thermal event: An intense widespread culmination of magmatic and hydrothermal activity at the SW Nevada volcanic field.

Jackson presented the results of a study of the extent and intensity of the Timber Mountain volcanic activity that occurred about 11 million years ago. He attributes alteration of the pre-Paintbrush tuffs to hydrothermal activity associated with the Timber Mountain volcanic activity.

Theme: Research in the Southern Great Basin: Past, Present, and Future

Ken Fox and Fran Singer Current U.S. Geological Survey research in the southern Great Basin: Location, scope, and potential contribution to understanding of late Cenozoic tectonics of the region.

D. Burton Slemmons and Rich Schweickert Present and proposed research at UNR in tectonics and neotectonics in the southern Great Basin.

The presentations made under this theme of a very general nature, basically reiterating many of the previous presentations. Therefore no comments were noted during their presentation.

ATTACHMENT B
REPORT FROM KEITH MCCONNELL DESCRIBING ACTIVITIES ASSOCIATED
WITH THE NOVEMBER 9 THROUGH NOVEMBER 13 CONFERENCE ON
THE LATE CENOZOIC EVOLUTION OF THE SOUTHERN GREAT BASIN

CONFERENCE SCHEDULE AND ITINERARY:

November 9* & 10 - Workshop on Great Basin geology (see attachment 1).
November 11 - Field conference: major topic was the Cedar Mountain earthquake.
November 12 - Field conference: major topic was the Furnace Creek fault zone.
November 13 - Field conference: major topic was faulting in the Yerington area.

PERSONS PRESENT:

No attendance list was received, however representatives from the State of Nevada, U.S. Geological Survey, Department of Energy, the University of Nevada, other Universities, and private consulting firms were present.

PURPOSE OF CONFERENCE:

As an adjunct to the State of Nevada's geologic investigations related to the high-level waste repository at Yucca Mountain, the University of Nevada, Reno, sponsored this conference on the tectonic evolution of the northern part of the Southern Great Basin (including Yucca Mountain). The U.S. Geological Survey, principal investigator for geology to the Department of Energy's NNWSI project, was a major contributor to this conference.

SUMMARY OF PERTINENT POINTS:

- 1) There appears to be very little correlation between seismicity and range front faults.
 - 2) The seismicity on the NTS is diffuse and cannot be related to specific faults.
 - 3) Detailed investigations of the Cedar Mountain fault zone have been unable to resolve slip-rates. In addition, fault segmentation was noted as a complicating factor in recurrence rate determination.
 - 4) Studies of the Fish Lake Valley fault zone indicate that there is a 5-1 lateral to vertical slip rate ratio and this figure is considered to be conservative.
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* Due to an illness, I was unable to attend the first day of the workshop, however, much of the material covered this day was revisited during the field conferences following the workshop.

5) Studies of the Pyramid Lake fault zone indicate four, post 6700 yr movements and slip-rates of between .5 and 1 mm/yr.

6) Studies in the Mina, NV, area indicate that most earthquake activity is located at the intersection of NE and NW trending fault zones.

7) Recent studies of the Rock Valley fault zone suggest that there is some temporal variation in the orientation of the greatest principal stress.

8) Mineralization in the area of Yucca Mountain is believed to have occurred approximately 9 - 13 Ma.

DETAILED MEETING AND FIELD DESCRIPTION

The following is an outline of pertinent points discussed in what were considered the most significant presentations. The pertinent points for the meeting presentation and field conference are listed in the order that they occurred. Attachment 1 lists the speakers and the titles of their presentation and Attachment 2 contains informal guides to the field conference.

Oral Presentations:

A) Frizzell and Zoback: Presentation on work on the Rock Valley fault zone. Pertinent points discussed include:

1) Their data suggested that there was a local interchange between the maximum and intermediate principle stress directions, however they interpreted the area to be in a predominantly normal faulting stress regime.

2) In the Hemple Wash area, the topographic expression of the Rock Valley fault was established after approximately 4-5 Ma. Holocene faulting in this area is suspected from the distribution of brush lines, but no Holocene material is offset.

3) Normal and strike-slip faults commonly occur along the same trend.

B) Anderson: Presentation on US Bureau of Reclamation seismotectonic investigations. Pertinent points discussed include:

1) Studies of the Pyramid Lake fault zone indicate that there were four post 6700 yr movements which suggest short recurrence rate between high-magnitude events. The slip rate was estimated to be between .5 and 1 mm/yr.

2) The Eldorado fault zone near Lake Mead is the first fault in this area with documented Holocene offset.

C) Rogers and Harmsen: Presentation on the seismicity of the southern Great Basin. Pertinent points discussed include:

1) Seismicity occurs on north-south trending segments of right-lateral strike-slip faults which extend at high-angles into the crust. Focal mechanisms suggest strike-slip movement.

2) Seismicity is not totally consistent with any of the late Cenozoic tectonic models.

3) There is very little correlation between seismicity and range-front faults, although Marith Reheis (USGS) pointed out that the traces of range-front faults are generally not accurately plotted.

4) The 1966 Clover Mountain earthquake was a magnitude 6 event on a north-south trending fault with no apparent surface expression of this event.

D) Priestley: Presentation on the 1987 Edgecombe, New Zealand, earthquake. Pertinent points discussed include:

1) This event had an associated 2 meter vertical offset.

2) Compressional features in the downthrown block caused most of the surface damage.

3) The fault length was approximately 12 km, surface ruptures extended for 15-20km.

E) Smith, Walter, Castro, Anoshepoor and Priestley: Presentation on earthquake clustering in the Mina, NV, region. Pertinent points discussed include:

1) The earthquake was associated with a secondary structure oblique to the range-front.

2) Most of the activity in this area appears to occur at the intersection of northeast and northwest trending structures.

E) Dohrenwend: Presentation on rates of piedmont evolution. Pertinent points discussed include:

1) Volcanic features in Crater Flat are polygenetic and represent multiple eruptions between 1.1 and 1.5 Ma.

2) 4 - 6 m.y. old basalts in the Reveille Range cover the crest and flanks.

E) Taylor: Presentation on late Quaternary paleoclimate studies. Pertinent points discussed include:

1) The Holocene is the last of the major interglacial periods which normally have lasted 15 - 20,000 yrs.

2) She indicates that the design of the repository should be able to withstand a major change in climate.

F) Jackson, Noble, Weiss and Larson: Presentation on hydrothermal activity in southwest Nevada. Pertinent points discussed include:

1) Ages of mineralization are suggested to be between 9 and 13 m.y. based on K-Ar dating of alunite.

2) Magma bodies were not necessarily limited to areas beneath presently recognized calderas. Work in the Bullfrog Hills suggests that a magma body could have extended into this area.

F) Fox and Singer: Presentation on current U.S.G.S. research in the southern Great Basin. Pertinent points discussed include:

1) The surficial geologic map of the Beatty 1:100,000 quadrangle is 99% complete.

2) Bob Scott is compiling a Nevada-Utah sequence of 1:100,000 sheets.

3) Prototype testing of seismic reflection techniques is being done in the Amargosa Desert.

4) Three additional holes will be drilled for in-situ stress measurements.

G) Slemmons and Schweickert: Presentation on state investigations in tectonics. Pertinent points discussed include:

1) Among other things, the state intends to review and analyze the work of the USGS and perform a detailed investigation on the Pahrump fault zone.

Field Conference:

Most of the discussions during the field conference were informal and very specific. Attachment 2 provides detailed information on this part of the trip. Below are listed several of the more interesting facts that were discussed in the field.

A) Depolo, Ramelli and Bell: Southern Part of the 1932 Cedar Mountain Earthquake ruptures, Monte Cristo Valley, Nevada. Pertinent points discussed include:

1) An intermediate stop at the Wassuk range-front fault was held. This fault has had three Holocene movements with the last event 2500 Ya. 1-3 meters of vertical offset was associated with this event.

2) Detailed efforts in the the Cedar Mountain fault zone have, at this stage, been unable to determine slip-rates.

3) The complexity of the orientation and movement patterns observed in surface ruptures for this event suggest that small simple events can develop into larger events by triggering multiple faults.

B) Reheis and Sawyer: Faulting in the Fish Lake Valley area. Pertinent points discussed include:

1) Estimates on the slip rate for the Furnace Creek fault zone in this area are approximately 0.27 mm/yr although the rate could be significantly higher.

2) Sawyer indicated that in his area, the Furnace Creek fault zone has experienced three events in the late Holocene. Cumulative vertical displacement from these three events was 61 cm. Estimated vertical slip rates are from .17 mm/yr to .36 mm/yr.

3) Sawyer estimates that the lateral vs. vertical movement ratio on this part of the Furnace Creek fault zone is 5 to 1.

C) Proffett: Detachment faulting in the Yerington District, NV. Pertinent points discussed include:

1) Low angle normal faults observed in this area were actually high angle range bounding faults when they were active (approximately 18-11 Ma.).

A Workshop

Abstracts submitted

**USBR Seismotectonic studies in the Lake Mead area
Nevada - Arizona**

Larry W. Anderson: Bureau of Reclamation

Major deformation in the Lake Mead area appears to have ceased by about 5 Ma. However, the occurrence of numerous earthquakes ($M \leq 5$) after initial reservoir filling and the presence of Quaternary faults indicates that the region is still under stress. Initial USBR studies have concentrated on faults in the Railroad Pass area (15 km southwest of Hoover Dam) and on the Wheeler fault near Spring Canyon (50 km east of the dam). The results of these limited studies suggest that M_s 6-1/2 - 7-1/2 earthquakes are possible in the area. Future studies will consist of more detailed analysis of Quaternary faulting in the region and possible seismic monitoring.

THE 1932 CEDAR MOUNTAIN EARTHQUAKE
AND ITS RELATIONSHIP TO YUCCA MOUNTAIN

John W. Bell, Craig M. dePolo, and Alan R. Ramelli
Nevada Bureau of Mines and Geology, University of Nevada-Reno

The 1932 Cedar Mountain earthquake ($M_s=7 \frac{1}{4}$) occurred along a fault zone in Stewart and Monte Cristo Valleys in central Nevada, an area lying within the Walker Belt, a broad zone of northwest-trending, right-lateral strike-slip faulting. Surface rupturing associated with the earthquake was predominantly characterized by right-slip on north-south to north-northeast-trending, discontinuous faults distributed through a zone approximately 15 km wide and 60 km long. This rupture pattern is best explained by conjugate faulting within a northwest-trending wrench fault system wherein the 1932 faults would be regarded as synthetic (Riedel) shears, a model proposed in various ways by several other previous investigators.

Detailed surficial mapping and exploratory trenching of selected 1932 ruptures in Monte Cristo Valley indicate that recurrent Quaternary movement has occurred in this zone, with the most recent pre-1932 event possibly being Holocene age. Detailed recurrence interval investigations are in progress. Results of the trenching indicate that movement on north-south-oriented faults is characterized by right-lateral strike-slip displacement. Near-horizontal slickensides and grooves suggest that 15-30 cm of vertical offset and 1-2 m of lateral offset occurred in 1932; these values are consistent with previous estimates of displacement of surface geomorphic features, and in particular agree well with the first-motion focal mechanism studies of Doser (1987). The trenching also shows that the fault trace is marked by a prominent upward splaying, a common feature of strike-slip faults that has been referred to as flower structure.

Similarities between the tectonic settings of the Cedar Mountain and the Yucca Mountain areas are recognized and should be considered in evaluating the potential for large-magnitude strike-slip faulting at Yucca Mountain. These similarities include: stress regimes which have northwest-oriented least principle stress directions; active right-lateral strike-slip faults oriented in a north-south to north-northeast direction; focal mechanisms with north-south nodal planes and right-lateral strike-slip motions; possible conjugate relationships between northwest and north-south-trending structures; and exposures of flower structures along faults in trenches.

Estimation and Tectonic Implications of the Curie-Temperature Isotherm of Nevada

RICHARD J. BLAKELY

U. S. Geological Survey, Menlo Park, CA 94025

A method to estimate the depth-extent of magnetic sources from statistical properties of magnetic anomalies was applied to a statewide compilation of aeromagnetic data from Nevada. Calculated basal depths of magnetic sources have no apparent correlation with the so-called magnetic quiet zone, which trends northerly through the eastern part of the state, or with basin-and-range topography. However, basal depths are in general agreement with heat-flow values and suggest that undulations in average depth to the bottom of magnetic sources may reflect undulations in the Curie-temperature isotherm. A narrow zone of shallow basal depths extends south from the Battle Mountain area along the 118°W meridian to at least latitude 38°N, and corresponds approximately with a north-south zone of historic surface offsets and high-magnitude earthquakes. The coincidence of this narrow zone of shallow basal depths with the Battle Mountain heat-flow anomaly, high lower crustal seismic velocities, attenuated P- and S-wave arrivals, historic faulting, and large earthquakes suggests that they each are related to an active, north-trending spreading zone in this part of the Basin and Range province.

Seismic Refraction Studies in the Great Basin:
A Review of USGS Efforts

T. M. Brocher, J. McCarthy, W. D. Mooney,
R. D. Catchings, E. L. Geist
(USGS, 345 Middlefield Road - MS 977,
Menlo Park, CA 94025)

C. Jarchow and W. S. Holbrook
(Dept. of Geophysics, Stanford University,
Stanford, CA 94325)

Seismic refraction studies conducted in SE California, central and SW Nevada, and W. Arizona by the USGS within the last 7 years have recently been supplemented by high-quality reflection profiles acquired by other investigators. Highlights from these studies include: the detection and mapping of shallow subhorizontal detachment surfaces; the importance of normal faulting during rifting; the occurrence of localized volcanism and its relation to Miocene extension; the correlation of mid-crustal reflectors with high-velocity rocks, possibly mafic intrusives related to rifting; a surprisingly thick (32-35km) crust in central Nevada and thinner (26-30km) crust in SE California and Arizona; and in addition, the depth to the Moho is relatively constant for several tens of km in the Great Basin, in contrast to the Basin and Range morphology observed at the surface.

Rates and patterns of piedmont evolution in the southwest Basin and Range

John C. Dohrenwend: U.S.G.S., Menlo Park.

Average long-term erosion rates in the southwest Basin and Range commonly range between 1 and 4 cm/10³ yr in upland areas and systematically decrease in a basinward direction. Middle piedmont areas in a variety of tectonic settings have changed little, remaining for millions of years in approximate geomorphic adjustment. Thus many of the region's piedmonts have been effected only superficially by Quaternary processes and are underlain by deposits of considerable antiquity.

Application of a refined method for determining principal stress orientations in southern Nevada

Virgill Frizzell and Mary Lou Zoback: U.S.G.S., Flagstaff, and Menlo Park.

Quantitative analysis of lineations on faults in a small area of southern Nevada yields a normal faulting stress regime with a N60°W least horizontal principal stress direction consistent with those inferred from other techniques. such analysis is a powerful tool for determining stress orientations where the results from other techniques are sparse or lacking.