Lawrence Livermore National Laboratory

NUCLEAR SYSTEMS SAFETY PROGRAM

L-196

December 22, 1987

Mr. M. E. Blackford, MS-623ss
Project Officer, WMGT
Technical Review Branch
Division of High-Level Management, NMSS
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Transmittal of Trip Report on Tectonic Workshop in Reno, NV 9-10 November 1987.

Reference: A0297

Dear Mr. Blackford:

This is to transmit the subject trip report prepared by H. Larry McKague. The trip report briefly describes the meeting organized jointly by the University of Nevada - Reno and the U.S. Geological Survey. The meeting was important in that many top quality researchers who are not involved in nuclear waste issues presented discussion papers. They provided new points of view and stimulated a number of discussions. We feel that, although several of the talks ranged beyond the Southern Great Basin, they were applicable to seismo-tectonic problems in that area.

If you have any questions, please let us know.

Sincerely yours,

Dae H. (Danny) Chung
Program Manager

DHC/ic
Attachment as stated.

cc: C. Abrams, NRC/WMGT

TRIP REPORT - LATE CENOZOIC EVOLUTION OF THE SOUTHERN GREAT BASIN

A workshop on the late Cenozoic Evolution of the Southern Great Basin was held in Reno, NV, November 9-10, 1987. The two day workshop was followed by a three day fieldtrip, which I did not attend. A mixer was held on the evening of 11/8/87.

The technical presentations were divided into distinct themes. Within each thematic block 3 to 6 presentations were given. After several similar papers were given there was a 20 minute period of open discussion. Abstracts for some of the papers were handed out before the meeting and are included in Appendix A. The University of Nevada-Reno plans to publish some of the papers in an open-file report. Others have already been published (Frizzell and Zoback (Tectonics, v. 6, p-89-96, 1987). Stewart's paper was previously planned to be published in a forthcoming Ruby volume. A description of the Edgecombe earthquake appeared in the Nov. 3, 1987 issue of EOS, although Priestly was not among the authors.

Some of the high points of the meeting included:

Brian Wernicke proposed up to 250 km of extension at the latitude of Las Vegas in the last 15 m.y. Much of this has occurred between the west side of the Spring Mountains and the Panamint Mountains. The analysis was based on using the line formed by the contact between stratigraphic units and cross cutting thrust faults.

Robert Smith again pointed out the fact that most focal mechanisms indicate strike slip, especially on larger earthquakes, while the geology indicates normal faulting predominates. (Bob Scott also discussed this paradox at the fall AGU Meeting. Scott concluded it did not cause a problem for the extension model because strike slip motion and listric faults occurred at different depths. He proposed the detachment surface separated different stress regimes.)

Al Rodgers discussed the data from the U.S.G.S. seismic net in Southern Nevada. His next report (1984? - Seismicity) is in press and will be out soon.

Bob Scott discussed his detachment model for Yucca Mountain. Basically the fault is hinged at its north end and rotated, as indicated by paleomagnetic data, at its south end. The direction of movement is WNW. This whole concept may be valid, but many of the arguments are arm waving and some lines of evidence can be used to support other models. This whole concept needs a hard critical look.

Late Cenozoic Evolution of the Southern Great Basin: A Workshop

Speaker Schedule

Presentations will be given in thematic blocks, followed by extended periods of discussion. We hope that this format will focus discussion around a theme, rather than individual talks. The discussion will be led by a designated neutral participant.

Coffee and refreshments will be available all the time, and so there will be no designated coffee breaks. We will try to break for lunch by 11:30 (in order to beat the student rush) and return by 1:00.

Each speaker will be given 20 to 30 minutes to present their material; after 25 minutes the sound of a small bell will echo through the room heralding the end of the lecture.

Abstracts that were submitted by authors (in their various forms) are attached. Proceedings of the meeting (including transcripts of discussion) will be published as an open file report by the Nevada Bureau of Mines and Geology, and will be available in the early part of 1988.

Monday, November 9, 1987

8:00 am D. Burton Slemmons and Michael Ellis
Opening remarks

Theme: Great Basin Extension: The Geology

Lauren Wright	Wrench faulting and normal faulting in the Cenozoic structural framework of the Death Valley region.
Brian Wernicke	Neogene extensional tectonism in the Basin and Range province at the latitude of Las Vegas, Nevada.
Bennie Troxel	Evidence for right slip along the south Death Valley fault zone.

Discussion

Gary Axen	Magnitude and style of Miocene upper crustal extension in the southern Nevada area.
Wanda Taylor and John Bartley	Style and timing of Cenozoic extension in the Dry Lake Valley area, southeast Nevada.
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.

Discussion

Theme: Great Basin Extension: Seismic Reflection and Refraction

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

Laura Serpa — Doming of the lower crust beneath an extensional orogen?

Discussion

(cont.)

Theme: Quaternary Faulting in the Walker Lane and Adjacent Region

Jack Stewart — Tectonics of the Walker Lane belt, western Great Basin. → TO BE PUBL IN A RUBY VOLUME

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

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

Discussion

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

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

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

Tuesday, November 10, 1987

Theme: Stress, Faulting, and Rotations

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

Larry Anderson — USBR seismotectonic studies in the Lake Mead area Nevada-Arizona.

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

Discussion

Theme: Seismicity of the Southern Great Basin

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

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

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

Discussion

Theme: Thermal and Flexural Character of the Crust: Implications

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

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

Discussion

Theme: Geomorphology, Dating, and Paleoclimates

John Dohrenwend	Rates and patterns of piedmont evolution in the southwest Basin and Range.
John Whitney (NOT GIVEN)	Dating the Beatty scarp: A comparison of Quaternary dating techniques.
Emily Taylor	Late Quaternary paleoclimate studies--geologic problems and questions.

Discussion

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.
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.

Discussion

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.

D. Burton Slemmons: Closing Remarks

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Note: Field trip participants: We will meet in the Alumni Room, Jot Travis Student Center, on Tuesday evening to informally discuss the geology and logistics of the trip. The time will be announced in the day.

Field Trip Logistics

The field trip will be leaving from the back of the New Mines Building at 7.30 am, and the Ramada Inn at 8 am. You may choose which place to be at the appropriate time. The first day is to be led by John Bell, Alan Ramelli, and Craig dePolo, and will be spent looking at the effects of the 1932 Cedar Mountain earthquake.

The first night will be spent in Tonopah in either the Mizpah or Butler Hotel. We will leave Tonopah by 7.30 am the following morning. Tom Sawyer and Marith Reheis will lead the trip on Thursday to the Furnace Creek fault zone. There may be stops en route to look at signs of active faulting.

The second night will be spent in Hawthorne at the El Capitan Best Western, and again we will leave the next morning at 7.30 am. Hal Bonham and Jack Stewart (and possibly John Proffett) will lead the third and final day to look at the Tertiary detachments around Yerington, Nevada.

We hope to arrive in Reno before 8 pm.

The cost of the trip is $75 and includes lodging and a packed lunch each day plus liquid refreshments en route. Payment for the field trip must be made before Tuesday lunch. Checks should be payable to Michael A. Ellis.

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

Laura Serpa — Doming of the lower crust beneath an extensional orogen?

Discussion

(cont.)

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 (Ms=7 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/10^3 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.

Timber Mountain magmato-thermal event: An intense widespread culmination of magmatic and hydrothermal activity at the SW Nevada volcanic field

Mac Roy Jackson, D. C. Noble, Steve Weiss, and L. T. Larson: University of Nevada-Reno.

Voluminous ash-flow sheets of the Timber Mountain volcanic center are but the most obvious manifestations of a major culmination of the SW Nevada volcanic field about 11 Ma ago. Evidence that magmatic activity of Timber Mtn. age extended well west of the Timber Mtn. - Oasis Valley caldera complex includes rhyolite lavas dated between 10.7 and 11.5 Ma and the tuffs of Fleur de Lis Ranch and Cutoff Road ($\geq$ 9.8 Ma), which are most likely related to vent areas, and possibly a collapse caldera, in the northern Bullfrog Hills.

Hydrothermal systems of the Bullfrog Hills and Tram Ridge, including several epithermal Au-Ag systems, have K-Ar ages equal to or only slightly younger than the Timber Mtn. tuff. Hydrothermal alteration at the Calico Hills affected the 13.4 Ma Topopah Springs Member. The areally extensive Timber Mtn. magmatic system also drove a major (laterally moving?) hydrothermal system that caused alteration dated at about 11 Ma (K-Ar, illite-smectite) in pre-Paintbrush Tuffs beneath Yucca mountain, site of the proposed nuclear waste repository site (Aronson and Bush, 1987). Much zeolitic and argillic alteration in originally glassy tuffs of the Test Site area may have been caused by magmatically heated meteoritic water in large hydrothermal convection systems rather than by much later, post-volcanic interaction with cool groundwater.

A K-Ar age of 11.3 Ma from muscovite in pre-Tertiary gneisses at bullfrog Mtn. may reflect high heat flow associated with Timber Mtn. magmatism. Subsequently, magmatic activity did not resume until after 8 Ma with the eruption of minor basalt and development of the relatively small outlying basalt-related peralkaline Black Mtn. and Stonewall Mtn. volcanic centers.

Doming of the lower crust beneath an extensional orogen

Laura Serpa: University of New Orleans

COCORP deep seismic reflection data from the Mojave and Death Valley regions provide a cross-section across an extensional orogen. Those data suggest that the lower crust domes beneath the area of rapid extension while the Moho remains relatively flat. In this report, potential causes of the doming and the significance of that doming on crustal models of extensional terranes are discussed.

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

Eugene I. Smith: University of Nevada, Las Vegas

In the Lake Mead area, andesite-dacite stratovolcanoes were separated from their subjacent plutons and transported to the west by detachment faults. The calc-alkaline / alkali-calcic nature of the igneous rocks of the Lake Mead area may be a manifestation of the magma mixing process. Basalts and rhyolites may mechanically mix in various proportions to produce intermediate rock types. The classic bimodal assemblage may only occur where mixing is incomplete or in closed structural situations where different magma types cannot mix.

Earthquake clustering in the Mina, Nevada, region July and August, 1987

Kenneth D. Smith, William A. Walter, Raul R. Castro, Rasool Anooshehpoor, and Keith Priestley: University of Nevada-Reno Seismological Laboratory

A shallow localized cluster of earthquake activity including several M_L 4 events occurred near the town of Mina, Nevada, during the summer of 1987. Focal mechanisms indicate strike slip motion. Activity conforms to a set of faults striking NNE oblique to the main range front fault, the Soda Springs Valley Fault of the northern Walker Lane.

Paradox and Paradigm of Normal Faulting Earthquakes
Deep vs Shallow, Listric vs Planar, Big vs. Really Big

by

Robert B. Smith
University of Utah
Salt Lake City, Utah

October 30, 1987

Idealized models of normal faulting range from planar geometries, that transect the entire crust, to listric faults that flatten at a few kilometers depth. Seismic reflection data in Basin-Range have provided the best subsurface evidence for listric faults. However prestack migrations and true-amplitudes are necessary to resolve these data for proper interpretation. Retrodeformable models of some listric faults from the Basin-Range, interpreted from reflection profiles, suggest that the fault geometry follows the condition of non-vertical simple shear and may require an additional 50% of extension produced from hanging wall deformation.

Moment tensors of active earthquakes in the Basin-Range suggests strain rates, from 10^{-16} to 10^{-17} s^{-1}, with an integrated east-west extension rate of 8-10 mm/yr across the northern Great Basin. Wheras rheologic models for a vertically inhomogeneous crust suggests a surface layer with little strength to depths of 4 km, a brittle layer 5 to 7 km thick that is underlain by a quasi-plastic layer. This model argues for a thin, 4-7 km thick seismogenic layer.

The paradox of normal faulting earthquakes however, is that focal mechanisms of the large, M7+, Basin-Range events suggest planar fault geometries with mid-crustal nucleation depths of 10 to 16 km, well below that depth of flattening of listric faults interpreted from the reflection data. The steeper nodal planes are corroborated by statistics of 30 well-studied normal faulting earthquakes in the western U.S. that showed that showed a range of dips from 40° to 80°.

On the basis of idealized rheologic models it appears that faulting associated with the large normal faulting earthquakes nucleate near the brittle-ductile transition (where shear strains of 10^{-4} s^{-1} must be achieved for brittle failure) then penetrate through the brittle layer to the surface. Evidence from some large normal faulting events in other areas of extension such as the Middle East suggests multiple source functions with later events occurring on low angle, <20°, nodal planes nucleating at the depth of the main shock. Only the 1959 Hebgen Lake event has clear evidence for multiple sources, but suggests dip increasing with depth.

Deviatoric stresses for normal faulting events, compared to thrust events, suggests that corresponding ground motions should be smaller for equivalent magnitude earthquakes. Strong ground motion data of moderate to large normal faulting earthquakes has been analyzed for 35 world-wide events shows, however, that the attenuation of strong ground motion for normal faulting events is not significantly different from standard attenuation curves incorporating strike-slip and thrust earthquakes. However, the distinguishing difference of strong ground motion for normal faulting events, computed from synthetic elastic wave solutions with basin-bounding fault sources, shows not only amplifications due to large impedances between the valley unconsolidated sediments and the hanging wall, but concentrations of strong ground motion on the edges of the basins due to the asymmetry of the valley fill.

Tectonics of the Walker Lane belt, western Great Basin

John H. Stewart: U.S.G.S., Menlo Park.

The Walker Lane belt is a broad northwest -trending zone of diverse topography and structure in the western Great Basin characterized by right- and left-lateral strike-slip faulting. The belt is divided into nine regional blocks, each of which, for the most part, acted independently of adjacent blocks. Strike-slip faults in any one structural block rarely, if ever, extend into an adjacent block. Lateral offsets on individual major faults ranges from a few to perhaps 100 km.

THE ROLE OF PRECONDITIONED CRUST AND FLEXURAL ISOSTASY IN THE DEVELOPMENT OF BASIN AND RANGE TERRAIN

Terry Wallace
Clem Chase
Karen Demsey
Phillip Pearthree

Department of Geosciences
University of Arizona
Tucson, Arizona 87521

One of the paradoxes of the development of the Basin and Range in Nevada is "how do you get such topographically high mountain ranges in an extensional regime?" Preconditioning of the crust and flexural isostasy offer a simple explanation: (1) Density variations are introduced into the crust during an orogenic event, producing a weak crust which is in local Airy compensation. (2) As time passes, the crust strengthens, acquiring elastic-plate-like behavior, and the density loads are compensated regionally by flexure of the plate. (3) If the elastic plate loses structural integrity (for example, during high-angle Basin and Range faulting), the density loads will seek local Airy compensation. This model suggests that there should be "true" uplift of mountain ranges in the Great Basin. The Wassuk Range and Walker Lake in west-central Nevada provide an ideal test of this hypothesis. Using high-stand shorelines of Walker Lake, which are cut by frontal faults, it is possible to constrain the amount of absolute uplift of the Wassuks in the last 13 ka: about 30% of the total vertical displacement is absolute uplift. This is much larger than the percentages observed in the Aegean or Iceland (also extensional environments), suggesting that the Wassuks are actually rising. We will explore the possibility that erosion of the range can be correlated with the earthquake cycle of the frontal fault system.

Neogene extensional tectonism in the Basin and Range Province at the latitude of Las Vegas, Nevada

Brian Wernicke: Harvard University

Westward motion of the Sierra Nevada relative to the Colorado Plateau in the last 15 Ma is probably more than 250 km at the latitude of Las Vegas, giving a minimum average displacement rate of 17 mm/a. This measurement has significant new implications for models of continental extensional tectonism and magmatism.

WM Record File
#02?

WM Project 10, 11, 16
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