YMP 1995c. *Safety and Health Plan.* YMP/90-37, Rev. 02. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. TIC 224308.

YMP 1995d. *Seismic Design Methodology for a Geologic Repository at Yucca Mountain.* Topical Report YMP/TR-003-NP. October 1995. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. TIC 232486.

YMP 1996. *Exploratory Studies Facility Design Requirements.* Project Baseline Document. YMP/CM-0019, REV 2. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. MOL.19960926.0065.

Yokoyama, I. and De la Cruz-Reyna, R.S. 1990. "Precursory Earthquakes of the 1943 Eruption of Paricutin Volcano, Michoacan, Mexico." *Journal of Volcanology and Geothermal Research, 44,* 265-281. Amsterdam, Netherlands: Elsevier Science Publishers. TIC 234990.

Yoshioka, N. and Scholz, C.H. 1989. "Elastic Properties of Contacting Surfaces Under Normal and Shear Loads 2. Comparison of Theory with Experiment." *Journal of Geophysical Research, 94,* 17,691-17,700. Washington, D.C.: American Geophysical Union. TIC 220167.

Young, R.A. 1972. *Water Supply for the Nuclear Rocket Development Station at the U.S. Atomic Energy Commission's Nevada Test Site.* USGS Water-Supply Paper 1938. Denver, Colorado: U.S. Geological Survey. NNA.19870519.0070..

Young, R.A. 1993. "Introduction to the Rietveld Method." The Rietveld Method. *International Union of Crystallography Monographs on Crystallography 5,* 1-38. New York, New York: Oxford University Press. TIC 239271.

Young, S.R.; Morris, A.P.; and Stirewalt, G. 1993. "Geometric Analysis of Alternative Models of Faulting at Yucca Mountain, Nevada, High Level Radioactive Waste Management." *High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26-30, 1993,* 1818-1825, Las Vegas, Nevada. La Grange Park, Illinois: American Nuclear Society. TBD

Youngs, R.R. and Coppersmith, K.J. 1985. "Implications of Fault Slip Rates and Earthquake Recurrence Models to Probabilistic Seismic Hazard Estimates." *Bulletin of the Seismological Society of America, 75* 939-964. El Cerrito, California: Seismological Society of America. TIC 237426.

Youngs, R.R.; Swan, F.H.; Power, M.S.; Schwartz, D.P.; and Green, R.K. 1987. "Probabilistic Analysis of Earthquake Ground Shaking Hazard along the Wasatch Frount, Utah." Gori, P.L. and Hays, W.W., Eds. *Assessment of Regional Earthquake Hazards and Risk Along the Wasatch Front, Utah.* USGS-OFR-87-585m 2m M1-M110. Denver, Colorado: U.S. Geological Survey. NNA.19890829.0270.

Younker, J.L.; Andrews, W.B.; Fasano, G.A.; Herrington, C.C.; Mattson, S.R.; Murray, R.C.; Ballou, L.B.; Revelli, M.A.; DuCharme, A.R.; Shephard, L.E.; Dudley, W.W.; Hoxie, D.T.; Herbst, R.J.; Patera, E.A.; Judd, B.R.; Docka, J.A.; and Rickertsen, L.D. 1992. *Report of the Early Site*

99020400045 - Part 3

Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada. SAIC-91-8000. Las Vegas, Nevada: Science Applications International Corporation. NNA.19910708.0111.

Yount, J.C.; Shroba, R.R.; McMasters, C.R.; Huckins, H.E.; and Rodriguez, R.A. 1987. "Trench Logs from a Strand of the Rock Valley Fault System, Nevada Test Site, Nye County, Nevada." USGS Miscellaneous Field Investigations MF-1824. Denver, Colorado: U.S. Geological Survey. GS930583117441.002; TIC 203093. [NON-Q]

Yudhbir, W.L. and Prinzl, F. 1983. "An Empirical Failue Criterion for Rock Masses." *Proceedings of the 5th Congress of the International Society for Rock Mechanics, B1-B8.* Held in Melbourne, Australia. Rotterdam, Netherlands: A.A Balkema for the International Society for Rock Mechanics. TIC 226278.

Zartman, R.E. and Kwak, L.M. 1993a. *Preliminary Study of Lead Isotopes in the Carbonate-Silica Veins of Trench 14, Yucca Mountain, Nevada.* USGS-OFR-93-690. Denver, Colorado: U.S. Geological Survey. GS930108315215.008; MOL.19941006.0043. [Q]

Zartman, R.E. and Kwak, L.M. 1993b. "Lead Isotope Composition of Late Proterozoic Marine Carbonate Rocks in the Vicinity of Yucca Mountain, Nevada." *High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference, Las Vegas, Nevada, April 26-30, 1993,* 1953-1959. La Grange Park, Illinois: American Nuclear Society. GS930108315212.004; TIC 225938. [Q]

Zelinski, W.P. 1995. *A Subregional Model of Lithologies, Stratigraphy, and Rock Properties Encompassing the Yucca Mountain Project Conceptual Controlled Area, Yucca Mountain, Nevada.* Milestone Number OS32222M12. DT#SNT05070195001.001. Albuquerque, New Mexico: Sandia National Laboratories. MOL.19960517.0088.

Zhang P.; Ellis, M.; Slemmons, D.B.; and Mao, F. 1990. "Right-lateral Displacements and the Holocene Slip Rate Associated with Prehistoric Earthquakes along the Southern Panamint Valley Fault Zone: Implications for Southern Basin and Range Tectonics and Coastal California Deformation." *Journal of Geophysical Research, 95*, 4857-4872. Washington, D.C.: American Geophysical Union. TIC 237567. [NON-Q]

Zhao, L.S. and Helmberger, D.V. 1994. "Source Estimation from Broad-band Regional Seismograms." *Bulletin of Seismological Society of America, 84*, 91-104. El Cerrito, California: Seismological Society of America. TIC 239122. [NON-Q]

Zimmerman, R.M. and Finley, R.E. 1987. *Summary of Geomechanical Measurements Taken in and Around the G-Tunnel Underground Facility, NTS.* SAND86-1015. Albuquerque, New Mexico: Sandia National Laboratories. TIC 202819.

Zimmerman, R.M. and Vollendorf, W.C. 1982. *Geotechnical Field Measurements, G-Tunnel, Nevada Test Site.* SAND81-1971. Albuquerque, New Mexico: Sandia National Laboratories. HQS.1980517.1720.

Zoback, M.L. 1989. "State of Stress and Modern Deformation of the Basin and Range Province." *Journal of Geophysical Research, 94*, 7105-7128. Washington, D.C.: American Geophysical Union. TIC 225191.

Zoback, M.D. and Healy, J.H. 1984. "Friction, Faulting, and In Situ Stress." *Annales Geophysicae, 2, 6*, 689-698. Paris, France: European Geophysical Society, Gauthier-Villars. TIC 234995.

Zoback, M.L. and Zoback, M. 1980. "State of Stress in the Conterminous United States." *Journal of Geophysical Research, 85*, 6113-6158. Washington, D.C.: American Geophysical Union. TIC 218504.

Zoback, M.L.; Anderson, R.E.; and Thompson, G.A. 1981. "Cainozoic Evolution of the State of Stress and Style of Tectonism of the Basin and Range Province of the Western United States." *Philosophical Transactions of the Royal Society of London. Series A, 300*, 407-434. London, England: Royal Society of London. TIC 218137. [NON-Q].

Zogg, W.D. 1994. "Exploration Drilling and Structural Interpretation of the Soda Spring Area, Railroad Valley, Nye County, Nevada." in Schalla, R.Q. and John, E.H., Eds., *Oil Fields of the Great Basin*, 185-196. Reno, Nevada: Nevada Petroleum Society. TIC 211290.

Zreda, M.G.; Phillips, F.M.; Kubik, P.W.; Sharma, P.; and Elmore D. 1993. "Cosmogenic ^{36}Cl Dates for a Young Basaltic Eruption Complex, Lathrop Wells, Nevada." *Geology, 21*, 57-60. Boulder, Colorado: Geological Society of America. TIC 225192.

3.12.2 Codes, Standards, and Regulations

10 CFR Part 60. Energy: Disposal of High-Level Radioactive Wastes in Geologic Repositories. 1997. Licensing Procedures, 1996. TIC 232902.

10 CFR Part 960. Energy: Nuclear Waste Policy Act of 1982; General Guidelines for the Recommendation of Sites for the Nuclear Waste Repositories. TIC 222719.

43 FR 68491-68500. *Offstream Storage of Colorado River Water and Interstate Redemption of Storage Credits in the Lower Division States; proposed rule*. 1997. TBD

Geothermal Steam Act of 1970. 30 USC 23. Mineral Lands and Mining: Geothermal Steam and Associated Geothermal Resources. TBD

Nuclear Waste Policy Amendments Act 1987. Public Law 100-203. Amendments to the Nuclear Waste Policy Act of 1982. TIC 223717.

Water Resource Plan. Southern Nevada Water Authority. January 1996, amended February 1997, February 1998. TBD

State of Nevada 1970. Water Supply for the Future of Southern Nevada, Special Planning Report. Reno, Nevada: State of Nevada, Department of Conservation and Natural Resources, Division of Water Planning. TBD

State of Nevada 1982. Water for Southern Nevada, Water Supply Report 2. Reno, Nevada: State of Nevada, Department of Conservation and Natural Resources, Division of Water Planning. TIC 219196.

State of Nevada 1992. Hydrographic Basin Summaries. Reno, Nevada: State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources and Water Planning. TIC 237049.

ASTM C135-86. *Test Method for True Specific Gravity of Materials by Water Immersion.* 1992. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 224453.

ASTM D854-92. *Standard Test Method for Specific Gravity of Soils.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 224456.

ASTM D2664-86. *Standard Test Method for Triaxial Compressive Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 226769.

ASTM D3148-96. *Standard Test Method for Elastic Moduli of Intact Rock Core Specimens in Uniaxial Compression.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 217302.

ASTM D3967-95. *Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 226771.

ASTM D4406-84. *Standard Test Method for Creep of Cylindrical Rock Core Specimiens in Triaxial Compression.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. MOL.19980625.0334.

ASTM D4535-85. *Standard Test Methods for Measurement of Thermal Expansion of Rock Using a Dilatometer.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 236774.

ASTM D4611-86. *Standard Practice for Specific Heat of Rock and Soil.* 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 236773.

ASTM D4971-89. *Standard Test Method for Determining the In Situ Modulus of Deformation of Rock Using the Diametrically Loaded 76-mm (3-in.) Borehole Jack.* 1991. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 238036.

ASTM E228-85. *Standard Test Method for Linear Thermal Expansion of Solid Materials With a Vitreous Silica Dilatometer*. 1989. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 217284.

ASTM F433-77. *Standard Praactice for Evaluating Thermal Conductivity of Gasket Materials*. 1993. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC 224458.

3.12.3 Procedures

M&O

QAP-2-0, *Conduct of Activities*. MOL.19980826.0209.

OCRWM

YAP-SIII.3Q, *Processing of Technical Data on the Yucca Mountain Site Characterization Project*. MOL.19980807.0208.

Sandia National Laboratories

SNL TP-202, *Measurement of Thermal Conductivity of Geologic Samples by the Guarded-Heat-Flow Meter Method*. NNA.19910724.0006.

SNL TP-203, *Measurement of Thermal Expansion of Geologic Supplies Using a Push Rod Dilatometer*. Cambridge, Massachusettes: Holometrix, Inc. NNA.19900522.0128.

SNL TP-204, *Measurement of Specific Heat of Geologic Samples by Adiabatic Pulse Calorimetry*. Cambridge, Massachusetts: Holometrix, Inc. NNA.19900522.0128.

SNL TP-229, *Bulk Properties Determinations of Tuffaceous Rocks: Dry Bulk Density, Saturated Bulk Density, Average Grain Density, and Porosity*. MOL.19971226.0036.

SNL TP-233, *Geotechnical Logging of Core by Examination of Core and Video Records*. TBD

U.S. Geological Survey

GCP-25, *Determination of Chemical Composition of Energy Dispersive X-ray Fluorescence Spectrometry*. NNA.19930816.0026.

GP-01, *Geologic Mapping*. NNA.19911001.0005; MOL.19980720.0043.

INTENTIONALLY LEFT BLANK

TABLES

Page

3.2-1 Precambrian and Paleozoic Stratigraphic Units of the Yucca Mountain Region T3.2-1
3.2-2 Mesozoic Stratigraphic Units of the Yucca Mountain Region T3.2-2
3.2-3 Tertiary and Quaternary Stratigraphic Units of the Yucca Mountain Region T3.2-3

3.4-1 Comparison of Depositional Units and Related Soils at Yucca Mountain With Local and Regional Surficial Stratigraphies T3.4-1
3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area T3.4-2
3.4-3 General Characteristics of Surfaces and Soils Developed on Surficial Deposits and Geomorphic Surfaces in the Yucca Mountain Area T3.4-15
3.4-4 Quaternary Boundary Ranges Used for the Stratigraphy of the Yucca Mountain Area T3.4-17
3.4-5 Descriptive and Calculated Data for the Cosmogenic 10Be Sample Analyses T3.4-18
3.4-6 Maximum Bedrock Erosion Rates on Yucca Mountain T3.4-19
3.4-7 Varnish Cation Ratio Age Estimates from Boulder Deposits Around Yucca Mountain T3.4-19
3.4-8 Ranges in Calculated Cation Ratio Dates (Revised Calibration) and Cosmogenic Nuclide Dates for the Four Boulder Deposits Around Yucca Mountain T3.4-19

3.5-1 Generalized Descriptions of Pre-Prow Pass Volcanic Rocks at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units T3.5-1
3.5-2 Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units T3.5-4
3.5-3 Primary, Secondary and Tertiary Processes, which Result in Lithologic Features, that Influence Matrix Properties, Geophysical Logs, and Mineral Chemistry. T3.5-16

3.6-1 Summary of Fracture Attributes, Tiva Canyon Tuff T3.6-1
3.6-2 Summary of Fracture Attributes, Lithostratigraphic Units Equivalent to the PTn Hydrologic Unit T3.6-2
3.6-3 Summary of Fracture Attributes, Topopah Spring Tuff T3.6-3
3.6-4 Summary of Fracture Attributes, Calico Hills Formation and Bullfrog Tuff T3.6-4

TABLES (Continued)

		Page
3.6-5	Comparison of Fracture Intensity and Network Geometry, Paintbrush Group, Yucca Mountain, Nevada	T3.6-5
3.6-6	Fracturing Associated with Faults in the Exploratory Studies Facility	T3.6-6
3.7-1	Comparison of Several Stratigraphic Subdivisions of Volcanic Rocks at Yucca Mountain and Encountered on the Yucca Mountain Site Characterization Project (no scale)	T3.7-1
3.7-2	Summary of Core Recovery Data for Tptpmn	T3.7-2
3.7-3	Rock Weathering Descriptions	T3.7-2
3.7-4	Estimated Rock Hardness Descriptions	T3.7-3
3.7-5	Summary of Dry Bulk Density (g/cc), Thermal/Mechanical Units	T3.7-4
3.7-6	Saturated Bulk Density (g/cc) by Thermal/Mechanical Unit	T3.7-7
3.7-7	Summary of Average Grain Density (g/cc), Thermal/Mechanical Units	T3.7-10
3.7-8	Summary of Porosity (Percent), Thermal/Mechanical Units	T3.7-13
3.7-9	Summary of Porosity and Density Measurements from the Thermal Test Facility of the Exploratory Studies Facility (TSw2 Thermal/ Mechanical Unit)	T3.7-16
3.7-10	Petrographic Characterization of NRG-6 Specimens	T3.7-17
3.7-11	Mineral Abundances for 10 Samples from the Single Heater Test Block of the Exploratory Studies Facility	T3.7-21
3.7-12	Mineral Abundances1 for 20 Samples from the Drift Scale Test Block of the Exploratory Studies Facility	T3.7-22
3.7-13	Rock Thermal Conductivities at Temperatures Below 100°C	T3.7-23
3.7-14	Rock Thermal Conductivities at Temperatures Above 100°C	T3.7-23
3.7-15	Thermal Data for Specimens from the Single Heater Test Block (Air Dry)	T3.7-24
3.7-16	Thermal Conductivity Data for Specimens from the DST Block (Saturated)	T3.7-25
3.7-17	Mean Coefficient of Thermal Expansion During Heat-Up	T3.7-26
3.7-18	Mean Coefficient of Thermal Expansion During Cool-Down	T3.7-27
3.7-19	Mean Coefficient of Thermal Expansion for TSw2 Specimens from the Single Heater Test Block	T3.7-28
3.7-20	Mean Coefficient of Thermal Expansion for Drift Scale Test Characterization Borehole Samples (TSw2; Air Dry)	T3.7-29
3.7-21	Thermal Capacitance (Cp) for TSw1 and TSw2 Thermal/Mechanical Units	T3.7-30
3.7-22	Mean and Standard Deviation of Intact Rock Elastic Modulus for Thermal/Mechanical Units and Lithostratigraphic Units	T3.7-31
3.7-23	Mean and Standard Deviation of Intact Rock Poisson's Ratio for Thermal/Mechanical units and Lithostratigraphic Units	T3.7-32
3.7-24	Comparison of the Mean and Standard Deviation of Compressional and Shear Wave Velocities on Dry Specimens—NRG and SD Boreholes	T3.7-33
3.7-25	Mean and Standard Deviation of Uniaxial Compressive Strength for Thermal Mechanical and Lithostratigraph Unit	T3.7-34

TABLES (Continued)

Page

3.7-26 Strength Parameters Calculated from the Confined Compressive Test Results, Stratigraphic Units T3.7-35
3.7-27 Brazilian Tensile Strength for Thermal/Mechanical and Lithostratigraphic Units T3.7-38
3.7-28 Creep Measurements, Borehole USW NRG-7/7A T3.7-39
3.7-29 Summary of Statistical Data for Schmidt Hammer Tests in Thermomechanical Units—NRG Holes T3.7-40
3.7-30 Average Fracture Normal Stiffness at 2.5 MPa Normal Stress for Each of the Four Thermal/Mechanical Units Sampled T3.7-41
3.7-31 Average Shear Strength Parameters for Fractures from Each of the Four Thermal/Mechanical Units Sampled T3.7-41
3.7-32 Peak Shear Stress, Residual Shear Stress, and Applied Normal Stress for Fractures T3.7-42
3.7-33 Geomechanical Classification of Rock Masses Based on Rock Mass Rating T3.7-43
3.7-34 Relative Rock Quality for Ranges of Q T3.7-43
3.7-35 Summary of Rock Mass Quality Values T3.7-44
3.7-36 Exploratory Studies Facility Ground Support Guidelines T3.7-45
3.7-37 Proportion of Tunnel within Each Thermal/Mechanical Unit and Ground Support Guideline for Exploratory Studies Facility Scanline Rock Mass Quality Data to 35+05m T3.7-46
3.7-38 Calculated Rock Mass Thermal Expansion Coefficient from SHT Data through Day 90 ..... T3.7-46
3.7-39 Thermal Expansion Coefficients from SHT Data for Longest Available Gage Lengths, Near, Heating Cycle T3.7-46
3.7-40 Estimated Rock Mass Mechanical Properties for Rock Mass Rating at 40 Percent Cumulative Frequency of Occurrence for Each Thermal/Mechanical Unit T3.7-47
3.7-41 Intact Rock Constants for Rock Mass Strength Criteria T3.7-47
3.7-42 Calculate Rock Mass Modulus in Borehole ESF-TMA-BJ-1 Using the Borehole Jack for the Single Heater Test T3.7-48
3.7-43 Summary of In Situ Stresses at the Repository Horizon T3.7-48
3.7-44 Blast Vibration Limits Specified for Construction of Alcove 2 ..... T3.7-48
3.7-45 Rock Bolt Load Cells, Load Versus Time T3.7-49

3.8-1 Correlation of Descriptive Rock Unit Names, YMP Stratigraphy, and Thermal/Mechanical Units of Ortiz et al. (1985) T3.8-1

3.9-1 Comparison of Potassium-Argon (Fleck et al. 1996) and 40Ar/39Ar Ages T3.9-1
3.9-2 Comparison of Estimated Disruption Probabilities T3.9-1

TABLES (Continued)

Page

3.10-1 Key Milestones for Earthquake Reporting of the Southern Great Basin T3.10-1
3.10-2 Networks Relevant to the Southern Great Basin T3.10-2
3.10-3 Regional Seismicity Catalogs Used For The Yucca Mountain Seismicity Catalog T3.10-3
3.10-4 Estimated Completeness Intervals for the Southern Great Basin T3.10-3
3.10-5 The 1992 Little Skull Mountain Mainshock Source Parameters T3.10-4
3.10-6 Small Magnitude Earthquakes at Yucca Mountain T3.10-5
3.10-7 Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults T3.10-6
3.10-8 Summary of Paleoseismic Data for Quaternary Faults in the Yucca Mountain Area T3.10-20
3.10-9 Preliminary Ages, Rupture Lengths, Displacements, and Magnitudes of Proposed Prehistoric Earthquake Rupture Scenarios at Yucca Mountain T3.10-21
3.10-10 Average Recurrence Intervals and Estimated Magnitudes for Different Recurrence Models Developed for Yucca Mountain Faults T3.10-22
3.10-11 Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region T3.10-23
3.10-12 Seismic Velocity Structure Developed for Thermal-Mechanical Units T3.10-30
3.10-13 Seismic Velocity Structure Developed for Application at Yucca Mountain Repository T3.10-30
3.10-14 Source Parameters for the Little Skull Mountain Earthquake and Two Major Aftershocks T3.10-30
3.10-15 Definition of Earthquake Scenarios T3.10-30
3.10-16 Empirical Attenuation Models Evaluated in the Probabilistic Seismic Hazard Analyses Ground Motion Characterization Study T3.10-31
3.10-17 Form of Attenuation Equations Adopted in PSHA Ground Motion Characterization Study T3.10-32
3.10-18 Mean Ground Motion Hazard at 10-3 and 10-4 Annual Exceedance T3.10-33
3.10-19 Mean Displacement Hazard at Nine Demonstration Sites T3.10-33
3.10-20a The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 km of CAB That Have Been Selected as Credible Independent Sources By at Least One PSHA Expert Team T3.10-34
3.10-20b The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 Km of CAB That Have Not Been Selected as Credible Independent Sources by at Least One PSHA Expert Team T3.10-37

3.11-1a Natural Resources Assessment Summary (Metallic Minerals) T3.11-1
3.11-1b Natural Resources Assessment Summary (Industrial Minerals) T3.11-2
3.11-1c Natural Resources Assessment Summary (Hydrocarbons) T3.11-3

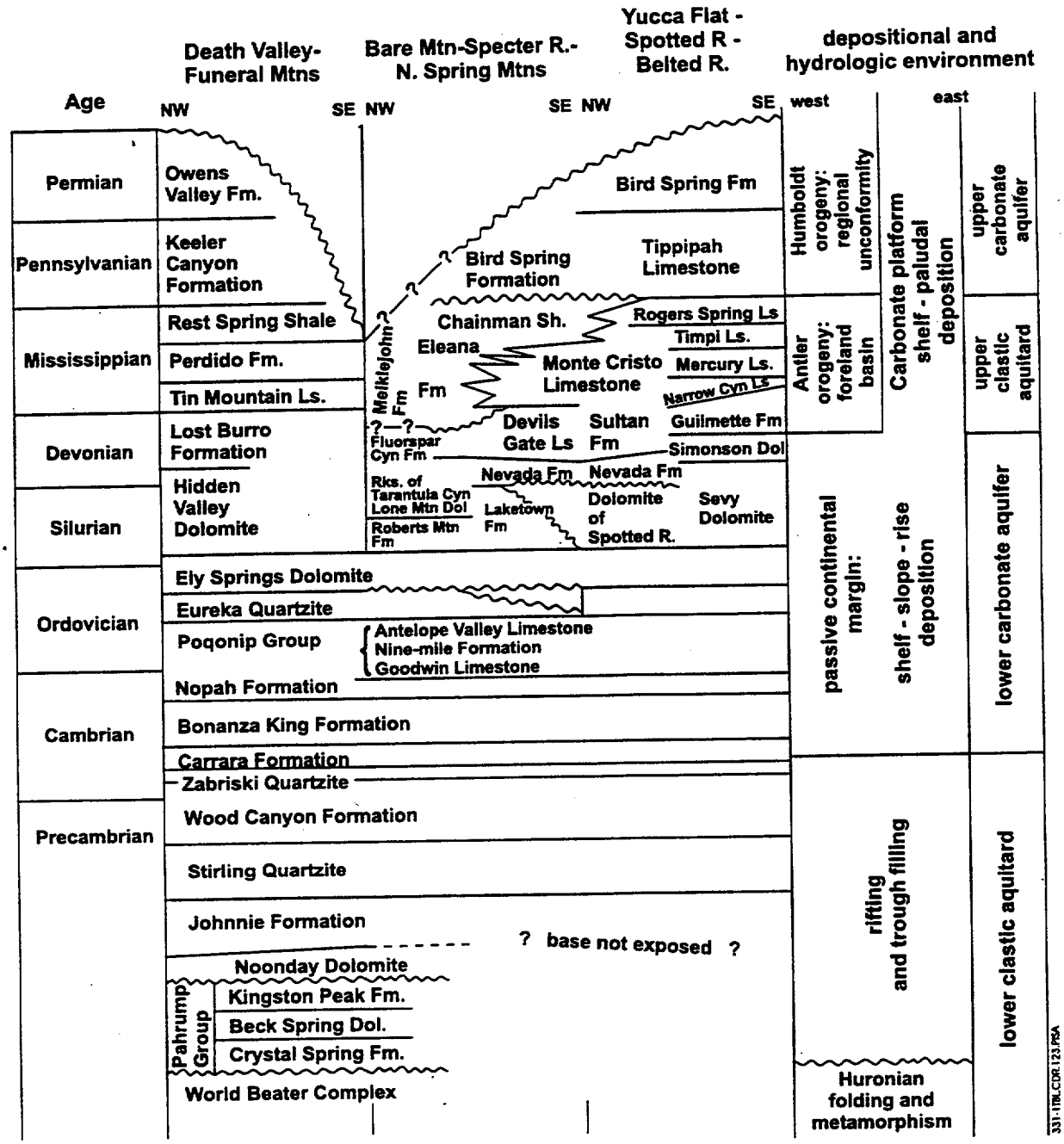
TABLES (Continued)

Page

3.11-1d Natural Resources Assessment Summary (Geothermal) T3.11-4
3.11-2 Surface and Underground Samples Collected From the YMCCA and Surrounding Areas and Mining Districts T3.11-5
3.11-3 Maximum Contents, Prices, and Values for Metallic Commodities in the YMCCA Metal Prices are 1996 Year-End Values from the Journal Metals Week T3.11-5
3.11-4 Summary of Geophysical Techniques Used to Characterize the YMCCA and Surrounding Region T3.11-6
3.11-5 Surface Samples from the YMCCA and Vicinity with 4 ppb or Higher Gold (analyses by USML) or 100 ppb or Higher Mercury (analyses by NBMG) or Both T3.11-7
3.11-6 Selected Trace Element Contents for Samples Near or Below the Tertiary-pre-Tertiary Contact in Borehole UE-25 p 1.; All Analyses by USML, except Ba by ACTLABS and F by NBMG T3.11-8
3.11-7 Geothermal Indications in the Yucca Mountain Area T3.11-9

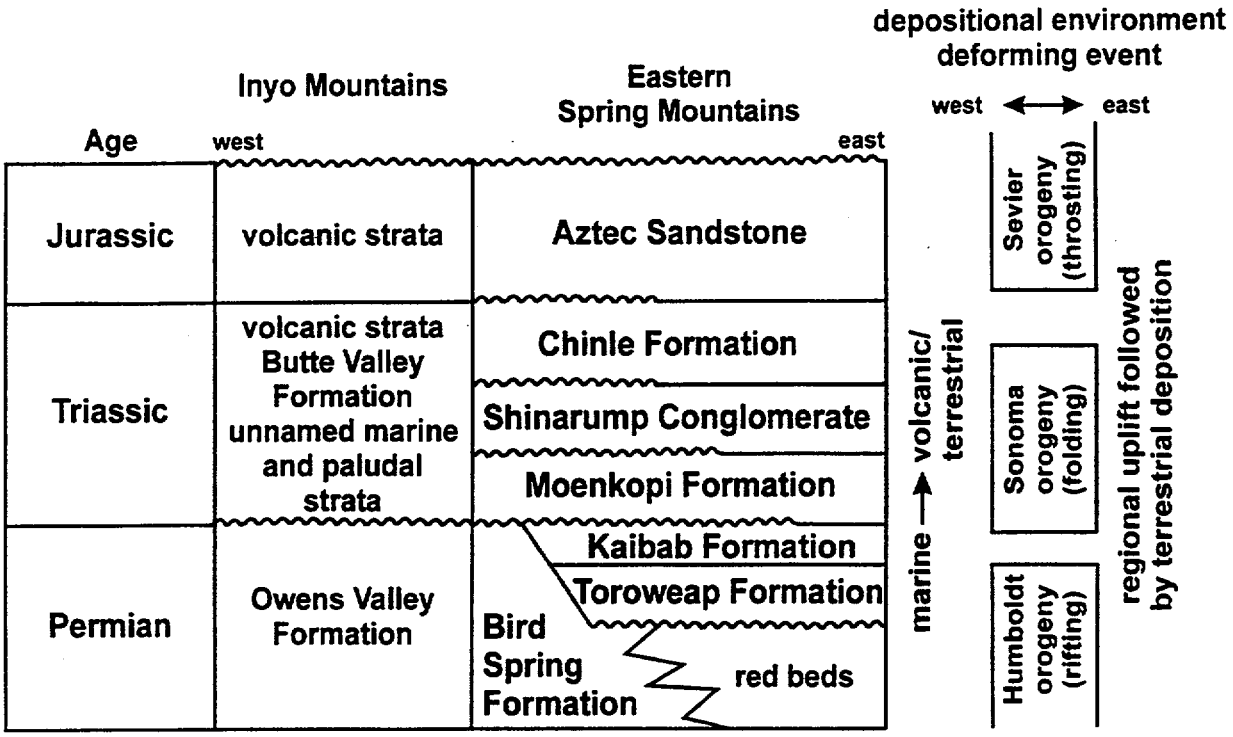
INTENTIONALLY LEFT BLANK

Table 3.2-1. Precambrian and Paleozoic Stratigraphic Units of the Yucca Mountain Region



Hunt and Mabey (1966)
Corbett et al. (1988)
Dunne (1986)
Cemen and Wright (1990)
Burchfiel (1965)
Fleck (1967, 1970)
Burchfiel and Davis (1988)
Monsen et al. (1992)
USGS (1976)
USGS (1984)

Table 3.2-2. Mesozoic Stratigraphic Units of the Yucca Mountain Region



32-2TEL.CDR.123.SITEDESC

Table 3.2-3. Tertiary and Quaternary Stratigraphic Units of the Yucca Mountain Region

Age			AGE GROUPING	UNIT	AGE (Ma)
Plio-Pleisto-cene				**Pliocene and Quaternary Volcanics:** (Interbedded with alluvium)	
				Lathrop Wells cone	0.1
				Bishop Tuff ashfall	0.7
				Crater Flat cinder cones	1.0
				Older Crater Flat flows	3.7
Miocene	late		Rocks of the Southwestern Nevada Volcanic	**Latest Miocene Units:**	
				Late Miocene basin fill	(10-7)
				(locally includes:)	
				Spearhead Tuff	7.5
				Unnamed ashfall	8-8.5
				Thirsty Canyon Tuff	9.4
				Rocks of Rainbow Mountain	10.47
				Rock-avalanche breccia	(10.5)
				Twisted Canyon basalt and tuff	10.7
				Major Volcanic Period (11-14 Ma) Units:	
				Rock-avalanche breccia	(11.5)
				Timber Mountain Group:	
				Ammonia Tanks Tuff	11.45
				Rainier Mesa Tuff	11.6
				Rhyo. of Fluorspar Canyon	11.6-7
				Rock-avalanche breccia	12.6-11.8
				Windy Wash lavas/tuffs	12.5
				Paintbrush Group:	
				Tiva Canyon Tuff	12.7
				Yucca Mountain Tuff	-
				Pah Canyon Tuff	-
				Topopah Spring Tuff	12.8
				Calico Hills Fm. tuffs	12.9
				Wahmonic/Salyer Fms.	13.0
				Crater Flat Group:	
				Prow Pass Tuff	13.1
				Bullfrog Tuff	13.25
				Rhyo. of Prospector Pass	13.35
				Tram Tuff	13.45
				Lithic Ridge Tuff	13.9
				Older tuffs	15.2-14
				(Tuff of Yucca Flat)	15.1
				Pre-Southwest Nevada Volcanic Field Units:	
				Rocks of Pavits Spring	(16-20)
				Joshua Hollow Fm	
				Winapi Wash/Titus Canyon Fm.	(25-30)
				Slide Breccia	?
				Monotony Tuff	27.3
Oligo-cene					

Funeral and Grapevine Mountains, Death Valley Region (Cemen et al. 1985 Wright et al. 1981)

Approx. Age			
3 Ma	Funeral Formation	basalt	
		cgl.	
5 Ma	Furnace Creek Fm (2000 m)	fluvio-lacustrine alluvium	
		local basalts	
6 Ma	Artist Drive Fm (~2500 m)	ss, cgl,	
		volcanics and basalts	
14 Ma	Bat Mtn. Fm	ss, fan - glomerate	
16 Ma	Kelley's Wells Ls (100 m)	ls	Esmeralda Formation (Turner 1900) = rocks of Pavits Spring
20 Ma	Amargosa Valley Fm (800 m)	ls, tuff	
		red ss	
		ls, tuff	Titus Canyon Formation
?25 Ma		cgl.	

INTENTIONALLY LEFT BLANK

Table 3.4-1. Comparison of Depositional Units and Related Soils at Yucca Mountain With Local and Regional Surficial Stratigraphies

Yucca Mountain Area, Nev. (this study)	Lower Colorado River, California-Arizona (Bull and Ku 1975; Ku et al. 1979; Bull 1991)	Yucca Wash, Nevada (Hoover, D.L. 1989; Taylor, E.M. 1986)	Crater Flat, Nevada (Peterson, F.F.1988; Peterson, F.F et al. 1995)	Silver Lake, California (Reheis, Harden et al. 1989; Wells, McFadden et al. 1990b)	Kyle Canyon Fan, Nevada (Reheis, Sowers et al. 1992)	Fish Lake Valley Nevada-California (Slate 1991; Reheis and Sawyer 1997)	Providence Mountains (McDonald and McFadden 1994; Wang et al. 1996)
				Holocene			
Q7 (<0.2)	Q4b (0)	Q1a (0)	Modern (0)	Modern (0)	Q4 (0)	Late Marble Creek (0-0.75 yrs)	Qf8 (0-2.8, <0.1)
Q6 (<1)	Q4a (0.1-2)	Q1b (<0.2)	Crater Flat (0.4-1.5)	Q3b3 (0.5-2.5)		Middle Marble Creek (1-1.6)	Qf7 (0-4.2, ~1)
	Q3c (2-4)			Q3b2 (2.0-4.5)		Early Marble Creek (1.9-5.3)	Qf6 (3-8, 4)
	Q3b (4-8)						
Q5 (2-17)	Q3a (8-12)	Q1c (3-30, ~10)	Little Cones (7-11)	Q3b1 (6-11)	Q3-upper (4-80, 15)	Leidy Creek (6.4-10)	Qf5 (8-18, ~10)
	Pleistocene						
Q4 (30-100)	Q2c (12-70)	Q2b (140-160)	Late Black Cone (>17-30)	Q3a (13-50)	Q3-lower (4-80, 50)	Indian Creek (50-130?)	Qf4 (17-75, ~50)
				Q2b (110-130)			
Q3 (100-250)	Q2b (70-200)	Q2c (270-300)	Early Black Cone (>159-200)	Q2a (140-190)	Q2 (18-750, 130)		Qf3 (29-758, ~150)
Q2 (~400)	Q2a (400-758)		Yucca? (>343-375)	Q1b (>400->650)			
Q1 (500->758)	Q2a (400-758)	QTa (900-2000)	Solitario (>433-<758)	Q1b (>400->650)	Q1 (750-800, 800)	McAfee Creek (600?-758)	Qf2 (29-758, ~600)
Q0 (>758)	Q1 (>1200)	QT (900-2000)		Q1 (>650->800)		Perry Aiken Creek (>758)	Qf1 (758-4000, ~1500)

NOTES: Numbers in parentheses refer to age estimates in thousands of years; number after range is reported preferred age estimate.
Preferred ages for "Yucca Mountain area, Nev (this study)" were determined using scientific judgment and considered all available data, including their reliability and uncertainty.

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area

NOTE: Fault locations are listed from east to west, and trenches from south to north, with the exception of the Stagecoach Road Fault, a northeast trending feature described on the east side of Yucca Mountain. Miscellaneous alluvial and spring deposits, from the west side of Yucca Mountain, are included at the end of the compilation. Samples are in stratigraphic order at a given site, irrespective of age estimates. The description of the material sampled includes the original sample number as it was described in the reference, and the correlation made to the unit Q0-Q7 stratigraphy--abbreviated here as Q0-Q7 and in parentheses if this stratigraphy was not described in the original reference. Stratigraphic boundaries, or units subdivided in the individual trenches, are not correlative between trenches. Where there is a discrepancy in the literature between the reported dates, the most recent reference is used in the compilation. However, frequently the older reference has a clear description and location map of the sample collected. Age estimates are reported with 1 sigma errors with the exception of thermoluminescence (Mahan), U-series (Paces), and ^{14}C and cation-ratio on rock varnish which are reported with 2 sigma errors. U-series age estimates were either determined using an alpha spectrometer (as) or a mass spectrometer (ms).

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Rock Valley Fault (Rock Valley), Trench RV2	Av horizon, E wall (TL-75)	Q5?	7±1	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Platy K horizon (HD 2126)	Q?	Not analyzed	U-series (ms)		
	Base of 3Btkb2 horizon, (TL-74)	Q4?	47±4	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Platy K horizon (HD 2127)	Q4?	70±18	U-series (ms)		Mahan, USGS, written commun. 1992
Rock Valley Fault (Rock Valley), Trench RV-3	Buried Av horizon, W wall (TL-57)	Q5?	11±4, 12±5	TL	Maximum age for most recent tectonic event	Mahan, USGS, written commun. 1992
	Upper platy K horizon, W wall (HD 1812)	Q3	45, 74, 79, 512	U-serie (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Silica-rich clast rind (HD 1954)	Q3	550±270, 367±55	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Silica-rich clast rind (HD 1955)	Q3	106±2, 102±3, 98±2	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
Rock Valley Fault (Rock Valley), Trench RV-4	Buried Av in fault zone, E wall (TL-53)	Q5	2.5±0.5, 1.7±0.5	TL	Minimum age for most recent tectonic event	Pa95
	Rhizolith, S wall (HD 1803, surrounding sand is TL-54)	Q3-4	26.5±0.2	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95
	Sandy lens in alluvium, below erosional unconformity (TL-54, rhizolith in lens is HD 1803)	Q3-4	88±72, 92±62	TL	Time when material was last exposed to sunlight	Pa95
	Opaline silica stringer in K horizon, S wall (HD 1805, equivalent to HD 1806)	Q3-4	16.4±0.3	U-series (ms)	opaline silica	
	Matrix K horizon, S wall (HD 1806, equivalent to HD 1805)	Q3-4	Not analyzed	U-series (ms)	opaline silica	
	Opal rind on volcanic clast in K horizon, S wall (HD 1804)	Q3-4	Not analyzed	U-series		

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Rock Valley Fault (Rock Valley), Trench RV-4 TP2	Fissure fill, W wall (TL-56)	fissure fill (Q5)	6±1, 7±1	TL	Infilling after most recent tectonic event	Mahan, USGS, written commun. 1992
	Fissure fill, E wall (TL-55)	fissure fill (Q5)	8±1, 10±1	TL	penultimate tectonic event	Pa95
	Laminate coating fissure, E wall (HD 1807, equivalent to HD 1810)	Laminae lining fissure fill	Not analyzed	U-series (ms)	opaline silica	
	Top of K horizon (HD 1810, equivalent to HD 1807)	Horizon rolls into laminae lining fissure	Not analyzed	U-series (ms)	opaline silica	
	Laminar K horizon, E wall (HD 1808, equivalent to HD 1809)	Q3-4	Not analyzed	U-series (ms)	opaline silica	
	Laminar K horizon, E wall (HD 1809, equivalent to HD 1808)	Q3-4	324	U-series (ms)	opaline silica	Paces, USGS, written commun. 1992
	Laminar K horizon, E wall (HD 1811, equivalent to HD 1808 and 1809)	Q3-4	Not analyzed	U-series (ms)	opaline silica	
Frenchman Flat, eolian depression fill	Silty sand, eolian (TL-72)	(Q5)	9±1	TL	Deposition post-dates most recent faulting event exposed in RV trenches	Mahan, USGS, written commun. 1992
	Bk horizon (TL-73, immediately above HD 2125)	(Q5)	27±2	TL	Deposition post-dates most recent faulting event exposed in RV trenches	Mahan, USGS, written commun. 1992
	Rock varnish (CFP-31)	Late Black Cone (Q4)	19±6.5	Cation-ratio average	Minimum age of surface	Pe95
	Silica rind on clast HD 2125, immediately below TL-73)	?	Not analyzed	U-series (ms)		
Paintbrush Canyon Fault (Busted Butte), Exposure BB1 (northern most wall)	Upper K horizon, hanging wall (HD 959)	9 (top) (Q-sand ramp)	20±6	U-series (as)	Composite soil sample	Me94, Pa94, Pa95
	Upper K horizon, footwall (HD 954)	7+8 top (Q-sand ramp)	70±28, 77±19, 79±20	U-series (as)	Composite soil sample	Me94, Pa94, Pa95
	Upper K horizon, rhizolith, footwall (HD 955A)	7+8 middle (Q-sand ramp)	134±23, 137±27, 142±20	U-series (as)	Composite sample of rhizoliths	Me94, Pa94, Pa95
	Rhizolith, main fault zone (HD 955B)	9 (middle) (Q-sand ramp)	187±8	U-series (as)	Age of secondary carbonate that replaced root	Me94, Pa95
Paintbrush Canyon Fault (Busted Butte), Exposure BB3	Upper K horizon, upper part, hanging wall (HD 57)	(Q3-sand ramp)	180±20	U-series (as)	Age of secondary carbonate	Muhs
	Upper K horizon, lowest part, hanging wall (HD 58 and HD 58R)	(Q3-sand ramp)	116±10, 179±17	U-series (as)	Age of secondary carbonate	Mu90, Muhs
	Rhizoliths immediately below upper K horizon, hanging wall (HD 59-1-A and HD 59-1-B)	(Q3-sand ramp)	318±23, 209±7	U-series (as)	Age of secondary carbonate that replaced root	Muhs
	Second K horizon below surface, lower part, hanging wall (HD 76)	(Q3-sand ramp)	182±11, 174±10	U-series (as)	Age of secondary carbonate	Mu90, Muhs
	Rhizoliths immediately below lower K horizon, hanging wall (HD 77-1-A and HD 77-1-B)	(Q3-sand ramp)	>350, 200±7	U-series (as)	Age of secondary carbonate that replaced root	Muhs

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Paintbrush Canyon Fault (Busted Butte), Exposure BB4 (southern most wall)	Above upper K horizon, hanging wall (TL-07)	9e (bottom) contains 2-4% disseminated black ash (Q3-sand ramp)	36±10	TL	Time when material was last exposed to sunlight	Me94, Pa94, Pa95
	Upper K horizon buried by basaltic ash, overlies fault zone (HD 1455)	9c (top) (Q3-sand ramp)	9.7±0.8, 43±8, 173±9	U-series (ms)	Age of secondary opaline silica	Me94, Pa95
	Upper K horizon buried by basaltic ash, overlies fault zone (HD 1455)	9c (top) (Q3-sand ramp)	127±19	U-series (as)	Composite soil sample	Pa95
	Rhizolith, footwall (HD 1453)	9 (bottom) (Q3-sand ramp)	63.7±1.2, 210±9, 212±25, 235±27, 342±50, 454±63, 590±∞/130	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95
	Upper K horizon, hanging wall (HD 1449)	8b (top) (Q3-sand ramp)	224±9, 270±11	U-series (ms)	Age of secondary carbonate/opaline silica	Me94, Pa94 Pa95
	Upper K horizon, hanging wall (HD 962)	8b (top) (Q3-sand ramp)	300±68, 340±107	U-series (as)	Composite soil sample	Pa95
	Lower K horizon, hanging wall (HD 961)	(Q3-sand ramp)	196±32, 400±∞/130, 410±∞/150, 750±∞/430	U-series (as)	Composite soil sample	Pa95
Paintbrush Canyon Fault (next to P1), Trench 17 or MWV-T4	Av soil horizon (TL-05)	IX (top), Q5	6±1	TL	Time when material was last exposed to sunlight	Me94,Pa94 Pa95, Gb92
	Bt soil horizon (TL-04)	VIIIb, Q4	38±6	TL	Time when material was last exposed to sunlight	Me94, Pa94 Pa95, Gb92
	Sand (TL-03)	VIIe, Q3	73±9	TL	Time when material was last exposed to sunlight	Me94, Pa94 Pa95, Gb92
	Rhizolith, hanging wall (HD 1371)	VI_I, Q3	44±0.5, 55±0.5, 63±1.6	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95, Gb92
	Rhizolith, hanging wall (HD 1372)	VI_I, Q3	119±2, 131±3	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95, Gb92
	Rhizolith, hanging wall (HD 1373)	VI_I, Q3	133±5, 140±5	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95, Gb92
	Opal stringer, hanging wall (HD 1370)	V(?), Q3	383±24, 423±44	U-serie (ms)	Age of secondary opaline silica	Pa95, Gb92
	Soil carbonate, footwall (HD 1368)	II, Q2	232±15, 344±35	U-series (ms)	Age of secondary carbonate	Pa95, Gb92
	Opaline silica, hanging wall (HD 1589)	I, QT(?)	600±∞/170	U-series (ms)	Constrain a faulting event	Pa95, Gb92

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Paintbrush Canyon Fault (Alice Ridge). Trench A1	Av horizon (TL-34). N wall, footwall	Unit 5	9±2	TL	Time when material was last exposed to sunlight	Pa95
	Buried A horizon (TL-35), N wall, footwall	Unit 4c	17±2	TL	Time when material was last exposed to sunlight	Pa95
	Opaline silica stringer (HD 1640), N wall, hanging wall	Unit 3a	127±4, 134±5	U-series (ms)	Age of secondary opaline silica	Pa95
	Rinds and opaline silica stringer (HD 1641), N wall, hanging wall	Unit 3a/b	26±2, 85±4, 101±4, 102±4	U-series (ms)	Age of secondary opaline silica	Pa95
	Laminar K horizon (HD 1622), N wall footwall	Unit 3b	16±4, 14±2	U-series (ms)	Age of secondary carbon-ate	Pa95
	Bt horizon (TL-36), S wall, footwall	Unit 3c	25±16	TL	Time when material was last exposed to sunlight	Pa95
	Sand (TL-37), S wall, hanging wall	Unit 2b	163±26	TL	Time when material was last exposed to sunlight	Pa95
	Rhizolith (HD 1623), S wall, hanging wall	Unit 2b	126±7, 224±21	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95
	Rhizolith (HD 1624), S wall, hanging wall	Unit 2b	71±2, 195±18, 266±9, 218±6	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95
	Opaline silica stringer (HD 1643), N wall, footwall	Unit 2c	193±6, 351±79	U-series (ms)	Age of secondary opaline silica	Pa95
	Soil carbonate and opa-line silica (HD 1625), S wall, footwall	Unit 1b	640, 700, 900	U-series (ms)	Age of opaline silica	Pa95
	Rhizolith (HD 1627), S wall, fault zone	Unit 1b/c	129±3, 403±64	U-series (ms)	Age of carbonate/opaline silica replacement of root cast	Pa95
Midway Valley (ESF portal pad), Trench MWV-T5a	Upper buried Av (noncalc soil) (TL-01)	Q4	27±5	TL	Time when material was last exposed to sunlight	Pa94, Pa95, Gb92
	Colluvium--upper part of platy K horizon, (HD 972)	Q3	41±8	U-series (as)	Composite soil sample	Pa94, Pa95, Gb92
Midway Valley Pit 10	Gravelly alluvium with sandy matrix (TL 42, adja-cent to HD 1637)	Q5	7±1	TL	Time when material was last exposed to sunlight	Pa95, Gb92
	Gravelly alluvium with sandy matrix (HD 1637, adjacent to TL-42)	Q5	7±5, 7±6	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Bt horizon (TL 48)	Q3	27±5	TL	Time when material was last exposed to sunlight	Pa95, Gb92
	(HD 1639)	Q3	Not analyzed	U-series		Paces, USGS, written commun. 1992
	(HD 1638)	Q3	Not analyzed	U-series		Paces, USGS, written commun. 1992
Midway Valley Pit 14	(HD 1635)	Q5	Not analyzed	U-series		Paces, USGS, written commun. 1992
	Sandy lens (TL 41)	Q5	4±0.4	TL	Time when material was last exposed to sunlight	Pa95, Gb92
	(HD 1636)	Q5	Not analyzed	U-series		Paces, USGS, written commun. 1992
Fortymile Wash, natural bluff exposure S of Pah Canyon	(HD 2122)	3f (Q3?)	22±0.4, 29±1, 29±9	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
Fortymile Wash, E side, Powerline eolianite site	Well sorted massive sand below 3f (HD 1739)	3f (Q3?)	220±9, 279±9	U-series (ms)	Max age of 3f (Q3)	Paces, USGS, written commun. 1992
	Rhizolith (HD 1079)	3f (Q3?)	460±∞/180	U-series (as)	Age of carbonate/opaline silica replacement of root cast	Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Fortymile Wash, E side, Calico Hills fan site	K horizon (HD 1743)	3f (Q3?)	21±0.2	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	K horizon (HD 1743)	3f (Q3?)	39±1, 42±0.5, 52±5	U-series (ms)	Age of secondary opaline silica	Pa95
	Sand below upper K horizon (TL-49)	3f (Q3?)	105±21	TL	Time when material was last exposed to sunlight	Pa95; Mahan, USGS, written commun. 1992
	Rhizolith (HD 1742)	3f (Q3?)	50±0.5	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rhizolith (HD 1742)	3f (Q3?)	61±1, 79±1	U-series (ms)	Age of secondary opaline silica	Pa95
Fortymile Wash, W side, main channel exposure (?)	Sand and silt burying Q5 (TL-08)	Q5	12±2	TL	Max age of Q5(?)	Pa95
Fortymile Wash, W side, Sever Wash borrow pits	Buried massive eolian sand burying Q5 (TL-13 and TL-14)	Q5	7±1, 8±1	TL	Max age of Q5(?)	Pa95
Fortymile Wash, W side, Sever Wash gooseneck site	Surface K horizon (HD 1917)	3f (Q3?)	40±36	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Ck horizon (HD 1916)	3f (Q3?)	27±3, 30±8, 74±3	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Reddened sand below upper K horizon (B horizon?) (TL-47)	Q3?	102±17	TL	Time when material was last exposed to sunlight	Pa95; Mahan, USGS, written commun. 1992
	2Btb horizon, surface of first buried soil (HD 1740)	Q3?	90±7, 93±4, 101±21, 108±8	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	First buried K horizon (HD 1741)	Q3?	152±8, 169±5, 170±3	U-series		Paces, USGS, written commun. 1992
Fortymile Wash, inset terrace, E side, natural exposure SE of road crossing	Clast rind in K horizon (HD 2123)	4f (Q4?)	21±3, 23±2, 25±6, 36±1	U-series (ms)	Constrain incision of Fortymile Wash	Paces, USGS, written commun. 1992
Fortymile Wash, inset terrace, W side, trench FW3, NW of road crossing	Clast rind in K horizon (HD 2124)	4f (Q4?)	27±2, 30±2, 31±3	U-series (ms)	Constrain incision of Fortymile Wash	Paces, USGS, written commun. 1992
Fortymile Wash UZ-N85, W side, bluff SW of road crossing	Surface soil, clast rind in K horizon (HD 2136)	3f (Q3?)	49±3, 53±2, 60±3	U-series (ms)	Constrain incision of Fortymile Wash	Paces, USGS, written commun. 1992
	Surface soil, clast rind in K horizon (HD 1375)	3f (Q3)	51±7	U-series (ms)	Constrain incision of Fortymile Wash	Pa95
	First buried soil below surface, prominent K horizon ledge (HD 2135)	Q?	305±21, 347±16, 449±53, 567±147	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Fine-grained silt and sand (TL-78, below HD 2135)	Q?	60	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Second buried soil below surface, K horizon (HD 2134)	Q?	411±63	U-serie (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992; Lundstrom, USGS, written commun. 1992
	Fine-grained silt and sand (TL-77, below HD 2134)	Q?	100	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Third buried soil below surface, K horizon (HD 2133)	Q?	Not analyzed	U-series		Paces, USGS, written commun. 1992

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Fortymile Wash, Hwy 95 gravel quarry	Fine-grained silt and sand, 20 cm below surface (TL-?)	Q5	3-6	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Fine-grained silt and sand (TL-?, below TL-?)	5f (Q5)	7-8	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Clast rind (HD ?)	5f (Q5)	8-9	U-series	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Fine-grained silt and sand (TL-?)	4f (Q4?)	28-35	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
Coyote Wash Cross-Channel trench	Bt horizon (TL-52)	Q5	3±0.6	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	(HD 1744)	Q5	2±7, 2±10	U-series (ms)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Bt horizon (TL-51)	Q5	4±3	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Bt horizon (TL-50)	Q5	26±4	TL	Max age for overlying Q5	Mahan, USGS, written commun. 1992
Bow Ridge Fault (Exile Hill), Trench 14	Upper K horizon, stage IV (HD 1-A)	Q2s, unit 3, (Q3 sand?)	88±5	U-series (as)	Age of secondary carbonate	Ta96b, Ta94
	Lower K horizon, stage IV (HD 2 and HD 12)	Q2s, unit 3, (Q3 sand?)	119±8 and 78±5	U-series (as)	Age of secondary carbonate	Ta96b, Ta94
	Calcrete in fault between welded tuff and alluvium (113 and 115)	Vein III?	>5 and >20	U-series (as)	Age of secondary carbonate and inferred minimum age of tectonic offset	Sz81
	Cemented silt and sand (HD 42-5)	Vein III center, contains black ash, (Q3 sand?)	228±11	U-series (as)	Age of secondary carbonate	Ta96b, Ta94
	Cemented silt and sand (HD 42-2)	Vein III near wall	324±∞/69	U-series (as)	Age of secondary carbonate	Ta96b, Ta94
	Dense opaline silica stringers above fault zone (TSV 412-1 (carbonate), -3 (opal), & -7 (opal))	Q2s, unit 3?, (Q3 sand?)	>350 and >400, >400, >400	U-series (as)	Age of secondary carbonate not offset by fault	Sw84, Ta96b, Ta94, Sz85
Bow Ridge Fault (Exile Hill), Trench 14C	Upper part K horizon (HD 966)	Q3 (sand?)	229±58, 224±58	U-series (as)	Composite soil sample	Pa94, Pa95
	Lower part K horizon (HD 965)	Q3 (sand?)	400±∞/230, 240±105	U-series (as)	Composite soil sample	Pa94, Pa95
Bow Ridge Fault (Exile Hill), Trench 14D	Colluvium--north wall (TL-06)	10, Q4 (sand?)	48±20	TL	Time when material was last exposed to sunlight	Pa95, Me94, Pa94
	Colluvium--south wall (HD 971)	7 (top), Q3 (sand?)	98±15, 137±32, 139±31, 144±33	U-series (as)	Composite soil sample	Pa95, Me94, Pa94
	Colluvium--south wall (TL-09)	4, Q3 (sand?)	132±23	TL	Time when material was last exposed to sunlight	Pa95, Me94, Pa94
	Colluvium--south wall (HD 970)	3, Q3 (sand?)	234±41	U-series (as)	Composite soil sample	Pa95, Pa94
	Colluvium--south wall (HD 969)	2, Q3 (sand?)	340± ∞/120	U-series (as)	Composite soil sample	Pa95, Pa94
Ghost Dance Fault (Drill Hole Wash), Trench 2	Opaline silica laminae (HD 1719)	Q3, 2Kb horizon	20±2, 25±1	U-series (ms)	Age of secondary opaline silica	Pa95, Ta96a
	Opaline silica laminae (HD 1717)	Q3, 2Kb horizon	26±13, 33±10	U-series (ms)	Age of secondary opaline silica	Pa95, Ta96a
	Dense rind on clast (HD 1717)	Q3, 2Kb horizon	88±12, 95±12,	U-series (ms)	Age of clast rind	Pa95, Ta96a
	Rhizolith (HD 1718)	Q3, 2Kb horizon	67±2, 67±2, 68±1	U-series (ms)	Age of opaline silica replacement of root cast	Pa95, Ta96a
	Rhizolith (HD 1720)	Q3, 2Kb horizon	71±3, 73±3	U-series (ms)	Age of opaline silica replacement of root cast	Pa95, Ta96a

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Ghost Dance Fault (Split Wash), Trench 4a	Densely cemented fluvial gravel, slope parallel (HD 1829)	Q3?, 3K horizon	45±0.5, 50±1	U-series (ms)	Age of secondary opaline silica	Pa95, Ta96a
	Slope parallel laminae in fractured bedrock (HD 1831)	Infiltrated material	22±1, 23±1, 37±2	U-series (ms)	Age of secondary opaline silica	Pa95, Ta96a
	Dense fracture fill in bedrock (HD 1830)	Infiltrated material	132±7, 253±13, 265±12	U-series (ms)	Age of secondary opaline silica	Pa95, Ta96a
Ghost Dance Fault (Whale Back Ridge), Whale Back Ridge Trench	S wall, E end, unfractured Kim horizon draping bedrock (HD 1721)	Q?, 2Kqm horizon	43±1, 53±0.5, 81±2, 83±2	U-series (ms)	Age of unfaulted opaline silica above bedrock fault zone	Pa95, Ta96a
	S wall, E end, unfractured Kim horizon draping bedrock (HD 1722)	Q?, 2Kqm horizon	10±0.1, 17±6	U-series (ms)	Age of unfaulted opaline silica above bedrock fault zone	Pa95, Ta96a
	S wall, E end, unfractured Kim horizon draping bedrock (HD 1723)	Q?, 2Kqm horizon	22±1, 85±2, 91±1	U-series (ms)	Age of unfaulted opaline silica above bedrock fault zone	Pa95, Ta96a
	S wall, center section, fractured Kim horizon (HD 2131)	Q?, 2Kqm horizon	65±0.3	U-series (ms)	Age of fractured soil horizon above bedrock fault zone	Paces, USGS, written commun. 1992; Ta96a
	S wall, center section, fractured Kim horizon (HD 2129)	Q?, 2Kqm horizon	42±0.2	U-series (ms)	Age of fractured soil horizon above bedrock fault zone	Paces, USGS, written commun. 1992; Ta96a
	S wall, center section, fractured Kim horizon (HD 2130)	Q?, 2Kqm horizon	38±0.5, 46±0.3	U-series (ms)	Age of fractured soil horizon above bedrock fault zone	Paces, USGS, written commun. 1992; Ta96a
	S wall, center section, fractured Kim horizon (HD 2128)	Q?, 2Kqm horizon	33±0.1, 64±0.3	U-series (ms)	Age of unfaulted opaline silica above bedrock fault zone	Paces, USGS, written commun. 1992; Ta96a
	Rind on faulted bedrock (HD 1724)	Infiltrated material	270±∞/220, 392±29, 392±74, 420±∞/110	U-series (ms)	Age of secondary opaline silica in rind on bedrock breccia	Pa95, Ta96a
Stagecoach Road Fault Trench, SCR-T1	Sand and silt, hanging wall (TL-2 and TL-26)	H (bottom), Av horizon, Q5?	12±6 and 9±1	TL	Age of material above rhizolith	Me94, Pa95
	Sand and silt, hanging wall (TL-25)	G (bottom), Q5-sand	12±1	TL	Age of material above rhizolith	Me94, Pa95
	Rhizolith, hanging wall (HD 1068)	F (contains black ash), Q4-sand	13±6, 17±2, 18±2, 20±2	U-series (as)	Age of secondary carbonate that replaced root cast	Me94, Pa95, Pa94
	Sand surrounding rhizolith (TL-16)	E, Q4-sand	28±4	TL	Compare TL age of sediment to U-series of rhizolith	Me94, Pa95
	Rhizolith in fault zone (HD 1439)	E, Q4-sand	13±5, 14±1, 15±1, 16±1, 16±1, 23±4	U-series (ms)	Age of secondary carbonate that replaced root cast	Me94, Pa95
	Rhizolith, hanging wall (HD 1067)	D, Q4-sand	24±1, 24±2, 25±4, 27±1	U-series (as)	Age of secondary carbonate that replaced root cast	Pa94, Pa95
	Sand and silt (TL-27)	D, Q4-sand	49±9	TL	Time when material was last exposed to sunlight	Me94, Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Stagecoach Road Fault, Trench SCR-T3	Sand (TL-28)	J (top), Av horizon, Q5	2.4±0.2	TL	Time when material was last exposed to sunlight	Me94, Pa95
	Sand (TL-18)	J (middle), Q5	22±5	TL	Time when material was last exposed to sunlight	Me94, Pa95
	Sand (TL-19)	G (top), Q4-sand	87±18	TL	Time when material was last exposed to sunlight	Me94, Pa95
	Sand (TL-29)	G (bottom), Q4, min age, possibly not reset	60±16	TL	Time when material was last exposed to sunlight	Me94, Pa95
	Carbonate cemented sand (HD 1447)	G (bottom), Q4-sand	57±15	U-series (ms)	Composite soil sample	Me94, Pa95
	Carbonate cemented sand (HD 1447)	G (bottom), Q4-sand	88±9, 94±35, 104±7, 107±9	U-series (as)	Composite soil sample	Pa95
Solitario Canyon Fault (Mile High Mesa), Trench GA-1B	Undisturbed carbonate above fault zone (TSV-395)	Q?	>32	U-series (as)	Age of secondary carbonate that is not offset by fault	Sz85
Solitario Canyon Fault (Solitario Canyon--W side of Yucca Mt.), Trench 8	Soil developed on fissure filling, Bk horizon (HD 1466)	Upper part of unit 12, Q4	101±4	U-series (ms)	Composite soil sample	Pa95, Ra96
	Soil developed on fissure/ vein filling (HD 1465)	Unit 13, Q4	47±9, 66±23	U-series (ms)	Composite soil sample	Pa95, Ra96
	Fissure fill containing black ash (TL-30)	Fissure fill, unit 11, Q4	36±3	TL	Time when material was last exposed to sunlight	Pa95, Ra96
	Carbonate cemented vein in fissure that cross cuts the black ash (HD 1071)	Fissure fill, unit 11, Q4(?)	15±4, 15±7, 16±3, 16±3	U-series (as)	Composite soil sample	Pa95, Ra96
	Rhizoliths in black ash filling fissure (HD 1070)	Fissure fill, unit 10, Q4	39±1, 27±1	U-series (ms)	Age of secondary carbonate that replaced root cast	Pa95, Ra96
	Rhizoliths in black ash filling fissure (HD 1070)	Fissure fill, unit 10, Q4	37±2, 40±3, 48±5, 56±3	U-series (as)	Age of secondary carbonate that replaced root cast	Pa95, Ra96
	Black ash filling fissure, bottom of trench, 1.5 m below surface	Black ash, unit 10	860	$^{40}Ar/^{39}Ar$	Age of black ash, probably contaminated by Miocene high-K rhyolite glass (Perry, LANL, written commun. 1997)	New Mexico Bureau of Mines, written commun. 1994
	Vertical carbonate adjacent of fissure (HD 1072)	Fracture fill, units 10-12, postdate Q3	114±5, 117±5, 119±6, 124±6	U-series (as)	Composite soil sample	Pa95, Ra96
Solitario Canyon Fault (0.5 km south of trench 8)	Calcrete in fault zone (TSV-368)	Q3(?)	70±5	U-series	Age of secondary carbonate in fault zone	Sz85
Solitario Canyon Fault (Solitario Canyon--W side of Yucca Mt.), Trench 8a	Upper portion of Av horizon (TL-10)	Q5	11±2	TL	Time when material was last exposed to sunlight	Pa95, Ra96
	Lower portion of Av horizon (TL-11)	Q5	14±2	TL	Time when material was last exposed to sunlight	Pa95, Ra96

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Solitario Canyon Fault (Solitario Canyon, W side of Yucca Mt.), Trench 3	Opaline silica stringer in upper Kim horizon (HD 1730)	Unit 8, Q1	25±0.1, 28±0.2	U-series (ms)	Age of opaline silica	Pa95, Ra96
	Opaline silica in rind on clast in upper Kim horizon (HD 1731)	Unit 8, Q1	170±3	U-series (ms)	Age of opaline silica	Pa95, Ra96
	Opaline silica in rind on clast in upper Kim horizon (HD 1731)	Unit 8, Q1	590±110, 870±150, 900±140, 970±450	U-age (ms)	Age of opaline silica	Pa95, Ra96
	Opaline silica in rind on clast (HD 1726)	Unit 7, Q1	144±4, 324±7	U-series (ms)	Age of opaline silica	Pa95, Ra96
	Opaline silica in rind on clast (HD 1726)	Unit 7, Q1	880±160, 950±140	U-age (ms)	Age of opaline silica	Pa95, Ra96
Solitario Canyon Fault (Solitario Canyon, W side of Yucca Mt.), Trench 1	Black ash, 3 m below surface	Black ash	80	^{36}Cl	Age of black ash	Ramelli, NBMG, oral communication 1994
Fatigue Wash Fault (Crater Flat), Trench CF1	Buried Av horizon, Trench CF1a 20 m S of CF1 (TL-12)	Q5	9±1	TL	Time when material was last exposed to sunlight	Co96, Pa95
	Carbonate fault filling adjacent to black ash, S wall, footwall (TSV-386)	QTa, fault filling (Q1)	27±3	U-series (as)	Age of secondary carbonate	Sw84, Sz85, Co96
	Laminar K horizon, S wall, hanging wall (HD 1611)	Q1, unit 7	38±4, 172±7, 189±7	U-series (ms)	Age of opaline silica	Co96, Pa95
	Laminar K horizon, S wall, hanging wall (HD 1612)	Q1, unit 7	130±2 avg (102-269, n=13)	U-series (ms)	Age of opaline silica	Co96, Pa95
	Boulder rind from massive carbonate cement, S wall, hanging wall (HD 1610)	Q1, unit 5	65±4, 79±3, 325±21, 329±117, 331±10, 449±35, 474±46, infinite	U-series (ms)	Age of opaline silica	Co96, Pa95
	Laminar K horizon and clast rind, S wall, footwall (HD 1729)	Q1, unit 4	89±1, 93±1, 102±2, 115±2, 141±1	U-series (ms)	Age of opaline silica	Co96, Pa95
	Laminar carbonate, S wall, footwall (TSV-387)	QTa (Q1, unit 4)	33±4	U-series (as)	Age of secondary carbonate	Co96, Sw84, Sz85
	Laminar horizon, N wall, footwall, (U6)	Solitario, (Q1, unit 4a)	59.5±0.9	U-series (as)	Age of secondary carbonate	Co96, Pe95
	Carbonate rinds on clasts, N wall, footwall (U5)	Solitario, (Q1, unit 3)	36.2±1.7	U-series (as)	Age of secondary carbonate	Co96, Pe95
	Rinds on clast, S wall, footwall (HD 1608)	Q0?, unit 1	377±103, 511±204, infinite	U-series (ms)	Age of opaline silica	Co96, Pa95
Windy Wash Fault (Crater Flat), Trench CF2	Secondary opaline silica laminae (HD 1618)	Upper part of unit J (Q3-sand)	105±2, 153±13	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1619)	Upper part of unit M (Q3-sand)	91±2, 96±2, 159±7, 264±12, 277±22, 278±13, 331±33	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1617)	Lower part of unit M (Q3-sand)	333±62	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1620)	Lower part of unit M (Q3-sand)	214±22 270±135, 287±13	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1621)	Lower part of unit M (Q3-sand)	267±14 311±56	U-series (ms)	Age of opaline silica	Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Windy Wash Fault (Crater Flat), Trench CF3	Buried Av horizon, Trench CF2.5 10 m E of CF3	Q1c (Q5)	3-6.5	TL	Time when material was last exposed to sunlight	Wh86
	(TL-59)	(Q4, unit C)	11±2	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Laminar horizon, footwall (U3)	Late Black Cone (Q4 at surface)	17±3	U-series (as)	Age of laminar K horizon	Pe95
	Carbonate rinds on clasts, footwall (U4)	Late Black Cone (Q4 at surface)	38±3	U-series (as)	Age of secondary carbonate rinds	Pe95
	Laminar horizon, hanging wall (U1)	Late Black Cone (Q4 buried)	39±3	U-series (as)	Age of laminar K horizon	Pe95
	Carbonate rinds on clasts, hanging wall (U2)	Late Black Cone (Q4 buried)	82±9	U-series (as)	Age of secondary carbonate rinds	Pe95
	Thin rinds/coats on clast (HD 1615 and HD 1820)	Top of unit E, 5Bk1b horizon (Q4)	52±4, 62±4, 78±5, 86±5	U-series (ms)	Age of opaline silica	Pa95
	Discrete stringers of opaline silica and one rhizolith (HD 1821)	Top of unit E, 5Bk1b horizon (Q4)	12±0.2, 13±1, 47±1	U-series (ms)	Age of opaline silica, oldest sample is rhizolith	Pa95
Crater Flat Fault, Trench 1a	2Bw soil horizon, hanging wall (TL-61)	Unit 2, Q5	9±1	TL	Max age of most recent faulting event	Mahan, USGS, written commun. 1992
	3K soil horizon, rind on clast, hanging wal (HD 1959)	Unit 3, Q3	40±2, 49±2, 60±9	U-series (as)	Event horizon, age of secondary opaline silica	Paces, USGS, written commun. 1992
Windy Wash Fault (Crater Flat), Trench CF2	Secondary opaline silica laminae (HD 1618)	Upper part of unit J (Q3-sand)	105±2, 153±13	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1619)	Upper part of unit M (Q3-sand)	91±2, 96±2, 159±7, 264±12, 277±22, 278±13, 331±33	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1617)	Lower part of unit M (Q3-sand)	333±62	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1620)	Lower part of unit M (Q3-sand)	214±22 270±135, 287±13	U-series (ms)	Age of opaline silica	Pa95
	Rind on clast (HD 1621)	Lower part of unit M (Q3-sand)	267±14, 311±56	U-series (ms)	Age of opaline silica	Pa95
Windy Wash Fault (Crater Flat), Trench CF3	Buried Av horizon, Trench CF2.5 10 m E of CF3	Q1c (Q5)	3-6.5	TL	Time when material was last exposed to sunlight	Wh86
	(TL-59)	(Q4, unit C)	11±2	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Laminar horizon, footwall (U3)	Late Black Cone (Q4 at surface)	17±3	U-series (as)	Age of laminar K horizon	Pe95
	Carbonate rinds on clasts, footwall (U4)	Late Black Cone (Q4 at surface)	38±3	U-series (as)	Age of secondary carbonate rinds	Pe95
	Laminar horizon, hanging wall (U1)	Late Black Cone (Q4 buried)	39±3	U-series (as)	Age of laminar K horizon	Pe95
	Carbonate rinds on clasts, hanging wall (U2)	Late Black Cone (Q4 buried)	82±9	U-series (as)	Age of secondary carbonate rinds	Pe95
	Thin rinds/coats on clast (HD 1615 and HD 1820)	Top of unit E, 5Bk1b horizon (Q4)	52±4, 62±4, 78±5, 86±5	U-series (ms)	Age of opaline silica	Pa95
	Discrete stringers of opaline silica and one rhizolith (HD 1821)	Top of unit E, 5Bk1b horizon (Q4)	12±0.2, 13±1, 47±1	U-series (ms)	Age of opaline silica, oldest sample is rhizolith	Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Crater Flat Fault, Trench 1a	2Bw soil horizon, hanging wall (TL-61)	Unit 2, Q5	9±1	TL	Max age of most recent faulting event	Mahan, USGS, written commun. 1992
	3K soil horizon, rind on clast, hanging wall (HD 1959)	Unit 3, Q3	40±2, 49±2, 60±9	U-series (as)	Event horizon, age of secondary opaline silica	Paces, USGS, written commun. 1992
	3Bk soil horizon, rind on clast, hanging wall (HD 1958)	Unit 3, Q3	120±5, 124±16, 128±6	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, hanging wall (HD 1957)	Unit 4, Q?	210±15, 236±13, 247±12	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, hanging wall (HD 1956)	Unit 4, Q?	263±16, 311±35, 352±8	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, footwall (HD 1961)	Unit 4, Q?	348±178, 260±∞/110	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
Crater Flat Fault, Trench 2a	Rind on clast, hanging wall (TL-62)	Unit 6	5±1	TL	Time when material was last exposed to sunlight	Mahan, USGS, written commun. 1992
	Rind on clast, hanging wall (4, HD 1965)	Unit 5b	33±1, 35±1	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, hanging wall (5, HD 1966)	Unit 5b	32±2, 493±∞/260	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, hanging wall (6, HD1967)	Unit 5	404±∞/230, 430±420	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
	Rind on clast, hanging wall (3, HD 1964)	Unit 2	>400	U-series (as)	Age of secondary opaline silica	Paces, USGS, written commun. 1992
Bare Mt. Fault (Tarantula Canyon) Trench BMT-1	Artifacts 30 cm below surface	Unit 4, (Q5)	7	Archaeological	Minimum age of surface, minimum age of faulting	Anderson, USBR, oral communication 1994
	Sediment surrounding artifact, N wall, hanging wall (TL-31)	Unit 4, (Q5)	6±1	TL	Minimum age of faulting	Pa95
	Sand, S wall, hanging wall (TL-32)	Unit 3, (Q4?)	16±2	TL	Minimum age of faulting	Pa95
Amargosa River bank exposure (Fluorspar Canyon), ARB-1	Charcoal (?)	Q1c (Q5)	8.3±0.075	Carbon-14	Time of deposition	Sw84
Amargosa River bank exposure (4 km south of Beatty), ARB-2	Carbonized wood	Q1c (Q5)	9.8±0.3	Carbon-14	Time of deposition	Sw88
Beatty scarp (N of Hwy 95, SE of Beatty), Trench BF-1	Carbonized wood disseminated in lowest silty unit	Q1c (Q5)	10±0.3	Carbon-14	Time of deposition compare age to U-trend age	Ro88
Root Cast Deposit (N of Hwy 95), RCD	Reworked ash (15%) in fine-grained noncalcareous silty deposit	Spring deposit (buried by Q3)	"Matches most closely with the Bishop ash bed group" (730-1200)	9 major oxide chemical correlation, petrography	Age of active spring	Sama-Wojcicki, USGS, written communcation 1992
Horse Tooth Deposit (Diatomite near Beatty), HTD	Rhizoith above diatomite, surface lag (HD 1385)	Spring deposit (buried by Q3)	12±3	U-series (as)	Time when ground was saturated/vadose zone	Pa95
	Fine-grained sand and silt (TL-43)	Spring deposit (buried by Q3)	25±4	TL	Time when material was last exposed to sunlight	
	Nodular carbonate at base of green punky silt (HD 1024)	Spring deposit (buried by Q3)	28±2	U-series (as)	Time when ground was saturated/vadose zone	Pa95, Pa93
	Cicada burrow cast, surface lag (HD 1384)	Spring deposit (buried by Q3)	26±5	U-series (as)	Time when ground was saturated/vadose zone	Pa95
	Discontinuous massive carbonate below diatomite	Spring deposit (buried by Q3)	40-160	U-series (as)	Time when ground was saturated/vadose zone	Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Fossil on surface	Horse tooth (*Equus hemionus tau*)	Spring deposit (buried by Q3)	10-1600 (probably >20 based on protein test)	Paleontological identification	Presence of animal and assumed water at surface	Repenning, USGS, written commun. 1992
Fossil on surface	*Mammuthus sp.* tusk	Spring deposit (buried by Q3)	10-1400	Paleontological identification	Presence of animal and assumed water at surface	Repenning, USGS, written commun. 1992
Fossil on surface	*Camelid sp.* tooth fragments	Spring deposit (buried by Q3)	10-1400	Paleontological identification	Presence of animal and assumed water at surface	Repenning, USGS, written commun. 1992
Crater Flat Deposit (S end of Crater Flat), CFD	Rhizolith on surface (HD 170)	Spring deposit	19±2	U-series (as)	Age of secondary carbonate that replaced root	Pa95, Pa93
	Rhizolith on surface (HD 170-1-D5 cabonate)	Spring deposit	16±0.1	Carbon-14	Age of living root	Pa95
Shallow pit on mound	Fine-grained sand and silt from shallow pit on mound (TL-21)	Spring deposit/ eolian component (buried by Q4?)	25±2	TL	Time when material was last exposed to sunlight	Pa95
	Nodular carbonate	Spring deposit (buried by Q4?)	~30	U-series (as)	Age of secondary carbonate formed in a spring deposit at the surface	Sz81
	Fine-grained sand and silt (TL-20)	Spring deposit/ eolian component (buried by Q4?)	34±4	TL	Time when material was last exposed to sunlight	Pa95
	Extremely hard dense carbonate cement in fine-grained sediment (HD 167)	Spring deposit (buried by Q4?)	38±6	U-series (as)	Time when ground was saturated/vadose zone	Pa95, Pa93
Natural exposure	Well cemented, crystalline carbonate cement in fine-grained sediment (HD 166)	Spring deposit	45±8	U-series (as)	Time when ground was saturated/vadose zone	Pa95, Pa93
Hand dug hole CFD-P1-1	Nodular carbonate, 17-50 cm below surface (HD 659)	Spring deposit	92±72	U-series (as)	Time when ground was saturated/vadose zone	Pa95, Pa93
	Well preserved carbonate-cemented vegetative mats, 70-89 cm below surface (HD 1607)	Unweathered spring deposit	73±5	U-series (as)	Time when ground was saturated/vadose zone	Pa95
	Fine grained sediment 110-120 cm below surface (HD 1606)	Spring deposit	94±27	U-series (as)	Time when ground was saturated/vadose zone	Pa95

Table 3.4-2. Compilation of Radiometric Age Data Collected on Quaternary Deposits in the Yucca Mountain Area (Continued)

Fault or Location and Trench Number	Material Dated and Sample Number	Stratigraphic Unit and/or Mapping Unit	Date/Age Estimate (10^3 years)	Dating Technique	Reason for Dating and/or Conclusion Drawn from Date	Reference
Crater Flat Allostratigraphic Unit	Rock varnish (CFP-41)	Crater Flat (Q6)	0.3±0.3[1], 1.1±0.4	Cation-ratio average	Minimum age of surface	Pe95
	Rock varnish (JWB-36)	Crater Flat (Q6)	1.3±0.07	Carbon-14	Minimum age of surface	Pe95
	Rock varnish (CFP-2, JWB-38, CFP-26, JWB-41)	Little Cones (Q5)	6.6±0.2, 8.4±0.07, 10.2±0.3, 11.1±0.1	Carbon-14	Minimum age of surface	Pe95
	Rock varnish (CFP-33, JWB-39, CFP-27, CFP-35, CFP-36, CFP-32)	Late Black Cone (Q4)	17.3±0.4, 19.7±0.2, 25.7±0.4, 27.0±0.4, 28.9±0.4, 30.3±0.5	Carbon-14	Minimum age of surface	Pe95
	Rock varnish (CFP-31)	Late Black Cone (Q4)	19±6.5	Cation-ratio average	Minimum age of surface	Pe95
	Rock varnish (CFP-37, FP-29, JWB-42, JWB-20)	Early Black Cone (Q3)	159±54, 167±56.5, 176±59.5, 201±68	Cation-ratio average	Minimum age of surface	Pe95
	Rock varnish (CFP-39, CFP-38)	Yucca (Q2?)	375±127, 373±126	Cation-ratio average	Minimum age of surface	Pe95
	Rock varnish (JWB-43, CFP-40, JWB-40)	Solitario (Q1)	433±,146 572±193, 659±222	Cation-ratio average	Minimum age of surface	Pe95

[1] ±2 sigma errors are an approximation because of the semilog nature of the 2 sigma error curves.

Co96	Coe 1996b
Gb92	Gibson et al. 1992
Me94	Menges, Wesling et al. 1994
Mu90	Muhs, Whitney et al. 1990
Muhs	Muhs, Rosholt et al. 1989
Pa93	Paces, Taylor et al. 1993
Pa94	Paces, Menges et al. 1994
Pa95	Paces, J.B., Mahan et al. 1995
Pe95	Peterson et al. 1995
Ra96	Ramelli, Oswald et al. 1996
Ro85	Rosholt, Bush et al. 1985
Ro88	Rosholt, Swadley et al. 1988
Sw84	Swadley, Hoover et al. 1984
Sw88	Swadley and Parnsh 1988 (map)
Sz81	Szabo et al. 1981
Sz85	Szabo and O'Malley 1985
Ta94	Taylor, E.M. and Huckins 1995
Ta96a	Taylor, E.M. 1996
Ta96b	Taylor, E.M., Menges et al. 1996
Wh86	Whitney, Shroba et al. 1986

Table 3.4-3. General Characteristics of Surfaces and Soils Developed on Surficial Deposits and Geomorphic Surfaces in the Yucca Mountain Area

Surface or Soil Characteristic[1]	Unit Q7	Unit Q6	Unit Q5	Unit Q4	Unit Q3	Unit Q2	Unit Q1	Unit Q0
Topography	Active channel	High-relief bar and swale	Bar and swale is subdued; bars are coarser grained than adjacent swales	Little or no evidence of bar and swale; surface is nearly smooth	Little or no evidence of bar and swale; surface is nearly smooth	Surface typically occurs infilling or adjacent to Q1	Surface is dissected; small rills and drainages common; underlying petrocalcic horizon is locally exposed	No original surface is preserved
Pavement	No pavement	No pavement	Pavement is generally absent; local incipient packing and horizontal orientation of clasts	Poorly to well packed	Moderately to well packed on remnant bars	Moderately to well packed, carbonate and silica rinds on clast fragments common in pavement	Moderately to well packed; pavement is being degraded; carbonate and silica rinds on clast fragments common in pavement	No pavement
Varnish	All varnish in inherited	All varnish in inherited	Most varnish is inherited, some very thin	Weakly to well developed	Moderately to well developed	Moderately to well developed	Moderately to well developed, sometimes lacking	No original varnish
General soil characteristics	No soil development, common reworked clast from older deposits	Very weak soil development, A/C profile	Incipient soil development, morphology is dominated by infiltrated fines	Moderate soil development, segregation of well developed B horizon	Moderate soil development	Moderate soil development	Well developed, K horizon is greater than one meter thick	Extremely well developed, surface is veneered by younger unconsolidated deposits
B or calcic horizon[2]	Not present	Cuk, Ck	Bw, Bwk Btjk, Bqj	Btkq, Bkq	Btkq, Btkqm, K	Btkqm, Kq, Kqm	Kqm	Kqm, extremely well cemented, fractures across clasts when hit with a hammer
Maximum reddening[3]	10YR	10YR	10YR	7.5YR	7.5YR	7.5-5YR	10-7.5YR	Eroded

Table 3.4-3. General Characteristics of Surfaces and Soils Developed on Surficial Deposits and Geomorphic Surfaces in the Yucca Mountain Area (Continued)

Surface or Soil Characteristic[1]	Unit Q7	Unit Q6	Unit Q5	Unit Q4	Unit Q3	Unit Q2	Unit Q1	Unit Q0
Maximum carbonate morphology[4]	Not present	Not present	I	II-III	III	III-IV	IV	IV+
Clay Films[5]	Not present	Not present	co & v1n pf	3n po & co	3mk-k pf	3-4n pf	2n-mk pf	Eroded
Structure[6]	sg	sg	1vf-f sbk	2m sbk	3m sbk	3c pl	2c pl & m	m
Secondary Silica[7]	Not present	Not present	1	2-3	3-4	3-4	4	4

[1] Terminology of Soil Survey Staff (1975) and Birkeland (1984)

[2] B horizon, a subsurface horizon that shows little or no evidence of original sedimentary or rock structure and is recognized on the basis of the kinds of material illuviated into it or residual concentrations of material (Birkeland 1984, p. 7); K horizon, a subsurface horizon that is impregnated with carbonate to the point that the carbonate controls the morphology of the horizon (Birkeland 1984, p. 8); C horizon, a subsurface horizon that lacks properties of A and B horizons but includes material in varying stages of weathering (Birkeland 1984, p. 8); j, juvenile or incipient formation (nonstandard terminology); k, accumulation of secondary carbonates; m, cemented horizon; q, accumulation of secondary silica; t, accumulation of clay; u, unweathered; w, color or structural B.

[3] Color from Munsell Soil Color Chart (Munsell Color Co., Inc. 1988).

[4] Terminology of Gile et al. (1966).

[5] (1) Frequency--v1, very few; 1, few; 2, common; 3, many; 4, continuous; (2) Thickness--n, thin; mk, moderately thick; k, thick; (3) Location--pf, faces of peds; po, lining pores; co, colloidal stains on mineral grains.

[6] (1) Grade--sg, single grain; m, massive; 1, weak; 2, moderate; 3, strong; (2) Size--vf, very fine; f, fine; m, medium; c, coarse; (3) Type--gr, granular; pl, plate; sbk, subangular blocky; m, massive.

[7] Terminology of E.M. Taylor and Huckins (1995).

Table 3.4-4. Quaternary Boundary Ranges Used for the Stratigraphy of the Yucca Mountain Area

Mapping Unit	Geologic Age	Age Range
Q7 ⇓ Q6	Latest Holocene	Historic
	Late Holocene	Historic-3 ka
Q5 ⇓ ⇓	Middle Holocene	3-7 ka
Q4 Q3	Early Holocene	7-10 ka
	Late Pleistocene	10-128 ka
Q2 Q1 ⇓	Middle Pleistocene	128-736 ka
Q0	Early Pleistocene	736-1650 ka (1.6-1.7 Ma)
⇓	Pliocene	1.65-5.0 Ma (5.0-5.5 Ma)

NOTE: Modified from Morrison 1991b.

Table 3.4-5. Descriptive and Calculated Data for the Cosmogenic ^{10}Be Sample Analyses

Sample	Lithology/Phase	Lat. (°)	Elev. (km)	Thickness (cm)	Factor 1	Factor 2	Factor 3	Factor 4	[10Be] (a/g) meas.	Age (kyr)	Unc ± 25%
JCG022095-003	Buckboard Mesa Basalt / WR	37.08	1.476	6	1.00	0.98	2.81	0.92	6.545000	509.0	127.00
JCG022095-004	Buckboard Mesa Basalt / WR	37.08	1.476	3	1.00	0.98	2.81	0.92	7.225000	554.0	139.00
JCG022195-006	Tuff / WR	36.82	1.36	10	1.00	1.00	2.58	0.95	5.605000	462.0	115.00
JCG022195-007	Tuff / WR	36.82	1.36	8	0.95	1.00	2.58	0.95	2.565000	205.0	51.000
JCG022195-008	Tuff / WR	36.82	1.36	8	1.00	1.00	2.58	0.95	2.105000	159.0	40.000
JCG022195-009	Tuff / WR	36.82	1.36	7	0.94	1.00	2.58	0.95	2.685000	216.0	54.000
JCG022195-010	Tuff / WR	36.82	1.36	10	1.00	1.00	2.58	0.95	1.500000	121.0	30.000
JCG022195-011	Little Skull Mtn Basalt / WR	36.75	1.165	12	1.00	1.00	2.24	0.91	6.685000	714.0	179.00
JCG022195-012	Little Skull Mtn Basalt / WR	36.75	1.165	8	1.00	1.00	2.24	0.91	3.825000	364.0	91.000
JCG022295-013	Little Skull Mtn Basalt / WR	36.75	1.165	8	1.00	1.00	2.24	0.91	9.245000	1,014.0	254.00
JCG022195-014	Black Cone Basalt / WR	36.8	0.984	10	1.00	0.77	1.97	0.90	4.145000	639.0	160.00
JCG022195-015	Black Cone Basalt / WR	36.8	0.984	6	1.00	0.77	1.97	0.92	2.745000	377.0	94.000
JCG022195-016	Black Cone Basalt / WR	36.8	0.984	6	1.00	0.97	1.97	0.91	4.225000	470.0	118.00
JCG022195-017	Black Cone Basalt / WR	36.8	0.994	8	1.00	1.00	1.98	0.92	7.125000	843.0	211.00
JCG050195-020	Tuff / WR	36.83	1.292	4	1.00	0.98	2.46	0.95	1.025000	944.0	236.00
JCG050195-021	Tuff / WR	36.83	1.299	3	1.00	0.98	2.47	0.95	2.085000	2,696.0	674.00
CG050195-022a	Tuff / WR	36.83	1.274	11	1.00	0.98	2.43	0.95	3.485000	300.0	75.000
CDH-AR-1	Tuff / QTZ	36.85	1.366	8	1.00	1.00	2.59	1.00	1.225000	1,063.0	266.00
CDH-AR-5	Tuff / QTZ	36.85	1.366	8	1.00	1.00	2.59	1.00	6.065000	462.0	116.00
CDH-AR-6	Tuff / QTZ	36.85	1.366	8.5	1.00	1.00	2.59	1.00	5.045000	380.0	95.000
CDH-WR-1	Tuff / QTZ	36.85	1.372	9	1.00	1.00	2.60	1.00	8.405000	676.0	169.00
CDH-WR-2	Tuff / QTZ	36.85	1.372	8	1.00	1.00	2.60	1.00	2.825000	201.0	50.000
CDH-WR-5	Tuff / QTZ	36.85	1.372	5	1.00	1.00	2.60	1.00	3.025000	212.0	53.000
CDH-WR-6	Tuff / QTZ	36.85	1.372	5	1.00	1.00	2.60	1.00	7.285000	550.0	137.00

Phases: Mineral separate (QTZ) or whole rock (WR); Factor 1: surface geometry correction, 1 if flat and horizontal; Factor 2: shielding correction, 1 if 2'; Factor 3: normalization to production at sea level, > 60° latitude (Lal 1991); Factor 4: normalization of production in whole rock samples to production in quartz; [10Be] is measured ^{10}Be concentration in atoms/g; Age is exposure age assuming no erosion and no burial using P = 6.01 atoms/g of quartz/yr, ρ = 2.65 g/cm^3, and Λ = 150 g/cm^2.

Table 3.4-6. Maximum Bedrock Erosion Rates on Yucca Mountain

Sample ID	10Be conc. (atoms/g)	Max Erosion Rate (cm/kyr) (unc)	
CDH-AR-1*	4.71	0.041	(0.028-0.064)
CDH-AR-5	2.33	0.11	(0.083-0.16)
CDH-AR-6	1.95	0.14	(0.10-0.19)
CDH-WR-1*	3.23	0.071	(0.052-0.10)
CDH-WR-2	1.08	0.27	(0.21-0.37)
CDH-WR-5	1.16	0.25	(0.20-0.35)
CDH-WR-6	2.80	0.090	(0.067-0.13)

NOTES: Samples partially processed by the University of Arizona and analyzed at the University of Pennsylvania
*Samples partially processed by the University of Arizona and analyzed at PRIME Lab

Table 3.4-7. Varnish Cation Ratio Age Estimates from Boulder Deposits Around Yucca Mountain

Sample	K+Ca / Ti'	AGE1[1] (±δ)	AGE2[2] (±δ)
YME-1	2.99	640 *(490-830)*	440 *(320-590)*
YME-2	4.52	170 *(130-220)*	100 *(80-140)*
YMW-1	3.34	470 *(360-610)*	310 *(230-420)*
YMW-2	2.97	670 *(500-850)*	440 *(330-600)*
YMW-3	2.88	700 *(540-920)*	480 *(360-660)*
YMN-1	2.79	760 *(580-1000)*	530 *(390-720)*
LSM-1	2.52	960 *(720-1270)*	680 *(500-930)*
SKM-1	2.74	790 *(600-1040)*	550 *(400-750)*
SKM-2	2.68	840 *(630-1100)*	580 *(430-800)*
SKM-3	2.28	1180 *(880-1580)*	850 *(600-1180)*
SKM-3A	2.49	990 *(740-1310)*	700 *(510-960)*
BM-1	2.09	1390 *(1030-1890)*	1020 *(730-1430)*

NOTES: [1] Age estimate using previous calibration (Figure 3.4-14)
[2] Age estimate using revised calibration (*cf.* Figure 3.4-15)

Table 3.4-8. Ranges in Calculated Cation Ratio Dates (Revised Calibration) and Cosmogenic Nuclide Dates for the Four Boulder Deposits Around Yucca Mountain

Buckboard Mesa	CR age 730-1430	Cosmogenic age 370-610
Skull Mt. Pass	CR age 500-930	Cosmogenic age 405-675
East side Yucca	CR age 320-590	Cosmogenic age 345-575
West side Yucca	CR age 360-660	Cosmogenic age 470-780

NOTE: The uncertainties in the CR ages are the 95% confidence limits of the curve regression line. The cosmogenic age 1σ uncertainties are 25% of the mean age. The cation ratio age estimates are still slightly older than the cosmogenic ages, except for the hourglass shaped deposit on the west slope of Yucca Mountain. An examination of the minimum cation ratio age estimate range compared to the cosmogenic age uncertainty shows close correspondence for three of four samples. The Buckboard Mesa sample does not overlap the cosmogenic age range.

INTENTIONALLY LEFT BLANK

Table 3.5-1. Generalized Descriptions of Pre-Prow Pass Volcanic Rocks at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
Tcb Bullfrog Tuff[9] Upper pyroclastic-flow deposit - unit is variably welded and altered (to zeolites and/or clay). Pumice clasts compose from 7 to 10% to as much as 15 to 25% of the rock mass; lithic clasts (<10 to >60 mm) diameter) are generally less than 2%. Phenocrysts of feldspar, quartz, biotite, and minor pyroxene generally from 10 to 15%, with the percentage of mafic phenocrysts increasing upward. Unit locally contains thin (6-15 cm) fallout deposits that separate flow units. Basal contact with underlying pumiceous fallout is gradational over a few cm.	Units not exposed in map area	bf	Tcb	Calico Hills nonwelded hydrogeologic unit (CHn) Or Crater Flat unit (CF)	BF3	Upper Crater Flat nonwelded unit (CFUn) ???	Bullfrog Tuff upper nonwelded zone (Tcb [unw]) ???
Pumiceous fallout - unit is partly to moderately welded, clast-supported, generally ungraded, and slightly coarser toward the base with lithic clasts increasing from 1 to 3% to 5 to 7%. Crystal content (feldspar, quartz, and biotite) varies from 10 to 30%, with a typical range of 15 to 20%. Basal contact is sharp						Bullfrog welded unit (BFw)	Bullfrog Tuff welded zone (Tcb [w])
Lower pyroclastic-flow deposit - unit is moderately welded in its central portion. Phenocrysts of feldspar, quartz, biotite, rare hornblende pseudomorphs, and very rare pyroxene (?) pseudo morphs compose 8 to 12% of the rock mass. Pumice clasts, containing scattered phenocrysts of feldspar, quartz, and biotite, typically compose 10 to 20%. Lithic clast content is generally from 1 to 3%. Basal contact is sharp and depositional.		Units not exposed in map area			BF2	Middle Crater Flat nonwelded (CFMn1)	Bullfrog Tuff lower nonwelded (Tcb[lnw])
Pre-Bullfrog Tuff bedded tuffs - sequence of reworked pyroclastic fallout and possible pyroclastic flow deposits; pumice clasts range from as low as 5% to as much as 50% of the rock mass, lithic fragments from 1-15 percent; pumice fragments are commonly argillically and zeolitically altered.						Middle Crater Flat nonwelded (CFMn2)	pre-Bullfrog Tuff bedded tuff ([bt])
Tct Tram Tuff[10] Lithic-poor unit - rock matrix is highly variable due to variations in the degree of welding and amount and type of alteration. Unit typically contains 1 to 7% lithic clasts, 3 to 15% pumice clasts, and 7 to 15% phenocrysts. Lithic clasts (2 to 40 mm, rarely as much as 80 mm) include numerous types of devitrified lava					lowest rocks characterized	Middle Crater Flat nonwelded (CFMn3)	Tram Tuff undifferentiated (Tct)

NOTE: Units are known primarily from borehole cores and samples, and have not been systematically studied or formally subdivided, only the Bullfrog Tuff is exposed at the site area.

Table 3.5-1. Generalized Descriptions of Pre-Prow Pass Volcanic Rocks at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
and tuff clasts. Pumice clasts, varying in size from less than 5 to greater than 40 mm, are argillically or zeolitically altered. Phenocrysts include quartz, feldspar, abundant biotite (30 to 50% of phenocrysts in upper part of unit) and very rare hornblende (?). Lithic-rich unit - unit contains 10 to 60% lithic clasts, 2 to 15 percent pumice clasts, and 7 to 15% phenocrysts. Lithic clasts, commonly argillically or zeolitically altered, include twenty or more rock types, including devitrified lavas and tuffs and siltstone and sandstone; sizes range from 5 to 90 mm. Phenocrysts include quartz, feldspar, biotite, and rare pyrite.	Units not exposed in map area	Units not exposed in map area	Units not exposed in map area	Calico Hills nonwelded hydrogeologic unit (CHn) or Crater Flat unit (CF) ??? All rocks are in the saturated zone	Units not in post-1991 boreholes; no data	Tram welded (TRw)	
Pre-Tram Tuff bedded tuffs - unit consists of altered and weathered pyroclastic fallout deposits, with minor pyroclastic-flow deposits. Rocks are typically fine-grained.				Units not defined in the unsaturated zone		Units not defined	pre-Tram Tuff bedded tuff ([bt])
Dacitic Lava and Flow Breccia[11] Dacitic flow breccia with interbedded thin lava flows: dacite breccia blocks are dark greenish gray to greenish black, and contain about 13% phenocrysts of which 70 to 80% are plagioclase and the remainder are mostly hornblende and clinopyroxene (quartz and sanidine are absent); much of unit is moderately altered to clay minerals and zeolites. Bedded tuff deposit: reworked pyroclastic fallout with abundant argillically and zeolitically altered pumice fragments; sparse to common lithic clasts; 5 to 10% phenocrysts of sanidine, quartz, plagioclase and biotite in some beds. **Lithic Ridge Tuff**[11] Pyroclastic-flow deposit: partially welded, moderately altered to clay minerals and zeolites; lithic inclusions, commonly rhyolitic to intermediate in composition, constitute 5 to 15% of the rock and range in size from 5 mm to 9 cm; phenocryst content averages about 10% of the rock (including quartz - 6%, sanidine - 34%, plagioclase - 55%). Unit is underlain by 6 m of bedded and reworked tuffs.					Units not defined in the unsaturated zone			Units not modeled separately

NOTE: Units are known primarily from borehole cores and samples, and have not been systematically studied or formally subdivided, only the Bullfrog Tuff is exposed at the site area.

Table 3.5-1. Generalized Descriptions of Pre-Prow Pass Volcanic Rocks at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84 1:24,000 Scale[4]	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]		Major[5]	Detailed[6]		
Pre-Lithic Ridge Tuff Volcanic Rocks[11] Upper part: partially to moderately welded, devitrified, and partially silicified pyroclastic-flow deposit; phenocrysts average 17% (plagioclase - 37%; sanidine - 34%; quartz - 26%); accessory minerals include apatite, zircon, and sphene; lithic fragments are <5%; 3 m of bedded tuff at base. Middle part: alternating partially to moderately welded pyroclastic-flow deposits with intervening bedded tuffs; forms transition between quartz-rich unit above and quartz-poor unit below. Lower part: moderately welded pyroclastic-flow deposits separated by rework tuffaceous sediments; plagioclase averages about 83% of phenocryst content, sanidine 3%, and quartz 1%; accessory minerals include hornblende, biotite, sphere, and rare pyroxene.	Units not exposed in map area	Units not exposed in map area	Units not exposed in map area	Units not defined in the unsaturated zone	Units not defined in the unsaturated zone	Units not defined	Units not modeled separately

1 Units are known primarily from borehole cores and samples, and have not been systematically studied or formally subdivided; only the Bullfrog Tuff is exposed at the site area. Contacts that are tentatively correlated are queried.
2 Mapping of the central block of Yucca Mountain by Day et al. (1996a milestone).
3 Mapping of the site area of Yucca Mountain by Day et al. (1997 milestone).
4 Mapping of the Yucca Mountain area by R. B. Scott and Bonk (1984)
5 Major hydrogeologic units from Montazer and Wilson (1984) with vitric and zeolitic designation added in the Site Characterization Plan (DOE 1988b). Could probably use the symbol Clinc for areas where the Clin is crystallized, although this has not been done. Montazer and Wilson (1984) defined a Bullfrog unit, but Wittwer et al. (1995) removed it from their UZ model.
6 Detailed hydrogeologic units of the unsaturated zone from L.E. Flint (1998a).
7 Thermal-mechanical units from Ortiz et al. (1985).
8 Three-dimensional site geologic model units are from the Integrated Site Model version ISM2.0 (CRWMS M&O 1997e)
9 Descriptions of Bullfrog Tuff units based primarily on studies of borehole G-1 (Spengler, Byers et al. 1981) and borehole G-4 (Spengler and Chornack 1984).
10 Descriptions of Tram Tuff units based on studies of boreholes p#1, G-1, b#1, G-3, and ll-1 (Carr, W.J., Byers et al. 1986; Spengler, Byers et al. 1981; Maldonado and Koether 1983; Scott, R.B. and Castellanos 1984).
11 Descriptions of Dacitic Lava and Flow Breccia, Lithic Ridge Tuff, and pre-Lithic Ridge Tuff volcanic rocks based primarily on study of borehole G-1 (Spengler, Byers et al. 1981).

NOTE: Units are known primarily from borehole cores and samples, and have not been systematically studied or formally subdivided, only the Bullfrog Tuff is exposed at the site area.

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
TIMBER MOUNTAIN GROUP	Not mapped as undivided unit			Unconsolidated surficial materials (UO)	Not in boreholes analyzed; no data	Undifferentiated overburden (UO)	Undifferentiated overburden (UO)
Tma Ammonia Tanks Tuff - rhyolitic tuff, does not occur at Yucca Mountain.	Unit not exposed in mapped area						
Tmr Rainier Mesa Tuff - Pyroclastic-flow deposit, vitric nonwelded to crystallized densely welded; 10 to 25% pumice clasts; 10 to 20 percent phenocrysts, including quartz, plagioclase, sanidine, and biotite; 1 to 5% lithic clasts	Tmrw	Tmrw	Tmrw				
	Tmr	Tmr	Tmr				
Tmbt1 Pre-Rainier Mesa Tuff bedded tuff - Pyroclastic-flow and fallout tephra beds, and locally redeposited material; lithic content 2 to 20%, pumice clasts 10 to 20%; phenocrysts include quartz, feldspar, and biotite with minor hornblende in some beds.	bt5	bt5	bt				
PAINTBRUSH GROUP - characterized by quartz-free phenocryst assemblage. (Symbol: Tp)	Not mapped as individual unit		Not mapped as undivided unit				
Tpk rhyolite of Comb Peak - rhyolite lava flows and related tephra; about 2% felsic phenocrysts (hornblende > biotite), and 0.05% sphene.	Tpkl	kl	Tfcl Tfcp				
Tpki pyroclastic flow deposit informally identified as tuff unit "x" (Carr 1992) and tentatively correlated with the rhyolite of Comb Peak on the basis of petrography and mineral chemistry (R. Warren, written communication, 1994).	Tpkt	kt	bt				
Tpv rhyolite of Vent Pass - Rhyolite lava flows and related tephra. Similar to crystal-rich Tiva Canyon tuff, with about 15% felsic phenocrysts (sanidine > plagioclase), 0.3% biotite, and 0.002% sphene.	Unit not exposed in mapped area	vp	Tfvl Tfvp				
Tpbt5 post-Tiva Canyon Tuff bedded tuff consists of tuffaceous rocks not correlated with known eruptive units based on detailed tephro-stratigraphic studies. This unit commonly consists of numerous depositional sequences separated by possible paleosols. In NRG#1 borehole complex and RF#3 and 8, Tpbt5 is divided into four depositional sequences, each capped by a possible paleosol (Geslin et al. 1995; Buesch, Spengler et al. 1996a).	bt5	bt5	bt				

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tpc Tiva Canyon Tuff[8]	Not mapped as undivided unit	cu	cu		Unconsolidated surficial materials (UO)	Not in boreholes analyzed; no data	Tiva Canyon welded unit (TCw)	Tiva Canyon welded undifferentiated unit (TCw)
Tpcr crystal-rich member: 10 to 15% felsic phenocrysts (sanidine » plagioclase, trace quartz), 0.8% mafic phenocrysts (biotite > pyroxene » hornblende), and 0.005% sphene. Pumice is mixed colors; light gray (N8-9), medium gray (N6), and very dark yellowish orange (10YR6/8)[10].		cr	Not mapped as undivided unit					
Tpcvr vitric zone Tpcrv3 nonwelded subzone - includes partially welded and locally devitrified tuff. Tpcrv3 nonwelded interval. Tpcrv3p partially welded interval. Tpcrv2 moderately welded subzone - moderately welded with macroscopically identifiable vitroclastic texture and porosity; locally devitrified tuff. Tpcrvl densely welded subzone - densely welded tuff; no macroscopically identifiable porosity. Tpcrvlc clastic texture interval - vitroclastic texture preserved; reddish brown (5YR4/3) to dark gray (N4) glass. Tpcrvlv vitrophyre interval - moderate brown (5YR3/2) to very dark gray (N3) glass. Vitroclastic texture is not macroscopically identifiable.	crv		ccr	non-welded to partially welded	Unit not specifically identified	CCR		
				Not described				
				vitro-phyre	Tiva Canyon welded hydrogeologic unit (TCw)			
Tpcrn nonlithophysal zone - moderately to densely welded; phenocrysts 10 to 15%; devitrified with minor vapor-phase minerals; no lithophysne, but ≤3-mm-diameter cavities in groundmass and pumice fragments.	Not mapped as undivided unit							
Tpcrn4 subvitrophyre transition subzone - pumice-rich, pumice clasts are locally argillic. Tpcrn4d densely welded interval - incipiently crystallized with less than 5% macroscopic porosity Tpcrn4m moderately welded interval - matrix/groundmass and pumice clasts are corroded to form macroscopic porosity of 10 to 25%	crn4			brown devit-rified yellow brown devit-rified		laterally equivalent		
Tpcrn3 pumice-poor subzone - pumice clasts less than 5%	crn3					CUC		
Tpcrn2 mixed pumice subzone - pumice-rich with mixed colors of pumice clasts.	crn2			brown-gray devit-rified		laterally equivalent		
Tpcrn1 crystal transition subzone - phenocrysts 5 to 10%, biotite and trace of pyroxene in matrix; few lithophysae. This subzone is locally absent.	crn1		cuc			CUL		

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tpcrl lithophysal zone - lithophysae are >5 percent. This zone is locally absent Tpcrll crystal transition subzone - phenocrysts 5 to 10%, biotite and trace of pyroxene in matrix; few lithophysae. This subzone is locally absent.	crnl	cr	cuc laterally equivalent cul		Tiva Canyon welded hydrogeologic unit (TCw)	CUC laterally equivalent	Tiva Canyon welded unit (TCw)	Tiva Canyon welded undifferentiated unit (TCw)
Tpcp crystal-poor member: 5% sanidine, 0.1% mafic phenocrysts (hornblende > biotite), and 0.05% sphene. Pumice is mostly light gray (N8-9) with rare, very dark yellowish orange (10YR6/8).	Not mapped as undivided unit	cp	Not mapped as undivided unit					
Tpcpul upper lithophysal zone - rhyolite and characterized by 10 to 20% lithophysae2. Tpcpull spherulite-rich subzone; spherulites are common; centimeter size lithophysal cavities are absent with few large (decimeter size) lithophysal cavities inferred from nonrecovered or rubbed intervals of core. This subzone is locally absent, but where it occurs the remainder of the zone is designated pul2.	cpul		cul			CUL		
Tpcpmn middle nonlithophysal zone - high-angle fractures with smooth surface are common. Locally divided into three subzones. Tpcpmn3 (upper) nonlithophysal subzone. (Use of upper is optional.) Tpcpmn2 lithophysae-bearing subzone. Commonly has veinlets and streaks that locally occur in vapor-phase partings parallel or subparallel to foliation. This partings may weather to small benches in surface exposures. This subzone increases thickness to the north and locally comprises the entire middle nonlithophysal zone. Tpcpmn1 (lower) nonlithophysal subzone. (Use of lower is optional.)	cpmn		cks/crs	clc cgks crks cml cuks clks		CW		
Tpcpll lower lithophysal zone - lithophysae 10 to 15% in surface exposures 2; few high-angle fractures with slightly rough surface. Tpcpllh hackly fractured subzone - lithophysae vary from 2 to 15%; hackly3 fracture with polygonal faces on freshly broken surfaces; hackly fracture is typically not as well developed as in the lower nonlithophysal zone.	cpll		cll	chl				

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
Tpcpln lower nonlithophysal zone - moderately to densely welded tuff; devitrified, locally with vapor-phase minerals. Two subzones are commonly identified. Tpcplnh hackly subzone - hackly fracture with polygonal faces, which are typically <5 mm across, on freshly broken surfaces. Subhorizontal partings, which are commonly coated with vapor-phase minerals, occur locally, and may weather to small benches in surface exposures. Tpcplnc columnar subzone - moderately to densely welded tuff; groundmass is devitrified to a high temperature mineral assemblage; hackly fracture is not well developed. The base of devitrification is locally in the partially welded tuff below the lowermost densely welded tuff. Tpcplnc3 spherulitic pumice interval - pumice fragments are devitrified to high temperature minerals, commonly with spherulitic morphology Tpcpln2 argillic pumice interval - pumice fragments are altered to reddish-pink (5R6/2) clay or zeolite. Tpcplnc1 vitric pumice interval - pumice fragments are preserved as dark-gray (N3) glass.	cpln	cp	Not mapped as undivided unit ch chl	Tiva Canyon welded hydrogeologic unit (TCw)	CW CMW	Tiva Canyon Welded unit (TCw)	Tiva Canyon undifferentiated unit (TCw)
Tpcpv crystal-poor vitric zone Tpcpv3 densely welded subzone - densely welded tuff; no macroscopically identifiable porosity. Tpcpv3v vitrophyre interval - moderate brown (5YR3/2) to very dark gray (N3) glass. Vitroclastic texture is not macroscopically identifiable. Tpcpv3c clastic texture interval - vitroclastic texture preserved; reddish brown (5YR4/3) to dark gray (N4) glass. Tpcpv2 moderately welded subzone - moderately welded with macroscopically identifiable vitroclastic texture and porosity. Tpcpv1 nonwelded to partially welded subzone; locally detrified. Tpcpvlp partially welded interval Tpcpvln nonwelded interval.	cpv		vitro-phyre flat-tened pumice basal	laterally equivalent Paintbrush Tuff nonwelded hydrogeologic unit (PTn)	laterally equivalent CNW	laterally equivalent Paintbrush Tuff nonwelded unit (PTn)	Tiva Canyon densely welded vitric subzone (Tpcpv3) Tiva Canyon nonwelded to moderately welded vitric subzone (Tpcpv1-2)
Tpbt4 pre-Tiva Canyon Tuff bedded tuff consists of tuffaceous rocks not correlated with known eruptive units based on detailed tephrostratigraphic studies.	Tpy	ym	bt		BT4		Tpbt4

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tpy Yucca Mountain Tuff - characteristically aphyric with « 1% phenocrysts. Nonwelded tuff is composed of light yellow to brown fine-grained bubble-wall glass shards. Where the Yucca Mountain Tuff is thick, it is densely welded, has two well-developed lithophysal zones, and stratigraphic nomenclature similar to the zones in the Tiva Canyon or Topopah Spring Tuffs can be applied.	Tpy	ym	ym	ymu ymm yml	Paintbrush Tuff nonwelded hydrogeologic unit (PTn)	TPY	Paintbrush Tuff nonwelded unit (PTn)	Yucca Mountain Tuff (TPY)
Tpg rhyolite of Black Glass Canyon - rhyolite lava flows and related tephra. Similar to crystal-poor part of Tiva Canyon Tuff, with about 5% sanidine phenocrysts, 0.1% mafic phenocrysts (hornblende > biotite), and 0.04% sphene.	Units not exposed in map area	bg	bt	Tfbf Tfbl		Not in boreholes no data		Tpbt3
Tpd rhyolite of Delirium Canyon - rhyolite lava flows and related tephra. Similar to rhyolite of Comb Peak, with about 5% felsic phenocrysts (sanidine > plagioclase), 0.5% hornblende and biotite, and 0.02 percent sphene.		dc						
Tpe rhyolite of Echo Peak - rhyolite lava flows and related tephra. Phenocrysts consist of about 10% sanidine and plagioclase, 0.5% mafic phenocrysts (biotite » pyroxene), and 0.5% sphene		Units not exposed in map area						
Tpz rhyolite of Zig Zag llill - rhyolite lava flows and related tephra. Phenocrysts consist of about 10% felsic phenocrysts (sanidine > plagioclase), 0.05% mafic phenocrysts (biotite » pyroxene), and no sphene.		rz		rz				
Tpb3 pre-Yucca Mountain Tuff bedded tuff consists of tuffaceous rocks not correlated with known eruptive units based on detailed tephrostratigraphic studies.	Tpp	pc				BT3		
Tpp Pah Canyon Tuff - characterized by large pumice clasts. Phenocrysts consist of about 10% felsic phenocrysts (plagioclase > sanidine), 0.5% mafic phenocrysts (biotite » pyroxene), and 0.005% sphene.			pc	pcu pcm pcl		TPP		Pah Canyon Tuff (Tpp)
Tpbt2 pre-Pah Canyon Tuff bedded tuff consists of tuffaceous rocks not correlated with known eruptive units based on detailed tephrostratigraphic studies. The lower 5- to 15-m-thick part of the bedded tuff sequence is moderately well sorted pumiceous tephra with a thin (2 cm) lithic-rich fallout at the base that overlies a thin (2 cm) very fine-grained ash bed. This basal bedset occurs across Yucca Mountain northeast to exposures near Fortymile Canyon.	bt2	bt2	bt			BT2		Tpbt2

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tpt Topopah Spring Tuff[9]	Not mapped as undivided unit	tu	tu		Paintbrush Tuff nonwelded hydrogeologic unit (PTn)	BT2	Paintbrush Tuff nonwelded unit (PTn)	Topopah Spring nonwelded to moderately welded vitric subzone (Tptrv2-3)
Tpbt bedded - nonwelded to partially welded vitric tuff; use "u" for upper and "l" for lower bedded tuff.	bt2	bt2	Not mapped as undivided					
Tptr crystal-rich member: 10 to 15% felsic phenocrysts (locally 8 to 15) (sanidine > plagioclase, trace of quartz), 0.1 percent mafic phenocrysts (biotite > pyroxene, trace of hornblende), and no sphene.		tr						
Tptrv vitric zone Tptrv3 nonwelded subzone - includes partially welded rocks; locally devitrified. The nonwelded subzone is moderately well sorted pumiceous deposits capped by a thin (2 cm) very fine-grained ash bed is in the moderately welded subzone. Tptrv3n welded interval Tptrv3p partially welded interval.	bt2		tc	non-welded				
Tptrv2 moderately welded subzone - moderately welded with macroscopically identifiable vitroclastic texture and porosity; locally devitrified.		trv						
Tptrv1 densely welded subzone - densely welded tuff; no macroscopically identifiable porosity. Tptrvlc clastic texture interval - vitroclastic texture preserved; weak red (5YR4/3) to dark gray (N4) glass. Tptrvlv vitrophyre interval - dusky red (10R3/2) to very dark gray (N3) glass. Vitroclastic texture is not macroscopically identifiable.	trv			vitro-phyre	Topopah Spring welded hydrogeologic unit (TSw)	TC	Topopah Spring welded unit, lithophysae-rich (TSw1)	Topopah Spring densely welded vitric subzone (Tptrvl)
Tptrn nonlithophysal zone - no lithophysae, but small cavities are in pumice fragments	Not mapped as undivided unit	tr		devit-rified				Topopah Spring crystal-rich nonlithophysal zone (Tptrn)
Tptrn3 dense subzone - densely welded; incipiently crystallized; minor amounts of porosity where pumice clasts were corroded by the vapor phase or argillically altered. This subzone, which is subjacent to the vitrophyre interval, is distinguished by a lack of vitreous luster and commonly breaks into thin (1- to 3-cm thick) fragments with smooth fractures.	trn3		tr					

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units			Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]		1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tptrn2 vapor-phase corroded subzone - small cavities in pumice clasts and groundmass appear to have resulted from corrosion by the vapor phase during cooling.	trn2	tr	trn	tr		Topopah spring welded hydrogeologic unit (TSw)	TR	Topopah Spring welded unit, lithophysae-rich (TSw1)	Topopah Spring crystal-rich nonlithophysal zone (Tptrn)
Tptrnl crystal transition subzone - phenocrysts 3 to 10% (locally 3 to 8%), biotite and trace of pyroxene in matrix; few lithophysae. This subzone is locally absent.	trn1								
Tptrl lithophysal zone - thin zone of 10 to 20% lithophysae near the base of the crystal-rich section, but with 8 to 10% phenocrysts. This zone was probably included in the upper lithophysal zone of some previous workers.					ttl		TUL		Topopah Spring crystal-rich lithophysal zone (Tptrl)
Tptrll crystal transition subzone - phenocrysts 3 to 10% (locally 3 to 8%). This subzone is locally absent									
Tptf lithic-rich zone - lithic-rich (10 to 50%) with crystal-rich matrix4,5. This zone straddles the contact of the crystal-rich and crystal-poor member.					Units not described		Not in boreholes no data		Topopah Spring lithic-rich member (Tptf) (member is restricted to the northern part of the site area)
Tptrf crystal-rich subzone - 3 to 10% phenocrysts									
Tptrfl lithophysal interval									
Tptrfn nonlithophysal interval									
Tptp crystal-poor member: Less than 3% felsic phenocrysts (sanidine ≈ plagioclase, trace quartz) and 0.05% mafic phenocrysts (biotite with trace of hornblende and pyroxene).	Not mapped as undivided unit								
Tptf lithic-rich zone - lithic rich rhyolite zone with crystal-poor matrix 4,5. This zone straddles the contact of the crystal-rich and crystal-poor member.	tpul	tp	tpul	trl					
Tptpf crystal-rich subzone-less than 3% phenocrysts									
Tptpfl lithophysal interval									
Tptpfn nonlithophysal interval.									
Tptpul upper lithophysal zone - lithophysae, with ≈ 5 mm-wide light-gray rims, volumetrically constitute 5 to 30% of core5 and 5 to 15% in surface exposures2; small (1-5 cm-diameter) lithophysae are ≥ 5%, and subordinate numbers of large (up to 0.5 x 1 m) lithophysae are observed in borehole televiewer log. Intervals of rubbled core and nonrecovered core are common.					tul tll tl		TUL		Topopah Spring crystal-poor upper lithophysae zone (Tptpul)
Tptpulc cavernous lithophysae subzone - small (1-5 cm-diameter) lithophysae are ≤ 2%, and numerous large (up to 0.5 x 1 m) lithophysae are observed in borehole televiewer log.									

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units			Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]		1:24,000 Scale[4]		Major[5]	Detailed[6]		
Intervals of rubbled core and nonrecovered core are common. Tptpuls small lithophysal subzone - small (1-5 cm-diameter) lithophysae are > 2% with numerous large (up to 0.5 x 1 m) lithophysae.	tpul	tp	tpul	trl	tul tll tl	Topopah Spring welded hydro-geologic unit (TSw)	TUL	(TSw1)	(Tptpul)
Tptpmn middle nonlithophysal zone - locally has a middle lithophysal subzone. Tptpmn3 (upper) nonlithophysal subzone. (Use of upper is optional.) Tptpmn2 lithophysae-bearing subzone - lithophysae are < 5%. Commonly has veinlets and streaks that locally occur in vapor-phase partings parallel or subparallel to foliation. Tptpmn1 (lower) nonlithophysal subzone. (Use of lower is optional.)	tpmn		tpmn	tnl	tgnl to tb tobl tob tbob		TMN	Topopah Spring welded unit, lithophysae-poor (TSw2)	Topopah Spring crystal-poor middle nonlithophysal zone (Tptpmn)
Tptpll lower lithophysal zone - large, but dispersed, irregularly shaped lithophysae with 10- to 15-mm-wide light gray rims. Characterized by < 10% lithophysae in core5 and 5 to 15% in surface exposures2. Lithophysae common along fractures. Large, light gray spots in matrix create distinctive mottled coloration. Tptllh hackly fractured subzone - lithophysae vary from 2 to 15%; moderate to well-developed hackly fractures are common in this zone.	tpll		tpll	tgrl	torl tml tpbl trbb tbol		TLL		Topopah Spring crystal-poor lower lithophysal zone (Tptpll)
Tptpln lower nonlithophysal zone - moderately to densely welded tuff; devitrified, locally with vapor-phase minerals. Subzones similar to those in the Tiva Canyon Tuff are locally identified. Tptplnh hackly subzone - hackly fracture with polygonal faces, which are typically < 5 mm across, on freshly broken surfaces. Tptplnc columnar subzone - densely welded tuff; groundmass is devitrified to a high temperature mineral assemblage. Tptplnc3 spherulitic pumice interval - pumice fragments are typically devitrified to a high temperature mineral assemblage.	Units not exposed in map area		tpln	tm			TM2 TM1		Topopah-Spring crystal-poor lower nonlithophysal zone (Tptpln)

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units			Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]		1:24,000 Scale[4]		Major[5]	Detailed[6]		
Tptpln Tptplnc2 argillic pumice interval - pumice fragments are altered to reddish-pink (5R6/2) clay or zeolite Tptplnc1 vitric pumice interval - pumice fragments are preserved as dark-gray (N3) glass.	Units not exposed in map area	tp	tpln	tm	Units not described	(TSw)	TM1	(TSw2)	(Tptpln)
Tptpv crystal-poor vitric zone. Tptpv3 densely welded subzone - densely welded tuff; no macroscopically identifiable porosity. Tptpv3v vitrophyre interval - dark to very dark gray (N4 to N3) glass. Vitroclastic texture is not macroscopically identifiable. Tptpv3c clastic texture interval - vitroclastic texture preserved; weak red (10R4/3) or reddish brown (5YR4/3) to dark gray (N4) glass.			tpv	tpv			PV3	Topopah Spring welded unit, vitrophyre (TSw3)	Topopah Spring crystal-poor densely welded vitric subzone (Tptpv3)
Tptpv2 moderately welded subzone - moderately welded with macroscopically identifiable vitroclastic texture and porosity. The top of this subzone is typically gradational to densely welded clastic texture interval (pv3c); locally devitrified with vapor-phase minerals.				Unit not described	??	Calico Hills nonwelded hydrogeologic unit (CHn)	PV2	Calico Hills and lower Paintbrush nonwelded unit (CHn1)	Topopah Spring crystal-poor nonwelded to moderately welded vitric subzone (Tptpv1-2)
Tptpv1 nonwelded subzone - partially welded to nonwelded vitric. Quartz only occurs as resorbed crystals and probably represents xenocrysts. Tptpvlp partially welded interval. Tptpvln nonwelded interval.				tpw			BT1 (where vitric) BT1a (where altered)		
Tpbt1 pre-Topopah Spring Tuff bedded tuff consists of tuffaceous rocks not correlated with known eruptive units based on detailed tephrostratigraphic studies.				Not mapped as undivided unit		(CHnv where dominantly vitric)			(Tptbt1)
Tac Calico Hills Formation - Characterized by abundance of nonwelded vitric material, some of which has authigenic zeolites. Tacl As many as five lava flows occur interstratified throughout the section exposed in and north of Yucca Wash and in boreholes WT#4, WT-6, WT#16, WT#18, but have not been divided. Tac5 Non- to partially welded, pumiceous pyroclastic-flow deposit: slightly elongated pumice clasts; bimodal distribution of pumice clast sizes; 20 to 30% pumice. Light colored pumice clasts; moderate reddish-orange to grayish-pink matrix. Base marked by thinly bedded fall deposits		acl (lava flows) act (pyroclastic and tuffaceous deposits)		Tht (pyroclastic and tuffaceous deposits) Thf (lava flows) Tha (autobrecciated lavas)		(CHnz where dominantly zeolitic)	CHV (vitric) or CHZ (zeolitic) (vitric-zeolitic boundary transects stratigraphic position)		Calico Hills Formation undifferentiated (Tac)

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
Tac4 Nonwelded, pumiceous pyroclastic-flow deposit: volcanic lithic clasts are large (20 to 70 mm), isolated or in swarms; prominent clasts of moderate reddish-orange tuff. Light colored pumice clasts; very pale orange to grayish orange-pink matrix. Lithic-poor sections appear similar to unit 2. Base marked by a heterolithologic sequence of fall deposits. Tac3 Nonwelded, lithic-rich pyroclastic flow deposit: lithic clasts comprise 5 to 10%, locally 10 to 30% (near the base and in several intervals within the unit); predominantly devitrified volcanic rocks with local obsidian. Grayish-orange to grayish-yellow or pinkish-gray matrix. The basal lithic-rich fallout is an excellent stratigraphic marker. Tac2 Nonwelded, pumiceous pyroclastic-flow deposit: 20 to 40% light colored pumice clasts; moderate pink or moderate orange-pink matrix. The fall deposit at the base of the unit contains porcelaneous ash layers. Tac 1 Nonwelded, lithic-rich pyroclastic-flow deposit: 15 to 20% devitrified volcanic lithic clasts near base; lithics decrease upward to 3 to 7%. Light colored pumice clasts; grayish orange-pink to light greenish-gray matrix; 7 to 12% phenocrysts.	Units not exposed in map area	acl (lava flows) act (pyroclastic and tuffaceous deposits)	Tht (pyroclastic and tuffaceous deposits) Thf (lava flows) Tha (autobrecciated lavas)	Calico Hills nonwelded hydrogeologic unit (Chn) (CHnv where dominantly vitric) (CHnz where dominantly zeolitic)	CHV (vitric) or CHZ (zeolitic) (vitric-zeolitic boundary transects stratigraphic position and hydrogeologic properties differ from north to south and west to east)	Calico Hills and lower Paintbrush nonwelded unit (CHn1)	Calico Hills Formation undifferentiated (Tac)
Tacbt Bedded tuff unit: interbedded coarse-grained fallout deposits, pyroclastic-flow deposits (many reworked or with paleosols), and thinly bedded porcelaneous ash-fall deposits. Pyroclastic-flow deposits have 13 to 25% phenocrysts. Tacbs Basal sandstone unit: massive to laminated, immature volcaniclastic sandstone; very pale orange to moderate red; medium to coarse grained; accumulations of argillic pumice clasts and rare sedimentary structures including load casts, pinch and swell structures, and flame structures. Locally interbedded with reworked pyroclastic-flow deposits.			Not mapped as undivided unit		BT	Calico Hills and lower Paintbrush nonwelded unit (CHn2)	pre-Calico Hills Formation bedded tuff (Tacbt)

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84	Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]	Major[5]	Detailed[6]		
Tcp1 Pumiceous pyroclastic-flow deposits: Upper subunit - devitrified; pumice clasts are from 10 to 40 mm and nondeformed; 1 to 3% lithic clasts; pervasively altered to zeolite minerals. Middle subunit - devitrified; pumice clasts are from 5 to 30 mm and nondeformed; 3 to 5% lithic clasts; pervasively altered to zeolite minerals. Lower subunit - devitrified; pumice clasts are from 5 to 25 mm and nondeformed; 1 to 3% lithic clasts; pervasively altered to zeolite minerals. The basal contact is depositional and separates an overlying pyroclastic-flow deposit from an underlying deposit of laminated ash.	Units not exposed in map area	PP	Tcpu	Calico Hills nonwelded hydrogeologic unit (CHn) (CHnv where dominantly vitric) (CHnz where dominantly zeolitic)	PP1	Upper Crater Flat nonwelded unit	
Tcpbt Bedded tuffs unit: Laminated ash subunit - thinly laminated fine-grained deposits that locally exhibit low-angle cross-stratification. Pumiceous tuffs subunit - A series of one to five locally preserved, nonwelded, variably altered deposits; upper pumiceous tuff, reworked, pumice content of 20 to 70%, rare biotite; upper pyroclastic-flow deposit, 5 to 7% phenocrysts including subordinate biotite, pyroxene pseudomorphs or hornblende, 3 to 5% lithic clasts; lower pyroclastic-flow deposit, 7 to 10% phenocrysts including abundant biotite, 10 to 15% lithic clasts; lower pumiceous tuff, reworked, pumice content of 25 to 80%, abundant biotite; breccia, clasts of Bullfrog Tuff and locally other felsic volcanic lithologies. The Bullfrog Tuff is recognized by abundant biotite and a higher percentage of quartz in the felsic phenocryst assemblage; it varies from nonwelded to moderately welded at the contact.		ppbt	bt				pre-Prow Pass Tuff bedded tuff ([bt])

1 Lithostratigraphic units and descriptions for the Rainier Mesa and pre-Rainier Mesa Tuff bedded tuff from Geslin et al. (1995) and Geslin and Moyer (1995), Paintbrush Group from Buesch, Spengler et al. (1996a), and Calico Hills Formation and Prow Pass Tuff from Moyer and Geslin (1995).
2 Mapping of the central block of Yucca Mountain by Day et al. (1996a milestone)
3 Mapping of the site area of Yucca Mountain by Day et al. (1997 milestone).
4 Mapping of the Yucca Mountain area by R.B. Scott and Bonk (1984). Tentative correlations of lithostratigraphic units with those in the left column are queried.
5 Major hydrogeologic units from Montazer and Wilson (1984) with vitric and zeolitic designation added in the Site Characterization Plan (DOE 1988b). Could probably use the symbol CHnc for areas where the CHn is crystallized, although this has not been done. Montazer and Wilson (1984) defined a Bullfrog unit, but Wittwer et al. (1995) removed it from their UZ model.
6 Detailed hydrogeologic units of the unsaturated zone from L.E. Flint (1998a).
7 Thermal-mechanical units from Ortiz et al. (1985)
8 Three-dimensional site geologic model units are from the Integrated Site Model version ISM2.0 (CRWMS M&O 1997e).
9 Locally where the Tiva Canyon and Topopah Spring Tuffs are mapped as brecciated on the 1:24,000 scale maps, these areas have the symbols cx and tx, respectively.
10 Color designations on dry samples using the Rock Color Chart (GSA 1991) and the Munsell Soil Color Chart (Munsell Color Company, Inc. 1988).

Table 3.5-2. Descriptions of Lithostratigraphic Units Within the Timber Mountain Group, Paintbrush Group, Calico Hills Formation and Prow Pass Tuff at Yucca Mountain, and Correlations with Mapped Units, Hydrogeologic Units, Thermal-Mechanical Units, and 3-D Site Geologic Framework Model Units (Continued)

Lithostratigraphic Units[1]	Map Units		Map Units 84		Hydrogeologic Units		Thermal-Mechanical Units[7]	3-D Site Geologic Model Units[8]
	1:6,000 Scale[2]	1:24,000 Scale[3]	1:24,000 Scale[4]		Major[5]	Detailed[6]		
CRATER FLAT GROUP - Distinguished by relative abundance of quartz and biotite phenocrysts. (Symbol: Tc)	Units not exposed in map area	Not mapped as undivided unit	Not mapped as undivided unit		Calico Hills nonwelded hydrogeologic unit (CHn) (CHnv where dominantly vitric) (CHnz where dominantly zeolitic)			
Tcp Prow Pass Tuff Tcp4 Pyroxene-rich pyroclastic-flow deposits: Upper submit - massive ash; pumice-poor; vitric, devitrified, or altered to clay and/or zeolite minerals. Middle subunit - 1 to 4 flow units; pumice clasts are from 3 to 12 mm; vitric, devitrified, or altered to clay and/or zeolite minerals. Lower subunit - 1 to 2 flow units; pumice clasts; vitric, devitrified, or altered to clay and/or zeolite minerals. The basal contact is a sharp break below which is intensely vapor-phrase altered and devitrified tuff.		pp	Tcpu			PP4	Calico Hills and lower Paintbrush nonwelded unit (CHn3)	Prow Pass Tuff uppermost nonwelded (Tcp [unw])
Tcp3 Welded pyroclastic-flow deposit: Strongly vapor-phase altered subunit - devitrified; intense vapor-phase alteration; corroded, nondeformed pumice clasts. Upper nonwelded to partially welded subunit - devitrified; minor vapor-phase alteration; nondeformed pumice clasts Upper moderately welded subunit - devitrified; minor vapor-phase alteration; deformed (elongated) pumice clasts Middle nonwelded to partially welded subunit - devitrified; minor vapor-phase alteration; nondeformed pumice clasts. Lower moderately welded subunit - devitrified; minor vapor-phase alteration; deformed (elongated) pumice clasts; locally oxidized and argillically altered.				Tcpp		PP3	Prow Pass welded unit (PPw)	Prow Pass Tuff welded zone (Tcp [w])
Lower nonwelded to partially welded subunit - devitrified; minor vapor-phase alteration; nondeformed pumice clasts; oxidized and locally altered to clay and/or zeolite minerals. The basal contact is a locally preserved ash-fall deposit that separates an overlying lithic-poor pyroclastic-flow deposit from an underlying lithic-rich pyroclastic-flow deposit.				Tcpm		PP2	Upper Crater Flat nonwelded unit (CFUn)	Prow Pass Tuff lower nonwelded zone (Tcp [lnw])
Tcp2 Lithic-rich pyroclastic-flow deposits: 1 to 3 flow deposits; 3 to 7% lithic clasts; nondeformed pumice clasts (locally elongated); devitrified, pervasively altered to zeolite and clay minerals. The basal contact is a locally preserved ash-fall deposit that separates an overlying pyroclastic-flow deposit with moderately sized pumice clasts and abundant lithic clasts from an underlying pyroclastic-flow deposit with larger pumice clasts and fewer lithic clasts.						PP1		

Table 3.5-3. Primary, Secondary and Tertiary Processes, which Result in Lithologic Features, that Influence Matrix Properties, Geophysical Logs, and Mineral Chemistry.

Primary Processes

- Mechanics of eruption
  - Effusive
  - Explosive (pyroclast formation, and initiation of pyroclastic flow or fallout)
- Depositional processes (transport by and deposition from)
  - Pyroclastic flow
  - Fallout tephra
  - Lava flow
  - Redeposition of material
- Textures and Structures (grain size and abundance of pyroclasts and lithic clasts)
  - Interstratified fallout tephra beds and ignimbrites
  - Fine- versus coarse-grained deposits
  - Grain-size sorting
  - Lithic and pumice concentrations

Secondary Processes (Post-Depositional) (first 100 Years?)

- Lava flows
  - Vitric
  - Crystallized (also referred to as devitrified)
  - Lithophysal zones
- Welding (zones of)
  - Nonwelded, partially welded, moderately welded, and densely welded
- Crystallization (zones of)
  - Vitric (shards and pumice remain vitric after cooling of the deposit)
  - Crystallization (also referred to as devitrification)
  - Vapor-phase activity
    - Corrosion (creates secondary porosity)
    - Mineralization (changes pore structure and permeability)
  - Lithophysal zones
  - Fumarolic alteration and crystallization
    - "Moderate" temperature (40 to 100°C) formed during cooling of ignimbrites near vitric-crystallized boundaries
- Fracturing during cooling of ignimbrites and lava flows

Tertiary Processes (hundreds to millions of years after deposition)

- Argillic and zeolitic alteration
  - "Low" temperature (diagenetic, geothermal, and hydrothermal)
    - Saturated zone beneath a paleowater table
    - Along fractures or where water was perched
- Formation of paleosols
- Tectonism
  - Faulting, fracturing, folding, tilting

NOTE: Underline indicates most influential at Yucca Mountain

Table 3.6-1. Summary of Fracture Attributes, Tiva Canyon Tuff

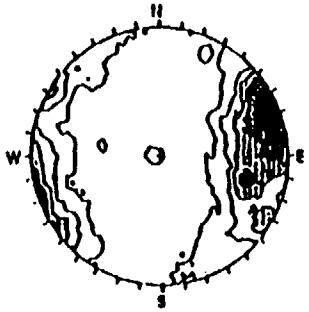
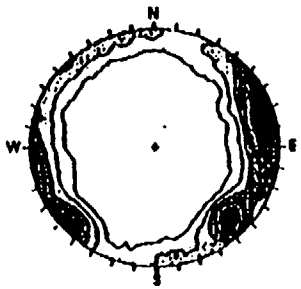
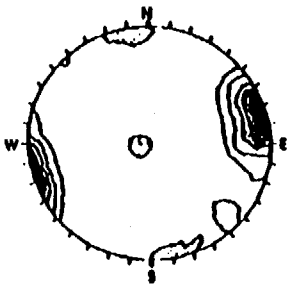
Lithostratigraphic Zone	Orientation Distribution	Length	Fracture Spacing (or frequency)	Distinguishing Features of the Joint Network
Crystal-rich member (Tpcr) (100% Q'd data)		Surface: Cooling joints, 1 to 2.5 m; Tectonic joints, 0.5 to 1 m ESF: 2.5 to 3 m	Spacing, surface: 0.5 to 2 m Spacing, ESF: mean, 1 m	Cooling joint sets of various orientations, including N. 14° E./85° W. and N. 50°W./85° W., and N. 14° E./85° W.
Crystal-poor upper lithophysal zone (Tpcpul) (40% Q'd data)		Surface: Cooling joints, mean, 2.5 m, range 2 to 10 m. Tectonic joints, 1 to 2 m ESF: 2.5 to 3 m	Spacing, surface: 0.5 to 3 m; Spacing, ESF: mean, 1 m Borehole fracture density (for Tpcr and Tpcpul combined): 17.5 fractures per 10 feet, range 16 to 21 per 10 feet	Two well developed sets of steeply dipping cooling joints (oriented N. 40 to 60° E./80° W.and N. 40 to 55° W./80° E.) that generally form a rectangular pattern.
Crystal-poor middle nonlithophysal zone (Tpcpmn) (100% Q'd data)		Surface: Mean, 1 to 2 m	Spacing, surface: variable, 0.5 to 1.5 m Spacing, ESF: 1.25 m for vapor phase partings	Abundant short (1 to 2 m or less), curving fractures of diverse orientation. In the ESF, closely spaced, foliation parallel cooling joints ("vapor-phase partings") are common.

Table 3.6-2. Summary of Fracture Attributes, Lithostratigraphic Units Equivalent to the PTn Hydrologic Unit

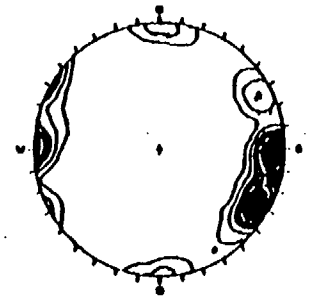
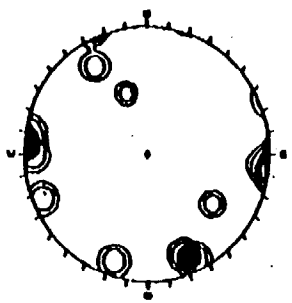
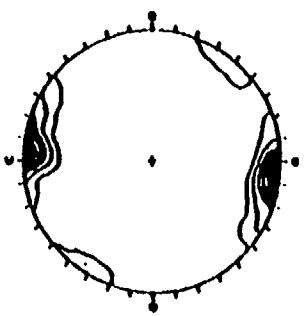
Lithostratigraphic Zone	Orientation Distribution	Length	Fracture Spacing (or frequency)	Distinguishing Features of the Joint Network
Tiva Canyon Tuff, crystal-poor vitric zone (Tpcpv) (100% Q'd data)	 389 poles, 2% CI	Surface: 1 to 3 m; ESF: 2.0 to 2.5 m	Spacing, surface: mean 0.5 m, range, 0.2 to 3 m; Spacing, ESF: mean, 0.57 m; range 0 to 3.1 m. Borehole fracture density: 18 fractures per 10 feet, range 7.5 to 28 per 10 feet.	Variably oriented cooling joints in densely to moderately welded vitric tuff give way downsection to north- and northwest-striking tectonic joints. Average joint spacing remains relatively close (0.5 m) to contact with poorly welded vitric tuff, where joint density drops abruptly.
Pre-Tiva Canyon bedded tuff (Tpbt4) (100% Q'd data)	 10 poles, 4% CI	Surface: 1 to 2 m ESF: 2.5 to 3.3 m	Spacing, surface: Indeterminate. Spacing, ESF: mean, 1.35 m; range 0 to 7.5 m.	Rough, short fractures with irregular spacing. Fractures in this unit commonly originated in Tpy and propagated into Tpbt4.
Yucca Mountain Tuff (Tpy) (100% Q'd data)	 191 poles, 3.5% CI	Surface: Mean, 1.5 m, range 2 to 5 m	Spacing, surface: 1 to 2 m Borehole fracture density: 9.0 fractures per 10 feet.	Non-welded Tpy has widely spaced north- and northwest-striking tectonic joints. Joint spacing decreases within welded Tpy where two sets of cooling joints are also present.

Table 3.6-3. Summary of Fracture Attributes, Topopah Spring Tuff

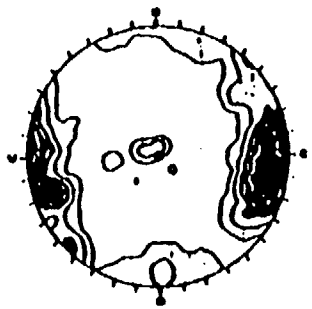
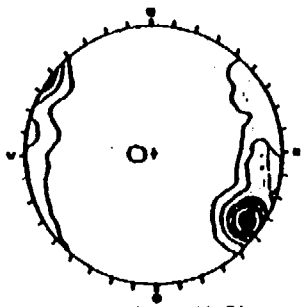
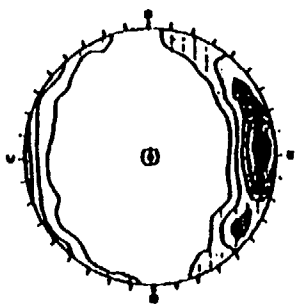
Lithostratigraphic Zone	Orientation Distribution	Length	Fracture Spacing (or frequency)	Distinguishing Features of the Joint Network
Crystal-rich vitrophyre (Tptrv1) (100% Q'd data)	 530 poles, 1% CI	Surface: 1 to 2 m; ESF: 2.0 to 3.8 m	Spacing, surface: 0.5 to 2 m; Spacing, ESF: mean, 0.84 m; range 0 to 14.5 m. Borehole fracture density: 40.4 fractures per 10 feet, range 19 to 67 per 10 feet.	Two steeply dipping cooling joints with strikes of N. 80° E. to N. 75° W., and N. 50°W. to N. 15° E. Exposed lengths of cooling joints typically range from 0.5 m to 2.5 m; tectonic joints are shorter, mostly less than 1 m. Many of the fractures near the top of the unit terminate in the welding transition at the top of Tpt.
Crystal-rich nonlithophysal zone (Tptrn) (100% Q'd data)	 931 poles, 2% CI	Surface: Cooling joints, 1 to 4 m, Tectonic joints, 0.4 to 4 m ESF: 3 to 4 m	Spacing, surface: 0.5 to 1.5 m; Spacing, ESF: mean, 0.98 m; range 0 to 11 m Borehole fracture density: 17.5 fractures per 10 feet, range 8 to 24 per 10 feet	Steeply dipping cooling joints of various orientations dominate this unit. Fracture intensity in the upper part of the unit is high; especially in vapor-phase altered tuff.
Crystal-poor upper nonlithophysal zone (Tptpul) (100% Q'd data)	 1592 poles, 1.5% CI	Surface: Mean, 2 m, range 0.5 to 4 m ESF: 3 to 3.5 m	Spacing, surface: 0.5 to 3 m; Spacing, ESF: mean, 1.5 m; range 0 to 15 m. Borehole fracture density: 9.4 fractures per 10 feet, range 2 to 40 feet.	Steeply dipping cooling joints are rare in this unit. North- and northwest-striking tectonic joints tend to be short, discontinuous and irregularly spaced within this zone. Many fractures end blindly in rock.

Table 3.6-4. Summary of Fracture Attributes, Calico Hills Formation and Bullfrog Tuff

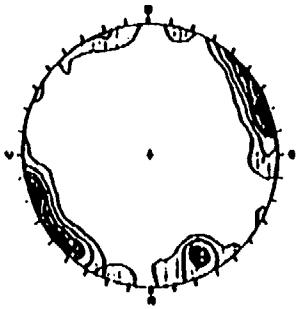
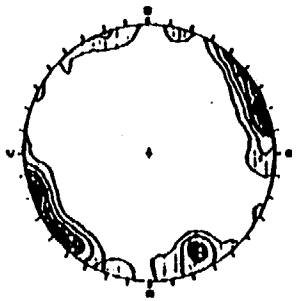
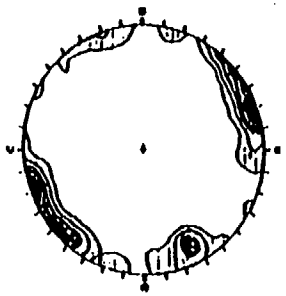
Lithostratigraphic Zone	Orientation Distribution	Length	Fracture Spacing (or frequency)	Distinguishing Features of the Joint Network
Calico Hills Formation pyroclastic flow units (100% Q'd data)	 198 poles, 2.5% CI	Surface: 1.5 to 5 m;	Spacing, surface: mean is 1 to 2 m. Northwest-striking joints occur as widely spaced northwest-trending zones. Joint spacing within a zone is typically 0.5 to 1 m. Between the zones the spacing of the northwest-striking joints is 2 to 4 m or more.	Two steeply dipping cooling joints with strikes of N. 80° E. to N. 75° W., and N. 50°W. to N. 15° E. Exposed lengths of cooling joints typically range from 0.5 m to 2.5 m; tectonic joints are shorter, mostly less than 1 m. Many of the fractures near the top of the unit terminate in the welding transition at the top of Tpt.
Calico Hills Formation bedded units (100% Q'd data)	 45 poles, 2.5% CI	Surface: 1 to 2.5 m ESF: 3 to 4 m	Spacing, surface: 1.5 to 3.5 m;	Steeply dipping cooling joints of various orientations dominate this unit. Fracture intensity in the upper part of the unit is high; especially in vapor-phase altered tuff.
Bullfrog Tuff, moderately welded (100% Q'd data)	 1199 poles, 1% CI	Surface: Mean, 1 to 2 m	Spacing, surface: mean, 0.3 m	Steeply dipping cooling joints are rare in this unit. North- and northwest-striking tectonic joints tend to be short, discontinuous and irregularly spaced within this zone. Many fractures end blindly in rock.

Table 3.6-5. Comparison of Fracture Intensity and Network Geometry, Paintbrush Group, Yucca Mountain, Nevada

Lithologic Unit	Fracture Intensity			Intersection Intensity		Termination Percentage
	#/m^2	m/m^2	#m	#m^2	#m	
Bedded tuff[1]	0.20	0.38	[0.38]	0.03	0.18 [0.1]	9.2 [18.4)
Nonwelded to partially welded pyroclastic flow[1]	0.67	0.73	[0.47]	0.33	0.44 [0.1]	27.1 [23.3]
Poorly to moderately welded vitric zone, Tiva Canyon Tuff[1]	0.66	0.96	[1.23]	0.28	0.3 [0.32]	23.4 [38.4]
Moderately to densely welded Tiva Canyon Tuff						
Crystal-rich member[2]	1.00	0.98	0.74 [1.2]	0.29	1.02	15.20
Upper lithophysal zone[3]	0.80	2.03	[1.79]	0.73	0.59 [0.23]	29 [22.8]
Middle nonlithophysal zone[4]	0.35	1.07	[2.64]	0.23	0.65 [0.56]	78 [60.7]
Moderately to densely welded Topopah Spring Tuff						
Upper lithophysal zone[5]	0.26	0.64	[1.23]	0.10	0.18 [0.25]	20.40
Middle nonlithophysal zone[5]	0.73	1.70	[3.73]	1.40	0.78 [0.71]	79.7 [56.7]

NOTE: Fracture intensity is calculated as number per area, #/m^2, and trace length per area, m/m^2, for two dimensional data and number per meter, #/m, for one dimensional data. Intersection intensity is calculated as number of intersections per area, #/m^2, for two dimensional data and number of intersections per unit fracture trace length, #/m, for one dimensional data. Termination percentage, given in percent, is calculated as number of abutting and intersecting terminations divided by the total number of fracture endpoints. Numerical values for each of the above parameters are coded by data collection method, as follows: plain type for data collected by the pavement method; data collected by detailed line surveys (DLS) within the ESF in brackets; and bold type for data collected by close-range photogrammetry within the ESF. Lower-limit trace length cutoffs are 0.3 and 0.15 m for the DLS and photogrammetry, respectively. Lower-limit trace length cutoffs for pavements are given in the footnotes.

[1]Pavement data; qualified, derived from maps of three exposures of the interval separating the Tiva Canyon Tuff from the Topopah Spring Tuff (Sweetkind, Verbeck et al. 1995a)

[2]Photogrammetry data; qualified, from Coe (1996a). Lower-limit trace length cutoff is 0.15 m.

[3]Pavement data; non-qualified, derived from maps of pavements 100, 200, and 300 (Barton, Larsen et al. 1993). Lower-limit trace length cutoff is 0.2 m.

[4]Pavement mapping and photogrammetry data of the UZ-7A exposure (Sweetkind, Williams-Stroud et al. 1997). Lower-limit trace length cutoff is,1 m.

[5]Pavement data; qualified, derived from map of pavement P2001 (Sweetkind, Verbeek et al. 1995b). Lower-limit trace length cutoff is 1.5 m.

Table 3.6-6. Fracturing Associated with Faults in the Exploratory Studies Facility

Fault Name	ESF Station	Amount of Offset (m)	Orientation		Offset Sense	Zone of Influence	Description
			Strike	Dip			
Bow Ridge	2+00	100 m	175	60	Normal, down to west	0-2 m in hanging wall, no apparent zone in footwall	Hanging wall is in pre-Rainier Mesa tuff, footwall is in Tpcpll. Rock around fault is virtually unfractured.
--	4+40	7 m	180	80	Normal, down to west	--	Relationships in this area cannot be clearly seen, in part due to the quantity of dirt on tunnel walls.
--	5+50	7.5 m	--	--	Normal, down to west	--	Rubble zone is completely covered by lagging and shotcrete, fracturing cannot be characterized.
--	6+15	3 to 4 m	220	73	Reverse, down to east	0.5-1 m in hanging wall, 0.5-1 m in footwall	Both hanging- and footwall are in Tpcpll. The Tpcpll/ Tpcpin contact occurs near springline. Complex zone of small faults. Each appears to be surrounded by a small zone of fracturing.
--	7+05	13 m	191	79	Normal, down to west	1 m in hanging wall, 2 m in footwall	Both hanging- and footwall are in Tpcpln. Fracture spacing next to fault in hanging wall is 0.1-0.2 m, in footwall is 0.1-0.2 m.
--	7+41	5 m	178	78	Normal, down to west	1.5 m in hanging wall, 1 m in footwall	Both hanging- and footwall are in Tpcpin. Fracture spacing next to the fault is approximately 0.02 m.
--	8+45	4 m	220	84	Normal, down to west	No apparent zone on either side	Both hanging- and footwall are in the pre-Tiva Canyon tuffs. Fracturing on either side appears to be consistent with that found elsewhere in these tuffs.
--	10+44	0.9 m	350	74	Normal, down to east	No apparent zone on either side	Both hanging- and footwall are in bedded tuffs.
--	11+20	12 m	--	--	Normal, down to west	6 m in hanging wall, 6 m in footwall	Both hanging- and footwall are in Tptrv. Rock is extensively covered on sides and crown in this area. Close to the fault, fracture spacing in footwall is 0.02-0.11 m, spacing in hanging wall is 0.3 to 0.5 m.
Drill Hole Wash	19+38	6 m	150	90	Normal, down to west, unknown strike-slip component	1-3 m in hanging wall, 0-2 m in footwall	Both hanging- and footwall are in Tptpul.

NOTE: Fault orientation, stationing and offset obtained from qualified full-periphery geologic maps and descriptions in Barr et al. (1996) and Albin et al. (1997). Description of zone of influence is from qualified report Sweetkind, Barr et al. (1997). Fault orientation is reported using the right-hand rule convention. Stratigraphic abbreviations and nomenclature follow informal usage of Buesch, Spengler et al. (1996a). ESF stationing is in meters, each station represents 100 m.

Table 3.6-6. Fracturing Associated with Faults in the Exploratory Studies Facility (Continued)

Fault Name	ESF Station	Amount of Offset (m)	Orientation		Offset Sense	Zone of Influence	Description
			Strike	Dip			
--	22+70	2 m	155	52	Normal, down to west, unknown strike-slip component	1-2 m in hanging wall, no apparent influence in foot-wall	Both hanging- and footwall are in Tptpul. Spacing of fracturing in footwall is 0.07-0.1 m subparallel to the fault.
Sundance	35+94	<1 m	155	84	Normal, down to west, unknown strike-slip component	2 m in hanging wall, 1-4 in footwall	Both hanging- and footwall are in Tptpmn.
Ghost Dance	57+30	2 m max	205	90	Normal, down to west, unknown strike-slip component	No obvious zone on either side	Tptpmn/Tptpll contact cuts across both hanging wall and footwall of fault near springline. There are possi-ble numerous shorter fractures (5 cm) adjacent to the fault in the hanging wall, giving the rock a rubbly appearance.
--	67+61	Unknown	173	75	Normal, down to west	1-2 m in hanging wall, 4 m in footwall	Hanging wall in Tpcpin, footwall in bedded tuffs and Tpcpv. Fractures in bedded tuff are discrete, typical of the bedded tuffs. Fractures in the hanging wall have lengths of 0.2-0.5 m.
Dune Wash	67+88 (west side)	65 m	140	86	Normal, down to west	6-7 m in hanging wall	Hanging wall in Tpcpin.
--	67+91 (east side)	--	175	60	Normal, down to west	2 m in footwall	Footwall in Tptpul, fracturing next to fault is <5 cm in length, radial fabric may or may not be fault related
--	70_58	55 m	170-209	60-81	Normal, down to west	5-10 m in hanging wall, unknown in footwall	Hanging wall in bedded tuffs, footwall in Tptpmn. Fracturing in footwall extends to next major fault at Sta. 71+30. Fracturing in hanging wall is composed of discrete shears with orientations of 155-162/81-88, offset of 0.06-0.15 m, and spacing of 1.5-2.5 m.

NOTE: Fault orientation, stationing and offset obtained from qualified full-periphery geologic maps and descriptions in Barr et al. (1996) and Albin et al. (1997). Description of zone of influence is from qualified report Sweetkind, Barr et al. (1997). Fault orientation is reported using the right-hand rule convention. Stratigraphic abbreviations and nomenclature follow informal usage of Buesch, Spengler et al. (1996a). ESF stationing is in meters, each station represents 100 m.

INTENTIONALLY LEFT BLANK

Table 3.7-1. Comparison of Several Stratigraphic Subdivisions of Volcanic Rocks at Yucca Mountain and Encountered on the Yucca Mountain Site Characterization Project (no scale)

Lithostratigraphic Units[1]		Thermal/Mechanical Units[2]	Hydrogeologic Units[3]
Timber Mountain Tuff (Tm)	Rainier Mesa member (Tmr)	Undifferentiated overburden (UO)	Unconsolidated Surficial Materials (UO)
	Pre-Rainier Mesa bedded tuff (Tmrbt1)		
Tuff unit "X" (Tpk)	tuff unit "X" (Tpki)		
	post-Tiva Canyon bedded tuff (Tpbt5)		
PAINTBRUSH GROUP (Tp)			
Tiva Canyon Tuff (Tpc)	crystal-rich member (Tpcr) vitric zone (Tpcrv) - nonwelded subzone (Tpcrv3) - moderately welded subzone (Tpcrv2) - densely welded subzone (Tpcrv1) nonlithophysal zone (Tpcrn) lithophysal zone (Tpcrl)	Tiva Canyon welded (TCw)[4]	Tiva Canyon welded (TCw)
	crystal-poor member (Tpcp) upper lithophysal zone (Tpcpul) middle nonlithophysal zone (Tpcpmn) lower lithophysal zone (Tpcpll) lower nonlithophysal zone (Tpcpln) - hackly subzone (Tpcplnh) - columnar subzone (Tpcplnc) vitric zone (Tpcpv) - densely welded subzone (Tpcpvv) - moderately welded subzone (Tpcpvm) - nonwelded subzone (Tpcpvn)	Paintbrush Tuff nonwelded (PTn)	Paintbrush nonwelded (PTn)
	pre-Tiva Canyon bedded tuff (Tpbt4)		
Yucca Mountain Tuff (Tpy)	Yucca Mountain Tuff (Tpyt)		
	pre-Yucca Mountain bedded tuff (Tpbt3)		
Pah Canyon Tuff (Tpp)	Pah Canyon Tuff (Tppt)		
	pre-Pah Canyon bedded tuff (Tpbt2)		
Topapah Spring Tuff (Tpt)	crystal-rich member (Tptr) vitric zone (Tptrv) - nonwelded subzone (Tptrv3) - moderately welded subzone ((Tptrv2) - densely welded subzone (Tptrv1) nonlithophysal zone (Tptrn) lithophysal zone (Tptrl)	Topopah Spring welded, lithophysae-rich (TSw1)	Topopah Spring welded (TSw)
	crystal-poor member (Tptp) upper lithophysal zone (Tptpul) [upper pt]		
REPOSITORY HOST HORIZON	upper lithophysal zone (Tptpul) [lower pt] middle nonlithophysal zone (Tptpmn) lower lithophysal zone (Tptpll) lower nonlithophysal zone (Tptpln)	Topopah Spring welded, lithophysae-poor (TSw2)	
	vitric zone (Tptpv) -densely welded subzone (Tptpv3) -moderately welded subzone (Tptpv2) -nonwelded subzone (Tptpv1)	Topopah Spring welded, vitrophyre (TSw3)	Topopah Spring basal vitrophyre (TSbv)
	pre-Topopah Spring bedded tuff (Tpbt1)	Calico Hills nonwelded (CHn)	Calico Hills nonwelded (CHn)
Calico Hills (Tac)	Calico Hills Formation (Tac)		
	pre-Calico Hills bedded tuff (Tacbt1)		

1) Buesch, Spengler et al. 1996a
2) Ortiz et al. 1985
3) Arnold et al. 1995
4) Where preserved, the base of the densely welded subzone forms the base of the TCw thermal-mechanical and hydrogeologic units. (Buesch, Spengler et al. 1996a)

Table 3.7-2. Summary of Core Recovery Data for Tptpmn

Boreholes	Total Logged (m)	Whole Core Recovered (m)	% of Total	Lost Core (m)	% of Total	Rubble Zones (m)	% of Total	Lost Core & Rubble (m)	% of Total
SD-7	36.6	21.2	57.9	3.9	10.7	11.5	31.4	15.4	42.1
SD-9	33.5	23.4	69.9	4.8	14.3	5.3	15.8	10.1	30.1
SD-12	39.6	27.4	69.2	3.5	8.8	8.7	22.0	12.2	30.8
NRG-6	30.5	21.8	71.5	2.7	8.9	6.0	19.7	8.7	28.5
NRG-7/7A	36.6	17.3	47.2	12.5	34.2	6.8	18.6	19.3	52.8
UZ-14	33.5	26.3	78.5	3.2	9.5	4.0	11.9	7.2	21.5
Total	210.3	137.4	65.3	30.6	14.5	42.3	20.1	72.9	34.7

Table 3.7-3. Rock Weathering Descriptions

Weathering Class	Log Abbreviation	Description
Fresh	F	Rock and fractures not oxidized or discolored; no separation of grains, change of texture, or solutioning
Slightly Weathered	S	Oxidized or discolored fractures and nearby rock; some dull feldspars; no separation of grains; minor leaching.
Moderately Weathered	M	Fractures and most of the rock oxidized or discolored; partial separation of grains; rusty or cloudy crystals; moderate leaching of soluble minerals.
Intensely Weathered	I	Fractures and rock totally oxidized or discolored; extensive clay alteration; leaching complete; extensive grain separation; rock is friable.
Decomposed	D	Grain separation and clay alteration complete.

Source: Sandia National Laboratories Technical Procedure SNL TP-233, *Geotechnical Logging of Core by Examination of Core and Video Records*

Table 3.7-4. Estimated Rock Hardness Descriptions

Hardness Class	Log Abbreviation	Description
Extremely Hard	1	Cannot be scratched; chipped only with repeated heavy hammer blows.
Very Hard	2	Cannot be scratched; broken only with repeated hammer blows.
Hard	3	Scratched with heavy pressure; breaks with heavy hammer blow.
Moderately Hard	4	Scratched with light-moderate pressure; breaks with moderate hammer blow.
Moderately Soft	5	Grooved (1/16th inch) with moderate heavy pressure; breaks with light hammer blow.
Soft	6	Grooved easily with light pressure; scratched with fingernail; breaks with light-moderate manual pressure.
Very Soft	7	Readily gouged with fingernail; breaks with light pressure.
Soil-Like	8	Cohesive
Soil-Like	9	Non-Cohesive

Source: Sandia National Laboratories Technical Procedure SNL TP-233, *Geotechnical Logging of Core by Examination of Core and Video Records*

Table 3.7-5. Summary of Dry Bulk Density (g/cc), Thermal/Mechanical Units

	UO			TCw			TCw-N			TCw-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	2.34	0.01	17	2.34	0.01	17	N/A	N/A	0
NRG-2A	1.23	0.06	12	1.86	0.22	19	1.86	0.22	19	N/A	N/A	0
NRG-2B	1.33	0.11	10	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	2.13	0.19	45	2.13	0.21	32	2.14	0.10	13
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-6	N/A	N/A	0	2.28	0.15	29	2.17	0.19	11	2.35	0.03	18
NRG-7	N/A	N/A	0	2.24	0.10	11	2.24	0.10	11	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	1.28	0.10	22	2.16	0.22	121	2.13	0.24	90	2.26	0.12	31
Range	1.13 to 1.53			1.45 to 2.37			1.45 to 2.36			1.95 to 2.37		
Mean	1.28			2.16			2.13			2.26		
Std. Dev.	0.10			0.22			0.24			0.12		
N	22			121			90			31		

Table 3.7-5. Summary of Dry Bulk Density (g/cc), Thermal/Mechanical Units (Continued)

Core Hole	PTn			TSw1			TSw1-N			TSw1-L		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	1.26	0.17	15	2.13	0.08	51	2.14	0.07	46	2.03	0.04	5
NRG-5	N/A	N/A	0	2.04	N/A	1	N/A	N/A	0	2.04	N/A	1
NRG-6	1.22	0.20	14	2.22	0.04	43	2.22	0.04	37	2.20	0.03	6
NRG-7	1.33	0.24	28	2.15	0.08	81	2.18	0.06	52	2.12	0.09	29
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	1.28	0.21	57	2.16	0.08	176	2.18	0.07	135	2.12	0.09	41
Range	1.00 to 1.78			1.94 to 2.40			1.98 to 2.40			1.94 to 2.26		
Mean	1.28			2.16			2.18			2.12		
Std. Dev.	0.21			0.08			0.07			0.09		
N	57			176			135			41		

Table 3.7-5. Summary of Dry Bulk Density (g/cc), Thermal/Mechanical Units (Continued)

Core Hole	TSw2			TSw3			CHn1		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	2.26	0.04	13	N/A	N/A	0	N/A	N/A	0
NRG-6	2.25	0.06	27	N/A	N/A	0	N/A	N/A	0
NRG-7	2.27	0.09	72	2.35	0.00	4	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES									
TOTAL	2.27	0.08	112	2.35	0.00	4			
Range	1.84 to 2.42			2.34 to 2.35					
Mean	2.27			2.35					
Std. Dev.	0.08			0.00					
N	112			4					

N—Number of samples; N/A—Not applicable; Std. Dev—Sample Standard Deviation

NOTE: The TCw and TSw1 thermal/mechanical units have been subdivided as follows (see text Subsection 3.7.1.1):
TCw-N represents non-lithophysal zones of the TCw unit.
TCw-L represents lithophysal zones of the TCw unit.
TSw1-N represents non-lithophysal zones of the TSw1 unit.
TSw1-L represents lithophysal zones of the TSw1 unit.

Table 3.7-6. Saturated Bulk Density (g/cc) by Thermal/Mechanical Unit

	UO (Tuff "X")			TCw			TCw-N			TCw-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	2.40	0.01	17	2.40	0.01	17	N/A	N/A	0
NRG-2A	1.66	0.05	13	2.11	0.12	19	2.11	0.12	19	N/A	N/A	0
NRG-2B	1.73	0.08	8	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	2.27	0.12	45	2.27	0.13	32	2.26	0.08	13
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-6	N/A	N/A	0	2.36	0.12	26	2.28	0.16	10	2.41	0.01	16
NRG-7	N/A	N/A	0	2.34	0.06	11	2.34	0.06	11	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	2.39	0.03	13	2.39	0.03	13	N/A	N/A	0
ALL HOLES												
TOTAL	1.69	0.07	21	2.30	0.14	131	2.29	0.14	102	2.34	0.09	29
Range	1.56 to 1.85			1.87 to 2.43			1.87 to 2.43			2.10 to 2.42		
Mean	1.69			2.30			2.29			2.34		
Std. Dev.	0.07			0.14			0.14			0.09		
N	21			131			102			29		

Table 3.7-6. Saturated Bulk Density (g/cc) by Thermal/Mechanical Unit (Continued)

	PTn			TSw1			TSw1-N			TSw1-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	1.71	0.12	15	2.28	0.05	51	2.28	0.05	46	2.21	0.03	5
NRG-5	N/A	N/A	0	2.23	N/A	1	N/A	N/A	0	2.23	N/A	1
NRG-6	1.82	0.00	2	2.33	0.03	40	2.34	0.03	34	2.32	0.02	6
NRG-7	1.75	0.15	28	2.29	0.06	72	2.30	0.04	46	2.26	0.07	26
SD-9	1.71	0.10	6	2.32	0.01	4	2.32	0.01	3	2.31	N/A	1
SD-12	1.78	0.17	5	2.30	0.03	8	2.30	0.03	8	N/A	N/A	0
ALL HOLES												
TOTAL	1.74	0.13	56	2.30	0.05	176	2.31	0.05	137	2.26	0.07	39
Range	1.56 to 2.04			2.12 to 2.46			2.16 to 2.46			2.12 to 2.37		
Mean	1.74			2.30			2.31			2.26		
Std. Dev.	0.13			0.05			0.05			0.07		
N	56			176			137			39		

Table 3.7-6. Saturated Bulk Density (g/cc) by Thermal/Mechanical Unit (Continued)

Core Hole	TSw2			TSw3			CHn1		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	2.36	0.03	13	N/A	N/A	0	N/A	N/A	0
NRG-6	2.36	0.04	27	N/A	N/A	0	N/A	N/A	0
NRG-7	2.38	0.03	55	2.35	0.01	3	N/A	N/A	0
SD-9	2.37	0.03	28	N/A	N/A	0	1.87	0.03	3
SD-12	2.39	0.04	10	2.36	0.00	3	N/A	N/A	0
ALL HOLES									
TOTAL	2.37	0.03	133	2.36	0.01	6	1.87	0.03	3
Range	2.26 to 2.45			2.35 to 2.37			1.85 to 1.90		
Mean	2.37			2.36			1.87		
Std. Dev.	0.03			0.01			0.03		
N	133			6			3		

N—Number of samples; N/A—Not applicable; Std. Dev—Sample Standard Deviation

NOTE: The TCw and TSw1 thermal/mechanical units have been subdivided as follows (see text Subsection 3.7.1.1):
TCw-N represents non-lithophysal zones of the TCw unit.
TCw-L represents lithophysal zones of the TCw unit.
TSw1-N represents non-lithophysal zones of the TSw1 unit.
TSw1-L represents lithophysal zones of the TSw1 unit.

Table 3.7-7. Summary of Average Grain Density (g/cc), Thermal/Mechanical Units

	UO			TCw			TCw-N			TCw-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	2.44	0.01	3	2.53	0.01	17	2.53	0.01	17	N/A	N/A	0
NRG-2A	2.34	0.03	12	2.55	0.04	15	2.55	0.04	15	N/A	N/A	0
NRG-2B	2.34	0.02	10	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	2.53	0.03	26	2.54	0.03	16	2.52	0.01	10
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-6	N/A	N/A	0	2.49	0.02	11	2.48	0.03	6	2.50	0.01	5
NRG-7	N/A	N/A	0	2.50	0.01	7	2.50	0.01	7	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	2.35	0.04	25	2.53	0.03	76	2.53	0.04	61	2.51	0.02	15
Range	2.30 to 2.46			2.44 to 2.61			2.44 to 2.61			2.49 to 2.55		
Mean	2.35			2.53			2.53			2.51		
Std. Dev.	0.04			0.03			0.04			0.02		
N	25			76			61			15		

Table 3.7-7. Summary of Average Grain Density (g/cc), Thermal/Mechanical Units (Continued)

Core Hole	PTn			TSw1			TSw1-N			TSw1-L		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	2.41	0.09	14	2.56	0.02	26	2.57	0.02	22	2.54	0.00	4
NRG-5	N/A	N/A	0	2.53	0.01	3	N/A	N/A	0	2.53	0.01	3
NRG-6	2.42	0.04	12	2.55	0.03	48	2.56	0.02	30	2.52	0.02	17
NRG-7	2.35	0.06	28	2.55	0.02	47	2.56	0.02	29	2.54	0.01	18
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	2.38	0.08	54	2.55	0.02	124	2.56	0.02	81	2.53	0.01	42
Range	2.24 to 2.65			2.50 to 2.60			2.50 to 2.60			2.50 to 2.56		
Mean	2.38			2.55			2.56			2.53		
Std. Dev.	0.08			0.02			0.02			0.01		
N	54			124			81			42		

Table 3.7-7. Summary of Average Grain Density (g/cc), Thermal/Mechanical Units (Continued)

Core Hole	TSw2			TSw3			CHn1		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	2.55	0.02	24	N/A	N/A	0	N/A	N/A	0
NRG-6	2.55	0.03	28	N/A	N/A	0	N/A	N/A	0
NRG-7	2.56	0.03	57	2.37	0.01	3	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES									
TOTAL	2.55	0.03	109	2.37	0.01	3			
Range	2.42 to 2.61			2.37 to 2.38					
Mean	2.55			2.37					
Std. Dev.	0.03			0.01					
N	109			3					

N—Number; N/A—Not applicable; Std. Dev—Sample Standard Deviation

NOTE: The TCw and TSw1 thermal/mechanical units have been subdivided as follows (see text Subsection 3.7.1.1):
TCw-N represents non-lithophysal zones of the TCw unit.
TCw-L represents lithophysal zones of the TCw unit.
TSw1-N represents non-lithophysal zones of the TSw1 unit.
TSw1-L represents lithophysal zones of the TSw1 unit.

Table 3.7-8. Summary of Porosity (Percent), Thermal/Mechanical Units

	UO			TCw			TCw-N			TCw-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	7.45	0.66	17	7.45	0.66	17	N/A	N/A	0
NRG-2A	46.81	2.07	15	27.48	9.16	19	27.48	9.16	19	N/A	N/A	0
NRG-2B	42.90	4.33	10	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	15.71	8.16	44	16.01	9.42	31	14.98	3.97	13
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-6	N/A	N/A	0	8.56	5.57	29	12.24	7.12	12	5.96	1.40	17
NRG-7	N/A	N/A	0	11.13	5.08	12	11.13	5.08	12	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	45.24	3.66	25	14.23	9.48	121	15.67	10.12	91	9.87	5.32	30
Range	35.20 to 51.00			4.80 to 44.50			5.20 to 44.50			4.80 to 22.60		
Mean	45.24			14.23			15.67			9.87		
Std. Dev.	3.66			9.48			10.12			5.32		
N	25			121			91			30		

Table 3.7-8. Summary of Porosity (Percent), Thermal/Mechanical Units (Continued)

	PTn			TSw1			TSw1-N			TSw1-L		
Core Hole	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	47.97	5.98	15	16.71	2.87	51	16.36	2.75	46	19.86	1.97	5
NRG-5	N/A	N/A	0	19.20	N/A	1	N/A	N/A	0	19.20	N/A	1
NRG-6	49.65	7.45	16	15.74	5.36	56	13.28	1.96	37	20.67	6.77	18
NRG-7	44.65	9.33	33	15.52	3.61	95	14.36	2.60	54	17.05	4.17	41
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES												
TOTAL	46.68	8.38	64	15.90	4.03	203	14.74	2.77	137	18.30	5.11	65
Range	27.90 to 59.40			6.80 to 32.10			6.80 to 22.80			10.60 to 32.10		
Mean	46.68			15.90			14.74			18.30		
Std. Dev.	8.38			4.03			2.77			5.11		
N	64			203			137			65		

Table 3.7-8. Summary of Porosity (Percent), Thermal/Mechanical Units (Continued)

Core Hole	TSw2			TSw3			CHn1		
	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count	Mean	Std. Dev.	Count
NRG-2	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2A	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-2B	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-3	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-4	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
NRG-5	11.00	2.16	24	N/A	N/A	0	N/A	N/A	0
NRG-6	12.01	3.17	38	N/A	N/A	0	N/A	N/A	0
NRG-7	11.05	3.13	81	1.15	0.31	4	N/A	N/A	0
SD-9	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
SD-12	N/A	N/A	0	N/A	N/A	0	N/A	N/A	0
ALL HOLES									
TOTAL	11.30	3.01	143	1.15	0.31	4			
Range	3.80 to 27.70			0.70 to 1.40					
Mean	11.30			1.15					
Std. Dev.	3.01			0.31					
N	143			4					

N—Number; N/A—Not applicable; Std. Dev—Sample Standard Deviation

NOTE: The TCw and TSw1 thermal/mechanical units have been subdivided as follows (see text Subsection 3.7.1.1):
TCw-N represents non-lithophysal zones of the TCw unit.
TCw-L represents lithophysal zones of the TCw unit.
TSw1-N represents non-lithophysal zones of the TSw1 unit.
TSw1-L represents lithophysal zones of the TSw1 unit.

Table 3.7-9. Summary of Porosity and Density Measurements from the Thermal Test Facility of the Exploratory Studies Facility (TSw2 Thermal/Mechanical Unit)

Single Heater Test Borehole Summary (Wet-Drilled)			
	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)
Single Heater Test Average	12.53	2.20	2.51
Standard Deviation	3.89	0.09	0.017

Drift Scale Test PERM Borehole Summary (Dry-Drilled)			
	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)
Drift Scale Test PERM Average	10.62	2.25	2.51
Standard Deviation	1.14	0.02	0.01

DST Heated Drift Borehole Summary (Wet Excavation)			
	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)
Drift Scale Test Heated Drift Average	12.54	2.20	2.51
Standard Deviation	2.75	0.06	0.01

Observation Drift Grab Sample Summary (Wet-Excavation)			
	Porosity (%)	Bulk Density (g/cc)	Particle Density (g/cc)
Observation Drift Average	9.34	2.26	2.49
Standard Deviation	0.91	0.02	0.02

Source: CRWMS M&O 1997g

PERM = permeability borehole

Table 3.7-10. Petrographic Characterization of NRG-6 Specimens

Yucca Mountain Project NRG-6 Drillcore	Mineralogy Petrology Description Summary																										
Depth	22.2	23.4	28.8	111.0	143.5	145.7	151.2	152.9	161.4	169.5	174.0	182.2	187.0	220.0	227.9	241.5	276.2	277.5	304.4	316.3	318.2	321.1	328.7	354.4	354.9	355.4
In-depth analysis for this sample? (Note 1)	Y		X	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y		Y				Y			Y	
USGS Stratigraphic Unit Designation	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpc	Tpb	Tpb	Tpb	Tpp	Tpp	Tpp	Tpbt	Tpbt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pll	pll	pll	plnc	pv	pv	pv	pv	3	4	4				2	2	m	m	m	m	m	m	m	m	m	m
USGS Subzone Division					2	2	1	1																		
Colors: White			Sec						15	15					50	10	10	5	Sec		10	5	5	5	5	5
Light Yellowish-Brown			Note		80	75	55	80				20	20	50	10	80			Note							
Black			4			15	25	10			10								4							
Gray		15		20	20		5	10	10		90			10	40	10	10			15	10		25	15		15
Purple-Gray	20	85		80													20	15			15	15			15	
Light-Pink-Gray																										
Orange																										
Rust-Reddish Brown																								5		10
Pale Orangish-Red																										
Gray Brick-Red	80								75	85				40			40	80		85	65	80	70	75	80	70
Reddish-pink						10	15					80	80													
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	0	3		3	1	0	1	1	1	1	1	2	2	2	0	2	1	1		1	1	1	3	3	1	3
Welding (0=none, 1=weak, 2=moderate, 3=strong)	2	2		3	0	0	0	0	0	0	0	0	0	0	0	0	1	2		1	1	2	2	3	3	3
Fiamme or Pumice (maximum size in mm)	5	20		10	5	15	10	15	20	5	10	25	10	15	10	10	20	5		20	15	30	30	40	20	25
Pumice Abundance (Note 2)	3	2		1	1	1	2	1	2	2	3	2	2	2	3	2	2	2		2	2	2	2	2	2	2
Glass Abundance (Note 2)	0	0		0	2	2	2	2	1	2	2	2	2	2	2	2	0	0		0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0		0	0	2	2	0	0	0	0	0	0	0	0	0	2	0		2	2	0	1	1	0	2
Pore Abundance (Note 2)	1	1		1	1	2	2	2	1	1	2	2	2	2	2	2	2	1		2	2	2	2	2	2	2
Lithophysae (maximum size in mm)																									3	15
Abundance (Note 2)	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1	1
Shape: 1=Flattened, 2=Irregular, 3=Ovoid																									1	1
Lithophysal Cavities (maximum size in mm)																									1	12
Abundance of Cavities (Note 2)	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1	1
Shape: 1=flattened or arcuate, 2=ovoid																									1	1
Lithics (maximum size in mm)	1	2		2	0.5	4	7	0.5	1	2	2	2	1.5	1	2	10	3	5		2	2	2	3	1	1	1
Abundance (Note 2)	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Modal Petrographic Data (See Note 3)																										
Component / Approximate Percentages																										
Phenocrysts (est. total modal %)	4.1	3		6	4	4	4	2	3	8	11	5.5	6.5	11.5	4.5	9.5	15	17		15	20	22.5	20	15	17	15
Alkali-Feldspar (est. modal %)	2			4	2			1	2	2	2	1.5	1.5	1.5	4	2		6				9			8.5	
(size in mm)	1.5			1	0.5			1.5	1	1	1	1		0.5				1							2	
Quartz (est. modal %)	1.5			1.5	1.5			1	1	2	2	1	3.5	3	0.3	2.5		4				5			3.5	
(size in mm)	1			1	0.5			1	0.5	0.5	1	0.5		0.5				1							2	
Plagioclase (est. modal %)	0.1			0	0.5			0	0	3	6	2.5	1	5	0.2	3		6				6			3.5	
(size in mm)	1				0.5					1.5	1	1		0.5				1							2	
Mafic (est. modal %)	0.5			0.5	0			0	0	1	1	0.5	0.5	2	0	2		1				2.5			1.5	
(size in mm)	0.2			1						0.5	1	0.5		0.5				1							1	
Matrix	7.0			21.0	49.7			26.6	22.0	23.3	10.7	16.0	15.7	26.4	17.2	14.5		29.3				18.2			25.3	
Shards	82.5			63.8	36.3			62.0	6.0	19.1	0.5	25.9	31.3	21.0	8.8	19.6		20.7				21.7			17.7	
Pumice or Fiamme	63.8			7.9	8.8			8.4	50.9	33.1	75.7	51.3	45.8	38.5	67.2	55.5		33.8				37.1			41.8	
Porosity Visible in Thin Section				0.1	1.3			11.4	16.1	5.8	36.4	31.5	23.5	24.5	35.8	24.2		0.8				0.9			1.3	
Semi Quantitative XRD Results (Note 5)																										
Mineral / Approximate Percentages																										
Quartz																		8				6			9	
Cristobalite	25		25	17																		3			5	
Tridymite	5																					85			79	
Feldspar	71		75	83														87				6			7	
Clay (Illite)																		5				100			100	
Total	100		100	100														100				0.18			0.26	
Total H2O in wt. % (from Chemical analysis)	0.46		0.45	0.70				4.81	4.96	6.48	4.23		3.87	5.58	7.11	4.87		0.15								

Note 1: Y indicates thin-section and XRD Mineralogy data acquired for sample. X indicates XRD Mineralogy data only.

Note 2: For all Abundance estimates, 0 or Blank=not noted, 1=rare, 2=common, 3=abundant. Estimates are qualitative.

Note 3: Percentage Estimates for samples with "in depth" analyses are from point counts of thin sections. For hand samples, only total phenocryst percentage was estimated qualitatively by visual examination. "Porosity Visible in Thin Section" occurs in fiamme and shards and is counted with these components as well as individually.

Note 4: No hand sample description and listed data is from thin-section. For thes samples either all of sample was crushed for laboratory analysis, or remainder is too small for representative description.

Note 5: Proportions are approximate, and normalized to 100% excluding unidentified minor components. See text for explanation. No XRD mineralogy data given for glassy interval (152.9 through 241.5).

Table 3.7-10. Petrographic Characterization of NRG-6 Specimens (Continued)

Yucca Mountain Project NRG-6 Drillcore	Mineralogy Petrology Description Summary																										
Depth	372.6	373.1	391.6	392.1	392.6	395.0	395.2	397.0	397.5	407.0	407.2	416.0	420.8	421.5	421.8	425.3	427.0	458.7	462.3	488.0	495.0	502.8	528.4	539.2	539.8	554.0
In-depth analysis for this sample? (Note 1)		Y		Y								Y				Y		Y					Y			
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	d	d	pul	pul	pul	pul	pul	pul	pul
USGS Subzone Division																		1	1	2	1	1	1	1	1	1
Colors White	5	5	10	5	5	5	10	10	10	10	10	10	15	15	20	5	10	5	10	20	10	10	[See			
Light Yellowish-Brown																							Note			
Black											5												4]			
Gray	10	5	20	20	10	10	15	20	10	20	20	15	10	5	10	5	10	25	20		50	40		50	40	40
Purple-Gray	20	40	20	40	40	30	10	20	25	20	20		20	25		20	40	70	50	70	20	10		10	10	20
Light-Pink-Gray																										
Orange																										
Rust-Reddish Brown	15		10			20		15	20	10	10		10	10					20	10		20		20	40	40
Pale Orangish-Red																										
Gray Brick-Red	50	50	40	35	45	35	65	35	35	40	35	75	45	45	70	60	40									
Reddish-pink																10					20	20		20	10	
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)	3	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3	1	1		1	1	1
Welding (0=none, 1=weak, 2=moderate, 3=strong)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3
Fiamme or Pumice (maximum size in mm)	40	15	25	20	30	30	20	30	25	35	50	15	20	20	50	40	25	25	25	15	10	5	4	25	5	5
Pumice Abundance (Note 2)	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	2	2	2	2	2	2	1	1
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	2	0	2	0	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)	2	1	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1	2	2	1	2	2	1	2	2	2
Lithophysae (maximum size in mm)	10	3		10	7			5		20	8	10	25	10	12	20	10	30	20	12	25	40		35	30	30
Abundance (Note 2)	1	1	0	1	1	0	0	1	0	1	1	2	2	2	1	2	1	2	1	1	3	3		3	3	2
Shape: 1=flattened, 2=irregular, 3=Ovoid	1	1		1	1			1		1	1	1	1	1	3	1	1	1	1	1	3	3		3	3	3
Lithophysal Cavities (maximum size in mm)	6	2		5	4			2		10	4	3	10	5	10	3	4	8	6	5	10	8		10	10	25
Abundance of Cavities (Note 2)	1	1	0	1	1	0	0	1	0	1	1	2	2	1	1	2	1	2	1	2	3	2		3	3	3
Shape: 1=flattened or arcuate, 2=ovoid	1	1		1	1			1		1	1	1	1	1	2	1	1	1	1	1	2	2		1	1	2
Lithics (maximum size in mm)	8		1		2	2	8	5	3	1	25		2	2	2	2	2	2	3	3	3				2	
Abundance (Note 2)	1	0	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	2	1	0		0	1	0
Modal Petrographic Data (See Note 3)																										
Component / Approximate Percentages																										
Phenocrysts (est. total modal %)	15	17	15	19.5	15	10	10	10	10	10	10	13	10	10	10	10	10	7.5	3	2	2	1	1.7	2	1	2
Alkali-Feldspar (est. modal %)		8		8.5								5				3.5		3					0.5			
(size in mm)		2		1								1				2		1					0.5			
Quartz (est. modal %)		5		4.5								3.5				2.5		2					0.2			
(size in mm)		2		0.5								0.5				4		0.5					0.2			
Plagioclase (est. modal %)		2.5		4								3.5				3		2					0.5			
(size in mm)		2		1								1				3		1					0.7			
Mafic (est. modal %)		1.5		2.5								1				1		0.5					0.5			
(size in mm)		1		0.5								0.5				2		0.5					0.5			
Matrix		28.3		35.9								29.7				27.2		29.3					47.0			
Shards		16.1		11.6								11.8				13.7		5.6					12.8			
Pumice or Fiamme		38.6		33.9								38.2				48.0		58.0					25.2			
Porosity Visible in Thin Section		1.2		0.7								2.5				0.2		2.7					0.2			
Semi Quantitative XRD Results (Note 5)																										
Mineral / Approximate Percentages																										
Quartz																		2								
Cristobalite		7		8								8				8		11					18			
Tridymite		8		9								9				13										
Feldspar		85		77								80				75		83					82			
Clay (Illite)				6								3				4		4								
Total		100		100								100				100		100					100			
Total H_2O m wt. % (from Chemical analysis)		0.55		0.48								1.23				1.20		1.38					0.77			

Table 3.7-10. Petrographic Characterization of NRG-6 Specimens (Continued)

Yucca Mountain Project NRG-6 Drillcore	Mineralogy Petrology Description Summary																										
Depth	539.8	554.0	564.9	640.0	648.6	649.6	662.2	673.4	687.5	693.1	720.6	729.2	742.3	742.9	757.0	762.9	773.5	777.8	784.8	785.6	788.3	802.4	802.7	806.0	806.8
In-depth analysis for this sample? (Note 1)					Y					Y		Y			Y			Y					Y		
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pul	pul	pul	pul	pul	pul	pul	pul	pul	pul	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn	pmn
USGS Subzone Division	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3	3	2	2	1	1	1	1	1	1	1
Colors: White						5	5	5		5		5			5		5	2	2						
Light Yellowish-Brown																									
Black																									
Gray	40	40	30	35	45	35	20	40	25	35	10		15	10	10	10	20	15	10	10	30	15	15	15	10
Purple-Gray	10	20	50	35	35	50	50	30	50	20	70	70				40	60	83	88	80	70	60	75	85	90
Light-Pink-Gray																									
Orange																									
Rust-Reddish Brown	40	40								40		25					15			10		25	10		
Pale Orangish-Red													85	90	85	50									
Gray Brick-Red			20	30	20	10	25	25	25		20														
Reddish-pink																									
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)																									
Welding (0=none, 1=weak, 2=moderate, 3=strong)	3	3	3	3	3	3	3	3	3	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2
Fiamme or Pumice (maximum size in mm)	5	5	5	5	3	10	40	10	10	3	10	5	15	8	8	20	4	30	5	5	10	6	15	30	3
Pumice Abundance (Note 2)	1	1	1	1	2	1	1	1	1	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2
Glass Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)																									
Lithophysae (maximum size in mm)	30	30	30	40	40	30	30	50	10	40	7						30								
Abundance (Note 2)	3	2	2	2	3	2	2	3	2	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid	3	3	3	3	2	3	3	1	1	2	3						1								
Lithophysal Cavities (maximum size in mm)	10	25	15	10	10	10	8	25		15	2						15								
Abundance of Cavities(Note 2)	3	3	3	2	2	1	1	2	1	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Shape: 1=flattened or arcuate, 2=ovoid																									
Lithics (maximum size in mm)	2		1		2	2	8		3		0	0			0	0	0	0		1	5	1	0	4	2
Abundance (Note 2)																									
Modal Petrographic Data (See Note 3)																									
Component / Approximate Percentages																									
Phenocrysts (est. total modal %)	1	2	1	1	1.2	1	1	1	1	1.6	1	1.5	2	1	0.9	1	1	1.1	1	1	1	1	1.2	1	1
Alkali-Feldspar (est. modal %)					0.5					0.5		0.4			0.2			0.4					0.2		
(size in mm)					1					0.5		0.5			0.5			0.5					0.5		
Quartz (est. modal %)					0.1					0.1		0.4			0.2			0.2					0.3		
(size in mm)					0.5					0.2		0.5			0.5			0.5					0.5		
Plagioclase (est. modal %)					0.5					0.5		0.4			0.4			0.4					0.5		
(size in mm)					1					0.5		0.5			0.5			0.5					1		
Mafic (est. modal %)					0.1					0.5		0.3			0.1			0.1					0.2		
(size in mm)																									
Matrix					51.6					42.7		21.2			19.8			2.5					10.8		
Shards					16.7					27.5		42.0			40.5			51.3					39.9		
Pumice or Fiamme																									
Porosity Visible in Thin Section																									
Semi Quantitative XRD Results (Note 5)																									
Mineral / Approximate Percentages																									
Quartz					12					7		2			6			2					3		
Cristobalite					11					13		17			18			20					21		
Tridymite																									
Feldspar					78					80		81			76			77					76		
Clay (Illite)																									
Total																									
Total H2O in wt. % (from Chemical analysis)																									

Table 3.7-10. Petrographic Characterization of NRG-6 Specimens (Continued)

Yucca Mountain Project NRG-6 Drillcore	Mineralogy Petrology Description Summary																								
Depth	848.0	849.9	886.5	900.4	901.0	906.0	908.2	911.2	926.3	934.0	940.5	952.2	953.2	956.8	963.3	969.3	971.4	972.4	985.7	987.6	1016.6	1017.8	1081.0	1085.0
In-depth analysis for this sample? (Note 1)		Y		Y					Y												Y		Y	
USGS Stratigraphic Unit Designation	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt	Tpt
USGS Subzone	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll	pll
USGS Subzone Division																								
Colors White						5			5	5	5	2		10	10			5	5	5	5		5	
Light Yellowish-Brown																								
Black																								
Gray	10	15	15	5		15	10	15			5	8			5	10	5	5	10	25	5	15		10
Purple-Gray	10		10					45	20	15	60	40	10	5	35	40	30	50	50	40			35	20
Light-Pink-Gray		85			80	65			40				15	30				20			40		50	50
Orange										45			25											
Rust-Reddish Brown	50		75				50	40		35	15	50	50	55	40	50	65	20	15	30				20
Pale Orangish-Red																								
Gray Brick-Red	30			95		15	40		35		15								20		50	85	15	
Reddish-pink																								
Color (0=uniform, 1=mottled, 2=irregular, 3=streaked)																								
Welding (0=none, 1=weak, 2=moderate, 3=strong)	2	2	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	2	2	2
Fiamme or Pumice (maximum size in mm)	40	35	20	3		50	15	25	20	50	10	40	25	20	25	15	15	40	10	20	20		50	50
Pumice Abundance (Note 2)	2	2	0	2		2	2	2	2	3	1	3	3	3	3	3	2	2	2	2	2	2	3	3
Glass Abundance (Note 2)	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vesicles Abundance (Note 2)	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pore Abundance (Note 2)																								
Lithophysae (maximum size in mm)									60	20	10	8											35	
Abundance (Note 2)	0	0	0	0		0	0	0	2	1	1	1	0	0	0	0	0	0	0	0	0	0	2	0
Shaped: 1=Flattened, 2=Irregular, 3=Ovoid									1	1	1	3											1	
Lithophysal Cavities (maximum size in mm)					0				12	15	6	4											12	
Abundance of Cavities(Note 2)	0	0	0	0		0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	2	0
Shape: 1=flattened or arcuate, 2=ovoid																								
Lithics (maximum size in mm)	8	0	15	3		1	1	10	0	15	5	20	10	4	3	15	10	3	15	15	0	17	3	8
Abundance (Note 2)																								
Modal Petrographic Data (See Note 3)																								
Component / Approximate Percentages																								
Phenocrysts (est. total modal %)	1	2.1	1	1.2	0	1	2	1	1.7	2	2	2	2	1	1	2	1	1	1	1	1.1	1	1.1	1
Alkali-Feldspar (est. modal %)		0.3		0.3					0.1												0.3		0.1	
(size in mm)		1		1					0.5												0.5		0.5	
Quartz (est. modal %)		0.3		0.4					0.2												0.3		0.3	
(size in mm)		0.5		0.5					0.5												0.5		1	
Plagioclase (est. modal %)		0.5		0.3					1.2												0.4		0.4	
(size in mm)		0.5		1					0.5												0.5		0.5	
Mafic (est. modal %)		1		0.2					0.2												0.1		0.3	
(size in mm)																								
Matrix		20.0		13.0					10.3												11.9		13.0	
Shards		19.4		33.2					27.8												33.3		21.1	
Pumice or Fiamme																								
Porosity Visible in Thin Section																								
Semi Quantitative XRD Results (Note 5)																								
Mineral / Approximate Percentages																								
Quartz		25		20					16												15		18	
Cristobalite									9												6		10	
Tridymite																								
Feldspar		75		80					75												79		72	
Clay (Illite)																								
Total																								
Total H2O in wt. % (from Chemical analysis)																								

Table 3.7-11. Mineral Abundances for 10 Samples from the Single Heater Test Block of the Exploratory Studies Facility

Sample	Quartz	Cristobalite	Albite	Sanidine	Smectite	Clinoptilolite	Mica	Total
BJ-1-1.0-B ymp014(1)	10	18	41	26	tr(1)	nd(3)	tr	95
BJ-1-10.0-B ymp019	8	19	38	25	3	nd	tr	93
BJ-1-18.0B ymp011a ymp011a(4)	8 8	18 17	40 49	26 25	3 2	nd nd	nd nd	95 101
MPBX-3-12.5-B ymp018 ymp018a	11 12	18 18	33 34	32 28	3 3	4 6	<1 <1	101 101
MPBX-4-5.0-B ymp015	4	24	44	22	2	nd	nd	96
H1-0.6-C ymp013	8	17	43	25	tr	2	<1	95
H1-11.3-C ymp012	9	19	38	24	3	nd	tr	93
H1-11.6-C ymp016	7	19	37	25	3	nd	tr	91
H1-22.2-B ymp017 ymp017a	9 8	20 20	34 36	31 24	3 3	2 1	<1 tr	99 92

(1) The identification ymp### refers to computer filenames associated with the diffraction pattern data.
(2) tr - trace amount; the phase is present, but the peak intensities are too small to measure an integrated intensity.
(3) nd - not detected.
(4) Trailing "a" refers to duplicate sample.

Table 3.7-12. Mineral Abundances[1] for 20 Samples from the Drift Scale Test Block of the Exploratory Studies Facility

Sample #	Quartz	Cristobalite	Albite	Sanidine	Tridymite	Zeolite Phase
SDM-MPBX1-1.0-1.2-D	12	23	34	32	nd[2]	nd[2]
SDM-MPBX1-21.0-21.2-D	10	27	25	35	3	nd[2]
SDM-MPBX1-21.0-21.2-D dup	9	27	25	35	4	nd[2]
SDM-MPBX1-31.9-32.1-D	4	31	32	33	nd[2]	nd[2]
SDM-MPBX1-40.4-40.6-D	20	14	31	29	7	nd[2]
SDM-MPBX1-62.0-D	11	26	27	36	nd[2]	nd[2]
SDM-MPBX1-80.7-80.9-D	12	24	31	33	nd[2]	nd[2]
SDM-MPBX2-29.0-29.2-D	4	31	33	32	nd[2]	nd[2]
SDM-MPBX2-29.0-29.2-D dup	4	29	34	33	nd[2]	nd[2]
SDM-MPBX2-48.6-D	18	18	30	34	nd[2]	nd[2]
SDM-MPBX2-72.0-D	6	28	34	32	nd[2]	nd[2]
SDM-MPBX2-85.0-D	7	26	34	33	nd[2]	nd[2]
SDM-MPBX3-17.5-17.7-D	8	25	33	34	nd[2]	nd[2]
SDM-MPBX3-38.5-38.7-D	5	31	24	40	nd[2]	nd[2]
SDM-MPBX3-85.6-D	11	22	30	34	nd[2]	3 - stilbite
AOD-HDFR#1-9.0-D	13	20	32	34	nd[2]	2 -clinoptilolite
AOD-HDFR#1-9.0-D dup	15	20	31	35	nd[2]	Trace - clinoptilolite
AOD-HDFR#1-48.5-D	12	25	26	37	nd[2]	nd[2]
AOD-HDFR#1-68.6-D	12	25	24	39	nd[2]	nd[2]
AOD-HDFR#1-98.0-D	37	4	29	30	nd[2]	nd[2]

[1] Mineral abundances were normalized to 100% after subtracting out the estimated abundance of the corundum standard. Sums may differ from 100% due to roundoff error.

[2] nd - not detected.

Table 3.7-13. Rock Thermal Conductivities at Temperatures Below 100°C

Thermal/ Mechanical Unit	Thermal Conductivity (W/mK)											
	Saturated			Partially Saturated			Air Dry			Dry		
	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count	Sample Mean	Sample Standard Deviation	Sample Count
TCw	1.89	0.12	18	1.39	0.56	18	1.58	0.16	9	1.17	0.35	18
PTn	0.92	0.13	42	0.57	0.12	33	0.35	0.13	12	0.38	0.10	49
TSw1	1.70	0.19	50	1.23	0.46	11	1.21	0.12	30	0.98	0.26	59
TSw2	2.29	0.42	51	ND	ND	ND	1.66	0.10	24	1.49	0.44	48

Source: CRWMS M&O 1997d

ND—No data. Sample refers to the number of test measurements, not the number of specimens tested. Measurements were made at multiple temperatures and during both heating and cooling for some specimens.

Table 3.7-14. Rock Thermal Conductivities at Temperatures Above 100°C

Thermal/Mechanical Unit	Thermal Conductivity (W/mK)		
	Dry		
	Sample Mean	Sample Standard Deviation	Sample Count
TCw	1.53	0.17	57
PTn	0.42	0.14	102
TSw1	1.15	0.15	173
TSw2	1.59	0.10	125

Source: CRWMS M&O 1997d

a) All high temperature data were acquired above 100 °C. 'Sample' refers to the number of test measurements, not the number of specimens tested. Measurements were made at multiple temperatures and during both heating and cooling for some specimens.

Table 3.7-15. Thermal Data for Specimens from the Single Heater Test Block (Air Dry)

Apparatus[a]	Temperature	Thermal Conductivity (W/m-K)				Mean[b]	Standard Deviation[b]
		ESF-H1-0.6-B	ESF-H1-11.3-B	ESF-H1-11.6-B	ESF-H1-19.9-B		
LT	30	1.50	1.76	1.37	1.76	1.60	0.195
LT	50	1.52	1.79	1.40	1.77	1.62	0.1913113
LT	70	1.54	1.81	1.44	1.77	1.64	0.178699
TCA	70	1.58	1.96	1.61	1.89	1.76	0.1930458
TCA	110	1.56	1.88	1.57	1.80	1.70	0.1621471
TCA	155	1.61	1.85	1.62	1.79	1.72	0.1209339
TCA	200	1.60	1.82	1.59	1.78	1.70	0.1195478
TCA	245	1.57	1.81	1.60	1.75	1.68	0.1158663
TCA	289	1.48	1.76	1.56	1.69	1.62	0.1260622
Mean		1.55	1.83	1.53	1.78	N/A	N/A
Standard Deviation		0.04	0.06	0.10	0.05	N/A	N/A

Source: CRWMS M&O 1996b

(a) The low temperature was used for testing at 70°C and below; the TCA was used for 70°C and above.
(b) Mean and standard deviation for all data in table are 1.67 W/(m-K) and 0.15 W/m-K), respectively.

Table 3.7-16. Thermal Conductivity Data for Specimens from the DST Block (Saturated)

Distance from Collar (ft)	Max. Temp. (°C)	Thermal Conductivity (W/m-K) 30°C	50°C	70°C	Mean	STD[a]	N[a]
ESF-SDM-MPBX1-C							
1.0	70	2.2	2.2	2.2	2.2	0.0	3
32.1	70	2.2	2.2	2.1	2.2	0.0	3
40.6	70	2.1	2.1	2.1	2.1	0.0	3
62.0	70	2.2	2.2	2.2	2.2	0.0	3
80.5	70	2.15	2.1	2.1	2.1	0.0	3
	N[a] =	5	5	5			
	Mean =	2.2	2.2	2.1			
	STD[a] =	0.1	0.0	0.0			
ESF-SDM-MPBX2-C							
13.0	70	2.1	2.1	2.1	2.1	0.0	3
29.0	70	2.1	2.1	2.1	2.1	0.0	3
48.4	70	2.0	2.0	2.0	2.0	0.0	3
71.5	70	2.3	2.3	2.3	2.3	0.0	3
84.6	70	2.0	2.0	2.1	2.0	0.1	3
	N[a] =	5	5	5			
	Mean =	2.1	2.1	2.1			
	STD[a] =	0.1	0.1	0.1			
ESF-SDM-MPBX3-C							
3.0	70	1.9	1.9	1.9	1.9	0.0	3
17.7	70	2.1	2.1	2.1	2.1	0.0	3
38.7	70	2.2	2.2	2.2	2.2	0.0	3
72.0	70	2.2	2.2	2.2	2.2	0.0	3
85.3	70	2.1	2.1	2.1	2.1	0.0	3
	N[a] =	5	5	5			
	Mean =	2.1	2.1	2.1			
	STD[a] =	0.1	0.1	0.1			
ESF-AOD-HDFR1-C							
8.6	70	2.0	2.0	2.0	2.0	0.0	3
32.2	70	2.1	2.1	2.1	2.1	0.0	3
48.7	70	1.9	1.9	2.0	1.9	0.0	3
68.8	70	2.1	2.1	2.0	2.1	0.0	3
97.5	70	2.3	2.3	2.3	2.3	0.0	3
	N[a] =	5	5	5			
	Mean =	2.1	2.1	2.1			
	STD[a] =	0.2	0.1	0.1			
All Drift Scale Characterization Boreholes							
N[a] =		20	20	20			
Mean =		2.1	2.1	2.1			
STD[a] =		0.1	0.1	0.1			
All Specimens, All Temperatures							
	N[a] =	60					
	Mean =	2.1					
	STD[a] =	0.1					

[a]N = Number of samples; STD = Standard deviation.

NOTE: Air dried. Lithostratigraphic unit: Tptpmn, except for HDFR1-97.5-C, which may be from Tptpll.

Table 3.7-17. Mean Coefficient of Thermal Expansion During Heat-Up

T/M Unit	Saturation State	Statistics[a]	Mean CTE on Heat-Up (10^{-6}/°C)										
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TCw	Saturated	Mean	7.09	7.62	8.08	10.34	13.17	15.20	16.99	18.99	21.38	27.42	42.99
		Std. Dev.	0.43	0.15	0.50	1.52	1.23	1.57	1.41	0.96	1.23	1.94	37.35
		Count	4	4	4	4	4	4	4	3	3	3	3
	Dry	Mean	6.60	8.29	9.62	10.53	12.69	14.90	17.03	20.68	29.64	36.49	49.15
		Std. Dev.	1.49	0.99	1.06	1.60	1.55	1.91	2.31	5.41	21.88	16.97	34.24
		Count	10	10	10	7	7	7	7	7	7	7	7
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
PTn	Saturated	Mean	4.46	4.28	-1.45	-30.42	5.54	4.47	0.64	-4.65	-9.79	-13.46	-12.96
		Std. Dev.	0.38	1.61	3.63	21.47	0.41	0.79	1.03	4.05	7.85	11.12	12.90
		Count	4	4	4	4	3	3	3	2	2	2	2
	Dry	Mean	4.55	4.24	3.36	-4.78	6.46	5.69	3.61	0.56	-2.98	-5.81	-7.25
		Std. Dev.	0.74	1.46	2.40	11.12	0.98	1.41	2.58	5.81	9.12	11.36	10.80
		Count	12	12	12	10	10	10	10	10	10	10	10
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TSw1	Saturated	Mean	6.56	7.32	6.83	6.92	10.72	14.28	20.98	36.82	41.64	42.76	43.81
		Std. Dev.	1.16	0.60	1.60	3.28	1.74	3.26	7.01	20.49	17.35	13.19	13.65
		Count	10	10	10	10	10	9	9	8	8	8	8
	Dry	Mean	6.29	7.60	8.39	8.96	10.37	15.51	23.67	34.24	34.00	36.07	38.74
		Std. Dev.	1.22	1.02	0.89	1.20	1.38	4.53	11.07	20.30	13.70	13.23	13.78
		Count	33	33	33	28	28	27	26	25	25	25	25
			25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C
TSw2	Saturated	Mean	7.14	7.47	7.46	9.07	9.98	11.74	13.09	15.47	19.03	25.28	37.19
		Std. Dev.	0.65	1.51	1.21	2.41	0.77	1.28	1.40	1.75	3.09	6.87	14.27
		Count	19	19	19	19	19	19	19	16	16	16	16
	Dry	Mean	6.67	8.31	8.87	9.37	10.10	10.96	12.22	14.52	20.79	25.13	35.13
		Std. Dev.	1.20	0.42	0.40	0.55	0.88	1.16	1.50	2.57	17.03	10.07	14.56
		Count	40	40	40	40	40	38	38	35	35	35	35

NOTE: [a]Std.Dev.—Standard Deviation. Source: CRWMS M&O 1997d

NOTE: The negative coefficients of the thermal expansion are apparent and indicate that some samples were observed to contract in the temperature ranges containing the negative values. The contractions are interpreted as drying phenomena.

Table 3.7-18. Mean Coefficient of Thermal Expansion During Cool-Down

T/M Unit	Saturation State	Statistics[a]	Mean CTE on Cool-Down (10^{-6}/°C)										
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TCw	Saturated	Mean	14.72	21.97	33.53	37.01	23.81	18.48	15.72	13.51	12.09	10.78	10.85
		Std. Dev.	3.76	6.79	16.44	26.18	10.01	3.25	1.96	1.48	1.28	1.36	1.96
		Count	3	3	3	3	4	4	4	4	4	4	4
	Dry	Mean	17.46	26.34	36.95	33.72	22.86	17.58	13.89	11.77	10.21	9.35	6.59
		Std. Dev.	3.70	6.88	11.50	14.21	3.16	2.00	2.39	2.22	1.56	1.15	2.20
		Count	7	7	7	7	7	7	7	7	9	9	9
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
PTn	Saturated	Mean	15.58	9.12	7.20	6.39	6.98	6.29	5.93	5.36	5.12	4.33	1.94
		Std. Dev.	1.04	0.84	0.29	0.17	1.51	0.78	0.47	0.36	0.34	0.84	2.93
		Count	2	2	2	2	3	3	3	4	4	4	4
	Dry	Mean	11.22	7.91	6.78	6.45	6.47	6.53	6.11	5.80	5.52	4.82	2.41
		Std. Dev.	2.46	1.00	0.81	0.90	1.14	1.35	1.30	1.16	0.89	0.84	0.86
		Count	10	10	10	10	10	10	10	10	12	12	12
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TSw1	Saturated	Mean	15.07	19.87	24.05	26.15	27.57	26.66	28.19	19.89	11.46	9.92	9.35
		Std. Dev.	4.68	7.82	9.85	7.37	8.36	9.91	18.04	8.05	2.01	1.54	1.06
		Count	8	8	8	8	9	9	10	10	10	10	10
	Dry	Mean	16.68	20.71	24.16	23.26	26.74	25.34	25.55	17.78	10.53	9.22	6.95
		Std. Dev.	4.13	7.78	10.61	7.29	9.32	9.35	14.94	8.53	2.15	1.51	2.49
		Count	25	25	25	25	26	27	28	28	33	33	33
			300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-35°C
TSw2	Saturated	Mean	21.89	27.83	26.55	21.38	17.31	14.06	12.49	11.52	10.27	9.48	8.81
		Std. Dev.	6.16	10.36	10.01	5.70	3.07	1.38	1.32	2.00	0.62	0.63	0.62
		Count	16	16	16	16	19	19	19	19	19	19	19
	Dry	Mean	20.57	24.31	24.20	21.16	18.45	14.34	11.74	10.51	9.54	8.87	7.48
		Std. Dev.	4.88	7.55	8.08	6.24	9.36	4.23	3.03	2.26	1.79	1.56	1.99
		Count	35	35	35	35	38	38	40	40	40	40	40

CTE—Coefficient of thermal expansion

Source: CRWMS M&O 1997d

Table 3.7-19. Mean Coefficient of Thermal Expansion for TSw2 Specimens from the Single Heater Test Block

Temperature Range (°C)		Mean Coefficient of Thermal Expansion (MCTE) (10^{-6}/°C)										
Low	High	ESF-H1-0.6-A	ESF-H1-11.3-A	ESF-H1-11.6-A	ESF-H1-22.2-A	ESF-MPBX-3-12.5-A	ESF-MPBX-4-5.0-A	ESF-MPBX-4-18.3-A	ESF-BJ-1-1.0-A	ESF-BJ-1-10.0-A	Mean MCTE	Standard Deviation
25	50	6.69	7.59	7.21	7.62	7.61	8.27	7.34	7.30	7.63	7.47	0.42
50	75	8.39	8.65	8.71	8.90	8.47	9.39	9.23	8.81	9.38	8.88	0.38
75	100	8.88	9.48	9.47	9.61	8.88	10.30	10.00	9.80	10.30	9.64	0.53
100	125	8.77	9.83	9.82	10.1	9.1	11.2	10.6	10.1	10.6	10.01	0.76
125	150	9.37	10.6	10.5	10.5	9.47	12.3	11.6	10.7	11.4	10.72	0.95
150	175	10.6	11.0	11.1	10.9	10.0	12.5	11.9	11.3	12.0	11.26	0.77
175	200	16.7	11.5	12.5	12.0	10.9	13.3	12.6	12.2	13.3	12.78	1.66
200	225	26.3	13.3	15.2	13.3	13.5	16.3	14.8	13.9	16.1	15.86	4.08
225	250	25.8	17.4	21.1	17.5	15.5	23.1	19.0	17.1	18.7	19.47	3.28
250	275	29.8	25.7	35.0	27.1	29.1	39.0	28.8	24.9	27.8	29.69	4.54
275	300	46.2	44.6	58.5	59.3	62.1	61.1	50.8	40.3	42.4	51.70	8.65
300	275	14.3	27.0	26.6	30.1	28.2	29.1	28.3	27.2	27.6	26.49	4.70
275	250	33.3	33.9	32.9	42.4	42.4	41.5	35.7	30.2	32.6	36.10	4.73
250	225	30.4	30.7	32.0	38.8	38.2	40.1	30.6	25.3	28.8	32.77	5.08
225	200	24.1	21.7	31.1	25.6	21.7	26.7	21.7	19.1	22.2	23.77	3.59
200	175	23.2	16.6	27.2	18.6	16.0	19.3	16.9	15.9	17.1	18.98	3.83
175	150	12.3	13.7	17.3	14.8	13.1	15.0	13.9	13.6	14.2	14.21	1.42
150	125	8.7	11.9	13.6	12.9	11.9	13.5	12.1	11.8	12.3	12.08	1.43
125	100	7.60	10.9	11.6	11.8	10.8	11.7	11.1	10.7	11.2	10.82	1.27
100	75	7.23	10.3	10.9	11.2	10.2	11.1	10.6	10.3	10.6	10.27	1.19
75	50	6.22	9.13	9.56	9.97	9.08	10.30	9.60	9.20	9.54	9.18	1.18
50	35	5.67	8.48	8.79	9.26	8.41	9.30	8.55	8.55	8.86	8.43	1.08

Source: CRWMS M&O 1996b

Table 3.7-20. Mean Coefficient of Thermal Expansion for Drift Scale Test Characterization Borehole Samples (TSw2; Air Dry)

First Heating Cycle

	MCTE on Heat-Up (10^{-6}/°C)											
	25-50°C	**50-75°C**	**75-100°C**	**100-125°C**	**125-150°C**	**150-175°C**	**175-200°C**	**200-225°C**	**225-250°C**	**250-275°C**	**275-300°C**	**300-325°C**
N[a] =	17	17	17	17	17	17	17	17	17	17	17	17
Mean =	7.34	8.99	9.73	10.22	10.91	12.20	14.74	22.31	27.34	33.88	54.13	52.28
STD[a] =	0.57	0.47	0.54	0.58	0.79	1.04	4.79	18.09	15.70	6.94	12.18	13.42
95% [a] =	0.27	0.22	0.26	0.28	0.38	0.49	2.28	8.60	7.46	3.30	5.79	7.29

First Cooling Cycle

	Mean CTE on Cool-Down (10^{-6}/°C)											
	325-300°C	300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-30°C
N[a] =	13	17	17	17	17	17	17	17	17	17	16	15
Mean =	15.74	24.07	35.63	36.01	26.50	24.19	18.30	14.14	12.36	11.05	10.24	9.67
STD[a] =	1.88	5.70	8.39	8.32	4.69	9.82	7.37	2.61	1.76	0.84	1.24	0.66
95% [a] =	1.02	2.71	3.99	3.96	2.23	4.67	3.50	1.24	0.84	0.40	0.61	0.33

Second Heating

	MCTE on Heat-Up (10^{-6}/°C)											
	25-50°C	50-75°C	75-100°C	100-125°C	125-150°C	150-175°C	175-200°C	200-225°C	225-250°C	250-275°C	275-300°C	300-325°C
N[a] =	17	17	17	17	17	17	17	17	17	17	17	17
Mean =	7.22	8.87	9.63	10.24	11.28	13.22	19.37	22.66	24.82	37.84	46.78	34.46
STD[a] =	0.76	0.59	0.54	0.61	0.98	2.98	14.97	10.66	5.47	9.52	11.63	10.17
95% [a] =	0.36	0.28	0.26	0.29	0.46	1.42	7.12	5.07	2.60	4.52	5.53	4.84

Second Cooling

	MCTE on Cool-Down (10^{-6}/°C)											
	325-300°C	300-275°C	275-250°C	250-225°C	225-200°C	200-175°C	175-150°C	150-125°C	125-100°C	100-75°C	75-50°C	50-30°C
N[a] =	17	17	17	17	17	17	17	17	17	17	17	17
Mean =	16.50	26.48	37.06	36.39	26.44	23.64	17.46	13.75	12.01	11.36	10.16	9.81
STD[a] =	2.23	4.89	8.42	7.94	4.51	9.46	6.15	2.08	1.18	1.83	0.65	0.70
95% [a] =	1.06	2.32	4.00	3.77	2.14	4.50	2.92	0.99	0.56	0.87	0.31	0.33

Table 3.7-21. Thermal Capacitance (Cp) for TSw1 and TSw2 Thermal/Mechanical Units

TSw1				TSw2			
Temperature (°C)	Mean Cp	Standard Deviation (J cm^{-3} K^{-1})	No. Of Tests	Temperature (°C)	Mean Cp	Standard Deviation (J cm^{-3} K^{-1})	No. Of Tests
25	1.58	0.05	3	25	1.79	0.11	7
50	1.68	0.05	3	50	1.88	0.11	7
75	1.80	0.05	3	75	1.97	0.11	7
100	1.91	0.05	3	100	2.16	0.11	7
125	2.03	0.06	3	125	2.32	0.11	7
150	2.14	0.11	3	150	2.45	0.13	7
175	2.13	0.10	3	175	2.43	0.18	7
200	2.09	0.07	3	200	2.40	0.16	7
225	2.07	0.06	3	225	2.39	0.17	7
250	2.05	0.05	3	250	2.39	0.19	7
275	2.03	0.05	3	275	2.39	0.22	7
300	2.03	0.06	3	300	2.43	0.26	7

Source: CRWMS M&O 1997d

Table 3.7-22. Mean and Standard Deviation of Intact Rock Elastic Modulus for Thermal/ Mechanical Units and Lithostratigraphic Units

T/M Unit	Lithostratigraphic Unit	Elastic (Young's) Modulus*	
		Mean (GPa)	Std. Dev. (GPa)
UO		3.86	1.86
	Tmr	3.36	2.69
	Tpki	4.28	0.81
	Tpbt5	-	-
TCw		29.36	10.80
	Tpcrv	-	-
	Tpcrn	15.16	8.39
	Tpcpul	23.72	6.89
	Tpcpmn	34.97	7.44
	Tpcpll	34.31	5.24
	Tpcpln	34.28	7.66
PTn		2.54	4.02
	Tpcpv	7.18	7.61
	Tpbt4	1.82	1.10
	Tpy	5.24	3.05
	Tpbt3	0.25	0.07
	Tpp	1.05	0.60
	Tpbt2	0.83	0.60
	Tptrv	0.93	0.87
TSw1		20.36	6.75
	Tptrn	20.72	6.25
	Tptrl	10.45	3.27
	Tptpul	21.44	8.54
TSw2		33.03	5.94
	Tptpmn	32.93	5.47
	Tptpll	27.54	7.49
	Tptpln	35.48	5.45
TSw3		37.43	15.02
	Tptpv	37.43	15.02
CHn		5.63	1.55
	Tpbt1	3.90	-
	Tac	6.50	0.57

*Quasi-Static
Std. Dev.—Standard deviation
- No Data

Source: CRWMS M&O 1997d

Table 3.7-23. Mean and Standard Deviation of Intact Rock Poisson's Ratio for Thermal/ Mechanical units and Lithostratigraphic Units

T/M Unit	Lithostratigraphic Unit	Poisson's Ratio*	
		Mean	Std. Dev.
UO		0.09	0.07
	Tmr	0.03	0.03
	Tpki	0.14	0.05
	Tpbt5	-	-
TCw		0.21	0.11
	Tpcrv	-	-
	Tpcrn	0.20	0.03
	Tpcpul	0.19	0.02
	Tpcpmn	0.27	0.29
	Tpcpll	0.21	0.05
	Tpcpln	0.21	0.02
PTn		0.20	0.06
	Tpcpv	0.11	0.06
	Tpbt4	0.16	0.01
	Tpy	0.16	0.01
	Tpbt3	0.24	0.06
	Tpp	0.29	0.12
	Tpbt2	0.23	0.09
	Tptrv	0.21	0.08
TSw1		0.23	0.07
	Tptrn	0.23	0.06
	Tptrl	0.29	0.02
	Tptpul	0.25	0.13
TSw2		0.21	0.04
	Tptpmn	0.21	0.03
	Tptpll	0.21	0.06
	Tptpln	0.24	0.05
TSw3		0.24	0.13
	Tptpv	0.24	0.13
CHn		0.17	0.12
	Tpbt1	0.11	-
	Tac	0.20	0.16

* Quasi-Static
Std. Dev.—Standard deviation
- No Data

Source: CRWMS M&O 1997d

Table 3.7-24. Comparison of the Mean and Standard Deviation of Compressional and Shear Wave Velocities on Dry Specimens—NRG and SD Boreholes

T/M Unit	TCw	TCw	PTn	PTn	TSw1	TSw1	TSw2	TSw2
Wave Type	P	S	P	S	P	S	P	S
Mean Velocity, km s^{-1}	4.369	2.811	2.687	1.900	3.739	2.352	4.158	2.786
Standard Deviation	0.494	0.132	0.703	0.308	0.393	0.204	0.672	0.110
Range (Min.–Max.)	2.865 – 4.787	2.352 – 3.009	1.538 – 3.750	1.365 – 2.464	2.767 – 4.629	2.048 – 2.928	2.673 – 4.709	2.408 – 3.007
Number of Samples	66	42	11	11	57	38	50	47

Source: CRWMS M&O 1997d

Table 3.7-25. Mean and Standard Deviation of Uniaxial Compressive Strength for Thermal Mechanical and Lithostratigraph Unit

T/M Unit	Lithostratigraphic Unit	Uniaxial Compressive Strength Mean (MPa)	Std. Dev. (MPa)
UO		7.14	4.92
	Tmr	7.60	7.48
	Tpki	6.75	1.84
	Tpbt5	-	-
TCw		127.54	92.66
	Tpcrv	-	-
	Tpcrn	36.02	32.98
	Tpcpul	62.14	26.54
	Tpcpmn	167.19	64.12
	Tpcpll	230.94	105.30
	Tpcpln	172.33	58.09
PTn		6.37	6.97
	Tpcpv	16.61	19.81
	Tpbt4	3.54	1.74
	Tpy	19.30	6.99
	Tpbt3	1.30	0.71
	Tpp	3.41	2.29
	Tpbt2	3.14	2.05
	Tptrv	3.50	2.02
TSw1		58.22	30.69
	Tptrn	58.99	28.27
	Tptrl	26.73	9.25
	Tptpul	65.21	44.40
TSw2		167.90	65.53
	Tptpmn	187.49	64.92
	Tptpll	103.82	60.68
	Tptpln	144.44	39.57
TSw3		16.40	-
	Tptpv	16.40	-
CHn		23.23	3.04
	Tpbt1	20.50	-
	Tac	24.60	2.69

Std. Dev.—Standard deviation
- No Data

Source: CRWMS M&O 1997d

Table 3.7-26. Strength Parameters Calculated from the Confined Compressive Test Results, Stratigraphic Units

Thermal/ Mechanical Unit	Lithostratigraphic Unit	Cohesion (MPa)	Angle of Internal Friction (degrees)	Data Source for Strength Parameters			
				Core Hole	Sample ID	Confined Pressure (MPa)	Axial Stress (MPa)
TCw	Tiva Canyon Tuff: Crystal-poor Middle Nonlithophysal Zone (Tpcpmn)	14.2	65	NRG-3	263.3-E	5	158.2
				NRG-3	263.3-D	10	291.4
				NRG-3	265.7-B	5	295.9
				NRG-3	265.7-D	5	275.1
				NRG-3	265.7-F	5	180.3
				NRG-3	265.7-C	10	369.0
				NRG-3	265.7-E	10	339.1
				NRG-3	265.7-G	10	309.9
TCw	Tiva Canyon Tuff: Crystal-poor Lower Lithophysal Zone (Tpcpll)	50.6	54	NRG-6	22.2-B	10	439.7
				NRG-6	22.2-C	10	434.6
				NRG-6	22.2-D	10	343.4
				NRG-6	22.2-E	10	417.3
				NRG-6	22.2-F	5	395.3
				NRG-6	22.2-G	5	391.2
				NRG-6	22.2-H	5	396.8
				NRG-6	22.2-I	5	307.1
				NRG-6	22.2-J	0	315.8
				NRG-6	22.2-K	0	284.2
				NRG-6	22.2-L	0	313.8
				NRG-6	22.2-M	0	332.4
TCw	Tiva Canyon Tuff: Crystal-poor Lower Nonlithophysal Zone (Tpcpln)	27.8	63	SD-12	144.7-A	0	278.4
				SD-12	156.0-A	5	313.6
				SD-12	161.7-A	10	418.2
				SD-12	165.8-A	0	169.8
				SD-12	176.1-A	10	410.4
				SD-12	195.3-A	0	259.9
				SD-12	202.9-A	5	323.3
TSw1	Topopah Spring Tuff: Crystal-rich Nonlithophysal Zone (Tptrn)	6.4	55	NRG-4	527.0-A	5	76.5
				NRG-4	527.0-B	5	108.9
				NRG-4	527.0-D	5	113.6
				NRG-4	527.0-E	5	90.0
				NRG-4	527.0-G	5	67.5
				NRG-4	527.0-C	10	160.8
				NRG-4	527.0-F	10	142.1
				NRG-4	527.0-H	10	131.4
				NRG-4	527.0-I	10	133.0
TSw1	Topopah Spring Tuff: Crystal-rich Nonlithophysal Zone (Tptrn)	3.4	53	NRG-6	416.0-B	10	119.9
				NRG-6	416.0-C	10	147.9
				NRG-6	416.0-E	10	61.1
				NRG-6	416.0-F	5	77.1
				NRG-6	416.0-G	5	39.6
				NRG-6	416.0-H	5	84.7
				NRG-6	416.0-I	5	58.8

Table 3.7-26. Strength Parameters Calculated from the Confined Compressive Test Results, Stratigraphic Units (Continued)

Thermal/ Mechanical Unit	Lithostratigraphic Unit	Cohesion (MPa)	Angle of Internal Friction (degrees)	Data Source for Strength Parameters			
				Core Hole	Sample ID	Confined Pressure (MPa)	Axial Stress (MPa)
TSw1	Topopah Spring Tuff: Crystal-rich Nonlithophysal Zone (Tptrn)	15.1	51	NRG-7/7A	344.4-A	10	185.0
				NRG-7/7A	344.4-B	10	139.1
				NRG-7/7A	344.4-D	10	208.3
				NRG-7/7A	344.4-E	5	56.5
				NRG-7/7A	344.4-F	5	163.9
				NRG-7/7A	344.4-G	5	75.9
				NRG-7/7A	344.4-H	5	110.2
				NRG-7/7A	344.4-I	0	106.2
				NRG-7/7A	344.4-J	0	89.5
				NRG-7/7A	344.4-K	0	97.3
				NRG-7/7A	344.4-L	0	88.7
TSw1	Topopah Spring Tuff: Crystal-rich Nonlithophysal Zone (Tptrn)	9.9	48	SD-12	339.4-A	5	88.8
				SD-12	343.4-A	10	124.6
				SD-12	354.1-A	0	44.4
				SD-12	370.1-A	5	87.4
				SD-12	401.5-A	10	102.9
				SD-12	406.1-A	0	48.4
				SD-12	410.2-A	5	99.4
TSw2	Topopah Spring Tuff: Crystal-poor Middle Nonlitho-physal Zone (Tptpmn)	42.8	50	NRG-7/7A	865.4-A	10	325.2
				NRG-7/7A	865.4-B	10	354.0
				NRG-7/7A	865.4-D	10	235.5
				NRG-7/7A	865.4-E	10	316.7
				NRG-7/7A	865.4-C	5	259.8
				NRG-7/7A	865.4-F	5	322.3
				NRG-7/7A	865.4-G	5	255.1
				NRG-7/7A	865.4-H	5	231.6
				NRG-7/7A	865.4-I	0	215.8
				NRG-7/7A	865.4-J	0	232.0
				NRG-7/7A	865.4-K	0	239.1
				NRG-7/7A	865.4-L	0	248.5
TSw2	Topopah Spring Tuff: Crystal-poor Middle Nonlitho-physal Zone (Tptpmn)	36.9	46	SD-9	761.5-A	0	231.5
				SD-9	764.8-A	6	231.9
				SD-9	764.8-B	10	218.3
				SD-9	766.0-A	15	210.8
				SD-9	768.7-A	0	254.5
				SD-9	771.7-A	0	160.8
				SD-9	774.6-B	0	60.1
				SD-9	774.6-C	10	212.3
				SD-9	775.8-A	15	280.9
				SD-9	775.8-B	6	181.7
				SD-9	815.9-B	10	344.2
				SD-9	817.1-A	15	334.4
				SD-9	826.7-A	0	224.9
				SD-9	832.8-C	0	183.3

Table 3.7-26. Strength Parameters Calculated from the Confined Compressive Test Results, Stratigraphic Units (Continued)

Thermal/ Mechanical Unit	Lithostratigraphic Unit	Cohesion (MPa)	Angle of Internal Friction (degrees)	Data Source for Strength Parameters			
				Core Hole	Sample ID	Confined Pressure (MPa)	Axial Stress (MPa)
TSw2	Topopah SpringTuff: Crystal-poor Lower Nonlithophysal Zone (Tptpln)	22.7	58	SD-12	1073.3-B	5	216.1
				SD-12	1077.1-B	10	246.1
				SD-12	1107.1-B	0	162.0
				SD-12	1112.1-B	5	280.6
				SD-12	1118.9-B	10	288.9
				SD-12	1209.0-B	0	128.0
TSw3	Topopah Spring Tuff: Crystal-poor Vitric Zone (Tptpv)	3.5	47	SD-12	1279.7-A	5	52.2
				SD-12	1284.2-A	10	80.0
				SD-12	1299.9-A	0	16.4

Source: CRWMS M&O 1997d

Table 3.7-27. Brazilian Tensile Strength for Thermal/Mechanical and Lithostratigraphic Units

T/M Unit	Lithostratigraphic Unit	Brazilian Tensile Strength	
		Mean (MPa)	Standard Deviation (MPa)
UO		0.88	0.72
	Tmr	1.23	1.27
	Tpki	0.70	0.24
	Tpbt5	-	-
TCw		8.88	3.66
	Tpcrv	-	-
	Tpcrn	5.23	2.80
	Tpcpul	9.63	0.73
	Tpcpmn	10.10	4.75
	Tpcpll	12.20	4.39
	Tpcpln	11.00	1.75
PTn		0.66	1.17
	Tpcpv	2.64	2.04
	Tpbt4	0.3	-
	Tpy	3.00	-
	Tpbt3	0.10	-
	Tpp	0.19	0.19
	Tpbt2	0.35	0.31
	Tptrv	0.1	-
TSw1		5.48	2.32
	Tptrn	5.49	2.09
	Tptrl	4.81	1.36
	Tptpul	5.69	3.06
TSw2		8.91	3.39
	Tptpmn	11.56	3.80
	Tptpll	8.29	2.99
	Tptpln	7.75	2.59
TSw3		3.97	0.32
	Tptpv	3.97	0.32
CHn		-	-
	Tpbt1	-	-
	Tac	-	-

- No Data

Source: CRWMS M&O 1997d

Table 3.7-28. Creep Measurements, Borehole USW NRG-7/7A

Depth, ft:	776.6	807.6	808.3	858.4	1264.5	1281.4	1400.5
Thermal/Mechanical Unit:	TSw2	TSw2	TSw2	TSw2	TSw2	TSw2	TSw2
Date Test initiated:	3/28/95	3/28/95	2/17/95	3/28/95	9/30/93	9/30/93	9/30/93
As Tested Bulk Density (g/cc):	2.249	2.273	2.295	2.307	2.295	2.295	2.295
Average Grain Density (gcc):	2.536	2.534	2.526	2.526	2.591	2.592	2.515
Porosity (%):	11.3	10.3	9.2	8.7	11.4	11.5	8.8
P Velocity (km/s):	4.357	4.426	4.455	4.488	4.064	4.431	N/A
S1 Velocity (km/s):	2.774	2.775	2.800	2.816	2.563	N/A	N/A
S2 Velocity (km/s):	2.730	2.712	2.848	2.769	2.510	N/A	N/A
Radial P Velocity (km/s):	4.388	4.418	4.471	4.465	4.450	4.618	N/A
Radial S Velocity (km/s):	2.808	2.836	2.824	2.847	2.703	2.815	N/A
Temperature, °C:	225	225	225	225	225	225	225
Confining Pressure, MPa	10	10	10	10	10	10	10
Stress Difference, MPa	70	40	129	100	98	132	131
Strain @ 1,000s (millistrain)	2.34	1.08	3.02	2.69	3.01	3.70	3.47
Strain termination (millistrain)	2.52	1.16	3.06	2.88	3.25	4.04	3.84
Duration of Test (days)	43.5	43.5	68.3	43.5	29.5	29.5	29.5
Duration of Test (millions of seconds)	3.76	3.76	5.90	3.76	2.55	2.55	2.55

NOTES: 1. Nominal Sample Dimensions: Length = 101.60 mm; Diameter = 50.80 mm. Source: CRWMS M&O 1997d
2. P is the compressional wave, S1 and S2 are the two orthogonally polarized shear waves.

Table 3.7-29. Summary of Statistical Data for Schmidt Hammer Tests in Thermomechanical Units—NRG Holes

Core Hole	UO (Tuff "X")			All TCw			TCw-NL			TCw-LR			PTn			All TSw1			TSw1-NL			TSw1-lr			TSw2		
	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N	mean	sdev	N
UE25 NRG-2				45.94	3.11	13	47.68	1.92	4	45.16	3.31	9															
UE25 NRG-2A				44.09	2.60	10	44.09	2.60	10																		
UE25 NRG-2B				27.60	11.61	11	24.61	10.62	9	41.09	1.04	2															
UE25 NRG-3				39.76	9.17	21	34.67	11.98	10	44.39	3.49	11															
UE25 NRG-4													17.88	2.86	2	46.21	4.88	16	46.53	5.06	14	43.99	3.59	2			
UE25 NRG-5																11.83	—	1				11.83	—	1	42.70	9.25	5
UE25 NRG-6				49.71	4.89	9	47.50	2.84	3	50.81	5.53	6	38.70	7.96	2	46.53	7.06	31	48.34	4.38	16	44.61	8.86	15	48.02	9.32	10
UE25 NRG-7/7A				41.08	7.99	6	41.08	7.99	6				26.07	11.77	4	48.35	4.28	19	48.37	4.68	10	48.33	4.06	9	48.29	5.10	14
ALL HOLES																											
—Range				11.48 - 56.95			11.48 - 50.15			36.33 - 56.95			15.85 - 44.33			11.83 - 56.58			35.75 - 56.58			11.83 - 54.70			23.65 - 56.45		
—Mean				41.01			37.82			45.78			27.18			46.45			47.71			44.59			47.23		
—Sdev				10.10			11.47			4.65			11.53			7.23			4.66			9.70			7.53		
—N				70			42			28			8			67			40			27			29		

Sdev = standard deviation
N = number of samples
NL = Nonlithophysal
LR = Lithophysae Rich
Shaded area = No tests conducted, thermomechanical unit not sampled by borehole.

Table 3.7-30. Average Fracture Normal Stiffness at 2.5 MPa Normal Stress for Each of the Four Thermal/Mechanical Units Sampled

Thermal/Mechanical Unit	Normal Stiffness at 2.5 MPa[a] (MPa/mm)	Number of Tests
TCw	37.3 ± 4.0	2
TSw1	50.1 ± 17.6	16
TSw2	73.5 ± 38.2	11
CHn1	47.7 ± 5.4	4

(a) Error bars indicate ± one standard deviation.

Source: CRWMS M&O 1997d

Table 3.7-31. Average Shear Strength Parameters for Fractures from Each of the Four Thermal/Mechanical Units Sampled

Thermal/Mechanical Unit	Cohesion (*C*)[a] (MPa)	Coefficient of Friction[a] (tan)	Number of Tests
TCw	0.03 ± N/A	1.03 ± N/A	2
TSw1	1.63 ± 0.68	0.76 ± 0.08	16
TSw2	0.86 ± 0.81	0.87 ± 0.09	12
CHn1	1.69 ± 1.55	0.78 ± 0.25	4

(a) Error bars indicate ± one standard deviation.
N/A—Not applicable

Source: CRWMS M&O 1997d

Table 3.7-32. Peak Shear Stress, Residual Shear Stress, and Applied Normal Stress for Fractures

Thermal/Mechanical Unit	Lithologic Unit	Specimen ID Number	σ (MPa)	T_p (MPa)	T_r (MPa)
TCw	Tpcpll	NRG-6-27.6-28.1-SNL	5.0	5.16	4.93
	Tpcplnc	NRG-6-102.9-103.4-SNL	15.0	15.46	10.20
TSw1	Tptrl	NRG-4-670.5-671.1-SNL	2.5	3.49	2.59
	Tptrn	NRG-6-380.9-381.3-SNL	2.5	3.68	2.95
	Tptpmn	SD-12-688.2-688.6-SNL	2.5	3.62	3.31
	Tptrn	NRG-4-537.8-538.2-SNL	5.0	5.48	5.21
	Tptrn	NRG-4-608.7-609.2-SNL	5.0	4.44	4.17
	Tptrn	NRG-6-297.4-297.7-SNL	5.0	5.16	5.01
	Tptrn	NRG-6-424.0-424.5-SNL	5.0	5.28	3.98
	Tptrn	NRG-7-367.2-367.8-SNL	5.0	6.47	4.2
	Tptrn	NRG-7-408.8-409.6-SNL	5.0	4.18	3.71
	Tptrn	NRG-6-296.0-296.4-SNL	10.0	11.89	6.59
	Tptrn	NRG-6-401.5-401.9-SNL	10.0	11.10	7.84
	Tptpul2	NRG-6-485.9-486.3-SNL	10.0	10.19	7.82
	Tptrn	NRG-7-434.7-435.3-SNL	10.0	6.85	6.02
	Tptrn	NRG-7-447.2-448.1-SNL	10.0	9.45	5.41
	Tptrn	NRG-7-317.3-317.8-SNL	15.0	11.50	10.70
	Tptrn	NRG-7-430.2-430.9-SNL	15.0	13.26	9.09
TSw2	Tptpmn	NRG-6-782.3-782.6-SNL	2.5	1.92	1.80
	Tptpln	SD-9-1255.9-1256.3-SNL	2.5	2.37	2.29
	Tptpln	SD-12-1072.5-1073.0-SNL	2.5	3.31	2.67
	Tptpll	SD-9-1132.2-1132.9-SNL	5.0	5.45	4.53
	Tptpll	SD-9-1171.1-1171.8-SNL	5.0	5.48	4.81
	Tptpln	SD-12-1072.5-1073.0-SNL	5.0	6.62	5.23
	Tptpln	SD-9-1254.7-1255.2-SNL	10.0	7.68	7.10
	Tptpln	SD-9-1254.7-1255.2-SNL	10.0	8.97	8.34
	Tptpmn	SD-12-778.1-780.0-SNL	10.0	12.00	10.38
	Tptpll	NRG-6-935.0-935.3-SNL	15.0	11.89	8.56
	Tptpll	SD-9-1141.2-1141.5-SNL	15.0	14.00	14.0
	Tptpll	SD-9-1144.2-1145.1-SNL	15.0	15.50	10.2
CHn1	Tac	SD-9-1480.7-1481.8-SNL	2.5	3.52	2.89
	Tac	SD-9-1480.7-1481.8-SNL	5.0	4.35	3.66
	Tac	NRG-7-1511.3-1512.0-SNL	5.0	7.03	4.81
	Tac	SD-9-1480.7-1481.8-SNL	10.0	9.45	5.46

(a) σ: normal stress; τ_p: peak shear stress; τ_r : residual shear stress

Source: CRWMS M&O 1997d

Table 3.7-33. Geomechanical Classification of Rock Masses Based on Rock Mass Rating

Rock Mass Class	Relative Rating	Range in RMR
I	very good	81 - 100
II	good	61 - 80
III	fair	41 - 60
IV	poor	21 - 40
V	very poor	<20

NOTE: Classification guidelines from Bieniawski (1979)

Table 3.7-34. Relative Rock Quality for Ranges of Q

Relative Rating	Q
Exceptionally Good	400 - 1000
Extremely Good	100 - 400
Very Good	40 - 100
Good	10 - 40
Fair	4 - 10
Poor	1 - 4
Very Poor	0.1 - 1
Extremely Poor	0.01 - 0.1
Exceptionally Poor	0.001 - 0.01

Source: Barton, N.R. et al. 1974

Table 3.7-35. Summary of Rock Mass Quality Values

Thermo/ Mechanical Unit	Rock Mass Quality Category	Cumulative Frequency	Rock Mass Rating (RMR)			Rock Mass Quality, Q				
			NRG Borehole[1]	Scanline	Full-Peripheral	ESF Design[2] (NRG Boreholes)	Scanline[3]	Full-Peripheral[3]	$Q_{modified}$ (Kirsten Approach Scanline[3]	$Q_{modified}$ (Kirsten Approach Full-Peripheral[3]
TCw	1	5%	51.00	47.00	43.00	0.38	0.21	0.33	0.99	0.46
	2	20%	56.00	53.80	54.00	0.68	0.44	0.81	2.35	2.27
	3	40%	59.00	58.80	60.00	2.08	1.01	1.80	4.96	4.39
	4	70%	67.00	66.60	66.00	5.66	5.22	4.15	18.12	9.60
	5	90%	72.00	74.10	74.00	9.14	38.44	14.50	67.78	22.24
UO	1	5%	50.40	48.90	51.00	--	5.03	2.00	7.79	3.90
	2	20%	52.90	62.60	59.00	--	18.67	16.00	8.62	7.19
	3	40%	55.88	66.70	64.00	--	30.00	24.00	12.55	9.69
	4	70%	59.42	72.60	86.00	--	38.00	33.00	15.84	14.58
	5	90%	60.00	87.00	86.00	--	625.00	42.00	244.64	17.36
PTn	1	5%	45.00	53.70	56.00	0.15	1.54	1.28	0.52	0.32
	2	20%	52.00	61.20	61.00	0.28	5.56	4.20	1.11	0.70
	3	40%	55.00	71.10	70.00	0.66	7.80	9.00	2.30	0.98
	4	70%	65.00	74.00	77.00	1.62	13.11	13.00	10.59	1.43
	5	90%	70.00	87.00	80.00	3.74	616.88	25.00	41.97	3.50
TSw1	1	5%	49.00	48.10	41.00	0.24	0.38	0.48	1.35	0.77
	2	20%	53.00	55.10	48.00	0.87	2.07	1.60	5.78	2.59
	3	40%	57.00	61.40	54.00	1.73	5.13	3.70	13.55	4.79
	4	70%	62.00	74.10	63.00	5.09	31.90	10.00	67.00	9.66
	5	90%	70.00	92.00	70.00	12.00	231.50	22.00	372.90	18.34
TSw2	1	5%	51.00	53.00	44.00	0.30	0.55	0.47	3.26	0.82
	2	20%	56.00	58.10	52.00	0.65	1.18	1.03	6.22	1.90
	3	40%	58.00	62.10	56.00	1.91	2.78	1.70	11.46	3.43
	4	70%	63.00	66.10	62.00	3.75	6.18	4.10	25.47	6.99
	5	90%	67.00	72.10	68.00	8.44	16.28	9.30	56.14	15.07

Source: CRWMS M&O 1997f

NOTES: 1. From SNL 1995b, "Data Transmittal for Rock Mass Mechanical Properties Estimates from NRG Drilling Program," TDIFs 304414 and 304415; DTNs SNF29041993002.062 and SNF29041993002.063.

2. From CRWMS M&O 1995b, "ESF Ground Support Design Analysis," BABEE0000-01717-0200-00002 Rev. 00.

3. Values of Q are extracted from rank-ordered intervals whose cumulative frequency is closest to the corresponding rock mass quality category cumulative frequency.

Table 3.7-36. Exploratory Studies Facility Ground Support Guidelines

Ground Support Class	Range of Q for Ground Support Class	ESF Ground Support Recommendation
V	0.01–0.1	W8 steel sets, spaced 610 mm with full lagging.
IV	0.1–0.4	W8 steel sets, spaced 610–1220 mm with WWF and lagging as necessary.
III	0.4–4.0	Rockbolts nominal 1000 × 1000 mm spacing with WWF. Spot bolt as necessary. Plus 100–150 mm shotcrete[1]. (Class III-A Alternative: W6 steel sets, spaced 1220 mm with WWF and partial lagging as needed).
II	4.0–10.0	Rockbolts nominal 1000 × 1000 mm spacing with WWF. Spot bolt as necessary. Pins and channel may be used to secure mesh as needed. (Class II-A Alternative: W6 steel sets, spaced 1220 mm with WWF).
I	>10.0	Rockbolts nominal 1500 × 1500 mm spacing with WWF. Spot bolt as necessary. Pins and channel may be used to secure mesh as needed. (Class I-A Alternative: W6 steel sets, spaced 1220–1800 mm with WWF).

WWF—Welded wire fabric or interlocking steel mesh

Source: CRWMS M&O 1996b

[1] Although shotcrete was called for by design, shotcrete was not used except in the starter tunnel.

Table 3.7-37. Proportion of Tunnel within Each Thermal/Mechanical Unit and Ground Support Guideline for Exploratory Studies Facility Scanline Rock Mass Quality Data to 35+05m

T/M Unit	YMP Ground Support Guideline				
	I	II	III	IV	V
	Proportion of Tunnel Length (%)				
UO	93	7	0	0	0
TCw	5	8	58	26	4
PTn	28	57	15	0	0
TSw1	51	17	25	5	2
TSw2	41	35	24	0	0

Source: CRWMS M&O 1997d

Table 3.7-38. Calculated Rock Mass Thermal Expansion Coefficient from SHT Data through Day 90

MPBX Number	Average∝ (10^{-6}/°C)	Average Temperature (°C)	Maximum Gage Length (m)
TMA-MPBX-1	5.02	118.64	2.0
TMA-MPBX-3	5.27	63.81	3.0

∝ = Coefficient of Thermal Expansion

Table 3.7-39. Thermal Expansion Coefficients from SHT Data for Longest Available Gage Lengths, Near, Heating Cycle

MPBX Number	Anchor Numbers	Average∝ (10^{-6}/°C)	Average Temperature (°C)	Gage Length (m)
TMA-MPBX-1	1 to 4	5.88	160.3	2.84
TMA-MPBX-3	2 to 6	4.14	70.07	4

∝ = Coefficient of Thermal Expansion

Table 3.7-40. Estimated Rock Mass Mechanical Properties for Rock Mass Rating at 40 Percent Cumulative Frequency of Occurrence for Each Thermal/Mechanical Unit

Rock Mass Mechanical Property	T/M Unit				
	UO	TCw	PTn	TSw1	TSw2
Strength = $A+B\sigma_3^C$					
Uniaxial Compressive Strength -A (MPa)	0.88	14.4	1.51	6.4	25.4
B	12.018	14.337	9.585	9.271	23.687
C	0.729	0.709	0.719	0.712	0.571
Mohr-Coulomb Failure					
Cohesion (MPa)	1.1	5.5	1.3	3.3	8.9
Angle of Internal Friction (degrees)	52	55	48	47	59
Dilation Angle (degrees)	26	27	24	24	30
Deformation Modulus (GPa)	4.3	25.7	2.5	18.9	31.1
Poisson's Ratio	0.14	0.21	0.2	0.26	0.21

Source: CRWMS M&O 1997d

Table 3.7-41. Intact Rock Constants for Rock Mass Strength Criteria

Thermal/Mechanical Unit		Yudhbir Criterion		Hoek & Brown Criterion	Intact Rock Compressive (MPa)
		B	α	m_i	σ_c
UO (Tuff "X")		8.10	1.00	125.64	6.8
TCw		2.50	0.64	18.50	125.1
PTn	Tiva Canyon, Yucca Mountain	4.56	1.00	17.64	8.0
	Bedded Tuffs, Pah Canyon	6.10	1.00	150.97	
TSw1		2.62	0.663	10.60	56.9
TSw2		1.63	43	19.68	178.5

Source: CRWMS M&O 1997d

Table 3.7-42. Calculate Rock Mass Modulus in Borehole ESF-TMA-BJ-1 Using the Borehole Jack for the Single Heater Test

Date	Distance from Collar				
	2.0 m	3.0	4.0 m	4.51 m	6.2 m
	Rock Mass Modulus GPa (Temp °C)				
8/26/96	6.9 (25)	3.71 (25)	No test	No test	No test
10/10/96	10.3 (27.5)	10.3 (27.7)	8.3 (30.2)	6.0 (34)	No test
11/26/96	Results discarded (31.1)	10.2 (35.9)	5.71 (46.4)	5.01 (55.4)	8.4 (141.8)
3/18/97	Results discarded (35)	6.3 (41)	10.3 (52)	5.7 (58.7)	22.8 (143.1)

Source: CRWMS M&O 1997d

NOTE: Italicized calculated moduli are based on field data in which the difference between the two borehole jack LVDT readings slightly exceeded the limits set in ASTM D4971-89. The fractured nature of the rock made setting the jack difficult. Discarded results were for data that far exceeded ASTM D4971-89 limits.

Table 3.7-43. Summary of In Situ Stresses at the Repository Horizon

Parameter	Average Value	Range of Values
Vertical Stress	7.0 MPa	5.0 - 10.0 MPa
Minimum Horizontal/Vertical Stress Ratio	0.5	0.3 - 0.8
Maximum Horizontal/Vertical Stress Ratio	0.6	0.3 - 1.0
Bearing of Minimum Horizontal Stress	N57°W	N50°W - N65°W
Bearing of Maximum Horizontal Stress	N32°E	N25°E - N40°E

Source: *Advanced Conceptual Design Report* (CRWMS M&O 1996f)

Table 3.7-44. Blast Vibration Limits Specified for Construction of Alcove 2

Structure	Peak Particle Velocity	
	(mm/sec)	(in/sec)
Opening Perimeter at 1 m Distance	700	28
Steel Sets	1250	50
Cast-in-Place Concrete (Age: 0-24 hours)	No Blasting	No Blasting
Cast-in-Place Concrete (Age: 24-60 hours)	10	0.4
Cast-in-Place Concrete (Age: >60 hours)	102	4

Source: CRWMS M&O 1996c

Table 3.7-45. Rock Bolt Load Cells, Load Versus Time

	TMA RLBC Gage	Days After Startup									
		0	14	28	42	56	70	84	96	112	126
		Average Load (lb.)									
Hot Side	RB-LC-1-AVG	22662	22262.8	22158	21732.3	21537.1	21444.1	21407.5	21380.8	21340.3	21308.5
	RB-LC-2-AVG	14859.4	14739.7	14708.6	14680.1	1463.7	14597	14559.8	14522.5	14496.5	14449.6
	RB-LC-3-AVG	22428	22402.2	22378.7	22348.4	22317.5	22281	22262.3	22243.2	22231	22224.1
	RB-LC-4-AVG	16663.9	16602.8	16580.3	16558.8	16522.1	16496.6	14647.4	16446.3	16424.2	16407.5
Ambient Side	RB-LC-5-AVG	25971.9	25928.5	25887	25856.6	25829.3	25802.6	25783.4	25765.5	25748.7	25738.1
	RB-LC-6-AVG	14642.7	14633.2	14632.7	14627.3	14619.4	14609.5	14601.2	14595.9	14589.2	14573.7
	RB-LC-7-AVG	4932.6	4921.1	4919.7	4911.8	4907.3	4893.6	4890.9	4883.8	4877.5	4873
	RB-LC-8-AVG	16862.8	16818.5	16783.6	16738.7	16738.7	16605	16592.7	16575.4	16566	16561.5
	TMA RLBC Gage	Days After Startup									
		140	154	168	182	196	210	224	238	252	266
		Average Load (lb.)									
Hot Side	RB-LC-1-AVG	21279.7	21254.3	21206.3	21176.9	21161.2	21145.9	21127.1	21112.2	21100.9	21102.1
	RB-LC-2-AVG	14422.7	14405.6	14389.9	14378.6	14369.9	14365.5	14353.4	14349	14342	14341.1
	RB-LC-3-AVG	22214.2	22206.8	22201.1	22194.3	22189.6	22183.4	22176.4	22171.7	22165.3	22158.4
	RB-LC-4-AVG	16394.3	16377.4	16361.5	16350.8	16340.4	16331	16320.2	16316.8	16312.1	16310.9
Ambient Side	RB-LC-5-AVG	25728.1	25722.2	25714.1	25705.1	25698.3	25692.7	25683.1	25676	25665.6	25652
	RB-LC-6-AVG	14567.1	14563.5	14562.3	14557.4	14553.9	14551.2	14549.3	14543.8	14543.4	14538.9
	RB-LC-7-AVG	4866.9	4866.7	4867.2	4866.6	4868.2	4865.2	4863.2	4863.9	4864.1	4867.1
	RB-LC-8-AVG	16552.8	16544.8	16538	16533.	16528.6	16522.3	16516.4	16514	16503.2	16501.5

INTENTIONALLY LEFT BLANK

Table 3.8-1. Correlation of Descriptive Rock Unit Names, YMP Stratigraphy, and Thermal/Mechanical Units of Ortiz et al. (1985)

Description of Modeled Units	Project Stratigraphy, Buesch, Spengler et al. 1996a; Sawyer, D.A., Fleck et al. 1994	Thermal/ Mechanical Units (Ortiz et al. 1985)
alluvium	NA	UO
Rainier Mesa Tuff	Trm	UO
rhyolite of Comb Peak	Tpk	N/A
Tiva Canyon Tuff undifferentiated	Tpc	TCw
crystal-poor densely welded vitric subzone of Tiva Canyon Tuff	Tpcpv3	TCw
cry-poor non- part. mod. welded vitric subzones of Tiva Canyon Tuff	Tpcpv1-2	PTn
pre-Tiva Canyon Tuff bedded tuff	Tpbt4	PTn
Yucca Mountain Tuff	Tpy	PTn
pre-Yucca Mountain Tuff bedded tuff	Tpbt3	PTn
Pah Canyon Tuff	Tpp	PTn
pre-Pah Canyon Tuff bedded tuff	Tpbt2	PTn
Topopah Spring Tuff upper non-partly-welded vitric subzones	Tptrv2-3	PTn
Topopah " " upper densely welded vitric subzone	Tptrv1	TSw1
Topopah " " crystal-rich nonlithophysal zone	Tptrn	TSw1
Topopah " " crystal-rich lithophysal zone	Tptrl	TSw1
Topopah " " lithic rich member	Tptf	TSw1
Topopah " " upper lithophysal zone	Tptpul	TSw1
Topopah " " middle nonlithophysal zone	Tptpmn	TSw2*
Topopah " " lower lithophysal zone	Tptpll	TSw2
Topopah " " lower nonlithophysal zone	Tptpln	TSw2
Topopah " " lower densely welded vitric subzone	Tptpv3	TSw3
Topopah " " non- partly mod. welded vitric subzones	Tptpv1-2	CHn1
pre-Topopah Spring Tuff bedded tuff	Tpbt1	CHn1
Calico Hills Formation undifferentiated	Ta	CHn1
pre-Calico Hills Formation bedded tuff	Tabt	CHn2
Prow Pass Tuff upper nonwelded zone	Tcp [unw]	CHn3
Prow Pass Tuff welded zone	Tcp [w]	PPw
Prow Pass Tuff lower nonwelded zone	Tcp [lnw]	CFUn
pre-Prow Pass Tuff bedded tuff	[bt]	CFUn
Bullfrog Tuff upper nonwelded zone	Tcb [unw]	CFUn
Bullfrog Tuff welded zone	Tcb [w]	BFw
Bullfrog Tuff lower nonwelded zone	Tcb [lnw]	CFMn1
pre-Bullfrog Tuff bedded tuff	[bt]	CFMn2
Tram Tuff undifferentiated	Tct	CFMn2, TRW
pre-Tram Tuff bedded tuff	[bt]	n/a
lower Tertiary units undifferentiated	n/a	n/a
Paleozoic and older units	n/a [pz]	n/a

* = The top of the Repository Host Horizon (RHH) as used in repository design is above the top of Tptpmn (CRWMS M&O 1997d).

NOTE: The Integrated Site Model includes all of the units listed. Informal usages including terminology internal to the model are shown in brackets. For correlation to hydrogeologic units, see CRWMS M&O (1996e) or Buesch, Spengler et al. (1996a). Thermal/mechanical units are shown because they are referred to directly in this report.

INTENTIONALLY LEFT BLANK

Table 3.9-1. Comparison of Potassium-Argon (Fleck et al. 1996) and $^{40}Ar/^{39}Ar$ Ages (Perry et al. 1998a)

Volcanic Episode	Fleck et al. 1996	Perry et al. 1998a	Percent Difference
Thirsty Mesa	4.63	4.78	3.24
SE Crater Flat	3.73	3.75	0.54
Buckboard Mesa	2.87	3.11	8.36
Quaternary Crater Flat	1.025	1.014	-1.09
Sleeping Butte	0.338	0.410	21.30
Lathrop Wells	0.119	0.075	-36.97

Table 3.9-2. Comparison of Estimated Disruption Probabilities (events/year)

Reference	Disruption Probability	Comment
Ho, C.-H. 1995	$2x10^{-9}$ to $6.6x10^{-7}$	range
Crowe, Perry et al. 1995	$1.8x10^{-8}$	median value
Connor and Hill 1995	1 to $5x10^{-8}$	range

INTENTIONALLY LEFT BLANK

Table 3.10-1. Key Milestones for Earthquake Reporting of the Southern Great Basin

Pre-1925	Historical compilations (Townley and Allen 1939; Slemmons et al. 1965; Meremonte and Rogers 1987); no systematic reporting, some low gain seismographs (e.g., at Reno, NV; Mt. Hamilton and Berkeley, CA; and Tucson, AZ) with detection capability of larger events (M_L~ ≥ 5.5) in the Southern Great Basin (e.g., 1916 Death Valley earthquake). UCB began systematic reporting of western Nevada earthquakes north of 37° latitude in 1910.
1925	U.S. Coast and Geodetic Survey began systematic compilation of earthquake felt reports (U.S. Department of Commerce annual catalogs, 1925-).
1932	Felt reports and instrumental locations for larger earthquakes computed by California Institute of Technology (CIT). First seismograph station installed in the southern Great Basin at Tinemaha in Owens Valley, CA by CIT in 1931. Four stations installed (1938-1941) by U.S. Bureau of Reclamation in vicinity of Lake Mead, NV to monitor for RIS. Detection threshold reduced to about M_L 4.0 in Southern Great Basin (D.H. von Seggern and J.H. Brune, *Seismicity in the Southern Basin*, 1868-1992, U.S. Geological Survey Open File Report, in press)
ca 1960	Worldwide Network of Standardized Seismographs (WWSSN) in operation–location capability (routine operations) and detection threshold about M_L 3.5 for Southern Nevada.
1961	Regional network installed around NTS by U.S. Coast and Geodetic Survey, Earth Science Laboratories to monitor NTS activity (King et al. 1971). No significant improvement in detection threshold.
1968	Short duration local networks sponsored by the Department of Defense in and around the NTS. Detection threshold decreased to about M_L 2.5 (D.H. von Seggern and J.H. Brune, *Seismicity in the Southern Basin*, 1868-1992, U.S. Geological Survey Open File Report, in press).
1972	Regional network installed and operated by the Seismological Laboratory at the University of Nevada, Reno for the State of Nevada- however no seismographs installed in Southern Nevada. No significant change in detection threshold.
1978	USGS Southern Great Basin network began operation–location capability (routine operations) about M_L < 1.0 in the vicinity of Yucca Mountain and M_L 1.3 regionally (Gomberg 1991a; D.H. von Seggern and J.H. Brune, *Seismicity in the Southern Basin*, 1868-1992, U.S. Geological Survey Open File Report, in press). Network operation taken over by University of Nevada, Reno in 1992.
1995	University of Nevada, Reno installed 3-component high dynamic range digital network and redesigned station configuration–detection capability M_L -0.5 in Yucca Mountain block and M_L 1.0 regionally (Von Seggern and Smith 1997).

Table 3.10-2. Networks Relevant to the Southern Great Basin

Network	Dates of Operation	Detection Threshold in Southern Great Basin	Location Accuracy	References
Only a few isolated seismograph stations	Pre-1932	M_L 5.5 regionally	Depends on population distribution and density	Townley and Allen (1939); Slemmons et al. (1965); Meremonte and Rogers (1987)
California networks (operated by UCB and CIT)	UCB 1910-1997 CIT 1932-1997	M_L 4.0 regionally	± 50 km in epicenter early on and no depth control, improved to ±10 km	Bolt and Miller (1975) Hileman et al. (1973)
Worldwide Standardized Seismographic Network (WWSSN)	ca 1960-1997	M_L 3.5 regionally	±20 km in 1960s, now ±5 km. Poor depth control.	
Local NTS networks (supported by the Dept of Defense)	1968-1978	M_L 3.5 regionally ~M_L 1.0 locally	±1 km in epicenter and ±2 km in depth locally	Hamilton, R.M., Smith et al. (1971); Smith, B.E. et al. (1971); Fischer et al. (1972); Rogers, A.M., Woulett et al. (1977); King et al. (1971).
Southern Great Basin network (operated by USGS till 1992 then UNR from 1992-1995)	1978-1995	M_L 1.3 regionally $M_L < 1.0$ in the vicinity of Yucca Mountain	± 1 km in epicenter, ± 2 km in depth	Rogers, A.M., Harmsen et al. (1987); Harmsen and Rogers (1987); Harmsen and Bufe (1992); Harmsen (1991, 1993a, 1993b)
Southern Great Basin digital network (operated by UNR)	1995-1997	M_L 1.0 regionally M_L -0.5 in the vicinity of Yucca Mountain	± 1 km in epicenter, ± 2 km in depth around Yucca Mountain ± 1 km regionally > 2 km in depth	Von Seggern and Smith (1997)

Table 3.10-3. Regional Seismicity Catalogs Used For The Yucca Mountain Seismicity Catalog

Catalog of Southern Great Basin earthquakes, 1868 to 1978, compiled by Meremonte and Rogers (1987)
Catalog for the Southern Great Basin network for the period 1978 to 1991 (Rogers, A.M., Harmsen et al. 1987) (SGB)
California Division of Mines and Geology catalog for California, 1868 to 1932 (CDMG)
California Institute of Technology Seismological Laboratory and USGS catalog for Southern California, 1932 to 1994 (CIT)
University of California at Berkeley Seismographic Station catalog for Northern California, 1910 to 1972 (UCB)
USGS catalog for Northern and Central California, 1969 to 1995 (USGS)
Seismological Laboratory of the University of Nevada, Reno catalog for Nevada, 1874 to 1994 including the Southern Great Basin network data for 1992 to 1994 (UNR)
Decade of North American Geology catalog, 1868 to 1985 (Engdahl and Rinehart 1988) (DNAG)
Northern Arizona University catalog for Arizona, 1891 to 1992 (NAU)
Stover, Reagor and Algermissen state catalogs for Utah and Arizona compiled by the National Earthquake Information Center (NEIC), 1881 to 1985 (SRA)
University of Utah Seismographic Stations catalog for Utah, 1881 to 1994 (UUTAH)
NEIC Preliminary Determination of Epicenters catalog for Utah and Arizona, 1938 to 1991 (PDE)

Table 3.10-4. Estimated Completeness Intervals for the Southern Great Basin

Magnitude (M_L)	Estimated Completeness Interval
1.5	1995-1997
2.0	1985-1997
2.5	1979-1997
3.0	1979-1997
3.5	1961-1997
4.0	1934-1997
4.5	1934-1997
5.0	1925-1997
5.5	1910-1997
6.0	1850-1997
6.5	1850-1997

Table 3.10-5. The 1992 Little Skull Mountain Mainshock Source Parameters

Information Source	Strike	Dip	Rake[1]	Mo x 10E24 dyne-cm
K.D. Smith et al., *The 1992 Little Skull Mountain Earthquake Sequence, Southern Nevada Test Site*, U.S. Geological Survey Open File Report, in press	N60°±15°	70°±13°SE	-70°±10°	NC[2]
Meremonte, Gomberg et al. (1995)	N55°E	56°SE	-72	NC
Romanowicz et al. (1993)	N43°E	66°SE	-73	3.5
Romanowicz et al. (1993)	N34°E	44°SE	-70	2.6
Zhao and Helmberger (1994)	N45°E	55°SE	-60	3.0
Walter (1993)	N35°E	54°SE	-87	4.1
Harmsen (1994)	N55°E	56°SE	-72	NC

Modified from Schneider et al. 1996.

[1] Rake is the angle between the strike direction and the slip vector. The negative sign indicates that this is a normal fault.

[2] NC = Not calculated

Table 3.10-6. Small Magnitude Earthquakes at Yucca Mountain

#	Date	Origin Hr/Min	Time Sec	Latitude Deg/Min	Longitude Deg/Min	Depth km	M	#P	Gap Deg	DMIN km	RMS sec	EH km	EZ km
1.	95 5 5	1321	33.12	36N50.66	116W24.08	6.15	0.58	22	41	1.3	0.11	0.3	0.5
2.	95 7 1	1526	56.69	36N40.84	116W30.88	8.65		13	242	5.7	0.13	1.0	0.9
3.	95 7 7	759	00.33	36N49.67	116W24.85	6.02	-0.27	16	94	1.3	0.11	0.3	0.4
4.	95 728	618	51.42	36N54.10	116W30.52	4.80	-0.48	3	250	5.5	0.01	0.2	0.1
5.	95 9 4	1239	47.11	36N44.43	116W30.02	4.45	0.72	31	101	4.3	0.11	0.3	0.6
6.	951119	2215	84.91	36N50.80	116W23.59	6.46	-0.25	5	115	4.1	0.06	0.5	0.7
7.	951120	226	57.44	36N50.81	116W23.67	5.95	-0.43	5	114	4.0	0.06	0.5	1.1
8.	9512 6	2327	15.90	36N43.74	116W29.06	7.80	0.29	10	210	3.7	0.12	0.7	0.6
9.	96 129	1020	32.32	36N44.23	116W29.44	9.90		3	211	4.0	0.02	1.2	0.2
10.	96 330	1957	28.63	36N48.60	116W27.98	7.24	-0.59	5	86	3.3	0.04	0.2	0.3
11.	96 4 8	714	49.64	36N49.96	116W25.21	8.23	-0.58	5	147	1.8	0.06	0.5	0.5
12.	96 6 2	1645	75.18	36N49.11	116W29.44	9.61	-0.69	6	171	2.1	0.04	0.7	0.5
13.	96 6 2	1015	33.29	36N49.23	116W29.55	9.87	0.01	14	63	3.8	0.11	0.3	0.4
14.	96 731	357	37.30	36N45.91	116W34.54	8.55	-0.76	5	195	3.0	0.14	1.3	0.9
15.	96 812	422	50.68	36N48.48	116W23.09	5.02	-0.62	3	237	3.3	0.00	0.1	0.1

#P Number of P-wave times used in the locations
Gap Azimuthal gap in the location
DMIN Epicentral distance to nearest station
RMS Root-mean-square error of residuals
EH Epicentral error
EZ Focal depth error

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults

Bare Mountain Fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min Pref Max	Number of Possible Fault Segments	Number of Trenches[1]
normal	N-S	60-80°E	20	1	3

Trench BMT-1

Event	Displacement (cm)[2a] Min Pref Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min Pref Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	150	D, F, T, U	NS[6]	14 35-50 100	T, S, Ar	NS[6]	trapezoid

Trench BMT-2

Event	Displacement (cm)[2a] Min Pref Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min Pref Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z		F, W	NS[6]	14 35-50 100	S	NS[6]	trapezoid
Y		F, U		300 375 450			triangle

Trench BMT-3

Event	Displacement (cm)[2a] Min Pref Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min Pref Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	80	D, F, U	NS[6]	14 35-50 100	S	NS[6]	trapezoid
Y	150 300	D, F		300 375 450	S		triangle

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Bow Ridge fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal-left lateral	N5-15°E	65-85°W	6	8.5	10	1	7

Trench 14

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	no displacement			F	NS[6]	30	73	80	A	NS[6]	triangle

Trench 14D

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	15	44	80	D, F, U, W	NS[6]	30	73	130	T, U, S	NS[6]	triangle
Y	4	13	45	D, F, U, W		130	140	150	T, U, S		triangle
X	1	14	40	D, W		250	340	500	U		triangle

Trench A/BR-3

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
No deformation of Quaternary deposits											

Northern Crater Flat fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]W
normal; normal-left lateral	NO - 20°E	70°W	1	10.5	20	1	1

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench CFF-T2a

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	3	5	D, F, T	H	5.5	8	10	T	NS[6]	triangle
Y	0	5	5	U	M	10	150-200	433	T, S		trapezoid
X		40		U, D, W	H		>433		S		
W		50		D	H		>>433		S		
V		50		D	M		>>>433		S		

Southern Crater Flat fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal; normal left lateral	N 4-28°E	82-90°W	4	8	20	1	2

Trench CFF-T1

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	7.5	8	10	D	M	3	4	7.4	S	H	triangle
Y	7.5	10	10	D, U, F	H	60	70	80	S	H	triangle

Trench CFF-T1a

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	2	18	18	D, W	H	3	4	7.4	T	M	triangle
Y	5	10	15	D, U, T, F	H	60	70	80	S	H	triangle
X	17	20	32	D, U, T	L	200	250	300	S	H	triangle

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Fatigue Wash fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]W
normal; normal - left lateral	N9°E	73°W	9.5	12	17	1	2

Trenches CF 1

Event	Displacement (cm)[2c] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	fractures			U	L	9	20-60	75	T, U, S	NS[6]	trapezoid
Y	15	25	35	F, D	NS[6]	15	65-75	100	T, U, S, A		trapezoid
X		105		F, W, U, T, D	NS[6]	189	250-300	450	T, U, S		trapezoid
W		54		W, D	L		450	730	T, U, S		boxcar
Pre- W				U	NS[6]		>730		T, U, S		

Ghost Dance fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal	N-S	77°-89°W	3	6	9	1	6

Trench 2 - Drill Hole Wash

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
No deformation of Quaternary deposits											

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench 4 - Split Wash

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
No deformation of middle Pleistocene - late Holocene deposits											

Trench 4 a- Split Wash

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	fracture (bedrock)			L	NS[6]		>275		U	NS[6]	

Whale Back Ridge trench (WBR)

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	fracture			U	L		> 91		U	NS[6]	

Iron Ridge fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal-left lateral	N-S	58-84°W	5	8.5	18.5	1	1

Trench SCF-T2

Event	Displacement (cm)[2e] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	5	10	F	L	15	25	60	R	NS[6]	triangle
Y	50	70	90	W	M				R		
X	70	100	130	W	M				R		
W	50	70	90	W	M				R		

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Paintbrush Canyon fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal-left	N10°E	70°W	10	19.5	28	2-3	6, plus 4 natural exposures

lateral

Trench A1

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	5	6	10	D, U	H	9	13	17	T, U, S	NS[6]	triangle
Y	29	39	49	U, D, W	H	100	120-140	170	T, U, S		trapezoid
X	0	7	14	U, D, F	L	220	250	280	T, U, S		triangle
W	100			D, W	L	280		U			

Trench A2

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution

No faulting observed

Trench MVT3

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution

No faulting observed

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Busted Butte Wall 1 (BB1)

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	(correlated to Wall 4)										
Y	(correlated to Wall 4)										
X	(correlated to Wall 4)										
W	(provisionally correlated to Wall 4)										
V	(provisionally correlated to Wall 4)										
T	(provisionally correlated to Wall 4)										
U	(provisionally correlated to Wall 4)										

Busted Butte Wall 2 (BB2)

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
S				D	NS[6]						
R				D							

Busted Butte Wall 4 (BB4)

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	44	72	D, W	NS[6]	35	50-60	70	U, T, S,A	NS[6]	trapezoid
Y	16	28	56	D, W, U		80	115	150	U, T, S		triangle
X	35	47	69	D		150	225	300	U, T, S		triangle
W	88	167	205	D, W		300	355	410	U, T, S		triangle
V	0	142	222	W				740	U, T, A		
U	12	105	257	W				740	U, T, A		
T	75	94	201	U, D				740	U, T, A		

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench MWV-T4

Event	Displacement (cm)[2d] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z		20		W, U	NS[6]	5	15	25	T	NS[6]	triangle
Y	44	62	77	W, U		55	65-75	80	T, U, S		trapezoid
X	53	98	143	W, U		70	90-95	110	U		trapezoid
W	0	40	140	W		100	122	143	U		triangle

Trench 16

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution

No faulting observed

Trench 16B

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution

Minor fractures only

Rock Valley fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Sites[1]
left lateral-oblique	N60°E	90°	19	32	65	3	5

*Sites consist of two or more closely spaced trenches

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Site RV1 (Medial Strand)

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z			85	D, U	NS[6]			<38	TR	NS[6]	

Site RV2 (Medial Strand)

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z			85	D, U	NS[6]			<38	TR	NS[6]	
Y				D, F, U	NS[6]				TR		

Site RV3

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Y	149	267	333	F, U, W	H	4	10	17	T,U	NS[6]	
X	201	362	451	W	M-H		pending		T,U		
W	114	204	254	W, D	M		pending		T,U		
V	184	330	411	W	M		pending		T,U		

Site RV4

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z				D, U, T	H	<1	2	3	T	NS[6]	
Y				F, U	M	3	10	38	T		
X				U, D	M				T		

Site RV5

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	fractures			U	L-M			6	T		
Y	58			F	H	3	10	38	T		
X				U	H						

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Solitario Canyon fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal; normal-left lateral	N8°E	72°W	12.5	18.5	22	3	9

Trench SCF-T1

Event	Displacement (cm)[2e] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	10	20	U	L	15	25	60	R	L	triangle
Y	50	70	90	F	H	60	70	80	R	M	triangle
X	no conclusive data										
W	no conclusive data										

Trench SCF-T3

Event	Displacement (cm)[2e] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	10	20	U	L	15	25	60	R	L	triangle
Y	60	80	100	F	H	60	70	80	R	M	triangle
X	no data										
W	20	35	50	F	H	150	200	250	R	L	triangle

Trench SCF-T4

Event	Displacement (cm)[2e] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	5	10	U	L	15	25	60	R	NS[6]	triangle
Y	20	30	40	F	H	60	70	80	R		triangle
X	not present										
W	10	20	30	F	H	150	200	250	R		triangle

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench SCF-T8

Event	Displacement (cm)[2e] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	5	10	20	U, dragged ash	M	15	25	60	R	L	triangle
Y	100	120	140	F	H	60	70	80	R, U, T	M	triangle
X	20	30	40	F	L	120	150	200	U	M	triangle
W	30	50	70	F	H	15	200	250	R	L	triangle

Trench T13

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution

No faulting observed

Stagecoach Road fault

Sense of Slip	Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal; normal-left lateral	N30°E	70°W	5	6	7	1	3

Trench SCR-T1

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	40	40	82	D, W	H	6	13	15	T, U, R	NS[6]	triangle
Y	28	42	70	W, F, U, T	H	17	26	32	T, U, R		triangle
X	14	47	99	U, T, W, F	M	35	55-70	80	T, U, R		trapezoid
W	24	51	74	U, T, W	M	80	100-110	118	T, U, R		trapezoid
V/U				D, F	M						

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench SCR-T2

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
No faulting observed											

Trench SCR-T3

Event	Displacement (cm)[2b] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	25	43	66	W, F	H	6	13	15	T, U, R	NS[6]	triangle
Y	20	59	77	U ,T, W	H	17	26	32	T, U, R		triangle
X	25	57	84	U, W	M	35	55-70	80	T, U, R		trapezoid
W	26	67	87	T, W	P	80	100-110	118	T, U, R		trapezoid
V		30-40		D, W, T	H						
U				F	M						
T				D, F	H						

Windy Wash fault

Sense of Slip		Fault Strike at surface	Fault Dip at surface	Fault Length (km) Min	Pref	Max	Number of Possible Fault Segments	Number of Trenches[1]
normal; normal left lateral	-	N 4-20° E	77-90° W	3	22	25	3	3

Trench CF-2 (northwall)

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	4	10	F	H	2.0	2.7	3.5	T	H	triangle
Y	14	20	24	F, D, U	M	30	40	90	U	M	triangle
X	20	23	30	W, U	L	70	75	120	U,A	M	triangle
W	18	20	25	W, U	M	130	150	160	U	M	triangle
V	70	73	83	W, F	M	180	200	220	R	L	triangle
U	30	45	60	W, F	M-L	220	240	260	R	L	triangle
T	48	50	78	W, U	M	300	340	370	U	M	triangle
S	65	80?	100?	W	M-L	390	400	?	R	L	

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench CF-2 (southwall)

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteri[a3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	4	10	F	H	2.0	2.7	3.5	T	H	triangle
Y	8	12	18	F, D	M	30	40	90	U	M	triangle
X	45	50	53	W	M	70	75	120	U, A	M	triangle
W	38	42	52	W, U	M	130	150	160	U	M	triangle
V	24	28	30	W	M	180	200	220	R	L	triangle
U	15	19	24	W	L	220	240	260	R	L	triangle
T	55	60	65	W, U	M	300	340	370	U	M	triangle
S	45	65?	95?	W, F	M	390	400	>400	R	L	

Trench CF-2.5 (only one fault strand exposed; Displacements, except Z, are minimums.)

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	4	6	10	F, D	H	2.0	2.7	3.5	T	H	triangle
Y	10	20	32	D, F	M-H	30	40	90	U	M	triangle
X	33	42	54	D, W	H	70	75	120	U	M	triangle
W	12	15	20	D, F, U	M	130	150	160	U	M	triangle
V	40			W	H	200			S,R	L	

Trench CF-3 (northwall)

Event	Displacement (cm)[2a] Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	4	6	F, D	M	2.0	2.7	3.5	T	H	triangle
Y	25	33	42	D, F	M-H	30	40	90	U	M	triangle
X	71	87	96	D, W	H	70	75	120	U	M-H	triangle
W	25	35	50	D	H	130	150	160	U	M	triangle
V	60	>65		D, W	M-H	>200			S,R	L	

Table 3.10-7. Event Displacements and Timing Data from Paleoseismic Studies of Yucca Mountain Faults (Continued)

Trench CF-3 (southwall)[2a]

Event	Displacement (cm) Min	Pref	Max	Event Criteria[3]	Event Confidence[4]	Event Timing (ka) Min	Pref	Max	Dating Method[5]	Dating Reliability[4]	Shape of Timing Distribution
Z	0	3	6	F, D	M	2.0	2.7	3.5	T	H	triangle
Y	25	35	45	D	M-H	30	40	90	U	M	triangle
X	78	88	98	D, U	H	70	75	120	U	M	triangle
W	not visible										

Notes:

1 Trenches with limited or no data are not included in this compilation; for information on excluded trenches see Chapter 4, Whitney, J.W., Taylor et al. (1996).
2a Vertical displacement, corrected for local deformation effects such as backtilting and graben formation.
2b Net tectonic displacement, adjusted from dip-slip values by including (a) oblique slip components and (or) (b) removal of local deformation effects such as backtilting and graben formation.
2c Apparent vertical displacement, not adjusted for local deformation effects or oblique slip components.
2d Apparent dip-slip displacement, displacement measured along the fault zone, not corrected for oblique slip components or local deformation.
2e Dip-slip displacements, slip along the fault zone, not adjusted for oblique components of slip.
3 D=Displacement of unit; F= Fault related fissure; W=Fault related colluvial wedge; U=Upward termination of fractures; T=Tilted and/or deformed units.
4 H=High; M=Moderate; L=Low.
5 T=Thermoluminescence; U=U-series; S=Soil Development; A=Ash; R= Relative correlation; Ar= Archeological; TR=U-Trend.
6 NS=Not specified by principal investigation

Table 3.10-8. Summary of Paleoseismic Data for Quaternary Faults in the Yucca Mountain Area

Fault	Number of Events	Displacement/ Event (cm)		Age-Most Recent Event (ka)		Average Recurrence Interval (ka)		Slip Rate (mm/yr)	
		Range	Pref.	Range	Pref.	Range	Pref.	Range	Pref.
Bare Mountain	1-2	150-300	80-150	14-100	35-50	10^4-10^5	100-200	0.01-0.06	0.01
Bow Ridge	2-3	1-80	14-44	30-130	48-73	70-215	100-140	0.002-0.007	0.003
No. Crater Flat	3-5	0-50	3-50	5.5-10	8	NA	120-160	0.002-0.003	0.002
So. Crater Flat	2-3	2-32	8-20	3-7.4	4	NA	5-60	NA	0.002
Fatigue Wash	3-6	NA	0-105	9-75 15-100	20-60 (Z) 65-75 (Y)	120-250	185	0.001-0.015	0.002-0.009
Iron Ridge	3-4	0-130	5-100	15-60	25	ND	ND	ND	ND
Paintbrush Canyon	3-7	0-257	6-167	9-17 35-70	13 (N)[ii] 50-60 (S)[iii]	20-270	20-120	0.001-0.03	0.002-0.015
Rock Valley	2-5	0-451	58-362	4-17 1-3	10 (N)[iv] 2(S)[v]	5->10	10^4	0.002-0.05	0.02-0.05
Solitario Canyon	4-6	0-140	10-120	15-60	25	35-100	50-70	0.01-0.02	0.01
Stagecoach Road	3-7	14-99	40-67	6-15	13	5-50	10-30	0.006-0.07	0.04
Windy Wash	5-8	0-100	4-80	2.0-3.5	2.7	40-57	40	0.009-0.01	0.011

NOTE: cm: centimeters; mm: millimeters; ka: thousands of years; yr: years; Range: maximum and minimum range of values; Pref.: preferred value; ND: No data; NA: Not applicable; Paleoseismic parameters are defined in text.

[i]Age constraint for possible event Z, which, if it exists, is the most recent event. Otherwise most recent event is Y, with age constraint below.

[ii]Age constraints for most recent event on northern end of fault.

[iii]Age constraints for most recent event on southern end of fault.

[iv]Age constraints for most recent event on northern strand of fault.

[v]Age constraints for most recent even on southern strand of fault.

Table 3.10-9. Preliminary Ages, Rupture Lengths, Displacements, and Magnitudes of Proposed Prehistoric Earthquake Rupture Scenarios at Yucca Mountain

Scenario	Faults[a]	Preferred Age[b] (ka)	Correlation Confidence[c]	Rupture Length[d] (km)		Rupture Displacement[e] (cm)	Estimated Magnitude[f]			Preferred Scenario Magnitude[g]
				Min.	Max.		Min. RL	Max. RL	Displ.	
Z	WW, SCF, NCF	5 ± 2	H	8.5	22	18	6.16	6.64	6.16	6.2
Y	PC, SCR	13 ± 3	H	18.5	25.5	43	6.55	6.71	6.43	6.5
X	SC, SCR, IR	26 ± 5	M	15	24	59	6.44	6.68	6.53	6.4
W	BM, WW, FW	40 ± 5	M	10	22	150	6.24	6.64	6.82	6.8
V	PC, SCR	59 ± 5	M	9	15.5	57	6.19	6.46	6.52	6.5
U	SCF, WW, FW, SC, BR, PC	75 ± 10	H	10.5	23	120	6.26	6.66	6.75	6.7 - 6.9[h]
T	PC, SCR	99 ± 10	M	14	20	98	6.41	6.59	6.68	6.6
S	PC, SCR?	120 ± 13	L-M	9.5	19.5	40	6.21	6.58	6.41	6.6
R	WW, BR	140 ± 10	L	8.5	22	42	6.16	6.64	6.42	6.5

NOTES:

a Fault abbreviations are as follows: BM - Bare Mountain; BR - Bow Ridge; FW - Fatigue Wash; IR - Iron Ridge; NCF - Northern Crater Flat; PC - Paintbrush Canyon; SC - Solitario Canyon; SCF - Southern Crater Flat; SCR - Stagecoach road; WW - Windy Wash.

b Event Age is the estimated age (in ka) of each rupture scenario based on the overlap of the timing distributions. The preferred age and a standard error are given; however, a better description of the age uncertainties are provided by the cumulative timing curves shown in the different plots of Figure 5-6 of Pezzopane, Whitney et al. (1996).

c Correlation Confidence is a subjective assessment of confidence in the correlation of individual paleoevents to form a rupture scenario: H = High, M = Moderate, L = Low.

d Minimum (Min.) and Maximum (Max.) Rupture Lengths are derived for each scenario on the basis of the trench locations with evidence of correlative events as well as locations that lack evidence of the correlative event.

e Rupture Displacement is the largest preferred displacement value (in cm) measured on an individual fault or at a single site involved in each rupture scenario.

f Estimated Magnitudes (moment magnitude) are derived from scenario rupture lengths (Max. RL is maximum rupture length; Min. RL is minimum rupture length) and rupture displacements (Displ. is rupture Displacement, see Note "e") using the appropriate empirical relation of Wells, D.L. and Coppersmith (1994):

g Preferred Scenario Magnitude (moment magnitude) is the preferred magnitude for the scenario rupture.

h Preferred value based on maximum rupture length is M 6.7; if slip is summed across all west side faults (assumes surface faults merge to a single rupture plane at seismogenic depth), a value of M 6.9 is preferred.

Table 3.10-10. Average Recurrence Intervals and Estimated Magnitudes for Different Recurrence Models Developed for Yucca Mountain Faults

Recurrence Model[a]	Average Recurrence Interval (ky)[b]	Estimated Magnitude[c]
1 (<500 ky)*	44 (+10, -7)	6.7 ± 0.4
1 (<150 ky)	19 (+8, -4)	6.7 ± 0.4
2 (<500 ky)*	13 (±5?)	6.4 (+0.5, -0.8)
2 (<150 ky)	35 (+15, -10)	6.4 (+0.5, -0.8)
3 (<150 ky)	17 ± 5?	6.5 (+0.4, -0.3)

NOTES:

a Recurrence models are described in the text and in Pezzopane, Whitney et al. (1996). Two different versions of models 1 and 2 are for two different time intervals, using all of the 500-ky paleoseismic record (those shown with a "*") or only the past 150-ky record, which is more complete. Model 3 is the preferred scenario ruptures of Pezzopane, Whitney et al. (1996).

b Average recurrence intervals (in ky) are calculated in different ways as described in Pezzopane, Whitney et al. (1996). The uncertainties are 1-sigma values; queries indicate rough approximation.

c Estimated magnitude is moment magnitude derived from the Wells, D.L. and Coppersmith (1994) relation as described in Pezzopane, Whitney et al. (1996).

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region

Minimum Distance to Controlled Area Boundary[a] (km)	Minimum distance to YMPR[b] (km)	Fault Name and Abbreviation	Relevant Fault[c]	Documented Quaternary Displacement[d]	Maximum Fault Length[e] (km)	Reference[f]	Maximum Moment Magnitude[g] (Mw)	Average Peak Acceleration[h] Median - 84th Percentile (g)	SEA96h Peak Acceleration[i] Median - 84th Percentile (g)
0	0	Ghost Dance GD	Yes?	No?	3	1, 2, 3, 25	5.6	0.44 - 0.74	0.23 - 0.38
0	0	Ghost Dance-Abandoned Wash GDAW	Yes?	No?	5[j]	1, 2, 3, 25	5.9	0.48 - 0.79	0.27 - 0.44
0	0	Sundance SD	Yes?	No?	1	1, 3, 4, 25, 26	5.1	0.38 - 0.66	0.18 - 0.29
0	1	Solitario Canyon SC	Yes	Yes	20	1, 2, 5, 25	6.6	0.58 - 0.94	0.39 - 0.64
0	1.5	Drill Hole Wash DHW	Yes?	No?	4	1, 2, 6, 25	5.8	0.46 - 0.77	0.25 - 0.42
0	2	Dune Wash DW	Yes?	No?	3	1, 2, 25	5.6	0.44 - 0.74	0.23 - 0.38
0	2.5	Bow Ridge BR	Yes	Yes	10	1, 2, 5, 7	6.2	0.52 - 0.85	0.31 - 0.52
0	3	Midway Valley MV	Yes?	Yes?	8	1, 2, 27	6.1	0.50 - 0.83	0.30 - 0.49
0	2.5	Pagany Wash PW	Yes?	No?	4	1, 2, 6, 25	5.8	0.46 - 0.77	0.25 - 0.42
0	3	Sever Wash SW	Yes?	No?	4	1, 2, 6, 25	5.8	0.46 - 0.77	0.25 - 0.42
0	2.5	Iron Ridge IR	Yes	Yes	9	1, 2	6.2	0.52 - 0.85	0.31 - 0.52
0	2.5	Boomerang Point BP	Yes?	No?	5	1, 2	5.9	0.48 - 0.79	0.27 - 0.44
0	3.5	Fatigue Wash FW	Yes	Yes	17	1, 2, 5, 8	6.5	0.56 - 0.92	0.37 - 0.60
0	4	Paintbrush Canyon PC	Yes	Yes	24	1, 2, 5, 7, 9	6.7	0.60 - 0.97	0.41 - 0.67
0	4	Paintbrush Canyon-Stagecoach Road PCSR	Yes	Yes	33[j]	1, 2, 5, 7, 9	6.8	0.62 - 1.00	0.43 - 0.71
1	4.5	Windy Wash WW	Yes	Yes	25	1, 2, 5	6.7	0.56 - 0.91	0.40 - 0.66
1	5	Yucca Wash YW	Yes?	No?	9	2, 9, 10, 25	6.2	0.47 - 0.78	0.31 - 0.51
2	6	Crater Flat CRF	Yes	Yes	18	1, 11, 24	6.5	0.48 - 0.79	0.35 - 0.57
4	10	Stagecoach Road SCR	Yes	Yes	9	1, 2, 5, 7	6.2	0.36 - 0.60	0.26 - 0.42
4	8.5	Black Cone BLK	Yes	Yes	7	1, 5, 11	6.1	0.35 - 0.58	0.24 - 0.40

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

Minimum Distance to Controlled Area Boundary[a] (km)	Minimum distance to YMPR[b] (km)	Fault Name and Abbreviation	Relevant Fault[c]	Documented Quaternary Displacement[d]	Maximum Fault Length[e] (km)	Reference[f]	Maximum Moment Magnitude[g] (Mw)	Average Peak Acceleration[h] Median - 84th Percentile (g)	SEA96h Peak Acceleration[i] Median - 84th Percentile (g)
10	14	Bare Mountain BM	Yes	Yes	16	5, 12, 21	6.5	0.27 - 0.44	0.19 - 0.31
12	19	Rocket Wash-Beatty Wash RWBW	Yes?	Yes?	17	5, 19	6.5	0.23 - 0.39	0.16 - 0.27
14	19	Mine Mountain MM	(Yes)	Yes?	27	5, 22	6.7	0.23 - 0.38	0.16 - 0.26
16	22	Wahmonie WAH	(Yes)	Yes?	15	5, 22	6.4	0.18 - 0.30	0.12 - 0.20
19	24	Oasis Valley OSV	Yes?	Yes?	20	5, 19	6.6	0.17 - 0.28	0.12 - 0.19
21	27	Rock Valley RV	Yes	Yes	65	5, 20, 22	7.2	0.22 - 0.35	0.15 - 0.24
21	29	Cane Spring CS	(Yes)	No?	27	5, 22	6.7	0.17 - 0.27	0.11 - 0.19
27	33	West Specter Range WSR	Yes	Yes	9	19	6.2	0.10 - 0.16	0.07 - 0.11
28	34	Ash Meadows AM	Yes	Yes	60	5, 20	7.1	0.16 - 0.26	0.11 - 0.18
31	36	Yucca Lake YCL	(Yes)	Yes?	17	5	6.5	0.10 - 0.17	0.07 - 0.12
32	37	Eleana Range ER	Yes	Yes	13	5	6.4	0.09 - 0.16	0.07 - 0.11
33	38	Amargosa River AR	Yes	Yes	15	5, 20	6.4	0.09 - 0.15	0.06 - 0.11
33	38	Amargosa River -Pahrump ARPR	Yes	Yes	130[j,k]	5, 20	7.5	0.18 - 0.28	0.11 - 0.19
34	38	Bullfrog Hills BUL	Yes?	Yes?	7	5	6.1	0.07 - 0.12	0.05 - 0.09
34	40	Yucca YC	Yes	Yes	32	5	6.8	0.11 - 0.18	0.08 - 0.13
35	42	Tolicha Peak TOL	Yes?	Yes?	22	5, 19	6.6	0.10 - 0.16	0.07 - 0.11
36	43	Keane Wonder KW	Yes	Yes	25	5, 19	6.7	0.10 - 0.16	0.07 - 0.11
37	43	Carpetbag CB	Yes	Yes	30	5	6.8	0.10 - 0.17	0.07 - 0.12
38	44	Area Three AT	Yes?	Yes?	12	5	6.3	0.07 - 0.12	0.05 - 0.09
39	44	Checkpoint Pass CP	Yes?	No?	7[l]	5	6.1	0.06 - 0.11	0.05 - 0.08
41	46	Plutonium Valley - N Halfpint Range PVNH	Yes?	No?	26	5	6.7	0.09 - 0.14	0.06 - 0.10
43	48	Crossgrain Valley CGV	Yes?	Yes?	9	5	6.2	0.06 - 0.10	0.04 - 0.07
43	48	Pahute Mesa PM	Yes?	Yes?	9	5	6.2	0.06 - 0.10	0.04 - 0.07
44	48	Mercury Ridge MER	Yes?	No?	10	5	6.2	0.06 - 0.10	0.04 - 0.07
44	50	Furnace Creek FC	Yes	Yes	145[m]	5, 23	7.6	0.14 - 0.23	0.09 - 0.15

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

Minimum Distance to Controlled Area Boundary[a] (km)	Minimum distance to YMPR[b] (km)	Fault Name and Abbreviation	Relevant Fault[c]	Documented Quaternary Displacement[d]	Maximum Fault Length[e] (km)	Reference[f]	Maximum Moment Magnitude[g] (Mw)	Average Peak Acceleration[h] Median - 84th Percentile (g)	SEA96h Peak Acceleration[i] Median - 84th Percentile (g)
44	50	Death Valley-Furnace Creek DVFC	Yes	Yes	205 [j,n]	5, 23	7.8	0.16 - 0.26	0.10 - 0.17
44	50	Death Valley-Furnace Creek-Fish Lake Valley DFFL	Yes	Yes	288 [j,p]	5, 13, 23	7.9	0.17 - 0.27	0.11 - 0.18
45	49	Ranger Mountains RM	No	Yes?	5	5	5.9	0.05 - 0.08	0.04 - 0.06
45	50	South Ridge SOU	Yes?	Yes?	19	5	6.6	0.08 - 0.12	0.05 - 0.09
45	52	Sarcobatus Flat SF	(Yes)	Yes?	51	5, 19	7.1	0.10 - 0.17	0.07 - 0.11
46	51	Boundary BD	No	Yes	7	5	6.1	0.05 - 0.09	0.04 - 0.07
47	53	Buried Hills BH	Yes?	Yes?	26	5	6.7	0.08 - 0.13	0.05 - 0.09
48	53	West Spring Mountain WSM	Yes	Yes	60	5, 19	7.1	0.10 - 0.16	0.07 - 0.11
48	53	Cockeyed Ridge-Papoose Lake CRPL	Yes?	Yes?	21	5	6.6	0.07 - 0.12	0.05 - 0.08
48	55	Death Valley DV	Yes	Yes	100 [q]	5, 23	7.4	0.12 - 0.19	0.08 - 0.13
50	55	Belted Range BLR	Yes	Yes	54	5, 19	7.1	0.09 - 0.15	0.06 - 0.10
50	57	Kawich Range KR	Yes	Yes	84	5, 19	7.3	0.11 - 0.17	0.07 - 0.11
52	57	Oak Spring Butte OAK	Yes?	Yes?	21	5	6.6	0.06 - 0.11	0.05 - 0.08
53	58	Grapevine GV	Yes	Yes	20	5	6.6	0.06 - 0.10	0.05 - 0.08
54	59	Spotted Range SPR	Yes?	Yes?	30	5	6.8	0.07 - 0.12	0.05 - 0.08
54	59	Cactus Springs CAC	No	Yes?	14	5	6.4	0.05 - 0.09	0.04 - 0.07
55	60	Emigrant Valley North EVN	Yes?	Yes?	28	5	6.8	0.07 - 0.11	0.05 - 0.08
55	60	Gold Flat GOL	No	Yes?	16	5	6.5	0.06 - 0.09	0.04 - 0.07
56	61	Kawich Valley KV	Yes?	Yes?	43	5	7.0	0.08 - 0.13	0.05 - 0.09
60	66	Emigrant Valley South EVS	No	Yes?	20	5	6.6	0.06 - 0.09	0.04 - 0.07

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

Minimum Distance to Controlled Area Boundary[a] (km)	Minimum distance to YMPR[b] (km)	Fault Name and Abbreviation	Relevant Fault[c]	Documented Quaternary Displacement[d]	Maximum Fault Length[e] (km)	Reference[f]	Maximum Moment Magnitude[g] (Mw)	Average Peak Acceleration[h] Median - 84th Percentile (g)	SEA96h Peak Acceleration[i] Median - 84th Percentile (g)
60	65	Chert Ridge CHR	No	Yes?	14	5	6.4	0.05 - 0.08	0.04 - 0.06
61	67	Indian Springs Valley ISV	Yes?	Yes?	28	5	6.8	0.06 - 0.10	0.04 - 0.07
61	67	Grapevine Mountains GM	Yes?	Yes?	31[r]	5	6.8	0.06 - 0.10	0.04 - 0.07
63	70	Pahrump PRP	Yes	Yes	70[k]	5	7.2	0.08 - 0.12	0.05 - 0.09
65	70	Fallout Hills FH	No	Yes?	8	5	6.1	0.04 - 0.06	0.03 - 0.05
68	74	Bonnie Claire BC	No	Yes?	27	5	6.7	0.05 - 0.08	0.04 - 0.06
70	74	Stumble STM	No	Yes?	33	5	6.8	0.05 - 0.09	0.04 - 0.06
70	76	West Pintwater Range WPR	Yes	Yes	60	5	7.1	0.07 - 0.11	0.05 - 0.08
71	76	Towne Pass TP	No	Yes	38	5	6.9	0.06 - 0.09	0.04 - 0.07
72	77	Jumbled Hills JUM	No	Yes?	27	5	6.7	0.05 - 0.08	0.04 - 0.06
74	80	Cactus Flat-Mellan CFM	No	Yes?	35	5	6.9	0.05 - 0.09	0.04 - 0.06
75	81	East Pintwater Range EPR	Yes?	Yes?	58	5	7.1	0.06 - 0.10	0.04 - 0.07
76	81	North Desert Range NDR	No	Yes?	24	5	6.7	0.05 - 0.07	0.03 - 0.06
76	82	La Madre LM	No	Yes?	33	5	6.8	0.05 - 0.08	0.04 - 0.06
77	84	Cactus Flat CF	No	Yes?	50	5	7.1	0.06 - 0.09	0.04 - 0.07
77	82	Groom Range Central GRC	No	Yes?	31	5	6.8	0.05 - 0.08	0.04 - 0.06
78	84	Three Lakes Valley TLV	No	No?	27	5	6.7	0.04 - 0.07	0.03 - 0.06
79	85	Groom Range East GRE	No	No?	20	5	6.6	0.04 - 0.07	0.03 - 0.05
80	87	Cactus Range -Wellington Hills CRWH	No	No?	29	5	6.8	0.05 - 0.07	0.03 - 0.06
82	87	Chalk Mountain CLK	No	Yes?	20	5	6.6	0.04 - 0.06	0.03 - 0.05

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

Minimum Distance to Controlled Area Boundary[a] (km)	Minimum distance to YMPR[b] (km)	Fault Name and Abbreviation	Relevant Fault[c]	Documented Quaternary Displacement[d]	Maximum Fault Length[e] (km)	Reference[f]	Maximum Moment Magnitude[g] (Mw)	Average Peak Acceleration[h] Median - 84th Percentile (g)	SEA96h Peak Acceleration[i] Median - 84th Percentile (g)
84	90	Chicago Valley CHV	No	Yes	20	5	6.6	0.04 - 0.06	0.03 - 0.05
85	90	Tin Mountain TM	No	Yes	29	5	6.8	0.04 - 0.07	0.03 - 0.05
87	92	Tikaboo TK	No	Yes	33	5	6.8	0.04 - 0.07	0.03 - 0.05
85	92	Stonewall Mountain SWM	No	Yes	22	5	6.6	0.04 - 0.06	0.03 - 0.05
90	95	Hunter Mountain HM	No	Yes	85	5	7.3	0.06 - 0.09	0.04 - 0.07
90	95	Panamint Valley PAN	Yes	Yes	100	5	7.4	0.06 - 0.10	0.04 - 0.07
90	95	Hunter Mountain - Panamint Valley HMPN	Yes	Yes	185[j]	5	7.7	0.07 - 0.12	0.05 - 0.08
92	97	Penoyer PEN	No	Yes	56	5	7.1	0.05 - 0.08	0.04 - 0.06
93	97	Racetrack Valley RTV	No	Yes?	22	5	6.6	0.03 - 0.06	0.03 - 0.04
101	106	Pahranagat PGT	No	Yes	91[s]	5	7.4	0.05 - 0.09	0.04 - 0.06
122	126	Owens Valley OWV	No	Yes	110	5	7.4	0.04 - 0.07	0.03 - 0.05
130	135	Fish Lake Valley FLV	No	Yes	83	5, 13	7.3	0.04 - 0.06	0.03 - 0.05
145	150	Garlock GAR	No	Yes	251[t]	14, 15	7.9	0.05 - 0.08	0.04 - 0.06
180	185	White Mountains and Cedar Mountain WMCM	No	Yes	115[v]	5, 16	7.5	0.03 - 0.05	0.02 - 0.04
285	291	San Andreas SAF	No	Yes	420[w]	17, 18	8.1	0.03 - 0.05	0.02 - 0.03

NOTES: This table lists faults that may be relevant to seismic hazards at the potential waste repository at Yucca Mountain, Nevada. Potential seismic sources are listed in order of their minimum distance to the boundary of the Yucca Mountain Conceptual Controlled Area (YMCCA) and to the center of the Yucca Mountain potential repository. The purpose of this study is to identify fault sources that are relevant to the potential repository's seismic hazard assessments. The results of this study, an inventory of relevant and potentially relevant faults, are tabulated to the right of the fault name. The remainder of the table lists supporting data and estimates of potential peak accelerations that could be produced at the Yucca Mountain site given maximum magnitude earthquakes on faults in the region. The footnotes and text provide additional explanation.

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

a Minimum Distance to the Controlled Area boundary refers to the closest distance (in km) from a point on the surface trace of the fault to the boundary of the Area. The Controlled Area boundary stretches outward approximately 5 to 7 km from the potential repository outline. Thus, most faults are from 7 to 9 km farther from the center of the potential repository (approximately lat. 36.85° N. and lon. 116.45° W.) than the minimum distance indicates. See note b, below.

b Minimum Distance to Yucca Mountain potential repository refers to the closest distance (in km) from a point on the surface trace of the fault to the center of the Yucca Mountain potential repository (approximately lat. 36.85° N. and lon. 116.45° W.).

c Relevant Faults (indicated with "Yes") are those with documented Quaternary activity and the potential to generate average 84th-percentile peak accelerations that equal or exceed 10 percent of gravity (0.1 g) at the Controlled Area boundary of the Yucca Mountain site (see footnote h). Potentially relevant faults ("Yes?") are those with suspected or questionable Quaternary activity (Yes? or No?) and the capability to produce at least 0.1 g peak acceleration at the 84th-percentile level. Potentially relevant faults that are considered subject to displacement on the basis of potential structural associations with seismicity or other Quaternary faults are tentatively identified as relevant faults (indicated with parentheses; "(Yes)"). Non-relevant faults (shown with a "No") are those that cannot produce at least 0.1 g average peak acceleration (84th-percentile) regardless of their Quaternary activity.

d Documented Quaternary Displacement designates the status of evidence for Quaternary fault activity with three alternatives: Yes; Yes?; and No?, depending upon whether there are published studies that document Quaternary (<2 Ma) displacement or other compelling evidence for Quaternary displacement potential, such as associated seismicity or field studies. Faults with a "Yes" are those for which there is demonstrated Quaternary displacement. Faults with a "Yes?" are those for which there is evidence to suspect Quaternary displacement, but commonly the faults have not been studied in detail to either document or disprove such displacement or complete stratigraphic sections including older Quaternary deposits are not preserved over the fault traces. Faults with a"No?" are those which lack evidence of Quaternary displacement or for which the data are inconclusive. See also discussion about faults subject to displacement in footnote above.

e Maximum Fault Length is the along-trace length of the fault zone (in km) as reported in published references or as estimated from maps and plates in cited references (Simonds et al. 1995; Scott, R.B. and Bonk, 1984; Piety, 1996). The maximum length represents the entire length of the mapped or inferred fault zone including sections portrayed as concealed or discontinuous or both.

f References for maximum fault length and Quaternary activity are keyed by number unless otherwise noted. 1 is Simonds et al. (1995); 2 is Scott, R.B. and Bonk (1984); 3 is Spengler, Braun et al. (1993); 4 is Spengler, Braun et al. (1994); 5 is Piety (1996); 6 is Scott, R. B., Bath et al. (1984); 7 is Menges, Wesling et al. (1994); 8 is Coe, J.A. et al. (1995); 9 is Dickerson and Spengler (1994); 10 is Langenheim and Ponce (1994); 11 is Faulds et al. (1994); 12 is Klinger and Anderson (1994); 13 is Reheis (1994); 14 is McGill and Sieh (1993); 15 is McGill and Sieh (1991); 16 is dePolo et al. (1993); 17 is Sieh (1978); 18 is USGS (1988); 19 is Anderson, R.E., Bucknam, et al. (1995); 20 is Anderson, R.E., Crone, et al. (1995); 21 is Anderson, L.W. and Klinger 1996); 22 is Coe, J.A., Yount et al. (1996); 23 is Klinger and Piety (1996); 24 is Ramelli, Bell, DePolo (1991); 25 is W.C. Day et al. (U.S. Geological Survey, written communication, to YMFB staff, Preliminary Site Geologic Map, October 1996); 26 is C.J. Potter (U.S. Geological Survey, written communication to S. Pezzopane, U.S. Geological Survey, 1996); 27 is Swan et al. (F.W. Swan et al., *Evaluation of the Location and Recency of Faulting Near the Prospective Facilities in Midway Valley, Yucca Mountain Project, Nye County, Nevada*, U.S. Geological Survey Open File Report, in press).

g Maximum Moment Magnitude (M_w) is the size of the earthquake associated with rupture of the maximum fault length. Moment magnitudes are calculated using maximum fault lengths and the empirical relation between surface rupture length and moment magnitude derived by Wells, D.L. and Coppersmith (1994) for all types of faults.

h Average Peak Acceleration (Median and 84th Percentile) are the average of four empirical attenuation relations appropriate for rock sites (Boore et al. 1993; Campbell 1981; Idriss 1991; Joyner and Boore 1981) calculated using the maximum moment magnitude and the minimum distance from the source to the boundary of the Controlled Area boundary. The value on the left is the average of the median peak accelerations derived from the four attenuation relations, and on the right is the average of the 84th-percentile peak acceleration. The attenuation relations and equations used to calculate the ground motions are described in Pezzopane (1996).

i SEA96h Peak Acceleration (Median and 84th Percentile) are calculated using the minimum distance from the source to the boundary of the Controlled Area boundary, maximum moment magnitudes, and the attenuation relation for extensional regimes and rock sites derived by Spudich et al. (1996). These ground motion values are listed for comparison and are not used to determine relevant faults.

Table 3.10-11. Fault Data and Ground Motion Estimates for Known and Suspected Quaternary Faults in the Yucca Mountain Region (Continued)

j Faults are assumed to join in a compound rupture of the entire zone.

k The maximum length of the Pahrump fault zone together with others along strike has been interpreted to be 130 km (summarized in Piety 1996). To obtain this length, the fault has to be projected across rather long areas where no surface trace is mapped. The length of such projections is approximately 60 km, almost one-half of the total length. The northernmost traces of this 130-km long zone may merge or intersect with recognized faults including the Amargosa River, Ash Meadows, and Rock Valley fault zones. The analysis embraces this possibility by considering the Amargosa River fault (see entry AR, above) as the northern continuation of the Pahrump fault zone. Given this interpretation (ARPR), there is an additional 40 km of unmapped fault length at the southeastern projection of the Pahrump fault zone.

l Maximum length is the sum of the northern and southern traces of the western half of the fault (see Piety 1996).

m Maximum fault length is measured from Cucomungo Canyon at the northern end to the southeastern end of Furnace Creek Wash, along the base of the Funeral Mountains east of Death Valley, almost to the town of Death Valley, California, in the Southern Amargosa Desert.

n Maximum fault length is measured from Cucomungo Canyon at the northern end of the Furnace Creek fault to the southern end of the southern Death Valley fault, almost to the Garlock fault.

p Maximum fault length includes the combined maximum lengths of the Death Valley and Fish Lake Valley faults and 105 km for the Furnace Creek fault, measured from the southern end of the Fish Lake Valley fault in Cucomungo Canyon to the northern end of the Death Valley fault where it merges with the Furnace Creek fault.

q Maximum fault length includes the southernmost part of the Southern Death Valley fault almost to the Garlock fault.

r Grapevine Mountains fault zone consists of an eastern and a western fault (Piety 1996). The maximum fault length is measured from the southern end of the eastern fault to the northern end of the western fault.

s Maximum length is for the Maynard Lake fault (see MAY in Piety 1996), which includes the northeastward fault continuation inferred to lie beneath Tertiary volcanic rocks.

t Maximum fault length assumes rupture of the entire fault (McGill and Sieh 1991). Minimum distance is measured to a site at lat 35.6° N. and long 117° W., at the eastern end of the Garlock fault, east of its junction with the Panamint Valley fault, not far from paleoseismic study sites that document the fault's Quaternary activity (McGill and Sieh 1991, 1993).

v The White Mountains - Cedar Mountain zone is an idealized seismic source that represents several of the larger faults in a broad area located between the 1872 Owens Valley, California, earthquake rupture and the 1932 Cedar Mountain, Nevada, rupture. Normal and oblique-slip faults in this area have documented Quaternary activity, have fault lengths between 20 and 70 km, and are considered capable of magnitude 6.8 to 7.4 earthquakes (dePolo et al. 1993). This table considers an idealized fault source that has an assumed moment magnitude of 7.5, which is larger than the expected magnitudes for rupture of the largest faults in the region, such as M 7.3 on the White Mountains fault zone (dePolo et al. 1993) and the historical M 7.2 Cedar Mountain earthquake. The minimum distance of 185 km is measured from lat 37.5° N. and long 118° W., which is slightly closer to Yucca Mountain than the minimum distances from the 1932 Cedar Mountain earthquake ruptures and from the White Mountains fault zone.

w The 420-km rupture length represents an event equivalent to, or slightly larger than, the 1857 and 1906 earthquakes; both were larger than magnitude 8 (Sieh 1978; Working Group on California Earthquake Probabilities 1988). The 1857 event ruptured SAF segments closest to the Yucca Mountain site. The minimum distance was measured to a point near Pallet Creek at lat 34.5 N. and long 118 W., a paleoseismic study site that provides evidence for the fault's Quaternary activity (Sieh 1978).

Table 3.10-12. Seismic Velocity Structure Developed for Thermal-Mechanical Units

Layer	Thermal Unit	Thickness (ft)	V_P (fps)	$\sigma_{ln\text{-}P}$	σ_{Vp}	V_S (fps)	$\sigma_{ln\text{-}S}$	σ_{Vs}	Poisson's Ratio
1	TCw	171	10290	0.46	0.079	5780	0.48	0.084	0.270
2	PTn TSw1	467	8470	0.29	0.029	5700	0.32	0.032	0.086
3	TSw2	541	10340	0.19	0.020	6190	0.26	0.027	0.222
4	TSw3	40	14040	0.20	0.089	7810	0.27	0.121	0.276
5	CHn	781	9540	0.20	0.023	5690	0.28	0.033	0.224
2a	PTn	128	7980	0.30	0.075	6280	0.37	0.059	<0.
2b	TSw1	339	8630	0.28	0.034	5520	0.30	0.027	0.15

NOTE: Thermal units defined by Ortiz et al. (1985)

Table 3.10-13. Seismic Velocity Structure Developed for Application at Yucca Mountain Repository

Depth (ft)	S-Wave Velocity (ft/sec)			Poisson's Ratio
	Lower Bound	Median	Upper Bound	
0 - 30	900	1700	300	0.35 ± 0.10
30 - 125 (gradient layer)	900 to 2500	1700 to 5700	3000 to 12000	0.30 ± 0.10
125 - 1000	2500	5700	12000	0.25 ± 0.10

Table 3.10-14. Source Parameters for the Little Skull Mountain Earthquake and Two Major Aftershocks

Event	Stress Drop (bar)
Main shock	37 ± 11
5 July Aftershock	23 ± 8
13 September Aftershock	34 ± 14

Source: Schneider et al. (1996)

Table 3.10-15. Definition of Earthquake Scenarios

Scenario	Fault	M	Rupture Distance (km)	Mechanism
1	Paintbrush Canyon-Bow Ridge	6.3	Paintbrush Canyon branch: 4.5 Bow Ridge branch: 2.5	Normal
2	Solitario Canyon	6.5	1.0	Normal
3	Rock Valley	6.7	25	Strike-Slip
4	Bare Mountain	6.4	15.5	Normal
5	Furnace Creek	7.0	50	Strike-Slip
6	Solitario Canyon-Fatigue Wash-Windy Wash	6.6	1.0	Normal

Source: Schneider et al. (1996)

Table 3.10-16. Empirical Attenuation Models Evaluated in the Probabilistic Seismic Hazard Analyses Ground Motion Characterization Study

Investigator	Date	Site Conditions
Abrahamson and Silva	1997	Rock
Boore, Joyner, and Fumal	1997	V_s model
Boore, Joyner, and Fumal	1994	Classes A and B
Campbell	1997	Soft and hard rock
Campbell[1]	1993, 1994	Hard rock
Campbell[1]	1990, 1994	Soft rock
Campbell	1990	Soil, soft rock
Idriss	1993	Rock, stiff soil
Idriss[2]	1997	Rock, stiff soil
Joyner-Boore	1988	Rock
McGarr	1984	Rock
Sabetta and Pugliese	1996	Rock
Sadigh et al.	1997	Rock
Spudich et al.	1996	Rock

Source: USGS 1998

[1] Campbell and Bozorgnia (1994)

[2] Written communication, Idriss, I.M., University of California, Davis, to Abrahamson, Norman, Consultant, 1997

Table 3.10-17. Form of Attenuation Equations Adopted in PSHA Ground Motion Characterization Study

	For M < m_1	**For M ≥ m_1**
Median motion (μ)	$\mu = a1 + a_2 (M-m_1) + a_6 (8.5-M)^2 + [a_3 + a_5 (M-m_1)] \bullet \ln(R^2 + a_8^2)^{1/2} + a7 F + a_9 W_H f_1(M,R) + a_{10} W_F f_1(M,R)$	$\mu = a1 + a_4 (M-m_1) + a_6 (8.5-M)^2 + [a_3 + A_5 (m-M_1)] \bullet \ln(R^2 + a_8^2)^{1/2} + a7 F + a_9 W_H f_1(M,R) + a_{10} W_F f_1(M,R)$
	For M < b_4	**For M ≥ b_4**
Aleatory variability (σ_{al})	$\sigma_{al} = b_1 + b_2 (M-b_4)$	$\sigma_{al} = b_1$
Epistemic Uncertainty in the Median (σ_μ)	$\sigma_\mu = c_1 + c_2 (M-c_6) + c_3 \ln(R+1) + c_4 [\ln(R+1)]^2 + c_5 F$	$\sigma_\mu = c_1 + c_2 (M-c_6) + c_3 \ln(R+1) + c_4 [\ln(R+1)]^2 + c_5 F$
Epistemic Uncertainty in the Aleatory Variability (σ_σ)	$\sigma_\sigma = d_1 + d_2 (M-d_4)$	$\sigma_\sigma = d_1$

where

$$f(M,R) = \begin{cases} 0 & for R \le x_1 \\ \dfrac{R - x_1}{x_2 - x_1} & x_1 < R < x_2 \\ 1 & x_2 \le R \le x_3 \\ \dfrac{x_4 - R}{x_4 - x_3} & x_3 < R < x_4 \\ 0 & R \ge x_4 \end{cases} \quad x \quad \begin{cases} 0 & for M \le a11 \\ \dfrac{M - a_{11}}{a_{12} - a_{11}} & a_{11} \le M \le a_{12} \\ 1 & M > a_{12} \end{cases}$$

In all cases,

$x_1 = 3$ $x_2 = 8$ $x_3 = 10$ $x_4 = 30$ $m_1 = 6.25$

For normal faulting, $W_F = 1$ for foot wall case and $W_H = 1$ for hanging wall case.

Source: USGS 1998

Table 3.10-18. Mean Ground Motion Hazard at 10^{-3} and 10^{-4} Annual Exceedance

Frequency	Horizontal		Vertical	
(Hz)	10^{-3}	10^{-4}	10^{-3}	10^{-4}
PGA	0.169 g	0.534 g	0.112 g	0.391 g
0.3	0.051 g	0.168 g	0.029 g	0.105 g
1.0	0.162 g	0.471 g	0.073 g	0.222 g
PGV	15.3 cm/sec	47.6 cm/sec	7.4 cm/sec	23.4 cm/sec

Table 3.10-19. Mean Displacement Hazard at Nine Demonstration Sites

Site	Location	Mean Displacement (cm) Annual Exceedance Probability	
		10^{-4}	10^{-5}
1	Bow Ridge fault	<0.1	7.8
2	Solitario Canyon fault	<0.1	32
3	Drill Hole Wash fault	<0.1	<0.1
4	Ghost Dance fault	<0.1	<0.1
5	Sundance fault	<0.1	<0.1
6	Unnamed fault west of Dune Wash	<0.1	<0.1
7	100 m east of Solitario Canyon fault		
7a	2-m small fault	<0.1	<0.1
7b	10-cm shear	<0.1	<0.1
7c	fracture	<0.1	<0.1
7d	intact rock	<0.1	<0.1
8	Between Solitario Canyon and Ghost Dance faults		
8a	2-m small fault	0.1	0.1
8b	10-cm shear	0.1	0.1
8c	fracture	0.1	0.1
8d	intact rock	0.1	0.1
9	Midway Valley	<0.1	0.1

Table 3.10-20a. The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 km of CAB That Have Been Selected as Credible Independent Sources By at Least One PSHA Expert Team.

Fault Name and Abbreviation *(Combined Faults)*[a]	Minimum Distance to CAB[b] (km)	Minimum Distance to YMPR[c] (km)	Potential Type I Fault[d]	Documented Quaternary Displacement[e]	Fault Length[f] (km)	Fault Dip[g] (deg)	Fault-Slip Type[h]	Mean Maximum Magnitude[i] (Mw)	Horizontal Spectral Acceleration[j] (g)			
									Frequency - 1 Hz		Frequency - 10 Hz	
									Median	84th Fractile	Median	84th Fractile
Faults within 5 km of CAB												
Black Cone (BLK)	4	8.5	Yes	Yes	6	60	N, H	6.05	0.12	0.27	0.40	0.75
Bow Ridge (BR)	0	2.5	Yes	Yes	13 (8)	60	N, H	6.3	0.23	0.50	0.74	1.38
Crater Flat North (CFN)	2	6	Yes	Yes	13	60	N, F	6.4	0.17	0.36	0.50	0.92
Crater Flat South (CFS)	1.5	8	Yes	Yes	8	60	N, F	6.1	0.10	0.22	0.32	0.60
Dune Wash (DW)	0	2	Yes?	No?	5	80	N, H	5.9	0.16	0.34	0.58	1.11
East Busted Butte (EBB)	1.5	7	Yes	Yes	5	60	N, F	5.95	0.09	0.21	0.33	0.63
Fatigue Wash (FW)	0	3.5	Yes	Yes	17	60	N, F	6.5	0.24	0.51	0.71	1.31
Ghost Dance (GD)	0	0	Yes?	No?	3	70	N, H	5.7	0.13	0.30	0.53	1.02
Ghost Dance-Abandoned Wash (GDAW)	0	0	Yes?	No?	7	70	N, H	6.1	0.21	0.45	0.70	1.32
Iron Ridge (IR)	0	2.5	Yes	Yes	9	60	N, F	6.4	0.25	0.53	0.76	1.40
Lathrop Wells Cone (LWC)	8	14	Yes	Yes	3	60	N, H	5.7	0.05	0.10	0.17	0.32
Midway Valley (MV)	0	3	Yes?	No?	8	60	N, H	6.15	0.19	0.42	0.66	1.24

Table 3.10-20a. The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 km of CAB That Have Been Selected as Credible Independent Sources By at Least One PSHA Expert Team. (continued)

Paintbrush Canyon (PBC)	0	4	Yes	Yes	24 (15)	60	N, H	6.7	0.28	0.58	0.75	1.37
Paintbrush Canyon-Stagecoach Road (PCSR)	0	4	Yes	Yes	33 (24)	60	N, H	6.75	0.28	0.60	0.76	1.38
Paintbrush Canyon-Stagecoach Road-Bow Ridge (PC-SR-BR)	0	2.5	Yes	Yes	33 (24)	60	N, H	6.8	0.37	0.85	1.03	2.05
Solitario Canyon (SC)	0	1	Yes	Yes	19	60	N, F	6.6	0.30	0.63	0.84	1.53
Solitario Canyon-Iron Ridge (SC-IR)	0	1	Yes	Yes	18	60	N, F	6.6	0.53	0.82	1.04	2.08
Solitario Canyon-Fatigue Wash-Windy Wash (SC-FW-WW)	0	1	Yes	Yes	25	60	N, F	6.7	0.39	0.90	1.13	2.24
Stagecoach Road (SCR)	4	10	Yes	Yes	9	60	N, H	6.3	0.15	0.32	0.41	0.76
Windy Wash (WW)	1	4.5	Yes	Yes	25 (21)	60	N, F	6.6	0.23	0.48	0.65	1.18
Windy Wash-Fatigue Wash-Crater Flat South (WW-FW-CFS)	0	3.5	Yes	Yes	25 (21)	60	N, F	6.7	0.33	0.77	0.98	1.95
Faults greater than 5 km from CAB												
Bare Mountain (BM)	10	14	Yes	Yes	20	60	N, H	6.7	0.15	0.32	0.33	0.60
Furnace Creek	44	50	Yes	Yes	115 (105)	90	S	7.35	0.07	0.15	0.08	0.15
Rock Valley	21	27	Yes	Yes	65 (48)	80	S	7.1	0.10	0.20	0.16	0.29

Table 3.10-20a. The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 km of CAB That Have Been Selected as Credible Independent Sources By at Least One PSHA Expert Team. (continued)

NOTE: km, kilometers; deg, degrees; Mw, moment magnitude units; g, horizontal spectral acceleratation as percentage of gravity. A seismogenic depth of 15 km is assumed for all faults widths.

a. Fault names and abbreviations are listed following nomenclature of Piety (1996) and Pezzopane (1996). Faults located within 5 km of the CAB of the site (see column 2 and footnote b) that have been selected as a credible source by at least one PSHA expert team are listed alphabetically. Individual faults that are combined together into one earthquake source are italicized; this includes, but is not limited to, the combined faults near the site with distributed ruptures.

b. Minimum Distance to CAB refers to the shortest distance from a point on the surface trace of the fault to the controlled area boundary at Yucca Mountain, consistent with guidance in NUREG-1451 (NRC 1992). The controlled area boundary stretches outward approximately 5 to 7 km from the potential repository outline. Thus, most faults are from 7 to 9 km farther from the center of the potential repository (approximately lat. 36.85°N. and lon. 116.45°W.) than the minimum distance indicates. See footnote c, below.

c. Minimum Distance to YMPR refers to the shortest distance from a point on the surface trace of the fault to the center of the Yucca Mountain potential repository (approximately lat. 36.85°N. and lon. 116.45°W.).

d. This column indicates whether a candidate Type I fault meets the criteria for a potential Type I fault relevant to vibratory ground motion hazard based on the criteria presented in NUREG-1451 (NRC 1992). Potential Type I faults indicated with "Yes" are those with documented Quaternary activity (Yes in column 5 of this table) and the potential to generate average 84th-percentile peak accelerations that equal or exceed 10 percent of gravity (0.1 g) at the controlled area boundary of the Yucca Mountain site. Potential Type I faults with a "Yes?" are those with questionable or indeterminate documentation of Quaternary activity (No? in column 5 of this table) and the capability to produce at least 0.1 g peak acceleration at the 84th-percentile level.

e. Documented Quaternary Displacement designates the status of evidence for Quaternary fault activity with two alternatives: Yes and No?, depending upon whether there are published studies that document Quaternary displacement or other compelling evidence for Quaternary displacement potential, such as associated seismicity or field studies. This is the primary criterion for classifying candidate and potential Type I faults. Faults with a "Yes" are those for which there is demonstrated Quaternary displacement. Faults with a "No?" are those which lack evidence of Quaternary displacement or for which the data are inconclusive.

f. Maximum Fault Length is the length of the fault zone (in km) as reported in published references or as estimated from maps and plates in cited references (Simonds et al. 1995; Scott, R.B. and Bonk 1984; Piety 1996). The maximum length represents the entire length of the mapped or inferred fault zone including sections portrayed as concealed or discontinuous or both. Values in parentheses indicate the probable length of late Quaternary rupture where it can be estimated from either paleoseismic data in trenches or, more commonly, by the extent of Quaternary fault scarps developed along the fault trace. The maximum length was used for M_w calculations. Lengths for combined faults are measured along the single longest combination of faults in the system, based on the assumption that the individual faults are joined in a compound rupture of the entire zone.

g. The preferred dips for faults assigned generally for various types of faults based on regional seismic and geophysical data.

h. This column indicates the slip type of the fault source entered into the ground motion attenuation equations developed by the ground motion experts for the PSHA (USGS 1998) (see footnote j and text). These equations differentiate between strike-slip and normal-slip faults, and subdivide the latter into whether the site is located on the hanging wall or footwall of the fault. Symbols are N - Normal-slip; S - Strike-slip; H - Hanging-wall; F - Footwall.

i. This column contains the deterministic mean M_w assigned to each fault in Table 2. It is the mean of a suite of M_w calculated from fault length, displacement per event, seismic moment, and rupture area data.

j. This set of columns contains the specific horizontal spectral acceleration ordinates calculated for site location using the mean of the attenuation relations developed for rock sites specifically for the Yucca Mountain area by the ground motion experts for the PSHA (USGS 1998). The median (50th) and 84th fractiles of spectral values are given at two frequencies (1 Hz and 10 Hz) for each source using the deterministic maximum magnitude (column 9) and the minimum YMPR distance (column 3). The fault-slip type (column 8) was included in the calculations as well as a scaling factor for multiple faults. See text for explanation.

Table 3.10-20b. The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 Km of CAB That Have Not Been Selected as Credible Independent Sources by at Least One PSHA Expert Team.

NOTE: km, kilometers; deg, degrees; Mw, moment magnitude units; g, horizontal spectral accelertation as percentage of gravity. All sources are candidate Type I faults. A seismogenic depth of 15 km is assumed for all faults widths.

Fault Name and Abbreviation *(Combined Faults)*[a]	Minimum Distance to CAB[b] (km)	Minimum Distance to YMPR[c] (km)	Potential Type I Fault[d]	Documented Quaternary Displacement[e]	Fault Length[f] (km)	Fault Dip[g] (deg)	Fault-slip Type[h]	Mean Maximum Magnitude[i] (Mw)	Horizontal Spectral Acceleration[j] (g)			
									Frequency - 1 Hz		Frequency - 10 Hz	
									Median	84th Fractile	Median	84th Fractile
Boomerang Point (BP)	0	2.5	Yes?	No?	5	60	N, F	6.0	0.17	0.37	0.61	1.16
Drill Hole Wash (DHW)	0	1.5	Yes?	No?	4	80	S	5.8	0.15	0.33	0.55	1.06
Pagany Wash (PW)	0	2.5	Yes?	No?	4	80	S	5.8	0.14	0.31	0.53	1.01
Sever Wash (SW)	0	3	Yes?	No?	4	80	S	5.8	0.16	0.38	0.63	1.33
Simonds Number 1	3	7	Yes?	No?	3	60	N, H	5.7	0.08	0.18	0.34	0.66
Simonds Number 2	2	6	Yes?	No?	3	60	N, H	5.7	0.09	0.20	0.37	0.72
Simonds Number 3	1	5	Yes?	No?	5	60	N, H	5.95	0.15	0.32	0.52	0.98
Simonds Number 4	1	5	Yes?	No?	5	60	N, H	5.95	0.14	0.30	0.50	0.95
Simonds Number 5	1	5	Yes?	No?	5	60	N, H	5.95	0.14	0.30	0.50	0.95
Simonds Number 7	4	9	Yes?	No?	5	60	N, F	5.95	0.08	0.17	0.26	0.49
Simonds Number 8	4	9	Yes?	No?	8	60	N, F	6.15	0.10	0.21	0.30	0.56
Simonds Number 9	5	10	Yes?	No?	7	60	N, F	6.1	0.08	0.18	0.26	0.49
Simonds Number 12	2	6	Yes?	No?	10	60	N, F	6.25	0.15	0.32	0.48	0.90
Simonds Number 14	0	4	Yes?	No?	5	60	N, H	6.0	0.15	0.34	0.56	1.06
Simonds Number 15 (East Ridge-EAR)	0	2	Yes?	No?	5	60	N, H	6.0	0.18	0.38	0.62	1.18
Simonds Number 16	1	7	Yes?	No?	4	60	N, H	5.9	0.11	0.24	0.40	0.77
Simonds Number 18	6	13	Yes?	No?	3	60	N, F	5.7	0.04	0.09	0.15	0.29

Table 3.10-20b. The Deterministic Maximum Magnitudes, Spectral Acceleration Ordinates, and Key Characteristics of Potential Type I Faults Within 5 Km of CAB That Have Not Been Selected as Credible Independent Sources by at Least One PSHA Expert Team. (continued)

a. Fault names and abbreviations are listed following nomenclature of Piety (1996) and Pezzopane (1996). Faults located within 5 km of the CAB of the site (see column 2 and footnote b) that have been selected as a credible source by at least one PSHA expert team are listed alphabetically. Individual faults that are combined together into one earthquake source are italicized; this includes, but is not limited to, the combined faults near the site with distributed ruptures.

b. Minimum Distance to CAB refers to the shortest distance from a point on the surface trace of the fault to the controlled area boundary at Yucca Mountain, consistent with guidance in NUREG-1451 (NRC 1992). The controlled area boundary stretches outward approximately 5 to 7 km from the potential repository outline. Thus, most faults are from 7 to 9 km farther from the center of the potential repository (approximately lat. 36.85°N. and lon. 116.45°W.) than the minimum distance indicates. See footnote c, below.

c. Minimum Distance to YMPR refers to the shortest distance from a point on the surface trace of the fault to the center of the Yucca Mountain potential repository (approximately lat. 36.85°N. and lon. 116.45°W.).

d. This column indicates whether a candidate Type I fault meets the criteria for a potential Type I fault relevant to vibratory ground motion hazard based on the criteria presented in NUREG-1451[2] (NRC 1992). Potential Type I faults indicated with "Yes" are those with documented Quaternary activity (Yes in column 5 of this table) and the potential to generate average 84th-percentile peak accelerations that equal or exceed 10 percent of gravity (0.1 g) at the controlled area boundary of the Yucca Mountain site. Potential Type I faults with a "Yes?" are those with questionable or indeterminate documentation of Quaternary activity (No? in column 5 of this table) and the capability to produce at least 0.1 g peak acceleration at the 84th-percentile level.

e. Documented Quaternary Displacement designates the status of evidence for Quaternary fault activity with two alternatives: Yes and No?, depending upon whether there are published studies that document Quaternary displacement or other compelling evidence for Quaternary displacement potential, such as associated seismicity or field studies. This is the primary criterion for classifying candidate and potential Type I faults. Faults with a "Yes" are those for which there is demonstrated Quaternary displacement. Faults with a "No?" are those which lack evidence of Quaternary displacement or for which the data are inconclusive.

f. Maximum Fault Length is the length of the fault zone (in km) as reported in published references or as estimated from maps and plates in cited references (Simonds et al. 1995; Scott, R.B. and Bonk 1984; Piety 1996). The maximum length represents the entire length of the mapped or inferred fault zone including sections portrayed as concealed or discontinuous or both. Values in parentheses indicate the probable length of late Quaternary rupture where it can be estimated from either paleoseismic data in trenches or, more commonly, by the extent of Quaternary fault scarps developed along the fault trace. The maximum length was used for M_w calculations. Lengths for combined faults are measured along the single longest combination of faults in the system, based on the assumption that the individual faults are joined in a compound rupture of the entire zone.

g. The preferred dips for faults assigned generally for various types of faults based on regional seismic and geophysical data.

h. This column indicates the slip type of the fault source entered into the ground motion attenuation equations developed by the ground motion experts for the PSHA (USGS 1998) (see footnote j and text). These equations differentiate between strike-slip and normal-slip faults, and subdivide the latter into whether the site is located on the hanging wall or footwall of the fault. Symbols are N - Normal-slip; S - Strike-slip; H - Hanging-wall; F - Footwall.

i. This column contains the deterministic mean M_w assigned to each fault in Table 2. It is the mean of a suite of M_w values calculated from fault length, displacement per event, seismic moment, and rupture area data.

j. This set of columns contains the specific horizontal spectral acceleration ordinates calculated for site location using the mean of the attenuation relations developed for rock sites specifically for the Yucca Mountain area by the ground motion experts for the PSHA (USGS 1998). The median (50th) and 84th fractiles of spectral values are given at two frequencies (1 Hz and 10 Hz) for each source using the deterministic maximum magnitude (column 9) and the minimum YMPR distance (column 3). The fault-slip type (column 8) was included in the calculations as well as a scaling factor for multiple faults. See text for explanation.

Table 3.11-1a. Natural Resources Assessment Summary (Metallic Minerals)

Metallic Mineral	**Highest Concentration in a Sample from the Yucca Mountain Area**			**Present Day (1996) Economically Mineable Concentration/Depth**	**Potential to be Economically Mineable at Yucca Mountain Site**
	pounds or ounce per short ton/ value per short ton*	*depth and location of sample*	*sample number*	*pounds or ounce* per short ton/ value per short ton*	
Antimony	0.095/$0.10	2704.2-2704.6 feet below surface. (Core sample from drillhole USW-G2)	G2/2704.2	(a)	
Bismuth	0.390/$1.40	Underground at Yucca Mountain	SPC00509204	(a)	
Copper	0.372/$0.39	3700.1-3700.3 feet below surface. (Core sample from drillhole USW-G3)	G3/3700.1	(a)	
Gold	0.0051*/$1.88	4856.7-4857.3 feet below surface. (Core sample from drillhole UE-25 p#1)	p1/4856.7	0.02*/$7.40 (for open pit mining)	
Lead	0.802/$0.39	Underground at Yucca Mountain	SPC00509201	(a)	
Mercury	0.003/$0.01	4856.7-4857.3 feet below surface. (Core sample from drillhole UE-25 p#1)	p1/4856.7	(a)	
Molybdenum	0.130/$0.58	4856.7-4857.3 feet below surface. (Core sample from drillhole UE-25 p#1)	p1/4856.7	(a)	
Selenium	0.033/$0.11	3700.1-3700.3 feet below surface. (Core sample from drillhole USW-G3)	G3/3700.1	(a)	
Silver	0.118*/$0.57	255-255.2 feet below surface. (Core sample from drillhole USW-SD9)	SD9/255.0	2.0 (a)	
Tin	61.834/$241.15	Float sample at Yucca Mountain	YMR 0366		
Zinc	2.200/$1.17	417.7-418.0 feet below surface. (Core sample from drillhole USW-GU3)	GU3/417.7	(a)	
Uranium				T	The potential for deposits of uranium resources is considered to be very low in the YMCCA. Uranium contents are mostly at background levels in rocks of the YMCCA.

(a) Within the Yucca Mountain are the cumulative value of all these commodities would still be less than the lowest economically mineable value for gold alone.

Table 3.11-1b. Natural Resources Assessment Summary (Industrial Minerals)

Mineral	Present/Past Production in Yucca Mountain Region	Potential at Yucca Mountain
Barite	none	Very minor amounts identified in deep borings. Potential is considered to be very low.
Borate	present	No occurrence known in the area and geologic setting is absent for borate formation. Potential is considered to be very low.
Building stone	present	Large amount of potential ornamental building stone present, however, the region contains similar material. Potential is considered to be low to moderate.
Clay	present	Significant amounts of smectite present in subsurface but do not have commercial value because of depth. Potential is considered to be low to moderate. The clay is also scattered throughout the rock mass, it is not concentrated as clay deposits.
Construction aggregate (sand and gravel)	present	Large amounts of sand and gravel and rock that may be suitable for crushed stone are present but since the transportation distance to a market is so great, the potential for development is considered to be low.
Dolomite	undeveloped resource *	Only found in a single drill hole at depth (about 1,200 m). Potential is very low.
Fluorspar	past	Not a significant resource or present at depth below the dolomite. Potential is considered to be low.
Limestone	undeveloped resource *	Not present in the controlled area. Potential is very low.
Perlite	undeveloped resource *	Potential units are thin or occur at depth. Potential is considered to be low.
Pumice and pumicite	past	Potential beds are thin and potential is considered to be low.
Silica	past	Not pure enough or not present in large enough quantities. Potential is considered to be very low.
Talc	present	Not known to occur in the area and geologic setting is absent except at great depths. Potential is considered to be very low.
Zeolite	present	The estimated large resource of clinoptilolite and mordenite in the subsurface is not considered to have economic potential because of the amount of overburden. Potential is considered to be low.

* The Mineral has been identified in the region but no production has been recorded.

Table 3.11-1c. Natural Resources Assessment Summary (Hydrocarbons)

Oil and Gas	Present in Southern Great Basin		Present in Yucca Mountain Area	Potential at Yucca Mountain Area
	Proven	*Potential*		
Source Rock	Chainman Shale and Sheep Pass Formation	Pilot Shale, Elko Formation, Kanosh Shale, Vinini Formation, Woodruff Formation, Webb Formation, Newark Canyon Formation.	None proven, scare potential. Roberts Mountain Formation, Eleana Formation and Chainman Shale were once source rocks and various Tertiary rocks have indications of source potential.	No significant volumes of oil or gas have been found in southern Nevada or adjacent California and Arizona. There are no proven source rocks in the region.
Oil and Gas	**Present in Southern Great Basin**		**Present in Yucca Mountain Area**	**Potential at Yucca Mountain Area**
	Proven	*Potential*	*Potential*	
Reservoir Rock	Sidehill Springs Formation, Telegraph Canyon Formation, Simonson Dolomite, Guilmette Formation, Joana Limestone, Dale canyon Formation, Chainman Shale-Diamond Peak Formation, Sheep Pass Formation, Garrett Ranch Group, Salt Lake Group, Neogene debris slides.	Indian Well Formation.	Paleozoic carbonate rocks (Bonanza King Formation, Antelope Valley limestone, and Devils Gate limestone), early Tertiary limestone, middle Tertiary ash-flow tuffs (Bullfrog Tuff), late Tertiary debris slides and basalt.	Reservoir rocks of the Yucca Mountain area compare favorably with those of the producing areas of the region.
Oil and Gas	**Present in Southern Great Basin**		**Present in Yucca Mountain Area**	**Potential at Yucca Mountain Area**
	Proven		*Potential*	
Seals	The unconformity at the base of valley fill of Railroad Valley, unconformity at the base of the Tertiary strata. Also, the Currant Tuff of the Garrett Ranch Group, impervious beds in the Salt Lake Group, the Humboldt Formation, the Indian Well Formation, and the Chainman Shale.		The unconformity at the base of the Tertiary section, bedded tuffs within the sequence of ash-flow tuffs.	Because production has not been established in the southern Great Basin, the identification of sealing elements within the stratigraphy is problematical. One of the important seals in the region, the unconformity at the base of valley fill, is not well developed in the Yucca Mountain area. Valley fill, although not identical to the seal, is present in Crater Flat but not above the repository site.
Oil and Gas	**Present in Southern Great Basin**		**Present in Yucca Mountain Area**	**Potential at Yucca Mountain Area**
	Proven	*Unproven*	*Potential*	
Trap	Every commercial accumulation known in the region can be classified as a Basin-Range trap in a basin setting. Fault seals are also noted.	Range traps and Mesozoic-age fold trap.	Thrust-fold traps of Mesozoic age (no production in the Great Basin has been established from a trap of this type), fault-block Basin-Range traps (they are in a different structural setting compared to the productive traps in the Great Basin)	Fault-block traps similar to those that produce elsewhere in the Great Basin are present at Yucca Mountain.
	Present in Southern Great Basin		**Present in Yucca Mountain Area**	**Potential at Yucca Mountain Area**
Tar sands	There are no known tar sands in the southern Great Basin of Nevada		It is extremely unlikely that tar sands are concealed at depth below Yucca Mountain but not exposed in rocks of the surrounding area.	In the unlikely event that tar sands of some richness do occur under Yucca Mountain, the minimum depth to such rocks is 1,200 m (in the Paleozoic marine rocks) which is uneconomical for extraction.
Oil shale	Only Mississippian rocks have a depositional environment compatible with oil shales.		Mississippian rocks may or may not be present at depth at Yucca Mountain.	In the unlikely event that oil shales of some richness do occur under Yucca Mountain, the minimum depth to such rocks is 1,200 m which is uneconomical for extraction.
Coal	There are no commercial deposits of coal in Nevada.		There are no reports of coal from Southern Nevada in the vicinity of Yucca Mountain.	In the unlikely event that coal of some richness do occur under Yucca Mountain, the minimum depth to such rocks is 1,200 m (base of the Tertiary) which is uneconomical for extraction.

NOTE: The basic elements of a viable petroleum system, generation site, reservoir rocks, trap geometry, and seals are present in the Yucca Mountain area with variations. Most of the variations have negative implications for the accumulation of hydrocarbons at the repository site.

Table 3.11-1d. Natural Resources Assessment Summary (Geothermal)

Characteristic	Yucca Mountain Area
Geological Data	The volcanic extrusive rocks at Yucca Mountain are not a heat source.
Late Tertiary or Quaternary volcanism	Small volume, isolated
Geysers, fumaroles, mud volcanoes, thermal springs	None nearby
Subsurface temperature gradients in deep wells that are two times normal	Low, below average
Heat source	None nearby
Other Geologic Indicators	
Siliceous sinter	None present
Geochemical Data	Most waters are non-thermal in origin
Elevated silica content of spring water	Non-thermal
Na/K anomaly (Na/K ratio in spring water)	None present
Geophysical Data	Gravity, magnetics, seismic and heat flow data failed to delineate any systematic structural evidence for a thermal anomaly.
Geophysical anomalies (Electrical, magnetic, gravity, airborne infrared, and other geophysical surveys)	None commonly associated with thermal resources
Heat flow (abnormally high heat flow)	Low, below average
Hydrological Data	Thermal fluids, where they exist, are restricted to faults, fractures, breccia zones, and the deep Paleozoic carbonate aquifers
Porosity and permeability of reservoir rocks	Deep carbonate aquifer
Other Items Considered	
Nearby discoveries and commercial developments	None above 50°C within 100 km
Competitive interests	None nearby

NOTE: No economically viable geothermal resources were identified within the Yucca Mountain area. Within 50 miles of Yucca Mountain, some recreational uses may be considered economic.

Table 3.11-2. Surface and Underground Samples Collected From the YMCCA and Surrounding Areas and Mining Districts

Area or District	Number and Type of Samples
YMCCA and immediate vicinity	374 surface samples 17 underground samples (ESF)
Calico Hills District	49 surface samples
Wahmonie District	14 surface samples
Mine Mountain District	20 surface samples
Bare Mountain District	14 underground mine samples 26 surface samples 3 drill cuttings samples
Bullfrog District	37 surface samples 235 drill samples
Northern Yucca Mountain	16 surface samples

NOTE: See Figure 3.11-2 for Mine Area or District location.

Table 3.11-3. Maximum Contents, Prices, and Values for Metallic Commodities in the YMCCA Metal Prices are 1996 Year-End Values from the Journal Metals Week

Metal	Sample	Highest YMCCA Content (ppm)	lb. or oz.* per short ton	Price ($/lb. or $/oz.*)	Gross Value ($ per short ton)
Antimony	G2/2704.2	47.4	0.095	1.10	0.10
Bismuth	SPC00509204	195	0.390	3.60	1.40
Copper	G3/3700.1	186	0.372	1.06	0.39
Gold	p1/4856.7	0.175	0.0051*	368.75*	1.88
Lead	SPC00509201	401	0.802	0.49	0.39
Mercury	p1/4856.7	1.3	0.003	2.24	0.01
Molybdenum	p1/4856.7	64.9	0.130	4.50	0.58
Selenium	G3/3700.1	16.5	0.033	3.25	0.11
Silver	SD9/255.0	4.03	0.118*	4.82*	0.57
Tin	YMR 0366	30917	61.834	3.90	241.15
Zinc	GU3/417.7	1100	2.200	0.53	1.17

Table 3.11-4. Summary of Geophysical Techniques Used to Characterize the YMCCA and Surrounding Region

Methods	Survey Type	Area of Coverage
Magnetic	aeromagnetic	regional scale area scale
	detailed studies physical properties	geophysical logs magnetic susceptibility magnetic field core samples magnetic properties paleomagnetic directions
	aeromagnetic	site area
	ground traverses	geologic features
Gravity	aerogravity	state scale 1:750,000
	Bouguer anomaly	regional scale 1:1,000,000
		1:2,500,000
		1:100,000
	physical properties	borehole logging core samples
Seismic	seismic refraction	regional scale
	seismic reflection	site region site structures
	teleseismic tomography	site region
Electrical and Electromagnetic	magneto telluric	site region
	electrical resistivity and controlled-source electromagnetic	site 2 YMCCA
Natural radioactivity	aerial gamma-ray	regional
Borehole geophysics	general suite	borehole

Table 3.11-5. Surface Samples from the YMCCA and Vicinity with 4 ppb or Higher Gold (analyses by USML) or 100 ppb or Higher Mercury (analyses by NBMG) or Both

Sample	Rock Type	Au (ppb)	Au (ppb)*	Hg (ppb)	As (ppm)
YMR 0015	calcrete vein	5		90	11.0
YMR 0212	calcrete vein	7	7	93	7.83
YMR 0254	calcrete-cemented breccia	0.4		108	30.4
YMR 0273	calcrete-cemented breccia	1		111	4.13
YMR 0309	calcrete vein	6	9	48	8.63
YMR 0352	bedded calcrete + opal	4		95	13.6
YMR 0395	bedded calcrete	6	8	218	6.90
YMR 0415	bedded calcrete + opal	3		156	8.36
YMR 0444	bedded(?) calcrete	5		18	13.8
YMR 0447	calcrete + opal	2		195	3.82
YMR 0450	calcrete + opal vein	1		153	11.5
YMR 0461	calcrete-cemented breccia	1		143	5.28
YMR 0477	bedded calcrete	6	8	177	6.54
YMR 0715	bedded(?) calcrete	5		21	10.1
YMR 0725	calcrete-cemented breccia	4		14	10.1
YMR 0727	calcrete-cemented breccia	4		94	12.4
YMR 0207	silicified breccia	1		127	1.60
YMR 0810	silicified breccia	1		186	1.86
YMR 0811	silicified breccia	1		139	1.56
YMR 0319	fault gouge	11	12	159	3.26

NOTE: Replicate gold analyses are denoted by an asterisk. Arsenic analyses (by USML) are also shown.

Table 3.11-6. Selected Trace Element Contents for Samples Near or Below the Tertiary-pre-Tertiary Contact in Borehole UE-25 p 1.; All Analyses by USML, except Ba by ACTLABS and F by NBMG

Sample	Rock Type	Ag ppm	As ppm	Au ppb
UE-25 p#1/3920.8	bedded tuff, calcitized with pyrite	0.06	1.9	0.0
UE-25 p#1/3922.3	light gray , sheared, calcitized tuff with pyrite	0.06	51.6	0.0
UE-25 p#1/4192.0	vuggy dolomite with abundant tool metal	0.22	16.1	0.8
UE-25 p#1/4208.1	dolomite "puzzle breccia"	0.16	5.1	0.7
UE-25 p#1/4364.2	dolomitic limestone with pyrite styolites	1.12	81.5	6.0
UE-25 p#1/4384.1	brecciated dolomite with pyrite	0.52	38.0	2.0
UE-25 p#1/4822.0	brecciated dolomite with pyrite	0.68	133.0	42.0
UE-25 p#1/4856.7	brecciated dolomite with pyrite styolite	2.26	378.0	142.0
UE-25 p#1/5906.0	dark gray dolomitic siltstone with pyrite	0.06	8.7	0.0
UE-25 p#1Ue-25 P#1/3980	mostly ash-flow tuff, some carbonate with pyrite	0.05	12.7	0.5
UE-25 p#1/4050	tuff, carbonate, and bluish-gray pyritic rock	0.10	45.2	0.6
UE-25 p#1/4150	carbonate, bluish-gray pyritic rock, minor tuff	0.20	72.2	4.0
UE-25 p#1/5300	gray carbonate, trace calcite vein chips	0.11	7.8	0.5
UE-25 p#1/5540	carbonate, minor pyrite	0.07	5.1	0.4
UE-25 p#1/5600	carbonate, pyrite	0.04	2.5	0.8
UE-25 p#1/5750	carbonate, vein carbonate	0.04	2.7	0.0

Sample	Ba ppm	F %	Hg ppm	Mo ppm	Pb ppm	Sb ppm	Se ppm	Tl ppm	Zn ppm
UE-25 p#1/3920.8	2600	0.15	0.16	0.1	11.4	0.26	0.32	0.46	31.9
UE-25 p#1/3922.3	1800	0.18	0.28	7.4	21.3	1.04	0.13	0.56	76.8
UE-25 p#1/4192.0	98	<0.05	0.10	1.9	122.0	1.09	0.18	0.50	179.0
UE-25 p#1/4208.1	<50	0.07	0.06	0.3	2.2	0.78	0.32	0.37	58.7
UE-25 p#1/4364.2	66	<0.05	0.24	9.3	38.6	9.43	2.49	0.47	236.0
UE-25 p#1/4384.1	67	0.06	0.08	5.1	10.1	3.64	0.82	0.47	54.3
UE-25 p#1/4822.0	<50	<0.05	0.32	5.2	6.0	6.26	1.27	1.43	121.0
UE-25 p#1/4856.7	<50	<0.05	1.06	64.9	19.3	21.30	3.59	4.00	280.0
UE-25 p#1/5906.0	<50	<0.05	0.09	6.0	6.7	1.83	0.64	0.74	16.0
UE-25 p#1/3980	630	0.14	0.08	2.3	31.6	2.06	0.41	0.11	95.3
UE-25 p#1/4050	480	0.25	0.12	2.6	13.4	1.50	0.47	0.34	36.5
UE-25 p#1/4150	200	0.24	0.16	2.7	8.4	1.63	0.40	0.47	49.8
UE-25 p#1/5300	<50	0.06	0.05	6.9	1.6	0.89	0.19	0.09	8.3
UE-25 p#1/5540	<50	0.06	0.09	32.1	64.9	2.08	0.51	0.16	18.3
UE-25 p#1/5600	<50	<0.05	0.06	6.6	8.9	0.60	0.55	0.16	7.6
UE-25 p#1/5750	<50	0.08	0.06	3.5	6.8	0.68	0.29	0.04	5.4

Table 3.11-7. Geothermal Indications in the Yucca Mountain Area

Characteristic	Yucca Mountain Area
Na/K anomaly	None present
Geothermal discoveries	None nearby
Siliceous sinter	None present
Temperature gradient heat flow	Low, below average
High silica water	
Recent volcanism	Small volume, isolated
Geophysical anomalies	Non-thermal
Geysers, fumaroles, and hot springs	None nearby

INTENTIONALLY LEFT BLANK

FIGURES

		Page
3.1-1	Contour Plot of Bouguer Gravity Data	F3.1-1
3.1-2	Contour Plot of Aeromagnetic Data	F3.1-2
3.2-1	Regional Tectonic Domains for Yucca Mountain and Surrounding Environs, Sections of the Walker Lane are Also Shown	F3.2-1
3.2-2	Geologic Setting of Yucca Mountain	F3.2-2
3.2-3	Distribution of Surface Exposures of Precambrian Rocks in the Yucca Mountain Geologic Setting	F3.2-3
3.2-4	Distribution of Surface Exposures of Cambro-Ordovician Rocks in the Yucca Mountain Geologic Setting	F3.2-4
3.2-5	Distribution of Surface Exposures of Siluro-Devonian Rocks in the Yucca Mountain Geologic Setting	F3.2-5
3.2-6	Distribution of Surface Exposures of Carboniferous and Permian Rocks in the Yucca Mountain Geologic Setting	F3.2-6
3.2-7	Distribution of Surface Exposures of Mesozoic Rocks (Igneous and Sedimentary) in the Yucca Mountain Geologic Setting	F3.2-7
3.2-8	Distribution of Surface Exposures of Tertiary Sedimentary Rocks in the Yucca Mountain Geologic Setting	F3.2-8
3.2-9	General Extent of the Southwestern Nevada Volcanic Field (dotted boundary) and Coeval Igneous Rocks of the Inyo-Mono Domain (shown by brown shading)	F3.2-9
3.2-10	General Distribution of the Monotony Tuff	F3.2-10
3.2-11	General Distribution of Surface Exposures of the Wahmonie and Salyer Formations	F3.2-11
3.2-12	Late Neogene and Pleistocene Features at and Near Yucca Mountain	F3.2-12
3.2-13	Pleistocene Depositional Basins and Drainage Features	F3.2-13
3.2-14	Generalized Location of Antler Orogenic Features	F3.2-14
3.2-15	Structures of the Central Nevada and Sevier Thrusts Zones	F3.2-15
3.2-16	Schematic Cross-Section Showing Kinematic Relationships Among Thrusts	F3.2-16
3.2-17	Correlative Thrusts of the Yucca Mountain Setting	F3.2-17
3.2-18	Region Expressed by Sedimentary Rocks Grouped by Systems	F3.2-18
3.2-19	Broad Folds of the Yucca Mountain Region	F3.2-19
3.2-20	Funeral Mountains Detachment	F3.2-20
3.2-21	Bullfrog Hills Detachment	F3.2-21
3.2-22	Las Vegas Valley Shear Zone	F3.2-23
3.2-23	Major Faults of the Death Valley Extended Area Inyo-Mono Domain	F3.2-24
3.2-24	General Geology of the Rock Valley Fault Zone	F3.2-25
3.2-25	Spotted Range-Mine Mountain Structural Zone of Carr, W.J. (1984) Depicted by Northeast-Trending Shaded Borders	F3.2-26
3.2-26	Interpretation of Seismic Reflection Profile Across Rock Valley	F3.2-27

FIGURES (Continued)

		Page
3.3-1	The Crater Flat Basin and Its Inferred Bounding Structures	F3.3-1
3.3-2	Coaxial Fault Sets of Yucca Mountain and Pahute Mesa Separated by Caldera Complex	F3.3-2
3.3-3	Least Principal Compressive Stress (σ_3) Values, Shown by Black Dots, Measured from Boreholes USW-G1 and USW-G2 at Yucca Mountain	F3.3-3
3.3-4	Stress Versus Depth Models	F3.3-4
3.3-5	Eastern Border of Walker Lane (heavy dashed line) (passes through Yucca Mountain as interpreted by Minor, Hudson et al. 1997, Figure 1)	F3.3-5
3.3-6	The Amargosa Desert Fault System (zone of dextral simple shear)	F3.3-6
3.3-7	Size and Extent of Inferred Calderas Beneath Crater Flat and Yucca Mountain	F3.3-7
3.3-8	Cross Sections of Yucca Mountain Showing Inferred Shallow Detachment Fault	F3.3-9
3.3-9	Conceptual Cross-Section Showing Inferred Levels of Detachment Beneath Yucca Mountain	F3.3-11
3.3-10	Detachment Structures Inferred Near Yucca Mountain	F3.3-12
3.3-11	Model of Crustal Extension from Death Valley to Yucca Mountain	F3.3-13
3.3-12	Conceptual Cross-Section from Bare Mountain to Jackass Flats Showing Interpretation of Yucca Mountain Vicinity as a Half-Graben Model.	F3.3-14
3.4-1	Generalized Map Showing Approximate Locations of the Physiographic Subdivisions of the West-Central and Southern Great Basin	F3.4-1
3.4-2	Physiographic Subdivisions of the Yucca Mountain Area	F3.4-2
3.4-3	Map of the Yucca Mountain Region Showing Trench Locations and Local Place Names	F3.4-3
3.4-4	Photograph of the South Wall of Trench 14 Showing Pedogenically Derived Calcite and Opaline Silica Veins	F3.4-4
3.4-5	The Isotopic Composition of Oxygen and Carbon in Pedogenic Carbonate as a Function of Elevation	F3.4-5
3.4-6	Isotopic Composition of Oxygen and Carbon	F3.4-6
3.4-7	Graph Showing the Isotopic Composition of Oxygen in Water and Calcite Crystallized in Equilibrium with Water as a Function of Temperature	F3.4-7
3.4-8	Graph Showing the Variation of Oxygen Isotopic Composition of Calcite at Devils Hole	F3.4-8
3.4-9	Map Showing the Isotopic Composition of Strontium (in δ^{87}Sr Units) in the Tertiary Aquifer	F3.4-9
3.4-10	Variation in the Isotopic Composition of Strontium in Calcite from Devils Hole as a Function of Time	F3.4-10

FIGURES (Continued)

		Page
3.4-11	Histogram showing the Isotopic Composition of Uranium in Water and Carbonates from Trench 14 and Busted Butte	F3.4-11
3.4-12	Variation in the Isotopic Composition of Uranium in Calcite from Devils Hole as a Function of Time	F3.4-12
3.4-13	Age Ranges of Quaternary Stratigraphic Units in the Yucca Mountain Area Compared to Regional Climatic Records	F3.4-13
3.4-14	Cation-ratio Rock Varnish Calibration Curve for the Yucca Mountain Region	F3.4-14
3.4-15	Recalibrated Cation-Ratio Rock Varnish Curve for Yucca Mountain Using Younger Ages for the Calibration Sites	F3.4-15
3.4-16	Genealized Cross Section of the Evolution of Fortymile Wash	F3.4-16
3.5-1	Principal Stratigraphic Units at Yucca Mountain	F3.5-1
3.5-2	Simplified Geologic Map Showing Distribution of Major Lithostratigraphic Units	F3.5-2
3.5-3	East-West Correlation of Stratigraphic Units, Based on Borehole Studies	F3.5-3
3.5-4	North-South Correlation of Stratigraphic Units	F3.5-4
3.5-5	Locations of Boreholes (Dots) and Measure Surface Sections (Triangles) at Yucca Mountain	F3.5-5
3.5-6	Photomicrographs of Vitric Nonwelded and Densely Welded Rocks in the Crystal-Poor Member of the Tiva Canyon Tuff	F3.5-6
3.5-7A,B	Photomicrographs of Crystallization Textures of Moderately to Densely Welded Tuff in the Lower Lithophysal and Middle Non-lithophysal Zones of the Crystal-Poor Tiva Canyon Tuff	F3.5-7
3.5-7C	Shows Crystallized, Densely Welded Tuff from the Lower Lithophysal Zone of the Topopah Spring Tuff	F3.5-8
3.5-8	Crystallization Features of Lithophysae, Spots, Veinlets, and Streaks	F3.5-9
3.5-9	Photomicrographs of Nonwelded Shards That Are Variously Altered to Clinoptilolite	F3.5-10
3.5-10	Development of Detailed Lithostratigraphic Units from Overlapping Relations of Depositional Features and the Zones of Welding and Crystallization	F3.5-11
3.5-11	Twenty-Three Rock Types That Comprise Yucca Mountain	F3.5-12
3.5-12	Graph Showing Concentrations of Titanium (Ti) and Zirconium (Zr) as a Function of Depth for Core Samples from Borehole G-1 (Zr data from Spengler and Peterman 1991; Ti data unpublished)	F3.5-13
3.5-13	Graph Showing Concentrations of Titanium (Ti) and Zirconium (Zr) as a Function of Depth for Core Samples from Borehole A#1 (from Peterman, Spengler et al. 1993)	F3.5-14
3.5-14	Graph Showing Strontium Concentration as a Function of Depth for Core Samples of Topopah Spring Tuff from Borehole A#1	F3.5-15

FIGURES (Continued)

Page

3.5-15 Graph Showing Concentrations of Titanium (Ti), Zirconium (Zr), and Barium (Ba) as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 ..... F3.5-16
3.5-16 Graph Showing Concentrations of Rubidium (Rb) and Niobium (Nb) as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 ..... F3.5-17
3.5-17 Graph Showing Abundances of a Suite of Elements Relative to the Abundances in the Average Crystal-poor Member of the Tiva Canyon Tuff (Tpcp) from Borehole NRG#3 ..... F3.5-18
3.5-18 Graph Showing the Measured (T = 0) and Initial (T = 12.7 Ma) $^{87}Sr/^{86}Sr$ Ratios as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 ..... F3.5-19
3.5-19 Geophysical Logs of Borehole G3/GU3 Showing Responses to Lithologic Features in the Topopah Spring Tuff and Older Formations F3.5-21
3.5-20 Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantative Mineralogy in Borehole UZ#16 ..... F3.5-23
3.5-21 Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantitative Mineralogy in Borehole WT-2 ..... F3.5-24
3.5-22 Rock Type Effects on Geophysical Logs F3.5-25
3.5-23 Bulk Density and Porosity Plotted Relative to Depth for the Composite Paintbrush Tuff Nonwelded Hydrogeologic Unit in Boreholes UZ-N33, UZ-14, UZ-N32, and UZ#16 ..... F3.5-26
3.5-24 Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantitative Minerology from the Paintbrush Tuff Nonwelded Hydrogeologic Unit Borehole UZ#16 and WT-2 ..... F3.5-27
3.5-25 Lithostratigraphic Units and Thermal Mechanical Properties Plotted Versus Depth in Borehole NRG-6 ..... F3.5-28

3.6-1 Index Map Showing Areas Where Miocene Volcanic Bedrock Is Exposed (In Gray), Along With Place Names in the Yucca Mountain Site Area, as Used in this Report F3.6-1
3.6-2 Index Map Showing Areas Where Miocene Volcanic Bedrock Is Exposed (In Gray), Conceptual Controlled Area Boundary, and Areas of Coverage of the Geologic Maps and by Scott, R.B. and Bonk (1984) and Day et al. (1998a) F3.6-2
3.6-3 Map Showing Block-Bounding Faults and Important Intrablock Faults in the Site Area F3.6-3
3.6-4 Simplified Version of Central Block Geologic Map F3.6-5
3.6-5 Map Showing Structural Domains in the Site Area, Superimposed on the Positions of Block-Bounding Faults and Important Intrablock Faults F3.6-7

FIGURES (Continued)

		Page
3.6-6	Simplified Version of Cross-Section B-B' from the Central Block Geologic Map	F3.6-8
3.6-7	Simplified Version of Central Block Geologic Map, with the Exploratory Studies Facility Plotted	F3.6-9
3.6-8	Large-Scale Detail Map of "Step-Over" in the Surface Trace of the Ghost Dance Fault on the North-Facing Slope of Antler Ridge	F3.6-10
3.6-9	Representative Detail of the Relatively Undeformed Yucca Crest Sub-Block in the Central Block, at 1:9,000-Scale (1"=750 ft)	F3.6-11
3.6-10	Large-Scale Detailed Geologic Map of Discontinuous Surface Traces of Minor Faults on the South-Facing Slope of Antler Ridge (East of the Ghost Dance Fault) near Coordinates 762,500 N., 563,350 E.	F3.6-13
3.6-11	Representative Detail of the Boundary Ridge Sub-Block in the Central Block, at 1:9,000-scale (1"=750 ft)	F3.6-15
3.6-12	Index Map Showing the Location of Geophysical Surveys in the Site Area	F3.6-17
3.6-13	Geophysical and Geologic Data along YMP-3	F3.6-18
3.6-14	Map of the Central Part of Yucca Mountain, Nevada, Showing Fracture Study Areas	F3.6-19
3.6-15	Comparison of Fracture Spacing from Surface, Exploratory Studies Facility, and Borehole Data	F3.6-20
3.6-16	Correlation of Fracture Network Properties to Degree of Welding, Paintbrush Group	F3.6-21
3.6-17a	Fracture Frequency as Measured in the Exploratory Studies Facility–North Ramp and Northern Portion of the Main Drift	F3.6-22
3.6-17b	Fracture Frequency as Measured in the Exploratory Studies Facility–Souther Portion of the Main Drift and Western Portion of the South Ramp	F3.6-23
3.6-18	Strike Distributions for Surface Fracture Study Areas and Exploratory Studies Facility Photogrammetry	F3.6-24
3.6-19	Diagram Illustrating the Hierarchy of Scales of Observation Used in the Series of Block Diagrams That Illustrate the Descriptive Structural Model	F3.6-25
3.6-20	Block Diagram Illustrating Geometry of Principal Structural Elements at the Scale of Yucca Mountain (10 km Width of Block)	F3.6-26
3.6-21a	Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Northern Yucca Mountain Versus Southern Yucca Mountain (4 km Width of Block) A: Northern Area	F3.6-27
3.6-21b	Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Northern Yucca Mountain Versus Southern Yucca Mountain (4 km Width of Block) B: Southern Area	F3.6-28
3.6-22a	Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Two Subdomains of the Central Block (400m Width of Block)	F3.6-29

FIGURES (Continued)

Page

3.6-22b Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Two Subdomains of the Central Block (400m Width of Block) F3.6-30
3.6-23 (A,B,C) Block Diagrams Illustrating the Variation in the Geometry of Principal Structural Elements in the Fracture Network at Different Stratigraphic Levels in the Paintbrush Group (10-50m Width of Block) F3.6-31
3.6-24 Representation of the relative Dependence on Local Stratigraphic Control versus Regional Tectonic Control, for the Genesis of Structural Elements at Yucca Mountain F3.6-32

3.7-1 Plan Map Showing the Exploratory Studies Facility and YMP Boreholes F3.7-1
3.7-2 Stratigraphic Cross Section Along the Exploratory Studies Facility North Ramp F3.7-3
3.7-3 Stratigraphic Cross Section Along the Exploratory Studies Facility South Ramp F3.7-5
3.7-4 Stratigraphic Cross Section Along the Exploratory Studies Facility Main Drift F3.7-7
3.7-5 Core Recovery, Lost Core, and Rubble Zones as a Percentage of Total Drilling in Thermal/Mechanical Units F3.7-9
3.7-6 Rock Quality Designation Frequency F3.7-10
3.7-7 Distribution of Rock Weathering Parameters F3.7-11
3.7-8 Distribution of Estimated Rock Hardness Rating F3.7-12
3.7-9 Measured (qualified) and Calculated (non-qualified) Values of Thermal Capacitance for TSw1 and TSw2 Thermal/Mechanical Units F3.7-13
3.7-10 Nine-Term Moving Average Rock Mass Rating vs Exploratory Studies Facility Tunnel Station F3.7-14
3.7-11 Nine-Term Moving Average Rock Mass Quality vs Exploratory Studies Facility Tunnel Station F3.7-15
3.7-12 Cumulative Distribution of Rock Mass Rating Values in the Exploratory Studies Facility Main Loop F3.7-16
3.7-13 Cumulative Distribution of Rock Mass Quality Values in the Exploratory Studies Facility Main Loop F3.7-17
3.7-14 Cumulative Distribution of Modified Rock Mass Quality (Qmodified) Values in the Exploratory Studies Facility Main Loop F3.7-18
3.7-15 Design Rock Mass Strength Envelopes for TSw2 Unit, Exploratory Studies Facility Scanline Data F3.7-19
3.7-16 Comparison of Qmodified (Nine-Term Moving Average) to the Installed Ground Support Class in the Exploratory Studies Facility Main Loop F3.7-20

3.8-1 Map of the 3-D Model Area F3.8-1

FIGURES (Continued)

Page

3.8-2 Locations and Names of Boreholes used to Create the Geologic Framework Model F3.8-2
3.8-3 Structural Contour Map on the Base of Tpbt4, the Pre-Tiva Bedded Tuff F3.8-3
3.8-4 Views to the Northeast of the 3-D Geologic Framework Model Version ISM2.0 ..... F3.8-4
3.8-5 Isochore (Thickness) Map of Rock Unit TPCPV3, the Lower Densely Welded Vitric Sub-Zone of the Tiva Canyon Tuff (the Vitrophyre) F3.8-5
3.8-6 Isochore (Thickness) Map of the Yucca Mountain Tuff F3.8-6
3.8-7 Isochore Map of the Pah Canyon Tuff, Including the Pre-Pah Bedded Tuff F3.8-7
3.8-8 Isochore Map of the PTn Hydrogeologic Unit F3.8-8
3.8-9 Isochore Map of the Topopah Spring Tuff F3.8-9
3.8-10 Isochore Map of Rock Unit Tptpv3, the Lower Densely Welded Vitric Zone of the Topopah Spring Tuff F3.8-10
3.8-11 Isochore Map of the Calico Hills Formation F3.8-11
3.8-12 Isochore Map of the Prow Pass Tuff F3.8-12
3.8-13 Isochore Map of the Bullfrog Tuff F3.8-13
3.8-14 Isochore Map of the Tram Tuff F3.8-14
3.8-15 Structural Contour Map of the Top of the Tertiary-Paleozoic Unconformity, Calculated from Gravity Data F3.8-15
3.8-16 Interpretive Structural Contour Map of the Tertiary-Paleozoic Unconformity F3.8-16
3.8-17 Seismic Line REG-3 with Interpretations of the Tertiary-Paleozoic Unconformity F3.8-17

3.9-1 Distribution of Late Cenozoic Basaltic Rocks in the Western United States Erupted During the Period 16-5 and 5-0 Ma Relative to the Margins of the Great Basin and Colorado Plateau Provinces F3.9-1
3.9-2 Estimated Volume versus Age for Volcanic Rocks of the SWNFV F3.9-2
3.9-3 Comparison of K-Ar (Fleck et al. 1996) and $^{40}Ar/^{39}Ar$ Measurements of the Age of Post-Miocene Volcanic Episodes in the Yucca Mountain Region F3.9-3
3.9-4 $^{40}Ar/^{39}Ar$ Dates from Quaternary Basalt Centers of Crater Flat F3.9-4
3.9-5 Percent Cumulative Volume Erupted versus Age of Volcanic Units of the SWNVF F3.9-5
3.9-6 Location of Vents of OPB Basalts (Circles) and YPB (post-Miocene) Basalt (Triangles) F3.9-6
3.9-7 Quaternary and Pliocene Basalt Centers of the Yucca Mountain Region F3.9-7
3.9-8 Major Structural Features of the Crater Flat Basin from the Fridrich (1998) Tectonic Model F3.9-8
3.9-9 Aggregate Results for Frequency of Intersection of the Potential Yucca Mountain Repository (CRWMS M&O 1996h) F3.9-9

FIGURES (Continued)

Page

3.10-1a Seismograph Stations Operating in the Western United States in 1925 ..... F3.10-1
3.10-1b Seismograph Stations Operating in the Western United States in 1934 ..... F3.10-2
3.10-1c Seismograph Stations Operating in the Western United States in 1965 ..... F3.10-3
3.10-2a Seismograph Stations Operating in the Southern Great Basin in 1980 ..... F3.10-4
3.10-2b Seismograph Stations Operating in the Southern Great Basin in 1996 ..... F3.10-5
3.10-3 Historical Earthquake Epicenters within 300 Kilometers of Yucca Mountain F3.10-6
3.10-4 Historical Seismicity Within 100 km of Yucca Mountain F3.10-7
3.10-5 Regions of Seismicity within 300 km of Yucca Mountain F3.10-8
3.10-6 Focal Depth Distribution of Earthquakes (1868-1993) Within 200 km of Yucca Mountain F3.10-9
3.10-7 Focal Mechanisms for Earthquakes of ML>3,5 in the Vicinity of Yucca Mountain from 1987 to 1997 ..... F3.10-10
3.10-8 Principal Stress Axes from Focal Mechanisms of Southern Great Basin Earthquakes F3.10-11
3.10-9 Epicenters and Focal Mechanisms of Earthquakes and Known or Suspected Quaternary Faults Near Yucca Mountain F3.10-12
3.10-10 Known or Suspected Quaternary Faults and Significant Local Faults Within 100 km of Yucca Mountain F3.10-13
3.10-11 Location Map of Local Faults and Paleoseismic Study Sites at Yucca Mountain F3.10-14
3.10-12a Example Trench Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain F3.10-15
3.10-12b Example Tranch Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Paintbrush Canyon Fault, Western Splay F3.10-16
3.10-12c Example Trench Logs from Peleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Bow Ridge Fault F3.10-17
3.10-12d Example Trench Logs from Peleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Stagecoach Road Fault F3.10-18
3.10-13 Map of Slip Rates of Late Quaternary Faults Near Yucca Mountain F3.10-19
3.10-14 Displacement Scenarios for Nine Possible Prehistoric Earthquakes in the Past 150 Kyr at Yucca Mountain F3.10-21
3.10-15 Plots Comparing Magnitudes Calculated for Rupture Scenarios at Yucca Mountain F3.10-23
3.10-16 Assessment of Relevant and Potentially Relevant Earthquake Sources for the Yucca Mountain Region F3.10-24
3.10-17 Locations Of Boreholes Where Vertical Seismic Profile Surveys Have Been Performed F3.10-25
3.10-18 Shear-Wave Interval Velocities Interpreted from Vertical Seismic Profile Surveys at Six Boreholes F3.10-26
3.10-19 Shallow Shear-Wave Seismic Velocity Model for Yucca Mountain and Thermal-Mechanical Layer Velocities F3.10-27

FIGURES (Continued)

Page

3.10-20 Deep Shear-Wave Seismic Velocity Model for Yucca Mountain F3.10-28
3.10-21 Spectral Acceleration (Median Ground Motion Estimates) for Several Western United States Attenuation Relations Compared with an Extensional Regime Relation F3.10-29
3.10-22 Spectral Acceleration (Median Ground Motion Estimates) for Several Western United States Attenuation Relations Compared with an Extensional Regime Relation F3.10-30
3.10-23 Spectral Acceleration (Median Ground Motion Estimates) for Several Western United States Attenuation Relations Compared with an Extensional Regime Relation F3.10-31
3.10-24 Results of Validation Studies in the Scenario Earthquake Modeling Study F3.10-32
3.10-25 Model Bias of Observed Spectra to Calculated Spectra for the Little Skull Mountain Earthquake Validation (Scenario Earthquake Modeling Study) F3.10-33
3.10-26 Model Standard Errors for the Little Skull Mountain Earthquake Validation (Scenario Earthquake Modeling Study) F3.10-34
3.10-27 Median Spectral Acceleration for Scenario Earthquakes F3.10-35
3.10-28 Example of Total Uncertainty and its Components (The scenario is the Paintbrush Canyon earthquake) F3.10-36
3.10-29 Expert Point Estimates for Median Horizontal Spectral Acceleration for a Mw 6.5 Earthquake at 4 km on the Hanging Wall of a Normal Fault F3.10-37
3.10-30 Median Horizontal Peak Ground Acceleration for a Mw 6.5 Earthquake on the Hanging Wall of a Normal Fault F3.10-38
3.10-31 Schematic Diagram of the Elements of a Probabilistic Seismic Hazard Analysis for Vibratory Ground Motions F3.10-39
3.10-32 Example Logic Tree for Expressing the Uncertainty in Characterizing Local Fault Sources F3.10-40
3.10-33 Example Logic Tree for Expressing the Uncertainty in Characterizing Regional Fault Sources F3.10-41
3.10-34 Example Logic Tree for Expressing the Uncertainty in Characterizing Areal Source Zones F3.10-42
3.10-35 Example Assessment of Maximum Magnitude for a Fault Source F3.10-43
3.10-36 Alternative Recurrence Models Constrained by Either the Recurrence Interval for Large Events (left) or by Fault Slip Rate Converted to Moment Rate (right) F3.10-44
3.10-37 Regional Fault Sources Considered by One of the Seismic Source Expert Teams F3.10-45
3.10-38a Location of Local Faults Considered by One of the Seismic Source Experts as Independent Sources F3.10-46
3.10-38b Location of Coalesced Faults Considered by One of the Seismic Source Expert Teams F3.10-47
3.10-39 Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources F3.10-48

FIGURES (Continued)

Page

3.10-40 Alternative Regional Source Zone Models Considered by One of the Seismic Source Expert Teams F3.10-56
3.10-41 Predicted Mean, 5th, and 95th-Percentile Recurrence Rates for (a) Local Fault Sources, (b) Regional Fault Sources, (c) Regional Source Zones, and (d) All Sources Combined for One of the Seismic Source Expert Teams..... F3.10-59
3.10-42 Predicted Mean, 5th, and 95th-Percentile Recurrence Rates for All Sources Combined and for All Teams Combined Compared to Mean Recurrence Estimates for an Individual Seismic Source Expert Team F3.10-60
3.10-43 Faults Within an Approximate 100 km Radius of Yucca Mountain Considered in the Deterministic Seismic Hazard Analysis F3.10-61
3.10-44 Local Faults Within the Controlled Area and Within 5 km of the Controlled Area Boundary Considered in the Deterministic Seismic Hazard Analysis F3.10-62
3.10-45 Deterministic Maximum Magnitudes in Relation to Minimum Distance to the Controlled Area Boundary For Fault Sources Within 100 km of the Yucca Mountain Site..... F3.10-63
3.10-46 Acceleration Response Spectra for 38 Local and 3 Selected Regional Deterministic Earthquakes at the Median (50th) and 84th Fractiles F3.10-64

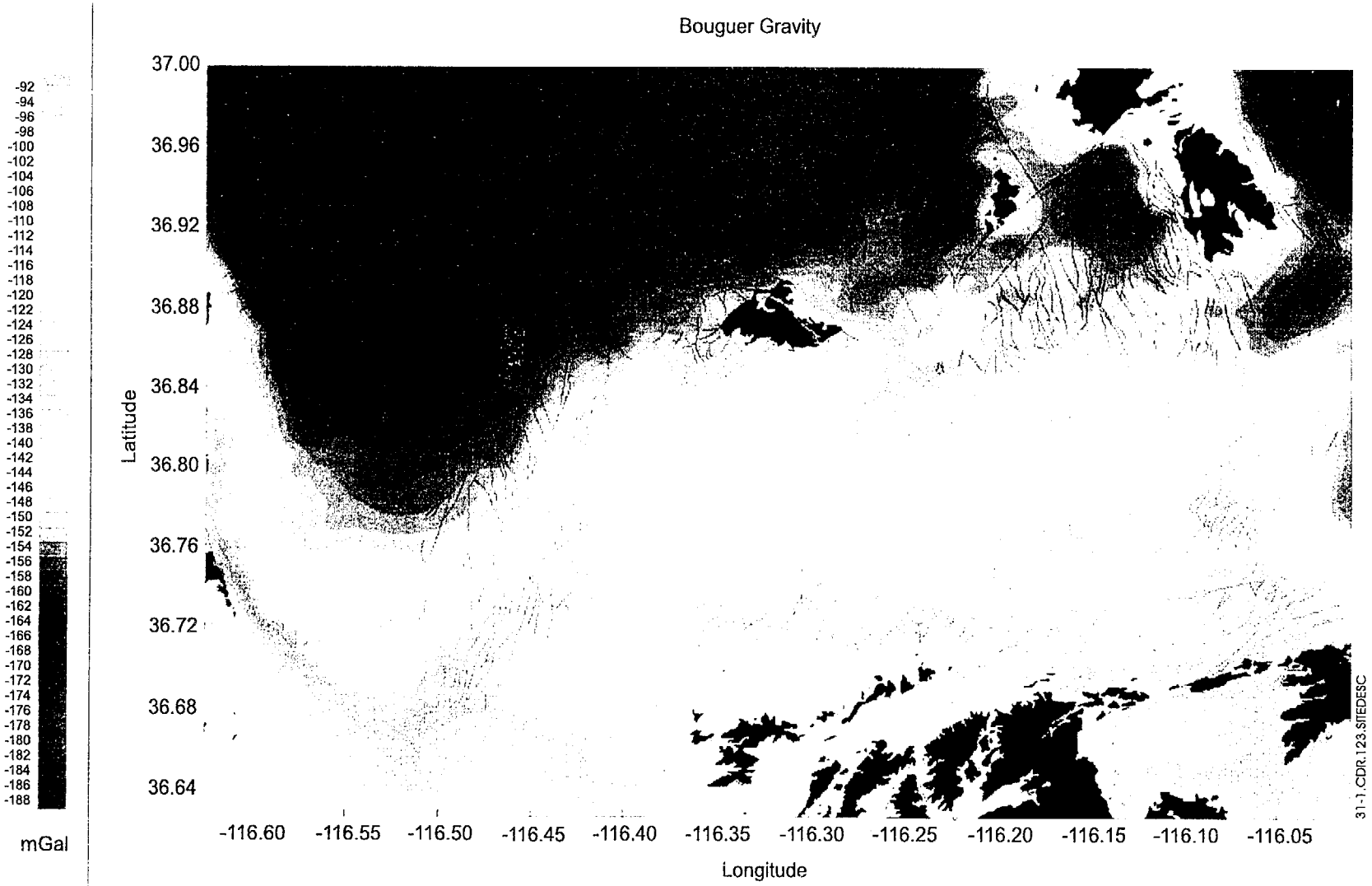
3.11-1 Locations of the Yucca Mountain Conceptual Control Area, Metal Mining Districts, and Metal Mines in the Yucca Mountain Region F3.11-1
3.11-2 Sample Locations and Drillholes in the Yucca Mountain and YMCCA and Vicinity..... F3.11-3
3.11-3 Industrial Mineral Occurrences in the Great Basin Vicinity of Yucca Mountain..... F3.11-5
3.11-4 Schematic Diagram Showing Tectonic Evolution of Extension in the Continental Western United States F3.11-7
3.11-5 Wildcat Drilling in the Great Basin Since 1900 ..... F3.11-8
3.11-6 The "Eagle Springs" Exploration Model F3.11-9
3.11-7 Location of Wells in The Vicinity of the Yucca Mountain Site Reviewed for Hydrocarbon Potential F3.11-11
3.11-8 Burial and Generation History of the Source Rocks of the Railroad Valley Area F3.11-13
3.11-9 Paleogeologic Map of Railroad Valley, Beginning of Oligocene Time..... F3.11-14
3.11-10 Cross-Section of the Railroad Valley Basin with the Geothermal Regime..... F3.11-15
3.11-11 Stratrigraphy of Yucca Mountain and Producing Areas of the Great Basin..... F3.11-17
3.11-12 Cross-Section Through Part of Trap Spring Field, Railroad Valley..... F3.11-19
3.11-13 Classification of Traps of the Great Basin Region F3.11-20
3.11-14 Structure Map of Yucca Mountain Area..... F3.11-21
3.11-15 Structure Map on the Top of the Prow Pass Tuff F3.11-22
3.11-16 Paleogeologic Map of Railroad Valley Area, Beginning of Oligocene Time.. F3.11-23
3.11-17 Distribution of Geothermal Springs and Wells in the Great Basin (>25°C) F3.11-24

FIGURES

Page

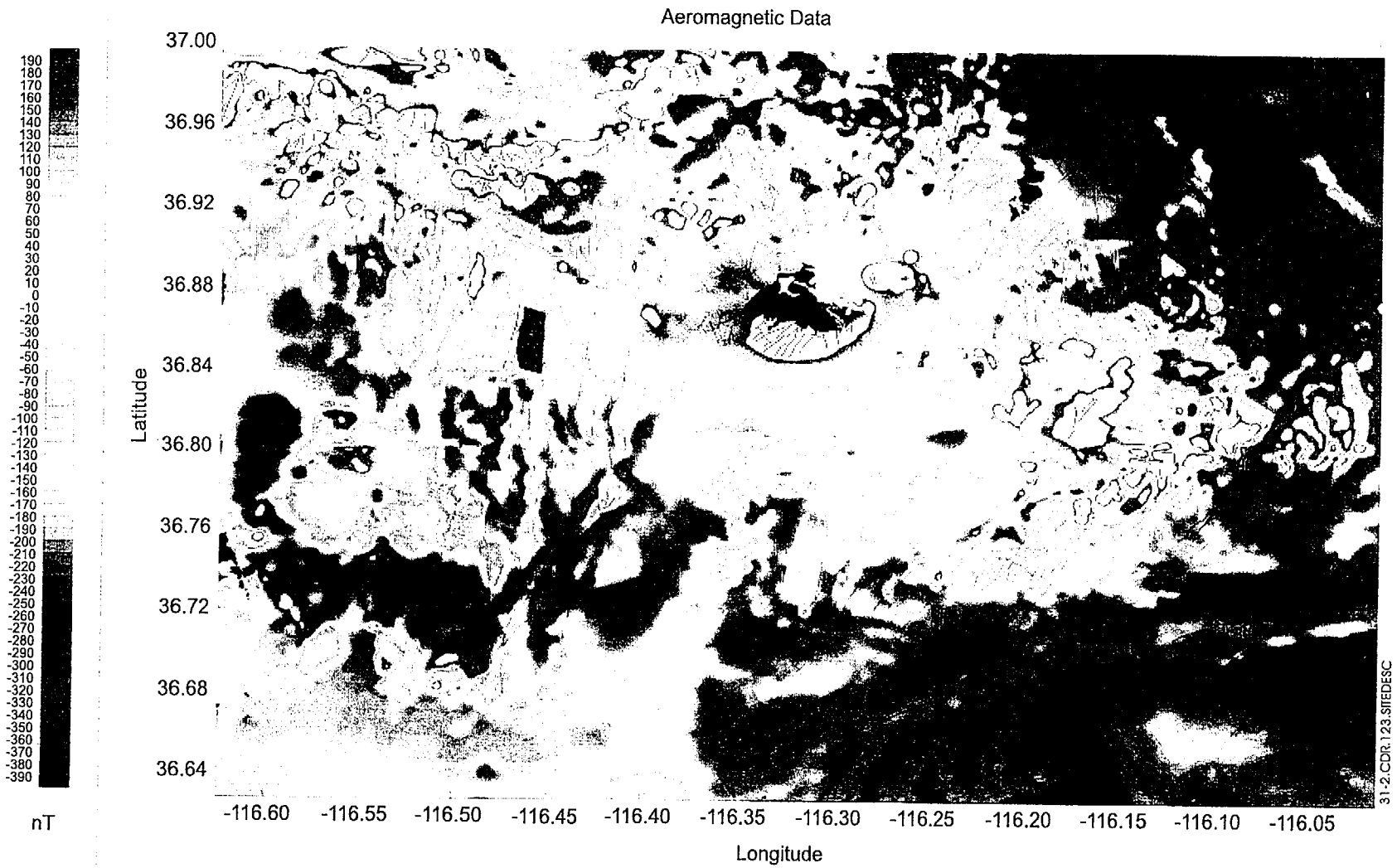
3.11-18 Water Level Elevations, Regional Bouguer Gravity, and Area of Reduced Heat Flow F3.11-25
3.11-19 Location and Output in Mwe of Geothermal Power Plants Discussed in this Report F3.11-26
3.11-20 Location of Geothermal Direct-Use Projects Discussed in this Report F3.11-27

INTENTIONALLY LEFT BLANK



NOTE: The data were obtained from the USGS and consist of publicly available datasets. The red polygon identifies the site above the proposed waste emplacement area. Paleozoic outcrops (dark blue regions) and faults are from Sawyer, D.A. et al. (1995)

Figure 3.1-1. Contour Plot of Bouguer Gravity Data



NOTE: Data are from the digital aeromagnetic dataset of McCafferty (USGS, Denver). This data report is included in the appendix of Feighner and Majer (1996). The red polygon identifies the site above the proposed waste emplacement area. Paleozoic outcrops (dark blue regions) and faults are from Sawyer, D.A. et al. (1995)

Figure 3.1-2. Contour Plot of Aeromagnetic Data

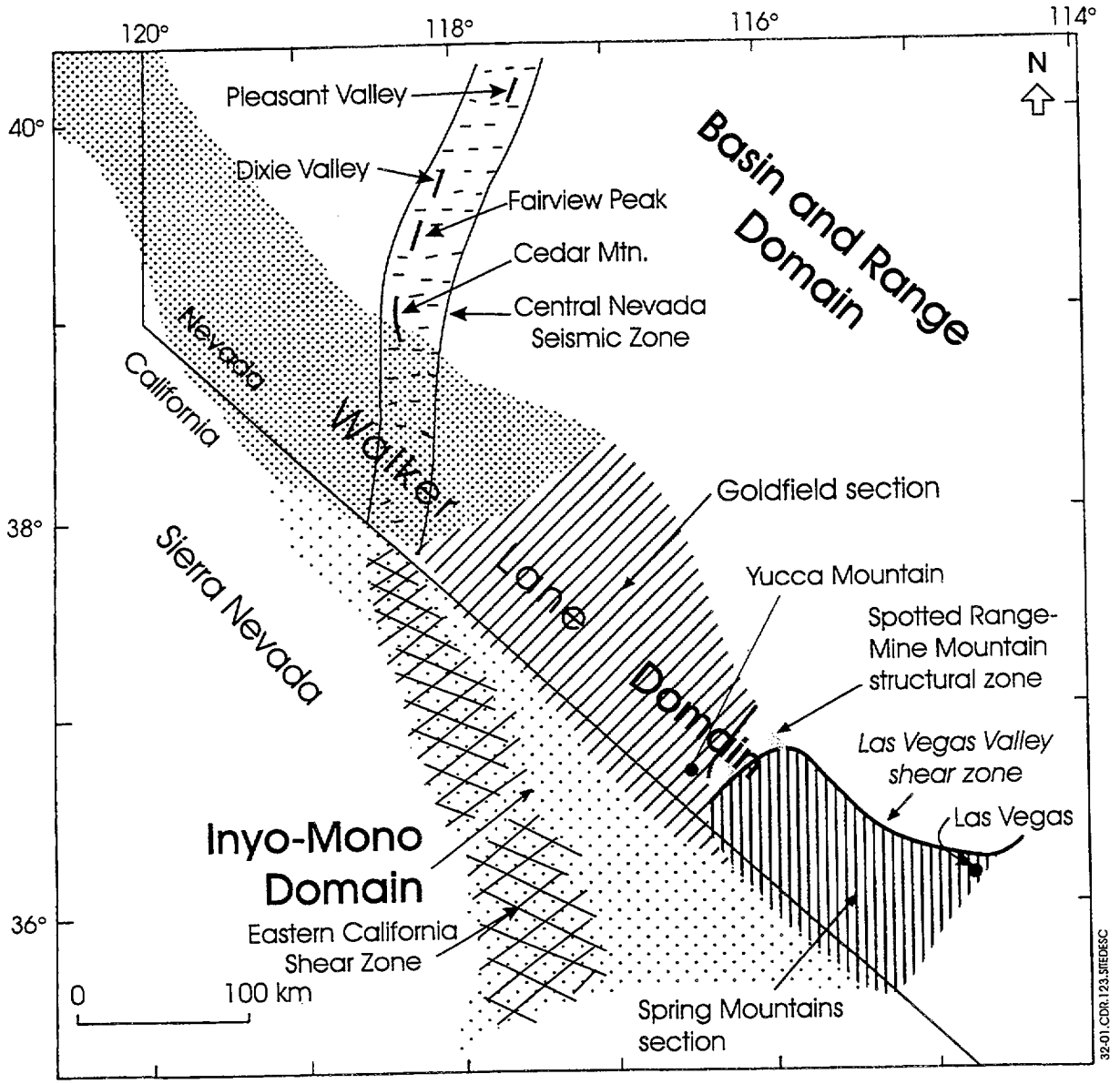
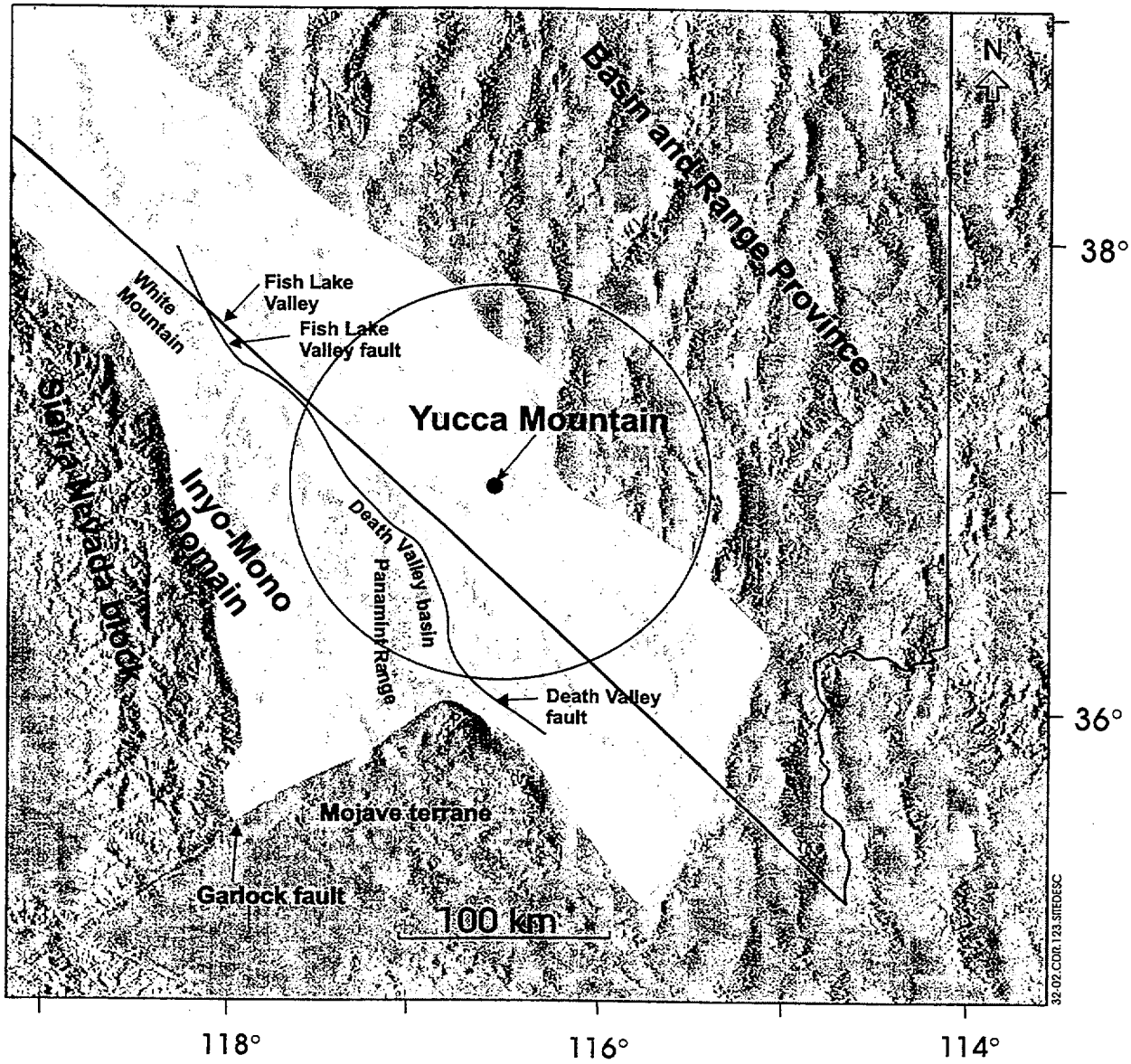
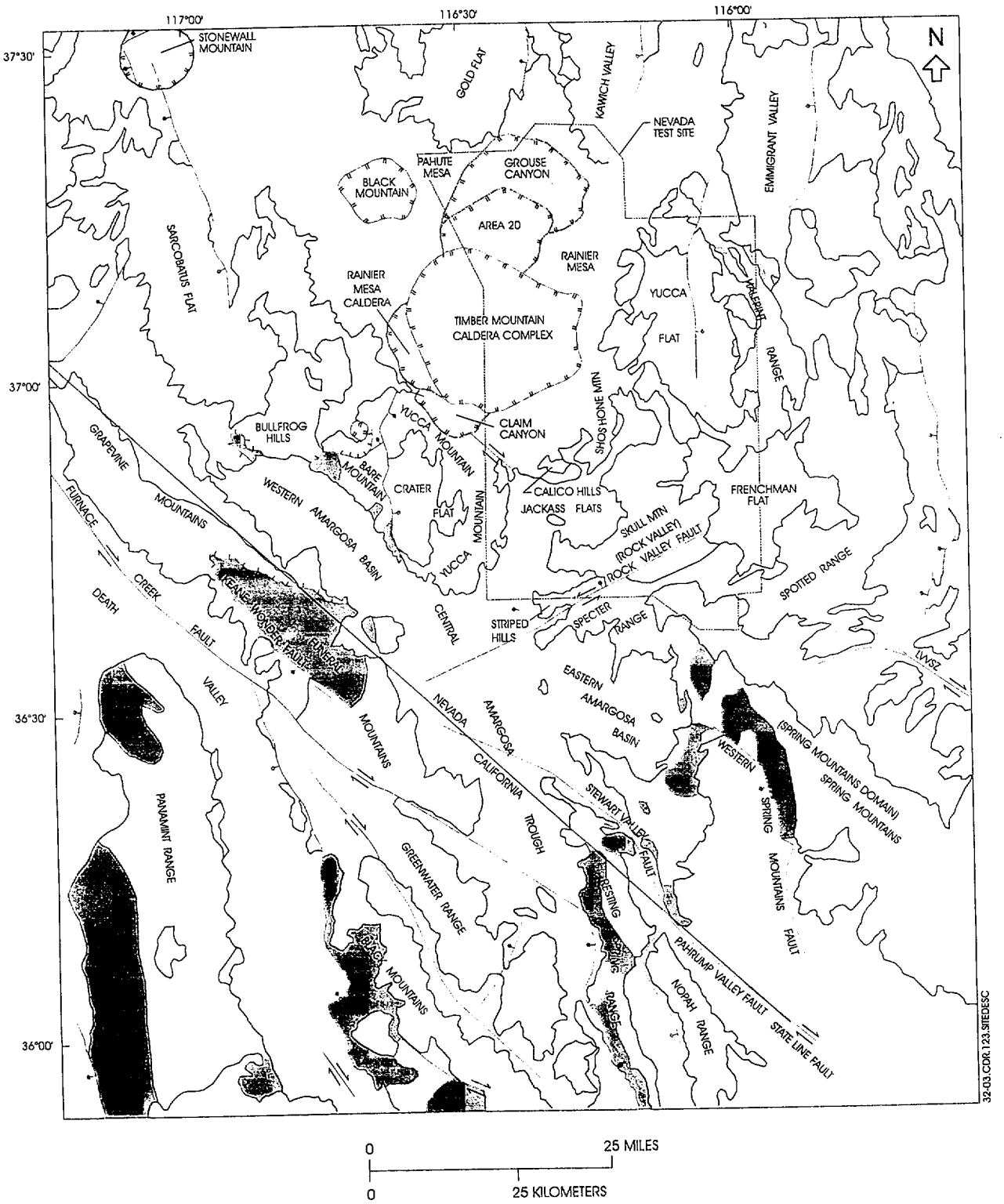


Figure 3.2-1. Regional Tectonic Domains for Yucca Mountain and Surrounding Environs, Sections of the Walker Lane are Also Shown (after Stewart 1988)



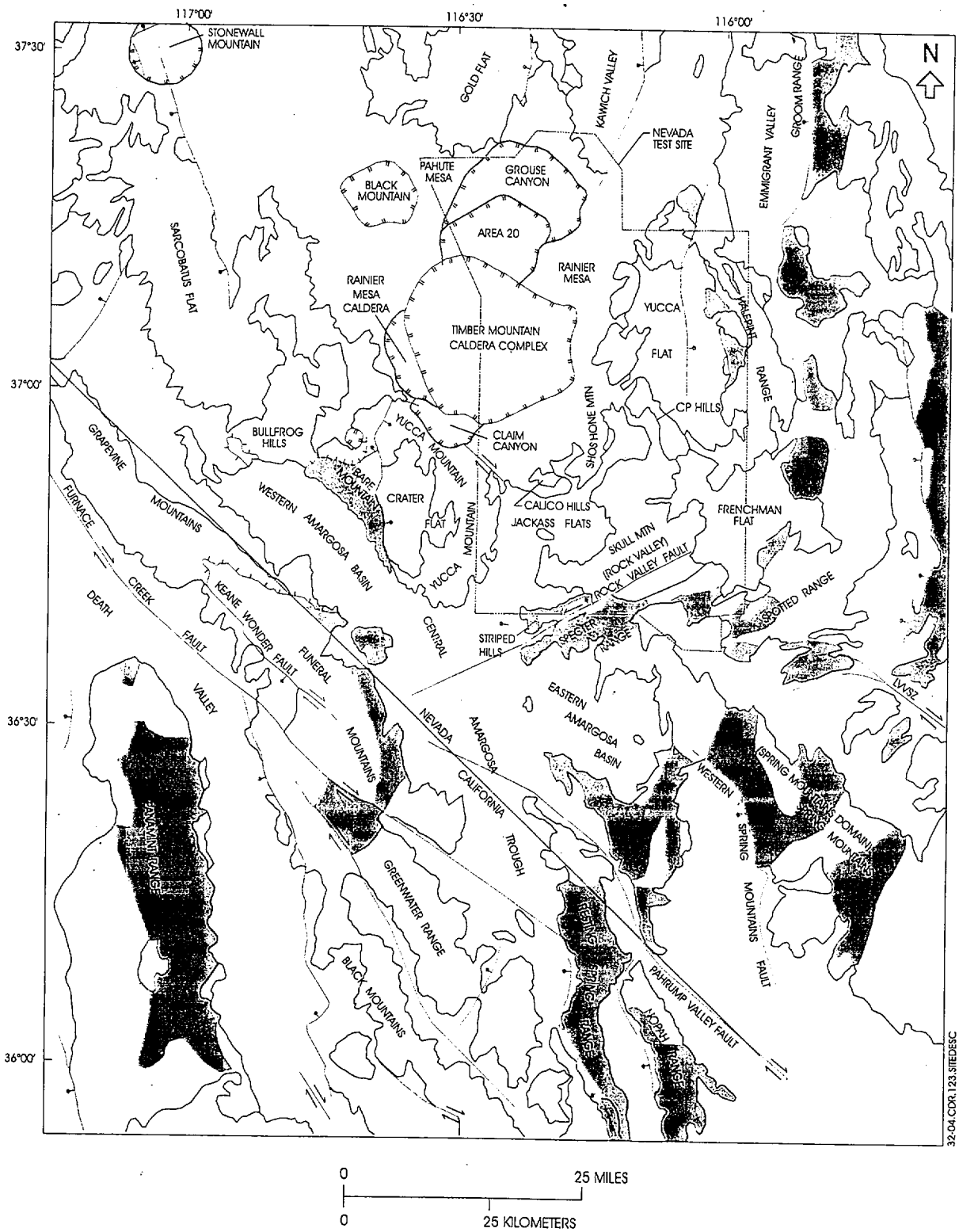
NOTE: Circle Encloses 100 km radius area centered on Yucca Mountain. Light screen shows the Walker Lane and, to the west of Death Valley Basin, the Inyo-Mono Domain.

Figure 3.2-2. Geologic Setting of Yucca Mountain



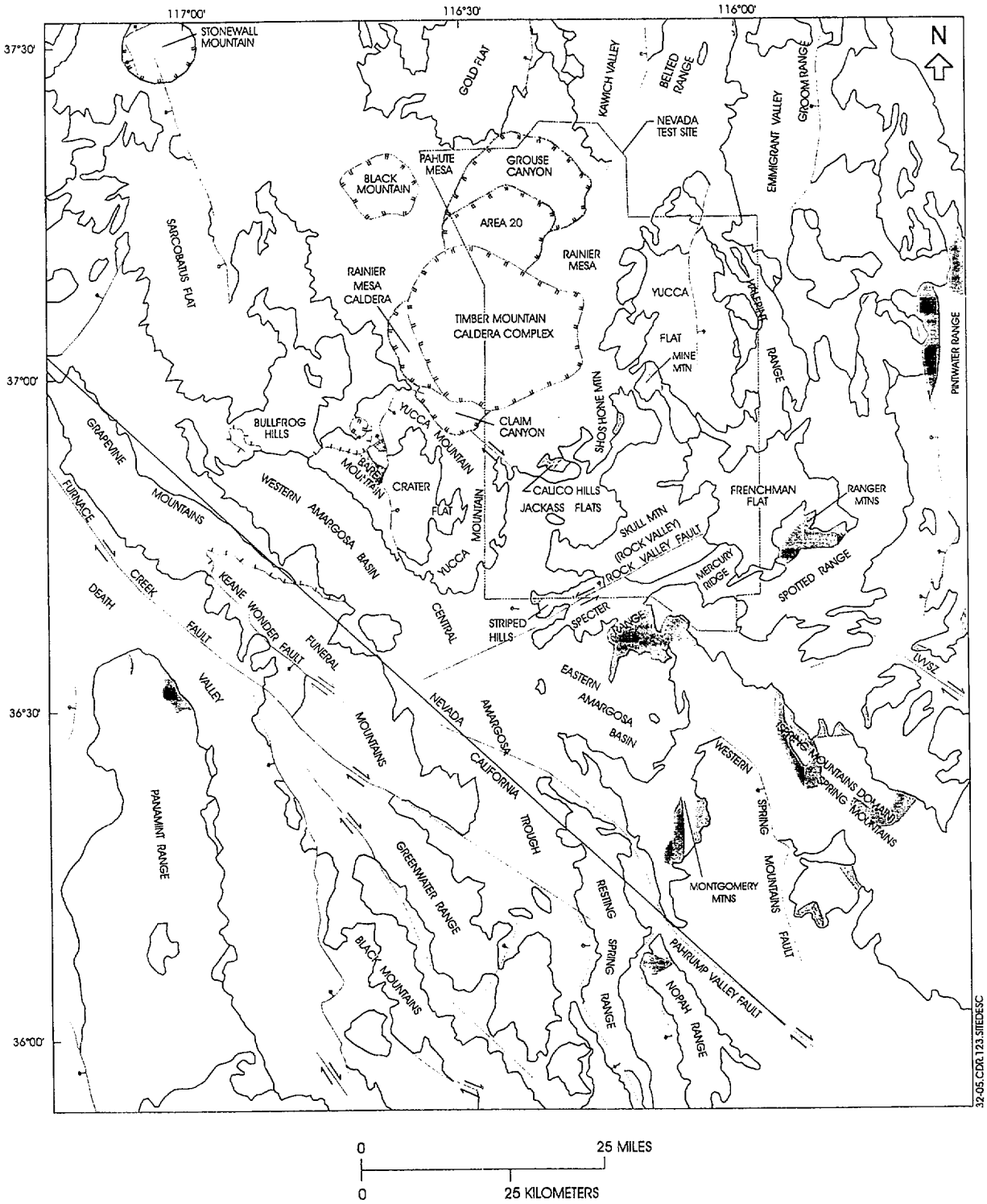
NOTE: Surface exposures are shown by shading.

Figure 3.2-3. Distribution of Surface Exposures of Precambrian Rocks in the Yucca Mountain Geologic Setting



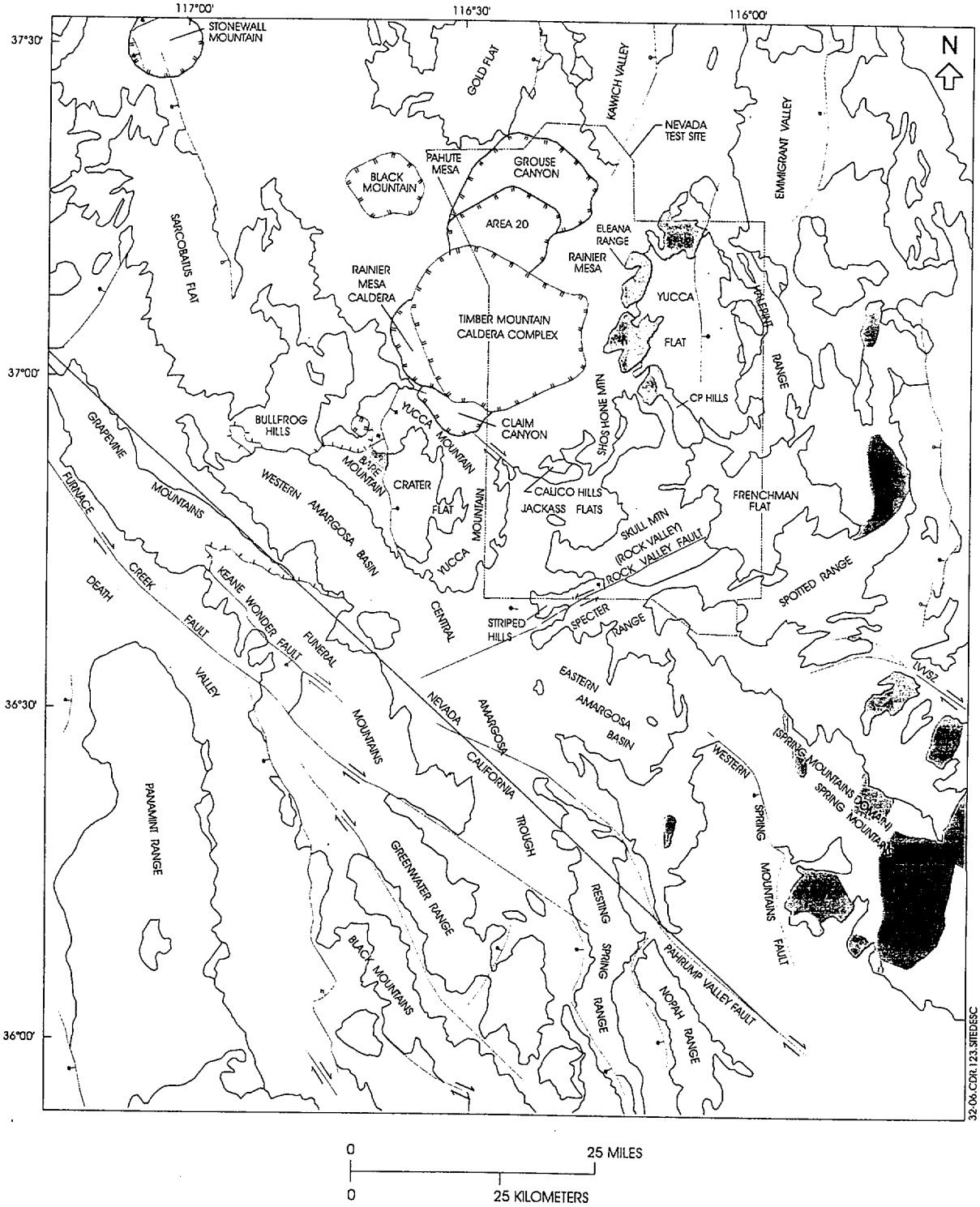
NOTE: Surface exposures are shown by shading.

Figure 3.2-4. Distribution of Surface Exposures of Cambro-Ordovician Rocks in the Yucca Mountain Geologic Setting



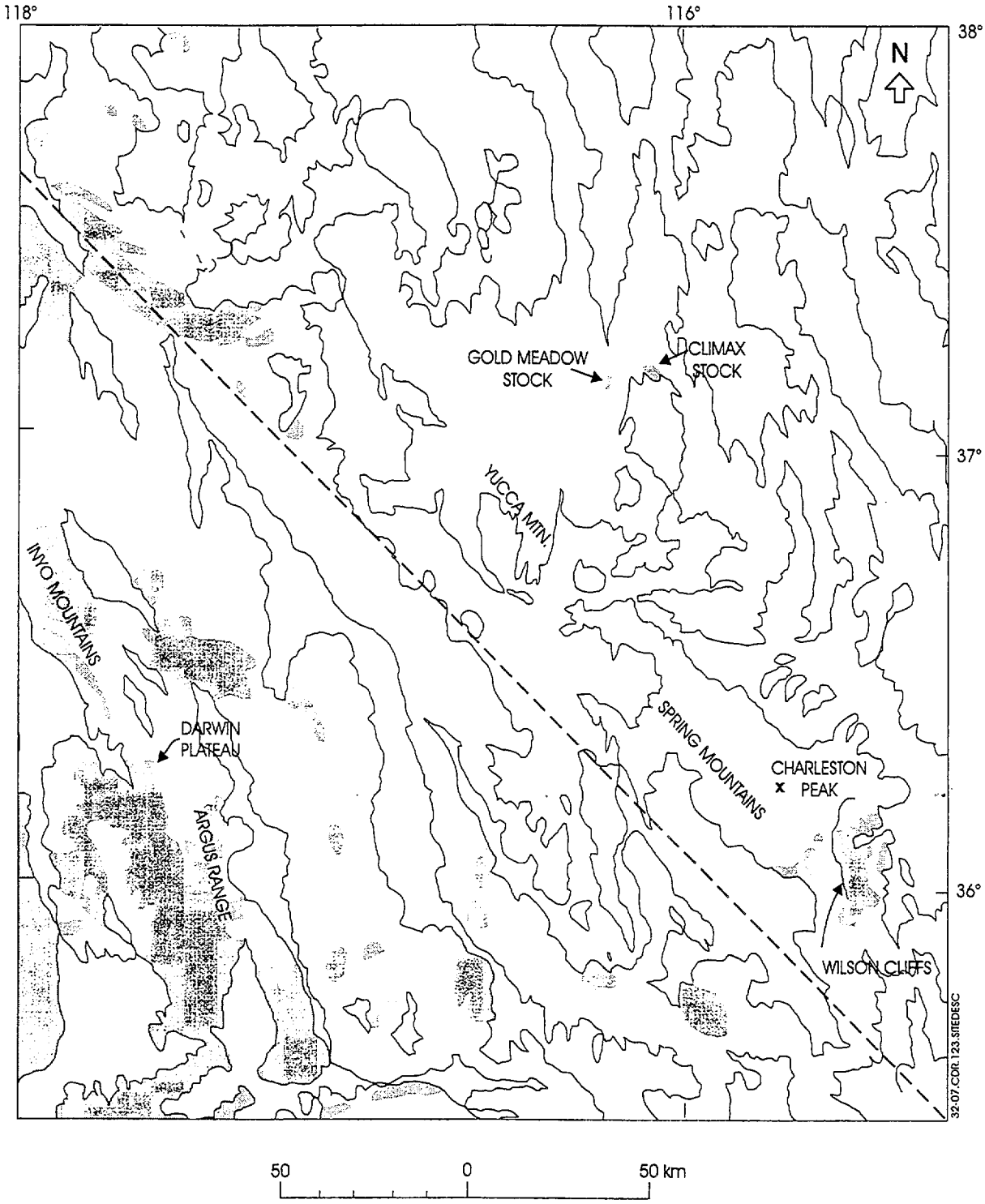
NOTE: Surface exposures are shown by shading.

Figure 3.2-5. Distribution of Surface Exposures of Siluro-Devonian Rocks in the Yucca Mountain Geologic Setting



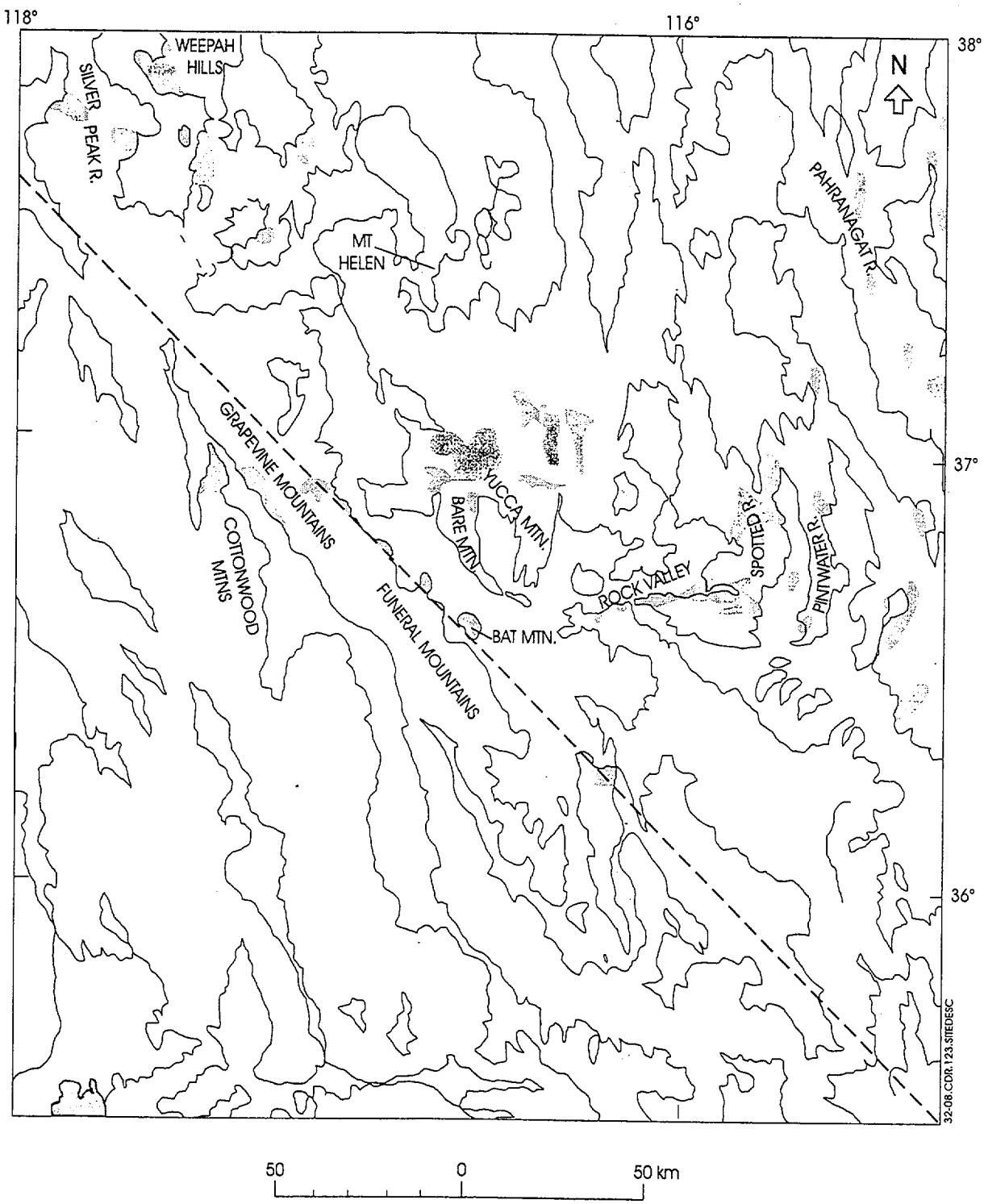
NOTE: Surface exposures are shown by shading.

Figure 3.2-6. Distribution of Surface Exposures of Carboniferous and Permian Rocks in the Yucca Mountain Geologic Setting



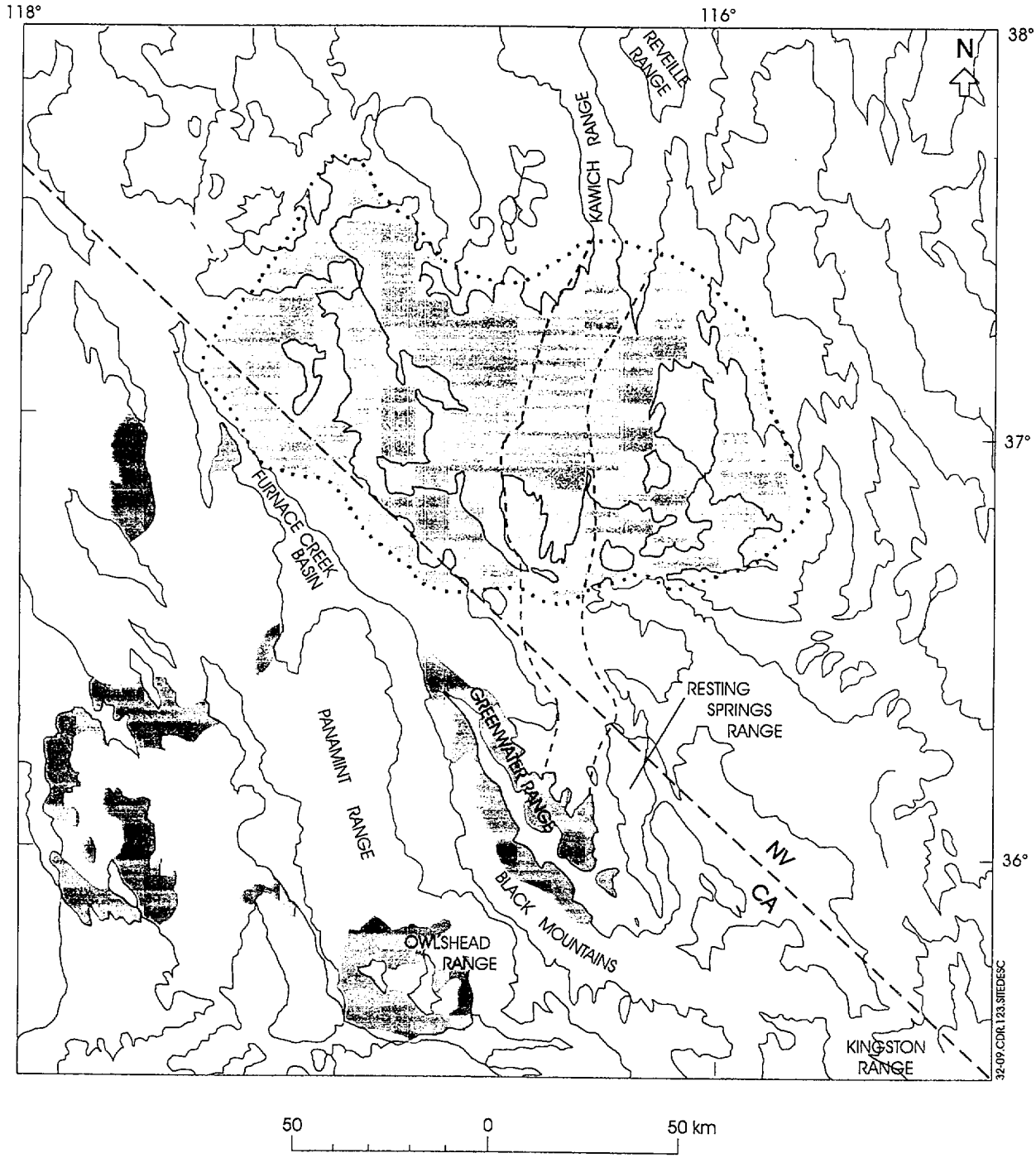
NOTE: Surface exposures are shown by shading.

Figure 3.2-7. Distribution of Surface Exposures of Mesozoic Rocks (Igneous and Sedimentary) in the Yucca Mountain Geologic Setting



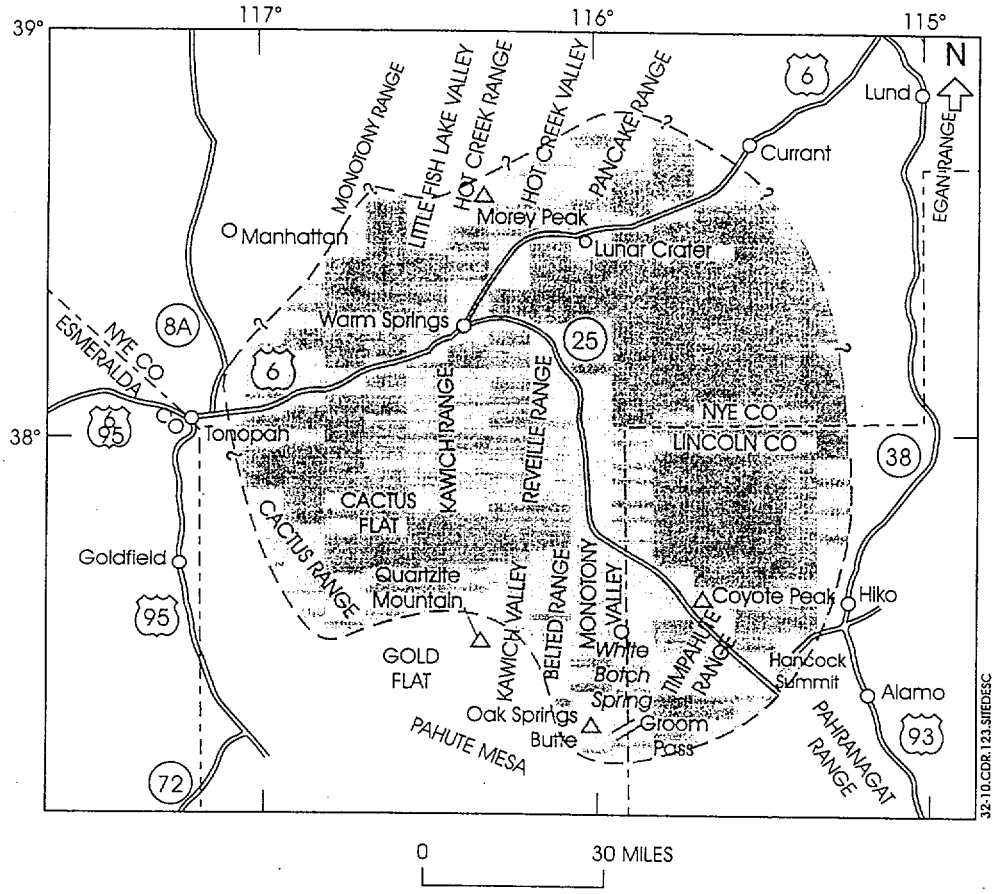
NOTE: Surface exposures are shown by shading.

Figure 3.2-8. Distribution of Surface Exposures of Tertiary Sedimentary Rocks in the Yucca Mountain Geologic Setting



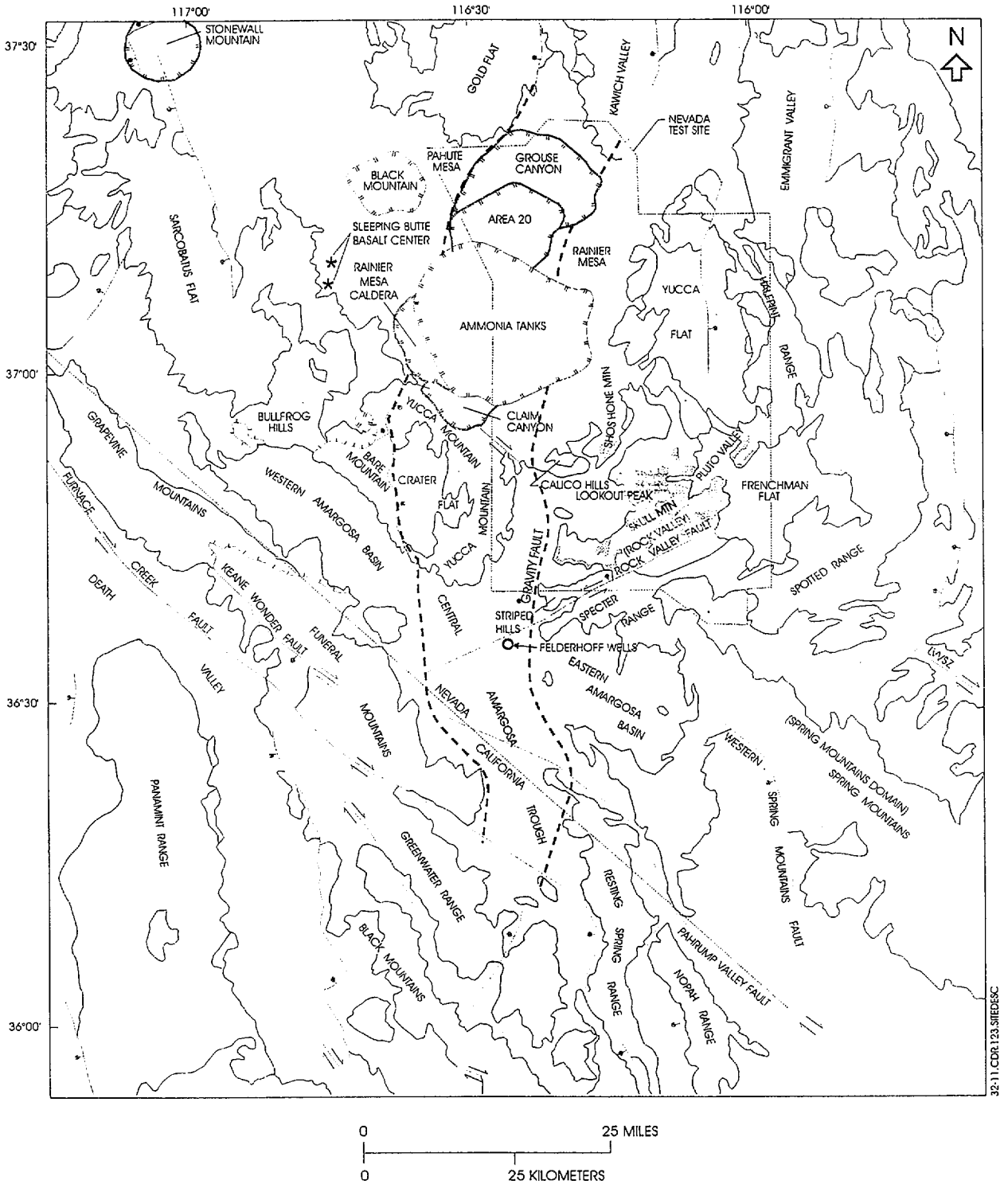
NOTE: Dashed lines indicate approximate borders of the Kawich-Greenwater Rift of Carr.

Figure 3.2-9. General Extent of the Southwestern Nevada Volcanic Field (dotted boundary) and Coeval Igneous Rocks of the Inyo-Mono Domain (shown by brown shading)



NOTE: Shown by shading.

Figure 3.2-10. General Distribution of the Monotony Tuff (from Ekren et al. 1971)



NOTE: Surface exposures are shown by shading; dashed lines show approximate borders of the Kawich-Greenwater Rift of Carr. (Carr, W.J., Grow and Keller 1995)

Figure 3.2-11. General Distribution of Surface Exposures of the Wahmonie and Salyer Formations

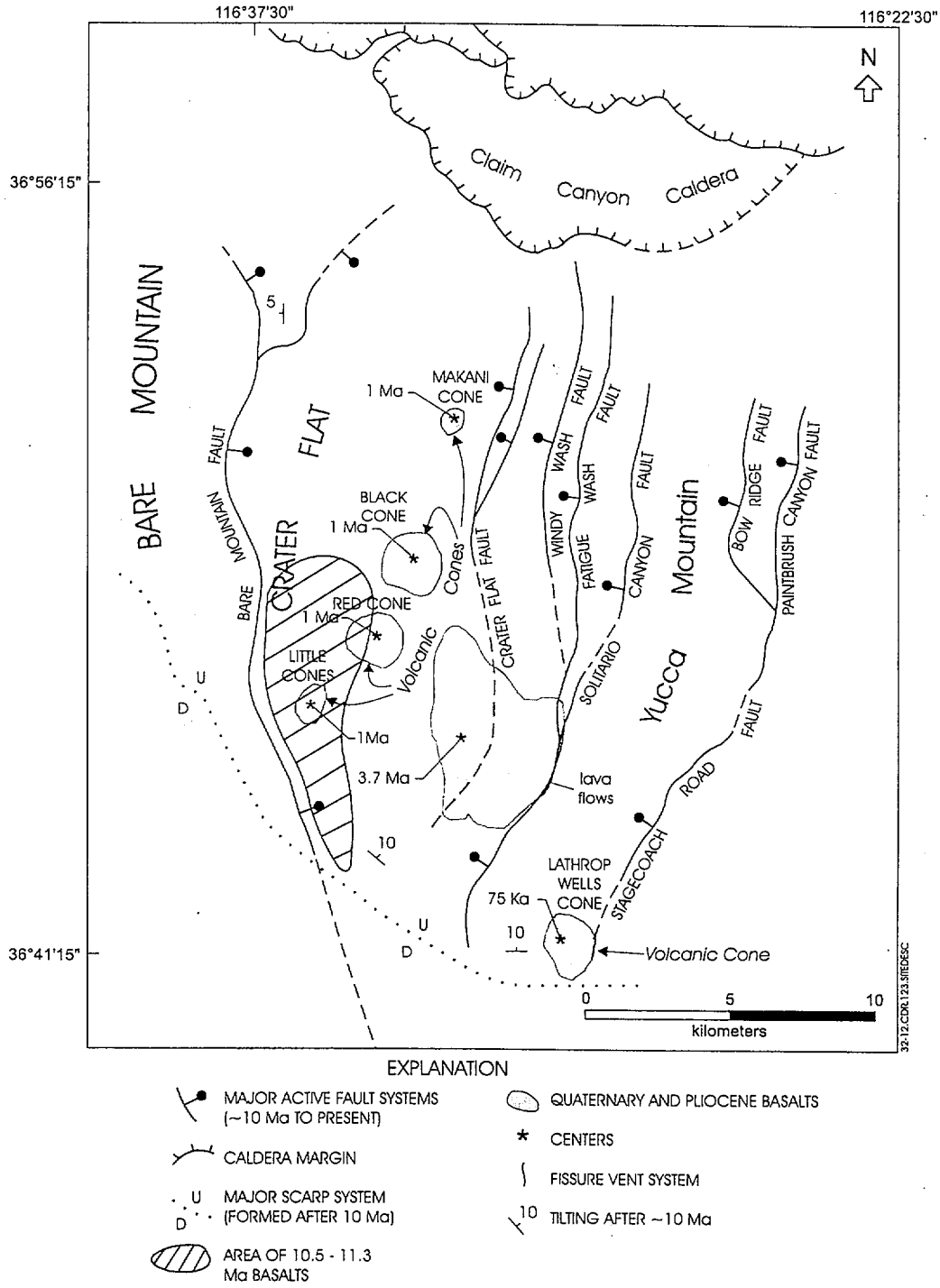


Figure 3.2-12. Late Neogene and Pleistocene Features at and Near Yucca Mountain (adapted from Fridrich 1998)

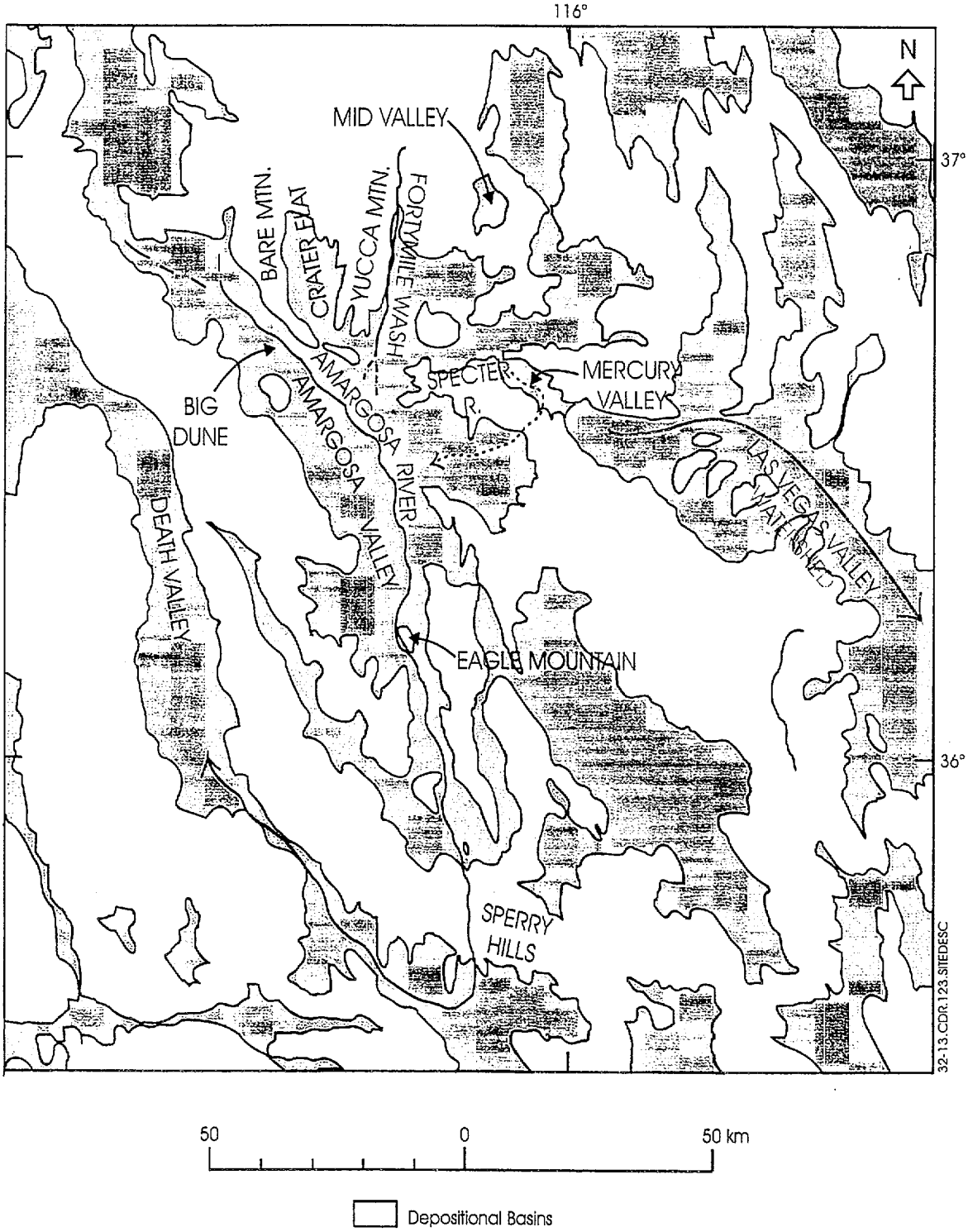


Figure 3.2-13. Pleistocene Depositional Basins and Drainage Features

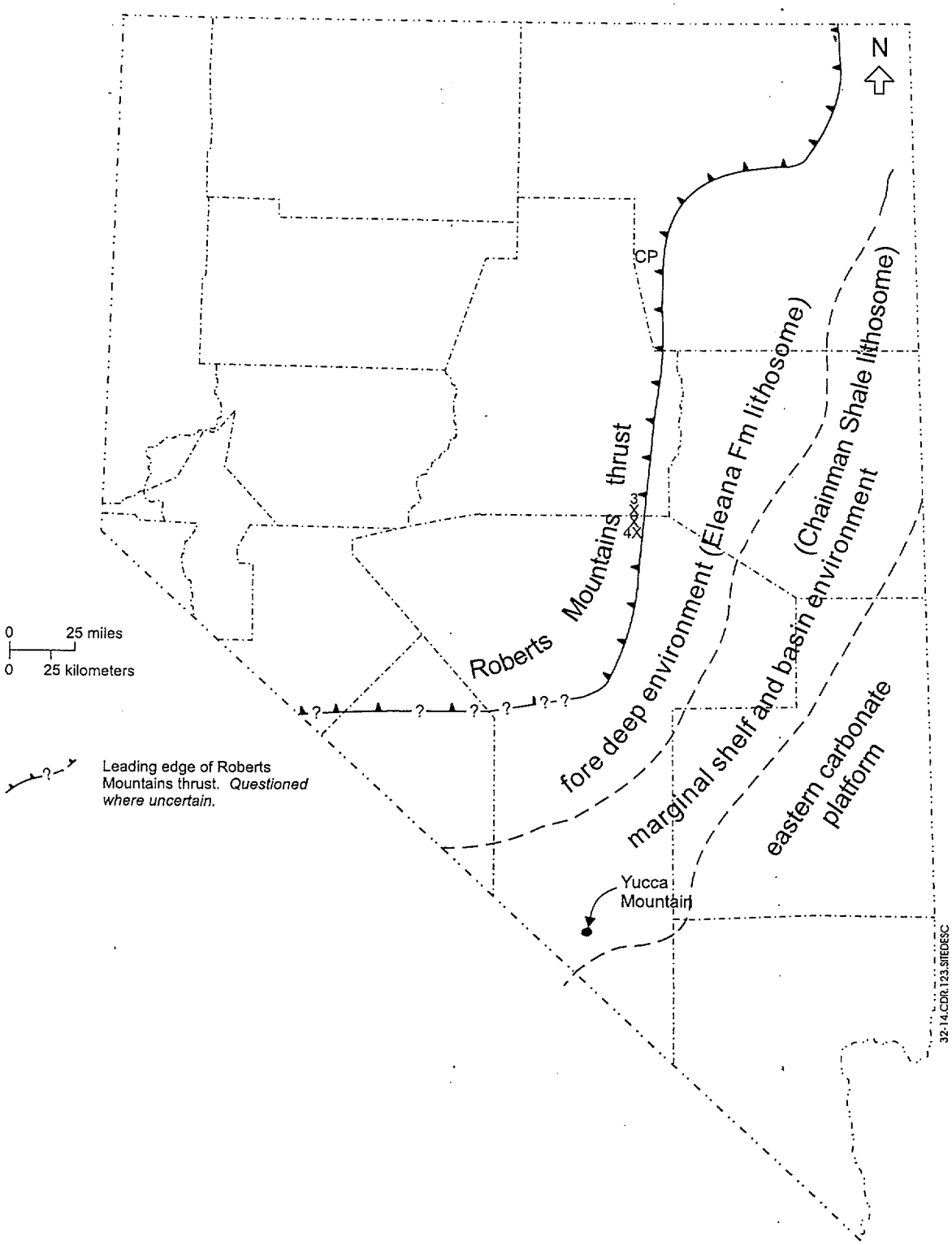
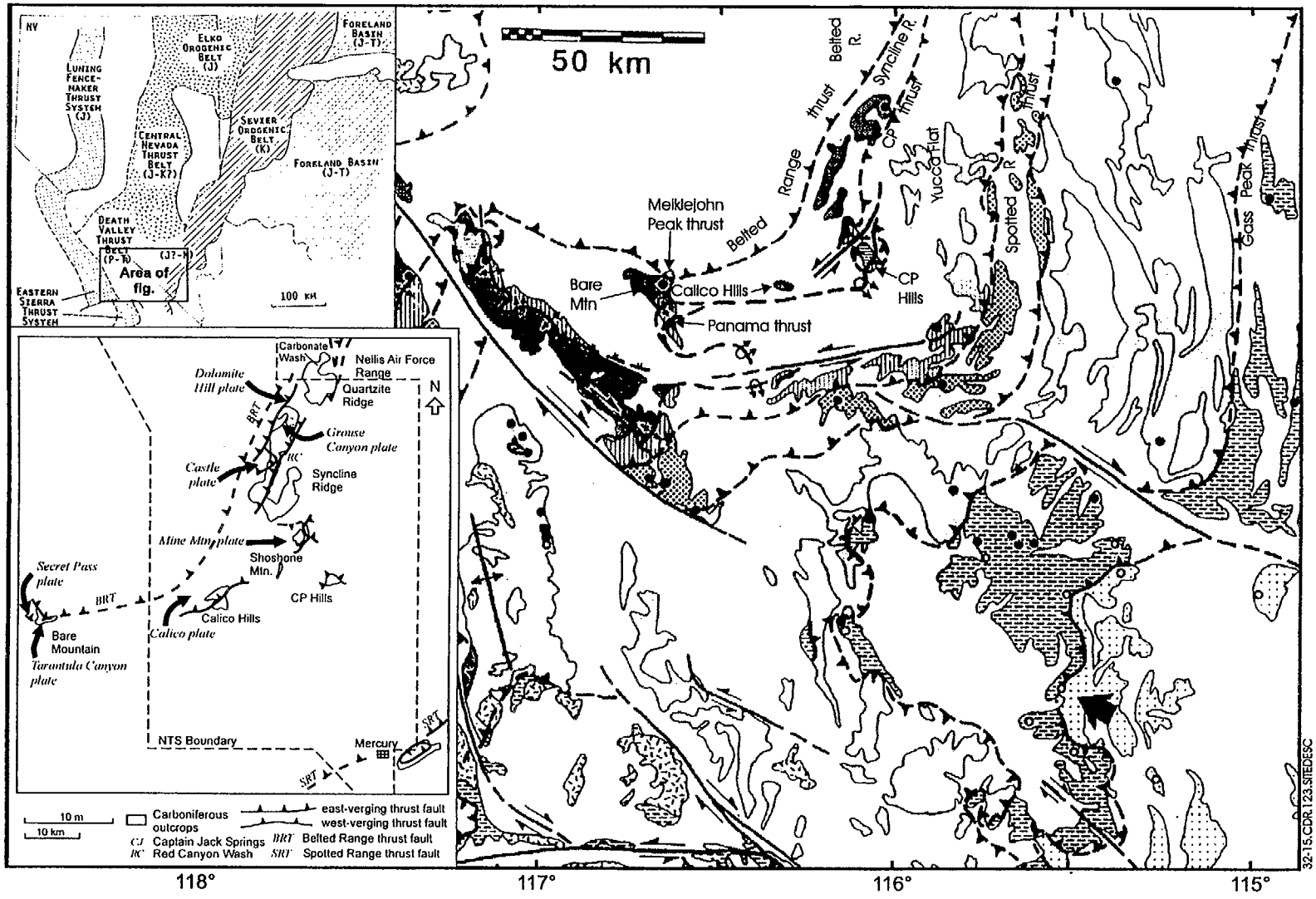


Figure 3.2-14. Generalized Location of Antler Orogenic Features (from Stewart 1980a; Trexler, J.H. et al. 1996)



NOTE: Fault traces dashed where covered; teeth point to overthrust (upper) plate; double-arrowed "U" indicates overturned fold.

Figure 3.2-15. Structures of the Central Nevada and Sevier Thrusts Zones (from Snow 1992; Taylor et al. 1993; Trexler , J.H. et al. 1996)

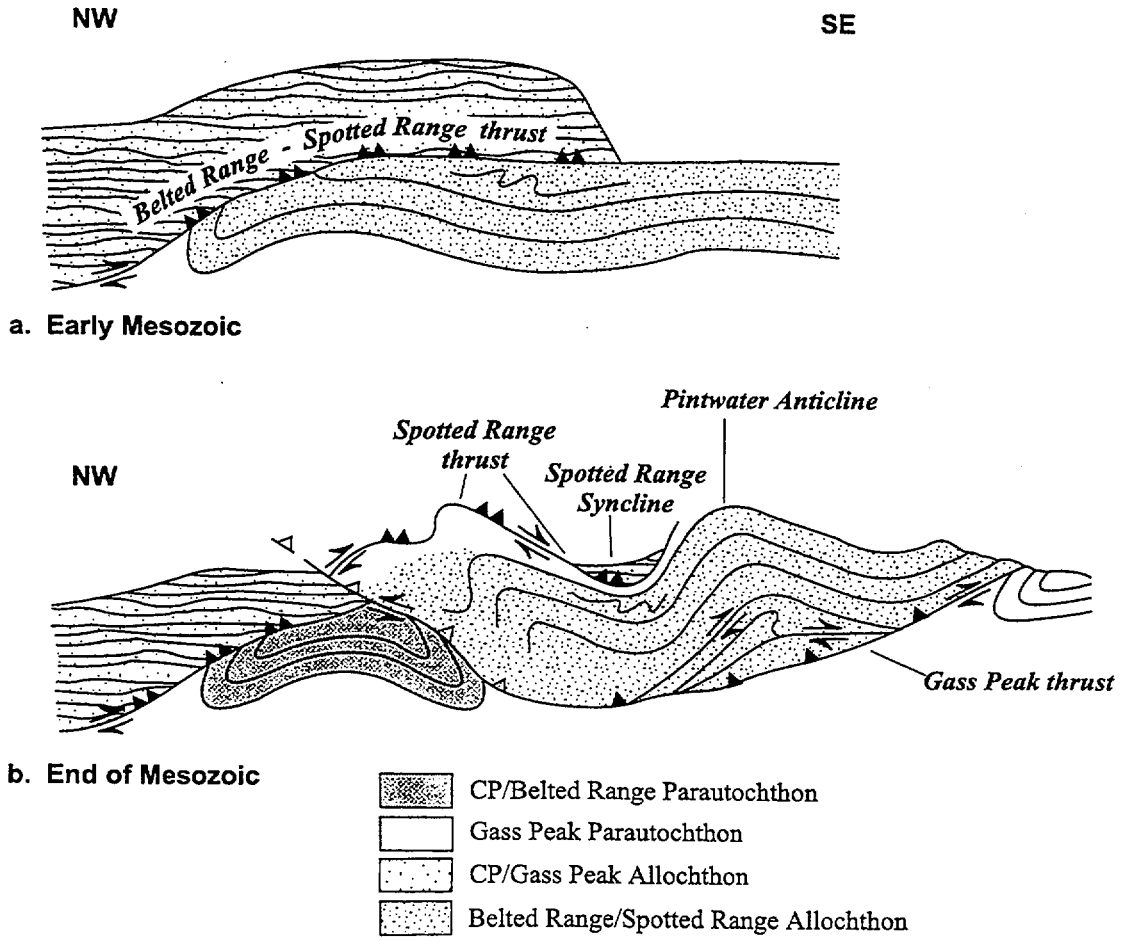
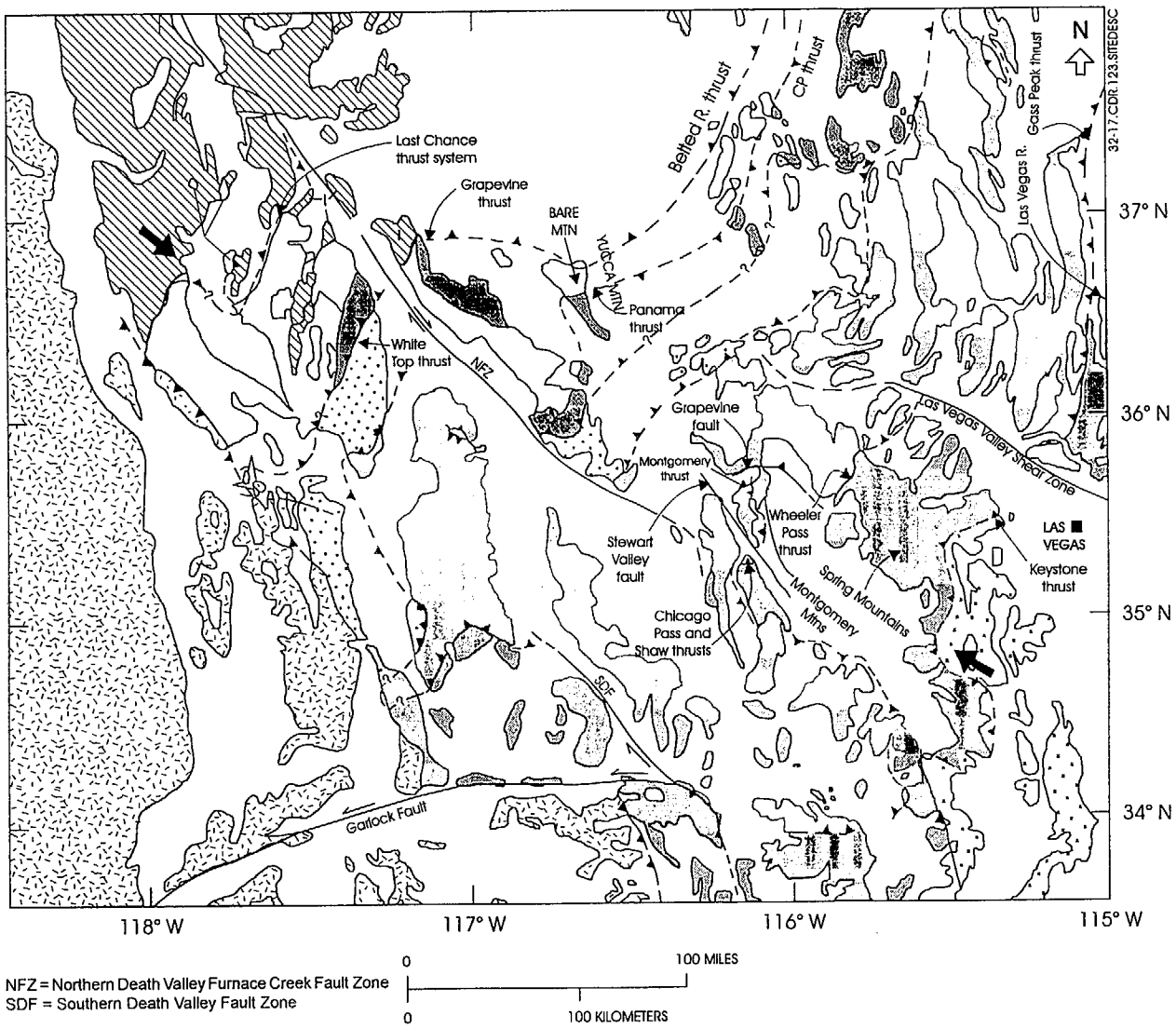
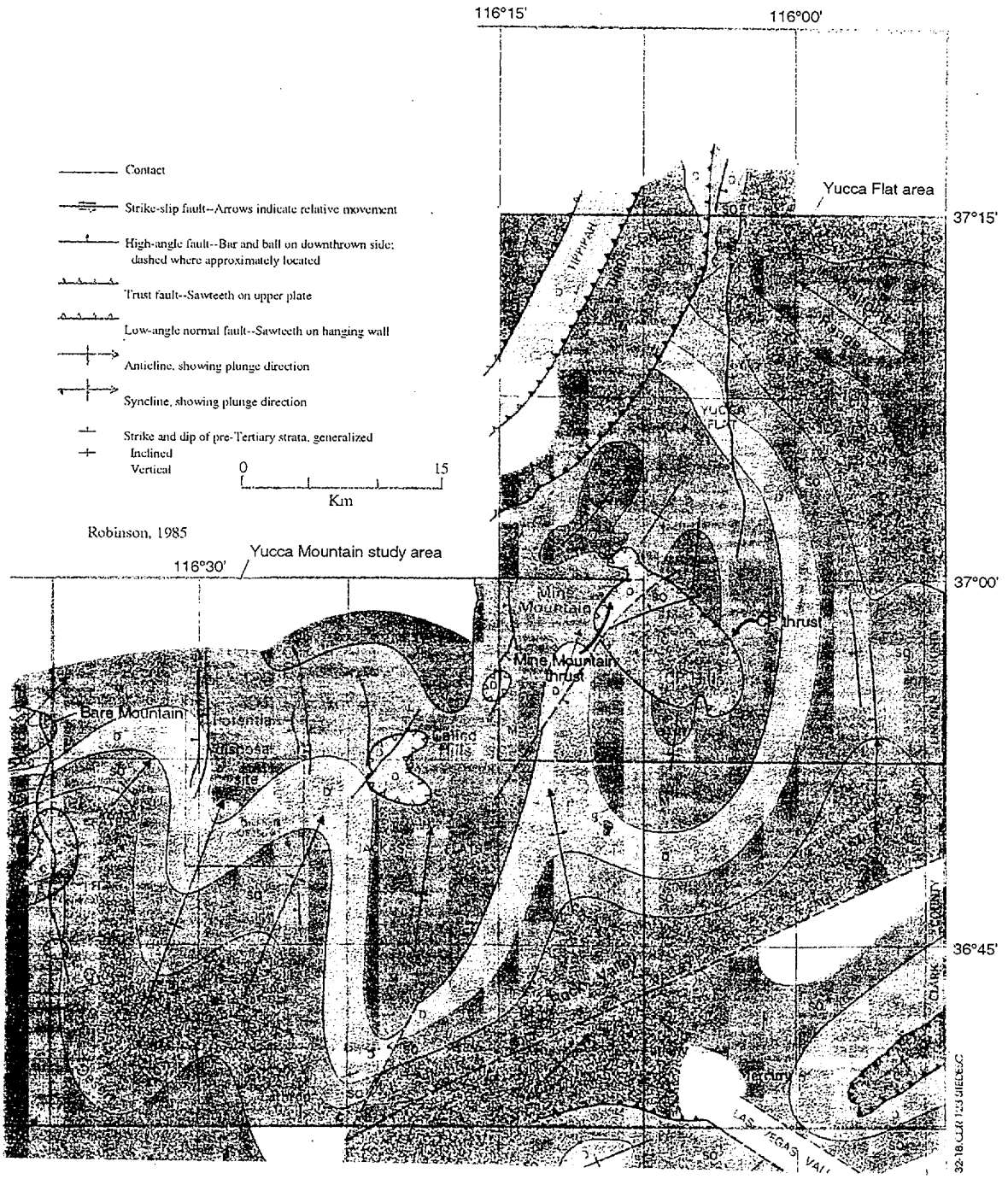


Figure 3.2-16. Schematic Cross-Section Showing Kinematic Relationships Among Thrusts (from Caskey and Schweickert 1992)



NOTE: Bar stipple (along left side of figure) is Sierra Nevada Block; diagonal rule is rocks above the Last Chance thrust; no pattern is rocks below the Last Chance and White Top thrusts; dark grey is rocks above the White Top thrust; dot stipple is rocks below the White Top thrust; light grey is rocks above the Wheeler Pass, Gass Peak, Chicago Pass, and Shaw thrusts; medium grey is rocks between the Wheeler Pass and Keystone thrusts; and x-pattern (lower right part of figure) is rocks below the Keystone thrust.

Figure 3.2-17. Correlative Thrusts of the Yucca Mountain Setting (from Wernicke, Snow et al. 1988; Burchfiel, Hamill et al. 1983)



Legend:

Proterozoic (P, brown)	Cambrian (C, pink)	Siluro-Ordovician (SO, green)
Devonian (D, yellow)	Mississippian (M, blue)	Permian-Pennsylvanian (PP, purple)

Figure 3.2-18. Region Expressed by Sedimentary Rocks Grouped by Systems (from Robinson 1985)

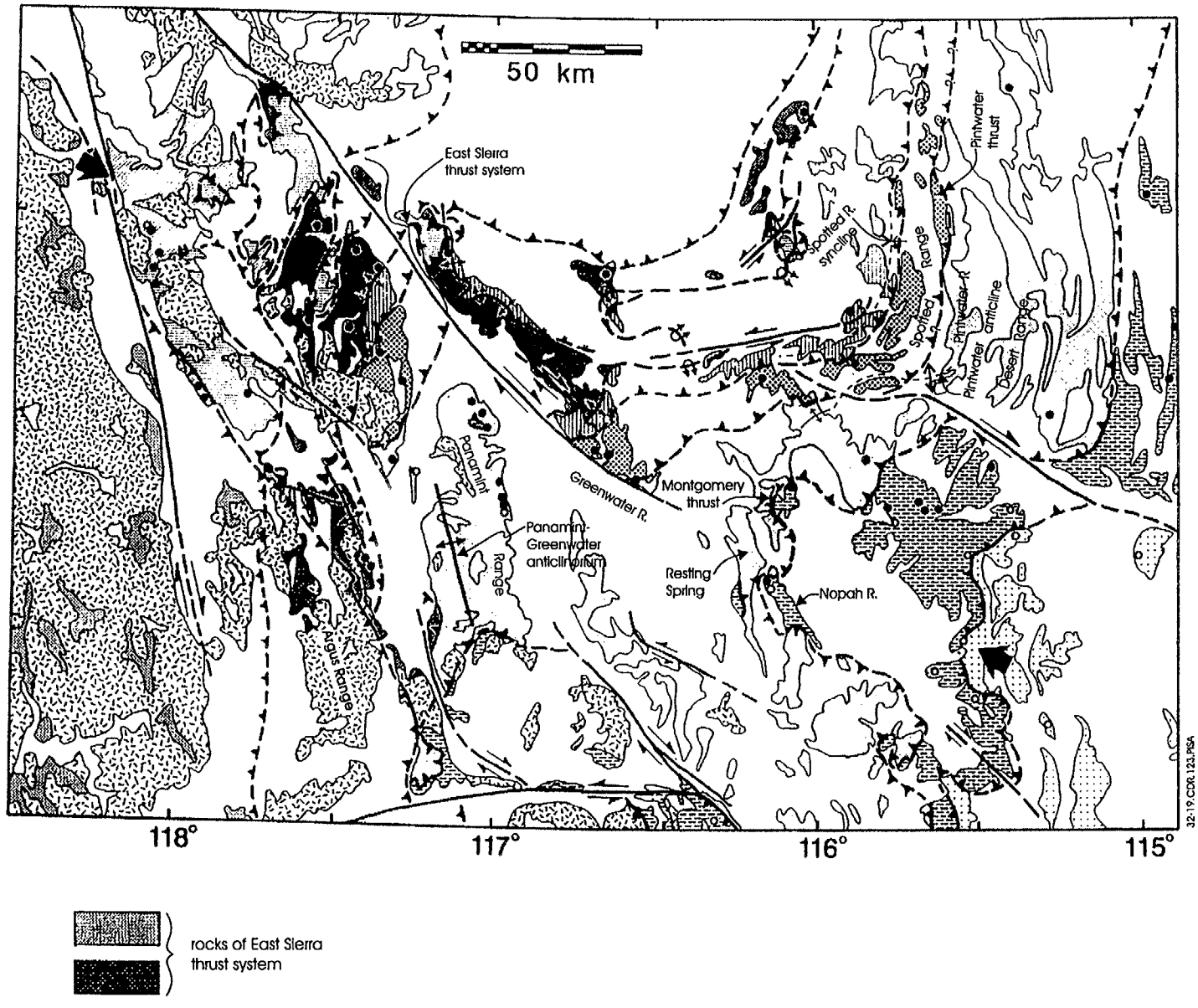


Figure 3.2-19. Broad Folds of the Yucca Mountain Region (from Snow 1992; Burchfiel, Hamill et al. 1983; Caskey and Schweickert 1992)

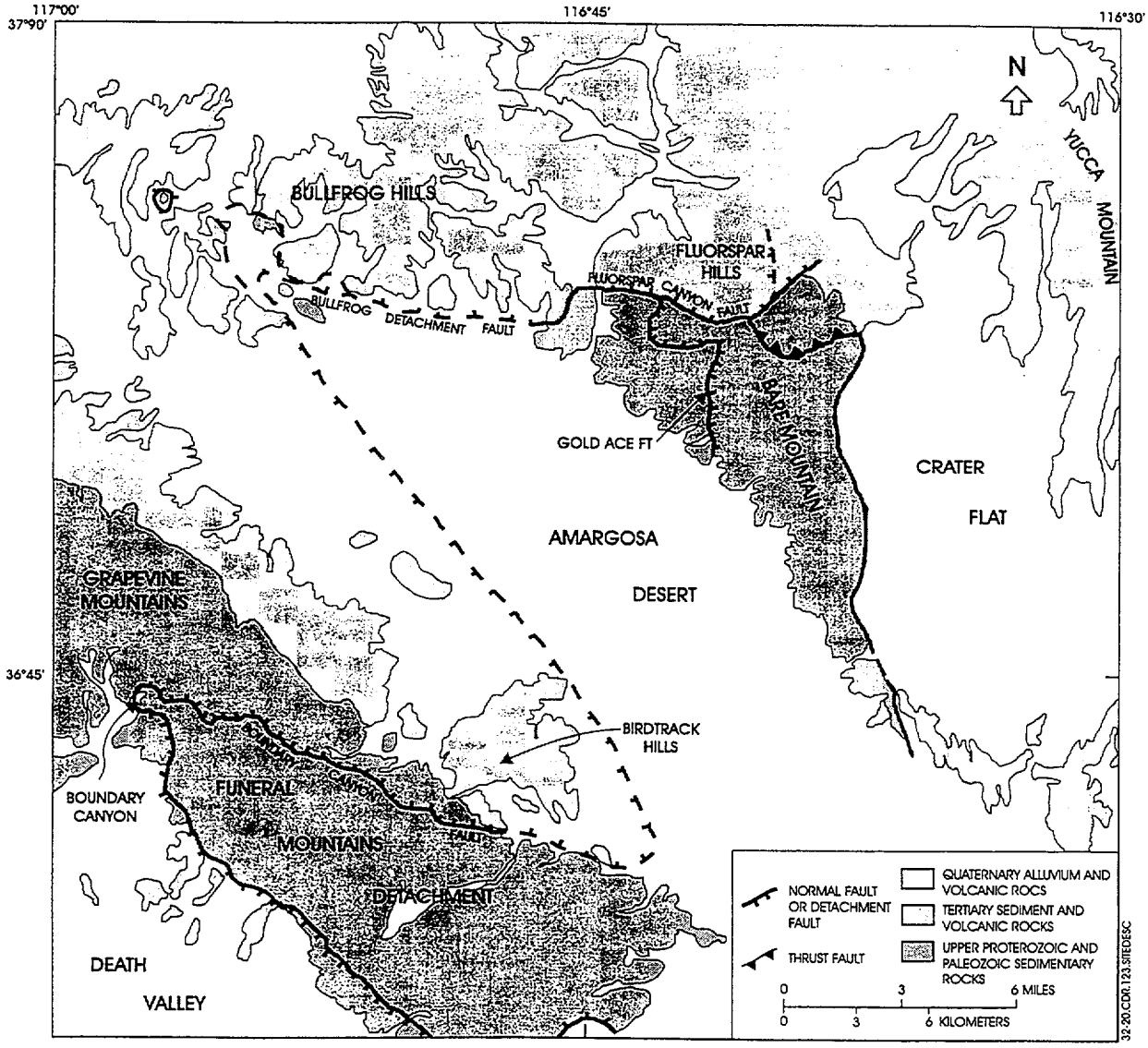
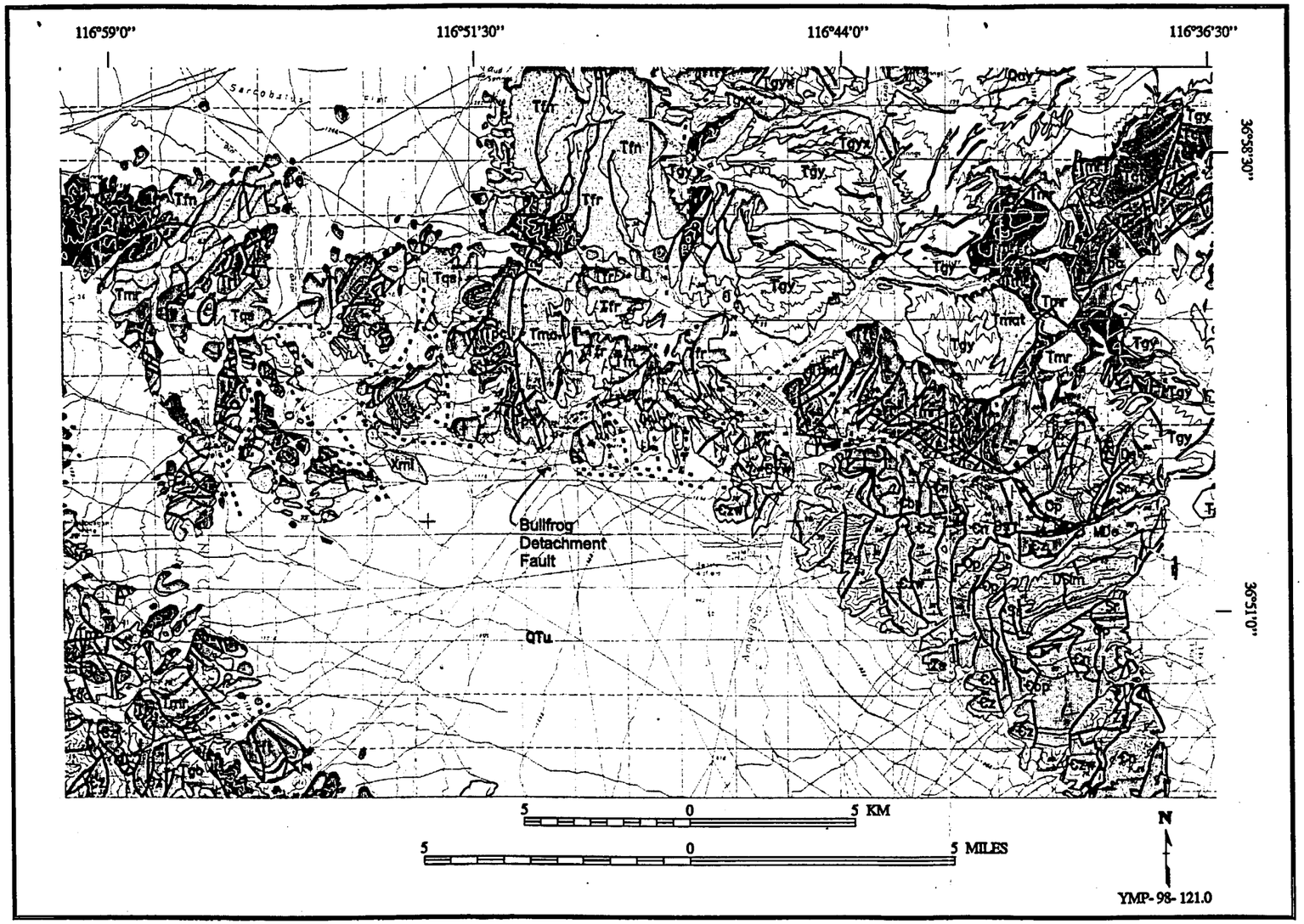


Figure 3.2-20. Funeral Mountains Detachment (from Hoist 1995)



KEY TO LITHOLOGIC SYMBOLS

Qtu	Undifferentiated surficial deposits
Tgy	Younger sedimentary deposits
Tgyx	Younger landslide and sedimentary breccias
Tfu	Upper Fortymile rhyolite lavas
Tfn	Trachyte of Donovan Mountain
Tly	Younger intrusive rocks
Tfr	Rhyolite of Rainbow Mountain
Tma	Ammonia Tanks Tuff
Tmat	Rhyolites of Tannenbaum Hill/Buried Canyon
Tmr	Rainier Mesa Tuff
Tmrf	Rhyolite of Fluorspar Canyon
Tpc	Tiva Canyon Tuff
Tcr	Rhyolites in the Crater Flat Group
Tct	Tram Tuff
Tgo	Rocks of Pavits Spring and older synvolcanic sedimentary deposits, undivided
Trl	Lithic Ridge Tuff
Trr	Rhyolite of Picture Rock
Tqs	Tuff of Sleeping Butte
MDe	Eleana Formation
Ds	Simonson Dolomite
Sr	Roberts Mountain Formation
Op	Pogonip Group
Cn	Nopah Formation
Cbp	Papoose Lake Member
Cz	Zabriskie Quartzite
CZw	Wood Canyon Formation
Zs	Stirling Quartzite
Xml	Metamorphic and intrusive rocks

APERTURE CARD
Also Available on Aperture Card

32-21.CDR.123.SITEDES

Figure 3.2-21. Bullfrog Hills Detachment (from Sawyer, D.A., Wahl et al. 1995)

 9902040045-06

INTENTIONALLY LEFT BLANK

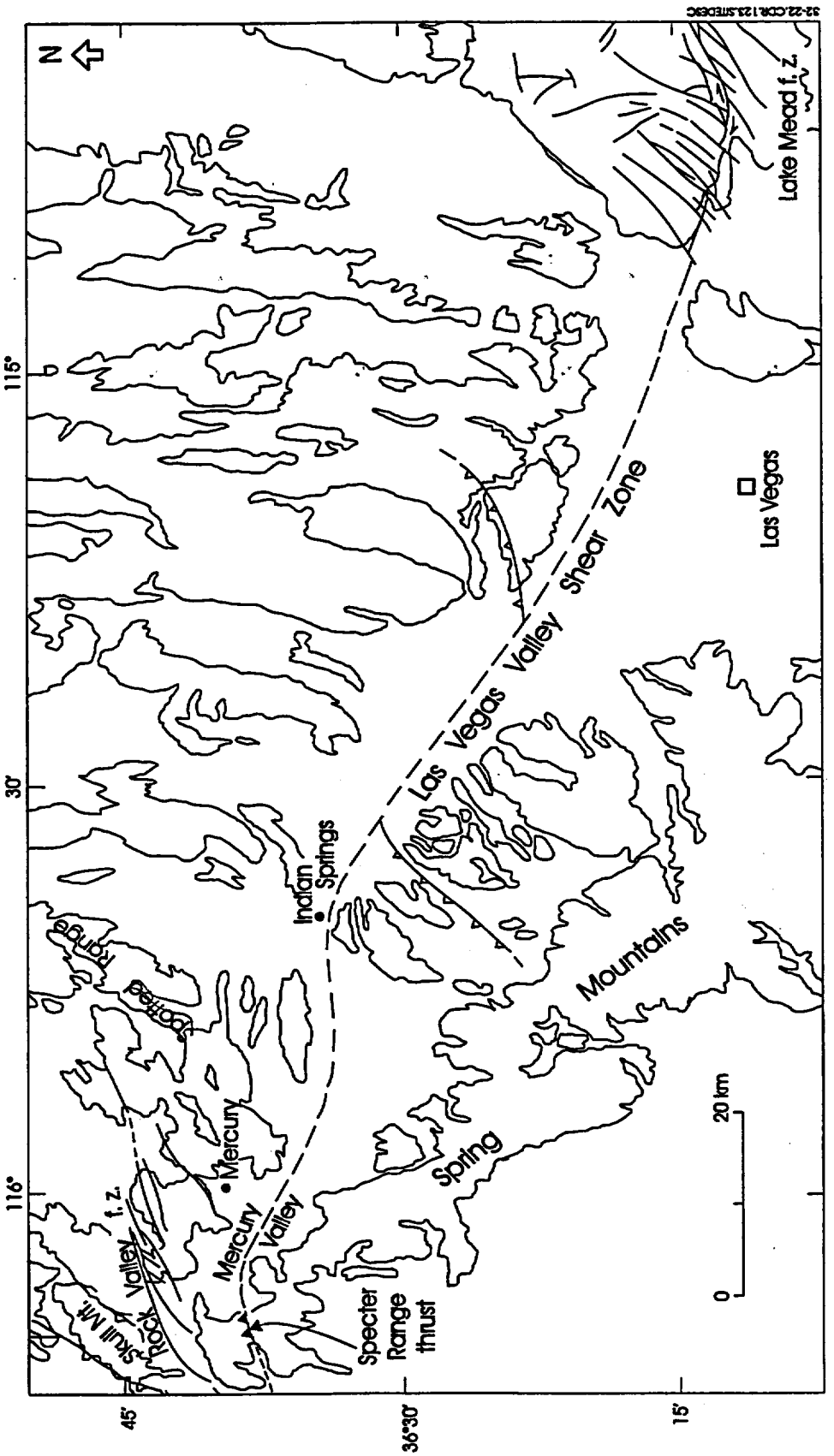


Figure 3.2-22. Las Vegas Valley Shear Zone (Burchfiel 1965)

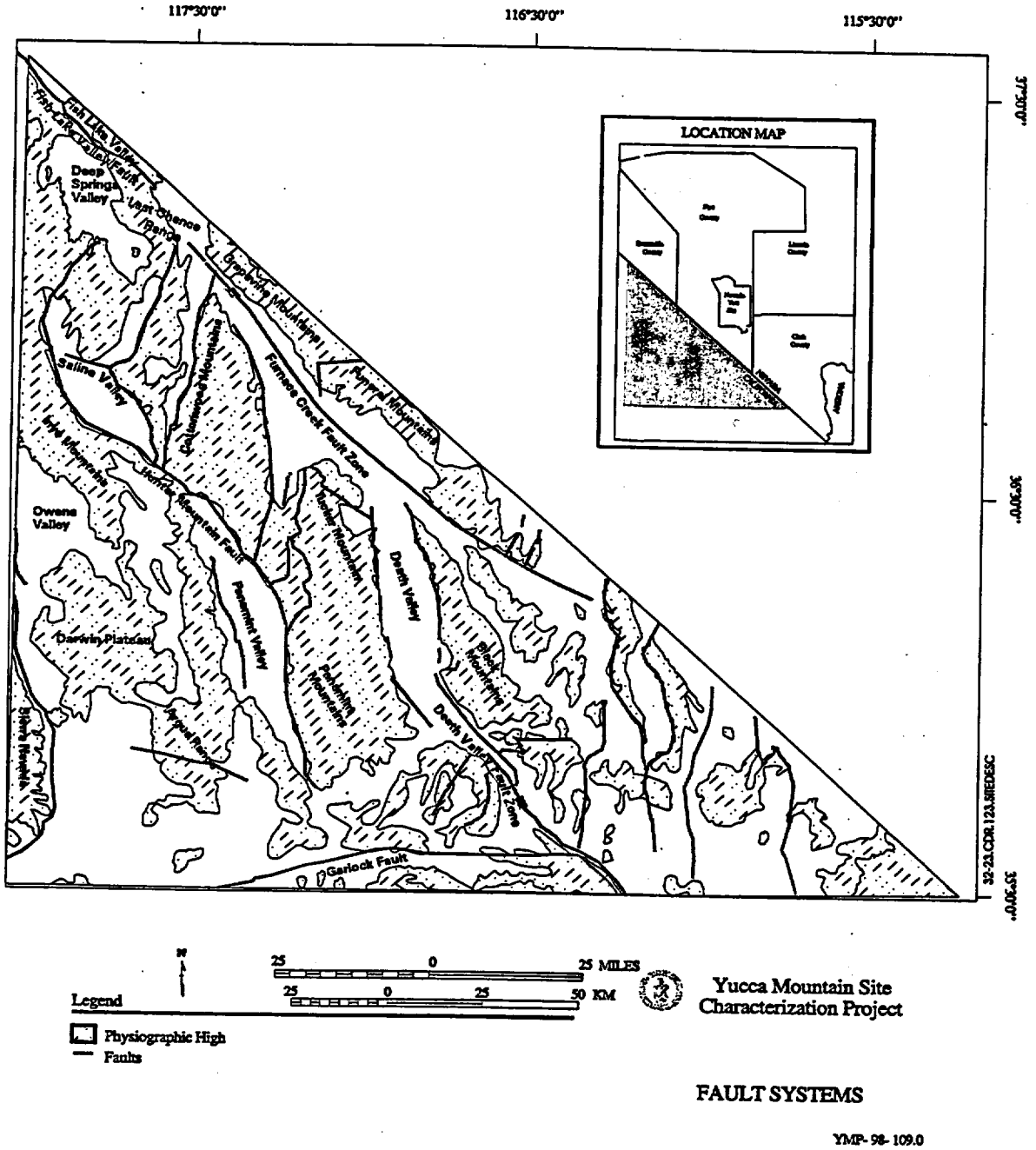
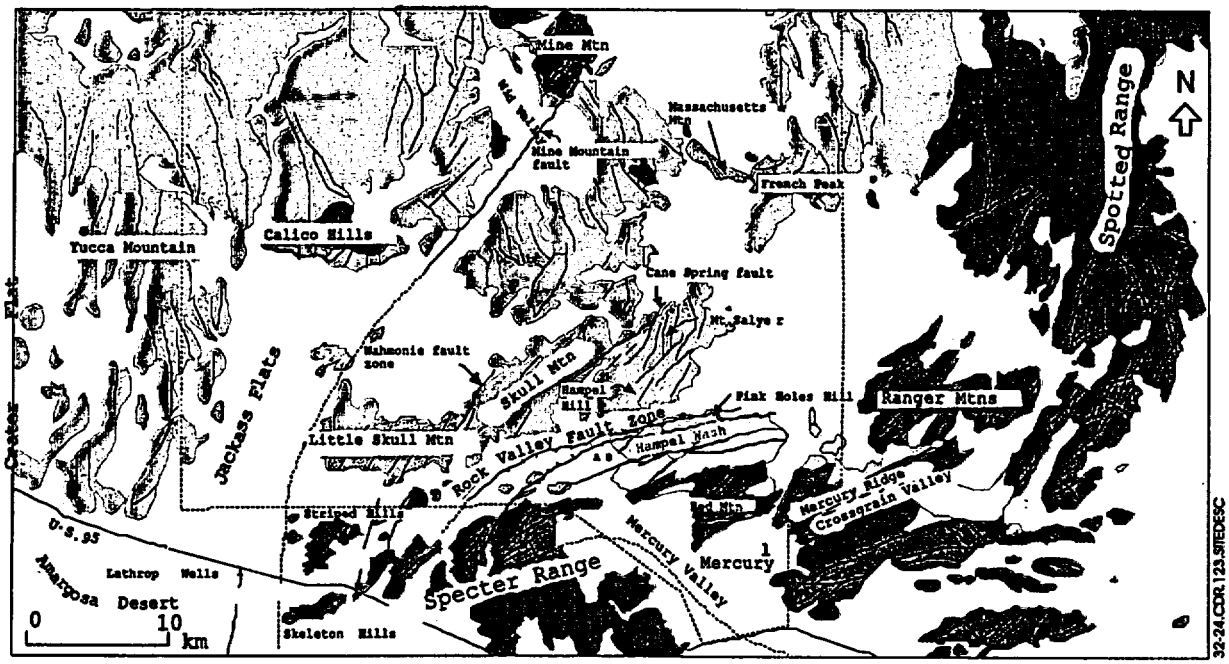


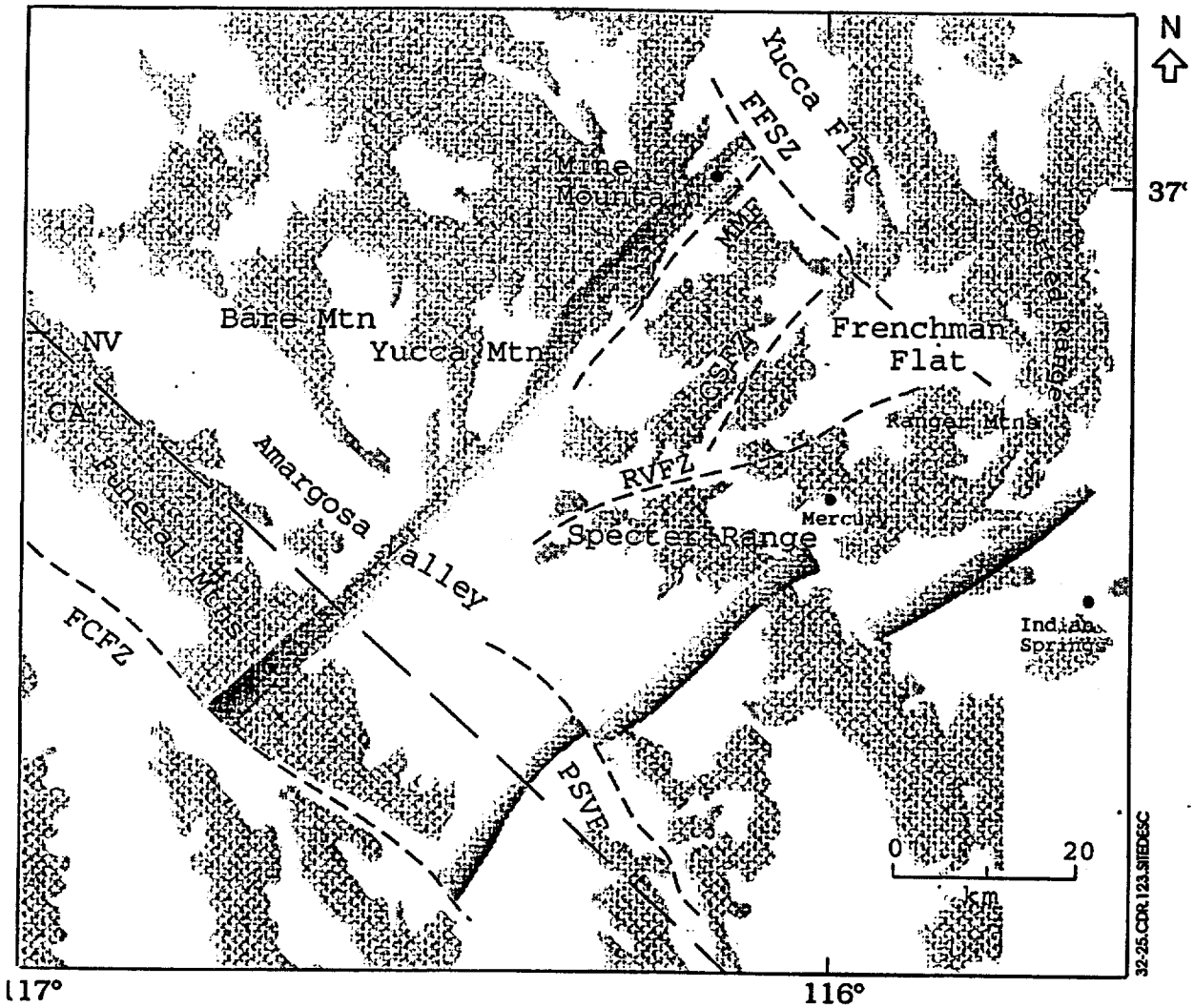
Figure 3.2-23. Major Faults of the Death Valley Extended Area Inyo-Mono Domain (from Wernicke, Hodges et al. 1986)



EXPLANATION

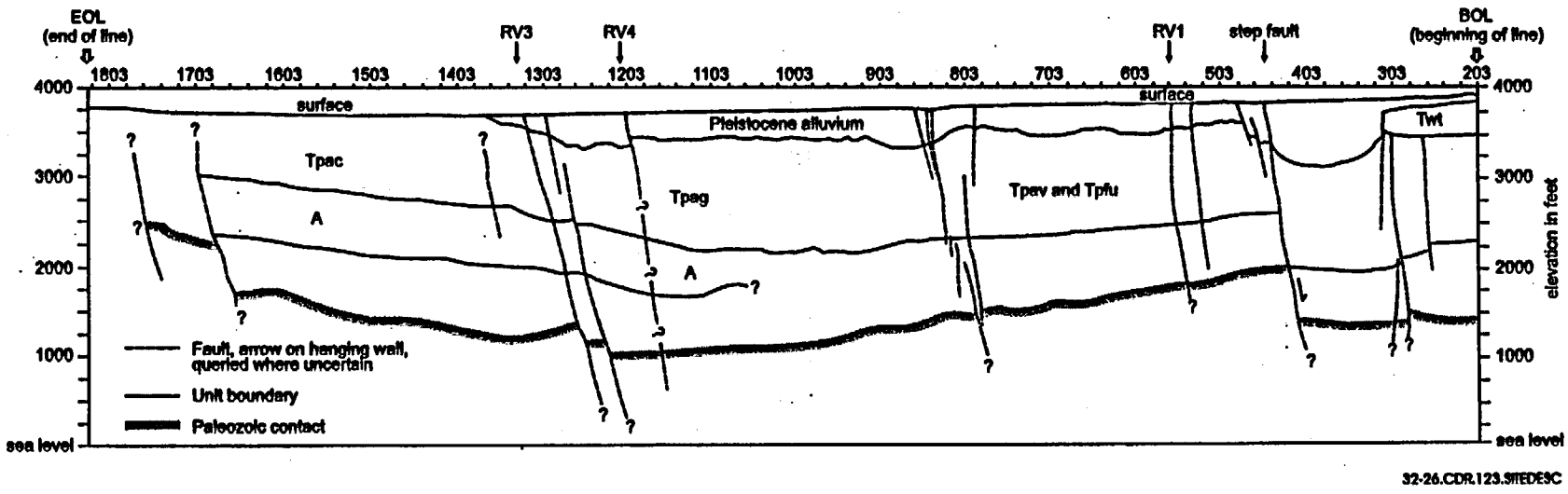
- Nevada Test Site perimeter
- fault; location and extent generalized; dash on down side
- locations of trenches (Yount et al. 1987) on fault trace (A B)
- Las Vegas Valley shear zone
- Holocene and Pleistocene surficial deposits
- Tertiary (chiefly upper Miocene) volcanic rocks
- Tertiary (middle to upper) volcanics and volcaniclastic sediments, fluvial and lacustrine rocks of Pavits Spring (Hinrichs 1968)
- Upper Oligocene lacustrine carbonates, marls, lesser tuffs, and roundstone gravels (rocks of Winapi Wash)
- Paleozoic to Precambrian undifferentiated; chiefly carbonates, lesser quartzites and shales

Figure 3.2-24. General Geology of the Rock Valley Fault Zone



CSFZ = Cane Spring fault zone
FCFZ = Furnace Creek fault zone
MMF = Mine Mountain fault zone
PSVF = Pahrump-Stewart Valley fault zone
RVFZ = Rock Valley fault zone
YFSZ = Yucca Frenchman shear zone

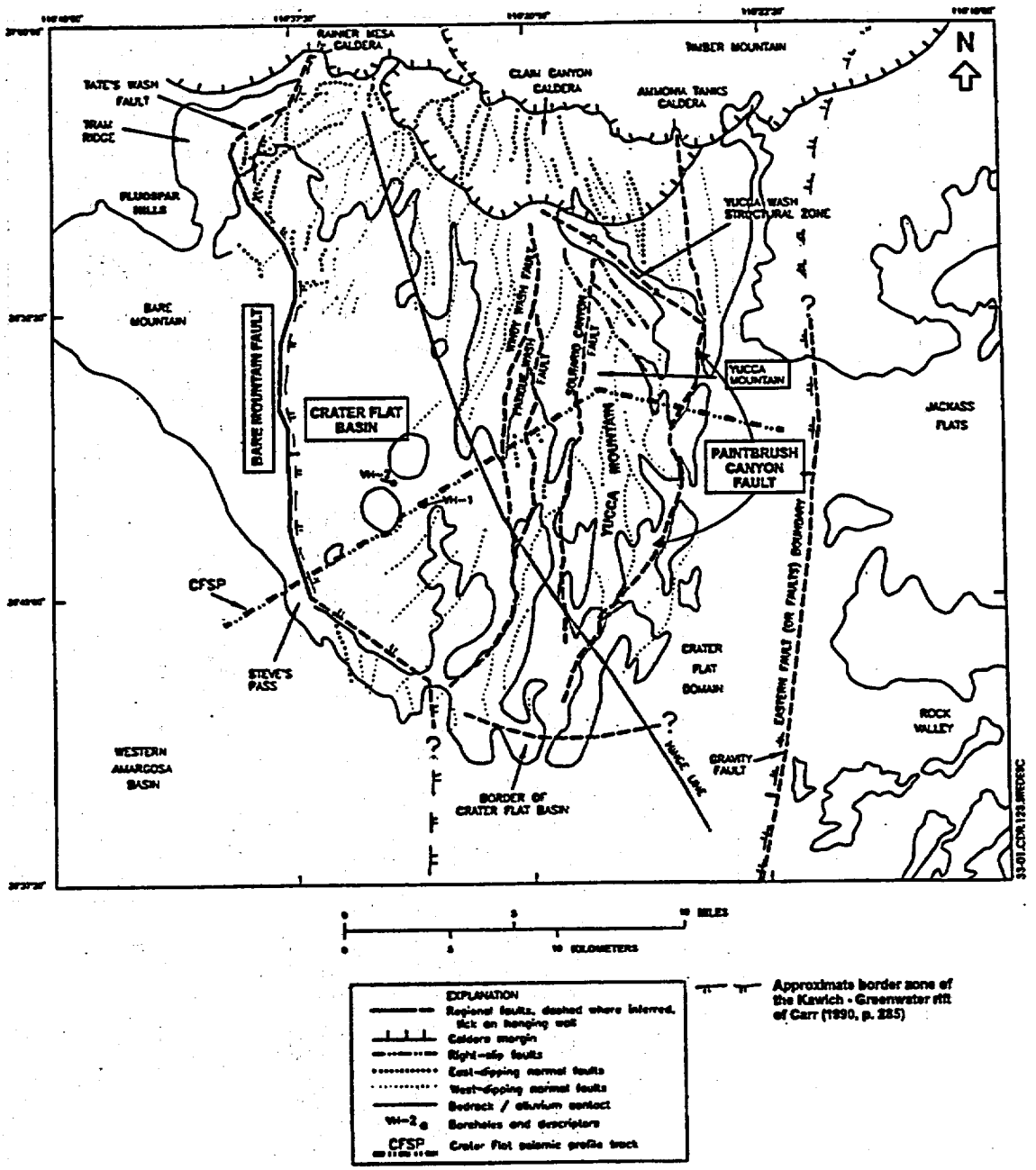
Figure 3.2-25. Spotted Range-Mine Mountain Structural Zone of Carr, W.J. (1984) Depicted by Northeast-Trending Shaded Borders



NOTE: RV1, RV3, and RV4 indicate major fault strands of the Rock Valley fault zone; BOL indicates beginning of line (northern end). Tpac, Tpag, Tpav and Tpfu are submits of Paulite Spring. Twt is the Wahmonie formation, A is the highly reflective part of Tpac, at underlying rock units.

Figure 3.2-26. Interpretation of Seismic Reflection Profile Across Rock Valley (after Whitney and Taylor 1996)

INTENTIONALLY LEFT BLANK



NOTE: The Gravity fault forms the eastern boundry and the Bare Mountain fault forms the western boundary. The Paintbrush Canyon fault is considered to be the eastern limit of the normal regime that characterizes Yucca Mountain.

Figure 3.3-1. The Crater Flat Basin and Its Inferred Bounding Structures

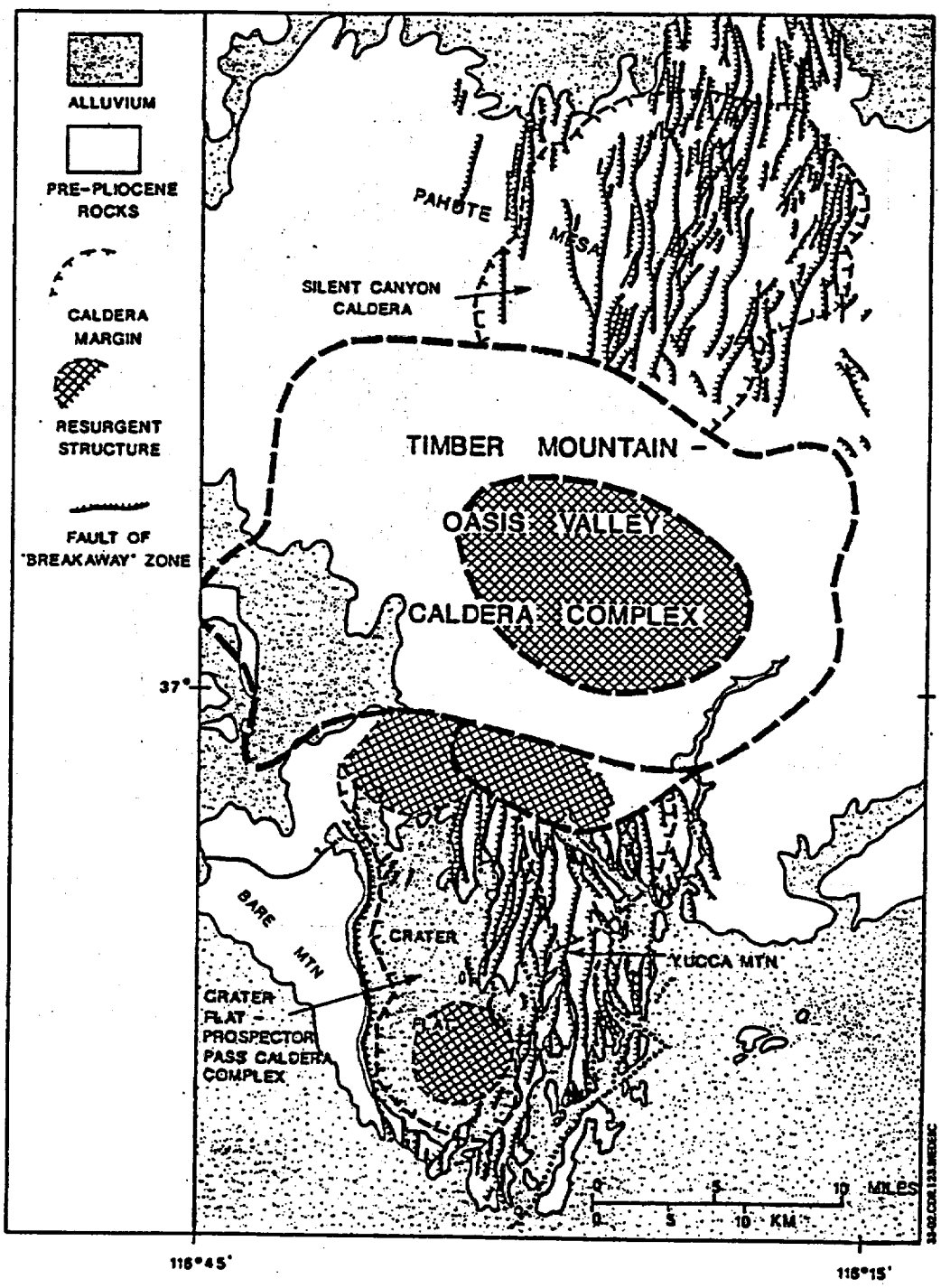
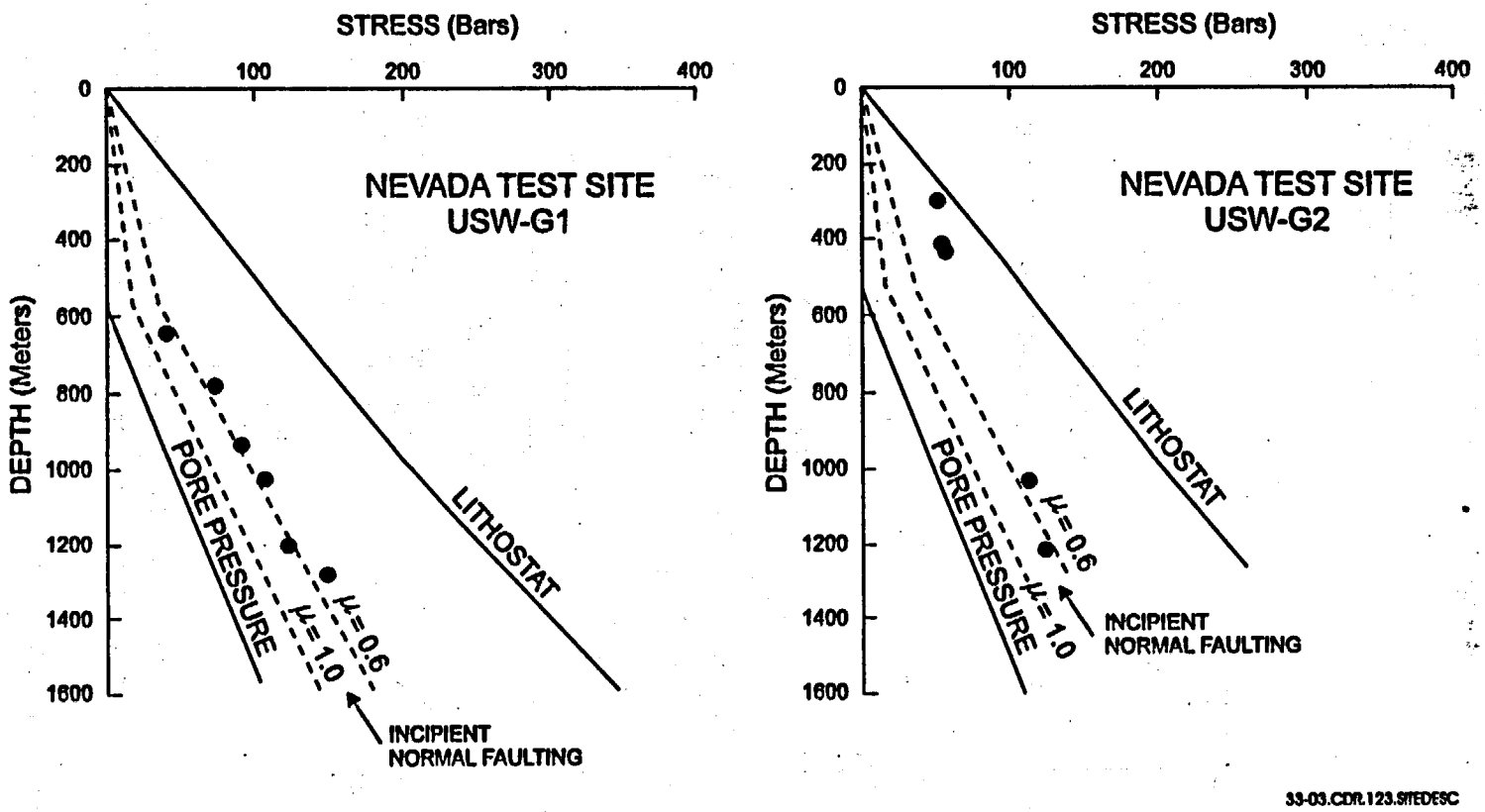


Figure 3.3-2. Coaxial Fault Sets of Yucca Mountain and Pahute Mesa Separated by Caldera Complex

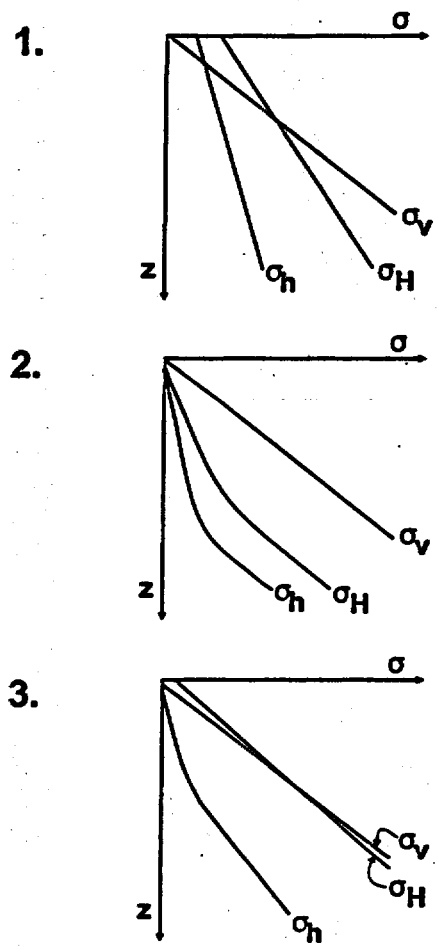


NOTE: Dashed lines show boundaries of fault instability for values of μ 0.6 and 1.0. Faults are stable for stress values to the right of the dashed lines. Note that 3 values fall close to the stability boundary for normal faults that have a typical μ=0.6 (Byerlee 1978). From Figure 40, USGS 1984.

Figure 3.3-3. Least Principal Compressive Stress (σ_3) Values, Shown by Black Dots, Measured from Boreholes USW-G1 and USW-G2 at Yucca Mountain

Model Of Stress Distribution With Depth

$$R = \frac{\sigma_1 - \sigma_2}{\sigma_1 - \sigma_3} = \frac{\sigma_v - \sigma_H}{\sigma_v - \sigma_h}$$



1. R highly variable

$0 \leq r \leq 1$

Vetter and Ryall Model (1983)

2. At some shallow depth R becomes approximately constant

R > 0.5

Yucca Mountain Hydrofrac Data (Stock, J.M. et al. 1985)

3. At some shallow depth R becomes approximately constant

R ≈ 0.0 - 0.3

Hypothetical model accounting for the existence of both strike-slip and normal fault events throughout the seismogenic crust.

33-04.CDR.123.SITEDESC

NOTE: Shows how vertical stress (σ_v) and horizontal stress (σ_h,σ_H) components might vary with crustal depth (z); model 3 shows σ_v and σ_H to be axially symmetric; R is the stress ratio.

Figure 3.3-4. Stress Versus Depth Models (from Rogers, A.M., Harmsen, Meremonte 1987, Figure 43)

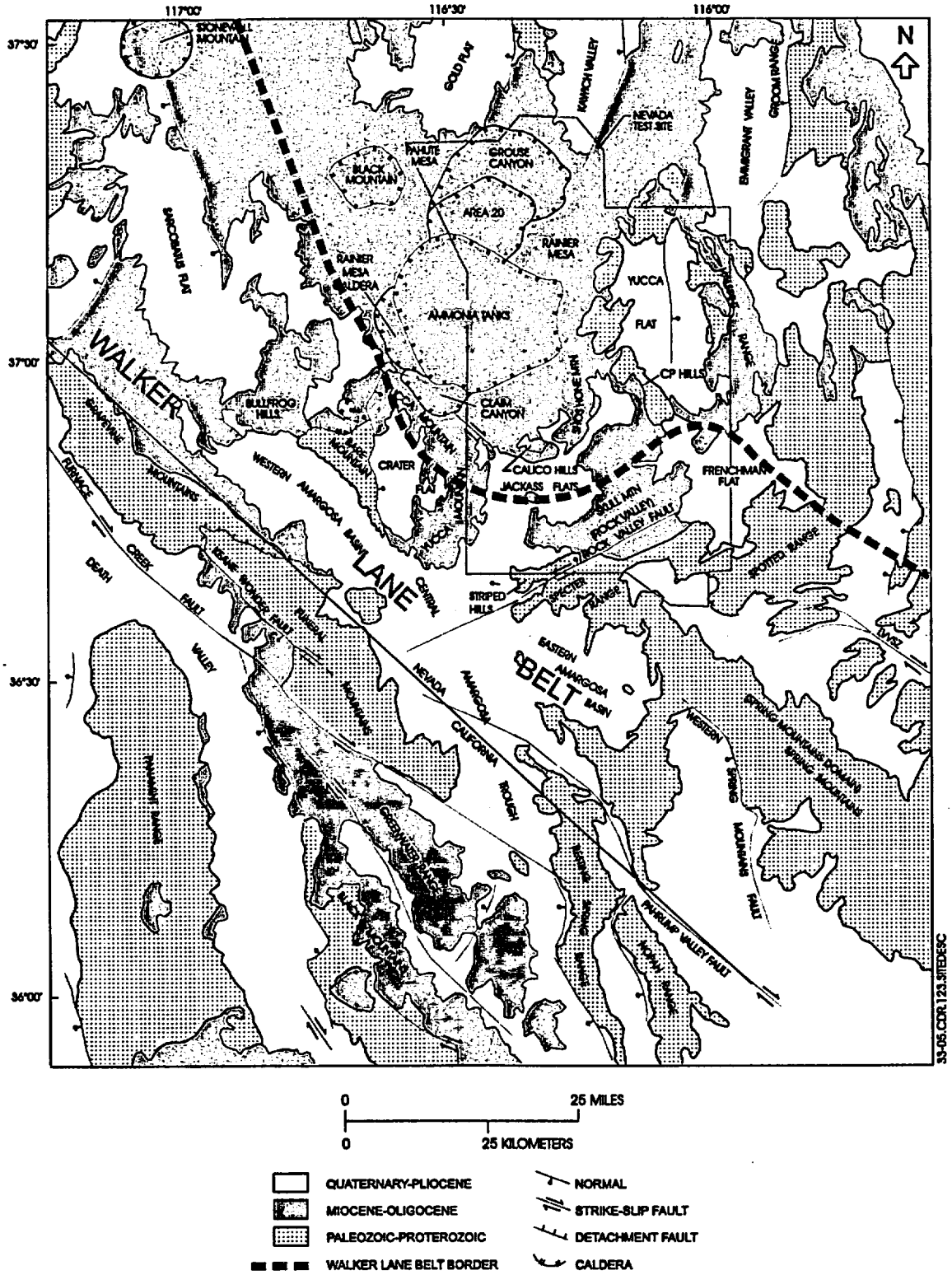
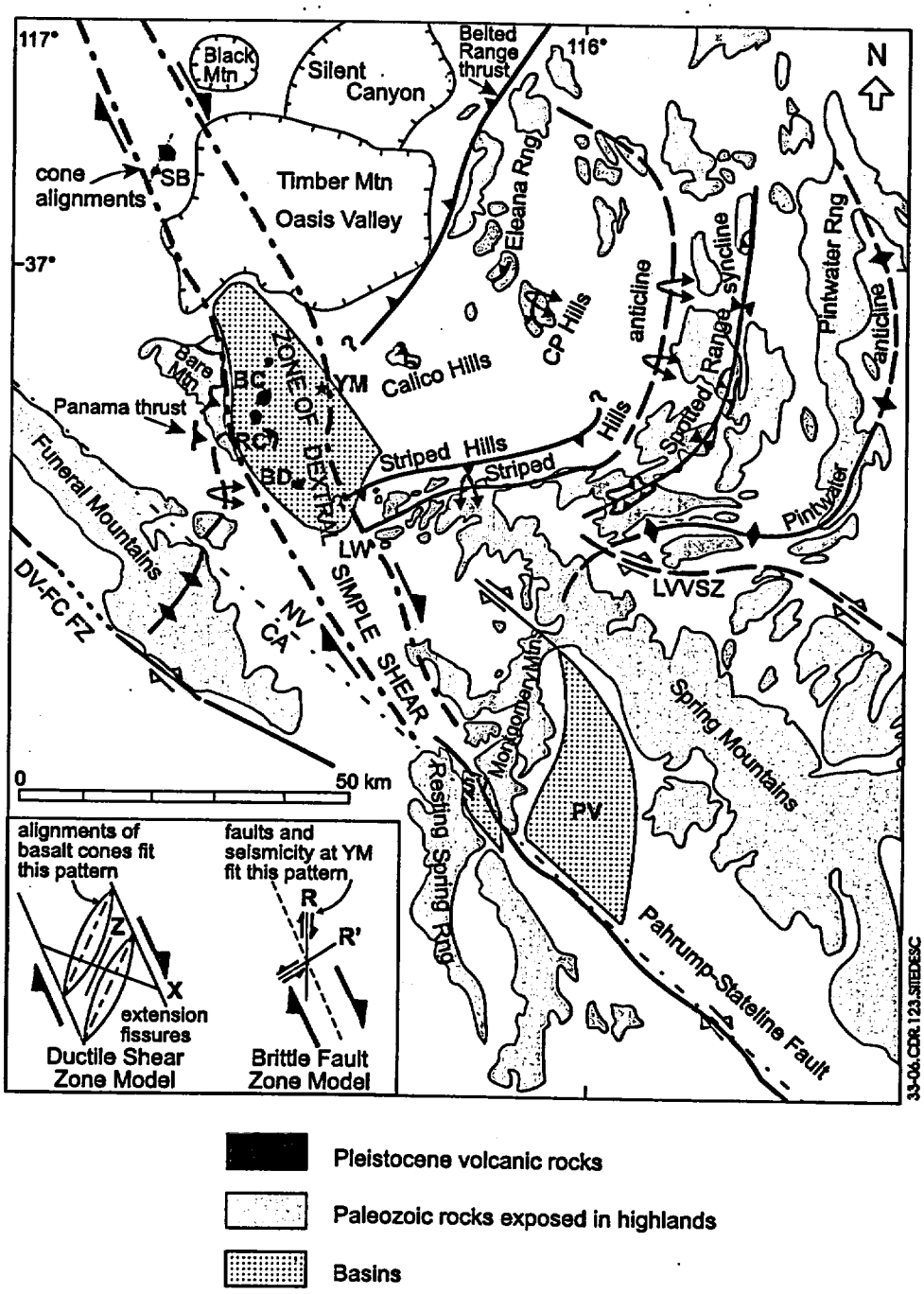


Figure 3.3-5. Eastern Border of Walker Lane (heavy dashed line) (passes through Yucca Mountain as interpreted by Minor, Hudson et al. 1997, Figure 1)



NOTE: BC=Black Cone, LVVSZ=Las Vegas Valley Shear Zone, PV=Pahrump Valley, RC=Red Cone, SB=Sleeping Butte, and YM=Yucca Mountain.

Figure 3.3-6. The Amargosa Desert Fault System (zone of dextral simple shear) (as Inferred by Schweickert and Lahren 1997, Figure 1)

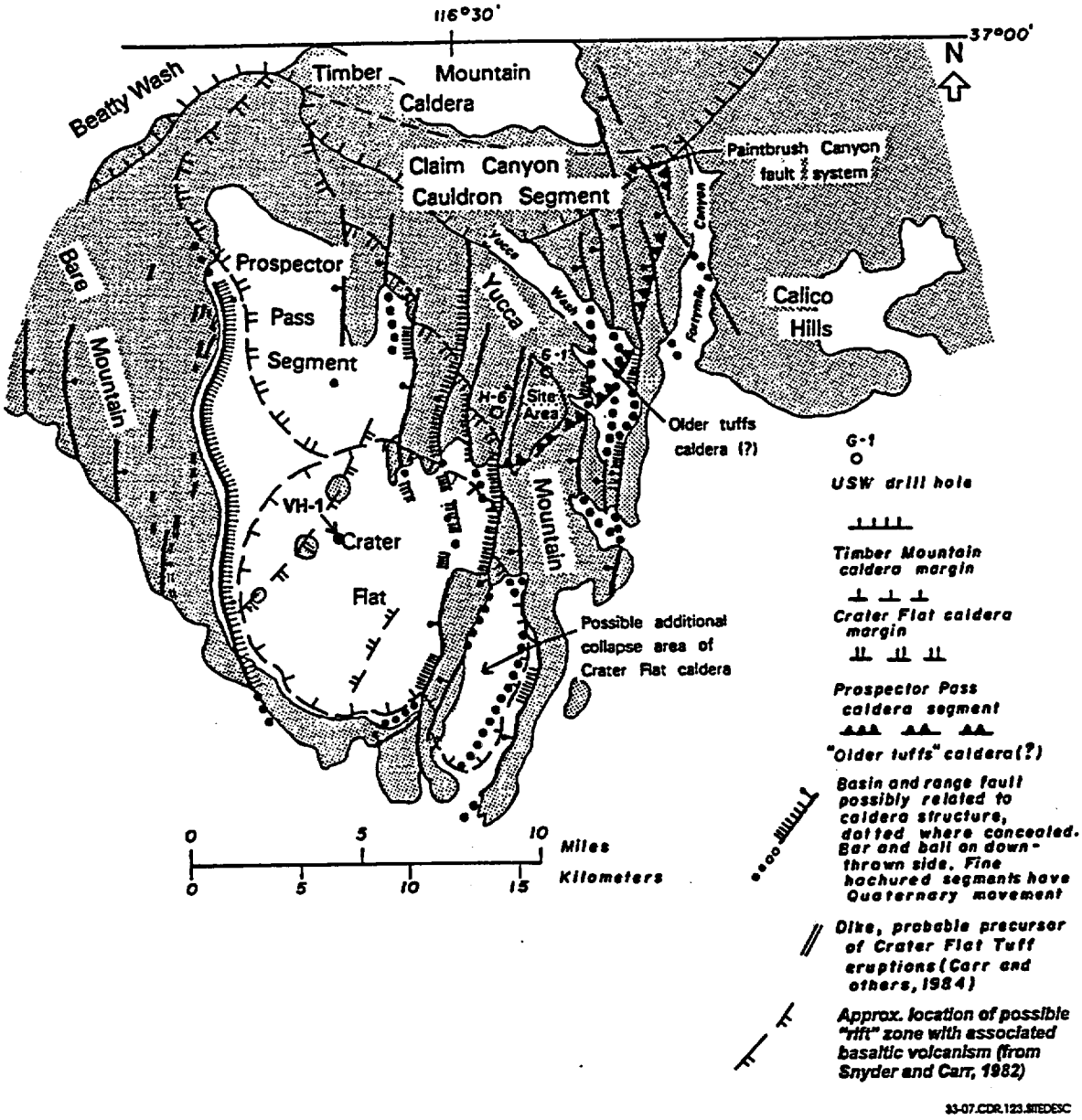
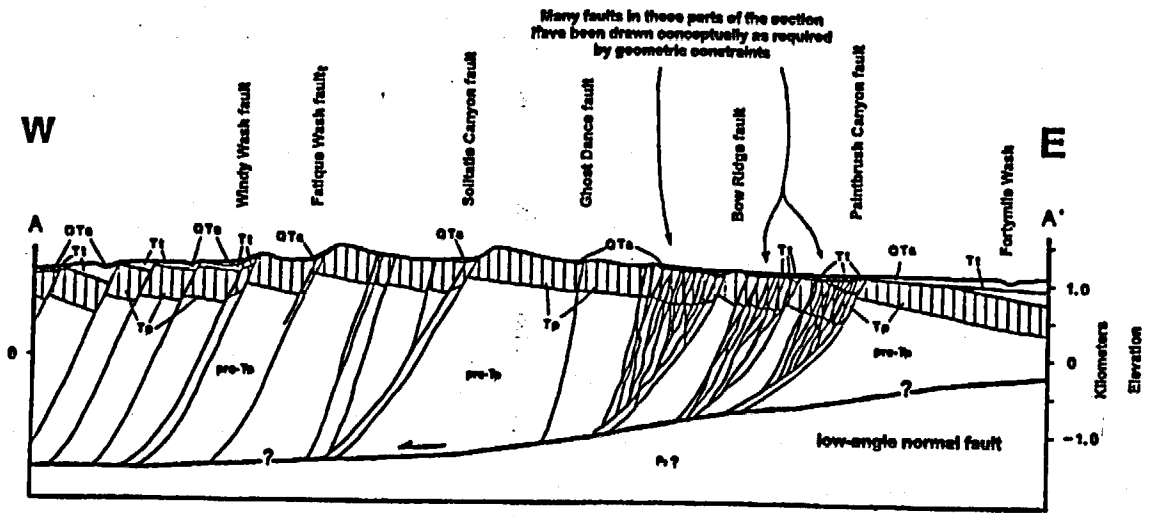
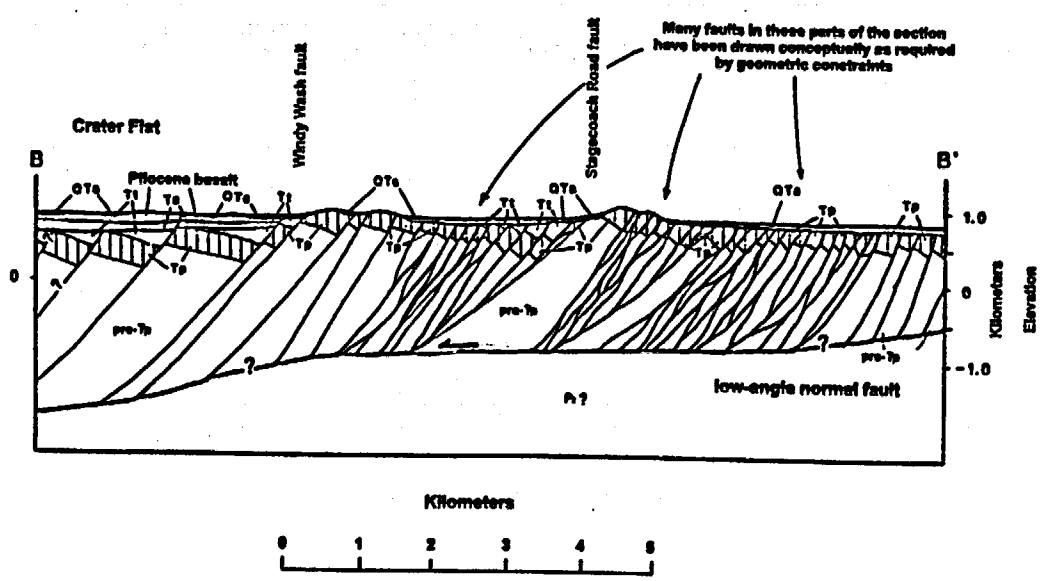


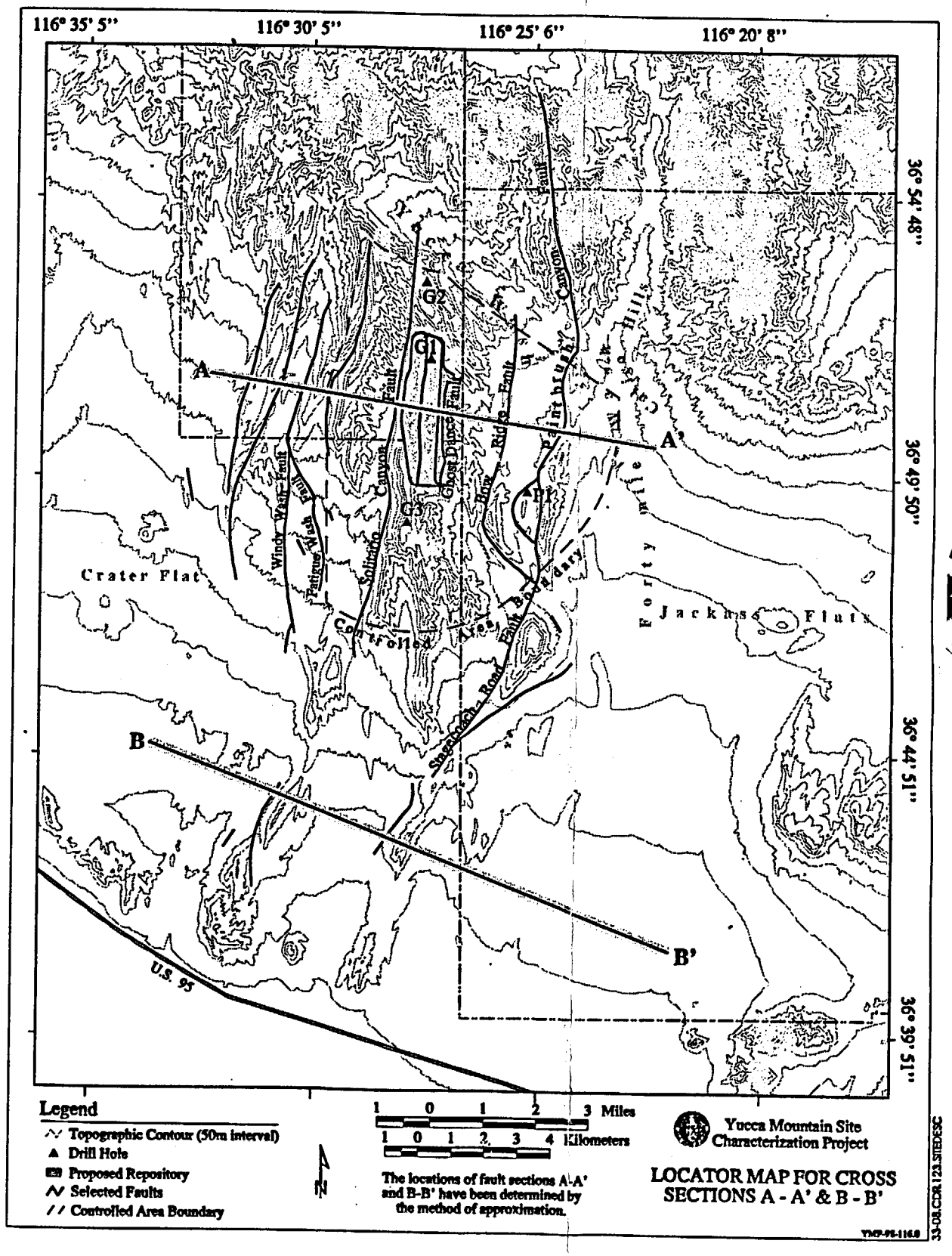
Figure 3.3-7. Size and Extent of Inferred Calderas Beneath Crater Flat and Yucca Mountain (after Carr, W.J. 1984)

INTENTIONALLY LEFT BLANK





Tp	Paintbrush Tuff
QTa	Quaternary and Tertiary alluvial deposits
Ta	Tertiary alluvial deposits
pre-Tp	Tertiary rocks predating the Paintbrush Tuff
Tt	Timber Mountain Tuff (post-Paintbrush Tuff unit)
Pz?	Paleozoic(?) rocks



APERTURE CARD
Also Available on Aperture Card

Figure 3.3-8. Cross Sections of Yucca Mountain Showing Inferred Shallow Detachment Fault (after Scott, R.B. 1990)

9902040045-07

INTENTIONALLY LEFT BLANK

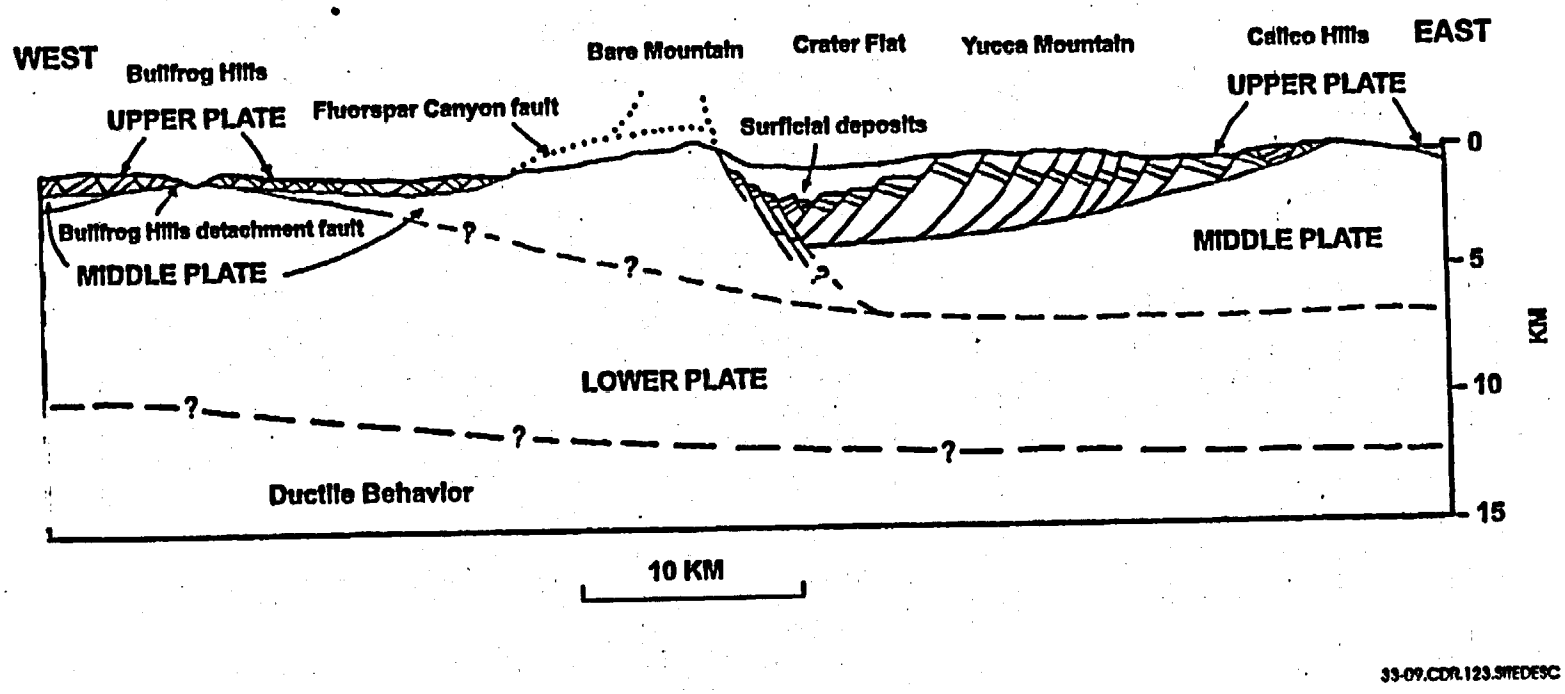


Figure 3.3-9. Conceptual Cross-Section Showing Inferred Levels of Detachment Beneath Yucca Mountain (after Scott, R.B. 1990)

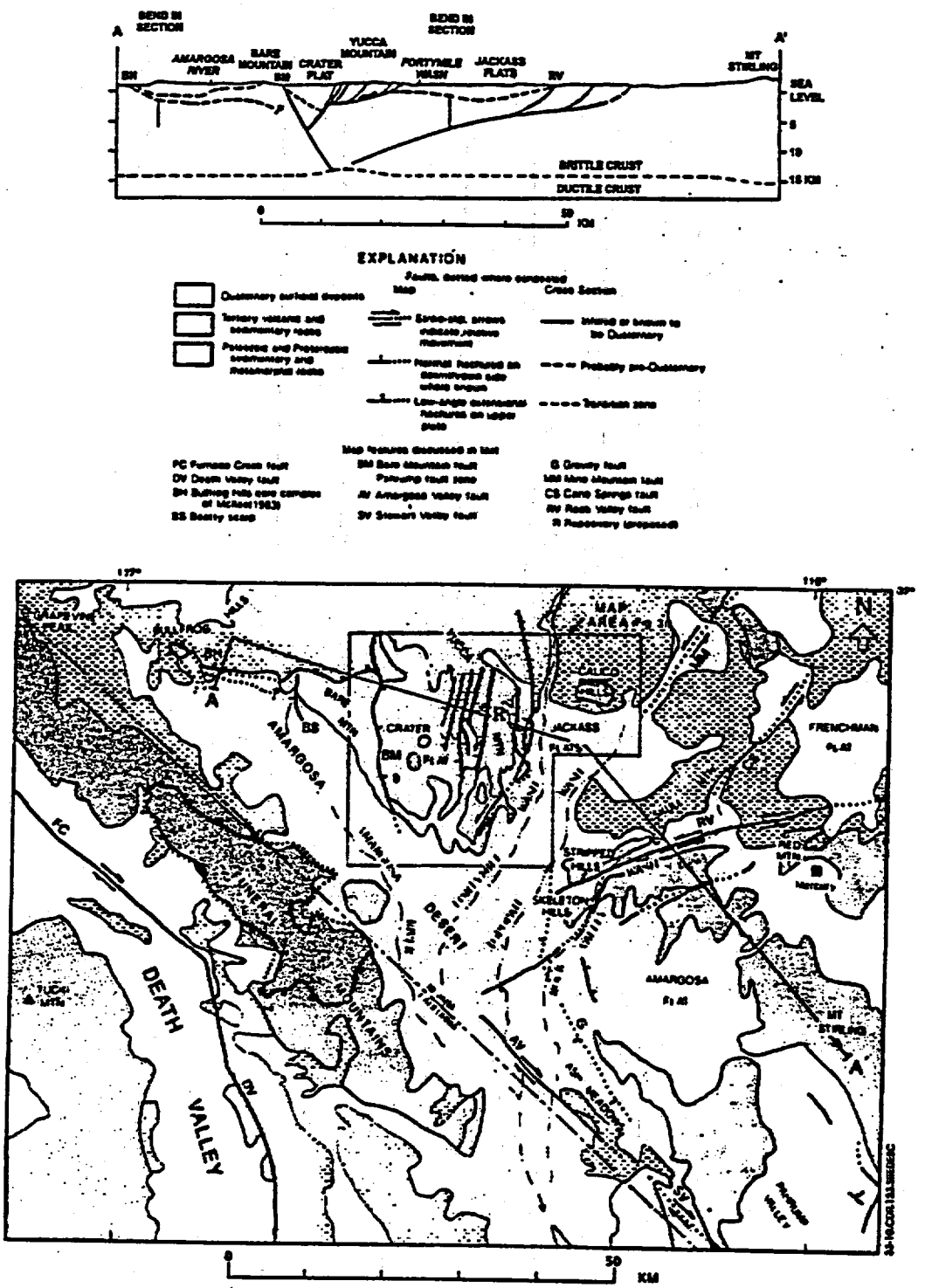


Figure 3.3-10. Detachment Structures Inferred Near Yucca Mountain (after Fox and Carr 1989)

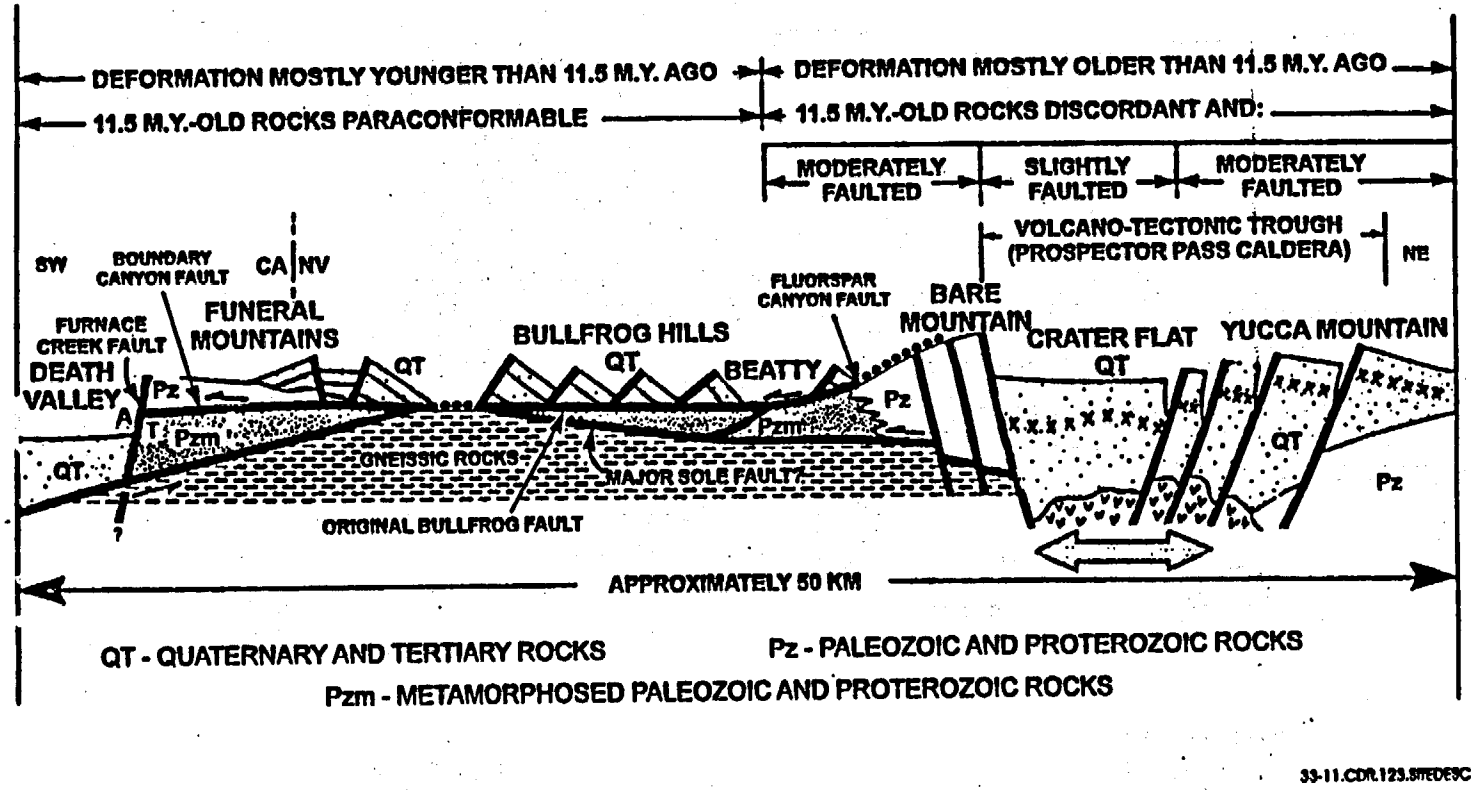


Figure 3.3-11. Model of Crustal Extension from Death Valley to Yucca Mountain (after Carr, W.J. 1990)

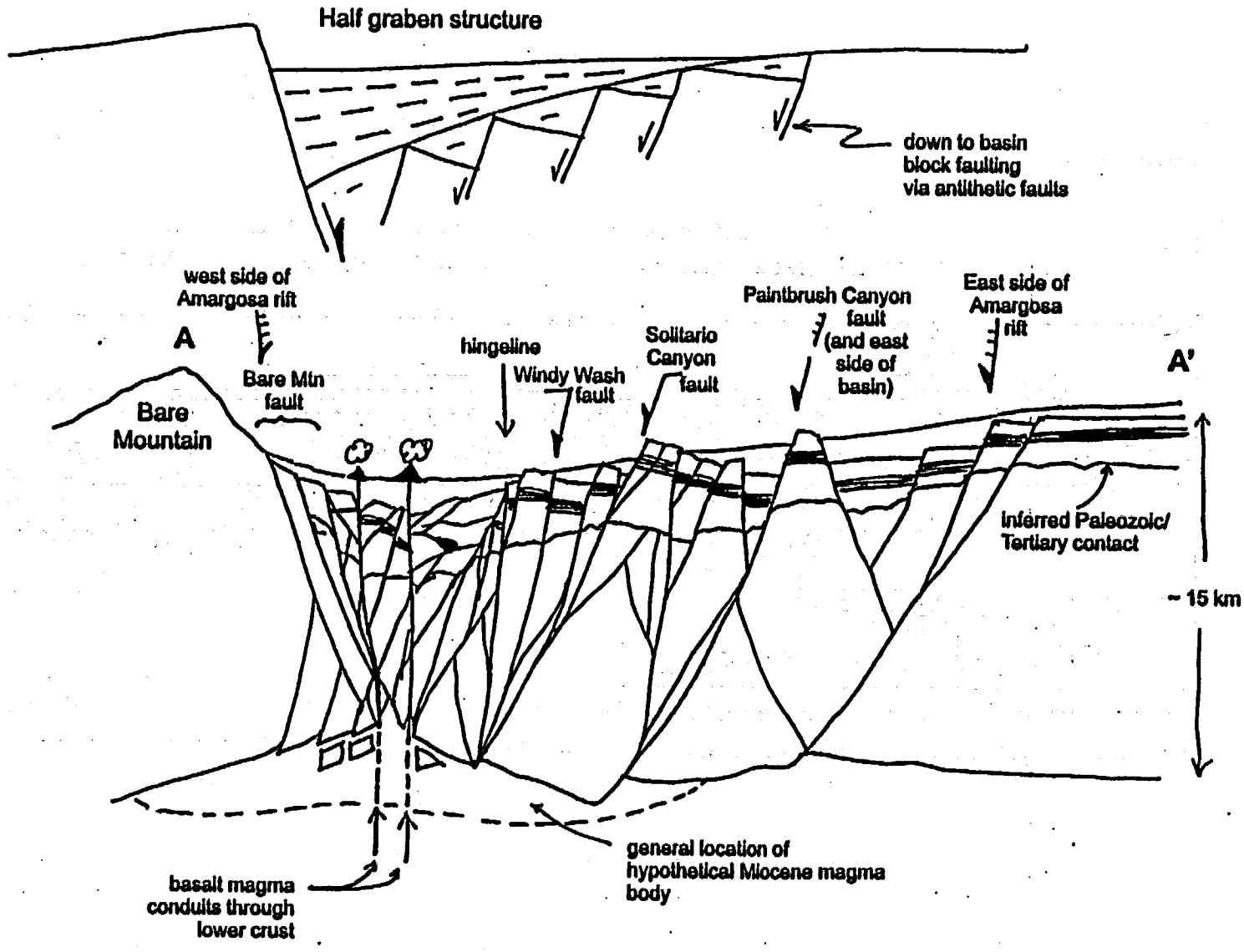


Figure 3.3-12. Conceptual Cross-Section from Bare Mountain to Jackass Flats Showing Interpretation of Yucca Mountain Vicinity as a Half-Graben Model.

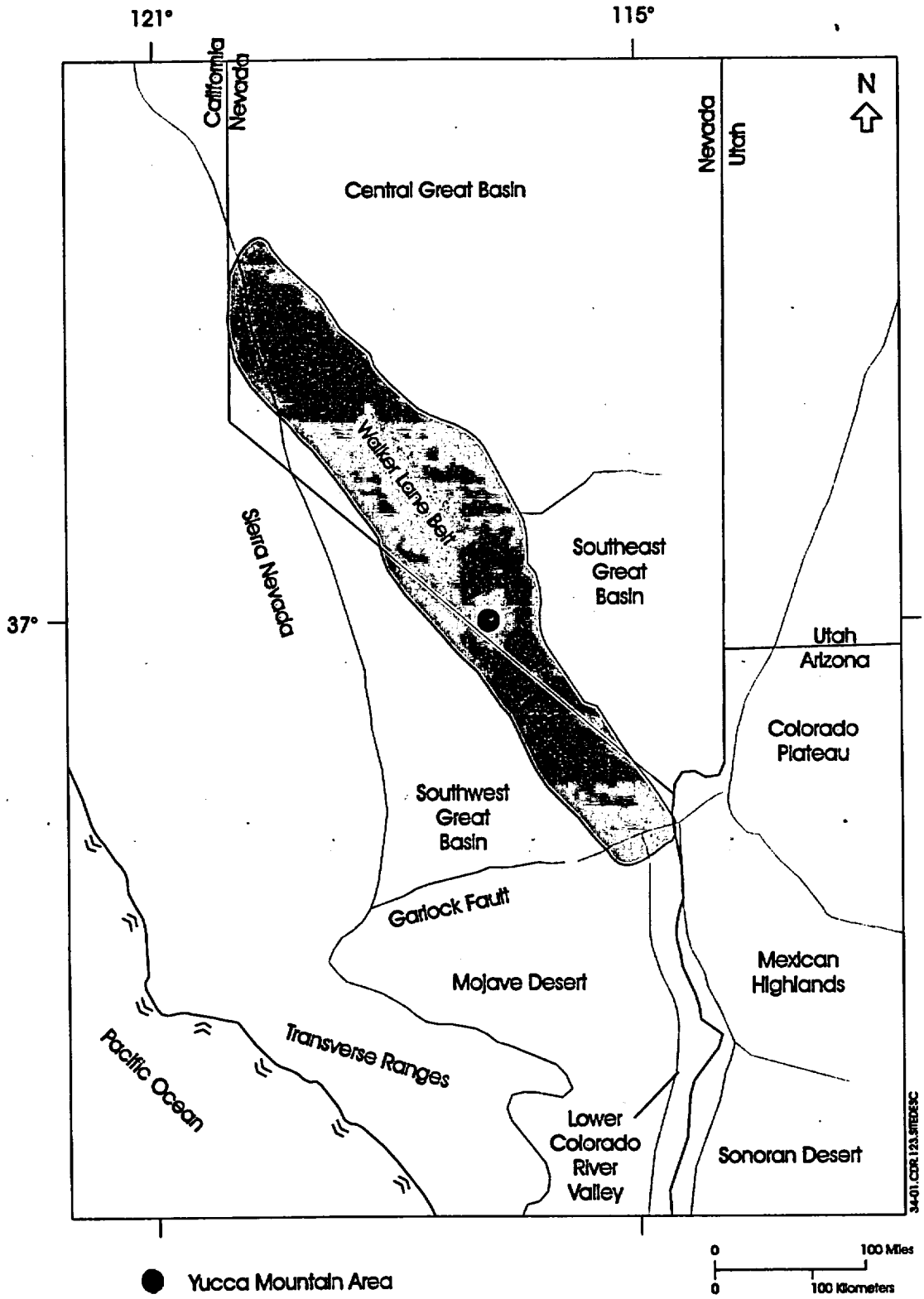


Figure 3.4-1. Generalized Map Showing Approximate Locations of the Physiographic Subdivisions of the West-Central and Southern Great Basin

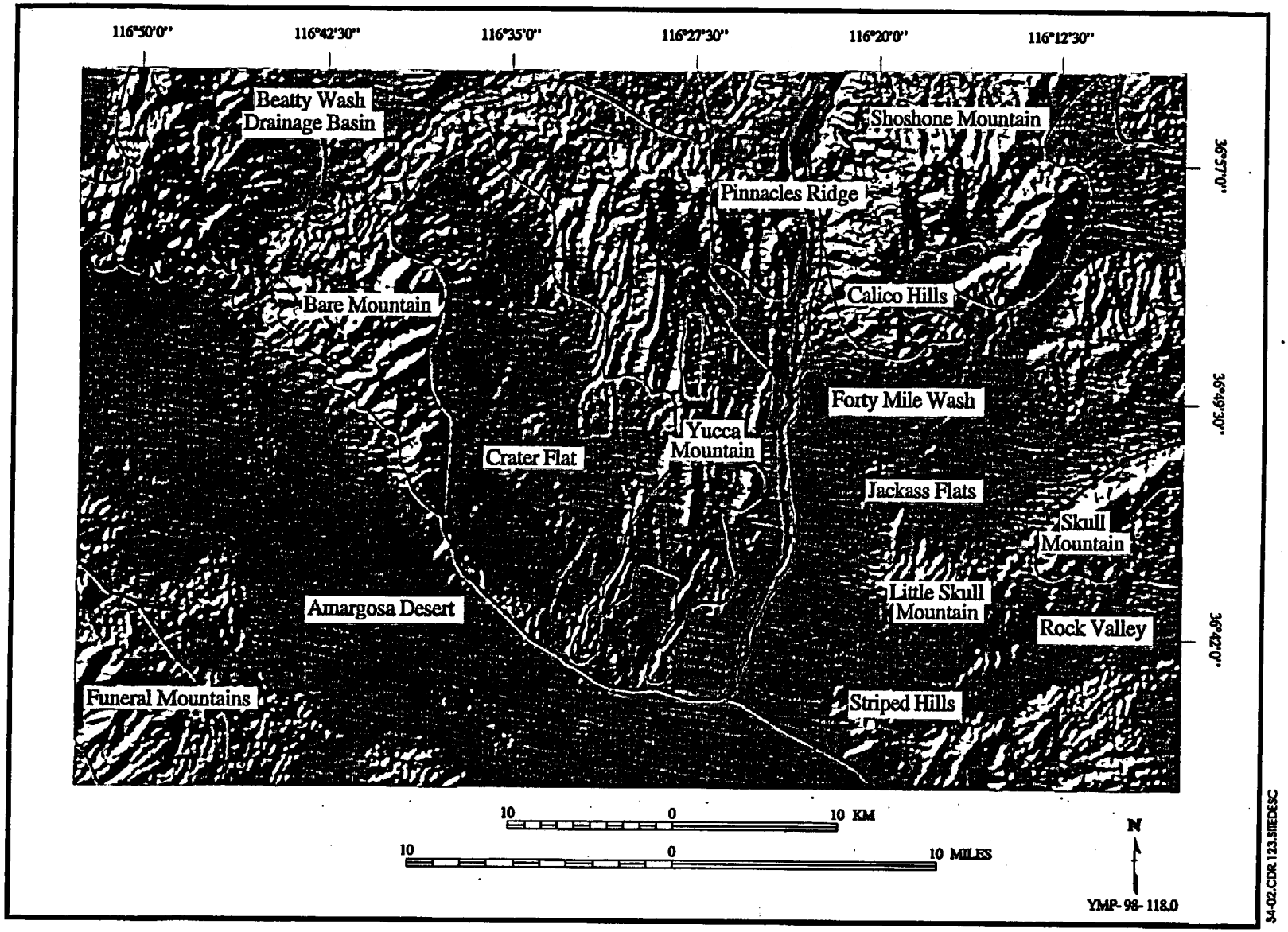


Figure 3.4-2. Physiographic Subdivisions of the Yucca Mountain Area

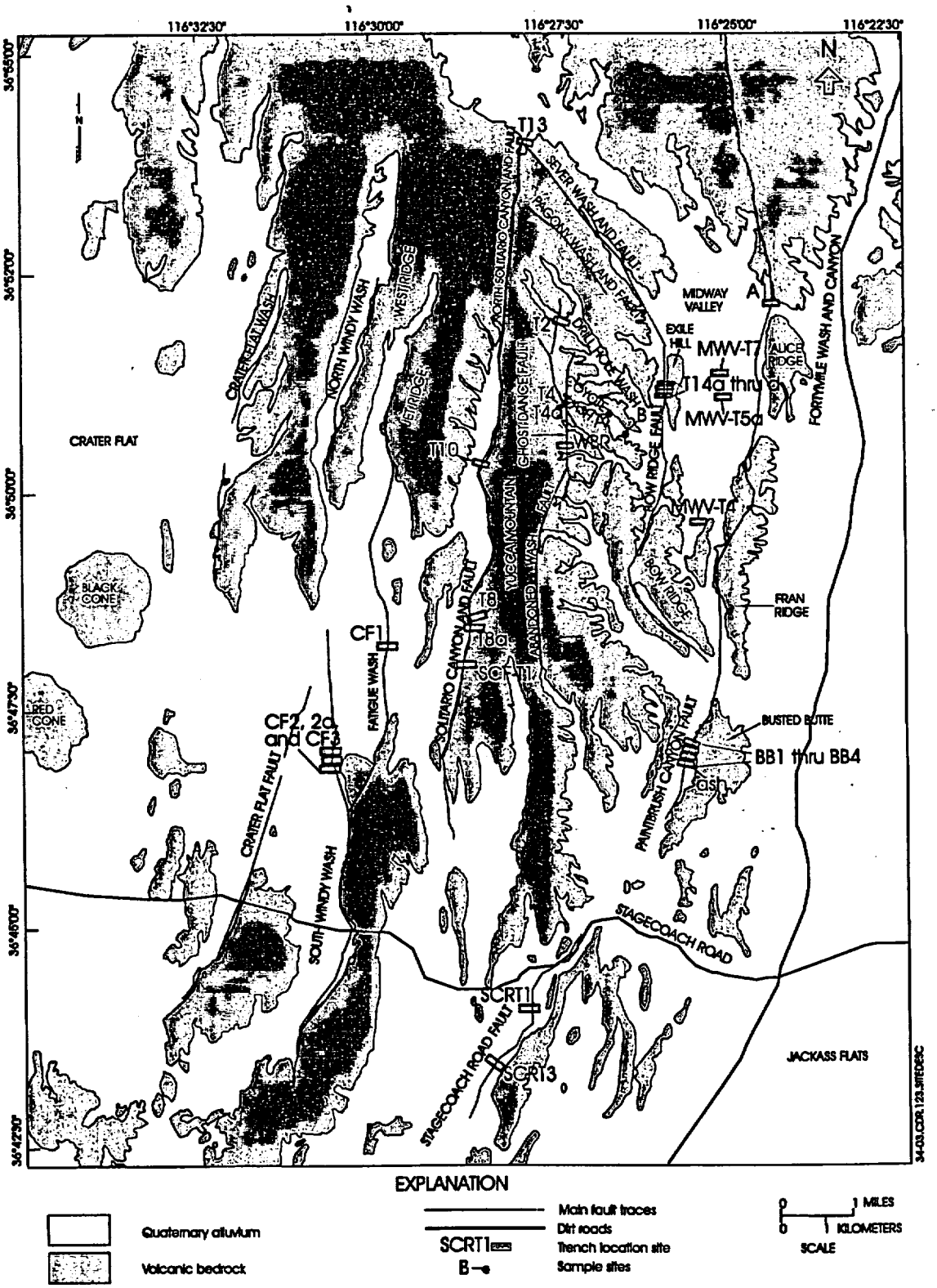


Figure 3.4-3. Map of the Yucca Mountain Region Showing Trench Locations and Local Place Names

34-04.CDR 123.SITEDESC

NOTE: Bull's-eye targets are spaced on a 1 m grid. Bottom of trench is approximately 4 m below original land surface.

Figure 3.4-4. Photograph of the South Wall of Trench 14 Showing Pedogenically Derived Calcite and Opaline Silica Veins

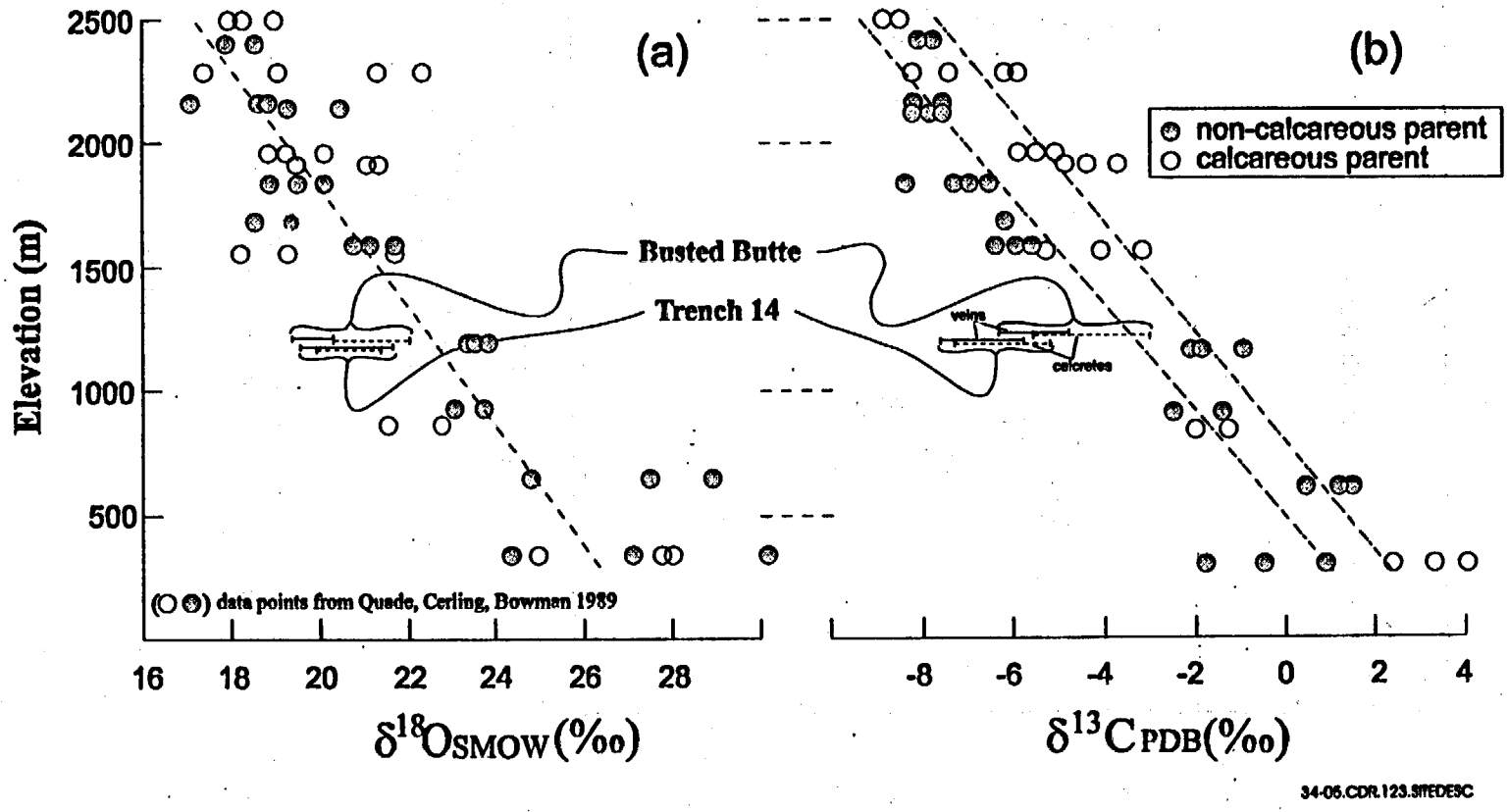
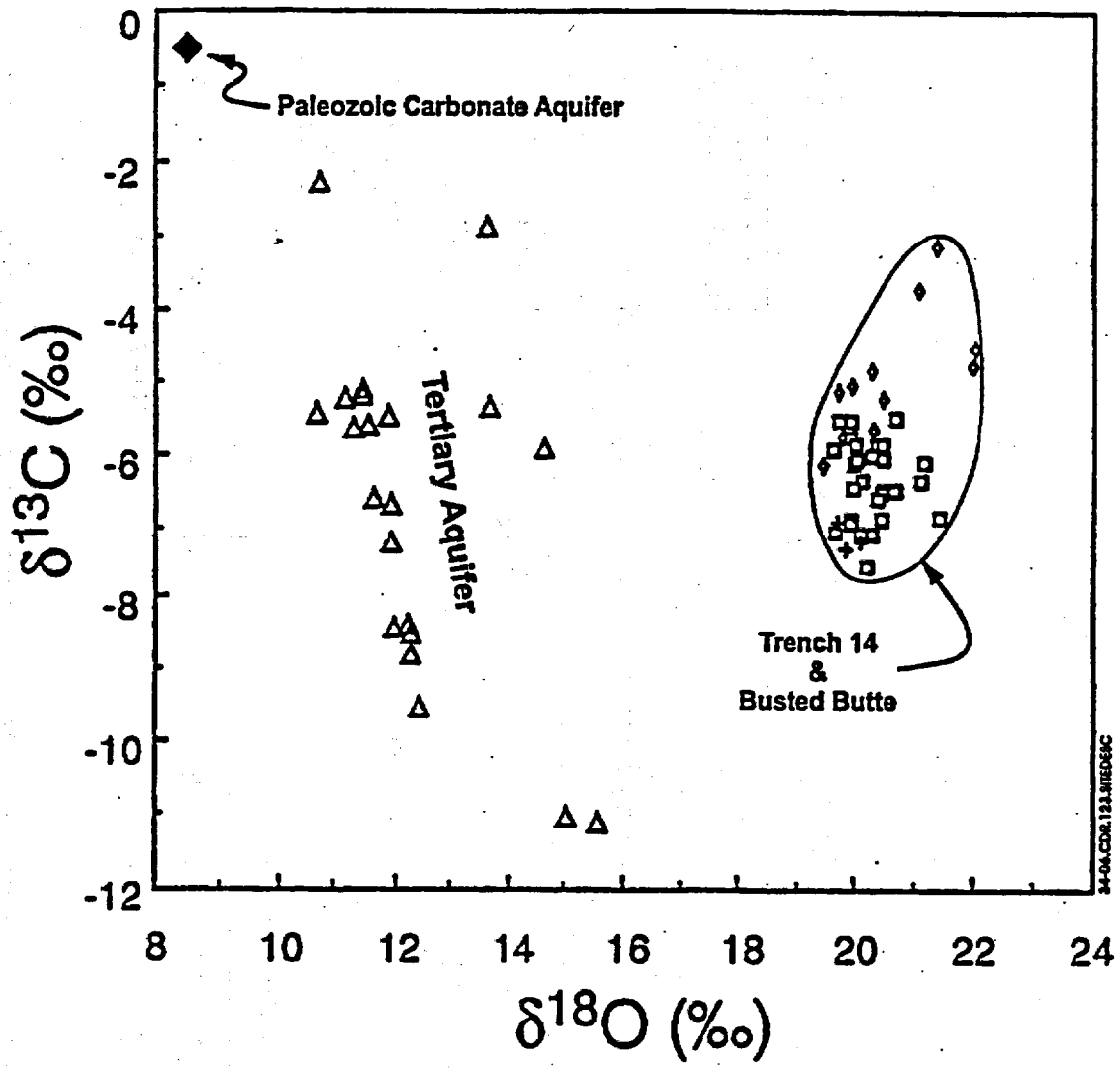
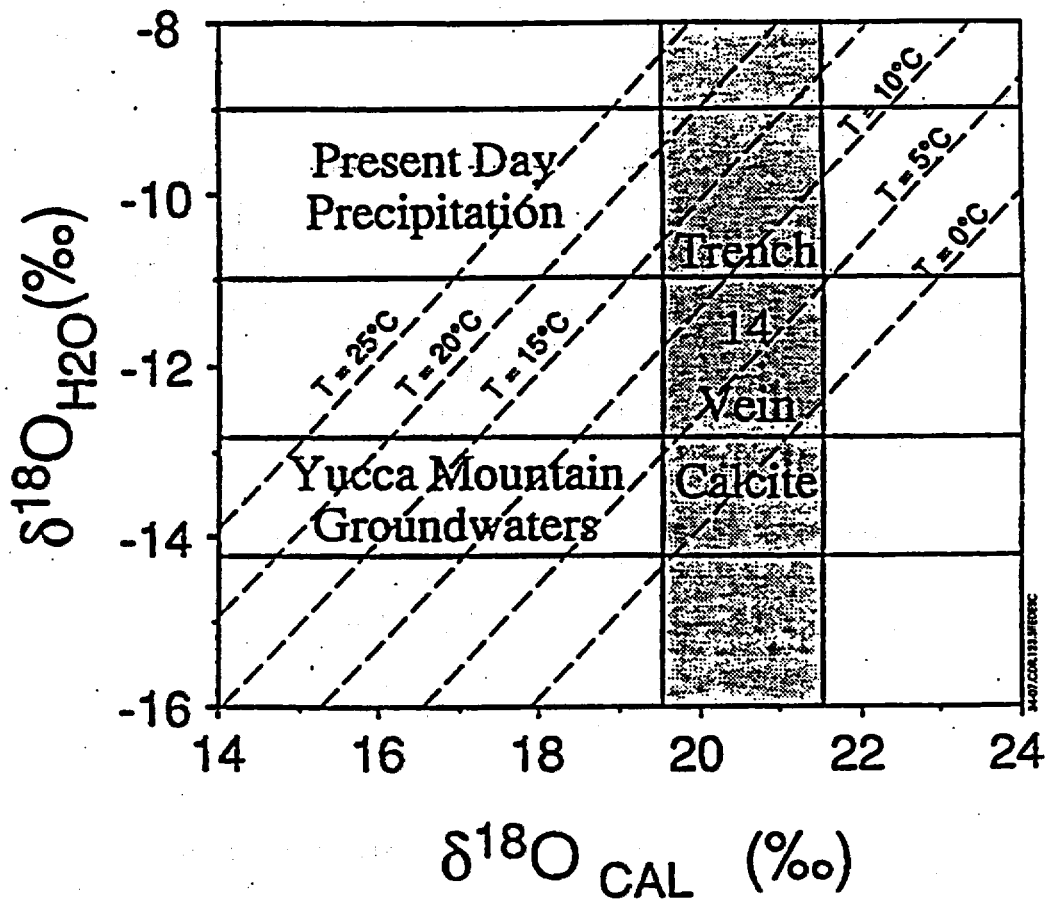


Figure 3.4-5. The Isotopic Composition of Oxygen and Carbon in Pedogenic Carbonate as a Function of Elevation (from Stuckless, Peterman et al. 1992)



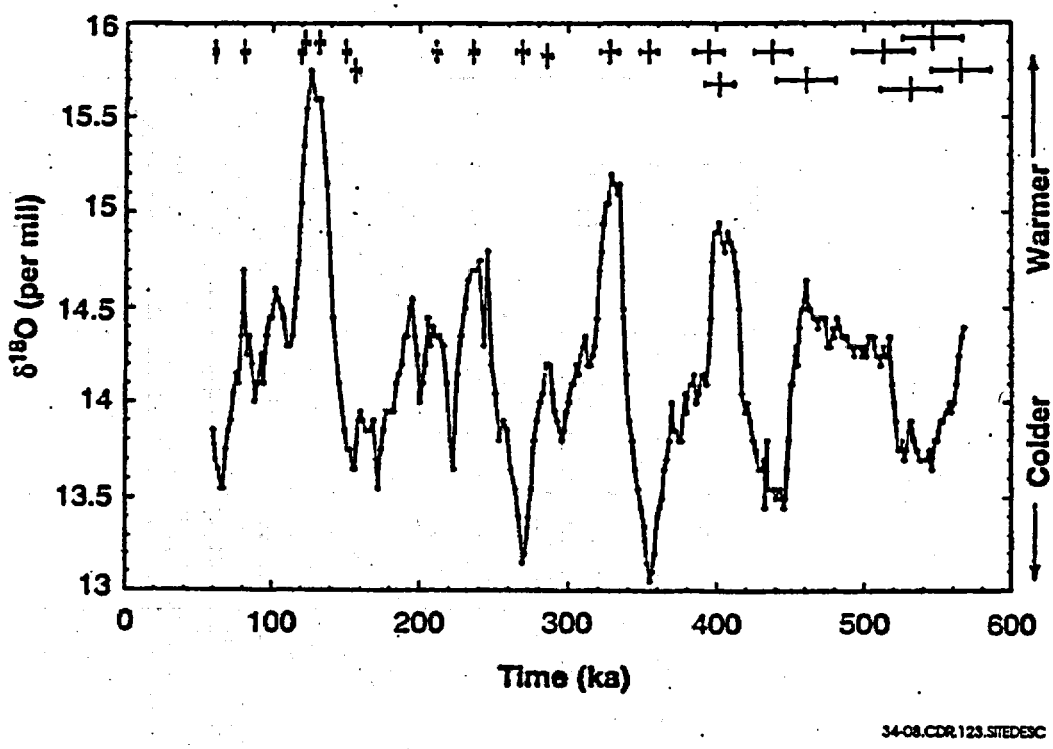
NOTE: Carbonates from Trench 14 (squares), Busted Butte (diamonds), and calcites crystallized in equilibrium with groundwater beneath Yucca Mountain (triangles for the Tertiary aquifer, diamonds for the Paleozoic aquifer, and plus (+) for breccia cement).

Figure 3.4-6. Isotopic Composition of Oxygen and Carbon (from Stuckless, Peterman et al. 1992)



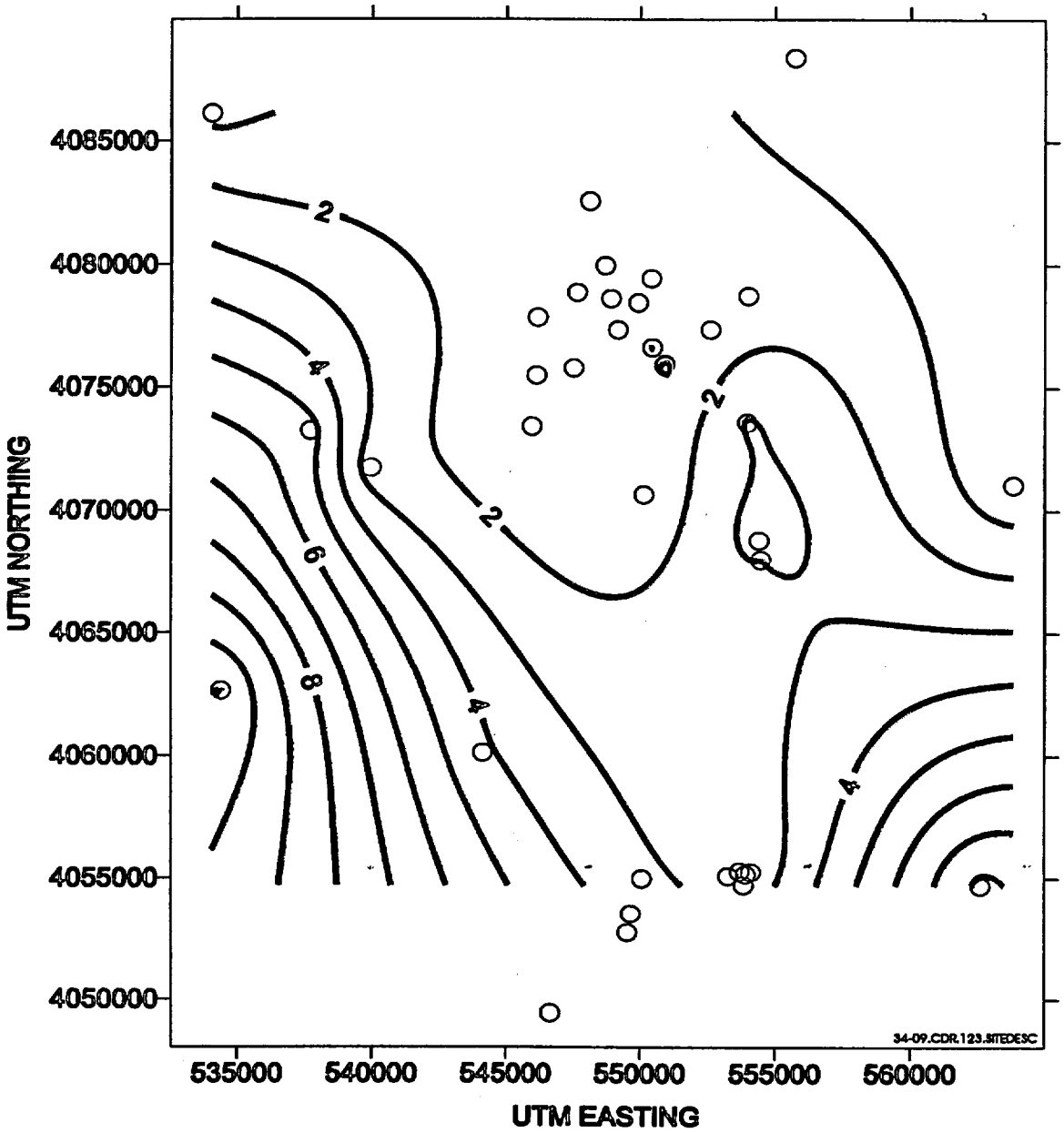
NOTE: Also shown are the fields of composition of modern precipitation, groundwater, and calcites from Trench 14.

Figure 3.4-7. Graph (from Stuckless, Peterman et al. 1992) Showing the Isotopic Composition of Oxygen in Water and Calcite Crystallized in Equilibrium with Water as a Function of Temperature



NOTE: Ages of dated samples are shown as crosses along the top of the figure with two sigma errors indicated by the width of the cross.

Figure 3.4-8. Graph Showing the Variation of Oxygen Isotopic Composition of Calcite at Devils Hole (from Winograd, Coplen et al. 1992)



NOTE: Circles represent data points.

Figure 3.4-9. Map Showing the Isotopic Composition of Strontium (in δ^{87}Sr Units) in the Tertiary Aquifer (based on data from Paces 1995)

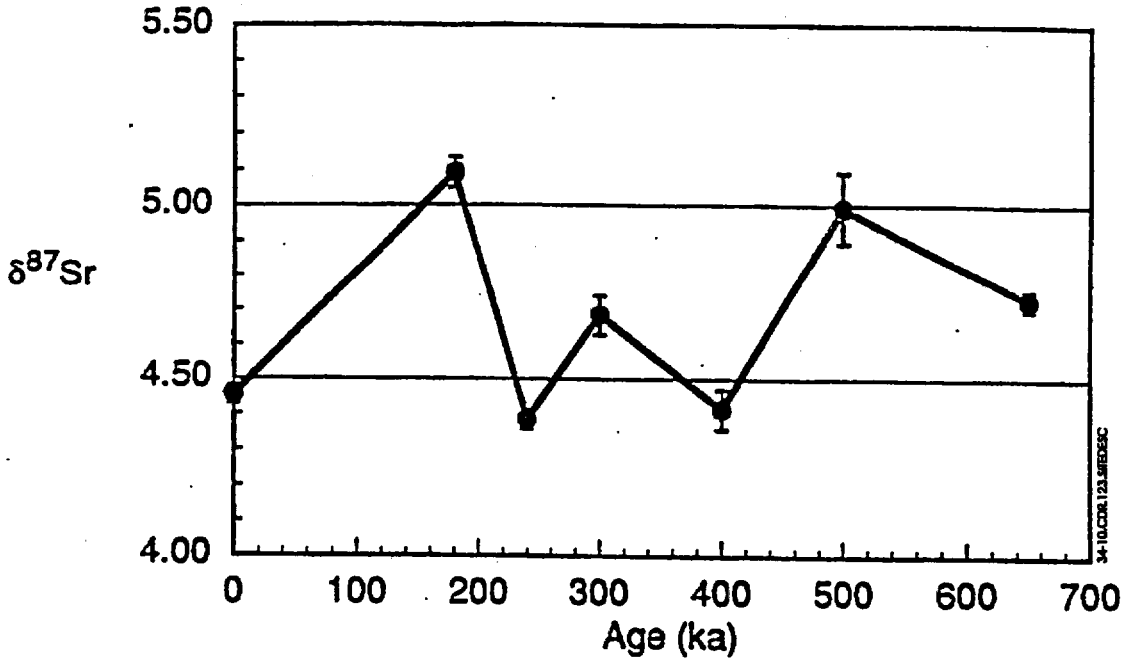


Figure 3.4-10. Variation in the Isotopic Composition of Strontium in Calcite from Devils Hole as a Function of Time (from Marshall et al. 1990)

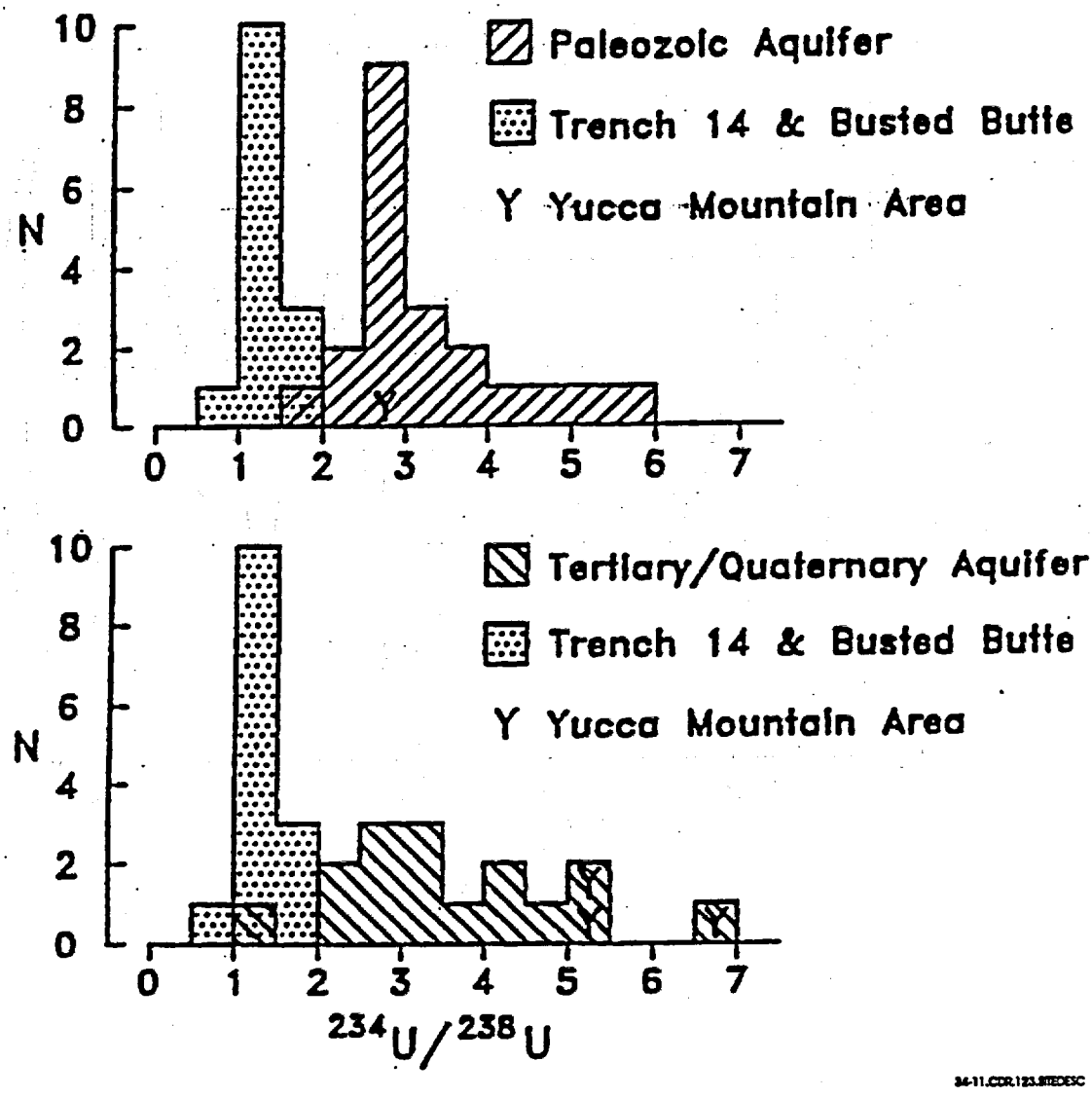
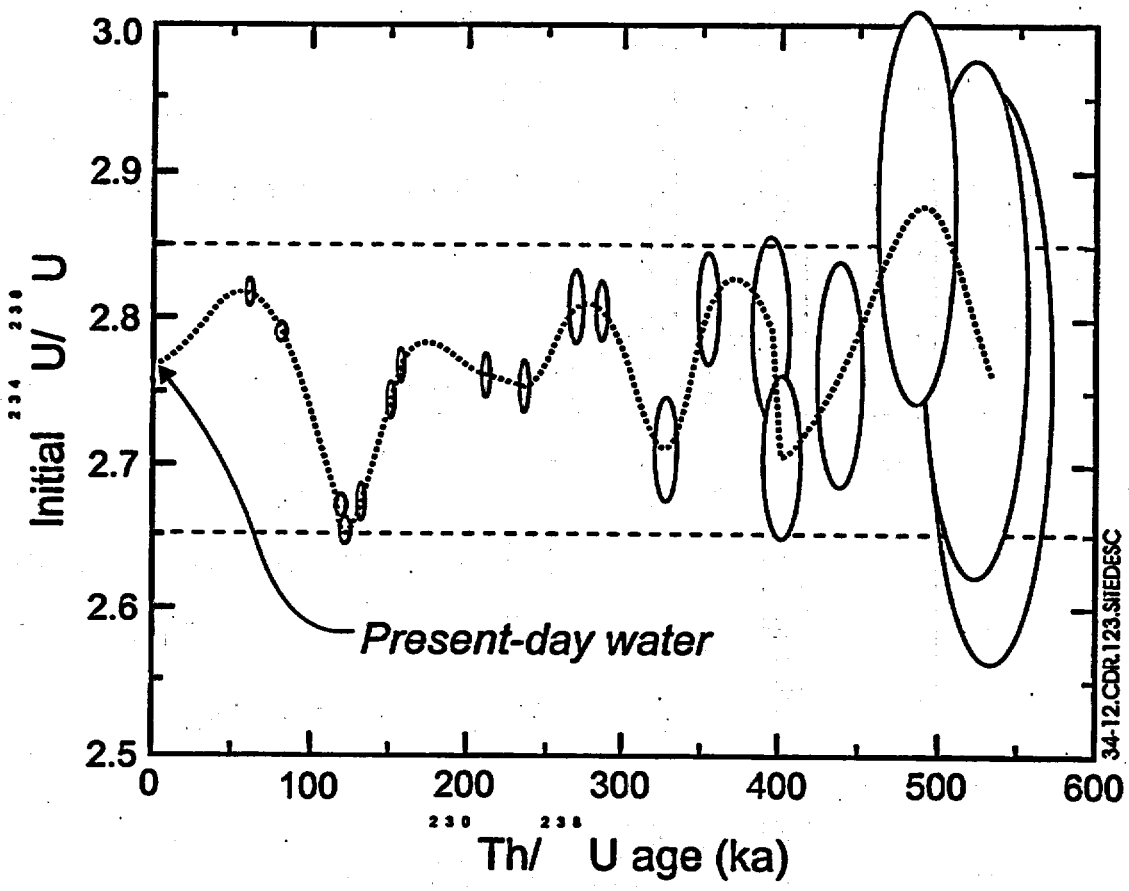


Figure 3.4-11. Histogram showing the Isotopic Composition of Uranium in Water and Carbonates from Trench 14 and Busted Butte (from Stuckless, Peterman et al. 1992)



NOTE: Two sigma uncertainties are indicated by the ellipses. Estimated maximum variation in initial $^{234}U/^{238}U$ shown by dashed horizontal lines.

Figure 3.4-12. Variation in the Isotopic Composition of Uranium in Calcite from Devils Hole as a Function of Time (from Ludwig et al. 1992)

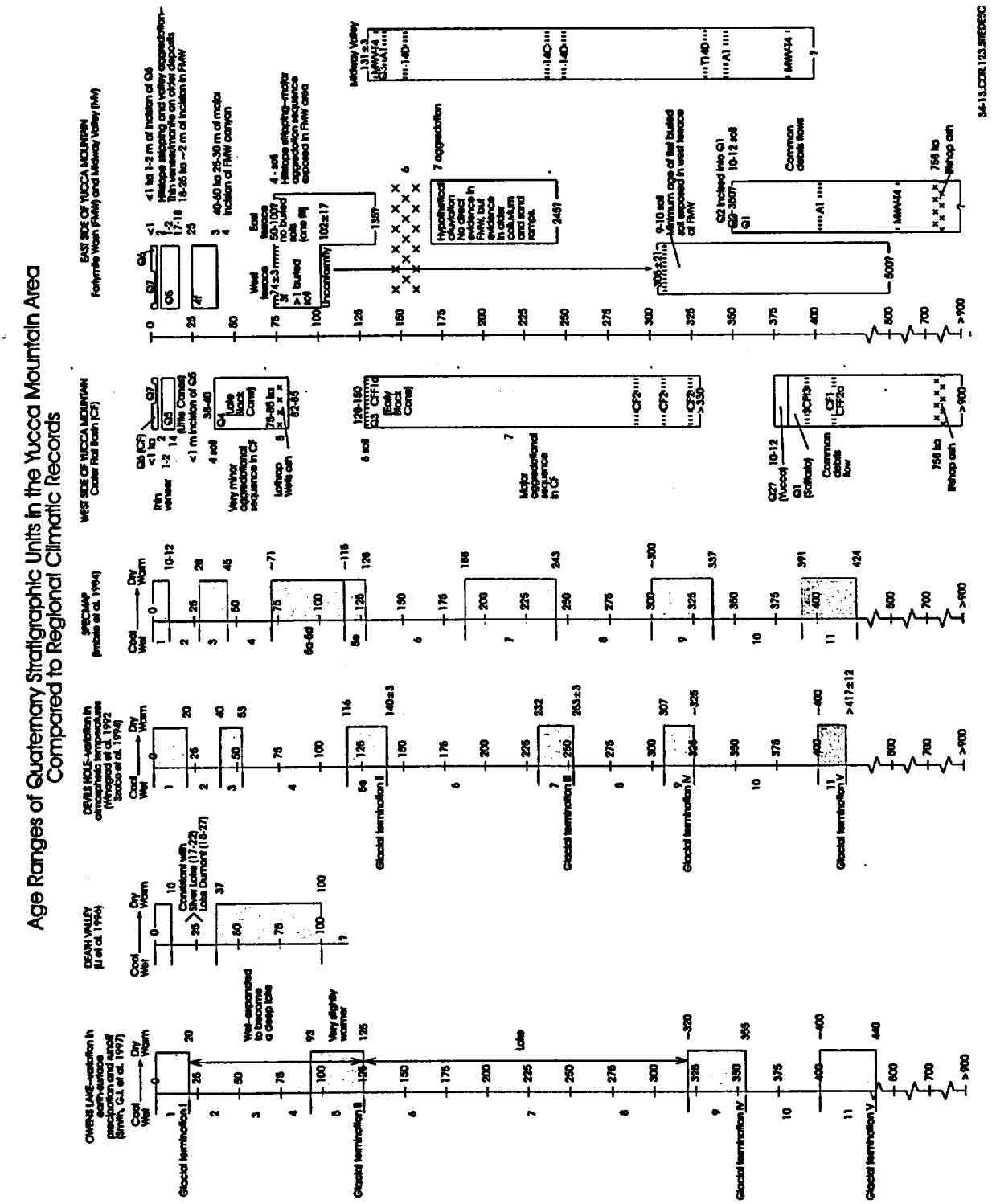


Figure 3.4-13. Age Ranges of Quaternary Stratigraphic Units in the Yucca Mountain Area Compared to Regional Climatic Records

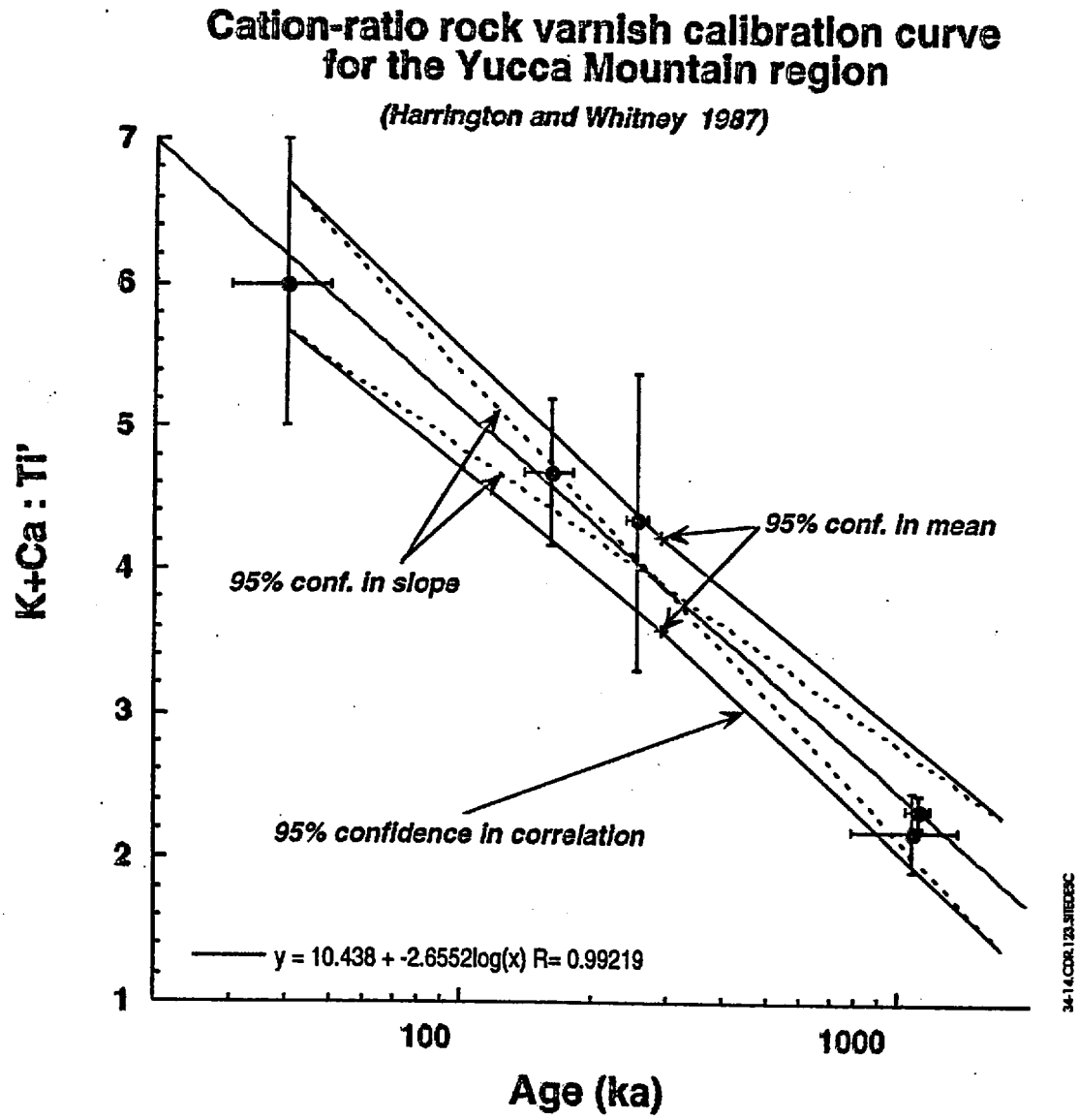


Figure 3.4-14. Cation-ratio Rock Varnish Calibration Curve for the Yucca Mountain Region (modified from Harrington and Whitney 1987)

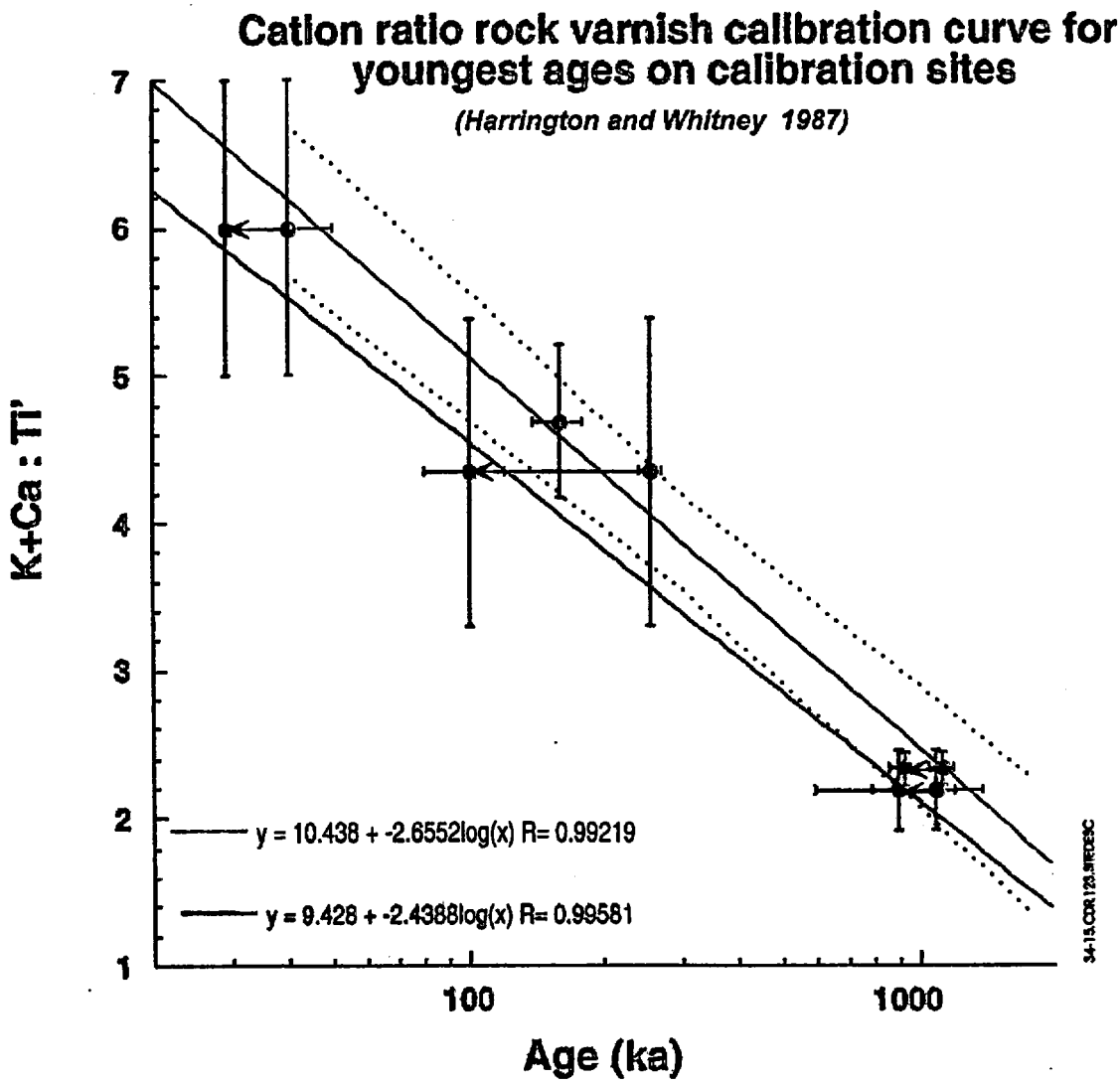


Figure 3.4-15. Recalibrated Cation-ratio Rock Varnish Curve for Yucca Mountain Using Younger Ages for the Calibration Sites

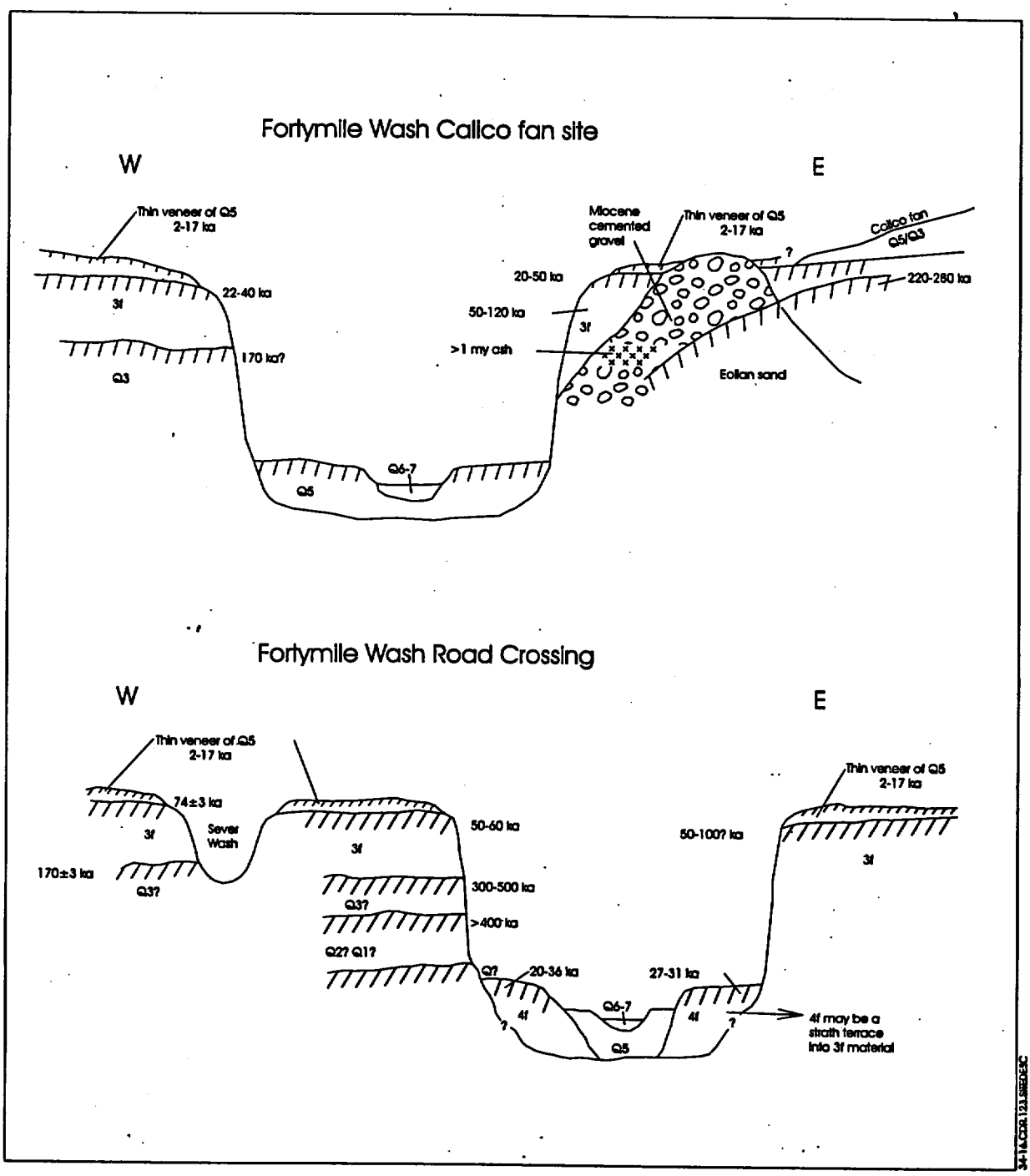
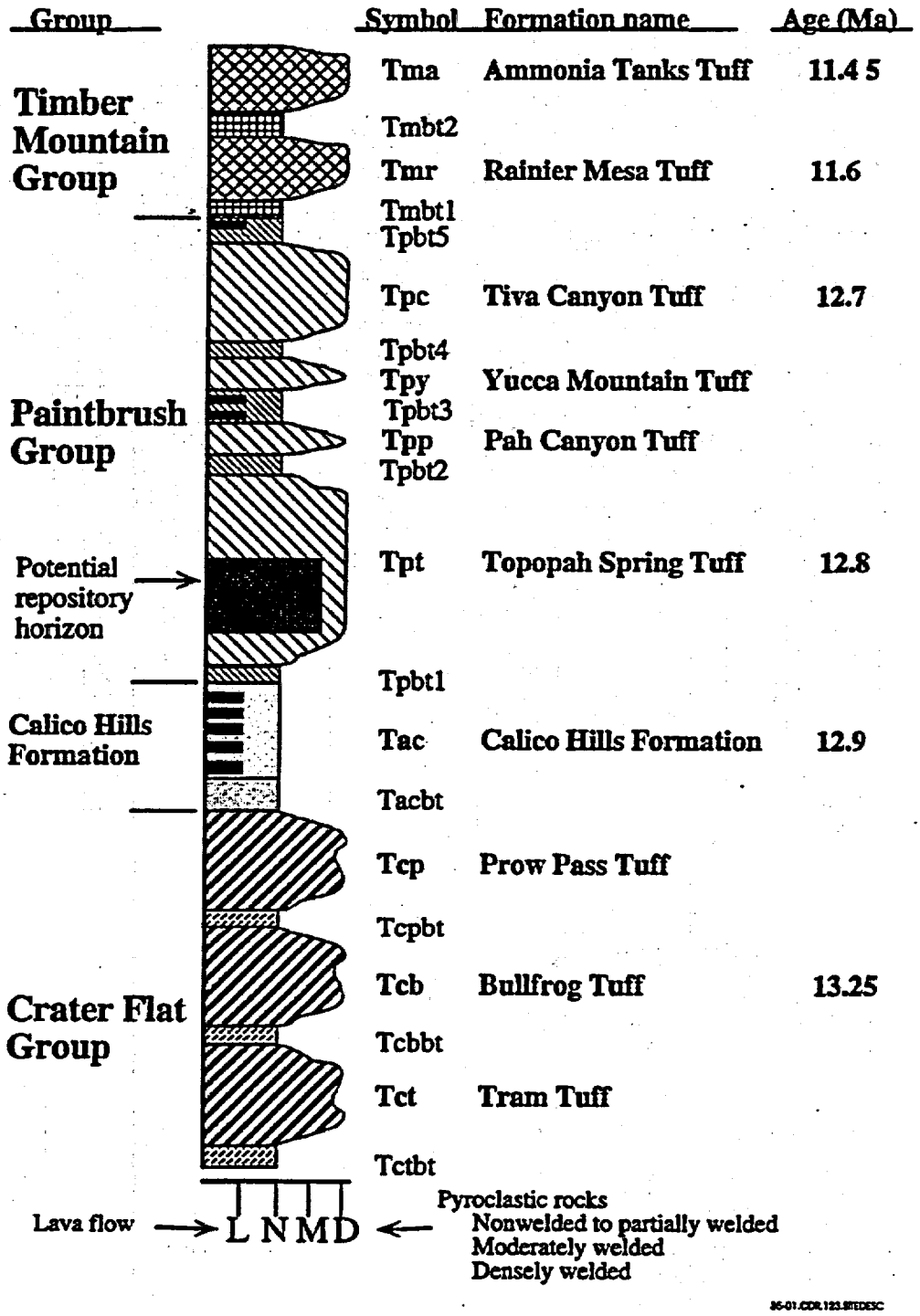
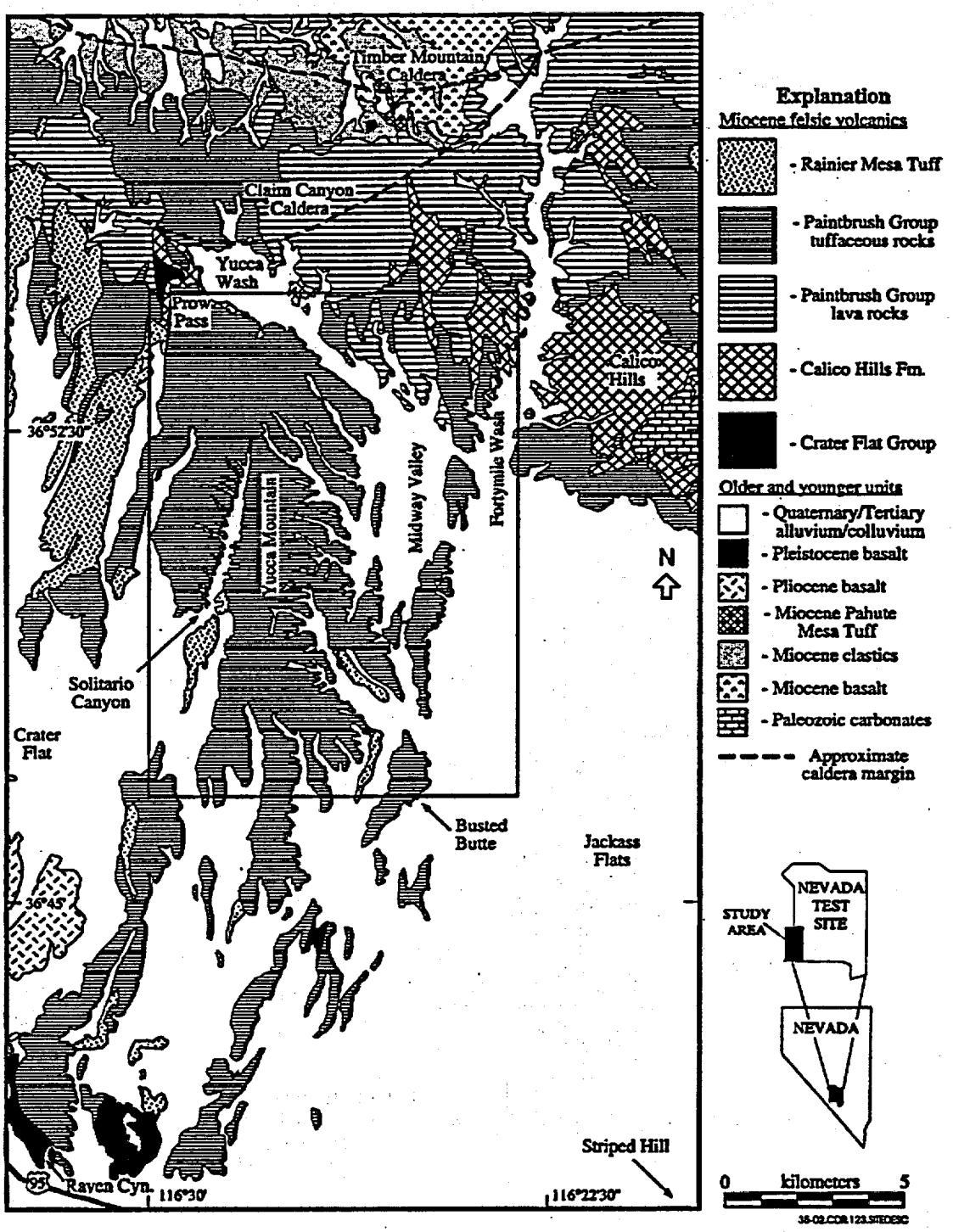


Figure 3.4-16. Genealized Cross Section of the Evolution of Fortymile Wash (based on Lundstrom et al., *Preliminary Surficial Deposits Map of the Northwest Quarter of the Busted Butte 7.5-minute Quadrangle*, USGS-OFR-95-133, scale 1:12,000, 1995 in press; Paces et al. 1995)



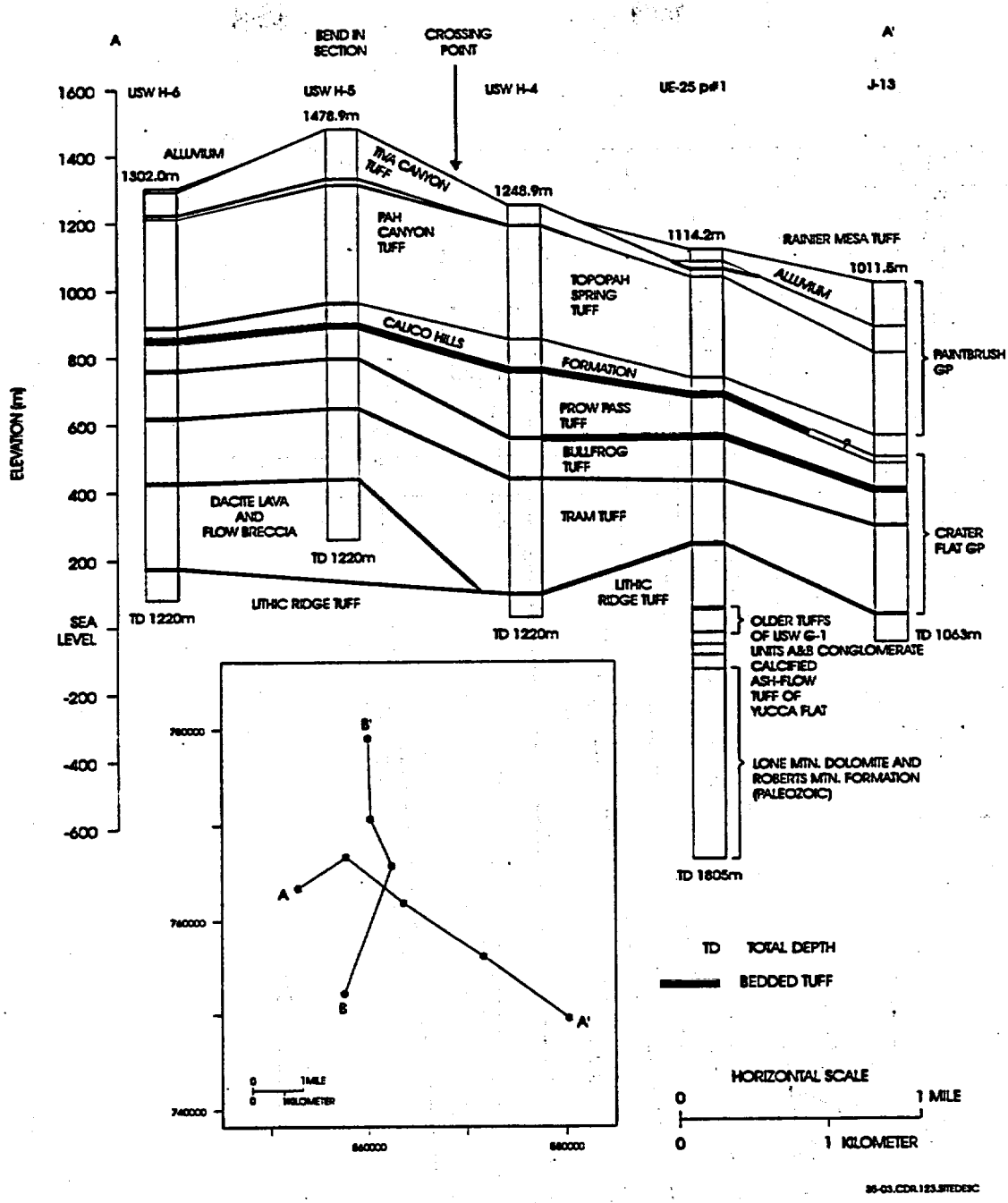
NOTE: Names and symbols referred to in Tables 3.5-1 and -2. Ages in millions of years (Ma) are from Sawyer, D.A., Fleck et al. (1994)

Figure 3.5-1. Principal Stratigraphic Units at Yucca Mountain



NOTE: Rectangular area in center is generally referred to as the "Site Area".

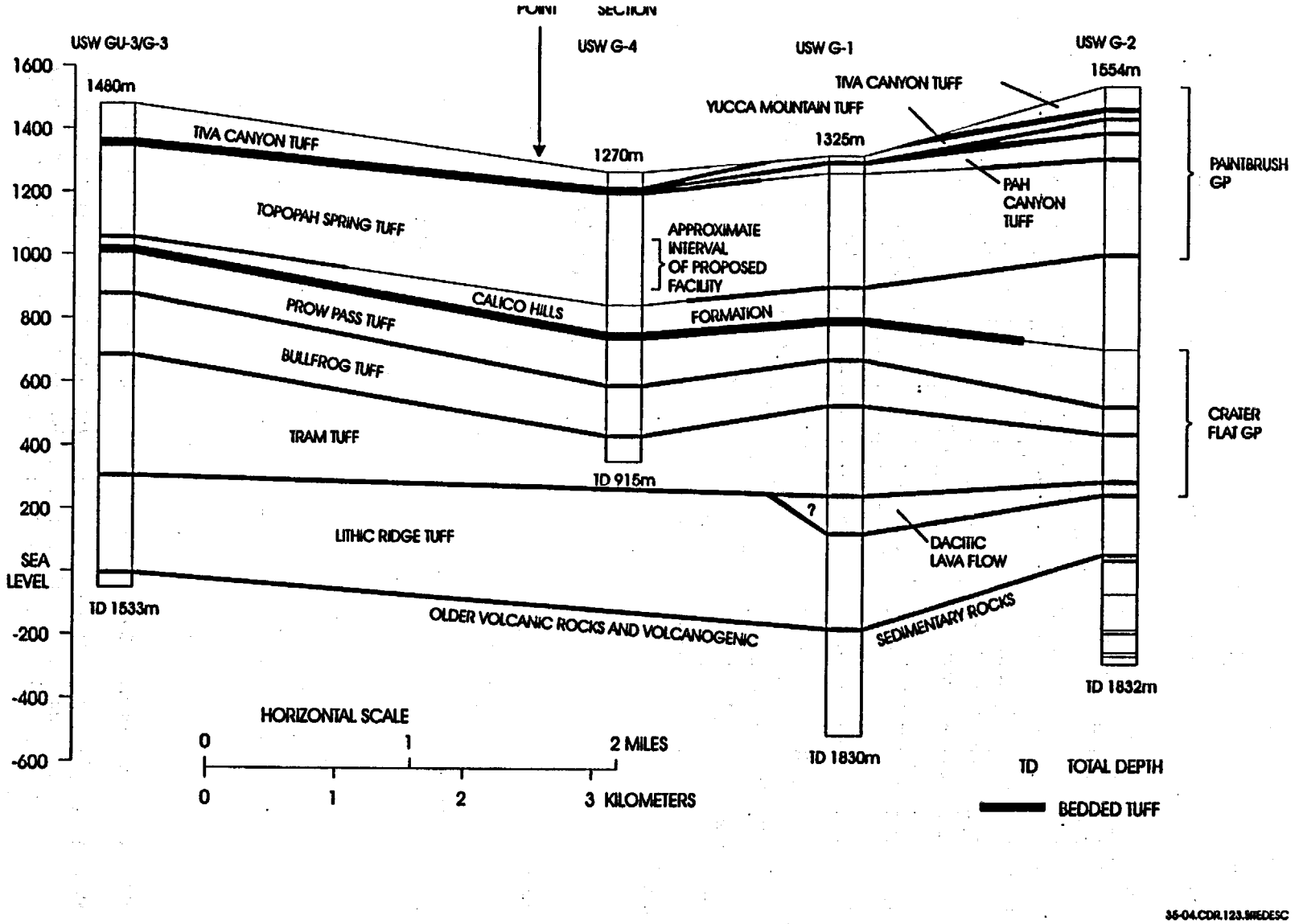
Figure 3.5-2. Simplified Geologic Map Showing Distribution of Major Lithostratigraphic Units (modified from Frizzell and Shulters 1990)



NOTE 1: Faults, such as the Solitario Canyon fault between borehole H-5 and H-6, are not shown.

NOTE 2: H-6, Craig et al. (1983); H-5, Bentley et al. (1983); H-4, Whitfield et al. (1984); UE-25 p#1, Craig and Johnson (1984); and J-13, Thordarson (1983). Inset map shows Yucca Mountain site area, with Nevada state plane coordinates. B-B is correlation line for Figure 3.5-4.

Figure 3.5-3. East-West Correlation of Stratigraphic Units, Based on Borehole Studies



NOTE: Subsurface correlations between boreholes G-1 and GU3/G3 below the level of borehole G-4 are schematic. Modified from USGS (1984).

Figure 3.5-4. North-South Correlation of Stratigraphic Units

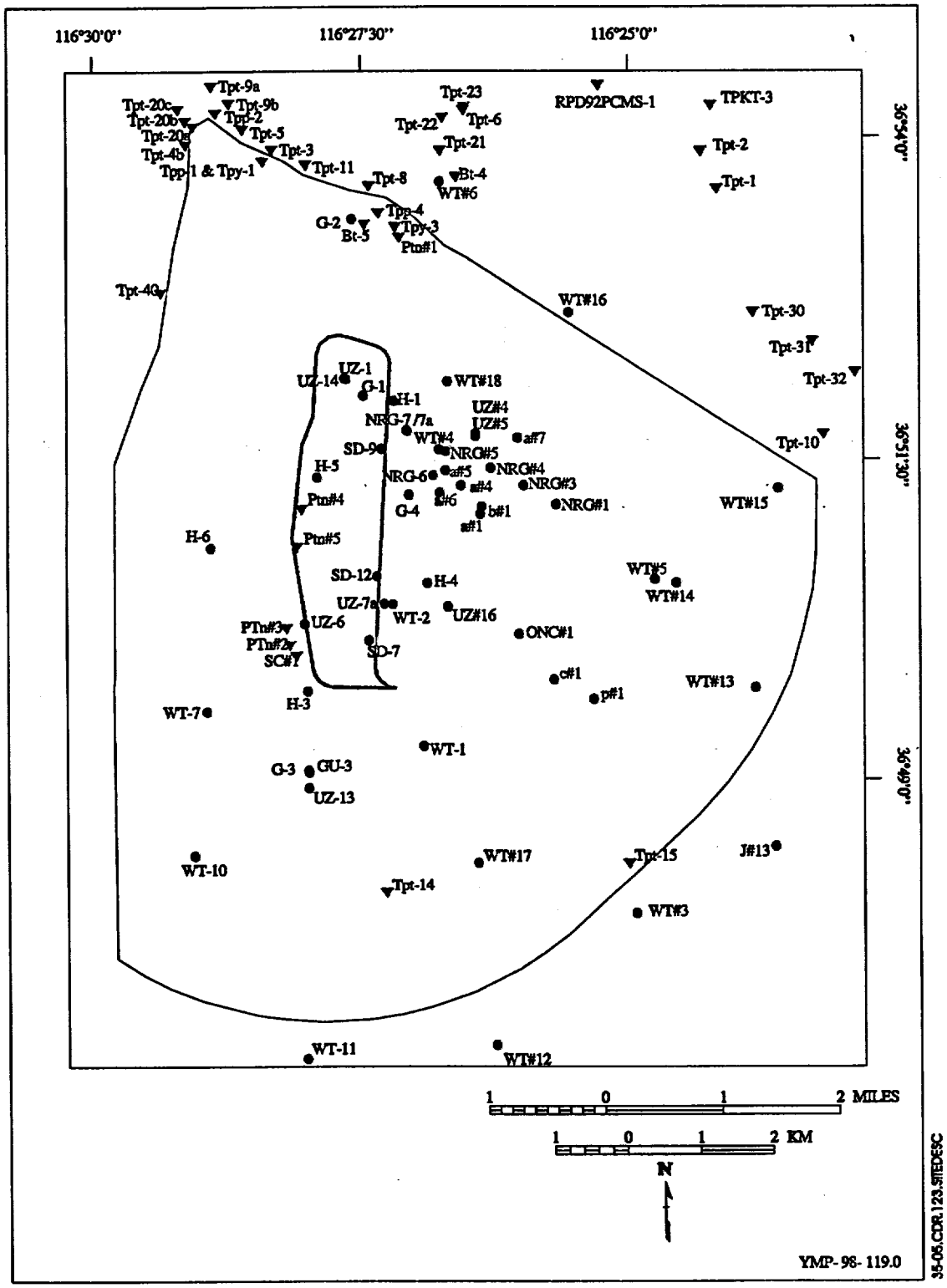
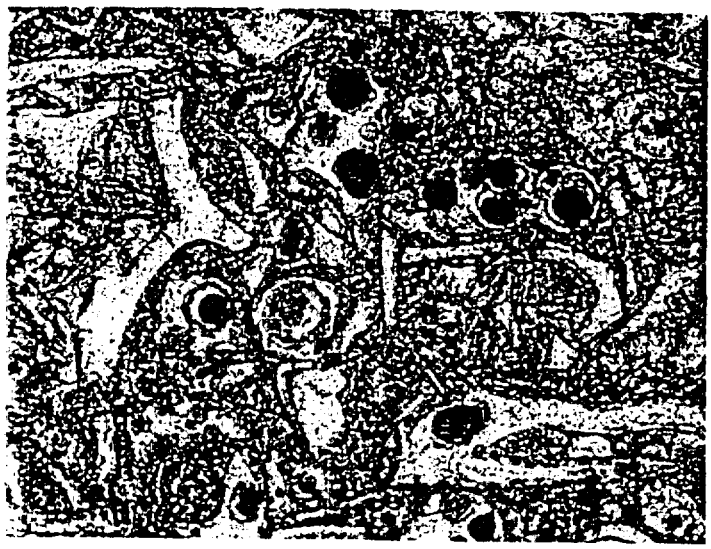
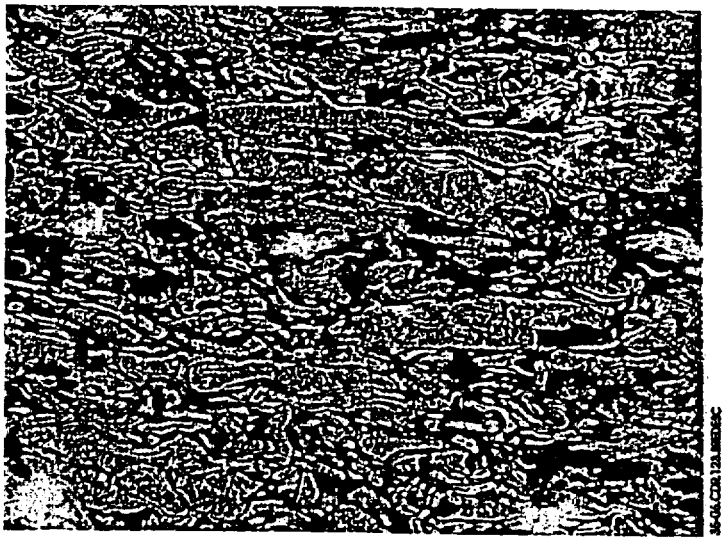


Figure 3.5-5. Locations of Boreholes (Dots) and Measure Surface Sections (Triangles) at Yucca Mountain

A



B



NOTE: Figure A is approximately 6X8 mm and shows vitric, nonwelded colorless, bubblewall shards in a matrix of glass dust. Most of the dust is pervasively impregnated with epoxy; therefore, there is a significant (possibly 25 to 35 volume percent) porosity in the matrix. Black circular areas are void space (typically vesicles in shards) filled with epoxy and polishing grit. Figure B is approximately 10X12 mm and shows vitric, densely welded tuff with no microscopic porosity. Small needle-like features that radiate from shard walls are small perlite fractures in glass and rod-like crystals that form in the initial stages of devitrification. The dust intersititial to shards is fused, but individual grain boundaries result in the semi-opaqueness. (Photomicrograph from F. Singer, SAIC/USGS, written communication 1995.)

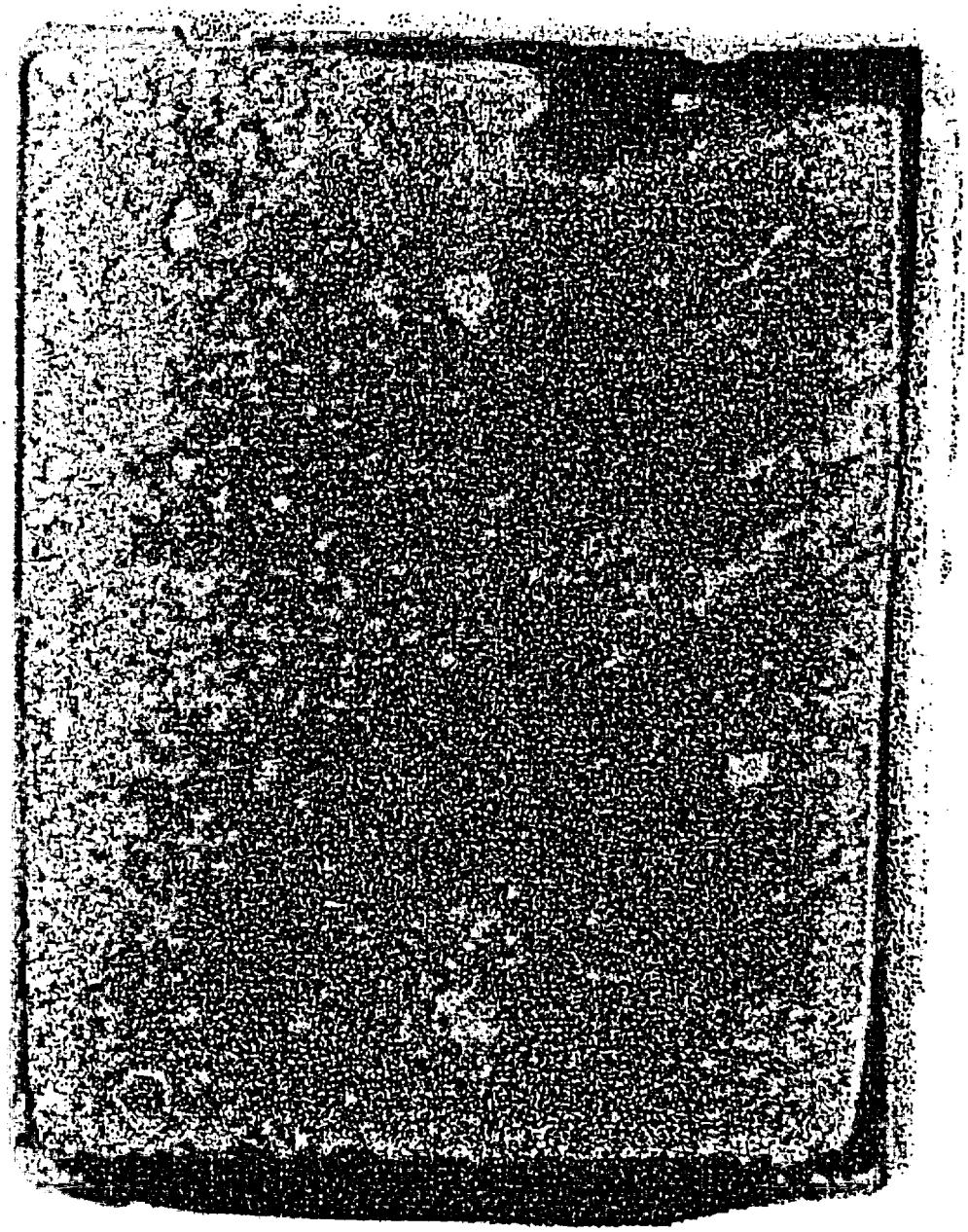
Figure 3.5-6. Photomicrographs of Vitric Nonwelded and Densely Welded Rocks in the Crystal-Poor Member of the Tiva Canyon Tuff

A

B

NOTE: Figure A is 8X10 mm and shows microcrystalline textures (light to moderate gray hues) that preserve most shard shapes. The circular dark gray area is actually light brown and consists of radiating, elongated, very fine-grained crystals that form a spherulite. Figure B is 10X12 mm and shows medium- to coarse-grained, microgranophyric crystallization that almost completely obscures the outlines of bubblewall shards. (Photomicrograph from F. Singer, SAIC/USGS, written communication 1995)

Figure 3.5-7A,B. Photomicrographs of Crystallization Textures of Moderately to Densely Welded Tuff in the Lower Lithophysal and Middle Non-lithophysal Zones of the Crystal-poor Tiva Canyon Tuff



35-07c.CDR.123.SITEDESC

NOTE: The thin section is 2X3 cm with fine-grained microgranophyric groundmass and medium-grained microgranophyric crystals in pumice clasts and coarse-grained shards. Thin section is impregnated with blue epoxy to show porosity. Note that there are only a few areas where porosity might be macroscopic, but there is a thin coating of blue epoxy in and around the medium-grained crystallized pumice clasts.

Figure 3.5-7C. Shows Crystallized, Densely Welded Tuff from the Lower Lithophysal Zone of the Topopah Spring Tuff

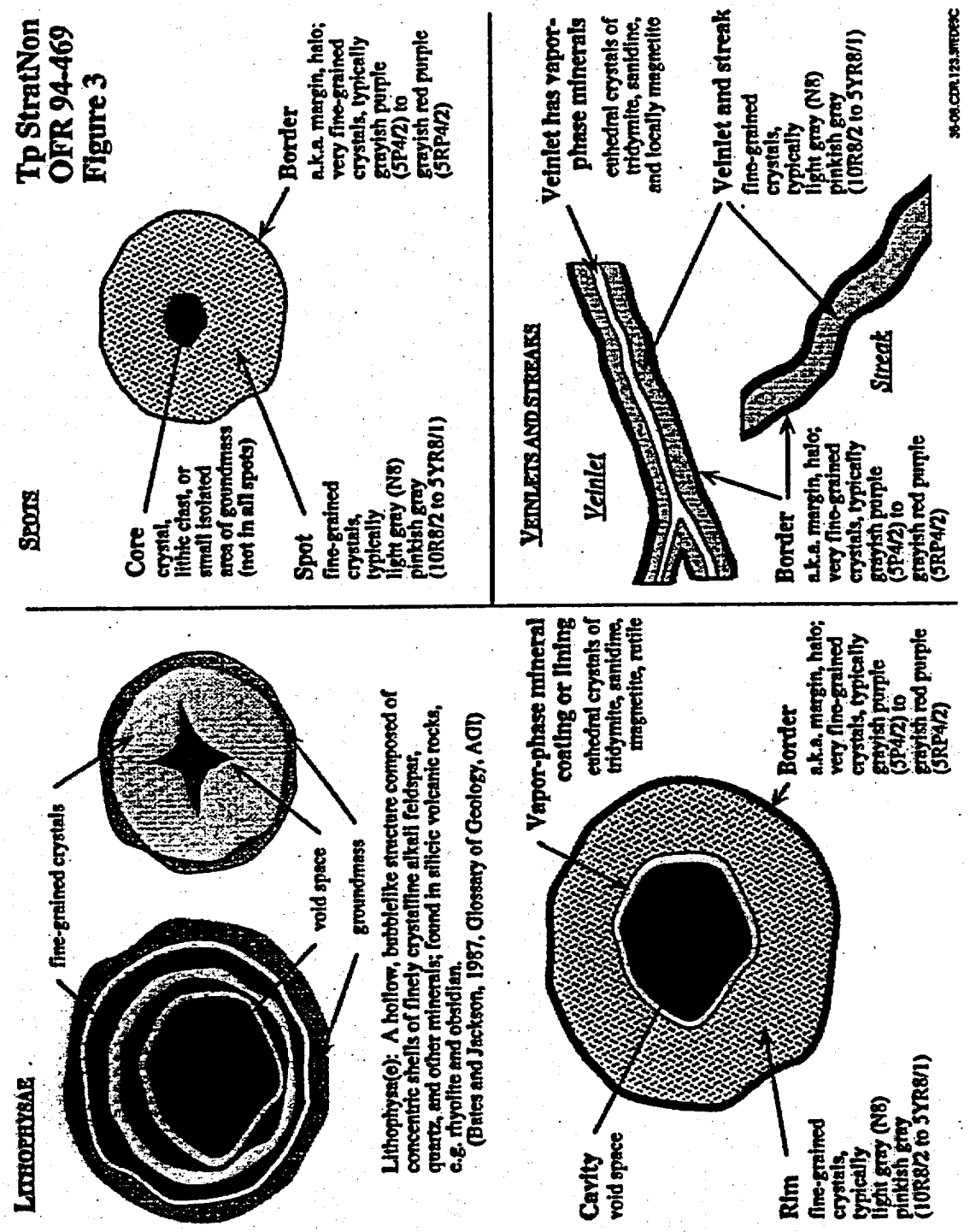
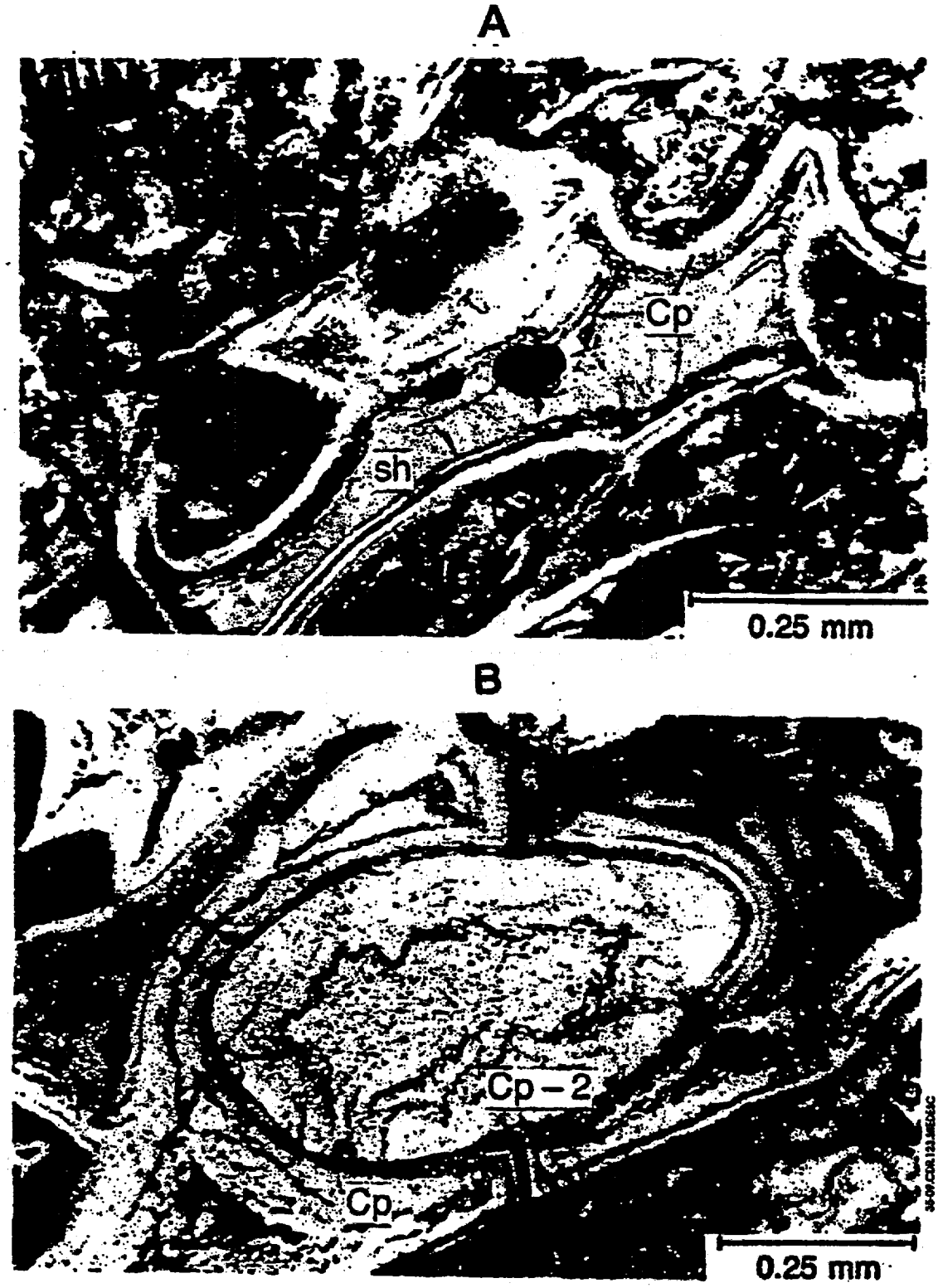


Figure 3.5-8. Crystallization Features of Lithophysae, Spots, Veinlets, and Streaks



NOTE: A: Glass (sh) rimmed with clinoptilolite (Cp) in the early stages of alteration. B: Shard completely replaced by clinoptilolite (Cp) with porosity reduced by growth of clinoptilolite (Cp-2) in vesicle (from Broxton, Bish et al. 1987).

Figure 3.5-9. Photomicrographs of Nonwelded Shards That Are Variously Altered to Clinoptilolite

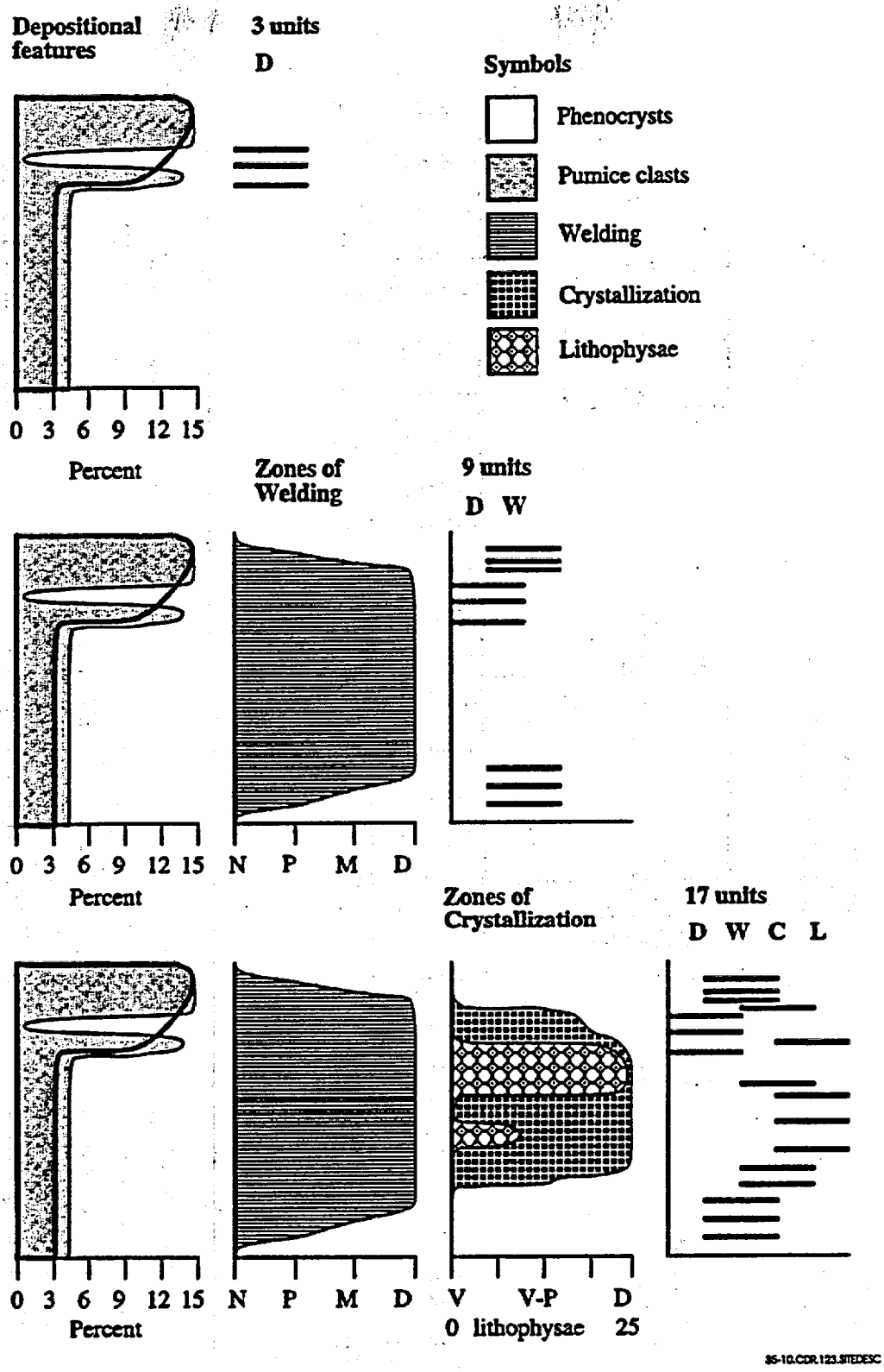
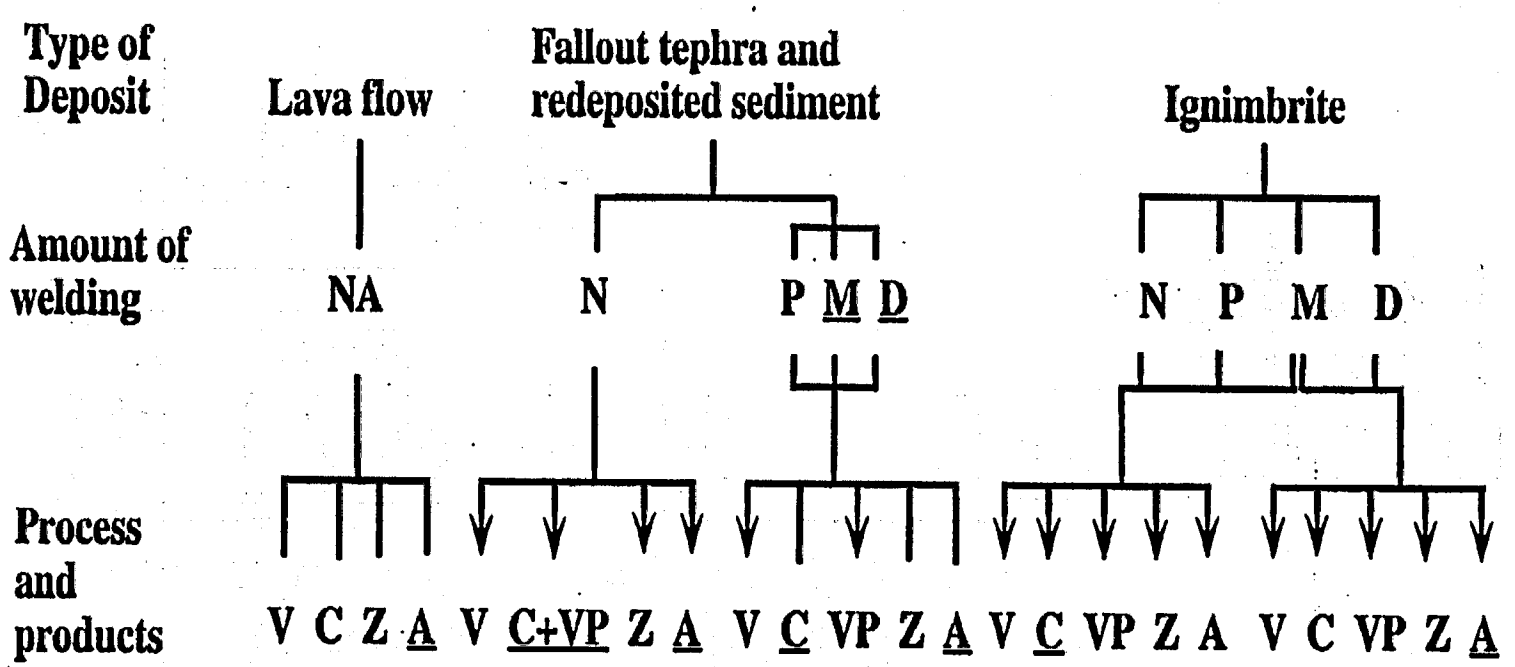


Figure 3.5-10. Development of Detailed Lithostratigraphic Units from Overlapping Relations of Depositional Features and the Zones of Welding and Crystallization



EXPLANATION

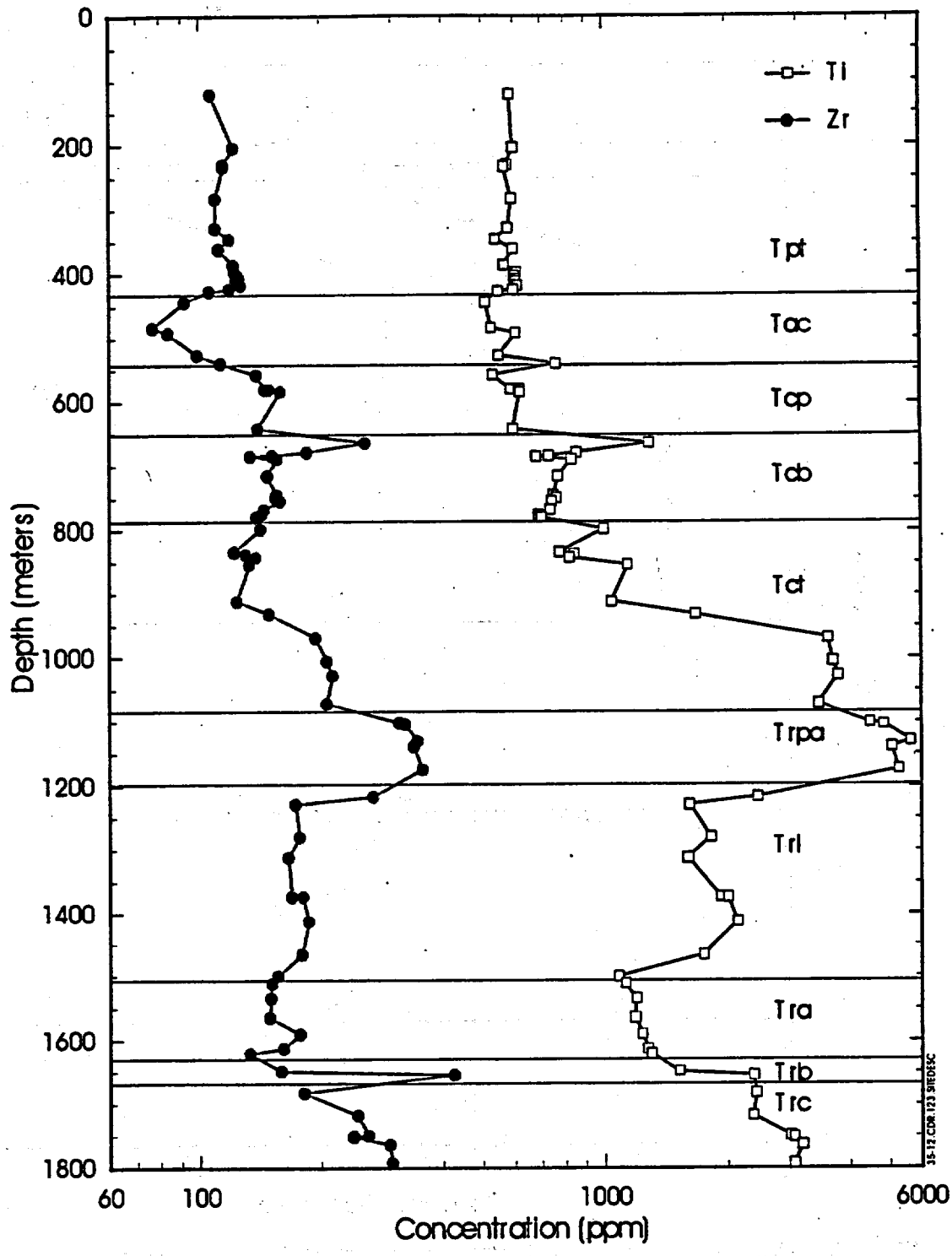
Amount of welding
- N Nonwelded
- P Partially welded
- M Moderately welded
- D Densely welded
- NA Not applicable

Process
- V Vitric (original glass)
- C Crystallized (high temperature)
- VP Vapor-phase crystallization
- Z Zeolitized ("low" temperature)
- A Argillic ("low" temperature)

Hydrogeologic significance
- ↓ Extensive and characteristic
- A Not common, but possibly of local importance

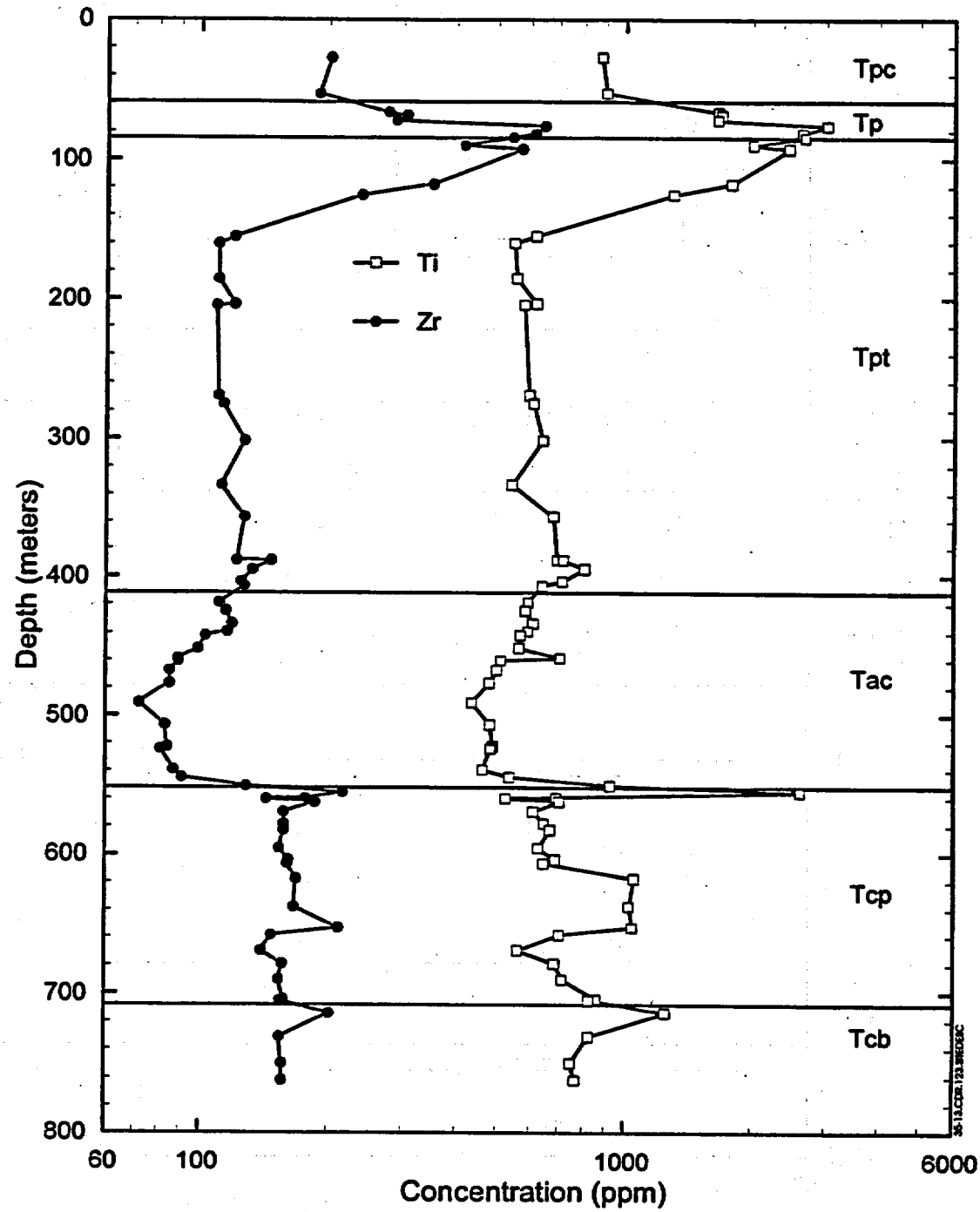
35-11.CDR.123.SIEDESC

Figure 3.5-11. Twenty-three Rock Types That Comprise Yucca Mountain



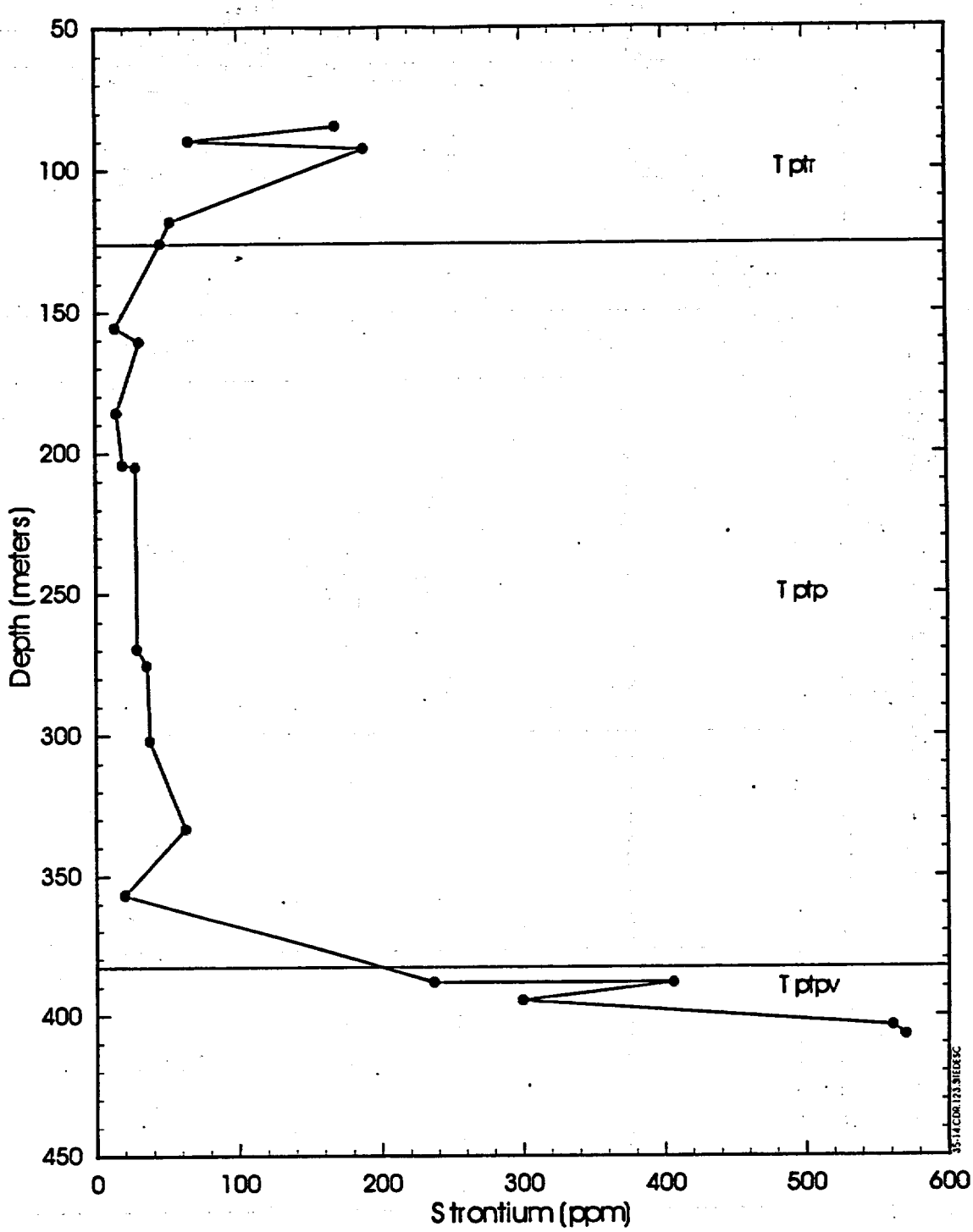
NOTE: Unit abbreviation from Tables 3.5-1 and 3.5-2; Units TRA, TRB, and TRC are pre-lithic ridge tuff lava flows. Note that unit boundaries often coincide with changes in element concentrations or trends.

Figure 3.5-12. Graph Showing Concentrations of Titanium (Ti) and Zirconium (Zr) as a Function of Depth for Core Samples from Borehole G-1 (Zr data from Spengler and Peterman 1991; Ti data unpublished)



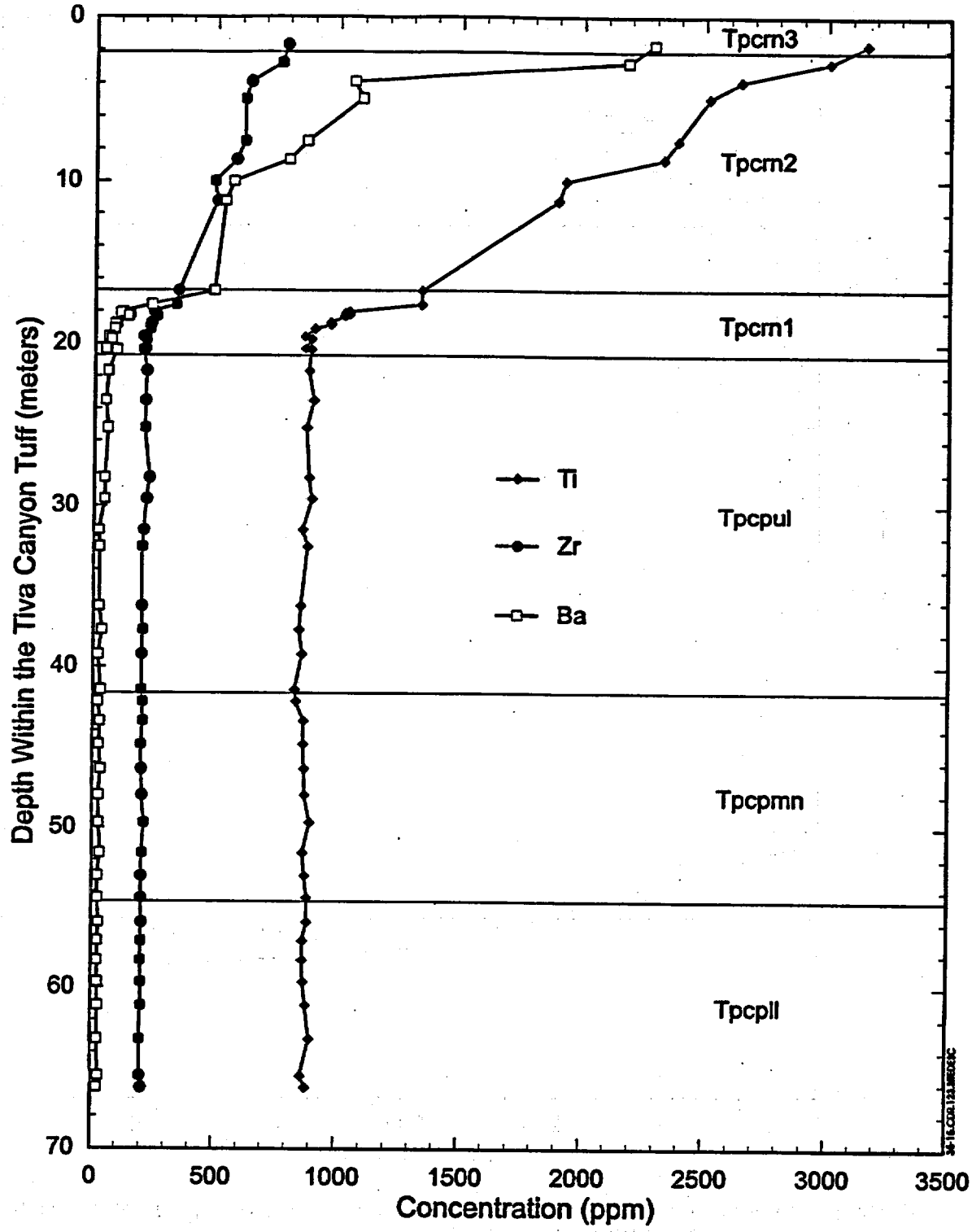
NOTE: Unit abbreviations from Table 3.5-2. the upper part of the Topopah Spring Tuff (Tpt) shows the sharp increases in these two elements typical of the crystal-rich member. Undivided units between the Tiva Canyon Tuff and the Topopah Spring Tuff (Tpt) identified as Tp.

Figure 3.5-13. Graph Showing Concentrations of Titanium (Ti) and Zirconium (Zr) as a Function of Depth for Core Samples from Borehole A#1 (from Peterman, Spengler et al. 1993)



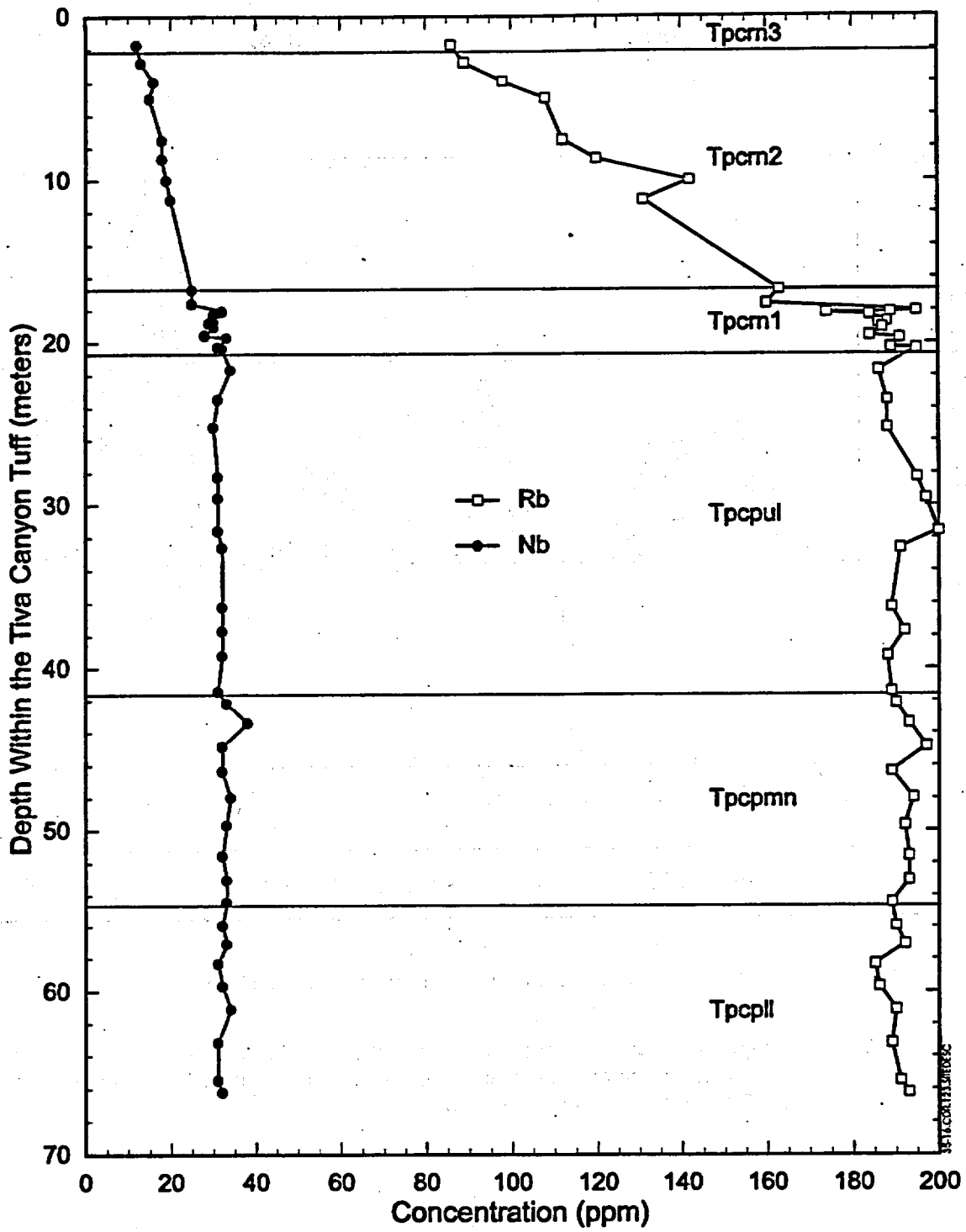
NOTE: Unit abbreviations from Table 3.5-2. At this locality, the basal vitrophyre (Tptpv) is altered which results in these unusually high strontium concentrations.

Figure 3.5-14. Graph Showing Strontium Concentration as a Function of Depth for Core Samples of Topopah Spring Tuff from Borehole A#1 (from Peterman, Spengler et al. 1993)



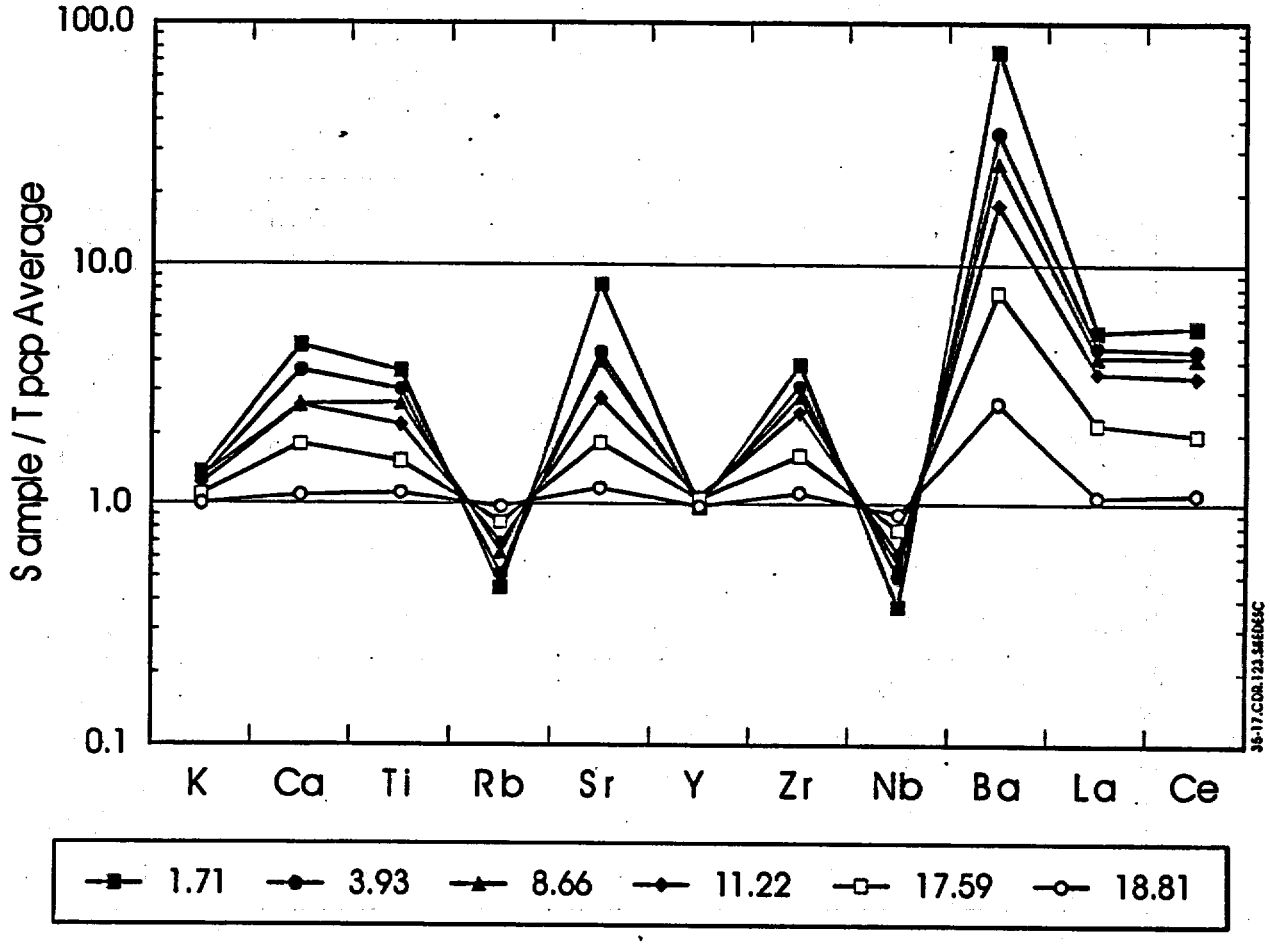
NOTE: This shows the typical gradual enrichment in these elements upsection in the crystal-rich member (Tpcr). Unit abbreviations from Table 3.5-2.

Figure 3.5-15. Graph Showing Concentrations of Titanium (Ti), Zirconium (Zr), and Barium (Ba) as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 (Peterman and Futa 1996)



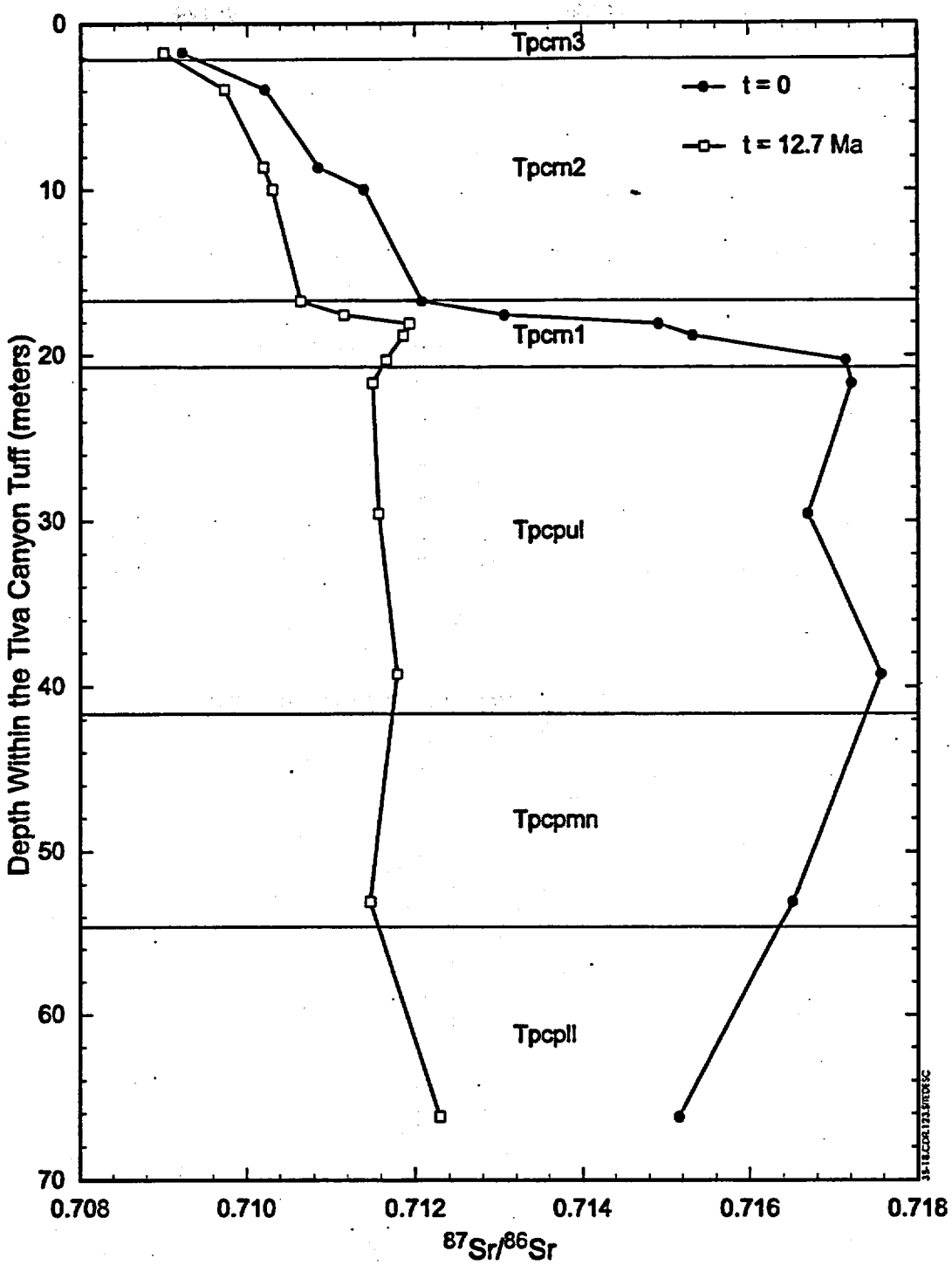
NOTE: The graph shows the typical depletion in Rb and Nb upsection in the crystal-rich member (Tpcr). Unit abbreviations from Table 3.5-2.

Figure 3.5-16. Graph Showing Concentrations of Rubidium (Rb) and Niobium (Nb) as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 (Peterman and Futa 1996)



NOTE: Samples are identified by their stratigraphic depth from the top of the hole.

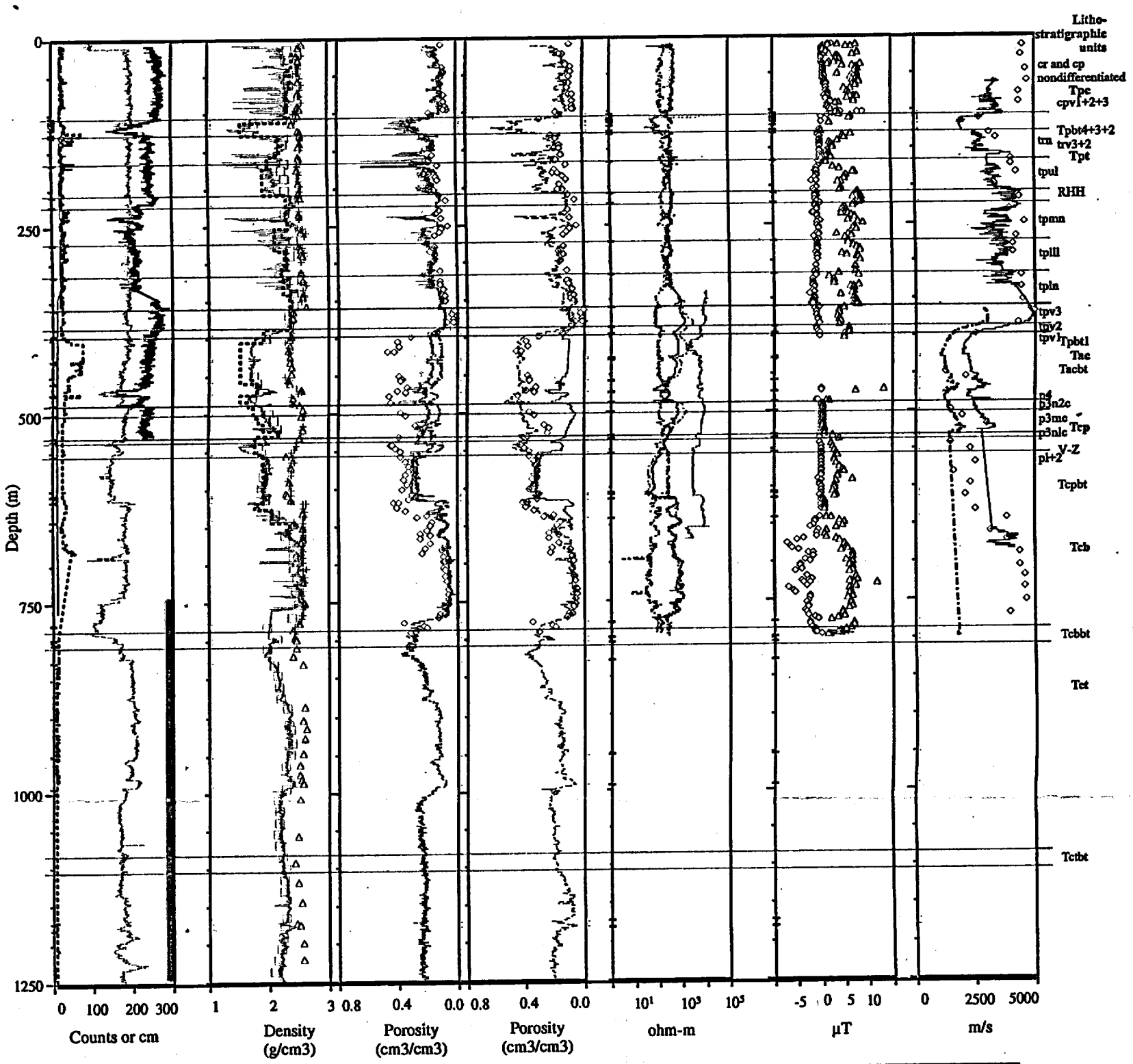
Figure 3.5-17. Graph Showing Abundances of a Suite of Elements Relative to the Abundances in the Average Crystal-poor Member of the Tiva Canyon Tuff (Tpcp) from Borehole NRG#3 (Peterman and Futa 1996)



NOTE: The graph shows that both the present-day and initial ratios change dramatically from the crystal-poor (Tpcp) to the crystal-rich (Tpcr) members. Unit abbreviations from Table 3.5-2.

Figure 3.5-18. Graph Showing the Measured (T = 0) and Initial (T = 12.7 Ma) $^{87}Sr/^{86}Sr$ Ratios as a Function of Stratigraphic Thickness for Core Samples of Tiva Canyon Tuff from Borehole NRG#3 (Peterman and Futa 1996)

INTENTIONALLY LEFT BLANK



KEY TO GEOPHYSICAL MEASUREMENT

CALGU3	Caliper, Borehole GU3	PHIWENP	Water Filled Porosity, based on Epithermal Neutron
CALG3	Caliper, Borehole G3	PHIENP	Porosity, based on Epithermal Neutron
TC (total counts)	Total Count, Spectral Gamma	PORCN	Porosity on Core from Holmes and Narver
GR (counts)	Gamma Ray		
SWL	Static Water Level	SN	Resistivity, Short Normal
Contact	Top of Lithologic Unit	LN	Resistivity, Long Normal
		ENP	Epithermal Neutron
DBC	Density, Borehole Compensated	RILD	Resistivity, Deep Induction
GRAV	Density, Borehole Gravimeter	NBCx10	Neutron-Borehole, Compensated – Multiplied by 10
GDCN	Grain Density on Core from Holmes and Narver		
GDMIN	Grain Density on Mineralogy	MAG/10	Total Magnetic Field, Fluxgate – Divided by 10
SBDCA2	Saturated Bulk Density on Core from USGS by Anderson	MS	Magnetic Susceptibility
		MSC	Magnetic Susceptibility, Core
PHIWNBC	Water Filled Porosity, based on Neutron-Borehole Porosity Compensated	MRSIGN	Remanent Magnetization Measured on Core
PHINBC	Porosity, based on Neutron-Borehole Porosity Compensated	PVEL	Comp. Velocity, Waveform
		SVEL	Sheer Velocity, Waveform
PORCN	Porosity on Core from Holmes and Narver	VELCA	Comp. Velocity, Core

35-19.CDR.123.SITEDESC

NOTE: Geophysical logs from Nelson, P.H. et al. (1991) and lithologic contacts from Scott and Castallanos (1984), Moyer and Geslin (1995), and Moyer et al. (1996). Lithologic symbols from Table 3.5-2 with the exception of divisions in Unit 3 of the Prow Pass Tuff (p3n1c - crystallized, nonwelded to partially welded; p3mc - crystallized,moderately welded; and p3n2c - crystallized, welded to partially welded). Other Symbols include: RHH - Top of the Repository Host Horizon, V-Z - Vitric-Zeolithic Boundary, SWL - Static Water Level).

Figure 3.5-19. Geophysical Logs of Borehole G3/GU3 Showing Responses to Lithologic Features in the Topopah Spring Tuff and Older Formations

APERTURE CARD
Also Available on Aperture Card

9902040045 - 08

INTENTIONALLY LEFT BLANK

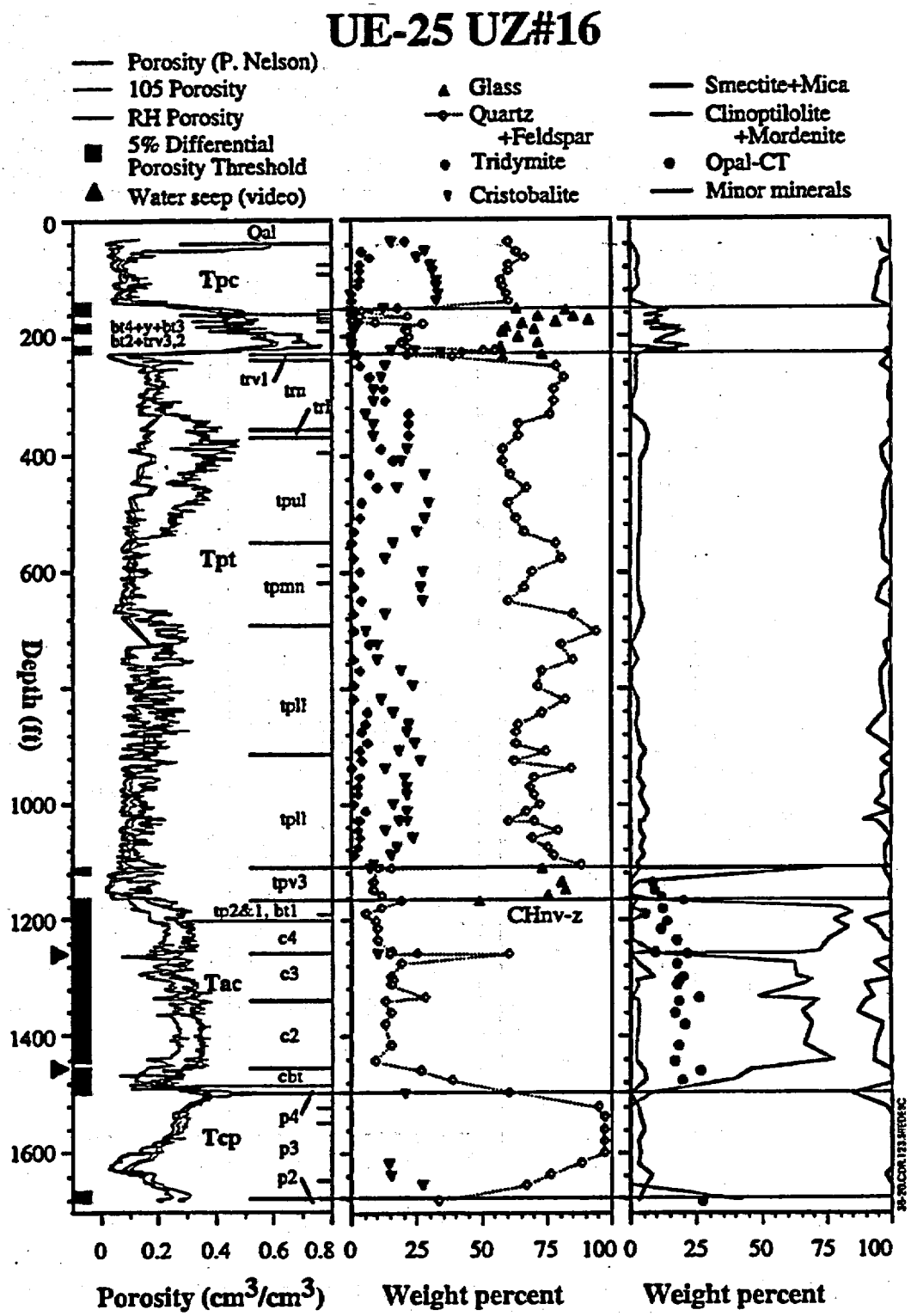


Figure 3.5-20. Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantative Mineralogy in Borehole UZ#16.

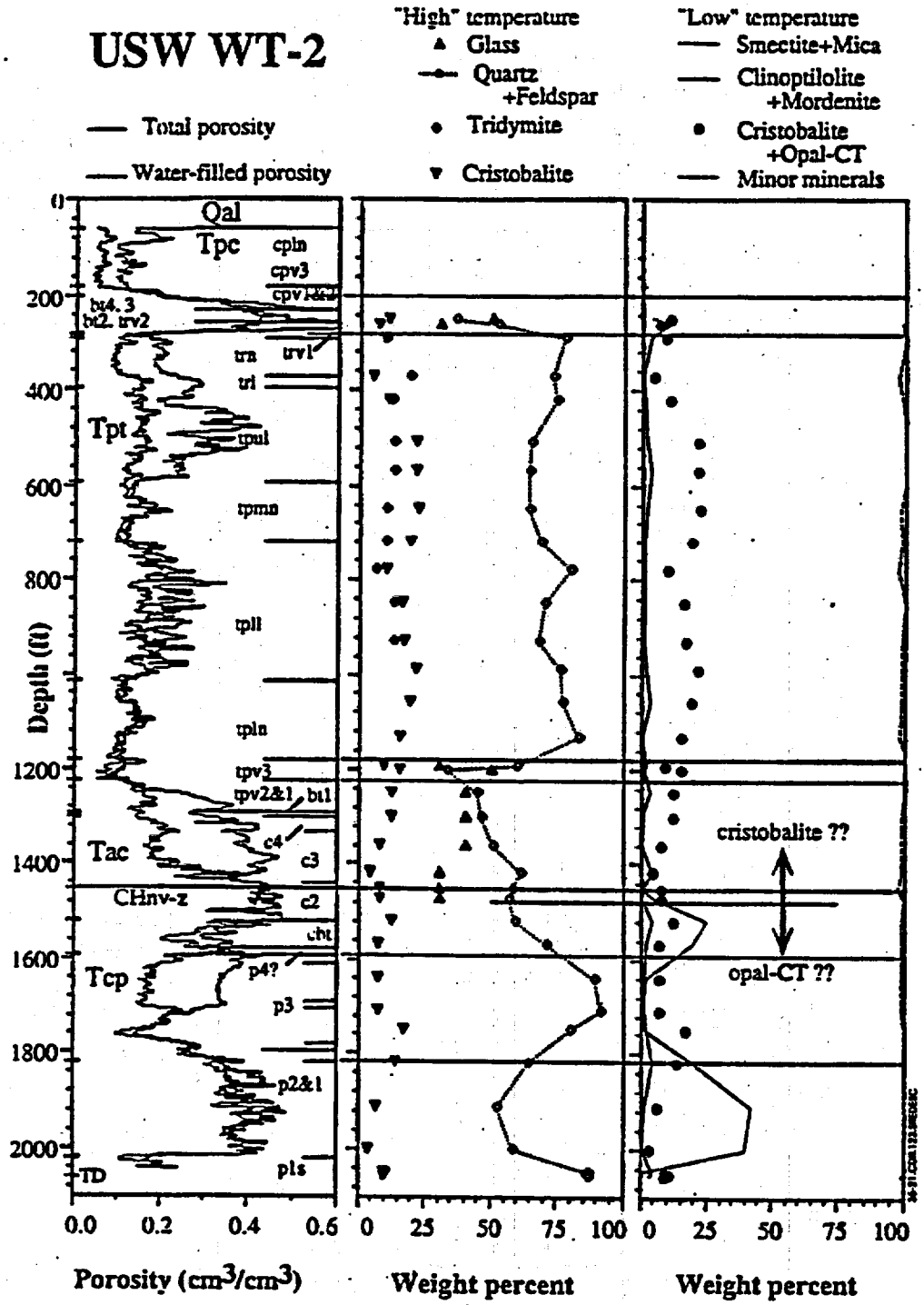
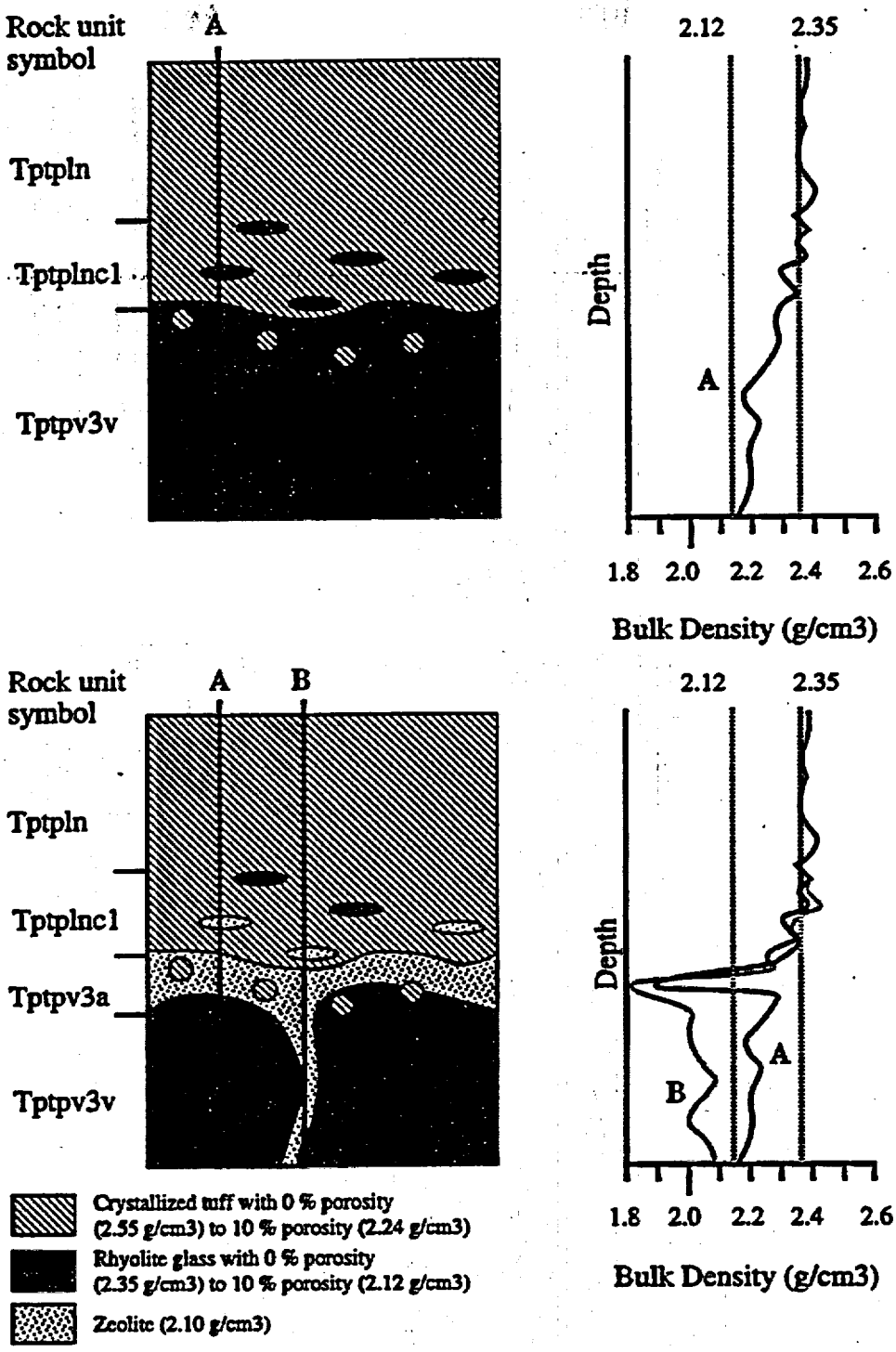
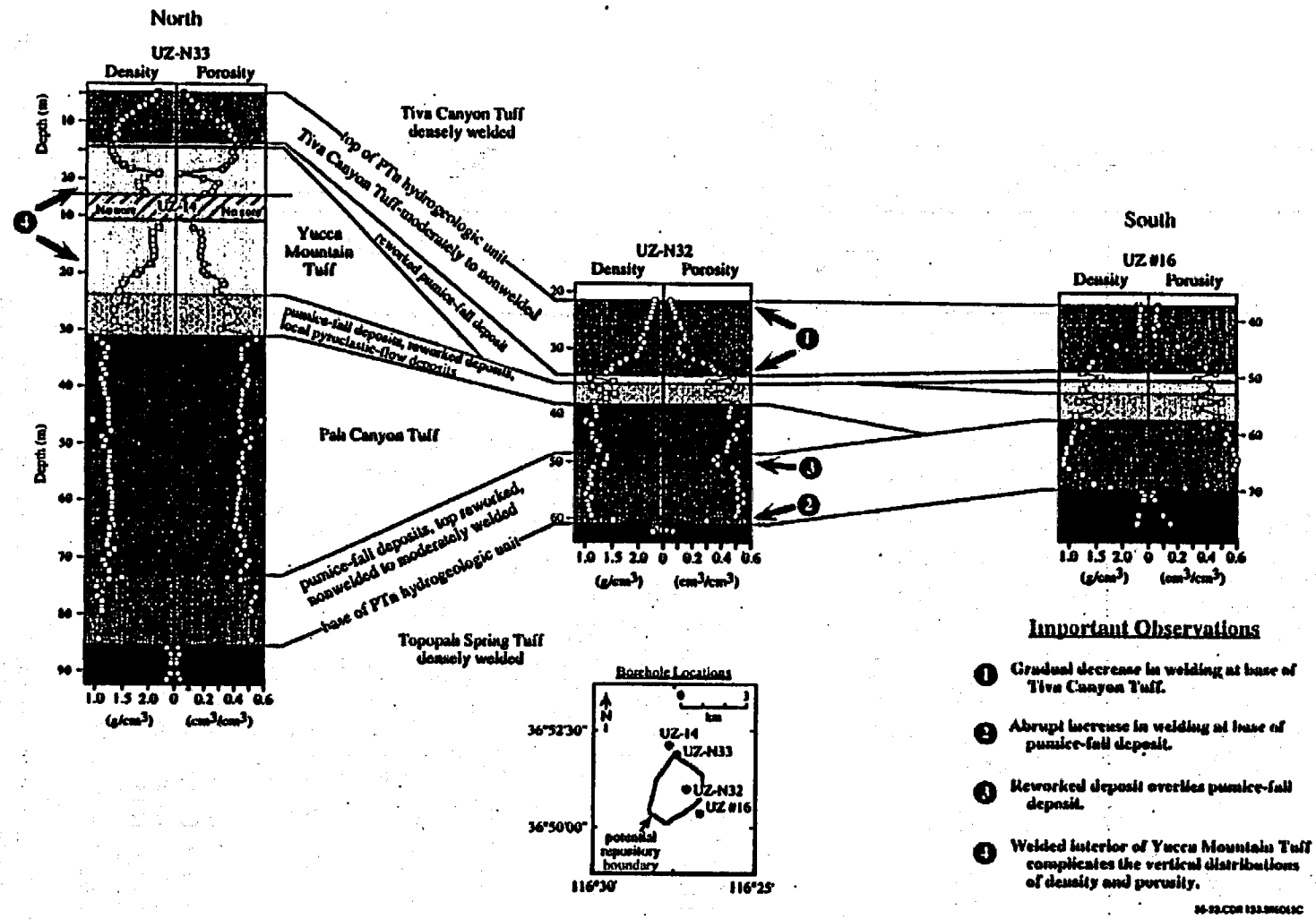


Figure 3.5-21. Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantitative Mineralogy in Borehole WT-2



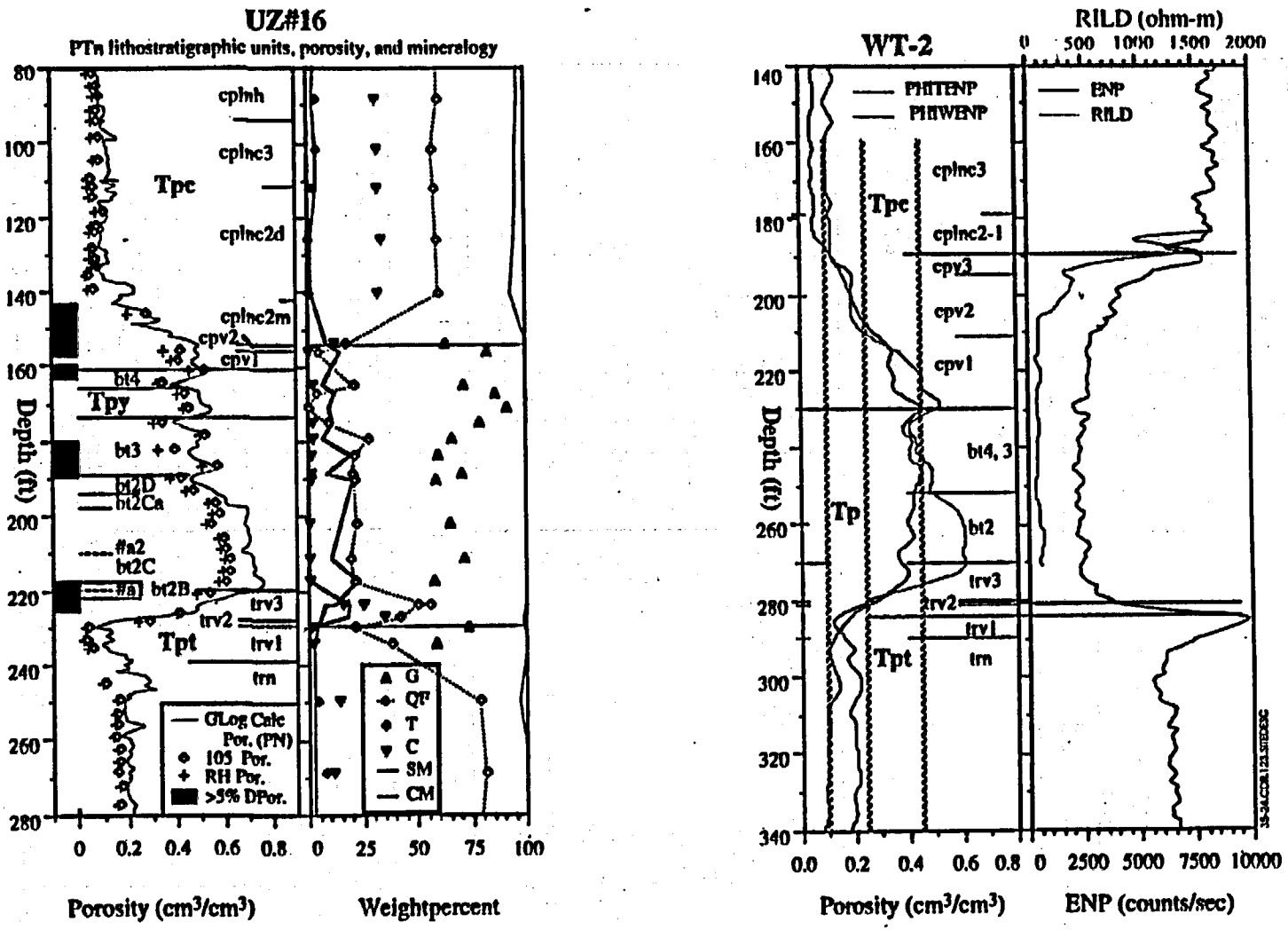
NOTE: Alteration near the crystallized-vitric contact and fractures in the vitric densely welded rocks in the Topopah Spring Tuff (see Table 3.5-2 for descriptions of the rocks).

Figure 3.5-22. Rock Type Effects on Geophysical Logs



NOTE: Data are from relative humidity oven determinations (from Moyer et al. 1996).

Figure 3.5-23. Bulk Density and Porosity Plotted Relative to Depth for the Composite Paintbrush Tuff Nonwelded Hydrogeologic Unit in Boreholes UZ-N33, UZ-14, UZ-N32, and UZ#16



NOTE: See Figures 3.5-20 and -21 for explanation of symbols.

Figure 3.5-24. Lithostratigraphy, Porosity from Core and Geophysical Logs, and Quantitative Minerology from the Paintbrush Tuff Nonwelded Hydrogeologic Unit borehole UZ#16 and WT-2

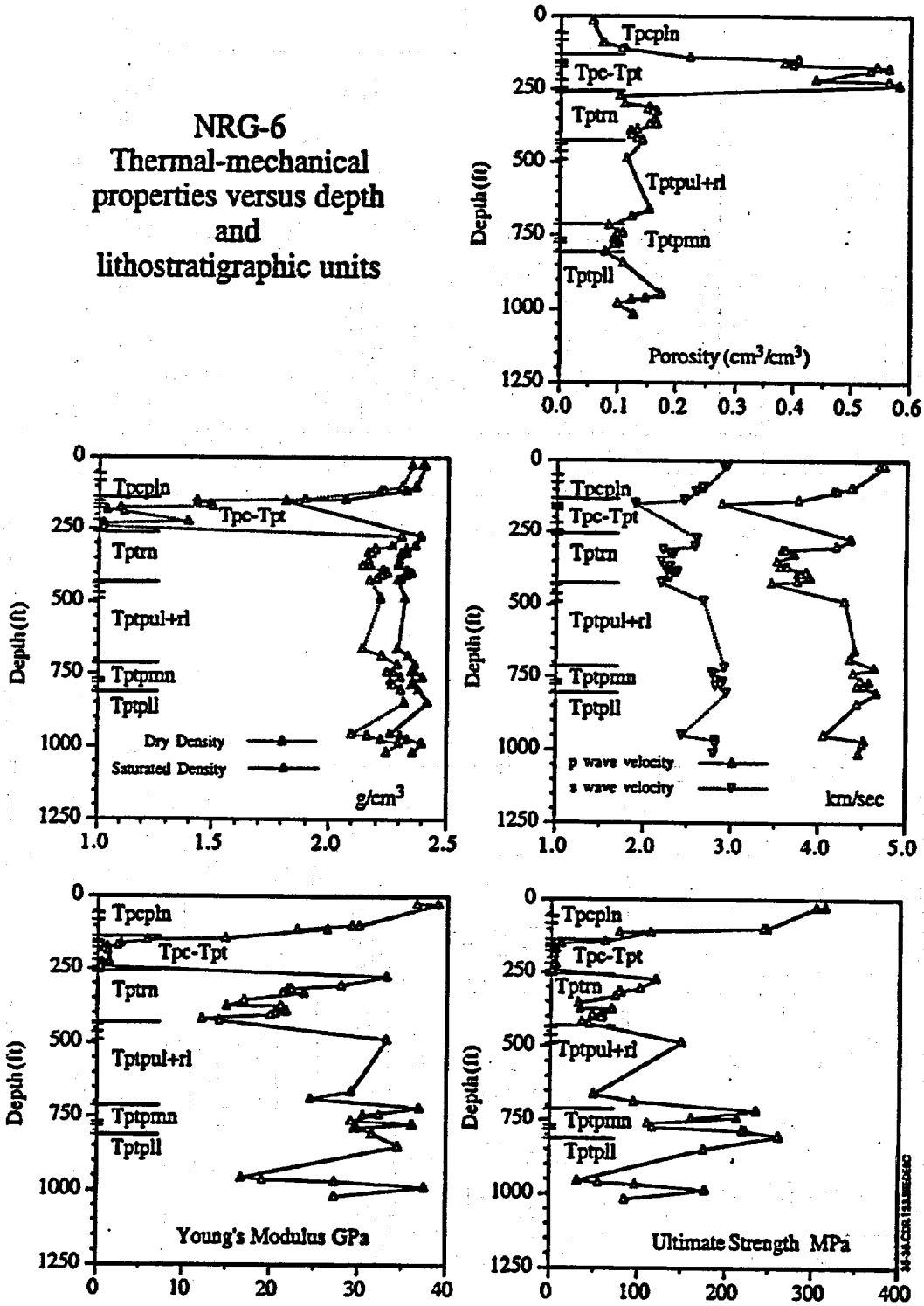
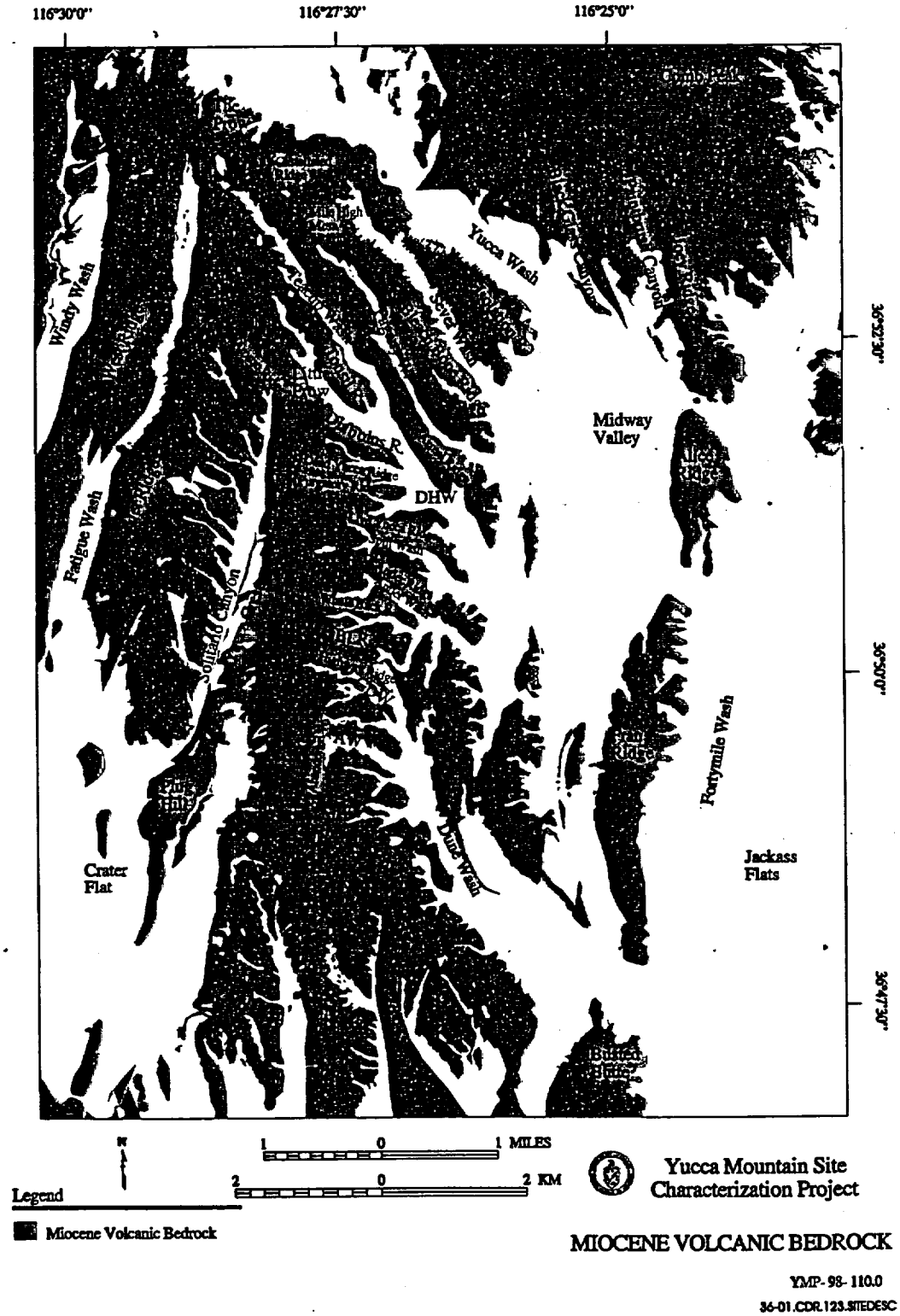
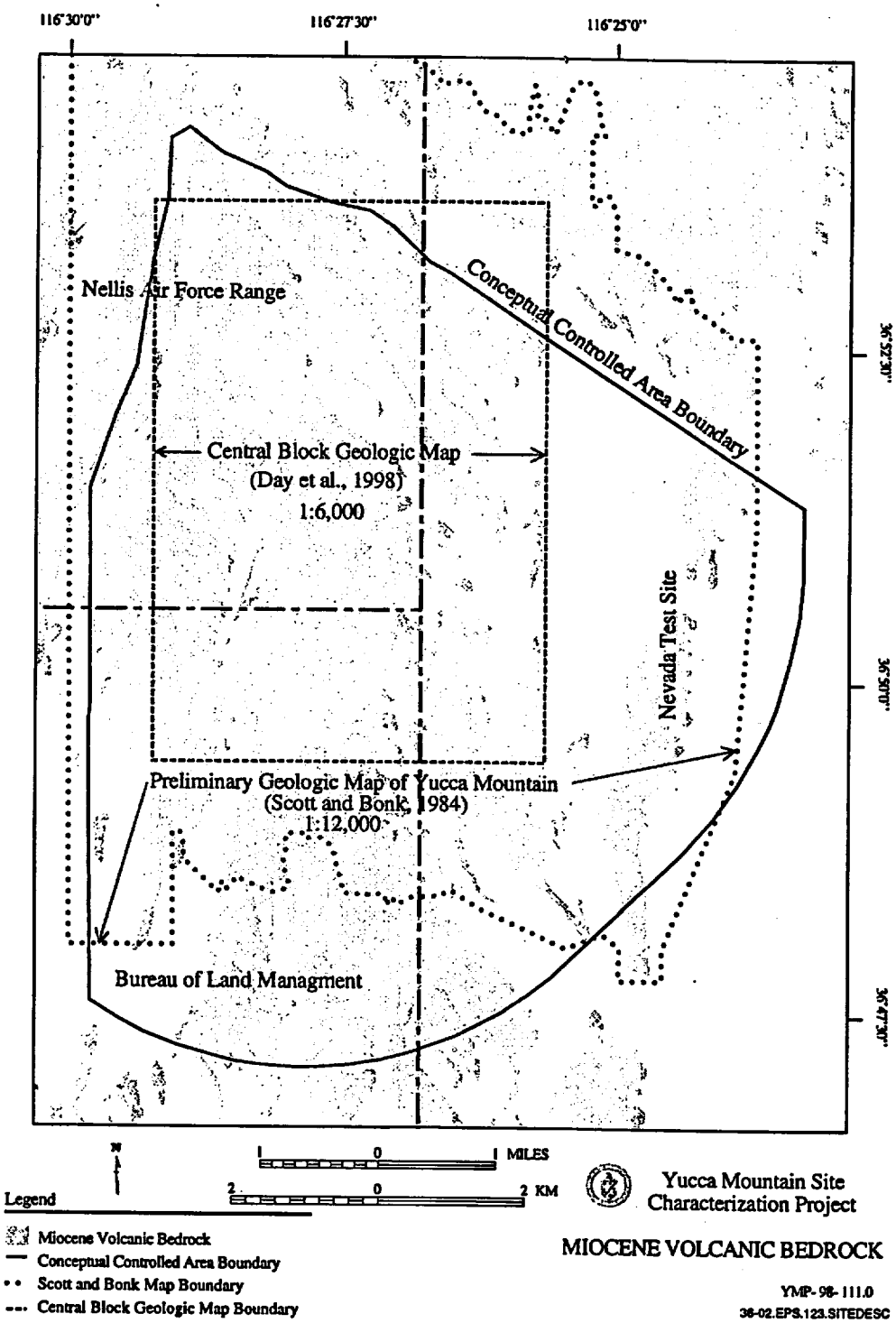


Figure 3.5-25. Lithostratigraphic Units and Thermal Mechanical Properties Plotted Versus Depth in Borehole NRG-6



NOTE: The outline of this figure corresponds to the outline of the 1:24,000-scale Site Area Geologic Map (Day et al. 1998b).

Figure 3.6-1. Index Map Showing Areas Where Miocene Volcanic Bedrock Is Exposed (In Brown), Along With Place Names in the Yucca Mountain Site Area, as Used in this Report



NOTE: The outline of this map corresponds to the outline of the 1:24,000 Site-area Geologic Map by Day et al. (1998b). The 1:12,000 Geologic Mapping of Scott, R.B. (1992) covers the areas of exposed bedrock south of the Scott, R.B. and Bonk (1984) coverage, both within the southern part of this figure, and in the southernmost part of Yucca Mountain to the south of the area covered by this figure.

Figure 3.6-2. Index Map Showing Areas Where Miocene Volcanic Bedrock Is Exposed (In Gray), Conceptual Controlled Area Boundary, and Areas of Coverage of the Geologic Maps and by Scott, R.B. and Bonk (1984) and Day et al. (1998a)

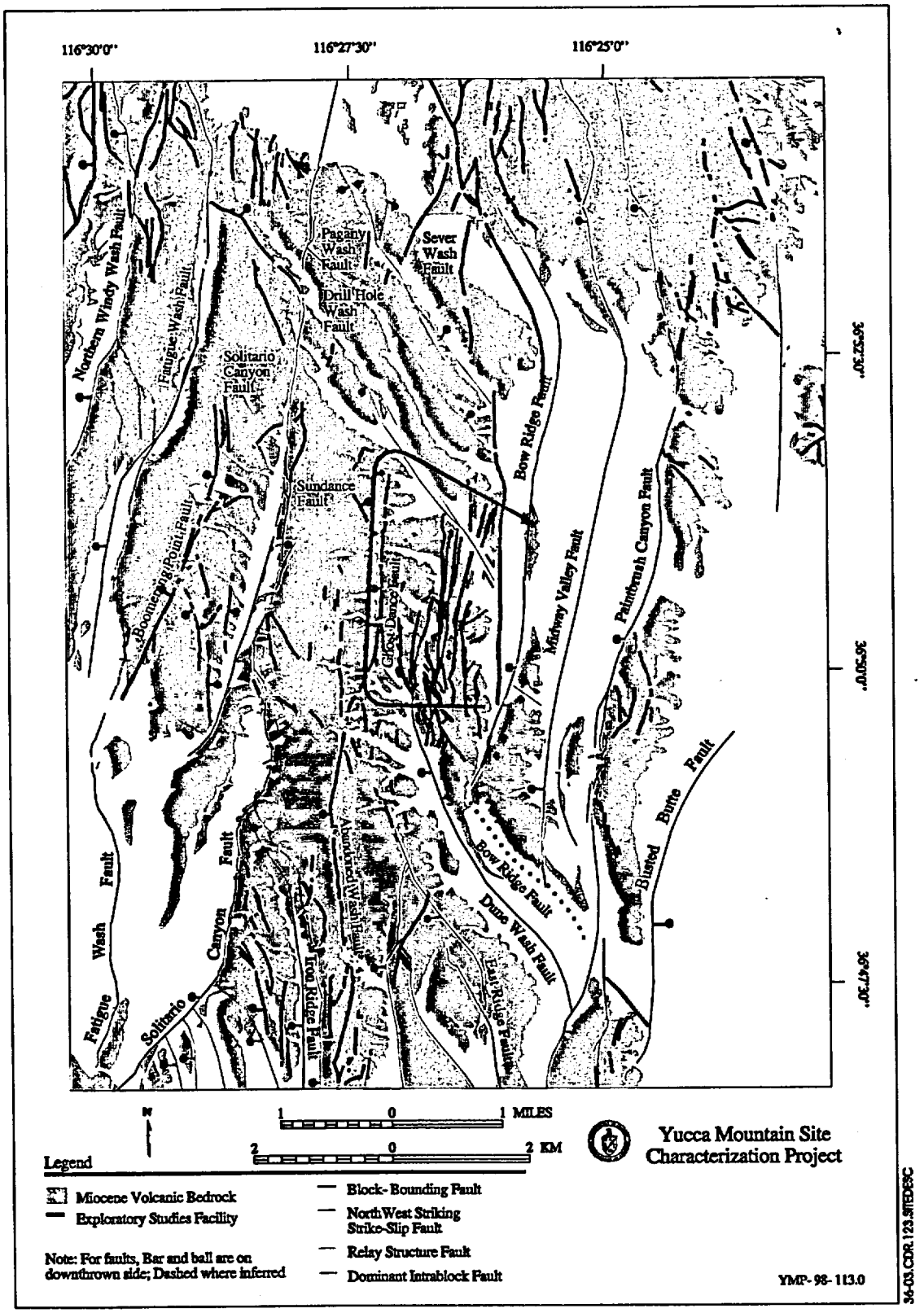
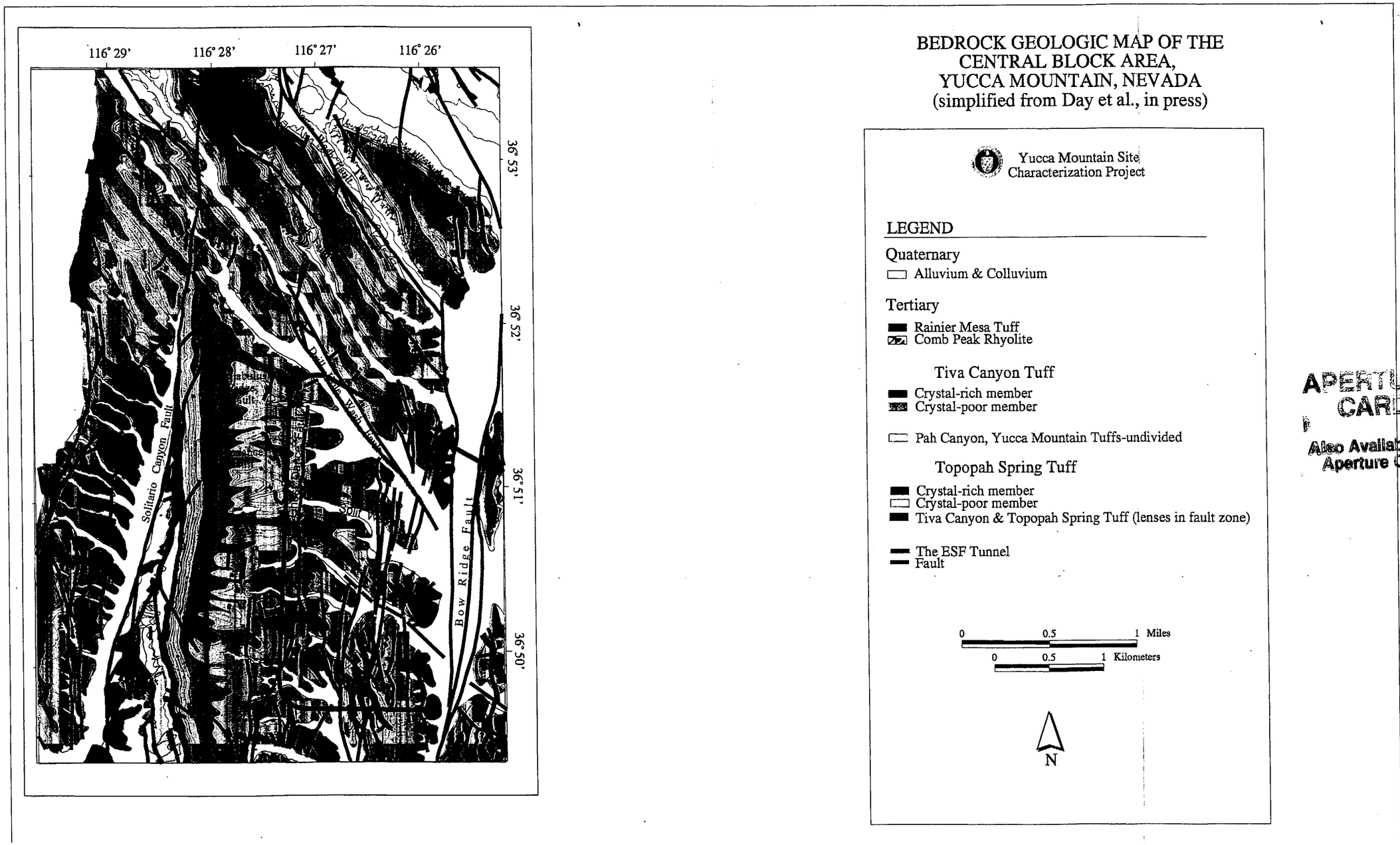


Figure 3.6-3. Map Showing Block-Bounding Faults and Important Intrablock Faults in the Site Area (based on the mapping of Day et al. 1998b).

INTENTIONALLY LEFT BLANK



NOTE: Solid black lines are faults, portrayed here as solid where exposed in bedrock and where concealed beneath unconsolidated surficial deposits. The reference coordinates correspond to the Nevada State Coordinate System, in feet.

APERTURE CARD
Also Available on Aperture Card

Figure 3.6-4. Simplified Version of Central Block Geologic Map (Day et al. 1998)

9902040045 - 09

INTENTIONALLY LEFT BLANK

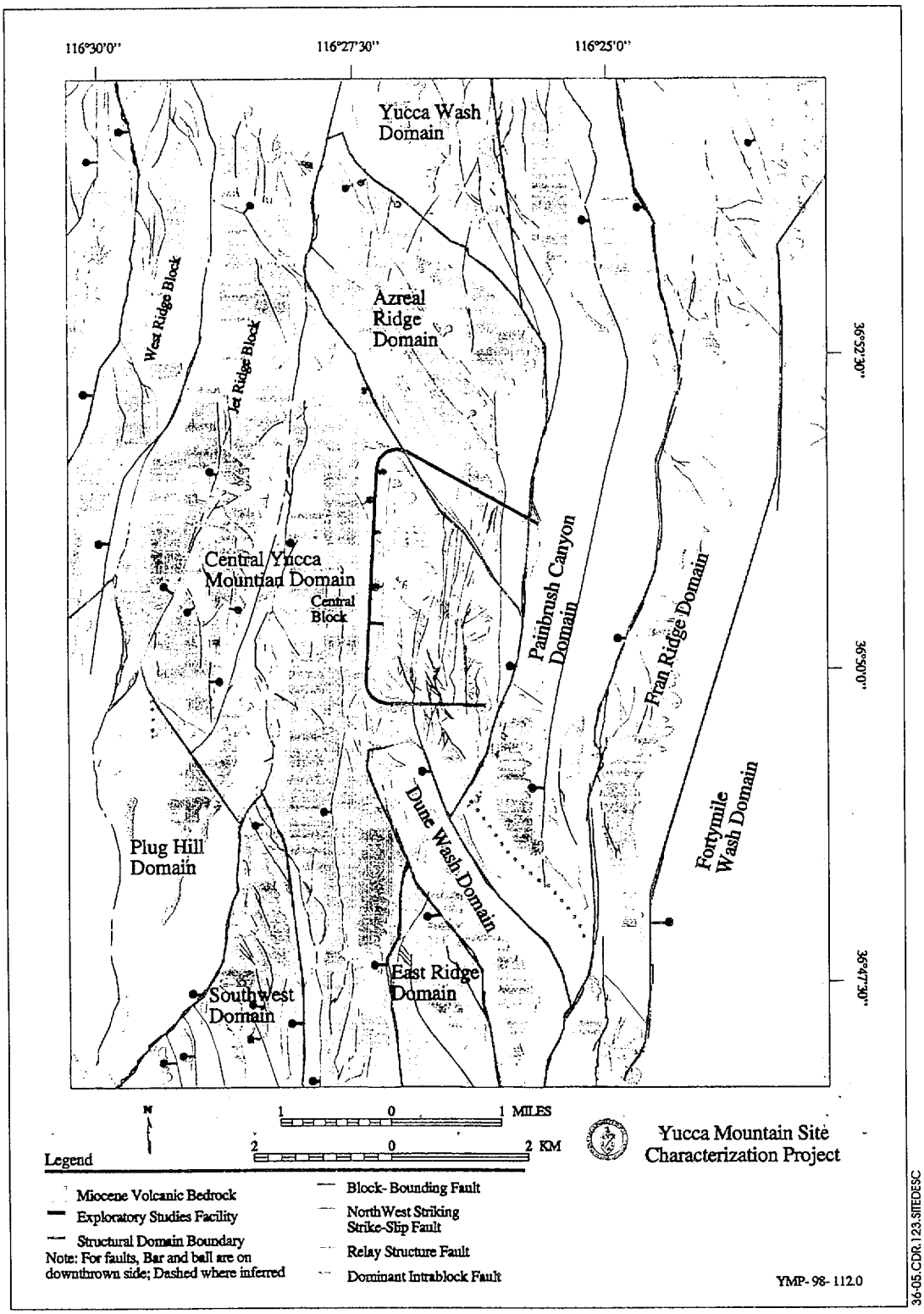
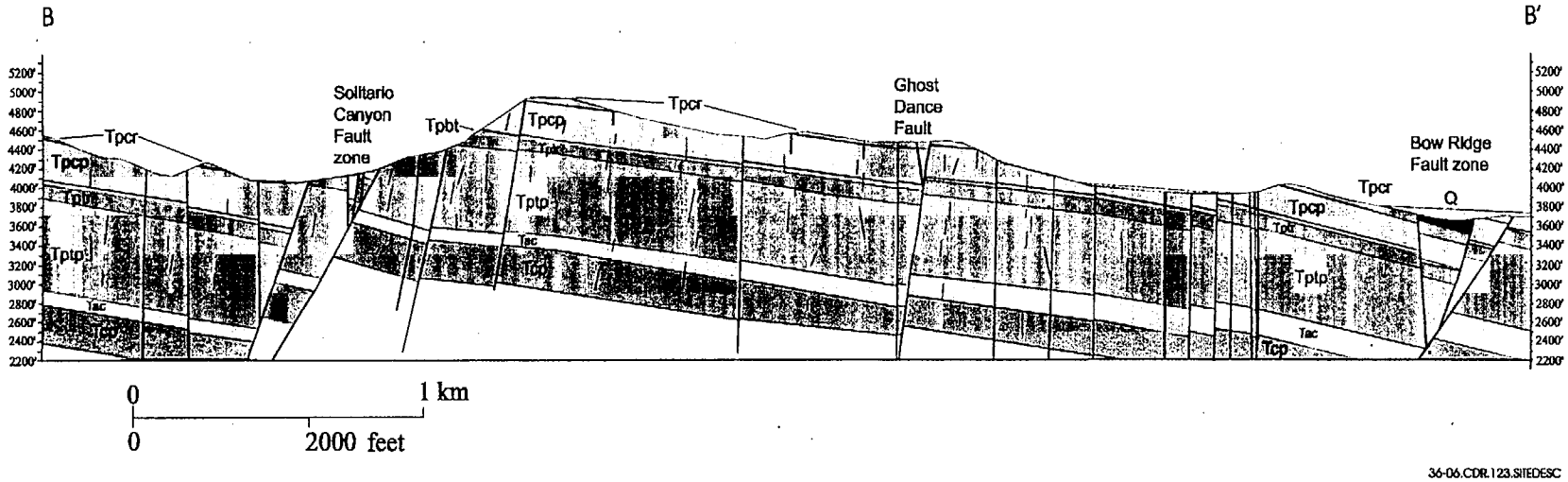
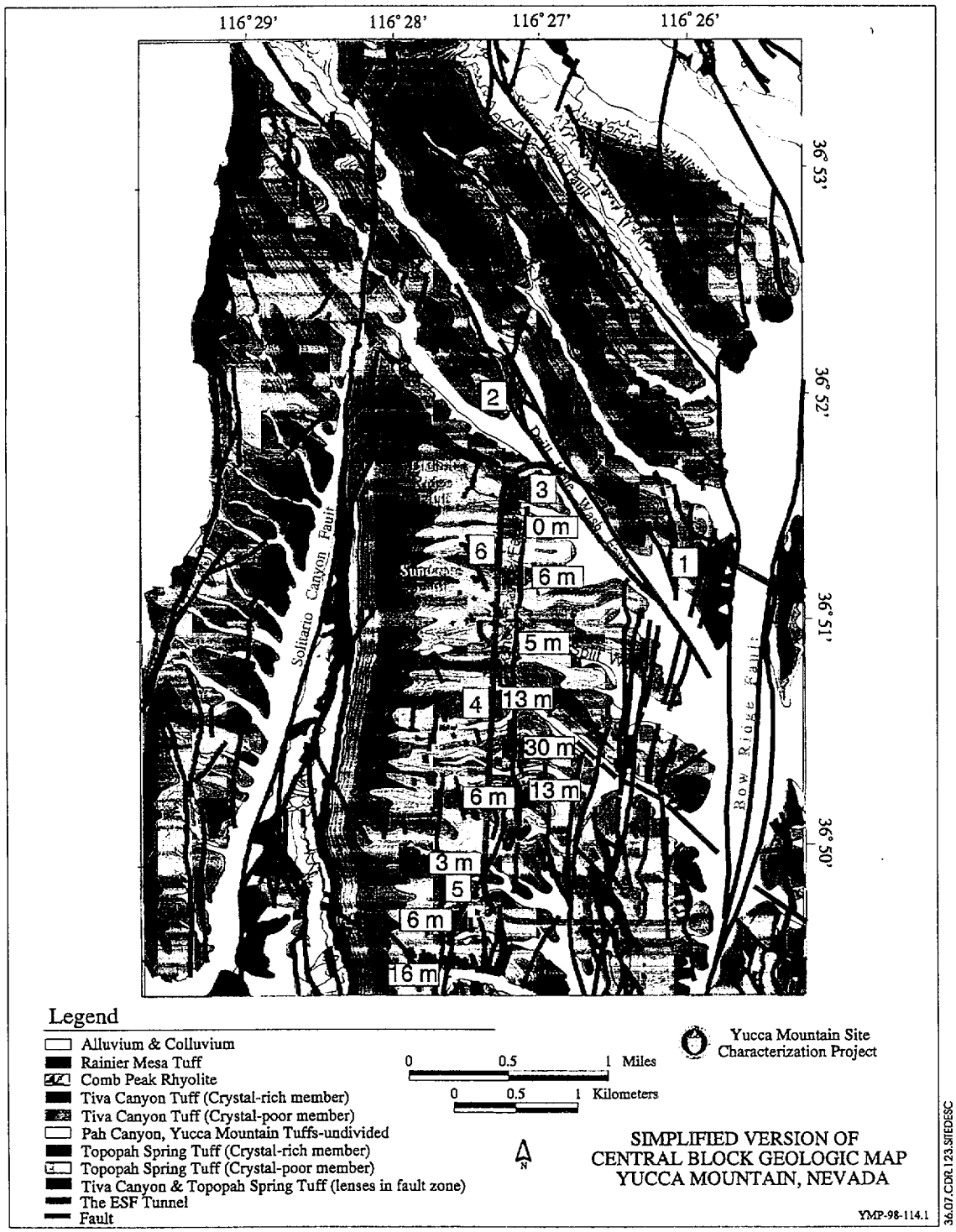


Figure 3.6-5. Map Showing Structural Domains in the Site Area, Superimposed on the Positions of Block-bounding Faults and Important Intrablock Faults (based on the mapping of Day et al. 1998b)



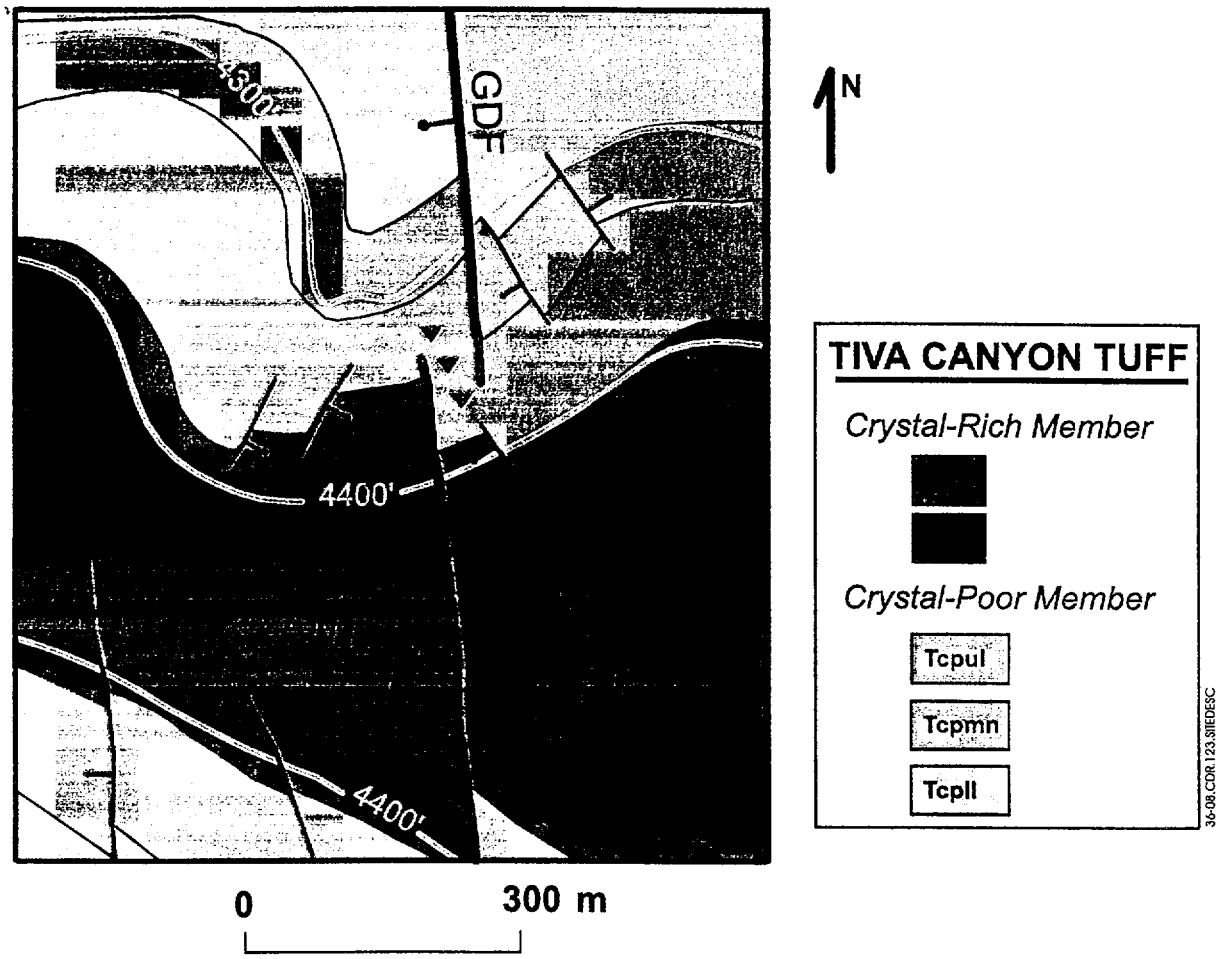
NOTE: See Table 3.5-2 for stratigraphic unit symbols.
The Cross-Section line is shown on Figure 3.6-4. Q, Unconsolidated Quaternary deposits; Tpcr, Crystal-rich member of the Tiva Canyon Tuff; Tpcp, Crystal-poor member of the Tiva Canyon Tuff; Tpbt, Post-Topopah Spring Tuff, Pre-Tiva Canyon Tuff bedded tuffs; Tptr, Crystal-rich member of the Topopah Spring Tuff; Tptp, Crystal-poor member of the Tonopah Spring Tuff; Tac, Calico Hills Formation; Tcp, Prow Pass Formation.

Figure 3.6-6. Simplified Version of Cross-Section B-B' from the Central Block Geologic Map



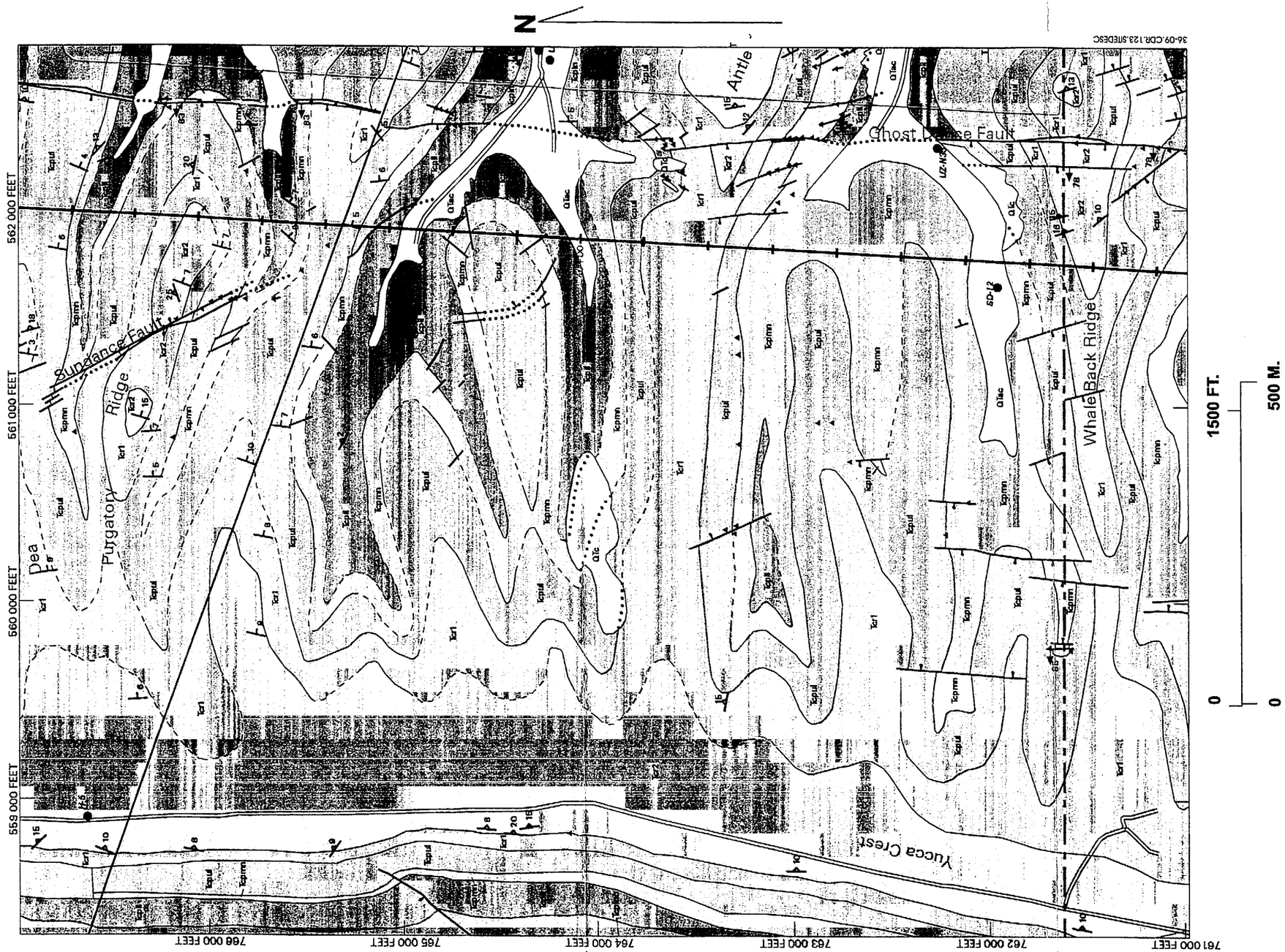
NOTE: Labels show variation in amount of post-Tiva Canyon Tuff displacement along the Ghost Dance Fault (in black-outlined boxes, in meters), and numbered locations for comparison of surface and subsurface mapping discussed in text (magenta numbers in magenta-outlined boxes). Colored and patterned geologic units are the same as those defined in Figure 3.6-4.

Figure 3.6-7. Simplified Version of Central Block Geologic Map, with the Exploratory Studies Facility Plotted



NOTE: See Table 35-2 for stratigraphic unit symbols; faults have bar and ball symbol on down thrown side.

Figure 3.6-8. Large-Scale Detail Map of "Step-Over" in the Surface Trace of the Ghost Dance Fault on the North-Facing Slope of Antler Ridge



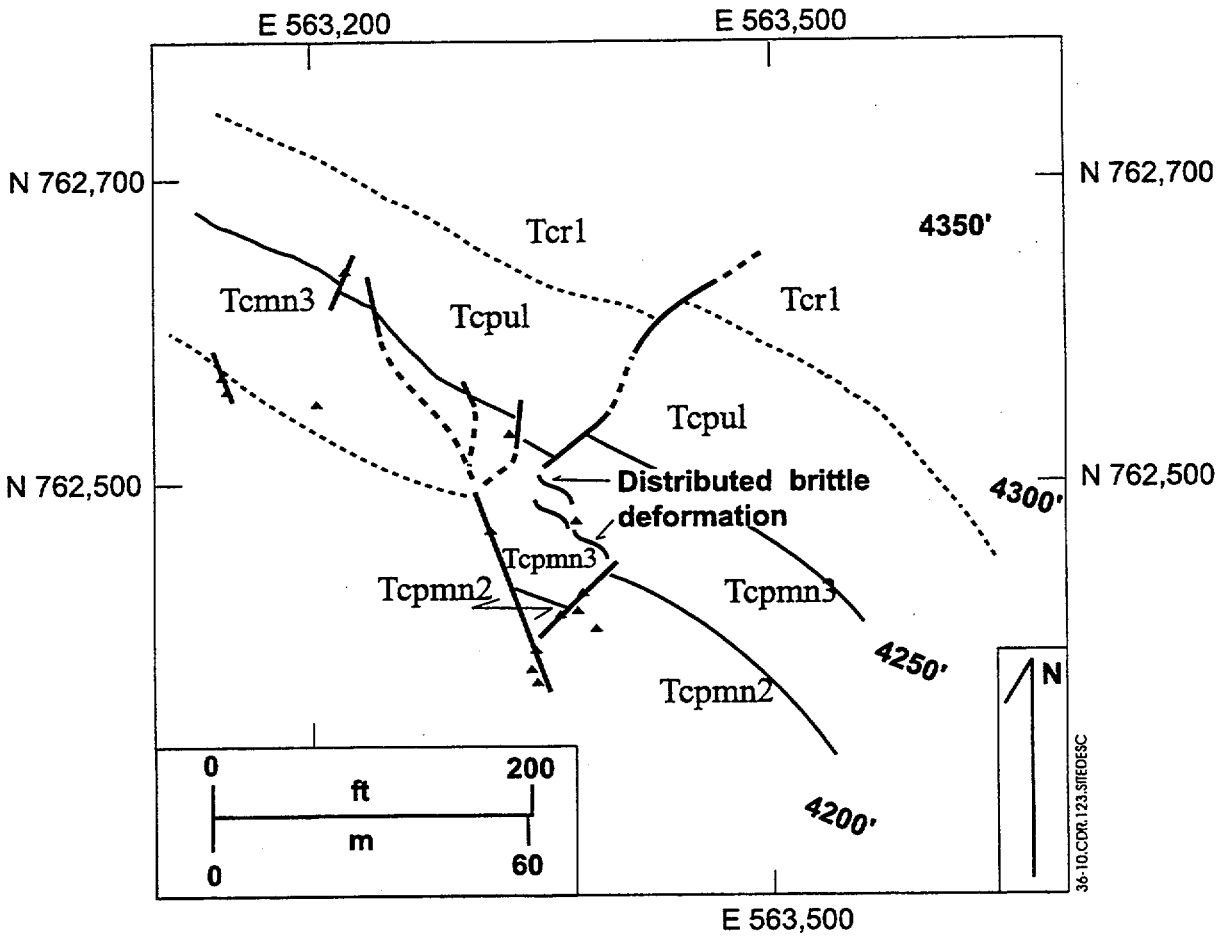
APERTURE CARD

Also Available on Aperture Card

Figure 3.6-9. Representative Detail of the Relatively Undeformed Yucca Crest Sub-Block in the Central Block

9902040045 - 10

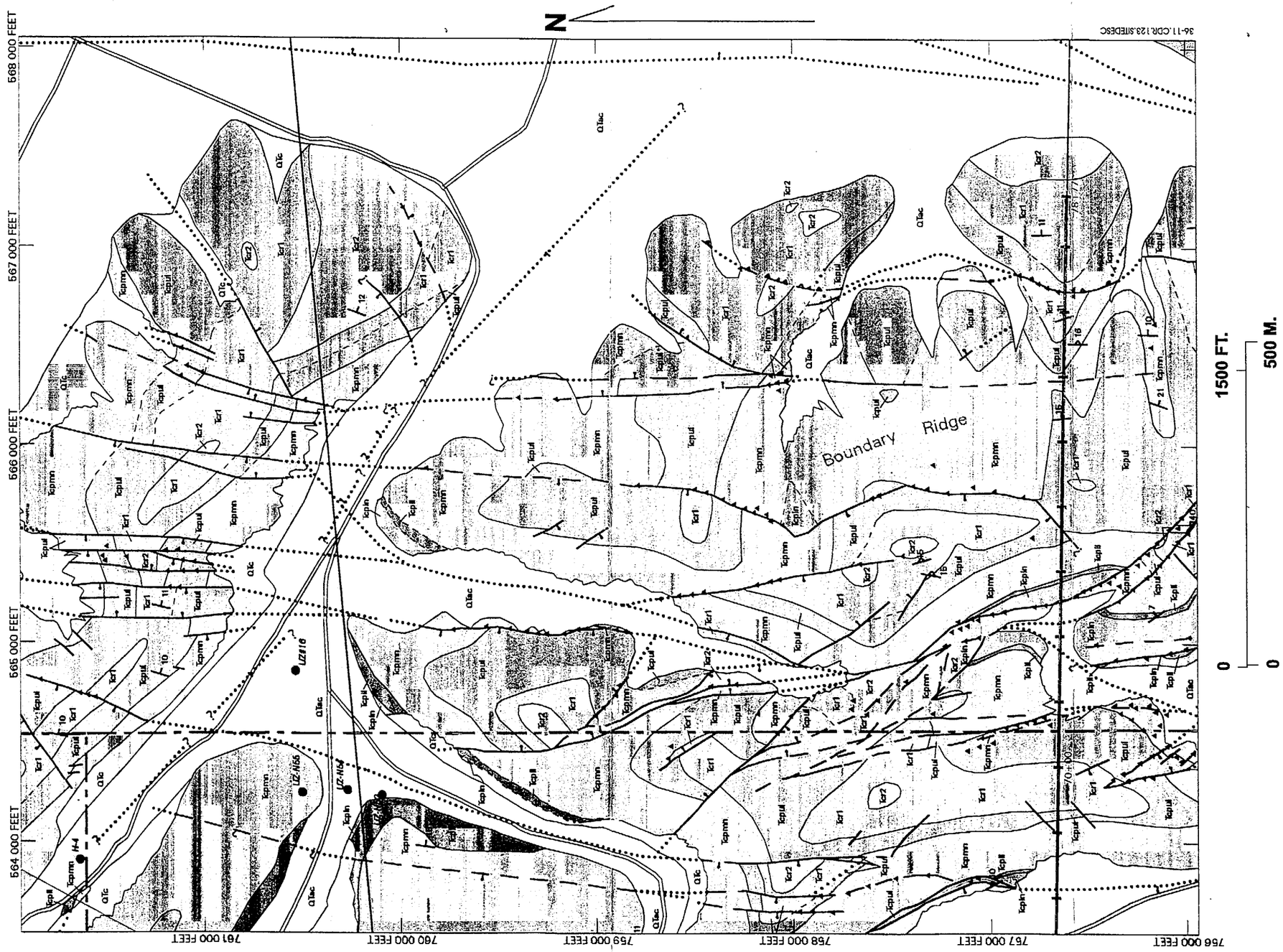
INTENTIONALLY LEFT BLANK



NOTE: Reference coordinates (Nevada State Coordinate System) are shown at map border. Stippled lines are topographic contours, labeled in feet above sea level. Bold black lines, faults; narrow black lines, stratigraphic contacts. Triangles denote breccia exposures. Wavy lines are an inferred zone of distributed brittle deformation that accommodates strain between discrete faults that are not collinear. See Table 3.5-2 for stratigraphic unit symbols

Figure 3.6-10. Large-Scale Detailed Geologic Map of Discontinuous Surface Traces of Minor Faults on the South-Facing Slope of Antler Ridge (East of the Ghost Dance Fault) near Coordinates 762,500 N., 563,350 E. (Nevada State Coordinate System) from Potter et al. (1995)

INTENTIONALLY LEFT BLANK



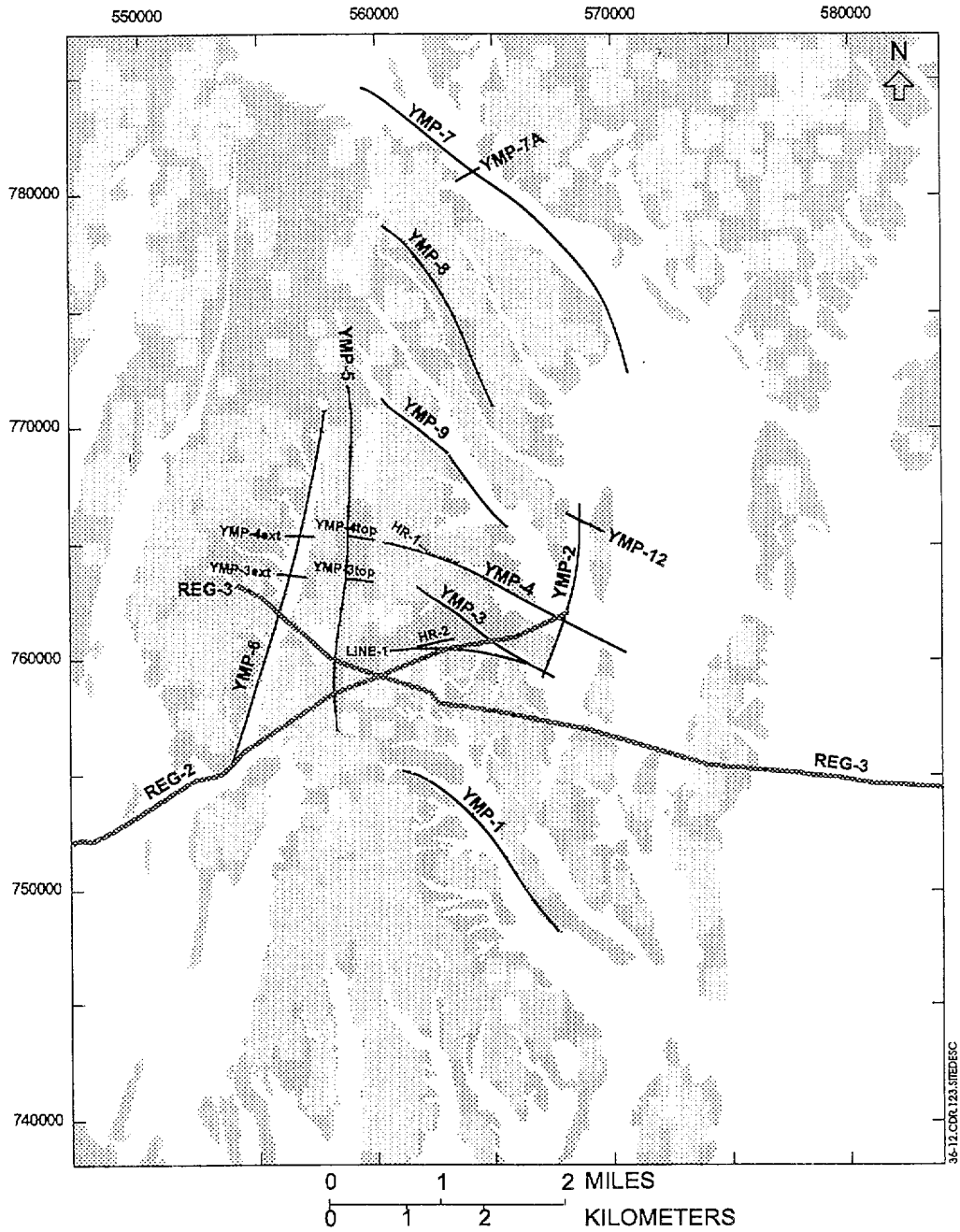
NOTE: See Table 3.5-2 for stratigraphic unit symbols; faults have bar and ball symbol on down thrown side.

Figure 3.6-11. Representative Detail of the Boundary Ridge Sub-Block in the Central Block

APERTURE CARD
Also Available on Aperture Card

9902040045 - //

INTENTIONALLY LEFT BLANK



Geophysical lines at Yucca Mountain

NOTE: Gray shading corresponds to areas where Miocene volcanic bedrock is exposed. Seismic reflection data were collected along all lines shown here. Of these, REG-2, and REG-3 are the regional seismic reflection lines (Brocher et al. 1996) HR-1 and HR-2 are very high resolution seismic reflection lines (station spacings of 1 to 2 m); all others are standard high-resolution seismic reflection lines (station spacings of 6 to 12 m) (Feighner et al. 1996). Ground-based gravity data were collected along all of the lines shown here, except YMP-3top, YMP-4top, YMP-7, HR-1, HR-2, and Line-1. Ground-magnetic data were collected along all of the lines shown here, expect YMP-3top, YMP-3ext, YMP-4top, YMP-4ext, HR-2, and Line-1. Magnetotelluric (MT) data were collected along YMP-3 only. The reference coordinates correspond to the Nevada State Coordinate System, in feet.

Figure 3.6-12. Index Map Showing the Location of Geophysical Surveys in the Site Area

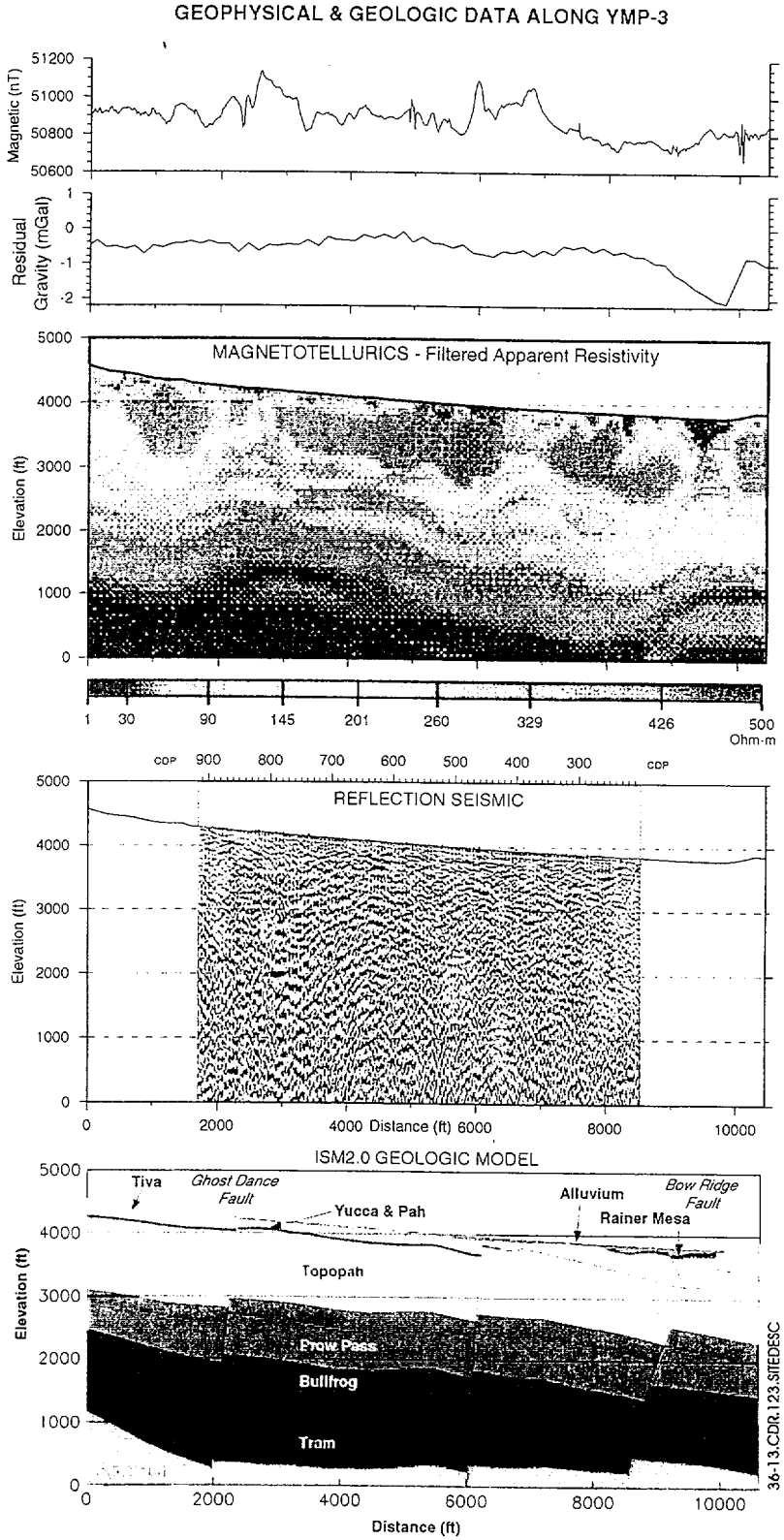


Figure 3.6-13. Geophysical and Geologic Data along YMP-3

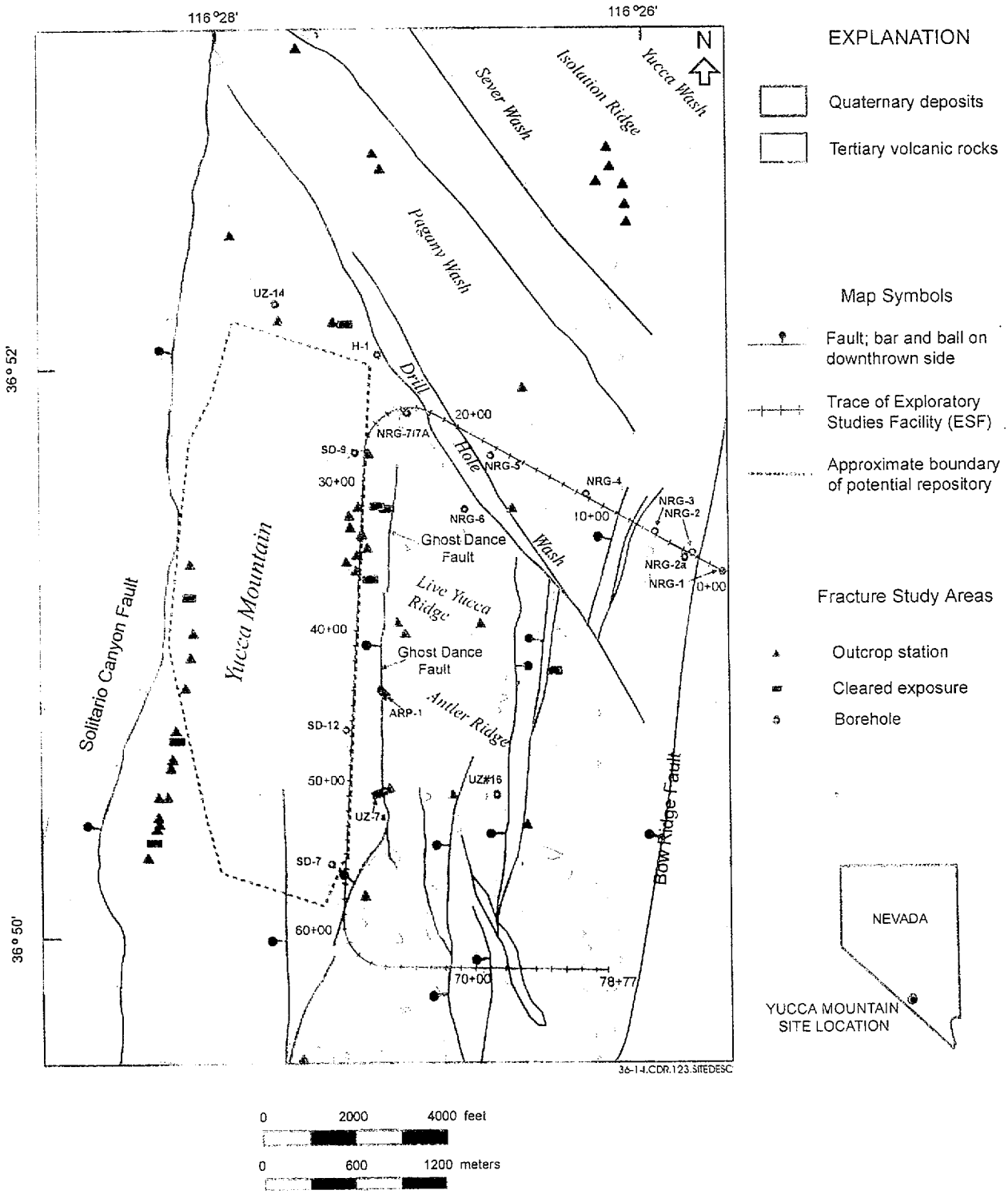
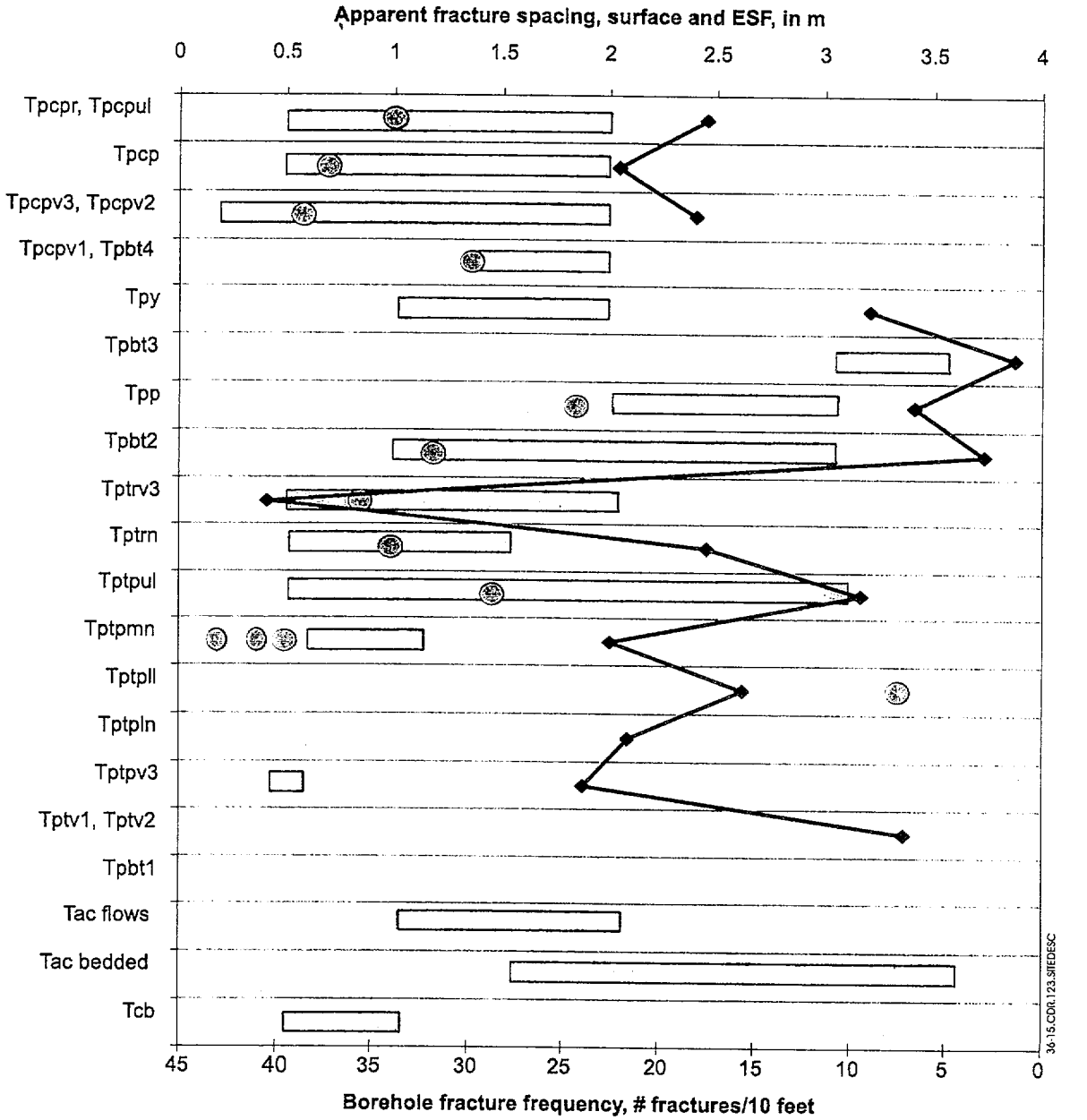


Figure 3.6-14. Map of the Central Part of Yucca Mountain, Nevada, Showing Fracture Study Areas (after Day et al. 1998a)



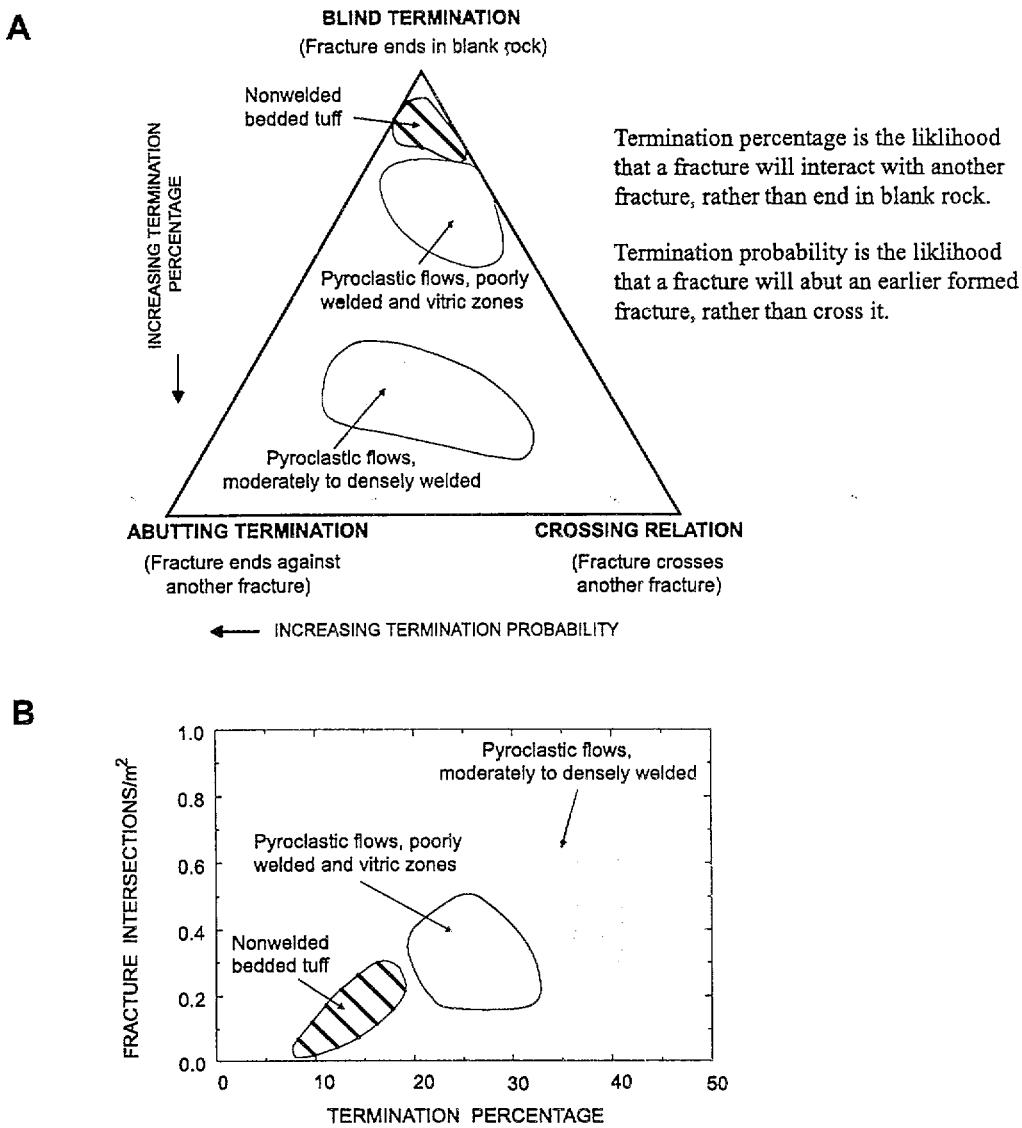
Surface fracture data, range of apparent fracture spacing

ESF fracture data, average apparent fracture spacing for entire lithostratigraphic unit.

Average fracture frequency from core, adjusted for core loss.

NOTE: The three dots for unit Tptpmn signify fracture spacing within, to the south of, and to the north of the intensely fractured zone, respectively.

Figure 3.6-15. Comparison of Fracture Spacing from Surface, Exploratory Studies Facility, and Borehole Data



DATA SOURCES FOR THE ABOVE DIAGRAMS

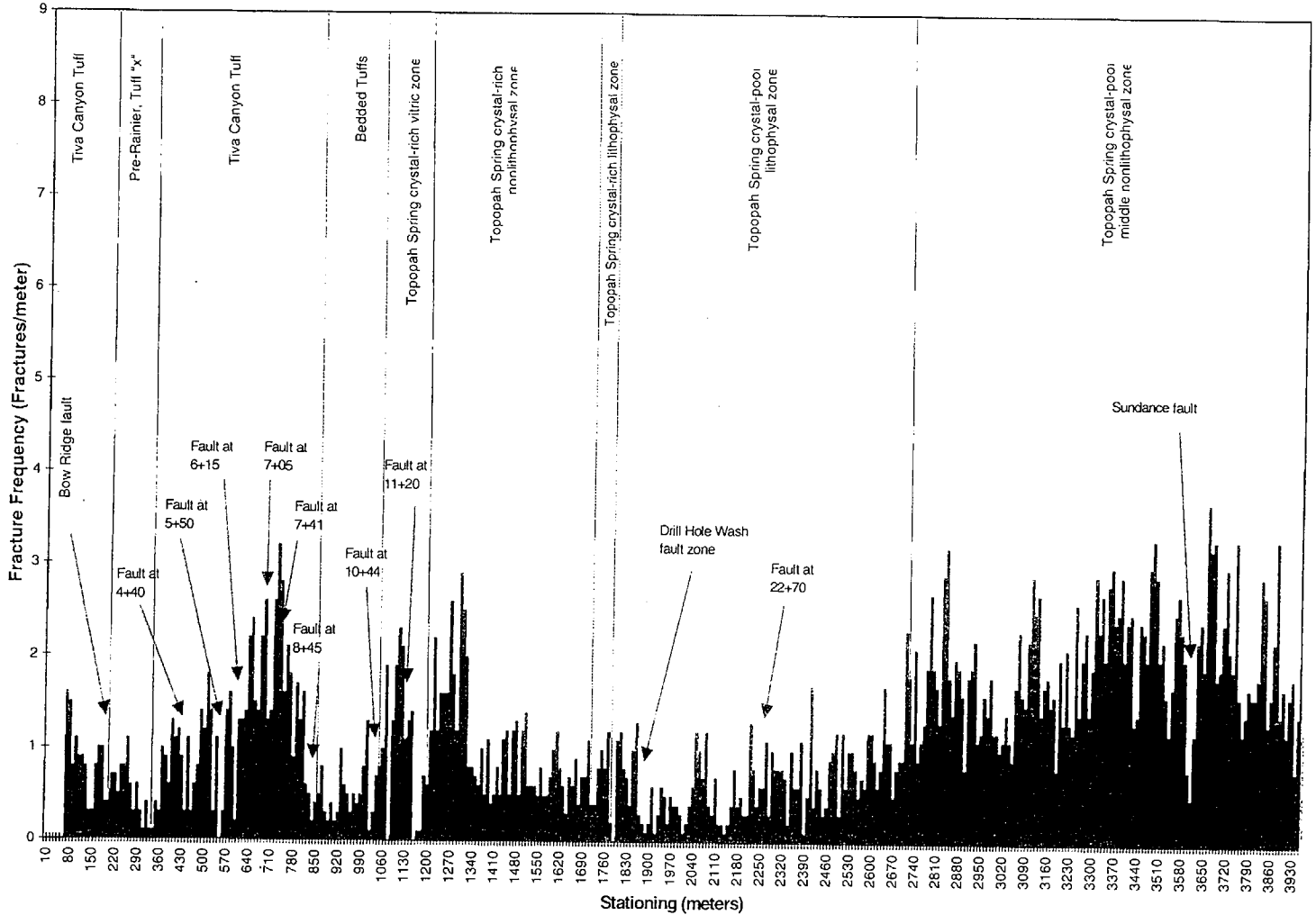
Data for moderately to densely welded pyroclastic flows are from geometric analysis of three cleared exposures constructed in the upper lithophysal zone of the Tiva Canyon Tuff (Barton et al., 1993) and from pavement P2001in the middle nonlithophysal and upper lithophysal zones of the Topopah Spring Tuff (Sweetkind, Verbeek, Singer, et al., 1995).

Data for poorly welded pyroclastic flows, vitric zones of pyroclastic flows, and bedded tuffs are from geometric analysis of maps of three natural exposuresin the interval separating the Topopah Spring and the Tiva Canyon Tuff (Sweetkind, Verbeek, Geslin and Moyer, 1995). Poorly welded pyroclastic flows include the Pah Canyon and Yucca Mountain Tuffs (Sawyer et al., 1994). The vitric zone is the vitric base of the Tiva Canyon Tuff.

36-16.CDR.123.SITEDESC

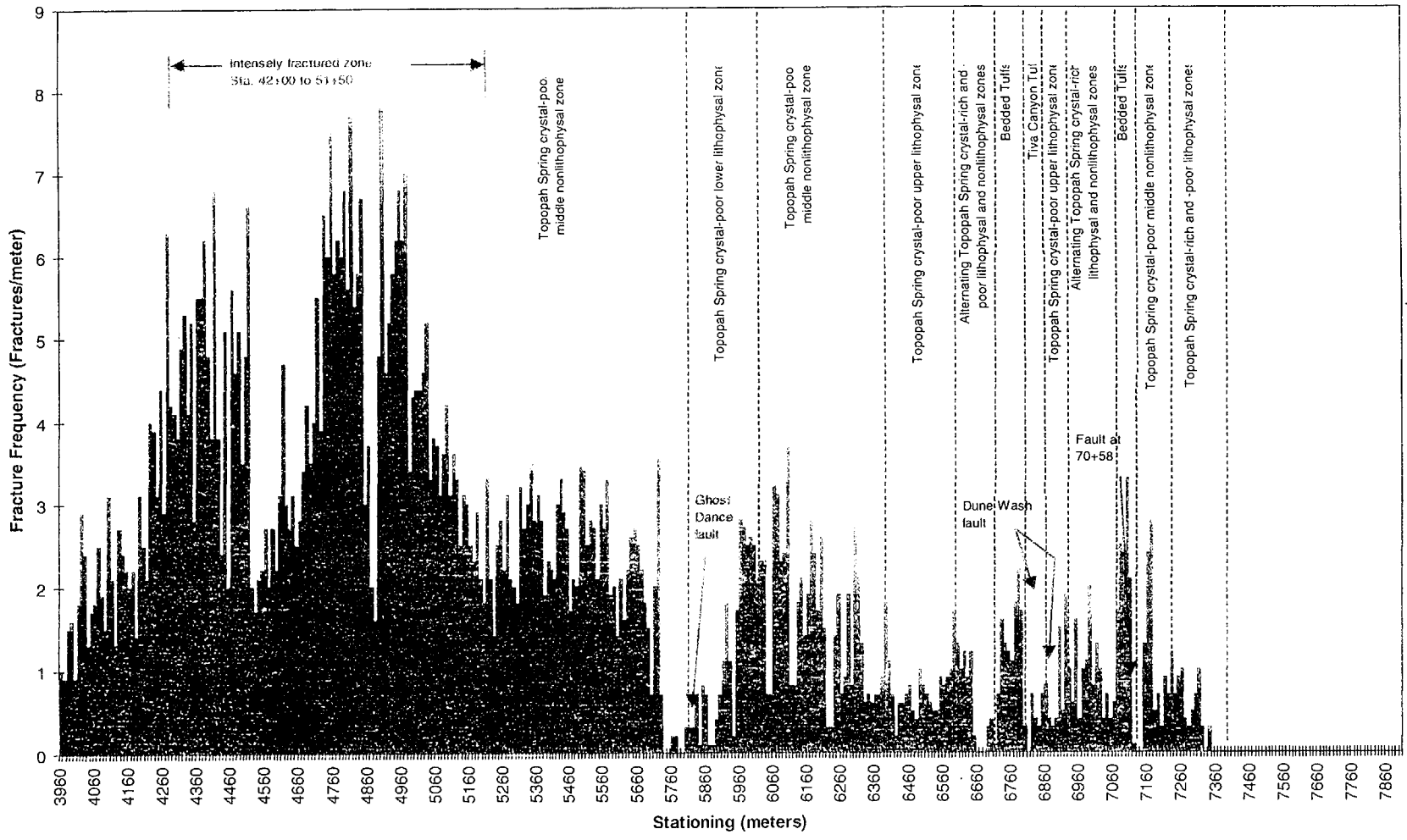
NOTE: Both qualified and non-qualified data are shown. A: Geometric analysis of fracture terminations from cleared pavements in the Paintbrush Group, subdivided by degree of welding. B: Changes in fracture intensity and termination relationships with degree of welding in the Paintbrush Group. Intensity is reported in terms intersection intensity, the number of fracture intersections per area (#/m^2).

Figure 3.6-16. Correlation of Fracture Network Properties to Degree of Welding, Paintbrush Group



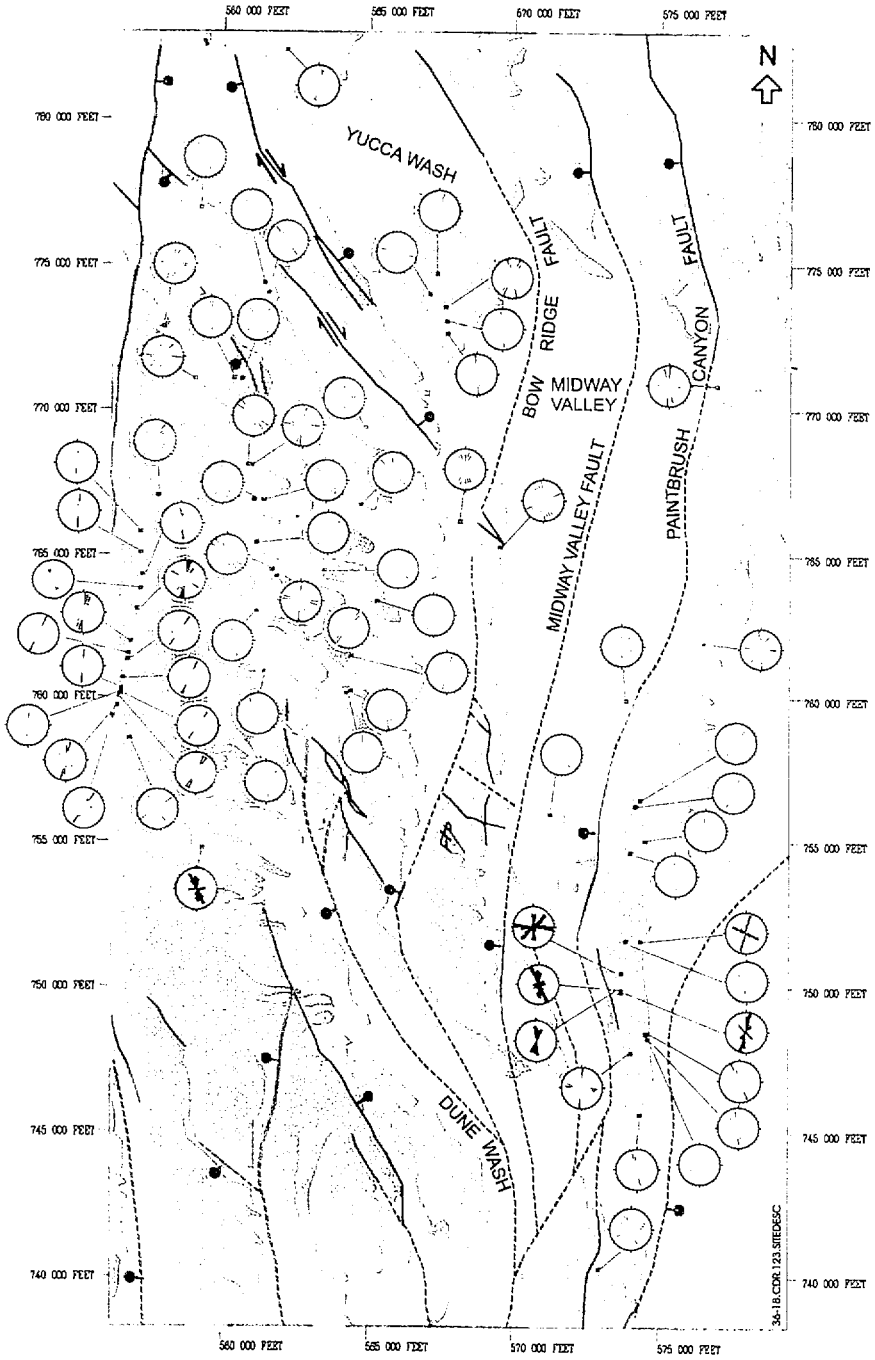
NOTE: Data are from detailed line survey for fractures 1 m or longer. Location of faults mapped in the Exploratory Sudies Facility that can be correlated with mapped surface faults.

Figure 3.6-17a. Fracture Frequency as Measured in the Exploratory Studies Facility–North Ramp and Northern Portion of the Main Drift (Day et al. 1996a)



NOTE: Data are from detailed line survey for fractures 1 m or longer. Location of faults mapped in the Exploratory Studies Facility that can be correlated with mapped surface faults.

Figure 3.6-17b. Fracture Frequency as Measured in the Exploratory Studies Facility–Southern Portion of the Main Drift and Western Portion of the South Ramp (Day et al. 1996a)



NOTE: Strike rosettes are subdivided by lithostratigraphic unit as follows: red, crystal-rich member of the Tiva Canyon Tuff; green, upper lithophysal zone of the crystal-poor member of the Tiva Canyon Tuff; light blue, middle nonlithophysal zone, crystal-poor member of the Tiva Canyon Tuff; orange, lower lithophysal and nonlithophysal zones of the crystal-poor member of the Tiva Canyon Tuff; black, lithostratigraphic units that comprise the PTn hydrologic unit, including the crystal-poor vitric zone of the Tiva Canyon Tuff, the Yucca Mountain Tuff, the Pah Canyon Tuff, the non- to partially welded and moderately welded subzones of the crystal-rich vitric zone of the Topopah Spring Tuff, and intervening bedded tuffs; and purple, the Topopah Spring Tuff.

Figure 3.6-18. Strike Distributions for Surface Fracture Study Areas and Exploratory Studies Facility Photogrammetry

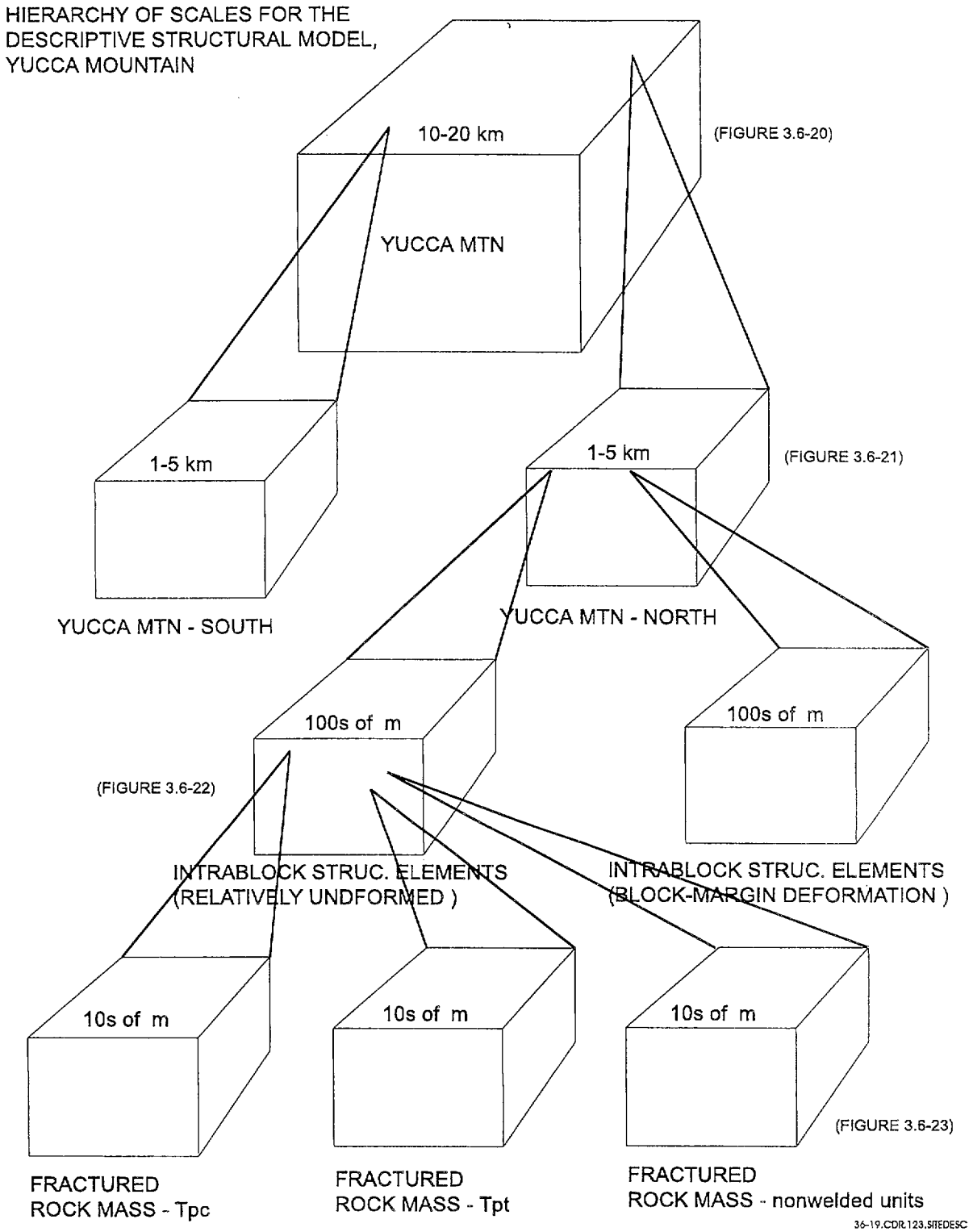


Figure 3.6-19. Diagram Illustrating the Hierarchy of Scales of Observation Used in the Series of Block Diagrams That Illustrate the Descriptive Structural Model

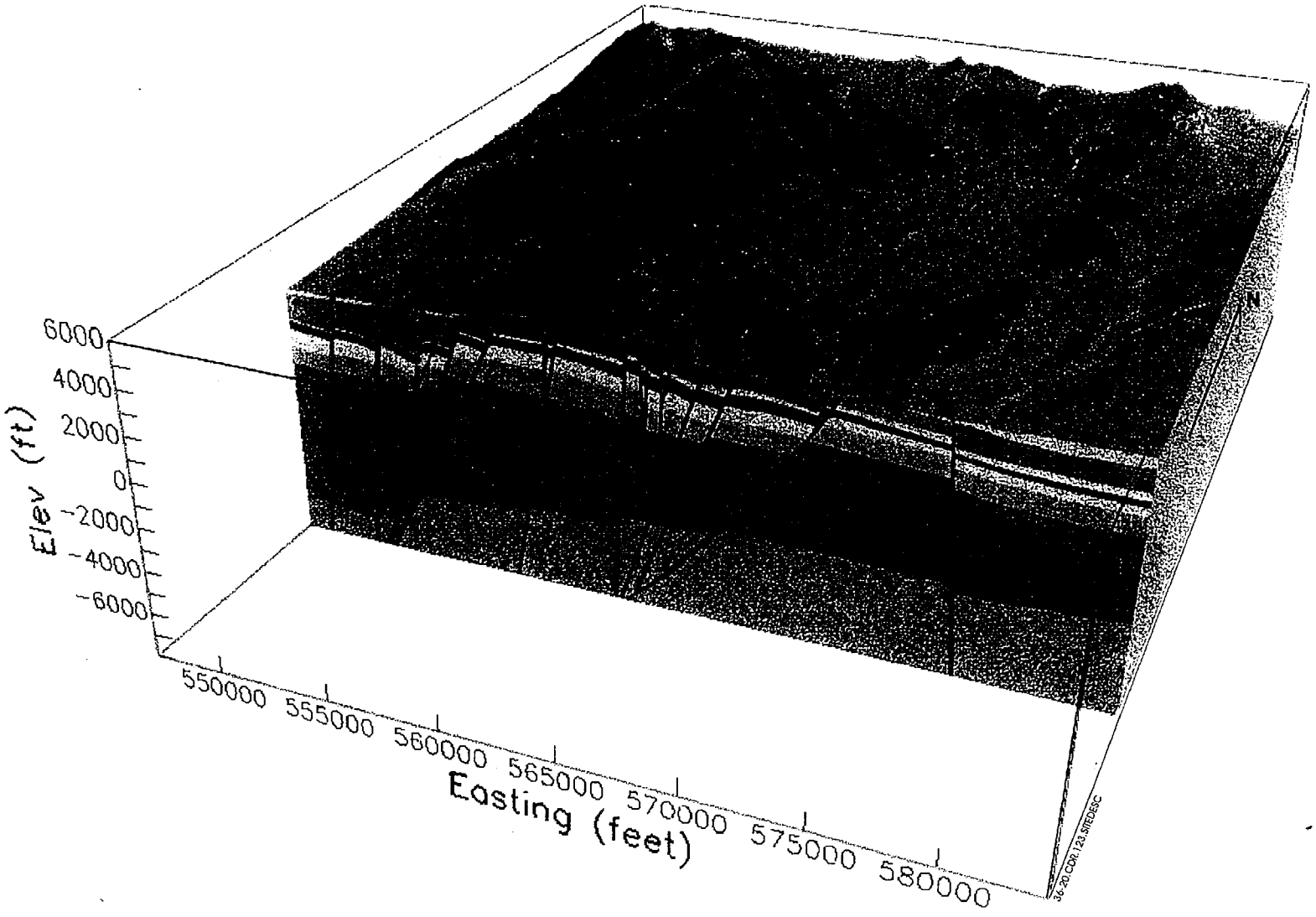


Figure 3.6-20. Block Diagram Illustrating Geometry of Principal Structural Elements at the Scale of Yucca Mountain (10 km Width of Block)

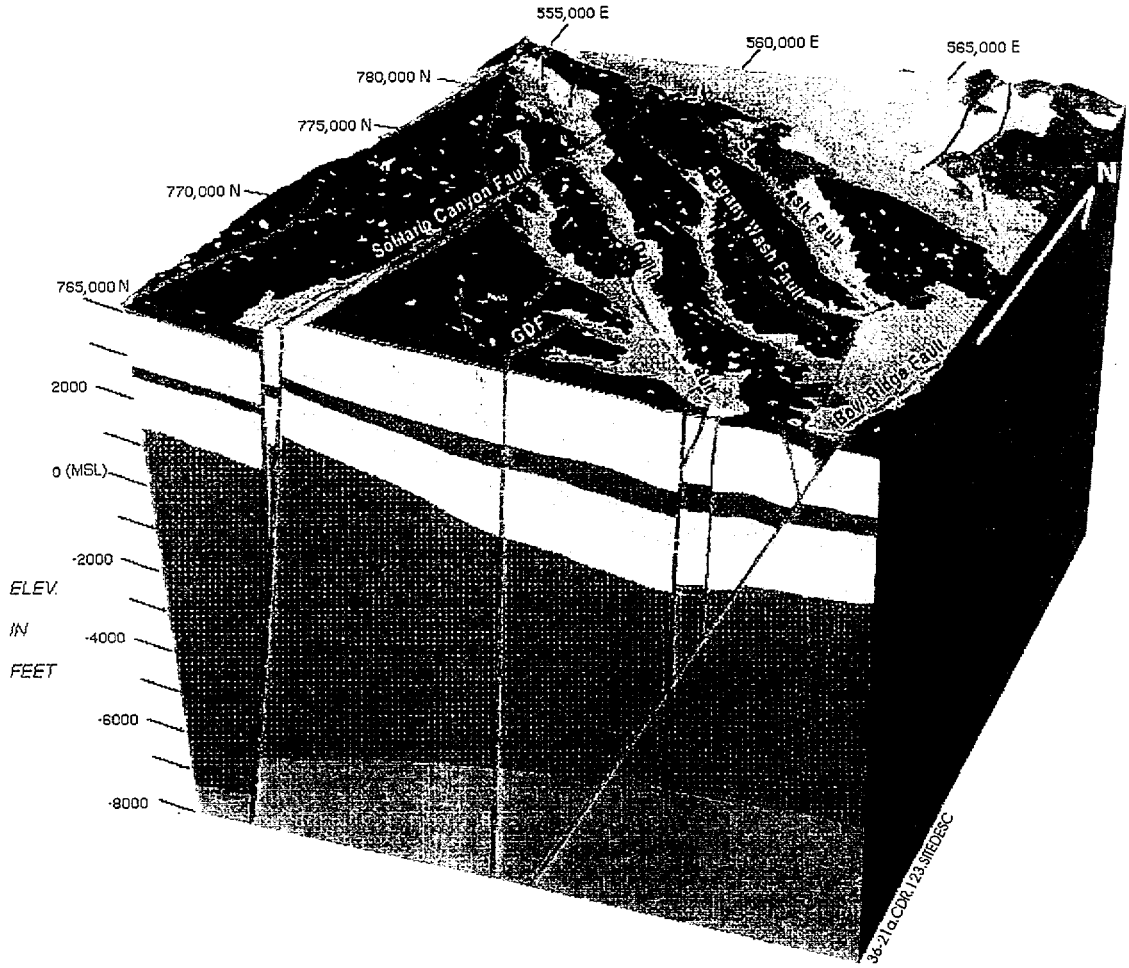


Figure 3.6-21a Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Northern Yucca Mountain Versus Southern Yucca Mountain (4 km Width of Block) A: Northern Area

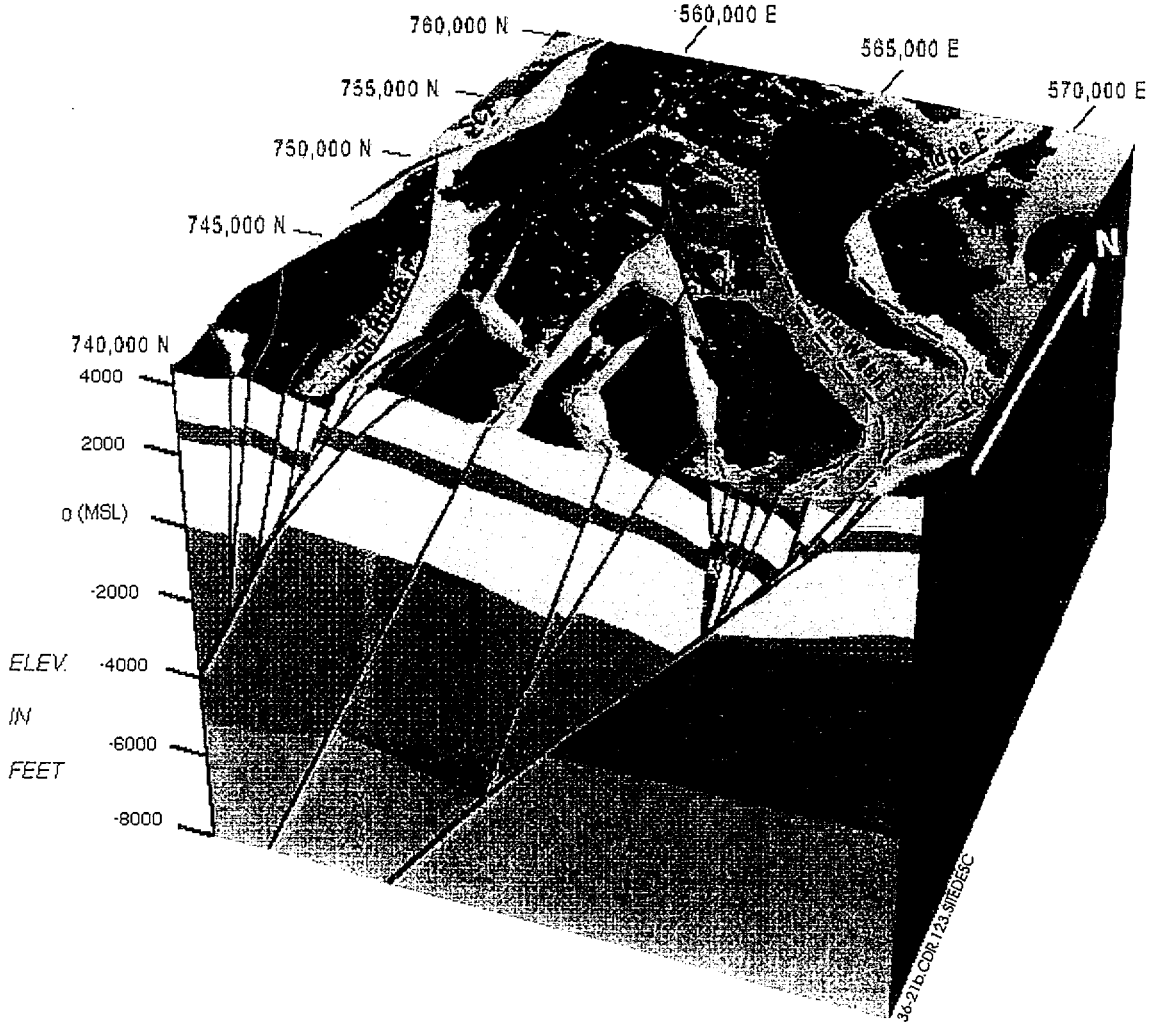
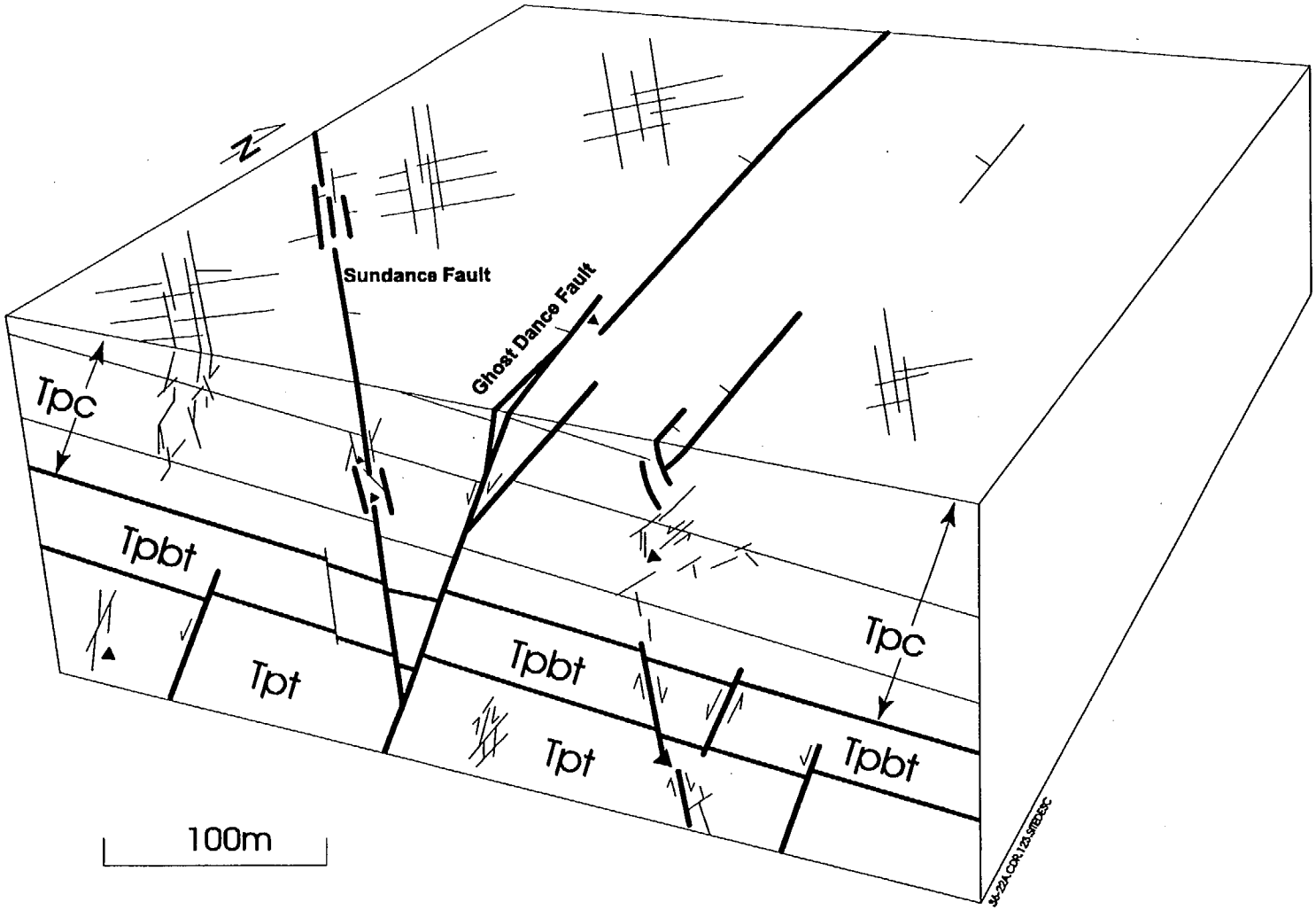
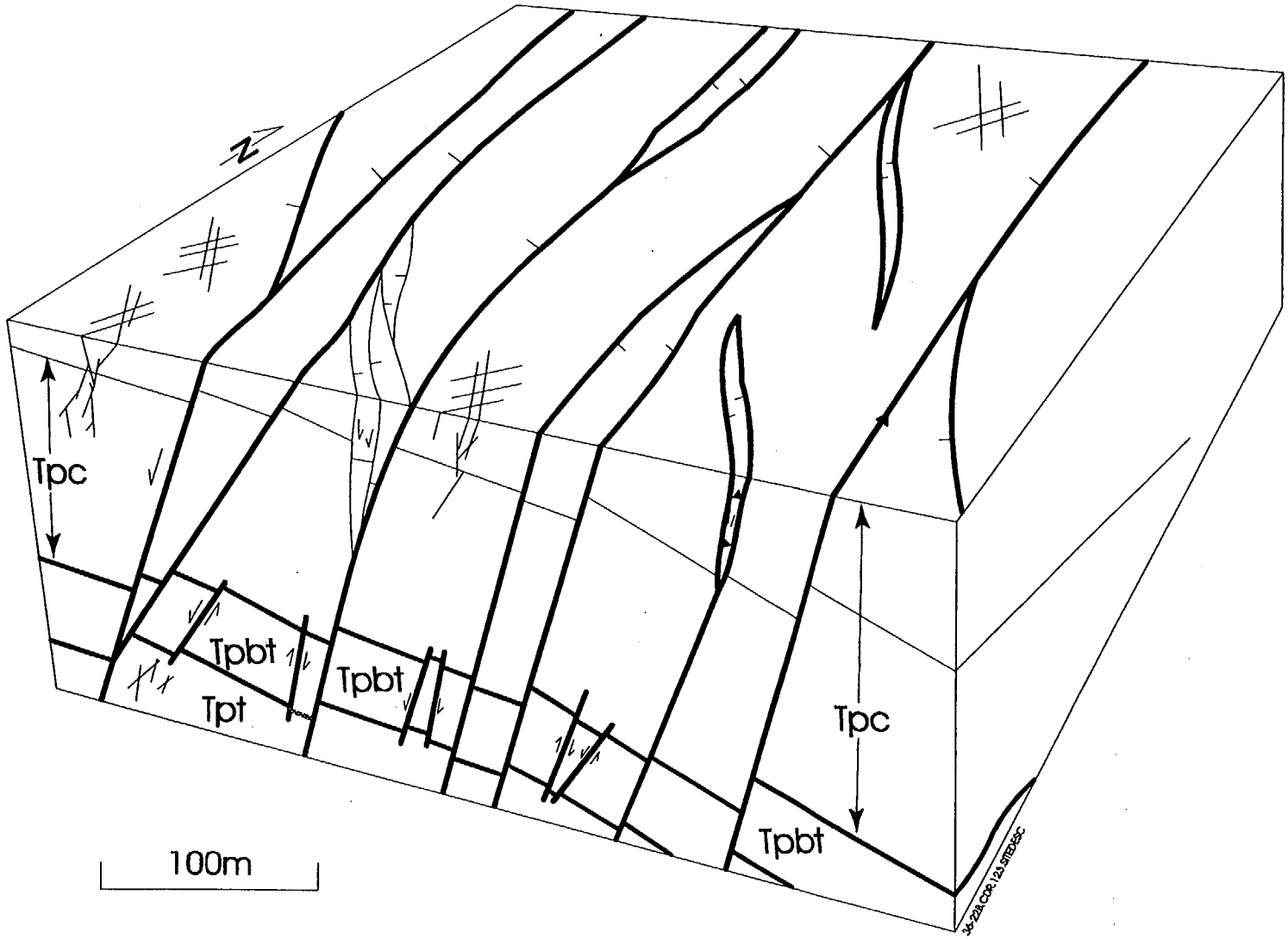


Figure 3.6-21b. Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Northern Yucca Mountain Versus Southern Yucca Mountain (4 km Width of Block) B: Southern Area



NOTE: Intrablock faults within Yucca Crest Sub-block of the Central Block.

Figure 3.6-22a. Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Two Subdomains of the Central Block (400m Width of Block)



NOTE: Block-margin faulting in the hanging wall of the Bow Ridge fault System.

Figure 3.6-22b. Block Diagram Illustrating the Variation in the Geometry of Principal Structural Elements in Two Subdomains of the Central Block (400m Width of Block)

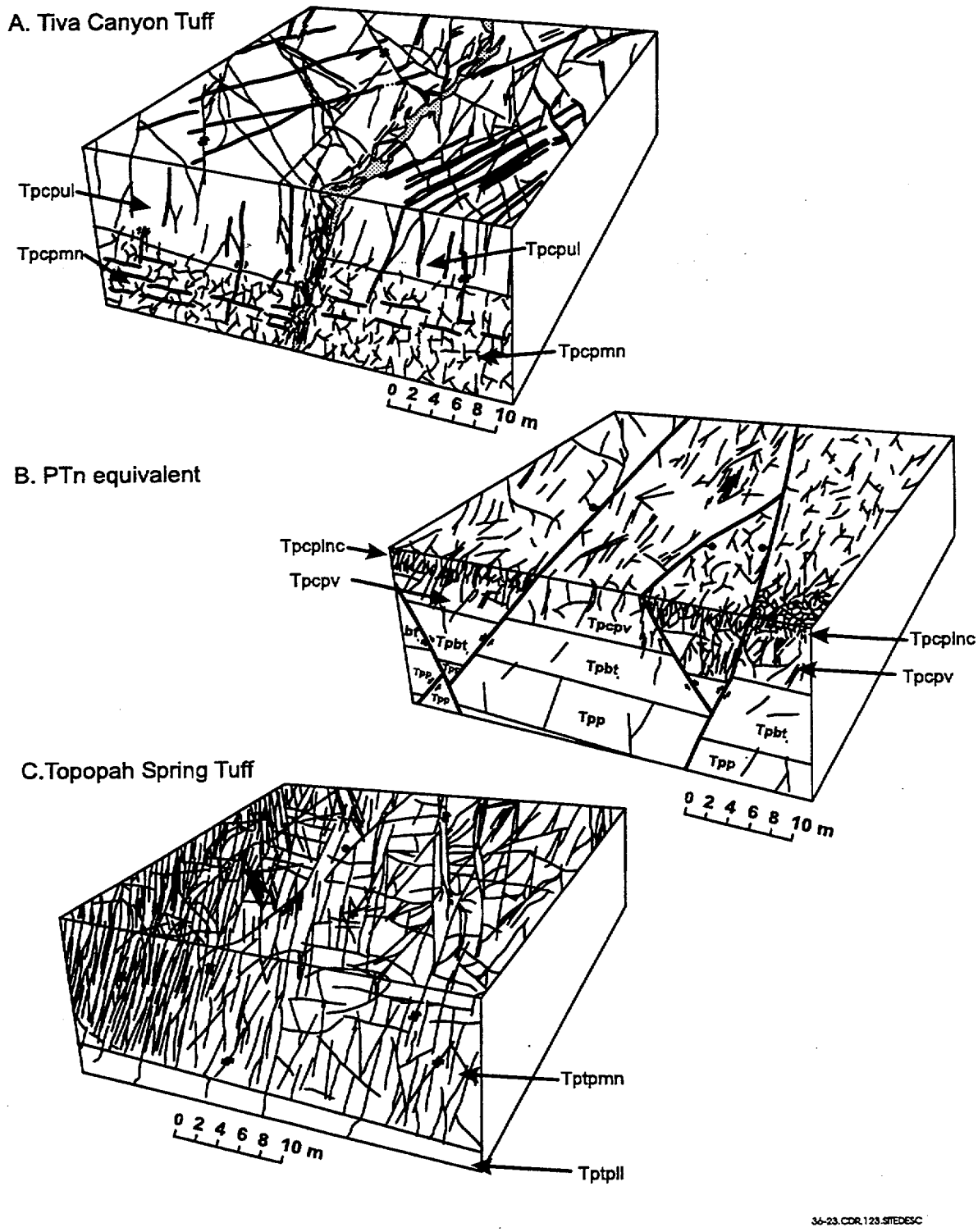


Figure 3.6-23. (A,B,C) Block Diagrams Illustrating the Variation in the Geometry of Principal Structural Elements in the Fracture Network at Different Stratigraphic Levels in the Paintbrush Group (10-50m Width of Block)

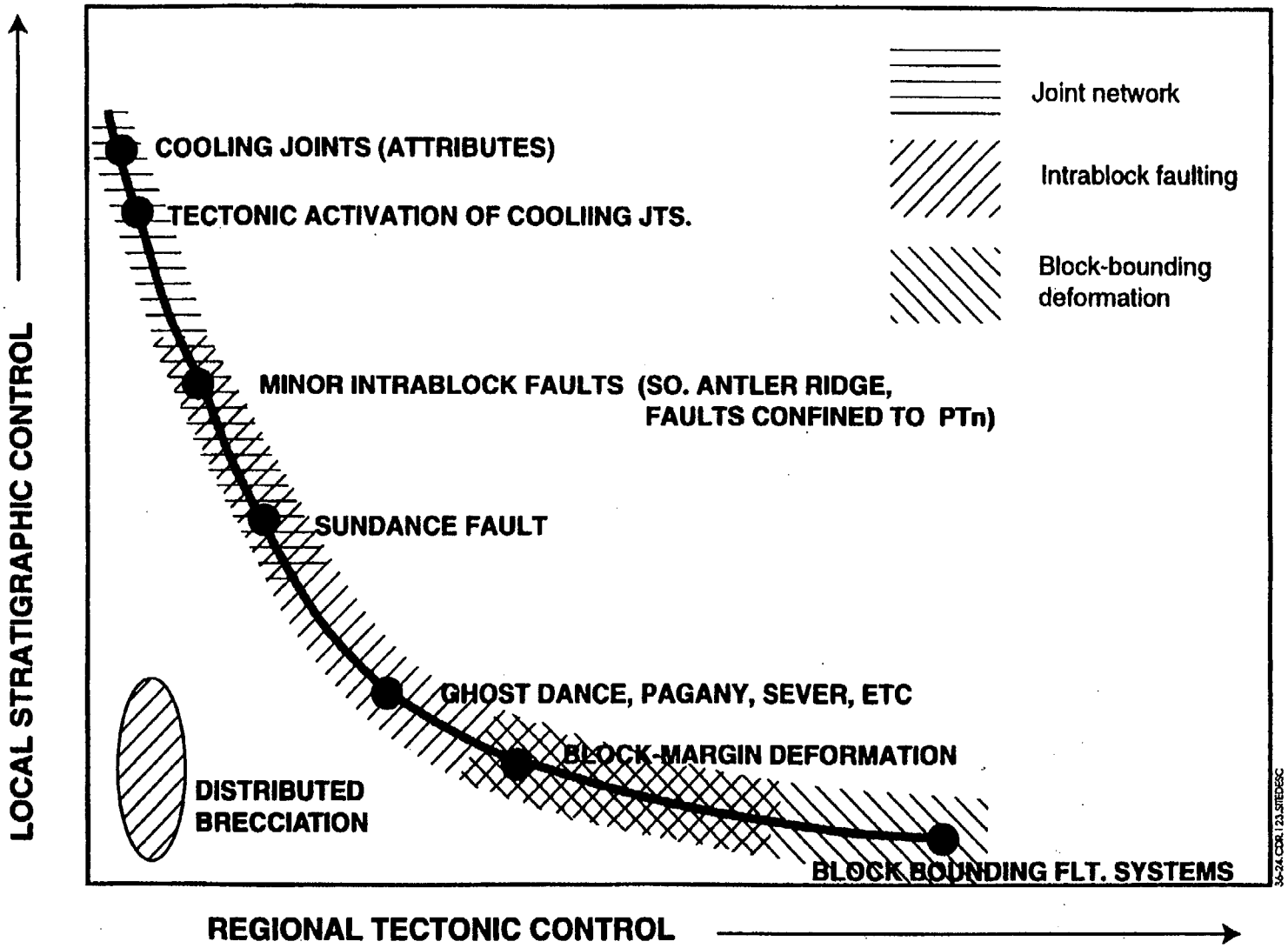
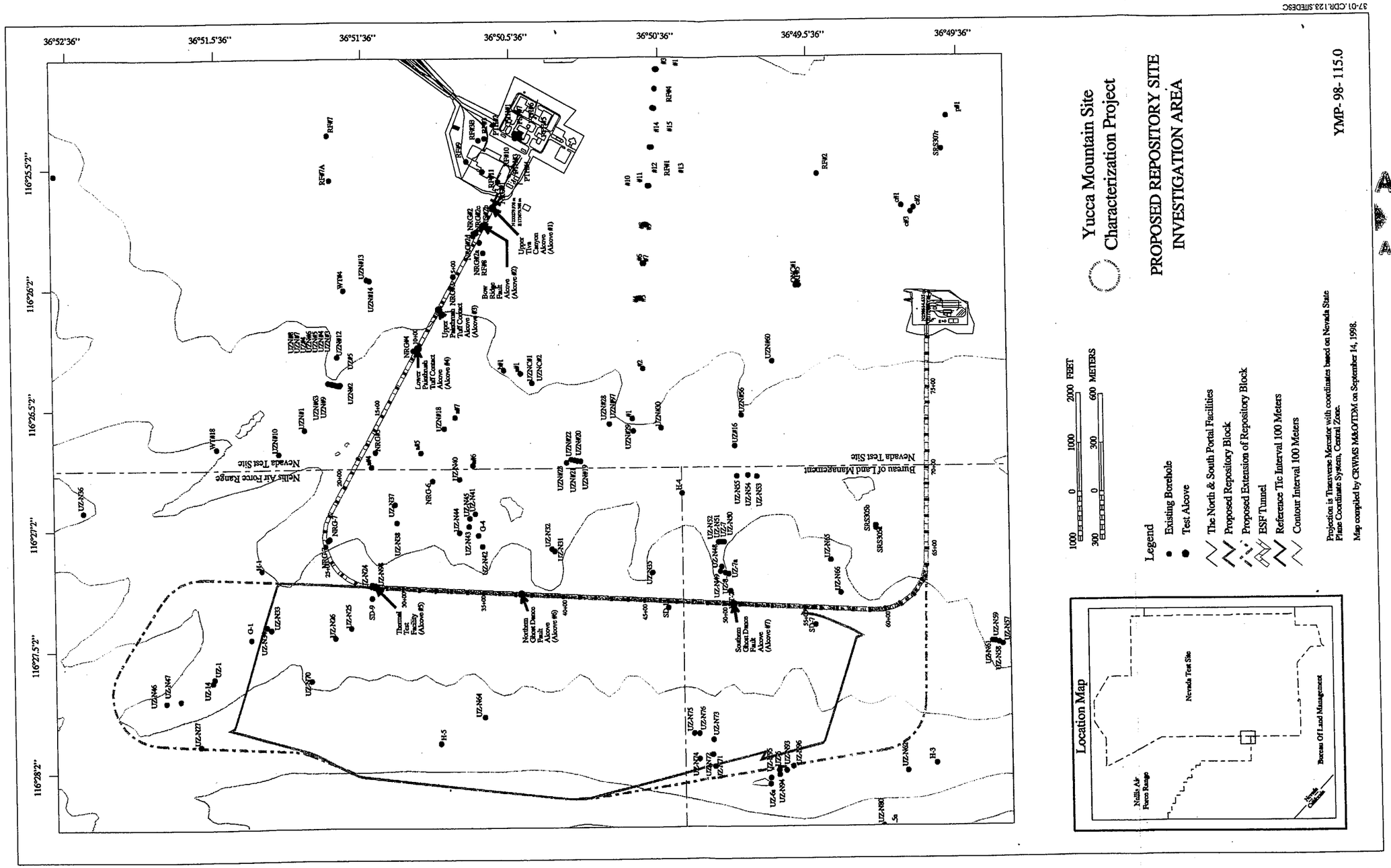


Figure 3.6-24. Representation of the Relative Dependence on Local Stratigraphic Control Versus Regional Tectonic Control, for the Genesis of Structural Elements at Yucca Mountain

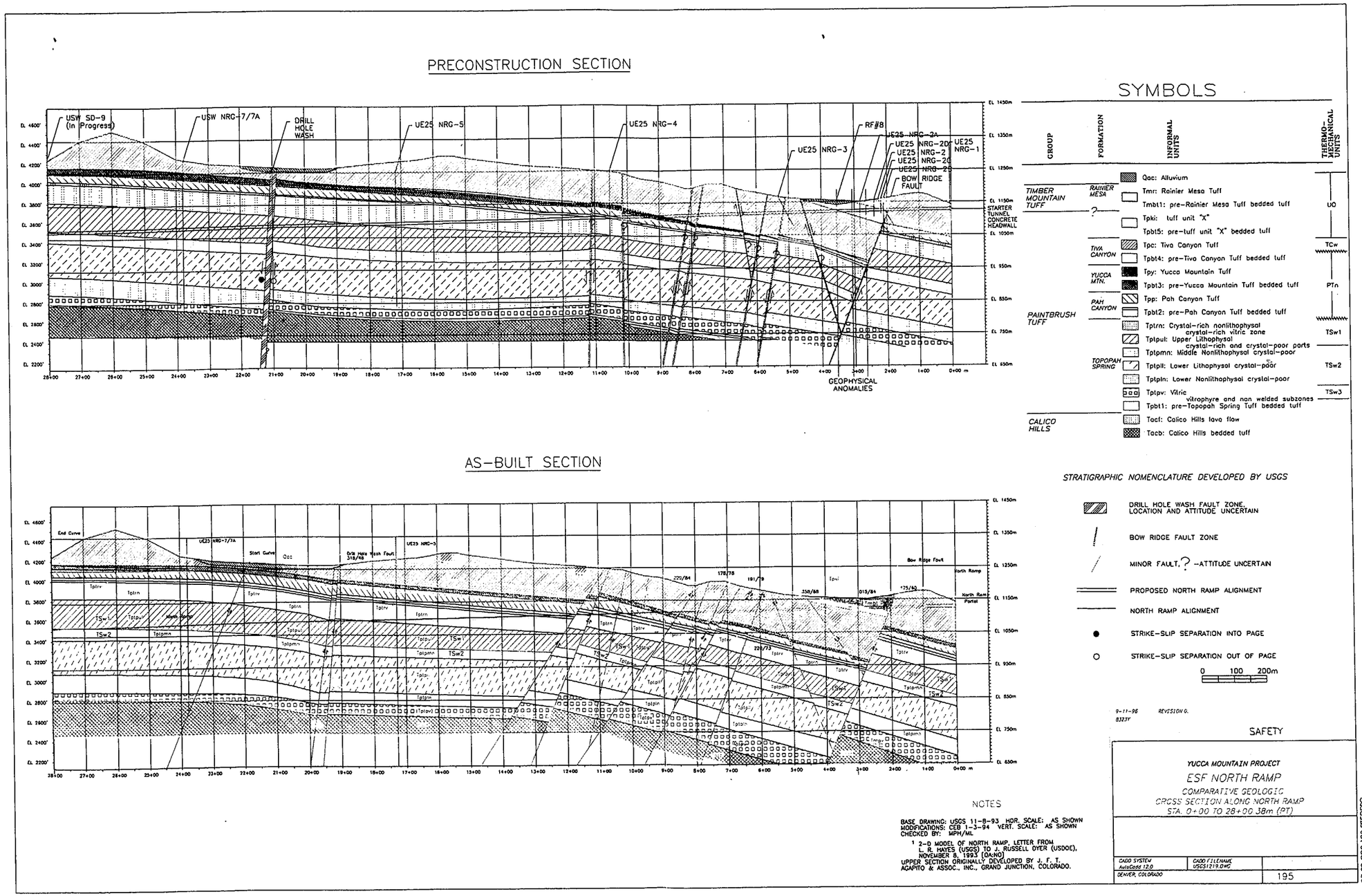


APERTURE CARD
Also Available on Aperture Card

Figure 3.7-1. Plan Map Showing the Exploratory Studies Facility and YMP Boreholes

9902040045 - 12

INTENTIONALLY LEFT BLANK



APERTURE CARD
Also Available on Aperture Card

Figure 3.7-2. Stratigraphic Cross Section Along the Exploratory Studies Facility North Ramp

9902040045-13

INTENTIONALLY LEFT BLANK

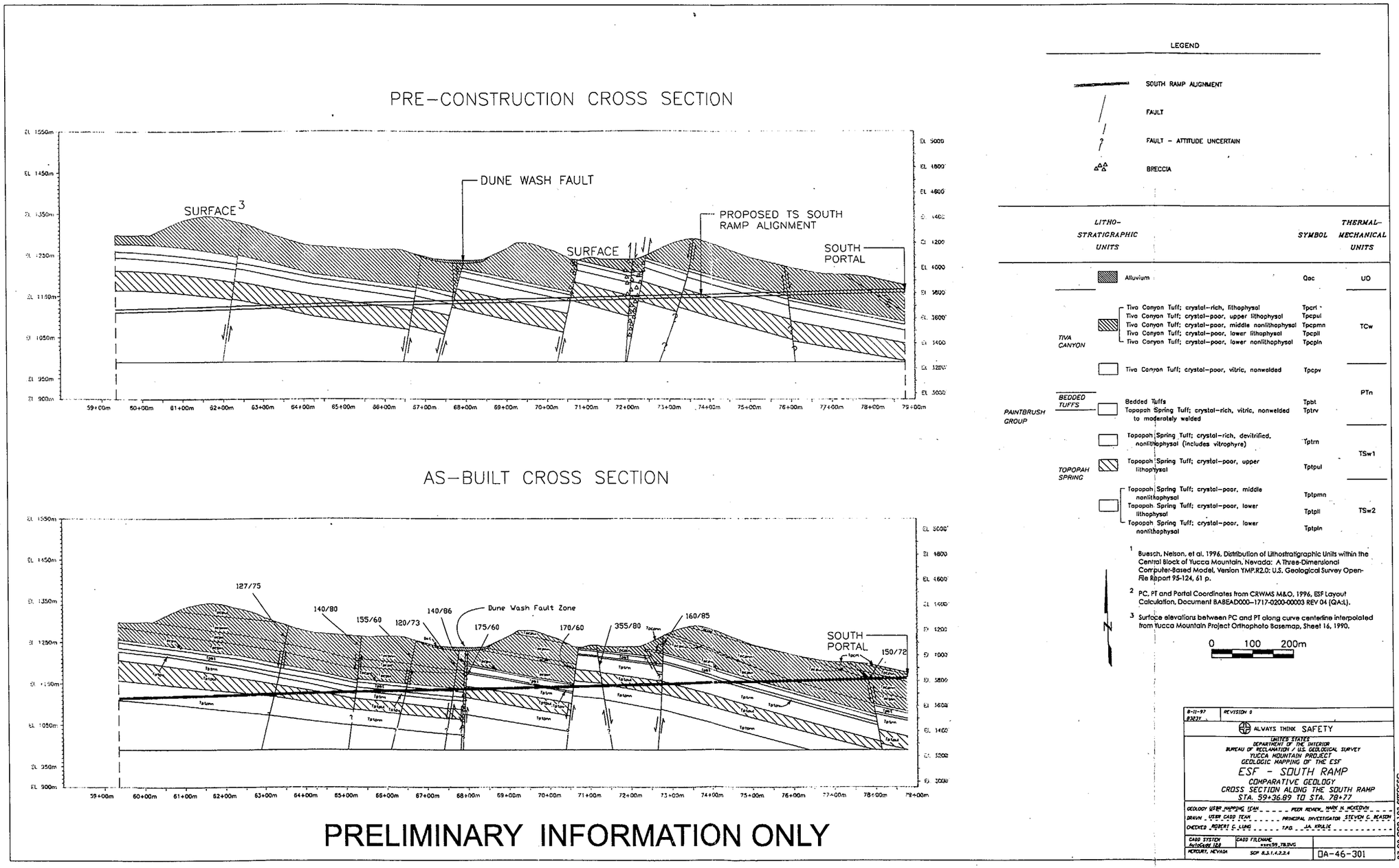
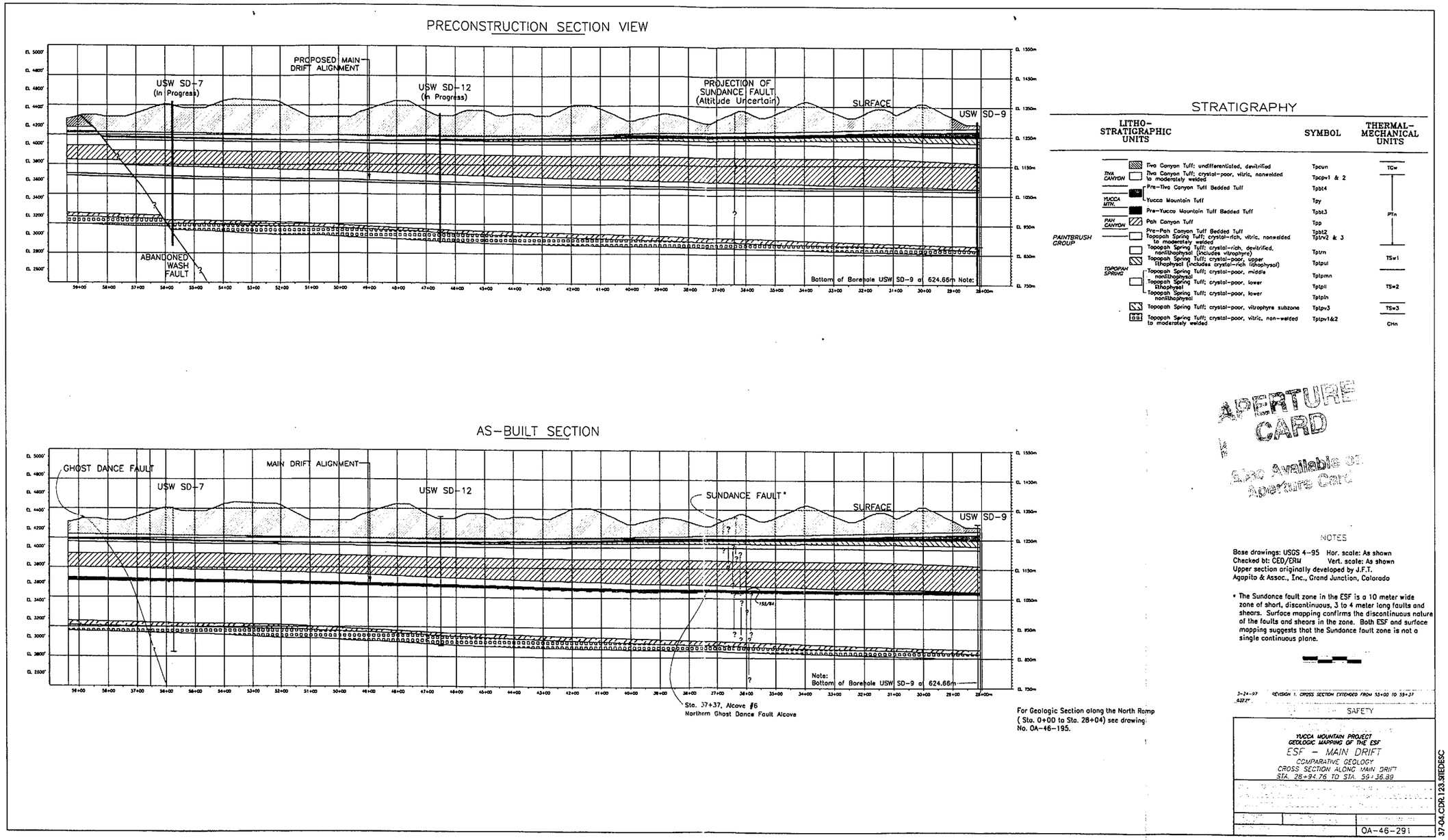


Figure 3.7-3. Stratigraphic Cross Section Along the Exploratory Studies Facility South Ramp

APERTURE CARD
Also Available on Aperture Card

9902040045 - 14

INTENTIONALLY LEFT BLANK



APERTURE CARD
Also Available on Aperture Card

Figure 3.7-4. Stratigraphic Cross Section Along the Exploratory Studies Facility Main Drift

9902040045 – 15

INTENTIONALLY LEFT BLANK

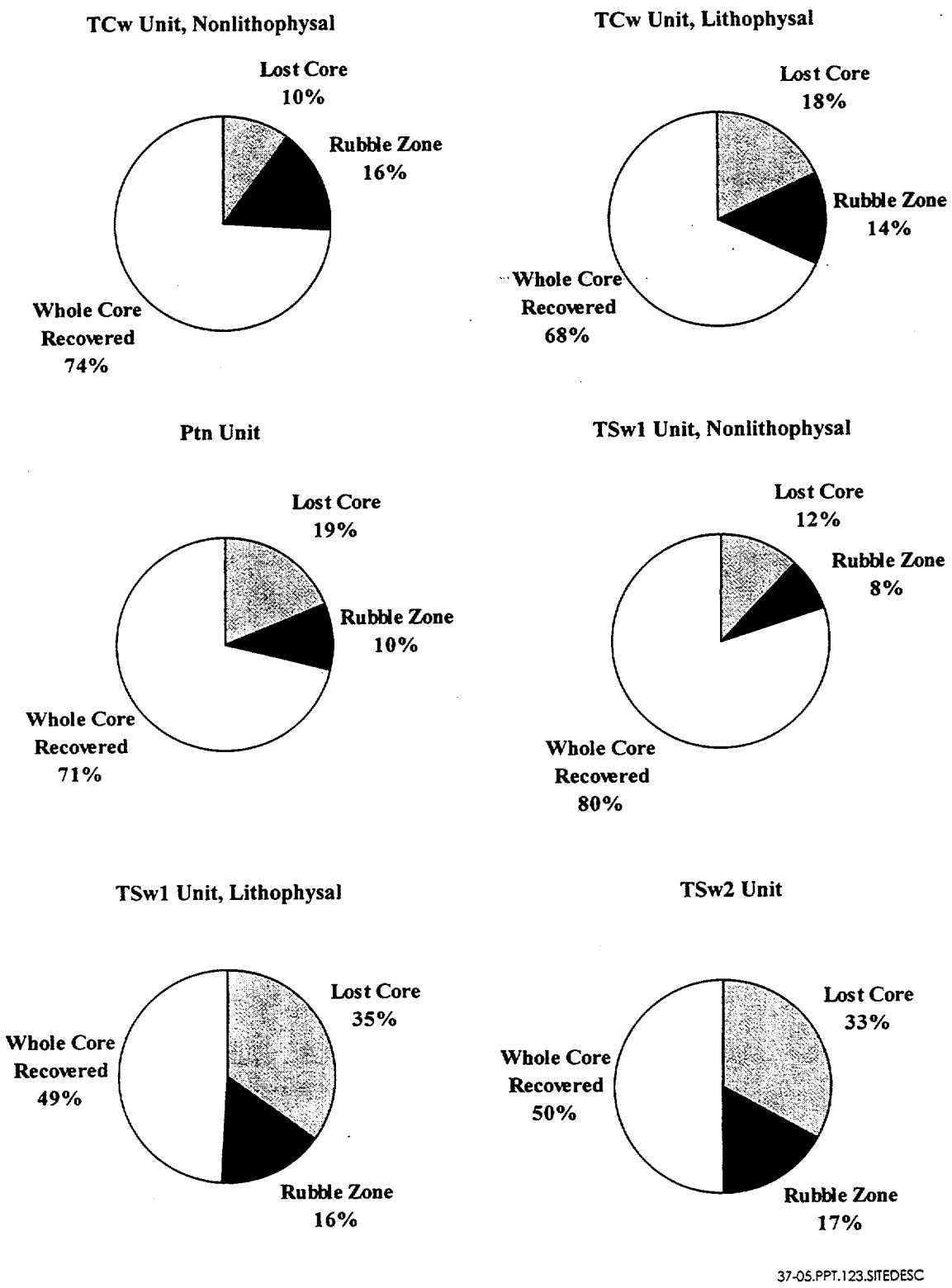


Figure 3.7-5. Core Recovery, Lost Core, and Rubble Zones as a Percentage of Total Drilling in Thermal/Mechanical Units

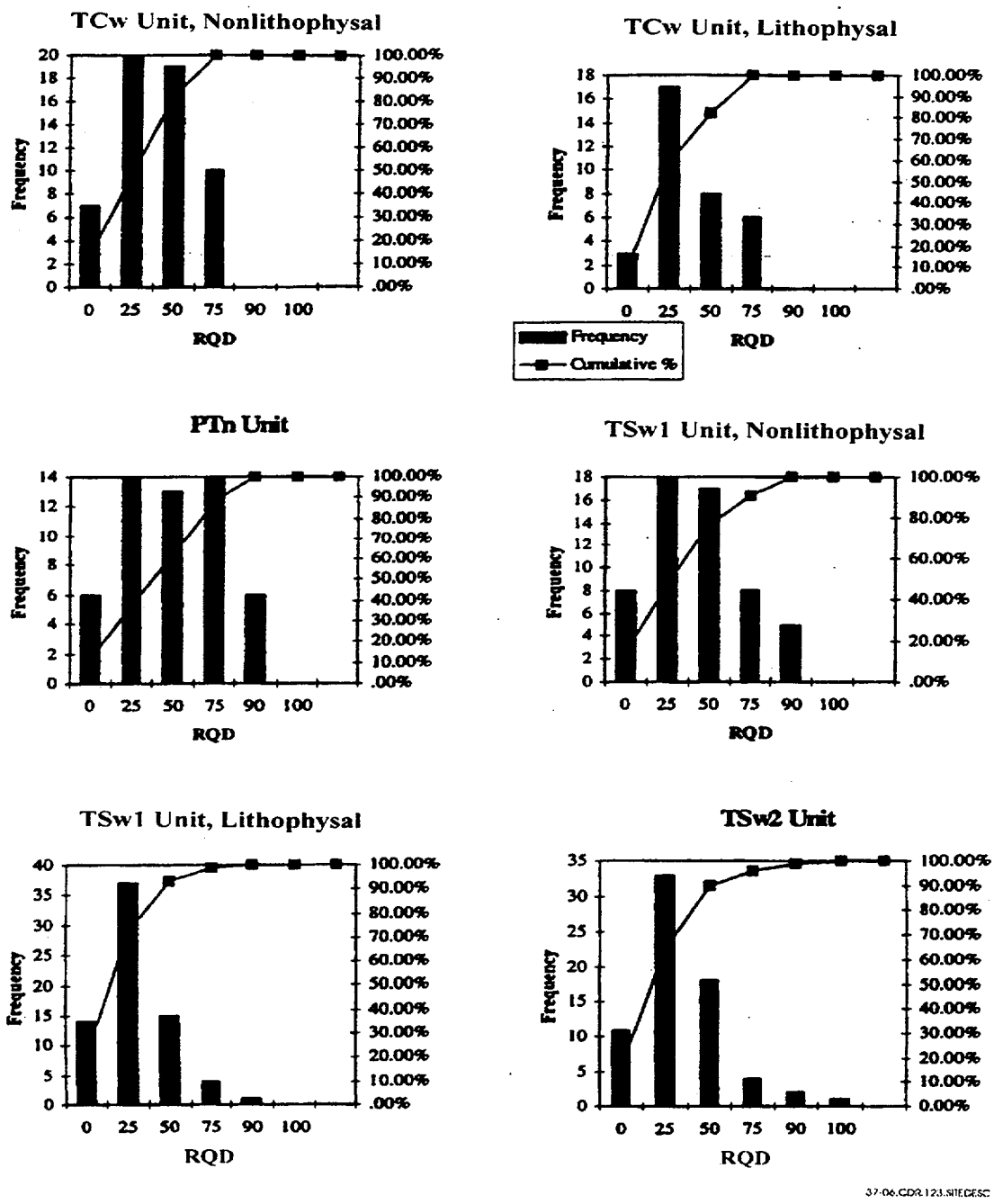
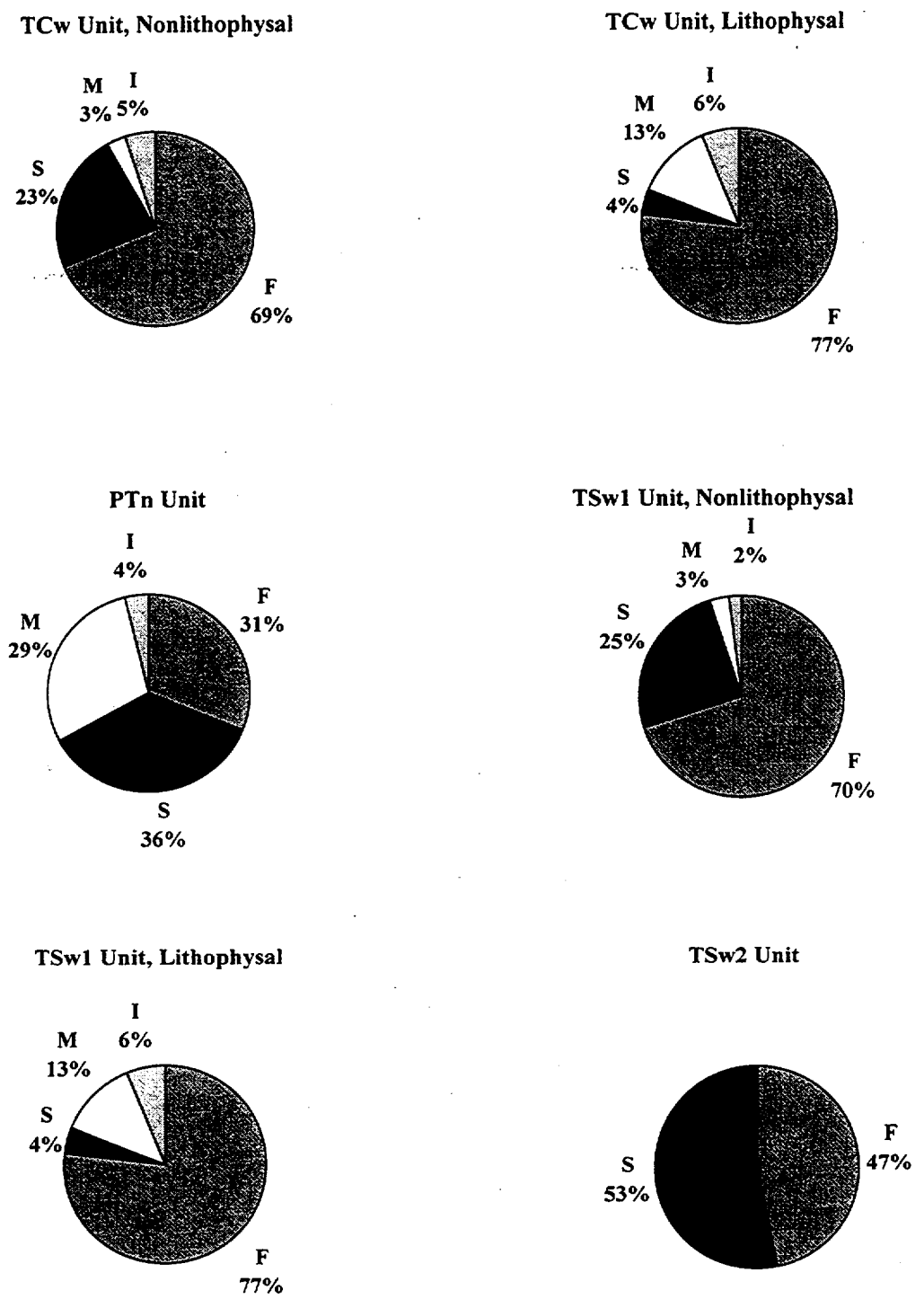


Figure 3.7-6. Rock Quality Designation Frequency



37-07 PPT.123.SITEDESC

Figure 3.7-7. Distribution of Rock Weathering Parameters

1=Extermely Hard, 2=Very Hard, 3=Hard, 4=Moderately Hard, 5=Moderately Soft, 6=Soft, 7=Very Soft, 8=Soil-Like, Cohesive, 9=Soil Like, Non-Cohesive

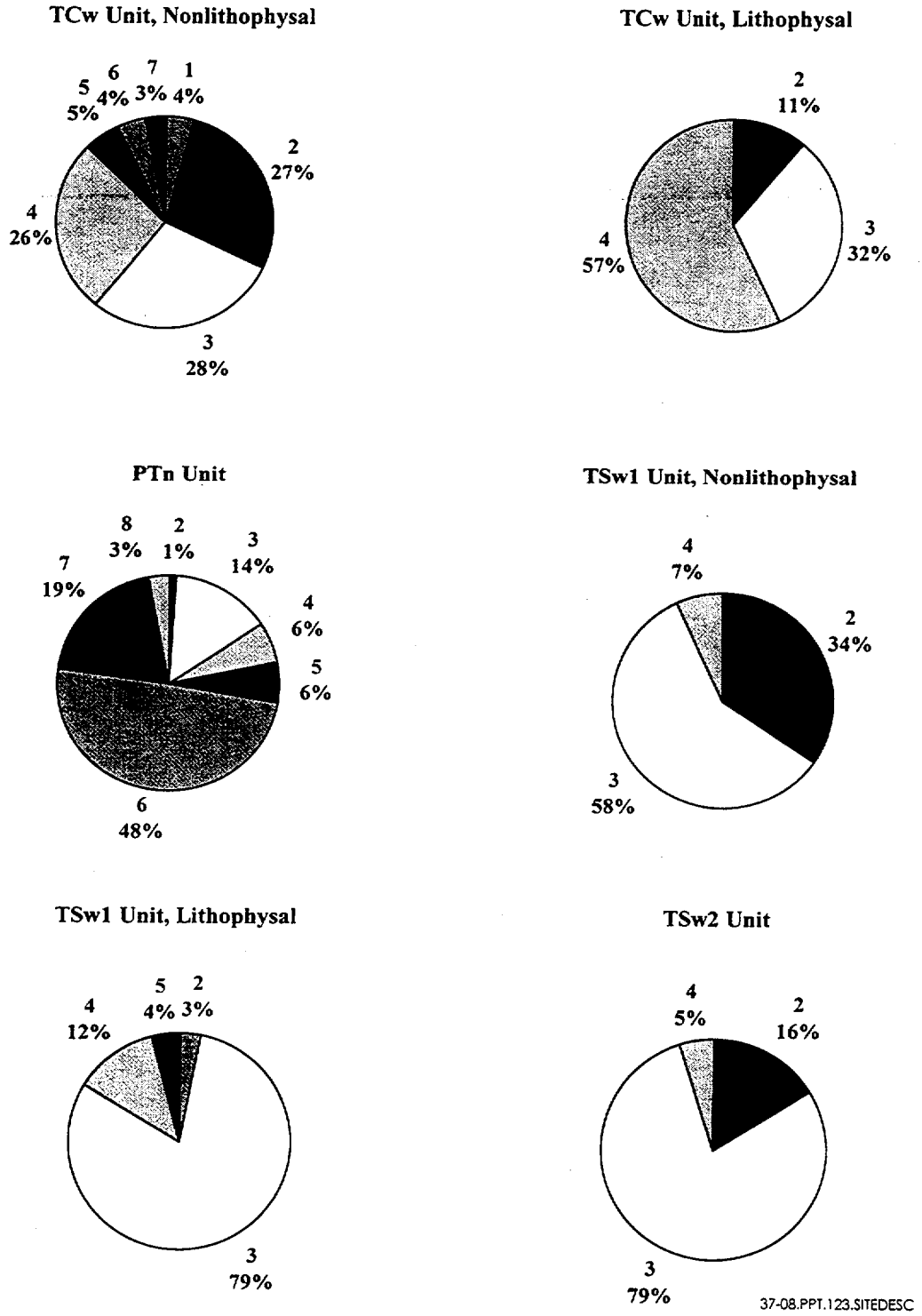


Figure 3.7-8. Distribution of Estimated Rock Hardness Rating

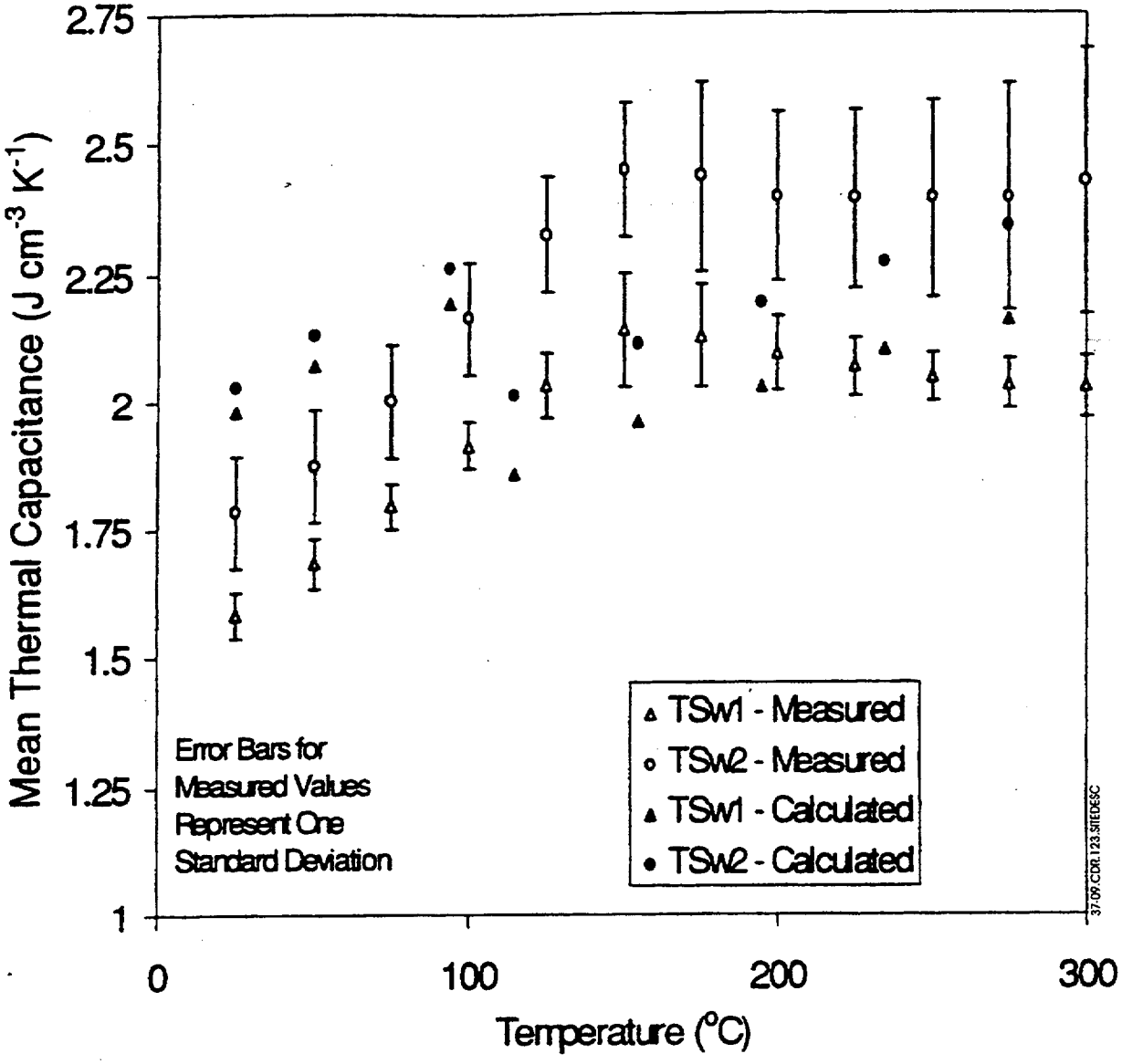
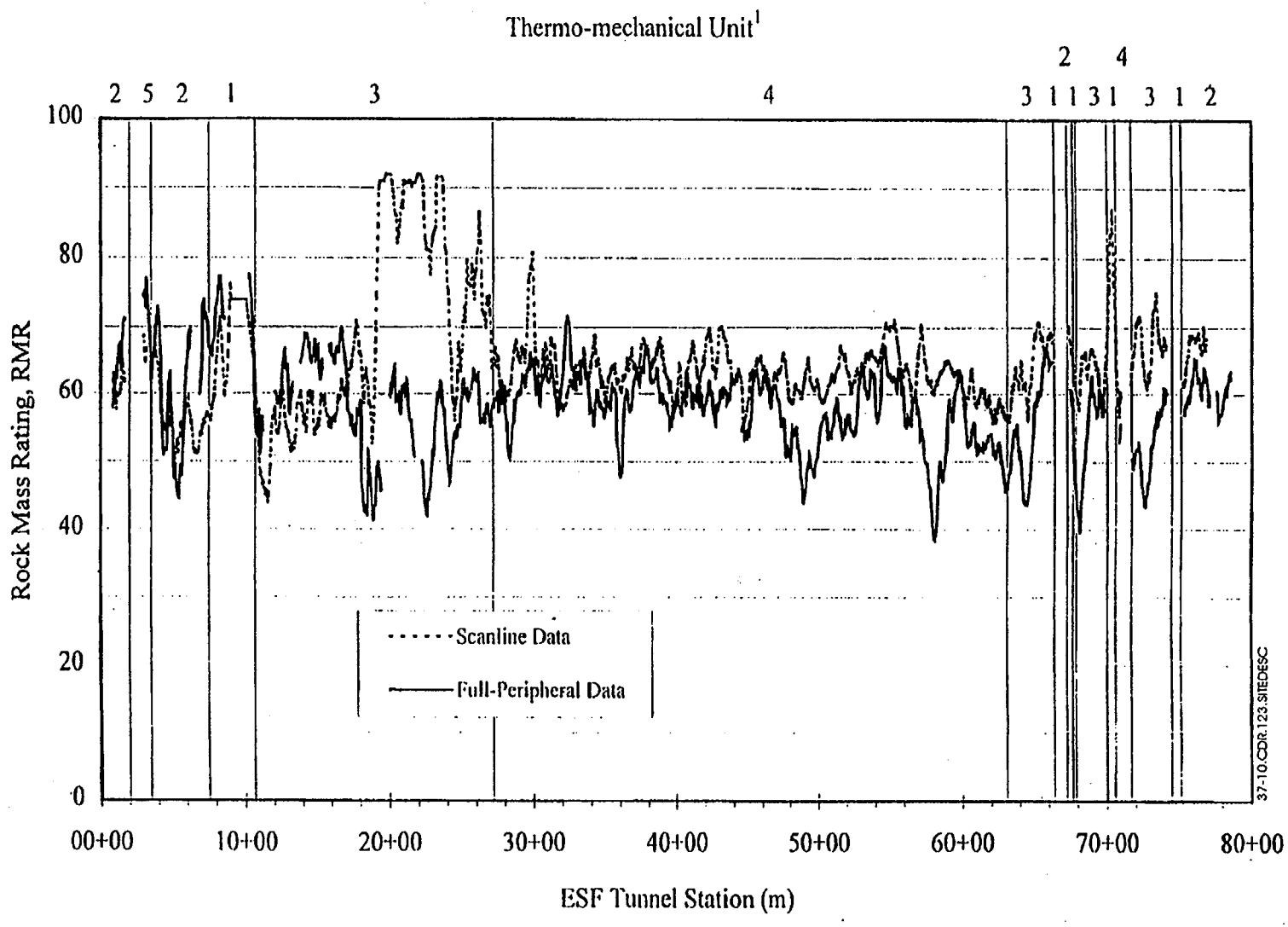
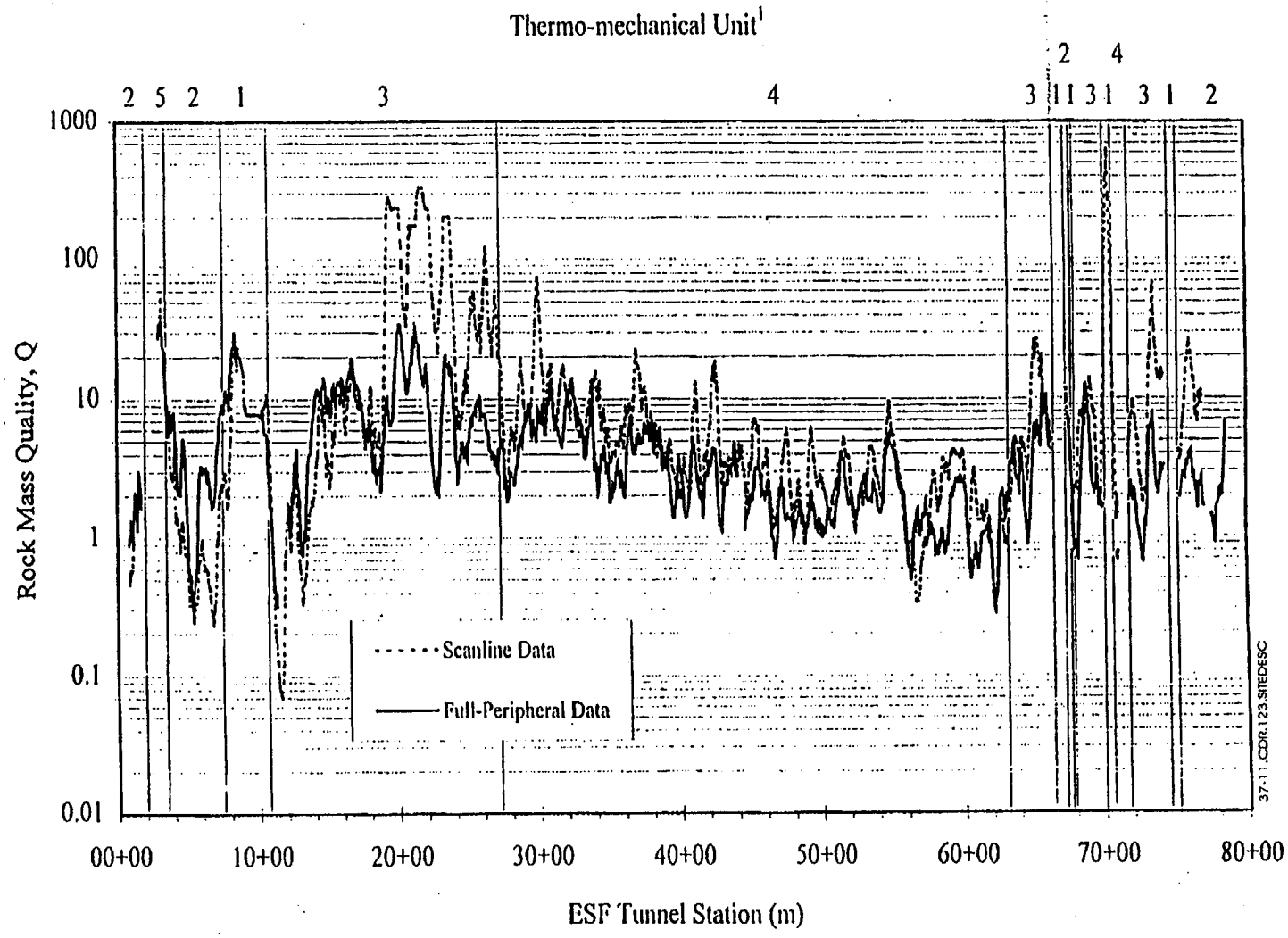


Figure 3.7-9 Measured (qualified) and Calculated (non-qualified) Values of Thermal Capacitance for TSw1 and TSw2 Thermal/Mechanical Units



[1]Thermo-mechanical Units in the ESF Main Loop: 1–*PTn*, 2–*TCw*, 3–*TSw1*, 4–*TSw2*, 5–*UO*

Figure 3.7-10. Nine-Term Moving Average Rock Mass Rating vs Exploratory Studies Facility Tunnel Station



[1]Thermo-mechanical Units in the ESF Main Loop: 1–*PTn*, 2–*TCw*, 3–*TSw1*, 4–*TSw2*, 5–*UO*

Figure 3.7-11. Nine-Term Moving Average Rock Mass Quality vs Exploratory Studies Facility Tunnel Station

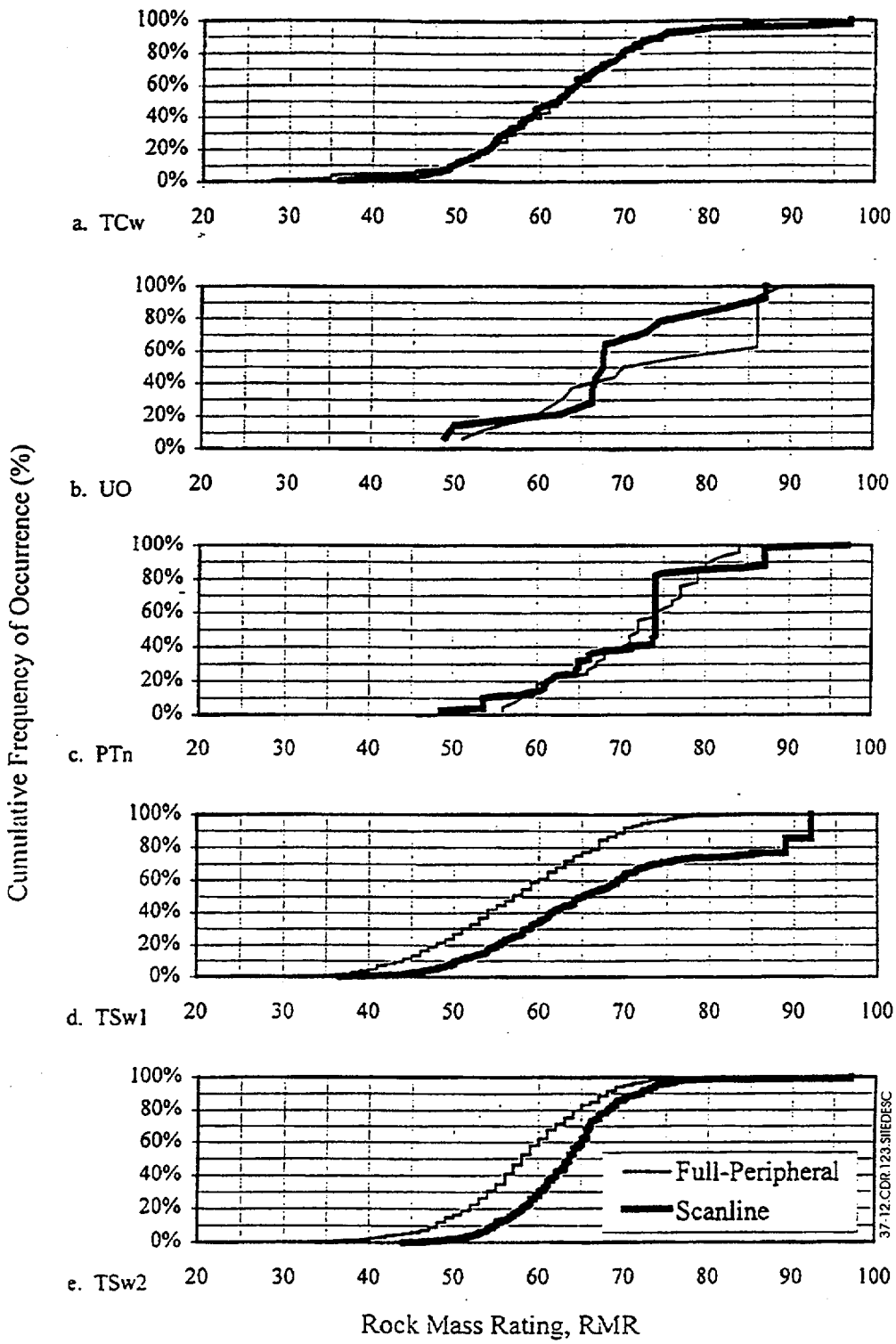


Figure 3.7-12. Cumulative Distribution of Rock Mass Rating Values in the Exploratory Studies Facility Main Loop

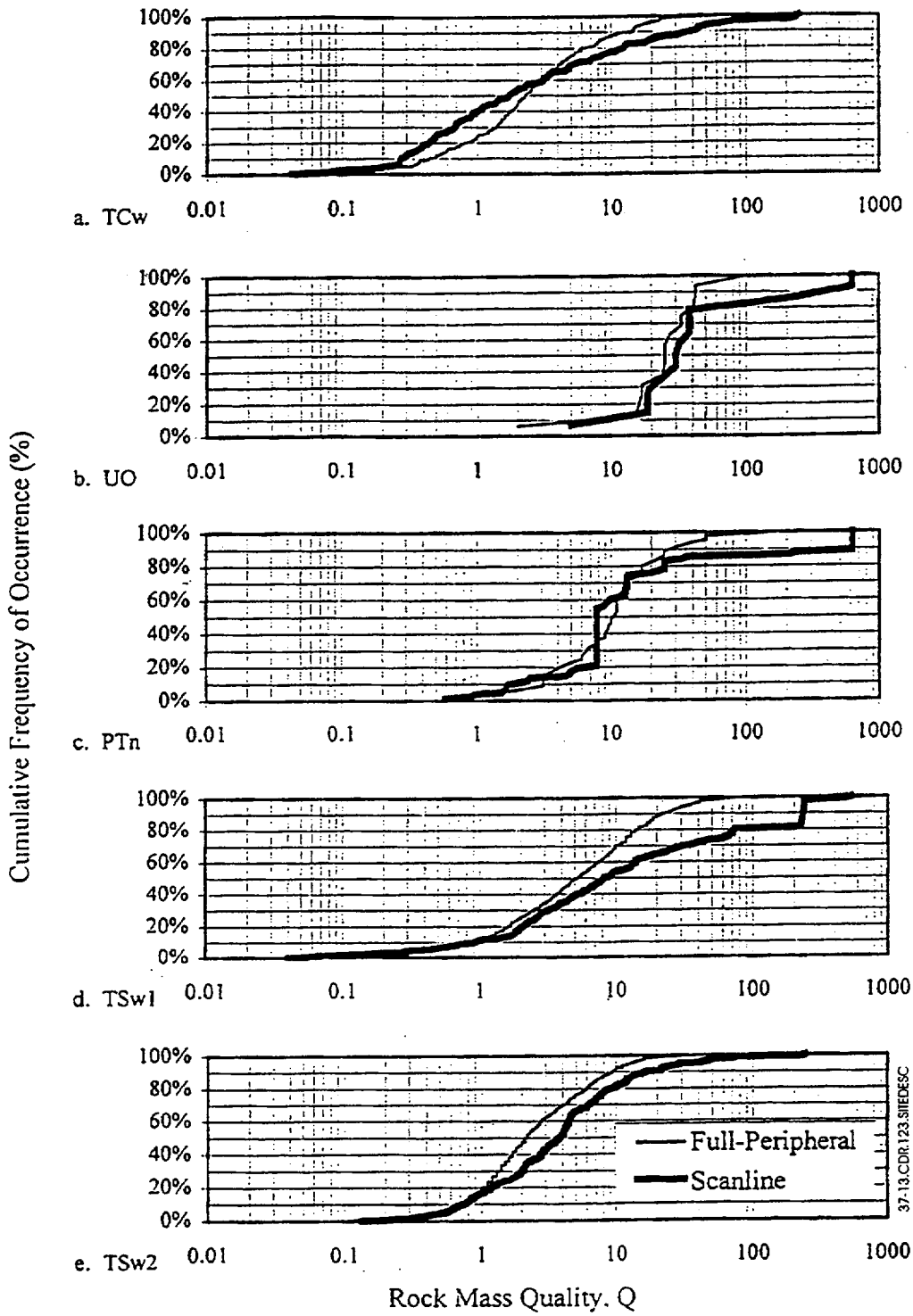


Figure 3.7-13 Cumulative Distribution of Rock Mass Quality Values in the Exploratory Studies Facility Main Loop

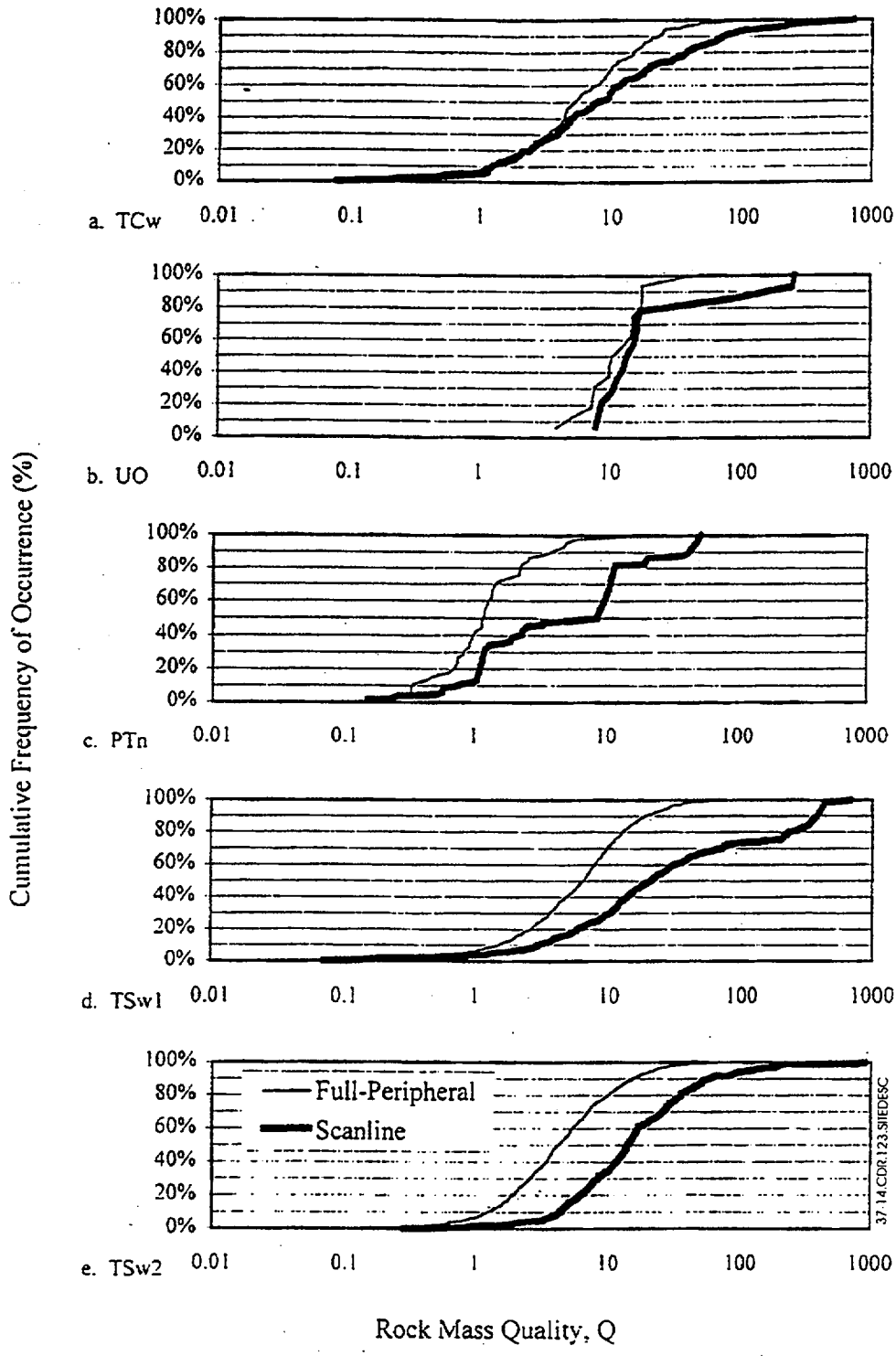


Figure 3.7-14 Cumulative Distribution of Modified Rock Mass Quality (Qmodified) Values in the Exploratory Studies Facility Main Loop

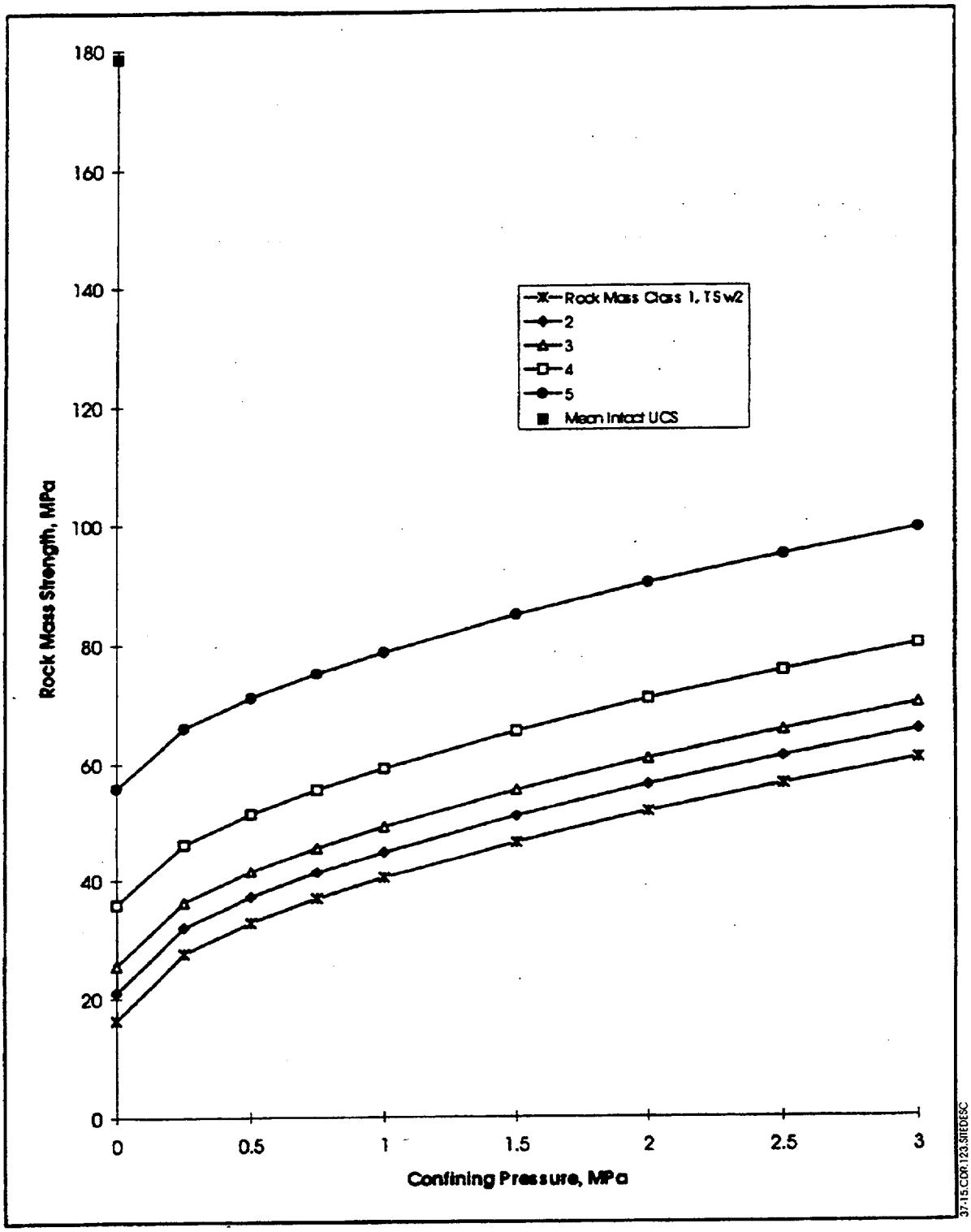
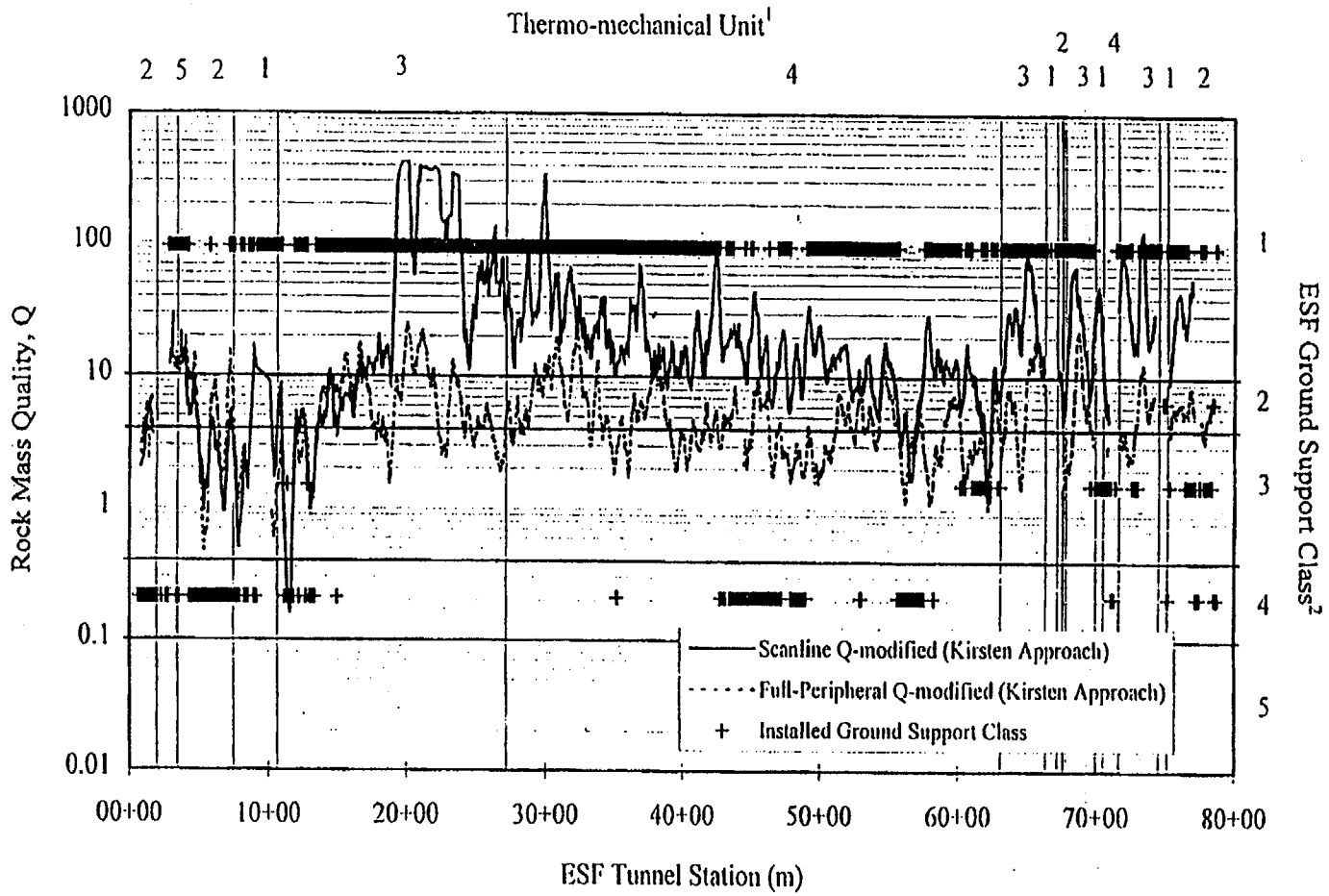


Figure 3.7-15. Design Rock Mass Strength Envelopes for TSw2 Unit, Exploratory Studies Facility Scanline Data

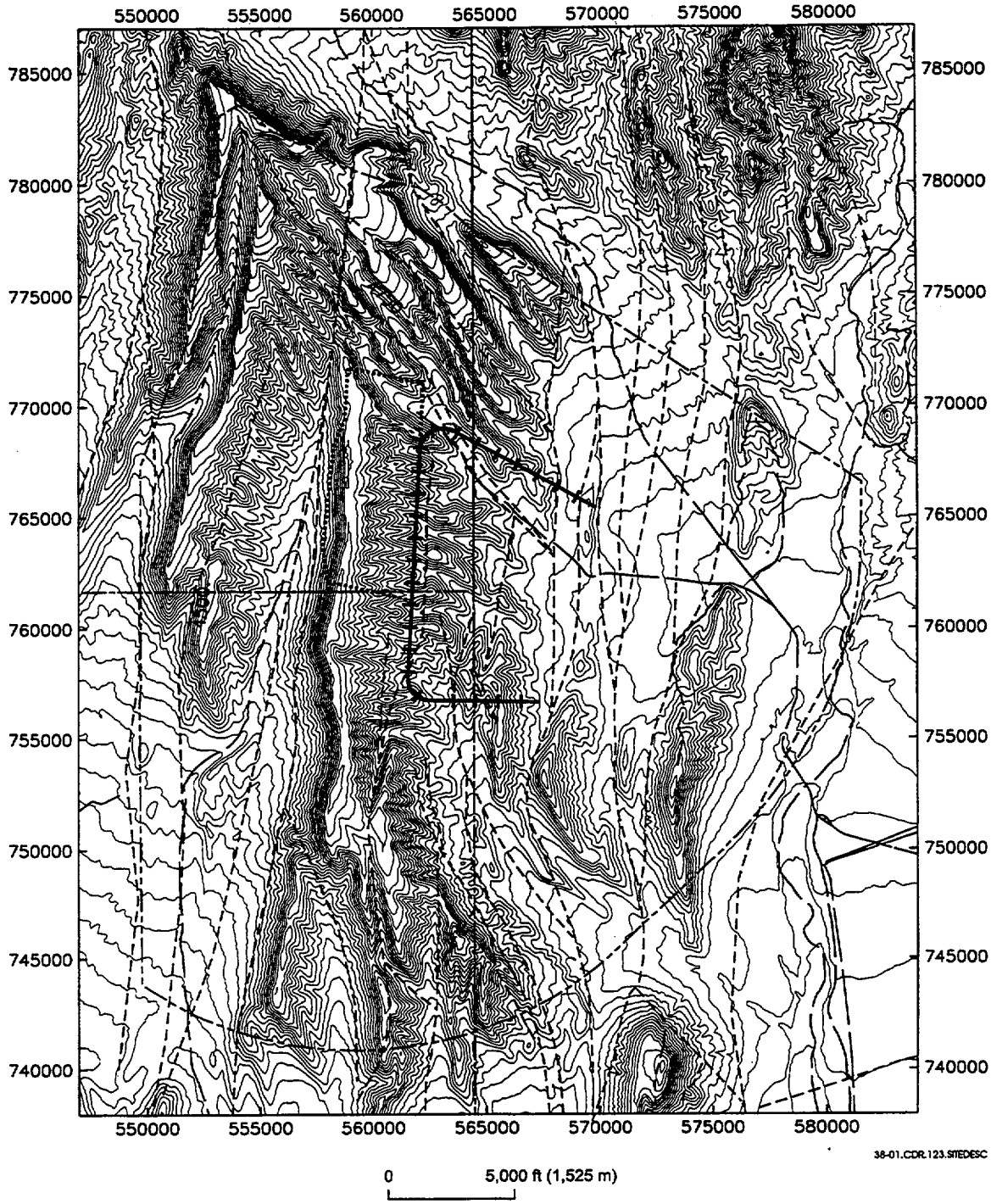


[1]Thermo-mechanical Units in the ESF Main Loop: 1–*PTn*, 2–*TCw*, 3–*TSw1*, 4–*TSw2*, 5–*UO*

[2]Range of Q values for each ground support class: Class 1–*1000 to 10*, Class 2–*10 to 4*, Class 3 –*1 to 0.4*, Class 4–*0.4 to 0.1*, Class 5–*0.01 to 0.1*

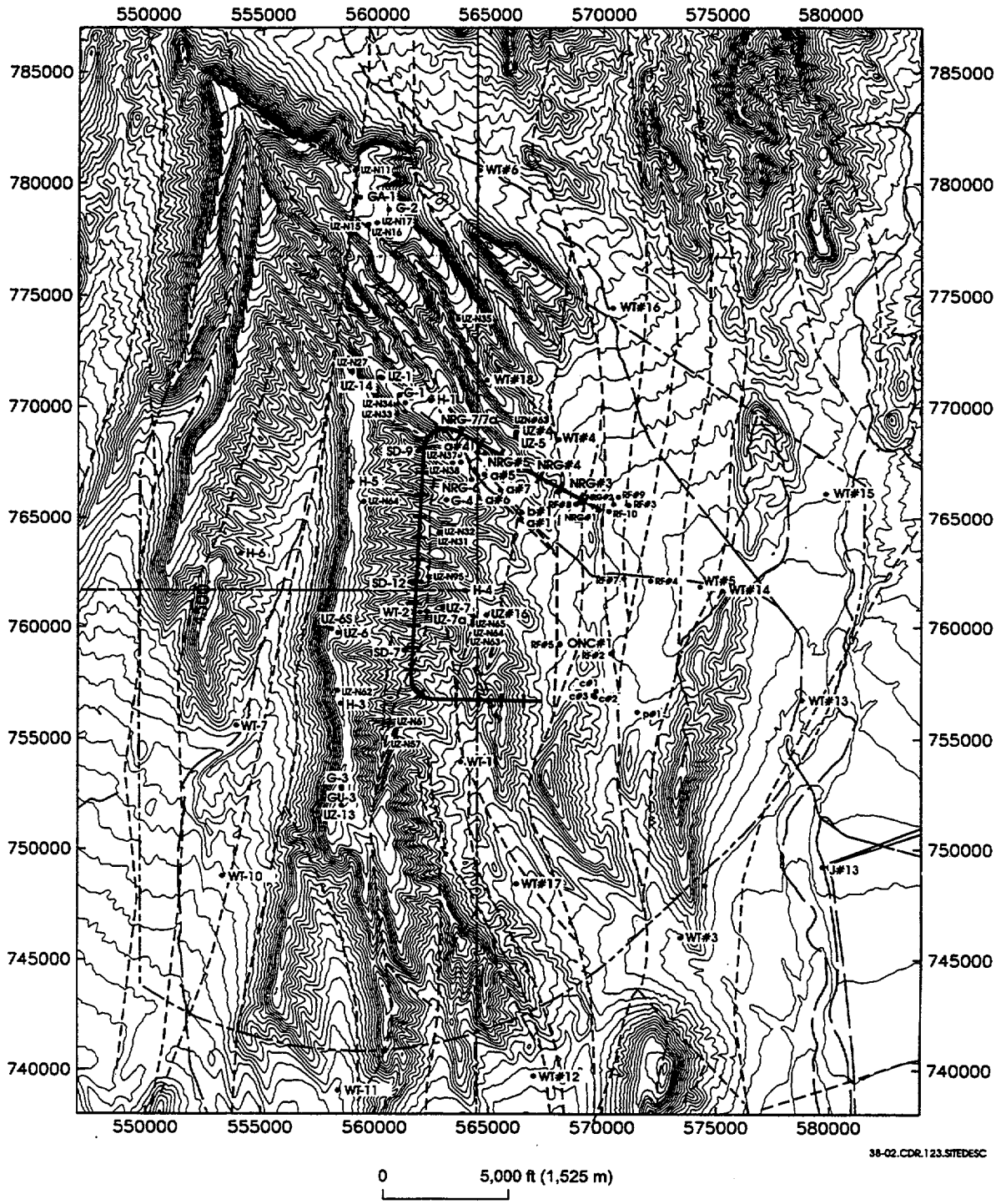
37-16.CDR.123 SITEDESC

Figure 3.7-16. Comparison of Qmodified (Nine-Term Moving Average) to the Installed Ground Support Class in the Exploratory Studies Facility Main Loop



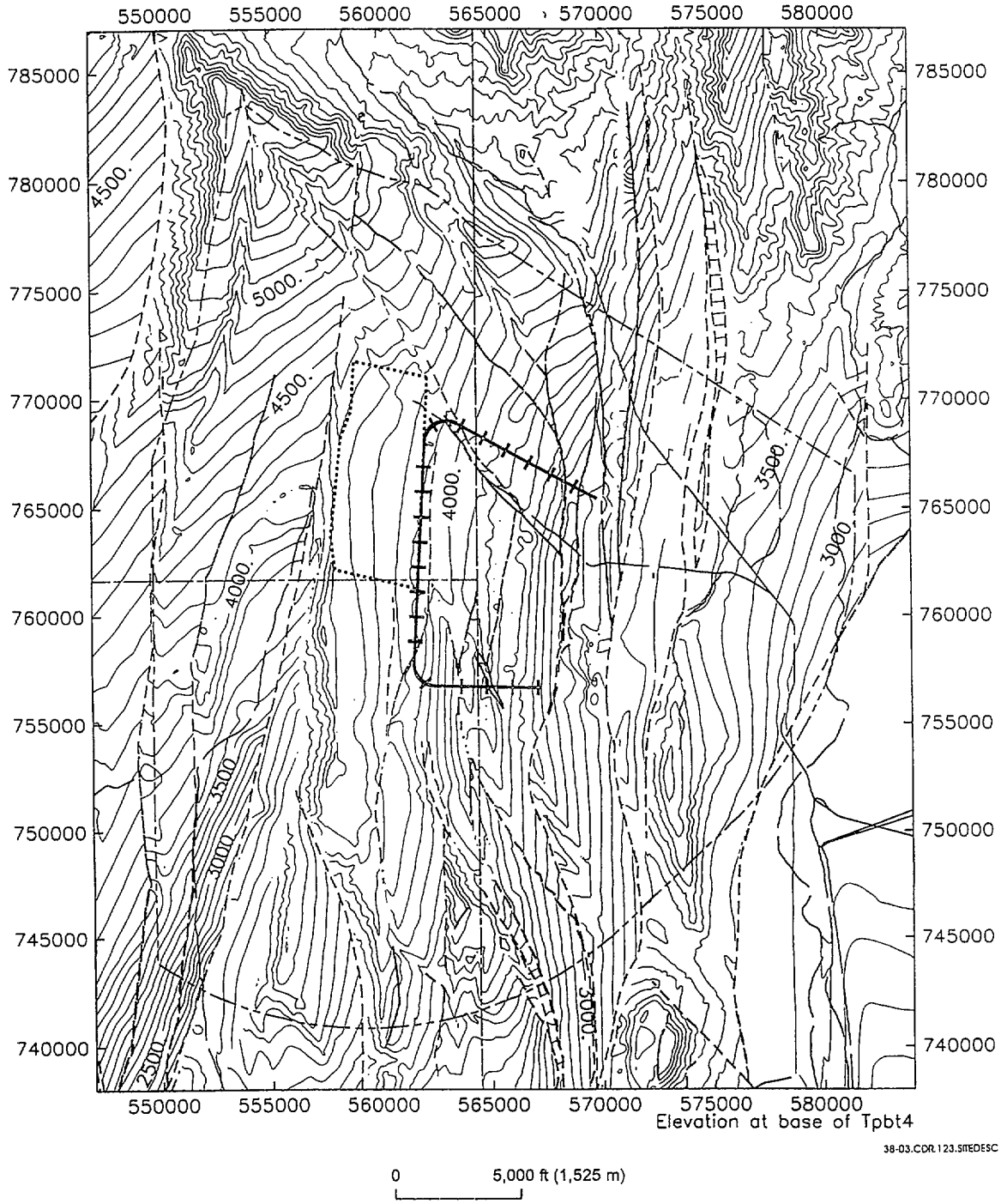
NOTE: Topographic Contour Interval is 50 ft (15.25m). In all figures, north is to the top of the page. On all subsection 3.8 figures, the Exploratory Studies Facility is a heavy hachured line; the conceptual controlled area boundary is a double-dashed line; faults are sinuous dashed lines; the NTS-BLM-Air Force land boundaries are straight, long-short dashed lines; and roads and streams are long-dashed lines.

Figure 3.8-1. Map of the 3-D Model Area



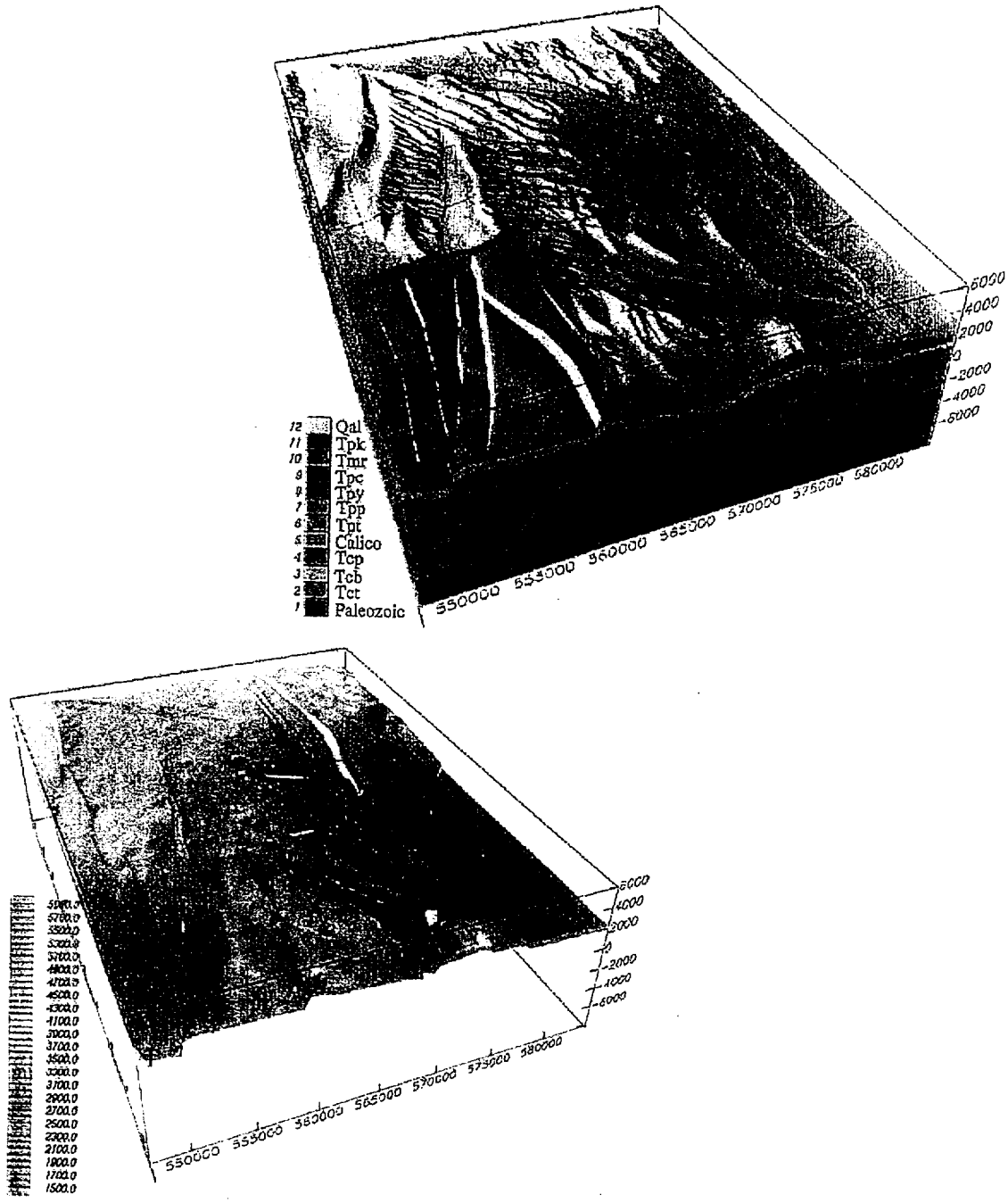
NOTE: Topographic Contour Interval is 50 ft. (15.25m)

Figure 3.8-2. Locations and Names of Boreholes used to Create the Geologic Framework Model



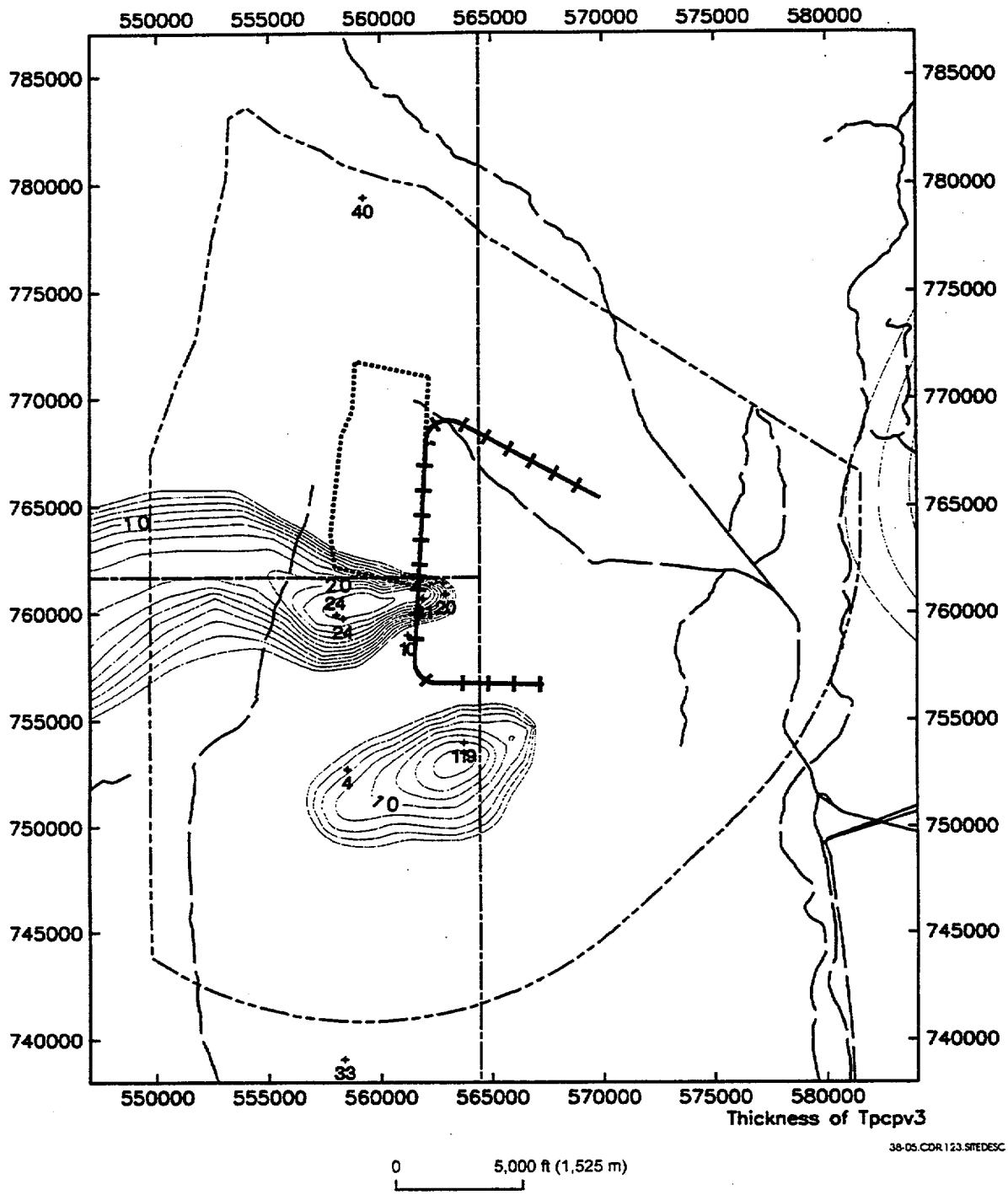
NOTE: Contour interval 100 ft (30 m). Data Density is similar to that of Figure 3.8.2.

Figure 3.8-3. Structural Contour Map on the Base of Tpbt4, the Pre-Tiva Bedded Tuff



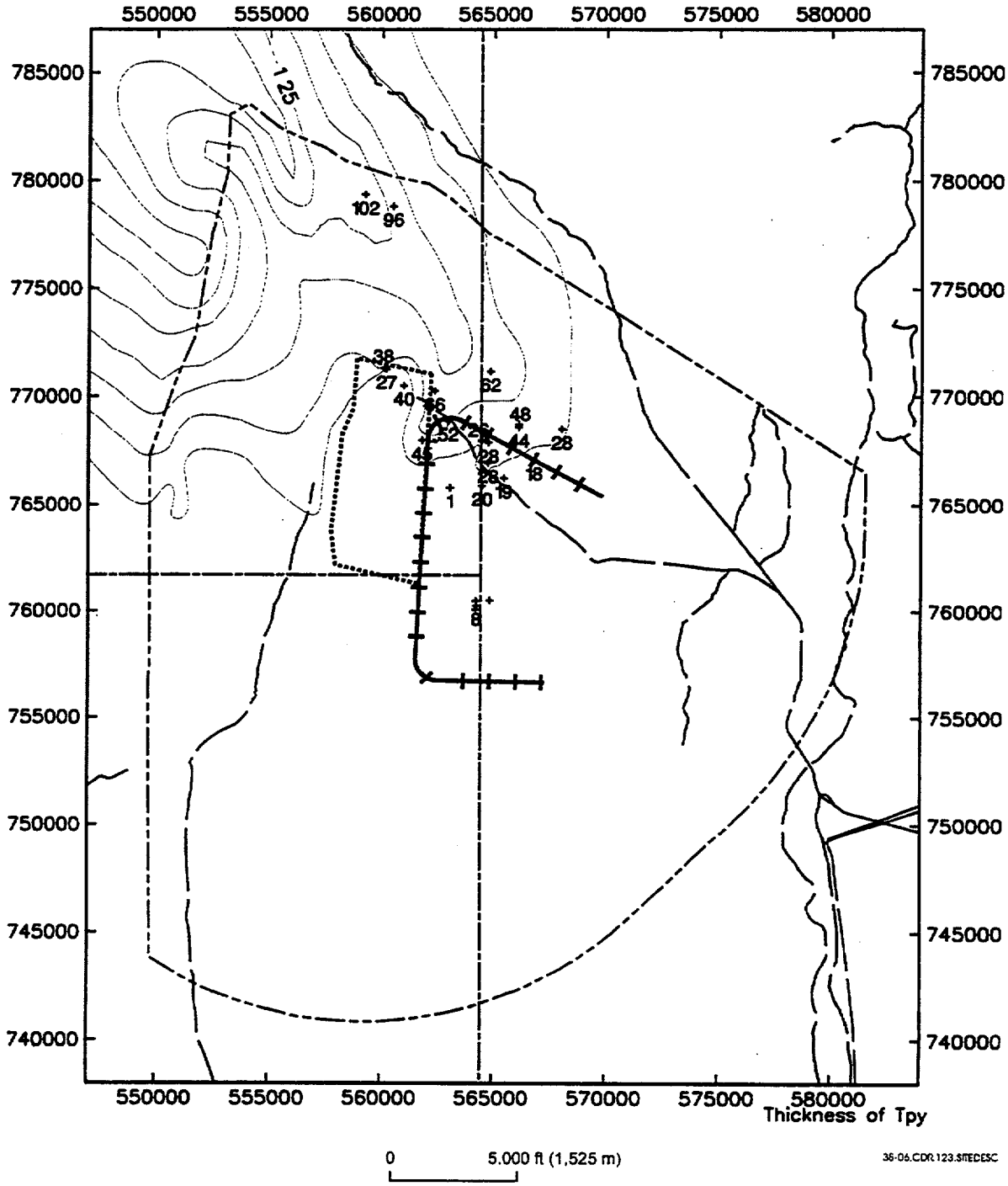
38-04.CDR.123.SITEDESC

Figure 3.8-4. Views to the Northeast of the 3-D Geologic Framework Model Version ISM2.0



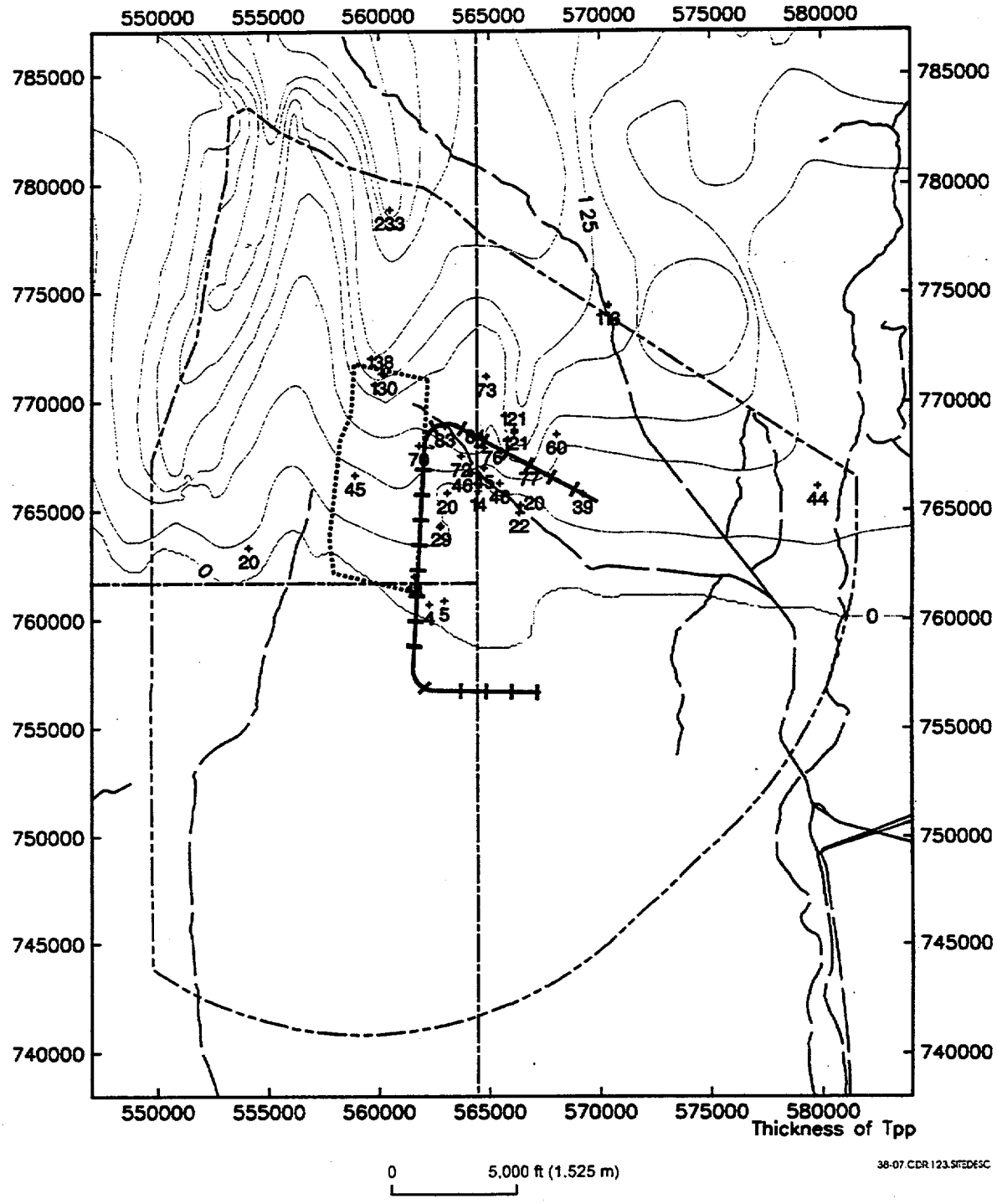
NOTE: Contour interval 2 ft (0.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-5 Isochore (Thickness) Map of Rock Unit TPCPV3, the Lower Densely Welded Vitric Sub-Zone of the Tiva Canyon Tuff (the Vitrophyre)



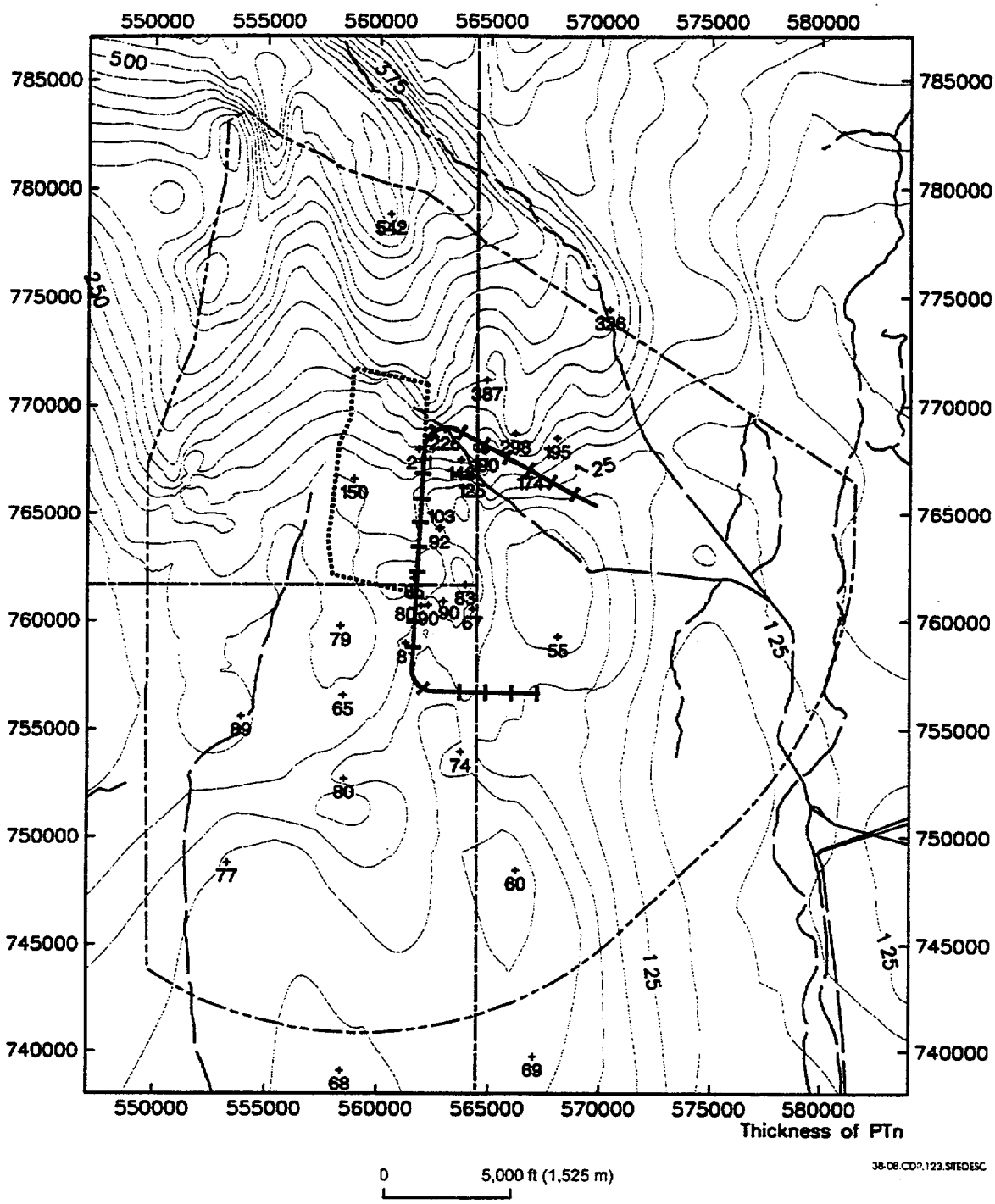
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-6. Isochore (Thickness) Map of the Yucca Mountain Tuff



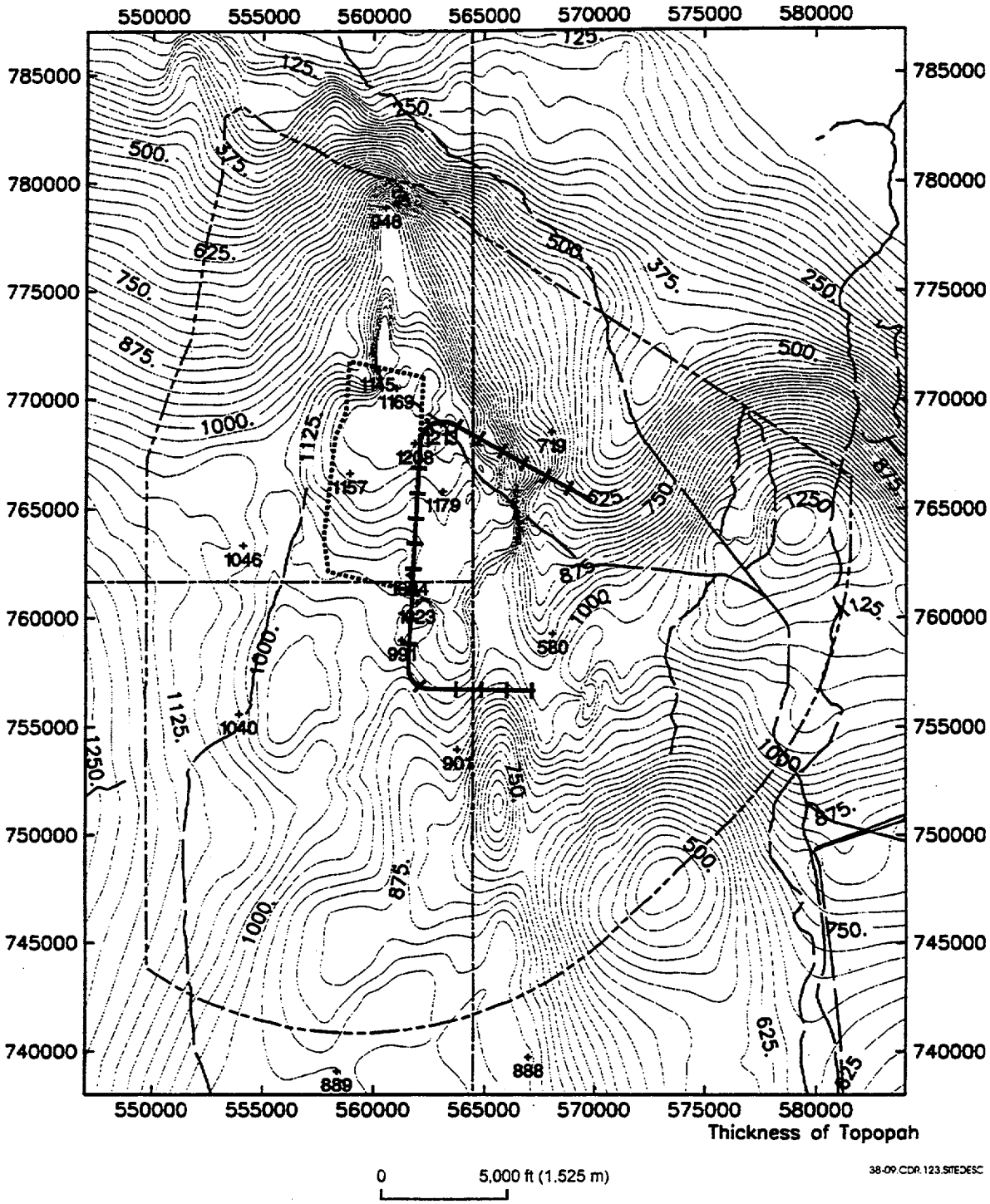
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-7. Isochore Map of the Pah Canyon Tuff, Including the Pre-Pah Bedded Tuff



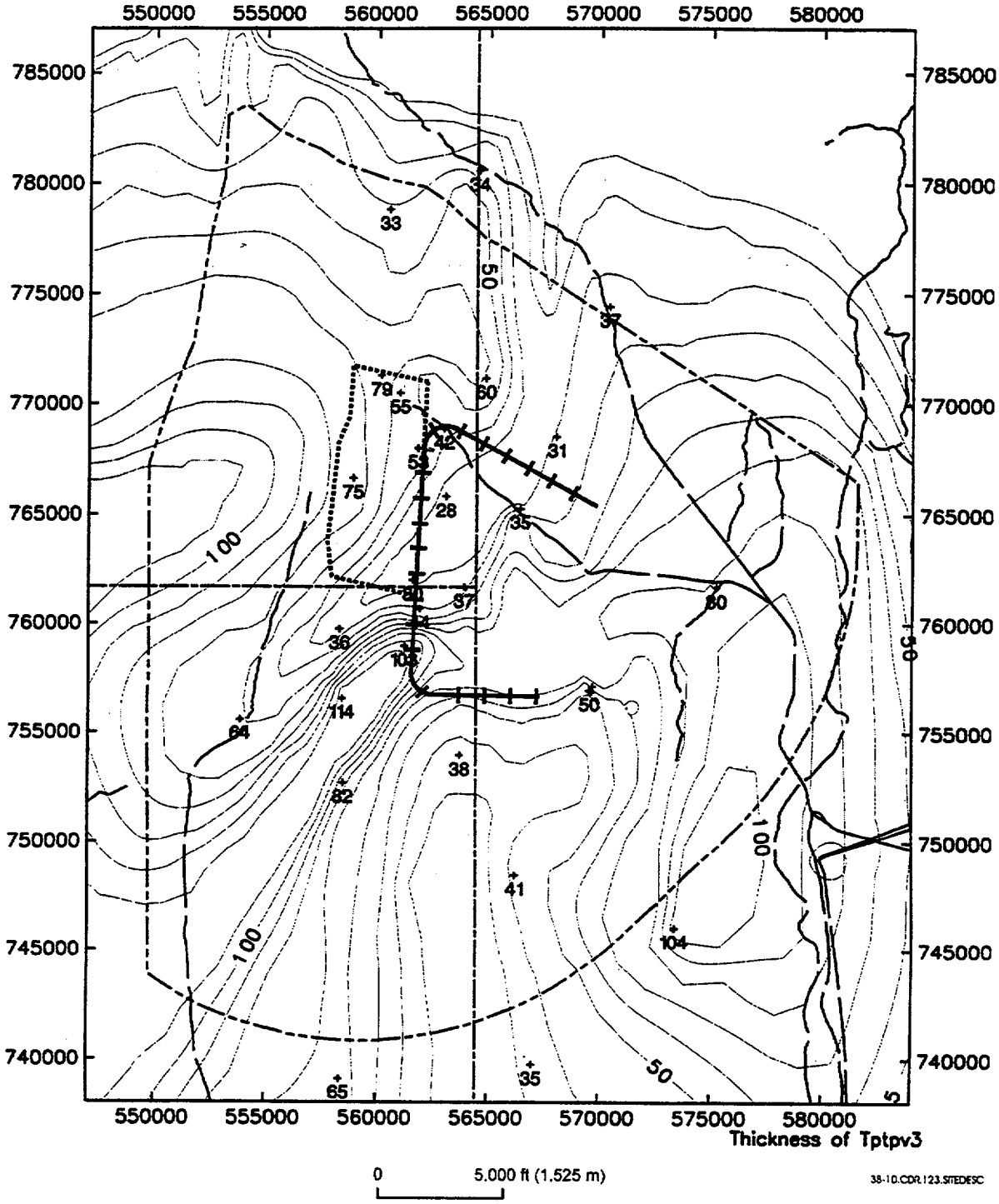
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-8. Isochore Map of the PTn Hydrogeologic Unit



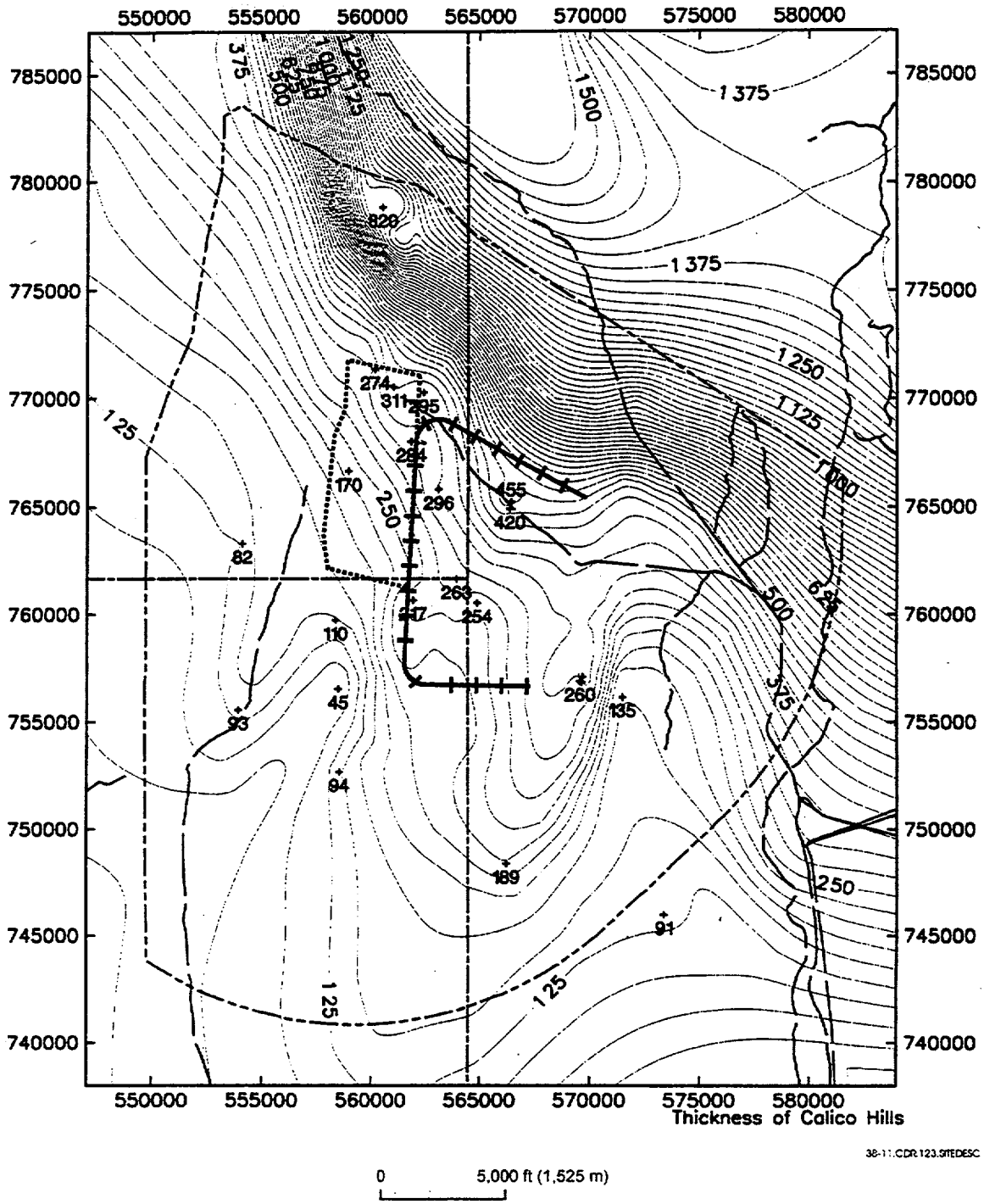
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-9. Isochore Map of the Topopah Spring Tuff



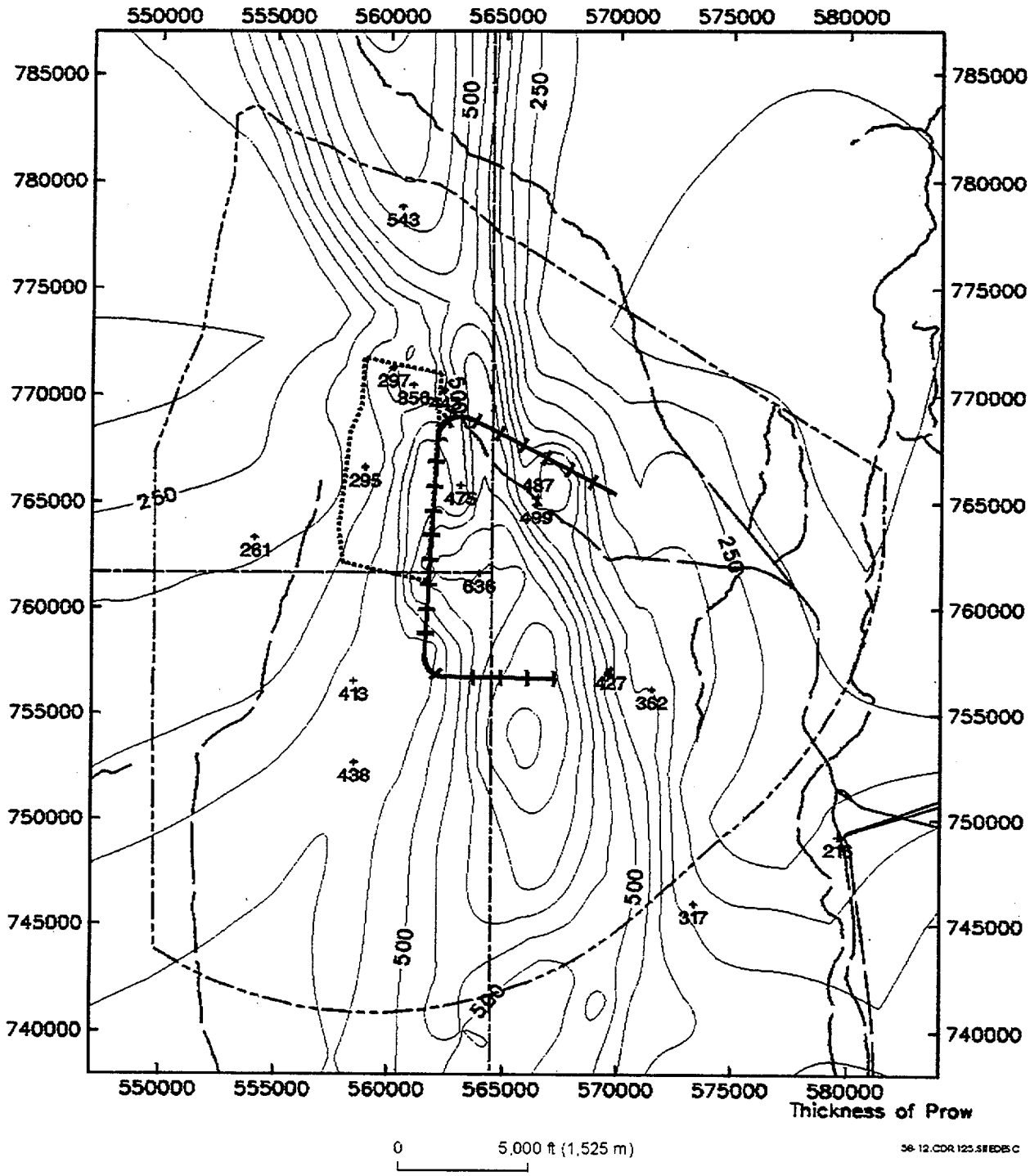
NOTE: Contour interval 10 ft (3 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-10. Isochore Map of Rock Unit Tptpv3, the Lower Densely Welded Vitric Zone of the Topopah Spring Tuff



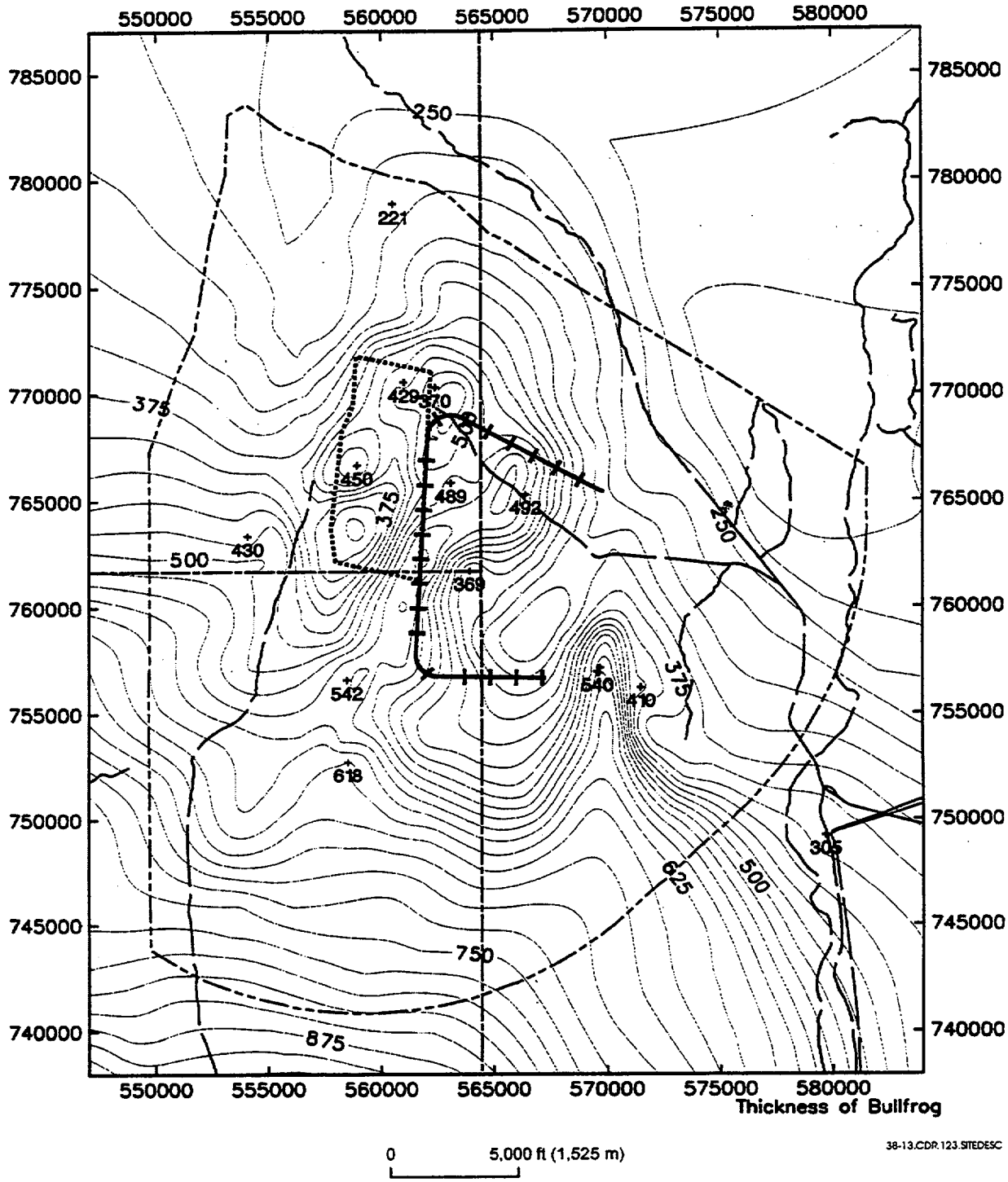
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-11. Isochore Map of the Calico Hills Formation



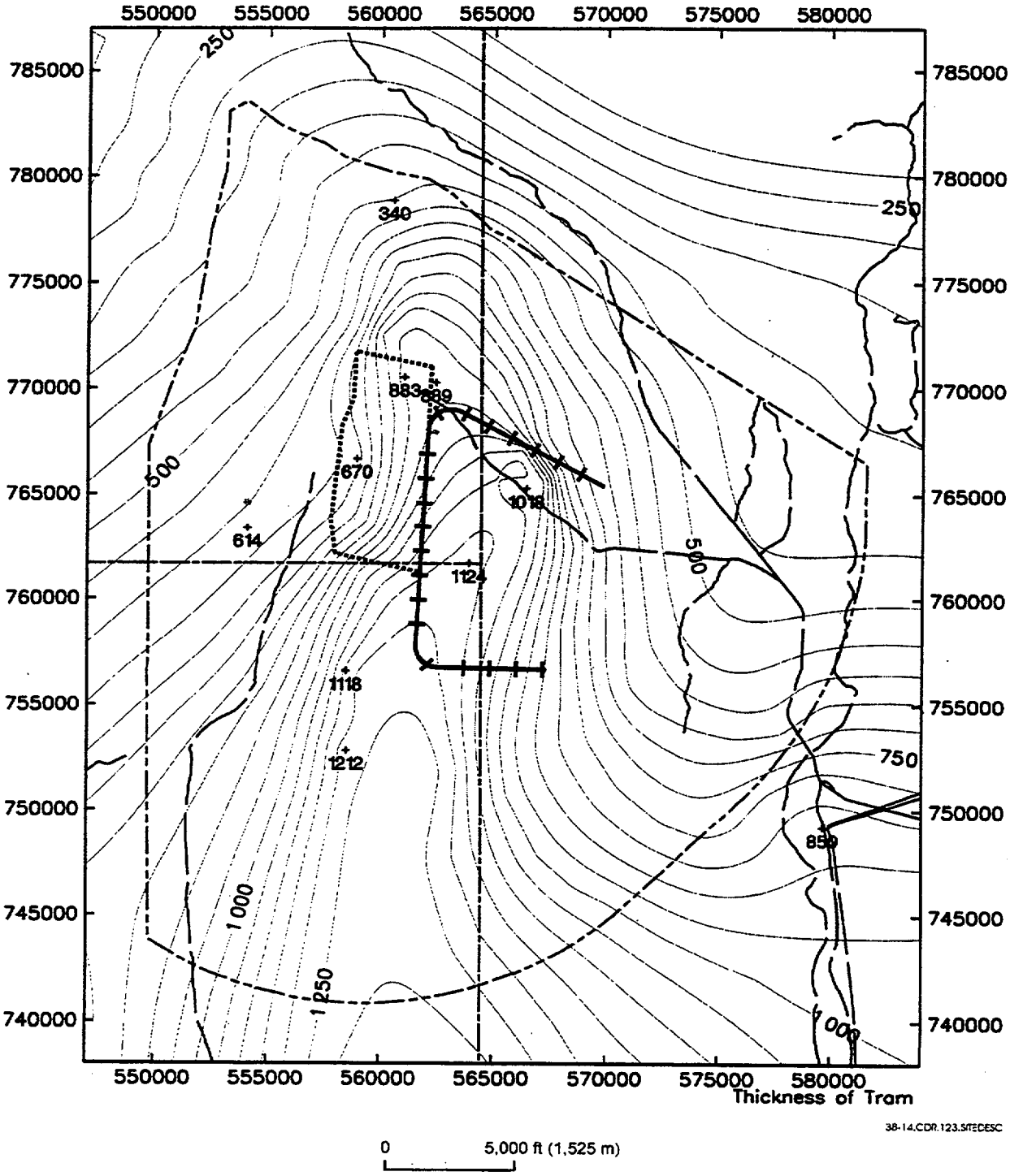
NOTE: Contour interval 50 ft (15 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-12. Isochore Map of the Prow Pass Tuff



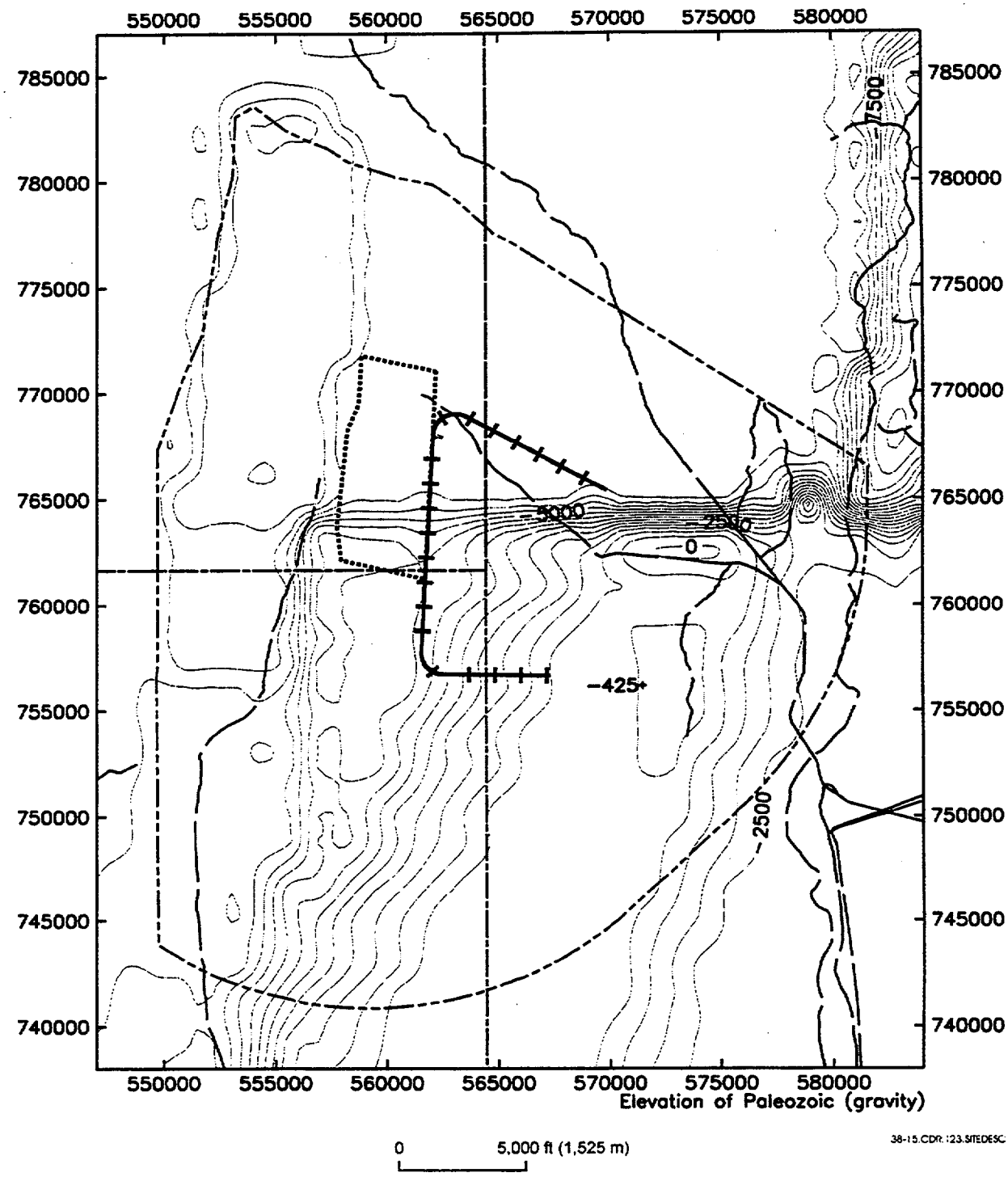
NOTE: Contour interval 25 ft (7.6 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-13. Isochore Map of the Bullfrog Tuff



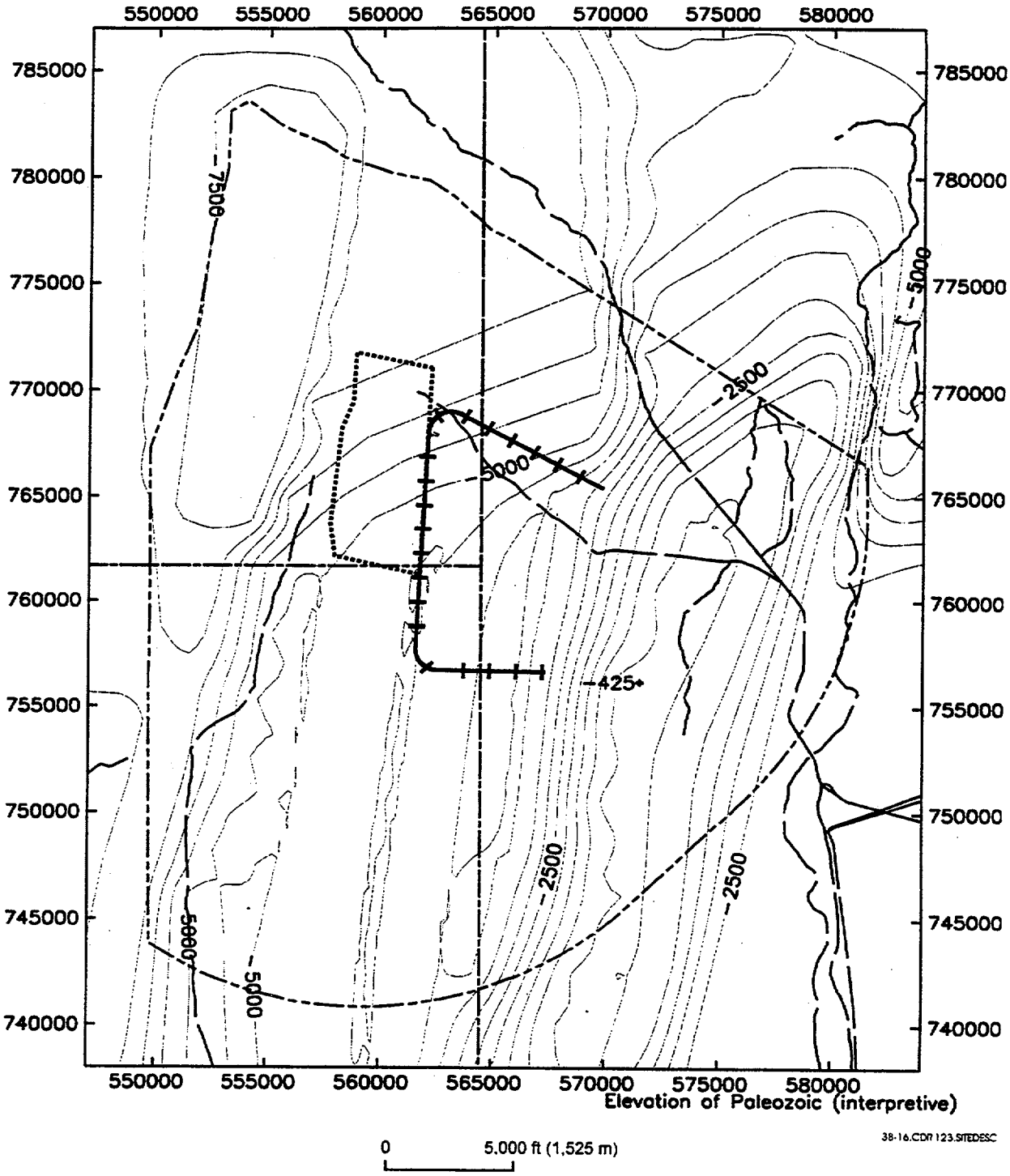
NOTE: Contour interval 50 ft (15 m); + indicates data points with thickness of rock unit in feet.

Figure 3.8-14. Isochore Map of the Tram Tuff



NOTE: Contour interval 500 ft (152 m)

Figure 3.8-15. Structural Contour Map of the Top of the Tertiary-Paleozoic Unconformity, Calculated from Gravity Data



NOTE: Contour interval 500 ft (152 m)

Figure 3.8-16. Interpretive Structural Contour Map of the Tertiary-Paleozoic Unconformity

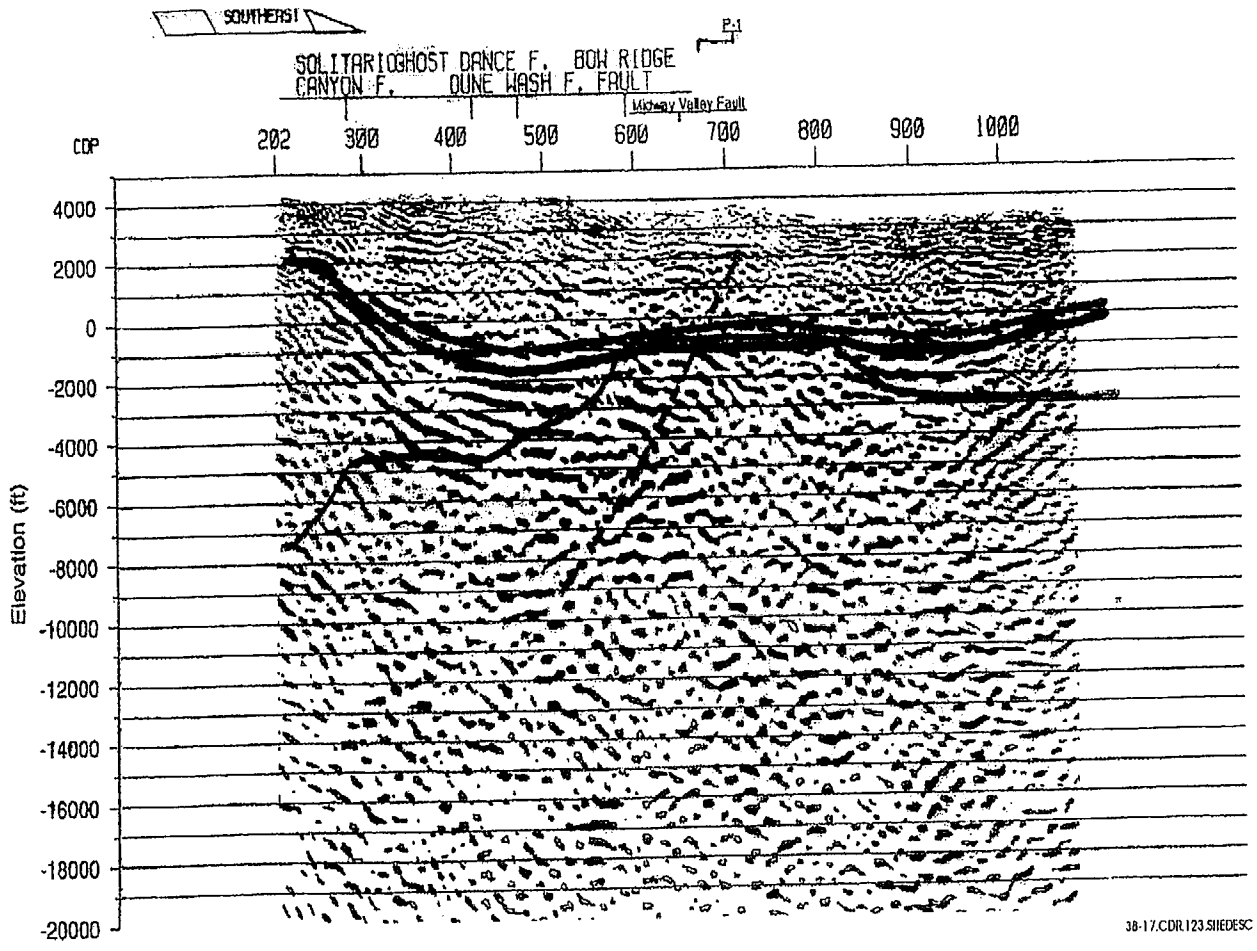
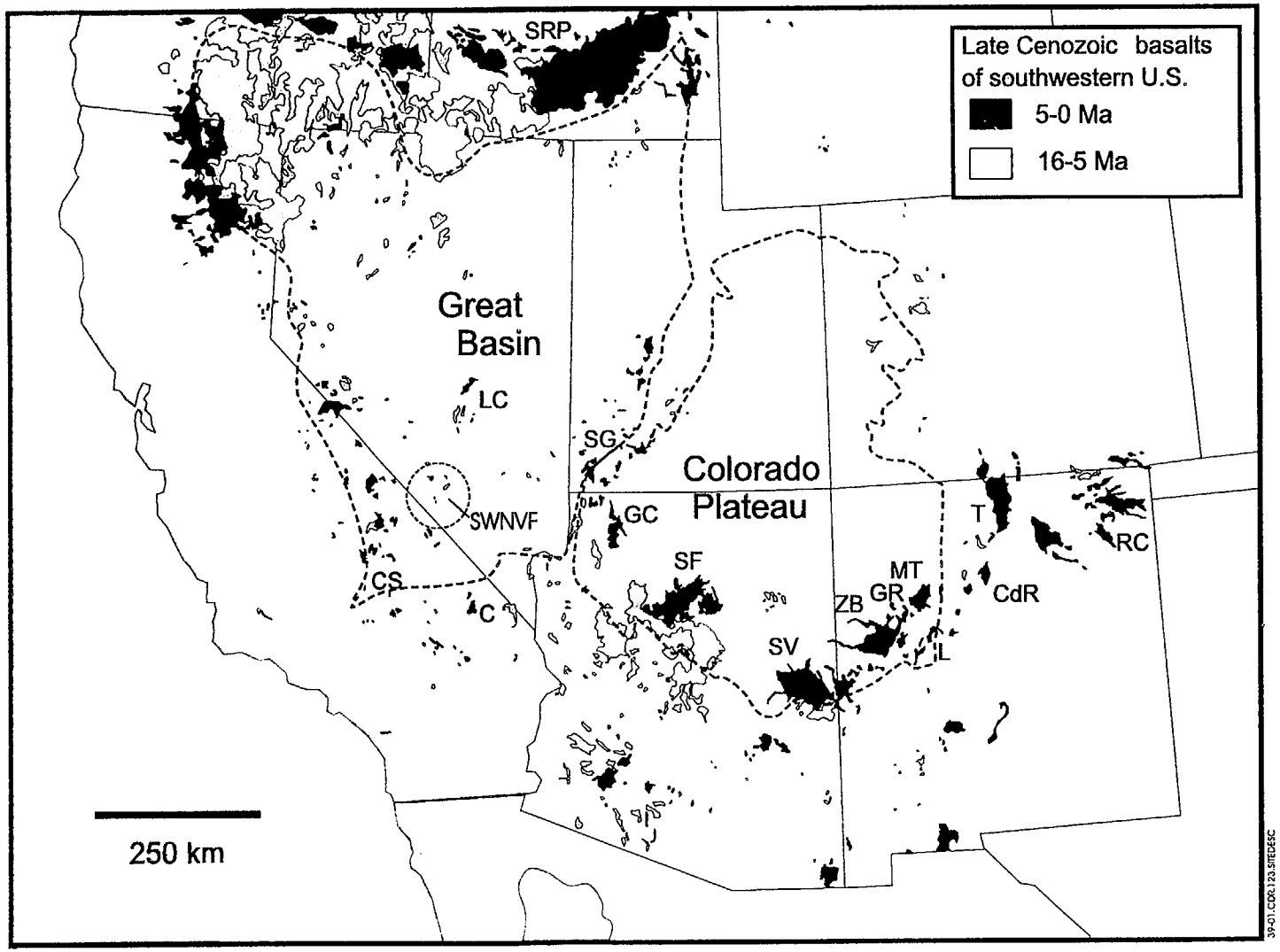


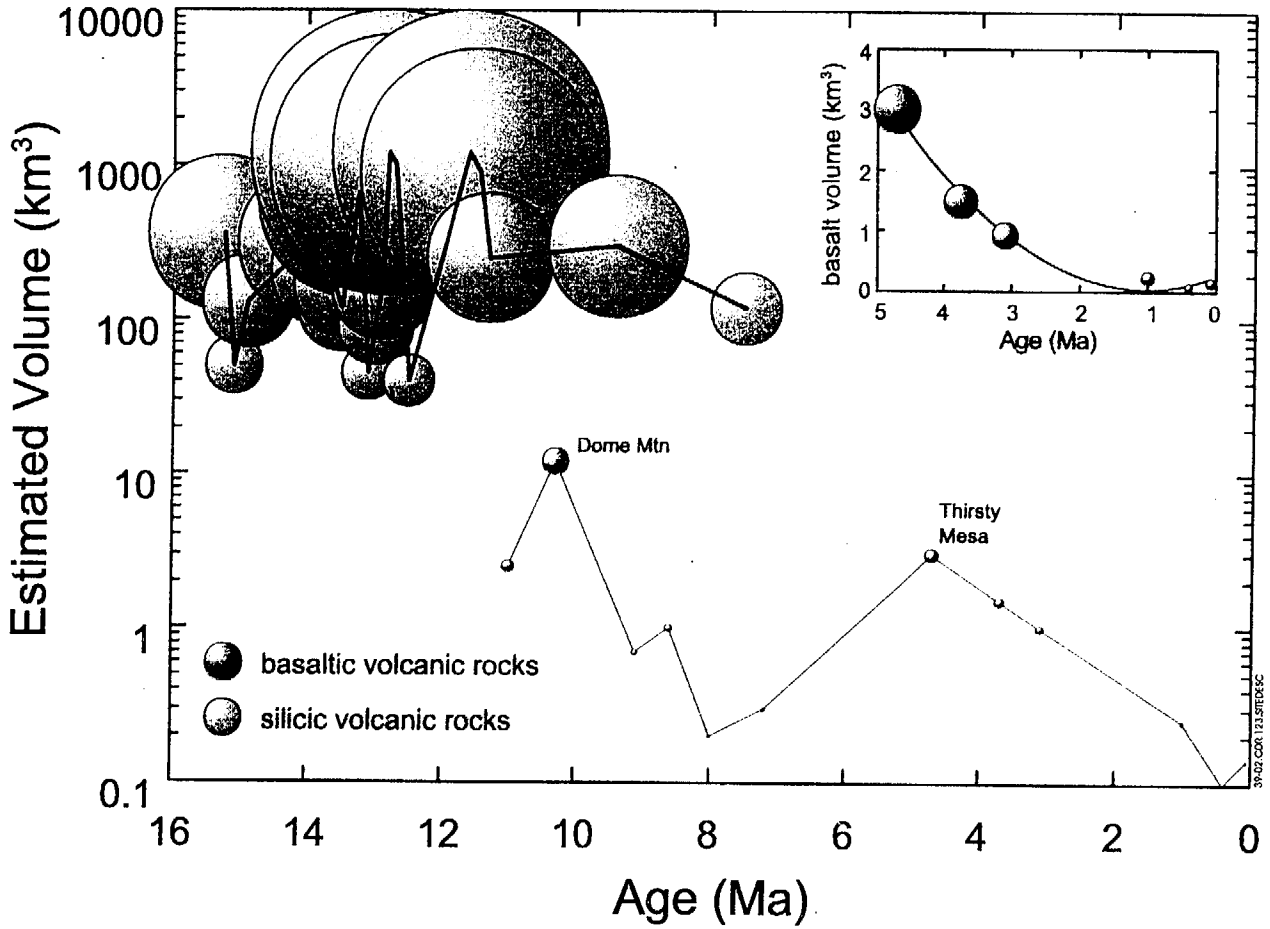
Figure 3.8-17. Seismic Line REG-3 with Interpretations of the Tertiary-Paleozoic Unconformity

INTENTIONALLY LEFT BLANK



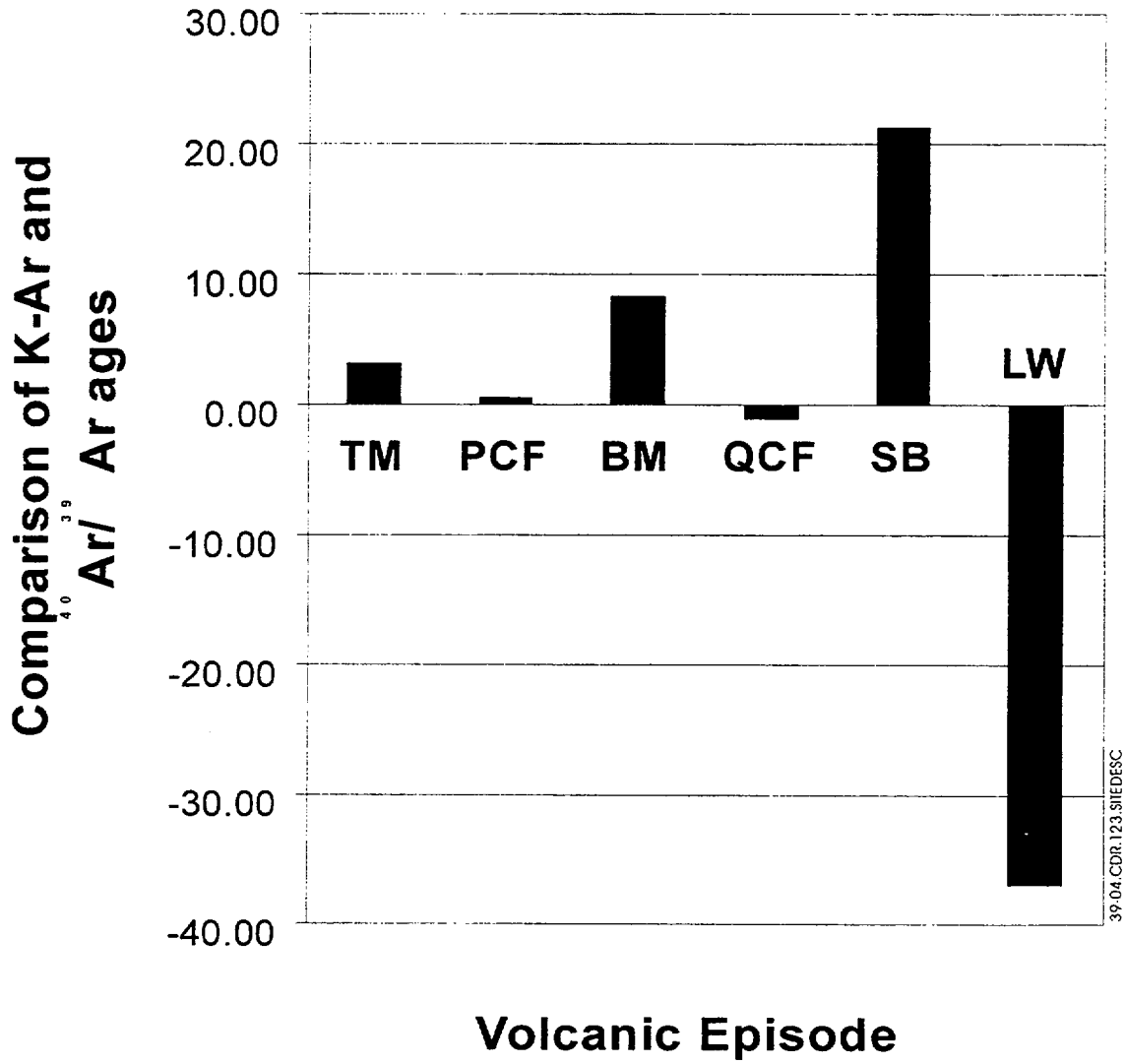
NOTE: The distribution of volcanic rocks of silicic and intermediate composition is not shown. The location of the Southwestern Nevada Volcanic Field (SWNVF), within which Yucca Mountain is located, is indicated as a circle of 50 km radius centered on Yucca Mountain. The circle encompasses post-5 Ma basaltic centers of the Yucca Mountain region. Other labeled volcanic fields are: C: Cima, CdR: Cerros Del Rio; CS: Coso; GC: Grand Canyon; GR: Grants Ridge; LC: Lunar Crater; L: Lucero; MT: Mount Taylor; RC: Raton-Clayton; SF: San Francisco; SG: St. George; SRP: Snake River Plain; SV: Springerville; T: Taos; ZB: Zuni-Bandera.

Figure 3.9-1. Distribution of Late Cenozoic Basaltic Rocks in the Western United States Erupted During the Period 16-5 and 5-0 Ma Relative to the Margins of the Great Basin and Colorado Plateau Provinces (after Fitton et al. 1991)



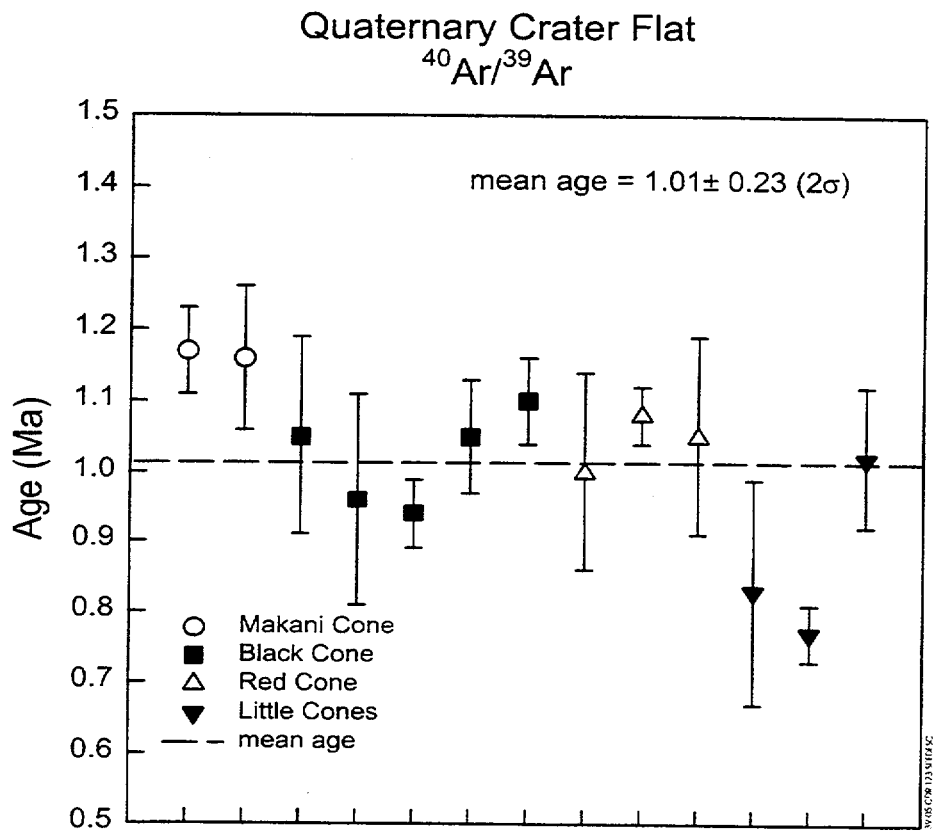
NOTE: Volume versus age of the post-Miocene basalts (YPB) of the Yucca Mountain region. Area of symbols are proportional to the estimated volume of each eruptive unit.

Figure 3.9-2. Estimated Volume Versus Age for Volcanic Rocks of the SWNFV



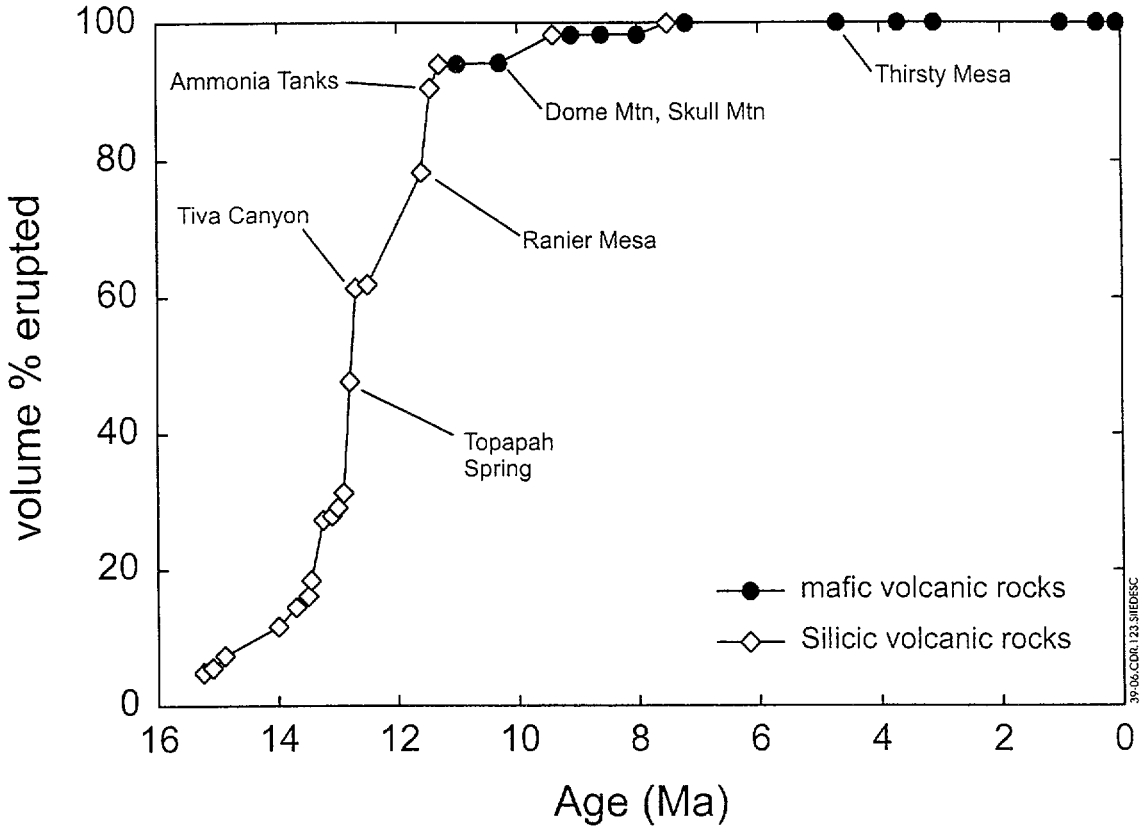
NOTE: The comparison is expressed as the percent difference in the best estimate age for each volcanic episode, relative to the K-Ar measurements of Fleck et al. (1996). No systematic difference in age determinations are apparent between K-Ar and $^{40}Ar/^{39}Ar$ ages. Age agreement on basalt older than 1 Ma is generally good; age agreement on basalt younger than 1 Ma is poorer because of the difficulty of dating young, K-poor rocks using K-Ar and $^{40}Ar/^{39}Ar$ methods. TM: Thirsty Mesa; PCF: Pliocene Crater Flat; BM: Buckboard Mesa; QCF: Quaternary Crater Flat; SB: Sleeping Butte; LW: Lathrop Wells.

Figure 3.9-3. Comparison of K-Ar (Fleck et al. 1996) and $^{40}Ar/^{39}Ar$ (Perry et al. 1998a) Measurements of the Age of Post-Miocene Volcanic Episodes in the Yucca Mountain Region



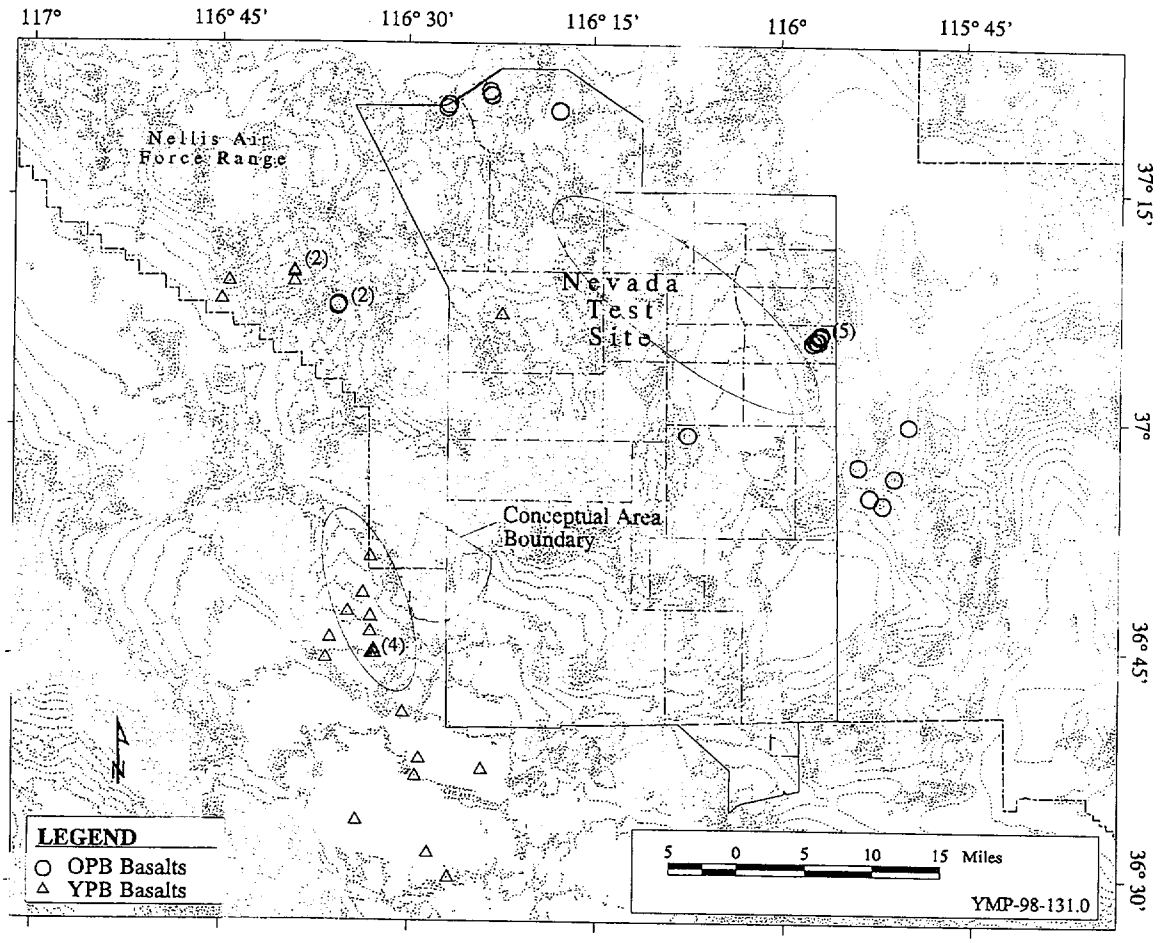
NOTE: Left to right on the figure corresponds to north to south for the location of basalt centers within Crater Flat.

Figure 3.9-4. $^{40}Ar/^{39}Ar$ Dates from Quaternary Basalt Centers of Crater Flat



NOTE: Most of the volume of the SWNVF consists of early erupted silicic volcanic rocks. Compare with Figure 3.9-3.

Figure 3.9-5. Percent Cumulative Volume Erupted versus Age of Volcanic Units of the SWNVF

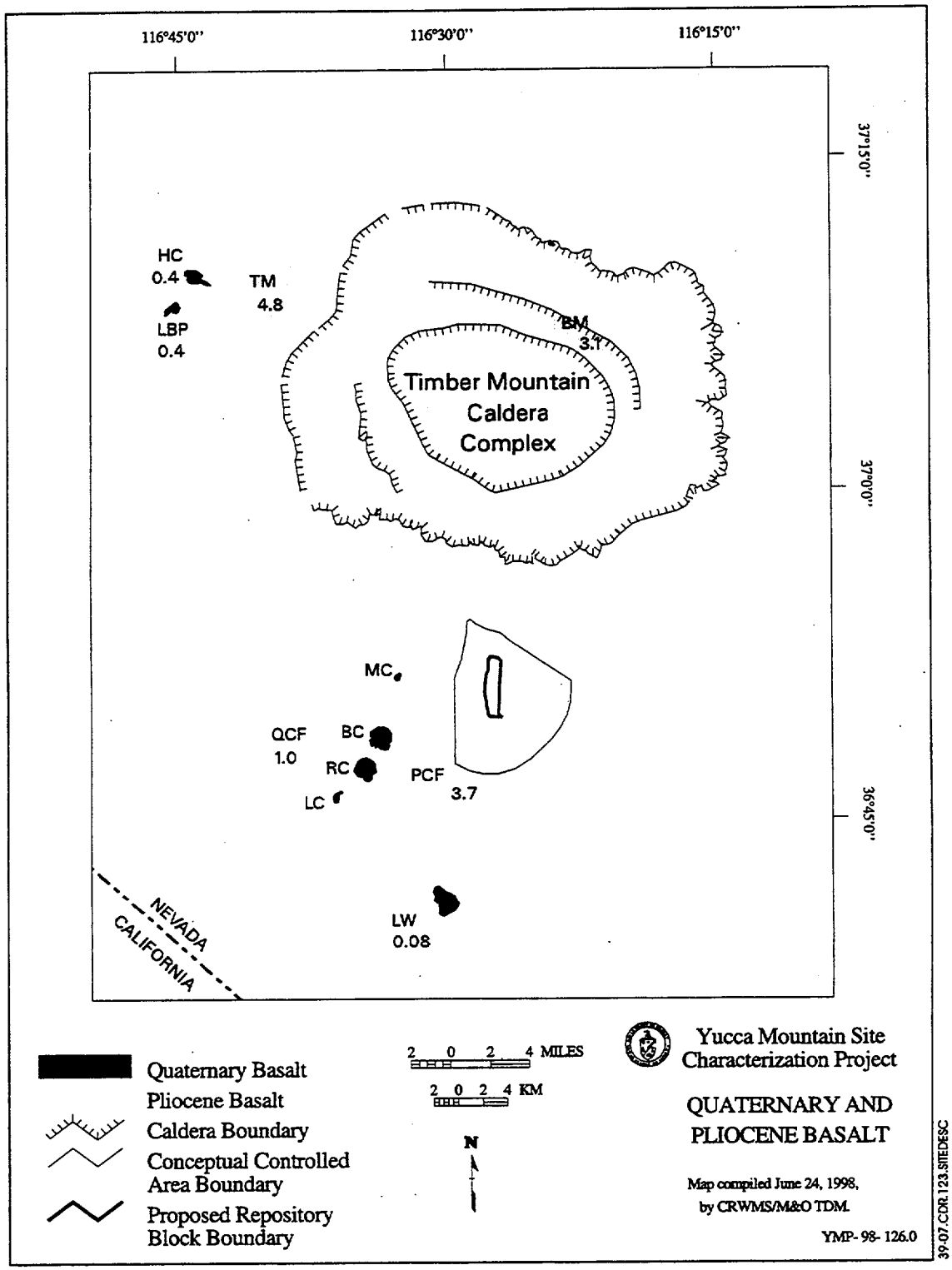


Location of Basaltic Vents

Yucca Mountain Site Characterization Project

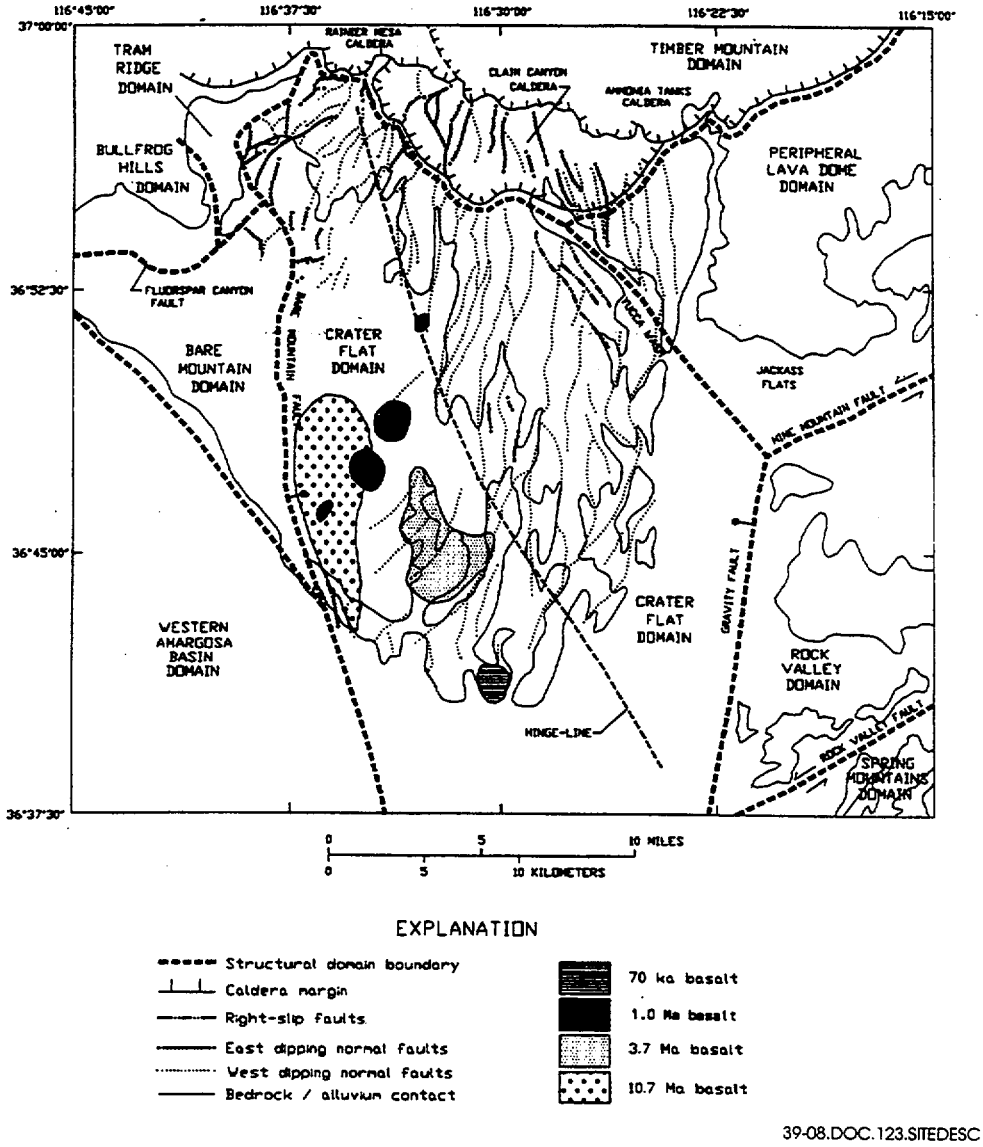
NOTE: Also shown are the 95 percent confidence intervals for the location of the centroid of the vents for each basalt cycle (after Crowe et al., in press [a]).
OPB = Older Post-Caldera Basalts; YPB = Younger Post-Caldera Basalts

Figure 3.9-6. Location of Vents of OPB Basalts (Circles) and YPB (post-Miocene) Basalt (Triangles)



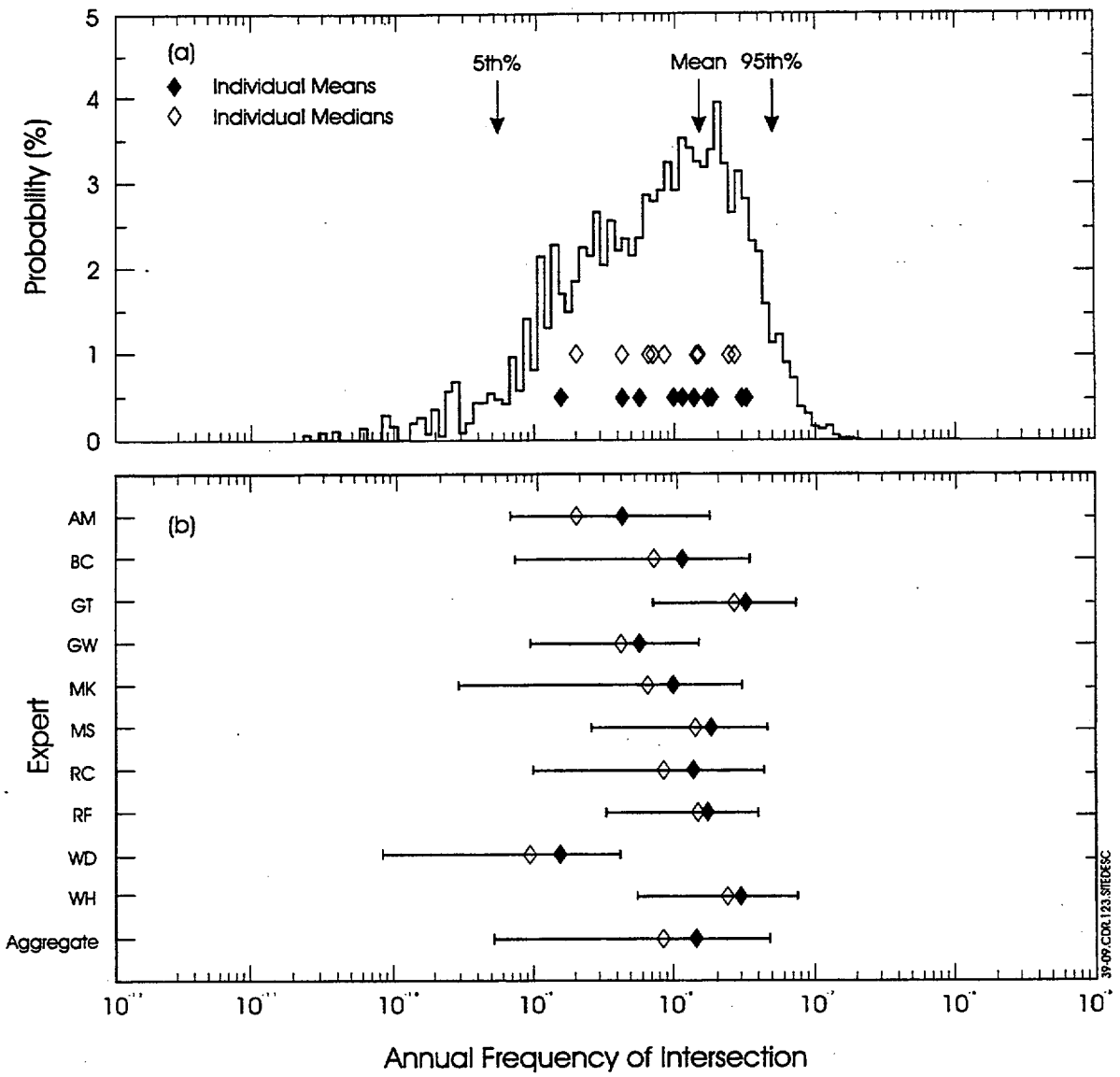
NOTE: HC=Hidden cone, TM=Thirsty Mesa, LBP=Little Black Peak, BM=Buckboard Mesa, LW=Lathrop Wells, MC=Makani cone, BC=Black cone, RC=Red cone, LC=Little cone, QCF=Quaternary Crater Flat, PCF=Pliocene Crater Flat

Figure 3.9-7. Quaternary and Pliocene Basalt Centers of the Yucca Mountain Region



NOTE: Shaded areas show the surface distribution of basaltic volcanism in the Crater Flat Basin. The major tectonic features of the basin and surrounding area are labeled on the figure.

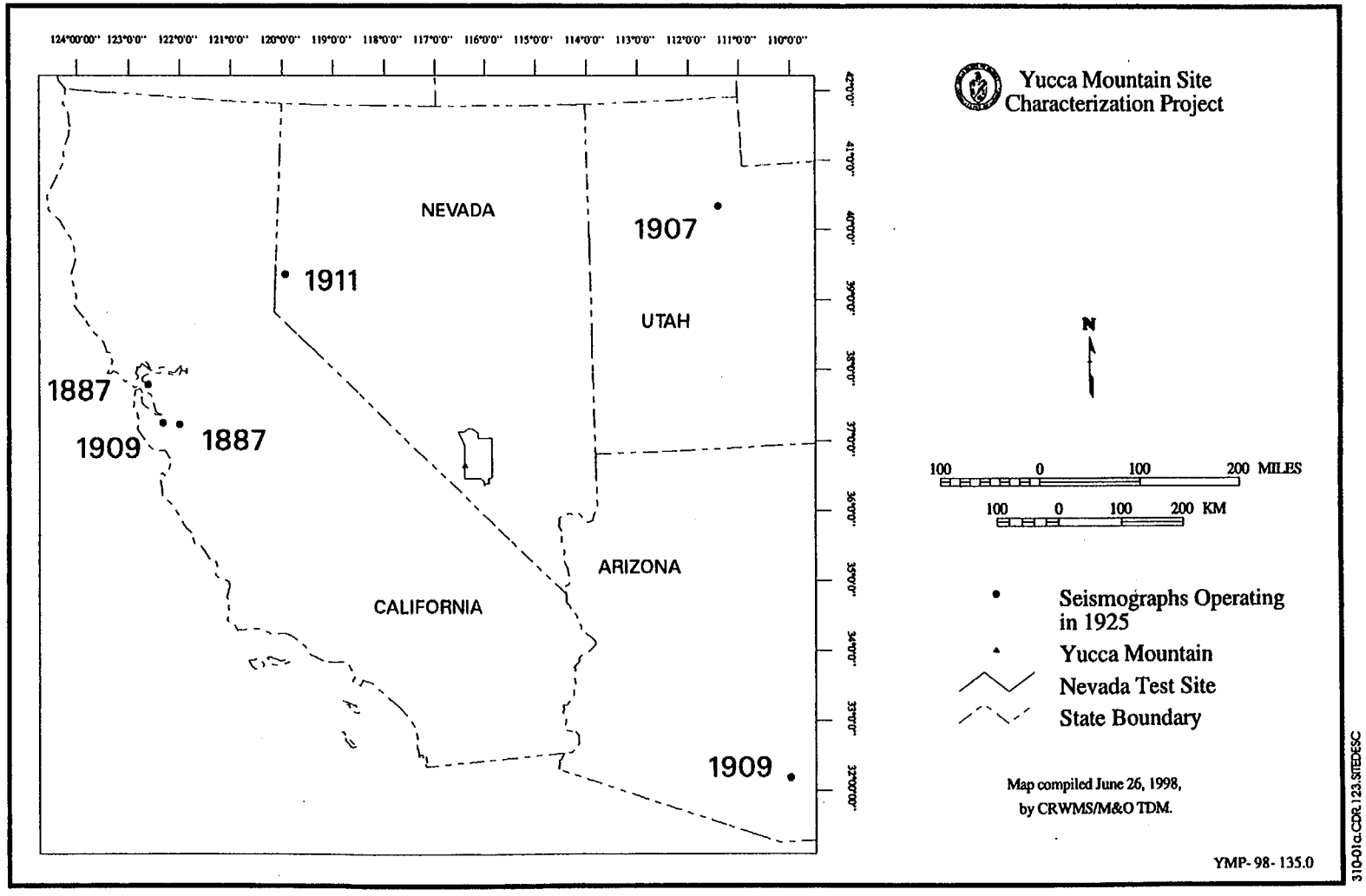
Figure 3.9-8. Major Structural Features of the Crater Flat Basin from the Fridrich (1998) Tectonic Model



NOTE: (a) Aggregate probability distribution for probability of intersection (b) Individual and aggregate means, medians and 90 percent confidence intervals

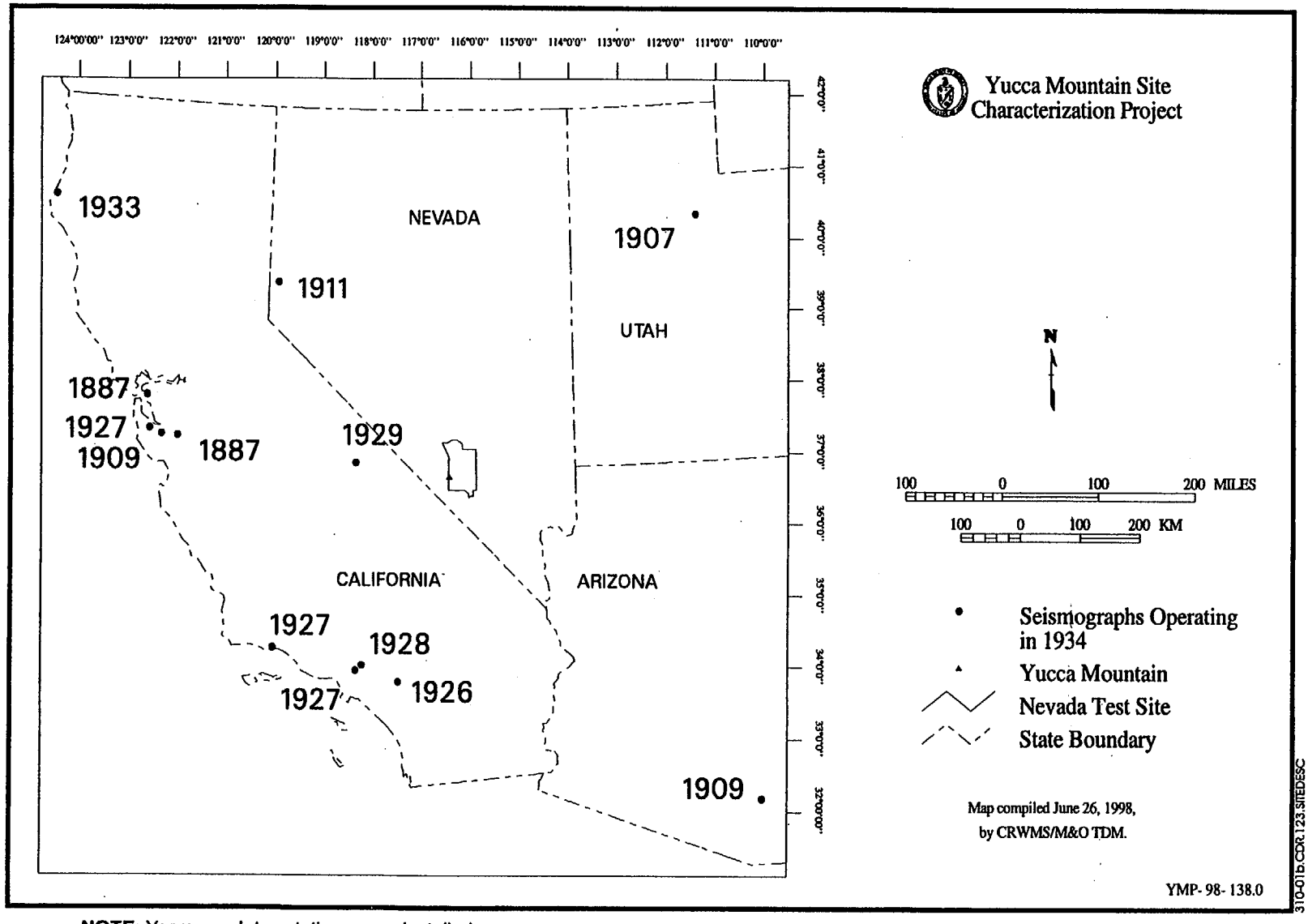
Figure 3.9-9. Aggregate Results for Frequency of Intersection of the Potential Yucca Mountain Repository (CRWMS M&O 1996h)

INTENTIONALLY LEFT BLANK



NOTE: Years are dates stations were installed. The outlines of the NTS and Yucca Mountain site are also shown.

Figure 3.10-1a. Seismograph Stations Operating in the Western United States in 1925



NOTE: Years are dates stations were installed.

Figure 3.10-1b. Seismograph Stations Operating in the Western United States in 1934

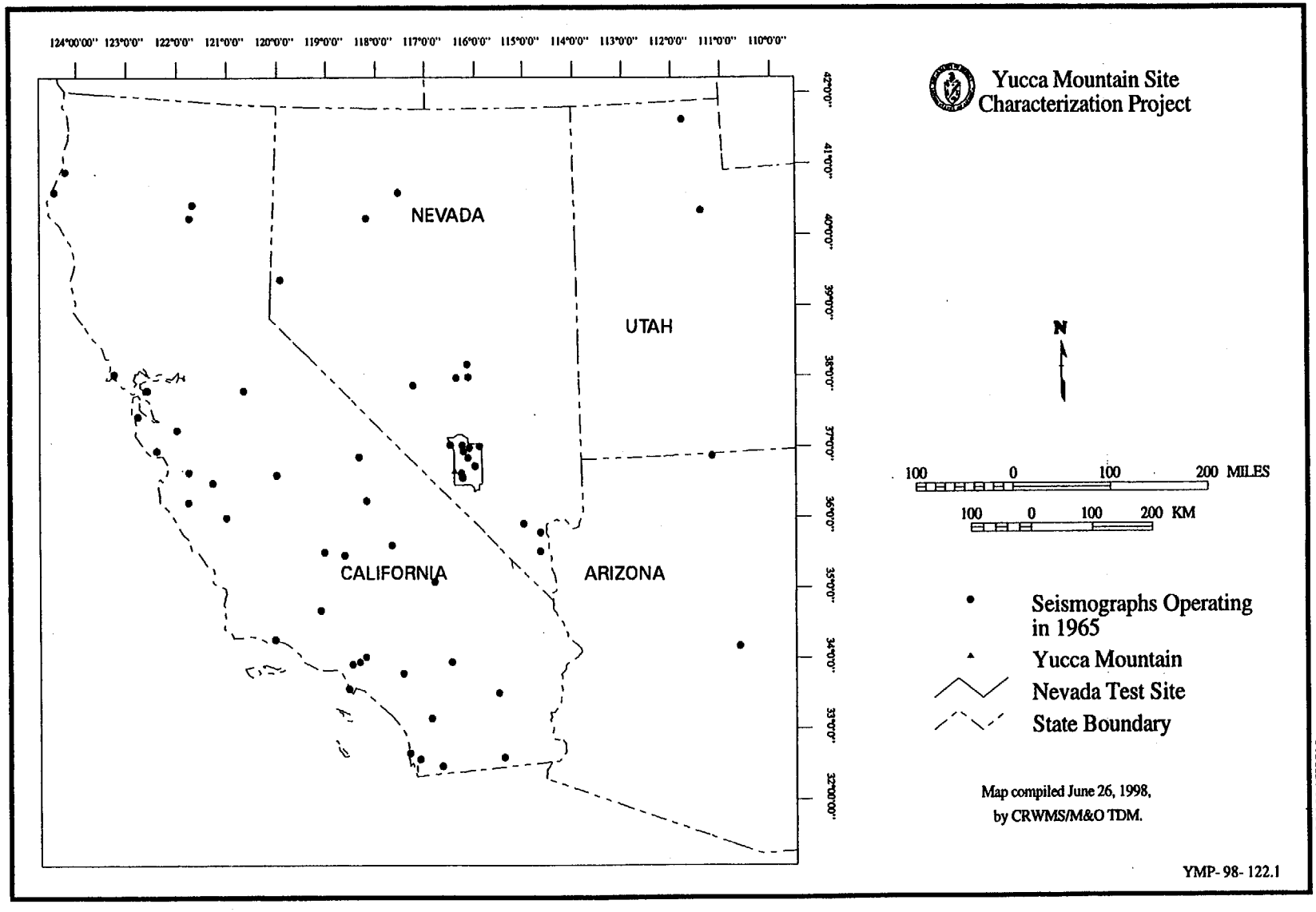


Figure 3.10-1c. Seismograph Stations Operating in the Western United States in 1965

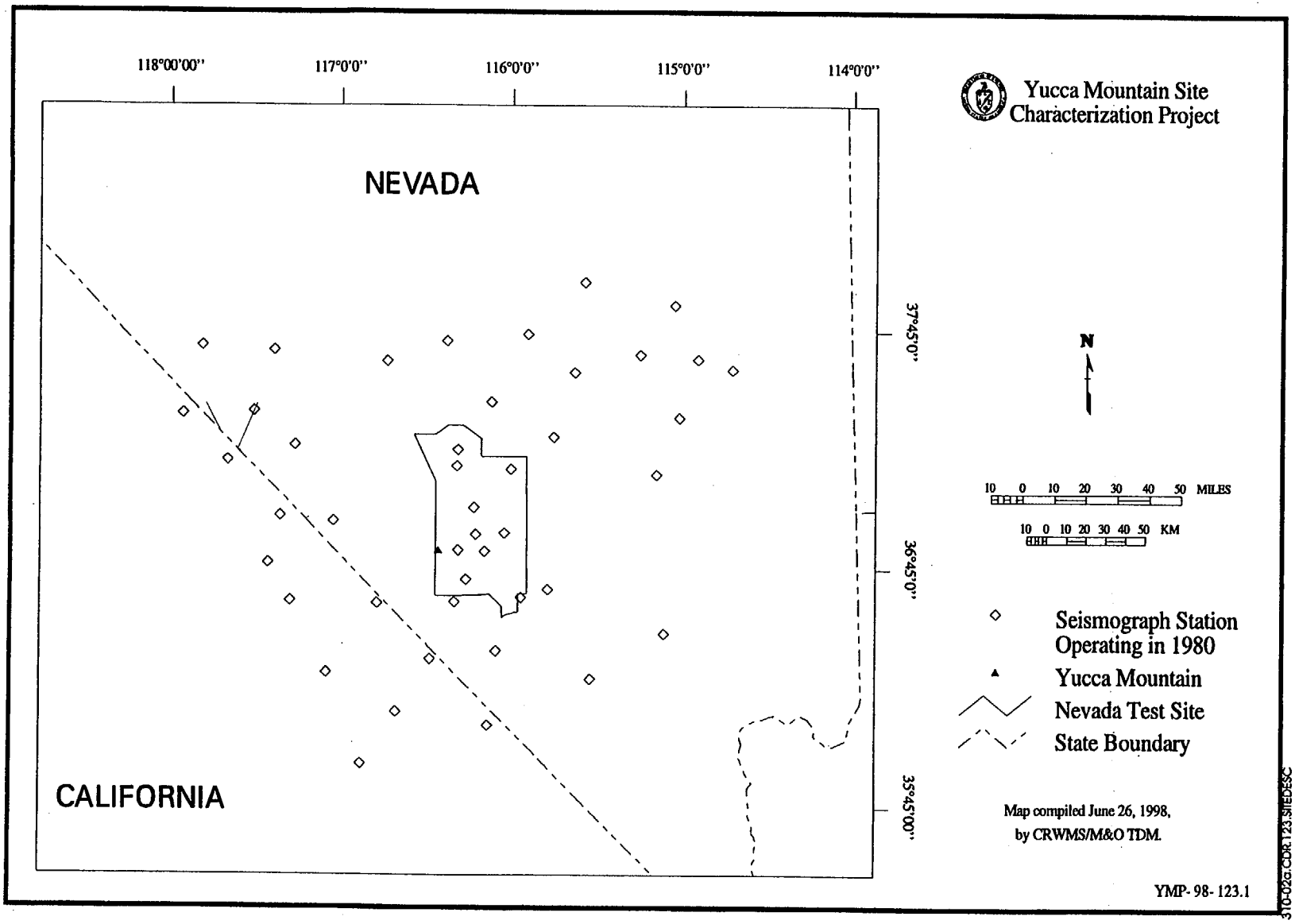


Figure 3.10-2a. Seismograph Stations Operating in the Southern Great Basin in 1980

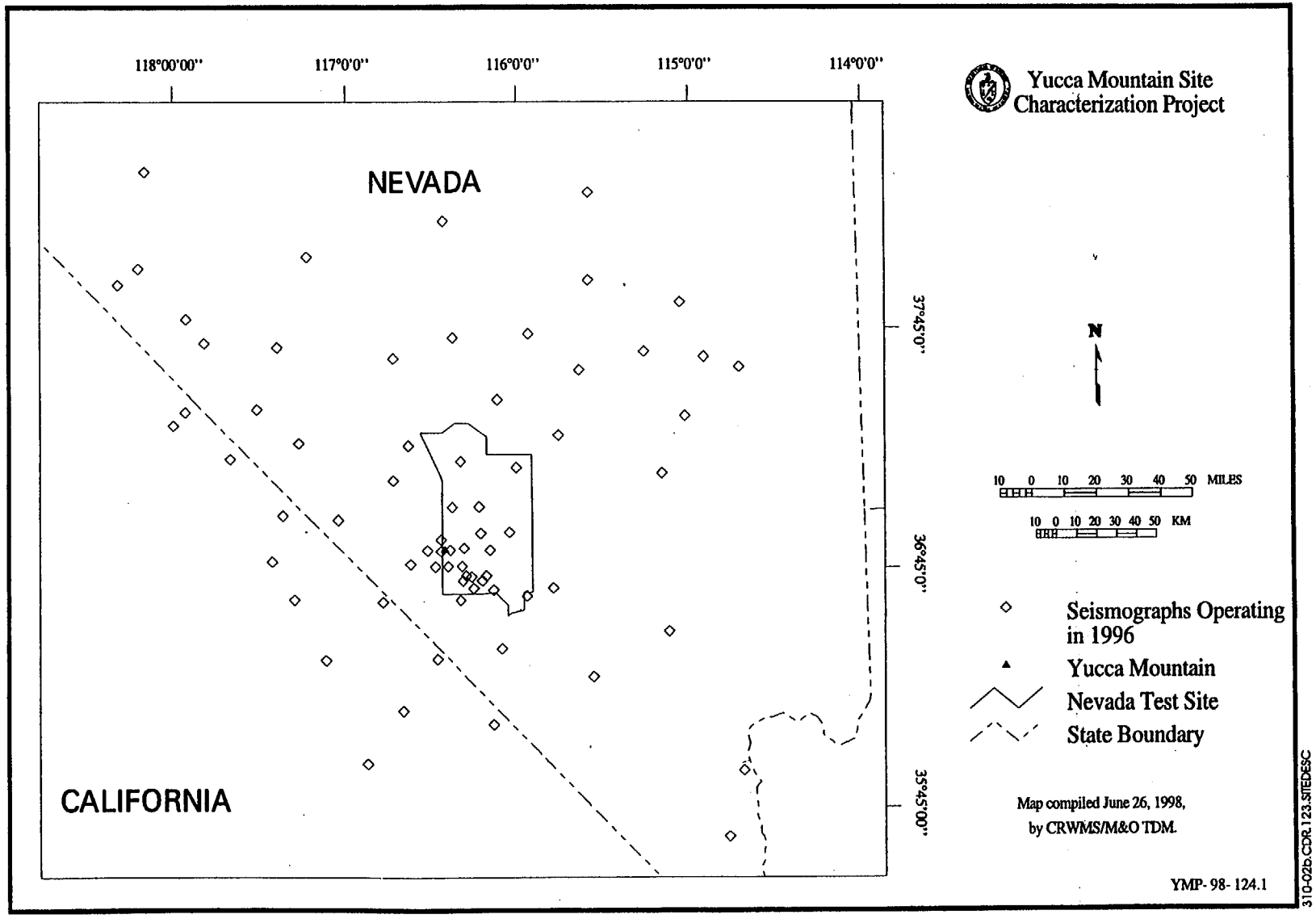
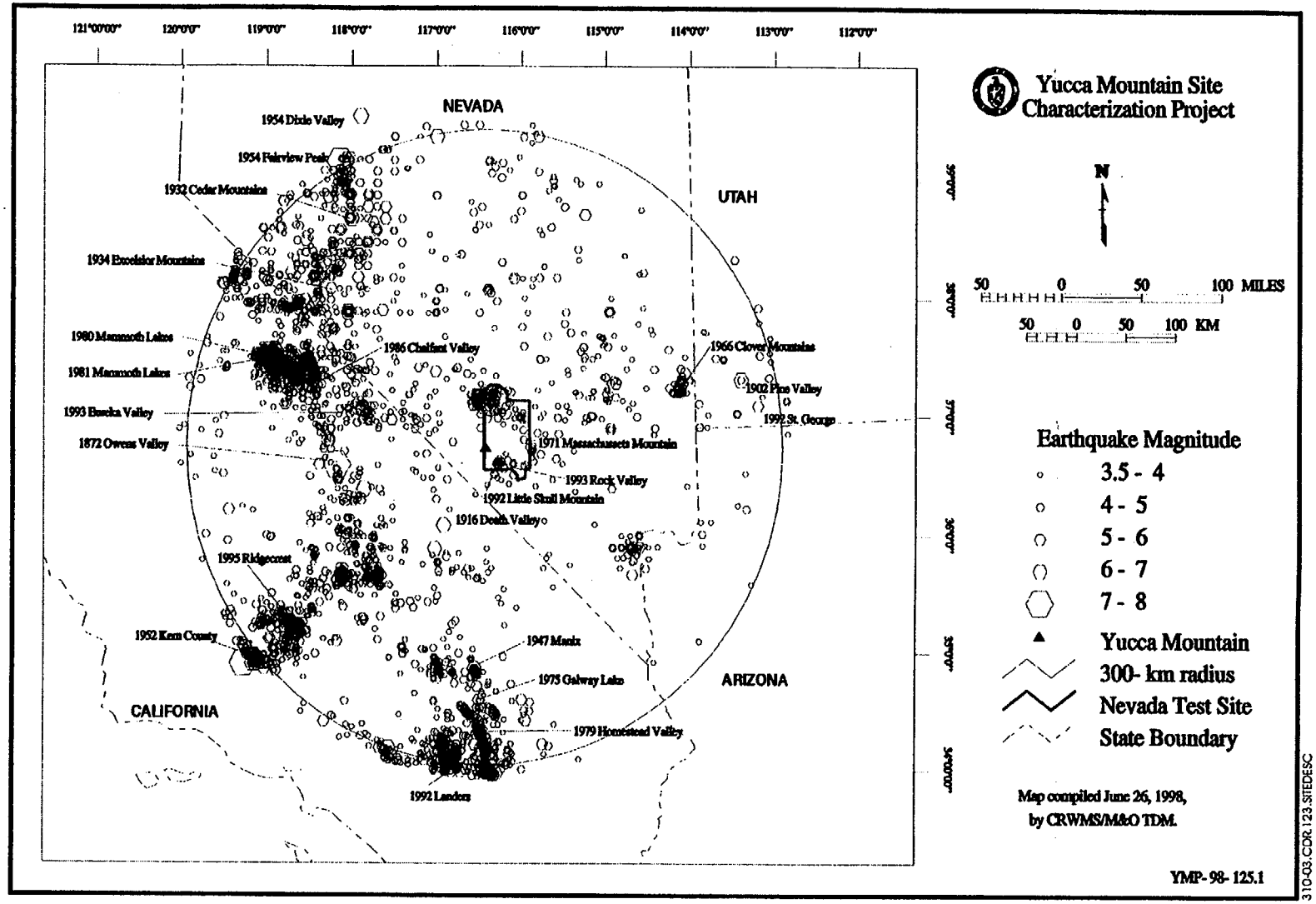
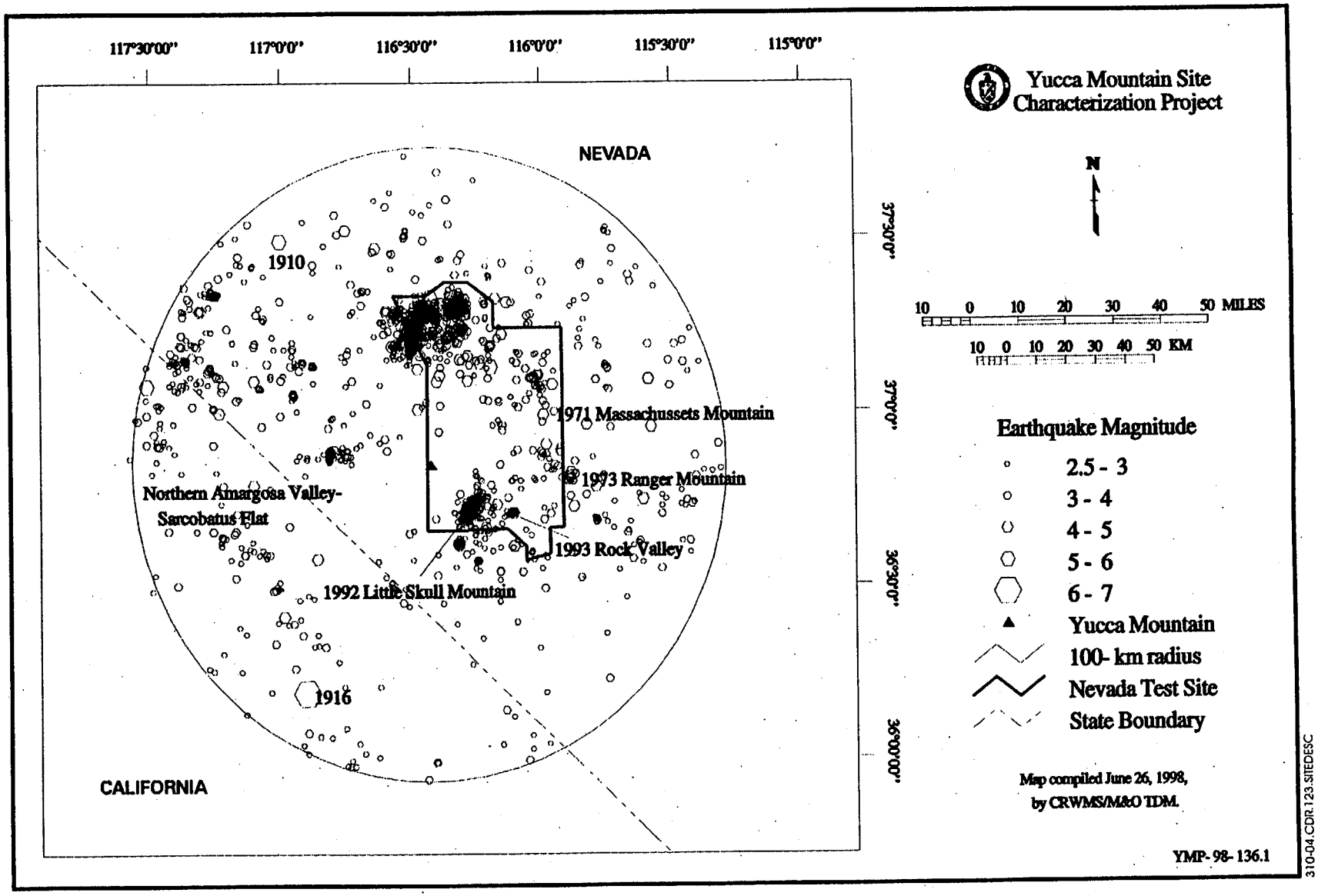


Figure 3.10-2b. Seismograph Stations Operating in the Southern Great Basin in 1996



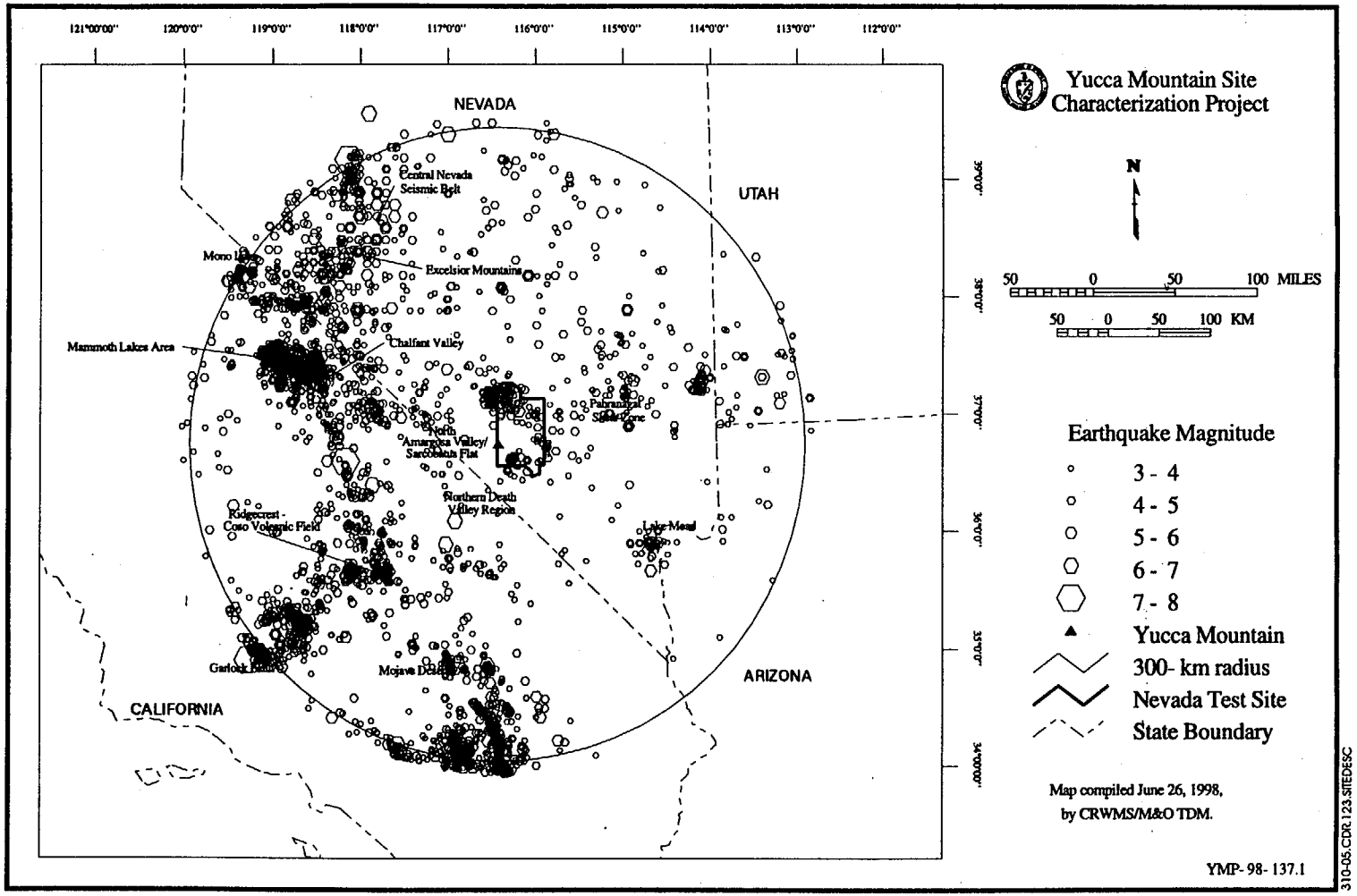
NOTE: Shown are earthquakes (1868 to 1996) M_W 3.5 or Modified Mercalli III or greater intensity in the Yucca Mountain region (note scaled symbols). The Yucca Mountain Site is marked with a triangle. The closed rectangular region outlines the boundaries of the Nevada Test Site. Significant earthquakes are shown with years of occurrence.

Figure 3.10-3. Historical Earthquake Epicenters within 300 Kilometers of Yucca Mountain



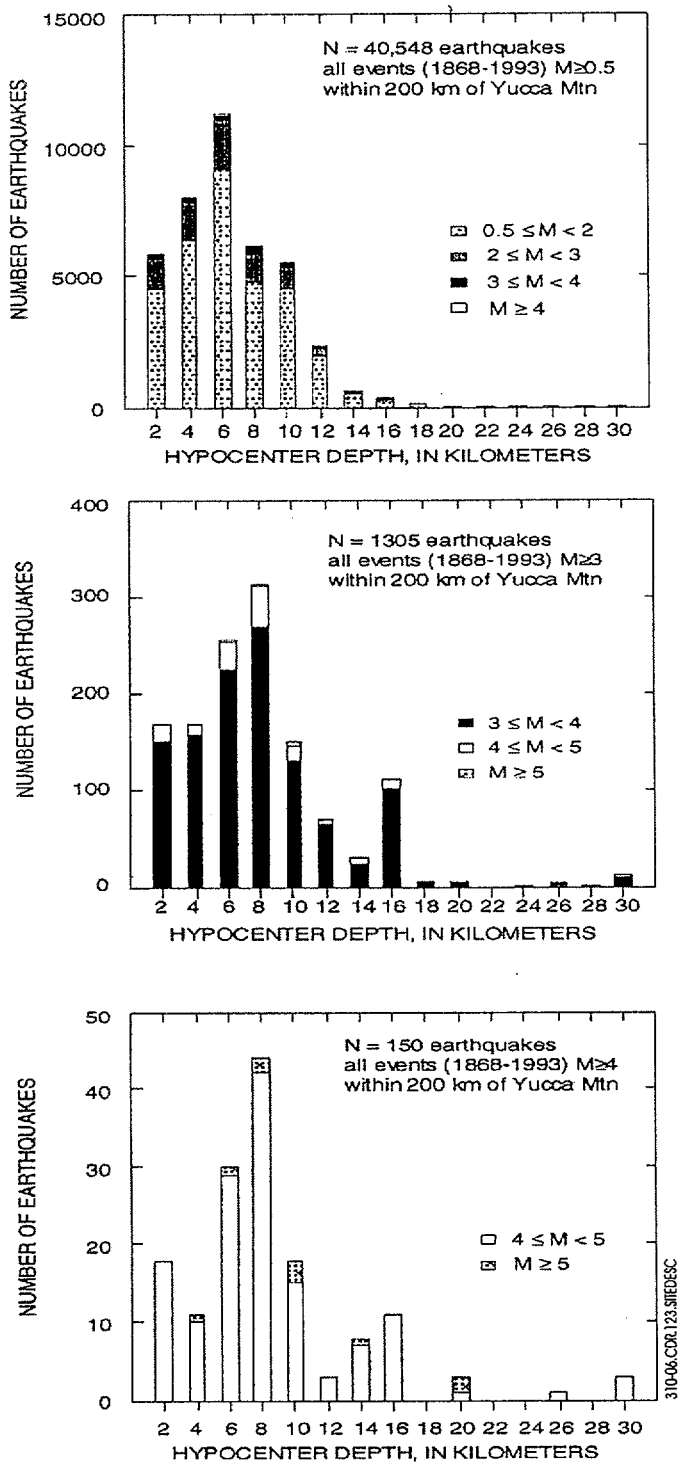
NOTE: Shown are earthquakes (1904-1996) of Mw 2.5 or greater. (Note scaled symbols).
Significant earthquakes or earthquake sequences are shown with years of occurrence.

Figure 3.10-4. Historical Seismicity Within 100 km of Yucca Mountain



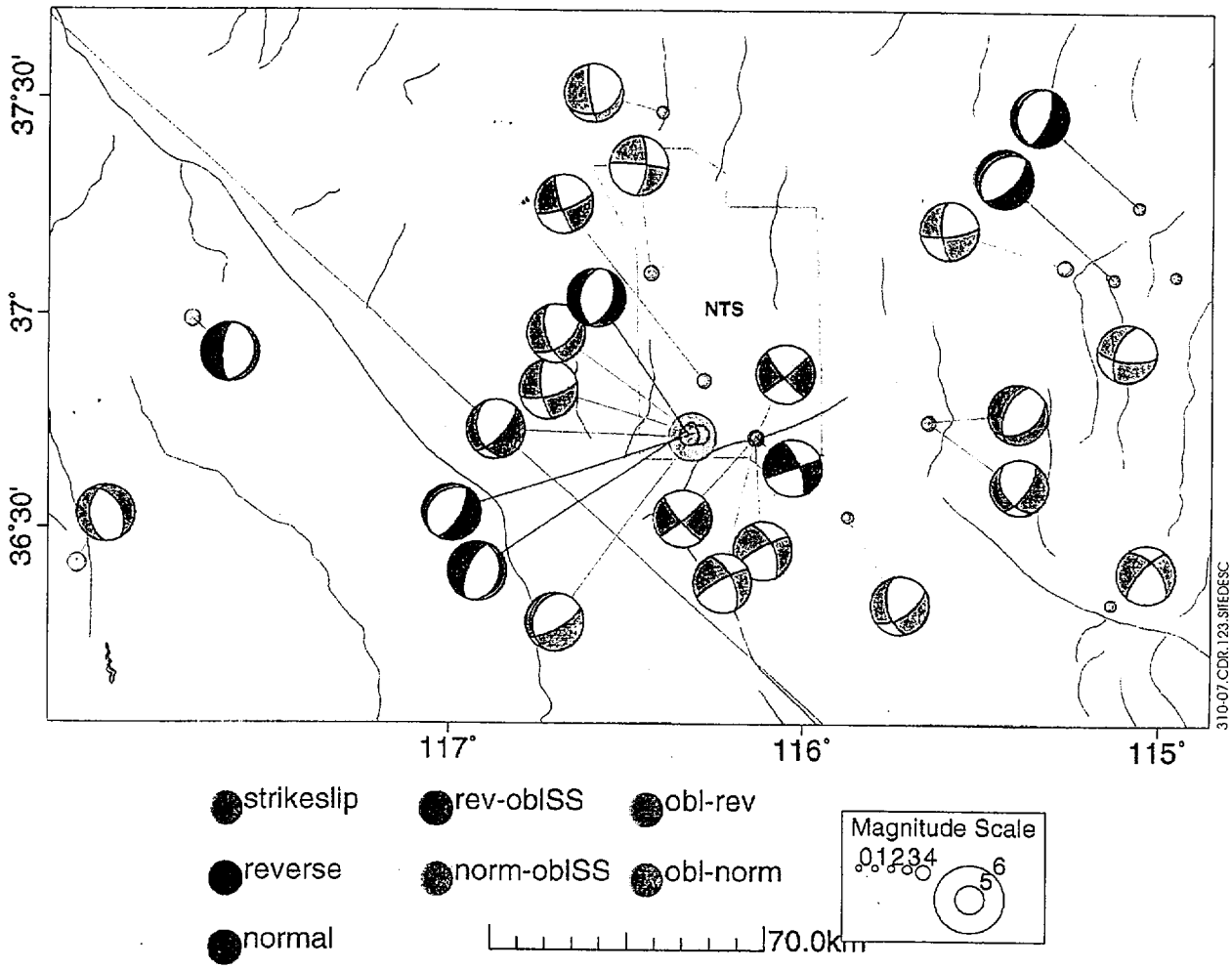
NOTE: Shown are earthquakes (1868-1996) of M_w 3.5 or Modified Mercalli III or greater intensity in the Yucca Mountain region (note scaled symbols).

Figrure 3.10-5. Regions of Seismicity within 300 km of Yucca Mountain



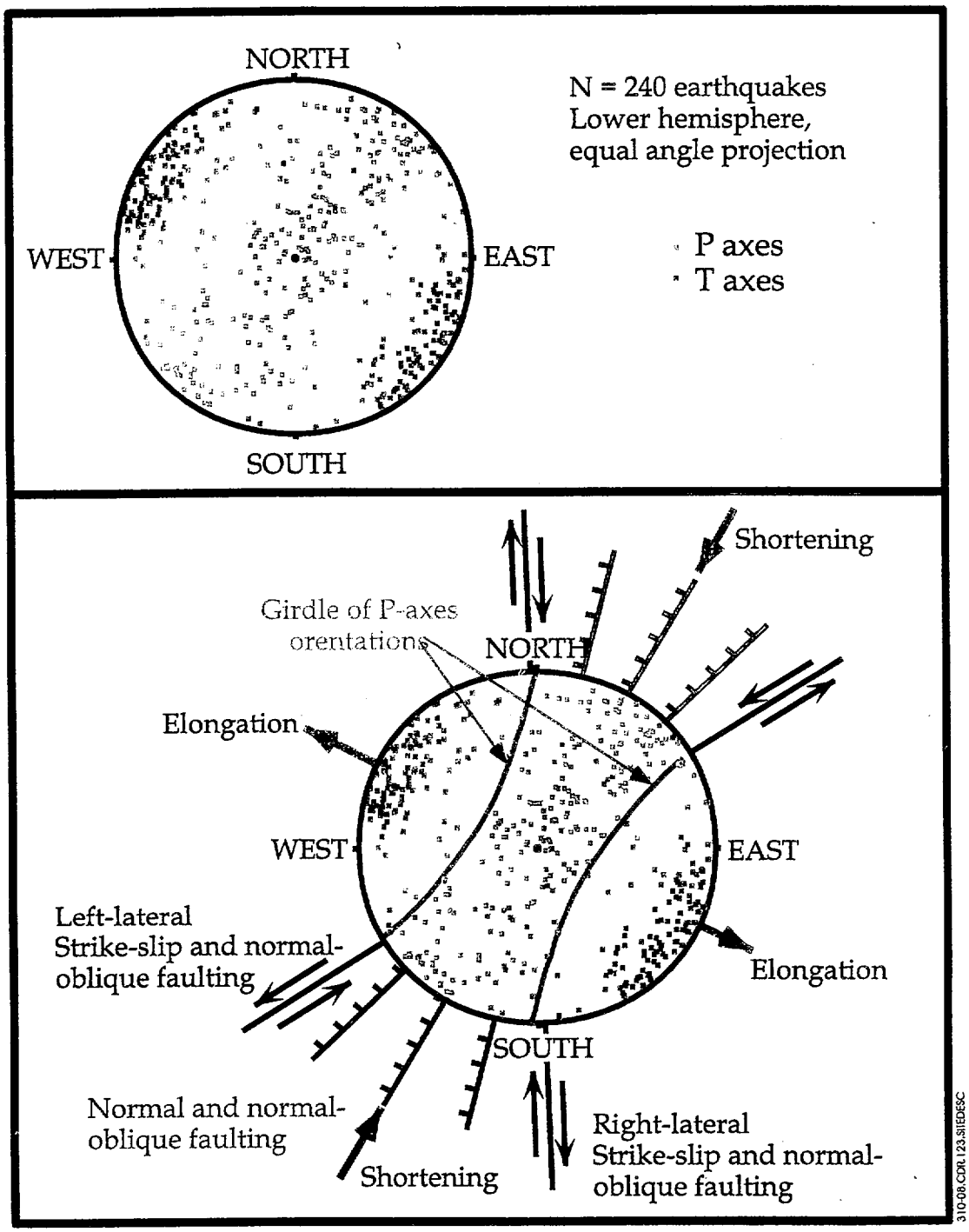
NOTE: Top graph: Earthquakes with M≥0.5; Center graph: Earthquakes M≥3.0; Bottom graph: Earthquakes M≥4.0.

Figure 3.10-6. Focal Depth Distribution of Earthquakes (1868-1993) Within 200 km of Yucca Mountain (from Pezzopane, Bufe et al. 1996)



NOTE: Data from K. Smith, University of Nevada, Reno (written communication to I. Wong, WCFS, 1998). Colors correspond to style of faulting: norm=normal slip, obl=oblique slip, rev=reverse slip, and SS=strike-slip.

Figure 3.10-7. Focal Mechanisms for Earthquakes of M_L>3,5 in the Vicinity of Yucca Mountain from 1987 to 1997



NOTE: Lower hemisphere equal angle projection of the principal stress axes. Upper plot shows the data, and the lower plot shows the inferred orientations of faulting consistent with the stress orientations. Maximum relative compression (P-) axes form a girdle from vertical to northeast-southwest orientations, whereas extensional (minimum relative compression) (T-) axes trend northwest-southeast. Focal mechanism data and figure are from Pezzopane, Bufe et al. (1996)

Figure 3.10-8. Principal Stress Axes from Focal Mechanisms of Southern Great Basin Earthquakes

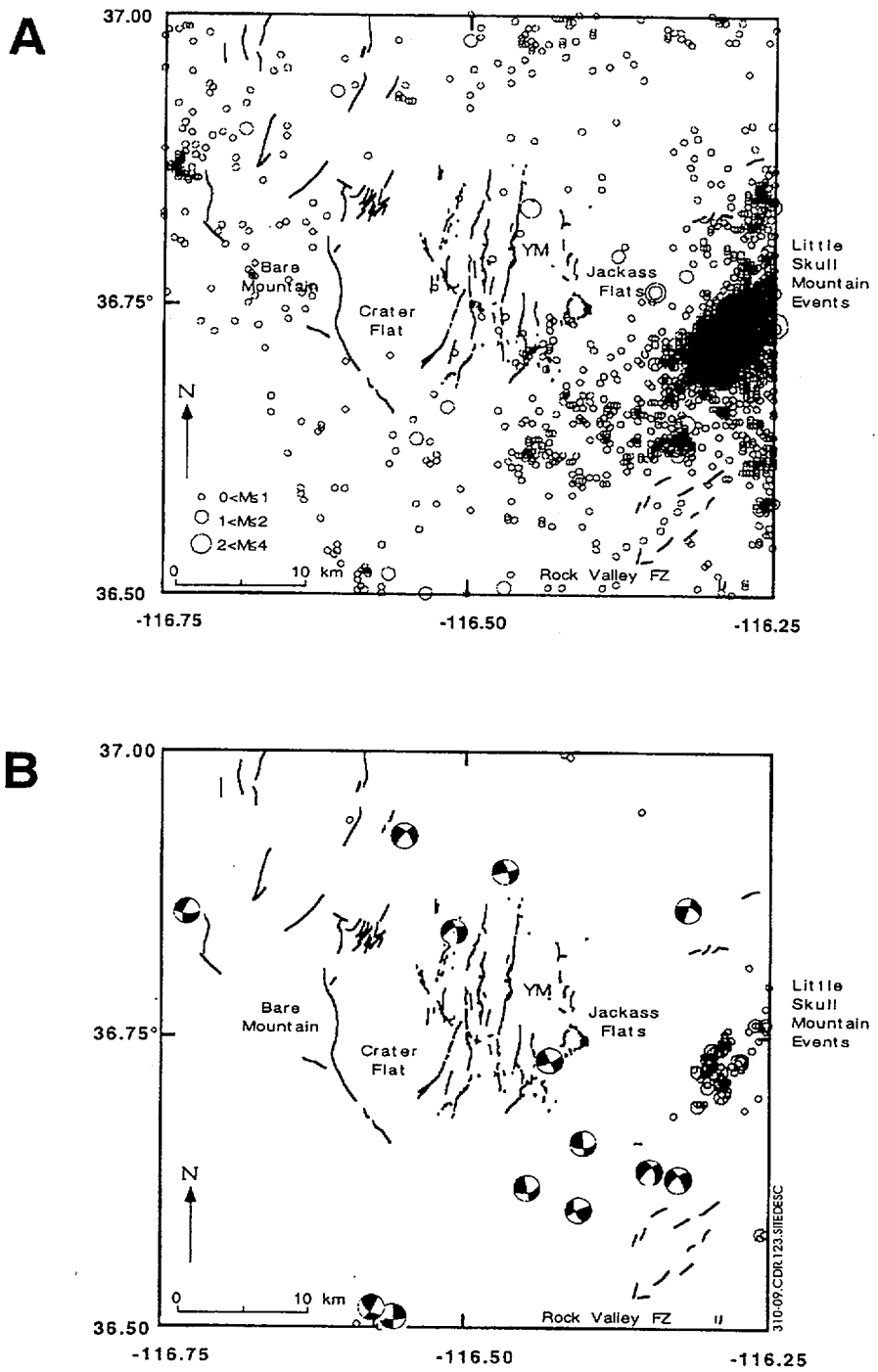
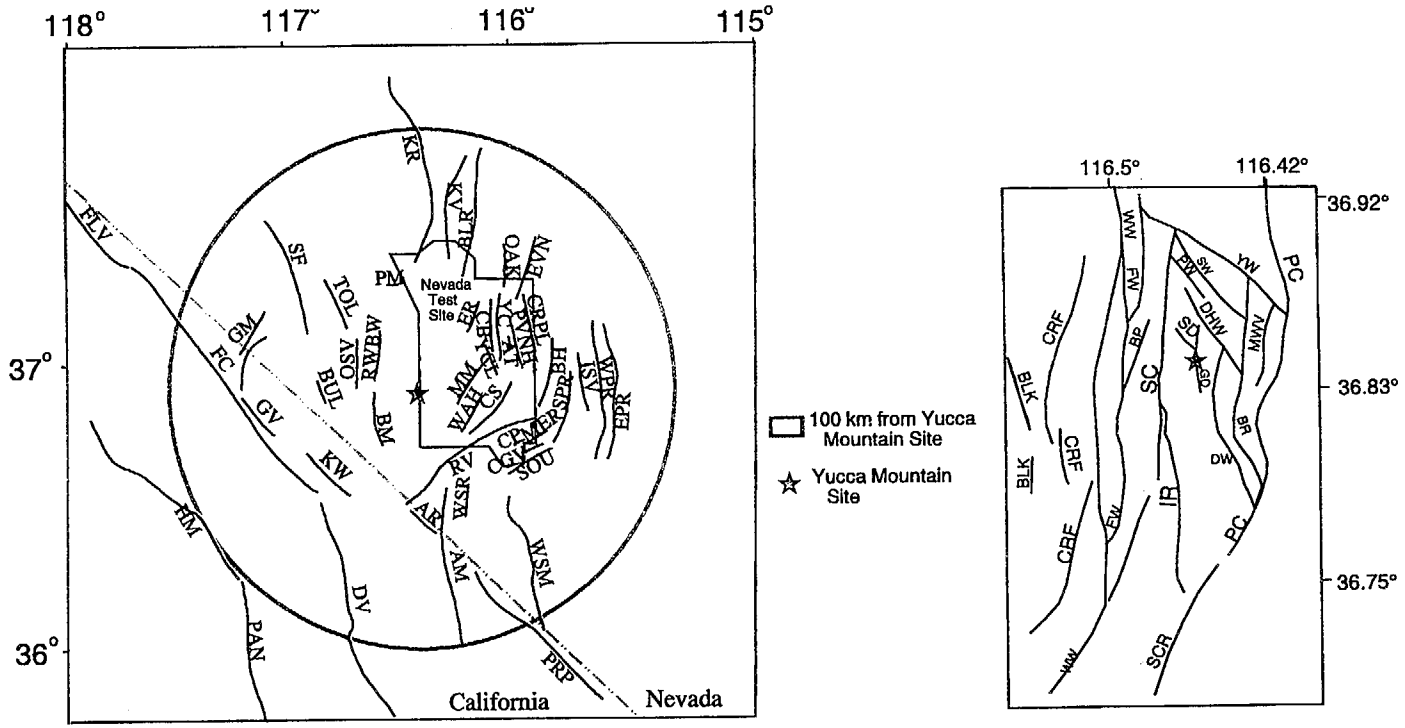


Figure 3.10-9. Epicenters and Focal Mechanisms of Earthquakes and Known or Suspected Quaternary Faults Near Yucca Mountain (from Pezzopane, Bufe et al. 1996)



AM Ash Meadows
AR Amargosa River
AT Area Three
BM Bare Mountain
BLR Belted Range
BUL Bullfrog Hills
BH Buried Hills
CFM Cactus Flat-Mellan
CB Carpetbag
CS Cane Spring
CHV Chicago Valley
CP Checkpoint Pass
CHR Chert Ridge
CRPL Cockeyed Ridge-Papoose Lake
CGV Crossgrain Valley
DV Death Valley
EPR East Pintwater Range
ER Eleana Range
EVN Emigrant Valley North
EVS Emigrant Valley South
FC Furnace Creek
FH Fallout Hills
GV Grapevine
GM Grapevine Mountains
HM Hunter Mountain
ISV Indian Springs Valley
KR Kawich Range
KV Kawich Valley
KW Keene Wonder
MER Mercury Ridge
MM Mine Mountain
OAK Oak Springs Butte
OSV Oasis Valley
PAN Panamint Valley
PRP Pahrump
PM Pahute Mesa
PVNH Plutonium Valley-North Hallfpint Ridge
RM Ranger Mountain
RV Rock Valley
RWBW Rocker Wash-Beatty Wash
SF Sacrobatus Flat
SOU South Ridge
SPR Spotted Range
TOL Tolicha Peak
WAH Wahmonie
WPR West Pintwater Range
WSR West Specter Range
WSM West Springs Mountain
YC Yucca
YCL Yucca Lake
BLK Black Cone
BP Boomerang Point
BR Bow Ridge
CRF Crater Flat
DHW Drill Hole Wash
DW Dune Wash
FW Fatigue Wash
GD Ghost Dance
IR Iron Ridge
MWV Midway Valley
PW Pagany Wash
SW Sever Wash
SC Solitario Canyon
SCR Stagecoach Road
SD Sundance
WW Windy Wash
YW Yucca Wash

Yucca Mountain Site Characterization Project

FAULTS WITHIN 100 km OF YUCCA MOUNTAIN

YMP-98-143.0

310-10.CDR.123.SITEDESC

Figure 3.10-10. Known or Suspected Quaternary Faults and Significant Local Faults Within 100 km of Yucca Mountain

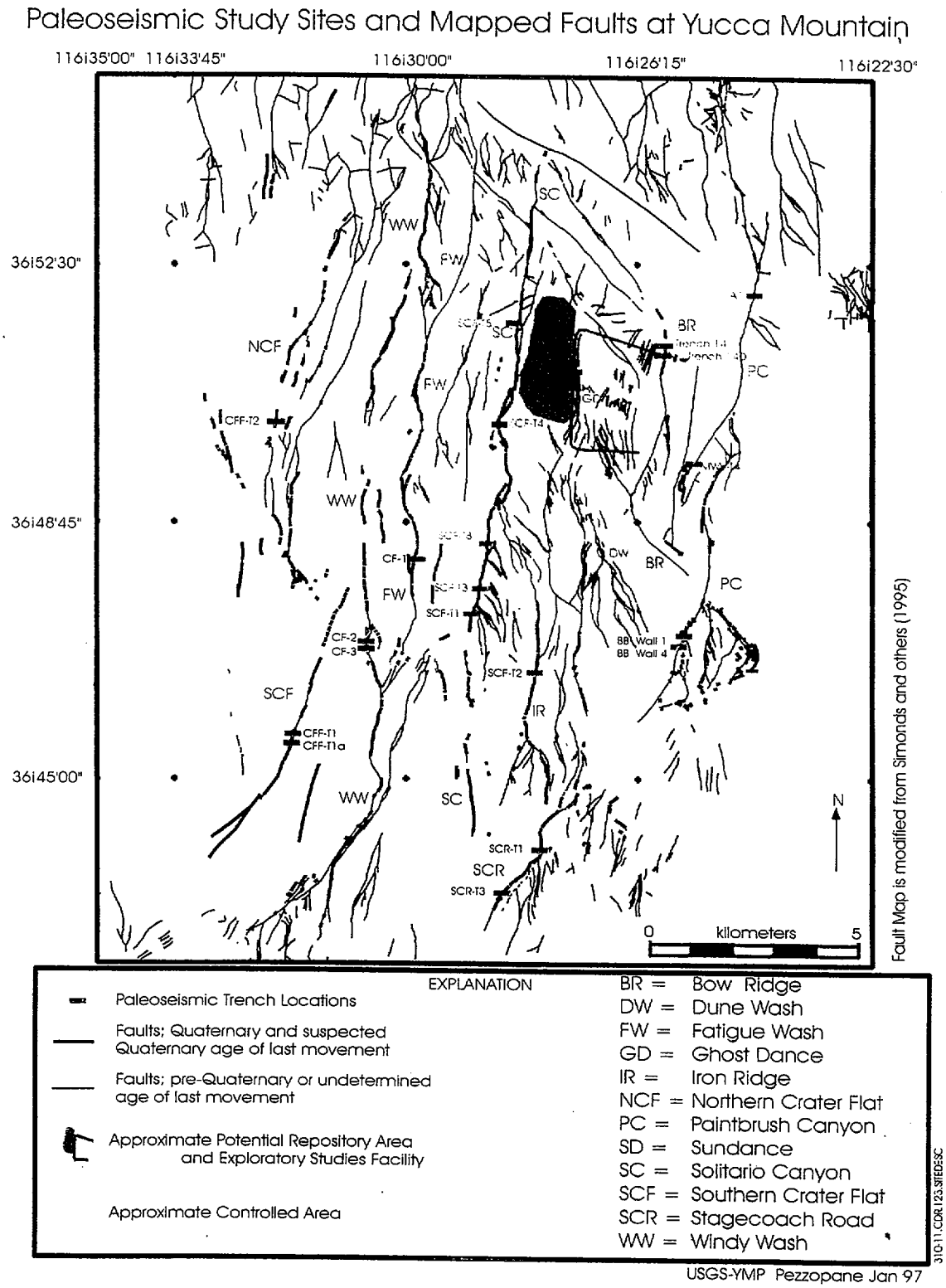
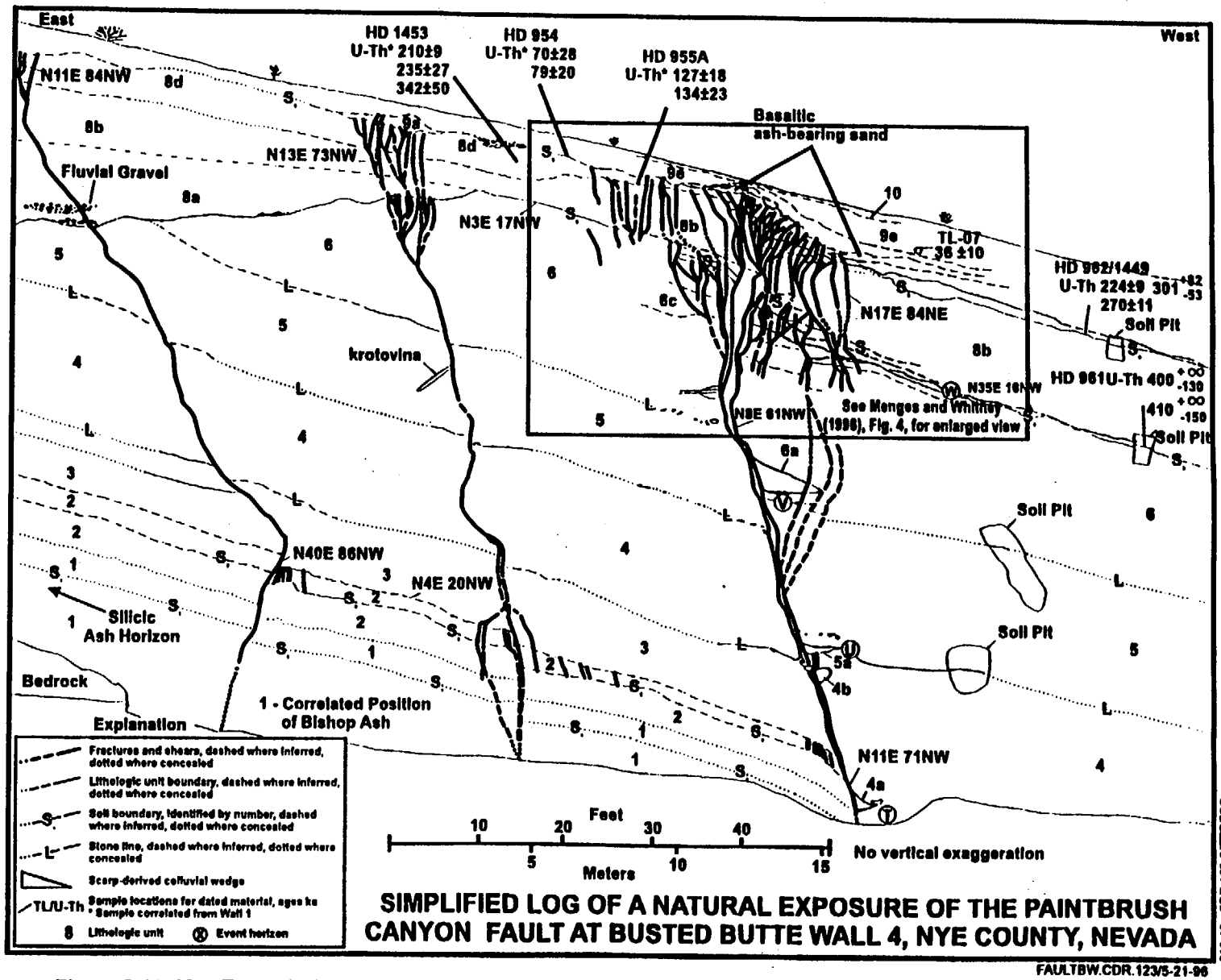


Figure 3.10-11. Location Map of Local Faults and Paleoseismic Study Sites at Yucca Mountain (from Pezzopane, Whitney et al. 1996)



SIMPLIFIED LOG OF A NATURAL EXPOSURE OF THE PAINTBRUSH CANYON FAULT AT BUSTED BUTTE WALL 4, NYE COUNTY, NEVADA

Figure 3.10-12a. Example Trench Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Paintbrush Canyon Fault at Busted Butte (from Menges and Whitney 1996b)

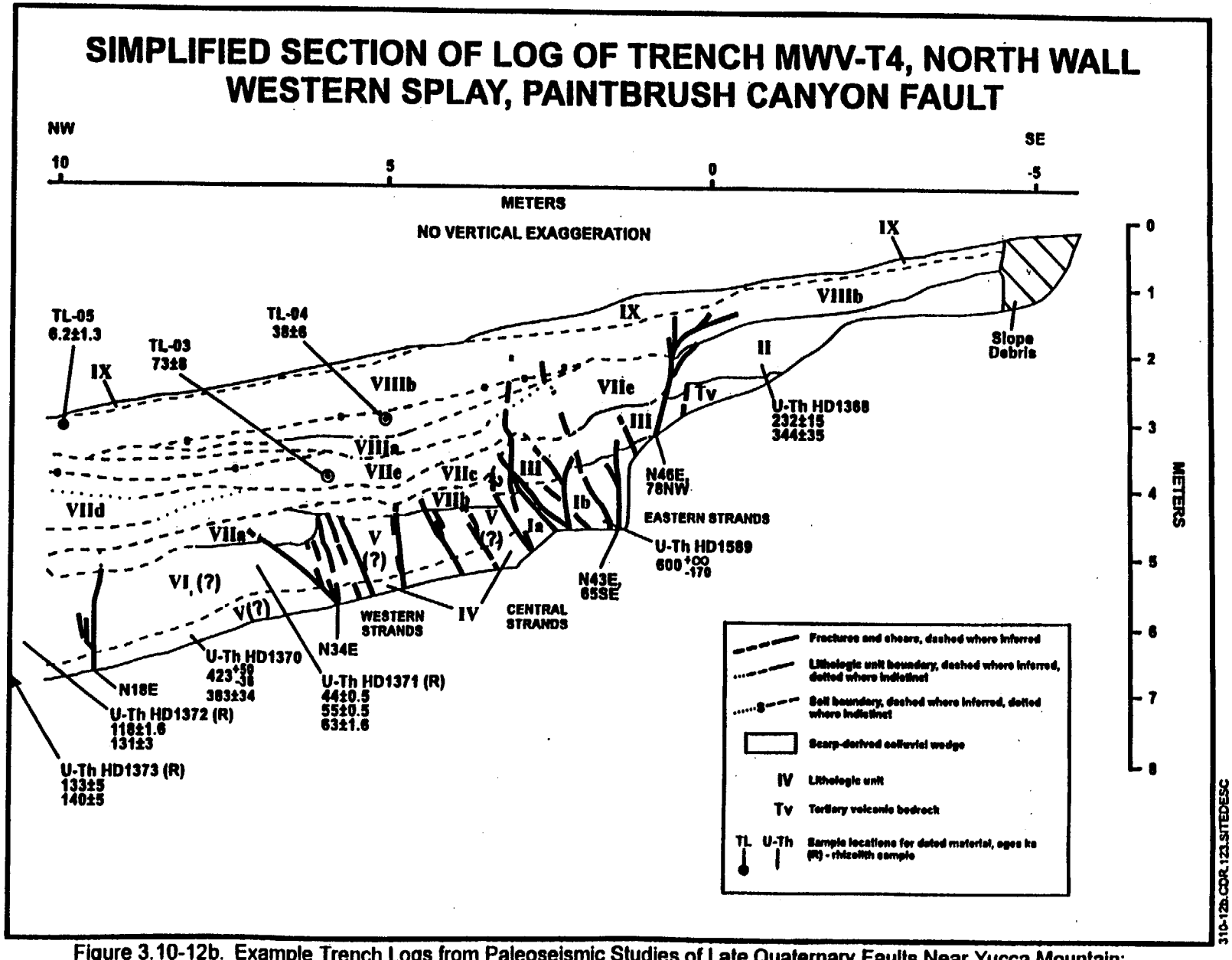


Figure 3.10-12b. Example Trench Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Paintbrush Canyon Fault, Western Splay

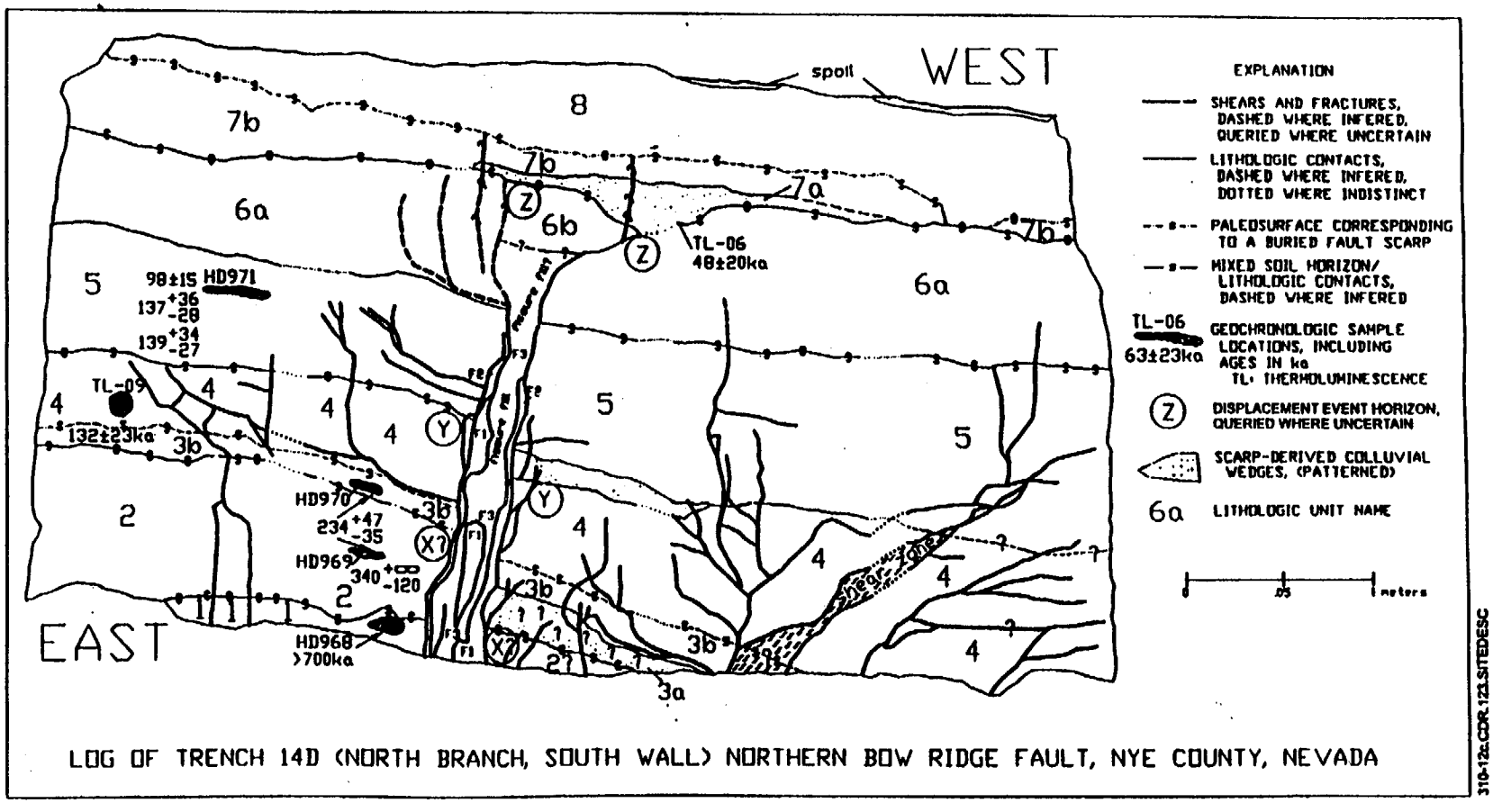


Figure 3.10-12c. Example Trench Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Bow Ridge Fault

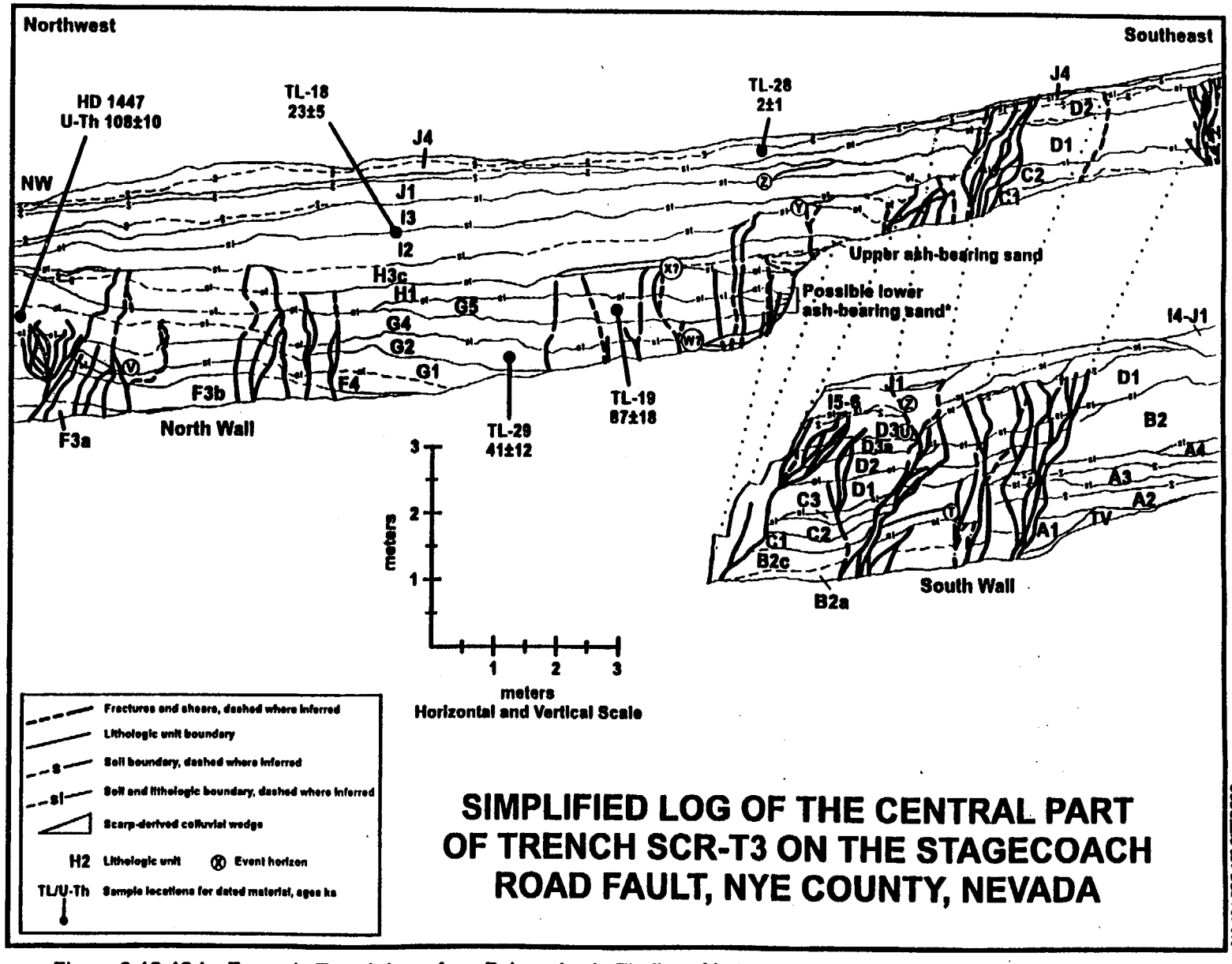
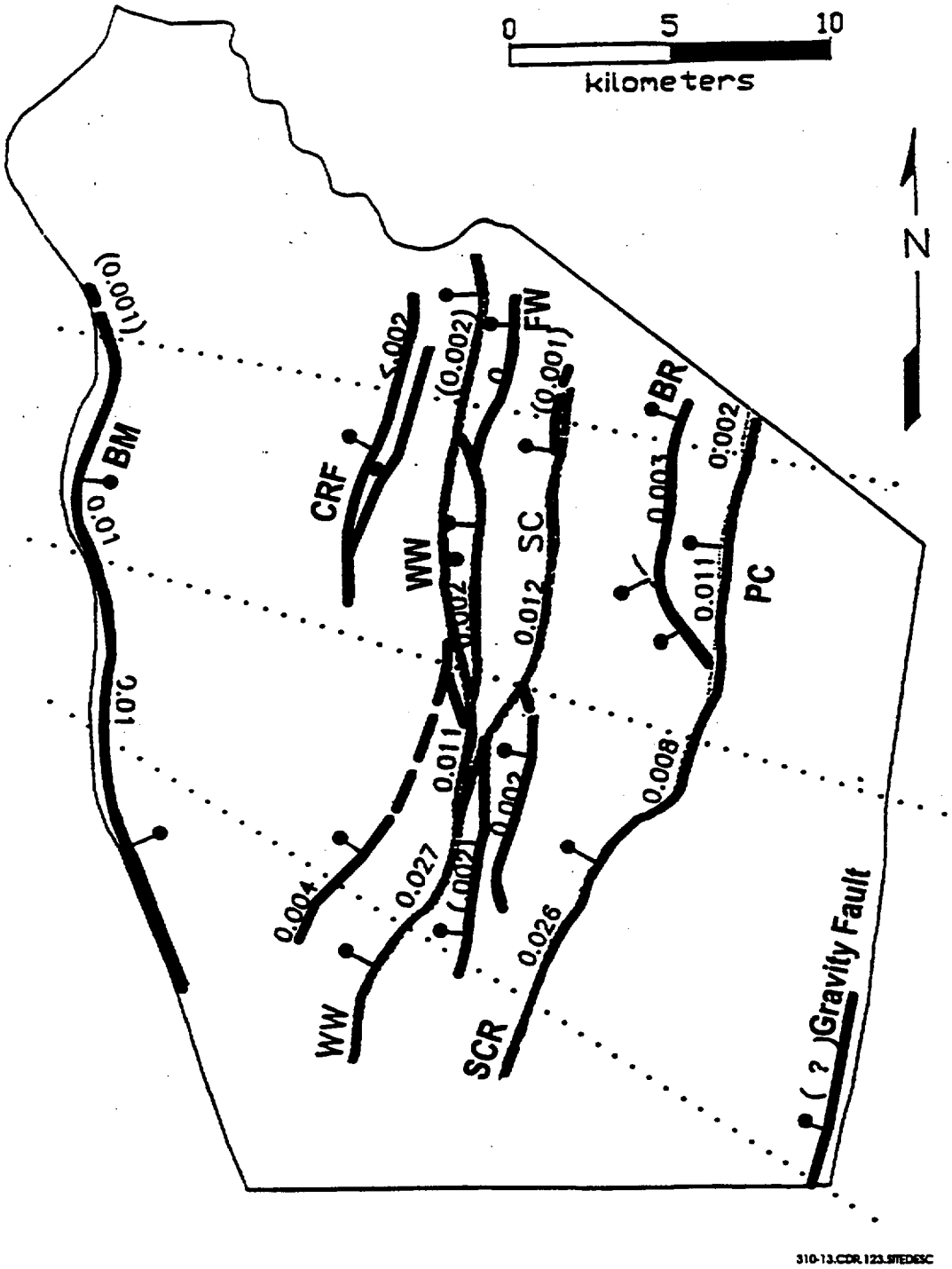


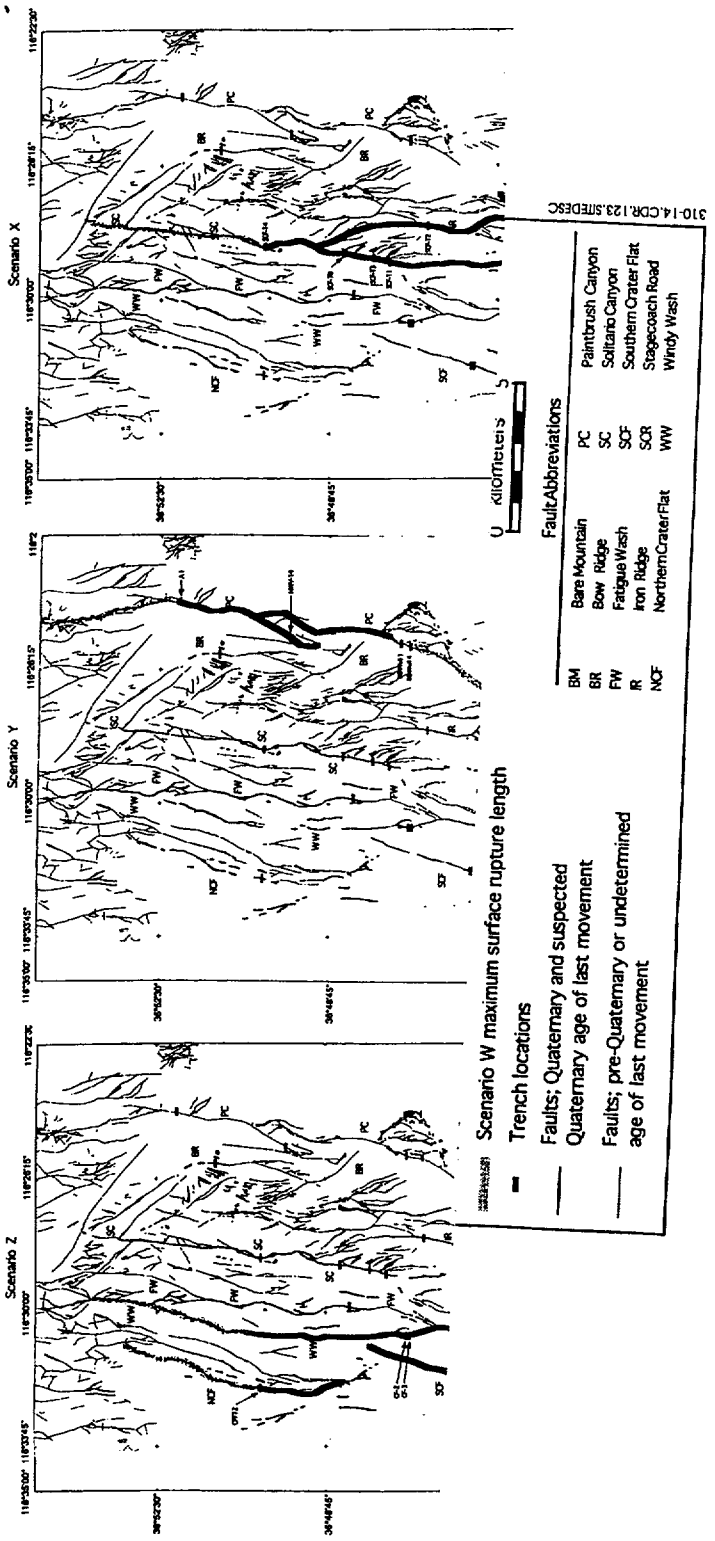
Figure 3.10-12d. Example Trench Logs from Paleoseismic Studies of Late Quaternary Faults Near Yucca Mountain; Stagecoach Road Fault



NOTE: Slip rates are in mm per year. Values in parentheses are inferred. Fault abbreviations from Figure 3.10-10.

Figure 3.10-13. Map of Slip Rates of Late Quaternary Faults Near Yucca Mountain (adapted from Fridrich, Whitney et al. 1996)

INTENTIONALLY LEFT BLANK



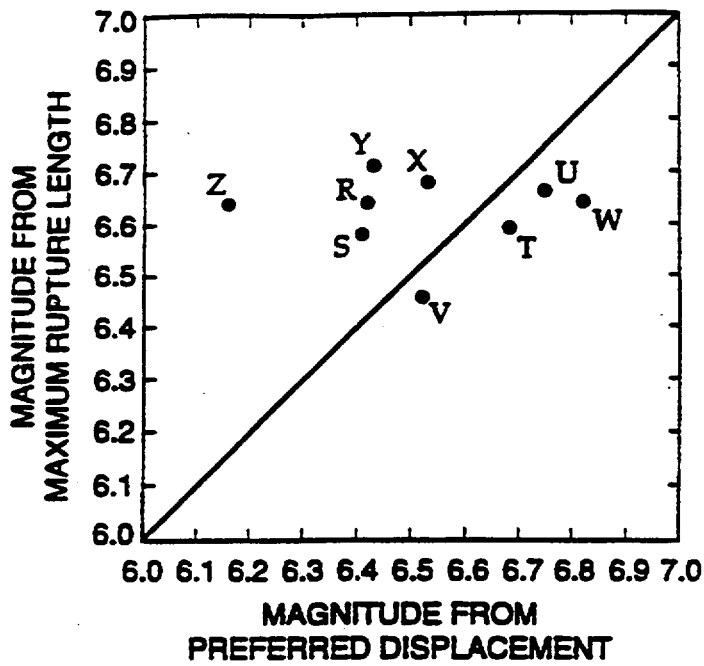
NOTE: Bold lines indicate possible extent of paleoearthquake surface rupture scenarios.

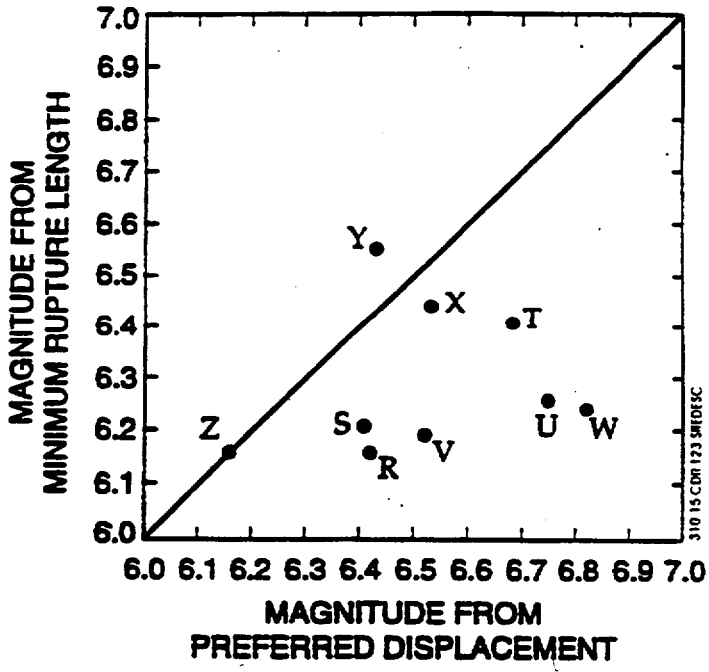
APERTURE CARD
Also Available on Aperture Card

Figure 3.10-14. Displacement Scenarios for Nine Possible Prehistoric Earthquakes in the Past 150 Kyr at Yucca Mountain (from Pezzopane, Whitney et al. 1996)

9902040045 - 116

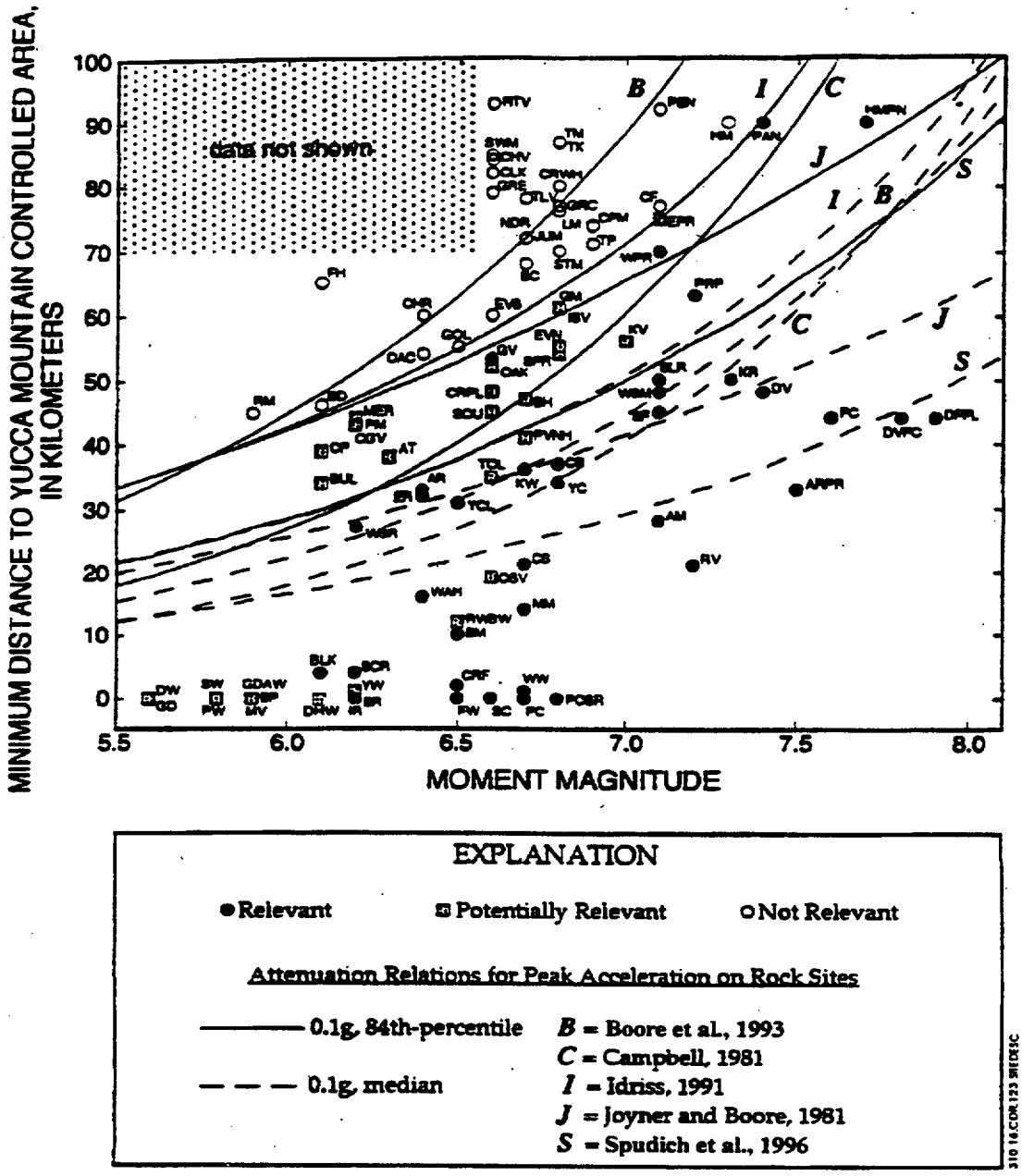
INTENTIONALLY LEFT BLANK





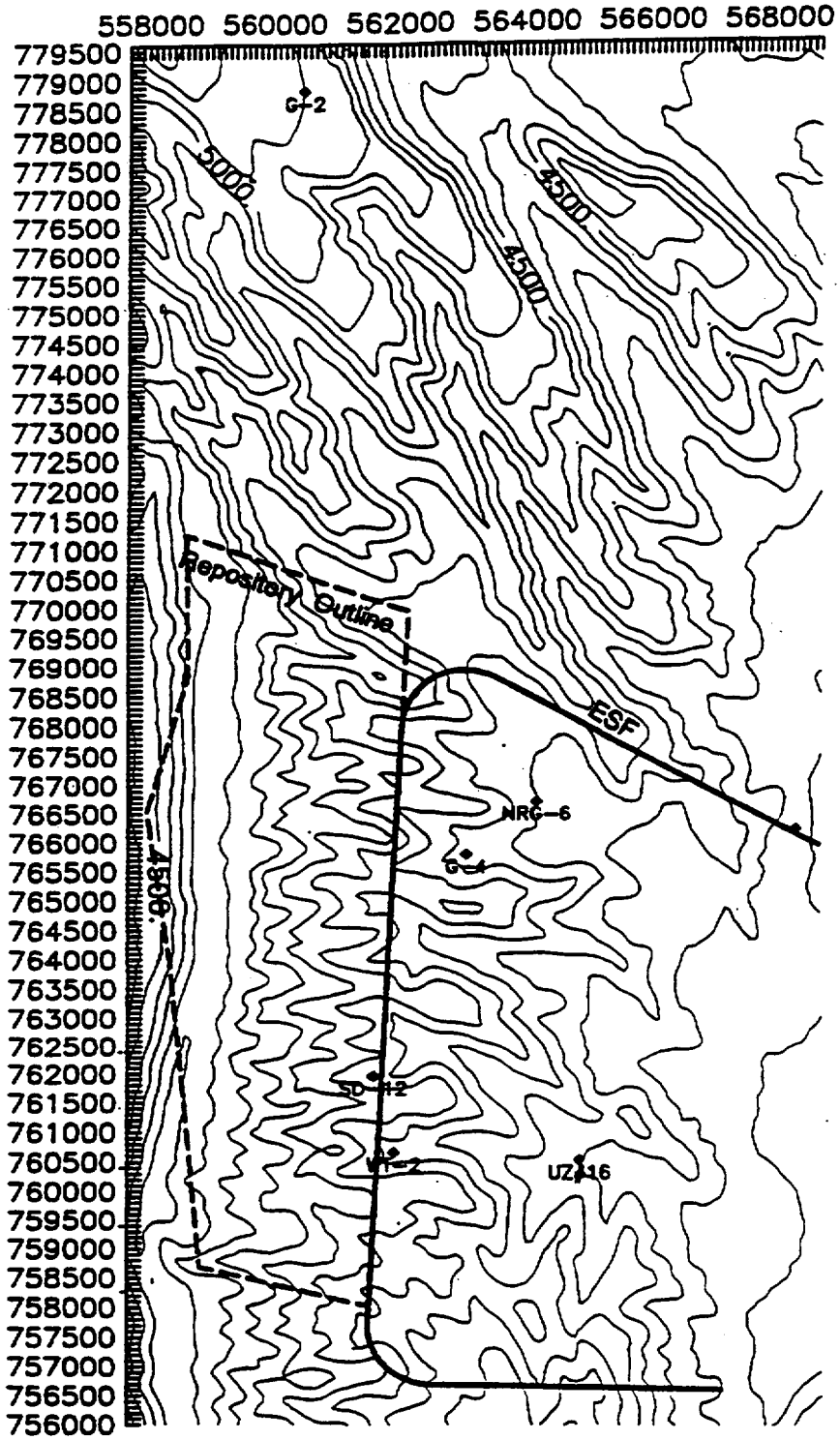
NOTE: Letters correspond to rupture scenarios.

Figure 3.10-15. Plots Comparing Magnitudes Calculated for Rupture Scenarios at Yucca Mountain (from Pezzopane, Whitney et al. 1996)



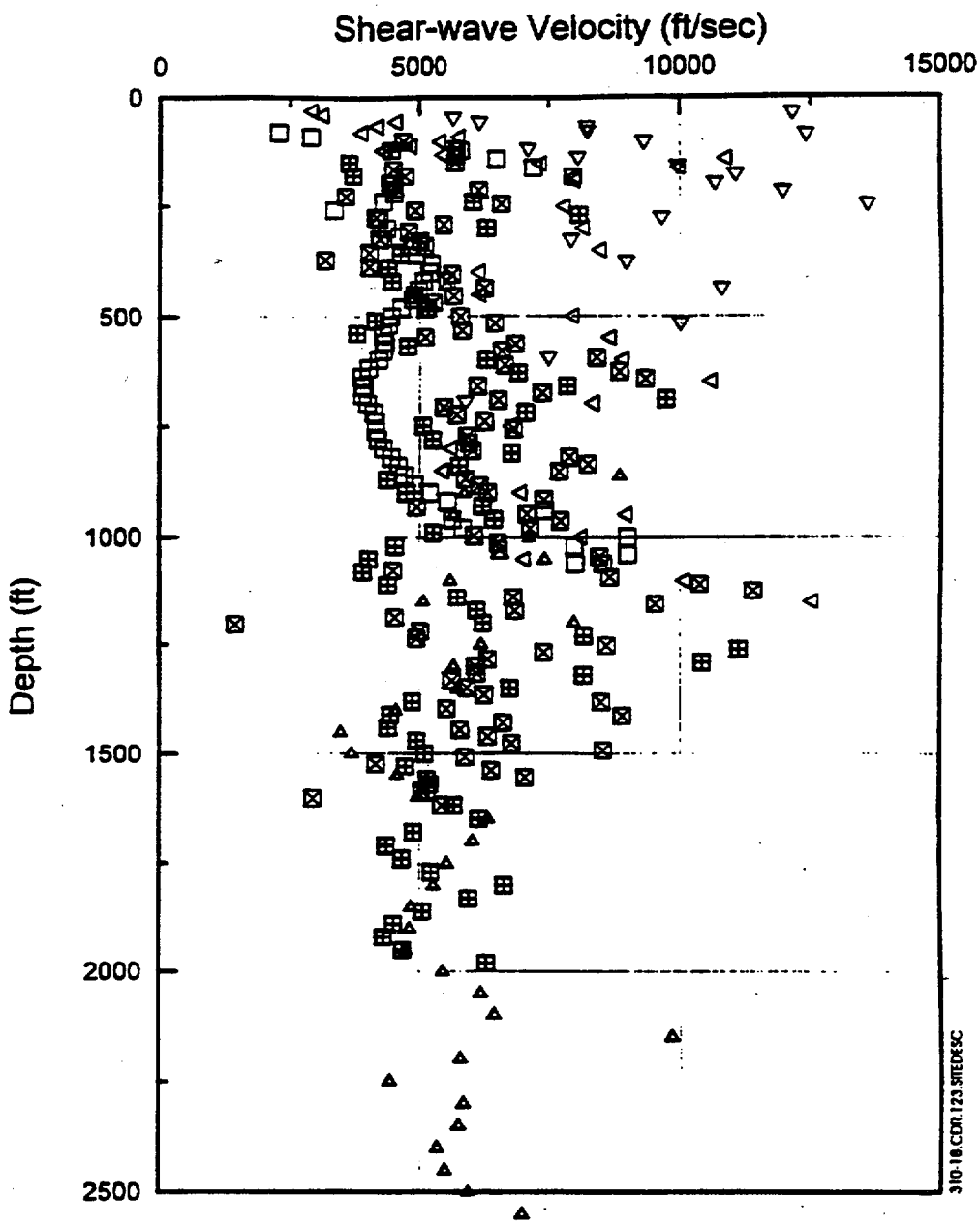
NOTE: Candidate seismic sources are plotted as a function of their closest distance to Yucca Mountain and their estimated maximum magnitude.

Figure 3.10-16. Assessment of Relevant and Potentially Relevant Earthquake Sources for the Yucca Mountain Region



NOTE: VSP data are shown on Figure 3.10-18. Scales are Nevada State Plan Coordinates (feet).

Figure 3.10-17. Locations Of Boreholes Where Vertical Seismic Profile Surveys Have Been Performed

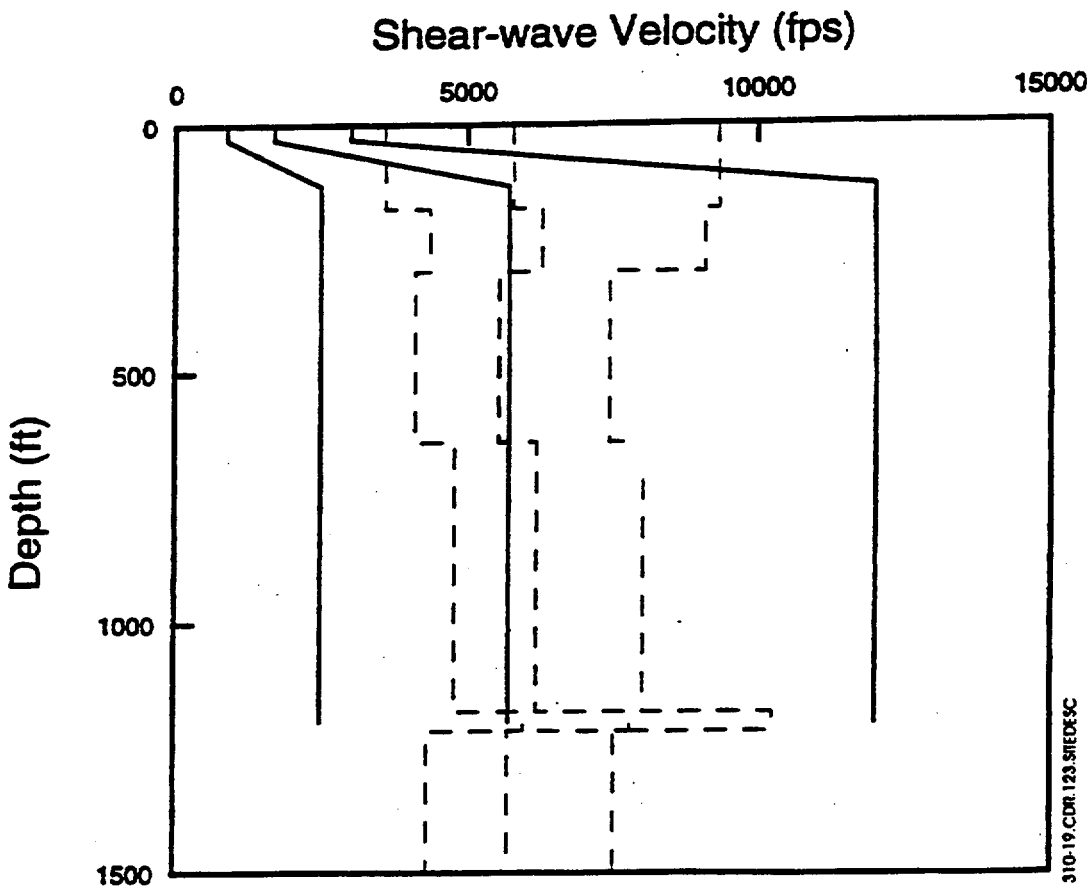


LEGEND

△ G2	□ NRG6	⊞ WT2
▽ G4	◁ SD12	⊠ UZ16

NOTE: Shown on Figure 3.10-17

Figure 3.10-18. Shear-Wave Interval Velocities Interpreted from Vertical Seismic Profile Surveys at Six Boreholes



Solid: Representative S-wave profile (Johnson, Majer, Daley, 1998)
Dashed: Thermal-mechanical layer velocities

NOTE: The solid lines show the best estimate (central line) and upper and lower bound velocities.

Figure 3.10-19. Shallow Shear-Wave Seismic Velocity Model for Yucca Mountain and Thermal-Mechanical Layer Velocities

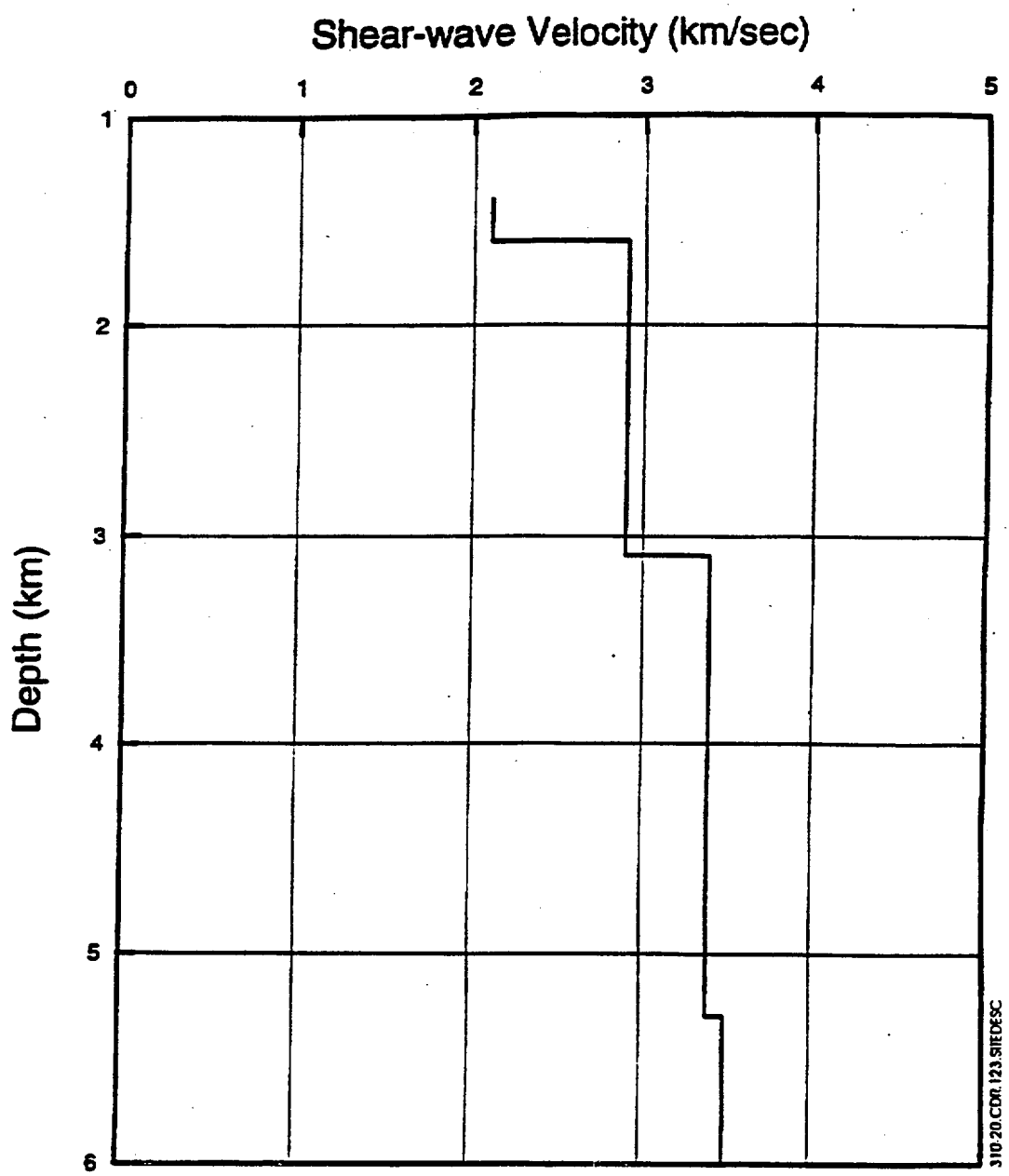
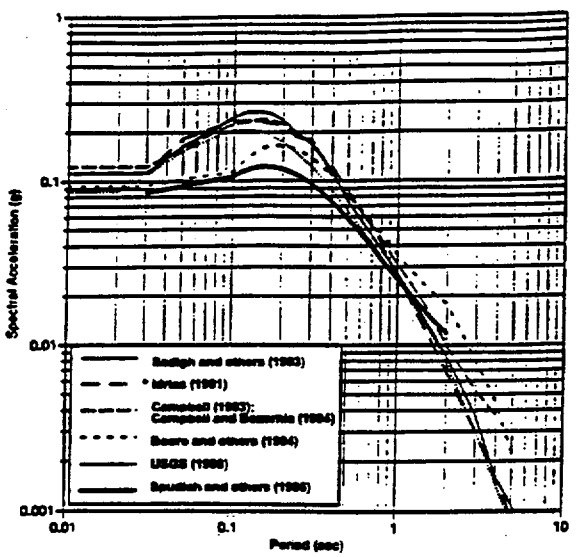
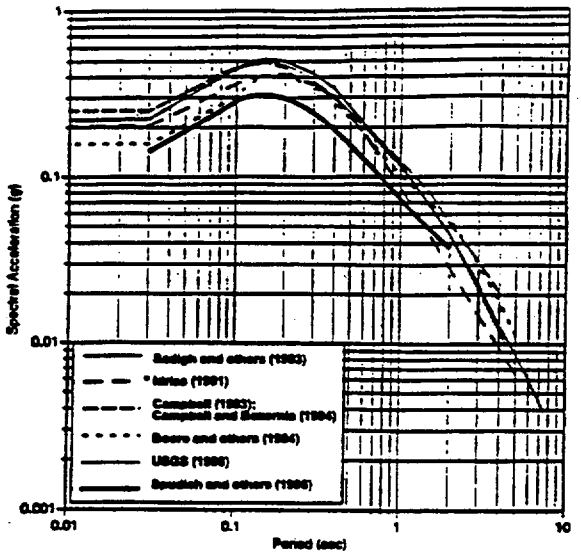


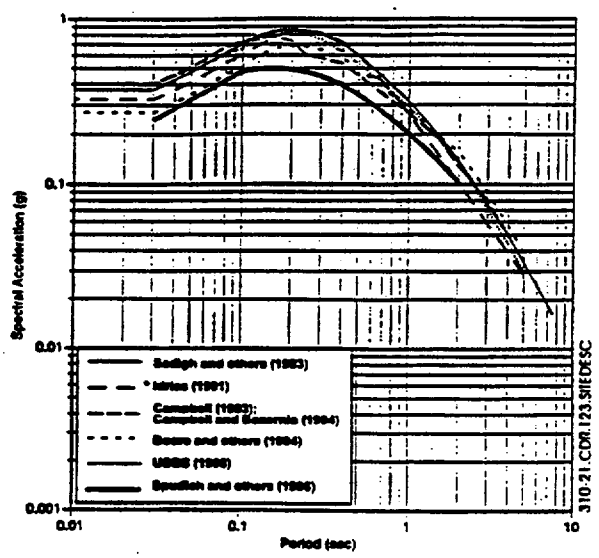
Figure 3.10-20. Deep Shear-Wave Seismic Velocity Model for Yucca Mountain (from Schneider et al. 1996)



a. Magnitude 5 at 10 km



b. Magnitude 6 at 10 km

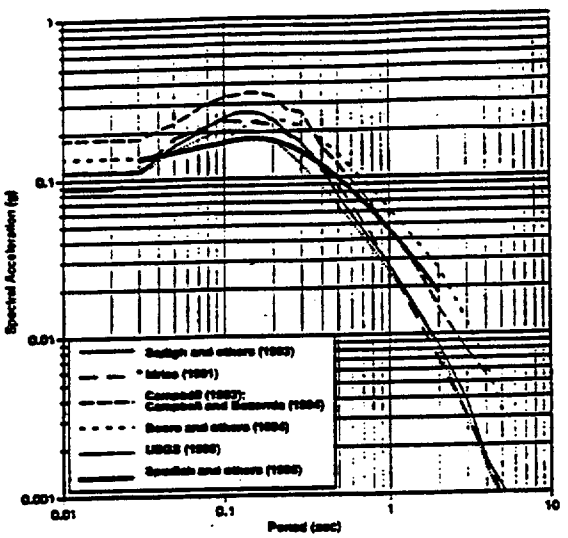


c. Magnitude 7 at 10 km

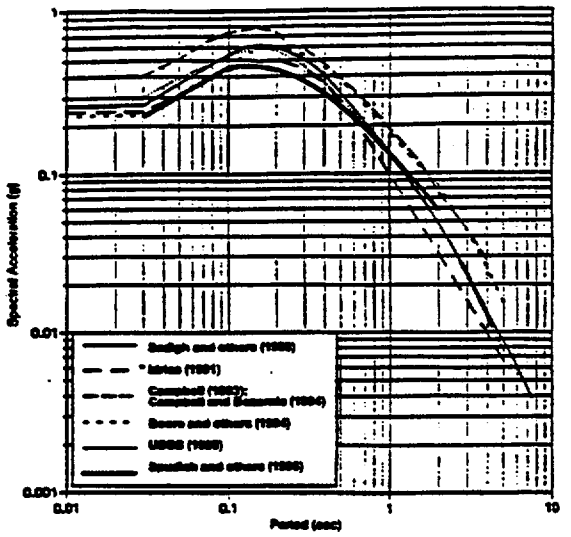
* Also, I.M. Idriss, University of California, Davis, written communication to N.A. Abrahamson, Consultant 1994.

NOTE: The comparisons are for a rock site on the foot wall of a normal fault (from USGS 1998).

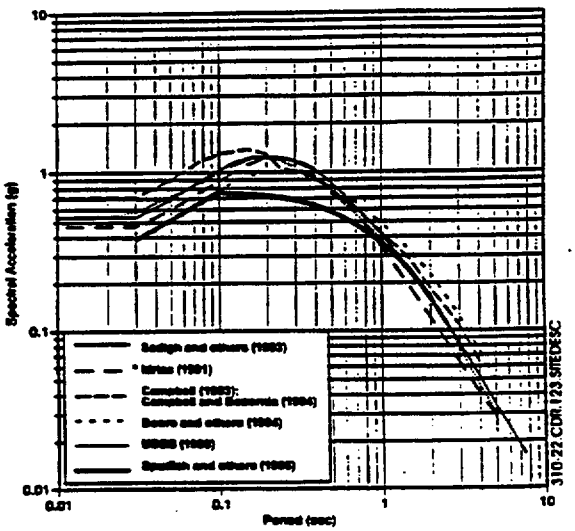
Figure 3.10-21. Spectral Acceleration (Median Ground Motion Estimates) for Several Western United States Attenuation Relations Compared with an Extensional Regime Relation (from Spudich et al. 1996)



a. Magnitude 5 at 10 km



b. Magnitude 6 at 10 km

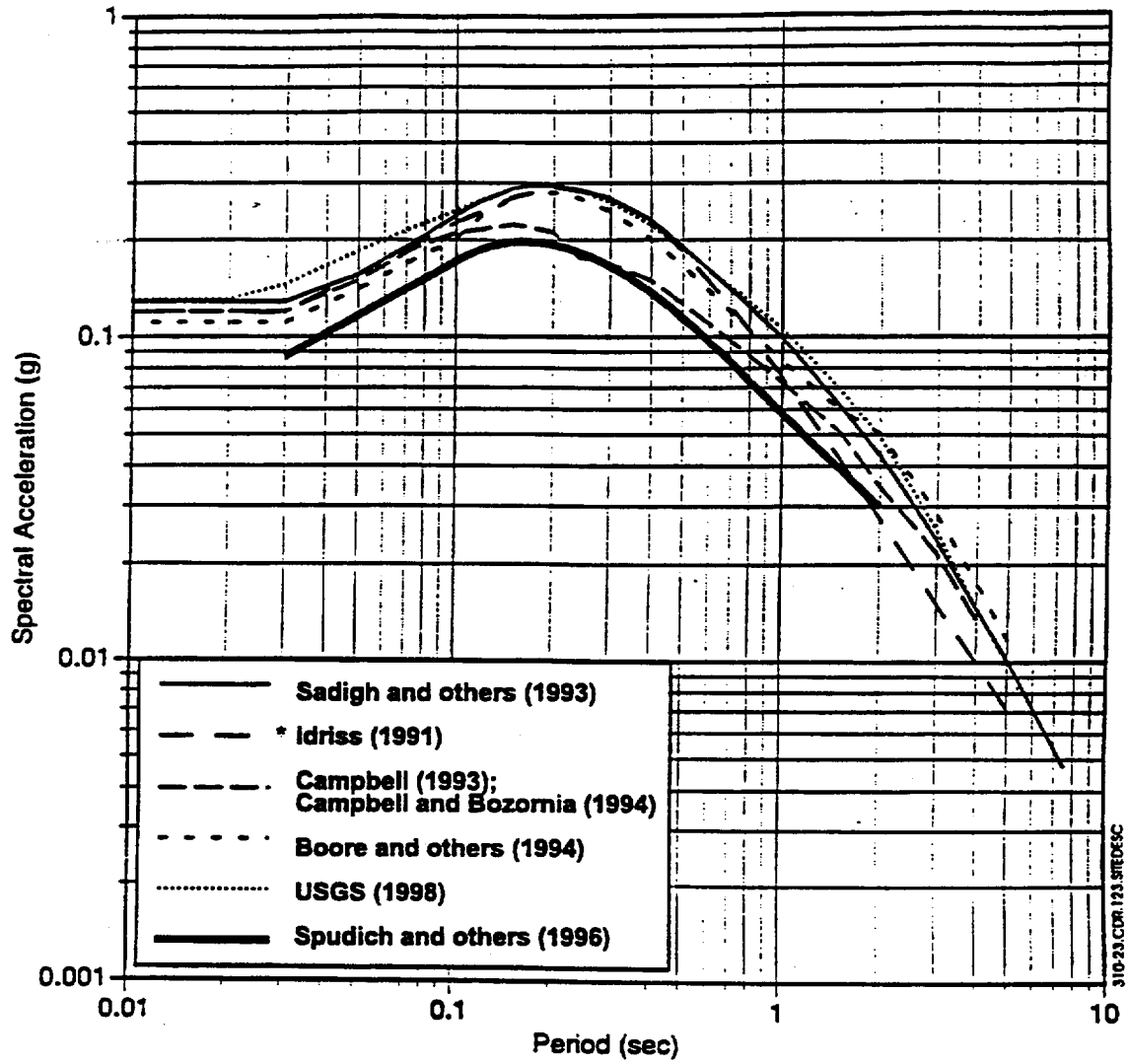


c. Magnitude 7 at 10 km

* Also, I.M. Idriss, University of California, Davis, written communication to N.A. Abrahamson, Consultant 1994.

NOTE: The comparisons are for a rock site on the hanging wall of a normal fault (from USGS 1998).

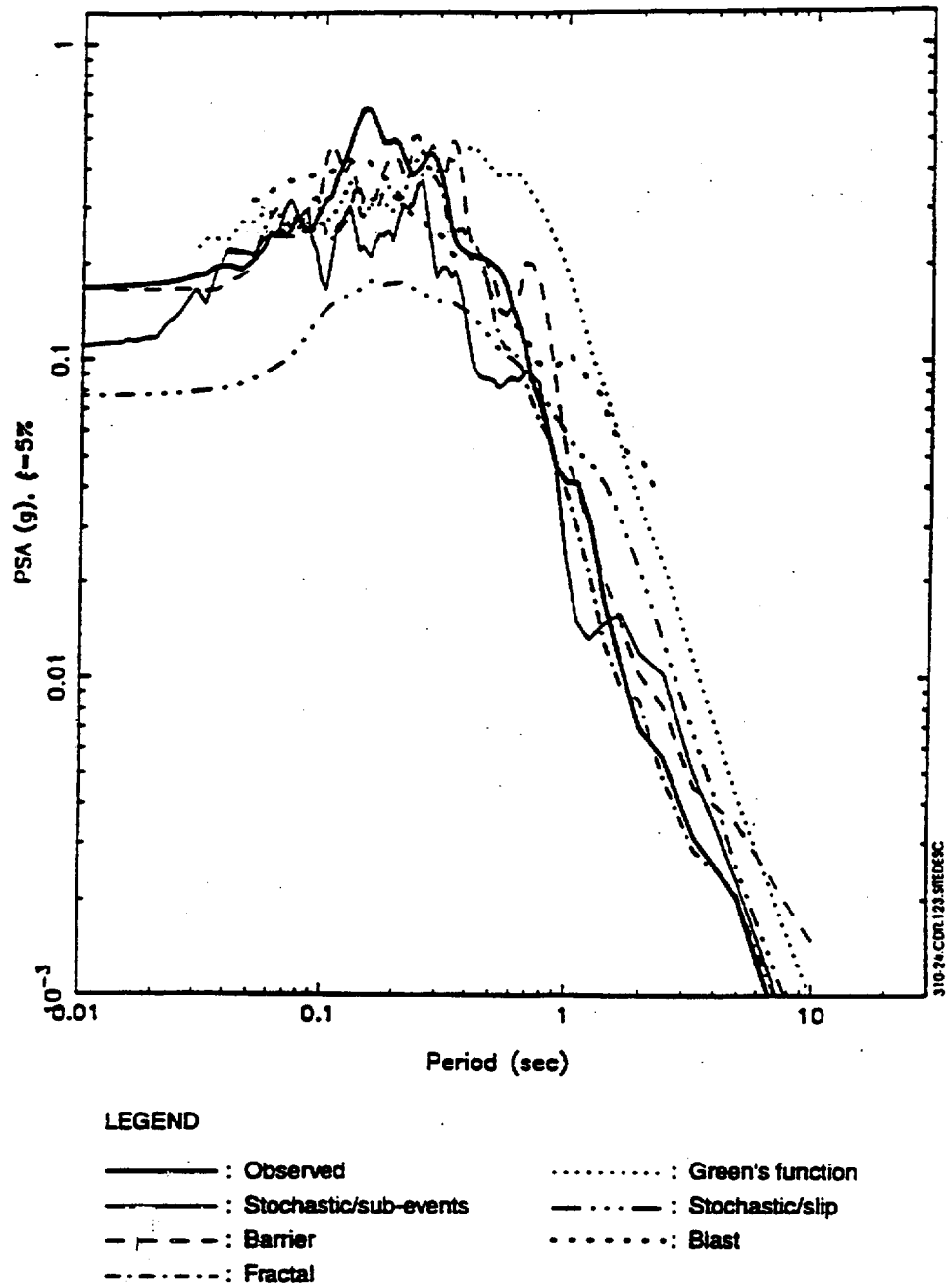
Figure 3.10-22. Spectral Acceleration (Median Ground Motion Estimates) for several Western United States Attenuation Relations Compared with an Extensional Regime Relation (from Spudich et al. 1996)



* Also, I.M. Idriss, University of California, Davis, written communication to N.A. Abrahamson, Consultant 1994.

NOTE: The comparisons are for a rock site and a M_w 6.5 strike-slip earthquake (vertical fault) at 25 km (from USGS 1998).

Figure 3.10-23. Spectral Acceleration (Median Ground Motion Estimates) for several Western United States Attenuation Relations Compared with an Extensional Regime Relation (from Spudich et al. 1996)



NOTE: Shown is an observed spectrum (5% damping) for a recorded motion in the Little Skull Mountain earthquake (Lathrop Wells Station) and spectra calculated by six teams using different modeling methods.

Figure 3.10-24. Results of Validation Studies in the Scenario Earthquake Modeling Study (from Schneider et al. 1996)

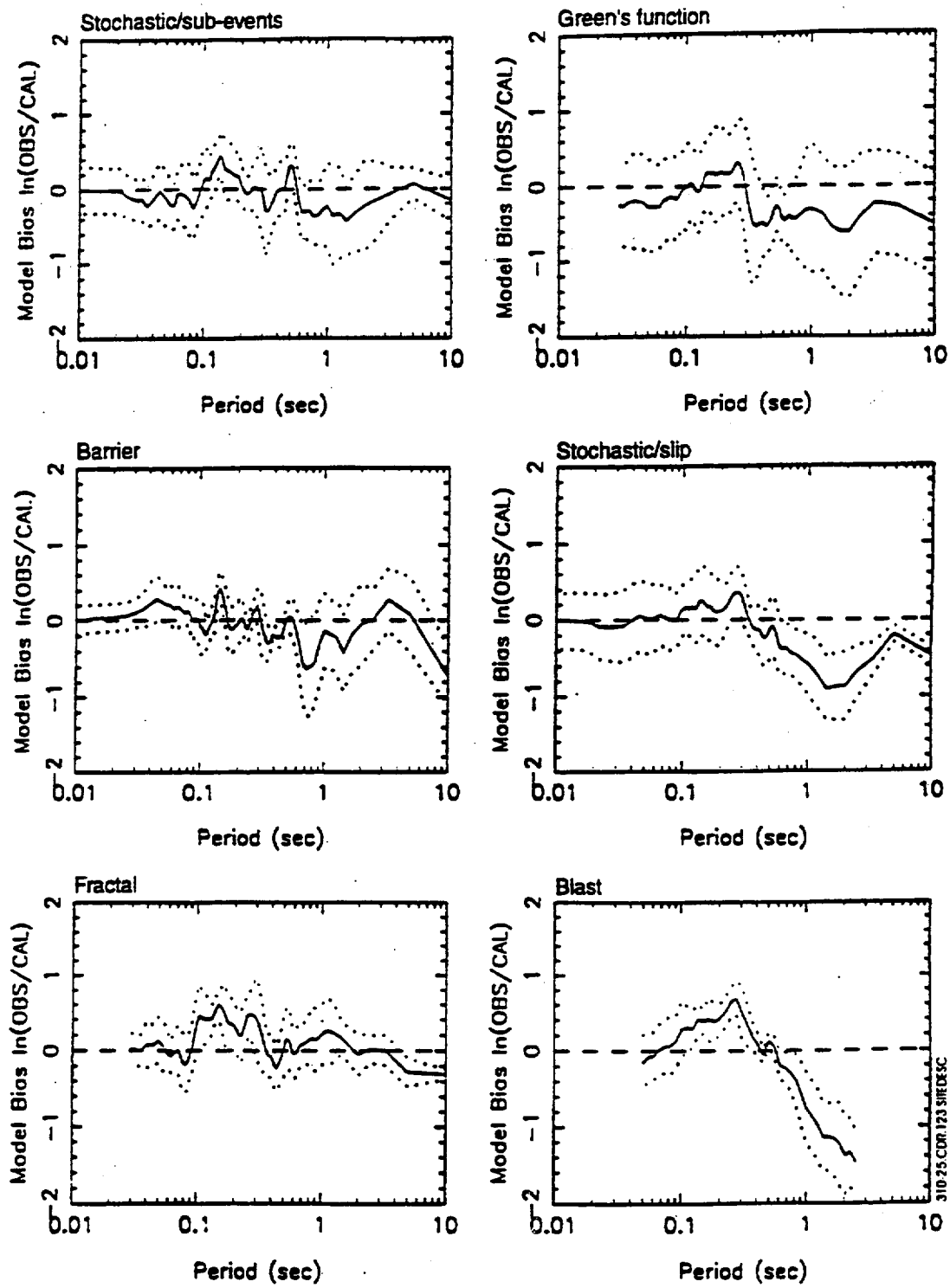
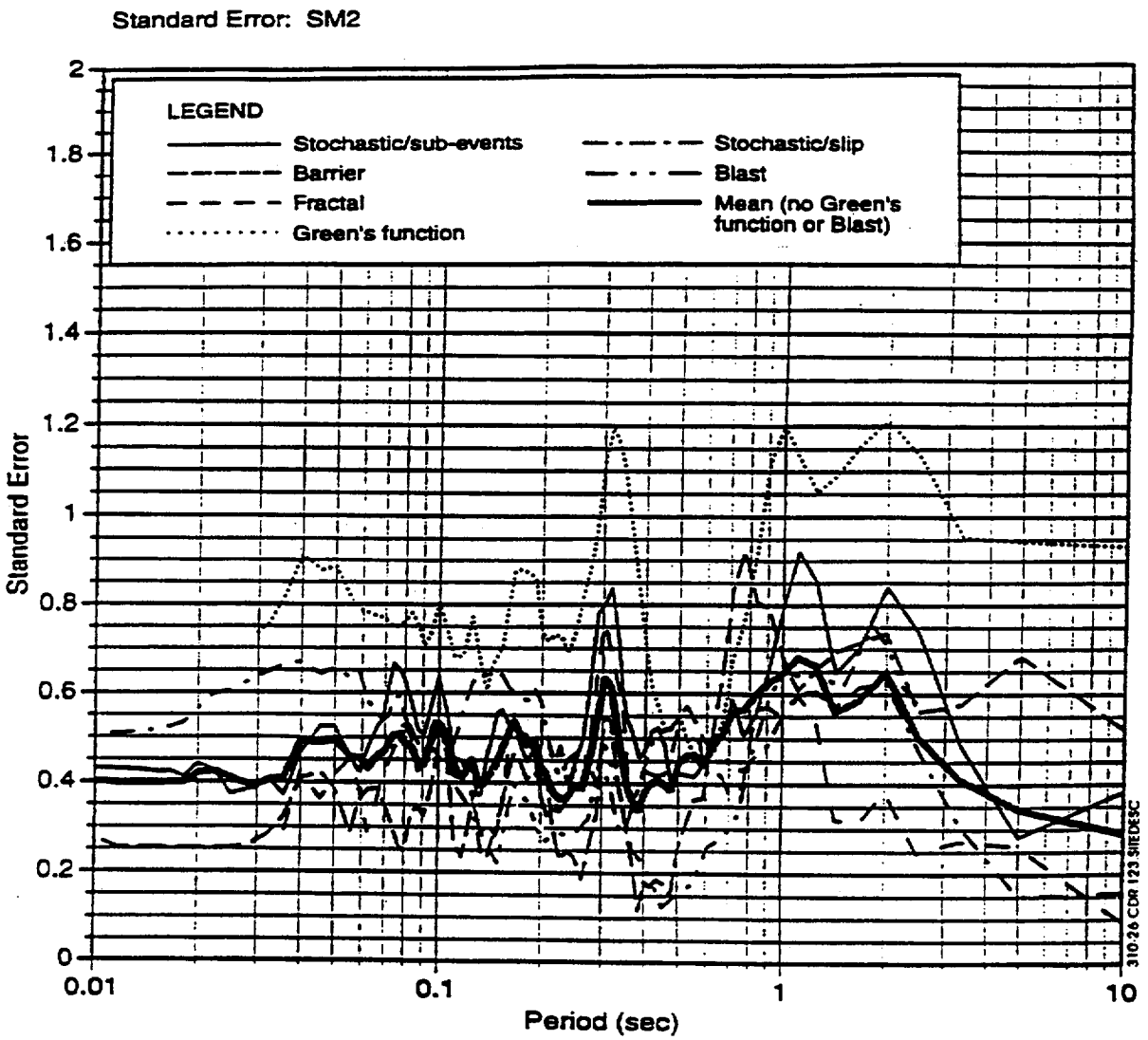


Figure 3.10-25. Model Bias of Observed Spectra to Calculated Spectra for the Little Skull Mountain Earthquake Validation (Scenario Earthquake Modeling Study) (from Schneider et al. 1996)



NOTE: The mean excludes the empirical blast model and the Green's function model.

Figure 3.10-26. Model Standard Errors for the Little Skull Mountain Earthquake Validation (Scenario Earthquake Modeling Study) (from Schneider et al. 1996)

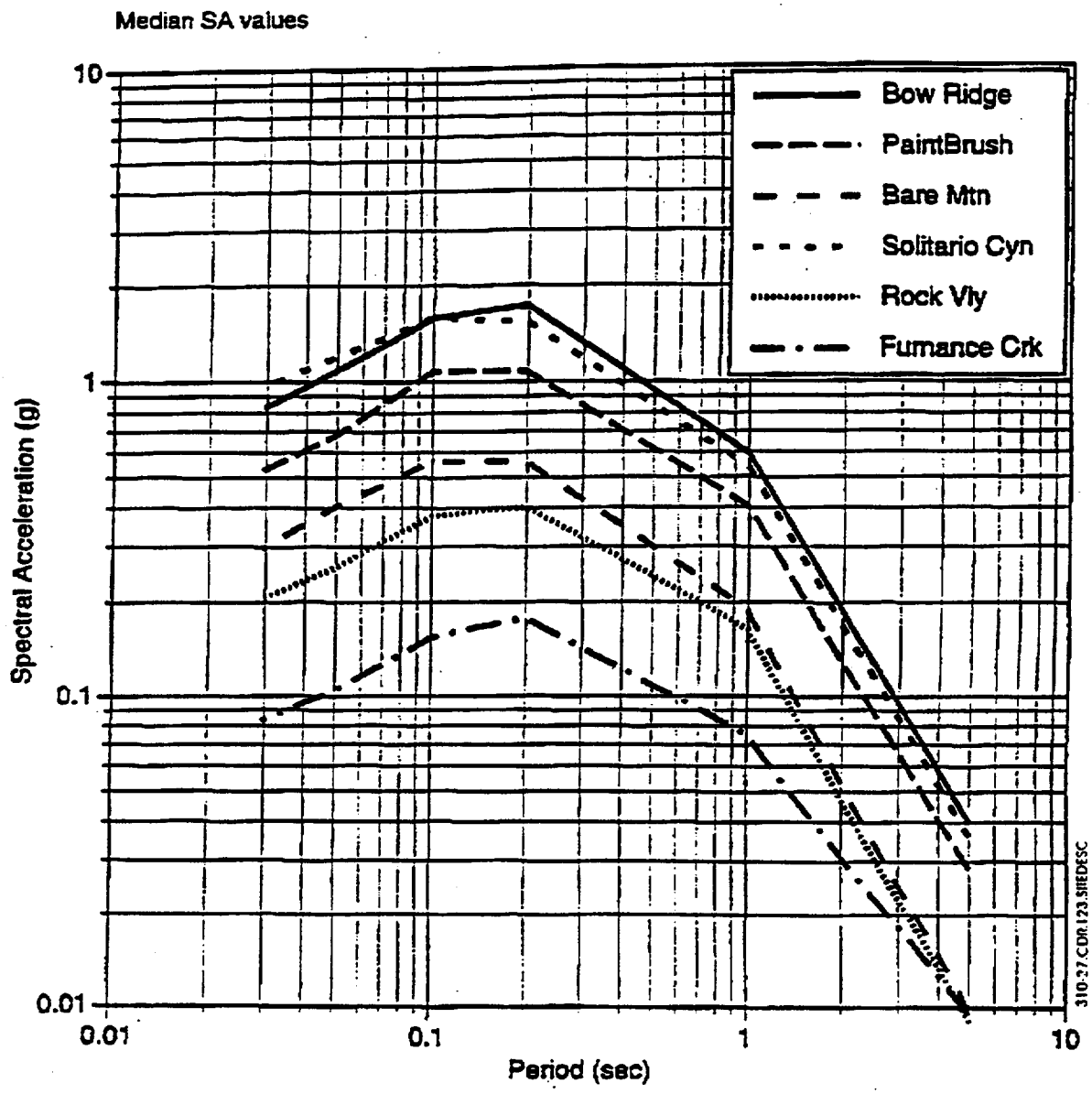


Figure 3.10-27. Median Spectral Acceleration for Scenario Earthquakes (from Schneider et al. 1996)

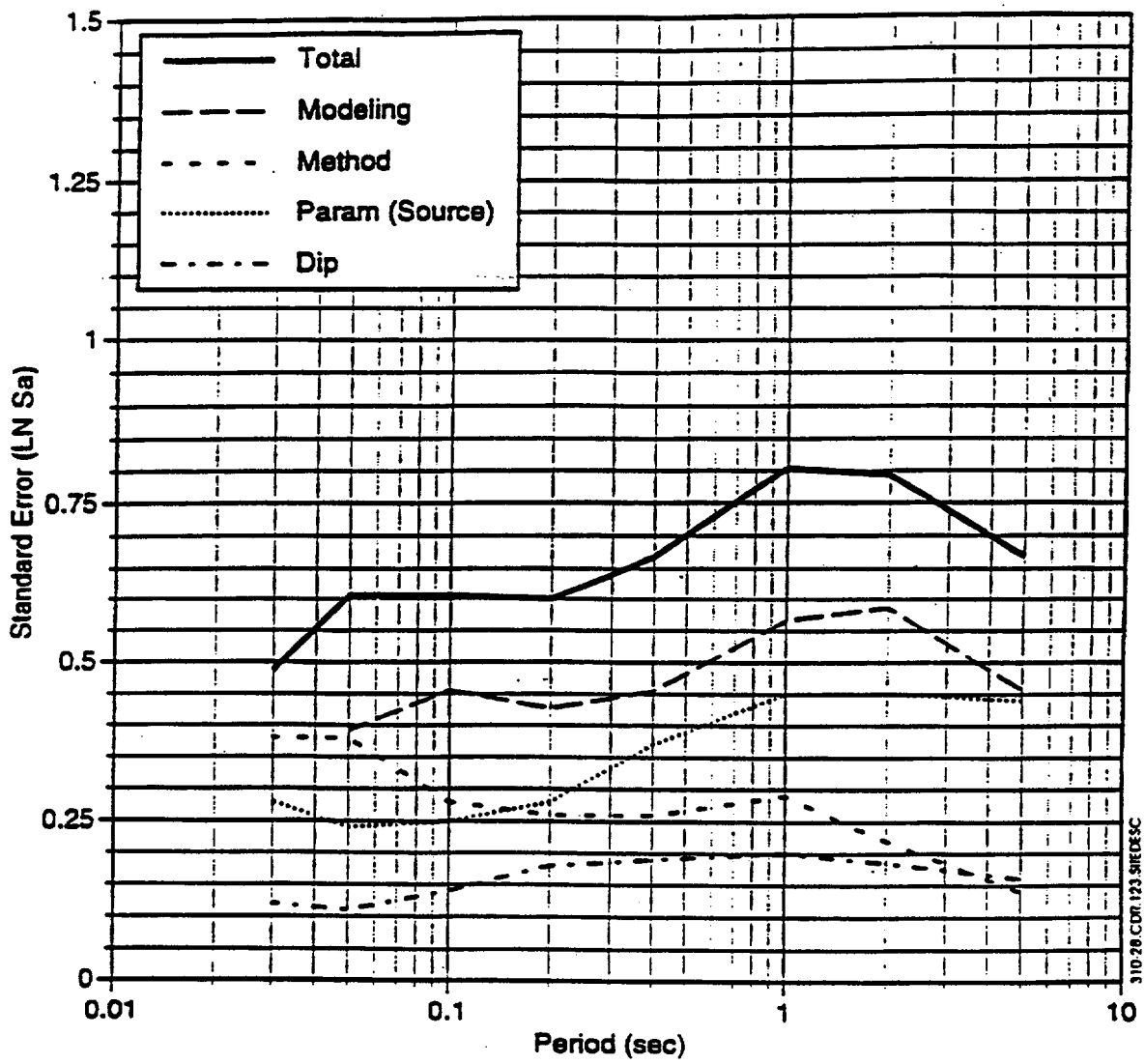


Figure 3.10-28. Example of Total Uncertainty and its Components (the scenario is the Paintbrush Canyon earthquake) (from Schneider et al. 1996)

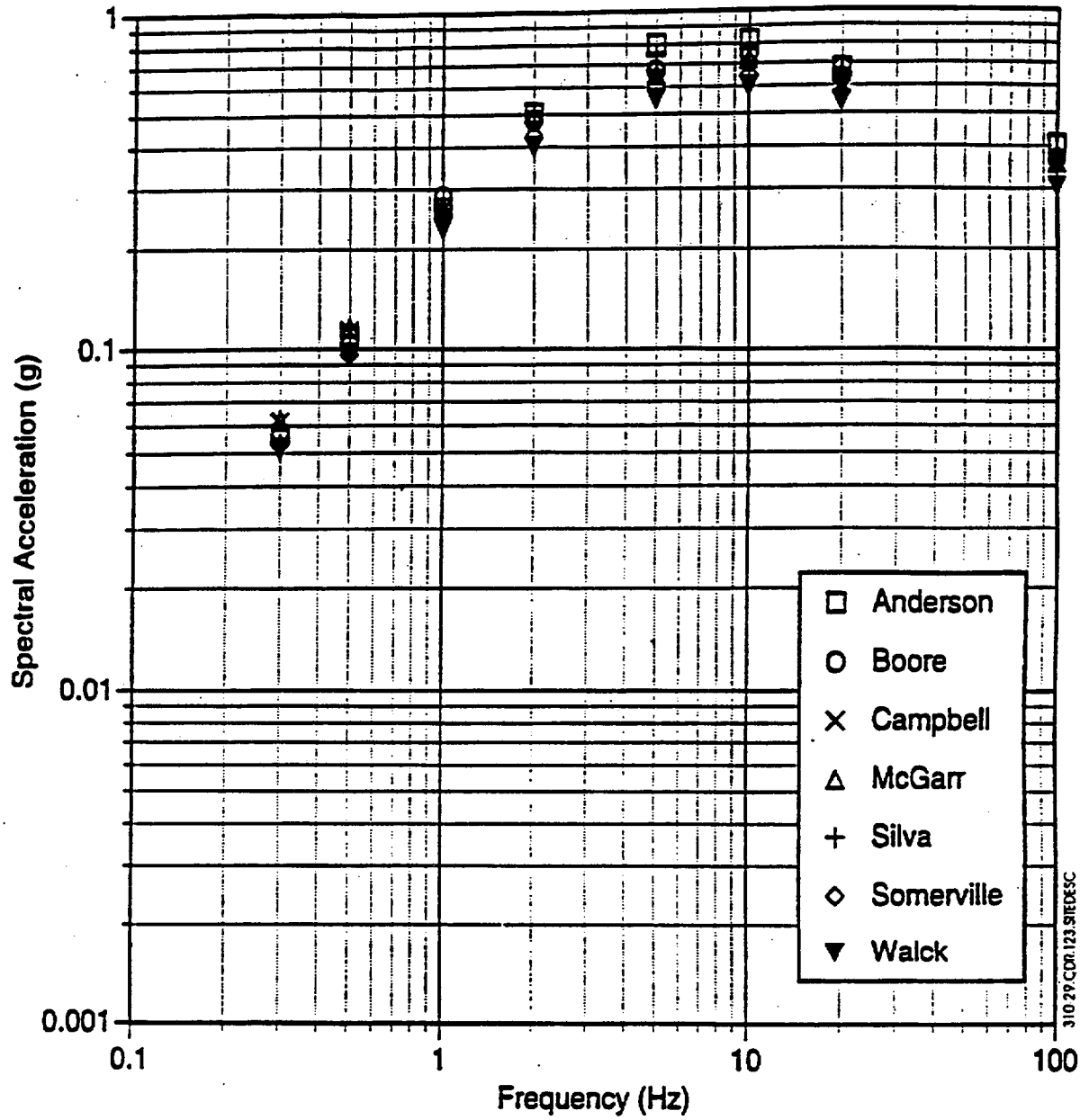
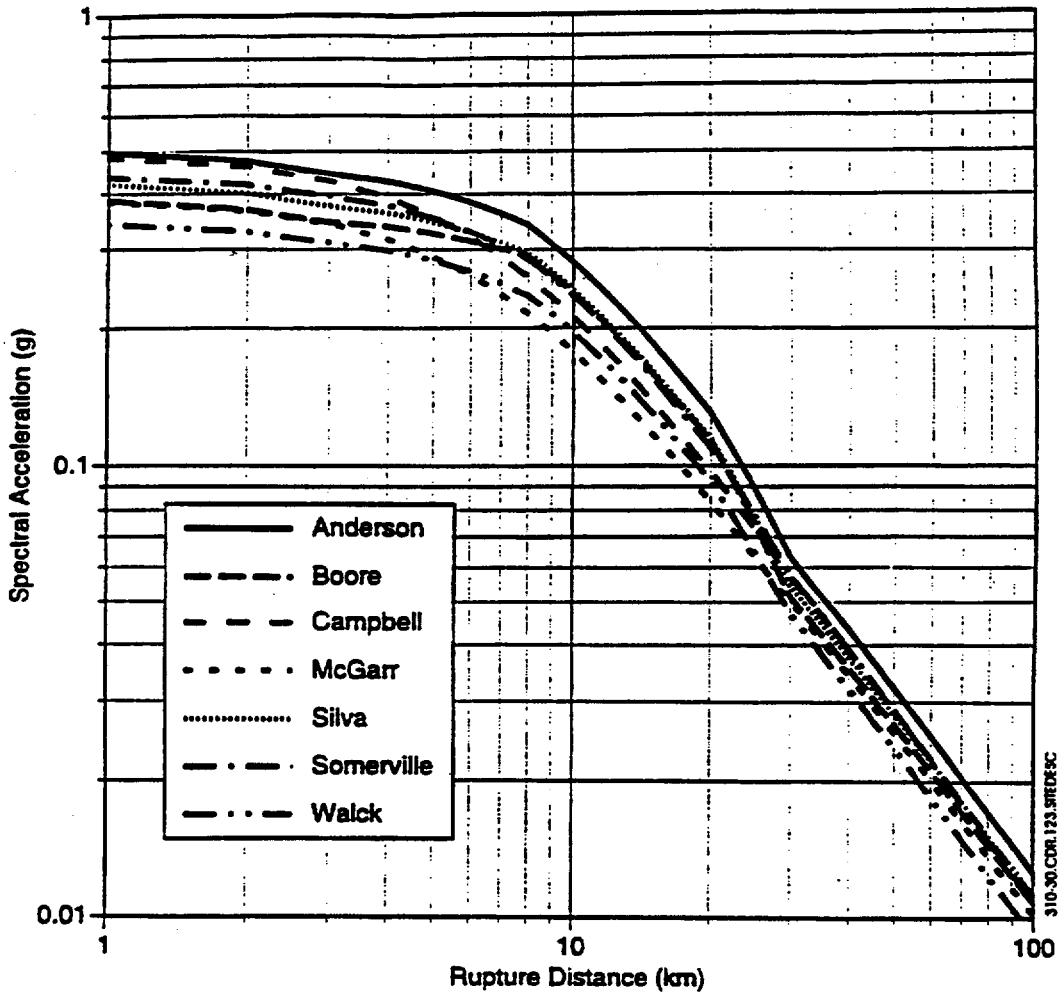


Figure 3.10-29. Expert Point Estimates for Median Horizontal Spectral Acceleration for a M_w 6.5 Earthquake at 4 km on the Hanging Wall of a Normal Fault (from USGS 1998)



NOTE: These estimates are computed from the expert's attenuation relations.

Figure 3.10-30. Median Horizontal Peak Ground Acceleration for a M_W 6.5 Earthquake on the Hanging Wall of a Normal Fault (from USGS 1998)

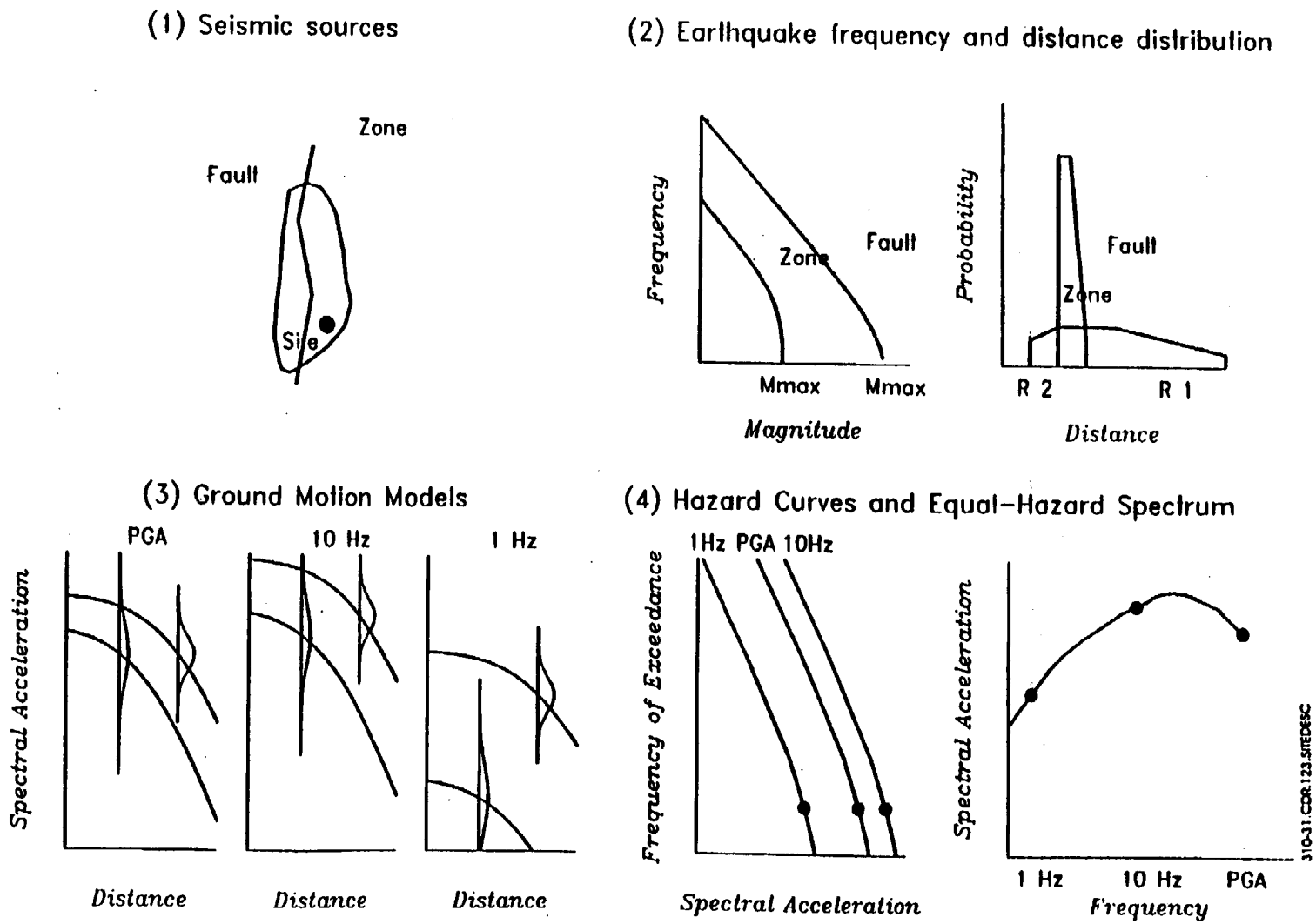


Figure 3.10-31. Schematic Diagram of the Elements of a Probabilistic Seismic Hazard Analysis for Vibratory Ground Motions (from USGS 1998)

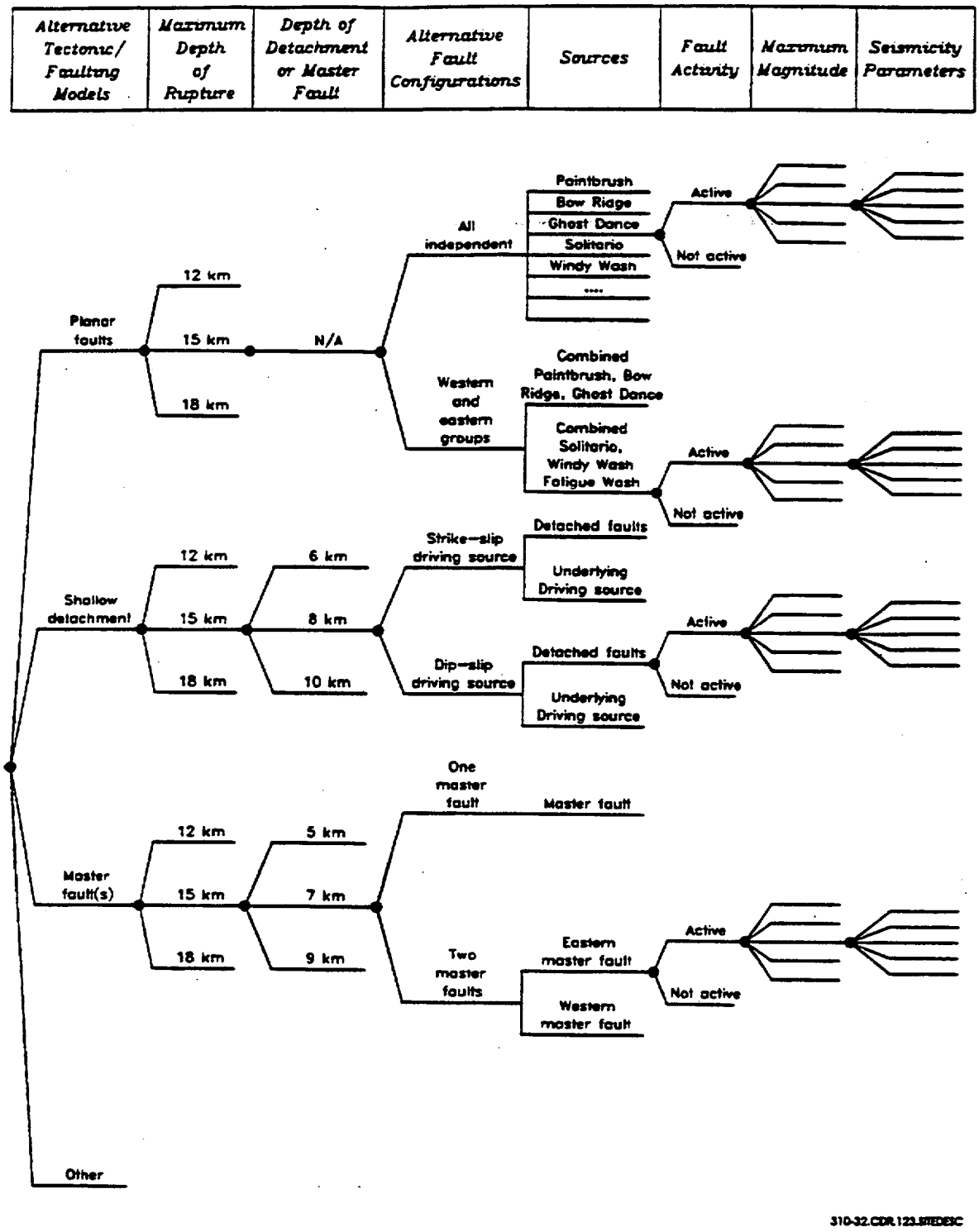


Figure 3.10-32 Example Logic Tree for Expressing the Uncertainty in Characterizing Local Fault Sources (from USGS 1998)

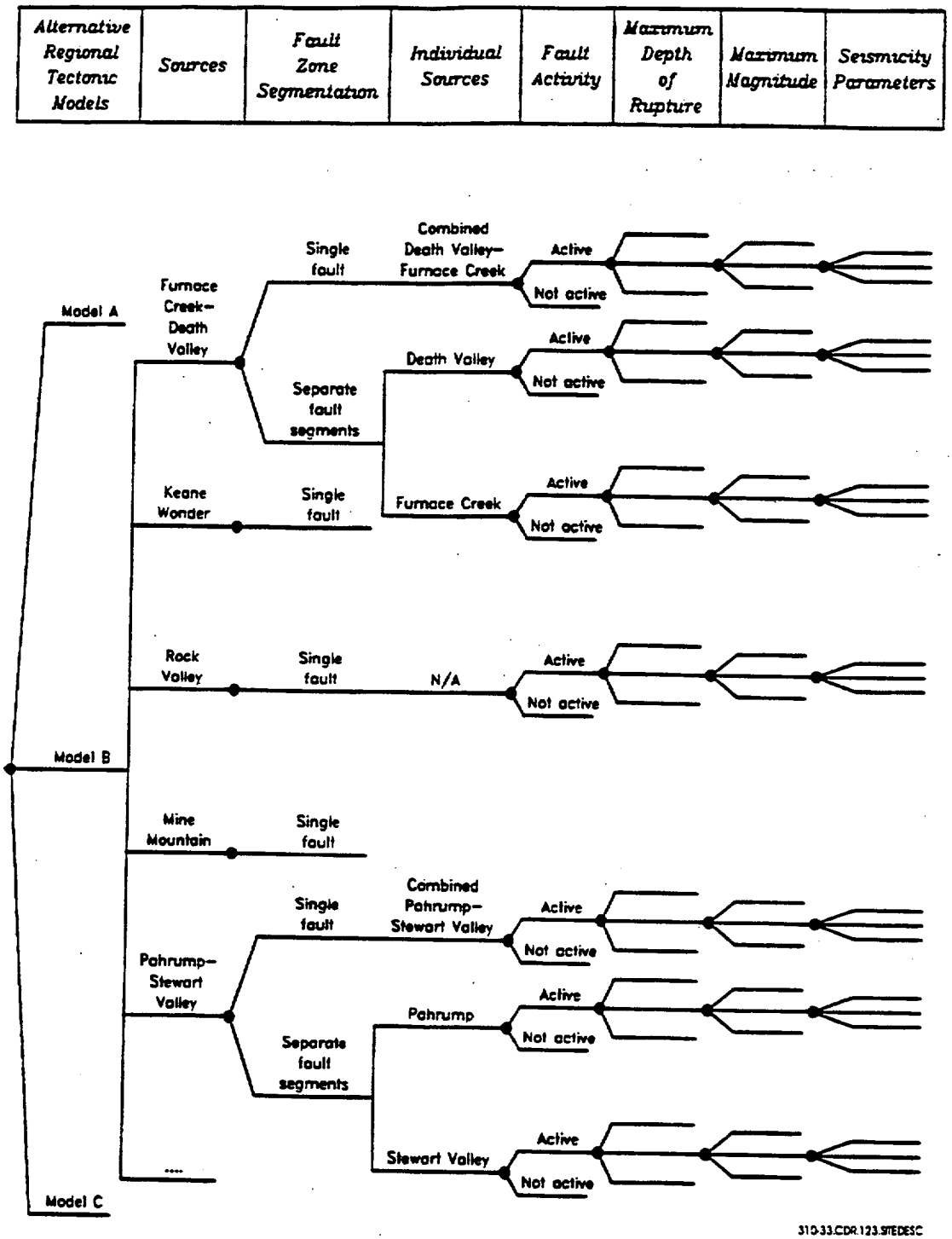


Figure 3.10-33. Example Logic Tree for Expressing the Uncertainty in Characterizing Regional Fault Sources (from USGS 1998)

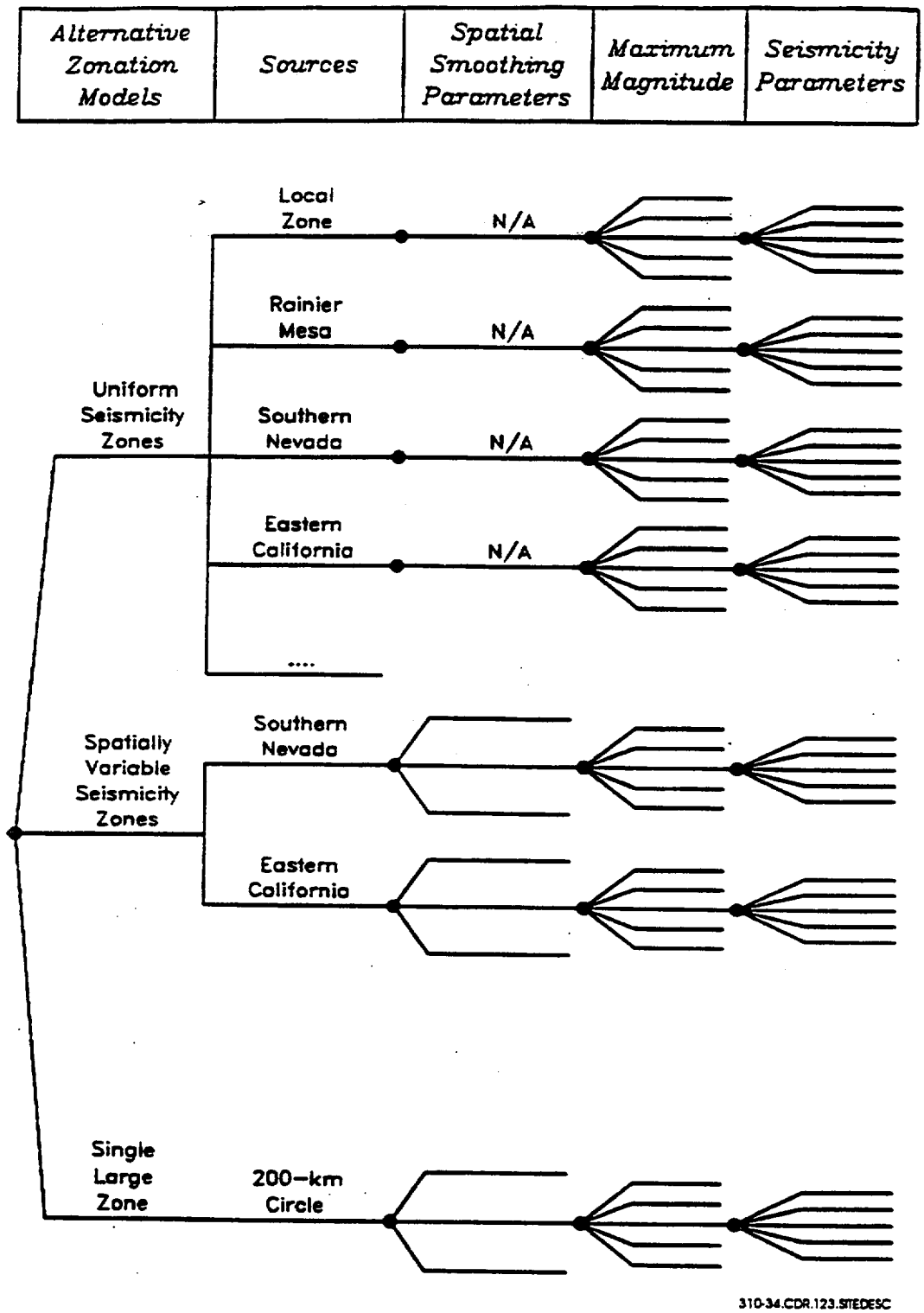
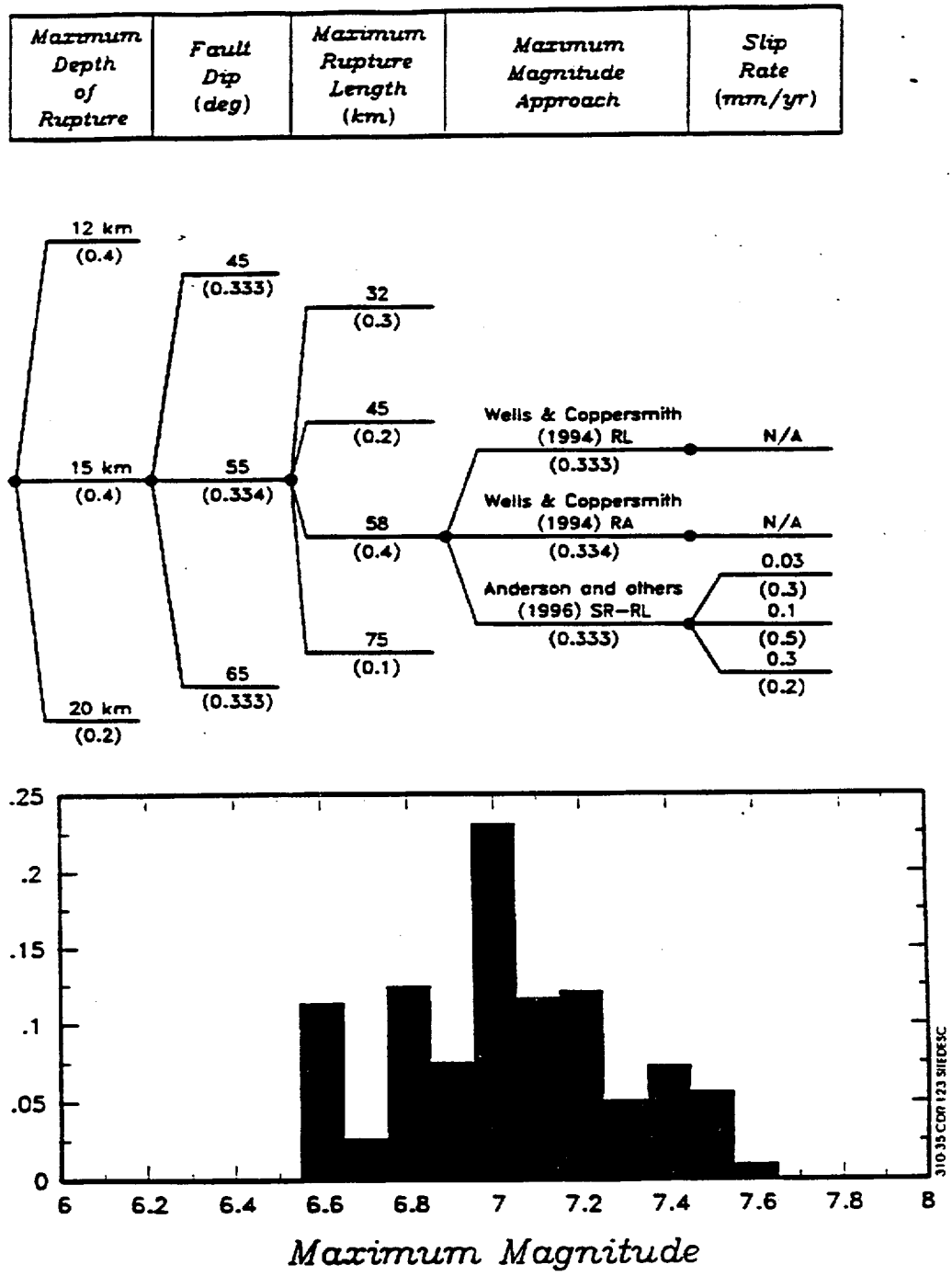


Figure 3.10-34. Example Logic Tree for Expressing the Uncertainty in Characterizing Areal Source Zones (from USGS 1998).



NOTE: Top, logic tree for uncertainty assessment. Bottom, resulting discrete distribution for maximum magnitude.

Figure 3.10-35. Example Assessment of Maximum Magnitude for a Fault Source (from USGS 1998)

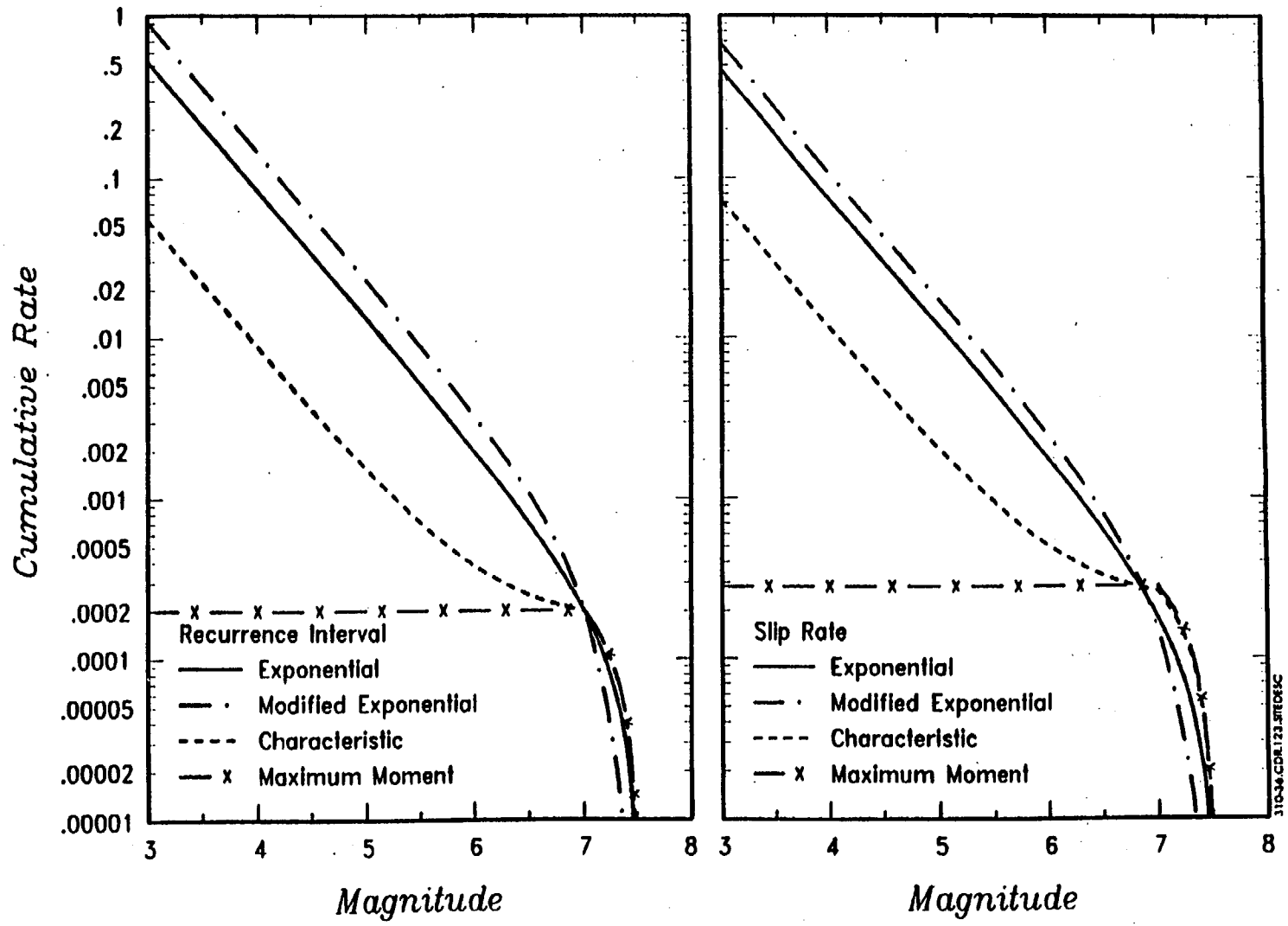


Figure 3.10-36. Alternative Recurrence Models Constrained by Either the Recurrence Interval for Large Events (left) or by Fault Slip Rate Converted to Moment Rate (right) (from USGS 1998)

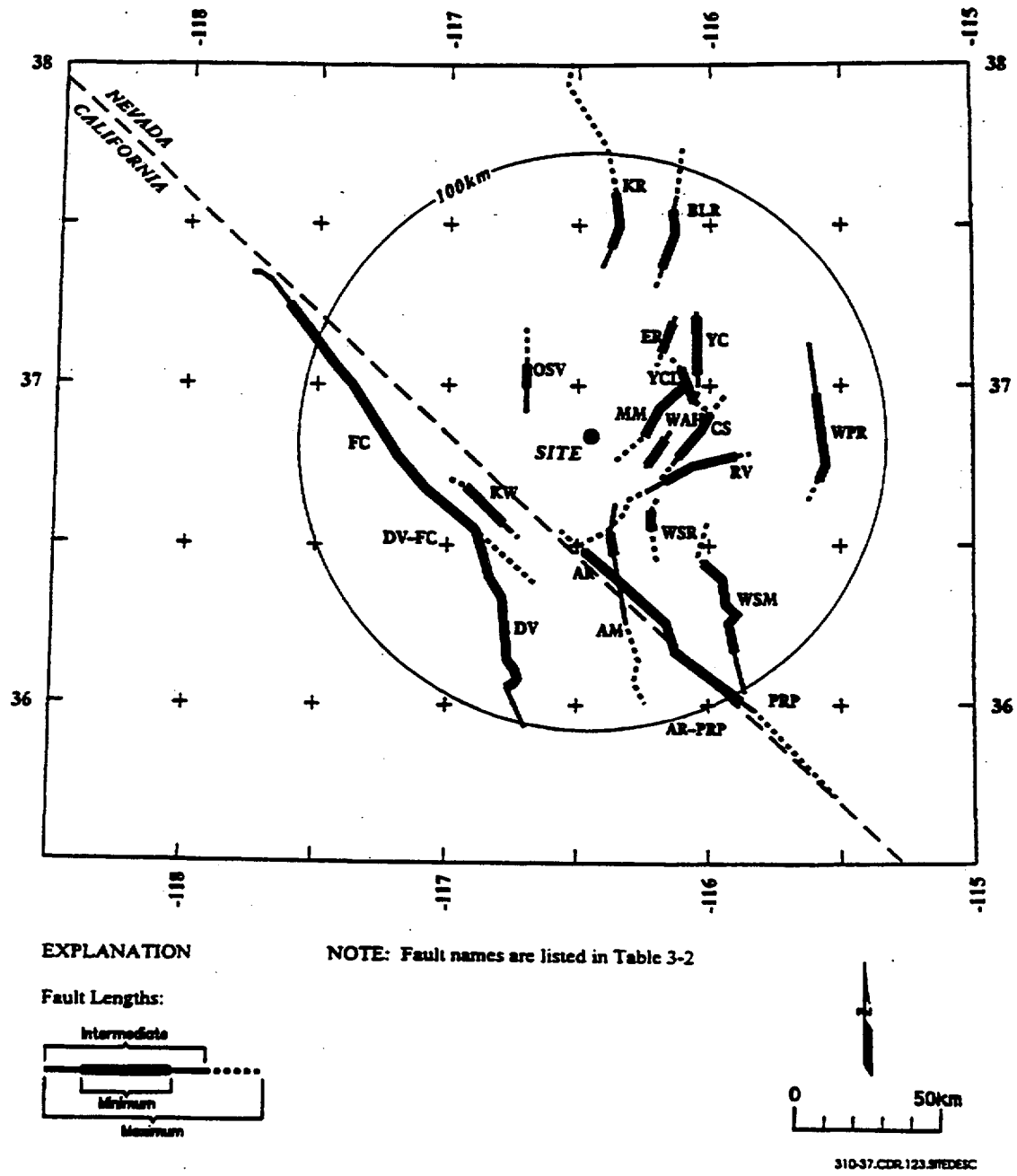


Figure 3.10-37. Regional Fault Sources Considered by One of the Seismic Source Expert Teams (from USGS 1998)

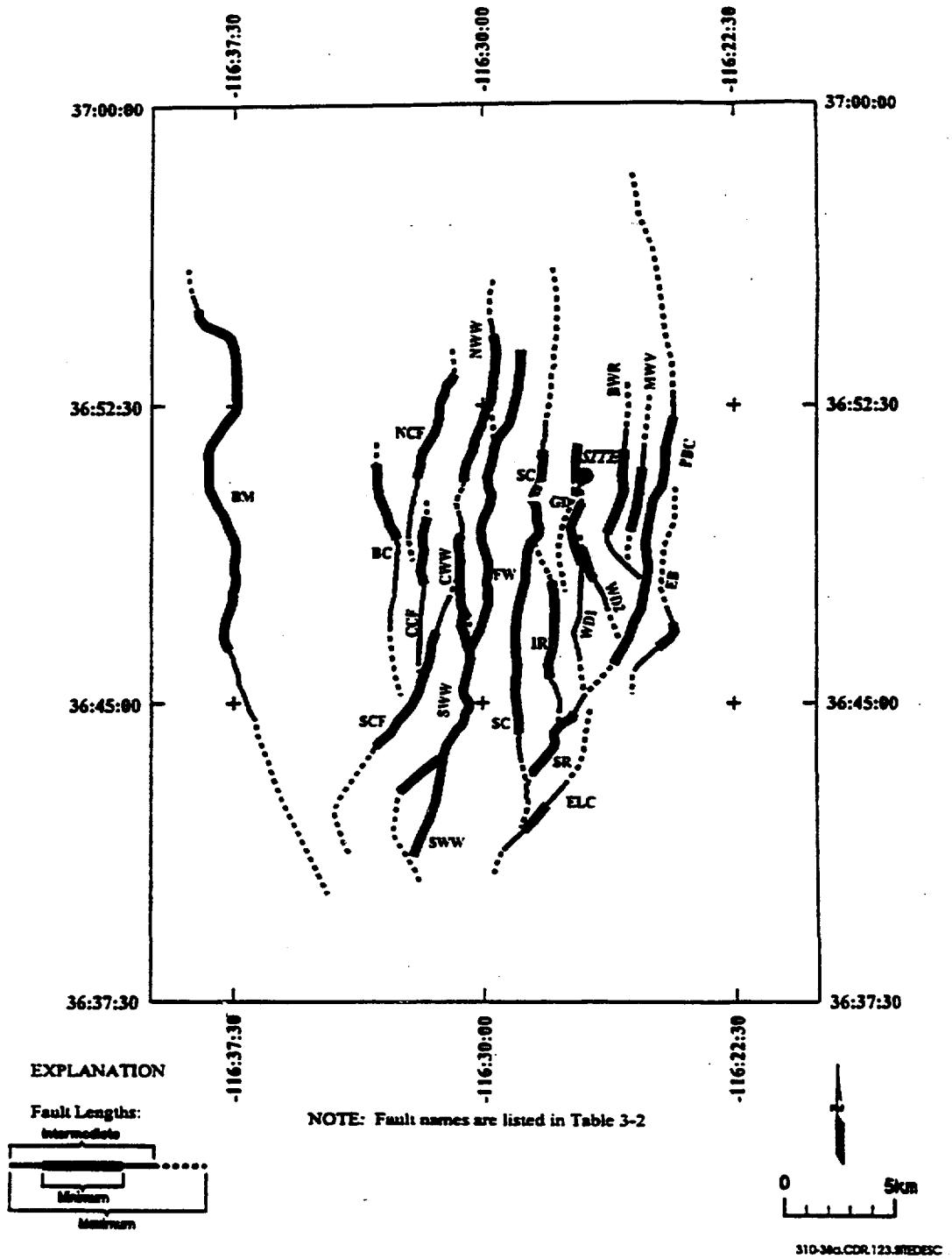


Figure 3.10-38a. Location of Local Faults Considered by One of the Seismic Source Experts as Independent Sources (from USGS 1998)

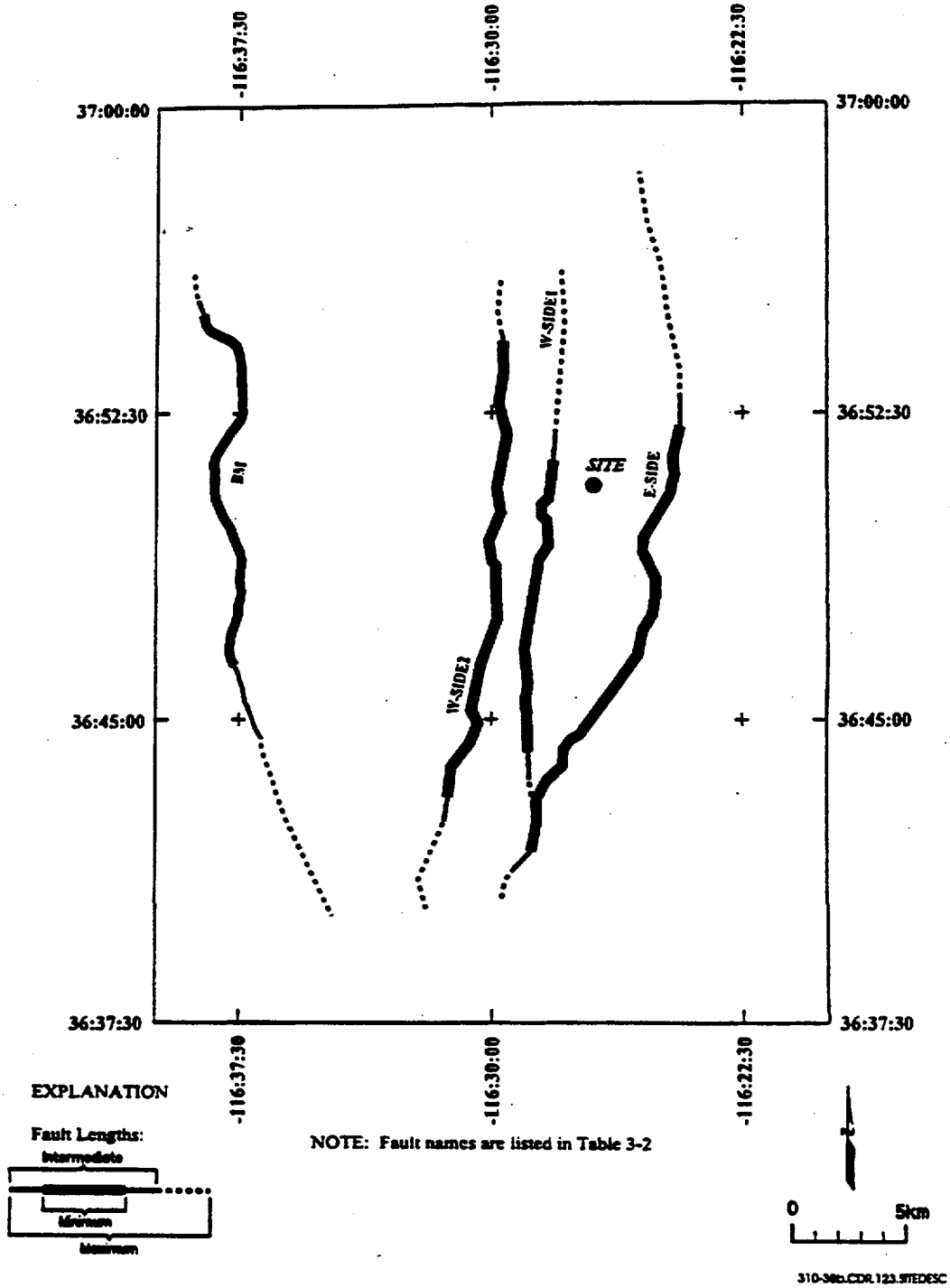
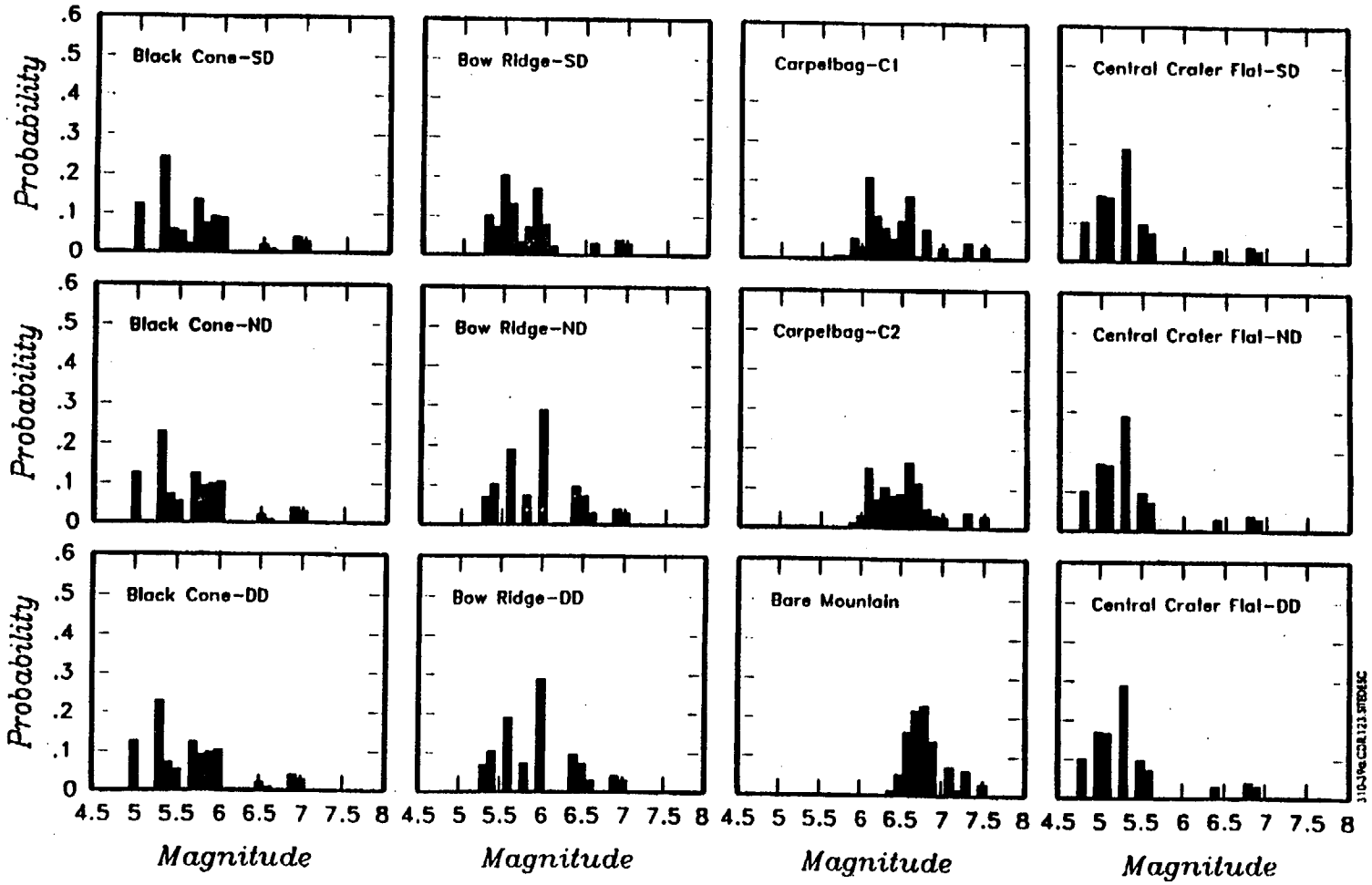


Figure 3.10-38b. Location of Coalesced Faults Considered by One of the Seismic Source Expert Teams (from USGS 1998)



NOTE: A, B, and C and numbers refer to variations of tectonic models A, B, and C; DD - deep detachment; ND - no detachment; SD - shallow detachment, SINGLE - single rupture (BM and YM faults), Single rupture of west-side faults (WS1+WS2), Single Yucca Mountain - coalesced single YM system.

Figure 3.10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998)

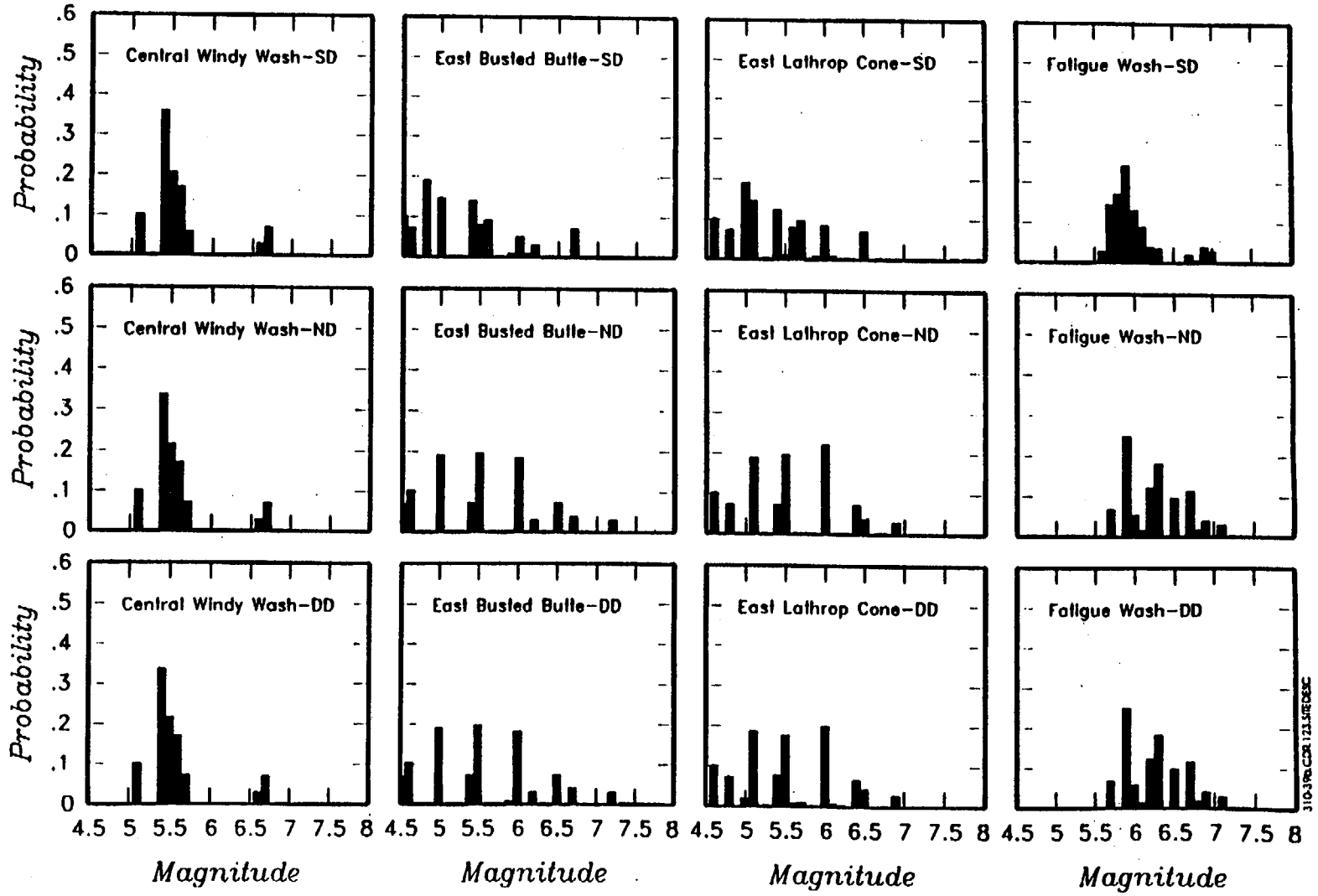


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

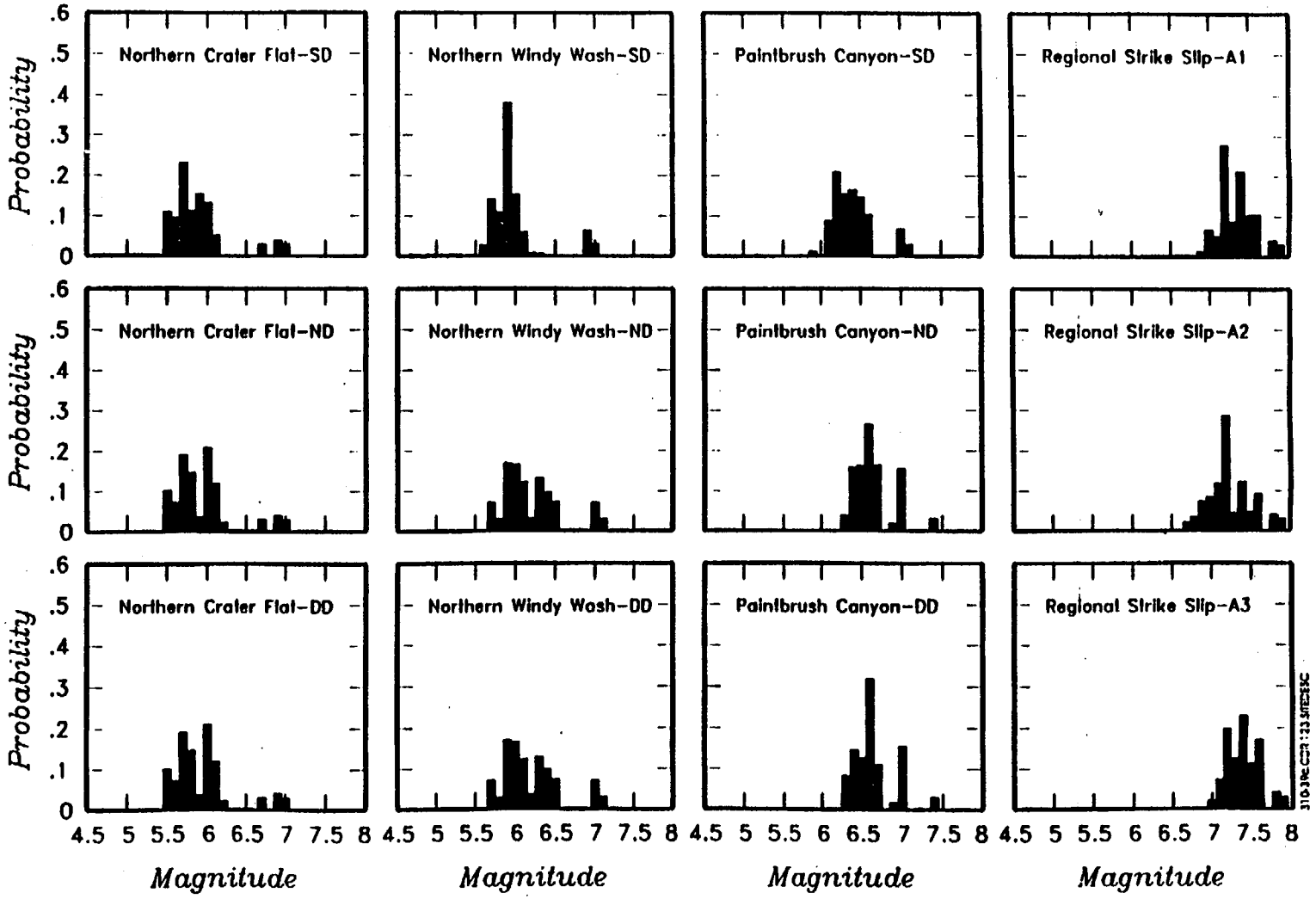


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

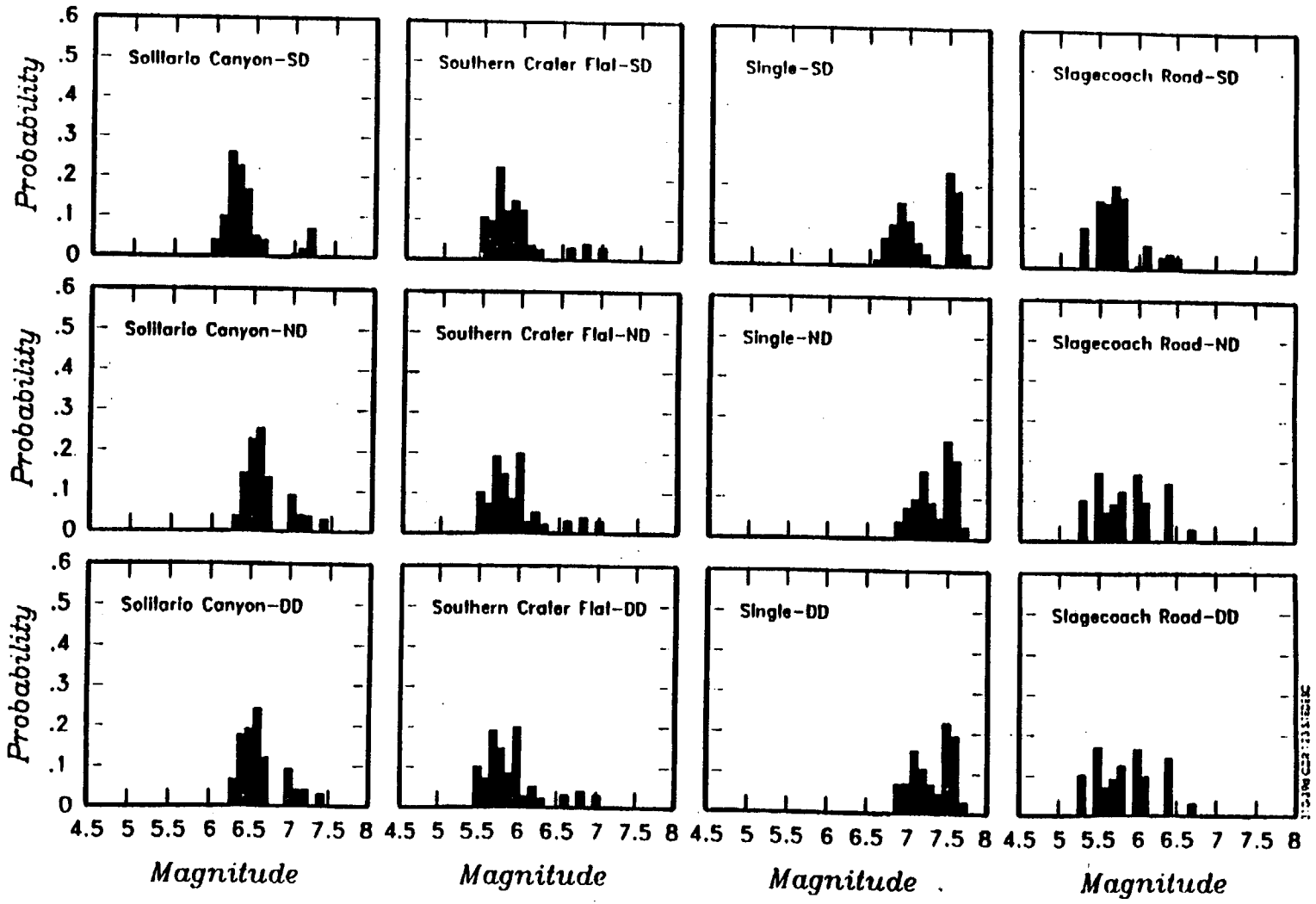


Figure 3.10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

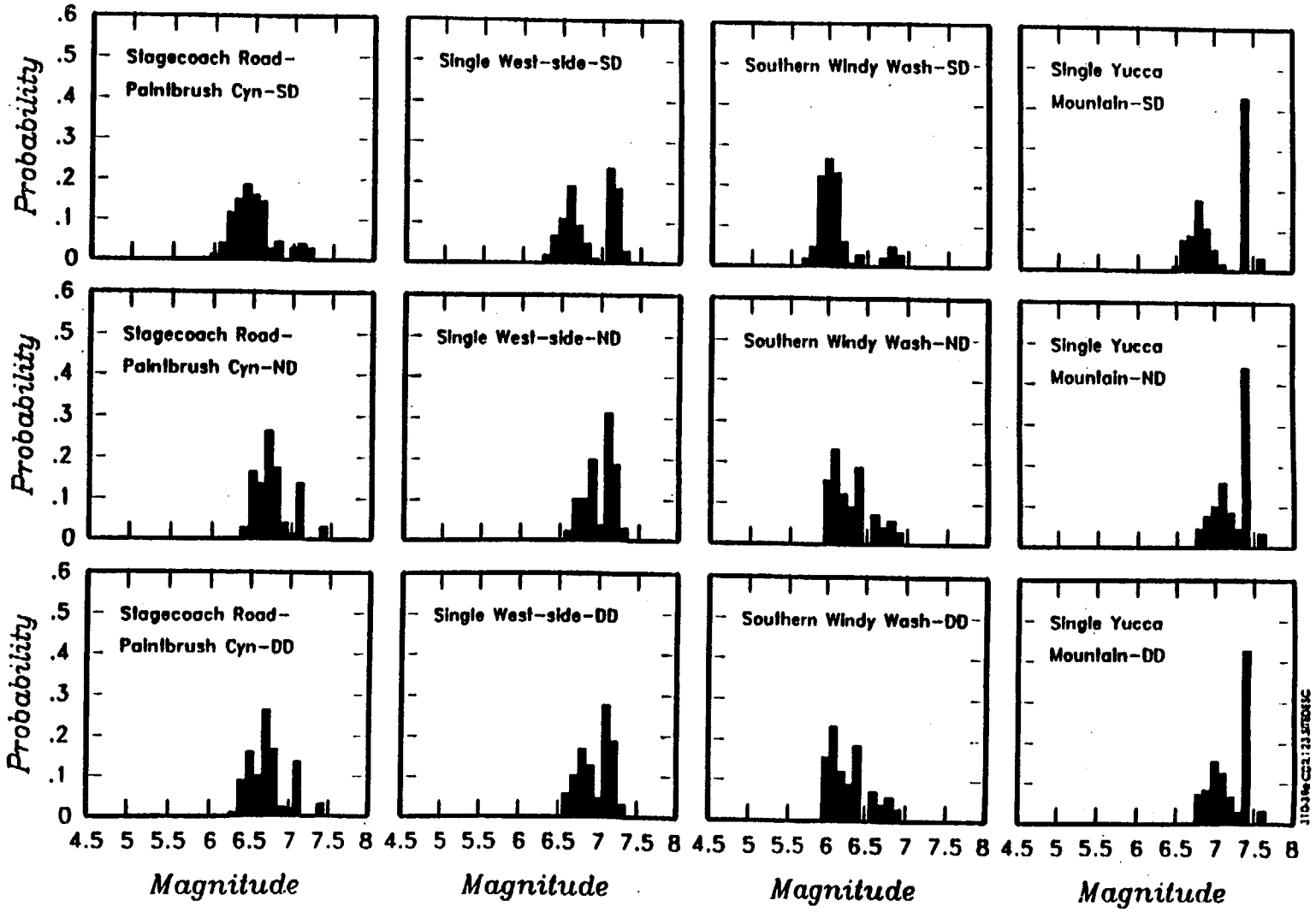


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

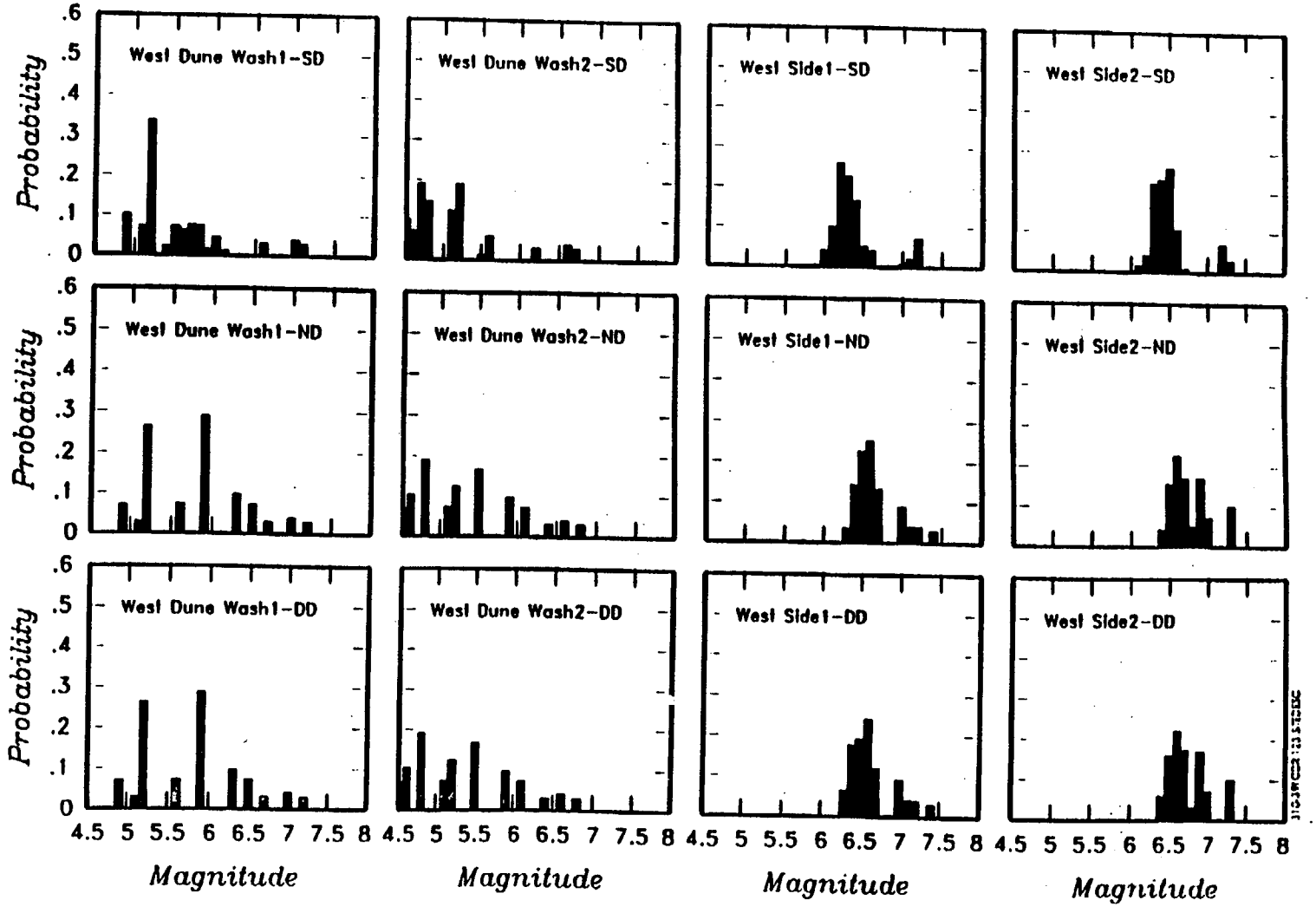


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

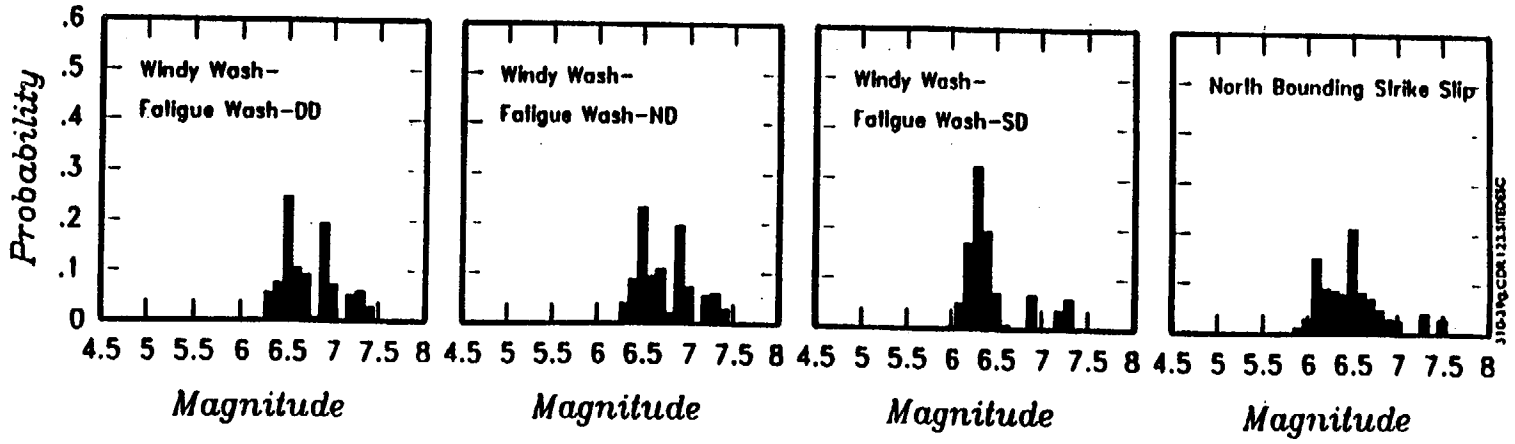


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

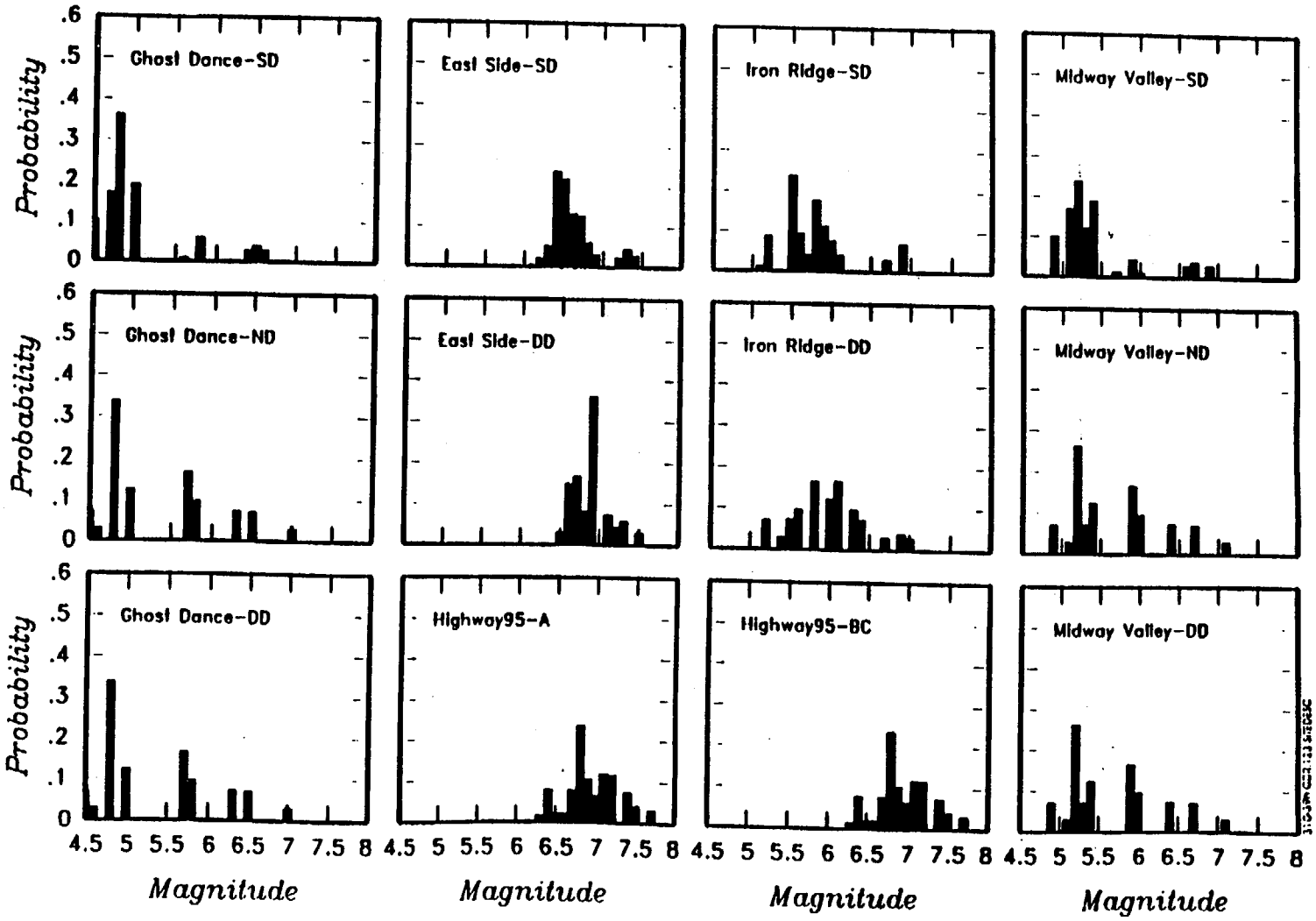


Figure 10-39. Maximum Magnitude Distributions for One Seismic Source Team's Local Fault Sources (from USGS 1998) (Continued)

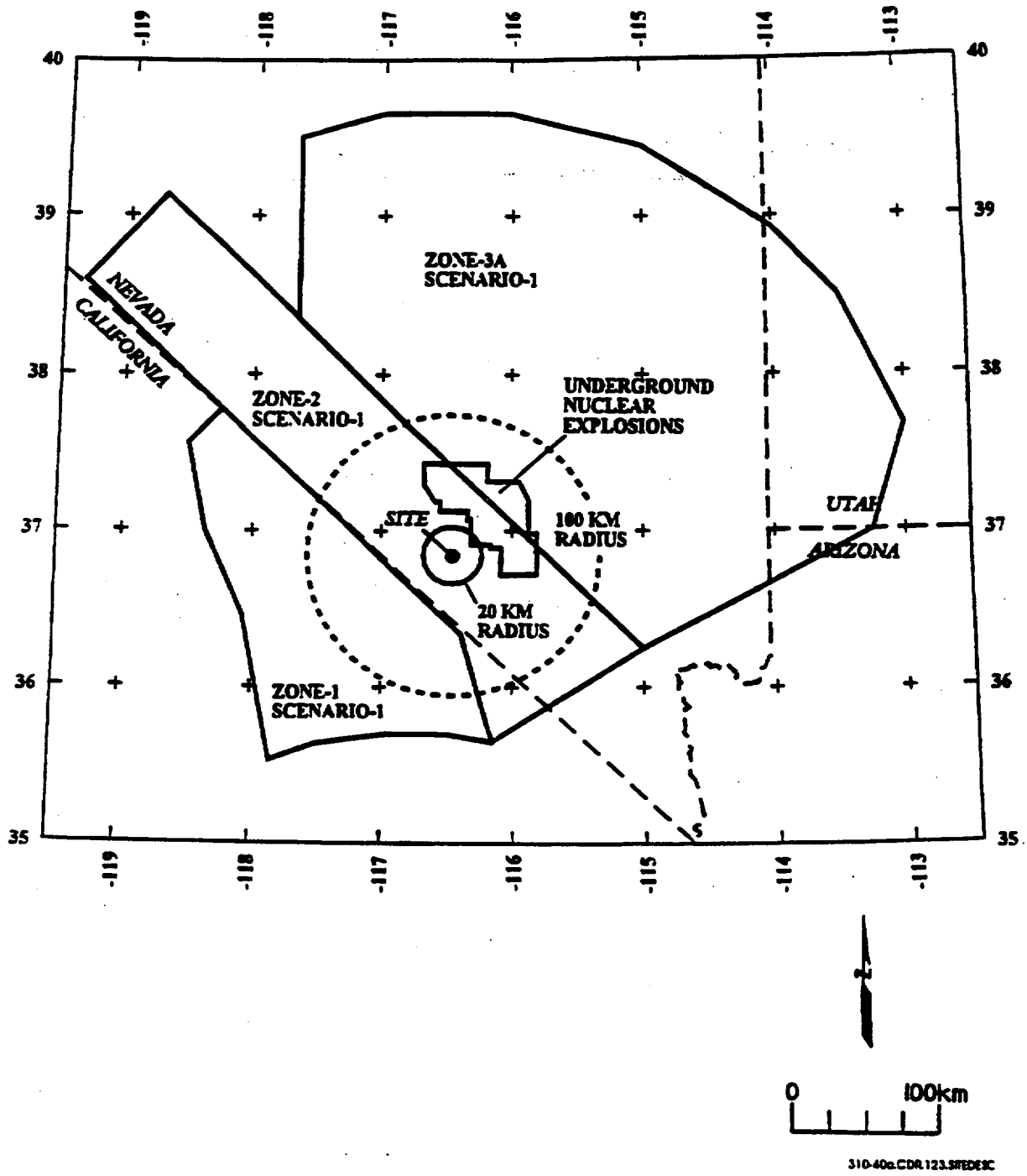


Figure 3.10-40. Alternative Regional Source Zone Models Considered by One of the Seismic Source Expert Teams (from USGS 1998)

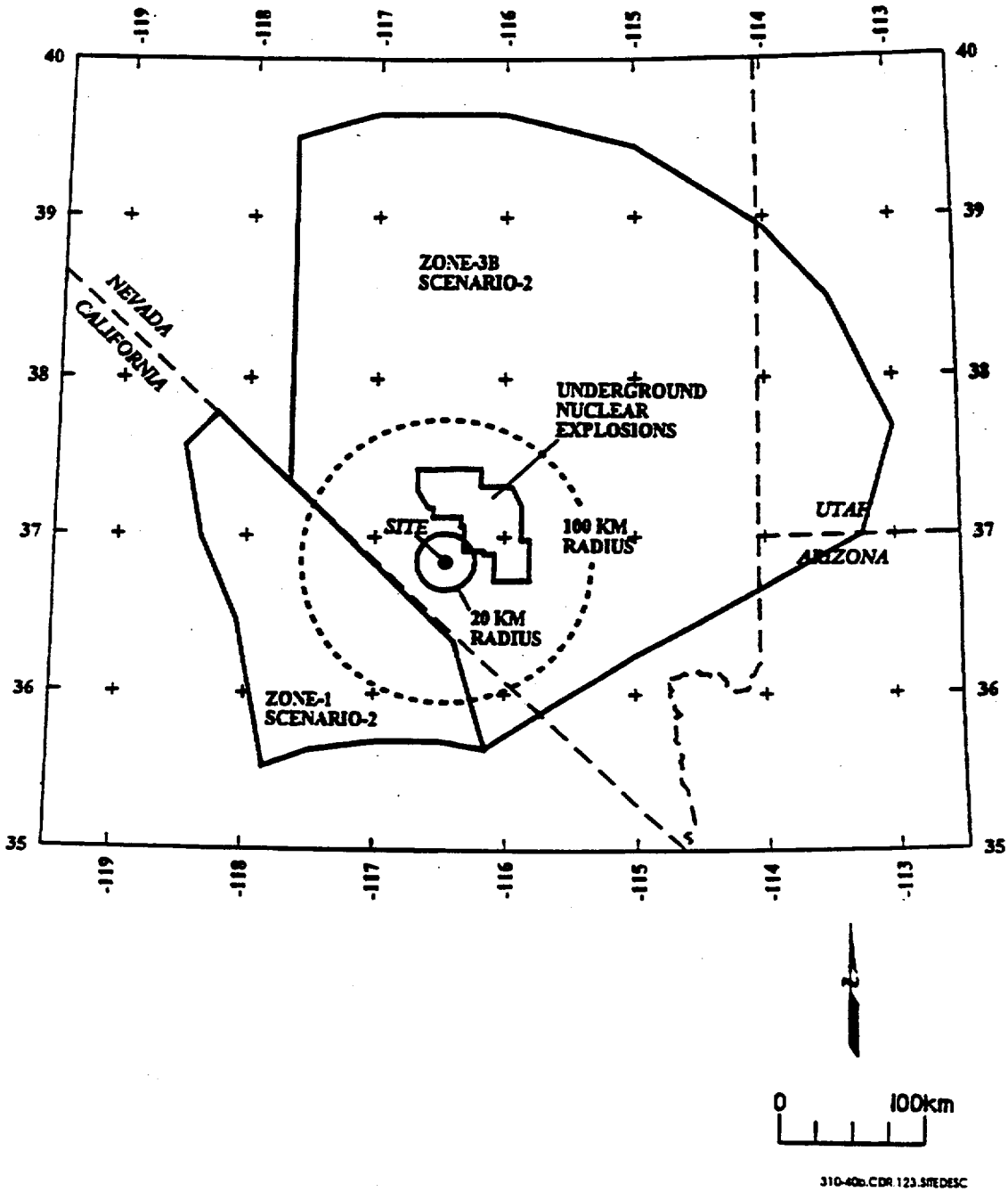


Figure 3.10-40. Alternative Regional Source Zone Models Considered by One of the Seismic Source Expert Teams (from USGS 1998) (Continued)

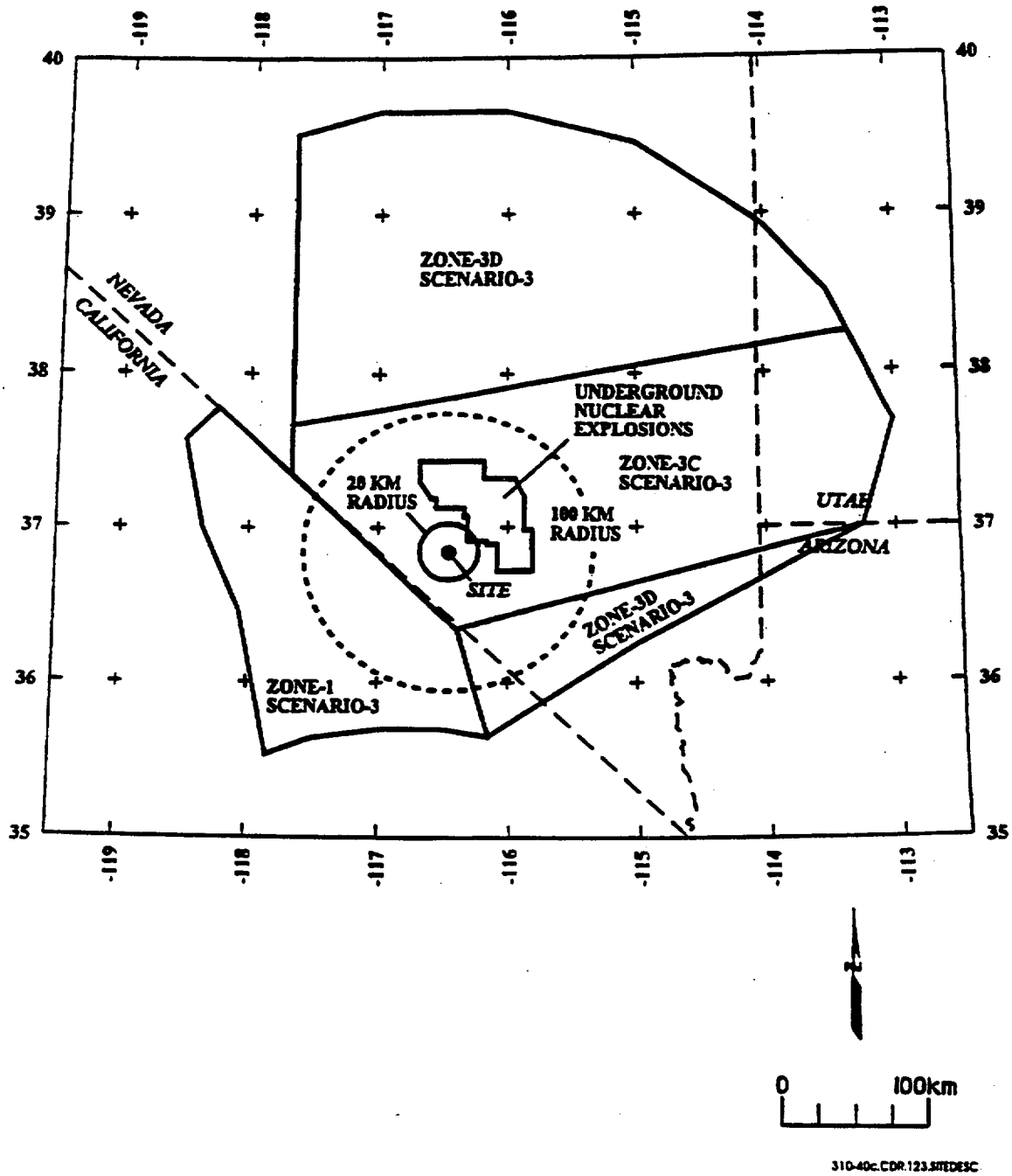
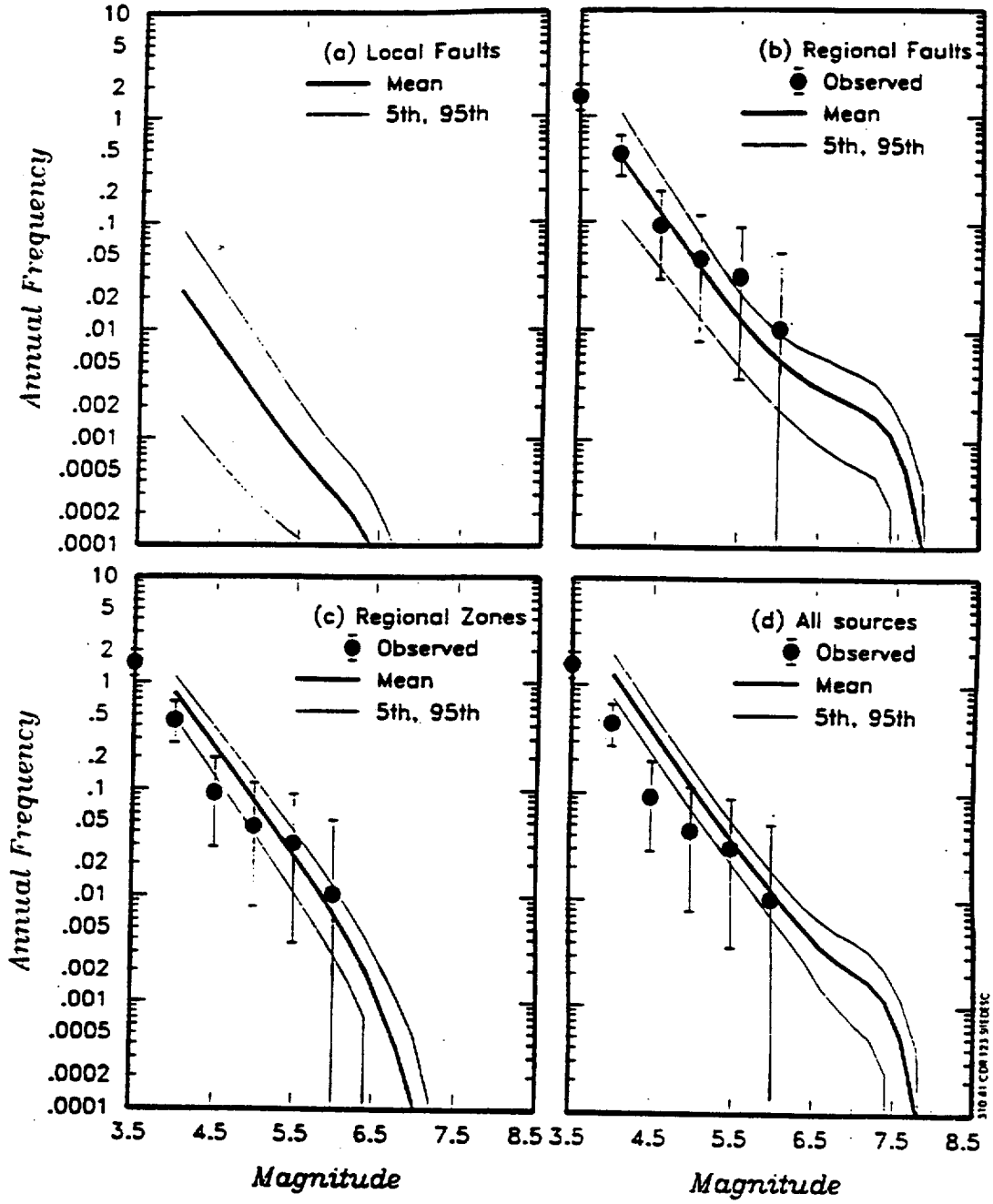
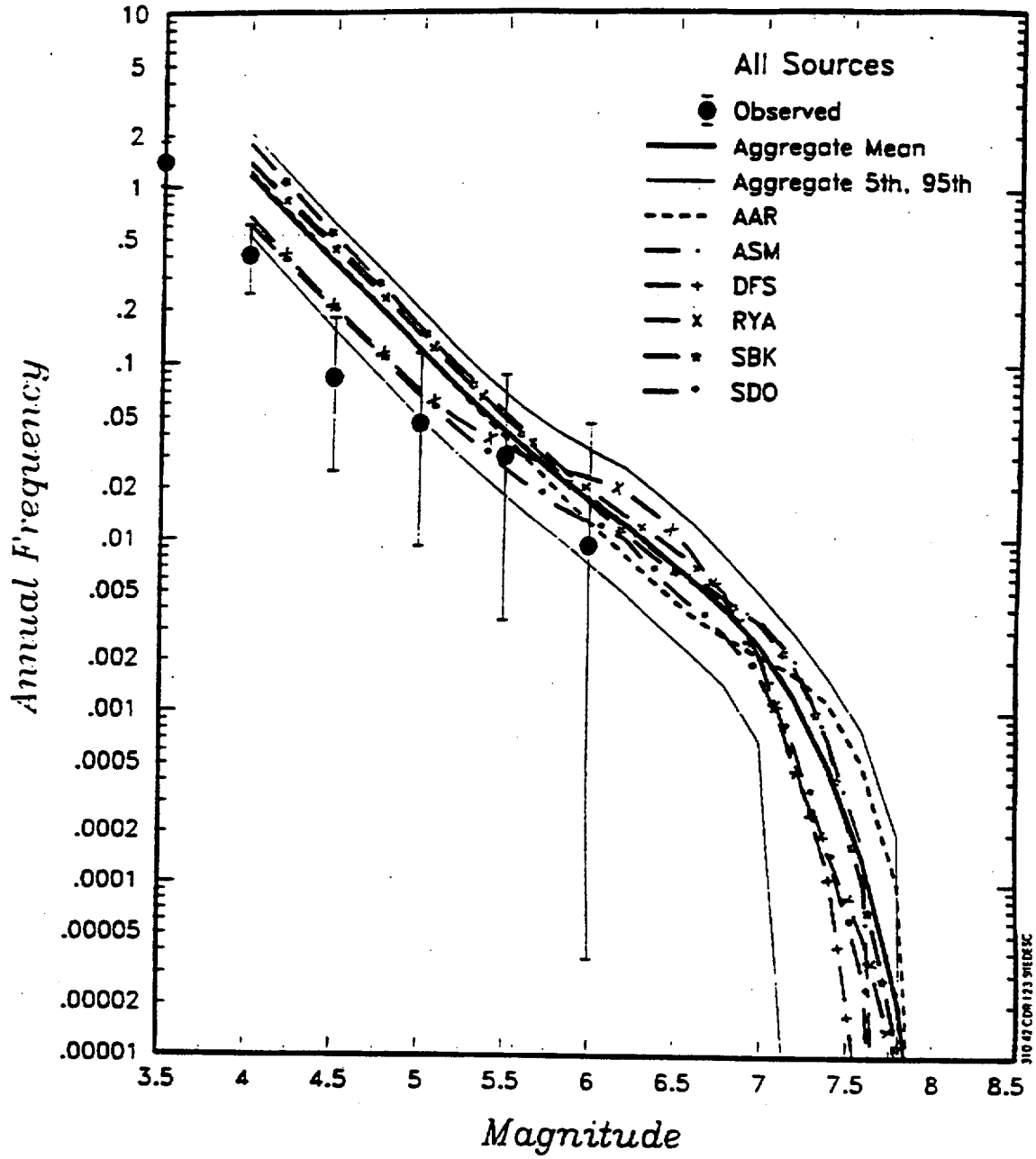


Figure 3.10-40. Alternative Regional Source Zone Models Considered by One of the Seismic Source Expert Teams (from USGS 1998) (Continued)



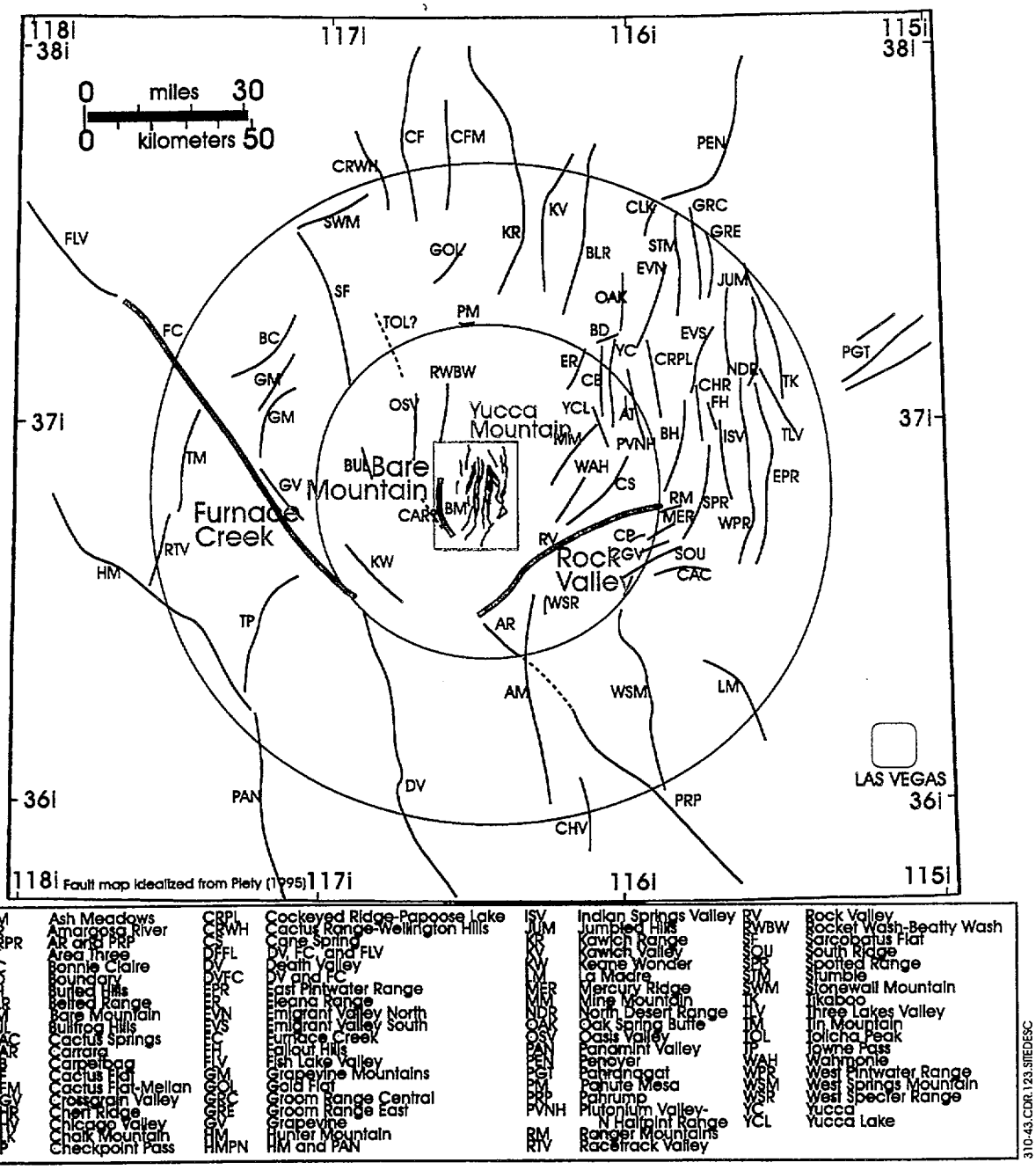
NOTE: The solid dots with vertical error bars represent the observed frequency of earthquakes occurring within 100 km of the Yucca Mountain Site.

Figure 3.10-41. Predicted Mean, 5th, and 95th-Percentile Recurrence Rates for (a) Local Fault Sources, (b) Regional Fault Sources, (c) Regional Source Zones, and (d) All Sources Combined for One of the Seismic Source Expert Teams (from USGS 1998)



NOTE: The solid dots with vertical error bars represent the observed frequency of earthquakes occurring within 100 km of the Yucca Mountain Site.

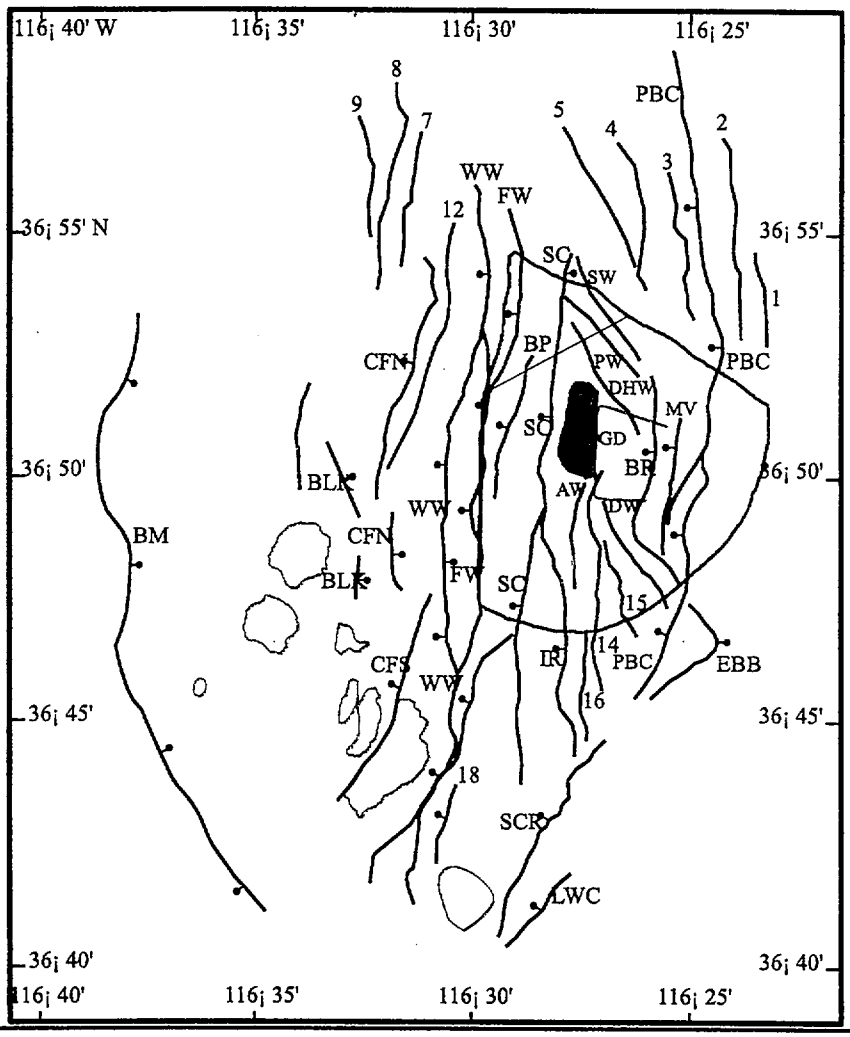
Figure 3.10-42. Predicted Mean, 5th, and 95th-Percentile Recurrence Rates for All Sources Combined and for All Teams Combined Compared to Mean Recurrence Estimates for an Individual Seismic Source Expert Team (from USGS 1998)



AM	Ash Meadows	CRPL	Cockeyed Ridge-Papoose Lake	ISV	Indian Springs Valley	RV	Rock Valley
AR	Amargosa River	CRWH	Cactus Range-Wellington Hills	JUM	Jumbled Hills	RWBW	Rocket Wash-Beatty Wash
ARPR	AR and PRP	CS	Cane Spring	KR	Kawich Range	SF	Sarcobatus Flat
AT	Area Three	DFFL	DV, FC, and FLV	KV	Kawich Valley	SOU	South Ridge
BC	Bonnie Claire	DV	Death Valley	KW	Keane Wonder	SPR	Spotted Range
BD	Boundary	DVFC	DV and FC	LM	La Madre	STM	Stumble
BH	Buried Hills	EPR	East Pintwater Range	MER	Mercury Ridge	SWM	Stonewall Mountain
BLR	Belted Range	ER	Eleana Range	MM	Mine Mountain	TK	Tikaboo
BM	Bare Mountain	EVN	Emigrant Valley North	NDR	North Desert Range	TLV	Three Lakes Valley
BUL	Bullfrog Hills	EVS	Emigrant Valley South	OAK	Oak Spring Butte	TM	Tin Mountain
CAC	Cactus Springs	FC	Furnace Creek	OSV	Oasis Valley	TOL	Tolicha Peak
CAR	Carrara	FH	Fallout Hills	PAN	Panamint Valley	TP	Towne Pass
CB	Carpetbag	FLV	Fish Lake Valley	PEN	Penoyer	WAH	Wahmonie
CF	Cactus Flat	GM	Grapevine Mountains	PGT	Pahranagat	WPR	West Pintwater Range
CFM	Cactus Flat-Mellan	GOL	Gold Flat	PM	Panute Mesa	WSM	West Springs Mountain
CGV	Crossgrain Valley	GRC	Groom Range Central	PRP	Pahrump	WSR	West Specter Range
CHR	Chert Ridge	GRE	Groom Range East	PVNH	Plutonium Valley-N Halfpint Range	YC	Yucca
CHV	Chicago Valley	GV	Grapevine	RM	Ranger Mountains	YCL	Yucca Lake
CLK	Chalk Mountain	HM	Hunter Mountain	RTV	Racetrack Valley		
CP	Checkpoint Pass	HMPN	HM and PAN				

310-43.CDR.123.SITEDESC

Figure 3.10-43. Faults Within an Approximate 100 km Radius of Yucca Mountain Considered in the Deterministic Seismic Hazard Analysis



EXPLANATION

Faults Ð Ball and bar on downthrown side

Approximate Potential Repository Area and Exploratory Studies Facility

Controlled Area Boundary

Quaternary and Late Tertiary Volcanic Centers

N

0 miles 3

0 km 5

Fault Lengend

Abbreviation	Fault Name	Abbreviation	Fault Name
AW	Abandoned Wash	1	Simonds Number 1
BLK	Black Cone	2	Simonds Number 2
BM	Bare Mountain	3	Simonds Number 3
BP	Boomerang Point	4	Simonds Number 4
BR	Bow Ridge	5	Simonds Number 5
CFN	Crater Flat North	7	Simonds Number 7
CFS	Crater Flat South	8	Simonds Number 8
DHW	Drill Hole Wash	9	Simonds Number 9
DW	Dune Wash	12	Simonds Number 12
EBB	East Busted Butte	14	Simonds Number 14
FW	Fatigue Wash	15	Simonds Number 15
IR	Iron Ridge	16	Simonds Number 16
LWC	Lathrop Wells Cone	18	Simonds Number 18
GD	Ghost Dance	SC	Solitario Canyon
MV	Midway Valley	SCR	Stagecoach Road
PW	Pagany Wash	SD	Sundance
PBC	Paintbrush Canyon	WW	Windy Wash
SW	Sever Wash		

310-44.CDR.123.SITEDESC

NOTE: Three additional faults including the Bare Mountain Fault which were beyond 5 km were also included in the analysis.

Figure 3.10-44. Local Faults Within the Controlled Area and Within 5 km of the Controlled Area Boundary Considered in the Deterministic Seismic Hazard Analysis

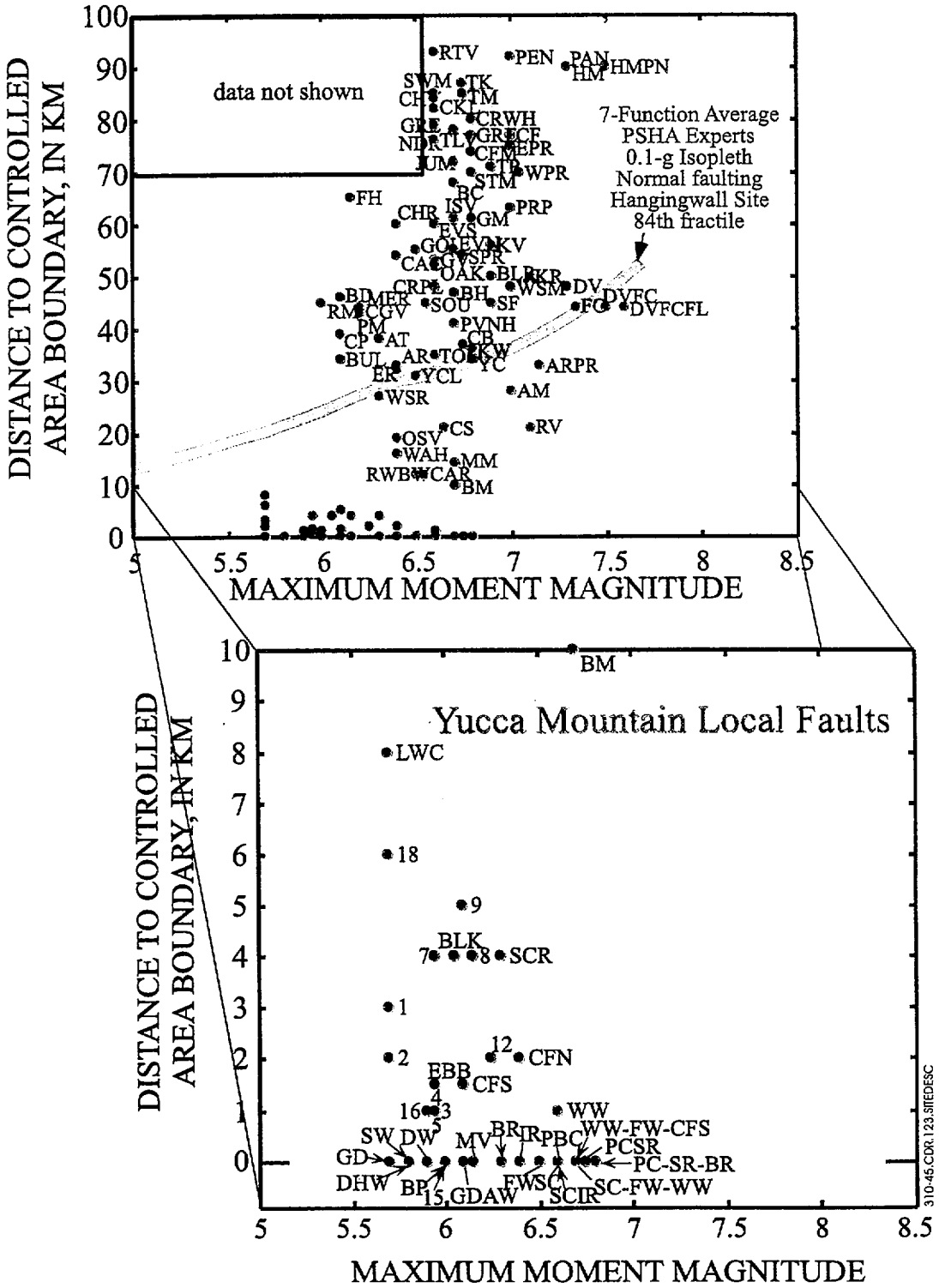
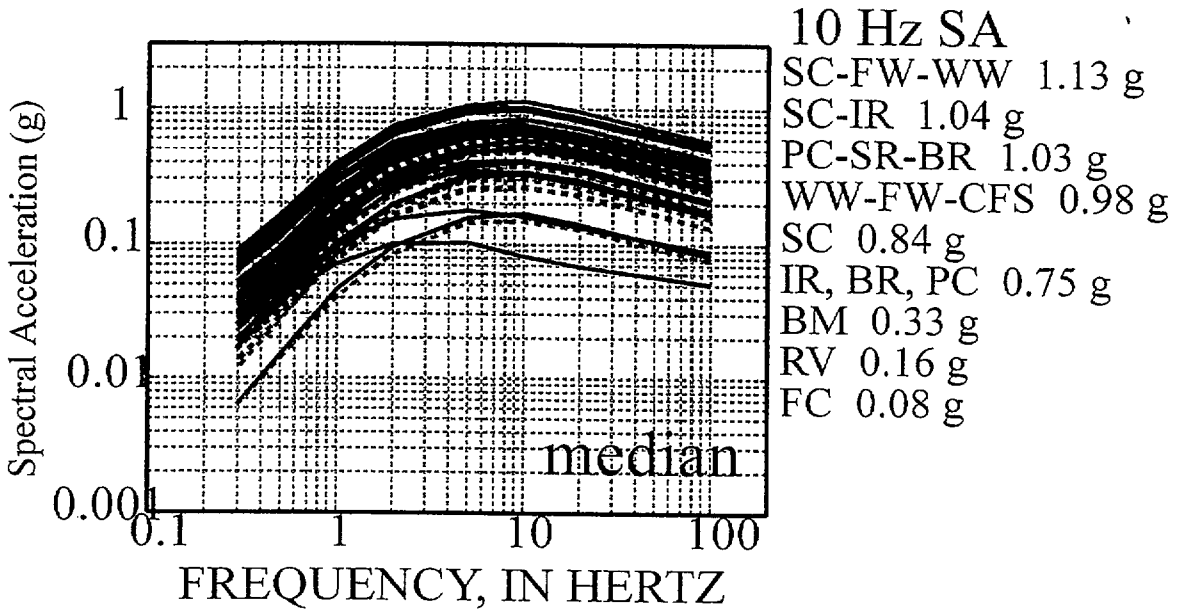
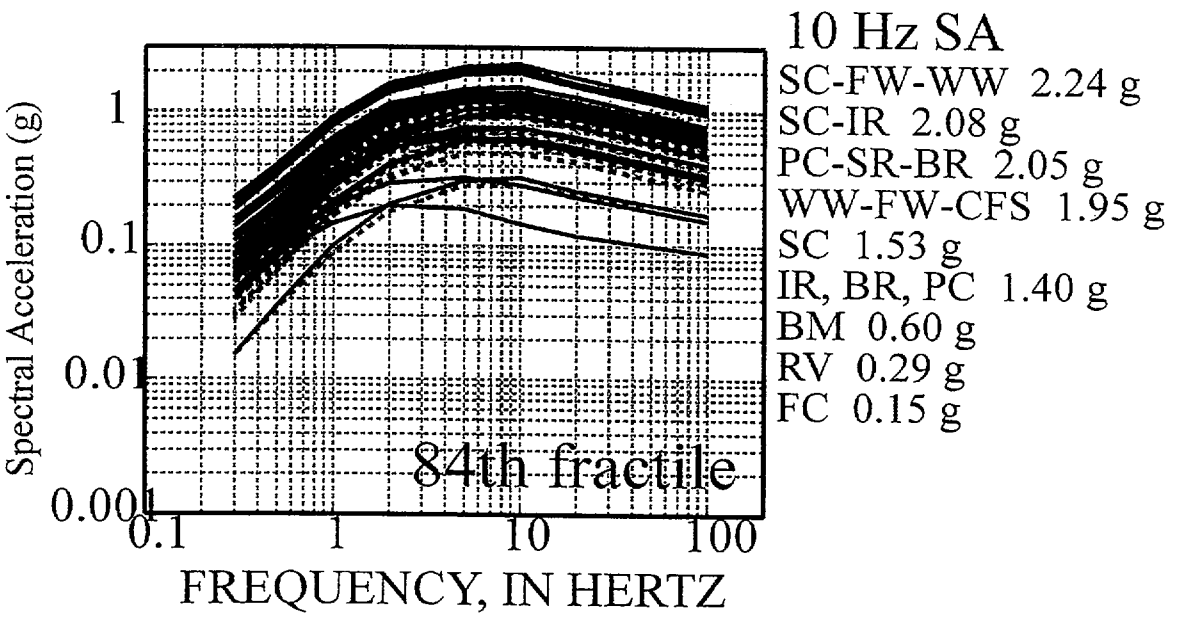


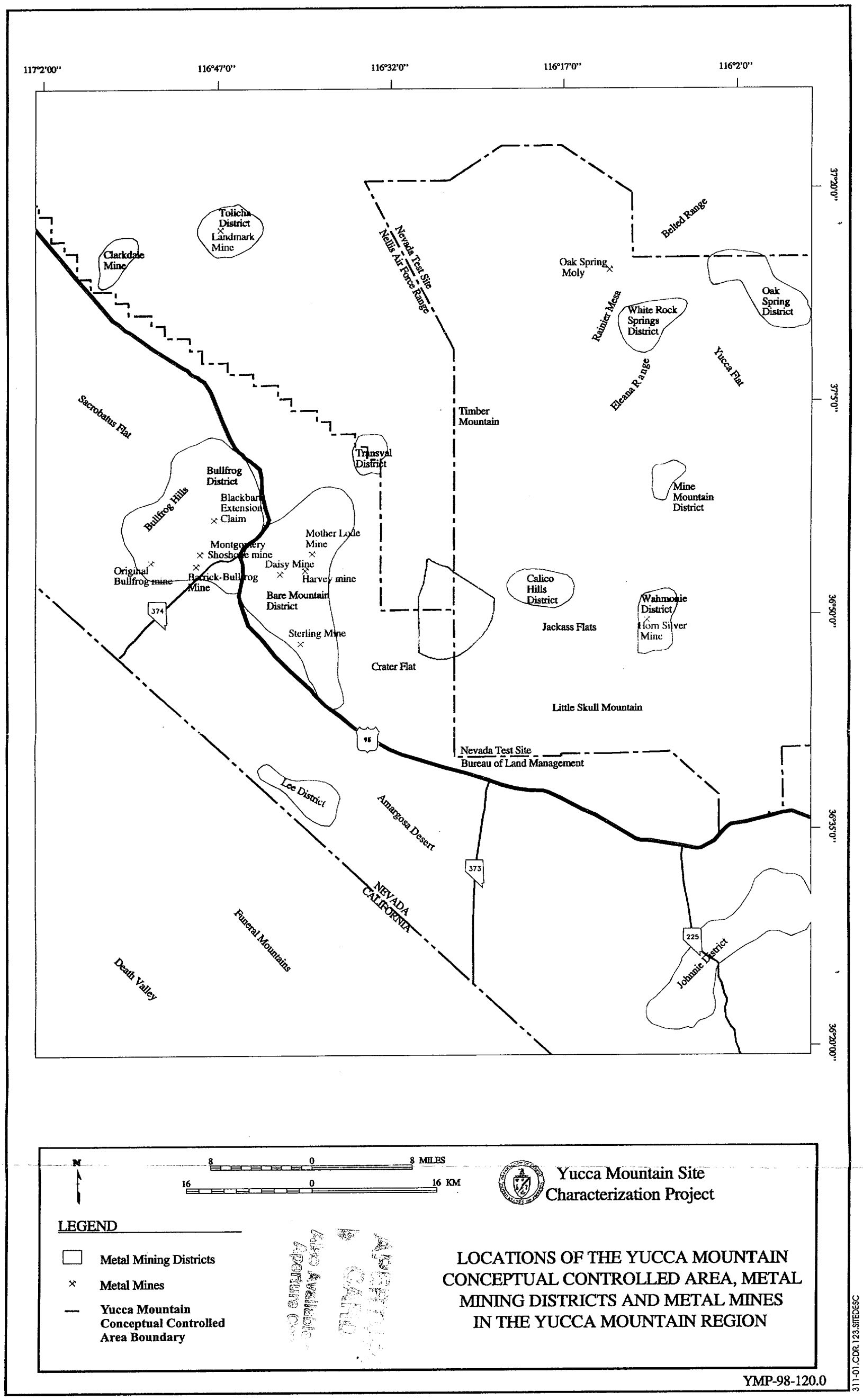
Figure 3.10-45. Deterministic Maximum Magnitudes in Relation to Minimum Distance to the Controlled Area Boundary For Fault Sources Within 100 km of the Yucca Mountain Site





310-46.CDR 123 SITEDESC

Figure 3.10-46. Acceleration Response Spectra for 38 Local and 3 Selected Regional Deterministic Earthquakes at the Median (50th) and 84th Fractiles

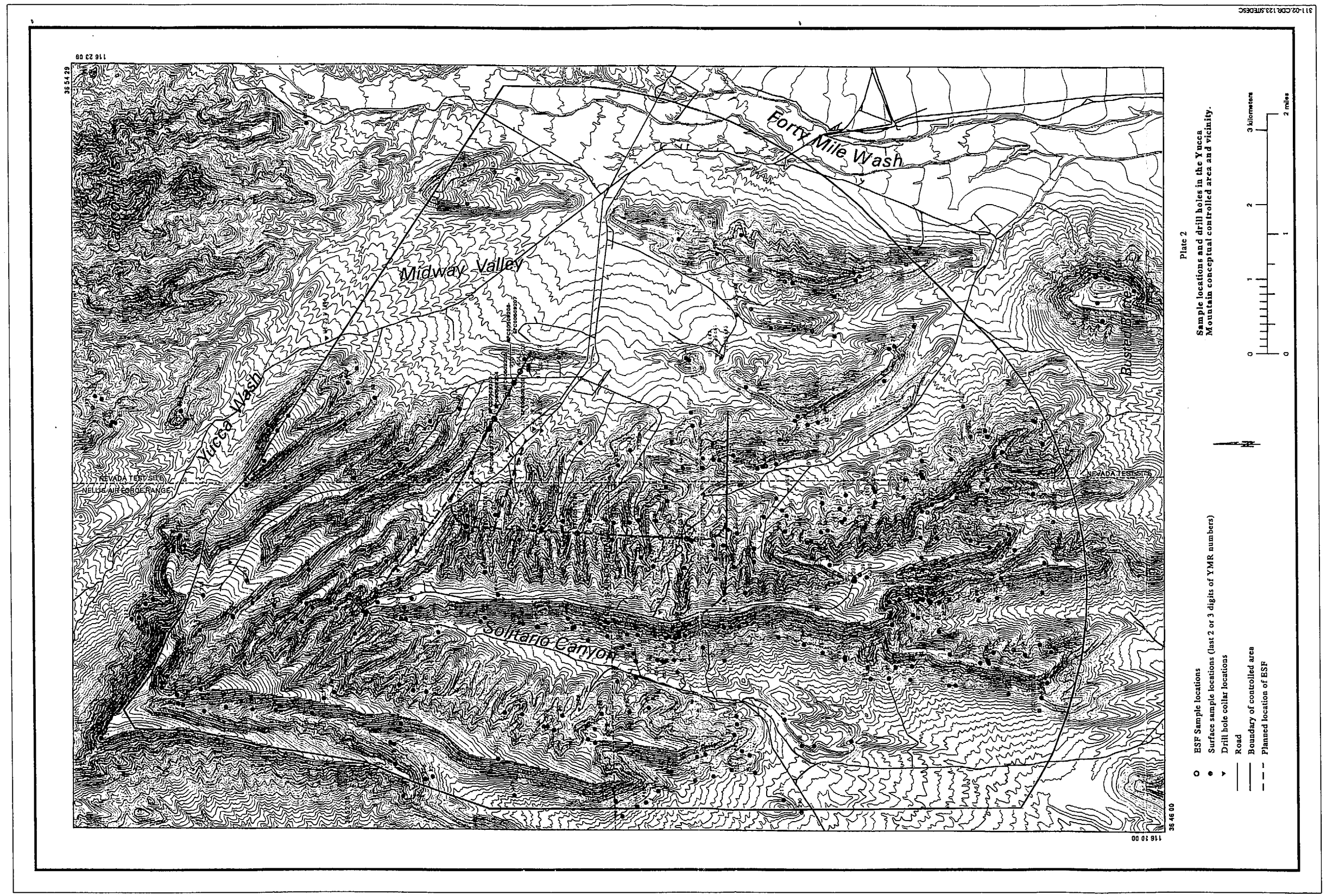


NOTE: Castor, S.B., Garside, L.J., Tingley, J.V., LaPointe, D.D., Desilets, M.O., Hsu, Liang-Ch, Goldstrand, P.M., in preparation 1997, Assessment of Metallic and Mined Energy Resources in the Yucca Mountain Conceptual Controlled Area, Nye County, Nevada. Published at Reno, Nevada, Nevada Bureau of Mines and Geology, (Deliverable UNR2M or SPT7CM4 T Department of Energy), 204p. Appendices; Plates.

Figure 3.11-1. Locations of the Yucca Mountain Conceptual Control Area, Metal Mining Districts, and Metal Mines in the Yucca Mountain Region

09020400 45 - 17

INTENTIONALLY LEFT BLANK



Castor, S.B., Garside, L.J., Tingley, J.V., LaPointe, D.D., Desilets, M.O., Hsu, Liang-Ch, Goldstrand, P.M., in preparation 1997, Assessment of Metallic and mined energy resources in the Yucca Mountain Conceptual controlled Area, Nye County, Nevada. Nevada Bureau of Mines and Geology, (Deliverable UNR2M or SPT7CM4 to M&O), 204p. Appendices, Plates.

APERTURE CARD
Also Available on Aperture Card

Figure 3.11-2. Sample Locations and Drill Holes in the YMCCA and Vicinity

9902040045-18

INTENTIONALLY LEFT BLANK

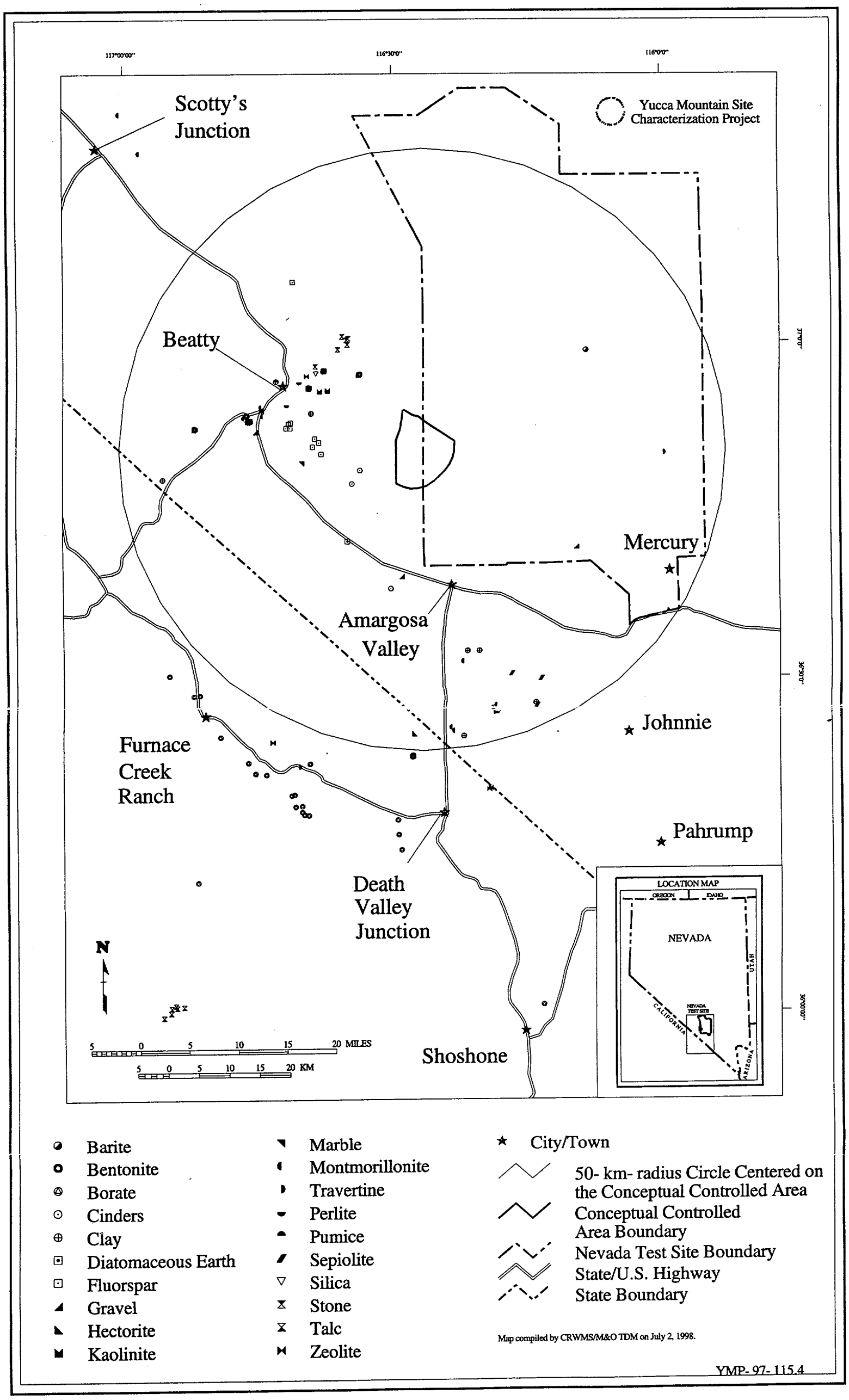
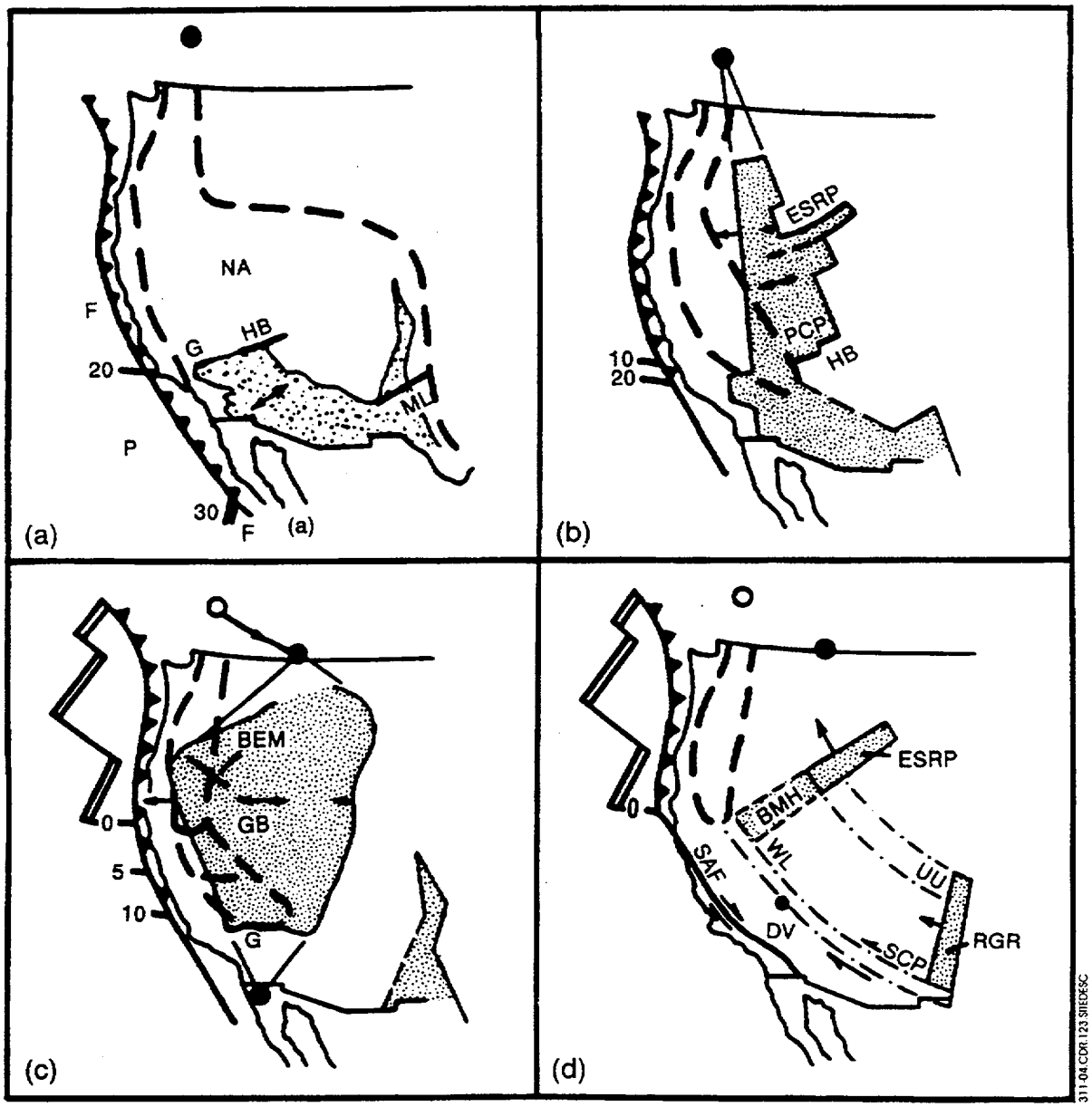


Figure 3.11-3. Industrial Mineral Occurrences in the Great Basin Vicinity of Yucca Mountain (Sherlock et al. 1996)

APERTURE CARD
Also Available on Aperture Card

9902040045 - 19

INTENTIONALLY LEFT BLANK



NOTE: Individual figures represent the following blocks of time: a. 30 to 20 million years ago; b. 20 to 10 million years ago; c. 10 million years ago to the present; and d. 7 million years ago to present. Toothed lines identify convergent plate boundaries and dashes lines, boundaries of volcanic arcs. The Mendocino triple junction is located at the intersection of the trench and the short, solid lines labeled 20, 10 5 and 0 million years. Stippling identifies approximate areas of active extension for each period; that of the period 30 to 20 million years ago was characterized by plastic stretching of the middle crust, hence the use of different stripple pattern. Labeled lines are postulated transform structures. Rifts and other features are also labeled. GB identifies the north-centeral Great Basin; SA, the San Andreas fault; RGR, the Rio Grande rift; BMH, The Battle Mountain High, and DV, the Death Valley, California region. Double-headed arrows show interpreted directions of quasi-rigid of stiff-plastic subplate rotations. Long arrows qualitatively indicate relatively greater total movement than short ones in diagrams b. c, and d. Solid dots mark locations of interpreted poles of opening. The open circle marks an abondoned pole location.

Figure 3.11-4. Schematic Diagram Showing Tectonic Evolution of Extension in the Continental Western United States

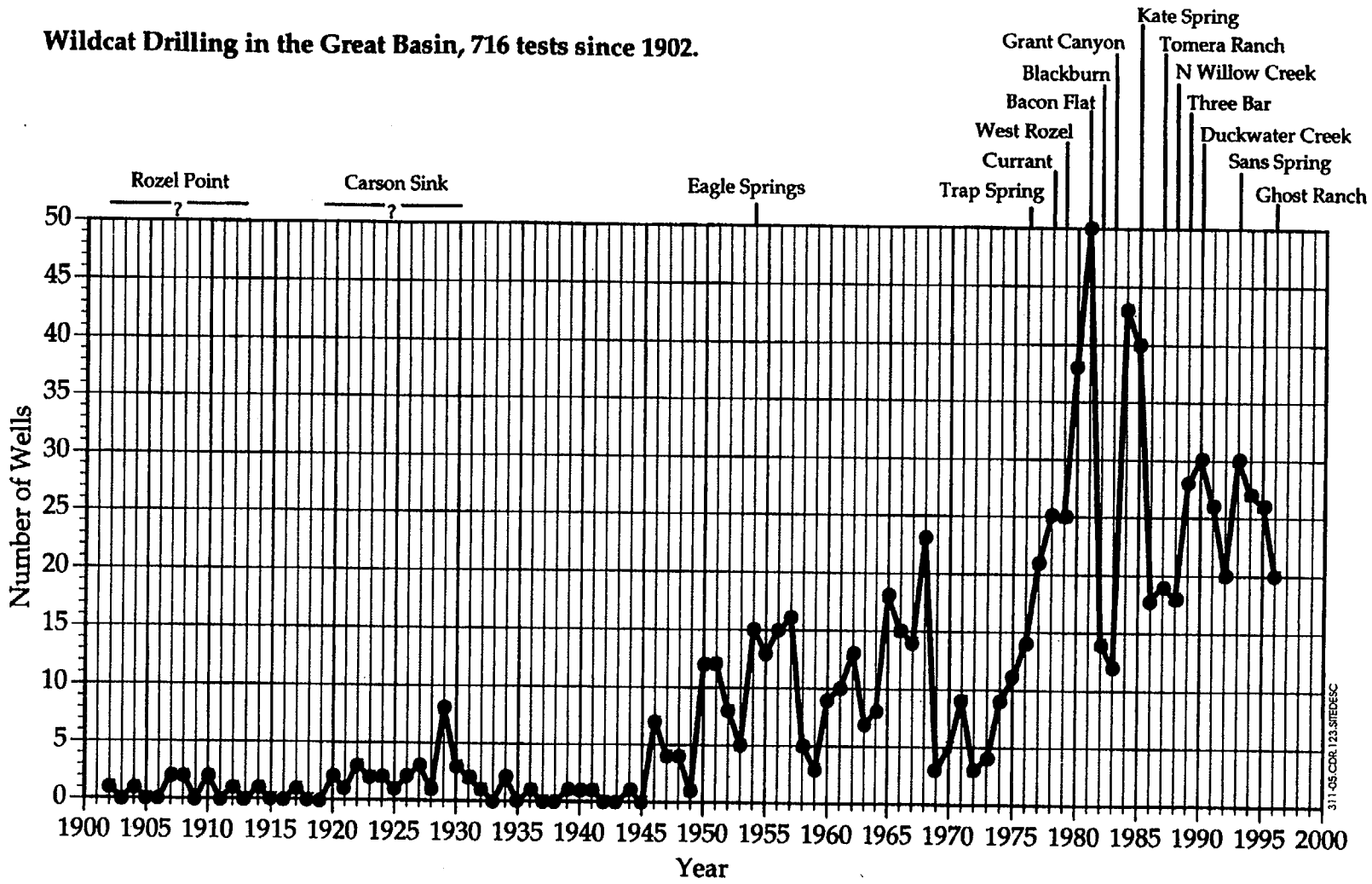
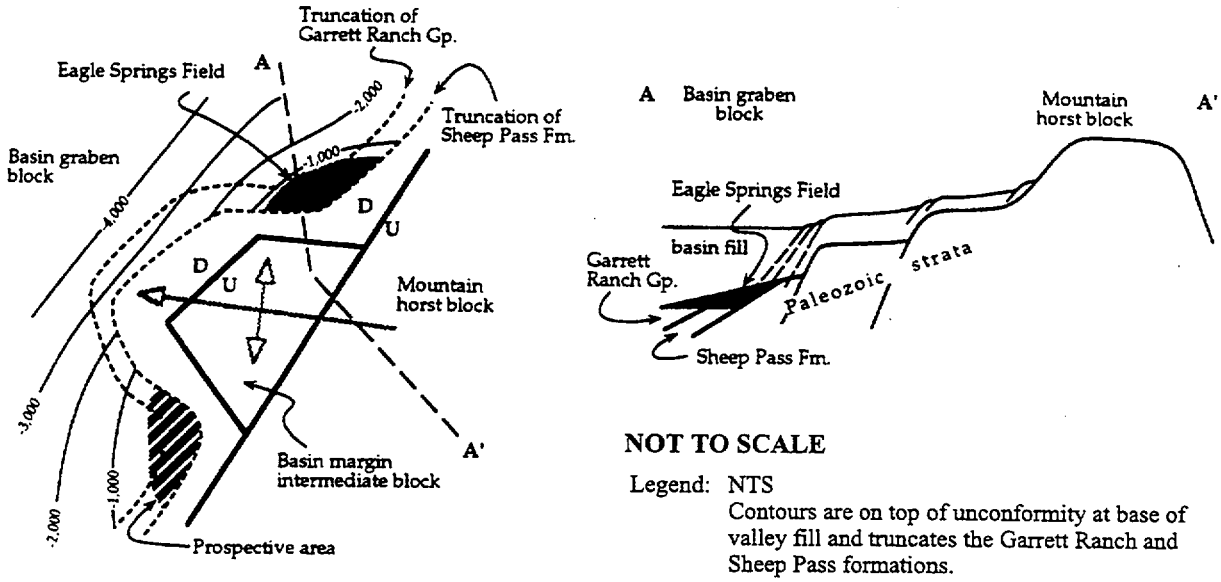


Figure 3.11-5. Wildcat Drilling in the Great Basin Since 1900 (D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press)

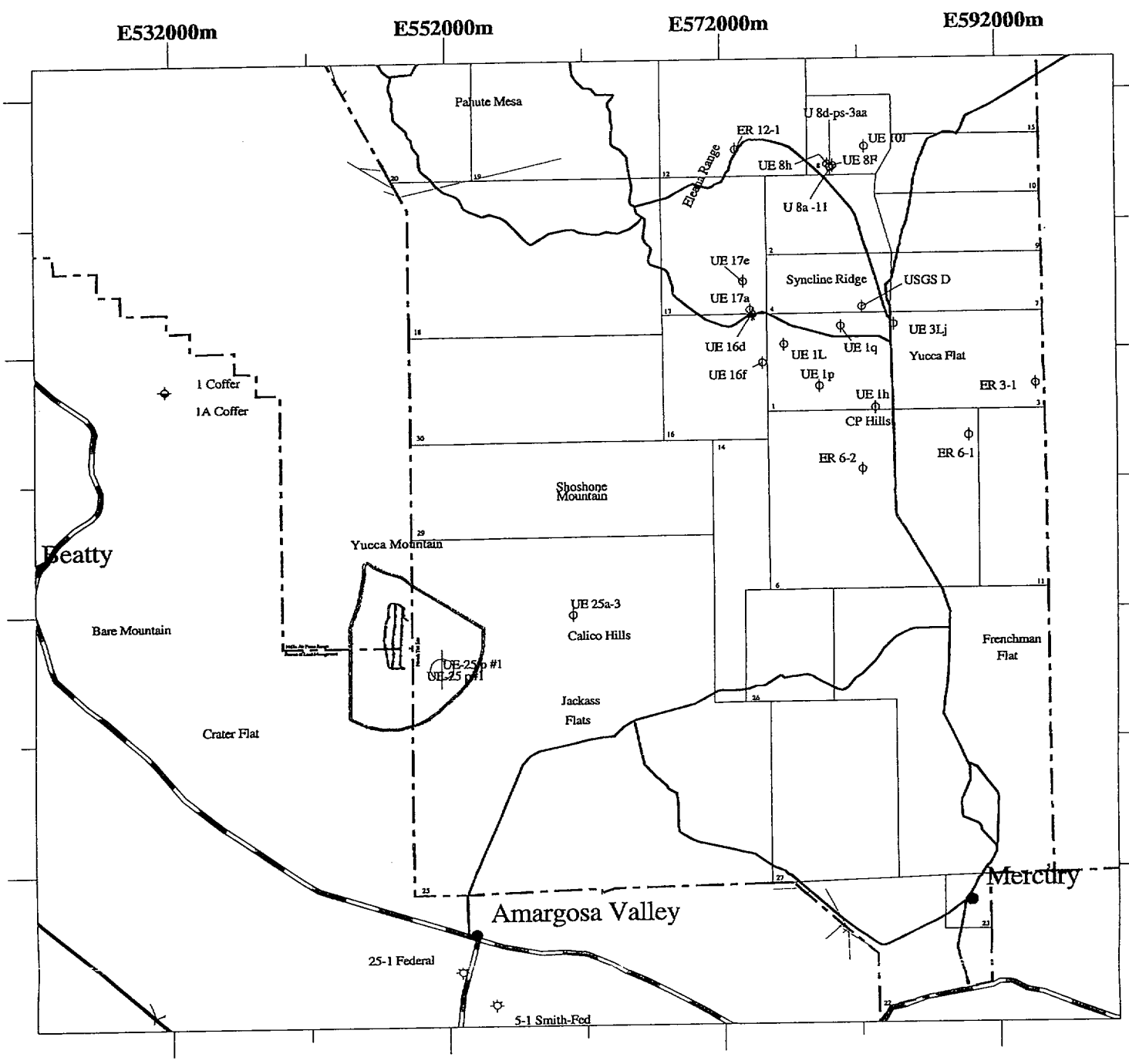


Legend: NTS Contours are on top of unconformity at base of valley fill and truncates the Garrett Ranch and Sheep Pass formations.

NOTE: The exploration project that led to the discovery of Trap Spring Field was based on the origin and habitat of oil at Eagle Springs Field. There, oil from Tertiary-age source rocks is produced from Tertiary-age reservior rocks in a Neogene fault-block trap. Basin-margin intermediate fault blocks were not considered prospective because requisite source and reservoir strata were eroded from them. Subsequent exploration found that the intermediate fault blocks contain accumulations and that excellent source and reservoir rocks are in the Paleozoic section (after Foster 1979, p. 479)

Figure 3.11-6. The "Eagle Springs" Exploration Model (D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press)

INTENTIONALLY LEFT BLANK



Locations of Oil and Gas Wells obtained from: Arizona Oil and Gas Conservation Commission; California Division of Oil, Gas, and Geothermal Energy; Nevada Bureau of Mines and Geology; Utah Division of Oil, Gas, and Mining

NTS borehole locations obtained from The Nevada Test Site Drilling and Mining Summary.

Road features obtained from 1:100,000 scale TIGER/line Precensus Files, 1990, United States Bureau of Census.

City locations were obtained from the 1990 Census of Population and Housing Summary Tape File 1A on CD-ROM, U.S. Dept. of Commerce Economics and Statistics Administration, Bureau of the Census.

Projection is Universal Transverse Mercator, Zone 11. Coordinates are displayed in meters.

Map compiled by CRWMS M&O/TDM on August 27, 1997.

PRELIMINARY - INFORMATION ONLY: YAP-SIII.3Q, Section 5.2.2 states that, "The data provided herein have not received complete technical and quality checks and, therefore are considered to be preliminary. These data are for information only and cannot be used for licensing activities..."

Yucca Mountain Site Characterization Project

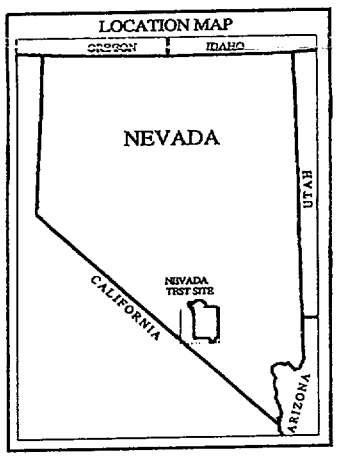
N

INDEX MAP
OF
YUCCA MOUNTAIN AREA

5 0 5 10 15 MILES

5 0 5 10 15 20 KM

LOCATION MAP



Legend

- Undrilled Locations
- Core Holes
- Dry Hole
- Dry Hole, Oil Show
- Dry Hole, Gas Show
- Dry Hole, Oil and Gas Show
- U.S. and State Highway
- Selected Road
- Administrative Boundary
- State Boundary
- Conceptual Controlled Area

YMP- 97- 122.3

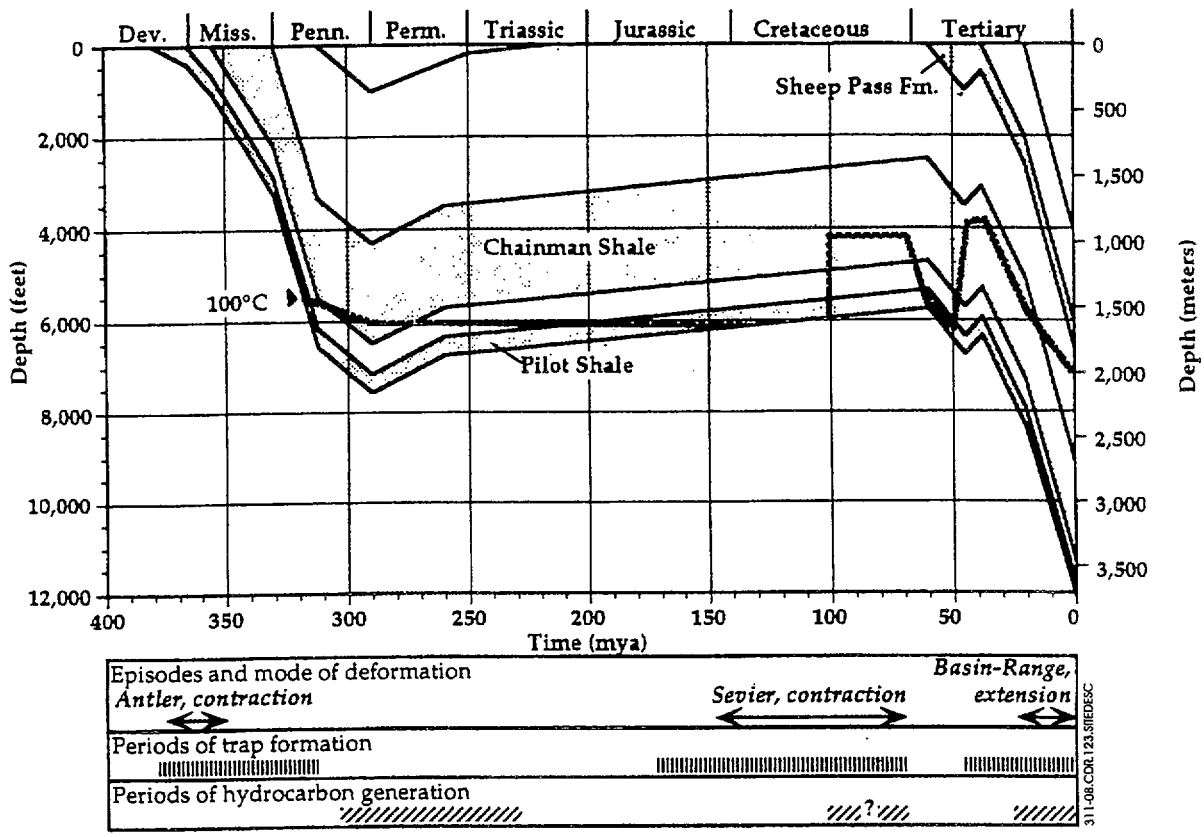
311-07.CDR.123.SITEDESC

Figure 3.11-7 Location of Wells in the Vicinity of the Yucca Mountain Site Reviewed for Hydrocarbon Potential

APERTURE CARD
Also Available on Aperture Card

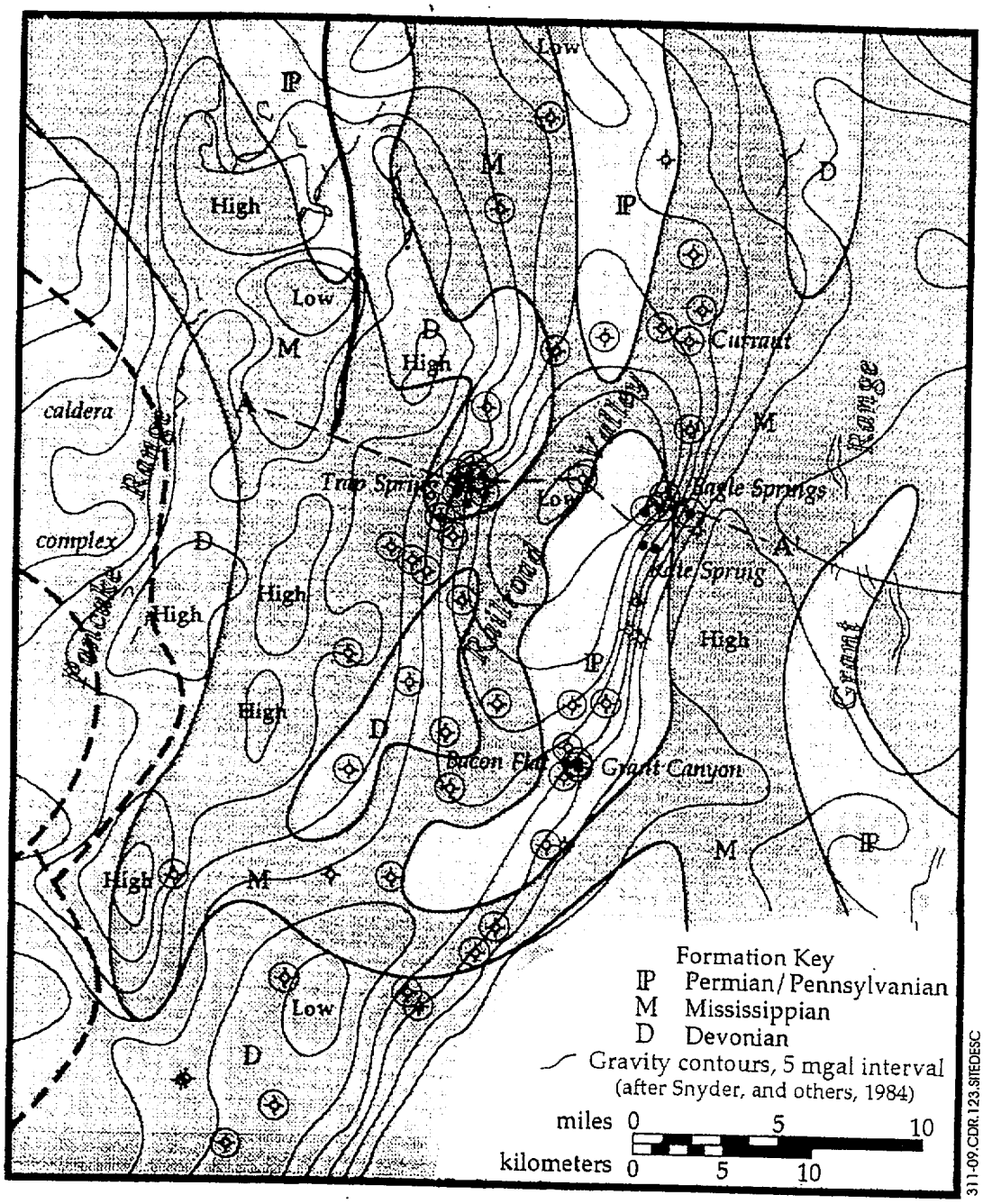
9902040045 - 20

INTENTIONALLY LEFT BLANK



NOTE: From D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press.

Figure 3.11-8. Burial and Generation History of the Source Rocks of the Railroad Valley Area



NOTE: From D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press.

Figure 3.11-9. Paleogeologic Map of Railroad Valley, Beginning of Oligocene Time

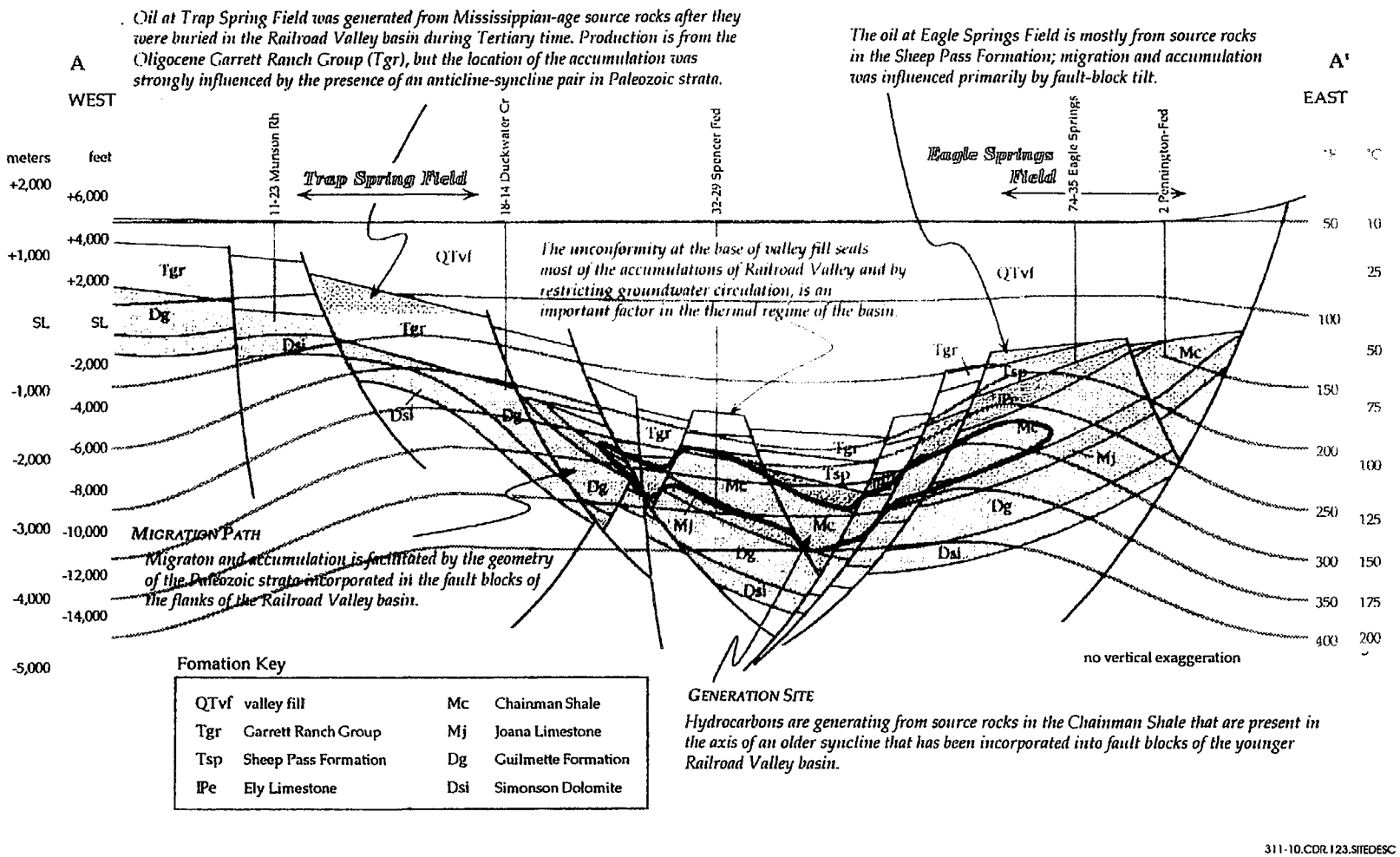
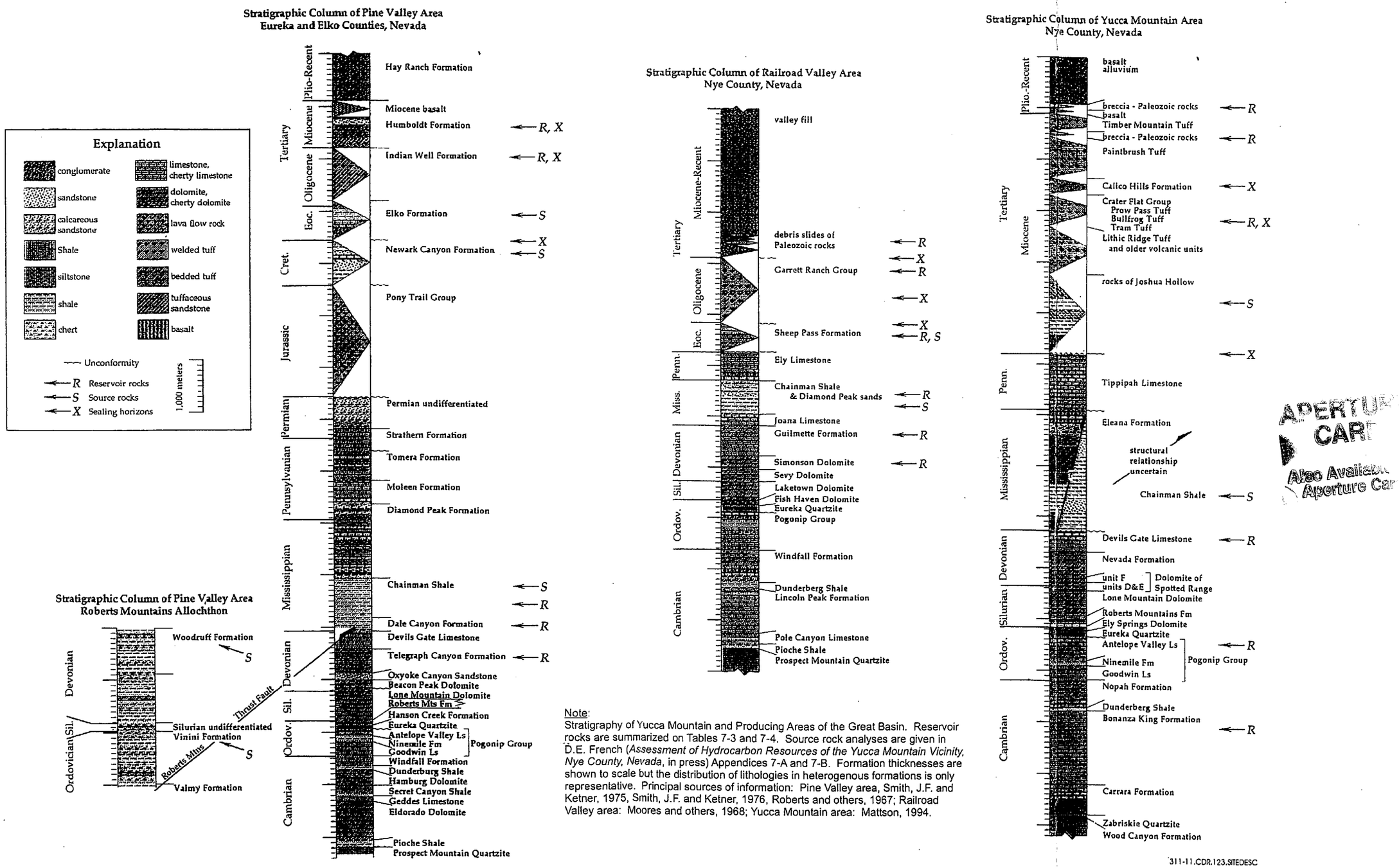


Figure 3.11-10. Cross-Section of the Railroad Valley Basin with the Geothermal Regime

INTENTIONALLY LEFT BLANK



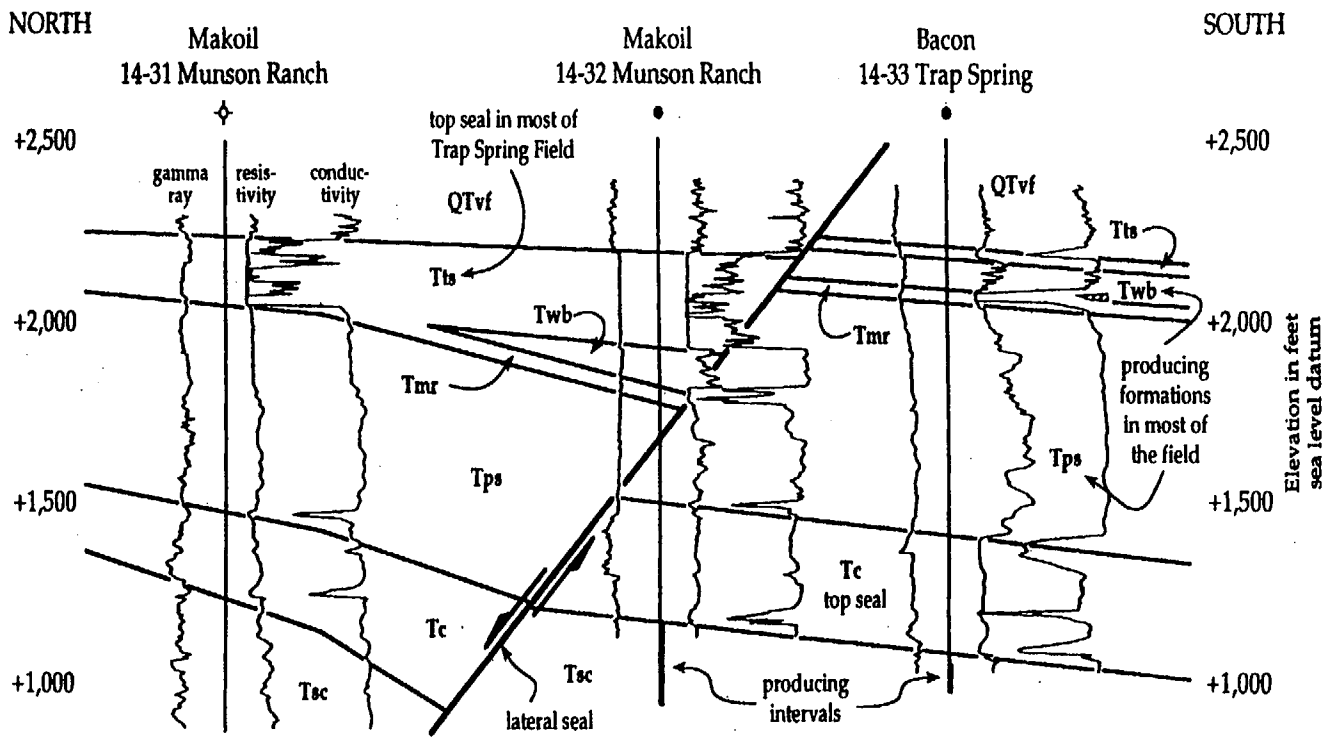
Note:
Stratigraphy of Yucca Mountain and Producing Areas of the Great Basin. Reservoir rocks are summarized on Tables 7-3 and 7-4. Source rock analyses are given in D.E. French (*Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press) Appendices 7-A and 7-B. Formation thicknesses are shown to scale but the distribution of lithologies in heterogenous formations is only representative. Principal sources of information: Pine Valley area, Smith, J.F. and Ketner, 1975, Smith, J.F. and Ketner, 1976, Roberts and others, 1967; Railroad Valley area: Moores and others, 1968; Yucca Mountain area: Mattson, 1994.

Figure 3.11-11 Stratigraphy of Yucca Mountain and Producing Areas of the Great Basin

APERTURE CARD
Also Available on Aperture Card

9902040045 - 21

INTENTIONALLY LEFT BLANK



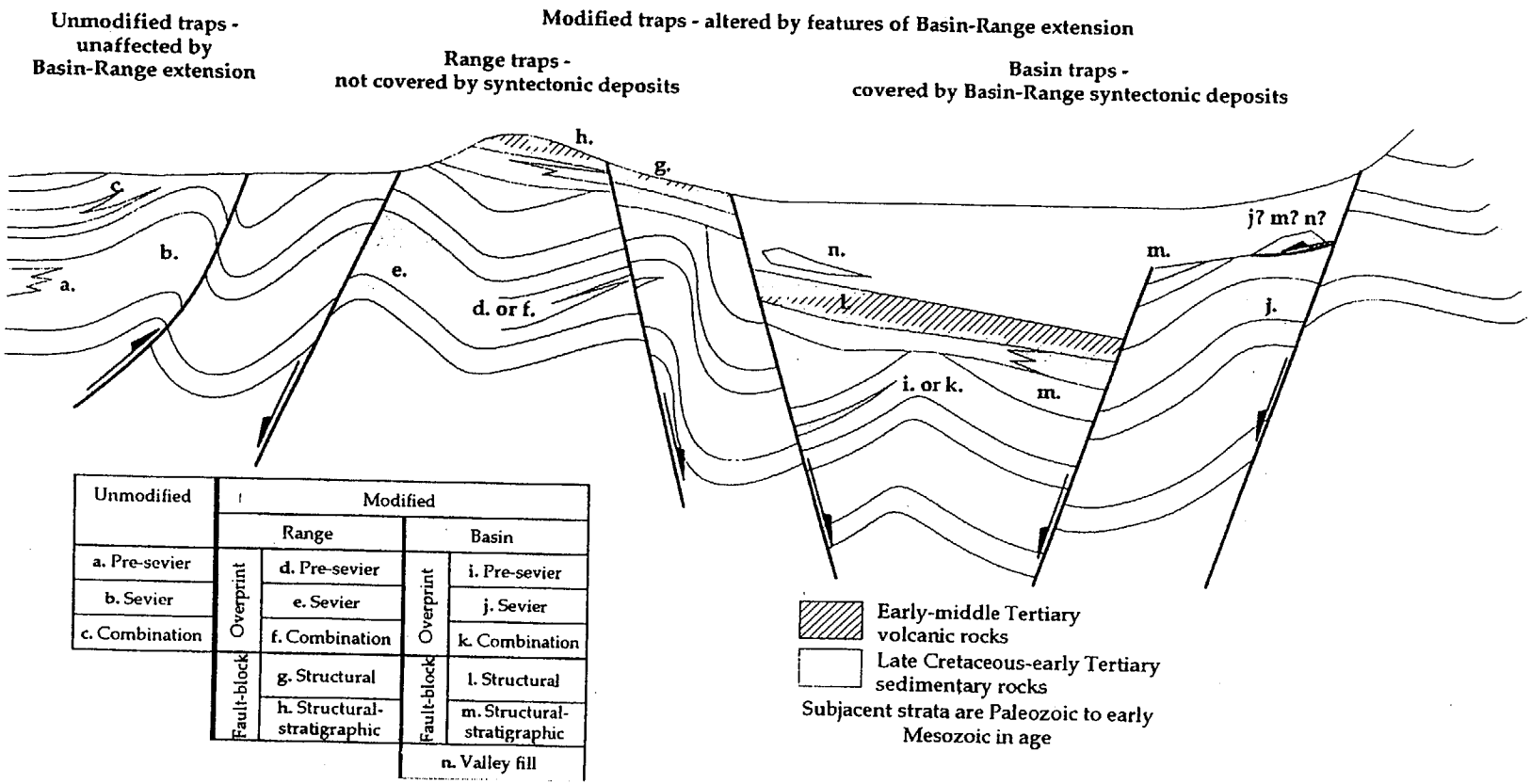
Abbreviation Key

QTvf valley fill
Garrett Ranch Group
- Tts Trap Spring caprock of altered tuff
- Twb Windous Butte Formation
- Tmr Tuff of Munson Ranch
- Tps Tuff of Pritchards Station
- Tc Currant Tuff
- Tsc Stone Cabin Formation

0 500 FEET
0 100 METERS

311-12.CDR.123.SITEDESC

Figure 3.11-12. Cross-Section Through Part of Trap Spring Field, Railroad Valley

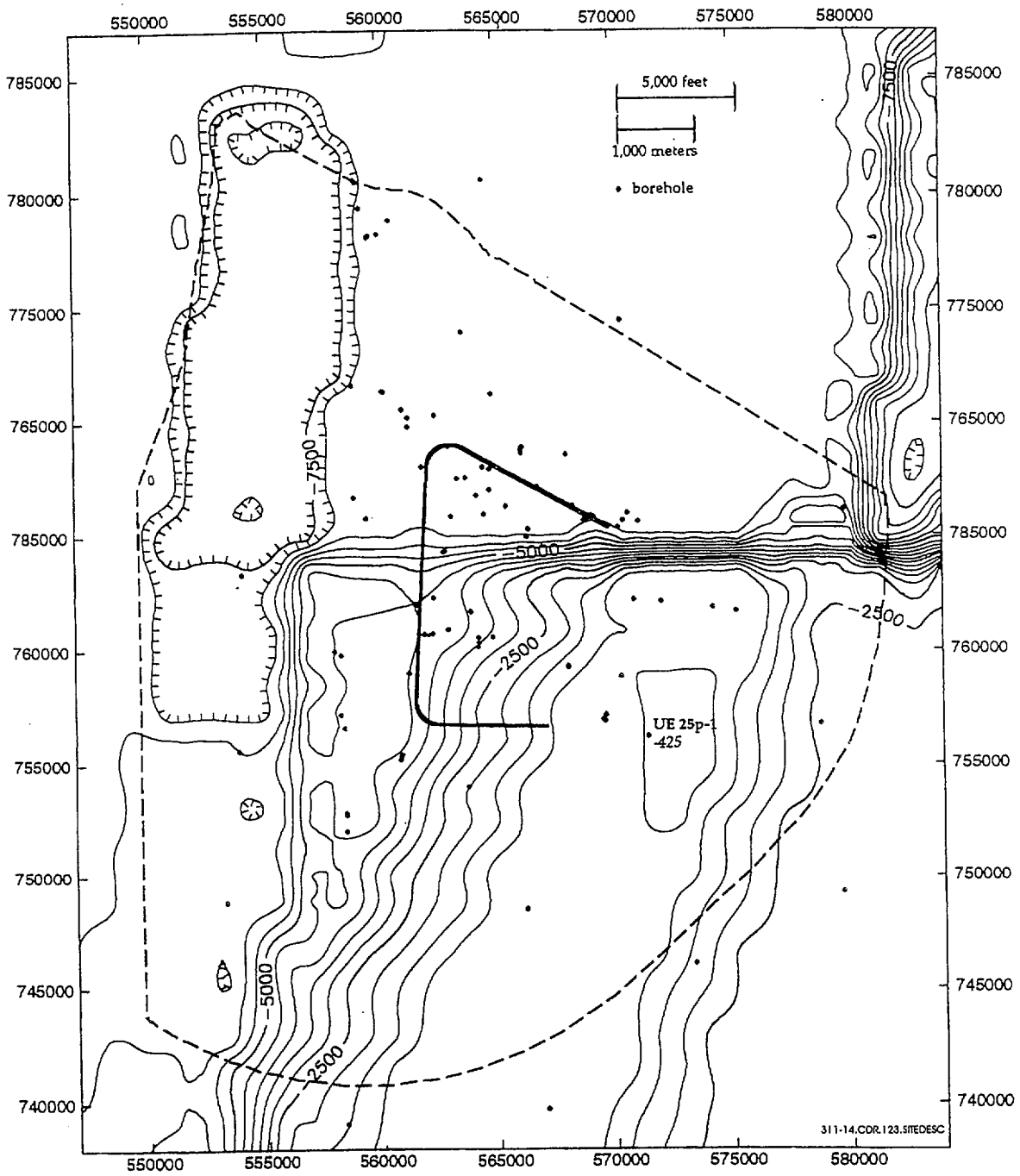


Unmodified	Modified			
	Range		Basin	
a. Pre-sevier	Overprint	d. Pre-sevier	Overprint	i. Pre-sevier
b. Sevier		e. Sevier		j. Sevier
c. Combination		f. Combination		k. Combination
	Fault-block	g. Structural	Fault-block	l. Structural
		h. Structural-stratigraphic		m. Structural-stratigraphic
				n. Valley fill

311-13.CDR 123.SITEDESC

NOTE: Geothermal Resource Assessment of the Yucca Mountain Area, Nye County, Nevada, (CRWMS M&O 1995c) completed for the DOE under contract number DE FC08-90NV10872.

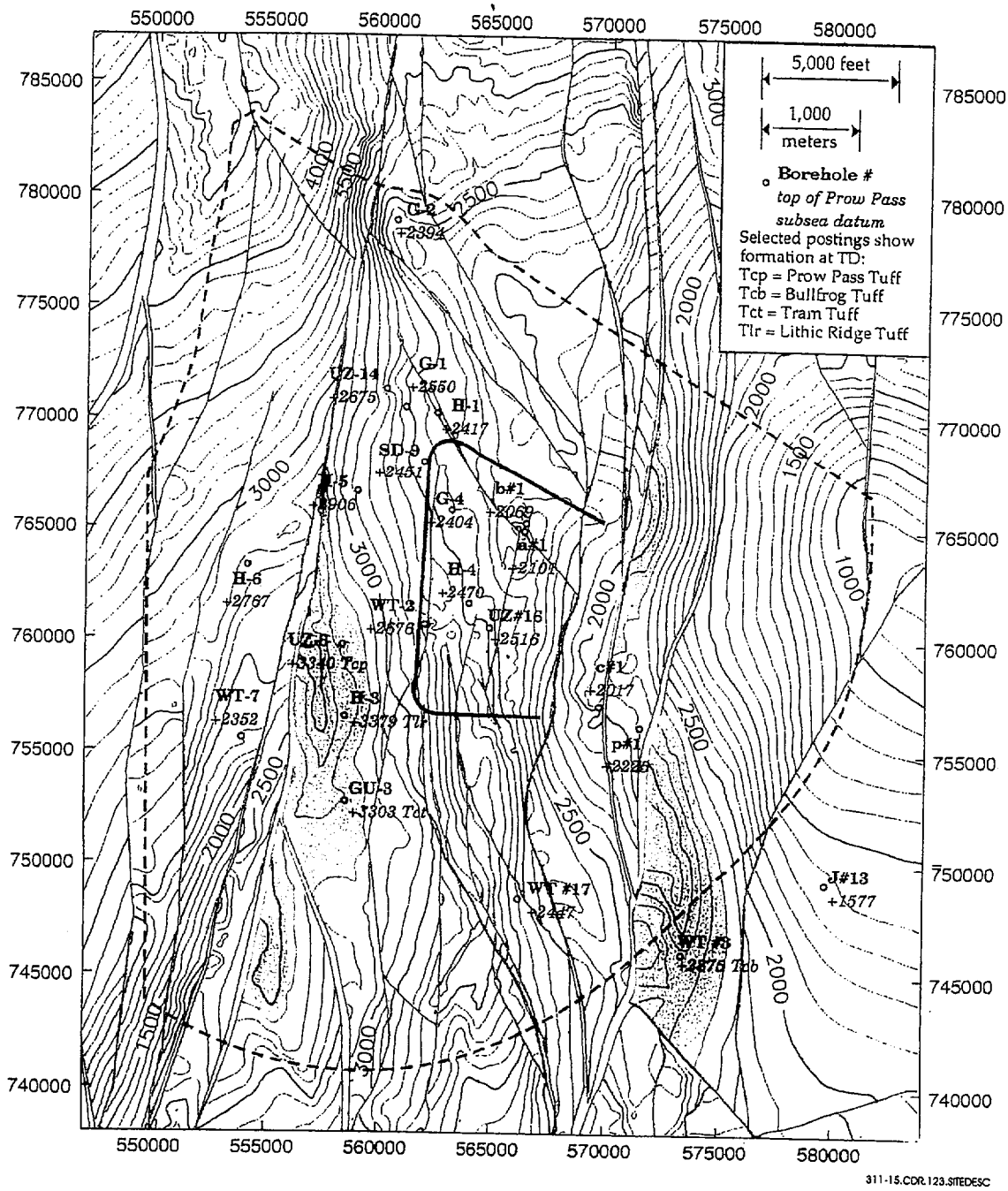
Figure 3.11-13. Classification of Traps of the Great Basin Region



NOTE: French, D.E. in press. Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County Nevada. Structure map of Yucca Mountain area, contoured on the unconformity at the base of the Tertiary. Contour interval = 500 ft.

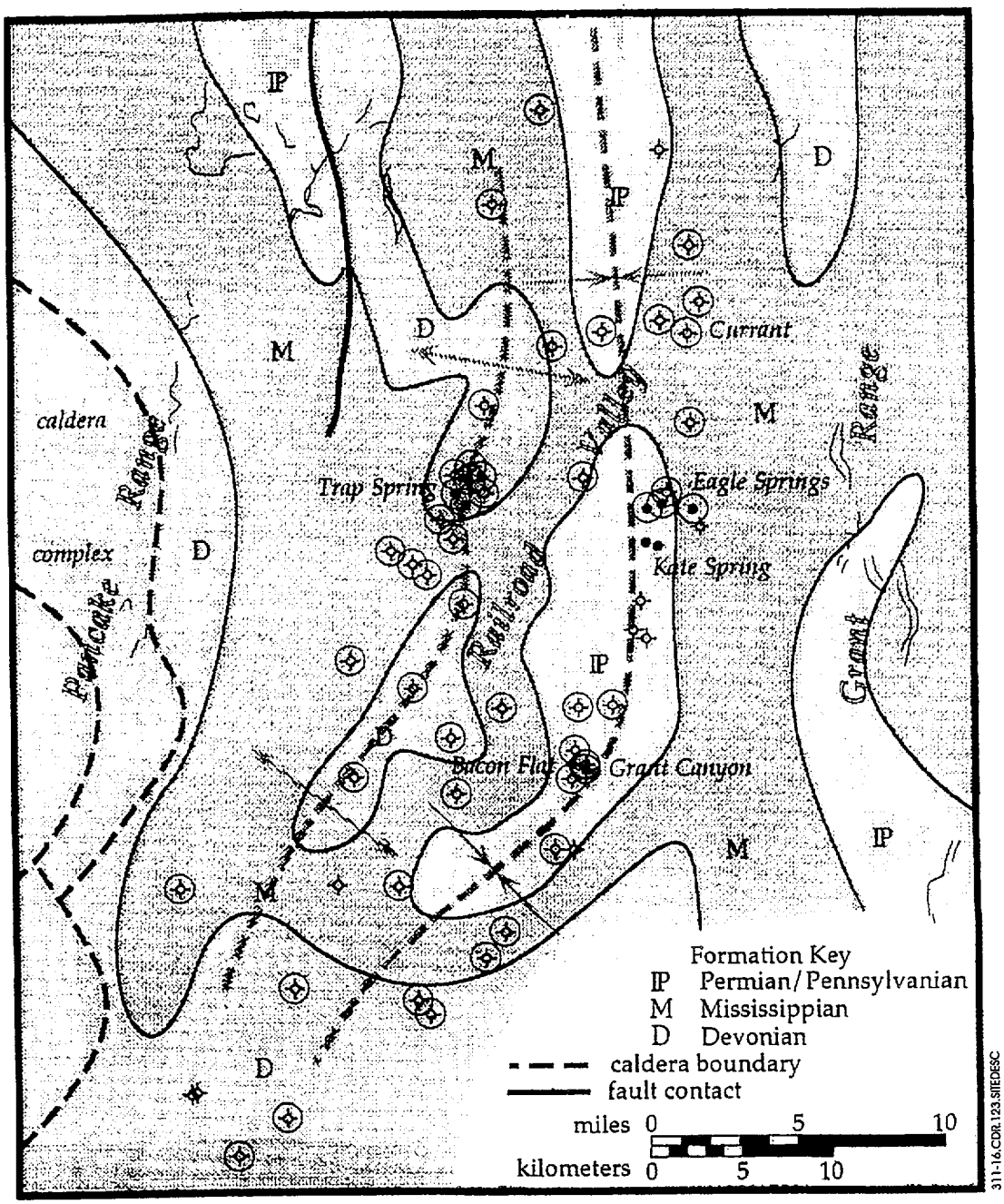
The interpretation is based on geophysical data and one borehole penetration. Fault planes are contoured, see Figure 3.11-15 for fault locations. The most attrictive exploration target in this area has been penetrated by UE 25p-l, which recorded no shows in Silurian strata beneath the unconformity. (Majer et al. 1996)

Figure 3.11-14. Structure Map of Yucca Mountain Area



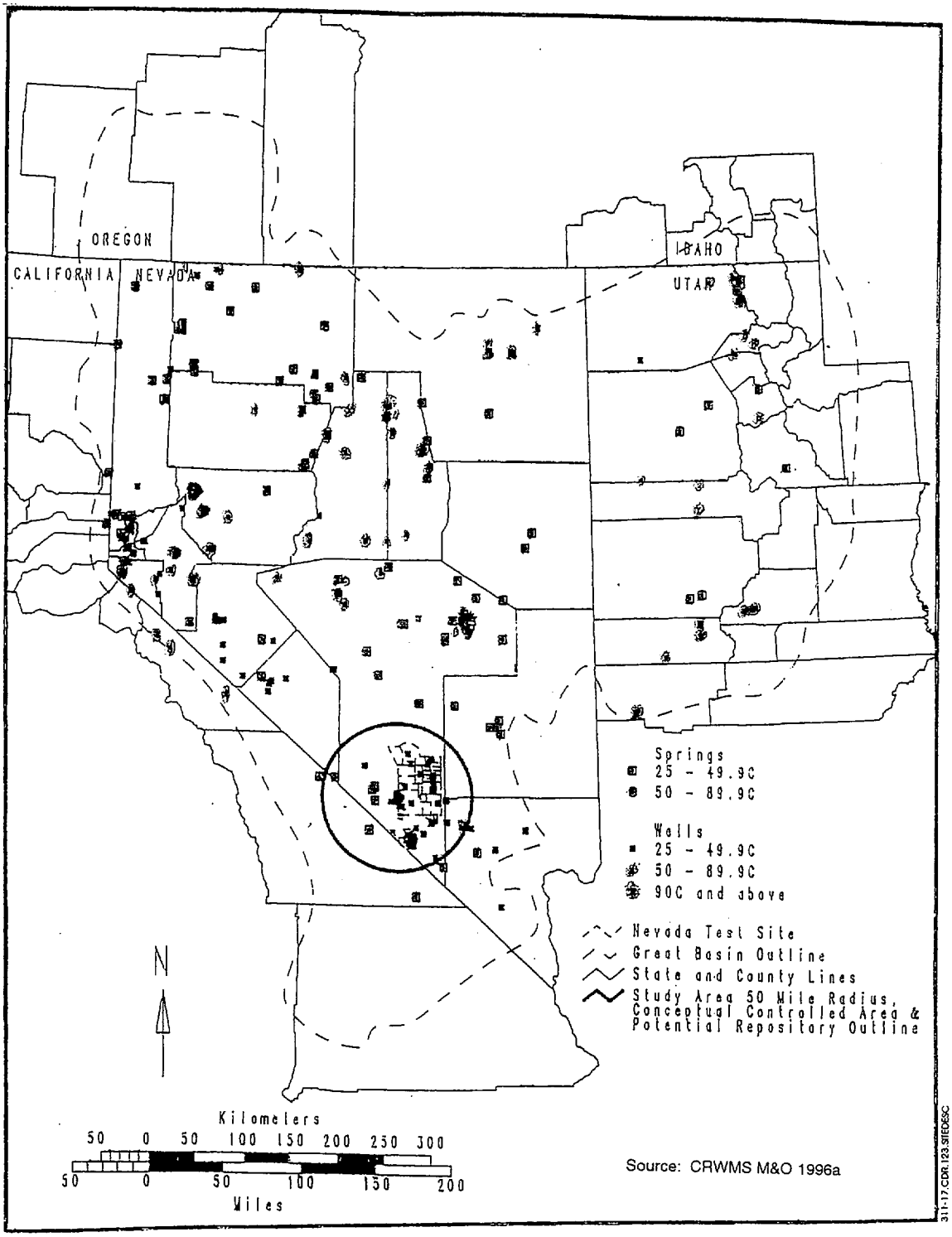
NOTE: D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada*, in press. Contour interval = 100 ft. Fault lines are in red. Green-shaded areas are possible hydrocarbon traps. The boreholes shown have penetrated the Prow Pass and have partially evaluated numerous fault blocks to that horizon (from 3-D Model ISM2.0).

Figure 3.11-15. Structure Map on the Top of the Prow Pass Tuff



NOTE: D.E. French, *Assessment of Hydrocarbon Resources of the Yucca Mountain Vicinity, Nye County, Nevada,* in press.

Figure 3.11-16. Paleogeologic Map of Railroad Valley Area, Beginning of Oligocene Time



NOTE: The density of points in some areas was reduced for clarity; the temperature distribution remains the same.

Figure 3.11-17. Distribution of Geothermal Springs and Wells in the Great Basin (>25°C)

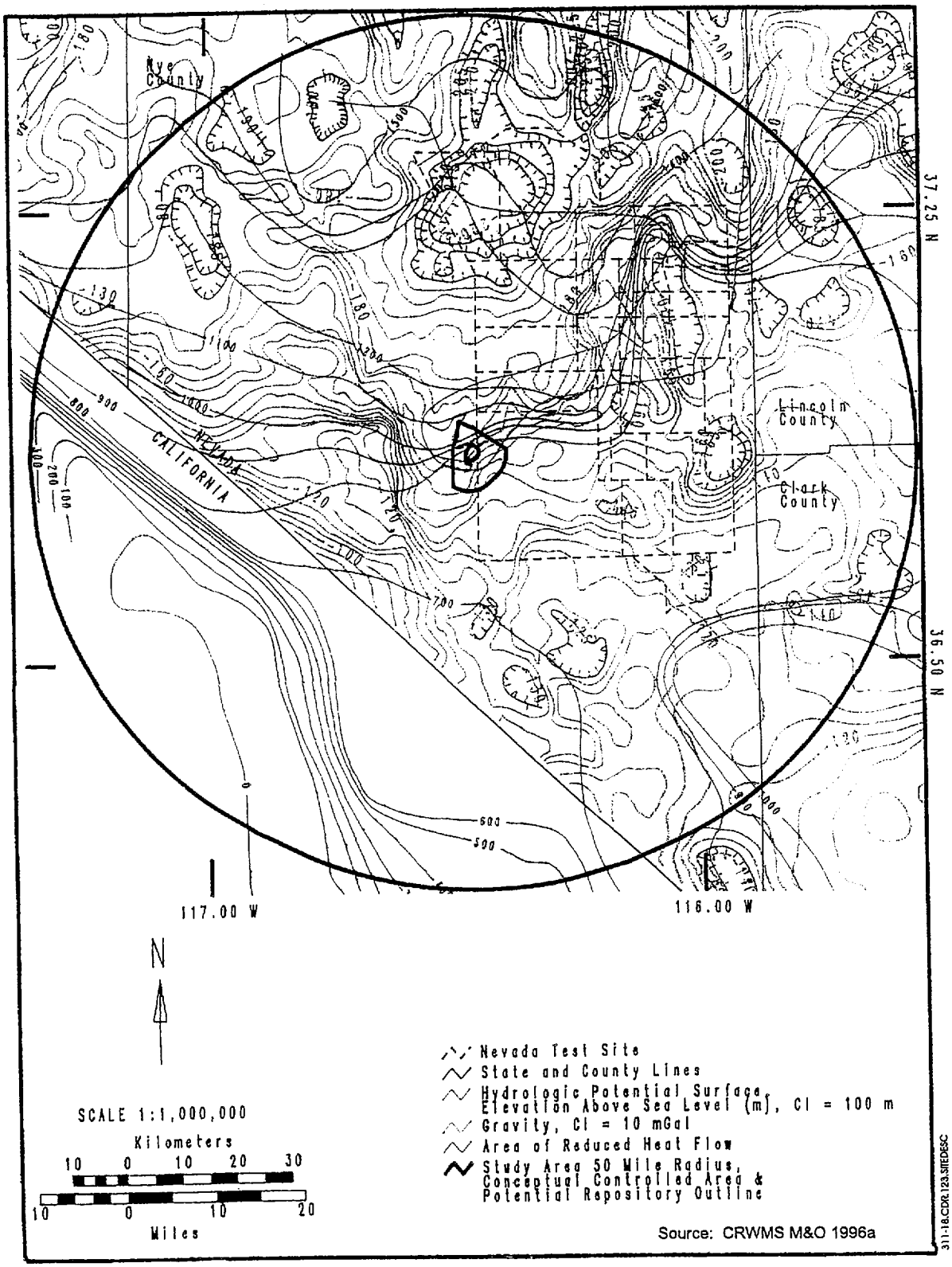
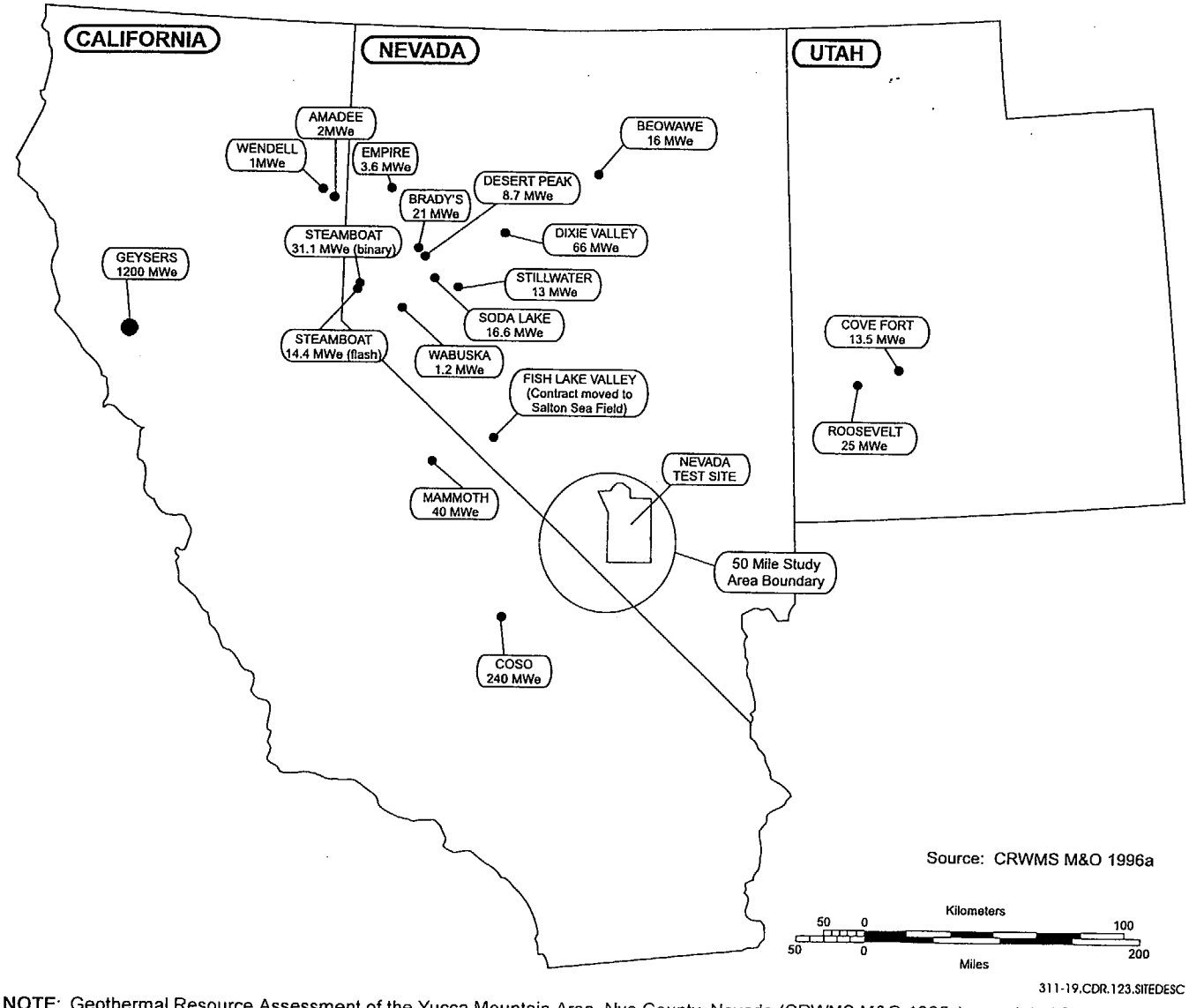
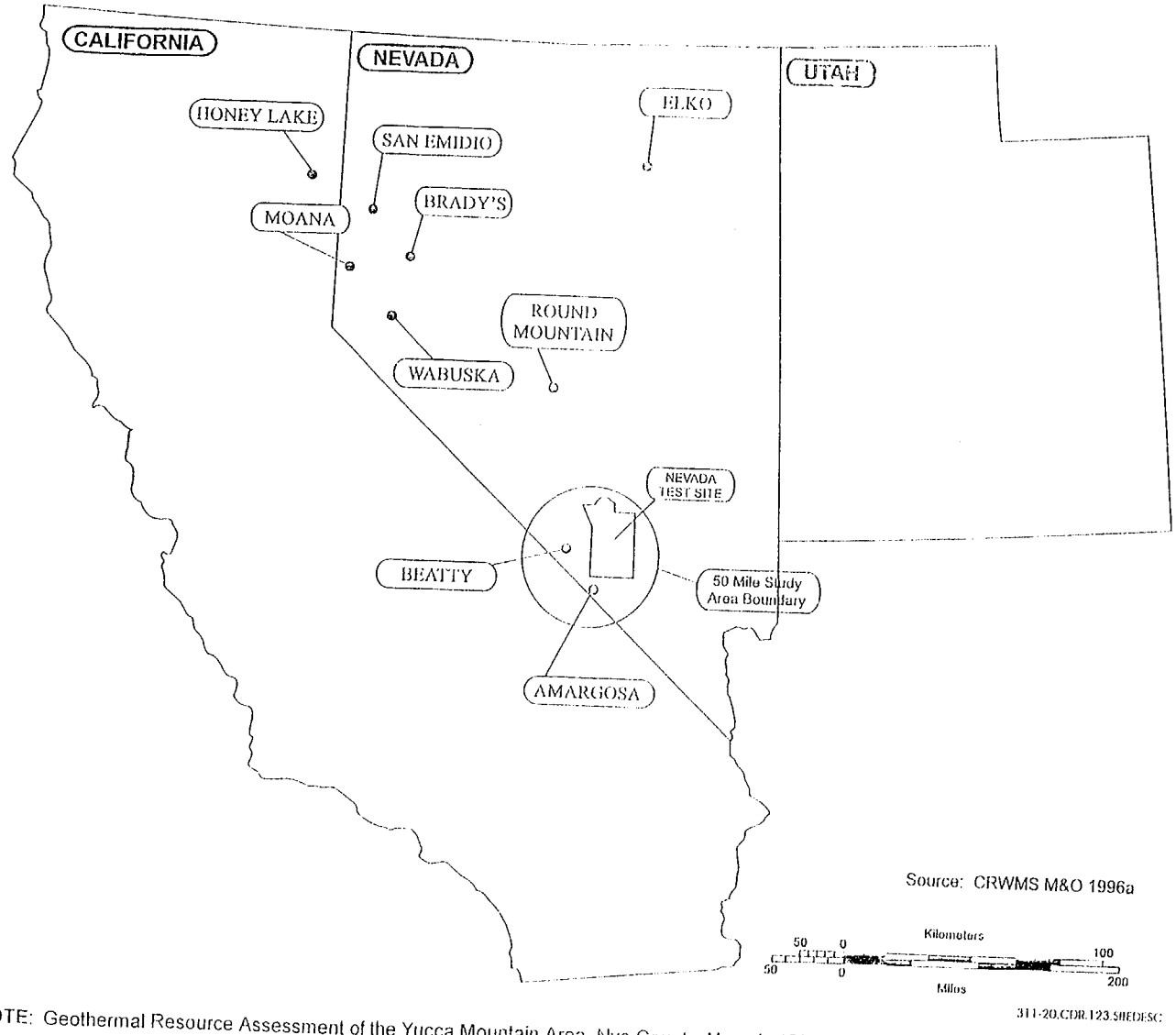


Figure 3.11-18. Water Level Elevations, Regional Bouguer Gravity, and Area of Reduced Heat Flow



NOTE: Geothermal Resource Assessment of the Yucca Mountain Area, Nye County, Nevada (CRWMS M&O 1995c) completed for the DOE under contract number DE FC08-90NV10872.

Figure 3.11-19. Location and Output in Mwe of Geothermal Power Plants Discussed in this Report



NOTE: Geothermal Resource Assessment of the Yucca Mountain Area, Nye County, Nevada (CRWMS M&O 1995c) completed for the DOE under contract number DE FC08-90NV10872.

Figure 3.11-20. Location of Geothermal Direct-Use Projects Discussed in this Report

INTENTIONALLY LEFT BLANK