Facies Analysis of Late Proterozoic through Lower Cambrian Rocks of the Death Valley Regional Ground-Water System and Surrounding areas, Nevada and California

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Open-File Report 01-351

Prepared in cooperation with the Nevada Operations Office,
U.S. Department of Energy, National Nuclear Security Administration,
under Interagency Agreement DE-AI08-96NV11967.

2001

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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Introduction

Late Proterozoic through Lower Cambrian rocks in the southern Great Basin form a westward-thickening wedge of predominantly clastic deposits that record deposition on the early western shelf edge of western North America (Stewart and Poole, 1974; Poole and others, 1992). Regional analyses of geologic controls on ground-water flow in the southern Great Basin typically combined lithostratigraphic units into more general hydrogeologic units that have considerable lateral extent and distinct hydrologic properties. The Late Proterozoic through Lower Cambrian rocks have been treated as a single hydrogeologic unit, named the lower clastic aquitard (Winograd and Thordarson, 1975) or the quartzite confining unit (Laczniak and others, 1996), that serves as the hydrologic basement to the flow system. Although accurate in a general sense, this classification ignores well-established facies relations within these rocks that might increase bedrock permeability and locally influence ground-water flow.

This report presents a facies analysis of Late Proterozoic through Lower Cambrian rocks (hereafter called the study interval) in the Death Valley regional ground-water flow system - that portion of the southern Great Basin that includes Death Valley, the Nevada Test Site, and the potential high-level nuclear waste underground repository at Yucca Mountain (fig. 1). The region discussed in this report, hereafter called the study area, covers approximately 100,000 km^2 (lat 35°-38° 15’ N., long 115°-118° W.). The purpose of this analysis is to provide a general documentation of facies transitions within the Late Proterozoic through Lower Cambrian rocks in order to provide an estimate of material properties (via rock type, grain size, and bedding characteristics) for specific hydrogeologic units to be included in a regional ground-water flow model.

Regional Setting

The oldest sedimentary rocks in the region are Middle and Late Proterozoic carbonate and clastic rocks of the Pahrump Group (including the Kingston Peak, Beck Spring, and Crystal Spring Formations) and the Late Proterozoic Noonday Dolomite. These rocks are as thick as 5 km in an east-west-trending depocenter through southern Death Valley and the Kingston Range, and they become thinner and eventually pinch out away from this east-west trending depocenter (Stewart, 1972; Wright and others, 1974). These rocks were interpreted as having been deposited in a failed rift by Wright and others (1974). In the southern part of the study area these rocks were deposited on an

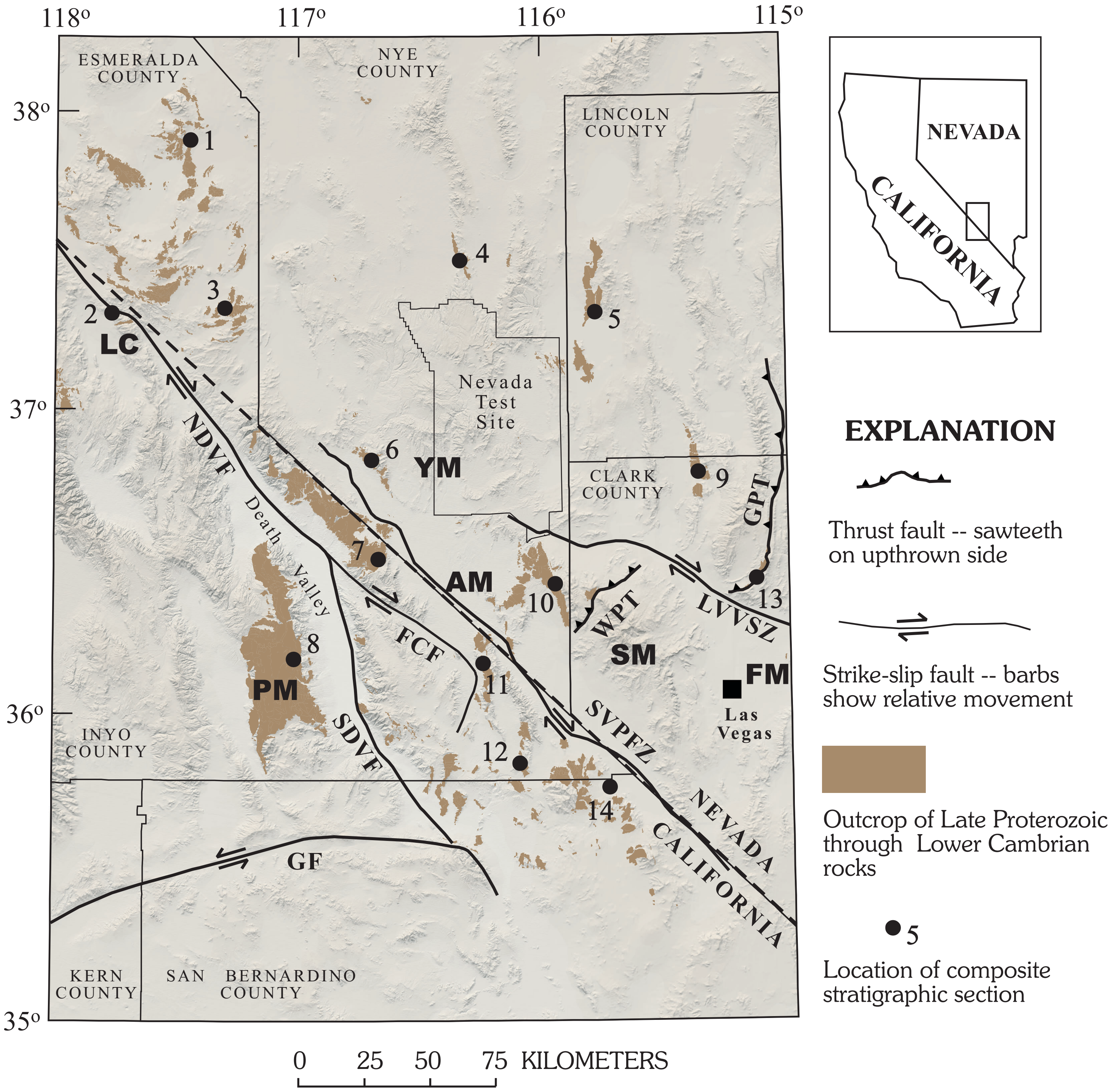

Figure 1. Regional map showing locations of composite stratigraphic sections, outcrops of Late Proterozoic to Lower Cambrian rocks, and major regional structures. NDVF, Northern Death Valley fault; SDVF, Southern Death Valley fault; FCF, Furnace Creek fault; GF, Garlock fault; SVPFZ, Stewart Valley-Pahrump fault zone; WPT, Wheeler Pass thrust; GPT, Gass Peak thrust. FM, Frenchman Mountain; SM, Spring Mountains; AM, Ash Meadows; PM, Panamint Mountains; LC, Last Chance Range; YM, Yucca Mountain.

older Proterozoic complex of gneiss and intrusive rocks, whereas in the Panamint and Funeral Mountains these rocks are metamorphosed to medium and high grades and intruded by granitic rocks (Labotka, 1980).

The basal sequence within the Cordilleran miogeocline consists of a clastic wedge that thickens from less than 100 m on the east, where basal strata are Lower Cambrian, to more than 3,000 m in western areas, where most of the sequence lies below basal Cambrian beds (fig. 2). The primary lateral facies changes within the study interval includes a transition from quartzite and siltstone in eastern exposures in Clark County and southern Nye County, Nev. (fig. 1) to predominantly shale and carbonate rocks in western exposures in Esmeralda County, Nev. and Inyo County, Calif. (fig. 1) (Stewart, 1970). The westward increase in fine clastics and carbonate within the clastic wedge indicates a transition from shelf to slope-and-rise facies (Stewart, 1972).

In the study area, the Late Proterozoic through Lower Cambrian interval may be subdivided into three broad regions - eastern, central, and western (Stewart, 1970; Nelson, 1978) (fig. 2). Each of these regions was originally mapped using separate stratigraphic nomenclature that reflected regional differences in the lithologic character of the strata; only later were these stratigraphic packages shown to be equivalent.

The study interval in the eastern region is very thin (a few hundred meters), mostly Early Cambrian in age, and the rocks are similar to the cratonic interval exposed in the Grand Canyon (Rowland, 1987; Poole and others, 1992). A unit of sandstone and conglomerate characterizes the basal part of the section; the unit is named the Tapeats Sandstone in the southeastern part of the region and the Prospect Mountain Quartzite farther to the north (Langenheim and Larson, 1973). Overlying the basal sandstone is a unit of shale, siltstone, and limestone. The unit is named the Bright Angel Formation in the southeastern part of the region and the Pioche or Chisolm farther to the north (Langenheim and Larson, 1973). The eastern region generally occurs to the east and southeast of the Death Valley ground-water basin, and includes Frenchman Mountain east of Las Vegas, Nev. (FM, fig. 1) (Longwell and others, 1965; Rowland, 1987).

Throughout much of the central region (fig. 2), the study interval is Late Proterozoic to Lower Cambrian in age and consists of a westward-thickening wedge of fine- to coarse-grained sandstone, conglomeratic sandstone, siltstone, and minor amounts of carbonate rock (Stewart, 1970). The section includes the Late Proterozoic Johnnie Formation and Stirling Quartzite, the Late Proterozoic to Lower Cambrian Wood Canyon Formation, and the Lower Cambrian Zabriskie Quartzite (Stewart, 1970). Interbedded carbonate and clastic rocks of the Lower and Middle Cambrian Carrara Formation represent the transition to an overlying carbonate succession (Palmer and Halley, 1979). Rocks characteristic of the central region are exposed in mountain ranges from the northwestern Spring Mountains (SM, fig. 1) (Burchfiel, 1964; Stewart, 1970) to the Nevada Test Site area (Barnes and Christiansen, 1967; Reso, 1963) and the Death Valley area (Hunt and Mabey, 1966; Diehl, 1974; Wright and others, 1974).

In the western region (fig. 2), strata that are laterally equivalent to those of the central region are thicker, finer grained, and more carbonate rich. They consist of

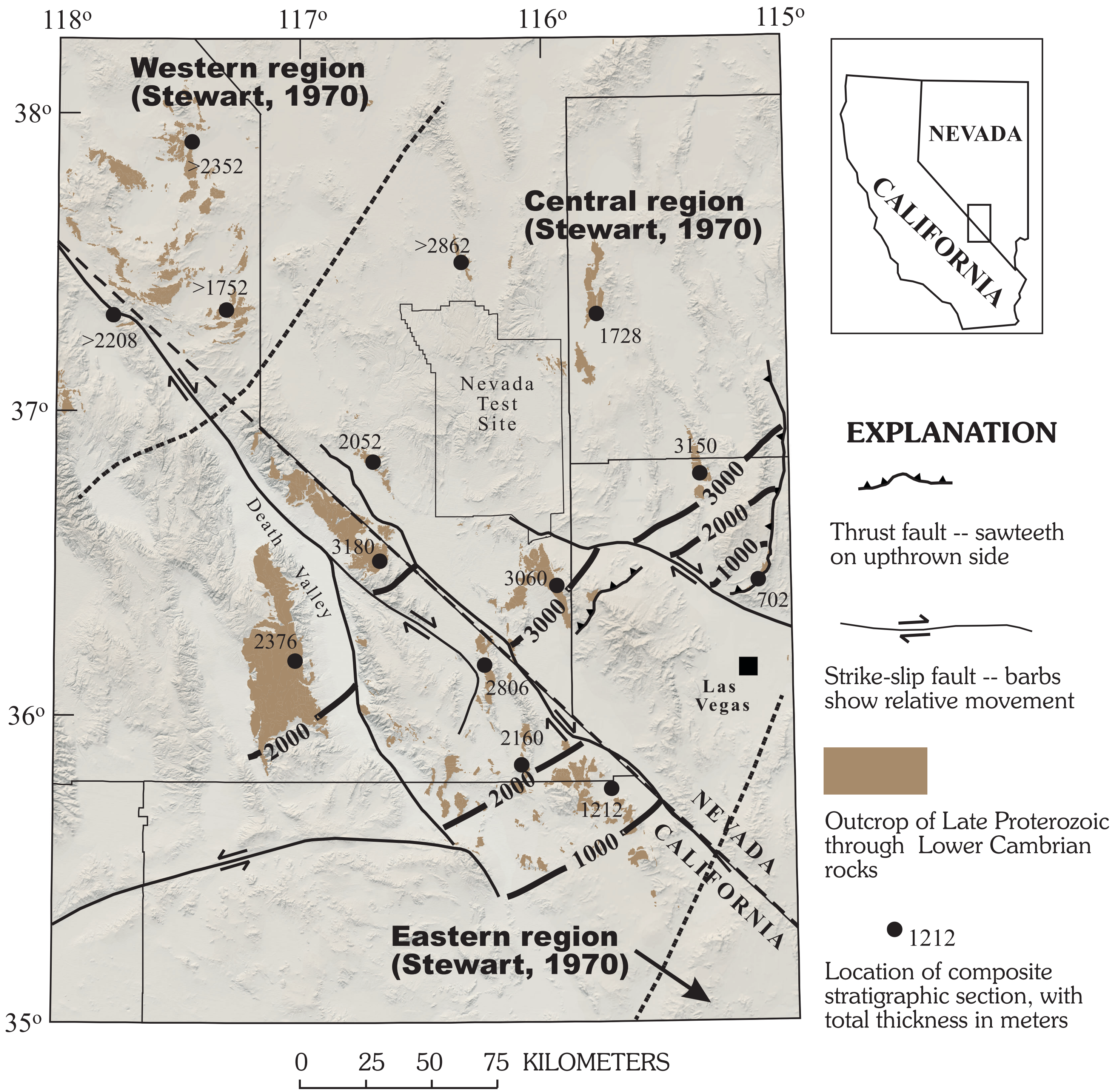

Figure 2. Total thickness of the Late Proterozoic to Lower Cambrian rocks in Death Valley region. Thickness is in meters; contour interval is 1000 m. A minimum thickness (for example, >1,752 m) is shown for incomplete sections or where base of section is not exposed.

interbedded siltstone, limestone, dolomite, and fine-grained quartzite (Nelson, 1962; Stewart, 1970; Albers and Stewart, 1972). The stratigraphic section of this region includes the Late Proterozoic Wyman Formation, the Late Proterozoic to Lower Cambrian Reed Dolomite and Deep Spring Formation, and the Lower Cambrian Campito, Poleta, and Harkless Formations. Typical exposures are found in the White and Inyo Mountains and Last Chance Range, Calif. (LC, fig. 1) (Nelson, 1962; Signor and Mount, 1986) and exposures in Esmeralda County, Nev. (Stewart, 1970; Albers and Stewart, 1972).

The interpretation of facies trends in the Death Valley region must take into account the structural complexity of the region. Late Proterozoic and Paleozoic rocks throughout the region were affected by south- and southeast-directed shortening in the form of late Paleozoic to Mesozoic regional thrusts and more localized folds (Fleck, 1970; Wernicke and others, 1988; Snow, 1992) (fig. 1). The major thrusts have stratigraphic offsets of several kilometers and horizontal displacements as much as several tens of kilometers, which result in offsets in regional facies trends (Fleck, 1970; Snow, 1992). Thrusts in the western and northwestern parts of the region consistently rocks of the study interval, including the Johnnie Formation, Stirling Quartzite, and Wood Canyon Formation, in their hanging walls.

All of the rocks of the Death Valley region were later deformed by complex Neogene extensional normal and strike-slip faults (Stewart, 1988; Wright, 1989; Wernicke and others, 1988). This deformation is characterized by a variety of structural patterns that overlap in space and time: (1) Basin and Range extension; (2) local extreme extension along detachment faults that currently have gentle dips; and (3) development of discrete strike-slip faults and transtensional basins within the Walker Lane belt. The northwest-trending Walker Lane belt (Stewart, 1988) transects the Death Valley region roughly parallel to the Nevada-California border and contains several large right-lateral faults with northwest orientations (fig. 1), such as the Stewart Valley-Pahrump fault zone, the Furnace Creek-Death Valley fault system and the Las Vegas Valley shear zone (Stewart and others, 1968; Longwell, 1974; Stewart and Crowell, 1992). In the western part of the region, the Walker Lane belt also includes the detachment faults and metamorphic core complexes of the Death Valley region that have accommodated large-magnitude northwest-directed horizontal extension.

Methods of Study

Using existing published data, 14 composite stratigraphic sections from throughout the region were selected (fig. 1) based upon the following criteria:

- the completeness of the section,
- the need for a broad geographic distribution of the locations providing stratigraphic information.

All the stratigraphic data used in this compilation appear in Stewart (1970) and references cited therein (table 1). In a number of cases, individual sections were combined to yield as complete a section as possible.

For each of the 14 composite sections, the following data were compiled: location, total thickness, aggregate thickness of sandstone and coarser units, aggregate thickness of siltstone and shale units, aggregate thickness of carbonate units (limestone and dolomite), and the thickest single bed or continuous interval of either carbonate or coarse clastic unit (table 2). For each section, the measured interval was from the top of the Lower Cambrian Zabriskie Quartzite (or in the northwestern region, the top of the Lower Cambrian Harkless Formation) to the base of the Late Proterozoic Johnnie Formation. Clastic units in the lower third of the Lower and Middle Cambrian Cararra Formation, which overlies the Zabriskie Quartzite, were not included in the measurements. Units below the Johnnie Formation, including the Late Proterozoic Noonday Dolomite and the Middle to Late Proterozoic Pahrump Group, were not considered in the thickness tabulations. These units are rarely exposed at the surface so thickness values are scarce. Moreover, in most places these units are too deep to impact the ground-water flow. In the western part of the region, the base of the sedimentary section is often not exposed and the thickness measurements are minimum values.

Table 1. Location of composite measured sections used for facies analysis.

Location Number	Location name	Corresponding sections (from Stewart, 1970)	Northing (UTM m)	Easting (UTM m)
1	Weepah Hills	Locations 44 and 45	4,195,849	461,318
2	Northern Last Chance Range	Locations 4, 5 and 6	4,132,338	431,327
3	Mount Dunfee	Locations 51 and 52	4,133,220	473,080
4	Quartzite Mountain and Belted Range	Locations 54 and 55	4,151,744	558,349
5	Groom District	Location 67	4,132,926	607,746
6	Bare Mountain	Location 57	4,077,943	526,593
7	Echo Canyon	Locations 11 and 12	4,042,365	528,357
8	Panamint Mountains (Trail Canyon and Hanaupah Canyon)	Locations 14 and 16	4,005,023	498,366
9	Desert Range	Locations 70 and 71	4,073,532	645,970
10	Spring Mountains	Locations 61, 63, 64 and 66	4,029,722	595,984
11	Northern Resting Spring Range	Locations 20 and 21	4,004,141	566,581
12	Nopah Range	Location 26	3,966,799	580,695
13	Las Vegas Range	Locations 73 and 74	4,035,602	668,022
14	Winters Pass Hills and Winters Pass	Locations 31 and 32	3,958,566	613,038

Table 2. Thickness data for litholofacies types from composite measured sections.

Location name	Total thickness (m)	Aggregate thickness, siltstone + shale (m)	Aggregate thickness, sandstone + conglomerate (m)	Aggregate thickness, limestone + dolomite (m)	Thickest single bed of either sandstone or carbonate (m)
Weepah Hills	2352	2022	0	330	48 (carbonate)
Northern Last Chance Range	2208	1434	408	366	222 (sandstone)
Mount Dunfee	1752	744	78	930	354 (limestone)
Quartzite Mountain and Belted Range	2862	1830	786	246	432 (sandstone)
Groom District	1728	942	768	18	402 (sandstone)
Bare Mountain	2052	1218	612	222	336 (sandstone)
Echo Canyon	3180	1752	1170	258	246 (sandstone)
Panamint Mountains (Trail Canyon and Hanaupah Canyon)	2376	1344	666	366	252 (sandstone)
Desert Range	3150	1752	1062	336	480 (sandstone)
Spring Mountains	3060	2046	864	150	258 (sandstone)
Northern Resting Spring Range	2232	1314	816	102	264 (sandstone)
Nopah Range	2160	1068	876	216	252 (sandstone)
Las Vegas Range	702	270	432	0	228 (sandstone)
Winters Pass Hills and Winters Pass	1212	642	426	144	252 (sandstone)

Analysis of Regional Facies Trends

Thickness

The total thickness of the study interval generally increases to the northwest from less than 1 km in the Winters Pass area (location 14, fig. 1) and in the Las Vegas Range (location 13, fig. 1), to between 2 and 3 km in the vicinity of the Nevada Test Site and Death Valley (fig. 2). The base of the stratigraphic section in the northwestern part of the region is poorly exposed, however, Stewart (1970) estimated that the total thickness of this interval might be as much as 5-6 km in the White and Inyo Mountains of California. Abrupt changes in the thickness of the Late Proterozoic through Lower Cambrian section are evident across the major strike-slip faults of the region (fig. 2). These changes have long been used to estimate the magnitude of offset along these faults (Stewart, 1967; Stewart and others, 1968; Prave and Wright, 1986).

Compositional trends

The main compositional trend within the study interval is the decrease of sandstone toward the northwest in conjunction with an increase in finer-grained clastic components, and some increase in the amount of carbonate. The proportion of sandstone and conglomerate within the study interval also decreases to the northwest (fig. 3). Because of the relatively minor amount of carbonate rocks in the section, a northwest decrease in the sand-shale ratio (fig. 4) mimics the proportion of sandstone and conglomerate within the study interval (fig. 3). In general, bedding characteristics mirror the compositional trends; toward the northwest the entire section in characterized by thinner bedding, with fewer thick, continuous intervals of quartzite (see pl. 2 in Stewart, 1970). The relative proportion of carbonate rocks within the section shows a gradual increase from southeast to northwest (fig. 5). Carbonate rocks become thicker and more continuous toward the northwest. In two of the composite sections from the northwestern part of the region, the thickest single intervals are composed of carbonate rocks. Carbonate rocks occur as dolomite interbeds in the Wood Canyon Formation and the upper part of the Stirling Quartzite throughout much of the central part of the study area, and in discrete formations, such as the Reed Dolomite, in Esmeralda County, Nev.

Structural aspect

In addition to regional stratigraphic changes, the rocks within the study interval exhibit differences in structural style across the region. In the eastern part of the region, the study interval is generally exposed in the upper plates of thrust faults or in rotated range blocks associated with normal faults. The interval is exposed in the hanging wall of the Wheeler Pass thrust in the Spring Mountains (WPT, fig. 1) (Burchfiel and others, 1974), the hanging wall of the Specter Range thrust in the Specter Range (small exposures just south of the southern boundary of the Nevada Test Site, fig. 1) (Burchfiel, 1965) and in the rotated range blocks of the Resting Spring (location 11, fig. 1) and Nopah Ranges (Burchfiel and others, 1983) and the Pintwater Range (location 9, fig. 1) (Tschanz and Pampeyan, 1970). The metamorphic grade is low at all of these exposures. For example, the shaly portions of the Wood Canyon Formation are phyllitic

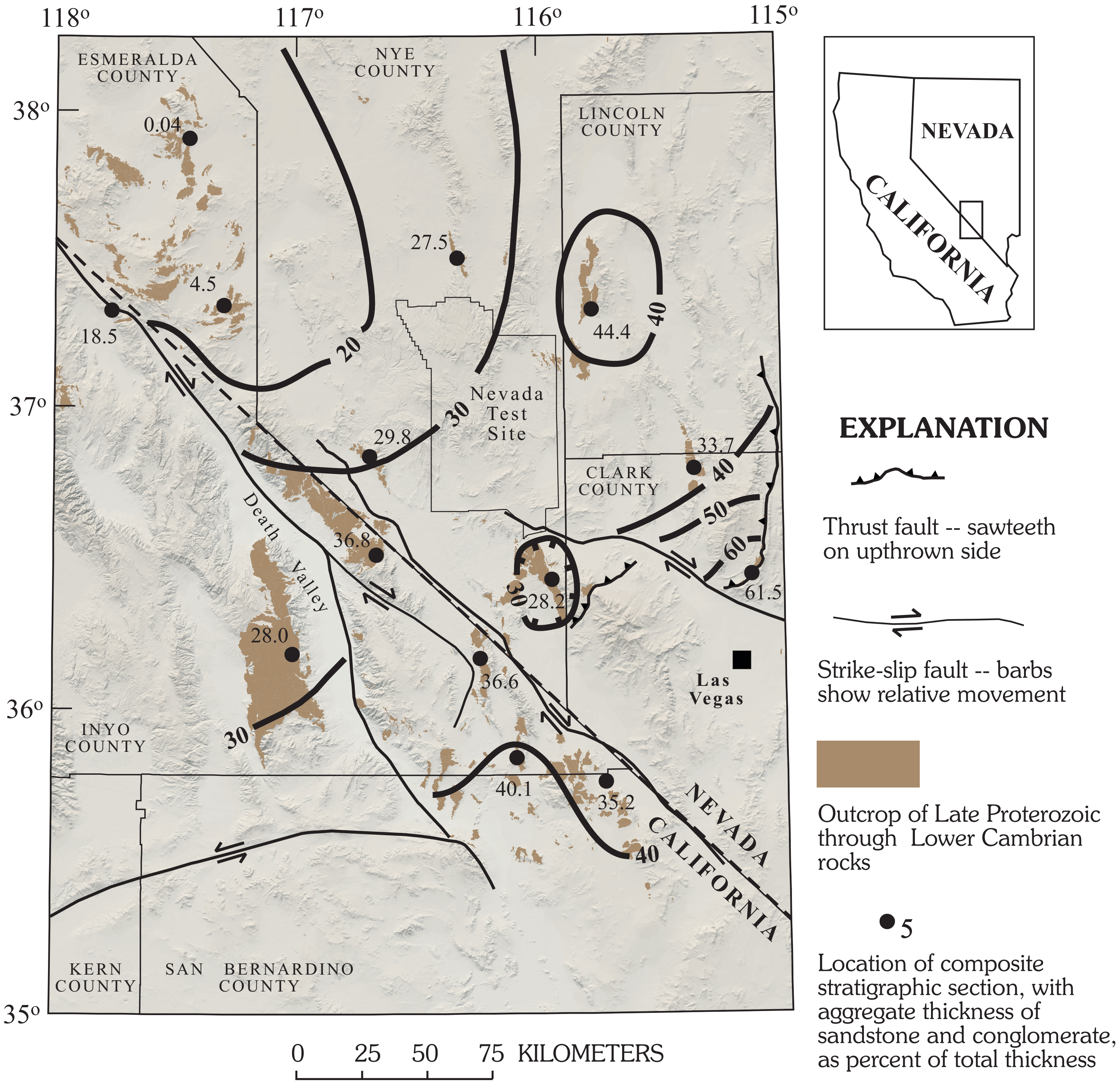

Figure 3. Aggregate thickness of sandstone and conglomerate as a percentage of total thickness for the composite stratigraphic sections. Contour interval is 10 percent.

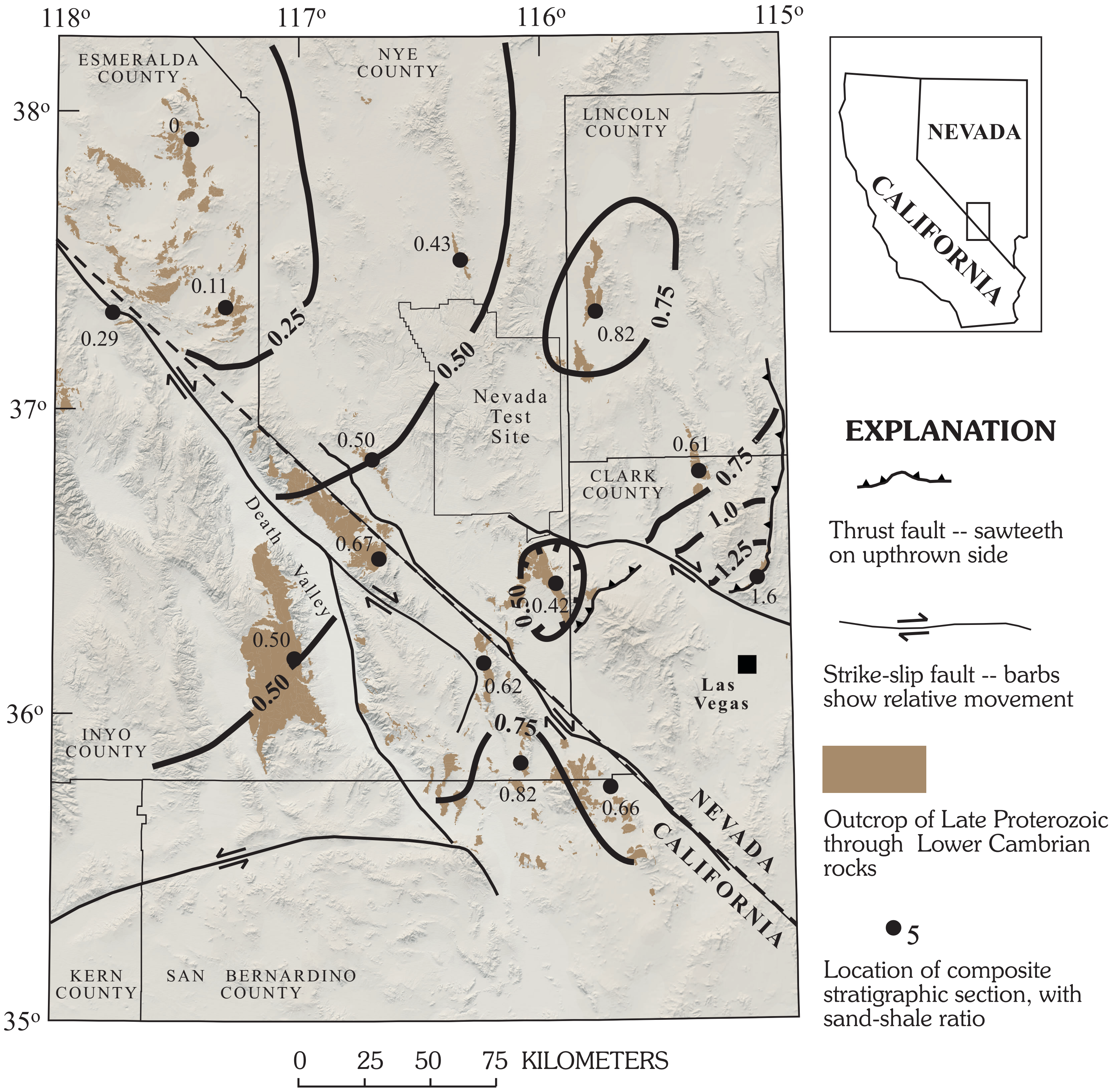

Figure 4. Sand-shale ratio for composite stratigraphic sections. Sand-shale ratio is computed as aggregate thickness of section that is sand-size or coarser divided by the aggregate thickness of section that is silt-size or finer. Contour interval is expressed as a unitless ratio, in intervals of 0.25.

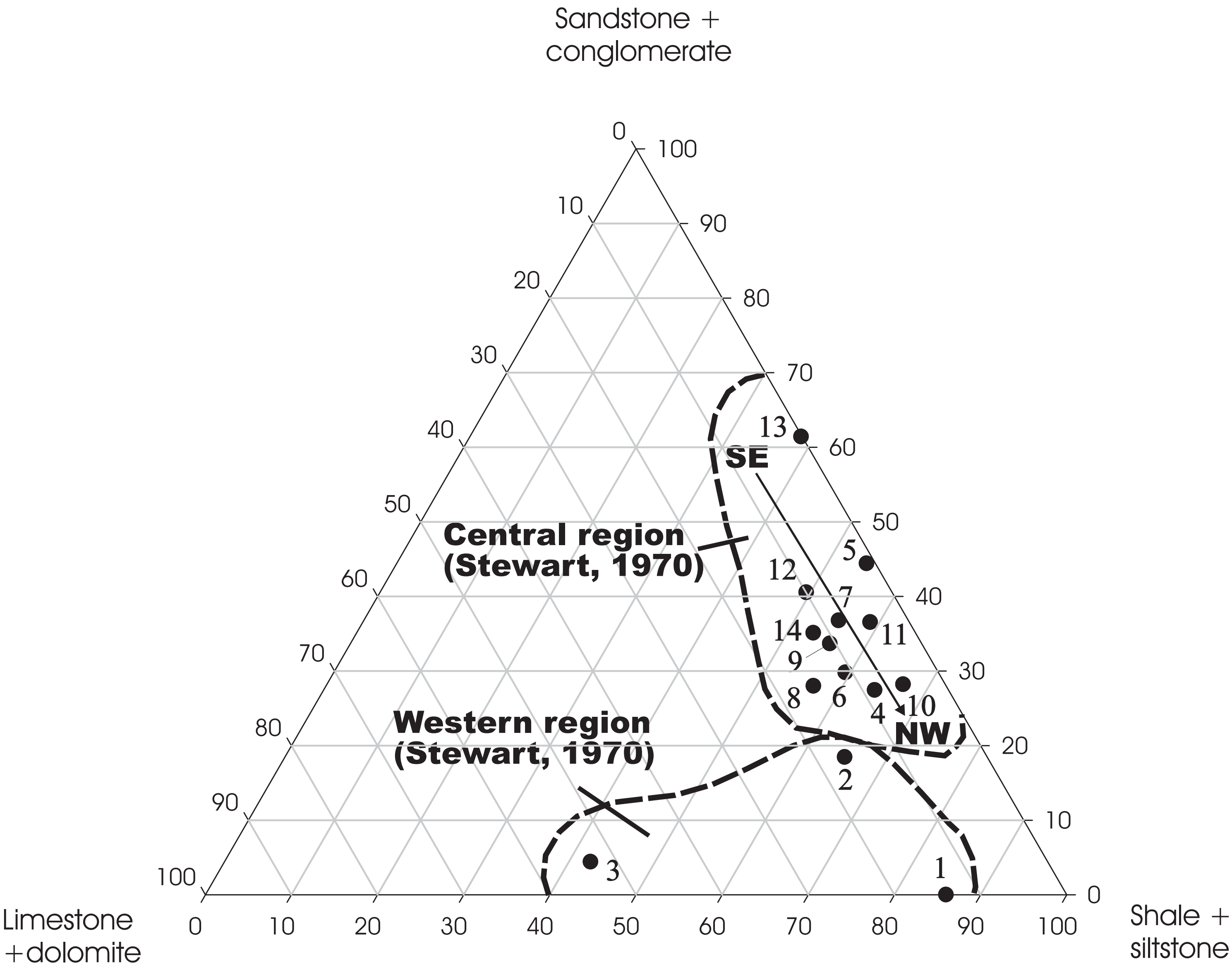

Figure 5. Three-component diagram for the composite stratigraphic sections.

(sub-greenschist-grade). In general, the rocks in the study interval in the eastern part of the region has been affected by brittle deformation in the upper crust. In contrast, the study interval in the western part of the region is exposed in the lower plates of major regional detachment structures. Examples include Bare Mountain (location 6, fig. 1) (Monsen and others, 1992), the Funeral Mountains (northwest of location 7, fig. 1) (Wright and Troxel, 1993), and the Panamint Mountains (PM, fig. 1) (Hunt and Mabey, 1966; Labotka and others, 1980). In these exposures, metamorphic grade is much higher (as high as amphibolite grade), rocks are foliated, and the deformation is more ductile in nature and characteristic of mid-crustal levels.

Brittle fracturing of clastic rocks in the Late Proterozoic part of the section, particularly the Stirling Quartzite, might result in locally enhanced permeability of the clastic units. The line of springs along the east margin of Ash Meadows (AM, fig. 1) represents discharge from the regional ground-water system (Winograd and Thordarson, 1975). Most of the major springs at Ash Meadows show a limited range of δ^{87}Sr that is interpreted to reflect flow through the regional Paleozoic carbonate aquifer. However, three springs at the very southeast end of the spring line have high δ^{87}Sr (Peterman and Stuckless, 1993; Peterman and others, 1992). These values are interpreted as reflecting travel through rocks with elevated levels of radiogenic strontium and probably reflect local flow through fractured Late Proterozoic quartzites in the northwest end of the Spring Mountains. Flow might be enhanced by fracturing that accompanied extensional faulting along a brittle, low-angle normal fault in the northwest end of the Spring Mountains (Burchfiel, 1965; Abolins, 1999).

Summary of Material Properties throughout the Region

On the basis of combined stratigraphic and structural data for the rocks of the study interval in the Death Valley ground-water basin, six broad zones have been delineated (fig. 6) that represent areas with potentially distinct material properties and potentially different hydraulic properties.

Zone 1: This zone corresponds to Stewart's (1970) eastern region and is characterized by a stratigraphic section that is very thin (a few hundred meters) and is similar to the cratonic sedimentary interval exposed in the Grand Canyon.

Zone 2: This zone corresponds to Stewart's (1970) central region and is characterized by a westward-thickening (but generally 2-3 km thick) wedge of fine- to coarse-grained sandstone, siltstone, conglomeratic sandstone, and minor amounts of carbonate rock.

Zone 3: This zone corresponds to Stewart's (1970) western region and is characterized by a thick (greater than 3 km) section of interbedded siltstone, limestone, dolomite, and fine-grained sandstone.

Zone 4: In this zone, between localities 12 and 14 (fig. 1) and the south end of Death Valley, the rocks in the study interval are underlain by rocks of the Pahrump Group, a locally thick accumulation of Middle and Late Proterozoic sedimentary rocks.

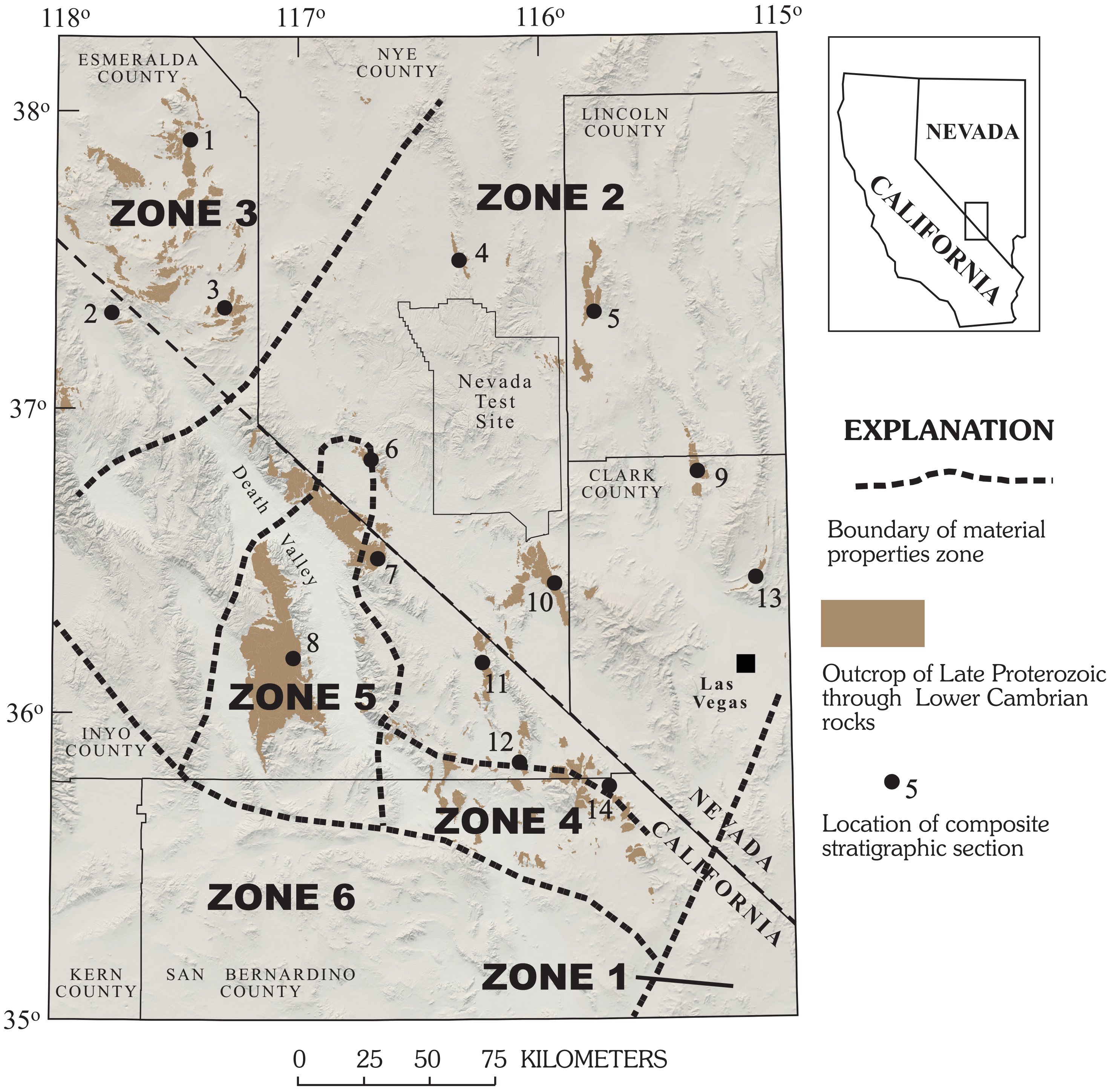

Figure 6. Regional map showing location of zones that define major regional differences in material properties of Late Proterozoic to Lower Cambrian rocks.

The Pahrump Group includes a significant thickness of dolomite and might locally be important to fluid flow.

Zone 5: In this zone the rocks in the study interval are exposed in the lower plates of major regional detachment structures. In these exposures, metamorphic grade is high, and the rocks are foliated and are potentially impermeable.

Zone 6: In this zone, located in the southwestern part of the region, rocks in the study interval are either missing or their character is completely unknown.

Summary

The main facies transition within the Late Proterozoic through Lower Cambrian stratigraphic section of the Death Valley region is from an eastern region dominated by thick intervals of coarse clastics interbedded with shale, to a more shale-dominated region with significant amounts of carbonate rocks. This transition documented as the boundary between the western facies and the central facies of Stewart (1970), or between the Death Valley facies and the White-Inyo facies of Nelson (1978). Accompanying the regional stratigraphic changes are regional differences in deformational style. Rocks in the east half of the region are affected by brittle deformation that occurs at shallow crustal levels. This brittle deformation affects the sand-rich facies of the Late Proterozoic through Lower Cambrian section and can result in significant fracture permeability. Rocks in the west half of the region are more ductilely deformed. These shale-rich, foliated metamorphic rocks have a tendency to shear and slip rather than fracture. In the western region, the section was deformed ductilely at much deeper crustal levels and did not fracture readily. Late Proterozoic to Lower Cambrian strata in the far northwestern part of the region that contain significant thickness of limestone or dolomite might have primary or secondary (fracture) porosity.

References Cited

Abolins, M.J., 1999, I, Stratigraphic constraints on the number of discrete Neoproterozoic glaciations and the relationship between glaciation and Ediacaran evolution; II, The Kwichup Spring thrust in the northern Spring Mountains, Nevada — Implications for large-magnitude extension and the structure of the Cordilleran thrust belt: Pasadena, Calif., California Institute of Technology Ph. D. dissertation, 366 p.

Albers, J.P., and Stewart, J.H., 1972, Geology and mineral deposits of Esmeralda County: Nevada Bureau of Mines and Geology Bulletin 78, 80 p.

Barnes, Harley, and Christiansen, R.L., 1967, Cambrian and Precambrian rocks of the Groom District Nevada, southern Great Basin: U.S. Geological Survey Bulletin 1244-G, 34 p.

Burchfiel, B.C., 1964, Precambrian and Paleozoic stratigraphy of Specter Range Quadrangle, Nye County, Nevada: American Association of Petroleum Geologists Bulletin, v. 48, p. 40-56.

—— 1965, Structural geology of the Specter Range Quadrangle, Nevada, and its regional significance: Geological Society of America Bulletin, v. 76, p. 175-192.

Burchfiel, B.C., Fleck, R.J., Secor, D.T., Vincelette, R.R., and Davis, G.A., 1974, Geology of the Spring Mountains: Geological Society of America Bulletin, v. 85, p. 1013-1022.

Burchfiel, B.C., Hamill, G.S., and Wilhelms, D.E., 1983, Structural geology of the Montgomery Mountains and the northern half of the Nopah and Resting Springs Ranges, Nevada and California: Geological Society of America Bulletin, v. 94, p. 1359-1376.

Diehl, Paul, 1974, Stratigraphy and sedimentology of the Wood Canyon Formation, Death Valley area, *in* Troxel, B.W., ed., Guidebook; Death Valley Region, California and Nevada: Shoshone, Calif. The Death Valley Publishing Company, p. 37-48.

Fleck, R.J., 1970, Tectonic style, magnitude, and age of deformation in the Sevier orogenic belt in southern Nevada and eastern California: Geological Society of America Bulletin, v. 81, p. 1705-1720.

Hunt, C.B., and Mabey, D.R., 1966, Stratigraphy and structure of Death Valley, California: U.S. Geological Survey Professional Paper 494-A, 162 p.

Labotka, T.C., Albee, A.L., Lanphere, M.A., and McDowell, S.D., 1980, Stratigraphy, structure and metamorphism in the central Panamint Mountains (Telescope Peak quadrangle), Death Valley area, California: Geological Society of America Bulletin, v. 91, pt. I, p. 125-129, and pt. II, p. 843-933.

Laczniak, R.J., Cole, J.C., Sawyer, D.A., and Trudeau, D., 1996, Summary of Hydrogeologic Controls on Ground-Water Flow at the Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Water-Resources Investigations Report 96-4109, 59 p.

Langenheim, R.L., and Larson, E.R., 1973, Correlation of Great Basin stratigraphic units: Nevada Bureau of Mines and Geology Bulletin 72, 36 p.

Longwell, C.R., 1974, Measure and date of movement on Las Vegas Valley shear zone, Clark County, Nevada: Geological Society of America Bulletin, v. 85, p. 985-990.

Longwell, C.R., Pampeyan, E.H., Bowyer, Ben, and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines and Geology Bulletin 62, 218 p.

Monsen, S.A., Carr, M.D., Reheis, M.C., and Orkild, P.P., 1992, Geologic map of Bare Mountain, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-2201, scale 1:24,000.

Nelson, C.A., 1962, Lower Cambrian-Precambrian succession, White-Inyo Mountains, California: Geological Society of America Bulletin v. 73, p. 139-144.

——1978, Late Precambrian–Early Cambrian stratigraphic and faunal succession of eastern California and the Precambrian-Cambrian boundary: Geology, v. 115, p. 121–126.

Palmer, A.R., and Halley, R.B., 1979, Physical stratigraphy and trilobite biostratigraphy of the Carrara Formation (Lower and Middle Cambrian) in the southern Great Basin: U.S. Geological Survey Professional Paper 1047, 131p.

Peterman, Z.E., and Stuckless, J.S., 1993, Isotopic evidence of complex ground-water flow at Yucca Mountain, Nevada, *in* High Level Radioactive Waste Management, Proceedings of the Fourth Annual International Conference: La Grange Park, Ill., American Nuclear Society; and New York, American Society of Civil Engineers, p. 1559-1566.

Peterman, Z.E., Stuckless, J.S., Mahan, S.A., Marshall, B.D., Gutentag, E.D., and Downey, J.S., 1992, Strontium isotope characterization of the Ash Meadows ground-water system, southern Nevada, U.S.A., *in* Kharaka, Y.K. and Maest, A.S., eds., Water-rock interaction: Proceedings of the 7th International Symposium on Water-Rock Interaction-WRI-7, Park City, Utah, p. 825-829.

Prave, A.R., and Wright, L.A., 1986, Isopach pattern of the lower Cambrian Zabriskie Point Quartzite, Death Valley region, California-Nevada—How useful in tectonic reconstructions?: Geology, v. 14, p. 251-254.

Poole, F.G., Stewart, J.H., Palmer, A.R., Sandberg, C.A., Madrid, R.J., Ross, R.,J., Jr., Hintze, L.F., Miller, M.M., and Wrucke, C.T., 1992, Latest Precambrian to latest Devonian time; development of a continental margin, *in* Burchfiel, B.C., Lipman, P.W., and Zoback, M.L., eds., The Cordilleran Orogen – conterminous U.S.: Geological Society of America, The Geology of North America, v. G-3, p. 9-54.

Reso, Anthony, 1963, Composite columnar section of exposed Paleozoic and Cenozoic rocks in the Pahranagat Range, Lincoln County, Nevada: Geological Society of America Bulletin, v. 74, p. 901-918.

Rowland, S.M., 1987, Paleozoic stratigraphy of Frenchman Mountain, Clark County, Nevada: Geological Society of America Centennial Field Guide—Cordilleran Section, p. 53-56.

Signor, P. W., and Mount, J. F., 1986, Position of the Lower Cambrian boundary in the White-Inyo Mountains of California and in Esmeralda County, Nevada: Newsletters in Stratigraphy, v. 16, p. 9–18.

Snow, J.K., 1992, Large-magnitude Permian shortening and continental-margin tectonics in the southern Cordillera: Geological Society of America Bulletin, v. 104, p. 80-105.

Stewart, J.H., 1967, Possible large right-lateral displacement along fault and shear zones in Death Valley-Las Vegas area, California and Nevada: Geological Society of America Bulletin, v. 78, p. 131-142.

——1970, Upper Precambrian and Lower Cambrian strata in the southern Great Basin, California and Nevada: U.S. Geological Survey Professional Paper 620, 206 p.

——1972, Initial deposits in the Cordilleran geosyncline; Evidence of a Late Precambrian (< 850 m.y.) continental separation: Geological Society of America Bulletin, v. 83, p. 1345-1360.

——1988, Tectonics of the Walker Lane belt, western Great Basin Mesozoic and Cenozoic deformation in a zone of shear, *in* Ernst, W.G., ed., Metamorphism and crustal evolution of the Western United States (Ruby Volume 7): Englewood Cliffs, N.J., Prentice-Hall, p. 683-713.

Stewart, J.H., Albers, J.P., and Poole, F.G., 1968, Summary of regional evidence for right–lateral displacement in the western Great Basin: Geological Society of America Bulletin, v. 79, p. 1407-1413.

Stewart, J.H., and Crowell, J.C., 1992, Strike-slip tectonics in the Cordillera region, western United States, *in* Burchfiel, B.C., Lipman, P.W. and Zoback, M.L., eds., The Cordilleran orogen — conterminous U.S.: Geological Society of America, Geology of North America, v. H-3, p. 609-628.

Stewart, J.H. and Poole, F.G., 1974, Lower Paleozoic and uppermost Precambrian Cordilleran miogeocline, Great Basin, western United States, *in* Dickinson, W.R., ed., Tectonics and sedimentation: Society of Economic Paleontologist and Mineralogists Special Publication 22, p. 28–57.

Tschanz, C.M., and Pampeyan, E.H., 1970, Geology and mineral deposits of Lincoln County, Nevada: Nevada Bureau of Mines and Geology Bulletin 73, 188 p.

Wernicke, B.P., Axen, G.J., and Snow, J.K., 1988, Basin and Range extensional tectonics at the latitude of Las Vegas, Nevada: Geological Society of America Bulletin, v. 100, p. 1738-1757.

Winograd, I.J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712-C, 126 p.

Wright, L.A., and Troxel, B.W., 1993, Geologic map of the central and northern Funeral Mountains and adjacent areas, Death Valley region, southern California: U.S. Geological Survey Miscellaneous Investigations Map I-2305, scale 1:48,000.

Wright, L.A., Troxel, B.W., Williams, E.G., Roberts, M.T. and Diehl, P.E., 1974, Precambrian sedimentary environments of the Death Valley Region, eastern California, *in* Troxel, B.W., ed., Guidebook; Death Valley Region, California and Nevada: Shoshone, Calif., The Death Valley Publishing Company, p. 27-35.