DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

National Petroleum Assessment
Western Basin and Range Province
(Province 83)

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Open-File Report

87-450L

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INTRODUCTION

Basin Location and Size

Province 83 encompasses about one-half of Nevada (Fig. 1). To call this province a single basin is obviously a misnomer. This province represents a collage of diverse basins and basin types that evolved in response to a number of sedimentologic and tectonic episodes along the western margin of North America (Figs. 2,3).

QUALITATIVE EVALUATION OF HYDROCARBONS

Within Province 83 the possibility of commercial accumulations of hydrocarbons is low. However, one area in Pershing County (Dixie Valley, lat. 40°N. and long. 117°45'W.) has been identified as a speculative play. This area is attractive enough to warrant additional field mapping and sampling the potential source and reservoir facies. This play, the Dixie Valley Play, is discussed below.

REGIONAL GEOLOGIC FRAMEWORK

This section will attempt to outline the regional structural setting and geologic history of the Cordillera. To gain a true perspective of the geologic evolution of western Nevada, one must look beyond this man-made boundary into eastern Nevada and California. The regional tectonics and stratigraphy of these three Cordilleran provinces have an intimate interwoven genesis that dates back to the Proterozoic (Figs. 2-6). Plate tectonic theory will be

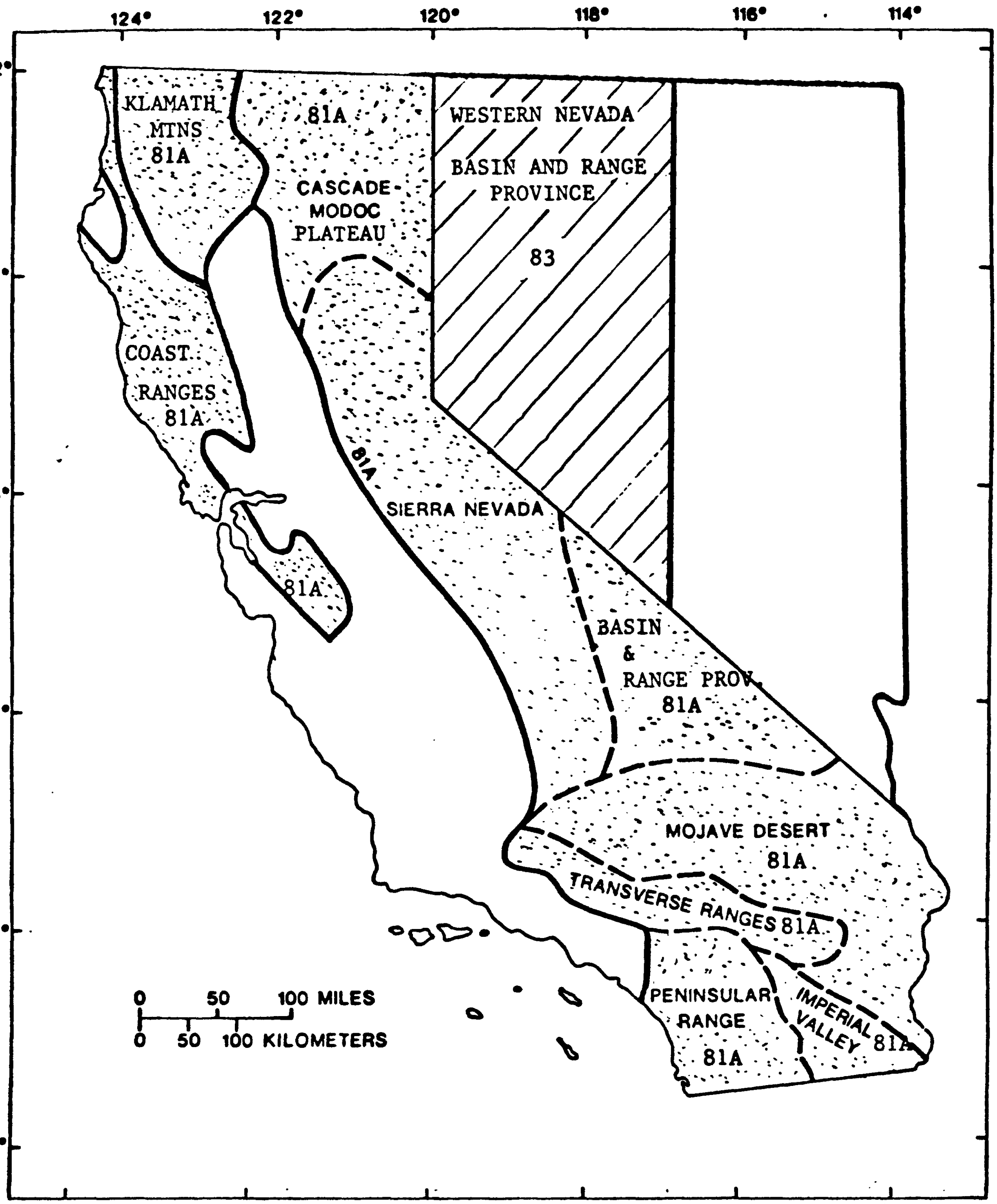

FIGURE 1 Index map of California showing the geomorphic divisions of the Eastern California province (81A) in stiples and Western Nevada, Basin and Range Province (83) in hachures. Modified after Scott (1983).

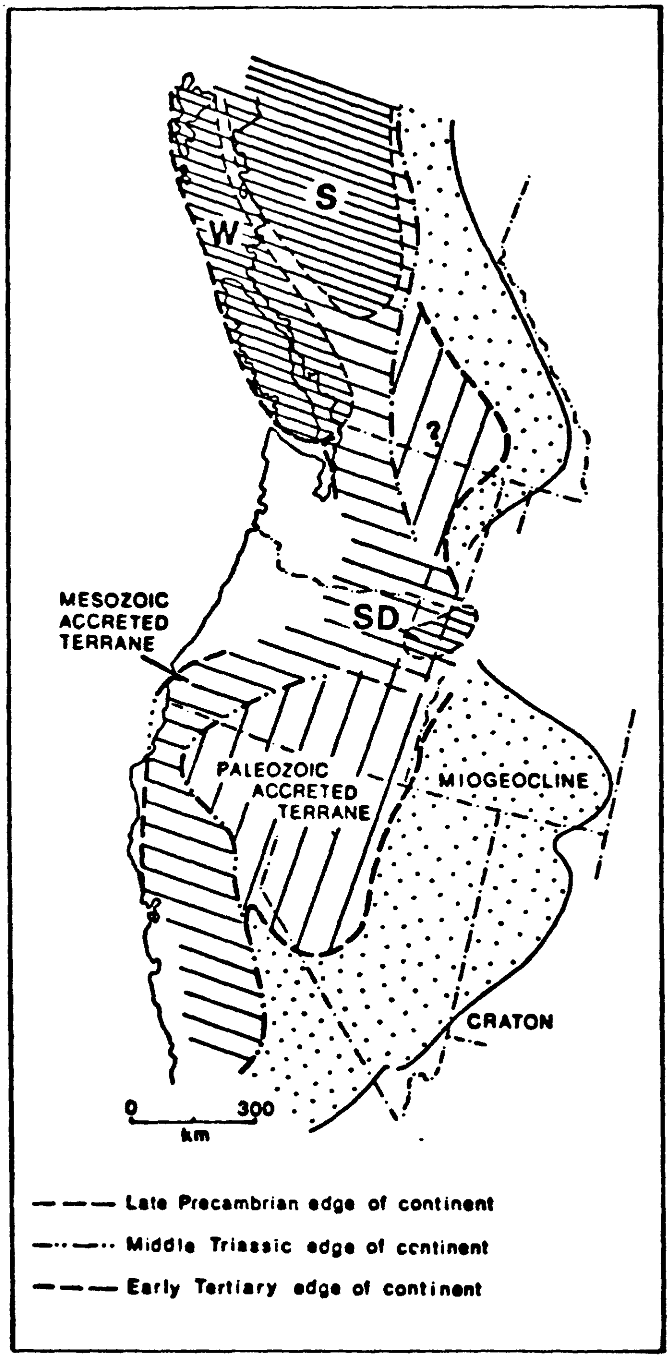

Figure 2. Major components of Cordilleran "collage". W = "Wrangellia"; S = Stikine arc; SD = "Seven Devils" arc.

From Davis et al (1978)

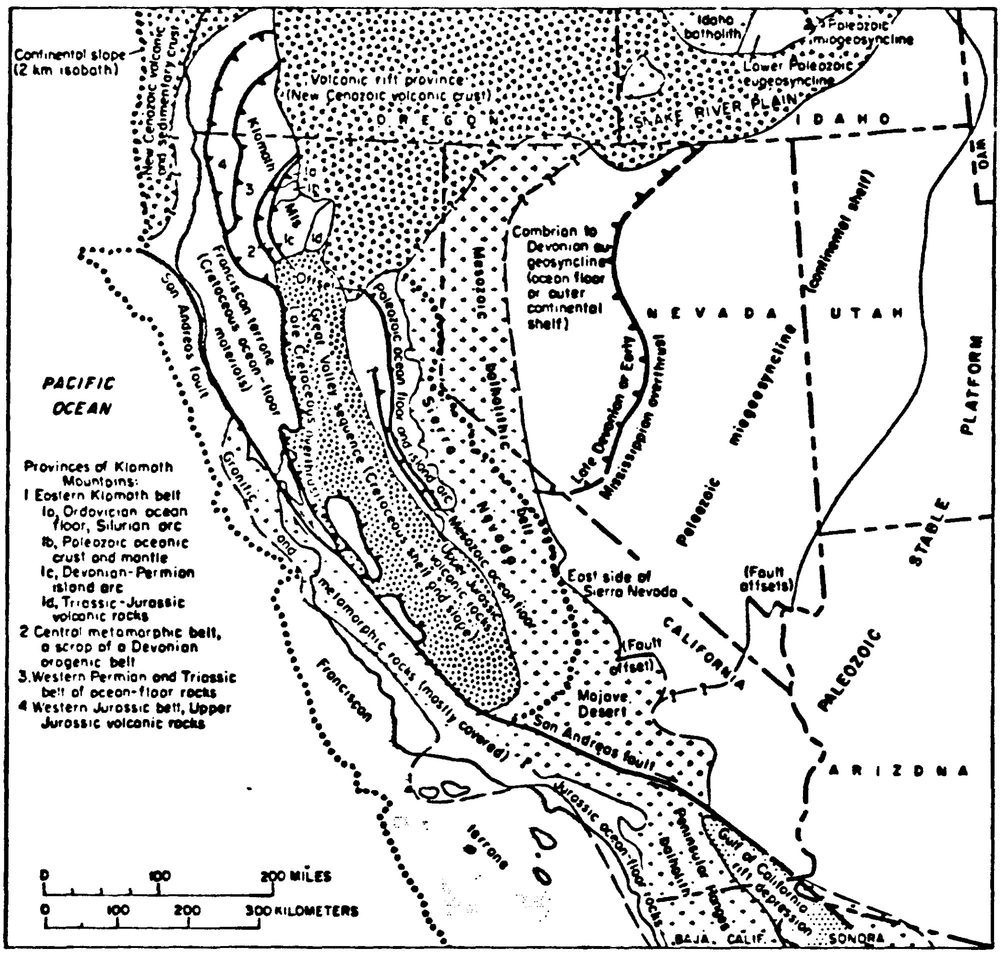

Figure 3. Tectonic elements of California, Nevada, and neighboring regions.

From Hamilton (1969)

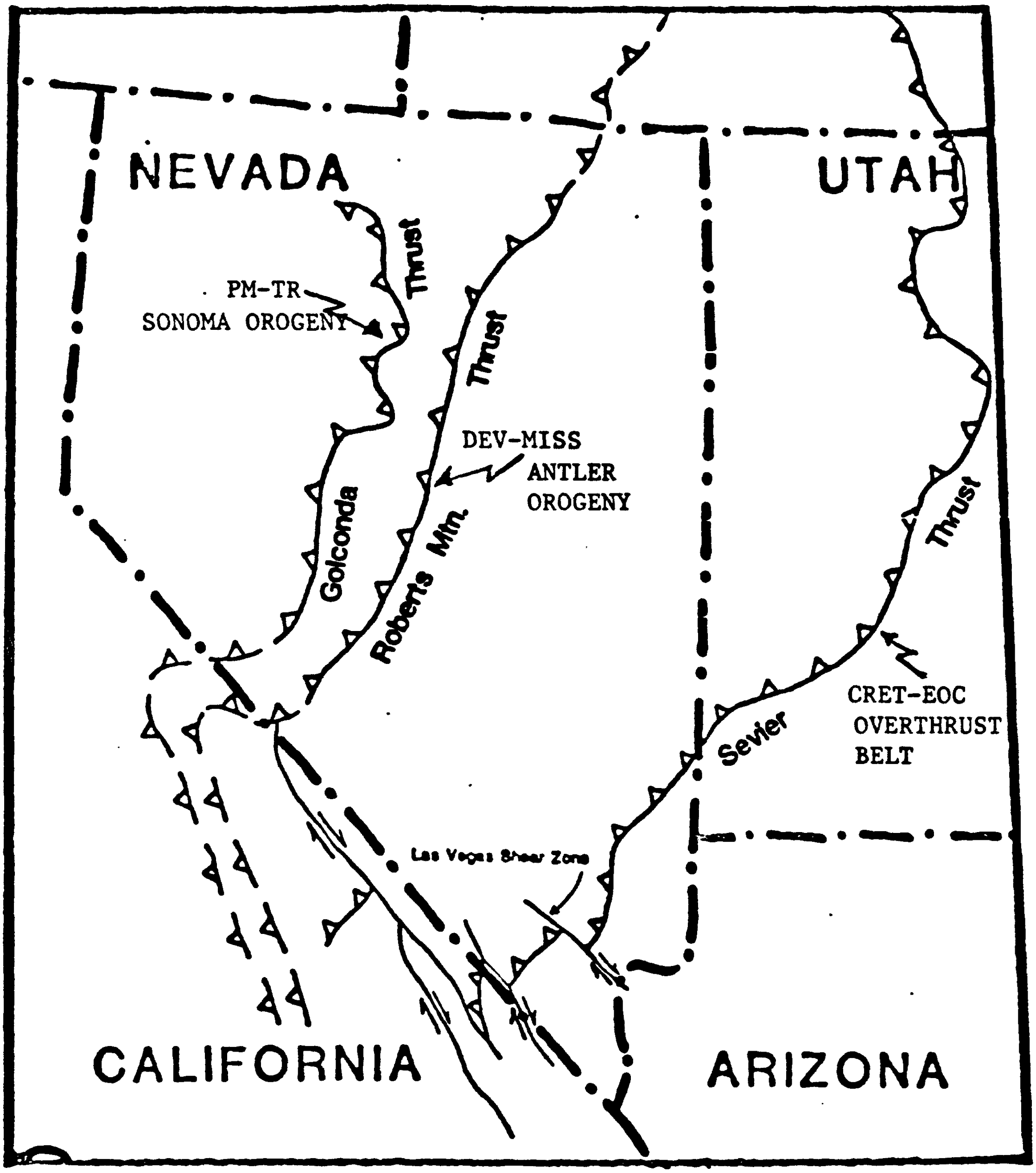

Figure 4. Map showing locations of Permo-Triassic Golconda thrust, Devonian-Mississippian Roberts Mountains Thrust, and the Cretaceous-Eocene Sevier thrust of the Overthrust Belt. From Cook and Taylor (1983).

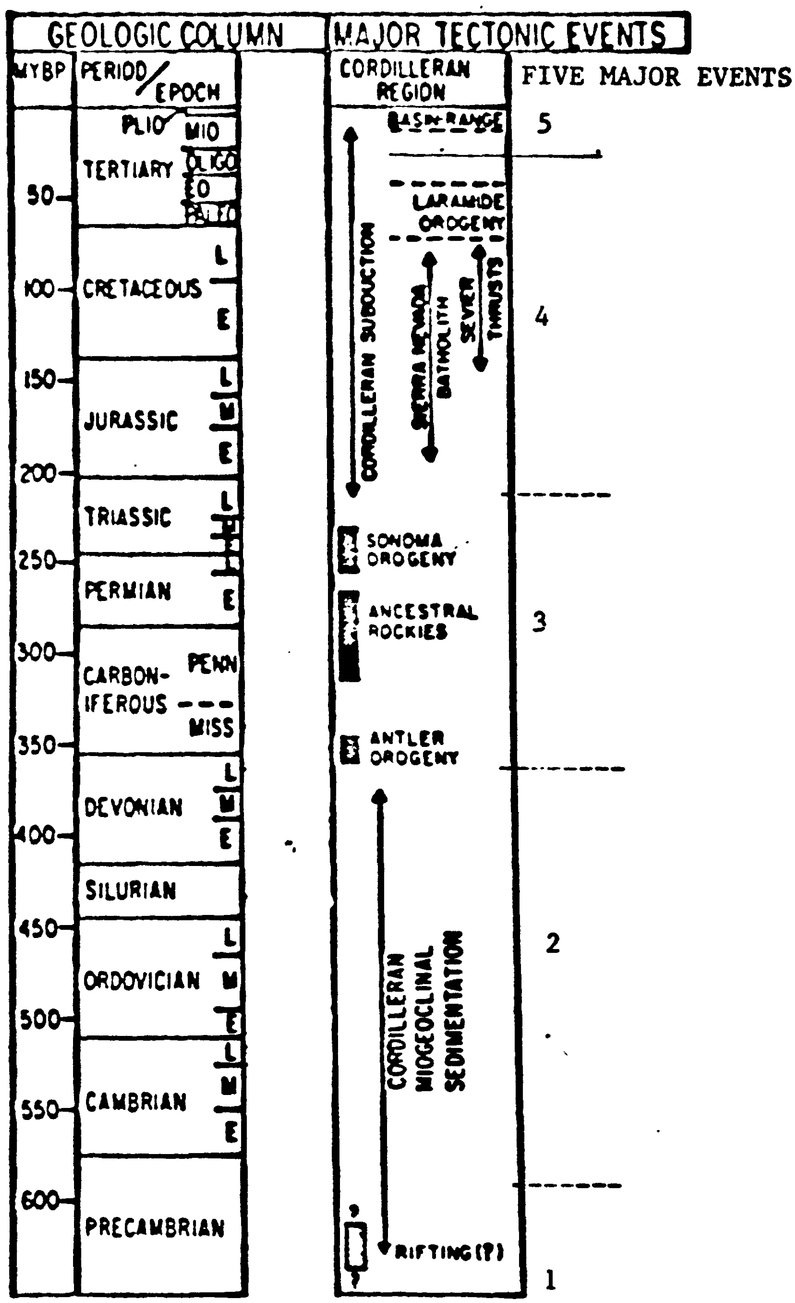

Figure 5. Major tectonic events in the Cordilleran. From Cook and Taylor (1983).

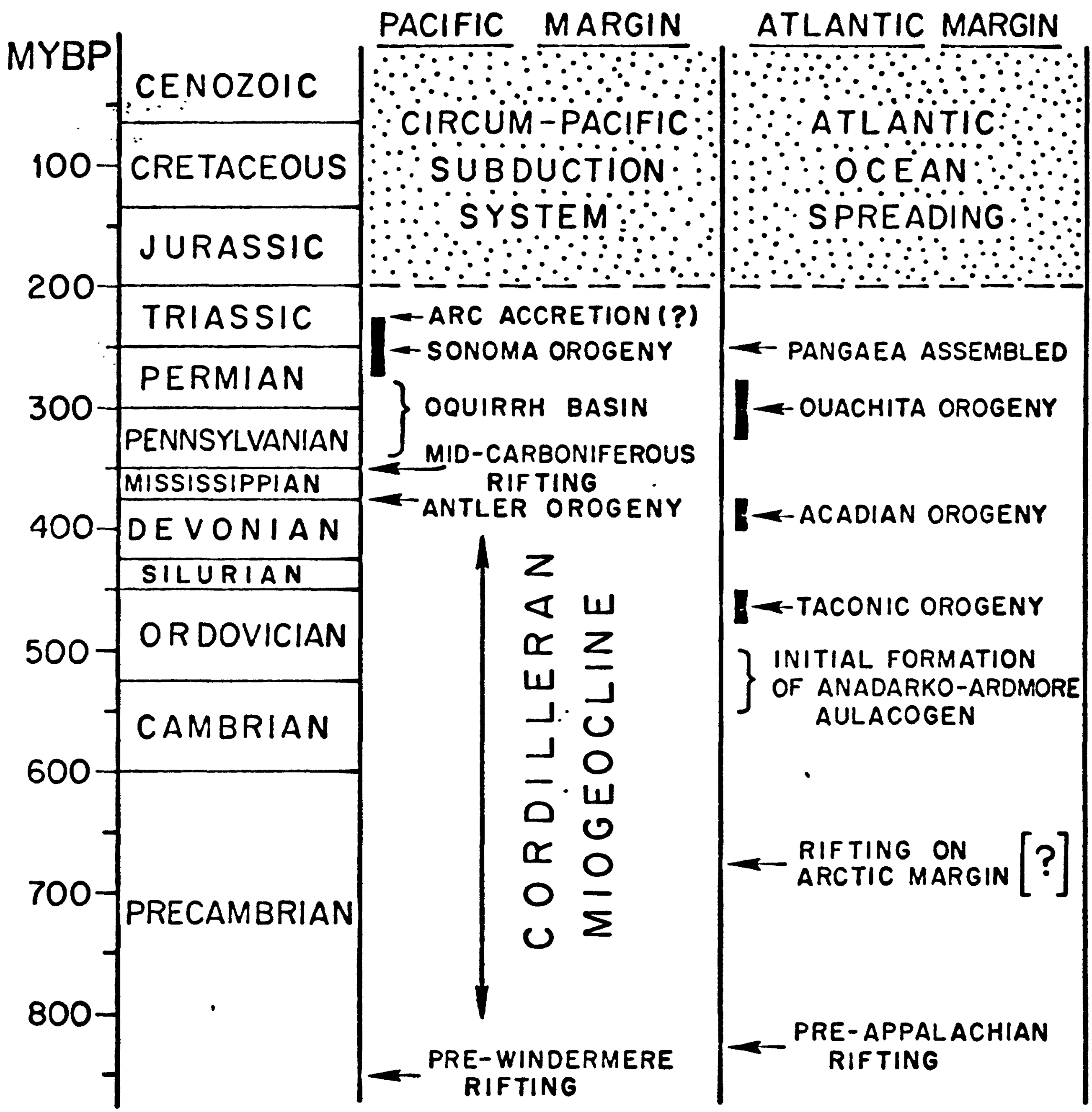

Figure 6 -Diagram to illustrate approximate relative timing of key events on Pacific and Atlantic margins of North America.

From Dickinson (1977).

liberally used to understand the complex geologic history of the Cordillera. This theory appears to offer unique unifying insights into the origin of the diverse tectonic-sedimentologic regimes in the provinces of Nevada and California.

Five tectonic events shaped the western margin of North America in the vicinity of California and Nevada (Fig. 5). Some of these events are confined to each respective province, but some events were of broader scale, and affected the entire western margin of North America simultaneously.

Event 1: Proterozoic Crystalline Basement

Strontium and neodymium isotopes have been used to define Precambrian crystalline basement of Proterozoic age. This continental crust is inferred to extend as far west as central Nevada (Fig. 7, 1Sr = 0.706) (Kistler, 1974; Farmer and DePaolo, 1983). Extensive metamorphism and intrusion of this basement occurred between 1,650 and 1,750 Ma (King, 1969).

Event 2: Late Precambrian Through Devonian--
Continental Rifting and Passive Margin Development

The Proterozoic continent was broken by a major rifting event near the end of the Precambrian (Figs. 8,9) (Stewart, 1972; Stewart and Suczek, 1977). Until the end of the Devonian a passive continental margin comprised western North America from Alaska to southeastern California (Figs. 10,11) (Churkin, 1974; Cook and Taylor, 1975). This rifting and initial development of the Cordilleran miogeocline is not well dated directly, but stratigraphic backstripping indicates that rifting happened between 625 and 550 ma (Bond and

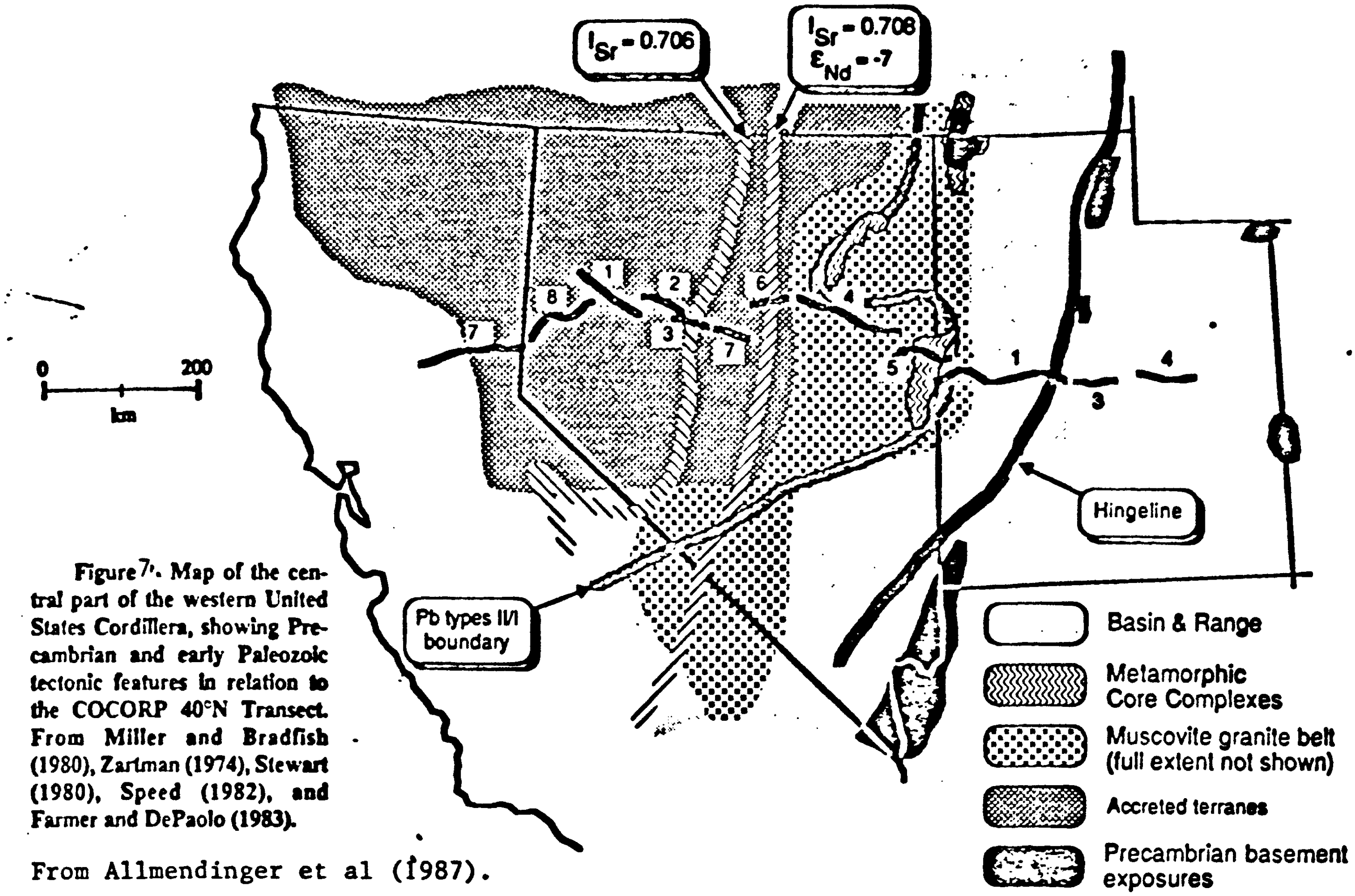

Figure 7. Map of the central part of the western United States Cordillera, showing Precambrian and early Paleozoic tectonic features in relation to the COCORP 40°N Transect. From Miller and Bradfish (1980), Zartman (1974), Stewart (1980), Speed (1982), and Farmer and DePaolo (1983).

From Allmendinger et al (1987).

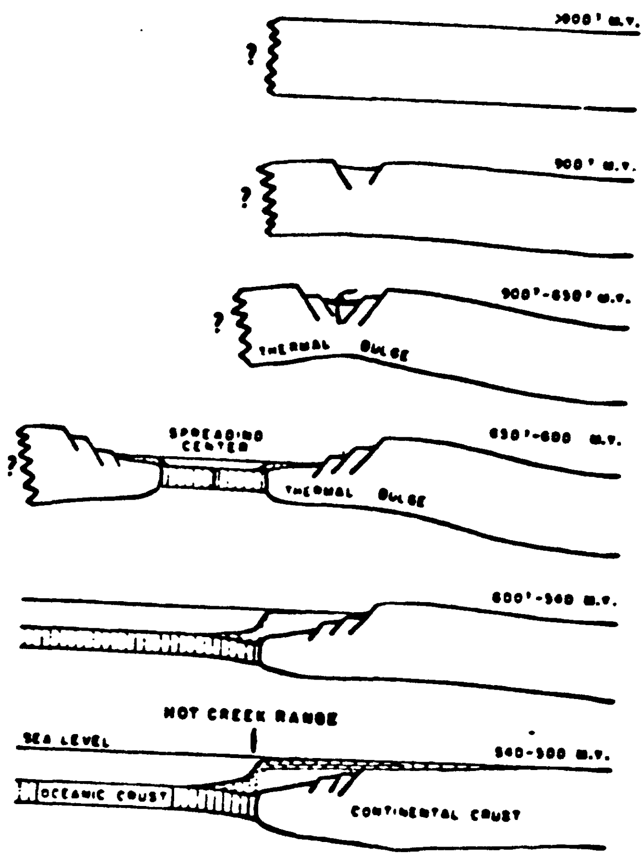

Figure 8.-Diagram showing a model of the late Precambrian and Cambrian development of the western United States

From Cook and Egbert (1981).

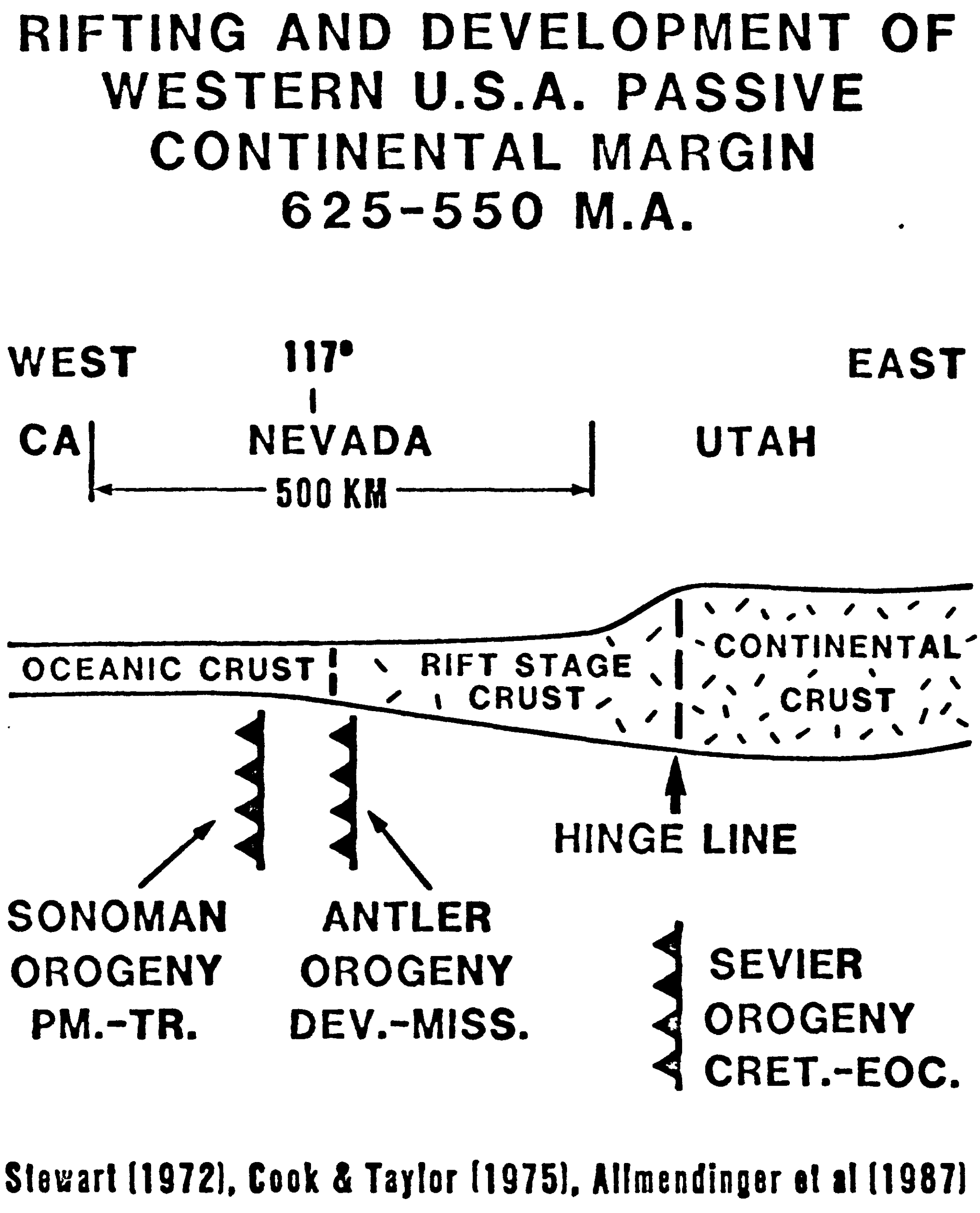

Figure 9. From Cook and Taylor (1987).

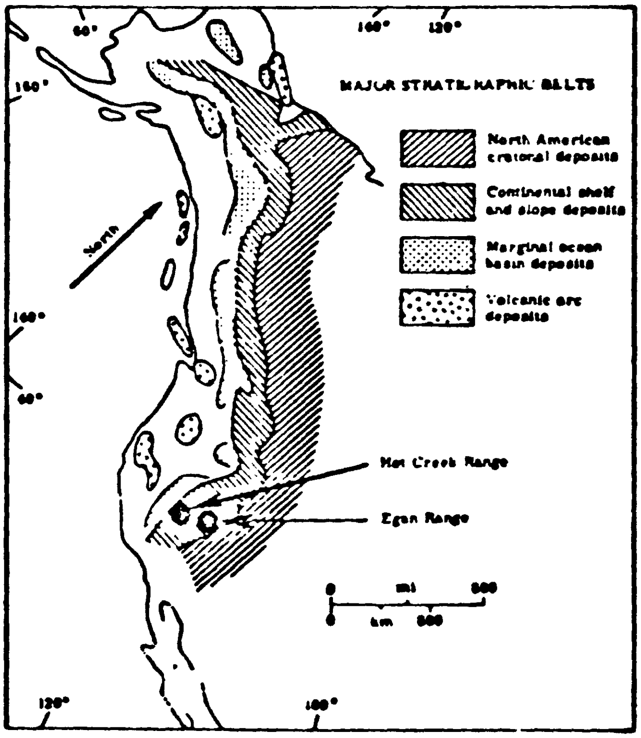

Figure 10. General location of sections in the Hot Creek Range and central Egan Range, Nevada, in relation to major regional stratigraphic belts.

From Cook and Taylor (1977).

LATE PRE-CAMBRIAN THROUGH LATE DEVONIAN
PASSIVE PULL-APART MARGIN

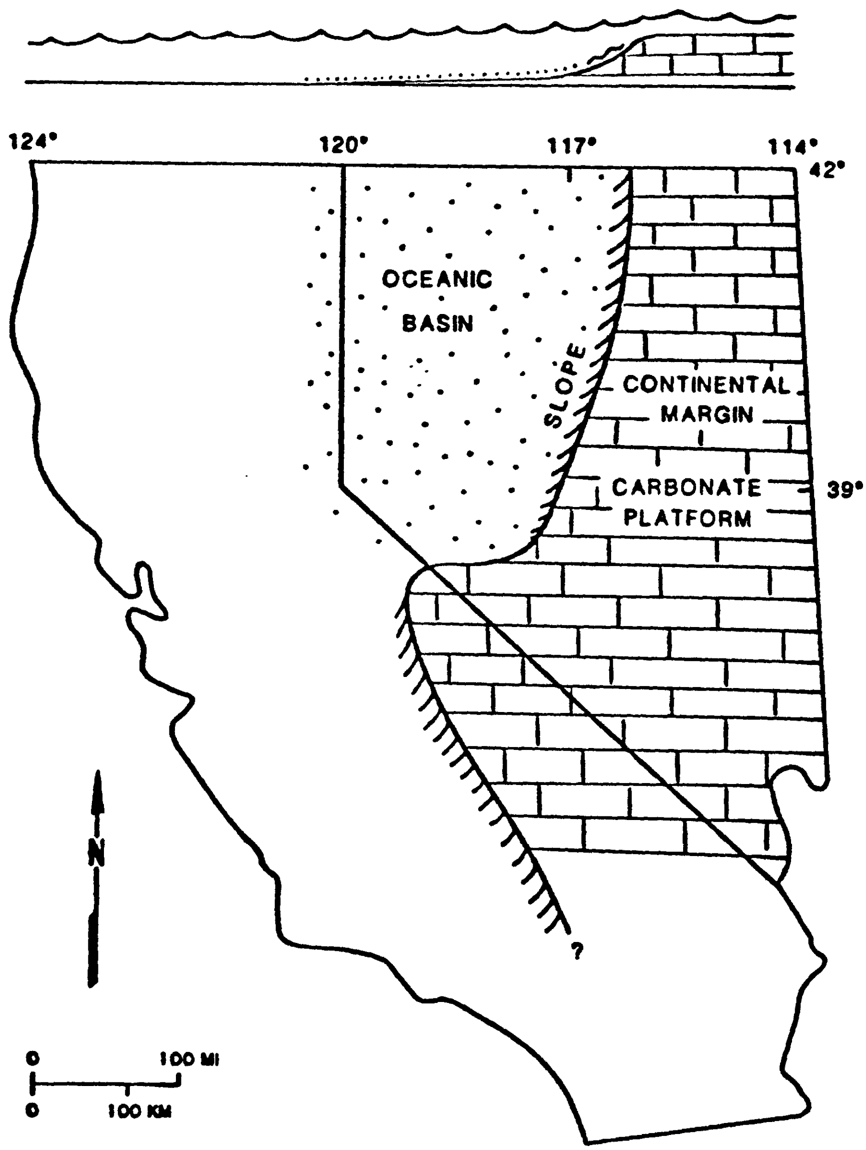

Figure 11. Paleogeographic map.

Kominz, 1984). On the basis of sedimentologic and biostratigraphic analyses between Asia and western North America, Cook and Taylor (1975) established that this rifting event occurred no later than about 520 ma.

This passive continental margin became the site of 5,000 m of shoal-water carbonate platform and basinal sediments from the Cambrian through the Devonian (Figs. 12,13) (Cook and Taylor, 1983; Cook and Taylor, 1987).

Event 3: Late Devonian Through Triassic--Terrane Accretion

Two major accretionary events occurred during the Late Devonian-Early Mississippian (Antler orogeny, Roberts et al., 1958; Speed, 1982,1983), and the Permian-Triassic (Sonoma orogeny, Silberling and Roberts, 1962; Speed, 1979,1982,1983) (Figs. 4,5,12). During the Antler orogeny the Roberts Mountains allochthon oceanic rocks were thrust eastward at least 100 km over the continental slope and platform margin carbonates. This event formed the Antler orogenic highlands and foreland basin (Figs. 4,12,14,15). Similarly, during the Sonoman orogeny, oceanic rocks in the Golconda allochthon (Figs. 4,12) were thrust eastward about 50-75 km over previously deformed continental-margin sediments (Fig. 12). The Sonoman orogeny, however, involved less crustal shortening than the Antler orogeny, and did not develop a foreland basin, as was the case during the Antler orogeny (Fig. 16).

The tectonic model that is commonly called upon to explain the distribution of lithofacies in both orogenies is that of a normal polarity arc; the back-arc (inner-arc) basin (Fig. 14) develops as a normal-trapped marginal basin (Fig. 17c). This model is basically a Japan sea-type (Mitchell and Reading, 1969) orogen (i.e., a continent bordered by a marginal sea with a nearby arc offshore (Dickinson, 1977).

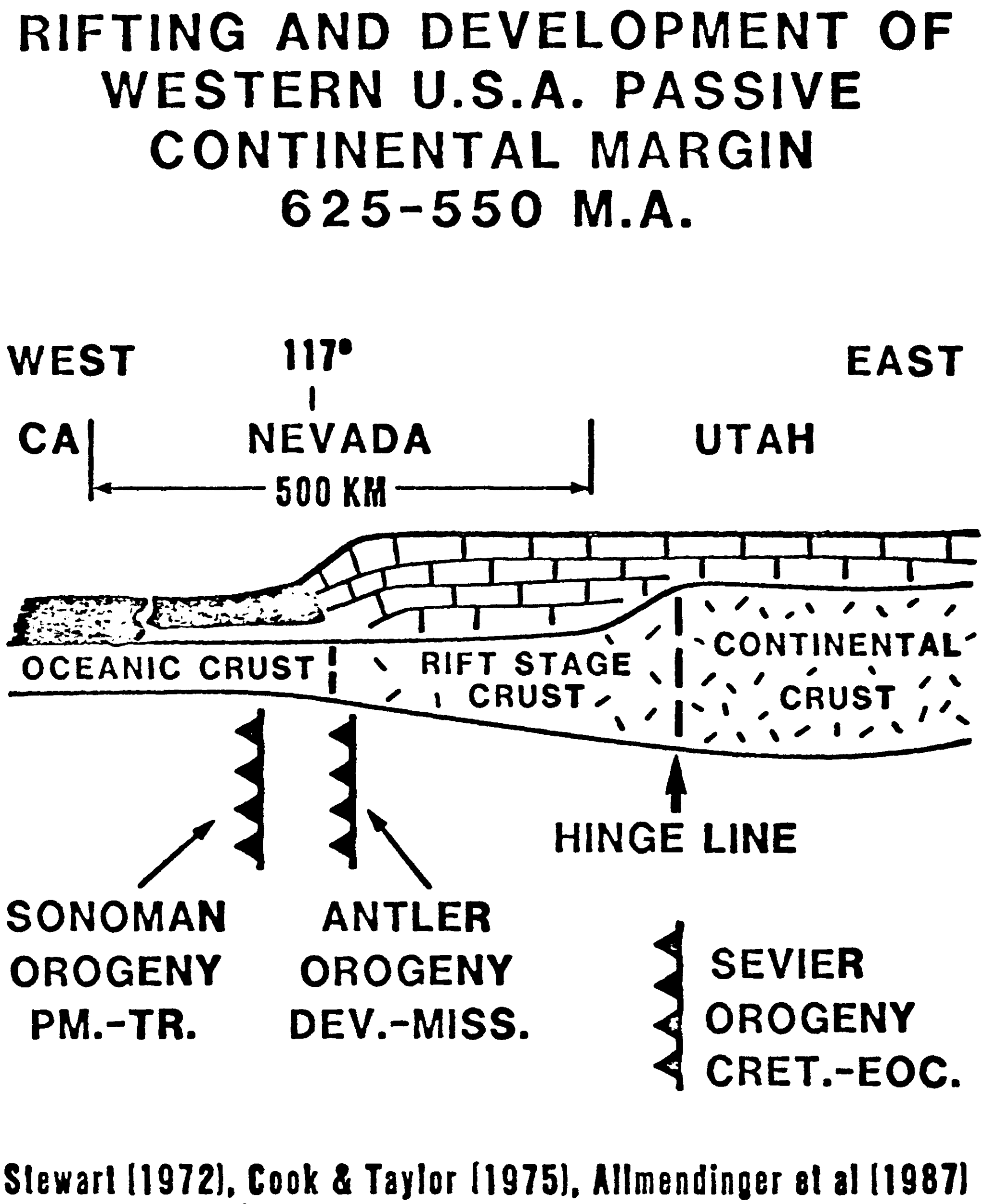

Figure 12. From Cook and Taylor (1987).

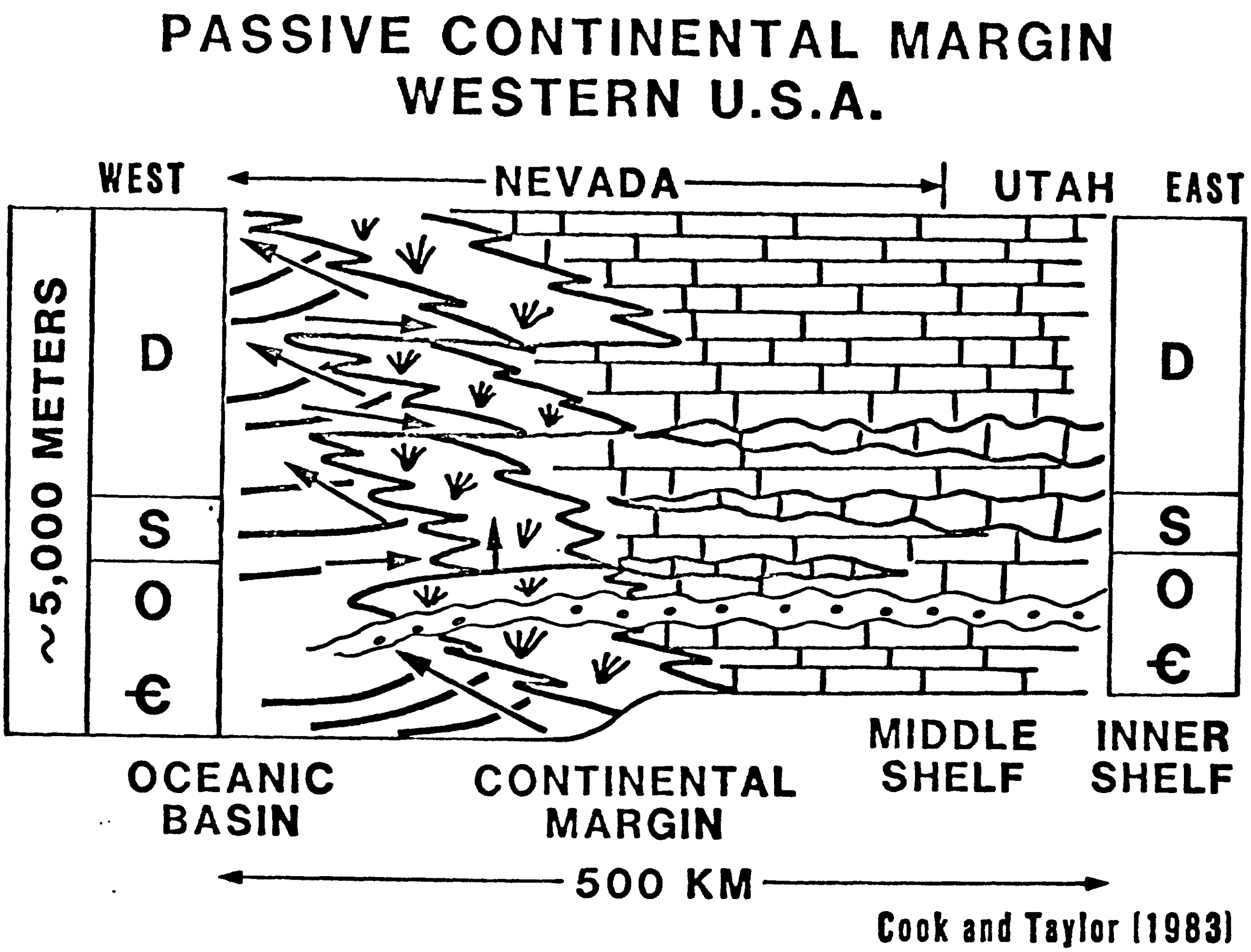

Figure 13. Generalized Pre-Antler orogeny depositional profile from western Utah to central Nevada. Based on data from Cook and Taylor (1975,1983,1987).

LATE DEVONIAN - EARLY MISSISSIPPIAN

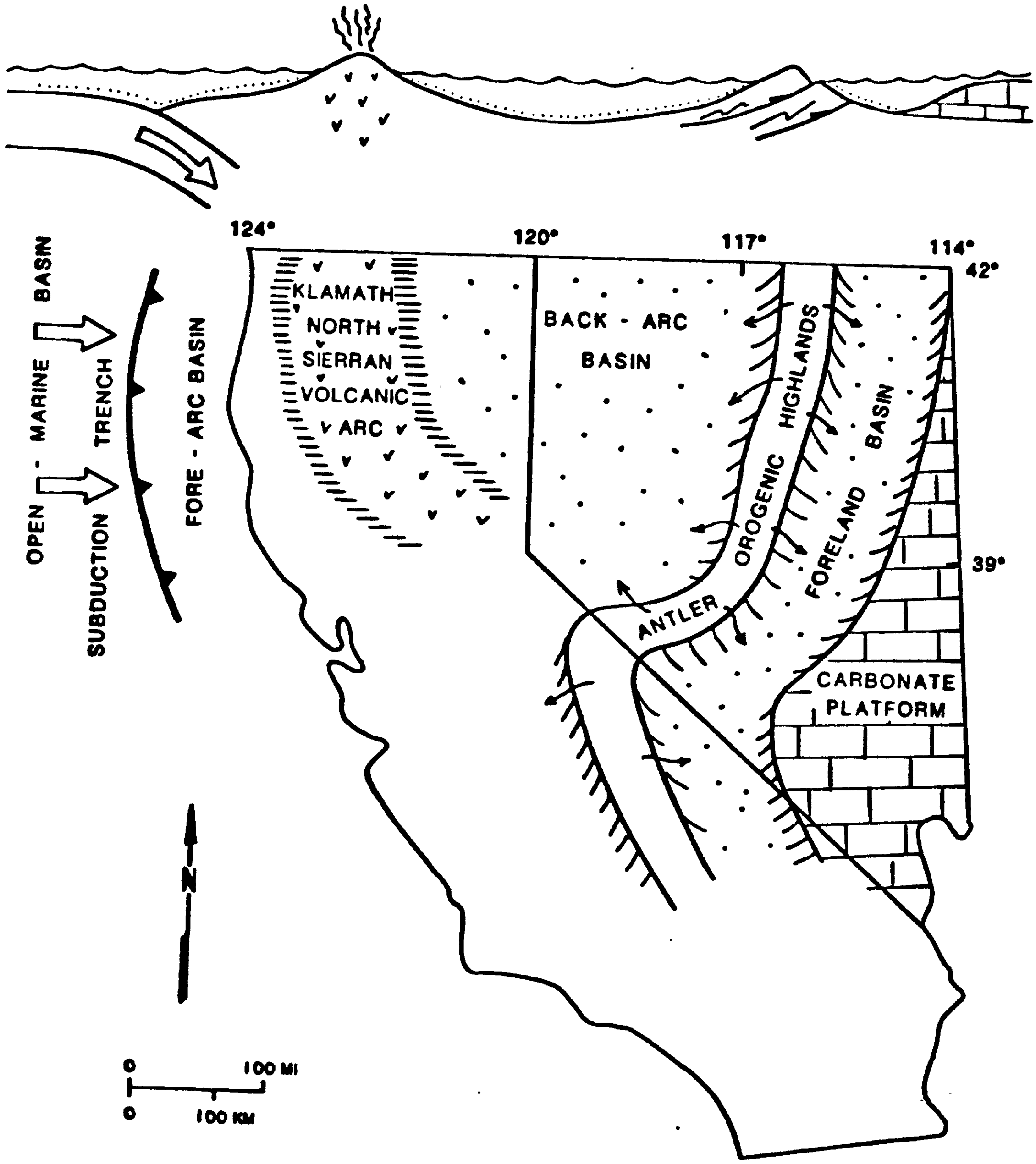

Figure 14. Paleogeographic map.

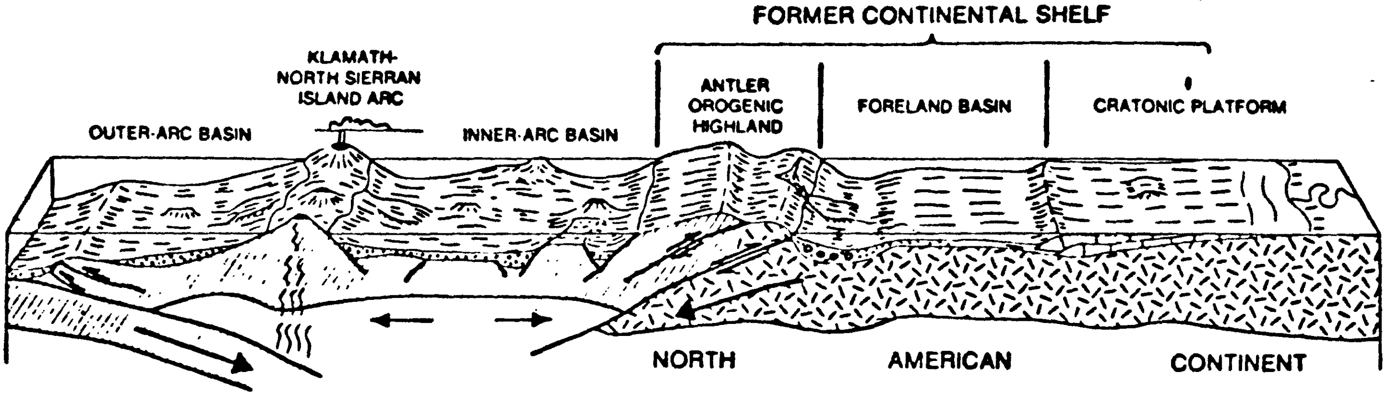

Figure 15. Hypothetical and generalized diagram showing relation between latest Devonian and Mississippian island-arc system and North American continent during Antler orogenic deformation.

From Poole et al (1987).

EARLY MESOZOIC

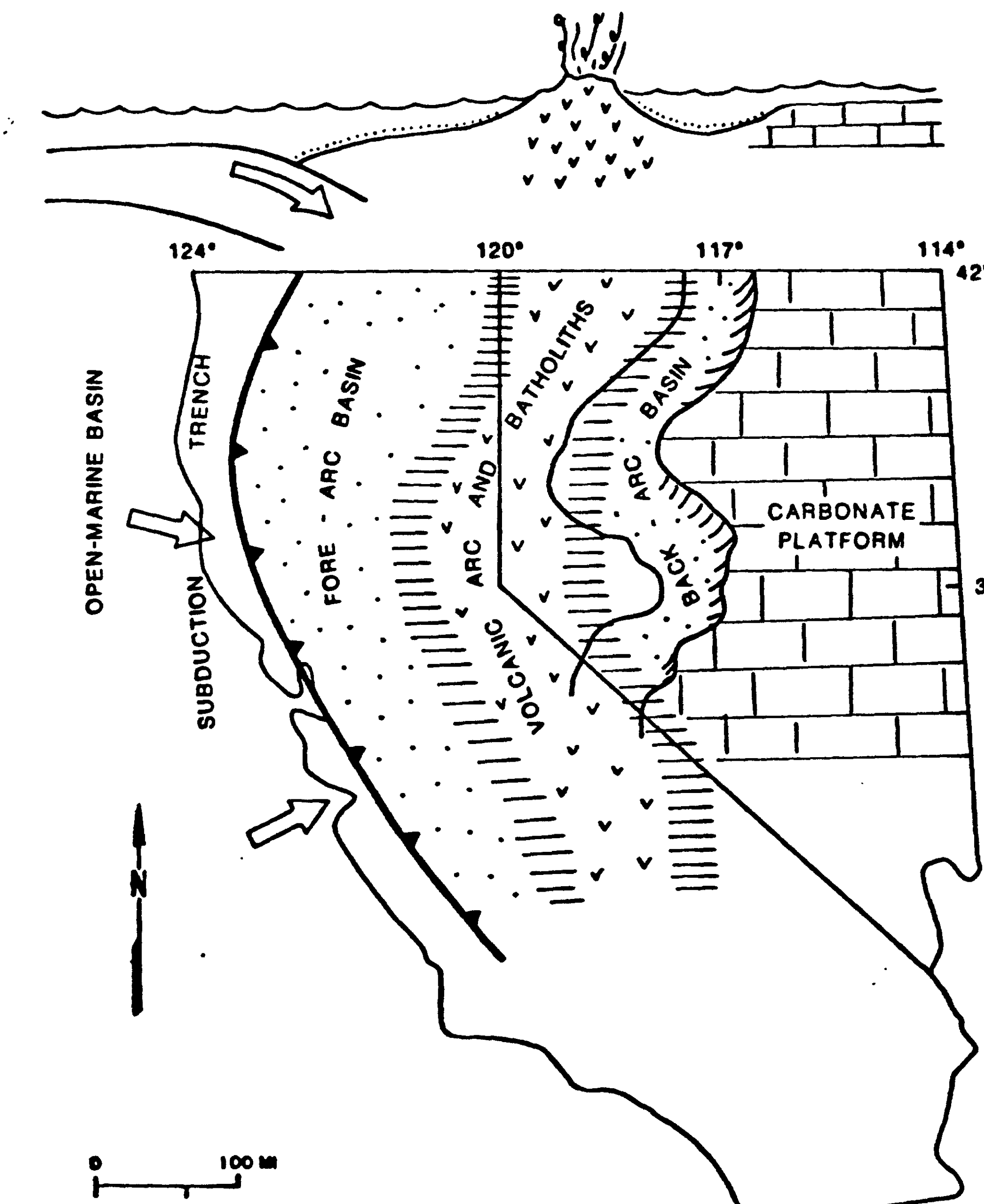

Figure 16. Paleogeographic map. Early Mesozoic.

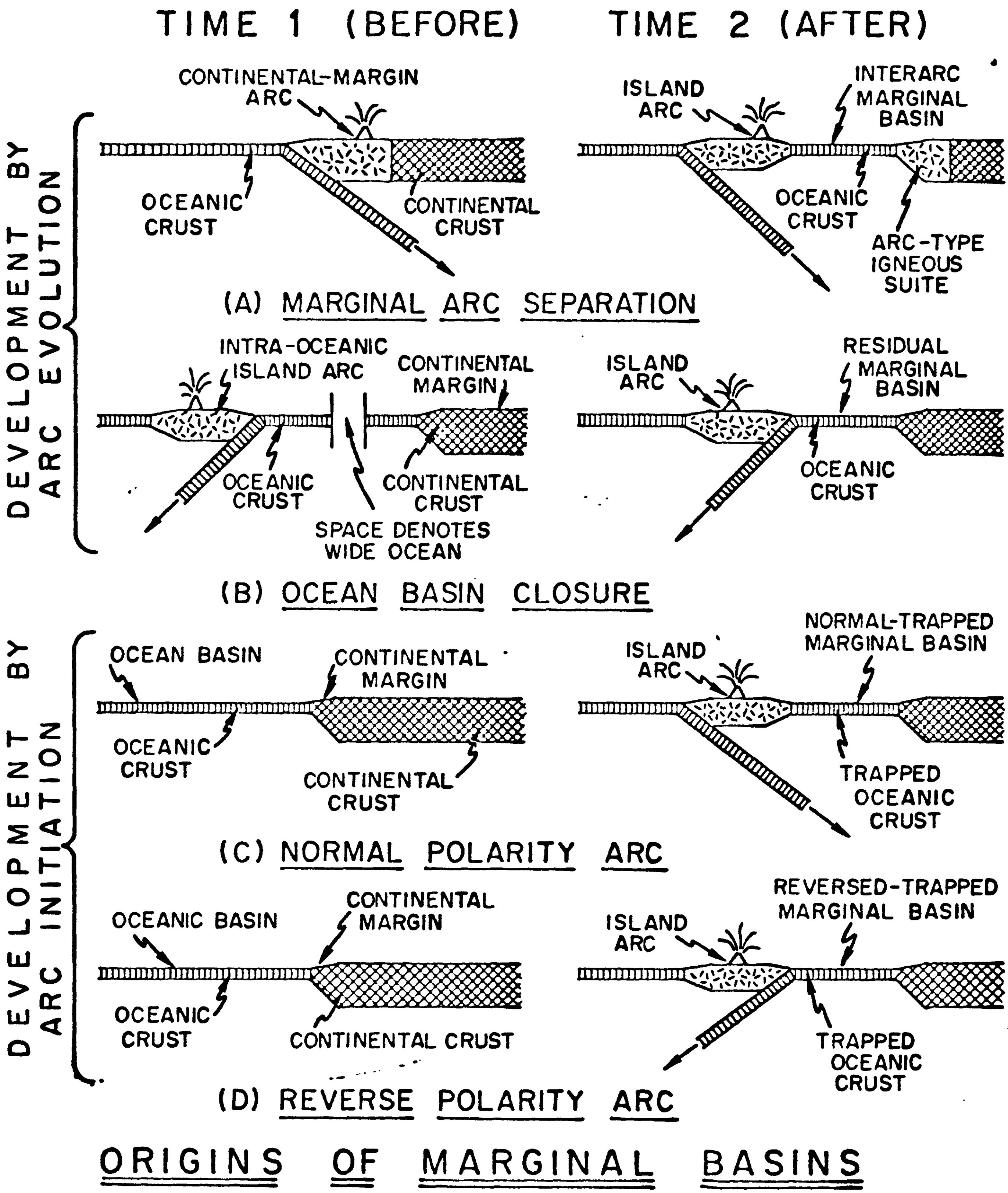

Figure 17–Sketches to illustrate alternate origins for oceanic marginal seas.

From Dickinson (1977).

Beginning sometime in the Triassic, scattered plutons were being emplaced in eastern California (Fig. 18) (Speed, 1978a,b). Simultaneously, ophiolite complexes were developing in northern California, signaling the beginning of major subduction systems and batholithic intrusions that were to dominate the Cordillera later in the Mesozoic.

Event 4: Cretaceous-Eocene--Andean-Type Continental Margin

In the Jurassic-Cretaceous the continental margin evolved into a setting similar to that of the modern Andes with eastward subduction beneath the continent (Fig. 20) (Hamilton, 1969, 1978; Allmendinger et al., 1987). The Cretaceous geology of northern and central California is dominated by three coeval complexes, now considered to be synchronous responses to subduction of the Pacific lithosphere beneath the North American continent (Hamilton, 1978). In the east is the Sierran magmatic arc and batholiths (Fig. 19), in the center is the fore-arc (outer arc) basin into which the Great Valley sequence accumulated, and to the west in thrust contact beneath the Great Valley sequence is the chaotic Franciscan melange (Fig. 20). East of the Sierra Nevada batholith the Basin and Range Province was undergoing fluvial and lacustrine sedimentation and minor amounts of volcanic activity (Fig. 20).

This Andean-type subduction was responsible for numerous thrust faults which telescoped sedimentary facies throughout much of the Cordillera. These thrusts are especially well exposed in the Basin and Range Province. The Sevier overthrust belt of Cretaceous to Eocene age was the largest of the Mesozoic thrust belts, and extended from southern Nevada northward into Canada (Fig. 4). Armstrong (1968) estimated about 100 km of eastward crustal shortening associated with the Sevier system.

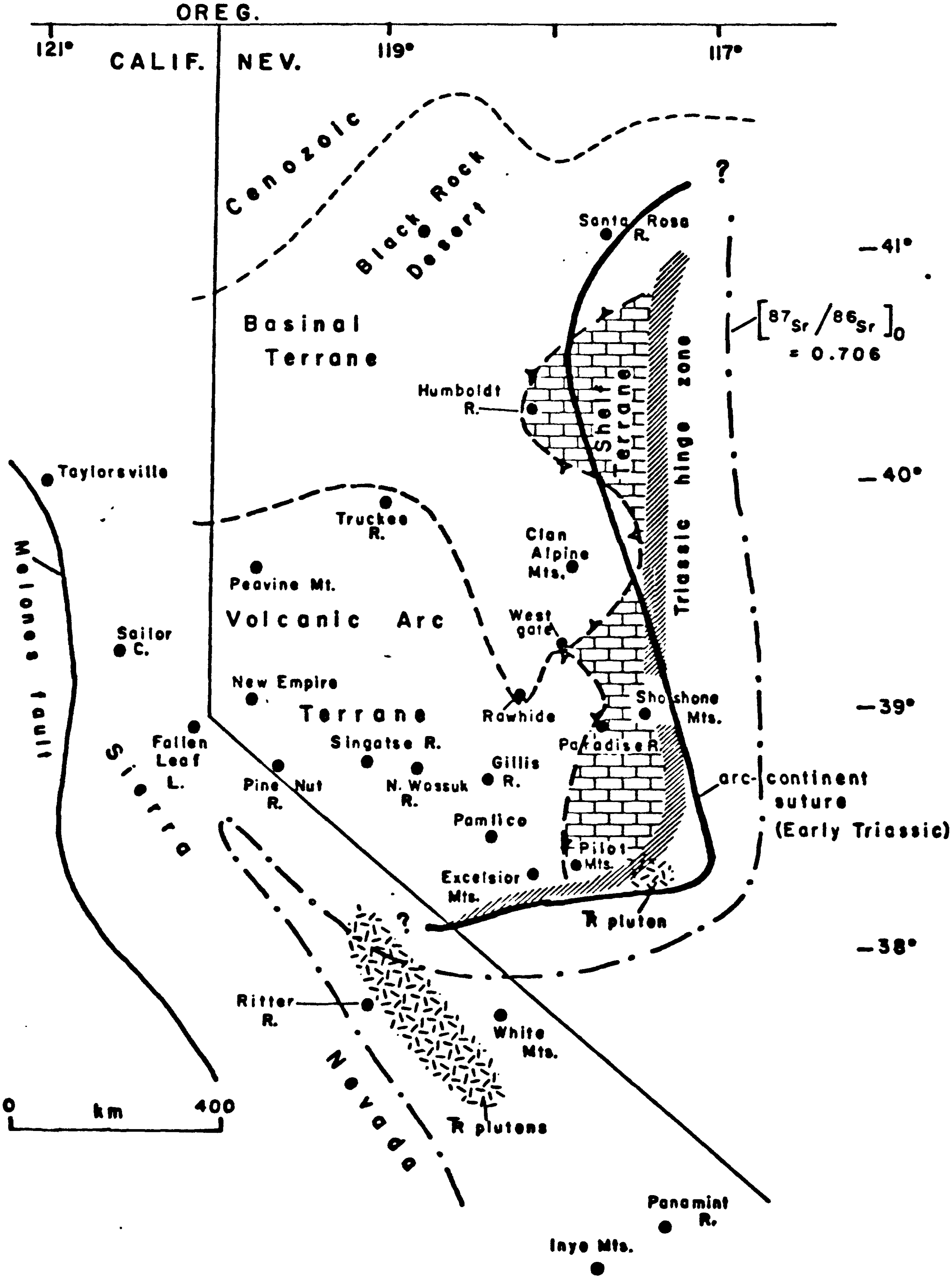

Figure 18. Map showing paleogeographic terranes of early Mesozoic marine province of the western Great Basin

From Speed (1978 b).

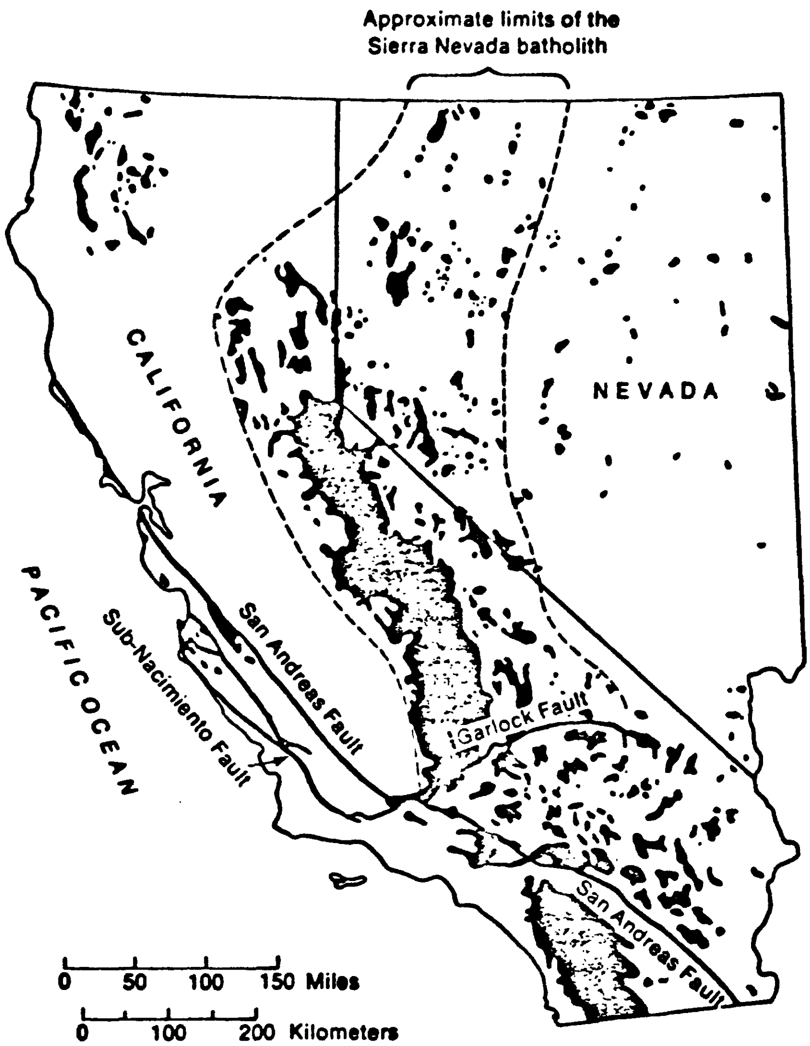

Figure 19. *Distribution of granitic rocks in the Sierra Nevada batholith. (Source: Geological Society of America)*

From Norris and Webb (1976).

LATE CRETACEOUS - TERTIARY

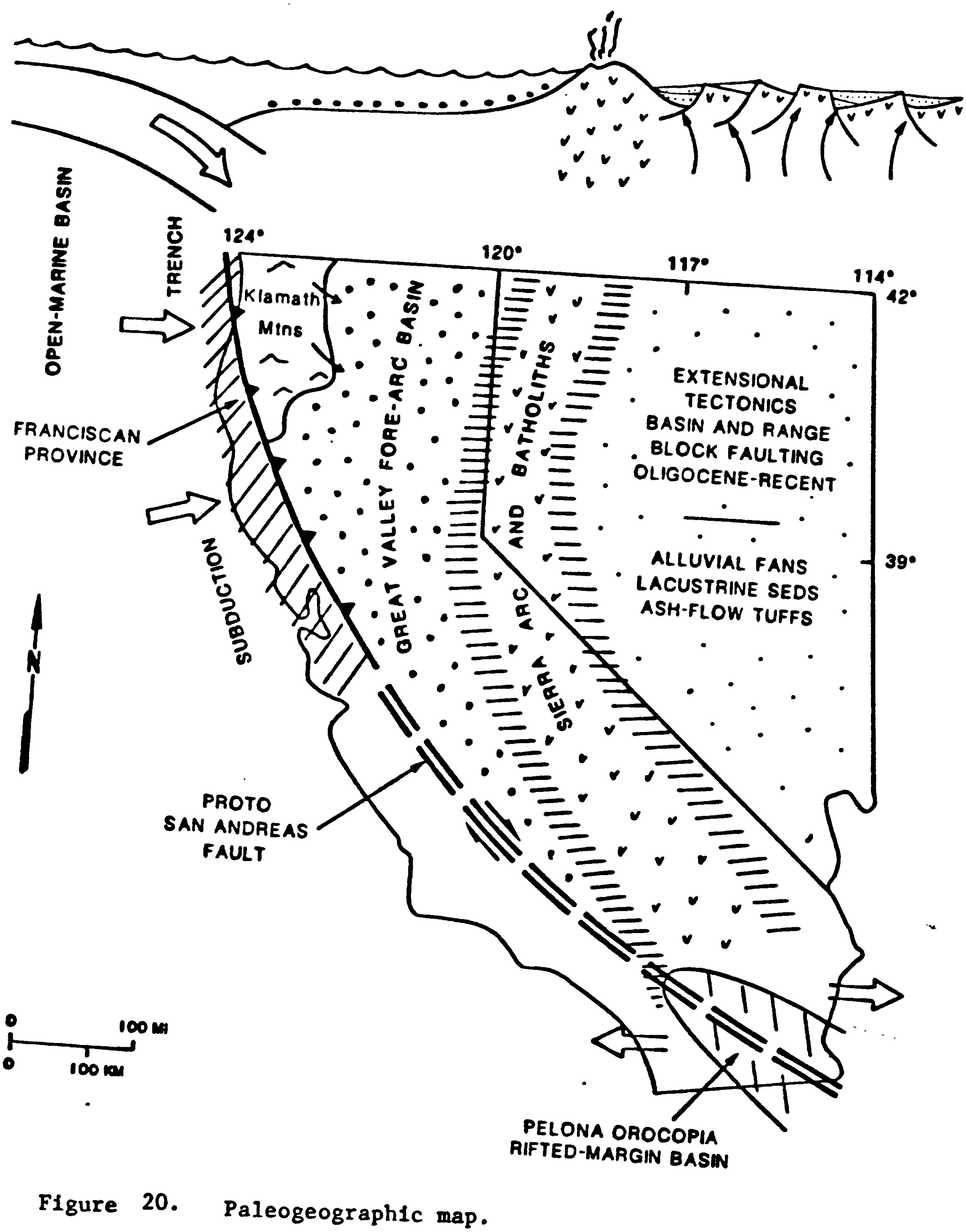

Figure 20. Paleogeographic map.

Event 5: Oligocene-Recent--Continental Extension

Extensional tectonics has characterized the western United States since at least the mid-Oligocene (Fig. 21). During continental extension two different tectonic interactions occurred along the North American plate to the west (Zoback et al., 1981). The earlier extension occurred during eastward subduction, and revived arc volcanism. This extension is characterized by low-angle normal faults (Allmendinger, 1987). These faults may have been the result of gravitational collapse of a tectonically thickened crust (Coney and Harms, 1984). In contrast, the typical basin and range morphology is characterized by evenly spaced mountain blocks, bounded by high-angle normal faults. These faults were produced during east-southeast extension that began 10 ma (Zoback et al., 1981). Several models exist to explain this later intracontinental extension (Fig. 22) (Allmendinger, 1987).

Continental extension allowed massive volumes of siliceous ash-flow tuffs (ignimbrites) to extrude and cover much of the Basin and Range Province to thicknesses up to 10,000 feet (3,000 m) (Figs. 23,24,25) (Cook, 1965; Cook, 1968). These fractured, welded ash-flow tuffs (ignimbrites) form many of the hydrocarbon reservoirs in eastern Nevada (Bortz and Murray, 1979; Bortz, 1983, 1985).

During this same period of time large masses of marine graywacke, mudstones, and oceanic carbonate seamounts, that formed above a subduction zone, were being tectonically accreted on the western margin of northern California (Fig. 20) (Tarduno et al., 1986).

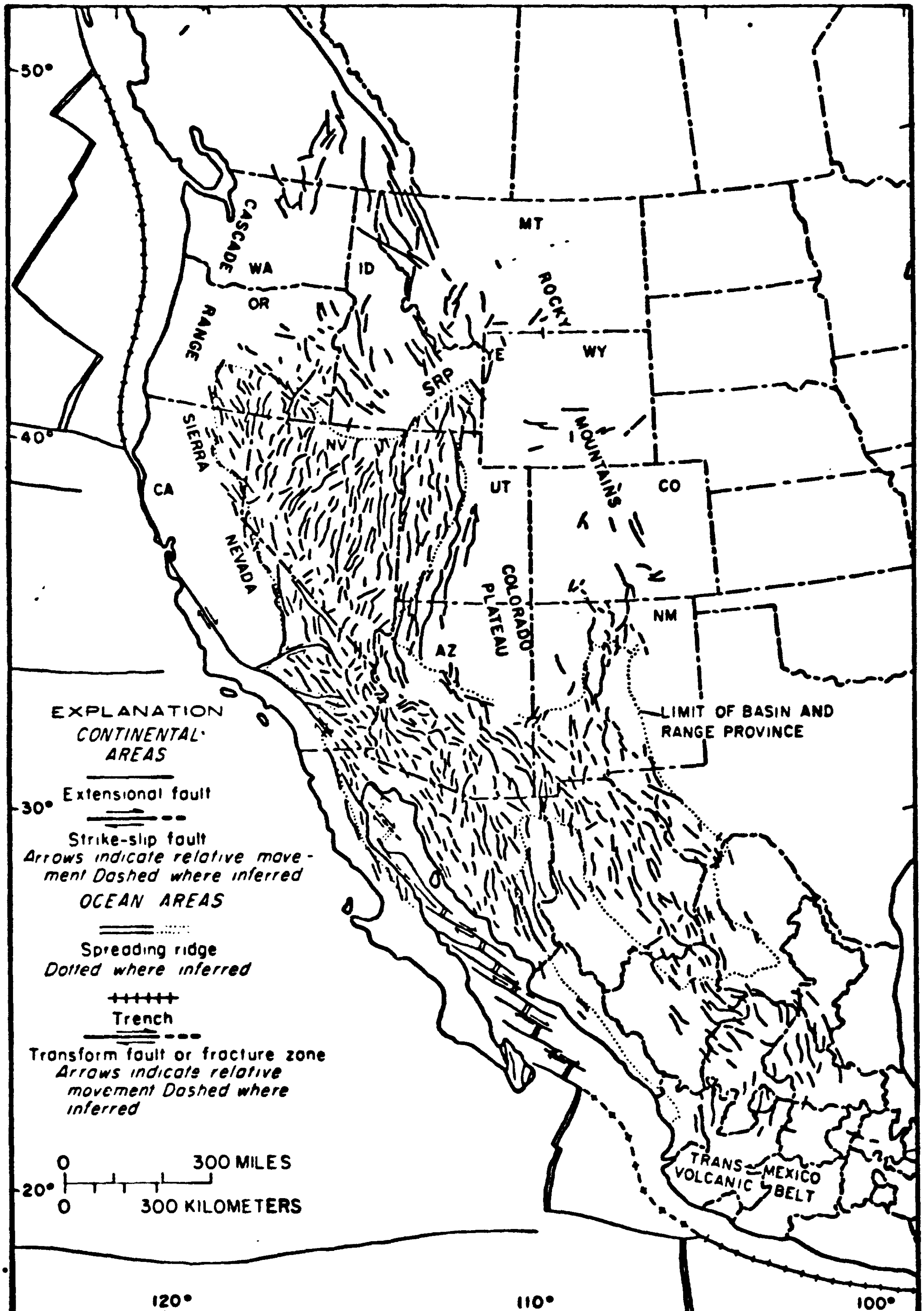

Figure 21. Distribution of late Cenozoic extensional faults, major strike-slip faults, and physiographic provinces in western North America and present-day lithospheric plate boundaries. From Stewart (1978). States: WA, Washington; OR, Oregon; CA, California; CO, Colorado; ID, Idaho; MT, Montana; WY, Wyoming; NV, Nevada; UT, Utah; AZ, Arizona; NM, New Mexico. Localities SRP, Snake River Plain: YE, Yellowstone.

From Stewart (1983).

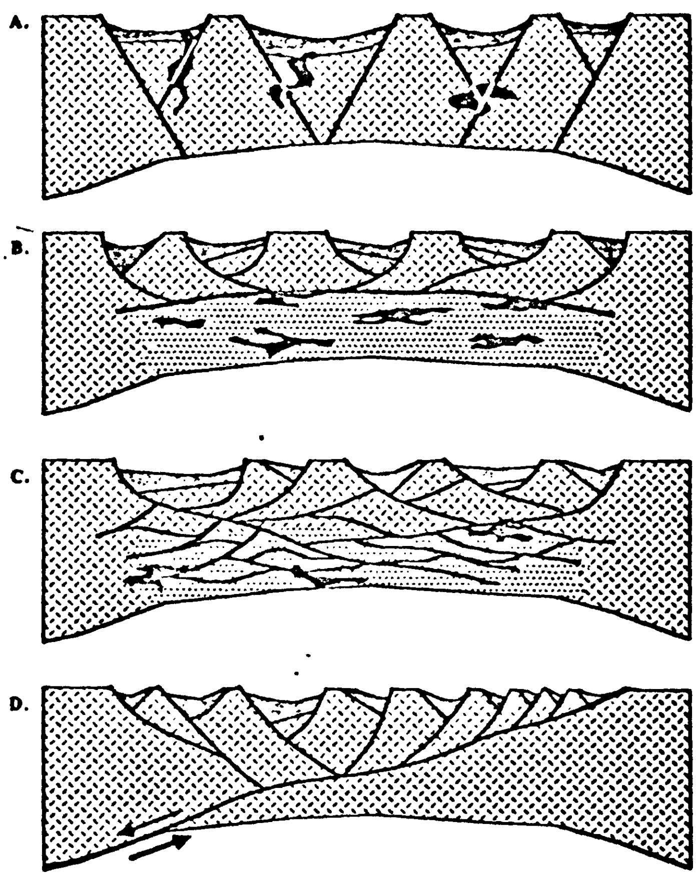

Figure 22. Simplified models of intracontinental extension. (A) Classic horst and graben model, (B) subhorizontal-decoupling-zone model, (C) anastomosing shear-zone or lenses model, and (D) crustal-penetrating shear-zone model.

From Allmendinger et al (1987).

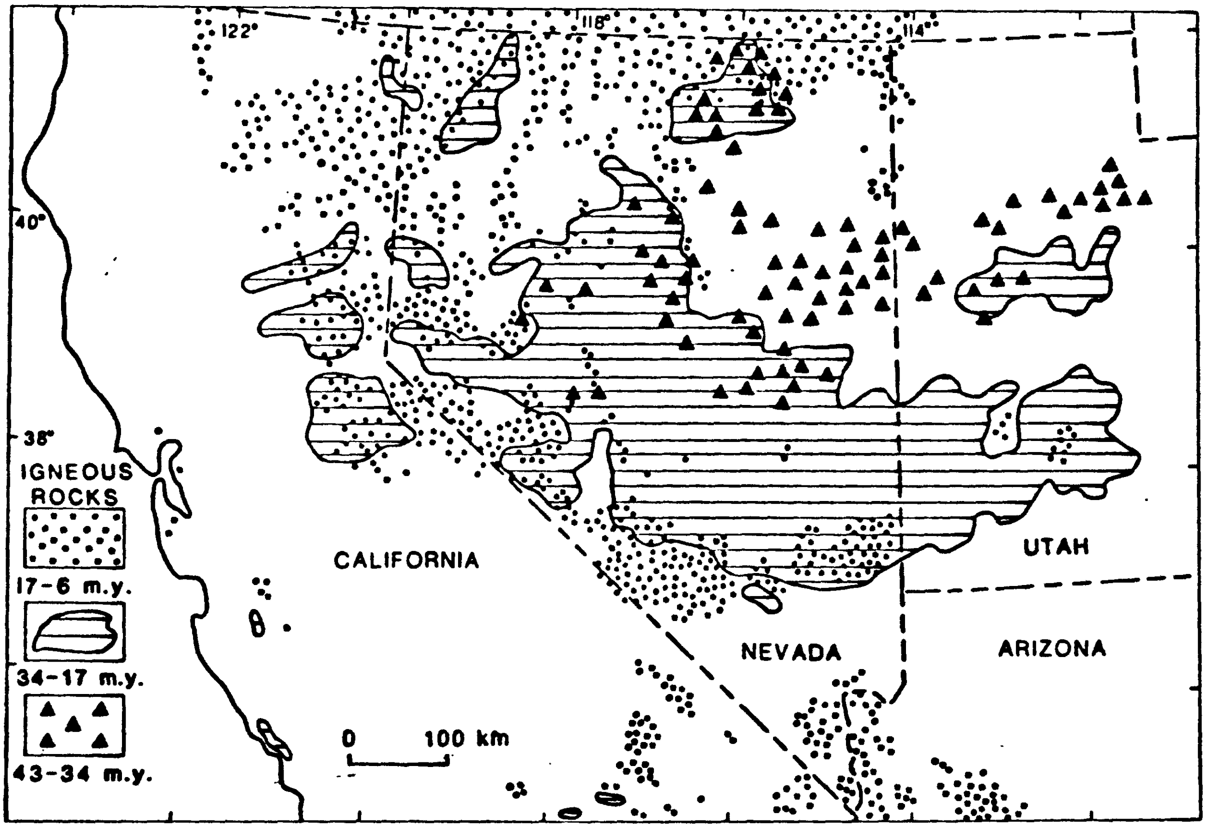

Figure 23. Distribution of 43- to 6-m.y.-old igneous rocks in Nevada, Utah, and parts of adjacent states. From Stewart and others (1977).

From Stewart (1983).

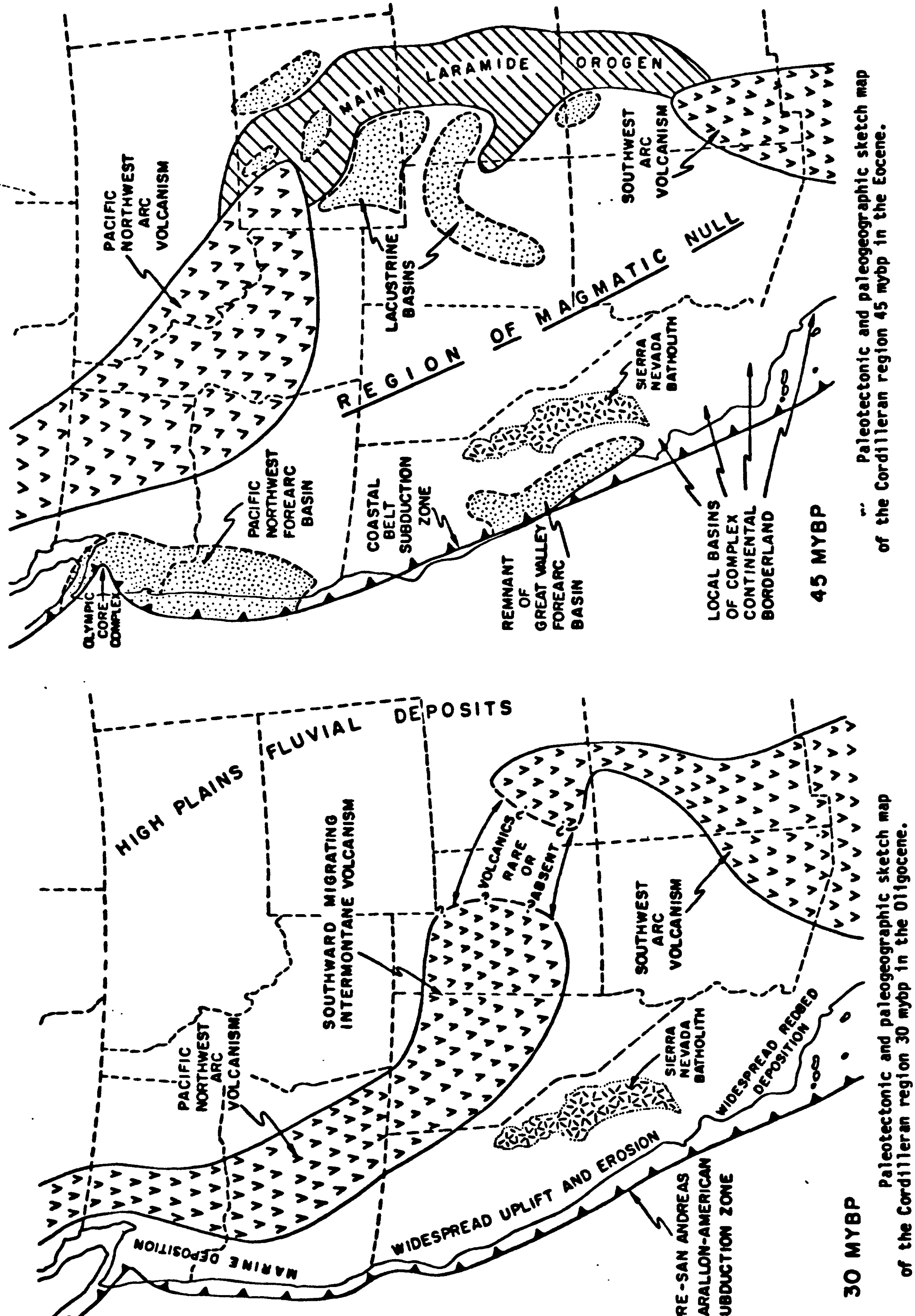

Figure 24. Paleotectonic and paleogeographic maps. From Dickinson (1979).

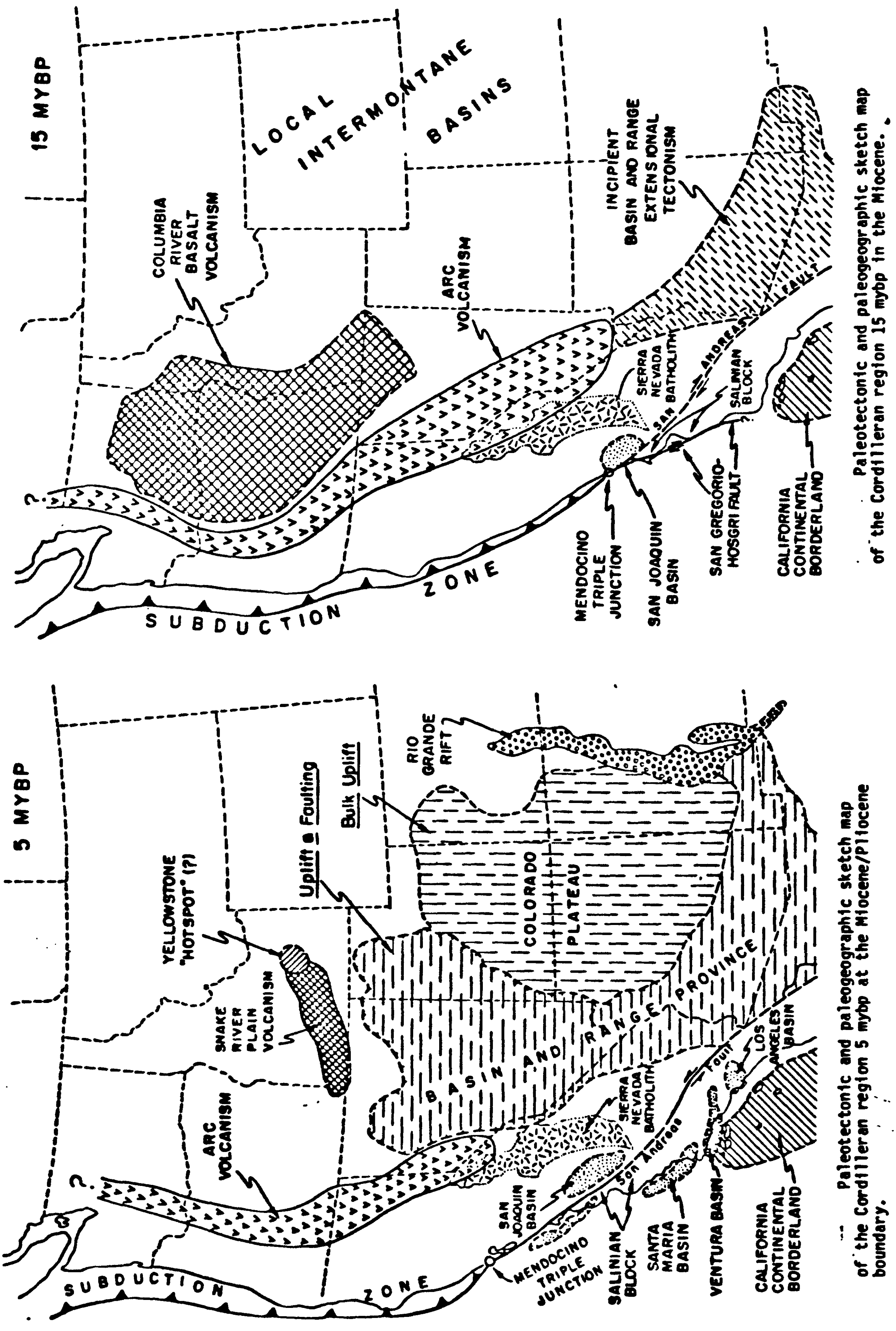

Figure 25. Paleotectonic and paleogeographic maps. From Dickinson (1979).

DIXIE VALLEY PLAY

Play Description and Type

During Middle Triassic times the Dixie Valley area (lat. 40°N. and long. 117°45'W.) was the site of 2,000 feet (1,200 m) of carbonate sedimentation within a back-arc basin (Figs. 26-28). These marine carbonates belong to the Star Peak Group (Figs. 29-32), and manifest themselves as a shoaling-upward, seaward-prograding (westerly) basin-plain to platform-margin complex (Fig. 33) (Nicols and Silberling, 1977). The Star Peak Group contrasts sharply with the unconformably underlying Lower Triassic Koipato Group, which is composed of siliciclastics and volcanics. Likewise, the Star Peak also is much different than the overlying Upper Triassic Auld Lang Syne Group, a sequence of metapelitic sediments and siliciclastic rocks (Nicols and Silberling, 1977).

Reservoir Rocks

Potential reservoirs in the Triassic rocks (ex. Favret Formation) could consist of carbonate turbidites and/or debris flows. However, whether or not significant amounts of mass-flow carbonates with good reservoir characteristics exist is not known at this time. Other potential reservoir rocks would be in the platform-margin facies and dolomitized shelf-lagoon facies (Figs. 32,33) (i.e., Home Station and Panther Canyon members of the Augusta Mountain Formation). However, this is speculative as these facies have not been evaluated for their reservoir characteristics. Another type of potential reservoir would be in the overlying densely welded and extensively fractured,

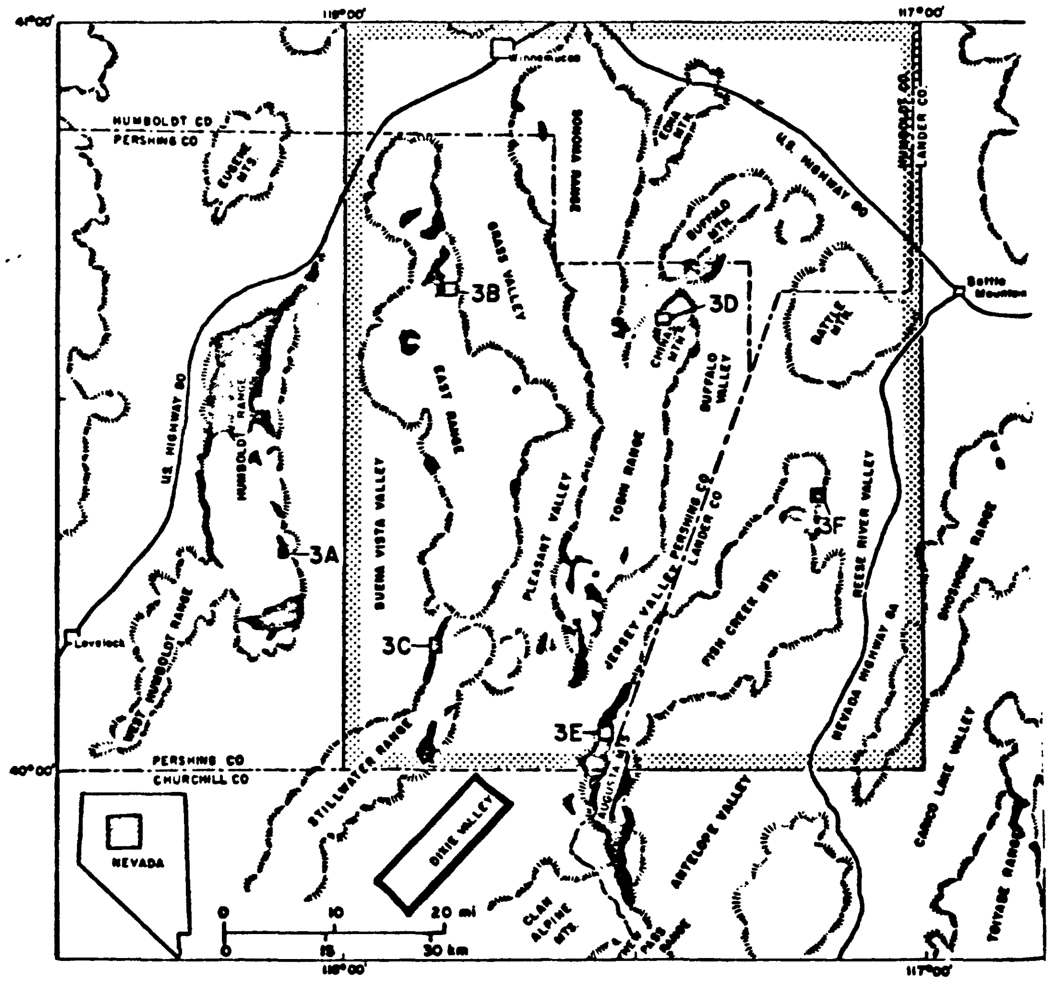

Figure 26 Index map showing location of Star Peak Group exposures (heavy stipple) in and near the Sonoma Range one-degree quadrangle (outlined by lightly stippled border). Location of maps shown in Figure 31 are indicated by labeled rectangles.

From Nicols and Silberling (1977).

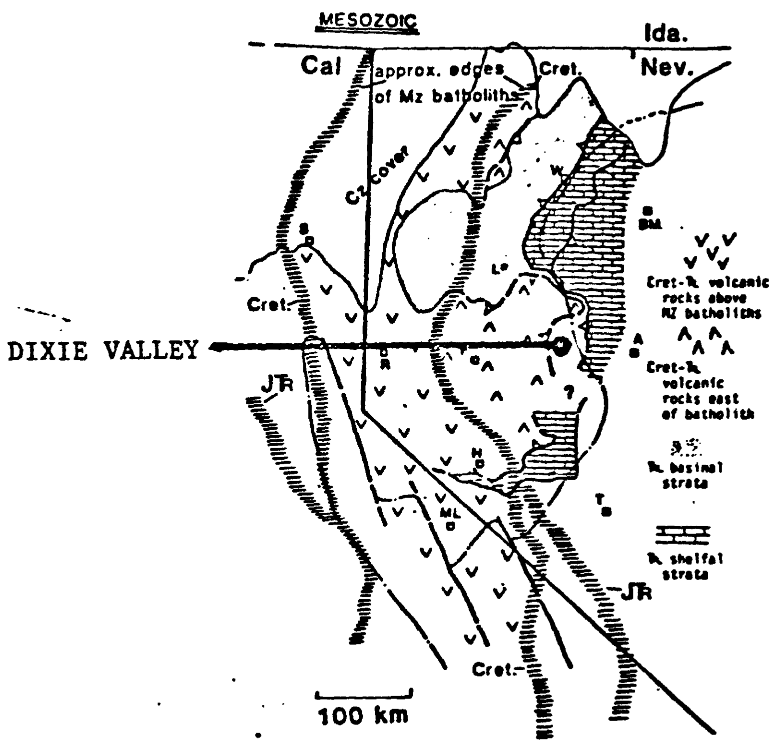

Figure 27. Map showing paleogeographic terranes of early Mesozoic marine and younger volcanic and intrusive rocks of the western Great Basin. Dash-dot line is isotopic 0.706 line.

Speed (1983).

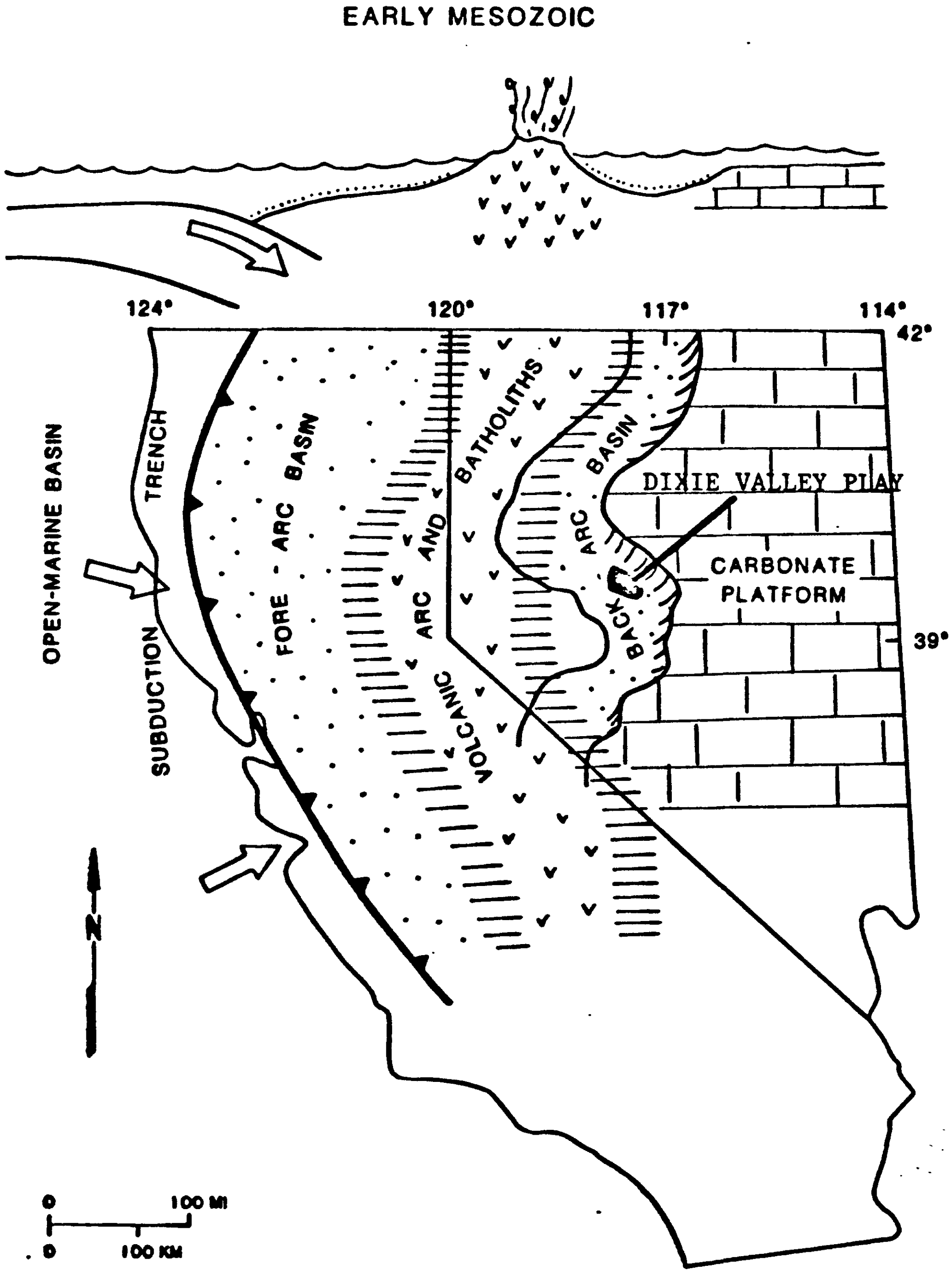

Figure 28. Paleogeographic map showing interpreted depostional setting for the Dixie Valley Play. Potential reservoir facies-- carbonate turbidites, debris flows, overlying prograding platform rocks, and fractured ignimbrites (Tertiary).

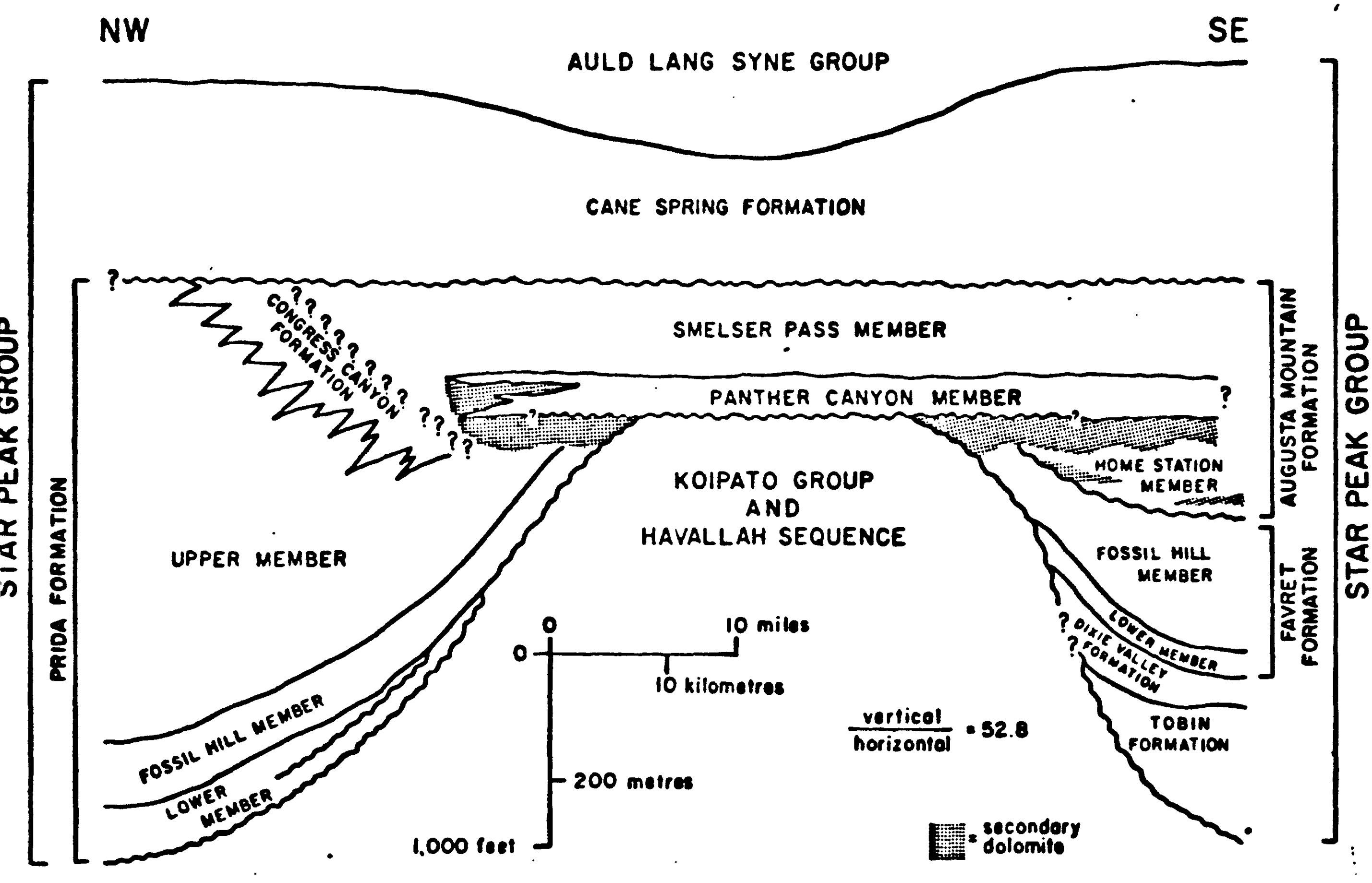

Figure 29 Diagrammatic cross section of the Star Peak Group trending southeasterly from the northern Humboldt Range through the southern Tobin Range to the Augusta Mountains.

From Nicols and Silberling (1977).

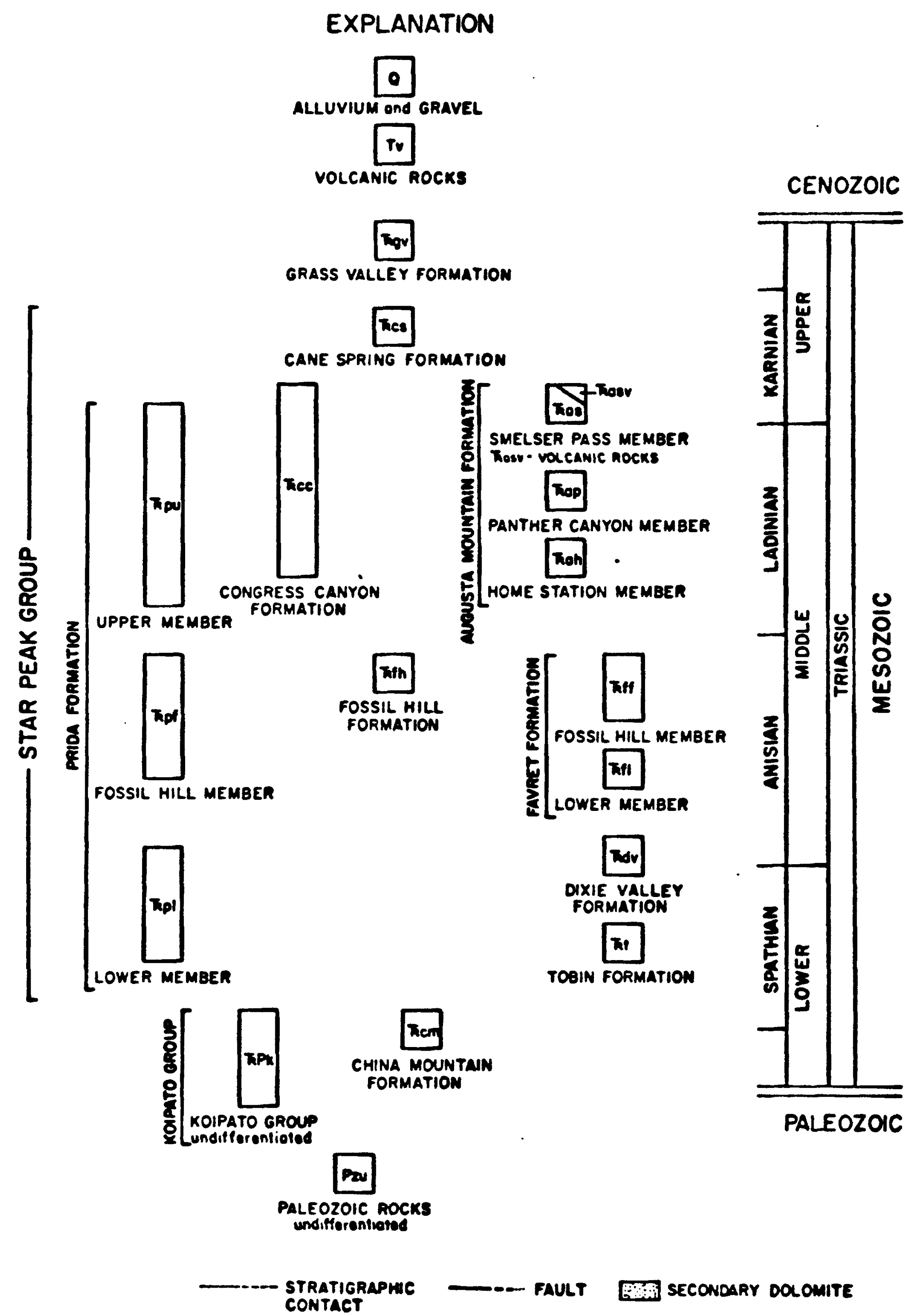

Figure 30 (facing pages). Geologic maps of selected exposures of the Star Peak Group in A, southern Humboldt Range; B, northern East Range; C, northern Stillwater Range; D, western

(other half of Figure 30 on next page)

From Nicols and Silberling (1977).

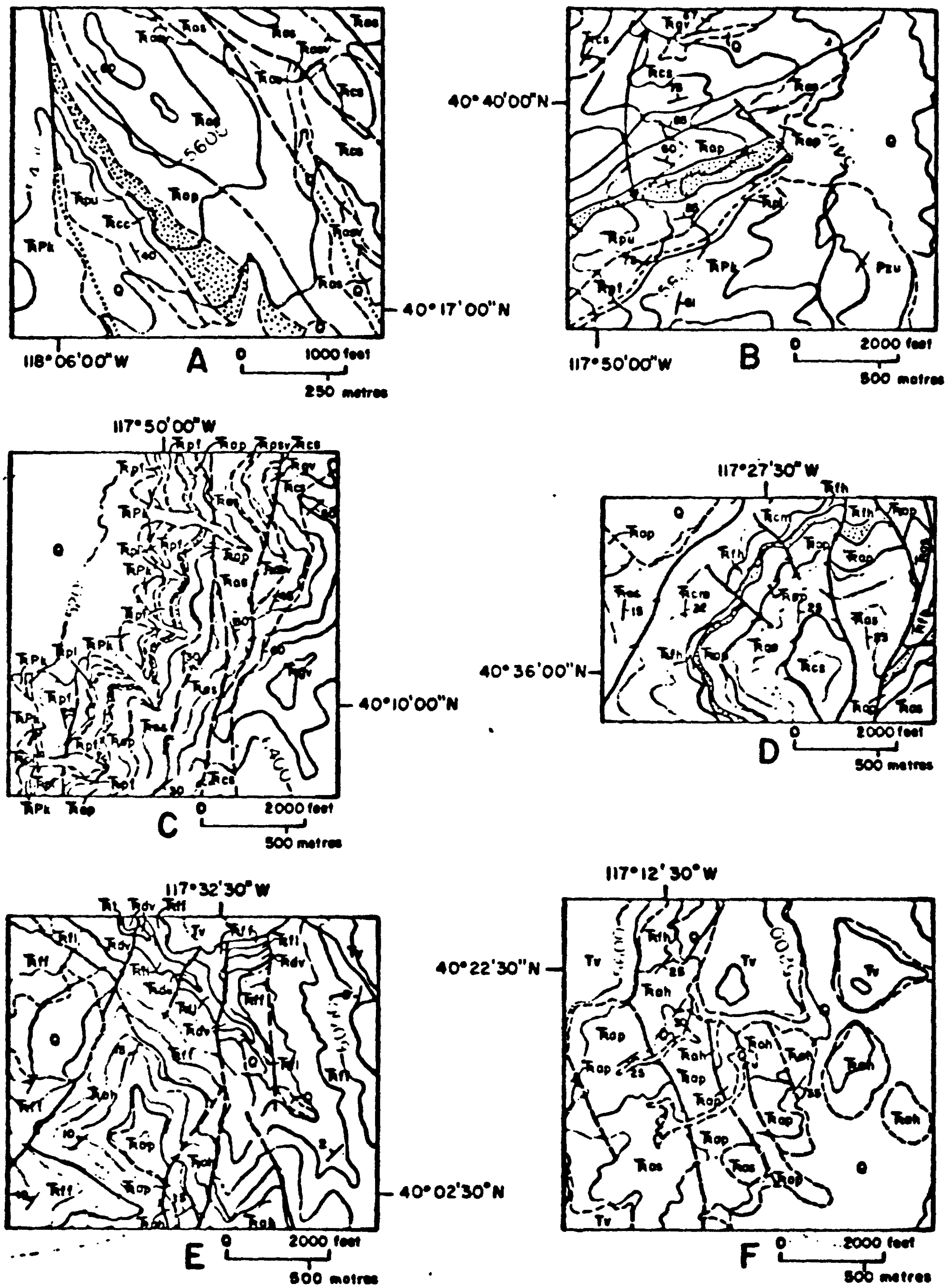

Figure 31. China Mountain; E, northern Augusta Mountains; F, northern Fish Creek Mountains. See Figure 26 for locations. Arrow on map B delineates rocks included in the "Natchez Pass Formation" of Ferguson and others (1951a).

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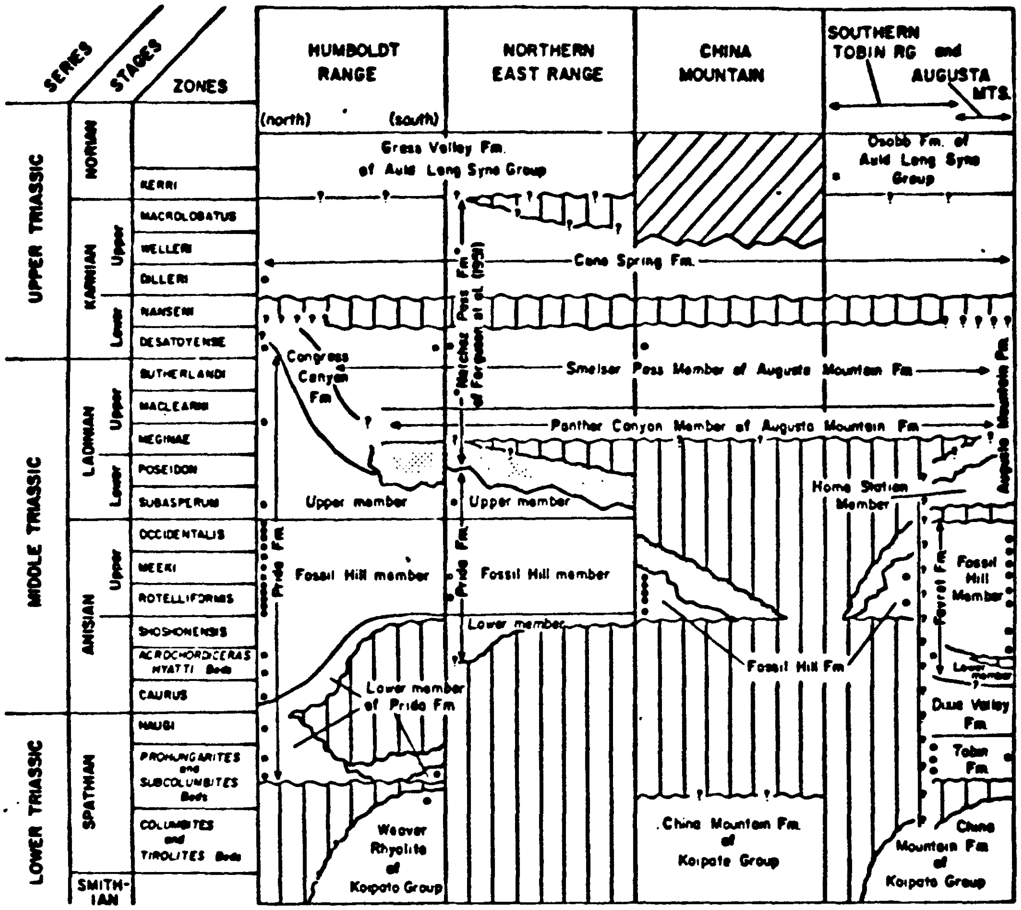
From Nicols and Silberling (1977).



32
Figure Time-stratigraphic correlation chart of the Star Peak Group at localities significant for stratigraphic nomenclature. Small circles represent occurrences of age-diagnostic fossils; stippled pattern indicates secondary dolomite; vertical ruling indicates stratigraphic hiatus, and diagonal ruling indicates lack of data.

From Nicols and Silberling (1977).

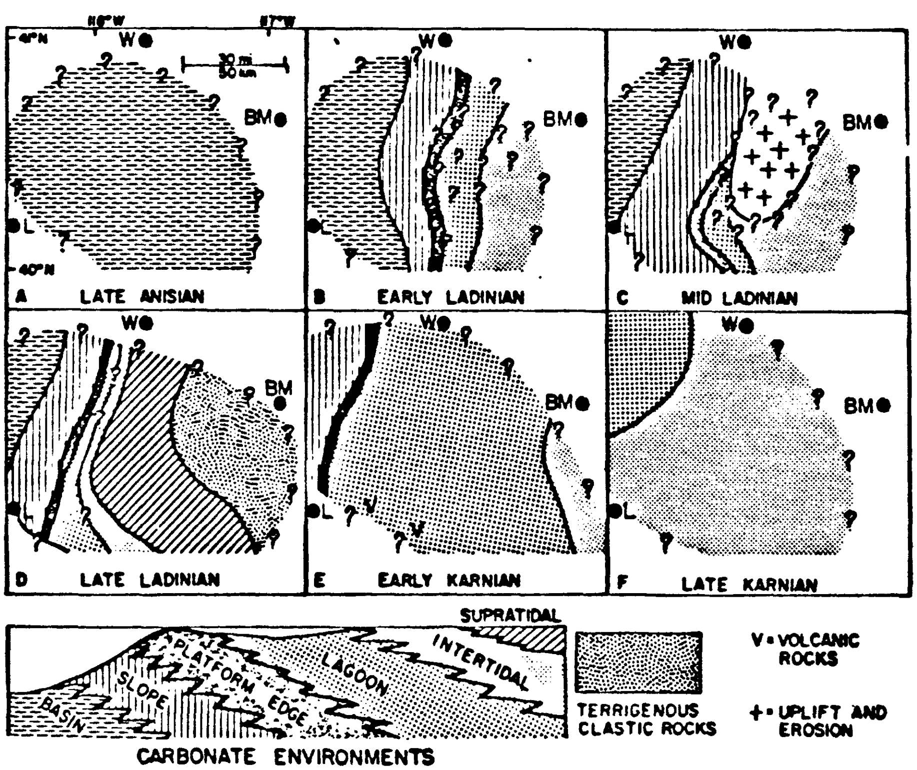


Figure 33 Paleogeographic maps of the Star Peak Group at different times during its deposition. See Figure 5 for series assignment of Triassic stages. Area of maps is approximatley that in Figure 1; L, Lovelock; W, Winnemucca; BM, Battle Mountain. The map patterns correspond to those on the conventional model of near-shore carbonate environments shown beneath the maps.

From Nicols and Silberling (1977).

welded ash-flow tuffs (ignimbrites) of Tertiary age. The ignimbrites that occur in the mountain ranges surrounding Dixie Valley probably underly Dixie Valley, and could be suitable as reservoir rocks. These same types of rocks form reservoirs in the oil fields of Railroad Valley in eastern Nevada (Bortz and Murray, 1979).

Traps and Seals

Both structural and stratigraphic traps could be expected if the Dixie Valley Basin has undergone similar Cenozoic structural modifications as in other parts of the Basin and Range Province. In this respect, one would be employing an Eagle Springs oil-field model (i.e., the first oil field discovered in Nevada), which utilizes both structural and stratigraphic traps (Fig. 34).

A seismic profile across the Carson Sink Valley (Fallon Basin), ten miles (16 km) west of Dixie Valley reveals an overall structural pattern similar to that in Railroad Valley (Figs. 35,37). It is quite probable that the structure of Dixie Valley would be similar to that of Carson Sink Valley (Fallon Basin).

Source Rocks

The petroleum industry is attracted to this area because the Triassic basinal sediments may be potential source rocks (Bortz, 1983, 1985). The Fossil Hill member of the Middle Triassic Favret Formation is a 600-foot-thick sequence (180 m) of dark-gray calcareous shale and lime mudstone which crops out in the mountain ranges flanking the northern part of Dixie Valley

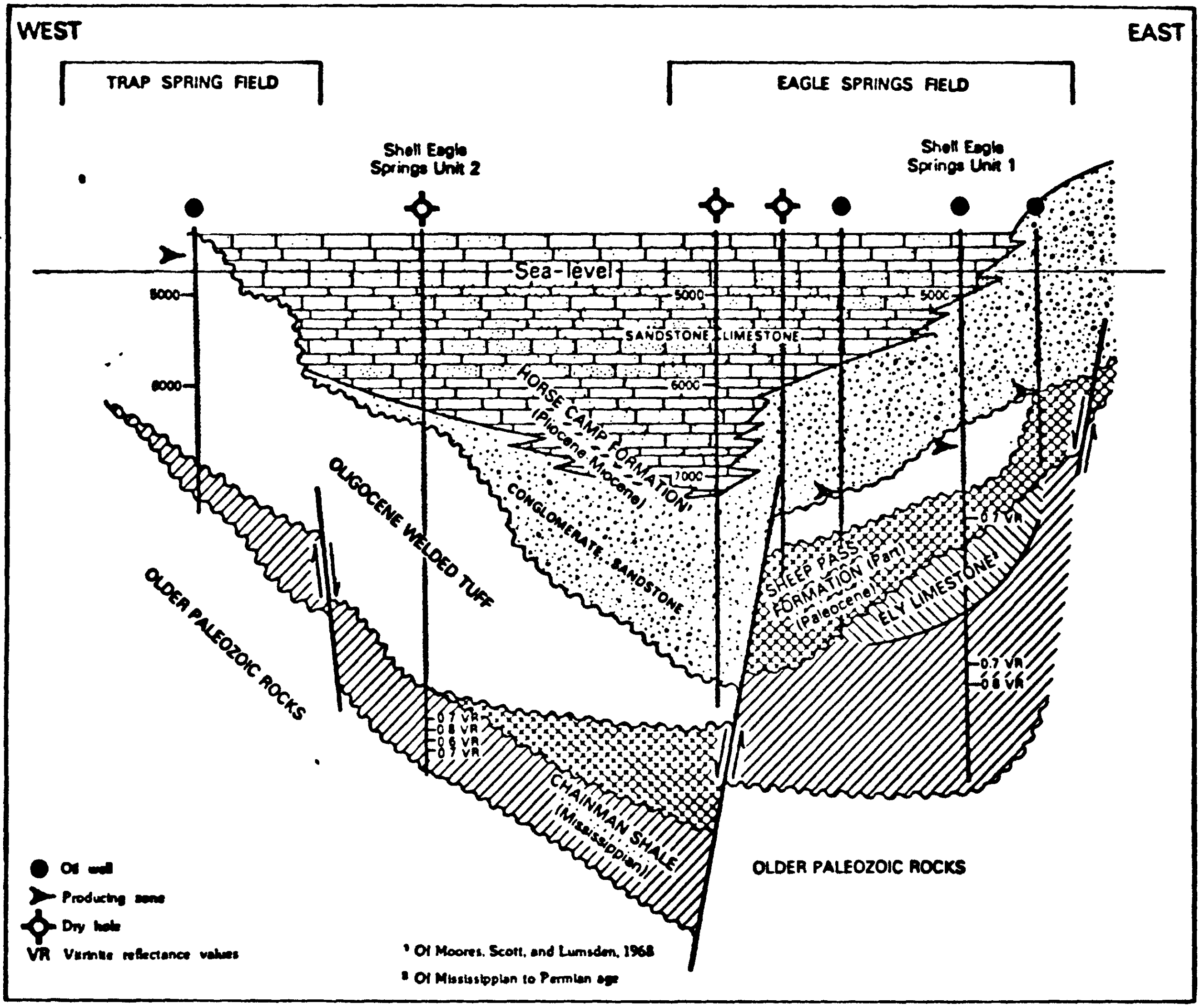


Figure 34. Generalized cross section of Railroad Valley showing rock units and vitrinite reflectance values obtained on cores from two wells.

From Poole et al (1983).

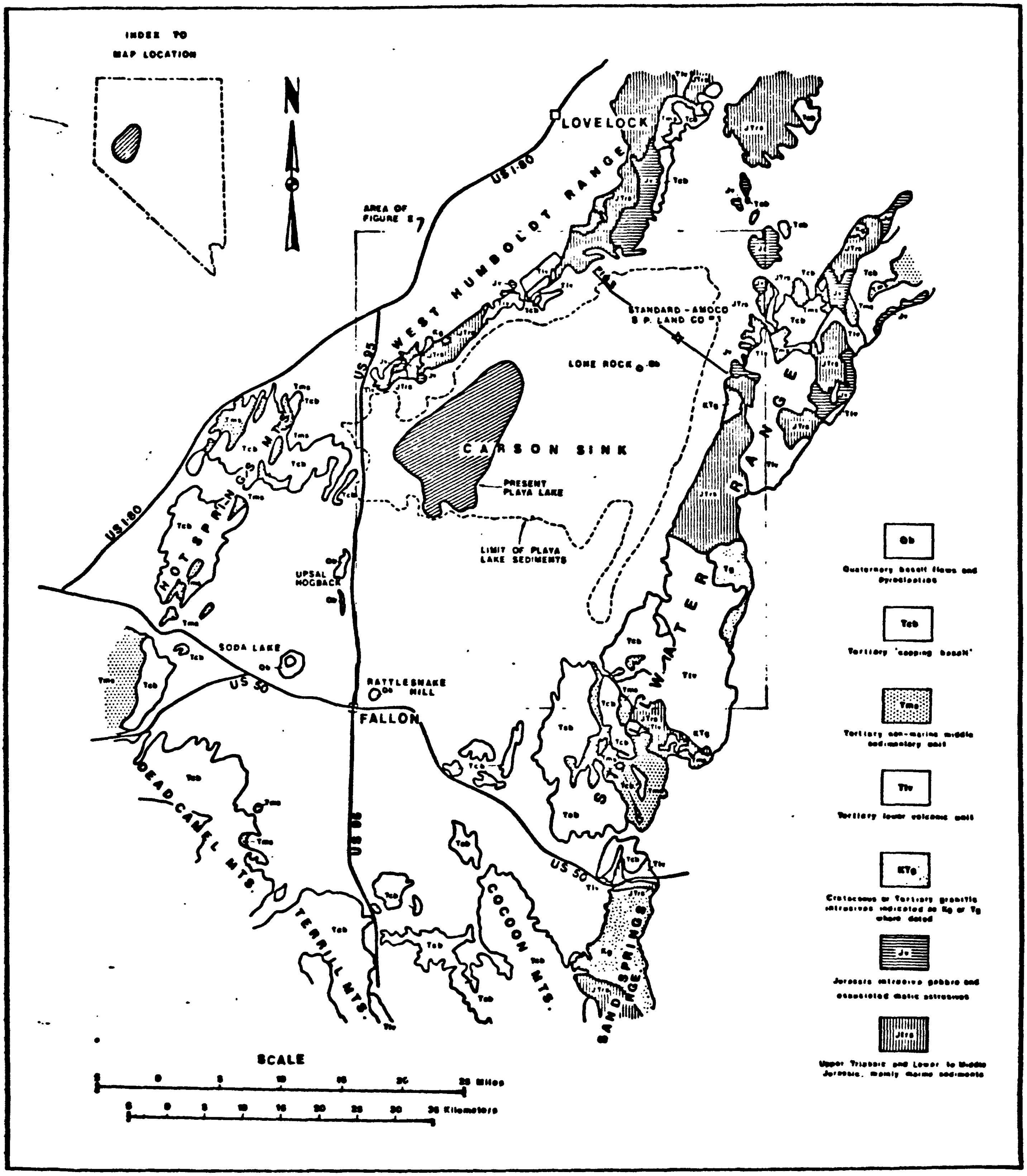
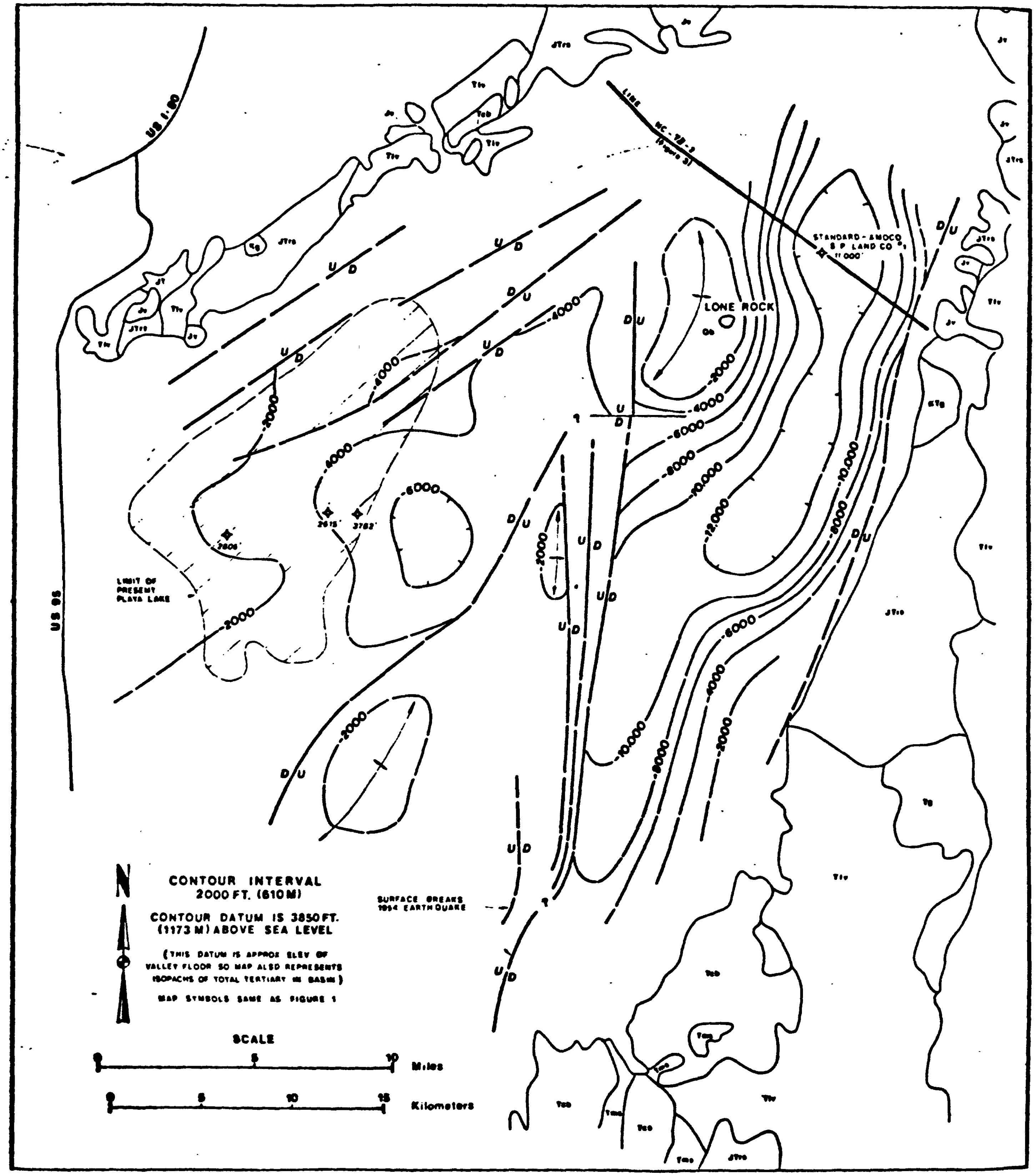


Figure 35 Generalized geologic map of the Fallon basin compiled from Page (1965), Willden & Speed (1974), and unpublished geologic maps from the Southern Pacific Company.

From Hastings (1979).



36.
Figure —Subsurface structure contour map of the northern Fallon basin drawn on the base of the Tertiary from reconnaissance seismic and gravity data.

From Hastings (1979).

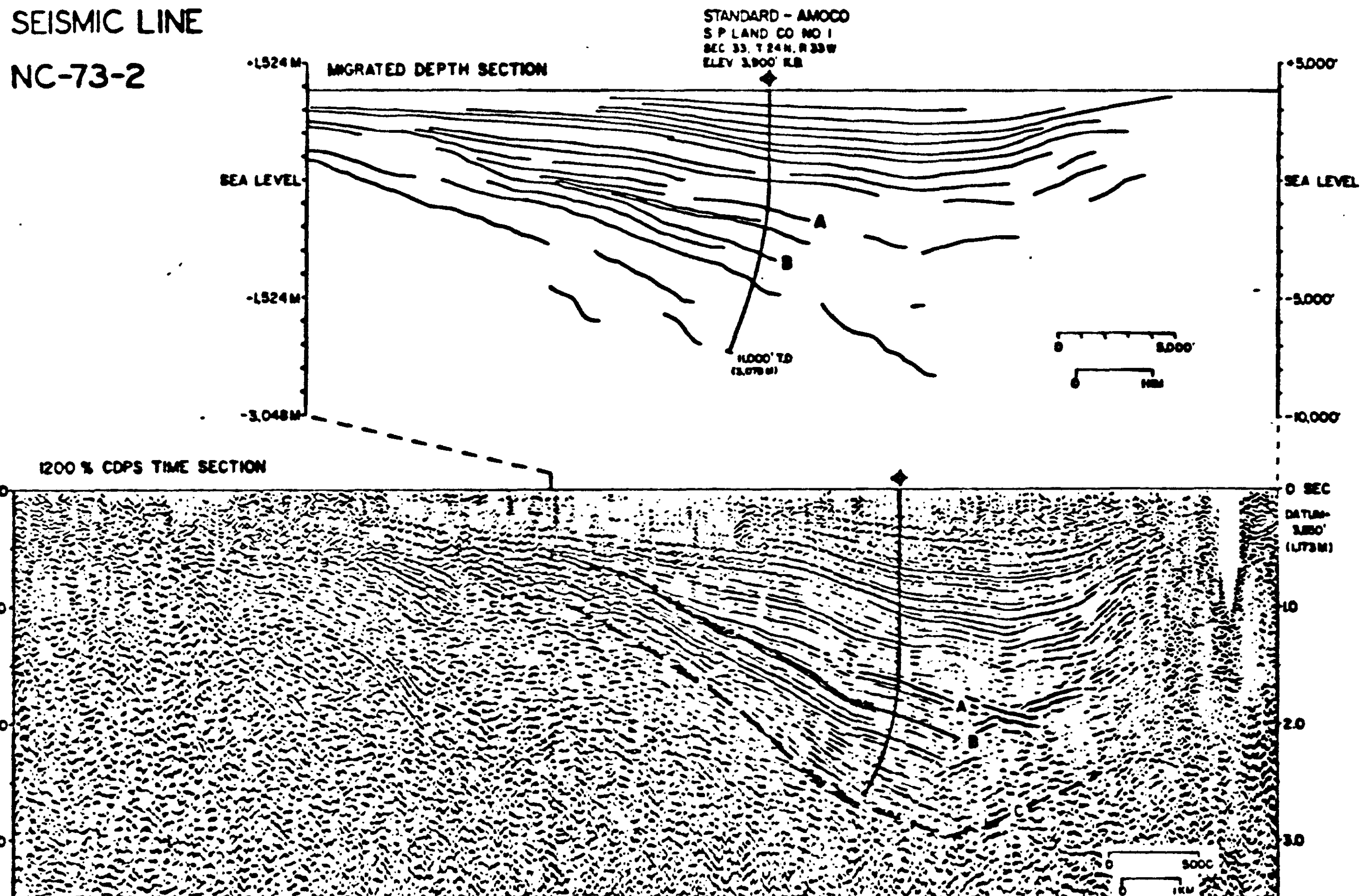


Figure 37. –Seismic line NC-73-2. A. is amplitude anomaly, B. the 'capping basalt' event, and C. the base of the Tertiary as interpreted from discontinuous seismic events and gravity modeling.

From Hastings (1979).

(Figs. 30,31,38). This sequence contains ammonoids which, when broken open, commonly yield hydrocarbons (Figs. 39,40) (Nicols and Silberling, 1977, p. 21). If the Favret Formation is a good source rock for hydrocarbons, its presence beneath the Cenozoic fill in Dixie Valley is highly probable.

Cenozoic lacustrine sediments are also a type of potential source rock in the Basin and Range Province (Fouch, 1979; Fouch et al., 1979; Poole et al., 1983; Poole and Claypool, 1984; Sandberg, 1983). In the Carson Sink Valley (Figs. 38,41) 5,000 feet (1,525 m) of silts and clays have excellent source-rock potential, but temperatures and depth of burial suggest that only modest amounts of oil have been generated from these rocks (Hastings, 1979).

Potential source rocks in the Paleozoic have been analyzed for their thermal maturity. Data based on conodont alteration index (CAI) values suggest that the Paleozoic sediments in western Nevada have been intensely baked and have CAI values 4.5 (Fig. 42) (Epstein et al., 1977).

Depth of Occurrence

The depth of the reservoir targets are uncertain, but may be on the order of 5,000-10,000 feet (1,500-3,000 m) for Tertiary ignimbrites, and 10,000-15,000 feet (3,000-4,500 m) for Mesozoic carbonates.

Exploration Status

At least a dozen geothermal wells have been drilled in Dixie Valley which range in depth from 3,000-12,000 feet (900-3,750 m) (Fig. 38) (Bortz, 1985). The only well drilled as an oil and gas exploratory well is the Standard-Amoco No. 1 S.P. Land Co. (Sec. 33, T. 24 N., R. 33 E.). This is located in the

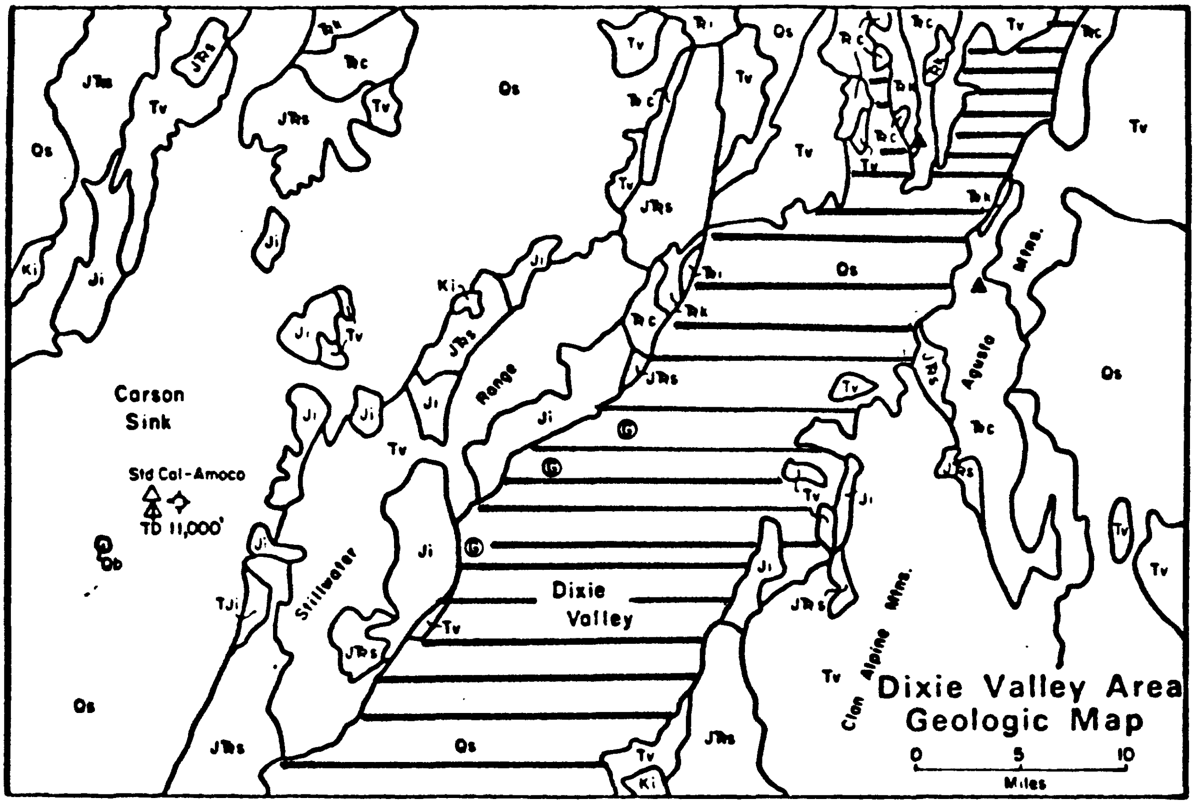


Figure 38. Dixie Valley area. Qs - Quaternary alluvial and playa deposits; Qb - Quaternary basalts; Tv - Tertiary volcanics; JTR s - Upper Triassic and Lower Jurassic sediments and volcanic rocks; TR c - Lower, Middle, and Upper Triassic (Tobin, Dixie Valley, Favret and Augusta Mtns. fms.); TR k - Lower Triassic Koipato volcanic and clastic rocks; Tji, Ki, Ji, TR i - Intrusives; Ⓖ - Geothermal well or test; △ - Minor oil show; ⯅ - Minor gas show; ▲ - Surface oil show.

PLAY OUTLINE

From Bortz (1983).

Figure 39. Concretion of calcareous mudstone from Triassic Favret formation in the August Mountains - chambers of this ammonite contained liquid hydrocarbons.

From Bortz (1983).

Figure 40. Outcrop of the Fossil Hill member of the Favret formation in the Augusta Mountains.

From Bortz (1983).

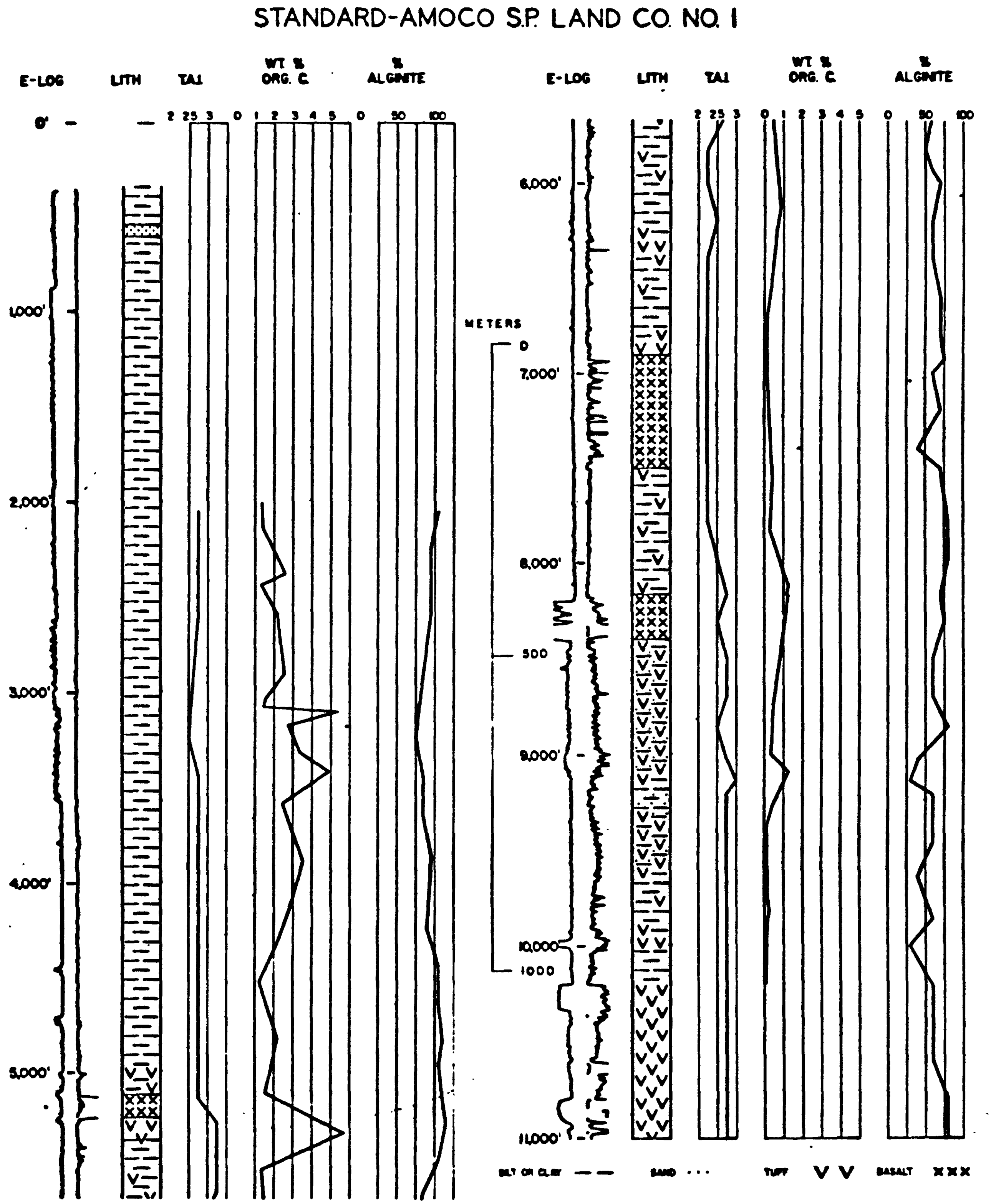


Figure 41 -Electric log and lithologic log of Standard-Amoco S.P. Land Co. #1. Thermal alteration index values are from ditch samples, and weight percent organic carbon and percent alginite component values from sidewall samples.

From Bortz (1983).

THERMAL MATURITY BASED ON
CONODONT ALTERATION INDEX VALUES (CAI)

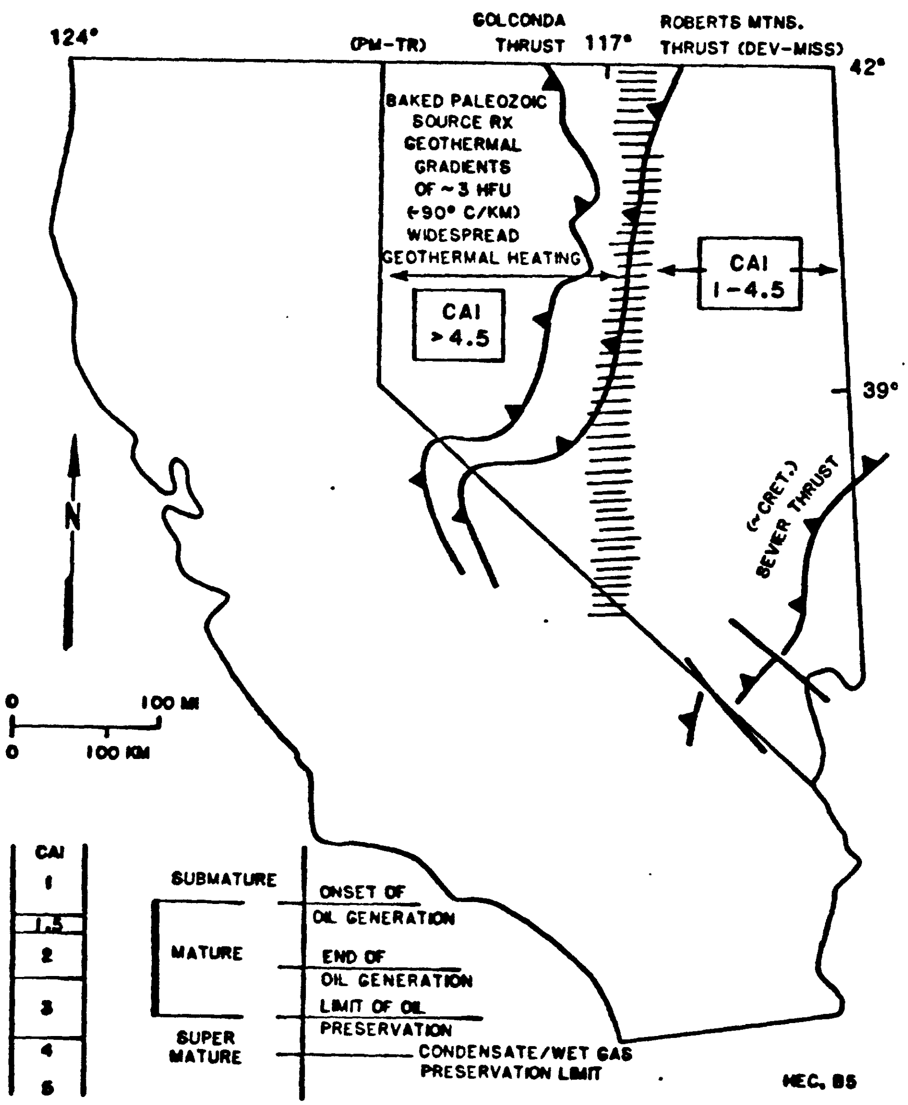


Figure 42. Map showing thermal maturity of Paleozoic source rocks in Nevada. In general these rocks are supermature in western Nevada and submature-to-mature in eastern Nevada. Based on data in Epstein et al (1977) and Poole and Claypool (1984).

adjacent Carson Sink Valley (Fallon Basin) (Fig. 38). This well penetrated 11,000 feet (3,300 m) of Tertiary playa sediments and volcanics (Fig. 41). Oil and gas shows, including free oil in vugs at the top of a basalt core at 8,168 feet (2,490 m) were present in the well. Results of formation tests of selected intervals showed that reservoir rocks were absent (Hastings, 1979). As discussed above, potential lacustrine source rocks are available, but they have not been subjected to sufficiently high temperatures to generate large quantities of hydrocarbons.

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