DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

National Petroleum Assessment
Eastern California
(Province 81A)

By Harry E. Cook[1]

Open-File Report

87-450K

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[1] U.S. Geological Survey, 345 Middlefield Rd., MS 999, Menlo Park, CA

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INTRODUCTION

Basin Location and Size

Province 81A encompasses about two-thirds of California, and is divided into nine geomorphic subprovinces (Figs. 1,2) following the general schemes of Norris and Webb (1976) and Scott (1983). To call this province a single basin is obviously a misnomer. These subprovinces collectively represent 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 (Fig. 3).

The Klamath Mountains and Coast Ranges subprovinces of Province 81A were originally called Province 902 in the 1983 USGS assessment (Scott, 1983). As these two subprovinces significantly increase the size of Province 81A, it is recommended that future assessment reports modify the province name "Eastern California" to some name that more accurately reflects the true geographic composition of Province 81A.

QUALITATIVE EVALUATION OF HYDROCARBONS

Within Province 81A the possibility of commercial accumulations of hydrocarbons is very low, and no formal plays are identified. The only areas where hydrocarbon shows and/or abandoned wells exist are in the Modoc Plateau, Coast Ranges, and the Peninsula Ranges subprovinces. Of these three subprovinces the Modoc Plateau, although not formally identified as a play, is presently considered to be the most likely to contain commercial hydrocarbons. The basis for this guarded optimism is discussed under the subprovince section of this report.

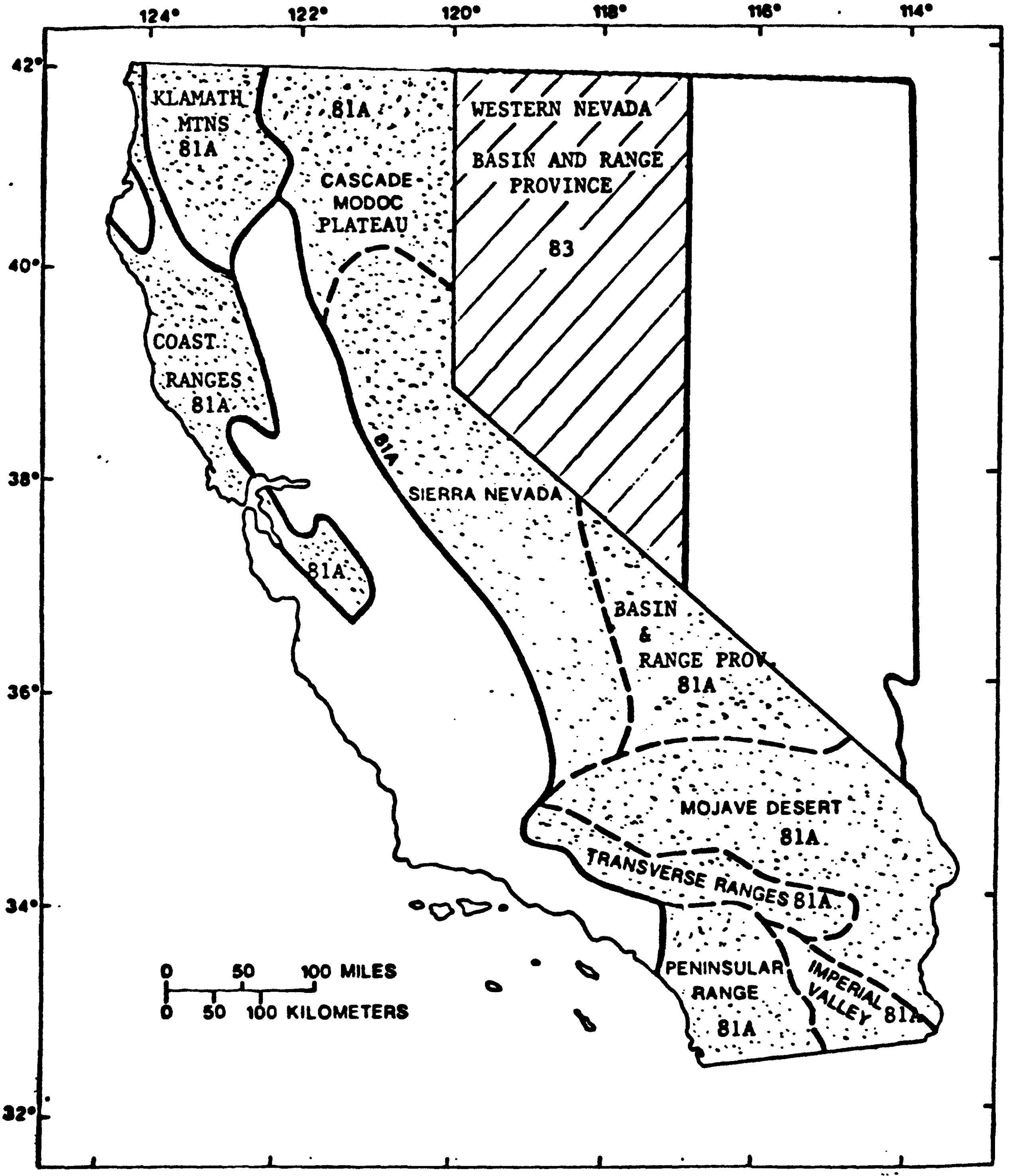

FIGURE 1 Index map of California showing the geomorphic divisions of the Eastern California province (81A) in stiples and Western Nevada, Basin and Range Province (83) in hachures. Modified after Scott (1983).

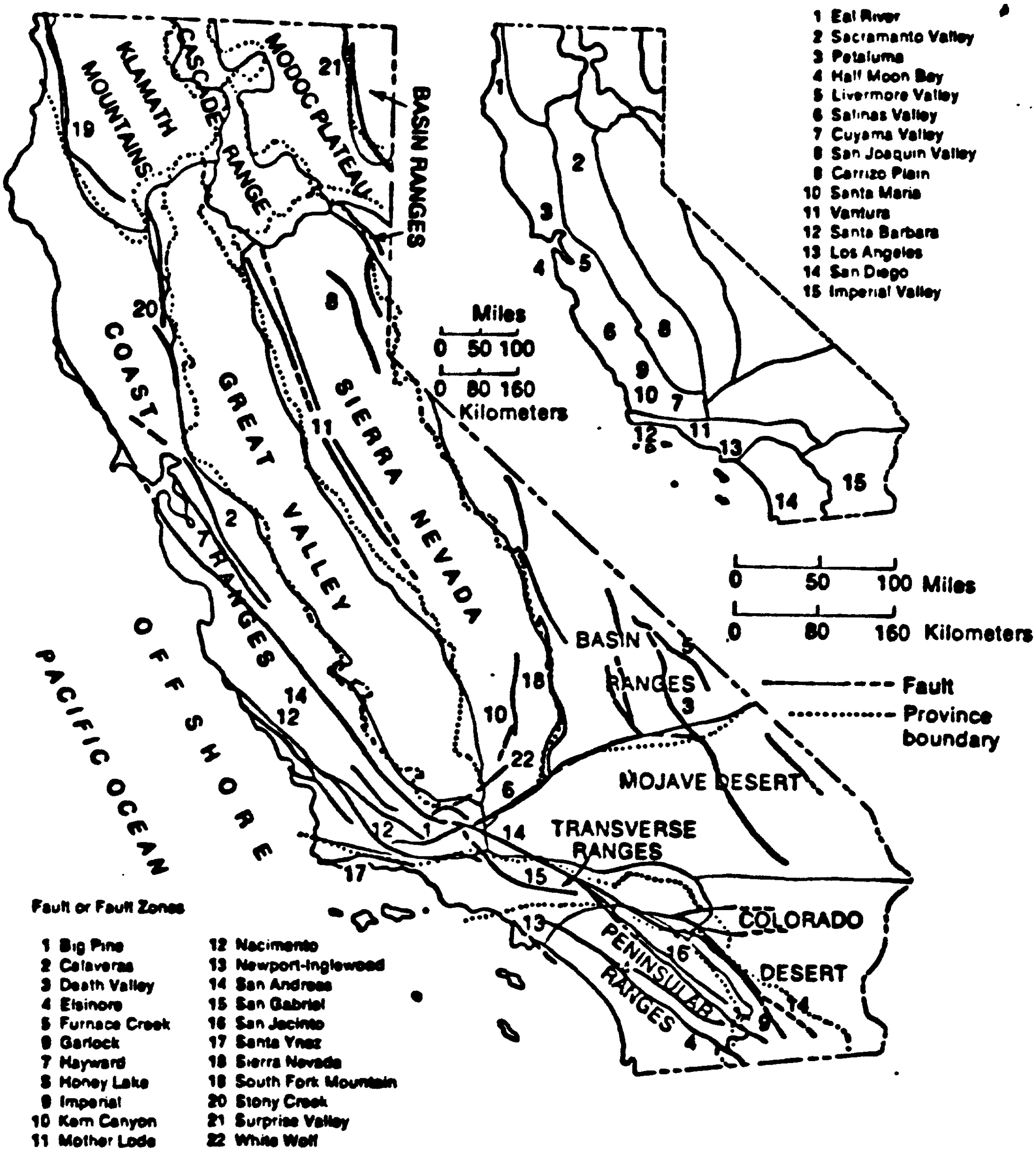

Figure 2.

Geomorphic provinces and principal faults. Insert (upper right) shows principal marine sedimentary basins. (Source: California Division of Mines and Geology) From Norris and Webb (1976).

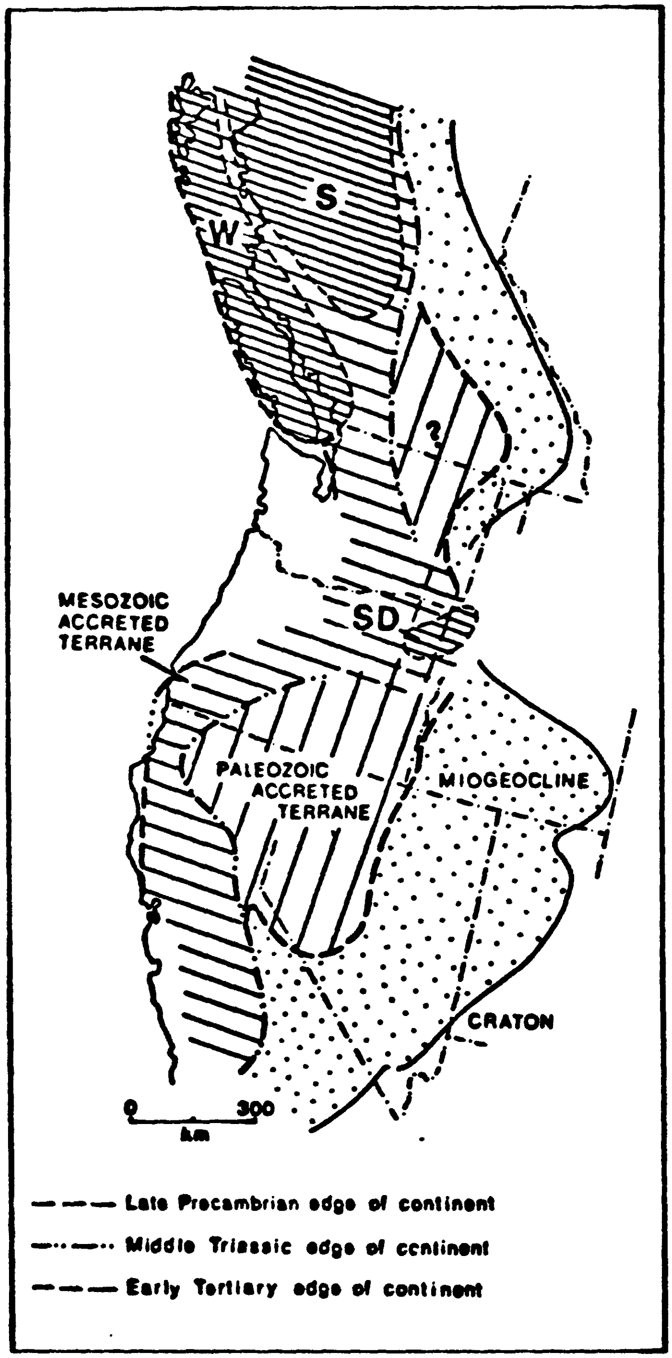

Figure 3. Major components of Cordilleran "collage". W = "Wrangellia"; S = Stikine arc; SD = "Seven Devils" arc.

From Davis et al (1978)

REGIONAL GEOLOGIC FRAMEWORK

This section will attempt to outline the regional structural setting and geologic history of the Cordillera, followed by a brief geologic description for each of the subprovinces in Province 81A. To gain a true perspective of the geologic evolution of California, one must look beyond its man-made boundaries into the Basin and Range Province of Nevada. The regional tectonics and stratigraphy of these two Cordilleran provinces have an intimate interwoven genesis that dates back to the Proterozoic (Figs. 3,4-6). Plate tectonic theory will be 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 these two adjacent provinces.

Five tectonic events shaped the western margin of North America in the vicinity of Province 81A and 83 (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).

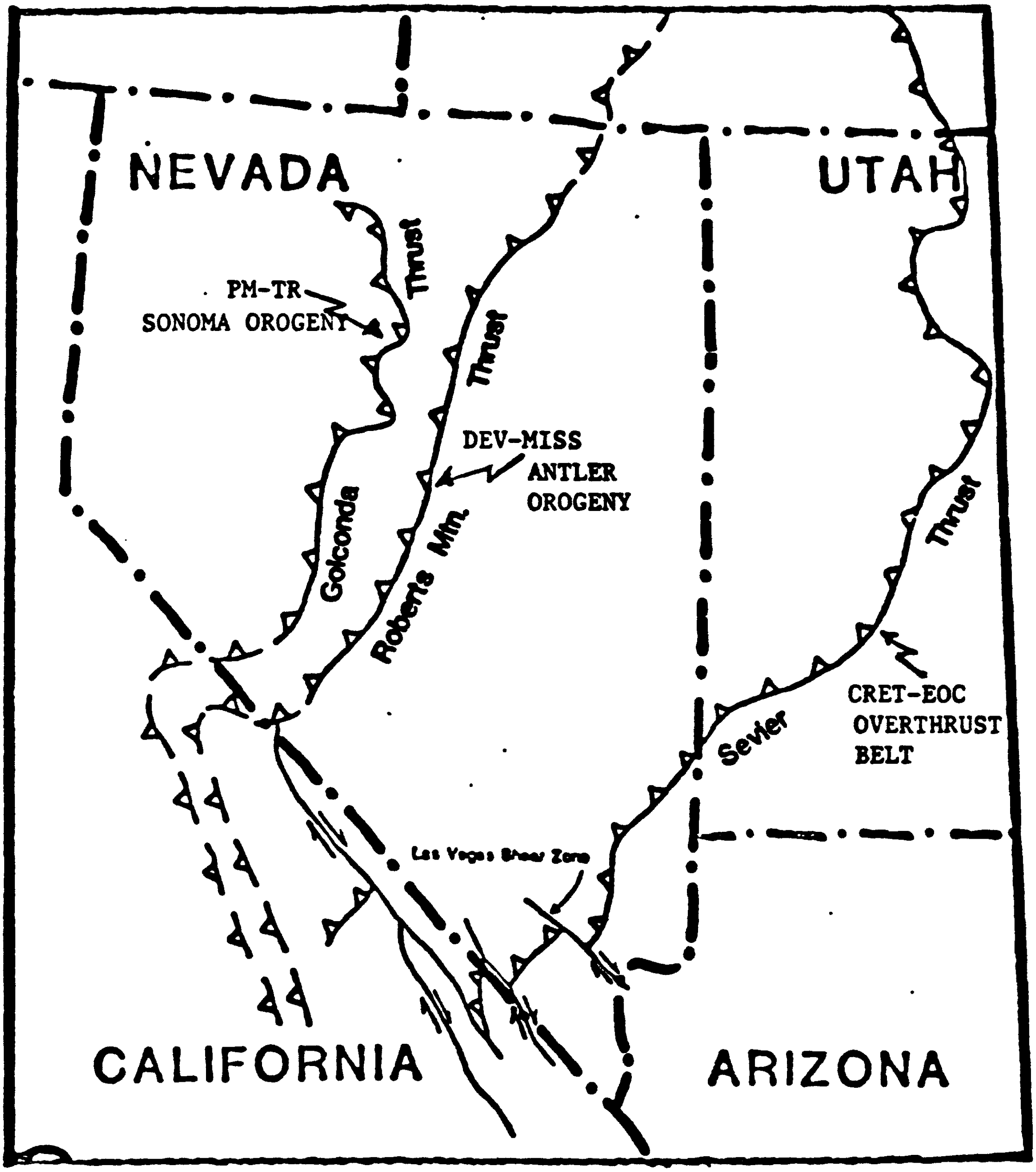

Figure 4 Map showing locations of Permo-Triassic Golconda thrust, Devonian-Mississippian Roberts Mountains Thrust, and the Cretaceous-Eocene Sevier thrust of the Overthrust Belt. From Cook and Taylor (1983).

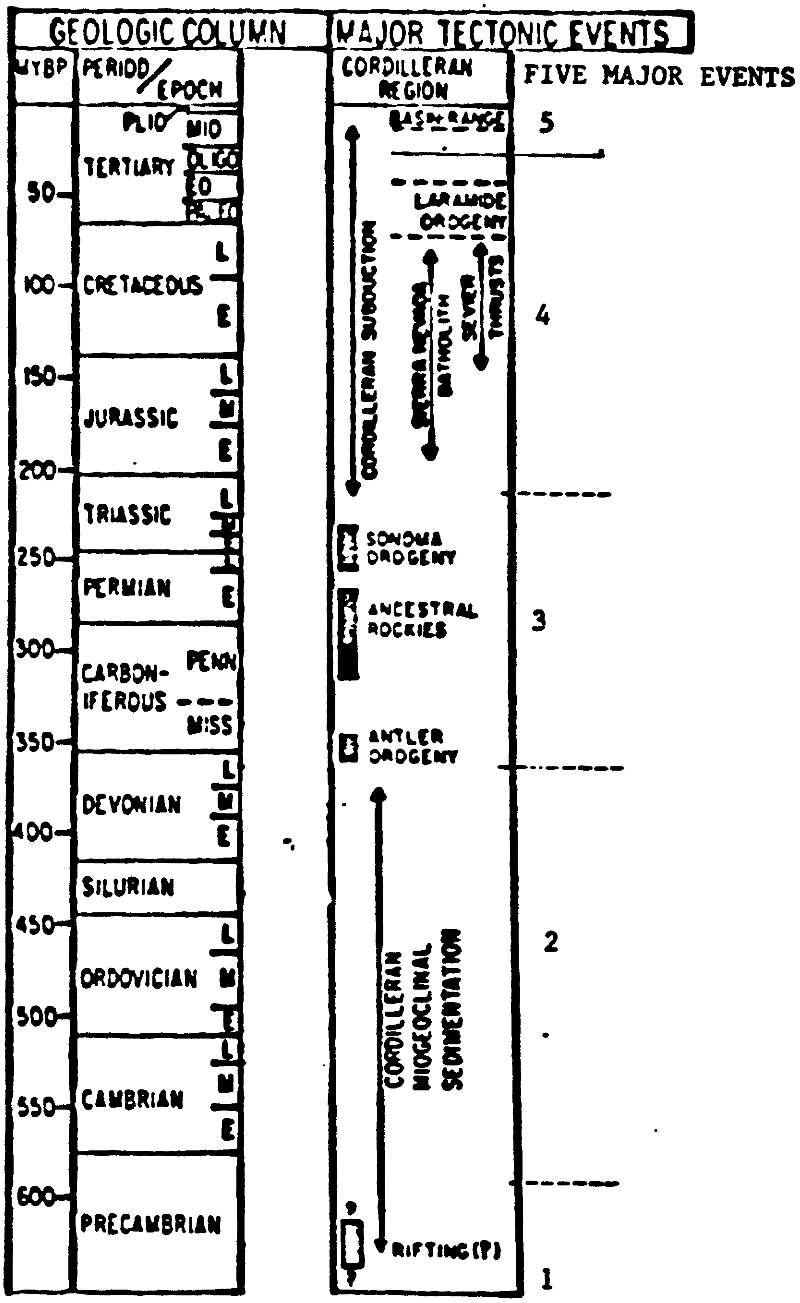

Figure 5 Major tectonic events in the Cordilleran. From Cook and Taylor (1983).

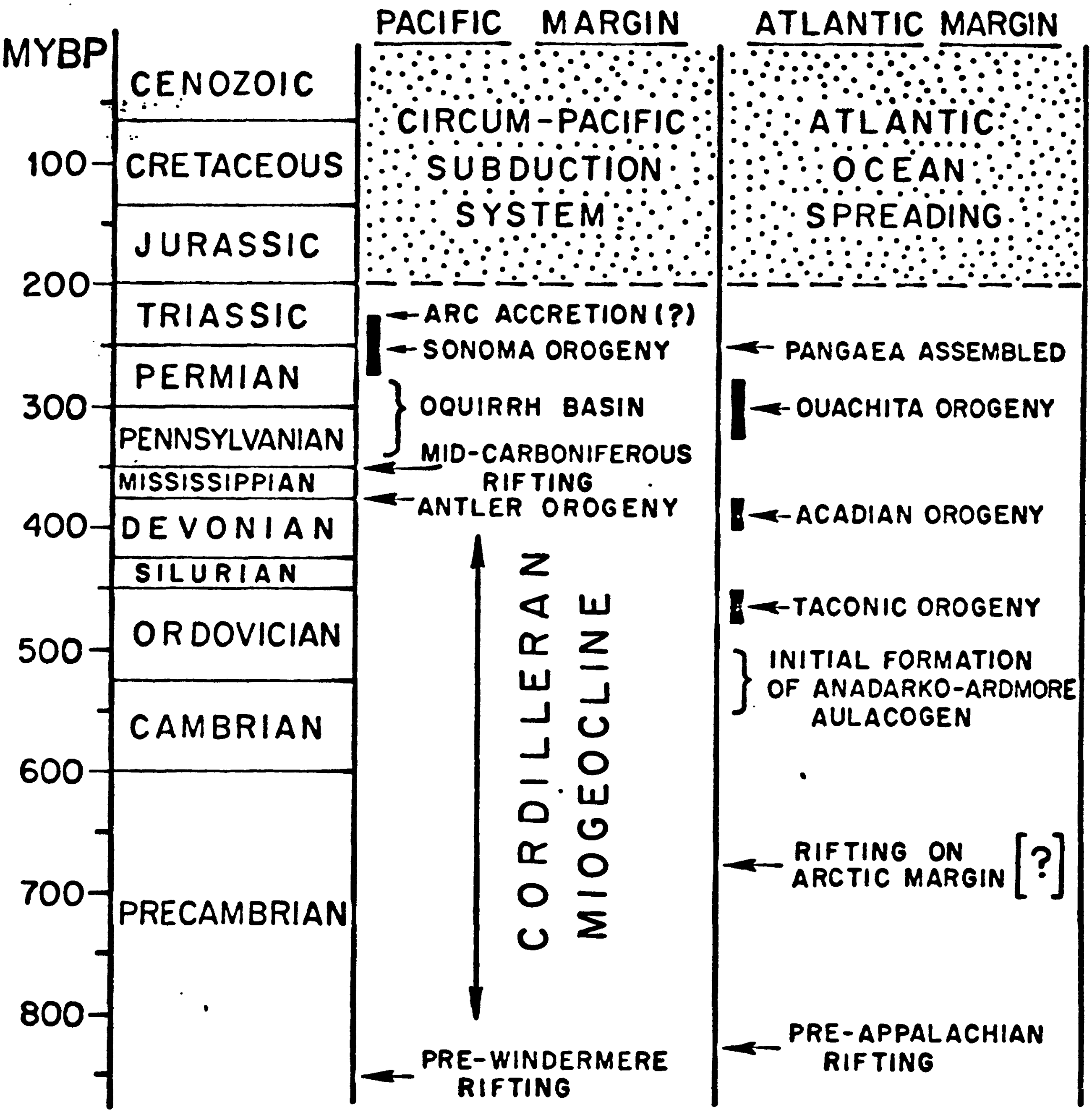

Figure 6 -Diagram to illustrate approximate relative timing of key events on Pacific and Atlantic margins of North America.

From Dickinson (1977).

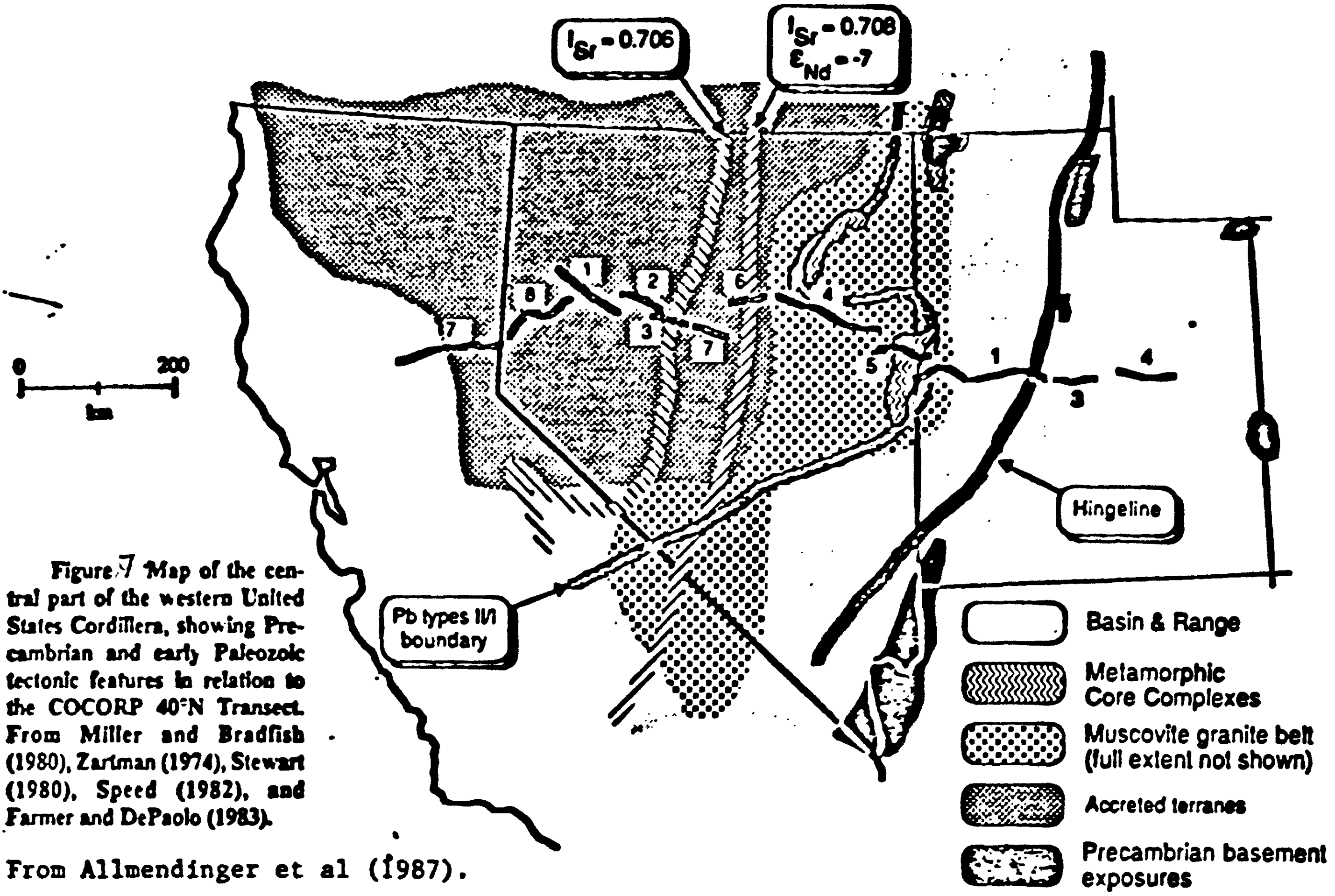

Figure 7 Map of the central part of the western United States Cordillera, showing Precambrian and early Paleozoic tectonic features in relation to the COCORP 40°N Transect. From Miller and Bradfish (1980), Zartman (1974), Stewart (1980), Speed (1982), and Farmer and DePaolo (1983).

From Allmendinger et al (1987).

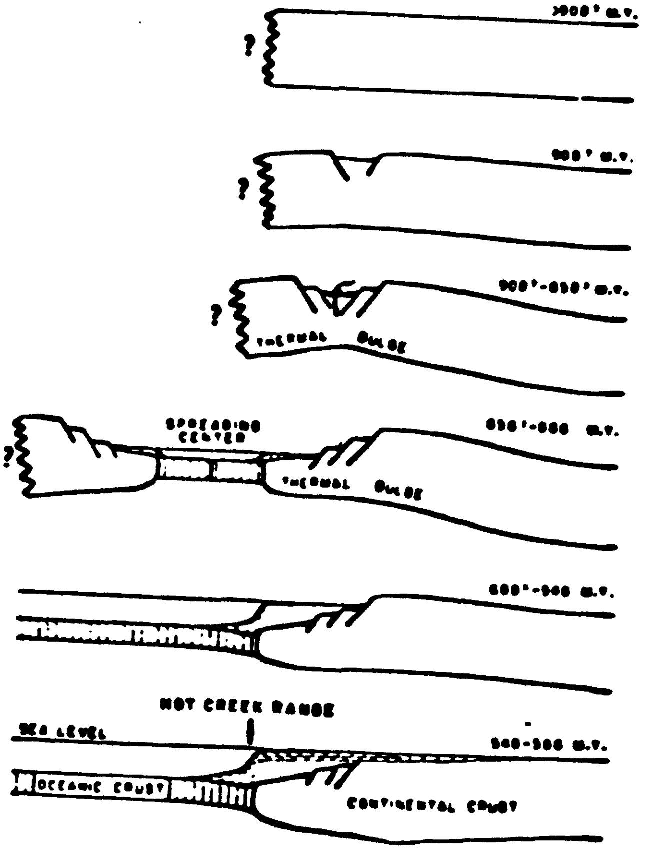

Figure 8 -Diagram showing a model of the late Precambrian and Cambrian development of the western United States

From Cook and Egbert (1981).

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

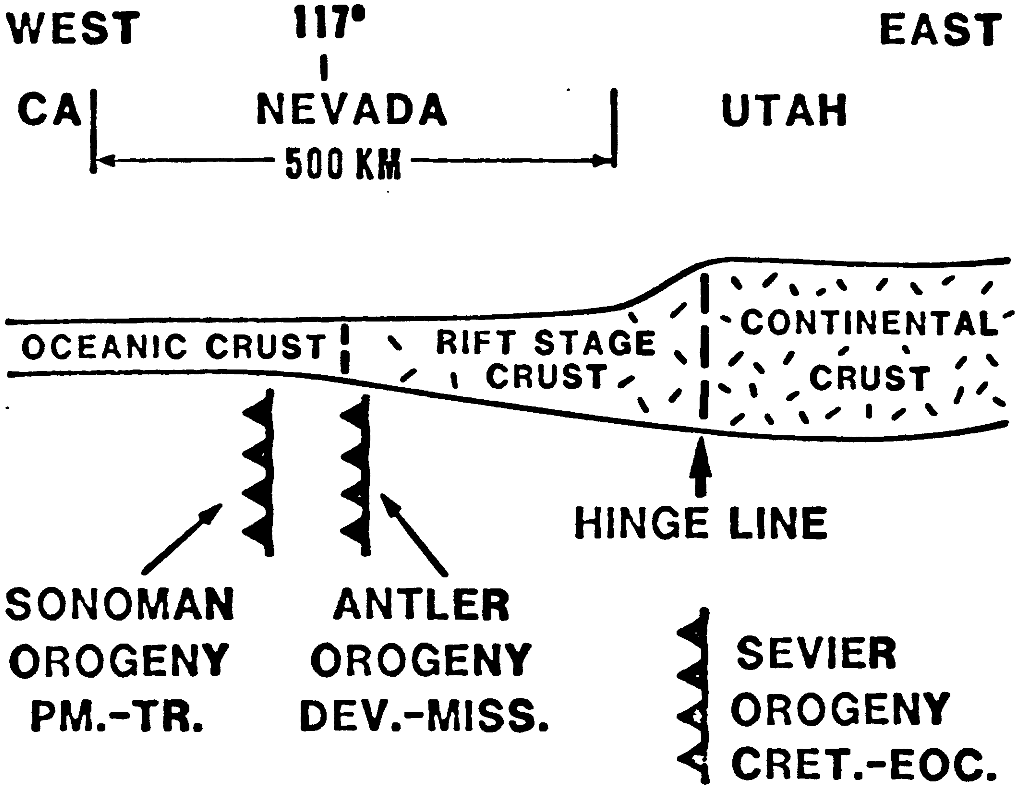
The Proterozoic continent was broken by a major rifting event near the end of the Precambrian (Figs. 8,9) (Stewart, 1972; Stewart and Suczek, 1977). Until the end of the Devonian a passive continental margin comprised western North America from Alaska to southeastern California (Fig. 10) (Churkin, 1974; 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 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. 11,12) (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. 4,5,11). 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. 4,11,13). Similarly, during the Sonoman orogeny, oceanic rocks in the Golconda allochthon

RIFTING AND DEVELOPMENT OF WESTERN U.S.A. PASSIVE CONTINENTAL MARGIN
625-550 M.A.



Stewart (1972), Cook & Taylor (1975), Allmendinger et al (1987)

Figure 9. From Cook and Taylor (1987).

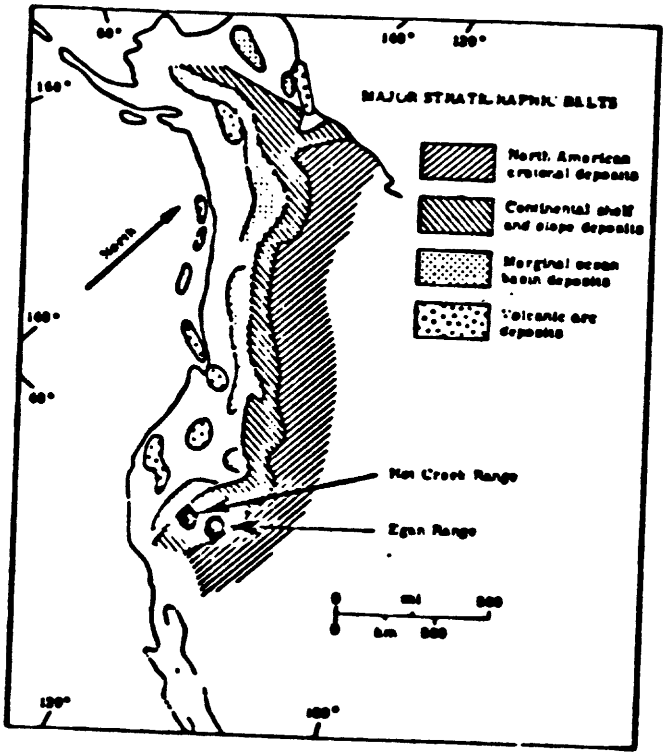


Figure 10 General location of sections in the Hot Creek Range and central Egan Range, Nevada, in relation to major regional stratigraphic belts.

From Cook and Taylor (1977).

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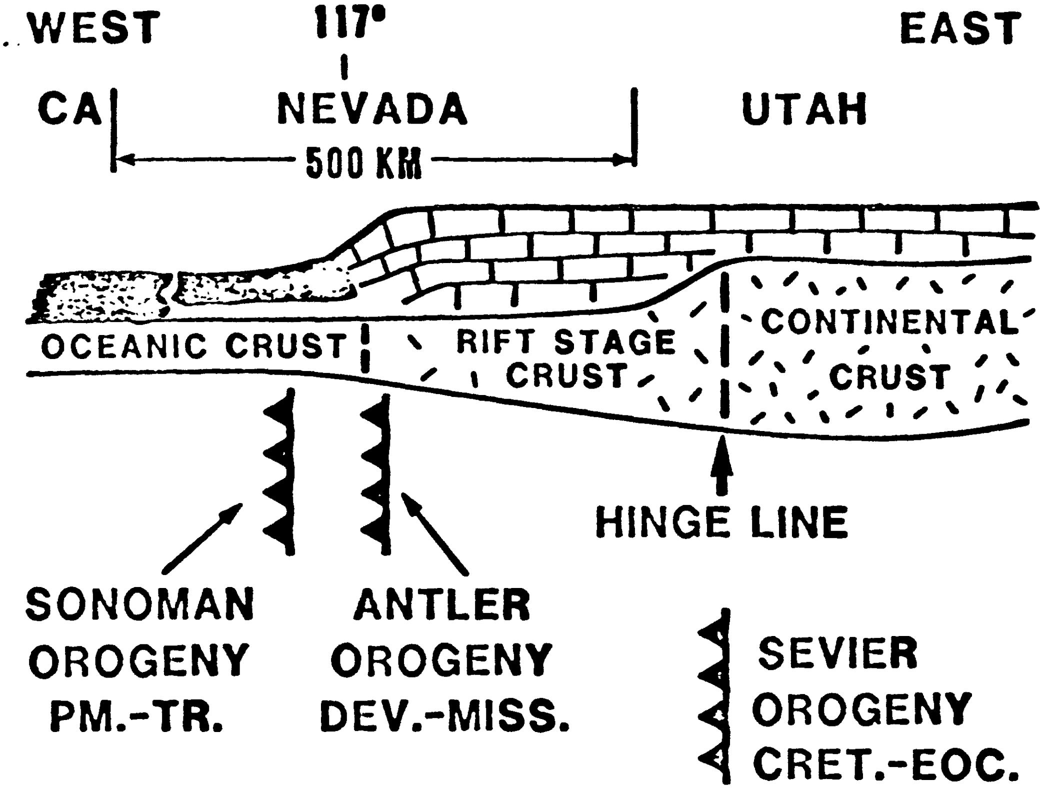
RIFTING AND DEVELOPMENT OF WESTERN U.S.A. PASSIVE CONTINENTAL MARGIN
625-550 M.A.



Stewart (1972), Cook & Taylor (1975), Allmendinger et al (1987)

Figure 11 From Cook and Taylor (1987).

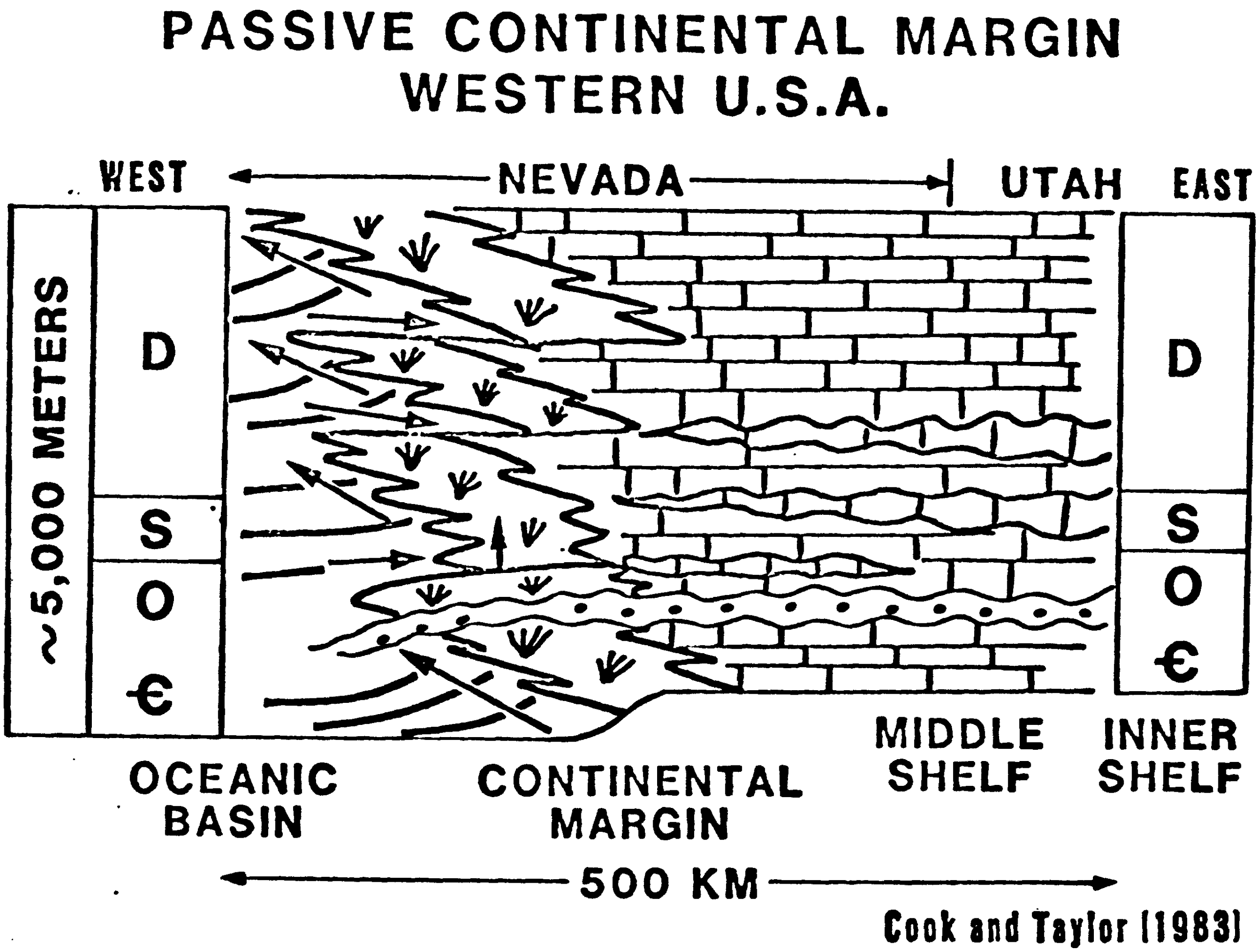


Figure 12 Generalized Pre-Antler orogeny deposional profile from western Utah to central Nevada. Based on data from Cook and Taylor (1975, 1983,1987).

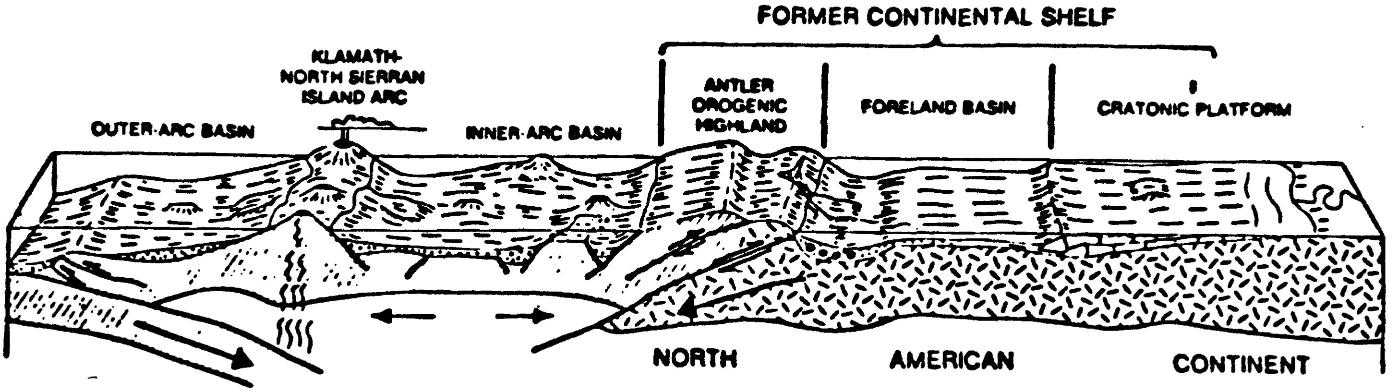


Figure 13 Hypothetical and generalized diagram showing relation between latest Devonian and Mississippian island-arc system and North American continent during Antler orogenic deformation.

From Poole et al (1987).

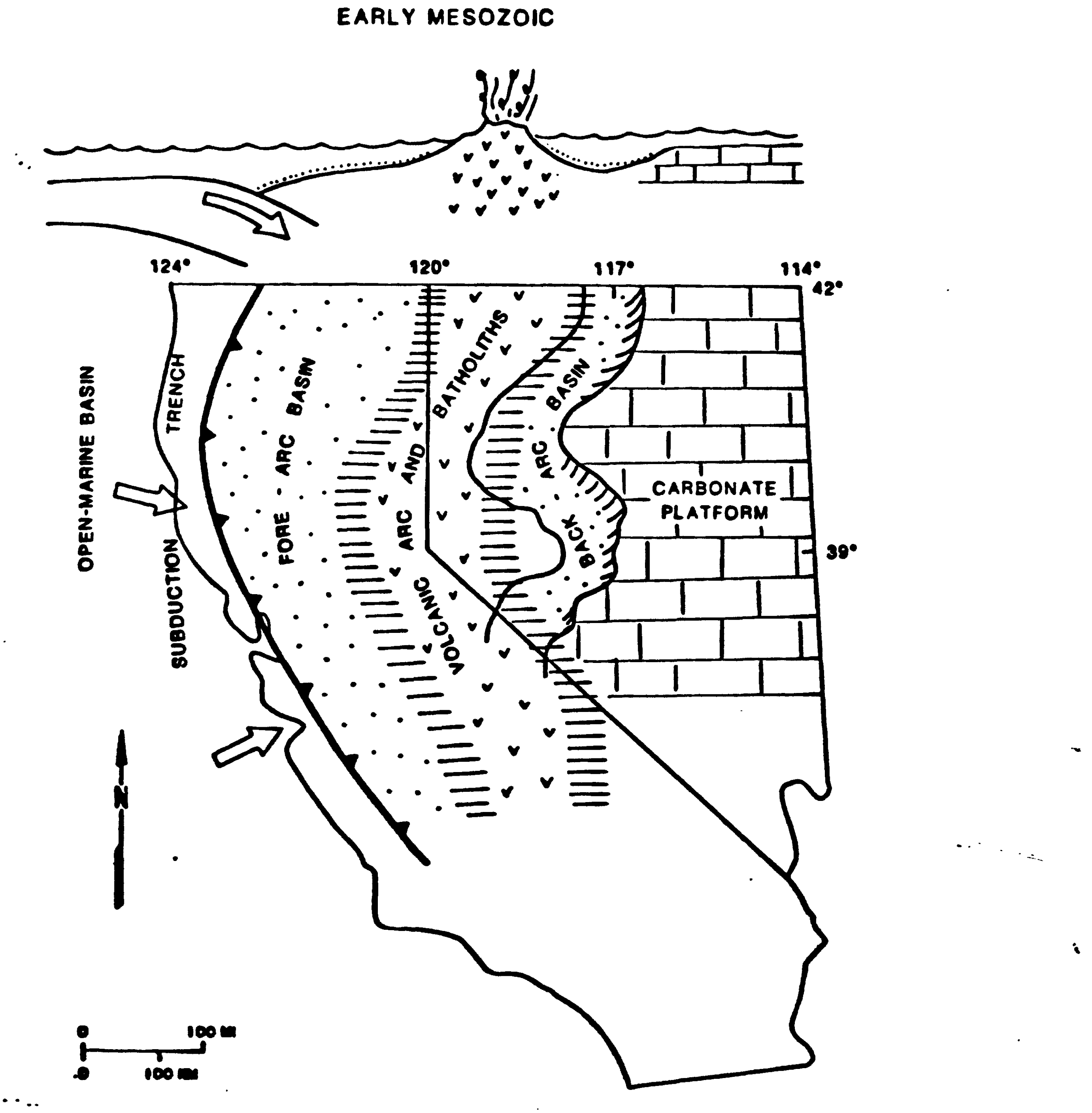


Figure 14 Paleogeographic map. Early Mesozoic.

(Figs. 4,11) were thrust eastward about 50-75 km over previously deformed continental-margin sediments (Fig. 11). 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. 14).

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 develops as a normal-trapped marginal basin (Fig. 15). 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).

Beginning sometime in the Triassic, scattered plutons were being emplaced in eastern California (Fig. 16) (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. 18) (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. 17), 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

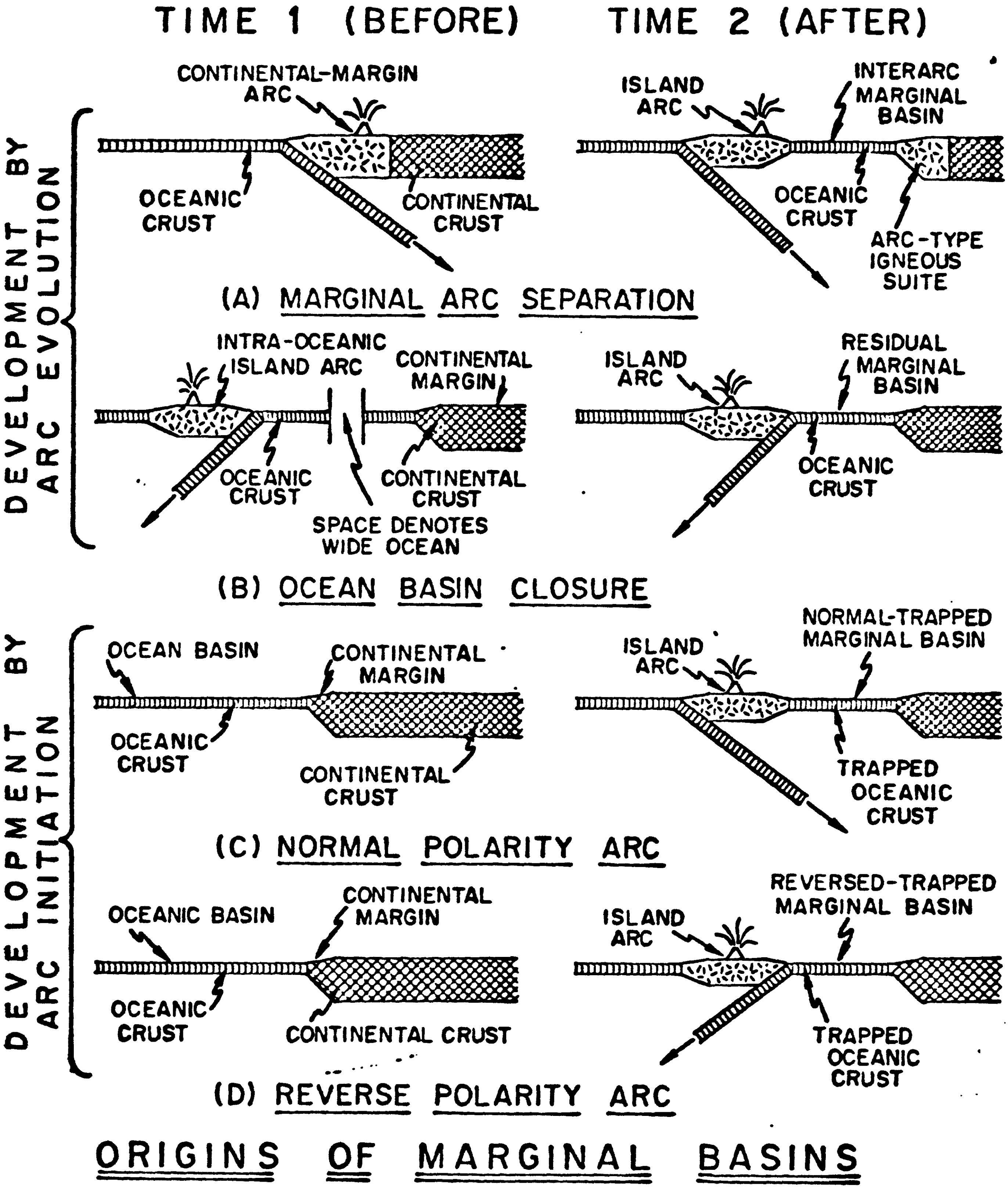


Figure 15 Sketches to illustrate alternate origins for oceanic marginal seas.

From Dickinson (1977).

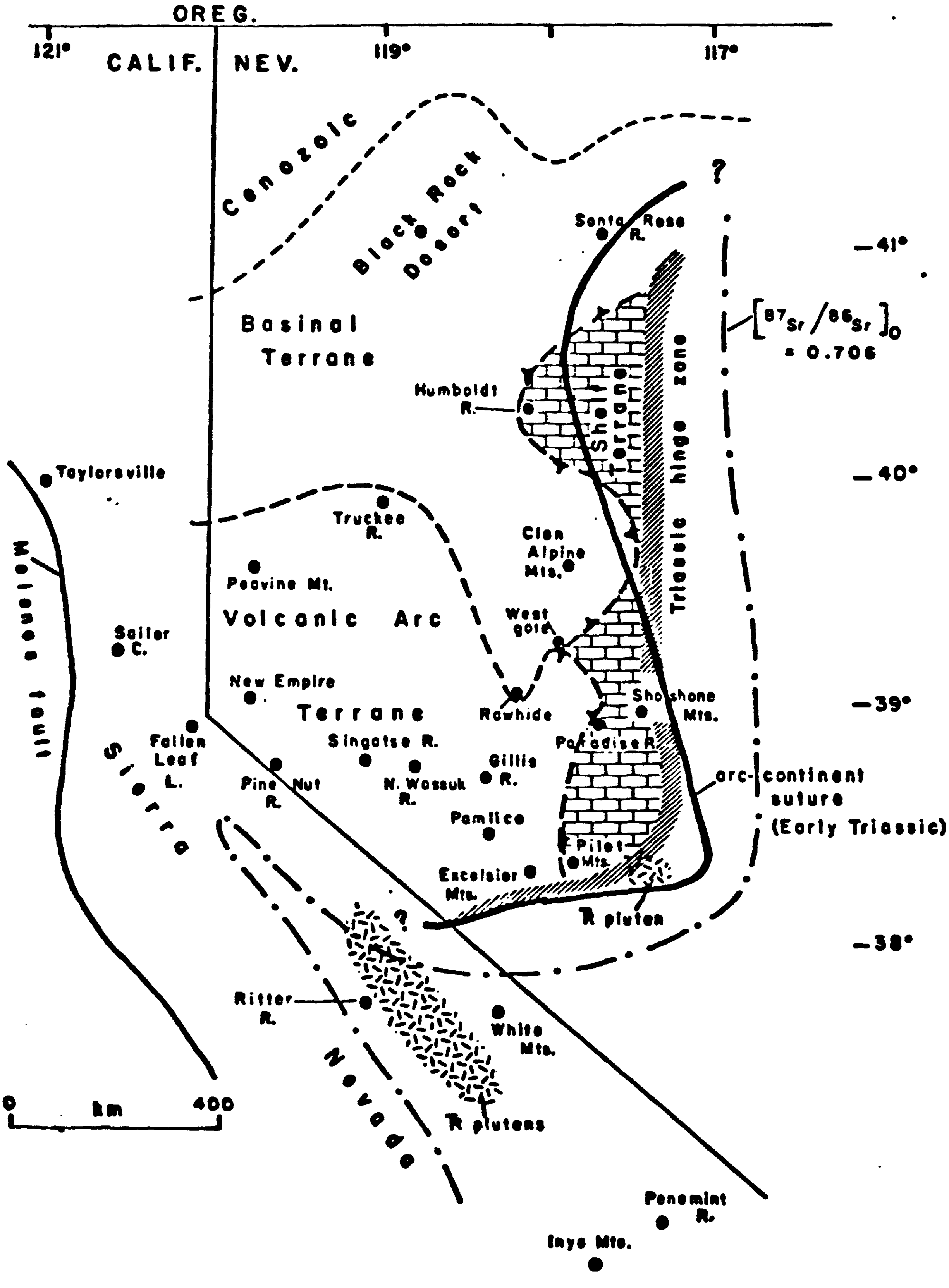


Figure 16 Map showing paleogeographic terranes of early Mesozoic marine province of the western Great Basin

From Speed (1978 b).

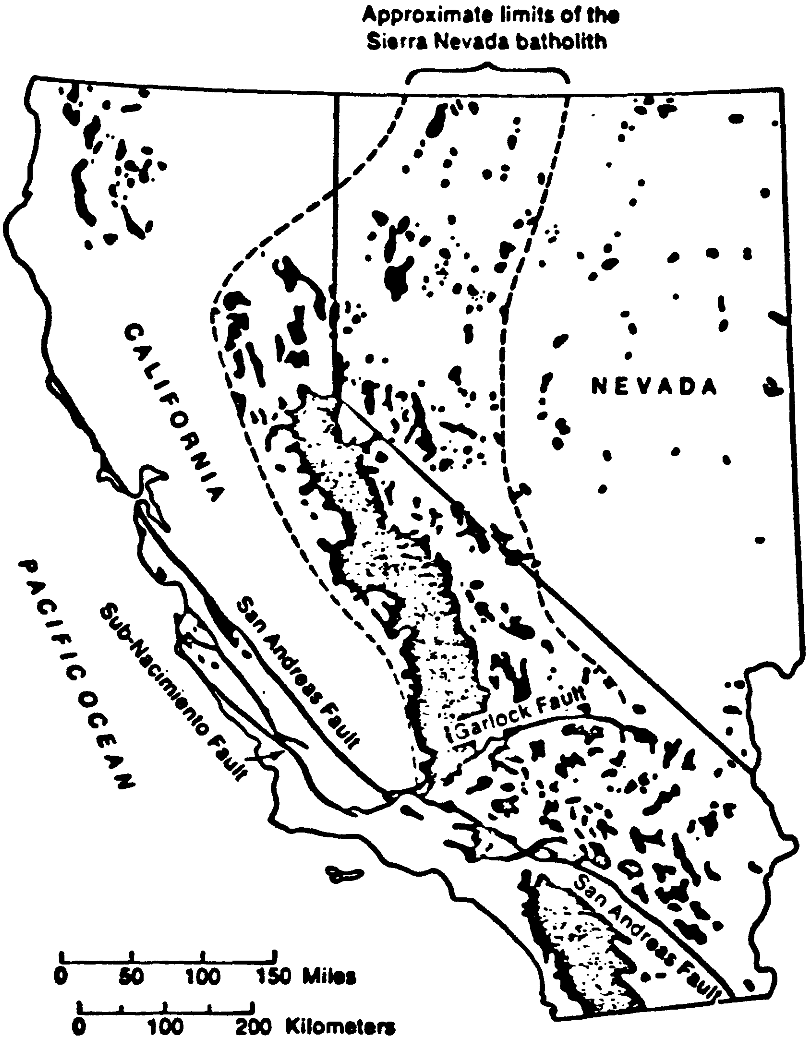


Figure 17 Distribution of granitic rocks in the Sierra Nevada batholith. (Source: Geological Society of America)

From Norris and Webb (1976).

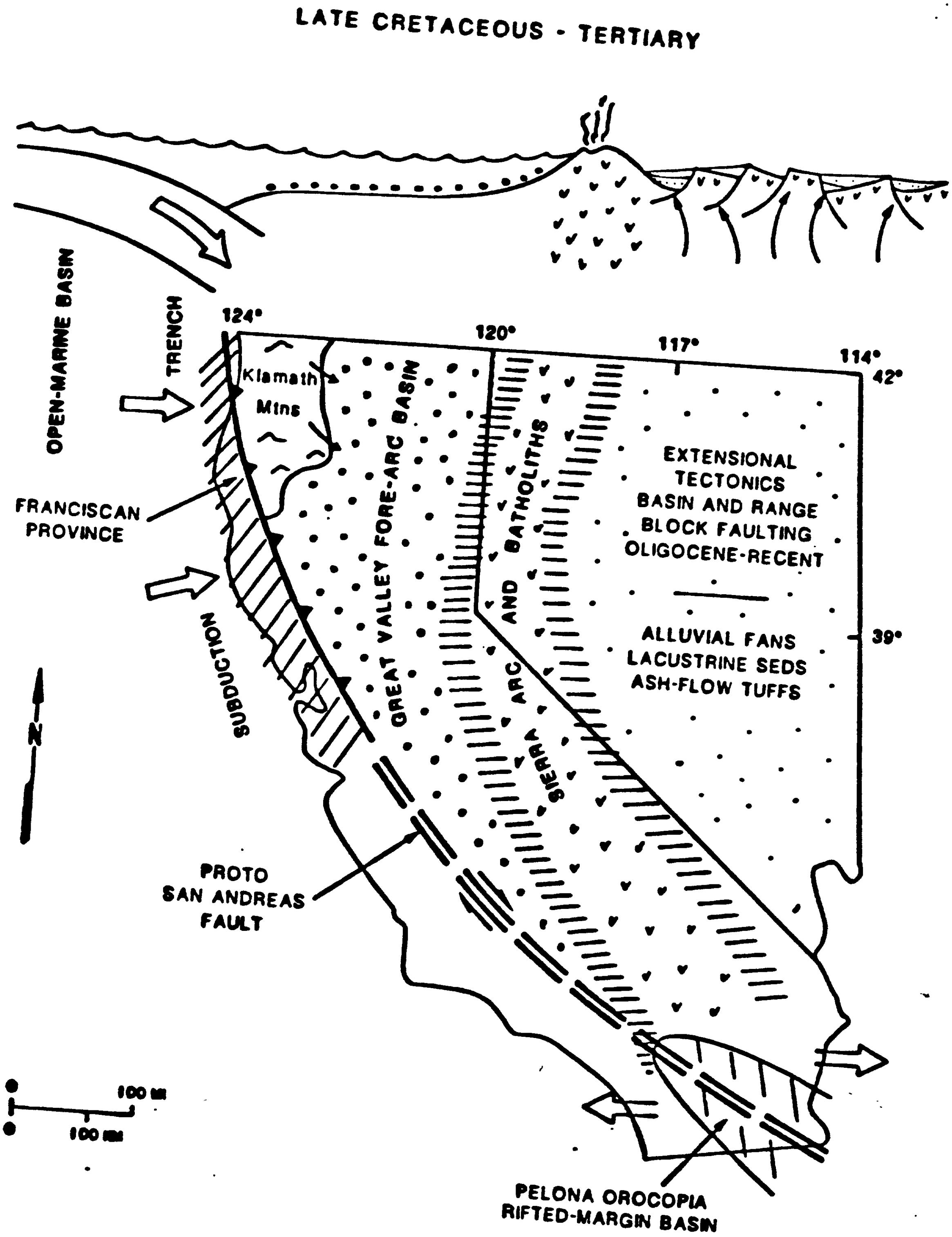


Figure 18 Paleogeographic map.

Valley sequence is the chaotic Franciscan melange (Fig. 18). East of the Sierra Nevada batholith the Basin and Range Province was undergoing fluvial and lacustrine sedimentation and minor amounts of volcanic activity (Fig. 18).

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.

Event 5: Oligocene-Recent--Continental Extension

Extensional tectonics has characterized the western United States since at least the mid-Oligocene (Fig. 19). 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. 20) (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

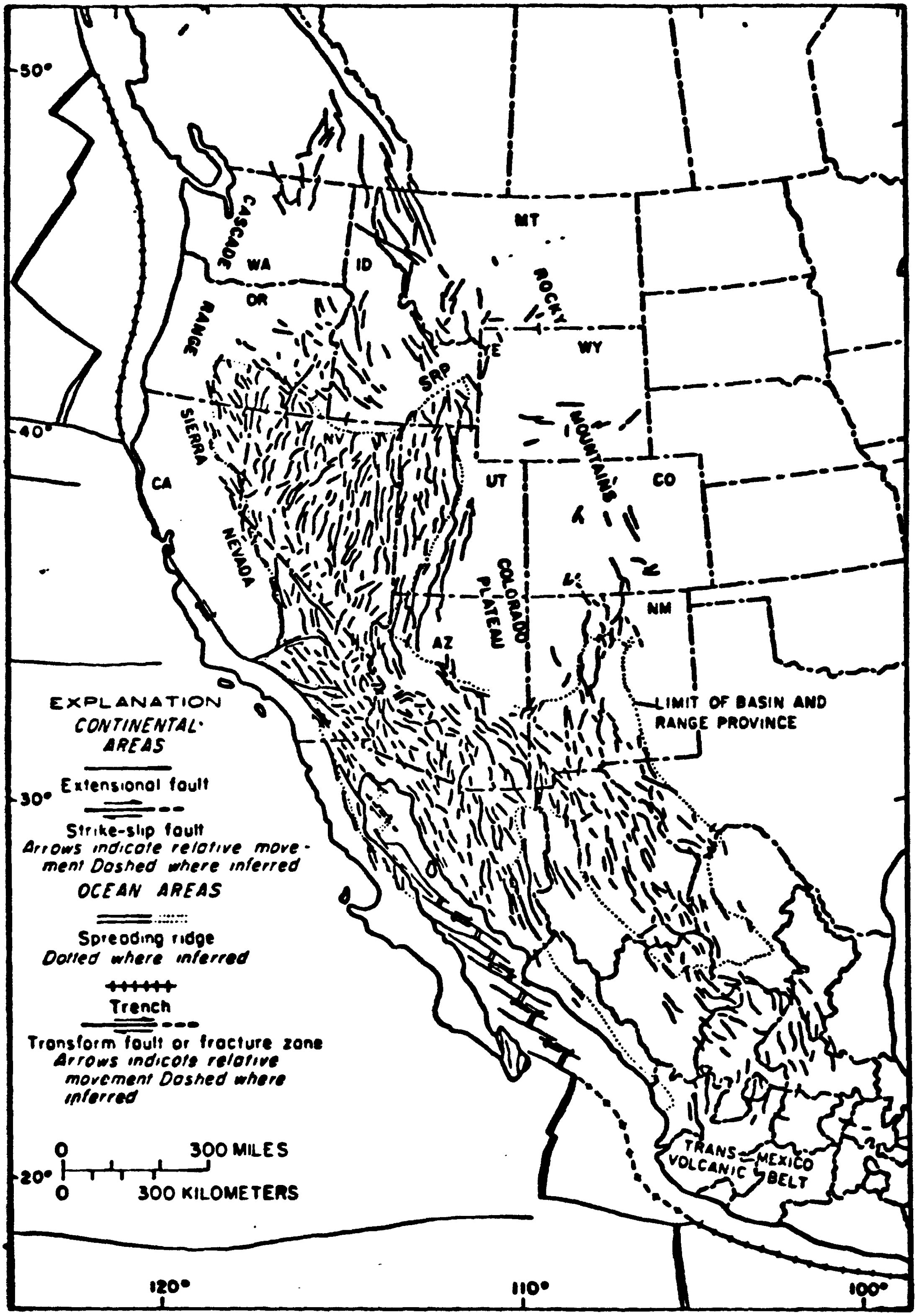


Figure 19. Distribution of late Cenozoic extensional faults, major strike-slip faults, and physiographic provinces in western North America and present-day lithospheric plate boundaries. From Stewart (1978). States: WA, Washington; OR, Oregon; CA, California; CO, Colorado; ID, Idaho; MT, Montana; WY, Wyoming; NV, Nevada; UT, Utah; AZ, Arizona; NM, New Mexico. Localities SRP, Snake River Plain: YE, Yellowstone.

From Stewart (1983).

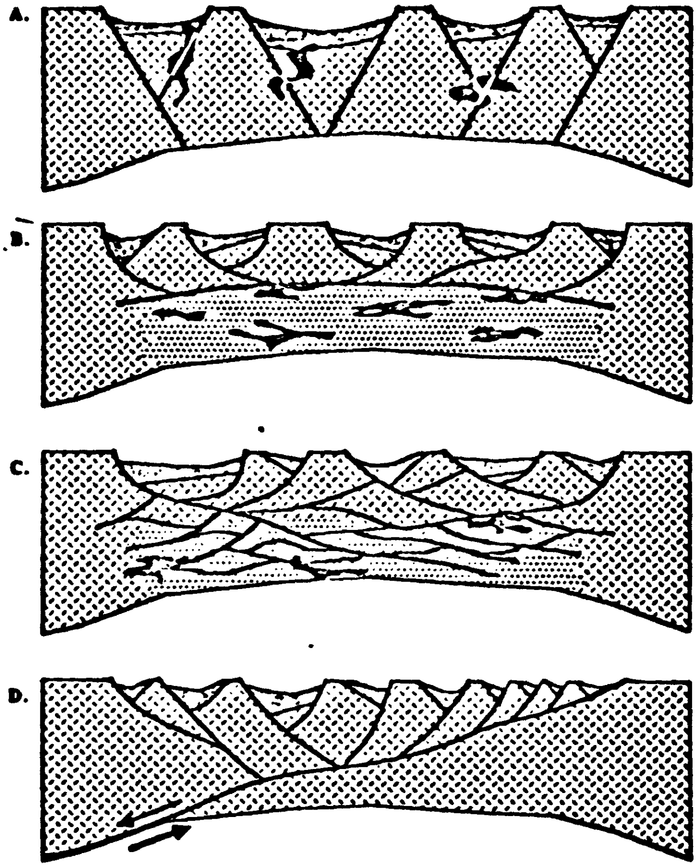


Figure 20 **·** **Simplified models of intracontinental extension. (A) Classic horst and graben model, (B) subhorizontal-decoupling-zone model, (C) anastomosing shear-zone or lenses model, and (D) crustal-penetrating shear-zone model.**

From Allmendinger et al (1987).

thicknesses up to 10,000 feet (3,000 m) (Figs. 21,22,23) (Cook, 1965; Cook, 1968). These fractured 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. 18) (Tarduno et al., 1986).

CALIFORNIA SUBPROVINCES

Sierra Nevada

This area is dominated by Mesozoic calc-alkalic plutonic rocks in addition to great thicknesses of metamorphosed Paleozoic and Mesozoic sediments (Figs. 3,24). This subprovince is not considered to have any hydrocarbon potential. The oldest known Sierran rocks are Ordovician metasediments. In places up to 50,000 feet (15,000 m) of hornfels, chert, marble, slate, and quartzite document Paleozoic sedimentation from Ordovician through the Permian (Norris and Webb, 1976). Triassic and Jurassic rocks consist of thousands of feet of metavolcanics and sedimentary rocks.

The Nevadan orogeny of Kimmeridgian age (Late Jurassic), ca. 150 Ma, involved the collision of a Pacific island arc with the continental margin arc. Magmatic activity ceased in both arcs when these two opposing arc-srench systems collided (Fig. 25) (Schweickert and Cowan, 1975). Later in the Cretaceous the main masses of the Sierran batholiths were emplaced. It was upon these batholiths, arc complexes, and Paleozoic sediments that the eastern

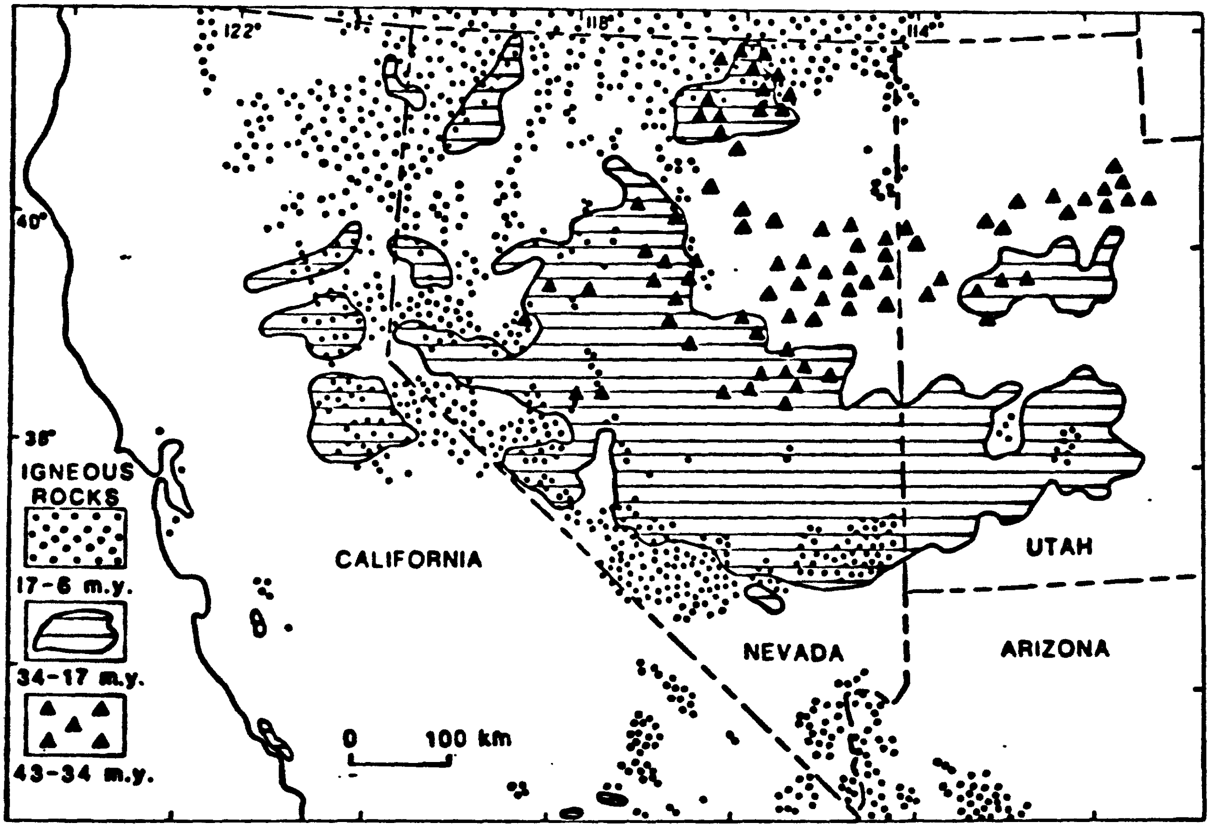
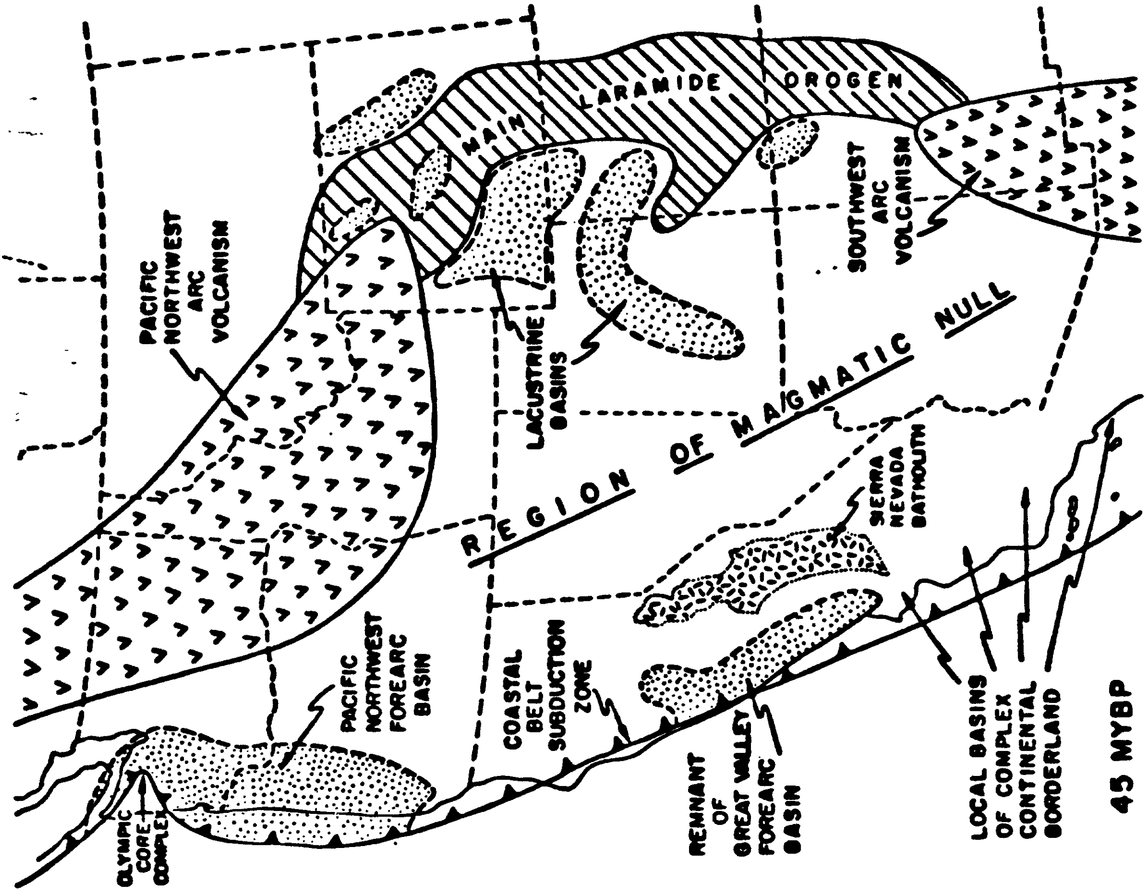
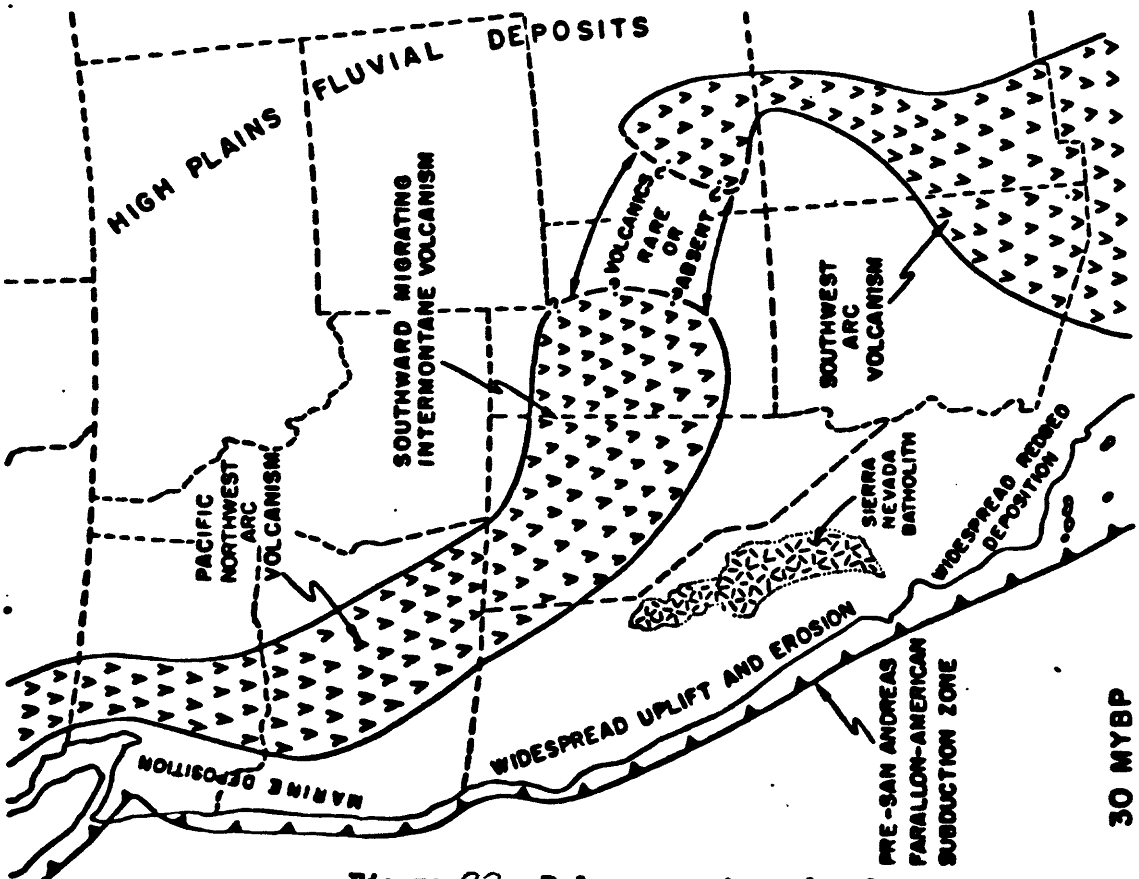


Figure 21. Distribution of 43- to 6-m.y.-old igneous rocks in Nevada, Utah, and parts of adjacent states. From Stewart and others (1977).

From Stewart (1983).

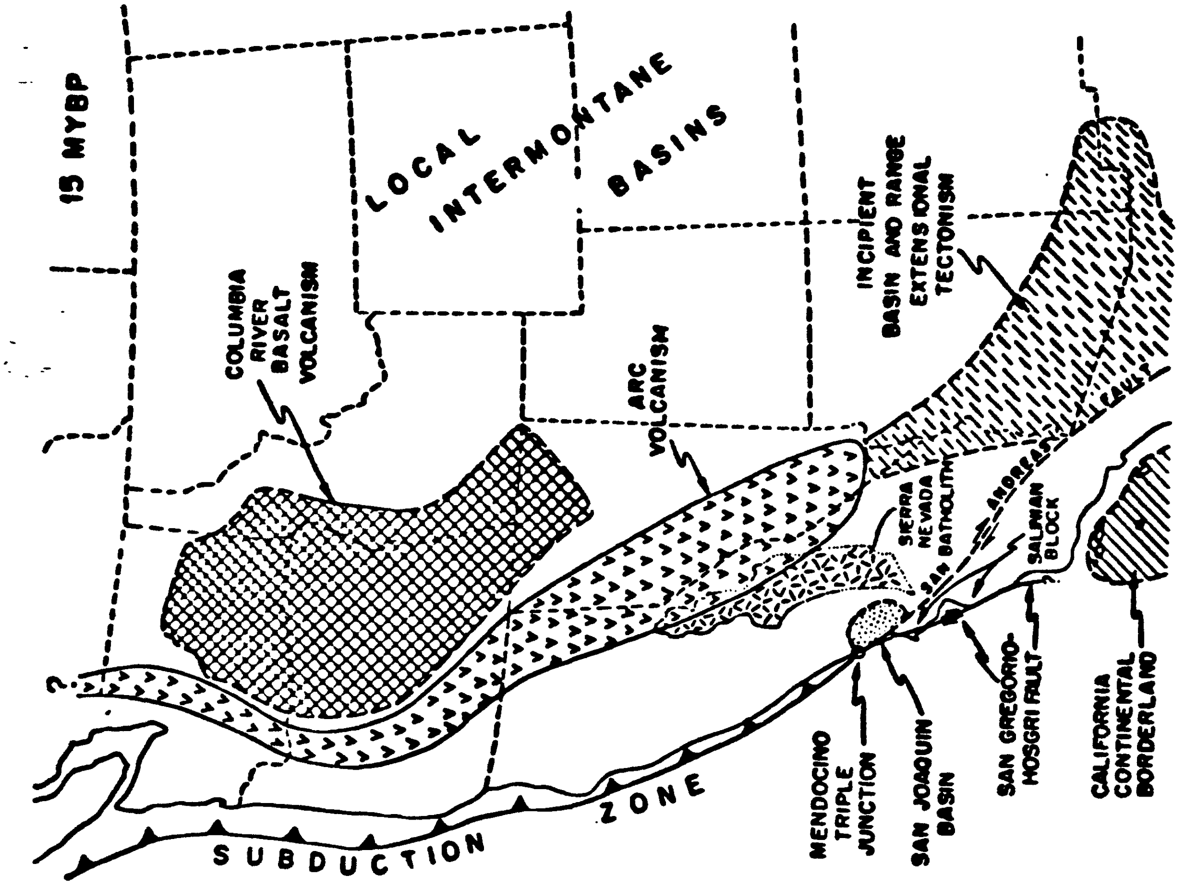


Paleotectonic and paleogeographic sketch map of the Cordilleran region 45 mybp in the Eocene.

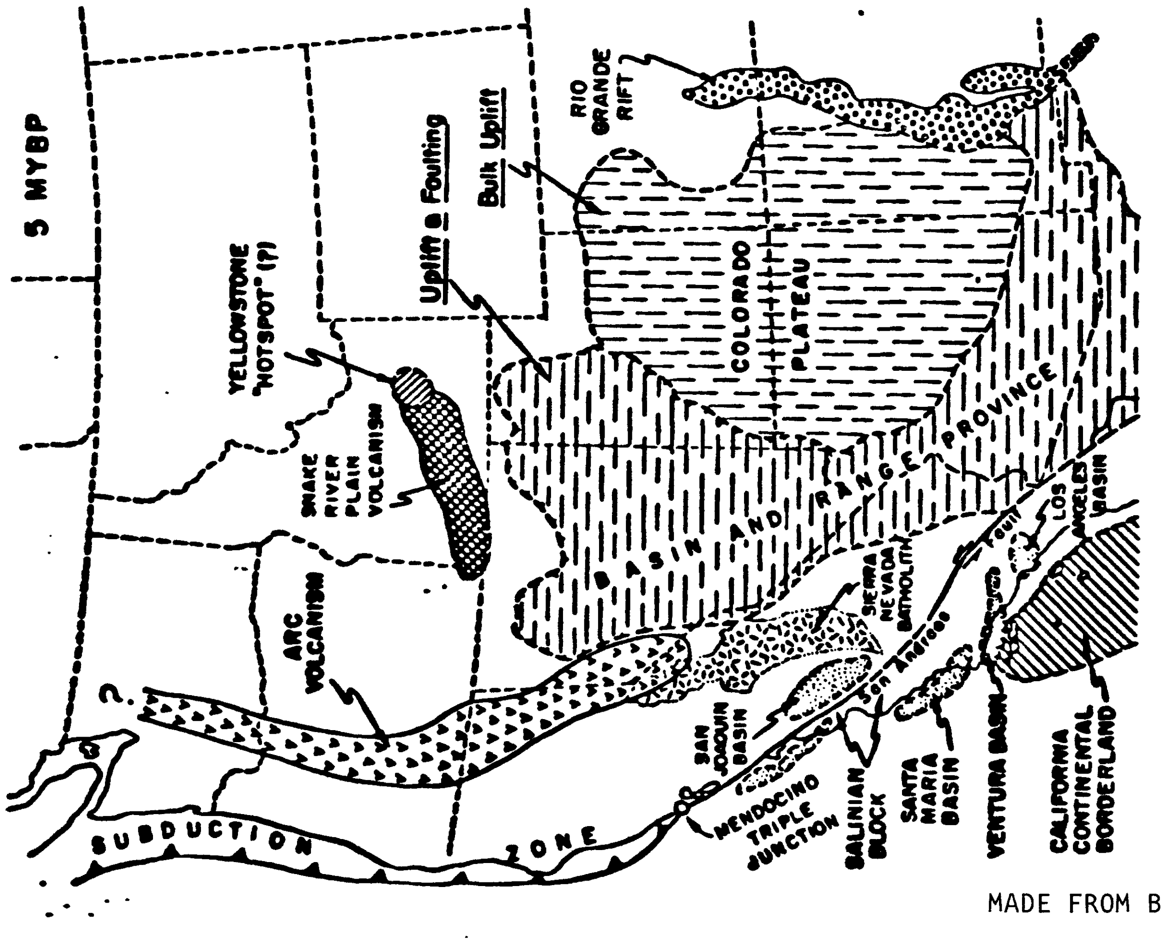


Paleotectonic and paleogeographic sketch map of the Cordilleran region 30 mybp in the Oligocene.

Figure 22. Paleotectonic and paleogeographic maps. From Dickinson (1979).



Paleotectonic and paleogeographic sketch map of the Cordilleran region 15 mybp in the Miocene.



-- Paleotectonic and paleogeographic sketch map of the Cordilleran region 5 mybp at the Miocene/Pliocene boundary.

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Figure 23. Paleotectonic and paleogeographic maps.
From Dickinson (1979)

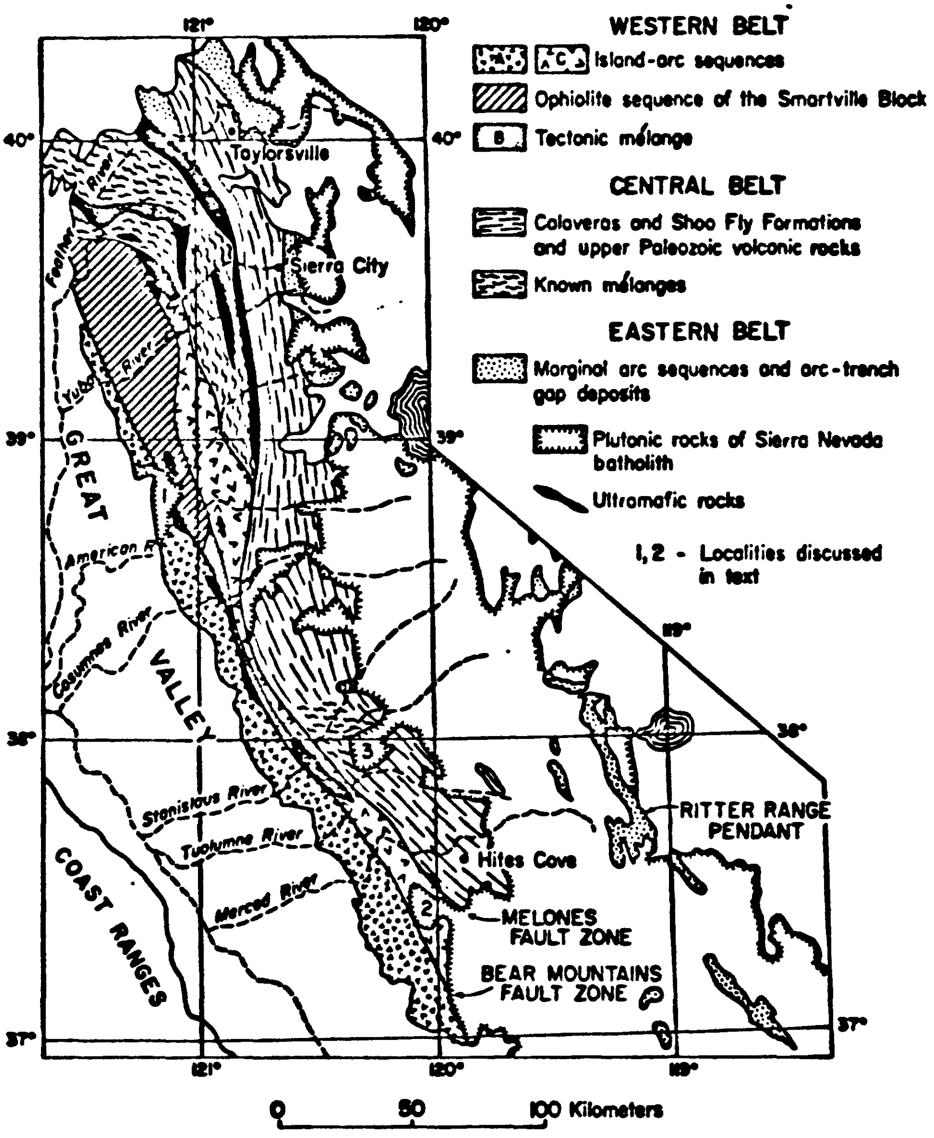

Figure 24. Generalized map showing the lithic belts of the Sierra Nevada in central California. Relations are shown diagrammatically. Mélanges are more extensive in the central belt than shown. Paleozoic rocks occur in many parts of the eastern belt but are not distinguished from Mesozoic rocks.

From Schweickert and Cowan (1975).

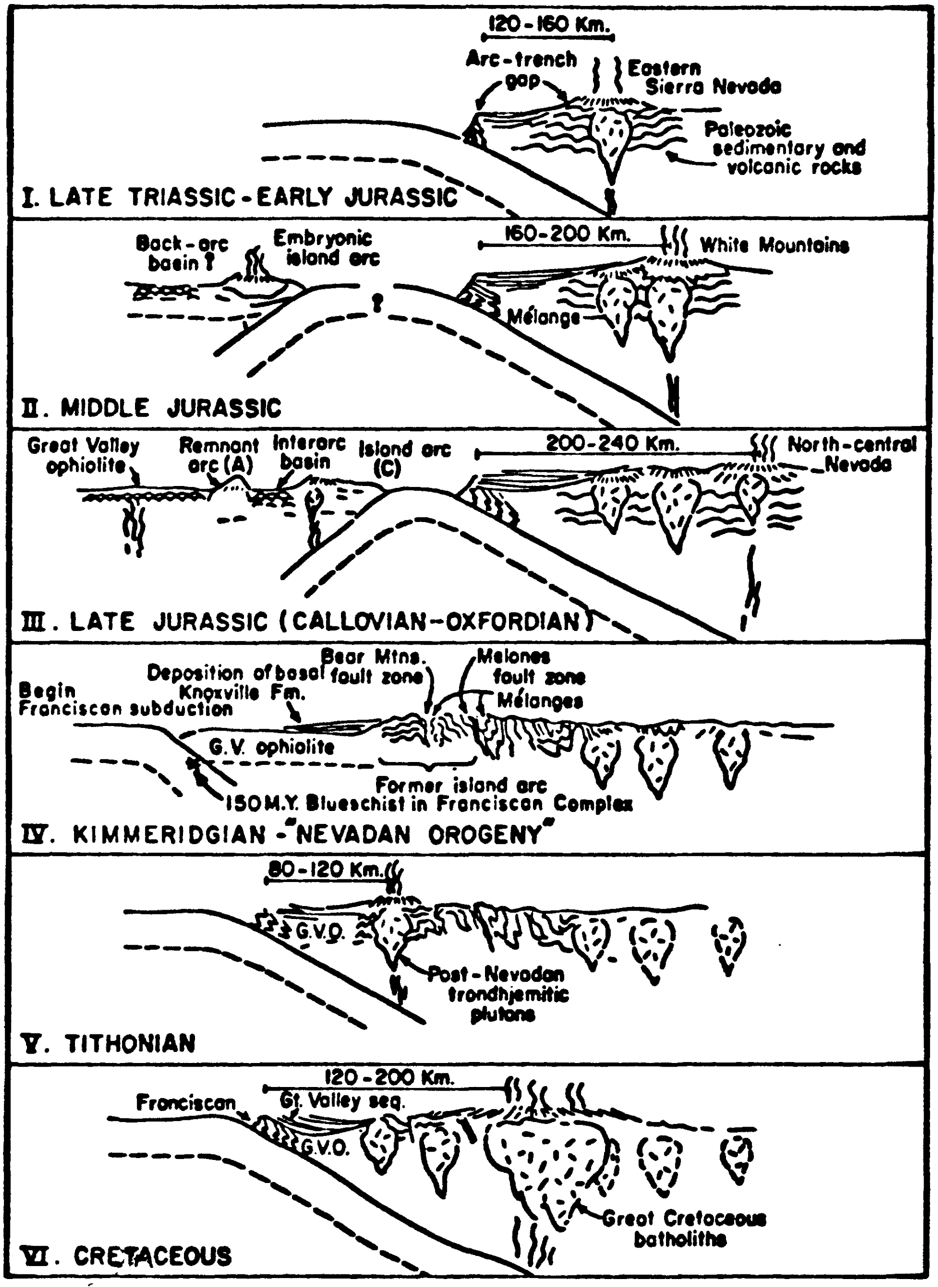

Figure 25. Hypothetical schematic sections showing postulated tectonic evolution of the Sierra Nevada during Mesozoic time.

FromSchweickert and cowan (1975).

margins of the Cretaceous Great Valley sequence onlapped unconformably (Figs. 18,25).

Klamath Mountains

This area is not considered to have a commercial hydrocarbon potential. The overall lithofacies and structural patterns suggest that the Klamath Mountains subprovince consists of slices of oceanic crust (ophiolites), island-arc volcanics, outer-arc and/or inter-arc basinal sediments, and displaced terranes, all of which have been accreted to the continental margin (Fig. 13) (Irwin, 1977).

Mesozoic pelagic limestones are imbedded within Paleozoic marine siliciclastics. These exotic limestones may be displaced limestone terranes from equatorial latitudes similar to the ones studied by Tarduno et al. (1986) in the Northern Coast Ranges of California.

Cascade Range-Modoc Plateau

The oldest sedimentary rocks exposed in this subprovince are the Late Cretaceous marine siliciclastics of the Hornbrook Formation (Nilsen, 1984). Hornbrook sediments are underlain by Paleozoic and Mesozoic metamorphic and plutonic rocks in the Klamath Mountains, and unconformably(?) overlain by nonmarine Tertiary sediments (Figs. 26-29). Cenozoic pyroclastics and volcanic flow rocks, ranging from Oligocene to Holocene, cover most of this subprovince to thicknesses up to 10,000 feet (3,000 m). There is considered to be only a remote chance for commercial quantities of hydrocarbons in this area; nevertheless, the following geologic framework related to hydrocarbons is included.

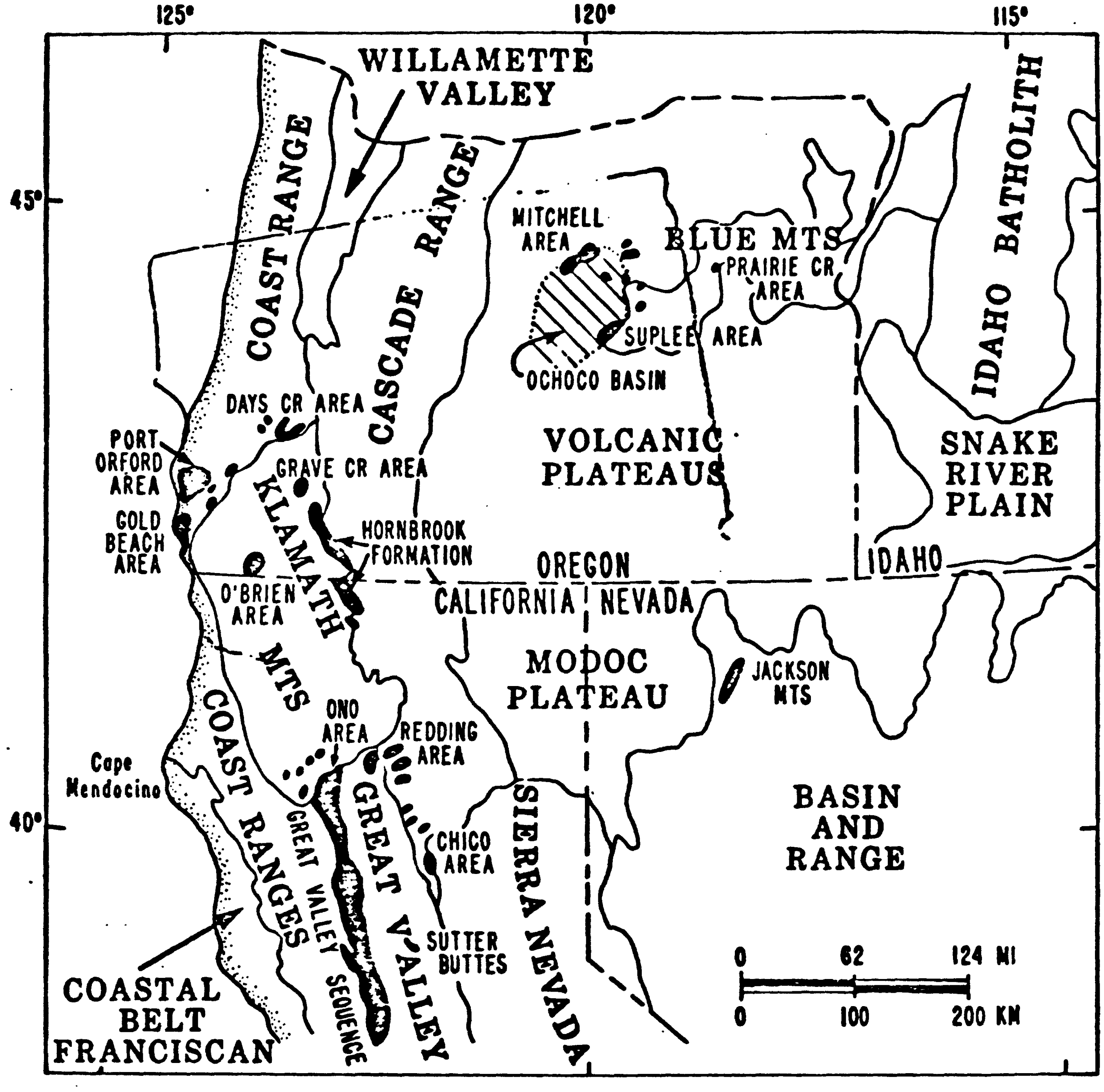

Figure 26. Index map showing in black the locations of outcrops of the Hornbrook Formation and other Cretaceous strata including the coastal belt part of the Franciscan assemblage, in northern California, Oregon, and northwestern Nevada (from Nilsen, 1984a, Fig. 6). Lines represent boundaries of major geomorphic provinces.

From Nilsen (1984).

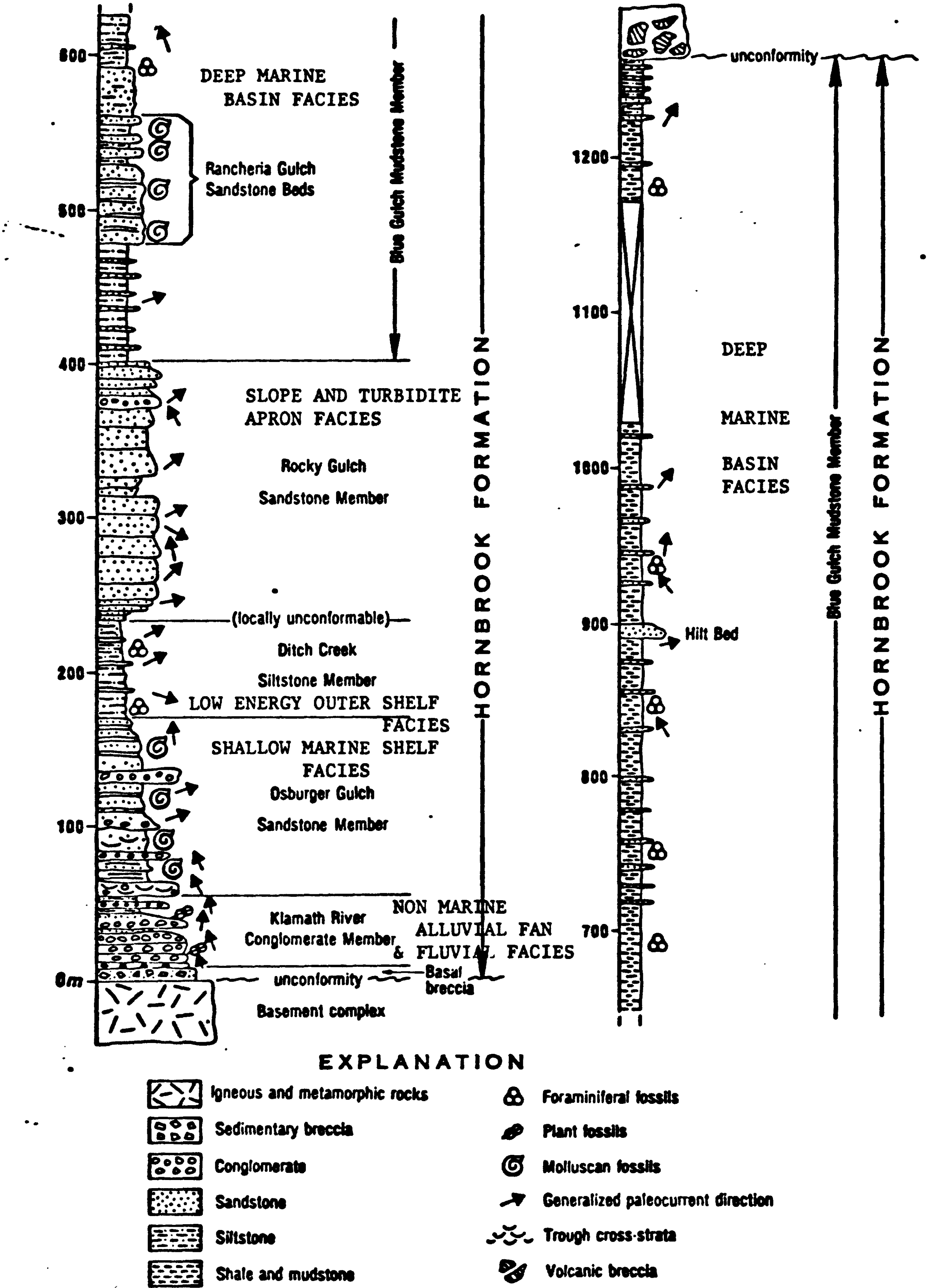

Figure 27. Composite measured section of the Hornbrook Formation in its type area

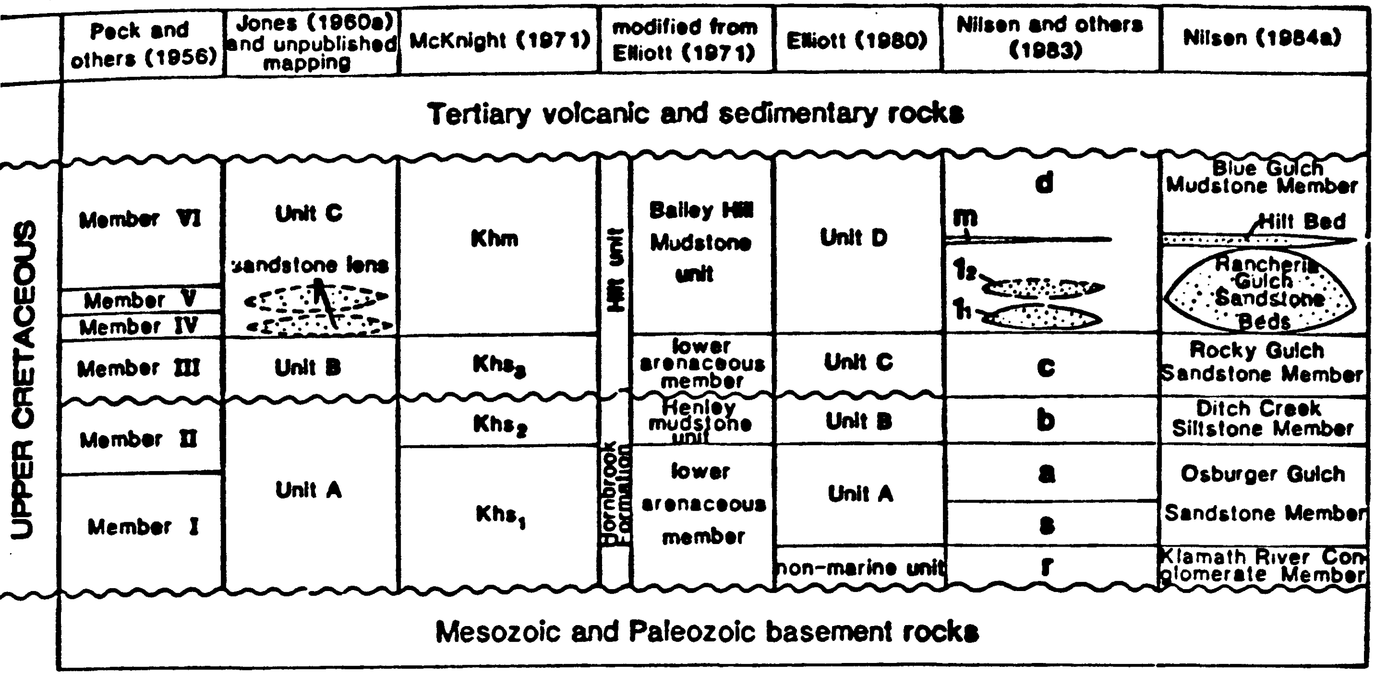

Figure 29. Correlation diagram showing the evolution of formal and informal stratigraphic nomenclature for the Hornbrook Formation.

From Nilsen (1984).

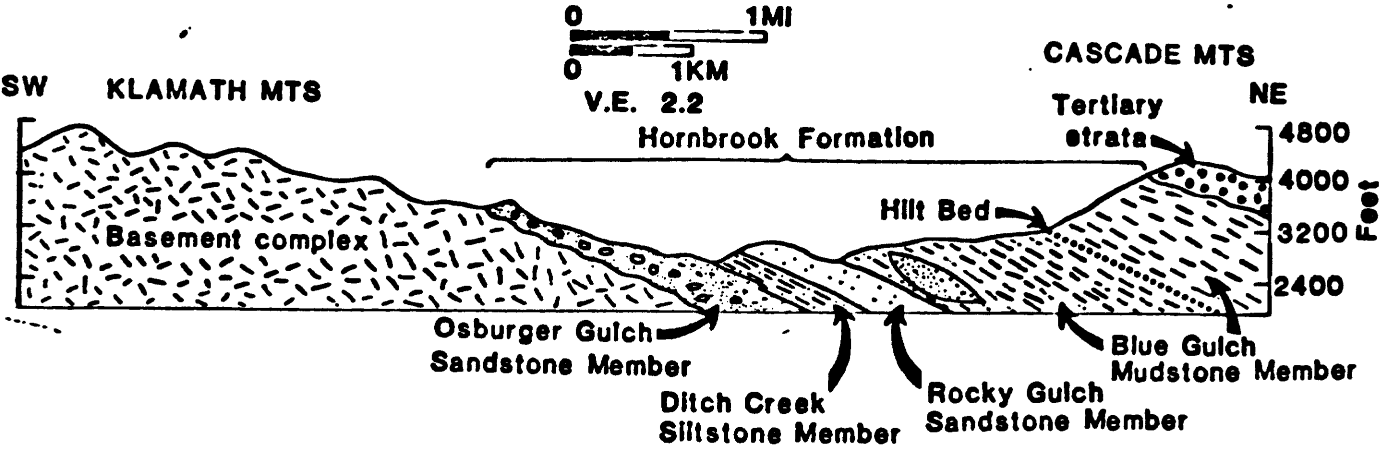

Figure 28. Northwest-southeast geologic cross-section across the Cottonwood Creek Valley area. The topography and stratigraphic boundaries are modified from Elliott (1971) and the stratigraphic nomenclature is from Nilsen (1984a).

From Nilsen (1984).

During the Late Cretaceous the Modoc Plateau area was part of a marine basin within which the Hornbrook Formation was deposited. This basin may have originally connected with the subsurface Ochoco basin of central Oregon to form a forearc basin west of the Late Cretaceous magmatic arc in the Idaho batholith (Figs. 18,30). This basin was bounded on the west by the Klamath Mountains of northern California and southern Oregon, on the southeast by the Sierra Nevada, and on the east by the Idaho Batholith. To the south, the basin may have been connected with the Great Valley forearc basin (Figs. 18,30). The Upper Cretaceous Hornbrook Formation is a deepening upward sequence which consists of about 4,000 feet (1,200 m) of nonmarine, shallow marine, and deep-marine slope and submarine fan siliciclastic facies (Fig. 27) (Nilsen, 1984).

Source-rock evaluations of samples collected from outcrops of the Hornbrook Formation indicate that they contain type III organic matter, and are, therefore, capable of generating mainly gas and little or no oil (Fig. 31) (Law et al., 1984). Vitrinite reflectance, Rock-Eval pyrolysis, extraction, and chromatograph data indicate these samples are immature to marginally mature with respect to the thermal maturation of gas (Law et al., 1984).

Potential reservoir rocks would include shoreline sands, offshore bar facies, and deep-water siliciclastic turbidites. However, whether or not these same facies, that outcrop discontinuously around the northwest margin of the basin, actually occur to the east at depth is not known. A fourth potential reservoir facies would be fractured andesite flows. Keighin and Law (1984) report measured helium porosities of 6.3 to 18.6 percent, and maximum permeabilities from .01 to 1.2 md in the Hornbrook sandstones. Both physical and chemical post-depositional processes have degraded the reservoir qualities of the sandstones. Overcompaction and a clayey matrix has reduced pore

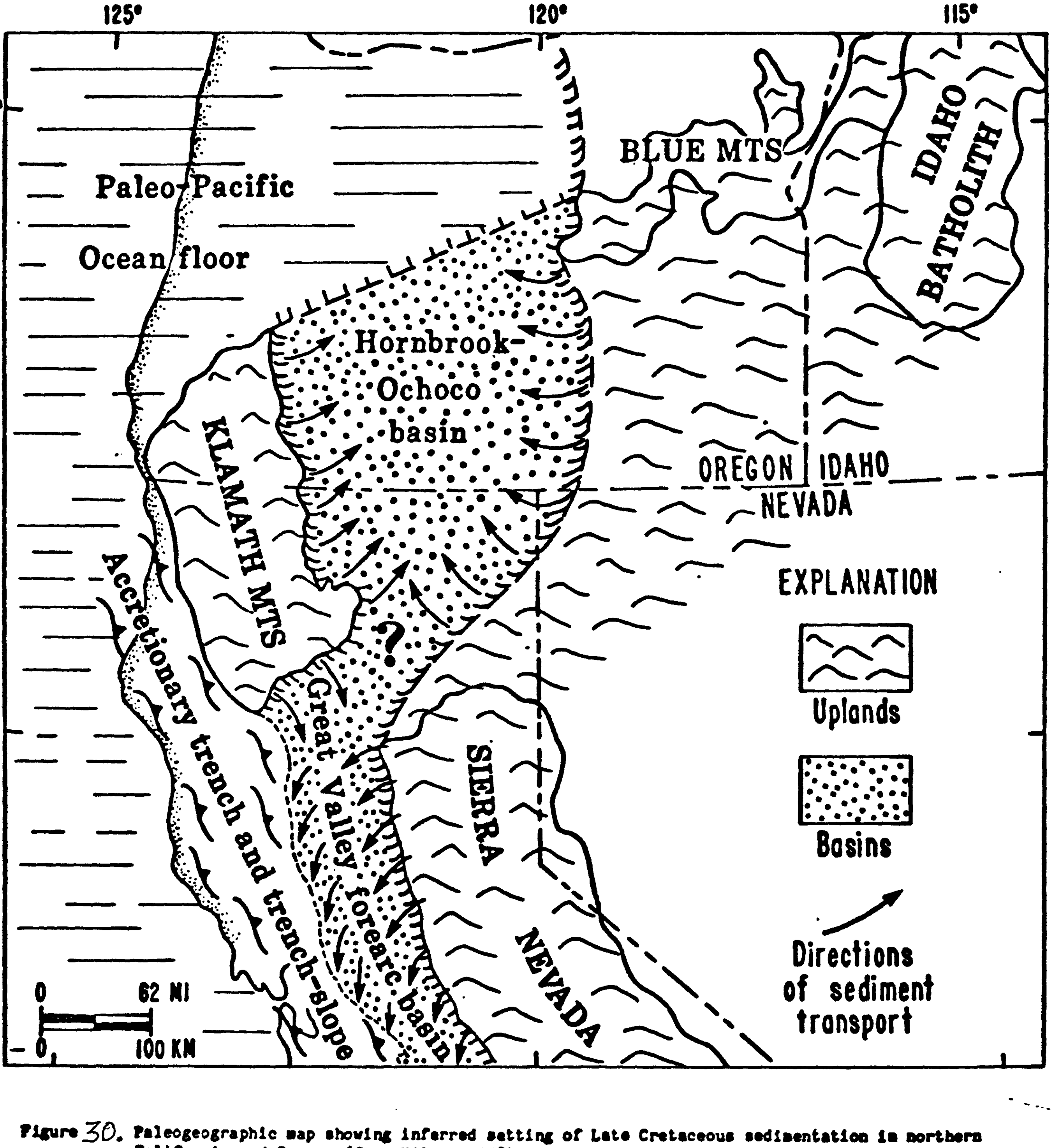

Figure 30. Paleogeographic map showing inferred setting of Late Cretaceous sedimentation in northern California and Oregon (from Nilsen, 1984

From Nilsen (1984).

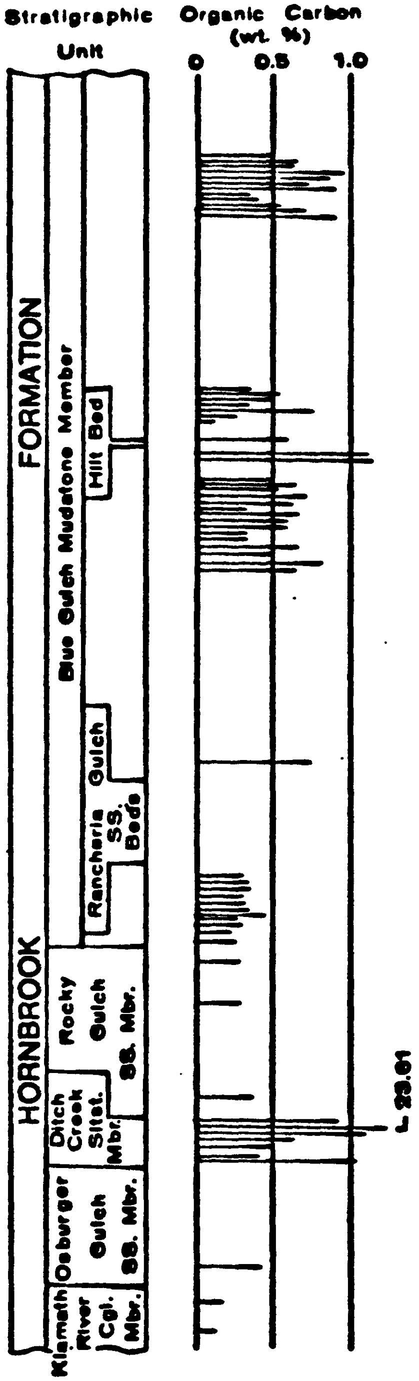

Figure 31. Generalized geologic column of Hornbrook Formation showing approximate stratigraphic location of samples and total organic carbon content.

From Law et al (1984).

throats to less than 10 microns across for most of the analyzed sandstones (Keighin and Law, 1984).

Tectonic movements of the basement reflect a history of both compressional and tensional deformation related to late Mesozoic arc-trench, transform, rift-basin motions, as well as to late Cenozoic basin and range faulting activity. Thus, a variety of structural traps could exist at depth, such as broad anticlines developed during compressional movements, and horst and graben structures that formed during extensional tectonics. Additionally, stratigraphic traps could exist.

Depth ranges for potential reservoir facies could be quite variable due to sedimentation pinchouts, as well as erosional pinchouts that are known to occur throughout this Late Cretaceous to Pleistocene sequence. For example, the Hornbrook could be buried as deep as 15,000 feet (4,500 m), or as was the case in a recent 1983 well in the northwestern part of the basin, the Hornbrook was encountered at 2,800 feet (850 m). This well is the only deep test in the basin. A wet gas or oil show may have been found at 3,700 feet (1,100 m) (Alldredge and Meigs, 1984). It terminated at 4,900 feet (1,470 m) in Paleozoic metamorphics. The well was plugged and abandoned in 1984.

Since 1983 geophysical activity has intensified in the area. Three other wells in the southeastern part of the Modoc Plateau drilled to 1,200 feet (360 m), and were completed as gas wells in Miocene sands. Flow rates of methane in these wells are 200-450 mcf, and maximum bottom-hole pressures are 415 psi (Alldredge and Meigs, 1984).

Basin and Range Province

This area shares much of the same geologic history as that of the Basin and Range Province in Nevada (Figs. 14,18). Numerous granitic intrusives of probable Mesozoic age are found in California's basins and ranges (Figs. 14,16,17). These intrusives have intensely baked much of the Paleozoic marine sequences, and as a result, this province is considered to have very limited possibilities for commercial hydrocarbons.

Mojave Desert

The Mojave Desert area has the same pre-Mesozoic geologic history as the Basin and Range and Sierra Nevada subprovinces. However, the Paleozoic and Mesozoic are not as well represented in the Mojave Desert, nor are the sedimentary sequences as thick as they are in the Sierra Nevada and Basin and Range Provinces (Norris and Webb, 1976). Cenozoic rocks appear throughout the Mojave Desert, and except for thin, restricted, Miocene marine sediments, deposition is nonmarine. Volcanic rocks interbedded with lake deposits and evaporites are widespread.

This subprovince has widespread evidence of Mesozoic plutonic activity, and this coupled with metamorphism, high geothermal gradients, and a nonmarine Cenozoic section makes the Mojave Desert very unattractive for commercial quantities of hydrocarbons.

Imperial Valley

Seemingly this area at first glance should offer good possibilities for commercial quantities of hydrocarbons. About 25 percent of the outcrops are marine siliciclastics with good reservoir characteristics, and potential source rocks. Also, there are significaint volumes of Cenozoic lacustrine strata that in Nevada, for example, make good source and reservoir rocks (Tarbet, 1971; Fouch, 1979a,b; Sandberg, 1983; Poole and Claypool 1984; Bortz, 1985). In addition, the structure is comparable to structures which form traps for petroleum in the fields adjacent to the San Andreas fault in other parts of California (Tarbet, 1971).

Unfortunately, the Pliocene marine siliciclastics were deposited so fast that the ratio of organic to inorganic matter is very low. Also, the lacustrine beds were deposited in highly oxidizing freshwater lakes. Thus, the Cenozoic rocks appear to be deficient in good source rocks. A number of wells have evaluated the petroleum potential of the marine strata without any favorable results (Tarbet, 1971). In addition, the high-temperature Salton Sea geothermal system (i.e., the Salton Sea field has brine temperatures up to 550°F (288°C) (Bilodeau, 1985)), which lies above a continental spreading zone, has severely altered the sediments. Also these high temperature brines have caused serious problems in hydrocarbon drilling operations.

A rather unique type of oil may exist in the area. As discussed by Tarbet (1971), a large volume of oil shale has been eroded from the Uinta basin, and transported down the Colorado River into the Imperial Valley. Natural distillation under the influence of the Salton Sea geothermal system could have produced large volumes of hydrocarbons. Other than this highly speculative source of oil, the possibility of obtaining commercial quantities of hydrocarbons appears to be very slight.

Peninsula Ranges

This area contains a thin marine (submarine fans) and nonmarine (fluvial) sequence of Cretaceous and Cenozoic siliciclastics that unconformably lap onto the Cretaceous southern California batholith and older metamorphic rocks (Gray et al., 1971). About 175 wildcats have been drilled in this subprovince, but evidence of hydrocarbons is virtually nonexistent. Two discoveries were reported prior to 1960, but both were noncommercial, and were abandoned after producing 4,000 barrels of oil and 11 mcf of gas (Scott, 1983).

Transverse Range

The part of the Transverse Range in Province 81A consists of Precambrian and Paleozoic metamorphic rocks and Mesozoic granitics (Norris and Webb, 1976). This subprovince has a very low to zero hydrocarbon potential.

Coast Ranges

The dominant element of the Coast Range subprovince is the Jurassic-Tertiary Franciscan Complex. This complex can be divided into three major northwest-southeast-trending tectonic belts (Fig. 32) (Blake and Jones, 1978; Tarduno et al., 1986). Rocks in these belts are all marine, and represent a complex melange of oceanic crust and forearc and backarc sediments. These sediments were complexly intermixed during subduction, accretion, and strike-slip faulting processes along the continental margin (Tarduno et al., 1986). The Jurassic-Cretaceous section is considered nonprospective for hydrocarbon accumulations.

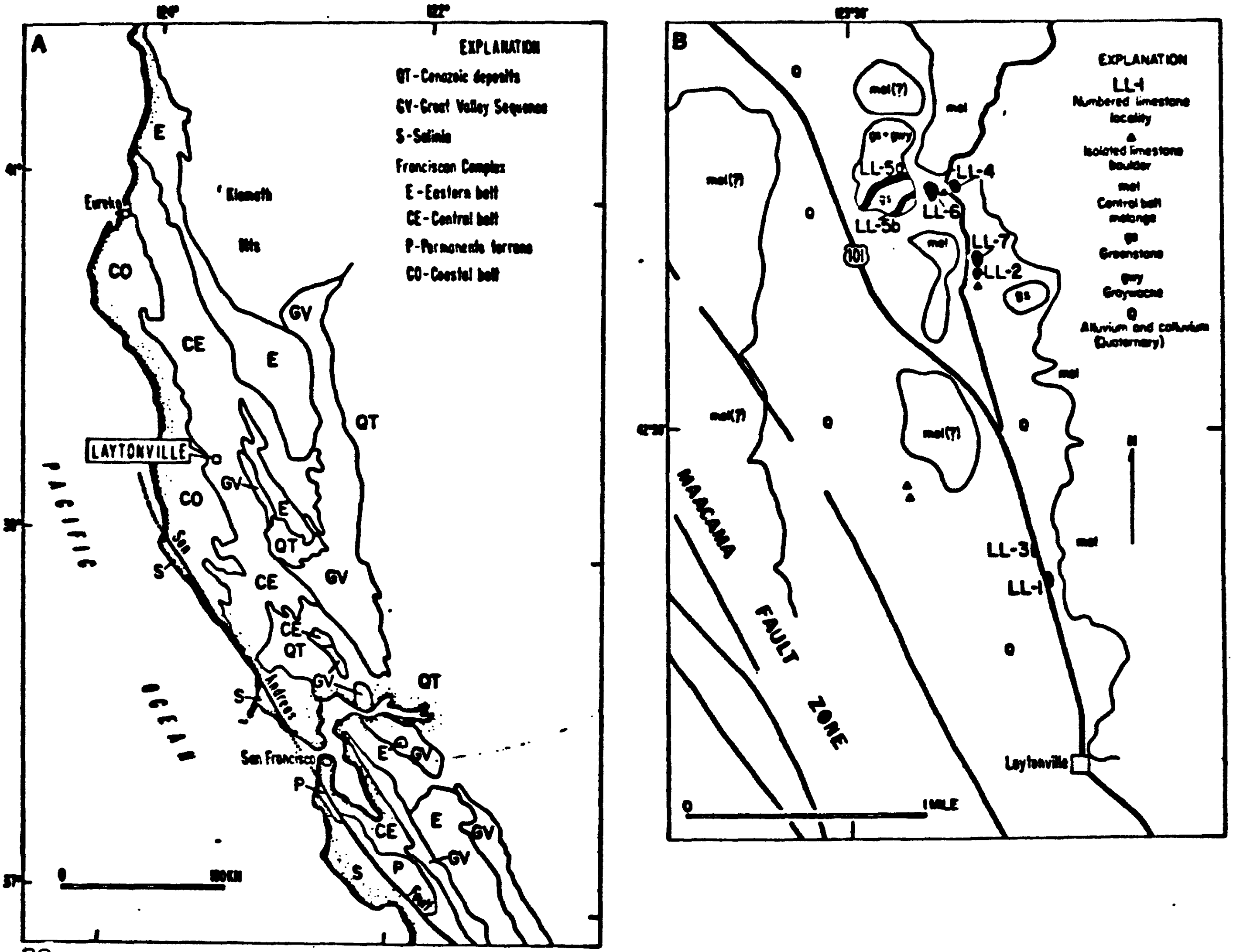

Fig.32 (A) Geologic map of California showing the three major tectonic belts of Franciscan rocks of the northern Coast Ranges that have been further subdivided into tectonostratigraphic terranes, Salinia, and the Great Valley sequence. (B) Geologic map of the Laytonville Limestone localities.

From Tarduno et al (1986).

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There are small, stratigraphically thin pods of Tertiary marine rocks that unconformably overly the chaotic Franciscan complex. These limited exposures locally have oil seeps. One field, the Petrolia field, produced 350 barrels of oil in Miocene strata, but was abandoned. This subprovince is not considered prospective for commercial accumulations of hydrocarbons.

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