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TRIASSIC AND JURASSIC STRATIGRAPHY AND PALEOGEOGRAPHY OF WEST-CENTRAL NEVADA AND EASTERN CALIFORNIA

by

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WITH A CORRELATION DIAGRAM OF TRIASSIC AND JURASSIC ROCKS

by

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ABSTRACT

Four major vertically stacked chronostratigraphic and lithostratigraphic successions are recognized in the Paradise, Pine Nut, and northern Sierra terranes of western Nevada and eastern California. These four successions show significant local and regional facies changes, but the general lithic contrasts between successions is nevertheless remarkably similar over large regions. The oldest succession is of Early? Triassic to early Late Triassic age and consists of widespread andesitic lava flows and breccias, pyroclastic breccias and tuffs, volcaniclastic sedimentary rocks, and lesser amounts of rhyolitic flows and domes, and rhyolitic to dacitic ash-flow tuffs. The next higher succession consists of Upper Triassic (late Karnian and Norian) rocks containing locally thick units of limestone, and minor amounts of siltstone, argillite, sandstone, and tuffs. The next overlying succession consists of uppermost Triassic (latest Norian) to Middle Jurassic (Bajocian) fine- to coarse-grained clastic rocks. This succession consists of thick units of mainly siltstone, very fine-grained sandstone (Volcano Peak Group, Gardnerville Formation, and Sailor Canyon Formation), as well as sandstone, sedimentary breccia, coarse conglomerate, siliceous volcanic rocks, and minor limestone (Dunlap Formation). The highest succession consists of Middle Jurassic volcanic and volcaniclastic rocks.

The rocks of the Lower? to lower Upper Triassic volcanic and volcaniclastic succession appear to have been deposited dominantly in a subaerial environment, although local subaqueous units are present. The carbonate rocks of late Karnian and Norian age are of shallow-water origin in the eastern part of the region, but both shallow-water and deep water environments are evident in the central and western parts of the region. The uppermost Triassic to Middle Jurassic fine- to coarse-grained clastic succession is interpreted to be predominantly of shallow-water origin in the eastern part of the region, but mainly of deep-water origin in the central and western parts. The Middle Jurassic volcanic and volcaniclastic succession represents a return to mainly subaerial deposition.

The four successions described here extend across three lithotectonic assemblages or terranes (fig. 1). The boundaries between these terranes appear to mark greater than normal facies changes in the four successions, but whether these facies changes indicate large or small tectonic displacement at terrane boundaries is uncertain.

INTRODUCTION

West-central Nevada and adjacent parts of California are a collage of lithotectonic assemblages or terranes (Oldow, 1984; Silberling and others, 1987; Silberling, 1991), each characterized by a different, or partly different, stratigraphic succession and tectonic history (Fig. 1 and 2). These terranes apparently have been assembled by major tectonic structures that have juxtaposed rocks that were once more widely separated. The stratigraphy of Mesozoic rocks in the Paradise and Pine Nut terranes and parts of the northern Sierra and Gold Range terranes is summarized. They contain stratigraphic successions that are somewhat consistent regionally, perhaps arguing against major dislocations between these terranes. Yet, lithic changes appear to be greatest at terrane boundaries, arguing in favor of major dislocations. The Mesozoic stratigraphy of adjacent parts of the Sand Springs, Jungo, Golconda, and Roberts Mountains terranes and other rocks is also described but in less detail.

This report was mostly prepared in 1991to 1992, and has not been updated to include references to article published subsequent to that time.

STRATIGRAPHY OF THE PARADISE AND PINE NUT TERRANES AND PARTS OF THE NORTHERN SIERRA AND GOLD RANGE TERRANES

The stratigraphy of the Paradise and Pine Nut terranes and parts of the northern Sierra and Gold Range terranes is described in terms of four major chronostratigraphic and lithostratigraphic successions (Fig. 3): (1) a Lower? to lower Upper Triassic (Scythian? to early Karnian) volcanic and volcaniclastic succession (2) an Upper Triassic (late Karnian and Norian) carbonate-rich succession, (3) an uppermost Triassic (latest Norian) to Middle Jurassic (Bajocian) fine- to coarse-grained clastic succession, and (4) a Middle Jurassic volcanic and volcaniclastic succession. These four successions are recognized throughout much of the region discussed here. Locally and regionally these successions show significant lateral facies changes, but the general lithic contrasts between successions are nevertheless maintained over a remarkably large region.

Greenschist-grade metamorphism is common in the rocks described here, but original protoliths are clearly identifiable in most areas. For simplicity, the protolith names are generally used in the descriptions.

Lower? to lower Upper Triassic volcanic and volcaniclastic succession

Lower? to lower Upper Triassic (Scythian? to early Karnian) volcanic and volcaniclastic rocks, or rocks presumably of this succession, are widely exposed in the Paradise and Pine Nut terranes (Fig. 4). They have not been recognized in the northern Sierra terrane, where the base of the Mesozoic rocks is either not exposed or, as in the North Fork of the American River, Upper Triassic limestone rests unconformably on Paleozoic rocks. The depositional base of rock sequences assigned to the Lower? to lower Upper Triassic volcanic and volcaniclastic succession is nowhere exposed. Rocks of the Lower? to lower Upper Triassic volcanic and volcaniclastic succession are dated isotopically or paleontologically in only a few areas (Table 1), and assignment of rocks to this age group in many places is based mainly on their position depositionally below paleontologically dated Upper Triassic (latest Karnian and Norian) rocks (Fig. 5 and 6). In some areas, rocks shown in this category on Figure 4 could be Paleozoic in age, particularly in the Shoshone Mountains (Silberling, 1959), Lodi Hills, and Paradise Range (Silberling and John, 1989). In other areas, some undated rocks here assigned to the Lower? to lower Upper Triassic volcanic and volcaniclastic succession could be part of the Middle Jurassic volcanic and volcaniclastic succession.

The Lower? to lower Upper Triassic volcanic and volcaniclastic succession consists primarily of andesitic lava flows and breccias, pyroclastic breccias and tuffs, volcaniclastic sedimentary rocks, and lesser amounts of rhyolitic flows and domes, and rhyolitic to dacitic ash-flow tuffs. Also included under this heading is the Grantsville Formation (late Ladinian to early Karnian in age), in the Shoshone Mountains of the Paradise terrane. The Grantsville Formation consists of limestone and terrigenous clastic rocks somewhat lithologically similar to the overlying Luning Formation.

Paradise terrane. Volcanic or volcaniclastic rocks assigned to the Lower? to lower Upper Triassic volcanic and volcaniclastic succession in the Paradise terrane include rocks in the Shoshone Mountains, Lodi Hills, and Paradise Range. In the Shoshone Mountains, two units are recognized in the succession. These are a lower unit, the greenstone of Shamrock Canyon, (Silberling and John, 1989) whose rocks were originally assigned to the Pablo Formation (Silberling, 1959) but are now considered to be unrelated to the Pablo Formation (Speed, 1977; Silberling and John, 1989) and an upper unit (the Grantsville Formation) of limestone and clastic rocks. The greenstone of Shamrock Canyon consists of 800 m or more of andesite flows, volcanic breccias, and tuffs; fine-grained tuffaceous sedimentary rocks; conglomerate with clasts of granitic rocks; and limestone. Poorly preserved fossils suggest that part of the lower unit could be late Paleozoic in age, but other parts of the unit could be early Mesozoic. The Grantsville Formation lies with an erosional disconformity on the lower unit and is about 200 m thick. It consists of argillite and conglomerate in its lower half and limestone in its upper half. The clastic rocks may contain volcanic material reworked from underlying volcanic rocks (Silberling, 1959), but much of the Grantsville Formation may not be volcaniclastic. The limestone of the Grantsville Formation contains late Ladinian (late Middle Triassic) to early Karnian (earliest Late Triassic) fossils (Silberling, 1959; Speed and others, 1989). Volcanic and volcaniclastic sequences in the Berlin allochthon (Silberling and John, 1989) in the Lodi Hills and Paradise Range consist of the greenstone of Shamrock Canyon (named for correlative rocks in the Shoshone Mountains) composed of andesite breccia and tuff, marble, and volcaniclastic rocks, all of late Paleozoic and (or) Triassic age. Rocks in the Lodi allochthon TRPzdv of Silberling and John, 1989) in the Lodi Hills and (unit Paradise Range consist of greenstone, volcanic breccia, comagmatic intrusive rocks, volcaniclastic conglomerate, and limestone. Some of these rocks in the Lodi allochthon are regarded as Late Triassic in age on the basis of regional correlations (Silberling and John, 1989), but some parts could be late Paleozoic. Volcaniclastic rocks and metamorphosed gabbro and basalt (units MzTRg and MzPzp of Silberling and John, 1989) that cannot be assigned with certainty to either the Berlin or Lodi allochthons also is present in the Paradise Range. One of these units (MzPzg) contains clasts of volcanic porphyries and granitic rocks as much as 0.5 m in diameter.

Rocks in the Gillis Range and Garfield Hills consist of a variety of volcanogenic and sedimentary rocks including lavas of intermediate composition, pillow breccias, ash-flow and airfall tuffs, accretionary lapilli tuffs, volcaniclastic sandstone and conglomerate which are locally graded and cross-bedded, fossiliferous limestone, and associated intrusive stocks, plugs, and dike-like masses of hypabyssal intrusive rocks of andesitic to rhyolitic composition (Hardyman, 1980, 1978, in volume; Ekren and Byers, 1985b). The fossiliferous limestone contains bivalves and oyster shells. Granitoid clasts are present in conglomerate in the Kinkaid area, suggesting a possible correlation with conglomerate containing granitoid clasts in the Shoshone Mountains and Paradise Range. These sequences of volcanogenic and sedimentary rocks in the Gillis Range and Garfield Hills consist of strata mapped as units TRv, Jql, Jiu, and Jl by Hardyman (1980) and as units TRv, TRt, and TRr by Ekren and Byers (1985b). The rocks are poorly dated, but conodonts of Anisian age have been recovered from limestone within the sequence in the Gillis Range (Table 1). In addition, the lower member of Pamlico Formation of Oldow (1978a, b), lying stratigraphically below the paleontologically dated (early to middle Norian) middle member of the Pamlico Formation, consists of about equal amounts of carbonate and volcanogenic rocks and could be equivalent to part of the Triassic volcanogenic and sedimentary sequence in the Gillis Range. Oldow (1978a, b) has suggested that this lower member of the Pamlico Formation correlates with pre-Grantsville Formation volcanogenic rocks in the Shoshone Mountains. Oldow (1984) considers Mesozoic rocks in the Garfield Hills and Gillis Range to be part of the same lithotectonic assemblage, his Pamlico assemblage.

Pine Nut terrane. Lower? to lower Upper Triassic volcanogenic rocks, or rocks possibly of this age, are widespread in the Pine Nut terrane. They crop out in the Wassuk Range, along the east side of Mason Valley, in the southern Desert Mountains, and in the Yerington area of the Singatse Range. These have been most extensively studied in the Yerington area (Proffett and Dilles, 1984; Dilles and Wright, 1988; Proffett and Dilles, written commun., 1995) where they are assigned to the Middle Triassic or older McConnell Canyon Volcanics. These volcanic rocks consist of a lower unit greater than 1,100 m thick of interbedded andesite breccias and lava flows, and associated interbedded andesitic sedimentary rocks, and an upper unit 250 to 300 m thick of rhyolite flows, domes, and intrusions surrounded by and interbedded with breccia, conglomerate, and tuffaceous sandstone. Quartz porphyry dikes that could be comagmatic with the McConnell Canyon Volcanics have been dated as 232.2 ± 2.3 Ma by the U-Pb method on zircon (Dilles and Wright, 1988). In the northeastern Wassuk Range, a possibly correlative section includes silicic ash-flow tuff and andesite breccia that is intruded by a metadiorite with a 232.7 ± 2.9-Ma age by the U-Pb method on zircon (Dilles and Wright, 1988, Proffett and Dilles, written commun., 1995). In the northwesternmost part of the Wassuk Range (Schurz

Highway section of J.M. Proffett, Jr. and J.H. Dilles, written commun., 1995) about 3000 m of andesite and dacite breccia; silicic ash-flow tuffs; tuffaceous sandstone; and minor conglomerate and sandy limestone are exposed. These rocks lie below paleontologically dated latest Karnian sedimentary rocks (Figs. 5 and 6) and are considered possible equivalents of the McConnell Canyon Volcanics. Northward from the northwesternmost Wassuk Range, presumed Lower? to lower Upper Triassic volcanogenic rocks, mostly andesitic flows and tuffs, are exposed in a series of outcrops along the east side of Mason Valley that end in the southern Desert Mountains. Extensive outcrops of andesitic lava and tuff, silicic welded tuff, and rhyolitic flows and domes are present in the central and southern Wassuk Range (Bingler, 1978; Stewart and others, 1981; R.C.Greene, written commun., 1995). A U-Pb isotopic date on zircon from a welded tuff near Mt. Grant yielded an age of 242 ± 4.2 Ma (Middle Triassic), the oldest age known for rocks of the volcanic and volcaniclastic succession.

The westernmost outcrops of volcanogenic rocks of presumed Early? to Late Triassic age are in the northern Pine Nut Mountains, where Bingler (1977) mapped the metavolcanic rocks of Brunswick Canyon that consist of interbedded lava flows and volcanic breccia of quartz latite, latite, and andesite, and minor amounts of welded tuff, tuff-breccia, and epiclastic and mudflow breccia. These rocks are undated but lie stratigraphically below a sequence of paleontologically dated Upper Triassic limestone and associated tuff, tuff-breccia, and graded chert beds. The metavolcanic rocks of Brunswick Canyon are broadly correlative with the McConnell Canyon Volcanics.

Depositional environments. The volcanogenic Lower? to lower Upper Triassic rocks include a wide variety of depositional environments. Subaerial environments are suggested by the presence of welded tuff with locally conspicuous flattened pumice, accretionary lapilli (believed to form in eruptive ash clouds, Fisher and Schmincke, 1984), and rare conglomerates with well rounded clasts that may have formed in fluvial systems. Shallow-water marine environments are indicated by the presence of limestone with bivalve and oyster shells in living positions. Sparse pillow breccia indicates subaqueous environments. Deeper water environments are indicated by graded (turbiditic?) volcaniclastic sandstone and conglomerate. Overall, the paleogeography is interpreted to have been characterized by local volcanoes with subaerial to locally submarine lava flows, subaerial airfall and ash-flow tuffs and tuff-breccia, associated subaerial mudflow and debris-flow deposits, and local fluvial systems. These subareal systems fed into scattered shallow- to moderately deep marine basins.

Upper Triassic (late Karnian and Norian) carbonate-rich succession

The most widespread and thickest accumulation of carbonate rocks during early Mesozoic time occurred in the late Karnian through the Norian. Clastic and volcanic rocks form locally thick sequences interstratified with these carbonate rocks. The succession shows considerable lateral lithic variability, but everywhere is characterized by the presence of one or several thick carbonate units. In some places, the contact between the underlying Lower? to lower Upper Triassic volcanic and volcaniclastic succession (e.g. in the Singatse Range) is sharp, whereas in other areas (e.g. in the Garfield Hills) volcanic rocks become less common upsection and the change from the volcanic and volcaniclastic succession to the carbonate-rich succession is gradational over many hundreds of meters. The thickest sequence of carbonate rocks (Luning Formation) is in the Paradise terrane and contains almost no volcanogenic rocks. Thick sequences of carbonate rocks are also present in the Pamlico Formation (Oldow,1978a, b), which contains interstratified volcaniclastic and volcanic rocks in its lower and middle parts. In the Pine Nut terrane, the carbonate-rich succession is widely exposed and generally contains a higher percentage of siltstone, volcaniclastic sandstone and conglomerate, and volcanic rocks than in the Paradise terrane. In the northern Sierra terrane, the carbonate-rich succession consists of relatively thin units of conglomerate, sandstone, limestone, and tuff that rest unconformably on Paleozoic rocks.

The Upper Triassic carbonate-rich succession contrasts lithically with the underlying succession of mostly volcanic and volcaniclastic rocks and with the overlying fine-grained rocks of the Volcano Peak Group (Taylor and others, 1983), Gardnerville Formation, and Sailor Canyon Formation. Considerable lateral facies changes, however, are recognized in the succession. In the eastern part of the region, the succession consists of the Luning Formation which is composed of thick carbonate units and interstratified siliciclastic rocks. The siliciclastic rocks are derived mainly from a nonvolcanic source area. Farther west where the Pamlico Formation is recognized, thick carbonate units are locally present, but volcanic and volcaniclastic rocks are also abundant, particularly in the lower part of the succession. In the central part of the region, from the Wassuk Range to the Pine Nut Mountains, the succession contains highly variable amounts of carbonate, volcanic, and volcaniclastic rocks, and correlation of subunits in the succession unit from area to area is generally not possible. The sections of Upper Triassic rocks in the northern Sierra terrane differ from those farther east in that they are thinner and rest unconformably on Paleozoic rocks.

Paradise terrane. Most of the carbonate rocks in the Paradise terrane are assigned to either the Luning Formation or the Pamlico Formation. In the Paradise Range, part of the rocks included with the carbonate-rich succession are limestone and clastic rocks (units TRdl and TRdc of Silberling and John, 1989) below the Luning Formation. The Luning Formation is exposed in the Shoshone Mountains (Silberling, 1959), the Paradise Range (Silberling and John, 1989), the Cedar Mountains (Mottern, 1962), the Pilot Mountains (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949; Oldow, 1978a, 1981), in the southern Gabbs Valley Range (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949; Ekren and Byers, 1985a), and possibly correlative carbonate rocks are present at Chalk Mountain and Westgate (Corvalán, 1962). The type locality of the Luning Formation is in the Pilot Mountains where it is at least 2,550 m thick and consists of three members, a lower member of interbedded carbonate and siliciclastic rocks, a middle member of interbedded conglomerate, arenite, wacke, and sandy mudstone, and an upper member of carbonate and fine-grained clastic rocks (Oldow, 1978a, 1981). Clasts in the conglomerate are rounded and composed of chert. The lower part of the middle member contains mostly nonfeldspathic debris, whereas the upper part contains feldspathic sand interpreted to have been derived from a volcanic source region (Oldow, 1978a, 1981; Reilly and others, 1980). Regionally, the Luning Formation contains similar rock types, characterized by thick limestone and dolomite units and thinner clastic units containing siliciclastic sandstone and chert-pebble conglomerate. Regionally, a dolomite unit (dolomite member of Milton Canyon) is present in the uppermost part of the Luning Formation. The Luning Formation contains an abundant fauna of pelecypods, brachiopods, ammonites, and corals. The fauna indicates a late Karnian to early late Norian age for the formation (Oldow, 1978a, 1981; Silberling, 1984; Speed and others, 1989; N.J. Silberling, written commun., 1991). In the Shoshone Mountains, the Luning Formation disconformably overlies the Grantsville Formation of late Ladinian to early Karnian age. In the northwestern Pilot Mountains, the Luning Formation was reported (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949) to lie depositionally on older rocks, but Oldow (1978a) considers this contact to be a fault, not a depositional contact. The Luning Formation in the southern Gabbs Valley Range, the Pilot Mountains, and areas to the west forms the main part of the Luning allochthon, a major thrust plate that emplaced Triassic and Jurassic rocks on the north over Paleozoic and Jurassic rocks on the south (Oldow, 1981, 1984).

The Pamlico Formation is an allochthonous unit named for exposures in the Pamlico district in the western part of the Garfield Hills (Oldow, 1978a, b). In its type area, it is about 1500 m thick and divided into three members. The lower member consists of carbonate rocks, volcaniclastic sedimentary rocks, and volcanic breccia; the middle member consists of carbonate rocks, volcaniclastic rocks, and porphyritic lava, and quartz-rich ash-flow tuff; and, the upper member consists of mostly carbonate rocks interstratified with thin units of porphyritic lava and volcaniclastic sandstone. Where the top of the Pamlico Formation appears to be unfaulted, the upper part of the Pamlico Formation consists of dolomite that is considered to be correlative (N.J. Silberling, written commun., 1991) with the dolomite member of Milton Canyon in the upper part of the Luning Formation. The middle member of the Pamlico Formation contains fossils of early or middle Norian age (Silberling, 1984), equivalent in age to part of the Luning Formation. The Pamlico Formation is overlain by the Upper Triassic and Lower Jurassic Volcano Peak Group (Taylor and others, 1983) that elsewhere overlies the Luning Formation. The presence of dolomite in the upper part of the Pamlico and Luning Formations, the presence of the Volcano Peak Group above both formations, and paleontologic information indicate that the middle and upper members of the Pamlico Formation are lateral time-equivalents of the Luning Formation, but of a different, partly volcanogenic, facies. The lower member of the Pamlico Formation, as mentioned above, may be part of the Lower? to lower Upper Triassic volcanic and volcaniclastic succession.

Thick successions of carbonate rocks and argillite are present in the southern part of the Gillis Range, north of the Garfield Hills. These carbonate rocks and argillite have been assigned to the Luning Formation by Muller and Ferguson (1939), Ferguson and Muller (1949), and Ekren and Byers (1985b), but Oldow (1984) included these rocks in his Pamlico lithotectonic assemblage. In the southeastern part of the Gillis Range, the carbonate rocks and associated argillite sequence are 1,600 m thick and consist of a lower unit of limestone, a middle unit of argillite, and an upper unit of dolomite (Ekren and Byers, 1985b). These rocks are undated, but on a lithic basis are clearly related to widespread Late Triassic carbonate deposition. In the western part of the Gillis Range, the stratigraphic relations of Triassic rocks are less clear. In the Wildhorse Canyon-Agai Pah Hills area in the western Gillis Range, a succession of volcanic and volcaniclastic rocks contains limestone from which Anisian conodonts have been identified (Table 1). These rocks have been described previously under the description of the Lower? to lower Upper Triassic volcanic and volcaniclastic succession. Close by, and perhaps in part interstratified with this volcanic and volcaniclastic succession, are limestone units, one of which has been dated as early Karnian in age on the basis of conodonts and another as middle early Norian on the basis of ammonites. The early Karnian age is compatible with the known or presumed age of the volcanic and volcaniclastic succession, but the middle early Norian age is equivalent to part of the Upper Triassic carbonate-rich succession (Luning and Pamlico Formations). The middle early Norian limestone could be a continuation of the thick regionally extensive Upper Triassic carbonate-rich succession, and its present association with volcanic and volcaniclastic rocks due to juxtaposition by faulting, possibly the Gillis Canyon thrust of Muller and Ferguson (1939). Alternately, significant volcanic activity may have continued in the Wildhorse Canyon-Agai Pah Hills area into the early Norian; whereas elsewhere volcanic activity had largely died out by the Norian. This relation is explainable if the Wildhorse Canyon-Agai Pah Hills area was a long-lived volcanic center.

Pine Nut terrane. Rocks of the Upper Triassic carbonate-rich succession are present at scattered localities in the Pine Nut terrane (Fig. 7). The best exposures and most extensively studied rocks of this succession are in the Singatse Range where J.M. Proffett, Jr., and J.H. Dilles (written commun., 1995) have divided the Upper Triassic rocks into three units consisting, in ascending order of the Malachite Mine Formation, the tuff of Western Nevada Mine, and the Mason Valley Limestone. The Malachite Mine Formation is divided into three members, which are , in ascending order, (1) a dolomitic limestone member (8 to 75 m thick) of latest Karnian age, (2) a black calcareous argillite member (210 to 245 m thick) of earliest and probably younger Norian age, and (3) a volcanic sandstone and limestone member (145 to 180 m thick) of Norian age. The Malachite Mine Formation is overlain by the tuff of Western Nevada Mine which is 80 to 104 m thick and composed of rhyolitic and andesitic tuff, and tuffaceous sandstone. The tuff of Western Nevada Mine is overlain by the Mason Valley Limestone which consists of a lower part of 260 to 275 m of massive limestone marble and upper part of 90 to 105 m of thin-bedded limestone. The tuff of Western Nevada Mine and the Mason Valley Limestone are undated in the Singatse Range. However, both are considered Norian in age (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995) because elsewhere they are bracketed by strata dated as Norian and because the Mason Valley Limestone contains fossils of late early Norian age in the Buckskin Range west of the Singatse Range.

Strata correlative with these rocks in the Singatse Range are recognized near the Northern Lights Mine in the Wassuk Range (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). Here the lowest exposed unit consists of at least 110 m of rhyolitic ash-flow tuffs interbedded with siliceous volcanic sedimentary rocks and breccias. These rocks lie below the Mason Valley Limestone in the Northern Lights Mine area and thus may correlate with the tuff of Western Nevada Mine in the Singatse Range. The Mason Valley Limestone in the Northern Lights Mine area consists of at least 240 m of massive marble overlain by a thin unit well bedded marble. A thick unit of rhyolitic ash-flow tuffs may be interbedded with the marble (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995).

The Malachite Mine Formation and the Mason Valley Limestone are also exposed in the northwestern part of the Wassuk Range (Schurz Highway section of J.M. Proffett, Jr., and J.M. Dilles, written commun., 1995) and probably correlative rocks are exposed on the east and north side of Mason Valley. The Malachite Mine Formation in the Schurz Highway section consists of 750 to 800 m of volcaniclastic sedimentary rocks, dacitic tuff, siltstone, argillites, limestone, and limestone conglomerate (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995) ranging in age from latest Karnian to late early Norian (Table 1). The section contains locally coarse debris-flow deposits and large blocks of shallow-water limestone that appear to have been transported into deep water. The lower 420 to 540 m of what is called the Malachite Mine Formation in the Schurz Highway section is probably older than the Malachite Mine Formation in the Singatse Range and is tentatively included in the formation (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). Four kilometers northwest of the Schurz Highway section, rocks probably correlative with the Malachite Mine Formation and the Mason Valley Limestone are present in low hills on the east side of Mason Valley. In this area, the sequence consists of interbedded limestone, siltstone, and tuff. Middle Norian fossils have been identified (Table 1). Near the site of Thompson smelter adjacent to the northwestern part of Mason Valley, small outcrops of recrystallized limestone have yielded late early Norian conodonts and late Karnian to middle Norian coelenterates, ammonites, and brachiopods (Table 1). This limestone here tentatively considered to be correlative with the Mason Valley Limestone.

In the Buckskin Range, west of the Singatse Range, the Mason Valley Limestone and questionable equivalents of the Malachite Mine Formation and (or) tuff of Western Nevada Mine are recognized. The lowermost part of the succession consists of as much as 370 m of silicic to intermediate tuff, tuff breccia, and interbeds of calcareous siltstone, limestone, and volcanic siltstone and sandstone. These rocks may be correlated with the Malachite Mine Formation and (or) the tuff of Western Nevada Mine. Overlying these strata is the Mason Valley Limestone (equivalent to the carbonate member of the Oreana Peak Formation of Hudson and Oriel, 1979) which is 150 to 195 m thick and has yielded late early Norian conodonts (Table 1).

Farther west in the Pine Nut terrane, dated Upper Triassic rocks are reported in the northwestern Pine Grove Hills (Table 1), and undated but presumably Upper Triassic carbonate rocks crop out on the east and west sides of the Wellington Hills (Stewart and others, 1989).

Well dated Upper Triassic carbonate and volcanic sequences are exposed in the southern and northern Pine Nut Mountains in the western part of the Pine Nut terrane. In the southern part of these mountains, Noble (1962, 1963) proposed the name "Oreana Peak

Formation" for a unit of carbonate, volcanic, and volcaniclastic rocks. In the southern Pine Nut Mountains, the base of the Oreana Peak Formation is not exposed and the formation is overlain by fine-grained clastic rocks of the Gardnerville Formation. Noble (1962, 1963) divided the Oreana Peak into four members. On the west side of the Pine Nut Mountains, these members consist of a lower volcanic member (more than 210 m thick) of crystal-rich tuff, lithic-rich tuff, volcaniclastic sandstone, mudstone, and andesite; a lower carbonate member (about 490 m thick); an upper volcanic member (about 245 m thick) of conglomerate with volcanic clasts, lithic-feldspathic sandstone, and subordinate crystal lithic lapilli-ash tuff, coarse conglomerate, and carbonate rocks; and, an upper carbonate member (about 120 m thick). Although Noble (1962) reported that part of the Oreana Peak Formation could be as old as Karnian, present information (Silberling, 1984) indicates that it is all early to late Norian in age. In the northern part of the Pine Nut Mountains, Bingler (1977) mapped a sequence of limestone and tuff that he correlated with the Oreana Peak Formation. This sequence lies depositionally on rocks considered to be part of the Lower? to lower Upper Triassic volcanic and volcaniclastic succession, and below argillites correlative with the Gardnerville Formation. The sequence contains Late Triassic fossils (Table 1).

Northern Sierra terrane. Upper Triassic rocks in the northern Sierra terrane consist of a basal conglomerate and sandstone, a limestone , and an andesitic tuff and lapilli tuff (Harwood, 1983; D. S. Harwood, written commun., 1995). In the North Fork of the American River (Clark and others, 1962; D. S. Harwood, written commun., 1995), a 23-m-thick chert breccia unconformably overlies complexly folded Paleozoic rocks, is conformably overlain by a 120-m-thick limestone that has yielded late Karnian through Norian conodonts (Table 1), and is in turn overlain by lapilli tuff, tuffaceous siltstone and sandstone, and chert-rich conglomerate. In the Mt. Tallac area (Fisher, 1989), a lithologically similar limestone at the base of the exposed section is considered to be Late Triassic in age on the basis of a similar stratigraphic position with the limestone in the North Fork of the American River (Fig. 5).

Depositional environments. Carbonate strata of the Upper Triassic Luning Formation in the eastern part of the Paradise terrane are considered to have been deposited mainly in shallow-water marine environments (Oldow, 1978a). Siliciclastic rocks are considered to be delta deposits (Oldow, 1978a). The Pamlico Formation is interpreted to represent shallow-water carbonate deposition in and around a volcanic archipelago (Oldow, 1978a, b). Volcanic activity decreased with time during deposition of the Pamlico Formation, and shallow-water carbonate strata largely covered the volcanic region by the end of Triassic time. Depositional patterns were more diverse in the region between the Wassuk Range and the Pine Nut Mountains. Carbonate strata were deposited in both shallow-water, based on what appear to be in-place shelly fossils and corals, and in relatively deep-water, based on the presence of the pelagic pelecypods (*Monotis*) and ammonites and of local debris-flow deposits and slide blocks. Volcanic activity was intermittent throughout Late Triassic time in the central part of the region, and carbonate strata probably were deposited on the flanks of volcanoes as well as in basins between volcanoes. The depositional setting of the Upper Triassic strata in the Sierra Nevada is poorly known, but in part is considered to be of a reef or platformal origin (D.S. Harwood, written commun., 1995), although thin laminations and graded beds may indicate moderately deep water in the Mt. Tallac area (Fisher, 1989).

Uppermost Triassic (latest Norian) to Middle Jurassic (Bajocian) fine- to coarse-grained clastic succession

The uppermost Triassic (latest Norian) to Middle Jurassic (Bajocian) fine- to coarse-grained clastic succession consists of fine- to coarse-grained siliciclastic rocks that contrast with the predominant carbonate rocks of the underlying succession. The transition from the underlying Upper Triassic carbonate rocks to the uppermost Triassic and Jurassic siliciclastic rocks is fairly abrupt, generally taking place within a stratigraphic thickness of 10 to 50 m. In the Paradise terrane and adjacent Gold Range terrane, the younger part of the uppermost Triassic to Middle Jurassic fine- to coarse-grained clastic succession consists of the locally thick Dunlap Formation composed of a laterally variable sequence of feldspathic and lithic sandstone, quartz arenite, breccia, conglomerate, siltstone, volcanic rocks, dolomite, and limestone. Rocks probably temporally equivalent to the Dunlap Formation in the Pine Nut terrane and Gold Range terrane include thin sequences of quartz arenite and gypsum at the top of the succession considered here. Age-equivalent rocks in the Sierra Nevada apparently include quartz arenite within the lower part of the Sailor Canyon Formation. Much of the generally fine-grained siliciclastic strata of the middle and upper parts of the Sailor Canyon Formation may have deposited at the same time as the Dunlap Formation. Thus, the succession described here, although composed predominantly of fine-grained siliciclastic rocks, is laterally variable in lithology, although it apparently has the same time duration throughout the region.

Paradise terrane and Gold Range terrane. In the Paradise terrane and Gold Range terrane, rocks of the uppermost Triassic to Middle Triassic fine-to coarse-grained clastic succession consist of the Volcano Peak Group (Taylor and others, 1983) and the Dunlap Formation (Fig. 8). Only the Dunlap Formation is present in the Gold Range terrane where it rests unconformably on Permian rocks.

The Volcano Peak Group crops out in the Westgate area (Corvalán, 1962; Taylor and others, 1983), the Paradise Range (Silberling and John, 1989), the Shoshone Mountains (Silberling, 1959; Taylor and others, 1983), the Pilot Mountains (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949; Oldow, 1978a, 1981), southern Gabbs Valley Range (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949; Laws, 1982; Taylor and others, 1983; Ekren and Byers, 1985a), and the Garfield Hills (Ferguson and others, 1949; Oldow, 1978b: Laws, 1982; Taylor and others, 1983). The Volcano Peak Group rests conformably on the Luning Formation, or in the Garfield Hills, on the Pamlico Formation. In its type area in the southern Gabbs Valley Range, the Volcano Peak Group consists of the Gabbs Formation of Late Triassic (Norian) age and the Sunrise Formation of Early Jurassic (Hettangian to Pliensbachian) age. The Gabbs Formation is divided into three members by Taylor and others (1983) composed of calcareous mudstone and siltstone, silty to sandy limestone, and limestone. The Sunrise Formation is divided into five members composed of mudstone, siltstone, silty limestone, and limestone. Some of the limestone in the Volcano Peak Group is bioclastic or oolitic. In areas away from its type area, the Volcano Peak Group has similar lithologic characteristics, generally characterized by siltstone, mudstone, and silty limestone. Some of the members recognized by Taylor and others (1983) have regional extent (Taylor and others, 1983; Silberling and John, 1989). The Volcano Peak Group is 520 m thick in the southern Gabbs Valley Range (Taylor and others, 1983), 830 m in the Shoshone Mountains, and about 370 m in an incomplete section in the Westgate area (Corvalán, 1962). The Volcano Peak Group has an abundant fauna of ammonites, pelecypods, cephalopods, and brachiopods (Muller and Ferguson, 1936, 1939; Hallam, 1965; Laws, 1982; Taylor and others, 1983; Silberling, 1984).

The Dunlap Formation crops out (Fig. 8) in the southern part of the Paradise Range and in adjacent parts of the Gold Range terrane. It consists of a laterally variable succession of red feldspathic and lithic sandstone, quartz arenite, sedimentary breccia, conglomerate, red siltstone, intermediate and siliceous volcanic rocks, and minor limestone (Muller and Ferguson, 1936, 1939; Ferguson and Muller, 1949; Stanley, 1971; Wetterauer, 1977; Oldow and Bartel, 1987). In many areas the Dunlap Formation lies conformably on strata of the Volcano Peak Group; locally in the Garfield Hills and in the Cedar Mountains, the Dunlap Formation is interpreted (Stanley, 1971; Mottern, 1962) as resting with a slight angular unconformity on the Luning Formation; south of the Luning thrust in the Pilot Mountains (Wetterauer, 1977), it rests with a marked angular unconformity (as much as 90 degrees) on the Mina Formation (Speed, 1977b) of Permian age or with a small angular unconformity (approximately 10 degrees) on local Triassic(?) and Lower Jurassic unnamed sedimentary rocks (Speed, 1981) in Water Canyon (Water Canyon assemblage of Oldow and Bartel, 1987). The Dunlap Formation is locally divisible into members (Oldow and Bartel, 1987), but the formation is highly variable lithically from area to area. Lithic sequences generally cannot be traced from one area to another (Ferguson and Muller, 1949; Wetterauer, 1977). Coarse conglomerate and sedimentary breccia, with clasts as large as boulders of chert, lithic, volcanic, and carbonate rock fragments are locally present. Pure quartz arenite locally with large-scale cross-strata (Wetterauer, 1977; Silberling and John, 1989) is characteristic of the Dunlap Formation. The Dunlap Formation is as thick as 1,530 m (Wetterauer, 1977).

Fossils collected from rocks mapped as the Dunlap Formation in the Garfield Hills by Ferguson and Muller (1949), but possibly better assigned to rocks in the uppermost part of the Sunrise Formation of the Volcano Peak Group (Silberling, 1984), are early to early late Pliensbachian in age. In and near the Excelsior Mountains (locs. 22, 24, and 25 of Silberling, 1984), rocks mapped, or seemingly mapped, as the Dunlap Formation by Ferguson and Muller (1949) contain datable fossils at three localities. One locality (loc. 22) contains poorly preserved Sinemurian to Toarcian ammonites, and the others (locs. 24 and 25) contain the Early Jurassic (probably middle early to middle late Sinemurian) pecten *Weyla*. *Weyla* also occurs in informally named sedimentary rocks (Water Canyon assemblage of Oldow and Bartel, 1987) unconformably below rocks mapped as the Dunlap Formation in the Pilot Mountains. The apparent older age (Sinemurian) for the *Weyla*-bearing rocks mapped as the Dunlap Formation as compared to the Pliensbachian age of beds either in the basal part or directly below the Dunlap Formation in the Garfield Hills suggests that the oldest age of rocks mapped as the Dunlap Formation varies regionally in age by at least one stage. This idea is supported also by the presence of *Weyla*-bearing rocks (Sinemurian) below the Dunlap Formation in the Pilot Mountains. At Westgate, Bajocian fossils are reported (Corvalán, 1962) in a limestone above sandstone that is perhaps comparable in age and lithology to the quartz arenite in the Dunlap Formation. On the basis of fossil information, the Dunlap Formation could range in age from Sinemurian to Bajocian, although parts of what has been mapped as the Dunlap Formation have been proposed to be possibly as young as Cretaceous (Speed, 1981; see also, fig. 3).

Pine Nut terrane. In the Pine Nut terrane, rocks of the uppermost Triassic to Middle Jurassic fine- to coarse-grained clastic succession consist of a lower fine-grained clastic sequence (the Gardnerville Formation and laterally equivalent rocks) and overlying gypsum and sandstone. This sandstone is called the Preachers Formation in the southern Pine Nut Mountains and vicinity, and gypsum and sandstone in the Singatse Range are part of the Ludwig Mine Formation.

The Gardnerville Formation was named (Noble, 1962, 1963) for outcrops in the southern Pine Nut Mountains. It, or lithologically comparable strata, have been recognized in the Wassuk Range (units Ja and Js of Bingler, 1978); the Singatse Range (units JTRcl, JTRvc, and Jl of Proffett and Dilles, 1984; Dilles and Wright, 1988); in the Buckskin Range (Hudson and Oriel, 1979); near Thompson smelter; on the northeast side of Churchill Butte (Moore, 1960; L. Fraticelli, written commun., 1988); in the Ramsey district in the eastern part of the Virginia Range (Moore, 1960; unit Jms of Rose, 1969); questionably in the western part of the Virginia Range and near Steamboat Springs (unit sr of Thompson and White, 1964); in the northern Pine Nut Mountains (Moore, 1960; units Ja, Jm, and Jp of Bingler, 1977); in Bull Canyon on the northeast side of the Pine Nut Range; in the southern Pine Nut Mountains (Noble, 1962; J.E. Wright, written commun., 1990); near Topaz Lake (units Jwa and JTRg of John and others, 1981); on the east and west sides of the Wellington Hills (Stewart and others, 1989); and in the easternmost Sierra Nevada west of Antelope Valley (part of the West Antelope sequence of Schweickert, 1976).

The Gardnerville Formation consists mostly of siltstone, generally calcareous and carbonaceous, and minor amounts of interstratified sandstone, limestone, volcaniclastic conglomerate, tuff, and volcanic rocks. The sandstone is generally fine-grained and locally is present in thin graded beds. Volcanic units are mostly thin to thick beds of lapilli tuff, but lava flows of intermediate composition are present locally (Noble, 1962). The Gardnerville Formation is about 240 m thick in an incomplete section at the Northern Lights Mine in the Wassuk Range (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995), about 515 m thick in the Singatse Range (Proffett and Dilles, 1984; J.M. Proffett and J.H. Dilles, written commun., 1995), and 1005 m thick in the southern Pine Nut Mountains according to Noble (1962). Fossils are fairly common in parts of the Gardnerville Formation and range in age from late Norian to middle late Toarcian (Table 1).

The lower contact of the Gardnerville Formation may be a local, or regional, unconformity. This possibility is suggested by the different ages of limestone beneath the Gardnerville Formation between the Buckskin Range, where the uppermost part of the underlying limestone is late early Norian in age, and the Pine Nut Mountains, where the uppermost part of the underlying limestone is early late Norian in age. In addition, an apparent truncation of limestone strata at the base of the Gardnerville has been mapped (J.H. Stewart, unpublished mapping, 1989) in the northern part of the Pine Nut Mountains

The Gardnerville Formation is approximately the same age as the Volcano Peak Group in the Paradise terrane, and both units are composed mainly of siltstone and calcareous siltstone. These two units are considered to be roughly correlative, although the Volcano Peak Group contains a locally abundant shallow-water fauna and is considered to be mainly intertidal to shallow marine in origin whereas the Gardnerville contains an apparently pelagic fauna and is considered to be mainly of moderately deep water origin.

On the west side of the Singatse Range, the Gardnerville Formation is overlain with apparent conformity, or possibly with a minor disconformity, by the Ludwig Mine Formation (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). The Ludwig Mine Formation is divided into three members, which are from bottom to top: the Ludwig Limestone Member, the gypsum member, and the quartzitic sandstone member. The Ludwig Limestone Member consists of 35 to 80 m of massive limestone. This limestone is in turn overlain with apparent conformably by the gypsum member that consists of 12 to 135 m of gypsum. The gypsum member is overlain with apparent conformity by the quartzitic sandstone member that is about 335 m thick (Proffett and Dilles, 1984; J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). The sandstone generally is light-colored, well sorted, fine- to medium-grained, and composed mostly of subround quartz grains, but the uppermost part of the member contains dark-colored lithic sandstone.

The Ludwig Mine Formation is also recognized in the Buckskin Range where surface outcrops of the formation consist entirely of the Ludwig Limestone Member (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). The gypsum member is reported in drill holes from the central part of the range (J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995).

Gypsum apparently correlative with the gypsum member of the Ludwig Mine Formation also crops out at the Regan Mine 23 km east of outcrops of the gypsum member in the Singatse Range (Proffett and Dilles, 1984). Possibly correlative gypsum also is present in the southern Virginia Range (Bingler, 1977) where it is associated with limestone in a small outcrop within an area mapped by Bingler (1977) as underlain by metavolcanic rocks, but considered in this report (see geologic map) to be mainly fine-grained diorite.

In the southern Pine Nut Mountains, the Preachers Formation, a unit apparently correlative with the quartzitic sandstone member of the Ludwig Mine Formation of the Singatse Range, conformably overlies the Gardnerville Formation. It is 200 to 300 m thick and consists of various types of quartzitic sandstone ranging from lithic- or feldspar-rich to quartz-rich (Noble, 1962; 1963; J.E. Wright, written commun., 1990). In Red Canyon on the east side of the southern Pine Nut Mountains, large-scale cross-strata are present in the formation. The Preachers Formation has also been mapped by D.M Hudson (*in* John and others, 1981, and Stewart and others, 1989) near Topaz Lake south of the southern Pine Nut Mountains.

Sandstone of the quartzitic sandstone member of the Ludwig Mine Formation in the Singatse Range and of the Preachers Formation in the Pine Nut Mountains in the Pine Nut terrane are lithically similar to quartz arenite in the Dunlap Formation in the Paradise terrane. The clastic rocks in both terranes are characterized by fine- to medium-grained subround quartz grains and local large scale-cross strata. The quartz arenites or quartzitic sandstone of the Paradise and Pine Nut terranes may be mostly of the same age, although the lowest quartz arenites in the Dunlap Formation (in a transitional interval between the Volcano Peak Group and the Dunlap) are Pliensbachian in age and clearly older than the Preachers Formation that lies above Toarcian strata of the upper part of the Gardnerville Formation.

Northern Sierra terrane. Rocks assigned to the uppermost Triassic to Jurassic fine- to coarse-grained clastic succession in the northern Sierra terrane consist of the widespread Sailor Canyon Formation and the locally recognized Blackwood Creek and Ellis Peak Formations. The Sailor Canyon Formation consists mostly of pyritic, calcareous, or carbonaceous siltstone or slate, and interstratified thin layers of feldspathic sandstone, fine-grained calcareous tuff or tuffaceous siltstone, and calcarenite (Fisher, 1989, 1990; Harwood, in press; D.S. Harwood, written commun., 1995). The sandstone is either quartzose or feldspathic, and parallel laminated or graded. The upper part of the formation locally contains coarse-grained feldspathic sandstone, rarely with volcanic pebbles, and scattered pebbly mudstone with clasts of feldspathic sandstone, tuffaceous sandstone,black slate, quartzite, chert, and mafic volcanic rocks, and gray calcarenite. Conglomerate in the upper part of the Sailor Canyon Formation is conspicuous in the Mt. Tallac and Perazzo Canyon areas (Fisher, 1989, 1990; Schweickert, this report). In the Jackson Meadows Reservoir and Perazzo Canyon area, the Sailor Canyon contains prominent limestone units (R. A. Schweickert, written commun., 1995). The Sailor Canyon Formation is about 1,300 m thick in the Mt. Tallac area, 3,500 m in the North Fork of the American River, 1,900 m in the Cisco Grove area, about 1,000 m thick in the Jackson Meadow Reservoir area, and in excess of 1,000 m in the Perazzo Canyon area.

The Blackwood Creek and Ellis Peak Formations are recognized in the Sierra Nevada 5 to 10 km west of the northwest shore of Lake Tahoe (Harwood, 1992). The Blackwood Creek Formation consists of carbonaceous pyritic shale, feldspathic sandstone, and sandy limestone (Fig. 5; Harwood, 1992). The overlying Ellis Peak Formation (Harwood, 1992; D.S.Harwood, written commun., 1995) consists of fine- to medium-grained quartz arenite and quartzose siltstone. The quartz arenite beds of the Ellis Peak Formation are very thin to thin bedded and parallel laminated or graded. Some beds have erosional bases and wavy bedforms suggestive of hummocky stratification. Quartzose beds (lithic unit c of fig. 2 of Fisher, 1990) in the middle and upper parts of the Sailor Canyon Formation in the Mt. Tallac area and sparse quartzose beds in the Sailor Canyon Formation in the Cisco Grove area are considered correlative with the Ellis Peak Formation (Fisher, 1990; Harwood, 1992).

Impressions of ammonites at several (Table 1) localities in the Sailor Canyon Formation indicate an Early and Middle Jurassic (late Sinemurian to middle Bajocian) age for the formation. The age of the Ellis Peak Formation and presumed correlative quartzose sandstone in the Mt. Tallac and Cisco Grove areas is post-late Pliensbachian and pre-early Bajocian (Fisher, 1990). Tenuous correlations in the Cisco Grove area suggests that the quartzose beds may be approximately the same age as strata that contain Toarcian ammonites (Davis, 1990).

Lithic and chronologic correlations suggest that the lower part of the Sailor Canyon Formation is age equivalent to the upper part of the Gardnerville Formation in the Pine Nut terrane. This is suggested by the presence of fossils as young as middle Bajocian in the Sailor Canyon Formation and as young as only middle late Toarcian in the Gardnerville Formation. This age difference is supported by lithic correlations that suggest that the quartz arenite of the Ellis Peak Formation and of the Sailor Canyon Formation at Mt. Tallac (lithic unit c of fig. 2 of Fisher, 1990) and the Cisco Grove area are related to the same influx of quartz sand that produced the quartz arenite in the Singatse Range and in the Preachers Formation in the Pine Nut terrane. If this lithic correlation is correct, only about the lower quarter of the Sailor Canyon Formation at Mt. Tallac overlaps the age range of the Gardnerville Formation (Fig. 6). A further difference in age is possible because the basal part of the Gardnerville Formation is apparently older than the lower part of the Sailor Canyon Formation.

Depositional environments

A variety of depositional environments are evident in the uppermost Triassic to Middle Jurassic fine- to coarse-grained clastic succession. In the Paradise terrane, strata in the Volcano Peak Group are interpreted (Laws, 1982; Taylor and others, 1983) as having been deposited in an intertidal to shallow-water marine shelf environment. This marine deposition was followed in the Paradise terrane and Gold Range terrane by the subaerial to restricted marine Dunlap Formation. The Dunlap Formation contains strata interpreted mainly as alluvial fan, stream channel, floodplain, and eolian dune deposits. Intertidal and restricted marine deposits occur locally (Stanley, 1971; Wetterauer, 1977). The eolian dune deposits consist of quartz arenite with local large-scale cross-stratification (Wetterauer, 1977; Silberling and John, 1989). The Dunlap Formation may include synorogenic deposits in extensional grabens (Oldow and Bartel, 1987)

The Gardnerville Formation in the Pine Nut terrane appears to be entirely marine and to have been deposited in relatively deep water compared to age-equivalent strata in the Paradise terrane. A relatively deep-water environment is suggested by the presence of thin graded beds suggestive of deposition by turbidity currents, the general fine-grained texture of the strata, and the absence of shallow-water sedimentary structures. Gypsum deposits overlie the Gardnerville Formation in the Singatse Range and indicate a restricted shallow marine environment that apparently followed infilling or tectonic destruction of the Gardnerville marine basin. Quartz arenite that depositionally overlies the gypsum in the Singatse Range and feldspathic, lithic, and quartz-rich arenite (Preachers Formation) in the southern Pine Nut Mountains appear to be correlative with lithically similar quartz arenite in the Dunlap Formation. Large-scale cross-strata in quartz and lithic arenite of the Preachers Formation in the Red Canyon area suggests an eolian dune origin similar to that of quartz arenite in the Dunlap Formation.

The Sailor Canyon Formation is interpreted to represent moderately deep-water deposition (Fisher, 1990) based on the presence of graded beds interpreted to be the products of turbidity currents, and on the presence of pyritic, carbonaceous strata that suggest deposition in a restricted euxinic basin. Graded beds in the Ellis Peak Formation are suggestive of turbidity flow deposits.

Middle Jurassic volcanic and volcaniclastic succession

Rocks of the Middle Jurassic volcanic and volcaniclastic succession are extensively exposed in the Pine Nut terrane and in the northern Sierra terrane (fig. 9). Rocks of this succession are not known in the Paradise terrane.

Pine Nut terrane. In the Pine Nut terrane, Middle Jurassic volcanic and volcaniclastic rocks are best known in the Singatse and Buckskin Ranges (Hudson and Oriel, 1979; Proffett and Dilles, 1984; Dilles and Wright, 1988; J. M.Proffett, Jr, and J.H. Dilles, written commun., 1995), in the Pine Nut Mountains (Noble, 1962,1963; J.E. Wright, written commun., 1990), and in the Peavine Peak area and nearby parts of Nevada and California (L. G. Garside, written commun., 1995). Two different sequences appear to exist in the terrane (R.A. Schweickert, written commun., 1995), one that was folded and developed a cleavage prior or during intrusion of the Yerington batholith (169.4 to 168.5 Ma) and the another that appears to post-date these events.

In the Singatse and Buckskin Ranges, Middle Jurassic volcanic rocks are assigned to the Artesia Lake and Fulstone Spring Volcanics (Dilles and Wright, 1988; J.M. Proffett, Jr., and J.H. Dilles, written commun., 1995). The Artesia Lake Volcanics consist of as much as 1,500 m of andesite and dacite lava flows and breccias; minor silicic pyroclastic rocks; volcaniclastic sedimentary rocks; and small shallow-level intrusions (Hudson and Oriel, 1979; Proffett and Dilles, 1984; Dilles and Wright, 1988; J.M. Proffett, Jr., and J.H.Dilles, written commun., 1995). The Fulstone Spring Volcanics (166.5 Ma) are locally as thick as 2,400 m and consist of latite quartz latite, and dacite porphyry domes, breccias, and flows and lesser amounts of latite ash-flow tuff, andesite, and conglomerate (Dilles and Wright, 1988; J.M. Proffett, Jr. and J.H.Dilles, written commun., 1995). The Artesia Lake Volcanics are considered to be comagmatic with the Yerington batholith, and the Fulstone Spring Volcanics are thought to be possibly cogenetic with the Shamrock batholith (Dilles and Wright, 1988). Major folds in Triassic and Jurassic rocks in the Yerington area considered by Dilles and Wright (1988) to have accompanied emplacement of the Yerington batholith (169.4 to 168.5 Ma) and to predate emplacement of the Shamrock batholith (165.8 Ma). Alternately, folding may have occurred in the interval between deposition of the quartz arenite in the Singatse Range (Fig. 6), which may be latest Toarcian or somewhat younger in age (approximately 190-180 Ma), and emplacement of the Yerington batholith (169.4 to 168.5 Ma). Whatever the timing, the Fulstone Spring Volcanics appear to be younger than the main folding event in the Singatse Range because they do not have a cleavage and do not appear to be as tightly folded as older rocks.

In the southern Pine Nut Mountains, rocks considered, at least at present, to be Middle Jurassic in age are divided into three formations (Noble, 1962, 1963; J.E. Wright, written commun., 1990), which are, in ascending order, the Veta Grande Formation, Gold Bug Formation, and Double Spring Formation. The Veta Grande Formation, which is about 1045 to 1770 m thick (Noble, 1962, 1963), consists, in ascending order, of the lapilli tuff member, the volcanic sandstone member, the andesite member, and the conglomerate and breccia member. The conglomerate and breccia member is absent on the east side of the southern Pine Nut Mountains, but constitutes over half of the formation on the west side of the range. It consists of volcanic pebble to boulder conglomerate and breccia interbedded with minor amounts of feldspathic sandstone. The Gold Bug Formation, which is 290 to 365 m thick (Noble, 1962; 1963), consists, in ascending order, of the welded tuff member and the flow member. These rocks are latitic to dacitic. The Double Spring Formation consists of tuffs, lapilli tuffs, volcanic flows of silicic to intermediate composition, and of a variety of sedimentary rocks. It appears to be thick; Noble (1962) indicated over 3,000 m, but its exact thickness is uncertain. Noble (1962) mapped a depositional contact between the Double Spring Formation and the underlying Gold Bug Formation, whereas D.M. Hudson (written commun., 1982) and J.E. Wright (written commun., 1990) have regarded the contact as a fault. The Veta Grande and Gold Bug Formations are folded with underlying Triassic and Jurassic rocks in the southern Pine Nut Mountains, whereas the Double Spring Formation is separated by a fault from these older units. The Double Spring Formation cannot be shown to have been folded at the same time as these older rocks. On this basis, R.A. Schweickert (written commun., 1995) considers the Double Spring Formation to be part of a younger volcanic sequence comparable to the post-deformation Fulstone Spring Volcanics in the Buckskin Range.

A fairly thick andesitic flow unit has been mapped above the Gardnerville Formation in the Wellington Hills. This flow unit could be part of the Middle Jurassic volcanic and volcaniclastic succession that overlies the Gardnerville Formation elsewhere, but whole-rock Rb-Sr isotopic dating gives an age of 209±11 Ma (A.C. Robinson *in* Stewart and others, 1989), within the lower part of the age span of the Gardnerville Formation based on fossil evidence. This andesitic flow unit is here considered to be part of the older volcanic sequence lying above the Gardnerville Formation, but the isotopic age is inconsistent with this interpretation.

The name "Peavine sequence" has been applied to presumed Middle Jurassic rocks in the Peavine Peak area and adjacent parts of Nevada and California (L.J. Garside, written commun., 1995). In the Peavine Peak area, the sequence is about 4,000 m thick and consists of silicic- to intermediate-composition ash-flow tuffs and flow-domes, andesitic to dacitic flows and hypabyssal intrusive rocks, and minor amounts of volcanic conglomerate and sandstone. A Rb-Sr isochron suggests that these rocks are Middle Jurassic in age (R.W. Kistler, oral commun., 1991). In the northern Verdi Range-Crystal Peak area, Sierra County, California, the Peavine sequence is about 7,000 m thick and consists of andesite and microdiorite, andesite laharic breccia, basalt, and sparse volcaniclasitc sandstone. In the southern Peterson Mountain area, the Peavine sequence is about 500 m thick and consists of andesitic laharic breccia, dacitic ash-flow tuff, hypabyssal(?) rhyodacite, and sparse feldspathic sandstone and conglomerate. North of Balls Canyon, Sierra County, California, the Peavine sequence consists of rhyolite, rhyodacite, andesite, and basalt flows, and sparse volcanic conglomerate.

Elsewhere in the Pine Nut terrane, the Middle Jurassic rocks have not been described in detail. Included with the Middle Jurassic rocks are such rock units as metavolcanic breccia and dacite porphyry in the northern part of the Pine Nut Mountains (units Jb and Jd of Bingler, 1977) and undated metavolcanic rocks in the Carson Range (units TRfs and TRmu of Pease, 1980; units Mzms, Mzmc, and Mzmv of Grose, 1985).

Northern Sierra terrane. Rocks assigned to the Middle Jurassic volcanic and volcaniclastic succession in the southern part of the northern Sierra terrane consist of the Tuttle Lake Formation (Harwood, 1992; Fisher, 1989;1990; D.S. Harwood, written commun., 1995). This formation is considered to be of Middle Jurassic age (Harwood, 1992). The Tuttle Lake Formation is composed of andesitic volcanic rocks, dioritic hypabyssal intrusive rocks, and mafic volcaniclastic sandstone and conglomerate. Monolithologic and polylithologic breccia comprise most of the volcanic rocks. Diamictite and polymict conglomerate containing clasts of volcanic and sedimentary rocks are abundant in the lower part of the formation in the Mt. Tallac area and sparse at other localities (Fisher,1990). The Tuttle Lake Formation is about 2,200 m thick in the Mt. Tallac area and at least 5,200 m thick in the North Fork of the American River. The Tuttle Lake Formation is younger than early Bajocian, the youngest age of rocks in the underlying Sailor Canyon Formation, and older than Kimmeridgian to late Tithonian, the age of the Late Jurassic orogeny that deformed the Tuttle Lake Formation (Fisher, 1989). Impressions of an Early to Middle Jurassic pelecypod are present in the lower part of the Tuttle Lake Formation on English Mountain (D.S. Harwood, written commun., 1995). The Tuttle Lake Formation lies disconformably on the Sailor Canyon Formation, but the Sailor Canyon Formation was not significantly deformed prior to deposition of the Tuttle Lake Formation. The Tuttle Lake Formation is considered (R.A. Schweickert, written commun., 1995) to be correlative with the younger sequence of Middle Jurassic rocks (Fulstone Spring Volcanics, Double Spring Formation) of the Pine Nut terrane.

Depositional environments. Middle Jurassic rocks comprise a volcanic terrane that includes welded ash-flow tuffs, air-fall tuffs, pyroclastic and flow breccia, lava flows, flow domes, and hypabyssal intrusions. The volcanic terrane probably was mostly subaerial on the basis of the abundance of ash-flow tuff with locally well defined flattened pumice. Associated volcaniclastic sandstone, conglomerate, breccia, and diamictite are locally thick and highly discontinuous, suggesting deposition in local sedimentary troughs. Fisher (1990), building on an idea by Busby-Spera (1988), has suggested that the conglomerate and diamictite in the Tuttle Lake Formation in the Sierra Nevada are syntectonic and were deposited in troughs developed by extensional or transtensional faulting within a magmatic arc. Other coarse conglomerate and breccia, particularly that in the Veta Grande Formation in the southern Pine Nut terrane, may have been deposited in an alluvial fan environment (J.E. Wright, written commun., 1990).

MESOZOIC STRATIGRAPHY IN REGIONS ADJACENT TO PARADISE, PINE NUT, NORTHERN SIERRA, AND GOLD RANGE TERRANES

In this section, the Mesozoic stratigraphy of the Sand Springs, Jungo, Golconda, and Roberts Mountains terranes, as well as that of the Snow Lake block and unassigned rocks, is described. These terranes and the other rocks have a different, or partly different, stratigraphic and tectonic setting than the Paradise, Pine Nut, northern Sierra, and Gold Range terranes previously described.

Sand Springs terrane. The Sand Springs terrane or lithotectonic assemblage (Oldow, 1984; Satterfield and Oldow, 1990) crops out in an area north and northwest of the Paradise terrane (Fig. 2). This terrane is characterized by a different tectonic and sedimentary history that involves an older phase of deformation and associated greenschist to epidote-amphibolite facies metamorphism (Satterfield and Oldow, 1990). Despite major structural dismemberment, Satterfield and Oldow (1990) describe a stratigraphic succession consisting of a lower sequence of Upper Triassic (late early Norian) deepwater, thin-bedded, distal carbonaceous-carbonate turbidites and carbonate conglomerate and breccia. These rocks grade upward into interbedded volcanogenic shale, sandstone, and conglomerate which contain a minor component of quartz and chert sand. Overlying this are volcanogenic shale and volcaniclastic sandstone, diamictite, and conglomerate containing plagioclase and volcanic rock fragments. The latter sequence contains a probable Early Jurassic (Sinemurian) ammonoid. Overlying the Lower Jurassic rocks are carbonate rocks interleaved with volcanic rocks. The deepwater Upper Triassic rocks contrast with the shallow-water shelf deposits of adjacent parts of the Paradise terrane, and the volcaniclastic and volcanic rocks, which are at least in part of Early Jurassic age, contrast with the largely nonvolcanic rocks of Early Jurassic age in the Paradise and Pine Nut terranes (Satterfield and Oldow, 1990).

In the northern part of the Gillis Range, 3 km south and also 1 km north of Gillis Canyon, a thick unit of limestone (unit Ŧlm of Hardyman, 1980) crops out. In addition, a unit of silty limestone and limy siltstone (unit Ŧsh of Hardyman, 1980) crops out at the southern exposure. Both units have been assigned by Oldow (1984) to the Sand Springs lithotectonic assemblage. The limestone units contain the pelecypod *Monotis* of early late Norian age (Silberling, 1984), a belemmite that ranges in age from latest Karnian through most of the Norian (Table 1), probable megalodontid clams of Norian age (Table 1), and poorly preserved ammonites of probable early or early middle Norian age in interstratified (?) siltstone (Table 1). The silty limestone and limy siltstone unit (unit Ŧsh of Hardyman, 1980) is undated. It lies adjacent to the Norian carbonate rocks, but its stratigraphic and structural relation to the carbonate rocks is uncertain. Conceivably, the Norian carbonate rocks could correlate with the Upper Triassic carbonate-rich succession of the Paradise and Pine Nut terranes and the silty limestone and limy siltstone unit with the Volcano Peak Group of the Paradise terrane or the Gardnerville Formation of the Pine Nut terrane.

Jungo terrane. The Jungo terrane (Silberling and others, 1987) is characterized by a thick marine sequence of fine-grained continentally derived, terrigenous clastic rocks exclusively of Norian (late Late Triassic) to Early Jurassic age. In the Clan Alpine Range, Speed (1978) estimated that the thickness of these fine-grained rocks is in excess of 5 km. The thick fine-grained terrigenous clastic rocks of the Jungo terrane contrast markedly with the Upper Triassic carbonate-rich succession of approximately the same age in the Paradise and Pine Nut terranes. Also included in the Jungo terrane is an overlying fine-grained clastic unit (Boyer Ranch Formation of Speed and Jones, 1969) of quartz arenite and subordinate amounts of limestone-dolomite conglomerate and limestone. The quartz arenite of the Boyer Ranch Formation lithically resembles quartz arenite of the Dunlap Formation, unit Jq of Proffett and Dilles (1984) in the Singatse Range, the Preachers Formation in the southern Pine Nut Mountains, and the Ellis Peak Formation and Sailor Canyon Formation in the Sierra Nevada. All these quartz arenites have been considered to be roughly coeval (Stanley, 1971; Fisher, 1990; J.M. Proffett, Jr., and J. H. Dilles, written commun., 1995). The youngest rocks in the Jungo terrane consist of Middle Jurassic gabbroic rocks (Humboldt lopolith of Speed, 1976) and associated mafic volcanic rocks.

Golconda terrane. The Golconda terrrane (Silberling and others, 1987) is present only in the northeasternmost part of the region considered here (Fig. 2), but is widespread in Nevada (Fig. 1). The terrane consists of a highly deformed sequence of Mississippian to Permian deep-marine pelagic and turbiditic sedimentary rocks and pillow lavas of the Golconda allochthon and unconformably overlying Triassic strata. In north-central Nevada, the Triassic rocks consist of Lower Triassic volcanic rocks of the Koipato Group, carbonate-platform rocks of the Star Peak Group which ranges in age from Early to Late Triassic, and fine-grained terrigenous clastic rocks, deltaic to basinal marine deposits of the Upper Triassic and Lower Jurassic Auld Lang Syne Group (Silberling and others, 1987). The Mesozoic depositional setting of the Golconda terrane is similar to that of the Paradise terrane in that both contain known or possible Lower Triassic volcanic rocks, Triassic shallow-water marine carbonate-platform sequences (shelf terrane of Speed, 1978), and Upper Triassic and Lower Jurassic fine-grained terrigenous clastic rocks. However, they differ in that carbonate-platform deposition extended from the Early to the Late Triassic in the Golconda terrrane, but only through the Late Triassic in the Paradise terrane. They differ also in that the Triassic rocks in the Golconda terrane lie unconformably on deformed rocks of the Golconda allochthon, whereas the rocks of the Paradise terrane are everywhere allochthonous.

Roberts Mountains terrane. The Roberts Mountains terrane (Silberling and others, 1987) is extensively exposed in Nevada, but is present only in a small area in the southeastern part of the region considered here (Fig. 2). Within the area considered here, it consists of deformed lower and middle Paleozoic deep-marine rocks of the Roberts Mountains allochthon unconformably overlain by Mississippian, Permian, and Lower Triassic rocks (Speed, 1984). The Lower Triassic rocks comprise the Candelaria Formation that is 1 km thick and consists of open marine marl and limestone in its lower part overlain by turbiditic volcaniclastic sedimentary deposits (Speed, 1984). These sedimentary rocks are considered (Speed, 1984) to record the encroachment of the Golconda allochthon onto the North American continent and event predating deposition of the Triassic to Jurassic volcanic and sedimentary rocks described in the Paradise, Pine Nut, Gold Range, and northern Sierra terranes.

Snow Lake block and unassigned rocks. Mesozoic rocks in the south-central part of the area considered here (Fig. 2) consist of volcanic rocks in the Twin Lake area (TL on Fig. 2) of the Sierra Nevada and adjacent parts of California and Nevada and of sedimentary rocks assigned to the Snow Lake block (Fig. 2). The volcanic rocks in the Sierra Nevada probably are a continuation of Upper Triassic and Lower Jurassic rocks (Schweickert and Lahren, 1987) that crop out a short distance south of the region shown on Figure IV-2 where they overlie rocks of both the Roberts Mountains and Golconda allochthons (Schweickert and Lahren, 1987). Metasedimentary and metavolcanic rocks to the east and northeast of these Sierra Nevada rocks are poorly known and are not assigned here to a specific terrane. A belt of rocks (Snow Lake block, Fig. 2) composed of calcareous siltstone and sandstone and associated conglomerate that contains abundant clasts of monzonite extends from eastern California into western Nevada (Schweickert and Lahren, 1991; R.A. Schweichert, written commun., 1995). Such rocks are distinctive of what has been referred to as the Fairview Valley Formation (Lahren and Schweickert, 1989; Lahren and others, 1990) in the Snow Lake pendant in the Sierra Nevada (Fig. 2). In the Snow Lake pendant, the Fairview Valley Formation lies unconformably on rocks correlated with miogeoclinal uppermost Proterozoic and Lower Cambrian quartzite, siltstone, and limestone. Paleozoic rocks may also occur in the belt in Nevada (Schweickert and Lahren, 1991). A major right-lateral fault (the Mojave-Snow Lake fault) may have transported rocks of the Snow Lake block northward as much as 400 km. The possible recognition of rocks of the Snow Lake block to the east in a northeast-trending belt may indicate that the Mojave-Snow Lake fault is oroclinally folded eastward (Schweickert and Lahren, 1991). Alternately, the proposed Mojave-Snow Lake fault may continue northward and constitute the boundary between the northern Sierra terrane and the Pine Nut terrane. In the latter case, either the rocks of the Snow Lake block have been misidentified east of the Snow Lake pendant, or some other structural interpretation is necessary to explain the relative position of Mesozoic rocks in the region.

PALEOGEOGRAPHY

Understanding the paleogeography of the Triassic and Jurassic rocks in eastern California and west-central Nevada depends on a plausible palinspastic reconstruction. Present stratigraphic information, however, does not define a unique reconstruction. Speculation about original paleogeography are divided into two concepts, one that the present relative positions of Mesozoic terranes is similar to the original positions (the "fixist" view), and the other that considerable tectonic displacement has occurred within and between terranes (the "mobilistic" view). In this section of the report, the general concepts of the fixist and mobilistic views area are described, followed by descriptions of four models of the paleogeography of the region.

The fixist view maintains that the Paradise, Pine Nut, Gold Range, and northern Sierra terranes (Fig. 11) have not been displaced significantly relative to each other. This idea does not preclude some structural dislocation (for example, late Cenozoic extension) within or between blocks, but suggests that the present relative positions of these terranes are similar to the original positions. This view is supported by the general similarity of Mesozoic stratigraphy in the region, in particular the four successions described previously. These similarities in the project area include abundance of volcanic rocks in the Middle and early Late Triassic, abundance of carbonate rocks in the Late Triassic, abundance of fine to coarse clastic rocks in the latest Triassic and Early Jurassic, and abundance of volcanic rocks in the Middle Jurassic. Quartz arenite of Toarcian to Bajocian age occurs in the Paradise, Pine Nut, Gold Range, and northern Sierra terranes. These similarities indicate a linkage of events between these four terranes. This linkage suggests that these terranes were at least in the same structural and volcanic province along the same continental margin.

The mobilistic view maintains that major dislocations have occurred within and between structural blocks, and that the present relative positions of these blocks are not the original positions. This view accepts the idea of similarities of successions across the region, but argues that these similarities could be related to similar sedimentary, volcanic, and tectonic events along a large segment of western North America. According to this view, tectonic dislocations of hundreds of kilometers within or between structural blocks are possible. In support of the mobilistic view, significant lithic changes in the successions described previously occur at the terrane boundaries and suggest the possibility that these boundaries are the locations of major structural dislocations. In particular, the boundary between the Paradise and Pine Nut terranes marks the following changes: thick sequences of carbonate rocks of the Luning Formation and Pamlico Formation of Oldow (1978a,b) contrast with relatively thin sequences in the Pine Nut terrane; shallow-water silty carbonate and calcareous siltstone of the Volcano Peak Group of Taylor and others (1983) in the Paradise terrane contrast with the relatively deep-water, less calcareous rocks of the Gardnerville Formation in the Pine Nut terrane; a thick sequence of siltstone, quartz arenite, sandstone, conglomerate, and volcanic rocks (Dunlap Formation) in the Paradise terrane contrasts with only thin presumably age-equivalent quartz arenite (Preachers Formation and related rocks) and gypsum in the Pine Nut terrane. The boundary between the Pine Nut and northern Sierra terranes marks the following changes: absence of known Paleozoic rocks in the Pine Nut terrane contrasts with widespread Paleozoic rocks unconformably below Mesozoic rocks in the northern Sierra terrane; presence of widespread Upper Triassic carbonate rocks in the Pine Nut terrane contrasts with only discontinuous thin carbonate rocks in the northern Sierra terrane; presence of the uppermost Triassic and

Lower Jurassic (latest Norian to Toarcian) Gardnerville Formation in the Pine Nut terrane contrasts with the partly younger Lower and Middle Jurassic (late Sinemurian to Bajocian) Sailor Canyon Formation. The quartz arenites (Preachers Formation and related rocks) that overlie the Gardnerville Formation in the Pine Nut terrane are correlated with the Ellis Peak Formation and correlative rocks in the middle two quarters of the Sailor Canyon Formation. If this correlation is correct, only the lower quarter of the Sailor Canyon Formation is age equivalent with the Gardnerville Formation, and no coeval strata lithically similar to the upper three quarters of the Sailor Canyon Formation are present in the Pine Nut terrane.

Paleogeographic models

Four models of the paleogeography of the Mesozoic rocks are described below. These include one model which indicates no significant movement between terranes (fixist view) and three models with significant movement between terranes (mobilistic views). Major structures considered in these models include (1) the Jurassic or Cretaceous northwest-trending left-lateral Pine Nut fault (Oldow, 1983, 1984) in west-central Nevada with proposed displacement of several hundreds of kilometers, (2) the Early Cretaceous northwest-trending right-lateral Snow Lake fault (proposed displacement of approximately 400 km) in the axial part of the Sierra and possible offset parts coextensive with the the Pine Nut fault in western Nevada (Lahren and Schweickert, 1989; Lahren and others, 1990; Schweickert and Lahren, 1990), (3) major Jurassic or Cretaceous northwest-trending right-lateral faults in the eastern part of the Sierra (such as the Lake Tahoe fault) (Oldow, 1984; Robinson and Kistler, 1986; Saleeby and others, 1986; Kistler, 1990) that have apparently offset the Sri=0.706 isopleth about 300 km, (4) the east-west-trending right-lateral Jurassic or Cretaceous Excelsior fault (45 to 55 km of displacement) and Coaldale fault (60 to 80 km of displacement) in western Nevada near the southern border of the area described here (Stewart, 1985), (5) the Jurassic or Cretaceous Pamlico and Luning thrusts whose upper plates may have had hundreds of kilometers of contraction (Oldow, 1983, 1984), (6) northwest-trending right-lateral and left-lateral late Cenozoic faults in the Walker Lane belt (Stewart, 1988), and (7) major late Cenozoic extensional faults with amounts of extension greater than 100 percent in the area from the Pine Nut Mountains to the Wassuk Range (Proffett, 1977).

Model 1. In this model (Fig. 11), the relative positions of the subterranes and terranes have not changed appreciably since they were originally formed. In particular, this model discounts possibilities of large strike-slip displacements on faults along the east side of the Sierra Nevada (like the Lake Tahoe fault) and the Pine Nut fault. In this model, Middle and lowermost Upper Triassic volcanic and volcaniclastic rocks and local terrigenous clastic rocks lie in the eastern two-thirds of the region. Rocks of this age are missing in the northern Sierra Nevada terrane, which apparently was a highland at this time. During much of the Late Triassic, shallow-water carbonate deposition and deltaic terrigenous clastic deposition were widespread in the eastern part of the region and gave way westward into a mixed carbonate and volcanic province. Upper Triassic rocks are thin in the northern Sierra Nevada terrane and indicate the persistence of a positive area in this part of the region. During the latest Triassic and Lower Jurassic fine-grained clastic and calcareous clastic rock characterize the Volcano Peak Group and Gardnerville Formation that, according to this model, were contiguous and perhaps deposited in the same depositional basin. The shape and size of this proposed basin, however, is not known. The Volcano Peak Group is more calcareous than the Gardnerville and interpreted to have been deposited in a shallow marine environment, presumably in the eastern part of the basin, whereas the Garderville Formation is a deeper-water deposit in a more central part of the basin. The deposition of these fine-clastics was terminated by the deposition in grabens of fine to coarse, mainly subaerial, clastics of the Dunlap Formation (Oldow and Bartel, 1987). In the northern Sierra Nevada terrane, the lower quarter of the Sailor Canyon Formation may be correlative to the Gardnerville, but much of the formation is younger than the Gardnerville. The depositional center of the Sailer Canyon, presumably a basin, lay west of the interpretive Gardnerville basin. Here again, the shape and size of the basin is unknown. The Sailer Canyon basin contains moderately deep-water sediments that locally are as thick as 3.5 km, much thicker than strata in the Gardnerville basin to the east. Based on the thickness of deposits, subsidence during deposition of sediments in the Sailer Canyon basin was much greater than during deposition of sediments in the Gardnerville basin. Following deposition of the Gardnerville and Sailer Canyon Formations, widespread Middle Jurassic volcanic and volcaniclastic rocks were deposited in the western half of the region.

Model 2. This model (Fig. 11) builds on the concept that the initial strontium 0.706 isopleth has been significantly distorted tectonically. Robinson and Kistler (1986) and Kistler (1990) have suggested that this isopleth has been displaced by northwest-trending right-lateral faults in the eastern Sierra Nevada region and many controversial explantions (see summary by Stewart, 1985) have been suggested for disruption of this isopleth in western Nevada. In this model, the exact positioning of disrupting structures is not considered in detail; the basic premise is that the isopleth line was originally linear or nearly linear. This reconstruction moves the Pine Nut subterrane and northern Sierra Nevada terrane significantly southward relative to each other and to the Paradise subterrane. In this concept, the Gardnerville marine basin lies adjacent to but southwest of shallow-water marine rocks of the Volcano Peak Group, and the Sailor Canyon marine basin is south of the Gardnerville basin.

Model 3. This model (Fig. 11) is based on ideas presented by Lahren and Schweickert (1989), Lahren and others (1990), and Schweickert and others (1990) that presume uppermost Proterozoic and Lower Cambrian rocks in the Sierra Nevada have been offset right-laterally about 400 km from the Mojave Desert region of southern California along a hypothetical fault, the Snow Lake fault. They suggest that rocks of the Pine Nut subterrane and northern Sierra Nevada terrrane originally were adjacent to each other (their Sailor Canyon basin). They further suggest that the Snow Lake fault is offset eastward into western Nevada along the Coaldale and Excelsior faults and then continues northward, perhaps along a fault that was an early right-lateral precursor of the proposed left-lateral Pine Nut fault. This reconstruction (Fig. 11) moves the Pine Nut subterrane and the northern Sierra Nevada terrane well south of the Paradise subterrane, and, in this case, the stratigraphic similarities of the Paradise subterrane and the Pine Nut subterrane-southern Sierra Nevada terrane are due to a similar sedimentary and tectonic history along a large segment of the Mesozoic continental margin.

Model 4. This model (Fig. 11) is based on the ideas presented by Oldow (1984) that a major northwest-trending left-lateral fault, the Pine Nut fault , separates the Paradise and Pine Nut subterranes. This fault was proposed to explain different structural histories of these two subterranes, and to provide a mechanism, by partial coupling across the fault, for the development of large-scale southward moving thrust faults east in the Paradise subterrane According to Oldow (1984), subsequent to movement on the left-lateral Pine Nut fault, right-lateral movement occurred to the west along major northwest-trending right-lateral faults in the eastern Sierra Nevada and adjacent parts of California and Nevada. In this model the Paradise and Pine Nut subterranes are separated, and the northern Sierra Nevada terrane is south of the Paradise subterrane. As in model 3, similarities between subterranes and terranes are due to similarities in the sedimentary and tectonic history along a large segment of the Mesozoic continental margin.

In this model, the Paradise and Pine Nut terranes originally were separated, with the Pine Nut terrane located several hundred kilometers northwest of the Paradise terrane, while the northern Sierra terrane would have originated to the southwest of the Paradise terrane. As in model 3, the similarities between terranes are considered to be due to similarities in the sedimentary and tectonic history along a large segment of the Mesozoic continental margin. Somewhat closer similarities might be expected to exist between the northern Sierra and Paradise terranes.

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Table 1. Fossil localities in Mesozoic rocks in the study area. Table prepared by J.H. Stewart and D.S. Harwood. Location of quadrangles named in table are shown on Figure 10. CAI, Conodont alteration index of Epstein and others (1977).

BRIDGEPORT 15' QUADRANGLE

Lobdell Lake district. Reported by Halsey (1953, p. 28), identified by S.W. Muller. Ammonite either a *Caloceras*? or *Arnioceras*?.
Age: Early Jurassic

CHURCHILL BUTTE 15' QUADRANGLE

Northeast side of Churchill Butte, SE1/4, Sec. 3, T17N, R24E. Collected and identified by V.P. Gianella (written commun., 1958 *in* Moore, 1960) *Arietites*.
Age: Early Jurassic

CB-22-86, Churchill Butte, Lat. 39° 22'N., Long. 119° 16.7' W., collected by L.A. Fraticelli. Identification by N.J. Silberling (April 21, 1987). Squashed ammonite. The specimen would best fit as an early dactylioceratid such as *Aveyroniceras* and is thus suggestive of about a middle Pliensbachian age.

Virginia Range, north central part Sec. 23, T18N, R23E. Reported by Moore (1960). Collected by V.P. Gianella and D.I. Axelrod, 1959. Identified by N.J. Silberling. Arietitid ammonite.
Age: Early Jurassic

Virginia Range, SW1/4, Sec. 23, T18N, R23E. Reported by Rose (1969). Marine pelecypods, possibly *Pinna* sp.
Age: Mesozoic

COMO 15' QUADRANGLE

Buckskin Range

RG-167 (USGS 33347-M), Lat. 39° 05' 37" N., Long. 119° 22' 20' W.. Northwest side of Buckskin Range. Mason Valley Limestone. Collected by J.H. Stewart. Trol unit of Hudson and Oriel (1979). Conodont identifications by B.R. Wardlaw (March 26, 90): *Epigondolella abneptis* subspecies B of Orchard (1983).
Age: Late early Norian (upper *dawsoni-magnus* ammonite zones)

USGS Mesozoic loc. D10339, Sec. 11, T14N, R23E, Churchill Canyon, northern Buckskin Range. Collected by Peter Kerwin. Identification by N.J. Silberling (Jan. 20, 1975). Arietite-like ammonites represented by loosely coiled impressions having regular, simple ribs.
Age: Early Jurassic

Northeast part of Buckskin Range, near intersection of Churchill Canyon and road to Lincoln Flat, NW 1/4, NE 1/4, Sec. 12, T14N, R23E. Listed in Moore (1960), identified by N.J. Silberling. "*Pecten*" aff. "*P*" *valoniensis*, *Pteria* sp., Nuculid: pelecypods.
Age: Early Mesozoic

DAYTON 15' QUADRANGE

Eldorado Canyon

Four miles southeast of Dayton. Bottom of canyon on east side of creek, west-central part of Sec. 6, T15N., R22E. Reported by Moore (1960) who credits Gianella (1936, p. 37). Identified by S.W. Muller. *Monotis subcircularis* Gabb.
Age: Late Triassic (late Norian)

M526, same general locality as above, south-central part of Sec. 6, T15N, R22E. Reported by Moore (1960), identified by N.J. Silberling. Arietitid ammonites.
Age: Early Jurassic, probably Sinemurian (late early Early Jurassic)

D-110-87, SE1/4 SW1/4, Sec. 2, T.15N, R21E. Collected by L.A. Fraticelli, identified by N.J. Silberling (Oct. 2, 1987). Late Late Triassic *Monotis* sensu stricto, such a *M. alaskana* and and *M. haueri* which may be a little younger than common *M. subcircularis*, but not much.

Brunswick-Sand Canyon area

Ridge crest 500 feet west of bridge across Carson River at site of Brunswick. Unit Ŧmm of Bingler (1977). Two miles east of New Empire. Reported by Moore (1960), identified by N.J. Silberling. Spherical and crescentic cavities suggest the globose ammonite *Arcestes*. If these are not inorganic, they indicate a Late Triassic age.

Sand Canyon, a southern tributary of Brunswick Canyon. Unit Ŧmm of Bingler (1977). Apparently locality M525 of N.J. Silberling West side of road at the boundary between Secs. 19 and 30, T15N, R21E. Reported by Moore (1960), identified by N.J. Silberling. *Monotis subcircularis* Gabb.
Age: Late Late Triassic (early late Norian)

Several localities in south-central part Sec. 24, T.15N, R20E, near, but on west side of, main ridge 1.5 km west of Sand Canyon. Unit Ja of Bingler (1977). Collections and identifications by N.J. Silberling on Sept. 18, 1960, and reported to J.H. Stewart in 1989. Arietitid ammonites and *Monotis.*
Age: Late Triassic and Early Jurassic

DESERT CREEK PEAK 15' QUADRANGLE

Northwest end of Pine Grove Hills, Lat. 38° 43.0'N , Long. 119° 15.4'W, collected by D.C. Noble and reported by Silberling (1984), in black, platy, crystalline limestone, *Halobia superba* Mojsisovics or *H. ornatissima* Smith.
Age: Zone 3 to possibly 6 of Silberling (1984), late Karnian to earliest Norian

In addition, Halsey (1953, p. 27) reports "Poorly preserved ammonites and *Halobia* of probable Triassic age have been collected in the Yerington area, in the ranges bordering Smith Valley, in the hills surrounding Topaz Lake, and in Risue Canyon." Risue Canyon is in the west-central part of the Desert Creek Peak 15' quadrangle; no further information is available about this reported fossil locality in Risue Canyon.

DUNCAN PEAK 15' QUADRANGLE

LC-61-7, Mesozoic loc. 29395, lat. 39°13'40" N., Long.. 120°30'55" W., NW1/4NE1/4NE1/4 Sec. 28, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 103 of Harwood (1991), *Dactylioceras* sp.

Age: Early Jurassic (late Pleinsbachian to early Toarcian) (Imlay, 1968)

LC-61-12a, Mesozoic loc. 28391, Lat. 39°13'20" N., Long. 120°33'48" W., NW1/4SW1/4 Sec. 27, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 104 of Harwood (1991), *Orthildaites*? sp., *Hildaites* sp., *Dactylioceras* cf. *D. Directum* (Buckman), *Protogrammoceras*? sp.
Age: late Early Jurassic (early Toarcian) (Clark and others, 1962)

DP-1, Mesozoic locality 31871, Lat. 39°13'20" N., Long. 120°31'07" W., SW1/4NE1/2 Sec. 28, T.16 N., R. 13 E., unnamed Triassic limestone, locality 85 of Harwood (1991), *Epigondolella* cf. *E. abneptis* (Huckriede).
Age: Late Triassic (late Karnian through Norian) (A.G. Harris, written commun. 1981)

EMIGRANT GAP 15' QUADRANGLE

CG-6196-1, Lat. 39°18'08" N., Long. 120°32'31" W. Sec. 29, T. 17 N., R. 13 E., locality 110(?) and 115 of Harwood (1991). Deformed ammonite impressions in Sailor Canyon Formation collected by D.A. Davis and identified as ?*Paltechioceras* spp. by D.G. Taylor (written commun., 1988) and *Arieticeras* sp. by J.W. Miller (written commun., 1987).
Age: Early Jurassic (late Pleinsbachian or late Sinemurian)

CG-636, Lat. 39°17'13" N., Long. 120°32'11 W., SW1/4SE1/4 Sec. 32, T. 17 N., R. 13 E., locality 111 of Harwood (1991). Highly deformed Hildoceratid (?) ammonites.
Age: late Early Jurassic (J.W. Miller, written commun., 1987)

CG-594, Lat. 39°18'49" N., Long. 120°32'32" W., Sailor Canyon Formation, locality 112 of Harwood (1991). ? *Paltechioceras* spp.
Age: Early Jurassic (late Sinemurian) (D.G. Taylor, written commun., 1988)

CG-544, Lat. 39°18'56" N., Long. 120°32'30" W., NE1/4NW1/4 Sec. 29, T. 17 N., R.13 E., Sailor Canyon Formation, locality 113 of Harwood (1991). *Reynesoceras*, cf. *R. razzoni* (Hauer), *Arieticeras* sp., *Ostrea*? sp.
Age: Early Jurassic (Pliensbachian) (J.W. Miller, written commun., 1987)

CG-8036-2, Lat. 39°18'44" N., Long. 120°32'40" W., NE1/4NW1/4 Sec. 29 T. 17 N., R. 13 E., Sailor Canyon Formation, locality 114 of Harwood (1991). *Polyplectus* sp. (identified by D.G. Taylor), *Paltarpites* cf. *P. arqutus* (Buchman) (identified by J.W. Miller)
Age: Early Jurassic (late Pleinsbachian to early Toarcian)

CG-6196-1, Lat. 39°18'08" N., Long. 120°32'31" W., NE1/4NW1/4 Sec. 29, T. 17 N., R. 13 E., Sailor Canyon Formation, locality 115 of Harwood (1991). *Paltechioceras* sp. (identified by D.G. Taylor), *Arieticeras* sp. (identified by J.W. Miller).
Age: Early Jurassic (late Sinemurian) (D.G. Taylor, written commun., 1988)

CG-543, Lat. 39°18'54" N., Long. 120°32'32" W., NE1/4NW1/4 Sec. 29, T. 17 N., R. 13 E., Sailor Canyon Formation, locality 116 of Harwood (1991). ?*Paltechioceras* sp.
Age: Early Jurassic (late Sinemurian) (D.G. Taylor, written commun., 1988)

CG-10136-1, Lat. 39°18'55" N., Long. 120°31'43" W., NW1/4NW1/4 Sec. 28, T. 17 N., R. 13 E., Sailor Canyon Formation; locality 117 of Harwood (1991), deformed ammonite.
Age: Early Jurassic(?) (D.G. Taylor, written commun., 1988)

L-1, Lat. 39°27'30" N., Long. 120°33'35" W., SE1/4NW1/4 Sec. 6, T. 18 N., R. 13 E., Elevation 7,330 feet on NW-trending spur ridge of English Mountain, Tuttle Lake Formation, locality 118 of Harwood (1991), *Posidonia* cf. *P. ornati.*
Age: late Early through Middle Jurassic (N.J. Silberling, written commun. to D. Stuart-Alexander, 1983)

_____, Lat. 39°18'45" N., Long. 120°32'31" W., SW1/4NW1/4 Sec. 29, T. 17 N., R. 13 E. Roadcut north side old Highway 40 at intersection with Fordyce Lake road, Sailor Canyon Formation, *Weyla.*
Age: Early Jurassic (Sinemurian to Pleinsbachian) (N.J. Silberling, written commun. to D.A. Davis, 1986)

FALLEN LEAF LAKE 15' QUADRANGLE

87-RV-56, Lat. 38°54'44" N., Long. 120°10'43" W., unsurveyed part T. 12 N., R. 16 E., Elevation 7,460 feet on west bank of Rubicon River, 10,210 feet bearing 158° from 7,814 knob (Sec. 34, T 13 N., R. 16 E.), "several kinds of primative hildoceratids") (N.J. Silberling, written commun. to G. Reid Fisher, Nov. 17, 1987)
Age: Early Jurassic (probably late Pleinsbachian) (N.J. Silberling, written commun., 1987)

GILLIS CANYON 15' QUADRANGLE

Aga Pah Hills and Wildhorse Canyon

RG-219A (USGS 33350-M), Lat. 38° 47' 28" N., Long. 118° 37' 14" W.. Wildhorse Canyon, Gillis Range. Limestone within volcanic sequence. Unit Ћv of Hardyman (1980). Collected by J.H. Stewart. Conodont identifications by B.R. Wardlaw (March 26, 1990): *Nicoraella* cf. *N. kockeli* (Tatge)
Age: These specimens belong to the inflated basal cavity members of the Xaniognathids that are generally ascribed to *Nicoraella*, which appear to be restricted to the Middle Triassic, and *Nicoraella* itself to the Anisian, indicating a probable Anisian age
CAI: 5.5-6.5

RG-219B, 100 m to east of RG-219A. Collected by J.H. Stewart; identified by N.J. Silberling (written commun., 1991). Thick-shelled, oyster-like clams *Hoernesia* aff. *H. socialis* and *Gervilleia*. This fauna bears some resemblance to that in the Grantsville Formation in the Shoshone Mountains, which is either latest Middle Triassic or earliest Late Triassic in age

RG-224A (USGS 33351-M). Lat. 38° 46' 12" N., Long. 118° 35' 48" W. Aga Pah Hills, Gillis Range. Unit ¥lm of Hardyman (1980). Collected by J.H. Stewart. Conodont identifications by B.R. Wardlaw (March 26, 1990): *Carinella diebeli* (Kozur and Mostler).
Age: early Karnian
CAI: 5.5 to 6.5

USGS D11132, Lat. 38° 46.3' N, Long. 118° 36.1'W, reported by Silberling (1984), *Malayites* sp. and other juvavitid ammonites from unit of black limestone a few tens of meters thick bounded by (intercalated with?) marine volcaniclastic rocks and volcanic tuff and breccia.
Age: Zone 7 of Silberling (1984), middle early Norian

Gillis Canyon

JS-90-66, south-central part SW1/4, NE1/4 Sec. 18, T.11N., R.30E. About 3 km south of Gillis Canyon in Gillis Range. In unit ŦRlm of Hardyman (1980). Collected by J.H. Stewart. Identification by N.J. Silberling (July 10, 1990): This longitudinally striated fossil is a distinctive kind of coleoid (a pre-Jurassic relative of the belemnite). Silberling reports that the generic name is *Aulacoceras* which apparently ranges from the latest Karnian through most or all of the Norian.

JS-90-74, SE part SW1/4, NW1/4 Sec. 18, T.11N., R.30E. About 3 km south of Gillis Canyon in Gillis Range. In unit ŦRsh of Hardyman (1980). Collected by R.F. Hardyman and J.H. Stewart. Identification by N.J. Silberling (July 10, 1990): Probably *Arcestes* and some smashed juvavitid ammonites, probably of early or early middle Norian age. Certainly Late Triassic in age and probably in the early half of the Norian.

JS-90-75, east central part NE1/4, SW1/4 Sec. 18, T.11N., R.30E. About 3 km south of Gillis Canyon in Gillis Range. In unit ŦRsh of Hardyman (1980). Collected by R.F Hardyman and J.H. Stewart. Identifications by N.J. Silberling (July 10, 1990). These ammonite impressions represent both an evolute, smooth form and discoidal forms having simple ribbing. They are permissive, if not actually suggestive of an Early Jurassic age, but they are not well enough preserved to prove this.

Clams 1.5 km north (south central part Sec. 29, T12N, R30E) and 3 km south of Gillis Canyon (SW1/4 NE1/4 Sec. 18, T11N, R30E). Identified by N.J. Silberling (July 10, 1990) in photographs taken by J.H. Stewart as almost certainly megalodontid clams characteristic of Norian rocks. Similar clams occur in several places in the Union Canyon unit of the Luning Formation in the Lodi allochthon in the Paradise Range. The Union Canyon unit is more or less middle Norian in age. Should be from inner-platform carbonate rocks. Strange occurrence near *Monotis* (USGS D11130, see below), a form that occurs in basinal rocks, unless megalodontid clams are transported.

USGS D11130, southeast part of Sec. 29, T12N, R30E. Collected by R.C. Speed in 1970. Identified by N.J. Silberling (1984 and written commun. 1991) as *Monotis subcircularis* Gabb and *M. alaskana* . From about 15 m of black limestone bounded on one side by a thick section of conformable massive limestone and on the other side by Tertiary volcanic rocks.
Age: Zone 12 to 13 of Silberling (1984), early late Norian

Northeastern side of Gillis Range

USGS D11131, Lat. 38° 52.3'N., 118° 31.6'W, reported by Silberling (1984), *Halobia halorica* Mojsisvics, *H.* cf. *H. fallax* Mojsisovics, ?*Himavatites* sp., and other ammonite impressions from isolated exposure of about 100 m of dark, laminated, partly sandy, basinal limestone.

Age: Zone 10 to 11 of Silberling (1984), late middle Norian

GRANITE CHIEF 15' QUADRANGLE

S-61-51, USGS Mesozoic loc. 28403, Lat. 39°11'31" N., Long. 120°29'56" W., NW cor. of Sec. 2, T. 15 N., R. 13 E, Sailor Canyon Formation, locality 100 of Harwood (1991), *Crucilobiceras* sp.
Age: Early Jurassic (late Sinemurian) (Imlay, 1968)

S-61-50, USGS Mesozoic loc. 28404, Lat. 39°11'53" N., Long. 120°29'52" W., NW cor. of Sec. 2, T. 15 N., R. 13 E., Sailor Canyon Formation, locality 101 of Harwood (1991), *Crucilobiceras* sp.
Age: Early Jurassic (late Sinemurian) (Imlay, 1968)

LC-61-17, USGS No. 28396 (probably the same locality as USGS collections 574 and 2464), Lat. 39°12'06" N., Long. 120°29'51" W., SE cor. Sec. 34, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 102 of Harwood (1991). USGS Colln. No. 574: *Harpoceras* sp., *Orthildaites* cf. *O. orthus* Buckman, *Hildaites* cf. *H. serpentinum* (Reinecke), *Dactylioceras* cf. *D. tenuicostatum* (Young and Bird), *D.* cf. *D. directum* Buckman, *Protogrammoceras*? sp., "Daonella"*bochiformis* Hyatt. USGS Colln. No. 2464: *Harpoceras* cf. *H. exaratum* (Young and Bird), *Hildaites* cf. *H. serpentinum* (Reinecke), *Eleganticeras*? sp., *Protogrammoceras*? sp., *Dactylioceras* cf. *D. tenuicostatum* (Young and Bird), *Zugodactylioceras?* sp., *Peroniceras*? sp., *Aptychus* undet., Gryphaea sp. (found about 1/2 mile from ammonite bed), "*Daonella*" *bochiformis* Hyatt, "*D.*" *cardinoides* Hyatt, "*D.*" sp. Hyatt (1894, p. 416), *Hemientolium*? sp. USGS Colln. No. 28396 (identified by Imlay): *Orthildaites* cf. *O. orthus* Buckman, *Hildaites* cf. *H. serpentinum* (Reinecke), *Dactylioceras* cf. *D. directum* (Buckman), *D.* cf. *D. tenuicostatum* (Young and Bird), *Zugodactylioceras* sp., *Protogrammoceras*? sp.
Age: Early Jurassic (late Pleinsbachian) (Imlay, 1968)

Mesozoic loc. 2467, Lat. 39°13'18" N., Long. 120°28'25" W., T. 16 N., R. 13 E., approximately on line between Sec. 25 and 26, Sailor Canyon Formation, locality 105 of Harwood (1991), *Tmetoceras* sp.
Age: Middle Jurassic (early Bajocian) (Imlay, 1968)

LC-61-13, Mesozoic loc. 28392, Lat. 39°13'20" N., Long. 120°29'58" W., NW1/4 SE1/4 Sec. 27, T. 16 N., R.13 E., Sailor Canyon Formation, locality 106 of Harwood (1991), *Protogrammoceras.*
Age: Early Jurassic (late Pleinsbachian to early Toarcian) (R.W. Imlay, written commun. to L.D. Clark, 1961)

LC-61-11, Mesozoic loc. 28390, Lat. 39°13'20" N., Long. 120°29'10" W., SE1/4NW1/4 Sec. 26, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 107 of Harwood (1991), *Posidonia*? sp.
Age: Early to Middle Jurassic

LC-61-10, Mesozoic loc. 28389, Lat. 39°13'08" N., Long. 120°29'10" W., SE1/4NW1/4 Sec. 26, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 108 of Harwood (1991), *Tmetoceras* sp., *Erycites* ??
Age: early Middle Jurassic (early Bajocian) (R.W. Imlay, written commun. to L.D. Clark, 1961)

LC-61-9, Mesozoic loc. 28388, Lat. 39°13'11" N., Long. 120°27'17" W., NW1/4SW1/4 Sec. 25, T. 16 N., R. 13 E., Sailor Canyon Formation, locality 109 of Harwood (1991), *Tmetoceras* ? sp., *Posidonia* sp.
Age: early Middle Jurassic (early Bajocian) (R.W. Imlay, written commun. to L.D. Clark, 1961)

MABLE MOUNTAIN 7 1/2' QUADRANGLE

SU882, central part of sec. 12, T7N, R32E, reported by Silberling (1984), in rocks assigned to the Dunlap Formation by Ferguson and Muller (1949), but according to Silberling (1984) an assignment to the Sunrise Formation would be justifiable, *Plicatostylus* cf. *P. gregarius* Lupher and Packard in massive, thick-bedded, sandy and coarsely bioclastic and conglomeratic limestone. As reported by Silberling (1984), in the Shoshone Mountains, about 70 km northeast of Mable Mountain quadrangle, this species occurs near the top of the Sunrise Formation and above the late Pliensbachian (or possibly late early Pliensbachian) ammonites *Protogrammoceras* cf. *P. varicostatum* (Fucini) and *Radstockiceras fannini* (McLearn) (identifications by P.L. Smith, writtten commun. 1981, *in* Silberling, 1984)
Age: Pliensbachian

Field number 81S11, central part sec. 6, T7N, R33E, reported by Silberling (1984), in rocks assigned to the Dunlap Formation by Ferguson and Muller (1949), but according to Silberling (1984) an assignment to the Sunrise Formation would be justifiable, hildoceratid ammonites, probably *Protogrammoceras* sp., in yellow-brown and yellow-orange calcareous siltstone and turbiditic sandstone intercalated with impure limestone and mudstone.
Age: Pliensbachian

Sec. 6, T7N, R33E, and sec. 12, T7N, R32E, reported by Silberling (1984), undivided Gabbs and Sunrise Formations, *Septocardia* sp.
Age: Zone 13 to 14 of Silberling (1984), late Norian

MT. SIEGEL 15' QUADRANGLE

Southwest of ridge crest 1/2 mile west of Alpine Mill on Pine Nut Creek, NE1/4 NE 1/4 Sec. 35, T12N, R21E. Probably same stratigraphic position as F-8 below. Reported by Moore (1960), identified by N.J. Silberling. *Monotis subcircularis* Gabb, *Heterastridium* sp., *Placites* sp., *Rhabdoceras* sp., *Sandlingites* ? sp., *Halorites*? sp., and choristoceratid.
Age: late Late Triassic (early late Norian)

USGS M528 (=USGS M1193), southeast part of Sec. 26, T12N, R21E, on strike with locality listed above. Reported by Silberling (1984). Oreana Peak Formation. *Rhabdoceras suessi* Hauer, *Lissonites* sp., *Gnomohalorites* sp., *Monotis subcircularis* Gabb, *Heterastridium* sp.
Age: Zone 12 of Silberling (1984), early late Norian

F-8, SE1/4 NW1/4 NE1/4 NE1/4 Sec. 35, T12N, R21E. Locality on strike with USGS M528 (=USGS M1193). Upper carbonate member of the Oreana Peak Formation. Identifications by S.W. Muller (*in* Noble, 1962). *Monotis subcircularis* Gabb, *Heterastridium conglobatum*.
Age: middle to late Norian

F-9, NW 1/4 NW1/4 SE 1/4 Sec. 26, T12N, R21E. Locality on strike with USGS M528 (=USGS M1193). Upper carbonate member of the Oreana Peak Formation. Identifications by Jose Corvalán (*in* Noble 1962). *Monotis subcircularis* Gabb
Age: late Norian

SU 3535 (erroneously reported as SU 3735 in Silberling, 1984), southwest part of Sec. 23, T12N, R21E, near Divide Mine, reported by Silberling (1984). Limestone interfingering with upper volcanic member of the Oreana Peak Formation according to Noble (1962). *Indojuvavites angulatus* (Diener). Apparently same locality as F-7 of Noble (1962). At F-7, S. W. Muller (*in* Noble, 1962) indicates *Juvavites* sp. (sensu lato)
Age: Zone 8 of Silberling (1984), late early Norian according to Silberling (1984)

SU 3534, north-central part of Sec. 10, T12N, R. 21E, reported by Silberling (1984). Lower volcanic member of the Oreana Peak Formation according to Noble (1962). *Lopha montiscaprilis*. Also previous report (locality F-2) by S.W. Muller (*in* Noble, 1962) indicates *Alectryonia montiscaprilis* Emmrich, *Myophoria whateleyea* Buch, *M.* cf. *M kefersteini* Munster, *Lima* sp(?).
Age: about Zone 8 of Silberling (1984), late early Norian according to Silberling (1984); age originally regarded as middle(?) Karnian by S.W. Muller (*in* Noble, 1962)

F-3, NE1/4 SW1/4 SE1/4 NW1/4 Sec. 10, T12N, R21E. Lower volcanic member of the Oreana Peak Formation according to Noble (1962). Identifications by S.W. Muller (*in* Noble, 1962): *Alectryonia montiscaprilis* Emmrich.
Age: probably early Norian according to N.J. Silberling (written commun., 1991); originally regarded as Karnian(?) by S.W. Muller (*in* Noble, 1962)

F-4, SE1/4 SW1/4 NE1/4 SW1/4 Sec. 10, T12N, R21E. Lower volcanic member of the Oreana Peak Formation according to Noble (1962). Identifications by S.W. Muller (*in* Noble, 1962). *Alectryonia montiscaprilis* Emmrich.
Age: probably early Norian according to N.J. Silberling (written commun., 1991). Age originally regarded as Karnian(?) by S.W. Muller (*in* Noble, 1962)

F-13 (=USGS M1194), SE1/4 NE1/4 SW 1/4 NW1/4 Sec. 35, T12N, R21E. Lower part of volcanic conglomerate member of the Gardnerville Formation. Collected and identified by Silberling (*in* Noble, 1962 and Silberling, 1984): *Grammoceras* sp., *Phymatoceras* sp.
Age: Zone 33 of Silberling (1984), middle late Toarcian

F-14, SU 3539, NE1/4 SW1/4 SW1/4 SW1/4 Sec. 20, T12N, R21E, on crest of small hill. Siltstone member of the Gardnerville Formation. Identified by S.W. Muller (in Noble, 1962): *Grammoceras radians*?, *Harpoceras*?, *Lytoceras aeguistriatum*?
Age: Toarcian

F-15, LSJU 3540, center of SW1/4 NW1/4 SE 1/4 Sec. 4, T11N, R21E, near bottom of gully. Lower 1000 feet of the Double Spring Formation. Identified by D.W. Taylor and F.S. MacNeil (*in* Noble, 1962): *Reesidella* sp. (molds of opercula only)
Age: Late Jurassic through Paleocene

F-19, LSJU 3541, SW1/4 SE1/4 SW1/4 NE1/4 Sec. 17, T10N, R22E, on creat of small knoll. Double Spring(?) Formation. Reported by Noble (1962): *Trigonia* sp., ammonite fragment.
Age: post-Triassic, pre-Tertiary

F-20, LSJU 3542, NW1/4 NW1/4 NE1/4 sec. 21, T10N, R22E. Double Spring(?) Formation. Reported by Noble (1962): *Trigonia* sp.
Age: post-Triassic, pre-Tertiary

PAMLICO 7 1/2' QUADRANGLE

USGS 11900, 12317, 12318, southeastern part of sec. 12 and northeastern part of sec. 13, T7N, R31E, reported by Silberling (1984), *Lopha* cf. *L. montiscoprilis* (Klipstein) and other shelly and coralline bioclasts. *Lopha* cf. *L. mantiscaprilis* observed in unit 12 of the Pamlico Formation of Oldow (1978a,b).
Age: about Zones 7 to 9 of Silberling (1984), early to middle Norian

USGS 12231, 12312, south-central part of sec. 8, T7N, R32E, reported by Silberling (1984), in rocks mapped as the undivided Sunrise and Gabbs Formations by Oldow (1978a,b), *Cycloceltites* sp., *Plicatula perimbricata* Gabb.
Age: Zone 13 of Silberling (1984), late Norian

USGS 11903, south-central part of sec. 8, T7N, R32E, reported by Silberling (1984), in rocks mapped as the undivided Sunrise and Gabbs Formations by Oldow (1978a,b), Psiloceratinid ammonites.
Age: Zones 15 and 16 of Silberling (1984), Hettangian

SCHURZ 15' QUADRANGLE

Northern Lights Mine area

NL-17A-JD-90, Near center, SW 1/4 of SE 1/4, Sec. 8, T12N., R28E. In black, carbonaceous, thin-bedded marble interbedded with abundant black argillite. Specimens from approximately 10-100 m west of contact with blue-gray Upper Triassic marble (interbedded or infolded?). Basal 30 m of the Gardnerville Formation. Collected by J.H. Dilles. Identifications by N.J. Silberling (Sept. 5, 1990). Ammonites, smooth, globose form like an arcestid, a very common kind of ammonite in Middle to uppermost Upper Triassic rocks.

NL-7A-JD-90, North part, SW 1/4, NE 1/4, Sec. 18, T12 N., R28E, at south shaft of Northern Lights Mine, immediately east (downsection) of buff marble bed. Locality is near spot where N.J. Silberling (*in* Bingler, 1978) identified Arietited ammonites suggesting an Early Jurassic, probably Sinemurian, age from a collection made by E.C. Bingler. Blue-gray, chippy-weathering calcareous siltstone, near top of the Gardnerville Formation. Collected by J.H. Dilles. Identifications by N.J. Silberling (Sept. 5, 1990). Ammonite impression in this collection is of an evolute, simple-ribbed form like that which would be common in the Early Jurassic, and the bivalves are of the kind assigned to the form-genus *Posidonia*, a common form in middle Early and younger Jurassic ammonite faunas. Sinemurian age would be a good call; an older age than this is unlikely, but an age somewhat younger is possible.

NL-65, Northern Lights Mine area, SW1/4, NW1/4, NE1/4 Sec. 18, T12N, R28E, collected by J.M. Dilles, identified by N.J. Silberling (Feb. 1, 1978). Impressions of a concentrically ribbed bivalve that is of no help for a refined age determination. Also present, however, is a fragmentary impression of ribbing suggestive of the simple kind of ribbing characterisitic of some Early Jurassic ammonites. This locality, even though stratigraphically well below E.C. Bingler's Jurassic locality, is evidently still within the Lower Jurassic section.

USGS M6682, Northern Lights Mine area, NE1/4, NE1/4, NW1/4 Sec. 18, T12N, R28E, collected by E.C. Bingler, identifications by N.J. Silberling (1971 *in* Bingler, 1978) and Silberling (1984). In gray siltstone in the uppermost part of unit Js directly above the bounding fault. Reported as arietitid ammonite impressions by Bingler (1978) and as asteroceratinid ammonites by Silberling (1984).
Age: reported as Zone 20, or possibly 21, of Silberling (1984), late early or possibly early late Sinemurian

TOPAZ LAKE 15' QUADRANGLE

SU 3541, Holbrook Junction area, Lat. 38° 44.6" N, Long. 119° 30.8' W, collected by D.C. Noble, identifications by R.W. Imlay (*in* Silberling (1984). In fine-grained calcareous sandstone and sandy or silty limestone. *Harpoceras* sp. or *Polyplectus* sp., *Haugia* sp. or *Phymatoceras* sp., *Catulloceras* sp. or *Tmetoceras* sp., and ?*Weyla* sp.
Age: questionably Zone 31 to 34 of Silberling (1984), late early Toarcian to late late Toarcian

USGS D11120, Lat. 38° 44.4' N, Long 119° 31.0' W, collected by D.C. Noble, identifications from Silberling (1984). From an isolated exposure, probably of the Oreana Peak Formation. *Septocardia*? sp.
Age: indicative of only a Late Triassic age

In addition, Halsey (1953, p. 27) mentions "Poorly preserved ammonites and *Halobia* of probable Triassic age have also been collected from limestones in the Yerington area, in the ranges bordering Smith Valley, in the hills surrounding Topaz Lake, and in Risue Canyon.". No further information is available on the reported Topaz Lake localities.

WABUSKA 15' QUADRANGLE

Thompson Smelter

RG-251 (USGS 33352-M), Lat. 39° 09' 32" N., Long. 119° 12' 36" W. About 1/2 mile west of Thompson Smelter. Limestone strata questionably belonging to the Mason Valley Limestone. Collected by J.H. Stewart, conodont identificatons by B.R. Wardlaw (March 26, 1990). *Epigondolella abneptis* subspecies B of Orchard (1983). *Cypridodella* sp.
Age: late early Norian (upper *dawsoni-magnus* ammonite zones)
CAI: 5.5

Mesozoic Loc. D10237, NE1/4, SW1/4, Sec. 17, T15N, R25E, 0.6 miles west of the site of Thompson smelter, in 6- to 12-inch-thick fossiliferous beds near the base of a silty thin-bedded blue-gray about 250-feet-thick limestone, partially recrystallized. Collected by J.H. Dilles, identifications by N.J. Silberling (Feb. 1, 1978). Colonial corals--several different kinds. Spongiomorph coelenterates--more than one kind. Ammonites--one arcestid. Bivalves--several kinds including a trigoniid, a parallenodonid, *Cassianella*, and fragments with ribbing like that of *Septocardia*. Gastropods--more than one kind. Spiriferid brachiopods with *Spondyospira*-like ribbing.

Age: the arcestid ammonite fixes the outer limits of the possible age range as being from middle Middle Triassic through Late Triassic. The coelenterates and some of the bivalves and brachiopods indicate a Late Triassic age, probably within the range from the late Karnian to the middle Norian or about age equivalent to the Luning Formation

East side of quadrangle

21-35J, Lat. 39° 5.0' N., Long. 119° 0.8' W., collected by J.H. Stewart, identifications by N.J. Silberling (April 21, 1987), *Halobia* , similar to middle Norian type

21-36J, Lat. 39° 5.3' N., Long. 119° 0.6' W., collected by J.H. Stewart, identifications by N.J. Silberling (April 21, 1987), *Halobia*, species indeterminate.
Age: same age as, or permissively older than 21-35J, 39J, or 40J

21-39J, Lat. 39° 4.9' N., Long. 119° 0.9' W., collected by J.H. Stewart, identifications by N.J. Silberling (April 21, 1987), *Halobia,* but different species than 21-35J or 21-39J
Age: either middle or early Norian

21-40J, Lat. 39° 5.0' N., Long. 119° 1.0' W., collected by J.H. Stewart, identifications by N.J. Silberling (April 21, 1987), probably same stratigraphic level as 21-35J. *Halobia*, similar to middle Norian type.
Age: middle Norian

Comments on section, starting on west side of hills and tranversing to northeast: Unit 1 (a few hundred meters thick) consists of siltsone, shale, limestone, and tuff containing 21-39J in the middle part and 21-35J and 21-40J at the top. Unit 2 consists of 500 to 600? m of fine tuff, some tuff with clasts as large as 1 cm, and minor siltstone and limestone. 21-36J is near the top of unit 2. Unit 3 consists of 100 m of cliff-forming medium-gray limestone. Unit 4 is tuff lithologicaly similar to that of unit 2. Several hundred meters are exposed.

WEBER RESERVOIR 15' QUADRANGE

Schurz Highway area

RG-198 (USGS 33348-M), Lat. 39° 03' 02', Long. 118° 59' 17". Northernmost Wassuk Range. About 1/2 mile north of highway between Yerington and Schurz. Basal part of unit ŦRla of Proffett and Dilles (1984). Collected by J.H. Stewart; conodont identifications by B.R. Wardlaw (March 26, 1990): *Neogondolella polygnathiformis augusta* (Kozur) (=*Epigondolella augusta* of Kozur)
Age: late Karnian
CAI: 5.0

RG-204A (USGS 33349-M), Lat. 39° 03' 03", Long. 118° 58' 39". Northernmost Wassuk Range. About 1/2 mile north of highway between Yerington and Schurz. Unit ŦRll of Proffett and Dilles (1984). Collected by J.H. Stewart; conodont identifications by B.R. Wardlaw (March 26, 1990): *Epigondolella abneptis* subspecies B of Orchard (1983).
Age: late early Norian (upper *dawsoni-magnus* ammonite zones)
CAI: 5.0

JS-90-71, NW1/4 Sec. 29, T14N., R27E., 700 meters north of Schurz Highway. Unit Ŧla of Proffett and Dilles (Map 77, NBMG). Collected by J.H. Stewart; identification by N.J. Silberling (July 10, 1990). *Arcestes* (globose ammonites) of Late Triassic kind plus an orthocone (a straight nautilus of no particular value). Late Triassic age is all that can be said for these fossils.

MZ-6, Schurz Highway section, northeast part of Sec. 29, T14N, R27E, collected by D.E. Cameron, identified by N.J. Silberling (June 8, 1977). Limy beds beneath the tuff unit. *Aulacoceras.*
Age: some old European references assign ages as old as late Middle Triassic to this genus, but I doubt that it is much older than late Karnian. In Nevada, *Aulacoceras* is fairly well represented in rocks of late Karnian through Norian age. According to J.H. Stewart, this and possibly MZ-2, -8, -9, and -10 may all be in clasts, some as much as 50 m across, in debris-flow units in the section.

MZ-2, 8, and 9, Schurz Highway section, northeast part Sec. 29, T14N, R27E, collected by D.E. Cameron, identification by N.J. Silberling (June 8, 1977). Echinodern bioclasts. *Elysastraea*-like scleractinian corals.
Age: corals indicate a latest Middle or Late Triassic age

MZ-10, Schurz Highway section, probably northeast part Sec. 29, T14N, R27E, collected by D.E. Cameron, identifications by N.J. Silberling (June 8, 1977). From an isolated locality. *Septocardia* and fragments of other bivalves and some variety of snails, none of which are identifiable.
Age: this *Septocardia* is suggestive of a late Karnian age, but objectively it could be somewhat younger within the Late Triassic

About at SE corner of Sec. 19, T14N., R27E., on southeast side of hills about 3/4 mile northwest of main Schurz Highway hill. Lat. 39° 3.3' N., Long. 118° 59.7' W. Collected by E.C.Bingler in 1975, identified by N.J. Silberling (May 11, 1976). Medium-bedded bluish-black to blue-gray marble interbedded with marine pyroclastic rocks. *Anatropites* sp., *Tropites* cf. *T. subquadratus* Silberling, *Arcestes* sp., Juvavitinid ammonites. Stratigraphic assignment to the Macrolobatus Zone (latest Karnian) is dictated by the abundance of *Anatropites* which is restricted to this zone

YERINGTON 15' QUADRANGLE

USGS D11128, McConnell Canyon, western part of Sec. 32, T13N, R25E, in unit Ŧll of Proffett and Dilles (1984), identifications by N.J. Silberling (*in* Proffett and Dilles, 1984) and Silberling (1984). *Anatropites* sp. and *Gonionotites* sp.
Age: Zone 5 of Silberling (1984), late late Karnian

USGS D11129, McConnell Canyon, southeastern part of Sec. 31, T13N, R25E, in unit Ŧla of Proffett and Dilles (1984) identification by N.J. Silberling (*in* Proffett and Dilles, 1984) and Silberling (1984). *Halobia alaskana* Smith sp.and *H.* cf. *H. cordillerana* Smith.
Age: Zone 6 of Silberling (1984), early early Norian

On south side of road near Malachite Mine, probably same locality as next above. Near SE1/4, SE1/4, Sec. 31, T13N, R25E. Identified by T.W. Stanton (*in* Knopf, 1918, p. 13) as *Daonella* sp. According to N.J. Silberling (*in* Moore, 1960) this is more likely *Halobia* sp. of Late Triassic age because of stratigraphic position.

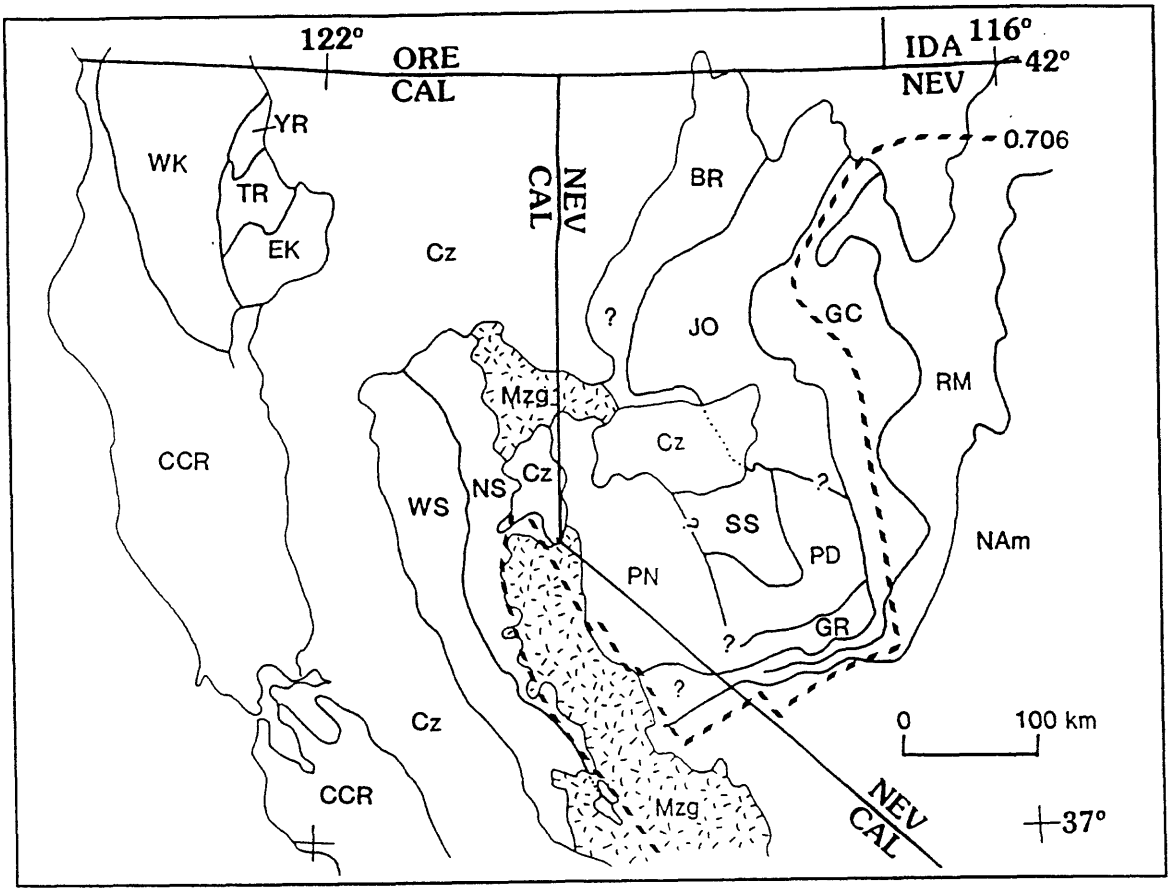


Figure 1. Lithotectonic terranes in northwestern Nevada and northern California, from Silberling (1991). BR, Black Rock terrane; CCR, California Coast Ranges; Cz, Cenozoic cover deposits; EK, eastern Klamath terrane; GC, Golconda terrane; JO, Jungo terrane; Mzg, Mesozoic Sierra Nevada batholith; NAm, North American miogeocline; NS, northern Sierra terrane; PD, Paradise terrane, PN, Pine Nut terrane; RM Roberts Moutains terrane; Sand Springs terrane; TR, Trinity terrane; WK, terranes of western and central Klamath Mountains; WS, terranes of western Sierra Nevada; and YR, Yreka terrane. Initial $^{87}Sr/^{86}Sr$ (Sr_i)=0.706 isopleth (dashed line) from Kistler (1990).

EXPLANATION (Figure 2)

NS	Northern Sierra terrane
PN	Pine Nut terrane
PD	Paradise terrane
JO	Jungo terrane
SS	Sand Springs terrane
GR	Gold Range terrane
GC	Golconda terrane
RM	Roberts Mountains terrane
SL	Snow Lake block
UR	Unassigned rocks
	Late Cenozoic high-angle normal fault. Bar and ball on downthrown side
	Late Cenozoic strike-slip fault. Arrows show relative movement
	Mesozoic thrust fault. Dashed where inferred. Saw-teeth on upper plate.
	Hypothetical Mesozoic strike-slip fault. Arrows show relative movement
	Terrane boundary where not at Mesozoic thrust fault or hypothetical strike-slip fault

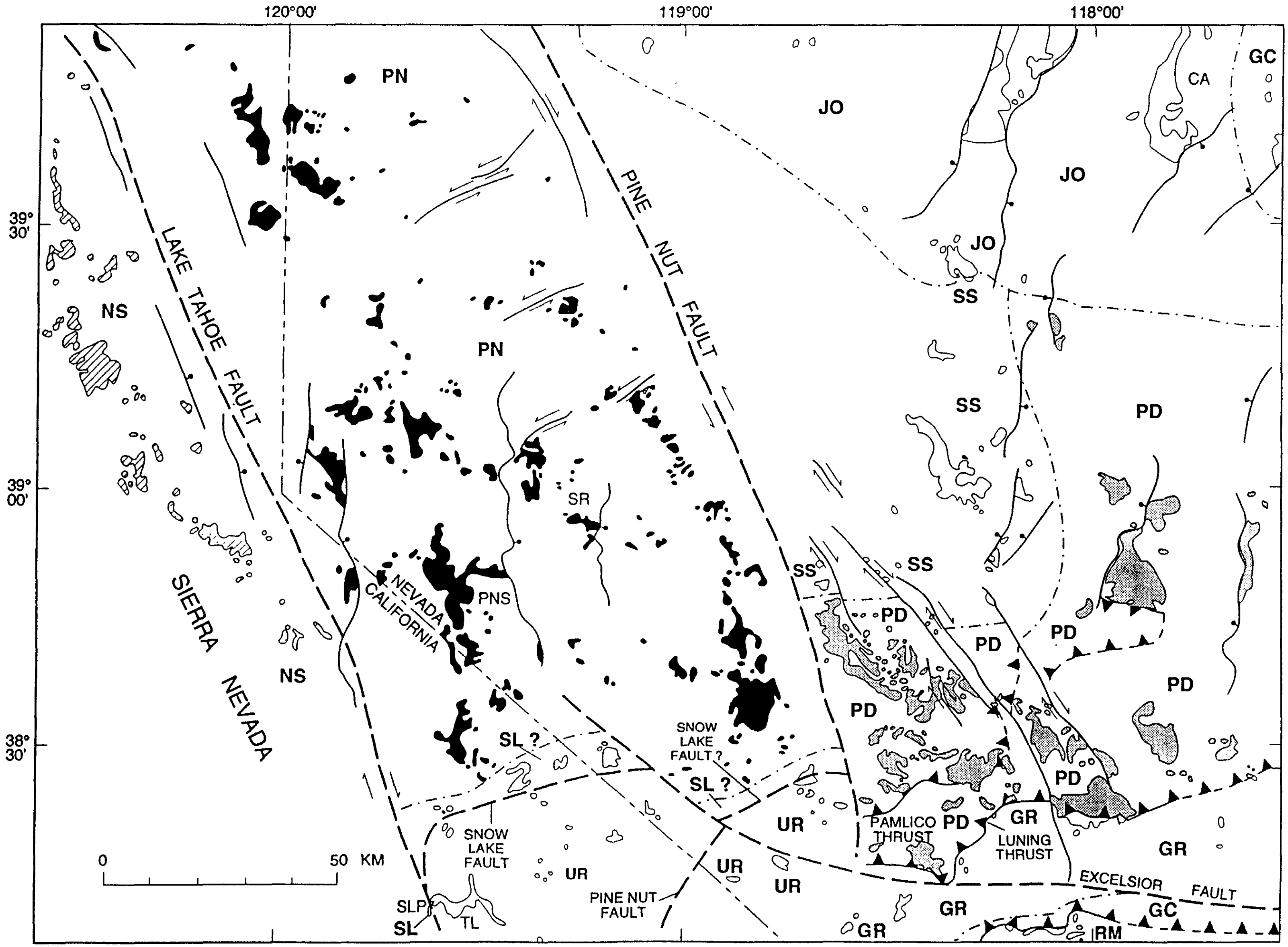


Figure 2. Distribution of Mesozoic terranes in west-central Nevada and eastern California, modified from Silberling (1991). Localities mentioned in text: CA, Clan Alpine Range; GC, Gillis Canyon; GR, Gillis Range; PNS, Pine Nut Mountains, southern part; SLP, Snow Lake pendant; SR, Singatse Range; TL, Twin Lakes area. Underlined letters: NS, northern Sierra terrane; PN, Pine Nut terrane; PD, Paradise terrane; JO, Jungo terrane; SS, Sand Springs terrane; GR, Gold Range terrane; GC, Golconda terrane; RM, Roberts Mountains terrane; SL, Snow Lake block. Terrane symbols given in figure 1.

Age (Ma)	Period	Epoch	Age	Northern Sierra terrane: Most of region	Northern Sierra terrane: Blackwood Creek	Pine Nut terrane: Pine Nut Mountains	Pine Nut terrane: Buckskin Singatse Ranges	Paradise terrane: Garfield Hills	Paradise terrane: Gabbs Valley Range and Pilot Mtns	Paradise terrane: Shoshone Mountains
	Jurassic	Upper	Oxfordian	not exposed ?	not exposed	not exposed ?	not exposed ?	not exposed	not exposed	not exposed
163		Middle	Collovian	Turtle Lake Formation ?		Double Spring Formation ?	Fulstone Spring Volcanics ?			
169			Bathonian	? ?		? Gold Bug Formation	? ?			
176			Bojocian	?		Veta Grande Formation	Artesia Lake Volcanics	? Dunlap Formation[4]	? Dunlap Formation[4]	? Dunlap Formation[4]
183			Aalenian	Sailor Canyon Formation	?	?	?			
187		Lower	Toarcian		Ellis Peak Formation; Blackwood Creek Formation	Preachers Formation	Ludwig Mine Formation[3]			
193			Pliensbachian		?	Gardnerville Formation	Gardnerville Formation	Volcano Peak Group[2]: Gabbs and Sunrise Formations	Volcano Peak Group[2]: Sunrise Formation	Volcano Peak Group[2]: Gabbs and Sunrise Formations
198			Sinemurian	?	not exposed					
204			Hettangian						Gabbs Formation	
208	Triassic	Upper	Norian	? Unnamed limestone and clastic rocks		Oreana Peak Formation	Mason Valley Limestone; Tuff of Western Nevada Mine	Pamlico Formation[1]	Luning Formation	Luning Formation
			Karnian	?		not exposed	Malachite Mine Formation		? not exposed	Grantsville Formation
		Middle	Ladinian				McConnell Canyon Volcanics[5]			?
			Anisian					? not exposed		Unnamed volcanic rocks
245		Lower								

[1] of Oldow (1978a and b)
[2] of Taylor and others (1983)
[3] Age in this report regarded as Early and (or) Middle Jurassic
[4] Upper age limit uncertain; unit probably includes Cretaceous rocks
[5] Age is Middle Triassic or older

Figure 3. Nomenclature and ages of Triassic and Jurassic rocks in west-central Nevada and eastern California. Queries indicate uncertain age boundaries. Wavy lines indicate unconformities. Diagonal lines indicate known or proposed absence of strata. Absolute time scale for base of the Triassic and for epochs and ages in the Jurassic is from Palmer (1983). Absolute time scale for epochs and ages within the Triassic are poorly known and ages are not shown.

EXPLANATION (Figure 4)

Volcanic and volcaniclastic rocks (lower Upper to upper Lower Triassic; lower Karnian to Scythian

Grantsville Formation (lower Upper to upper Middle Triassic)

Late Cenozoic high-angle normal fault. Bar and ball on downthrown side

Late Cenozoic strike-slip fault. Arrows show relative movement

Mesozoic thrust fault. Dashed where inferred. Saw-teeth on upper plate.

Hypothetical Mesozoic strike-slip fault. Arrows show relative movement

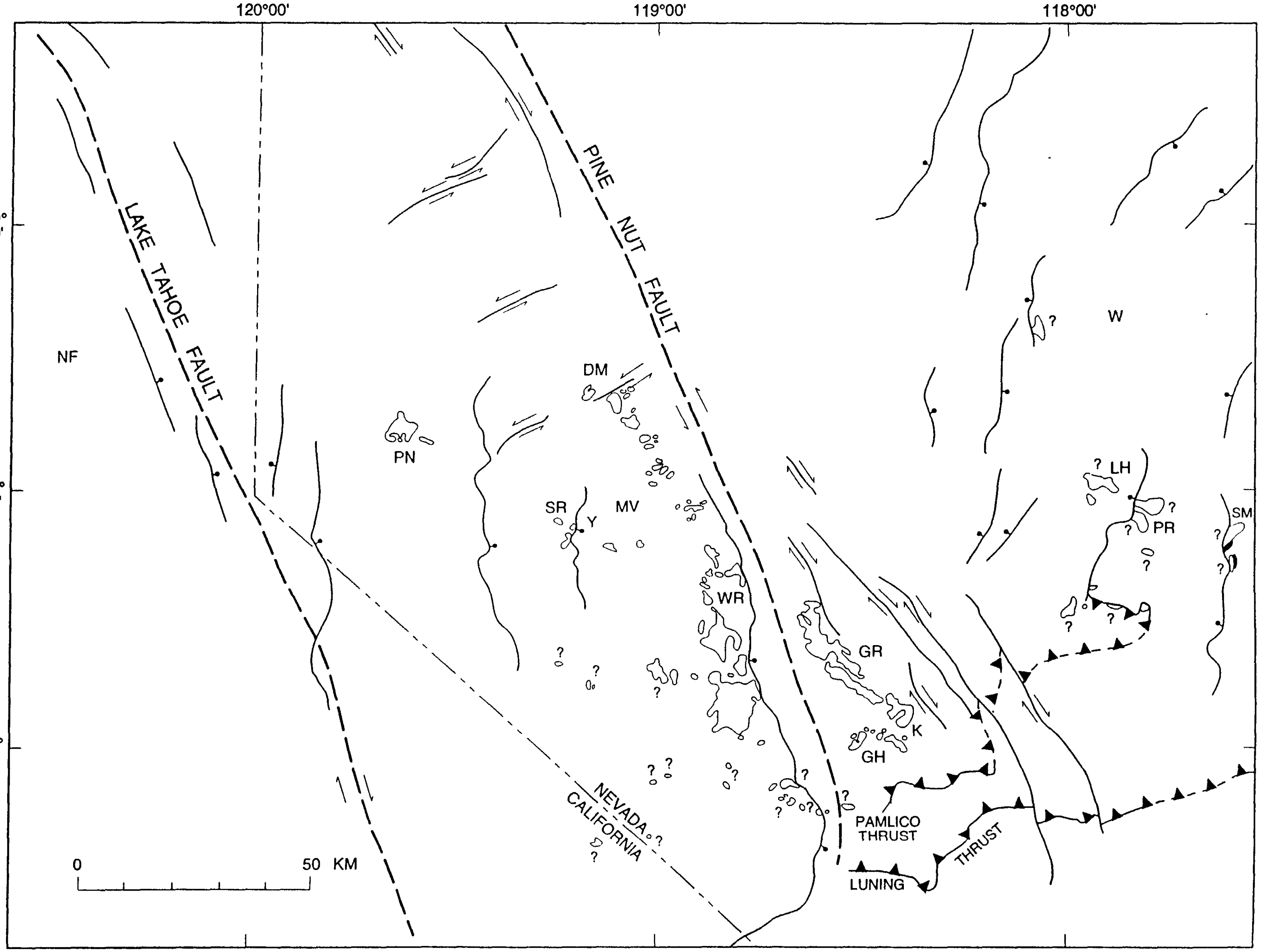


Figure 4. Distribution of the Lower? to lower Upper Triassic (Scythian to early Karnian) volcanic and volcaniclastic succession. Quieries indicate uncertain assignment of rocks to this succession. Localities mentioned in text: DM, Desert Mountains; GH, Garfield Hills; GR, Gillis Range; K, Kinkaid; LH, Lodi Hills; MV, Mason Valley; NF, North Fork of the American River; PN, Pine Nut Mountains; PR, Paradise Range; SM, Shoshone Mountains; SR, Singatse Range; W, Westgate; WR, Wassuk Range; Y, Yerington.

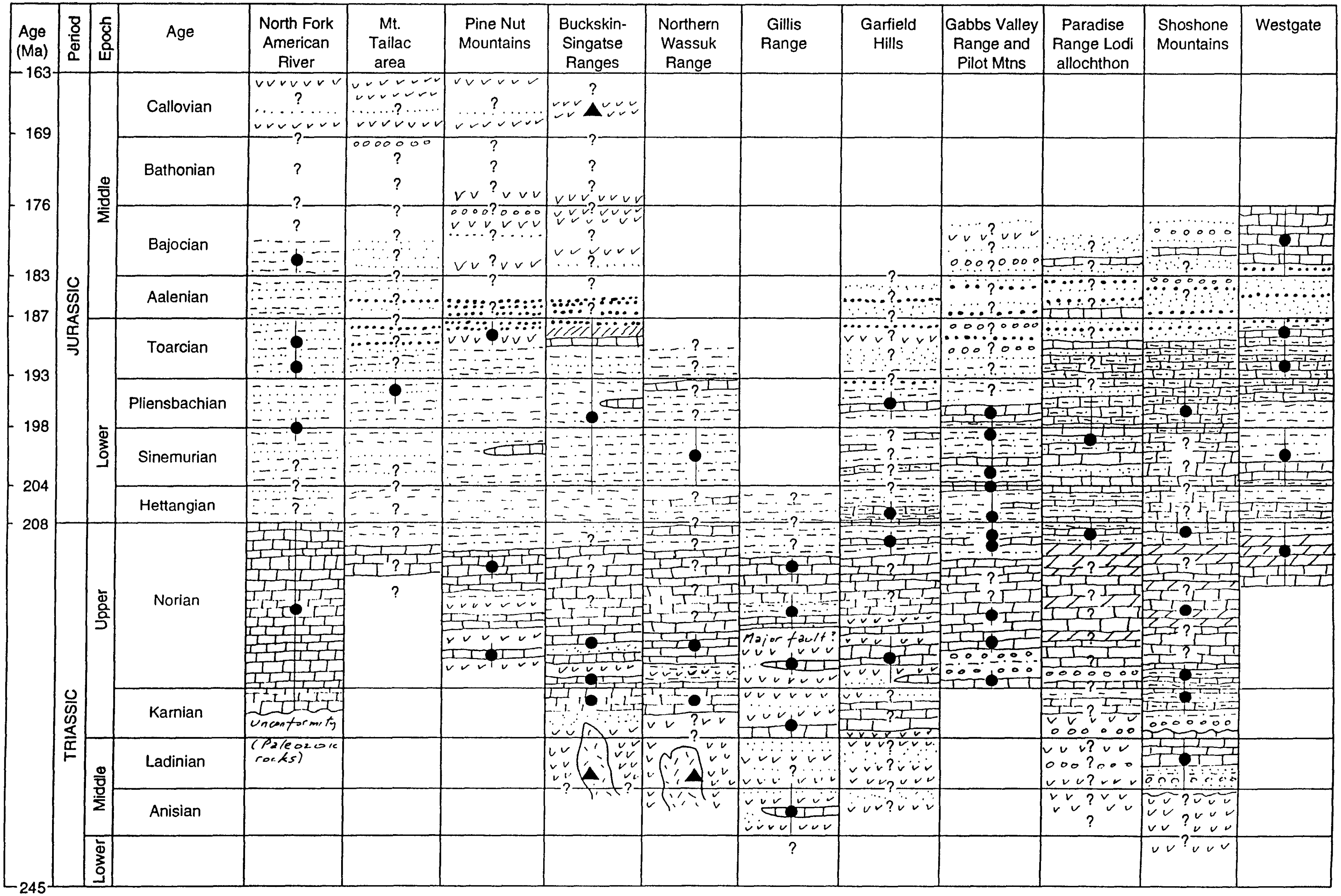


Figure 6. Time-lithic correlations of Mesozoic strata in eastern California to west-central Nevada. Sources of data shown on figure 5 or described in text. Time scale for base of the Triassic and for epochs and ages in the Jurassic from Palmer (1983). Absolute time scale for epochs and ages within the Triassic are poorly known and are not shown.

EXPLANATION (Figure 7)

East of Pine Nut fault

Luning Formation and related rocks. undivided

Pamlico Formation of Oldow (1978a and b)

Luning or Pamlico Formation

Between Pine Nut and Lake Tahoe faults

Oreana Peak Formation, Malachite Mine Formation, Mason Valley Limestone, and related rocks, undivided

West of Lake Tahoe fault

Unnamed limestone, clastic rocks, and tuff

Late Cenozoic high-angle normal fault. Bar and ball on downthrown side

Late Cenozoic strike-slip fault. Arrows show relative movement

Mesozoic thrust fault. Dashed where inferred. Saw-teeth on upper plate.

Hypothetical Mesozoic strike-slip fault. Arrows show relative movement

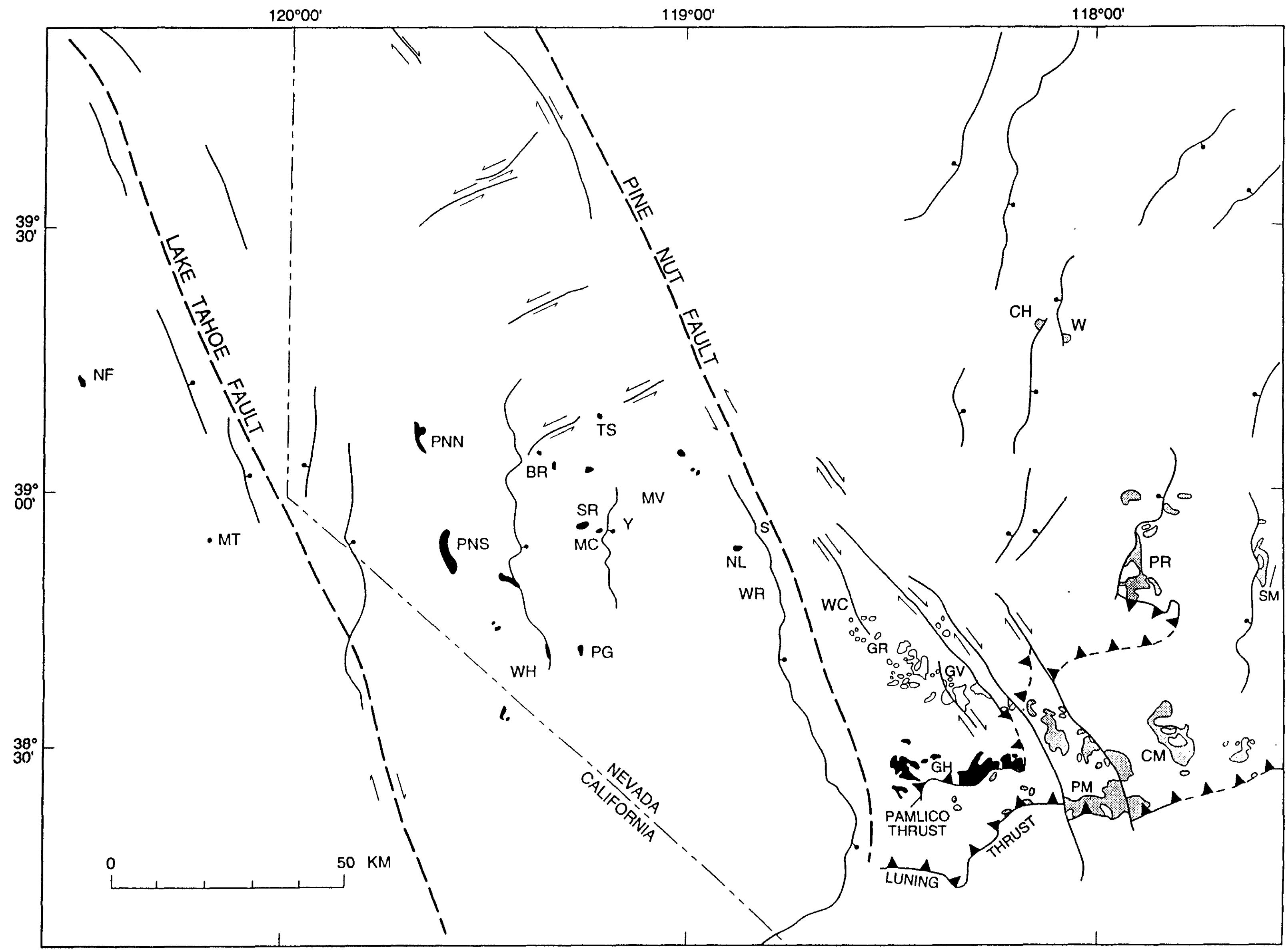


Figure 7. Distribution of the Upper Triassic (late Karnian and Norian) carbonate-rich succession. Localities mentioned in text: BR, Buckskin Range; CH, Chalk Mountain; CM, Cedar Mountains; GH, Garfield Hills; GR, Gillis Range; GV, Gabbs Valley Range; MC, McConnnell Canyon; MT, Mt. Tallac; MV, Mason Valley; NF, North Fork of the American River; NL, Northern Lights mine; P, Pamlico district; PG, Pine Grove Hills; PM, Pilot Mountains; PNN, Pine Nut Mountains, northern part; PNS, Pine Nut Mountains, southern part; PR, Paradise Range; S, Schurz; SM, Shoshone Mountains; SR, Singatse Range; TS, Thompson smelter; W, Westgate; WC, Wildhorse Canyon-Aga Pah Hills; WH, Wellington Hills; WR, Wassuk Range; Y, Yerington.

EXPLANATION (Figure 8)

East of Pine Nut fault

Dunlap Formation and related rocks, undivided

Volcano Peak Group of Taylor and others (1983)

Between Pine Nut and Lake Tahoe faults

Quartz arenite and gypsum--Gypsum and quartzitic sandstone members of Ludwig Formation in Singatse Range, Preachers Formation in southern Pine Nut Mountains and adjacent areas, gypsum in Virginia Range, and gypsum at the Regan Mine, 23 km east of Singatse Range

Gardnerville Formation

West of Lake Tahoe fault

Sailor Canyon, Blackwood Creek, and Ellis Peak Formations, undivided

Late Cenozoic high-angle normal fault. Bar and ball on downthrown side

Late Cenozoic strike-slip fault. Arrows show relative movement

Mesozoic thrust fault. Dashed where inferred. Saw-teeth on upper plate.

Hypothetical Mesozoic strike-slip fault. Arrows show relative movement

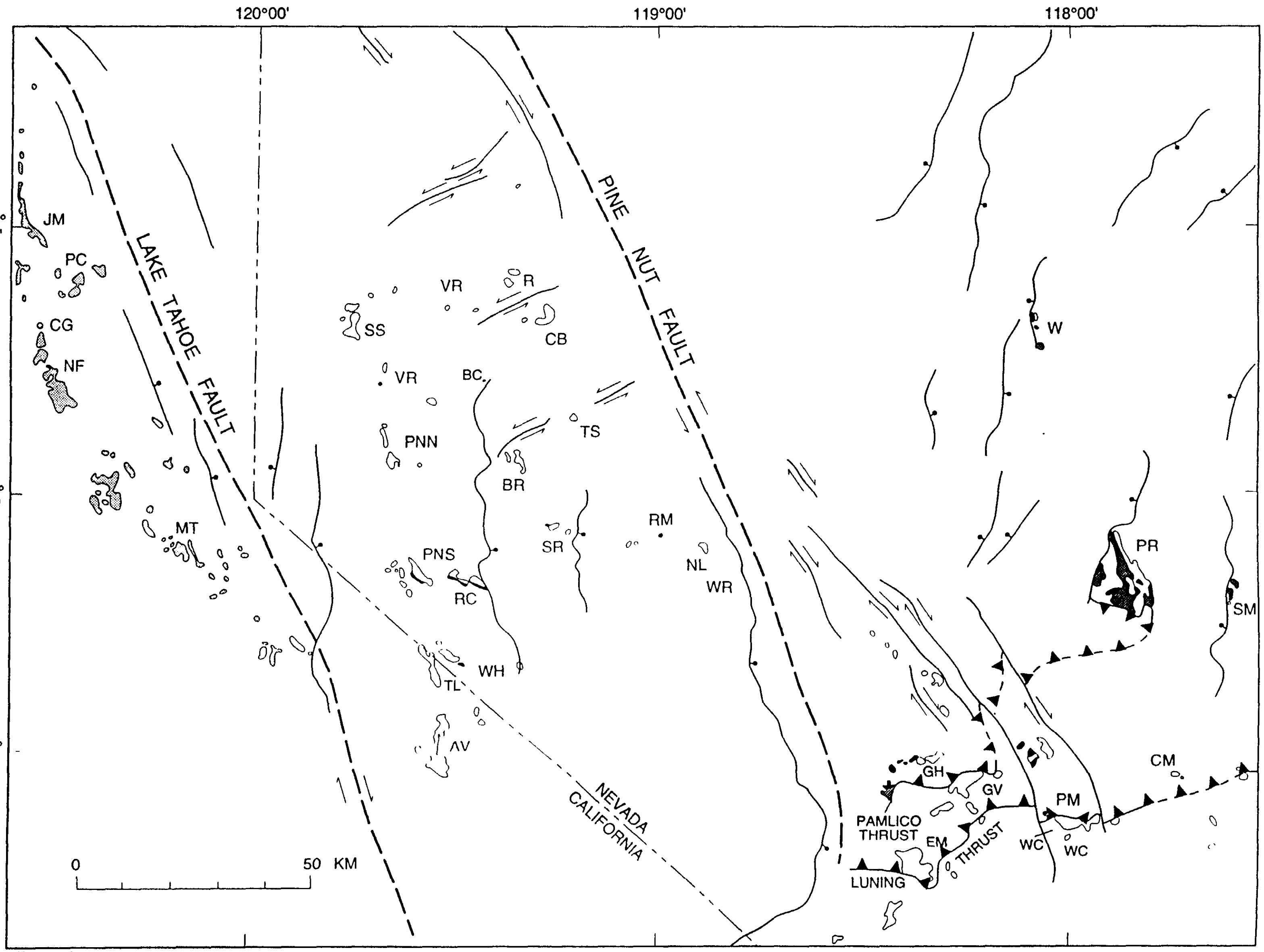


Figure 8. Distribution of the uppermost Triassic (latest Norian) to Middle Jurassic (Bajocian) fine- to coarse-grained clastic succession. Localities mentioned in text: AV, Antelope Valley; BC, Bull Canyon; BR, Buckskin Range; CB, Churchill Butte; CG, Cisco Grove; CM, Cedar Mountains; EM, Excelsior Mountains; GH, Garfield Hills; GV, Gabbs Valley Range, southern part; JM, Jackson Meadow Reservoir; MT, Mt. Tallac; NF, North Fork of the American River; NL, Northern Lights Mine; PC, Perazzo Canyon; PM, Pilot Mountains; PNN, Pine Nut Mountains, northern part; PNS, Pine Nut Mountains, southern part; RM, Regan Mine; PR, Paradise Range; R, Ramsey district; RC, Red Canyon; SM, Shoshone Mountains; SR, Singatse Range; SS, Steamboat Springs; W, Westgate; WC, Water Canyon; WH, Wellington Hills; WR, Wassuk Range; TL, Topaz Lake; TS, Thompson smelter; VR, Virginia Range.

EXPLANATION (Figure 9)

Fulstone Spring Volcanics, Double Spring Formation, and Tuttle Lake Formation, undivided

Artesia Lake Volcanics, Veta Grande Formation, and Gold Bug Formation, undivided

Late Cenozoic high-angle normal fault. Bar and ball on downthrown side

Late Cenozoic strike-slip fault. Arrows show relative movement

Mesozoic thrust fault. Dashed where inferred. Saw-teeth on upper plate.

Hypothetical Mesozoic strike-slip fault. Arrows show relative movement

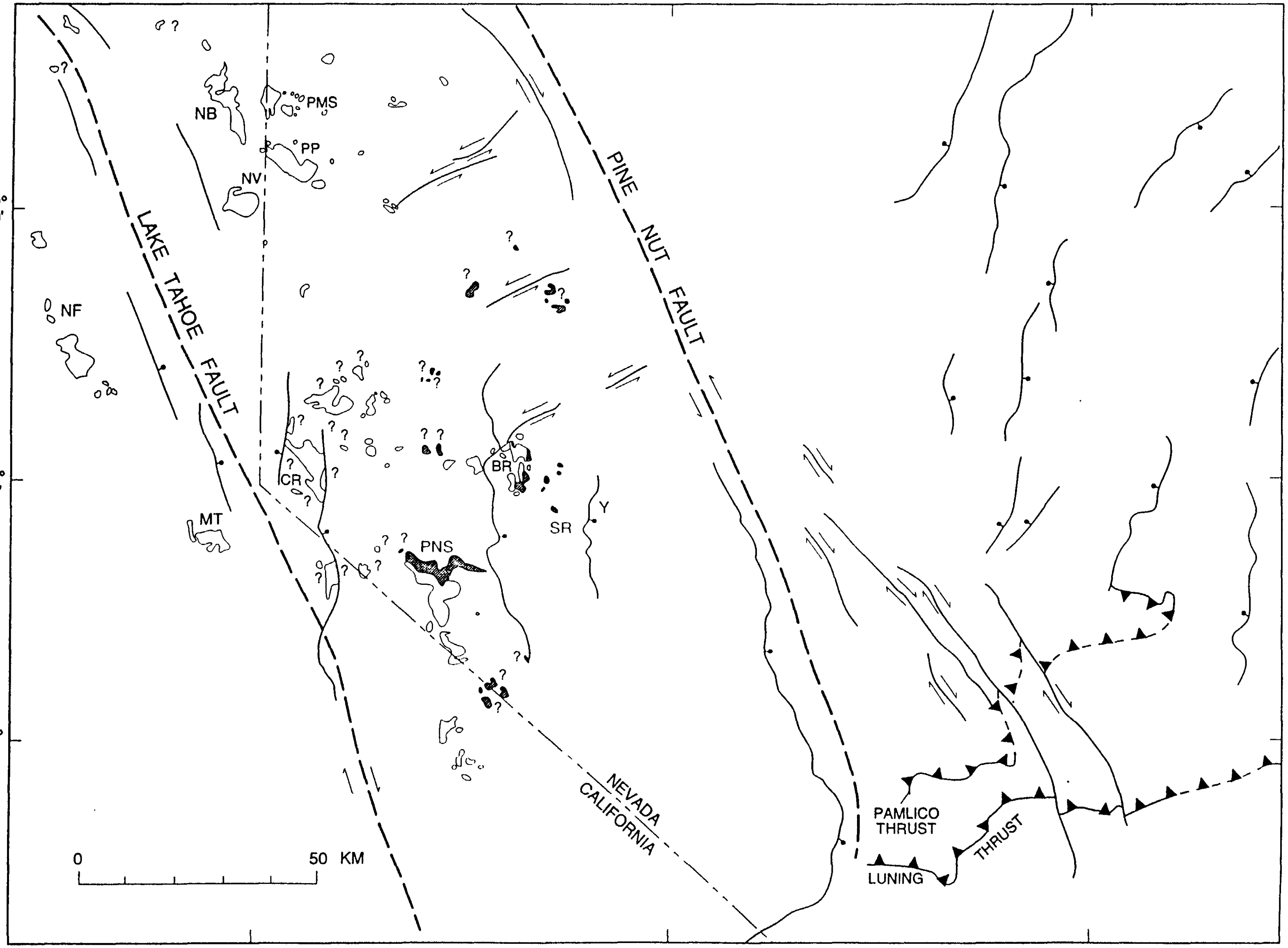


Figure 9. Distribution of the Middle Jurassic volcanic and volcaniclastic succession. Quieries indicate uncertain assignment of rocks to this succession. Localities mentioned in text: BR, Buckskin Range; CR, Carson Range; MT, Mt. Tallac; NB, north of Balls Canyon; NF, North Fork of the American River; NV, Northern Verdi Range-Crystal Peak area; PMS, Peterson Mountain, southern part; PNS, Pine Nut Mountains, southern part; PP, Peavine Peak; SR, Singatse Range; Y, Yerington.

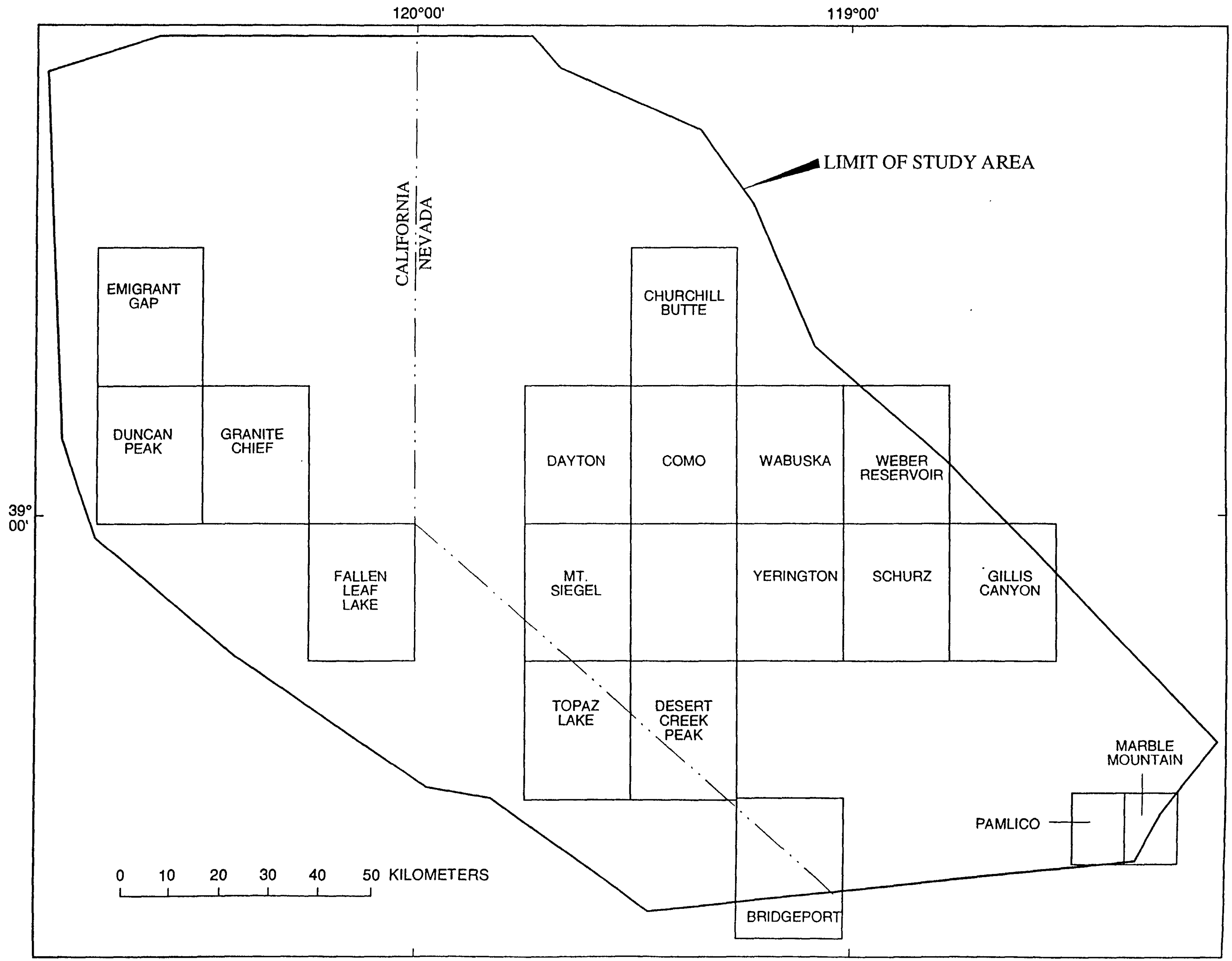
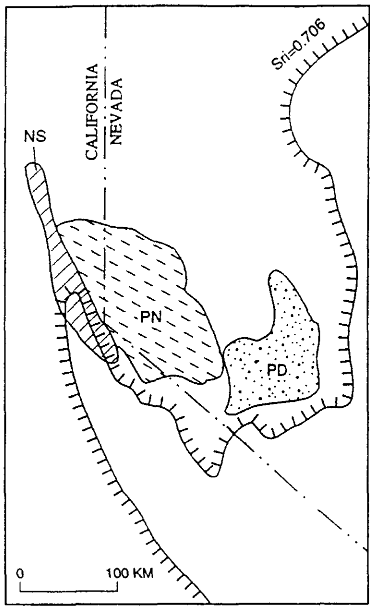


Figure 10. Index map showing location of quadrangles named in Table 1.



MODEL 1

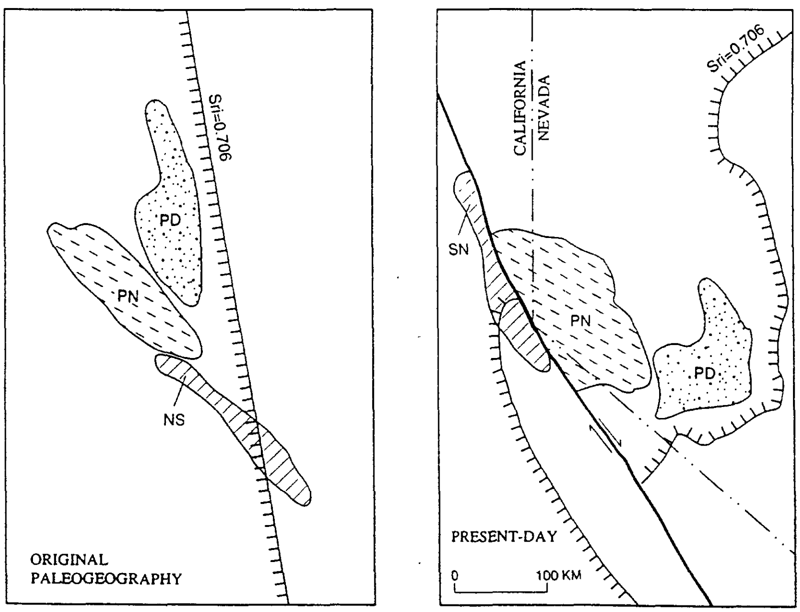
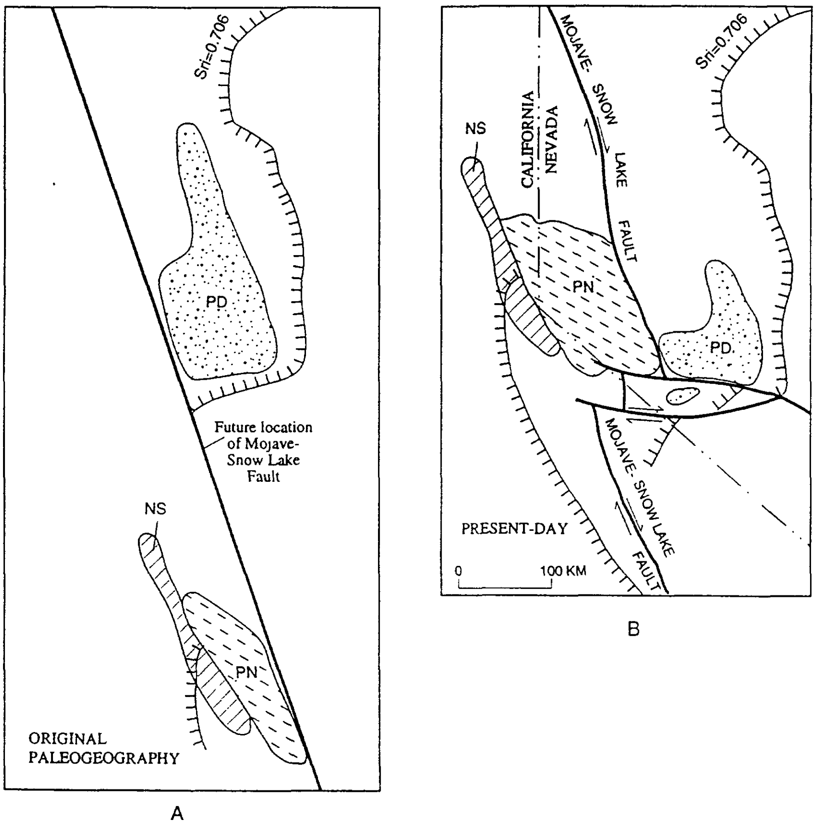


Figure 11A

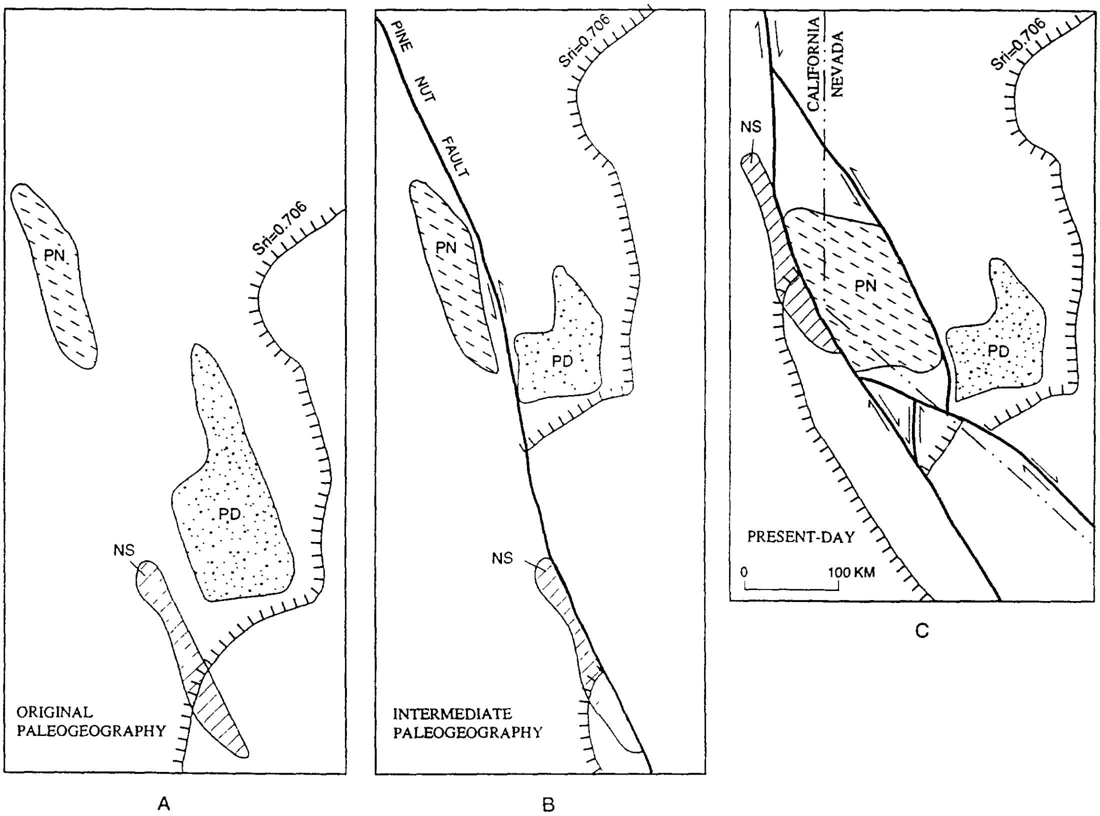
MODEL 2

Figure 11A, B, C (this page and following two pages). Paleogeographic models of Triassic and Jurassic rocks of the Paradise, Pine Nut, and northern Sierra terranes. NS, Mesozoic volcanic and sedimentary rocks in the northern Sierra terrane; PN, Pine Nut terrane; PD, Paradise terrane and adjacent parts of Gold Range terrane, undivided. Hachured line, initial $^{87}Sr/^{86}Sr$ (Sr_i)=0.706 after Kistler (1990). Shape of Pine Nut terrane in reconstructions adjusted to compensate for Mesozoic contraction and Cenozoic extension in models 2, 3, and 4, but not in model 1. Model 1: No major displacements between terranes. Model 2: Reconstruction made on basis that Sr_i isopleth was originally straight. Model 3: Reconstruction based on model of Lahren and Schweickert (1989) and Schweickert and Lahren (1990) showing about 400 km of right-lateral displacement on Mojave-Snow Lake fault. Model 4: Reconstruction based on model of Oldow (1984) showing early left-lateral movement on the Pine Nut fault and later right-lateral movement on the east side of the Sierra Nevada.



MODEL 3

Figure 11B



MODEL 4

Figure 11C