Stratigraphy of Paleozoic and Lower Mesozoic Rocks in the Northern Sierra Terrane, California

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Stratigraphy of Paleozoic and Lower Mesozoic Rocks in the Northern Sierra Terrane, California

By DAVID S. HARWOOD

Revised stratigraphic and structural interpretations of predominantly volcanic and basinal rocks; catalog of 118 old and new fossil localities

U.S. GEOLOGICAL SURVEY BULLETIN 1957

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Stratigraphy of Paleozoic and Lower Mesozoic Rocks in the Northern Sierra Terrane, California

By David S. Harwood

ABSTRACT

Since 1863 more than 100 fossil localities have been found in Paleozoic and lower Mesozoic rocks that lie east of the Feather River peridotite belt in the northeastern Sierra Nevada. New fossil data refine the stratigraphy and, in some cases, provide the basis for new structural interpretations for parts of the northern Sierra terrane.

Conodonts from the Lang sequence of the Shoo Fly Complex indicate a middle Middle to Late Ordovician depositional age for the lowest tectonic block in this Ordovician(?) to Devonian(?) accretionary wedge of quartz-rich rocks and melange. Tectonic amalgamation of the Shoo Fly occurred from the late Early Silurian to the Late Devonian. Serpentinite-bearing melange formed during the late Early Silurian to Late Devonian amalgamation and includes blocks of upper Upper Ordovician bioclastic limestone that contains conodonts and megafossils of North American affinity.

Upper Devonian epiclastic rocks of the Grizzly Formation locally unconformably overlie amalgamated thrust slices of the Shoo Fly Complex and form the oldest unit in the (herein informally designated) Taylorsville sequence, which also includes the Sierra Buttes, Taylor, and Peale Formations. Arc volcanism during deposition of the Taylorsville sequence lasted about 30 m.y. from the Late Devonian into the early Early Mississippian (Kinderhookian). In the late Early Mississippian (Osagean), the volcanic arc cooled, subsided, and was overlapped by siliceous pelagic sediments now recorded in the chert member of the Peale Formation. Pelagic sedimentation, without dilution by other debris, lasted at least to the Middle Pennsylvanian (Desmoinesian).

An erosional unconformity, spanning the Late Pennsylvanian and early Early Permian (early Wolfcampian), separates the Taylorsville arc and pelagic cover rocks from the Permian volcanic sequence. The Permian volcanic sequence consists of a western epiclastic and volcaniclastic facies (the Arlington Formation), a pillow basalt facies (the Goodhue Formation) that gradationally overlies the Arlington locally, and an eastern andesitic volcanic facies (the Reeve Formation and the Robinson Formation of McMath). Megafossils and conodonts date the lower part of the Arlington Formation at its principal reference locality as late Early Permian (late Wolfcampian? to early Leonardian). Radiolarians, fusulinids, conodonts, and megafossils from numerous localities indicate that the Reeve Formation ranges in age from late Wolfcampian to Wordian. Fusulinids in the Reeve have affinity with fusulinids from the McCloud Limestone in the eastern Klamath terrane. Conodonts from a lens of limestone in the Robinson Formation are indicative of an early Late Permian (Capitanian) age. The Taylorsville sequence was differentially eroded prior to deposition of the Permian volcanic sequence. This differential erosion and the distribution of the Permian lithofacies may have been controlled by fault-block basins that formed during heating and uplift related to initial phases of Permian volcanism in late Wolfcampian or early Leonardian time.

An angular unconformity separates mid-Permian and older rocks from Upper Triassic (late Karnian through Norian) conglomerate and limestone at the North Fork of the American River. Upper Triassic rocks in this area are overlain by Lower and Middle Jurassic black slate and volcaniclastic rocks of the Sailor Canyon Formation. The Sailor Canyon Formation is overlain along a local disconformity by a thick section of Middle and lower Upper(?) Jurassic andesitic volcanic rocks of the Tuttle Lake Formation.

West of Lake Tahoe, the Tuttle Lake Formation is faulted on the east against rocks of the Lake Tahoe sequence. The Picayune Valley Formation, the oldest unit in the Lake Tahoe sequence, is composed of black slate, quartzite, and chert-rich conglomerate that are interbedded locally with felsic and andesitic volcaniclastic rocks, which are correlated with the Sierra Buttes Formation of the Taylorsville sequence. The Picayune Valley Formation unconformably overlies the Shoo Fly Complex and is gradationally overlain by metachert of the Serena Creek Formation, which is correlated with the chert member of the Peale Formation. The Onion Creek Formation gradationally overlies the Serena Creek Formation and is composed of quartzite, calc-silicate rock, and limestone. On the basis of lithologic correlations and sparse fossil data, the Picayune Valley Formation is considered to be Late Devonian and Early Mississippian in age, the Serena Creek Formation is considered to be Mississippian or younger, and the Onion Creek Formation is considered to be Mississippian(?) and younger(?). Previous reports correlated these rocks with the Sailor Canyon Formation. The upper part of the Lake Tahoe sequence consists of black slate and limestone of the Blackwood Creek Formation, quartz arenite of the Ellis Peak Formation, and an unnamed black pelite unit. On the basis of poorly preserved ammonites in the Blackwood Creek Formation, the three units in the upper part of the Lake

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Tahoe sequence are considered to be Jurassic in age and correlative, in part, with the Sailor Canyon Formation.

New fossil data from the Taylorsville area have revised the stratigraphy and structure in the northern part of the northern Sierra terrane. North of Genesee, the oldest Mesozoic rocks are ammonite-bearing Middle Triassic (middle Ladinian) tuffaceous slate and volcaniclastic sandstone herein assigned to the Pit Formation. The Pit Formation is conformably overlain by the Hosselkus Limestone, which contains conodonts indicative of a Late Triassic (late Karnian to early Norian) age. The Hosselkus Limestone is juxtaposed on the east against the Upper Triassic (late Norian) Swearinger Slate along a normal fault. Late Triassic (late Karnian to early Norian) conodonts have been recovered from two lenses of limestone at the contact between the Sierra Buttes and Taylor Formations on the northeast slope of Grizzly Peak. These limestone lenses are interpreted to be tectonic slivers of the Hosselkus Limestone entrained along the Taylorsville thrust fault as originally mapped by Diller.

The Taylorsville fault apparently is not folded around the southern end of Mount Jura as shown previously by McMath. The presence of Upper Triassic limestone structurally juxtaposed between strata mapped as the Upper Devonian Sierra Buttes Formation and the Upper Devonian and (or) Lower Mississippian Taylor Formation requires that the Paleozoic and Mesozoic rocks around Mount Jura be interleaved by Jurassic thrust faults much as Diller had originally envisioned.

In the vicinity of Butt Valley Reservoir southwest of Lake Almanor, Upper Triassic conglomerate and limestone overlie andesitic rocks assigned to the Taylor Formation. The Upper Triassic rocks grade up into tuffaceous slate, volcaniclastic sandstone, polymict conglomerate, and lenses of mafic volcanic rocks. The tuffaceous slate contains poorly preserved ammonites of probable Early Jurassic age. This block of Triassic and Jurassic rocks is thrust eastward over the Shoo Fly Complex.

Black tuffaceous slate, volcaniclastic sandstone, and polymict conglomerate, all containing lenses of Permian and Triassic limestone, are tectonically juxtaposed against the block of Triassic and Jurassic rocks southwest of Lake Almanor. The Permian limestone lenses contain fusulinids indicative of zone A of the McCloud Limestone of the eastern Klamath terrane, and the Triassic limestone lenses contain Middle and Late Triassic fossils. These tectonic slivers of Permian and Triassic rocks occur in three separate localities between the Shoo Fly Complex and the Feather River peridotite belt. A pronounced structural and metamorphic break separates these tectonic slivers from the lower part of the Shoo Fly Complex, which was metamorphosed to greenschist facies prior to the Early Jurassic. Therefore, the tectonic slivers of Permian and Triassic rocks apparently were juxtaposed between the Shoo Fly Complex and the Feather River peridotite belt in the Early to Middle Jurassic.

A catalog of fossil localities, collected from 1890 to 1989, gives data on collector, location, geologic setting, and fossil identifications and ages for 118 localities in the northern Sierra terrane. A plate shows the geology of this terrane and the fossil localities.

INTRODUCTION

Protoliths of the metavolcanic rocks now exposed in the northeastern part of the Sierra Nevada were deposited during three successive periods of island-arc volcanism from the Late Devonian to the late Middle Jurassic. Regional unconformities separate the island-arc sequences from each other, and an angular unconformity separates the volcanic sequences from the Ordovician(?) to Devonian(?) Shoo Fly Complex. The volcanic rocks, together with their basement of the Shoo Fly Complex, constitute a multiply deformed but stratigraphically coherent package of rocks referred to as the northern Sierra terrane by Coney and others (1980).

The northern Sierra terrane, like similar Paleozoic and lower Mesozoic volcanic-arc sequences in the North American Cordillera, is generally regarded to be an allochthonous fragment accreted to the west margin of the North American plate. There is no doubt that the northern Sierra terrane formed outboard of the North American miogeocline, but whether it is an exotic, far-travelled terrane or whether it formed along an active North American margin is still very much in debate (Miller and Harwood, 1989). Because the northern Sierra terrane was metamorphosed and remagnetized in situ during the Late Jurassic (Hannah and Verosub, 1980), its paleogeographic ties to other volcanic sequences in the Cordillera and to North America must be established or refuted by comparing detailed stratigraphic, paleontologic, structural, and tectonic data. Fortunately, the metavolcanic rocks and associated chert and limestone strata in the northern Sierra terrane contain enough fossils so that the Late Devonian to Late Jurassic depositional and tectonic evolution of the terrane is fairly well known.

Since 1863, when W.H. Brewer and his field assistant, Clarence King, found the first fossils in the northeastern Sierra Nevada (Whitney, 1865), more than 100 fossil localities have been found in the northern Sierra terrane. Most of the fossil localities have been found in the past 5 years; a fact that reflects improved extraction techniques and a better understanding of radiolarian and conodont taxonomies as well as an intensified search for fossils by geologists working in the area. The new fossil data have established ages for previously undated units and, in so doing, have provided tighter age constraints on unfossiliferous units and the major hiatuses that separate the sequences of rocks. In addition to the fossil data, a few new isotopic ages, primarily U/Pb ages on zircon from the Shoo Fly Complex and granitic plutons that intrude it, provide some constraints on the depositional and tectonic evolution of the Shoo Fly and on the age of magmatic rocks associated with Late Devonian volcanism (Girty and others, 1984; Girty and Wardlaw, 1984, 1985; Hanson and others, 1986; Saleeby and others, 1987).

Recent geologic mapping, much of it associated with Ph.D. dissertations, has provided detailed information on the composition, structure, and stratigraphy of units in small parts of the northern Sierra terrane. Regional syntheses by D'Allura and others (1977), Schweickert (1981), Harwood (1983), Schweickert and others (1984), Hannah and Moores (1986), and Harwood (1988) have integrated many of the local studies into generalized maps and stratigraphic discussions of the terrane. However, new fossil data show a need to revise some of the stratigraphic relations discussed in these summary reports, and many points need clarification.

This report relates the new fossil data to the local geology of several specific areas through the use of large-scale maps included with the text. In several areas, the fossil data provide the basis for revised structural as well as stratigraphic interpretations. The stratigraphic and structural interpretations are set in regional context through the use of stratigraphic columns and a regional map (pl. 1) showing the fossil localities in the northern Sierra terrane. Paleontological data from published reports are integrated with the new fossil data in the "Catalog of fossil localities" (locs. 1–118). The geographic locations of some of the older published fossil localities are not accurately known, but their approximate locations are given, even if the original localities were not found during recent field work. The validity of the faunal lists published in the older reports has not been verified, and anyone using the older paleontologic data should study the original material or recollect the locality.

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To make the regional map, I have relied heavily on the thesis maps and published reports of J.A. D'Allura, Cordell Durrell, G.H. Girty, J.L. Hannah, R.E. Hanson, A.S. Jayko, V.E. McMath, E.M. Moores, R.A. Schweickert, L.A. Standlee, D.E. Stuart-Alexander, and R.J. Varga. In some cases, the original work was modified on the basis of the new paleontologic data and my field work.

Fossils were identified by K.E. Denkler, R.C. Douglass, J.T. Dutro, Jr., Mackenzie Gordon, Jr., A.G. Harris, O.L. Karklins, J.W. Miller, B.L. Murchey, W.A. Oliver, Jr., J.H. Pojeta, Jr., N.J. Silberling, B.R. Wardlaw, and E.L. Yochelson of the U.S. Geological Survey; D.L. Jones, of the University of California, Berkeley; C.H. Stevens, of San Jose State University; and D.G. Taylor of Portland State University. Their efforts to identify deformed, fragmentary, and poorly preserved material is gratefully acknowledged. Helpful reviews of the stratigraphic nomenclature and age assignments were made by James R. Le Compte. Field trips, information on fossil localities, and helpful discussions with M.C. Blake, Jr., C.J. Busby-Spera, Geoff Christe, G.R. Fisher, J.V. Gardner, G.H. Girty, J.L. Hannah, R.E. Hanson, A.S. Jayko, D.L. Jones, M.M. Miller, J.B. Saleeby, R.A. Schweickert, N.J. Silberling, C.H. Stevens, D.E. Stuart-Alexander, J.H. Stewart, B.J. Waugh, and J.C. Yount added greatly to my understanding of the northern Sierra terrane and adjacent regions, but the responsibility for accuracy of the compilation and interpretation is mine alone.

GEOLOGIC SETTING

The northern Sierra terrane consists of Paleozoic and Mesozoic rocks in the northeastern part of the Sierra Nevada, an uplifted and west-tilted range that covers much of eastern California (fig. 1). The terrane lies east of the Feather River peridotite belt (Day and others, 1985) and predates Late Jurassic and Cretaceous plutons of the Sierra Nevada batholith. To the north, the terrane is overlapped by Tertiary and Quaternary volcanic rocks of the Cascade Range, which prevent direct tracing of the Paleozoic and Mesozoic rocks into partly coeval rocks exposed in the eastern part of the Klamath Mountains (Miller and Harwood, 1990). Plutonic rocks of the Sierra Nevada batholith and Tertiary volcanic rocks separate the eastern part of the terrane from coeval rocks in the northwestern Nevada.

The Shoo Fly Complex, which contains the oldest rocks in the northern Sierra terrane, extends along the west flank of the Sierra Nevada to latitude 37°30'N. (Merguerian, 1982; Merguerian and Schweickert, 1987). However, most of the detailed mapping in the Shoo Fly has been done north of the 39th parallel, and only that part of the Shoo Fly is discussed in detail in this report. North of the 39th parallel, the Shoo Fly Complex is composed of four regionally extensive thrust blocks of lower Paleozoic rocks that were structurally amalgamated from the late Early Silurian to the Late Devonian (Saleeby and others, 1987). Limestone interbedded with quartzite-pelite turbidites in the westernmost and structurally lowermost thrust block has yielded middle Middle to Late Ordovician conodonts (Harwood and others, 1988). The tectonically highest thrust block is composed of serpentinite-bearing melange that contains a lens of isotopically dated, upper Lower Silurian tuff (Saleeby and others, 1987) and blocks of Upper Ordovician bioclastic limestone (Hannah and Moores, 1986; Potter and others, 1990).

Between Lake Almanor and the North Fork of the American River, a distance of 120 km, the Shoo Fly Complex is unconformably overlain by Upper Devonian volcanic rocks and local epiclastic deposits derived from the Shoo Fly (Hanson and Schweickert, 1986). The Upper Devonian rocks form the lowest units of a submarine volcanic-arc sequence deposited from the Late Devonian (Frasnian) to the Early Mississippian (Kinderhookian). The

Lower Mississippian volcanic rocks are gradationally overlain by a thin chert unit that contains late Early Mississippian (Osagean) to Middle Pennsylvanian (Desmoinesian) radiolarians (Murchey and others, 1986; Harwood, 1988; Harwood and Murchey, 1990).

A regional unconformity separates the Devonian to Pennsylvanian rocks from an overlying mid-Permian volcanic sequence. The mid-Permian rocks, which range in age from late Wolfcampian(?) to early Guadalupian (Capitanian), consist of a western volcaniclastic and epiclastic facies (Arlington Formation), a central facies of pillow basalt (Goodhue Formation), and an eastern andesitic facies (Reeve Formation and Robinson Formation of McMath, 1958, 1966). Harwood (1988) suggested that these lithologic variations reflect deposition in fault-block basins produced by thermal uplift and extension related to the onset of late Early Permian volcanism.

In the southern part of the northern Sierra terrane, Upper Triassic (upper Karnian through Norian) conglomerate and limestone rest unconformably on mid-Permian volcanic rocks and grade up into Lower and Middle Jurassic volcanic and volcaniclastic rocks. The Mesozoic rocks form a southward-transgressive sequence that progressively overlaps the Paleozoic volcanic rocks and rests directly on the Shoo Fly Complex at the North Fork of the American River (Lindgren, 1897; Clark and others, 1962; Harwood, 1983, 1988; Harwood and others, in press). Mesozoic rocks occur in scattered areas throughout the eastern part of the terrane, and stratigraphic and structural relations become more complex toward the north. East of Taylorsville, Middle Triassic (middle Ladinian) tuffaceous slate of the Pit Formation occurs below the type Hosselkus Limestone (upper Karnian to Norian) and above mid-Permian rocks. Both Diller (1908) and McMath (1958) considered this contact between the Permian and Triassic rocks to be an unconformity along which there may have been subsequent minor faulting. The boundary is locally faulted; however, the amount of transport is unknown, but it could be significant in view of the complex tectonic interlayering of Paleozoic and Mesozoic rocks along Jurassic thrust faults in the Taylorsville area (pl. 1).

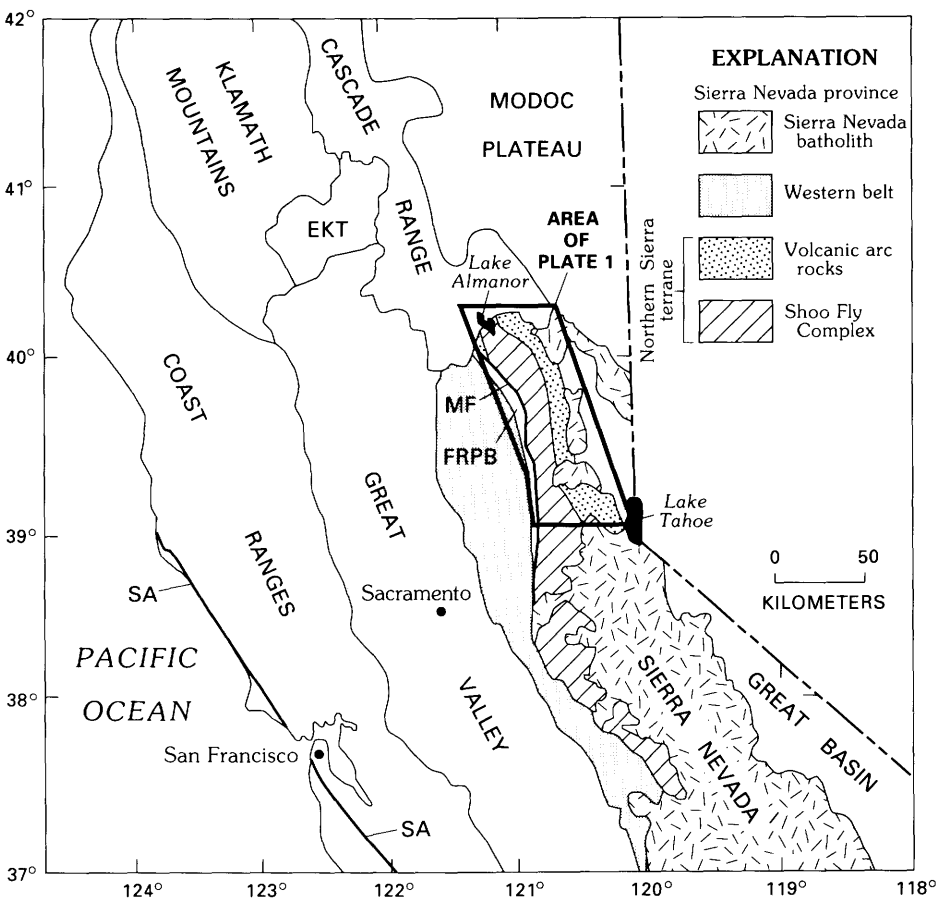


Figure 1. Index map of northern California showing area of plate 1, generalized geology of the northern Sierra terrane, and the Sierra Nevada relative to other physiographic provinces. EKT, eastern Klamath terrane; FRPB, Feather River peridotite belt; MF, Melones fault zone; SA, San Andreas fault zone.

West of Lake Tahoe (pl. 1), Mesozoic volcanic rocks (Tuttle Lake Formation) are structurally juxtaposed on the east with quartz-rich and carbonate rocks of presumed middle Paleozoic age, which are overlain by rocks of probable Jurassic age. Harwood (1988) referred to these rocks as the "Tahoe sequence," but they are referred to herein as the "Lake Tahoe sequence" to avoid possible confusion with deposits of the Tahoe glaciation. The lowest unit in the Lake Tahoe sequence consists of black slate and quartzite that contains eastward-thickening and -coarsening lenses of chert-rich polymict conglomerate. The western part of this unit contains felsic and andesitic volcanic rocks typical of the Upper Devonian Sierra Buttes Formation. Harwood (1988) and Harwood and Murchey (1990) suggested that the Paleozoic rocks of the Lake Tahoe sequence formed in a basin that was receiving volcanic sediment from the Late Devonian and Early Mississippian volcanic arc and quartz-chert-rich sediment shed from the evolving Antler orogenic highland on the continent. Some rocks in the upper part of the Lake Tahoe sequence are considered to be Mesozoic in age, probably no younger than Middle Jurassic.

Along most of the west boundary of the northern Sierra terrane, the Shoo Fly Complex is in fault contact with serpentinite, serpentinized mafic and ultramafic rocks, mafic volcanic rocks, and local slices of garnet amphibolite and blueschist, collectively referred to as the Feather River peridotite belt (Day and others, 1985) or, farther south, as the Foothills ophiolite (Sharp and Leighton, 1987). North of the 39th parallel, slivers of Permian and Triassic rocks occur locally between the lowest thrust block of the Shoo Fly Complex and the Feather River peridotite belt (Harwood and others, 1988). Available evidence suggests that the Permian and Triassic rocks were juxtaposed between the Shoo Fly and the Feather River peridotite belt during or after the Early to Middle Jurassic.

STRATIGRAPHY

Shoo Fly Complex

Diller (1892, 1908) gave the name "Shoo Fly Formation" to interbedded quartzite and slate exposed near Shoo Fly Bridge, which was located on the stage road between Quincy and Crescent Mills to the north. That bridge or a successor is still standing over Indian Creek (NE¼NW¼ sec. 10, T. 25 N., R. 9 E.; Crescent Mills 7.5-minute quadrangle), but it is no longer used nor is it labelled on the Crescent Mills map. The formation name was derived from the settlement of Shoo Fly, which is now shown on the Crescent Mills map as the settlement of Indian Falls. Diller (1908) noted that the unit "is well exposed" near Shoo Fly Bridge and assigned it a Carboniferous age (which at that time included the Permian) on the basis of fusulinids found by Turner (1897) in lenses of limestone associated with slate and quartzite near Spanish Ranch west of Quincy (pl. 1, loc. 75). The fusulinids are now known to occur in limestone blocks that are in tectonic slivers of Permian and Triassic rocks rather than in the Shoo Fly Complex.

In the past 30 years, our understanding of the Shoo Fly has changed remarkably as more and more detailed mapping has been completed. Mapping by Clark and Huber (1975), Clark (1976), D'Allura (1977), D'Allura and others (1977), Standlee (1978), Varga (1980), as well as by R.A. Schweickert and his students (see Schweickert and others, 1984), shows that the Shoo Fly extends geographically southeastward from the area where it was originally mapped. These studies have revealed a degree of stratigraphic and structural complexity in the formation that prompted Schweickert (1981) to suggest the name "Shoo Fly Complex" for the unit. Following Schweickert's lead, the formation was redesignated the Shoo Fly Complex by Harwood (1983).

The Shoo Fly Complex forms a belt as much as 15 km wide that extends for 340 km along the west slope of the Sierra Nevada from Lake Almanor to the Merced River south of this study area (Merguerian and Schweickert, 1987). North of the 39th parallel, the Shoo Fly has been divided into four regionally extensive thrust blocks informally called the (ascending) (1) Lang sequence, (2) Duncan Peak allochthon, (3) Culbertson Lake allochthon, and (4) Sierra City melange (Schweickert and others, 1984; Harwood, 1988). South of the 39th parallel the Shoo Fly consists primarily of interbedded quartzite and pelite with minor chert and limestone that are lithologically similar to the Lang sequence.

Several smaller fault-bounded lithologic units were mapped (Standlee, 1978) west of the Lang sequence in the vicinity of the Middle Fork of the Feather River. Standlee and Nestell (1985) proposed informal names for these fault slices, which they termed terranes; but, until the regional extent of the fault slices is better known, it seems prudent to refer to them as unnamed lithologic units. Some of the fault slices west of the Lang sequence, but east of the Feather River peridotite belt, contain blocks of Lower Permian and Upper Triassic limestone associated with black tuffaceous slate. Harwood and others (1988) proposed that the fault slivers of Permian and Triassic rocks were tectonically juxtaposed against the previously metamorphosed Lang sequence between the Late Triassic and the Middle Jurassic.

Several units, formally named in the older literature, are included here in the Shoo Fly Complex. These units have problems in synonymy that need clarification. Diller (1908) gave the name "Taylorsville Formation" to slate, quartzite, and chert exposed on Grizzly Mountain south of Taylorsville (pl. 1). He considered the serpentinite bodies in the Taylorsville Formation to be

intrusive. McMath (1958) first recognized that the Taylorsville Formation contained distinct blocks of limestone, limestone breccia, and chert in a disrupted matrix of slate and quartzite. Furthermore, he suggested a correlation between the Taylorsville and the Shoo Fly based primarily on the lithologic similarity of quartzite beds in these formations. The lithologic assemblage and degree of structural complexity in the Taylorsville Formation as used by Diller (1908) are identical to those in the Sierra City melange, and the two are considered equivalents in this report. Because of these lithologic and structural similarities, the Taylorsville Formation is here abandoned and its rocks are reassigned to the Sierra City melange of the Shoo Fly Complex.

The Montgomery Limestone, which was named by Diller (1908) for exposures in Montgomery Creek south of Taylorsville, was originally mapped as a discontinuous, but stratigraphically recognizable horizon lying above the Taylorsville Formation and beneath the Grizzly Formation. McMath (1958) clearly recognized that the Montgomery Limestone had no stratigraphic continuity, and he considered it to represent intraformational slump blocks in the Taylorsville Formation. Because a few limestone blocks locally contain megafossils, primarily corals and brachiopods dated by Walcott and Ulrich as Middle Silurian in age (cited in Diller, 1908; see also Merriam, 1972), the Montgomery Limestone has had a significant influence on the age assigned to the Taylorsville Formation and, through McMath's correlation, on the age applied to the Shoo Fly (see Clark, 1976). Boucot and Potter (1977) restudied the megafossils in the Montgomery Limestone and concluded they were Late Ordovician in age (see also D'Allura and others, 1977). Recent studies of conodonts by A.G. Harris (cited in Hannah and Moores, 1986; Saleeby and others, 1987) and of megafossils (Potter and others, 1990) from blocks of the Montgomery Limestone confirm the Late Ordovician age. Because the Montgomery Limestone as used by Diller (1908) is now known to occur as separate blocks of Upper Ordovician limestone in the Sierra City melange of the Shoo Fly Complex rather than as a distinct stratigraphic unit, the Montgomery Limestone is here abandoned and its rocks are reassigned as unnamed limestone blocks in the Sierra City melange.

Lindgren (1900) gave the name "Blue Canyon Formation" to interbedded slate and quartzite exposed in the Colfax quadrangle between the belt of serpentinite, now referred to as the Feather River peridotite belt, and the Jurassic Sailor Canyon Formation. Clark and others (1962) abandoned the Blue Canyon Formation because it was one of three names applied to various segments of the same belt of rocks. Its rocks, which were mapped only in the Colfax quadrangle, were reassigned by them to the Shoo Fly as that name had priority. Recent mapping by Schweickert and others (1984) and Harwood and others (in press) has shown that the Blue Canyon Formation as used by Lindgren (1900) consists of the Lang sequence, the Duncan Peak and Culbertson Lake allochthons, and the Sierra City melange of the Shoo Fly Complex, as well as the Upper Devonian to Permian volcanic rocks that overlie the Shoo Fly.

The age of the Shoo Fly Complex is poorly known because fossils are scarce and very few isotopic studies have been done, as yet, on the sparse volcanic rocks that are interbedded with or structurally interleaved with the dominant quartz-rich rocks. Furthermore, because the Shoo Fly is a tectonic complex composed of numerous thrust slices, an age or range of ages established for rocks in one thrust slice may not apply to those in other thrust slices. The age or ages of the rocks in each thrust slice must be determined independently, and an age or range of ages must be determined for the tectonic amalgamation of the complex as a whole. The depositional history and the tectonic evolution of the Shoo Fly Complex remain the major unsolved problems in the northern Sierra terrane.

In spite of this rather pessimistic introduction to a difficult problem, some data on the age of the rocks in the Shoo Fly Complex are available (fig. 2). All of the major thrust slices in the Shoo Fly Complex are unconformably overlain on the east by Upper Devonian rocks of the Grizzly or Sierra Buttes Formations; therefore, the rocks in these thrust slices and the thrusting must be pre-Late Devonian in age. A block of bioclastic limestone in the Sierra City melange contains Late Ordovician conodonts indicative of North American midcontinent faunas 12 and 13 and a relatively warm-water shelfal or platform depositional setting (pl. 1, loc. 2) (A.G. Harris, written commun., 1985). A second block of limestone in the melange contains a less varied conodont assemblage (pl. 1, loc. 4) that can be dated only as Middle to Late Ordovician in age (K.E. Denkler and A.G. Harris, written commun., 1986). A third block of limestone in the melange (pl. 1, loc. 3) contains corals and brachiopods which were originally identified as early Middle Silurian (see Diller, 1908), then Early Silurian (Merriam, 1972), but which were later dated as Late Ordovician by Boucot and Potter (1977) and Potter and others (1990). A block of chert in the melange yielded Ordovician to Silurian radiolarians (Varga and Moores, 1982). None of these blocks date the formation of the melange. However, zircons from a felsic tuff interbedded with the melange (I1, table 1, pl. 1) have yielded a late Early Silurian U/Pb age ($423^{+5}/_{-15}$ Ma) (Saleeby and others, 1987) that does establish a time line near the base of the melange. This zircon age, coupled with the minimum age provided by the Late Devonian unconformity, indicates that the Sierra City melange formed within the time interval of late Early Silurian to Late Devonian. Furthermore, the biogeographic affinities of conodonts and megafossils from limestone blocks in the melange indicate that the structural amalgamation of the Shoo Fly Complex occurred within the North American biographic province.

Repeated efforts to obtain identifiable conodonts and radiolarians from limestone and chert in the Culbertson Lake and Duncan Peak allochthons have been unsuccessful. However, a lens of limestone in slate and quartzite of the Lang sequence produced middle Middle to Late Ordovician conodonts (pl. 1, loc. 1). The maximum middle Middle Ordovician age for the limestone is the oldest depositional age known, thus far, in the Shoo Fly Complex. In this report the depositional age of Shoo Fly strata is considered to range from the Ordovician(?) to the Devonian(?), while the unit's tectonic age is regarded as ranging from the late Early Silurian to the Late Devonian.

Detrital zircon suites from sandstone in the Shoo Fly have provided valuable provenance ages. Girty and Wardlaw (1984) obtained a minimum U/Pb age of 506±22 Ma on detrital zircons from feldspathic, volcanic-lithic sandstone in the Sierra City melange. Because there is no obvious source for this monocyclic, volcanic zircon suite, Girty and Wardlaw (1984) suggested that it may have been derived from a passing volcanic arc such as the Alexander terrane. The number of uncertainties and assumptions inherent in this interpretation make it highly speculative (see Gehrels and Saleeby, 1987). Quartz arenites with variable amounts of alkali feldspar and plagioclase in the Culbertson Lake allochthon produced detrital zircons that give upper intercept U/Pb ages ranging between 2.0 and 2.1 Ga. Similar Proterozoic provenance ages have been reported in Ordovician and Silurian rocks in the Roberts

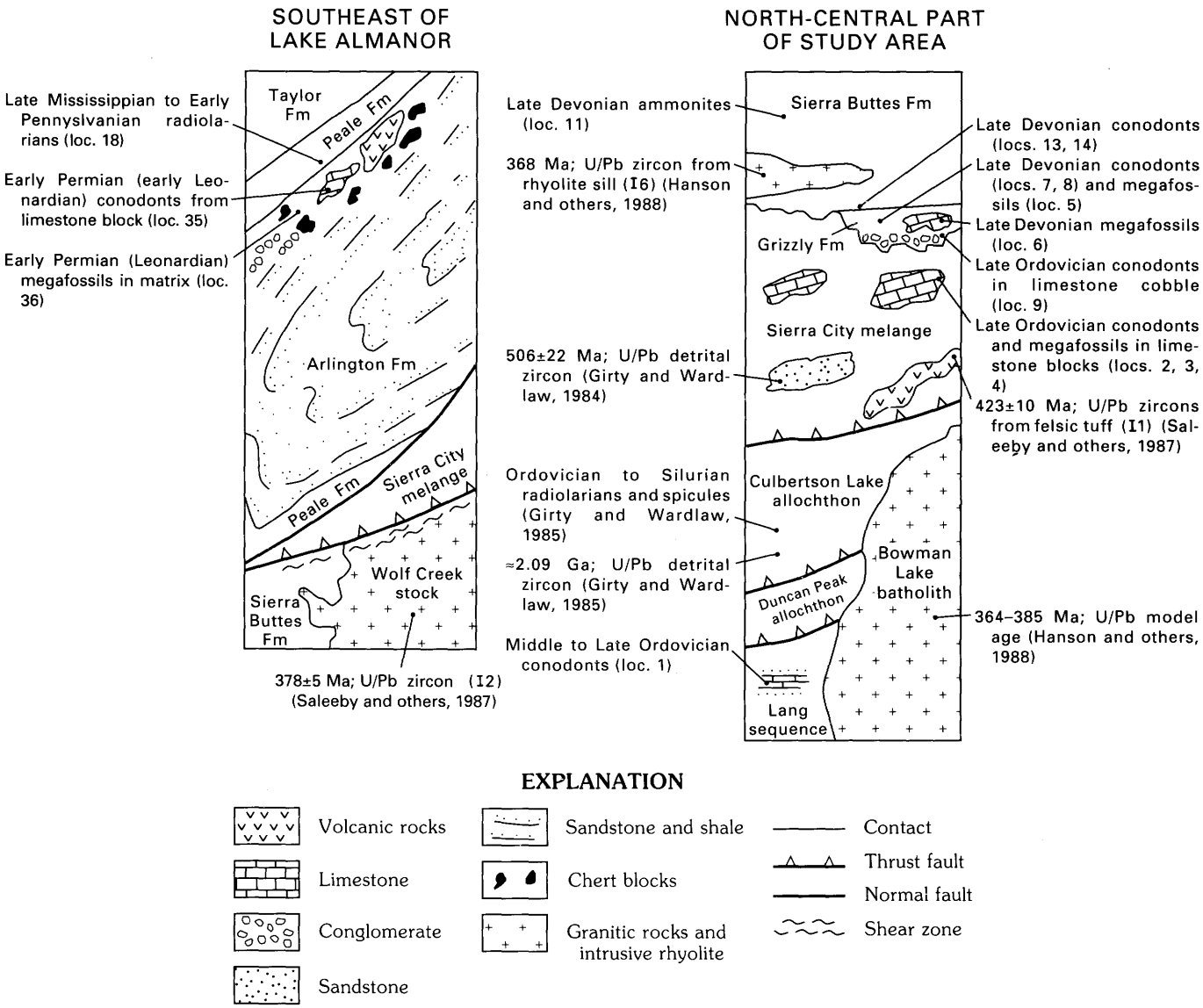


Figure 2. Schematic cross sections showing stratigraphic, structural, fossil, and isotopic-age data that limit depositional and tectonic ages of the Shoo Fly Complex in northern California (expanded from Saleeby and others, 1987). Loc. numbers refer to "Catalog of fossil localities"; I numbers refer to samples on table 1; sites of fossil localities and I samples shown on plate 1.

Table 1. Zircon isotopic-age data, northern Sierra terrane, California

[See pl. 1 for sample site; —, no data]

Sample No. and analyzed fractions	Rock type (map unit, pl. 1)	Isotopic ages (Ma) $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
Sierra City melange (Saleeby and others, 1987)				
I1a	Tuff (DOss)	421	422	422
b		429	429	431
c		444	448	462
Wolf Creek stock (Saleeby and others, 1987)				
I2a	Granite (Dgr)	316	320	354
b		368	368	371
c		378	379	382
Bowman Lake batholith (Hanson and others, 1988)				
I3a	Trondhjemite (Dbit)	379	380	386
b		385	388	405
I4	Granodiorite (Dbgd)	380	381	395
I5a	Granite (Dbg)	365	366	369
b		373	374	380
c		320	325	362
d		289	296	355
e		341	344	369
f		346	349	369
g		352	356	380
Hypabyssal intrusive rocks (Hanson and others, 1988)				
I6	Rhyolite sill (Dhi)	368	368	377
Emigrant Gap mafic complex (Snoke and others, 1982)				
I7	Granodiorite (Jedg)	163	—	—

Mountains allochthon in Nevada (Girty and Wardlaw, 1985). Framework grains in these sandstones indicate a continental-block provenance (Dickinson and Suczek, 1979); however, nothing in the 2-billion-year-old provenance ages demands or negates a North American cratonal source.

Lang Sequence

Rocks forming the lowest major thrust block of the Shoo Fly Complex are referred to informally as the Lang sequence. The Lang sequence is composed primarily of interbedded quartz arenite and pelite with scattered lenses of chert and limestone. Petrographic studies by Bond and DeVay (1980) indicate that the quartz arenites have mature compositions of more than 90 percent quartz and generally less than 10 percent feldspar and lithic grains. Most of the coarser quartz grains are polycrystalline, and some contain inclusions of one or more of the following minerals: orthoclase, plagioclase, apatite, tourmaline, zircon, biotite, muscovite, or hornblende. Bond and DeVay (1980) concluded that the rocks they studied in the Lang sequence were derived from a continental source and deposited as turbidites in a slope or rise environment.

In the Duncan Peak area south of Interstate 80, Harwood and others (in press) divide the Lang sequence into the (ascending) Antoine Canyon Formation, Screwauger Breccia, Big Valley Bluff Formation, and Barney Cavanah Ridge Formation (fig. 3; pl. 1). The Antoine Canyon Formation is composed primarily of thick packets of parallel-laminated, locally ripple crossbedded, fine-grained quartz arenite that probably were deposited in a fairly high-energy, relatively shallow-water environment. The Screwauger Breccia locally overlies the Antoine Canyon Formation and is composed of large blocks of massive quartz arenite, chert, and quartz-granule conglomerate in a chaotic matrix of disrupted quartz arenite and dark pelite.

EXPLANATION

- QTsv — Sedimentary and volcanic rocks (Quaternary and Tertiary)
- Jsc — Sailor Canyon Formation (Jurassic)
- Shoo Fly Complex (Devonian? to Ordovician?)—In this area, consists of:
  - Duncan Peak allochthon—Divided into:
    - DOsdc — Chert
    - DOsdb — Chert breccia
    - DOsda — Argillite, chert, and minor quartzite
  - Lang sequence—In this area, divided into:
    - DOsls — Screwauger Breccia (Devonian? to Ordovician?)—Quartzite, q; chert, c; and granule conglomerate, gc
    - DOslb — Barney Cavanah Ridge Formation (Devonian? to Ordovician?)—Quartzite, q; chert, c; and granule conglomerate, gc
    - DOslv — Big Valley Bluff Formation (Devonian? to Ordovician?)
    - DOsla — Antoine Canyon Formation (Devonian? to Ordovician?)

Contact

Soft-sediment slump contact—Dashed where approximately located; sawteeth on slump deposit

Thrust fault—Dashed where approximately located; sawteeth on upper plate

Strike and dip of bedding and foliation—Dot indicates top of beds

75 Inclined

Vertical

23 Overturned

Figure 3.—Explanation

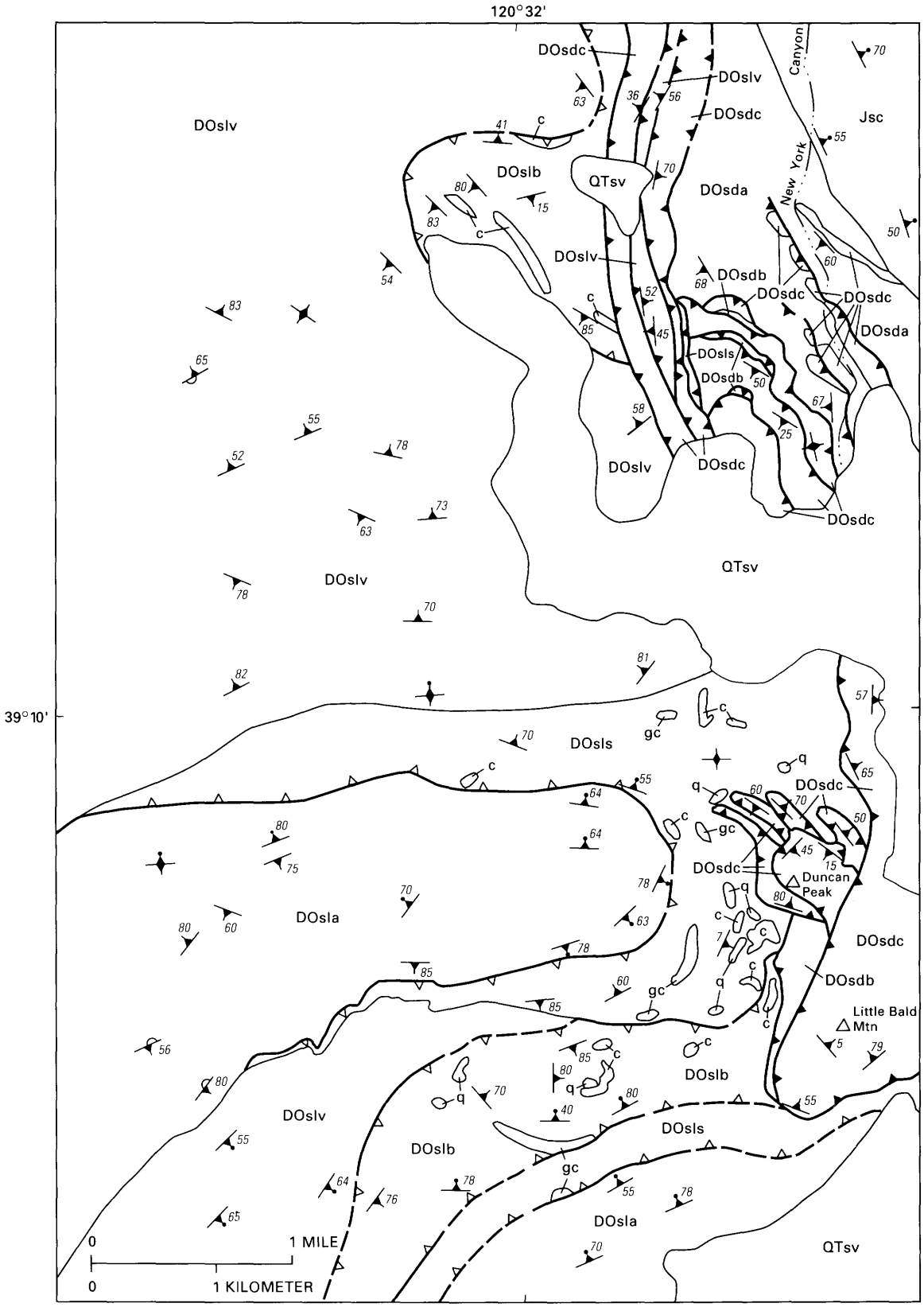


Figure 3. Geologic map of part of Duncan Peak 7.5-minute quadrangle, Calif., showing stratigraphic and structural relations in the Shoo Fly Complex. Geology by D.S. Harwood, 1987.

The breccia probably represents slump deposits (type I melange of Cowan, 1985) that formed when the thrust blocks of the Shoo Fly Complex were amalgamated. The Big Valley Bluff Formation is composed predominantly of distinctly graded beds of quartz arenite and pelite as much as 2 m thick that contain scattered packets of amalgamated coarse-grained quartzite and lenses of quartz-granule conglomerate, chert, and limestone. The lithologic assemblage in the Big Valley Bluff Formation is most typical of the undivided Lang sequence in the rest of the northern Sierra terrane. The Barney Cavanah Ridge Formation is composed of purple and green slate interbedded with thin beds of parallel- and ripple cross-laminated siltstone. Parts of the Barney Cavanah Ridge Formation are chaotic and contain large blocks of massive quartz arenite, chert, and quartz-granule conglomerate lithologically very similar to blocks in the Screwauger Breccia.

Duncan Peak Allochthon

The Duncan Peak allochthon structurally overlies and locally is interleaved with thin slices of the Lang sequence (fig. 3; pl. 1). The Duncan Peak allochthon is composed primarily of chert locally interlayered with chert breccia, and black siliceous argillite. Radiolarians extracted from the chert are indeterminate, and only a minimum Late Devonian age can be established for the allochthon by the unconformably overlying Upper Devonian rocks.

Culbertson Lake Allochthon

South of Bowman Lake (pl. 1), chert in the Duncan Peak allochthon is structurally overlain by rocks of the Culbertson Lake allochthon; but to the north, the Culbertson Lake allochthon rests directly on rocks of the Lang sequence (Schweickert and others, 1984). The Culbertson Lake allochthon is composed of a lower sequence of pillow basalt and basaltic breccia interlayered with chert and overlain by limestone, chert, and argillite (Girty, 1983; Girty and Schweickert, 1984). Girty (1983,1985) interpreted the lower sequence of the allochthon as part of an intraplate seamount. The lower sequence is overlain by thick-bedded subarkosic and quartz-rich sandstone that contains a suite of 2.09-billion-year-old detrital zircons. Girty and Wardlaw (1985) interpreted the upper sequence to be a submarine fan complex deposited off a continental source area composed of Precambrian plutonic and metamorphic rocks and probably Precambrian supracrustal rocks.

Sierra City Melange

The Culbertson Lake allochthon and the underlying Lang sequence are structurally overlain by the Sierra City melange. The melange has been traced north from Bowman Lake, where it is unconformably buried by Upper Devonian rocks, to the vicinity of Taylorsville where it was originally mapped as the Taylorsville Formation by Diller (1908). The melange is composed of blocks of serpentinite, gabbro, pillowed and massive basalt, chert, sandstone, pebbly mudstone, limestone breccia, and bioclastic limestone in a sheared matrix of slate, sandstone, and chert (Schweickert and others, 1984; Girty and Pardini, 1987).

Detailed mapping and petrographic studies by Pardini (1986) and Girty and Pardini (1987) identified a wide variety of sedimentary rocks that occur as clasts in the melange. In addition to the abundant clasts of feldspar-rich and relatively quartz-rich sandstone, they identified inclusions of pebbly mudstone, conglomeratic mudstone with volcanic clasts, and siltstone intimately mixed with blocks of radiolarian chert. Girty and Pardini (1987) concluded that the pebbly mudstone and related clastic rocks represent gravity-flow deposits that were poorly lithified when they were incorporated into the melange as subaqueous gravity slides and slumps. Because the slide deposits are associated with blocks of mafic and ultramafic rocks as well as abundant chert, they concluded, as did many others whom they cited, that the melange formed in an evolving subduction complex. The Screwauger Breccia is remarkably similar in deformation and composition of some inclusions to the Sierra City melange. Although the Screwauger Breccia lacks the variety of blocks present in the Sierra City melange, it probably formed in a similar fashion within the same accretionary complex.

Late Devonian Unconformity

Between Lake Almanor and the North Fork of the American River (pl. 1), lithotectonic units in the Shoo Fly Complex are unconformably truncated by the Upper Devonian Grizzly and Sierra Buttes Formations. In the northern part of the northern Sierra terrane, Upper Devonian rocks lie on the Sierra City melange and, toward the south, they unconformably truncate successively lower lithotectonic units until they lie within a few tens of meters of the Lang sequence at the North Fork of the American River. On the basis of the maximum thicknesses of the Sierra City melange and the Culbertson Lake and Duncan Peak allochthons, as much as a 10-km thickness of the Shoo Fly Complex could have been truncated by the Late Devonian unconformity in a horizontal distance of 120 km (fig. 4) (Schweickert and others, 1984).

Schweickert and Girty (1981) suggested that the unconformity represents a shallow-marine planation surface. However, no littoral deposits have been recognized above the unconformity, and the local accumulations of conglomerate, sandstone, and mudstone, which are mapped as the

Grizzly Formation immediately above the unconformity, are graded turbidites and debris-flow units that contain rip-up clasts and blocks of relatively shallow-water deposits (McMath, 1958; Hanson, 1983). Both McMath and Hanson interpreted the basal Upper Devonian epiclastic rocks as representing submarine slump and fan deposits. Paleocurrent directions have not been determined in the basal Upper Devonian rocks, so the orientation of the paleoslope of the Shoo Fly Complex is unknown.

Taylorsville Sequence

McMath (1958) informally referred to the Paleozoic volcanic rocks in the Taylorsville area as the pyroclastic sequence. This term is misleading in two respects. First, most of the Paleozoic volcanic rocks represent fragmental debris-flow deposits that only locally contain recognizable pumice-rich horizons; thus, the name "pyroclastic sequence" is not really appropriate. Second, and more importantly, the Paleozoic volcanic rocks comprise two temporally and compositionally distinct sequences that are separated by a pronounced erosional unconformity. The older volcanic sequence consists of the (ascending) Grizzly, Sierra Buttes, Taylor, and Peale Formations, which were deposited from the Late Devonian to the Middle Pennsylvanian. The younger volcanic sequence consists of the (ascending) Arlington, Goodhue, Reeve, and Robinson Formations, which were deposited from the Early Permian (late Wolfcampian?) to the Late Permian (late Guadalupian) (fig. 5).

Harwood (1988) referred to all of the Paleozoic volcanic rocks in the northern Sierra terrane as the Taylorsville sequence, which solved the pyroclastic rocks problem but obscured the existence of two Paleozoic volcanic sequences. In this report, the informal name "Taylorsville sequence" is defined as comprising the Grizzly, Sierra Buttes, Taylor, and Peale Formations. The mid-Permian volcanic rocks are referred to informally as the Permian volcanic sequence. The informal and collective name "Taylorsville sequence" is proposed in recognition of McMath's work in the Taylorsville area, which resolved many of the stratigraphic and structural problems in the Paleozoic and Mesozoic volcanic rocks of the northeastern Sierra Nevada that had thwarted regional syntheses for more than half a century.

The Taylorsville sequence comprises the (ascending) Grizzly, Sierra Buttes, Taylor, and Peale Formations, which range in overall age from the Late Devonian (Frasnian) to the Middle Pennsylvanian (Desmoinesian). Fossils have been found in each of the units except the Taylor Formation, whose age is tightly constrained by Late Devonian fossils in the underlying Sierra Buttes Formation and Early Mississippian (Kinderhookian) fossils in the overlying lower (volcanic) member of the Peale Formation.

In the southern and central parts of the northern Sierra terrane, the Taylorsville sequence and the Permian volcanic sequence dip steeply east and form an east-facing homoclinal section that contains significant lateral facies changes, but no major structural dislocations. North of Mohawk Valley (pl. 1), however, the Paleozoic volcanic rocks are overturned, dip steeply to moderately southwest, and are repeated and interlayered with Mesozoic rocks along southwest-dipping thrust faults (pl. 1; fig. 8).

Grizzly Formation

The Grizzly Formation (Diller, 1908) is a discontinuous epiclastic unit, composed primarily of conglomerate, sandstone, and pelite, that lies unconformably on the Shoo Fly Complex and grades upward abruptly into the Sierra Buttes Formation (McMath, 1958). At its here-designated principal reference locality on Grizzly Mountain (sec. 14, T. 25 N., R. 10 E.; Taylorsville 7.5-minute quadrangle; pl. 1) and at Sierra Buttes, the formation is about 300 m thick and has a strike length of 15 to 20 km. Elsewhere, the formation has not been mapped separately, but it may be represented by thin lenses of conglomerate and sandstone that have been included within the Sierra Buttes Formation by other workers.

Significant lithologic variations occur in the formation between Grizzly Mountain and Sierra Buttes. At Grizzly Mountain, the formation is primarily sandstone and pelite interbedded in variable proportions with sandstone comprising about three-quarters of the unit. Chert-quartzite-pebble conglomerate lenses are scattered throughout the formation. McMath (1958) found that the sandstones were predominantly graded quartz arenites composed of about 85 percent rounded quartz grains associated with minor amounts of feldspar, chert, and detrital muscovite. Feldspathic grit beds are interspersed in the formation and contain rip-up clasts and blocks of pelite. McMath (1958) found sponge spicules in the Grizzly Formation on Grizzly Mountain, but they were indeterminate in age and no sample locality was given.

At Sierra Buttes, the Grizzly Formation consists of locally abundant polymict conglomerate and breccia that fill channels cut into interbedded sandstone, pelite, and phosphate-streaked black chert (Hanson, 1983; Hanson and Schweickert, 1986). The conglomerate contains rounded and angular clasts of chert, sandstone, limestone, and dolostone and lesser amounts of diabase and silicic volcanic rocks.

On the basis of sandstone composition, bed forms, and field relations, McMath (1958) and Hanson (1983) concluded that the Grizzly Formation formed below storm-wave base as a series of submarine-fan deposits derived from the Shoo Fly Complex. Hanson (1983), recovered *Palmatolepis* conodont fragments from chert interbeds within the Grizzly Formation (locs. 7, 8) and corals and

gastropods (locs. 5, 6) from shallow-water limestone and sandstone, which he interpreted to be a large slump block incorporated in the submarine-fan deposits. All of these fossils are Late Devonian in age, but the corals and gastropods are indicative of a Frasnian age and the conodonts are middle Famennian (Hanson and Schweickert, 1986). The corals and gastropods currently provide the evidence for the oldest age limit for the Late Devonian unconformity and, at the same time, constrain the early deformation in the Shoo Fly Complex to pre-Frasnian time.

Conodonts extracted from a coral-bearing limestone clast found in polymict conglomerate of the Grizzly Formation at Sierra Buttes (loc. 9) are Late Ordovician in age. Although this conodont assemblage could not be identified to the species level, it contains some of the same genera as the assemblages extracted from the limestone blocks in the Sierra City melange of the Shoo Fly Complex south of Taylorsville (locs. 2, 4). This assemblage not only supports the conclusion that the Shoo Fly Complex was the source of much of the detritus now found in the Grizzly Formation, but it also suggests that the limestone clasts may have been derived from an area generally north of Sierra Buttes because all of the limestone lenses west of Sierra Buttes are barren of megafossils and conodonts.

Sierra Buttes Formation

The Sierra Buttes Formation is characterized by quartz-bearing felsic pyroclastic and volcaniclastic rocks, but locally it contains significant amounts of andesitic tuff breccia, felsic and andesitic intrusive masses, and black phosphate-streaked chert. It lies either gradationally above the Grizzly Formation or unconformably on the Shoo Fly Complex where the Grizzly Formation is missing (fig. 5, 8). McMath (1958, 1966) named the formation for prominent exposures at Sierra Buttes (pl. 1), which have been described in detail by Hanson and Schweickert (1986). Hanson and Schweickert (1986) designated exposures on Sierra Buttes as the type section for the formation (secs. 16, 17, 20, T. 20 N., R. 12 E.; Sierra City 15-minute quadrangle). These exposures should have been designated as the principal reference section in accordance with Article 8(e) of the North American Stratigraphic Code (1983).

At their type section, Hanson and Schweickert (1986) recognized four lithologic members, which they designated as members A, B, C, D. Member A, the lowest unit, consists of felsic and andesitic lapilli tuff and tuff breccia interbedded with chert and tuff. The lower part of member B is composed primarily of massively bedded, amalgamated, felsic breccia and tuff breccia debris-flow units. The upper part of member B contains andesitic clastic debris intermixed with felsic debris and the heterogeneous debris-flow units are interlayered with horizontally laminated felsic tuff and tuffaceous turbidites. Member B is separated from member C by 290 m of andesitic hyaloclastite breccia and pillows, 130 m of coeval intrusive rhyolite, and 50 m of intrusive andesite, which post-dates the lower part of the Sierra Buttes Formation. Member C is composed primarily of coarse-grained felsic tuff-breccia mass-flow deposits interbedded with pumiceous tuff, lapilli tuff, and chert. Member D is composed almost entirely of andesitic tuff, tuffaceous turbidites, and coarse tuff-breccia mass-flow deposits. As shown in figure 6, member D only occurs south of Sierra Buttes where it is overlain by the Peale Formation. In the Sierra Buttes area, member C is overlain by coarse andesitic tuff breccia of the Taylor Formation. Although member D and the Taylor Formation contain similar andesitic deposits, Hanson and Schweickert (1986) separated them on the basis

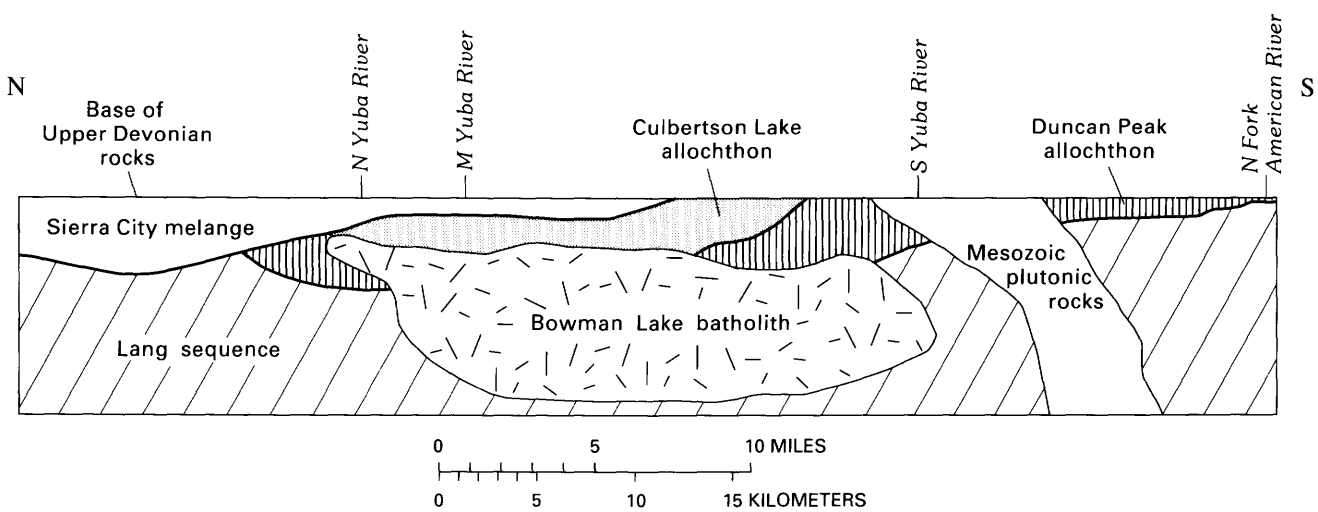
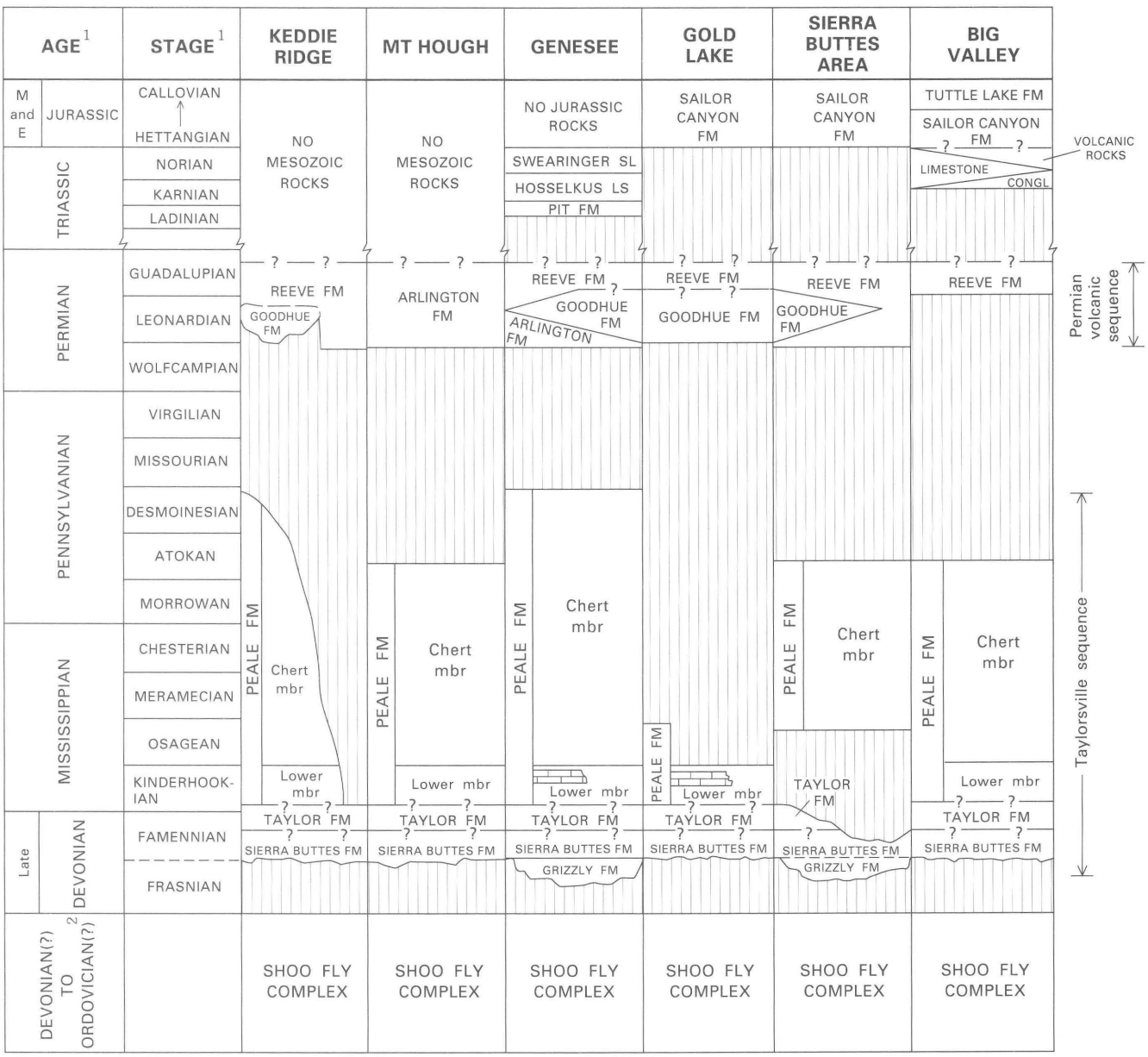


Figure 4. Diagrammatic cross section showing structural imbrication of major thrust blocks in the Shoo Fly Complex and stratigraphic overlap by the Upper Devonian rocks, northern California (modified from Schweickert and others, 1984). Faults shown by heavy lines.

of penecontemporaneous felsic sills (see also Brooks and others, 1982), that occur in the Sierra Buttes Formation but not in the Taylor. At the type section, the Sierra Buttes Formation is about 1,750 m thick (Hanson and Schweickert, 1986).

Significant variations in lithology and thickness occur in the Sierra Buttes Formation north and south of the type section. At the north end of the northern Sierra terrane on Keddie Ridge (pl. 1), Hannah (1980) found that the lower part of the formation consists primarily of felsic to intermediate dikes and felsic hypabyssal intrusive rocks that cut quartz-rich felsic tuff, tuff breccia, and sparse chert. The upper part of the formation contains felsic tuff, tuff breccia, quartz-bearing volcaniclastic sandstone and siltstone, and black phosphate-streaked chert. Hannah (1980) mapped the volcaniclastic rocks and black chert as the Elwell Formation of Durrell and D'Allura (1977). As pointed out by Brooks and others (1982), Harwood (1983), and Hanson and Schweickert (1986), the Elwell Formation of Durrell and D'Allura (1977) has been recognized as a distinct stratigraphic unit only in local areas; therefore, the Elwell Formation of Durrell and D'Allura (1977) is not



[1] See text for specific age and stage assignments for all units shown in this figure

[2] Depositional age range of unit

Figure 5. Stratigraphic columns for the northern Sierra terrane, California, north of 39th parallel. Note erosional unconformity separating the Permian volcanic sequence from the Taylorsville sequence. Ruled lines indicate a hiatus.

shown separately on plate 1, and its rocks are included in this report as part of the Sierra Buttes Formation.

In the vicinity of Taylorsville, McMath (1958) recognized two lithologic units in the Sierra Buttes Formation. Both units are composed primarily of felsic tuff breccia and lapilli tuff, but the breccia fragments in the lower unit commonly contain quartz and plagioclase phenocrysts, whereas those in the upper unit are commonly aphyric. The lower unit of the Sierra Buttes, as well as the underlying Grizzly Formation and Shoo Fly Complex, contain abundant felsic and andesitic dikes.

South of Interstate Highway 80, Harwood (1983) and Harwood and others (in press) have divided the Sierra Buttes Formation into a lower member composed of coarse-grained, quartz-rich felsic tuff breccia with abundant intraclasts of black chert and an upper member composed of black tuffaceous slate that contains sparse beds of tuff breccia and scattered lenses of quartz- and chert-granule conglomerate. Hanson and Schweickert (1986) correlated the lower member with their member C, which forms most of the formation south of its type section. The upper member has not been recognized north of Interstate 80.

From the Taylorsville area south to Bowman Lake (pl. 1), the Sierra Buttes Formation is about 1,750 m thick (McMath, 1958; D'Allura and others, 1977; Hanson and Schweickert, 1986). Immediately south of Interstate 80, the formation is about 800 m thick. The coarse tuff breccia of the lower member pinches out at the North Fork of the American River, where the formation is only 300 m thick and composed solely of fine-grained tuff and tuffaceous slate of the upper member.

The abundance of hypabyssal intrusive rocks in the Sierra Buttes Formation near Taylorsville and Sierra Buttes and the greater thickness of the formation in those areas suggest that submarine vents were located in the northern and central parts of the northern Sierra terrane. The fine-grained tuffaceous slate south of Interstate Highway 80 probably represents a distal facies deposited on the apron of the volcanic pile that accumulated near Sierra Buttes.

The age of the Sierra Buttes Formation is Late Devonian (Frasnian? and Famennian). Radiolarians from chert in the lower part of the formation at the southeast end of Keddie Ridge (loc. 10) are Frasnian or Famennian in age (Hannah, 1980). Conodonts from member C of Hanson (1983), found east of Bowman Lake (loc. 14) and near Culbertson Lake (loc. 13), are middle Famennian in age (Hanson and Schweickert, 1986). Ammonoids from Dugan Pond (loc. 11) are also indicative of a middle Famennian age (Anderson and others, 1974).

A conflict exists in the age of the Sierra Buttes Formation, based on its contained fossils and the isotopic ages from plutonic rocks that are considered coeval with the

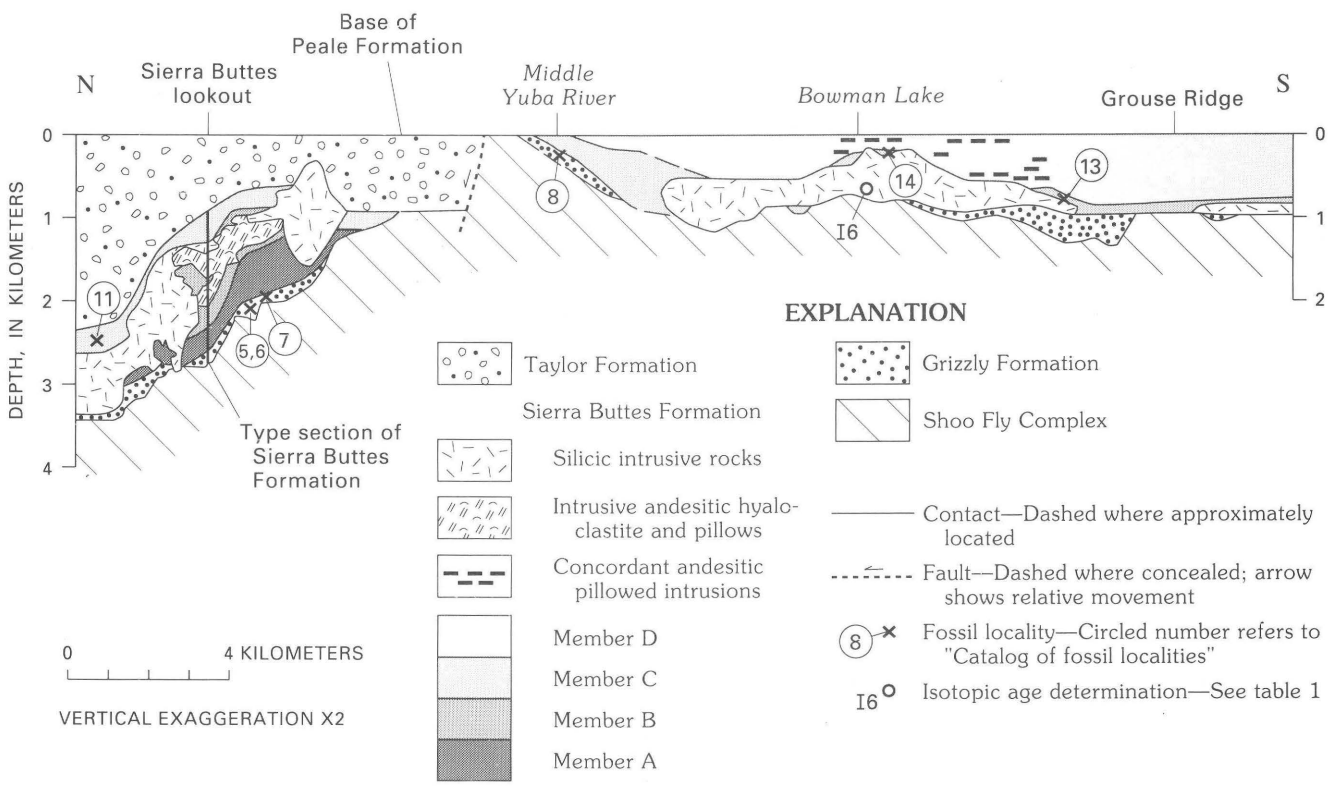


Figure 6. Longitudinal cross section showing stratigraphic and structural relations in the Sierra Buttes and Taylor Formations at and south of Sierra Buttes, Calif. (from Hanson and Schweickert, 1986).

formation in one area and intrude the formation at a second locality. The Bowman Lake batholith, which Hanson (1983) interpreted as the magmatic root of the Sierra Buttes Formation, has been dated (U/Pb on zircon) at 375±10 Ma (table 1, I3–I5) (Hanson and others, 1988). Similarly, Saleeby and others (1987) reported a 378±5-Ma U/Pb age on zircon from the Wolf Creek stock (table 1, I2), which intrudes the lower part of the Sierra Buttes Formation southeast of Lake Almanor. These isotopic ages suggest that magmatism predated initial phases of volcanism represented by the rocks of the Sierra Buttes Formation. However, the uncertainties in the isotopic data, and the uncertainty in the age of the boundary between the Middle and Late Devonian render the discrepancies between the isotopic and fossil ages pointless at this time. The fact that probable plutonic roots to the Devonian volcanic rocks have been identified seems far more significant than the discrepancies in the relative and absolute ages of the Sierra Buttes Formation and the Bowman Lake batholith.

Taylor Formation

Throughout most of the northern Sierra terrane, felsic volcanic and volcaniclastic rocks of the Sierra Buttes Formation are overlain conformably by augite-phyric andesitic rocks. Diller (1908) gave the name "Taylor Meta-andesite" to these rocks and derived the name of the unit from Taylor Rock (pl. 1). Although andesitic material characterizes the Taylor, McMath (1958, p. 61; 1966) recognized a variety of lithic types in the formation including flows(?), sills, tuff breccia, tuff, and slate, and he gave the name Taylor Formation to the Taylor Meta-andesite unit (see also, Burnett and Jennings, 1962). McMath (1958) designated the exposures along the Western Pacific Railroad in the canyon of Indian Creek between Indian Falls and Moccasin as the type section (secs. 34, 35, T. 26 N., R. 9 E.; Crescent Mills 7.5-minute quadrangle) of the formation.

At the type section, McMath (1958) reported that 80 percent of the formation is composed of coarse-grained, augite-phyric andesitic tuff breccia interbedded with tuff and slate and about 20 percent is composed of nonfragmental andesitic flows(?) and diabasic sills. Tuff breccia beds range in thickness from 6 to 30 m and are composed of subrounded to angular fragments that average 10 to 25 cm in diameter but attain a maximum length of 1.5 m. Tuff breccia beds commonly are normally graded; tuff beds are normally graded and commonly parallel laminated. The andesitic fragments are characterized by stubby "apple-green" augite phenocrysts, which make up about 20 percent of the clasts. Plagioclase phenocrysts occur in variable amounts. The matrix of the fragments is composed of felted or trachytic aggregates of plagioclase and interstitial mats of chlorite and white mica. Augite phenocrysts are partially rimmed by actinolite, and plagioclase phenocrysts are altered to calcite, epidote, and sericite. The type section of the Taylor is about 3,000 m thick.

In the vicinity of Gold Lake (pl. 1), Durrell and D'Allura (1977) divided the Taylor Formation into six informal lithologic units designated as units I–VI. Although these informal units have only local stratigraphic significance, Durrell and D'Allura's description of the units provides an important reference section for the formation in the middle part of the northern Sierra terrane (sec. 1, T. 21 N., R. 11 E., and secs. 5, 6, T. 21 N., R. 12 E.; Sierra City 15- minute quadrangle). Unit I contains quartz-rich felsic-tuff breccia typical of the Sierra Buttes Formation interbedded with andesitic tuff breccia and chert fragments. In view of the fact that Hanson and Schweickert (1986) found abundant andesitic breccia in the upper part of the Sierra Buttes Formation, it is unclear whether unit I of Durrell and D'Allura (1977) is equivalent to part of the Sierra Buttes Formation or whether it is a gradational zone at the base of the Taylor. Unit II lies gradationally above unit I and is composed of coarse-grained andesitic tuff breccia in which the augite-phyric andesite fragments commonly range in size from 3 to 45 cm, but attain a maximum length of 1 m. Durrell and D'Allura (1977, p. 848) reported that many of the tuff breccia beds in unit II are calcareous but that no fossil fragments were found in them. Well-bedded tuff, tuff breccia, and pillow lava characterize unit III. Unit IV is composed primarily of schistose andesitic lapilli tuff and breccia. Unit V contains pillow lava, tuff breccia, and crystal-rich tuff. Massive and pillowed andesitic flows characterize unit VI. The flows contain altered augite and plagioclase phenocrysts in a matrix of albite, epidote, hornblende, and chlorite. Amygdules filled with quartz, calcite, epidote, and chlorite are common in the flows. The Taylor is about 3,300 m thick in the vicinity of Gold Lake (Durrell and D'Allura, 1977).

Just north of Sierra Buttes (pl. 1), the Taylor Formation consists primarily of fragmental andesite debris-flow deposits composed of massively bedded, very poorly sorted lapilli tuff and tuff breccia interbedded with finer grained andesite tuff (Hanson and Schweickert, 1986). Andesitic pillow lava and pillow breccia occur locally (Brooks and others, 1982). The tuff breccia contains angular to subangular clasts of massive and amygdaloidal clinopyroxene-plagioclase andesite porphyry dispersed in a matrix of ash and lapilli-sized andesite fragments. The lowermost debris-flow units contain scattered quartz-porphyry clasts apparently derived from the Sierra Buttes Formation. The Taylor thins toward the south, ranging from about 2,300 m thick north of Sierra Buttes to about 1,000 m thick a few kilometers north of the Middle Yuba River (pl. 1) (Hanson and Schweickert, 1986), where it is covered by Tertiary volcanic rocks.

The Taylor Formation is missing at the Middle Yuba River (pl. 1), where the chert member of the Peale

Formation lies disconformably on the Sierra Buttes Formation (Hanson and Schweickert, 1986). This abrupt change in the thickness of the Taylor and the absence of the lower member of the Peale Formation, which normally occurs between the Taylor and the chert member of the Peale, undoubtedly represents a submarine topographic high caused either by synvolcanic high-angle faulting or thermal inflation of the crust due to volcanism or hypabyssal intrusion (Hanson and Schweickert, 1986; Harwood and Murchey, 1990). The three-dimensional extent of this topographic high cannot be determined because the rocks dip steeply east, but it may have been a fairly local feature because the Taylor and the lower member of the Peale occur again south of Interstate Highway 80. The topographic high was overlapped by the chert member of the Peale Formation probably in late Early Mississippian time, but repeated efforts to obtain radiolarians from the chert member at the Middle Yuba River have been unsuccessful. The oldest radiolarians obtained from the chert member elsewhere are Osagean in age, which, at this time, must be viewed as the maximum age for the overlap.

South of Interstate Highway 80 (pl. 1), D'Allura and others (1977) and Harwood (1983) mapped about 400 m of andesitic tuff and crystal-lithic tuff turbidites as the Taylor Formation. The andesitic rocks are characteristically well bedded. Beds range in thickness from 2 to 20 cm and are commonly graded from a fine- to medium-grained feldspar-rich base to an extremely fine grained, parallel-laminated, vitreous top (fig. 7). Faint cross laminations and convolute bed forms occur below the laminated, vitreous tops of some beds. The bed forms suggest T_{a-d} and $T_{a,c,d}$ turbidites in the classic Bouma (1962) sequence. A few lenses of coarser andesitic debris containing angular, clinopyroxene-phyric fragments as much as 3 cm in diameter are scattered in the turbidite sequence. However, andesitic lava flows and coarse debris flows, which are common in the Taylor to the north, are absent in this area. The andesitic turbidites thin toward the south and pinch out north of the North Fork of the American River, where the lower member of the Peale Formation lies on the Sierra Buttes Formation. Harwood (1983) interpreted the andesitic tuff turbidites to represent a distal submarine-fan deposit of the Taylor Formation.

Hanson and Schweickert (1986) suggested that the andesitic turbidites south of Interstate Highway 80, which Harwood (1983) mapped as the Taylor Formation, might be equivalent to their member D of the Sierra Buttes Formation. Felsic sills that distinguish member D from the Taylor are absent south of the highway, so this question is unresolved. However, the andesitic tuff turbidites south of the highway mark a profound change from felsic to andesitic volcanism that is represented by the change from the Sierra Buttes to the Taylor Formations in most of the northern Sierra terrane. Therefore, in this report the andesitic crystal-lithic tuff turbidites are considered to represent a distal part of the Taylor Formation.

No fossils have been found in the Taylor Formation, but its age can be no older than Late Devonian (Famennian) and no younger than Early Mississippian (late Kinderhookian)—the age of the fossils in the overlying lower member of the Peale Formation. Thus, the Taylor is considered to be Late Devonian and (or) Early Mississippian (Famennian and (or) Kinderhookian) in age in this report.

Peale Formation

Diller (1908, p. 24) gave the name "Peale Formation" to a heterogeneous sequence of shale, tuffaceous sandstone, volcanic conglomerate, and chert exposed on the horse trail between Ward Creek and the Peale diggings. Peale diggings are not identified on Diller's map, but they probably are represented by abandoned hydraulic pits in a remnant of Tertiary gravel that caps the 5,725-ft knob on the ridge between Little Grizzly and Ward Creeks, which is labelled Peel Ridge on the Genesee Valley 7.5-minute quadrangle (fig. 8*A*) Because none of the earlier maps label this ridge, it appears that confusion over spelling of the name "Peale" is a relatively recent problem and one of minor consequence. There is no doubt that Diller intended the exposures on the east slope of Peel Ridge to be the "type" locality of the Peale Formation.

McMath (1958) revised Diller's mapping of the Peale Formation and divided the formation into lower and upper members. Furthermore, McMath recognized the Peale Formation west of the Grizzly Mountain fault and thus tied the stratigraphy of the Hough block to that of Peel Ridge in the Genesee block.

The lower member of the Peale Formation consists primarily of alkali-feldspar-phyric tuff breccia, tuff, and flows. The upper member is characterized by varicolored

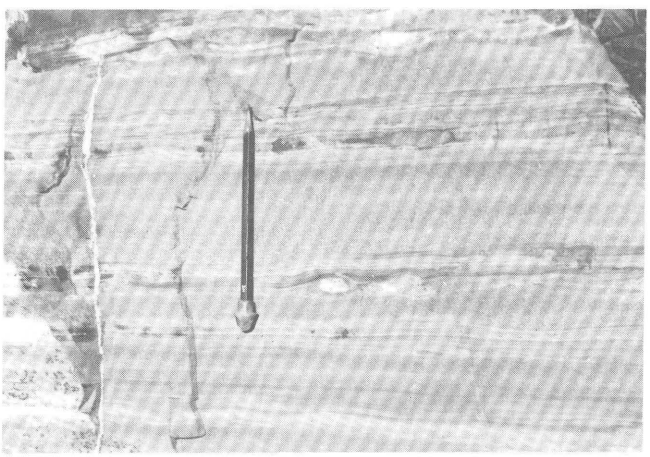
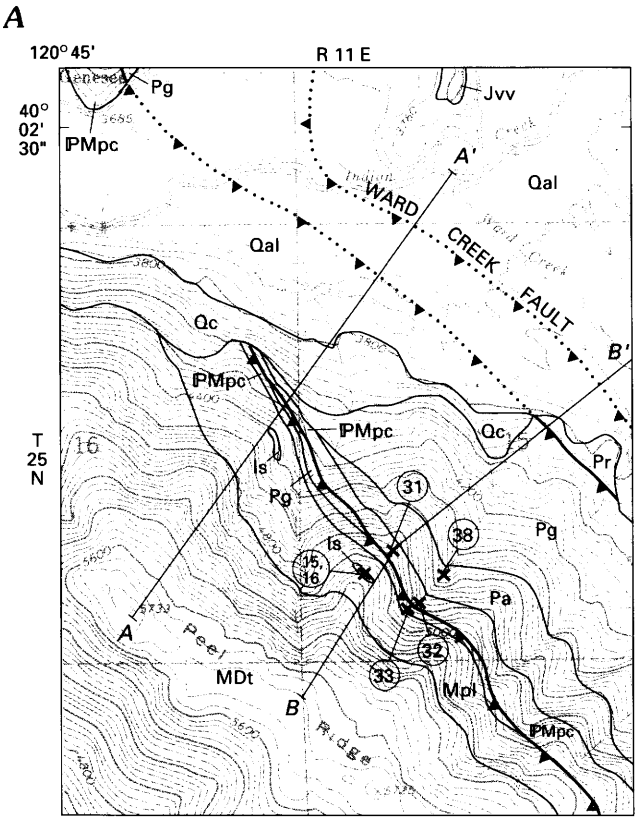


Figure 7. Well-bedded crystal-lithic tuff turbidites in the Taylor Formation south of Lake Valley Reservoir, Calif.



EXPLANATION

Qal	Alluvium (Quaternary)
Qc	Colluvium (Quaternary)
Jvv	Volcanic and volcaniclastic rocks (Jurassic)
Pr	Reeve Formation (Permian)
Pg	Goodhue Formation (Permian)
Pa	Arlington Formation (Permian)
	Peale Formation (Pennsylvanian and Mississippian)—Divided into:
PMpc	Chert member (Pennsylvanian and Mississippian)
Mpl	Lower member (Mississippian)—Includes limestone lenses (Is)
MDt	Taylor Formation (Mississippian and (or) Devonian)
———	Contact
——▲——	Thrust fault—Dotted where concealed
(31)—×	Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 8. Geologic map and cross sections showing fossil localities along Peel Ridge, Calif. Base from U.S. Geological Survey 1:24,000-scale Genesee Valley 7.5-minute quadrangle, 1972. *AA'* and *BB'*, locations of cross sections. *A*, Geologic map along northeast side of Peel Ridge. *B*, *C*, Cross sections showing relations between fossil localities (projected to section *B–B'*), stratigraphic units, and faults on Peel Ridge.

chert, but, as defined by McMath (1958), it also contains locally significant amounts of volcaniclastic graywacke, chert- and volcanic-fragment breccia, red and green slate, and greenstone flows or sills that contain coarse clinopyroxene phenocrysts. New fossil data from Mount Hough and Peel Ridge indicate that the volcaniclastic sandstone, slate, and breccia, included within the upper member of the Peale Formation by McMath (1958) and by Hannah and Moores (1986), are late Early Permian in age and are separated from the varicolored chert by a regional unconformity that spans the Late Pennsylvanian and part of the Early Permian. The greenstone on Peel Ridge, which McMath included in the upper member of his Peale Formation, is part of the Permian Goodhue Formation and is structurally interleaved with the chert member of the Peale Formation (fig. 8*C*).

Hannah and Moores (1986) proposed the name "Keddie Ridge Formation" for the alkali-feldspar-rich, locally quartz-phyric volcanic rocks that make up the lower member of the Peale Formation as recognized by McMath (1958). They stratigraphically restricted the Peale Formation to those rocks that McMath included within his upper member of the Peale. Although Hannah and Moores (1986) cited the exposures on the east flank of Keddie Ridge as typical of the formation, they designated no type locality

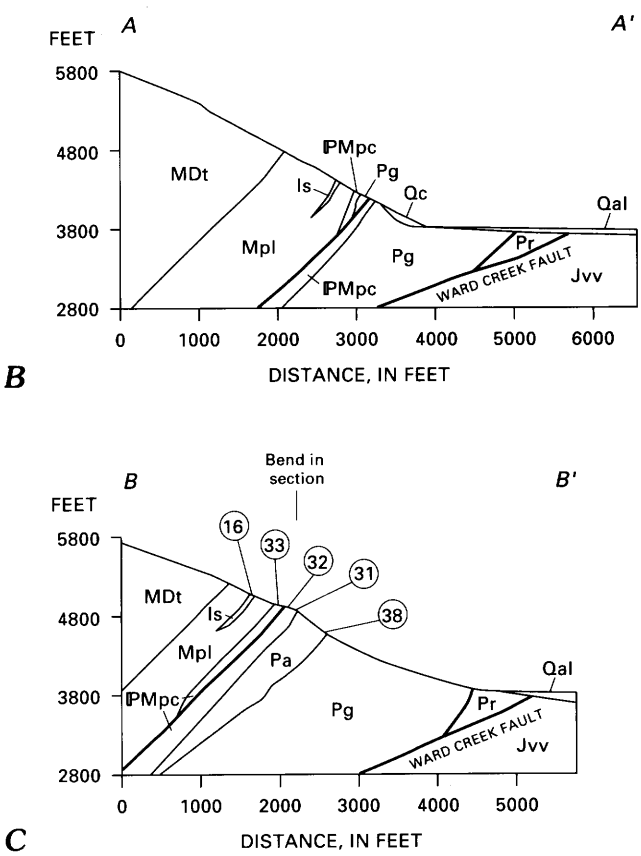


Figure 8. —Continued

and gave only a brief lithologic description of the unit. Furthermore, they considered the Keddie Ridge Formation to be Late Devonian in age because it lies above the Upper Devonian Elwell Formation of Durrell and D'Allura (1977) (considered herein to be part of the Sierra Buttes Formation) and beneath their (restricted) Peale Formation, which they erroneously noted as containing Early Mississippian brachiopods and trilobites reported by McMath (1966). Actually, McMath (1966) stated that the Early Mississippian megafossils occur in the "middle of the formation", but D'Allura and others (1977) erroneously placed the megafossils in the upper member of the Peale as defined by McMath (1958). The Devonian age assignment introduces a significant measure of confusion into the proposed Keddie Ridge Formation because the Early Mississippian fossils reported by McMath (1966) occur in lenses of limestone that are completely surrounded by alkali-feldspar-phyric volcanic rocks (loc. 16), which he mapped as the lower member of the Peale. As Hannah and Moores (1986) pointed out, the lower volcanic part of the Peale represents a significantly different depositional environment and tectonic setting than the upper chert-rich part, and each probably should be given separate formational status. However, because the Keddie Ridge Formation is so poorly defined and erroneously dated by faulty correlation, the name is not used in this report.

The Peale Formation is divided here into two members: a lower member, characterized by volcanic and volcaniclastic rocks, and a chert member, which gradationally overlies the lower member. Following the intent of both Diller (1908) and McMath (1958), exposures on the northeast-trending spur ridge and those in the bed of the ephemeral creek just southeast of the spur ridge on the northeast slope of Peel Ridge (SW¼ sec. 15, T. 25 N., R. 11 E.; Genesee Valley 7.5-minute quadrangle (fig. 8*A*) are here designated as the principal reference locality of the Peale Formation.

Lower Member

At the principal reference locality and elsewhere in the northern Sierra terrane, the lower member of the Peale Formation lies conformably on andesitic volcanic rocks of the Taylor Formation. The contact is marked by an abrupt change in lithologic composition in the volcanic rocks from dark-green andesite of the Taylor to purplish-gray or light-green, alkali-feldspar-phyric, locally quartz-bearing keratophyric tuff of the lower member of the Peale Formation. These lithologies are not interbedded, and andesitic clasts of the Taylor have not been reported in the lower member of the Peale. Feldspar-rich tuff and tuff breccia are the dominant lithologies of the lower member north of Interstate Highway 80 (pl. 1). Volcanic fragments range in size from a few millimeters to 20 cm. Flow banding is common in the larger fragments, and the smaller fragments commonly appear porous and vesicular on the weathered surface. At several localities, notably north of Mount Hough, on Keddie Ridge, and east of Gold Lake (pl. 1), purplish-black pillow lava makes up a significant part of the lower member. Both the fragmental volcanic rocks and the flows are characterized by equant, pink, alkali-feldspar phenocrysts. Limited whole-rock chemical data (D'Allura, 1977) indicate that the volcanic rocks are quartz normative, but quartz phenocrysts are generally sparse. Amygdules of quartz and chlorite are locally abundant in the flows.

Lenses of light-gray-weathering, dark-gray crinoidal limestone, as much as 4 m thick, are interbedded with lapilli tuff of the lower member on Peel Ridge and north of the trail to Fraizer Falls (pl. 1). Near the limestone lenses, the tuff is calcareous and weathers to a dark-rusty-brown, rough surface. On Peel Ridge, limestone lenses occur in the upper part of the lower member; near Fraizer Falls they occur in the middle part of the member.

South of Interstate Highway 80, the lower member is composed primarily of thinly laminated fine-grained tuff and tuffaceous siltstone (Harwood, 1983). The lowermost 50 m of the lower member locally contain dark-purplish-green tuff breccia composed of alkali-feldspar-phyric volcanic fragments. Lenses of chert-pebble conglomerate occur within the tuff breccia, and locally the conglomerate contains sparse pebbles of quartzite derived from the Shoo Fly Complex. Chert-granule conglomerate lenses also occur in the dominant tuff and tuffaceous siltstone that overlie the tuff breccia. South of SP Lakes (pl. 1), the upper part of the lower member is composed of massive, thick-bedded, debris-flow deposits that are locally interbedded with tuff and tuffaceous siltstone. These debris-flow deposits locally contain large clasts of jasper, feldspar-phyric volcanic rocks, and sparse limestone.

The thickness of the lower member ranges from 500 to about 1,000 m throughout its exposure area; the thickest section occurs in the vicinity of Fraizer Falls. D'Allura and others (1977) identified possible vent areas for the lower member near Mount Hough, on the east side of Grizzly Mountain, and near Fraizer Falls, where the unit contains major accumulations of volcanic debris and flows. Clearly, the tuff and tuffaceous siltstone in the southern part of the northern Sierra terrane represent distal submarine deposits derived from a northern source that were mixed with epiclastic conglomerate derived in part, at least, from the Shoo Fly Complex. Because no Shoo Fly clasts occur in the northern exposures of the lower member, it appears that the source of the epiclastic debris was located to the south.

The only direct age control on the lower member of the Peale Formation comes from the lenses of limestone interbedded with lapilli tuff on Peel Ridge (loc. 16) and at Fraizer Falls (loc. 17). Conodonts from the limestone lenses are indicative of the *Siphonodella isosticha*–Upper *S. crenulata* zone of the Early Mississippian (late Kinder-

hookian) (A.G. Harris, written commun., 1984; K.E. Denkler, written commun., 1985). However, the age of the lower member can be no older than Late Devonian (mid-Famennian), based on fossils from the underlying Sierra Buttes Formation, and no younger than mid-Mississippian (Osagean), based on radiolarians obtained from the overlying chert member. Thus, the age of the lower member is regarded as Early Mississippian (Kinderhookian) in this report (fig. 5).

Chert Member

Black, red, green, and gray chert with thin interbeds of siliceous argillite make up the chert member of the Peale Formation. Volcaniclastic sandstone, conglomerate, chert breccia, and slate, included within the Peale Formation by Diller (1908) and considered to be part of the upper member of the Peale by McMath (1958), are here stratigraphically restricted from the chert member because they contain late Early Permian fossils and are reassigned to the lower part of the overlying Arlington Formation. Chert conglomerate, which Harwood (1983) erroneously placed within the uppermost part of the chert member south of Interstate Highway 80, is stratigraphically restricted from the chert member as defined here and reassigned to the overlying Reeve Formation. Black and green chert interbedded with volcaniclastic sandstone near Homer Lake on Keddie Ridge (locs. 41, 42, 43) was included within the upper member of the Peale by Hannah (1980) and cited by Hannah and Moores (1986) as evidence of a depositional contact between the Peale and Reeve Formations. That chert contains late Early Permian radiolarians (loc. 45) and is reassigned in this report to the Reeve Formation.

Harwood (1983) reported latest Late Mississippian and (or) Early Pennsylvanian radiolarians from the chert member in the southern part of the northern Sierra terrane (loc. 34). Subsequent investigations in the northern part of the terrane have yielded radiolarian assemblages that range in age from late Early Mississippian (late Osagean) to the Middle Pennsylvanian (Desmoinesian) (loc. 18 to 33). Because of the sparse number of species in the youngest radiolarian assemblages, the upper age limit of the chert member is uncertain and could possibly extend into the Early Permian (Wolfcampian); but, at this time, a Middle Pennsylvanian minimum age seems most likely (B.L. Murchey, written commun., 1990).

No section has been found that contains all of the radiolarian assemblages typical of the chert member. The oldest assemblage has been found in situ only at the principal reference locality (loc. 33), where a gradational contact with the lower member is exposed. Typically, the lowest part of the chert member contains latest Late Mississippian and (or) Early Pennsylvanian radiolarians, but in most localities the base of the chert member is not exposed, or the lower part of the chert member is barren, or its contact with the lower member is a fault. Clearly, pelagic sedimentation began locally in the late Early Mississippian, but it cannot be demonstrated that it began simultaneously at that time throughout the northern Sierra terrane. If the pelagic sedimentation were time transgressive, however, one might expect epiclastic deposits in the lower part of the chert member, but none have been found. The youngest derived radiolarian assemblage in the chert member varies from place to place throughout the terrane because the chert member is separated from the overlying Permian rocks by an erosional unconformity (see fig. 5). Thus, the chert member is considered to be Early Mississippian (Osagean) to Middle Pennsylvanian Desmoinesian) in age (fig. 5) in this report. The overall age of the Peale is regarded to be Early Mississippian to Middle Pennsylvanian (Kinderhookian to Desmoinesian).

Late Pennsylvanian–Early Permian Unconformity

Schweickert (1981, p. 102) first recognized the unconformity between the Taylorsville sequence and the Permian volcanic rocks in the Middle Yuba River (pl. 1). There, volcaniclastic sandstone interbedded with chert-rich conglomerate and breccia locally fill channels eroded as much as 30 m deep into the chert member of the Peale Formation. D'Allura and others (1977, p. 402) had assigned the chert- and volcanic-rich epiclastic rocks, in which they had found Early Permian fusulinids 3 km to the south (loc. 52), to their upper member of the Peale. Schweickert, however, found that the epiclastic rocks were associated with plagioclase porphyry typical of the Reeve Formation, and he concluded that the unconformity spanned "much if not most of the Pennsylvanian Period" (Schweickert, 1981, p. 102).

Harwood (1983) reported Late Mississippian to Early Pennsylvanian radiolarians from the chert member of the Peale Formation (loc. 34) and mid- Permian fossils (loc. 56) near the base of the overlying Reeve Formation. Although the contact between the Peale and Reeve Formations is not exposed between these fossil localities, Harwood concluded that it must mark a regional hiatus spanning "part or all of the Early Permian and probably the Late Pennsylvanian as well" (Harwood, 1983, p. 419).

Since 1983, about 20 radiolarian localities have been found that indicate the chert member of the Peale ranges in age from late Early Mississippian (Osagean) to Middle Pennsylvanian (Desmoinesian) (Harwood, 1988; see fig. 5 and "Catalog of fossil localities" in this report) and that much of the northern Sierra terrane contains only the lower part of the chert member. Harwood (1988) proposed that an erosional unconformity separates the upper part of the Taylorsville sequence from the Permian volcanic

rocks. The lack of recognized compressive structures in the Devonian to Pennsylvanian rocks and the presence of Shoo Fly detritus in the Permian epiclastic rocks led Harwood (1988) to conclude that the Late Pennsylvanian–Early Permian unconformity represents a period of uplift probably associated with crustal heating and extensional faulting prior to the initiation of late Early Permian volcanism.

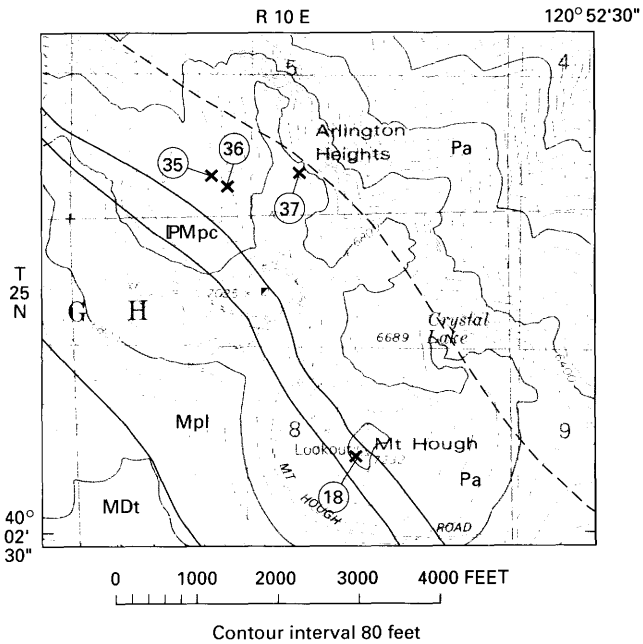
Permian Volcanic Sequence

The Permian volcanic sequence consists of the Arlington, Goodhue, Reeve, and Robinson Formations. The Arlington Formation is composed primarily of volcaniclastic sandstone, slate, conglomerate, and breccia. The Goodhue Formation is composed of pillow basalt and basaltic tuff breccia. The Robinson Formation is composed primarily of volcaniclastic conglomerate, sandstone, and shale, and the Reeve Formation consists primarily of plagioclase-rich andesitic tuff, flows, and hypabyssal intrusive rocks, but it also contains volcaniclastic sandstone, chert, and conglomerate. The Arlington contains plagioclase-rich tuff breccia typical of the Reeve, and the Reeve locally contains chert- and volcanic-pebble conglomerate, like that of the Arlington, at its base. McMath (1958) first recognized the interbedded lithologies of the Arlington and Reeve Formations and suggested that they are probably laterally equivalent lithofacies. He was uncertain about the stratigraphic position of the Goodhue Formation, however, and suggested that it either interfingered with or rested unconformably on the Arlington.

It is now clear that Lower Permian sandstone, slate, and conglomerate, which are lithologically similar to rocks in the Arlington Formation at its principal reference locality, are gradational into the basal part of the Goodhue Formation on Peel Ridge (fig. 8). Therefore, the Arlington Formation is here interpreted to represent a western, predominantly volcaniclastic facies that is the lateral equivalent of the (undivided) Goodhue, Robinson, and Reeve Formations—an interpretation favored by McMath (1958). Stratigraphic and paleontologic data indicate that all of the Permian rocks are separated from the older rocks by a pronounced regional unconformity (fig. 5).

Arlington Formation

Diller (1908) assigned sandstone, shale, and conglomerate exposed on the northeast slope of Mount Hough to the Arlington Formation. He divided the formation into three informal lithologic members on the basis of the relative abundance of sandstone, shale, and conglomerate. However, these lithologic variations are not consistent along strike, and Diller's informal members have not been recognized or perpetuated in subsequent mapping. Diller did not designate a type locality for the formation, but he made reference to the excellent exposures on Arlington Heights (fig. 9), from which he apparently derived the formation name. Following Diller's implied intent, the exposures on and about Arlington Heights that extend northeast toward Hough Creek to an elevation of about 4,400 feet are here designated as the principal reference locality of the Arlington Formation (secs. 4 and 5, T. 25 N., R. 10 E.; Greenville 15-minute quadrangle). Excellent exposures of the conglomerate-rich lower part of the formation occur along the west side of Crystal Lake (fig. 9).



EXPLANATION

Pa	Arlington Formation (Permian)
	Peale Formation (Pennsylvanian and Mississippian)—Divided into:
PMpc	Chert member (Pennsylvanian and Mississippian)
Mpl	Lower member (Mississippian)
MDt	Taylor Formation (Mississippian and (or) Devonian)

——— Contact

(37) × Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 9. Geologic map of Mount Hough–Arlington Heights area, Calif., including lower part of principal reference locality of the Arlington Formation. Dashed line is approximate eastern limit of coarse breccia and conglomerate. Base from U.S. Geological Survey 1:24,000-scale Crescent Mills 7.5-minute quadrangle, 1980.

McMath (1958) recognized the Peale Formation on Mount Hough in strata that Diller had previously included in the Arlington Formation. He also demonstrated that the rocks on Mount Hough were overturned toward the northeast and structurally separated by the Grizzly Mountain fault from the Taylorsville Formation as used by Diller (1908), which is herein recognized as the Sierra City melange of the Shoo Fly Complex. McMath included the sandstone, slate, and conglomerate exposed at Crystal Lake in his upper member of the Peale Formation and placed the lower contact of the Arlington Formation about 100 m northeast of the position shown in figure 9. I agree with McMath's restriction of Diller's Arlington to exclude the volcanic rocks and ribbon chert on Mount Hough and their reassignment to the Peale Formation. However, I do not agree with McMath's assignment of conglomerate and breccia at that locality to his upper member of the Peale; these rocks are here reassigned to the lower part of the Arlington.

Between Crystal Lake and Arlington Heights, the lowermost 100 m of the Arlington Formation consists primarily of chert-rich pebbly mudstone and conglomerate interbedded with variable amounts of green, gray, and reddish-gray volcaniclastic sandstone and slate. Chert fragments are angular to subrounded and range in size from a few millimeters to 20 cm. Sandstone beds are coarse grained, lenticular, and commonly graded. They locally contain folded intraclasts of sandstone, wispy slate fragments, scoured channels, and flame(?) structures. Large blocks of dark-green, aphyric volcanic rocks as much as 50 m in length, as well as blocks of red and gray chert 1 to 10 m in length, occur sporadically throughout the conglomerate-rich lower part of the formation. West of Arlington Heights, two blocks of gray crinoidal limestone, each about 1 m in length, occur in the conglomerate about 50 m above the base of the formation. The limestone blocks are widely dispersed in conglomerate composed of red, green, and gray chert, jasper, and volcanic fragments. Quartz grains are rare in the sandstone beds at the principal reference locality.

The conglomerate grades up into rusty-weathering green volcaniclastic sandstone and slate that contain only scattered thin lenses of chert-granule conglomerate. Locally the sandstone and granule-conglomerate lenses are calcareous and weather to a rough dark-rusty-brown surface. Interbedded slate and volcaniclastic sandstone make up the upper part of the formation.

About 5 km southeast of Arlington Heights along the drainage divide between Montgomery and Taylor Creeks, McMath (1958) found plagioclase-rich andesitic tuff breccia typical of the Reeve Formation interlayered with volcaniclastic sandstone of the Arlington. The andesitic tuff breccia occurs near the structural top of the Arlington and establishes an important lithologic connection between the Arlington and Reeve Formations.

Three fossil localities have been found in the lowermost 100 m of the Arlington Formation at the principal reference locality. One block of gray crinoidal limestone (loc. 35, fig. 9, pl. 1) yielded late Early Permian (early Leonardian) conodonts. Megafossils from the matrix of the conglomerate that contains the limestone blocks are also indicative of an Early Permian age (loc. 36, fig. 9, pl. 1). The most distinctive megafossil is one specimen of *Omphalotrochus*, a gastropod first described by Meek from the McCloud Limestone in the eastern Klamath terrane. This genus has an age range of late Wolfcampian through Leonardian (J.T. Dutro, Jr., written commun., 1986). The third locality (loc. 37, fig. 9, pl. 1) occurs in a lens of volcaniclastic siltstone near the top of the conglomerate, but it contains indeterminate productoid and spiriferoid brachiopod fragments and extremely deformed and flattened bivalve fragments that could not be related to the other collections from the Arlington at the principal reference locality (J.T. Dutro, Jr., written commun., 1986).

The conglomerate and breccia at the base of the Arlington Formation grade upward into dark-green volcaniclastic sandstone and slate. On Arlington Heights, the sandstone and slate are strongly deformed into northwest-plunging, northeast-verging overturned folds that extend through the exposures northeast of the principal reference locality. Chert-rich conglomerate and breccia, which are abundant near the base of the formation at the principal reference locality, pinch out about 4 km northwest and southeast of Arlington Heights, and volcaniclastic sandstone lies directly on the chert member of the Peale Formation.

Intense deformation in the Arlington at the principal reference locality precludes exact measurement of the formational thickness, but McMath (1958) estimated it to be about 2,400 m and Diller (1908, p. 22) measured it at 1,738 m. To the east, the Grizzly Mountain fault places the inverted Arlington Formation in contact with the Sierra City melange of the Shoo Fly Complex. To the west, the Arlington lies unconformably on the chert member of the Peale Formation.

McMath (1958) mapped the Arlington Formation only in the Hough block. However, as much as 200 m of chert-rich conglomerate, red and green volcaniclastic sandstone, and red slate, which are here assigned to the Arlington Formation, occur above the chert member of the Peale Formation on the northeast slope of Peel Ridge (fig. 8). This assignment is made primarily on the basis of lithologic similarity, because fossil fragments found in the conglomerate (loc. 38, fig. 8, pl. 1) are largely indeterminate, except for *Neospirifer*? sp., and cannot be related very closely to the collections from the Arlington at the principal reference locality. The *Neospirifer*? sp. is probably Permian in age (J.T. Dutro, Jr., oral commun., 1986).

Conglomerate beds, 1 to 3 m thick, are abundant in the lower part of the Arlington on Peel Ridge. They contain

rounded to subrounded clasts, as much as 3 cm in diameter, composed primarily of gray and green chert with lesser amounts of felsic volcanic fragments and sparse rounded cobbles of quartzite, apparently derived from the Shoo Fly Complex. The conglomerate grades up into green and purplish-red volcaniclastic sandstone that contains lenses of chert-rich granule- to pebble-conglomerate. Purple and green tuffaceous slate with thin interbeds of volcaniclastic sandstone overlies the conglomerate-rich lower part of the formation, thus producing a distinctly upward-fining unit.

At an elevation of about 4,430 feet in the ephemeral stream that drains the southwest quadrant of section 15 (T. 25 N., R. 11 E.; Genesee Valley 7.5-minute quadrangle, fig. 7), green tuffaceous slate of the Arlington Formation is interbedded with clinopyroxene-rich basalt at the base of the Goodhue Formation. This gradational contact establishes the stratigraphic relation between the Arlington and Goodhue Formations and provides a maximum late Early Permian age, presumably early Leonardian, for the Goodhue Formation in this part of the northern Sierra terrane. Available fossil evidence establishes an Early Permian (late Wolfcampian? and early Leonardian) age for the lower part of the Arlington Formation. The fact that the Arlington and Reeve lithologies locally interfinger suggests that these formations are laterally equivalent facies and that fossil data for the Reeve apply equally well to the Arlington. Therefore, the overall age of the Arlington is regarded as Early Permian, ranging from late Wolfcampian(?) into the Wordian (early Guadalupian) (fig. 5).

Goodhue Formation

McMath (1958, 1966) gave the name "Goodhue Greenstone" to dark-green, augite-porphyry breccia and minor tuff in the Genesee block in the Taylorsville area (Kettle Rock 15-minute quadrangle) that Diller (1908) mapped originally as the Taylor Meta-andesite (since redefined as the Taylor Formation, see usage in this report). Durrell and D'Allura (1977) geographically and stratigraphically extended the Goodhue into the Sierra City 15-minute quadrangle where they referred to it as the Goodhue Formation. This report adopts as the Goodhue Formation the rocks mapped as the Goodhue Greenstone (McMath 1958, 1966) and the Goodhue Formation (Durrell and D'Allura, 1977). The previous designations of a type section (NE¼ sec. 22, T. 25 N., R. 11 E.; Kettle Rock 15-minute quadrangle) and a type locality (east slope of Peel Ridge immediately west of Ward Creek) by McMath are also accepted here. The formation name is derived from the Goodhue homestead located on Ward Creek (building shown on earlier topographic maps but not on the Genesee 7.5-minute quadrangle, 1972).

Although the Goodhue somewhat resembles the Taylor lithologically, it is more mafic, and the augite phenocrysts are larger and more abundant, locally composing 50 percent of the rock. Plagioclase phenocrysts are rare, and the Goodhue contains relicts of a second ferromagnesian phenocryst, probably olivine, pseudomorphically replaced by serpentine, chlorite, and epidote. Moreover, the Goodhue overlies the Peale Formation and locally overlies the Arlington Formation on Peel Ridge, whereas the Taylor Formation underlies the Peale Formation throughout the northern Sierra terrane.

A striking feature of the Goodhue is the monolithologic character of its breccia and flows. Except for an area near Fraizer Falls (pl. 1) where Durrell and D'Allura (1977) reported hornblende-bearing tuff at the base of the formation, the breccia is composed of dark-green, fine-grained, basalt fragments studded with equant phenocrysts of green to black augite as much as 10 mm in diameter. Pillowed basalt flows are locally abundant and much of the breccia is composed of disrupted pillow structures. Neither the breccia nor the flows contain traces of pelagic sedimentary deposits between the fragments or pillows, and bedding is rarely observed. The groundmass of the basalt is composed of plagioclase microlites, chlorite, epidote, calcite, magnetite, and acicular calcic amphibole partially rimming augite. Equant mats of chlorite, epidote, talc(?), magnetite, and sphene, which probably represent pseudomorphic replacement of olivine, are scattered in the groundmass of the basalt.

On Peel Ridge (fig. 8*A*), the lowermost 2 m of the Goodhue Formation is gradational into green tuffaceous slate at the top of the Arlington Formation. On strike to the northwest and southeast, however, the Goodhue lies on either the chert member or the lower member of the Peale Formation with apparent local conformity. However, radiolarians in the chert member below the Goodhue are no younger than Middle Pennsylvanian in age and are commonly no younger than Early Pennsylvanian, indicating the presence of a major hiatus between the chert member of the Peale Formation and the Goodhue.

In the lower part of the Goodhue east of Fraizer Falls (pl. 1), Durrell and D'Allura (1977) found about 500 m of hornblende-bearing andesitic tuff that grades upward into augite-bearing basalt typical of the Goodhue elsewhere in the northern Sierra terrane. They argued that the hornblende-bearing andesitic tuff is lithologically identical to the matrix of a float block that contains a single specimen of *Helicoprion sierrensis* (Wheeler, 1939) found in glacial debris in Fraizer Creek (pl. 1). Wheeler (1939) concluded from its world-wide occurrences that *Helicoprion* ranged in age from the Uralian to the Artinskian (Late Pennsylvanian to late Early Permian), and Durrell and D'Allura (1977) assigned this age range to the Goodhue. More recently, however, Chorn (1978) has shown that the only undisputed reports of *Helicoprion* are restricted to the Early Permian. This age is more compatible with the gradational contact between the Goodhue and the poorly fossiliferous volcaniclastic rocks herein assigned to the Ar-

lington on Peel Ridge. This depositional contact suggests that the Goodhue is no older than Early Permian (Leonardian) in age. At Little Grizzly Creek (loc. 48, pl. 1), the Goodhue is overlain by the Reeve Formation that contains fossils indicative of a late Early Permian (Wordian) age. Therefore, the age of the Goodhue is considered to be Early Permian (Leonardian to early Guadalupian) in this report. The youngest occurrence of *Helicoprion* is early Guadalupian (Chorn, 1978).

The chert member of the Peale Formation is missing at Fraizer Falls, and the Goodhue lies directly on volcanic rocks of the lower member of the Peale. Either the chert member was not deposited near Fraizer Falls or it was eroded from the area before the Goodhue was deposited. D'Allura and others (1977) suggested that the Goodhue may have been erupted from a vent located near the Fraizer Falls area. Harwood (1988) has suggested that the Goodhue was erupted into a restricted, extension-related fault-block trough (see also Lauman and others, 1987).

Near Peel Ridge the maximum thickness of the Goodhue is about 1,200 m (McMath, 1958), and Durrell and D'Allura (1977) reported 2,800 m of the Goodhue at Fraizer Falls. East of Sierra City the Goodhue is only 220 m thick (Schweickert and others, 1984), and it pinches out north of the Middle Yuba River. In the southern part of the northern Sierra terrane, the Reeve Formation lies unconformably on the chert member of the Peale Formation.

Reeve Formation

Diller (1908) gave the name "Reeve Meta-andesite" to plagioclase-rich breccia and tuff that occur near Genesee (pl. 1). Although he recognized the fragmental character of the igneous rocks, he considered the Reeve to represent brecciated flows and tuff gradationally bounded on both sides by locally fossiliferous tuff, sandstone, and conglomerate that he assigned to the Robinson Formation. McMath (1958, 1966) renamed the Reeve Meta-andesite as the Reeve Formation and included within it much of the interbedded tuff, sandstone, and conglomerate that Diller had mapped as the Robinson. I agree with McMath's definition of the Reeve. Neither Diller nor McMath established a type section for the Reeve, but McMath (1958) designated the exposures in the Hosselkus Creek drainage (sec. 4, T. 25 N., R. 11 E.; Genesee Valley 7.5-minute quadrangle; fig. 10) as part of the type locality. He also included the readily accessible outcrops north of the road in Genesee Valley (NW¼, sec. 10, T. 25 N., R. 11 E. Genesee Valley 7.5-minute quadrangle) as part of the type locality. I concur with this designation. The derivation of the name "Reeve" is unknown.

At the type locality, andesitic tuff breccia and lapilli tuff make up about three-quarters of the Reeve Formation, and tuffaceous slate, volcaniclastic sandstone, calcarenite, and chert-rich conglomerate make up the remainder of the unit exposed there (McMath, 1958). The andesite flows mentioned by Diller (1908) have not been found at the type locality, but D'Allura (1977) and D'Allura and others (1977) noted massive and pillowed flows as well as sills in several areas to the south. Hannah (1980) also mapped a large body of plagioclase porphyry as part of the Reeve on Keddie Ridge (pl. 1).

The andesitic tuff breccia, lapilli tuff, flows, and intrusive rocks in the Reeve are characterized by abundant white-weathering plagioclase phenocrysts that locally attain a length of 10 mm. Clinopyroxene phenocrysts are generally small and sparse. D'Allura (1977, p. 163) noted rare mats of ferrostilpnomelane, magnetite, and albite in some thin-section samples, which he interpreted as pseudomorphic after olivine, but no primary olivine has been recognized in the Reeve. The phenocrysts occur in a dark-gray or bluish-gray, fine-grained groundmass composed of plagioclase microlites and variable amounts of chlorite, calcite, sericite, magnetite, ferrostilpnomelane, epidote, and garnet depending on the grade of metamorphism. The flows locally contain large irregularly shaped amygdules filled with calcite (D'Allura and others, 1977). At the type locality and, to a lesser extent, elsewhere in the northern Sierra terrane, tuff breccia is interlayered with volcaniclastic sandstone, tuffaceous slate, and chert-rich volcaniclastic conglomerate. In local areas, such as on Keddie Ridge and at Fir Hill (loc. 52, pl. 1), interbedded volcaniclastic sandstone, thin stringers of chert, and chert-rich conglomerate, totaling a few hundred meters thick, form the lower part of the formation.

At the type locality, the Reeve ranges in thickness from 330 to 700 m. The western, stratigraphically lower contact of the Reeve Formation is not exposed, but D'Allura and others (1977) reported a conformable, possibly gradational, contact with the Goodhue east of Quincy (pl. 1). In the Hosselkus Creek drainage (fig. 10), the Reeve is overlain by the conglomerate-rich Robinson Formation and by the Triassic Pit Formation and Hosselkus Limestone. McMath (1958) suggested that the contact between the Reeve and Robinson is a disconformity. The contact between the Reeve and the Hosselkus is interpreted by Diller (1908) and McMath (1958, 1966) as an unconformity that was subsequently dislocated by faulting.

The Reeve Formation is Early Permian (late Wolfcampian or early Leonardian ranging into Wordian). This age range has been established by numerous fossil occurrences located sporadically along the length of the northern Sierra terrane. However, as some of these fossil localities have been included within other formations in the past, the stratigraphic relations at these fossil localities need clarification.

On the northeast slope of Dyer Mountain (pl. 1), Hannah (1980) found fusulinids in the poorly sorted volcaniclastic matrix of chert-pebble conglomerate (loc. 39, fig. 11, pl. 1). The fusulinid-bearing conglomerate occurs

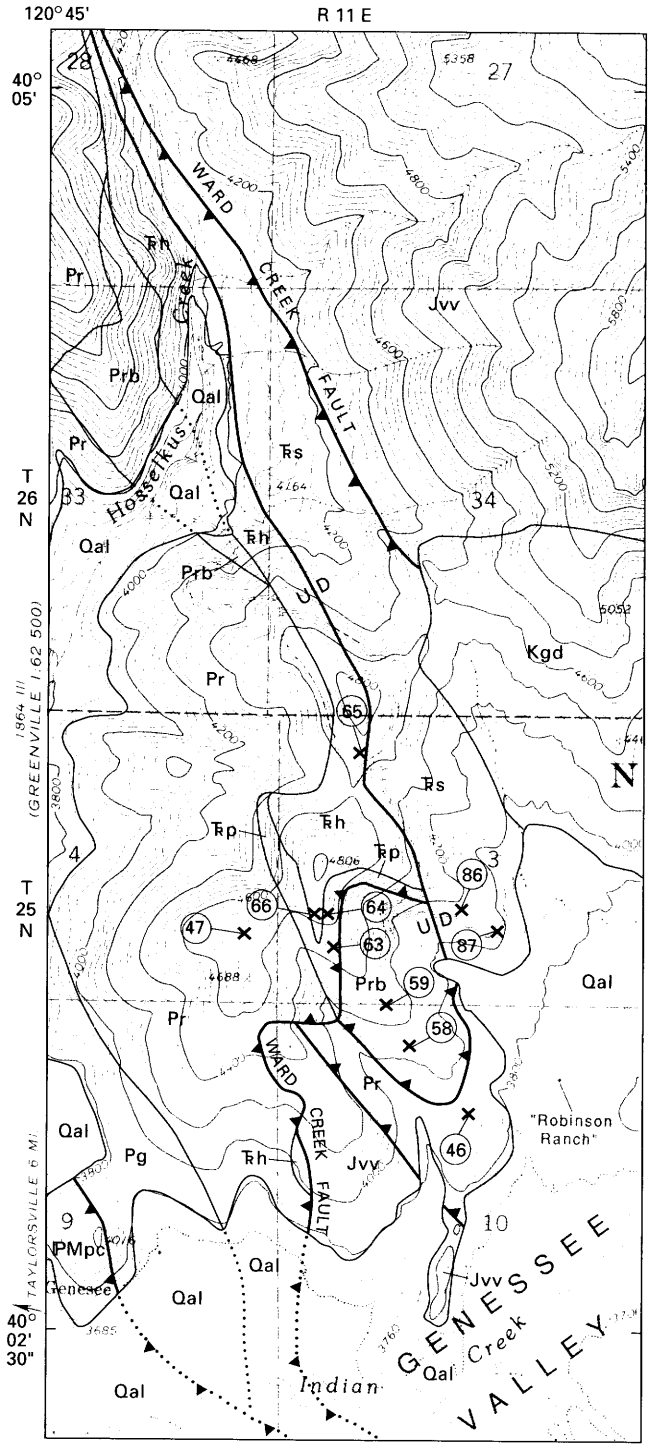


Figure 10. Geologic map of an area near Genesee, Calif., showing fossil localities in the Permian and Triassic rocks (modified from McMath, 1958). Base from U.S. Geological Survey 1:24,000-scale Genessee Valley quadrangle, 1972.

10 m above a thick section of red, gray, and black ribbon chert typical of the chert member of the Peale Formation. The fusulinids were studied by C.A. Ross who concluded that they were "Early Permian and probably late Wolfcampian to middle Leonardian" in age (Hannah and Moores, 1986, p. 792). Radiolarians from the uppermost part of the ribbon chert (loc. 20, fig. 11, pl. 1) are Pennsylvanian in age, probably no younger than Middle Pennsylvanian, and those from the lowermost part of the chert (loc. 19, fig. 11, pl. 1) are latest Late Mississippian or Early Pennsylvanian in age. Furthermore, radiolarians from chert clasts in the fusulinid-bearing conglomerate (loc. 40, fig. 11, pl. 1) are Late Mississippian in age but older than those found in the basal part of the ribbon chert section. These radiolarians indicate that the chert conglomerate is not a pure littoral deposit reworked from the underlying chert section. Hannah and Moores (1986) recognized the major hiatus between the ribbon chert and the fusulinid-bearing conglomerate, which had been documented farther south by Schweickert (1981) and Harwood (1983), but they included the Permian conglomerate and overlying volcaniclastic rocks in their Peale Formation. They placed the base of the Reeve Formation about 300 m above the ribbon chert where the first plagioclase-rich vol-

EXPLANATION

Qal	Alluvium (Quaternary)
Kgd	Granodiorite (Cretaceous)
Jvv	Volcanic and volcaniclastic rocks (Jurassic)
Ts	Swearinger Slate (Triassic)
Th	Hosselkus Limestone (Triassic)
Tp	Pit Formation (Triassic)
Prb	Robinson Formation of McMath (1958,1966)(Permian)
Pr	Reeve Formation (Permian)
Pg	Goodhue Formation (Permian)
	Peale Formation (Pennsylvanian and Mississippian)—In this area, consists of:
PMpc	Chert member

Contact—Dotted where concealed

Thrust fault—Dotted where concealed; sawteeth on upper plate

U/D Normal fault—U, upthrown block; D, downthrown block

(58)—× Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 10.—Continued

canic rocks occur. Hannah and Moores (1986, p. 793) stated,

> It is reasonable to include all known Permian rocks above the depositional hiatus, whether volcanic or sedimentary, in the Permian Reeve Formation. Until consistent criteria for recognition of the hiatus in the absence of fossil control are agreed upon, however, the Reeve is restricted to the characteristic volcanogenic rocks.

This restricted definition of the Reeve is exactly what McMath (1958) found untenable at the type locality, where volcanic tuff breccia and tuff are intimately interbedded with volcaniclastic sandstone and conglomerate. Therefore, the Permian fusulinid-bearing conglomerate and associated volcaniclastic sandstones at Dyer Mountain, referred to the Peale Formation by Hannah and Moores (1986), are assigned to the Reeve Formation in this report.

The problem of recognizing the base of the Permian volcanic sequence is rooted primarily in the original description of the Peale Formation (Diller, 1908) and in the definition of the upper member of the Peale by McMath (1958). Both Diller and McMath included chert-rich conglomerate and volcaniclastic sandstone in the upper part of the Peale. However, the available fossil evidence indicates that these chert-rich conglomerates are Early Permian in age—no older than late Wolfcampian and probably early Leonardian, for the most part. The youngest known rocks below the conglomerate are Middle Pennsylvanian in age. If the composition of the chert member of the Peale is restricted to ribbon chert, which reflects a period of relatively slow pelagic deposition, the influx of chert-rich conglomerate and volcaniclastic sandstone, which overlies the

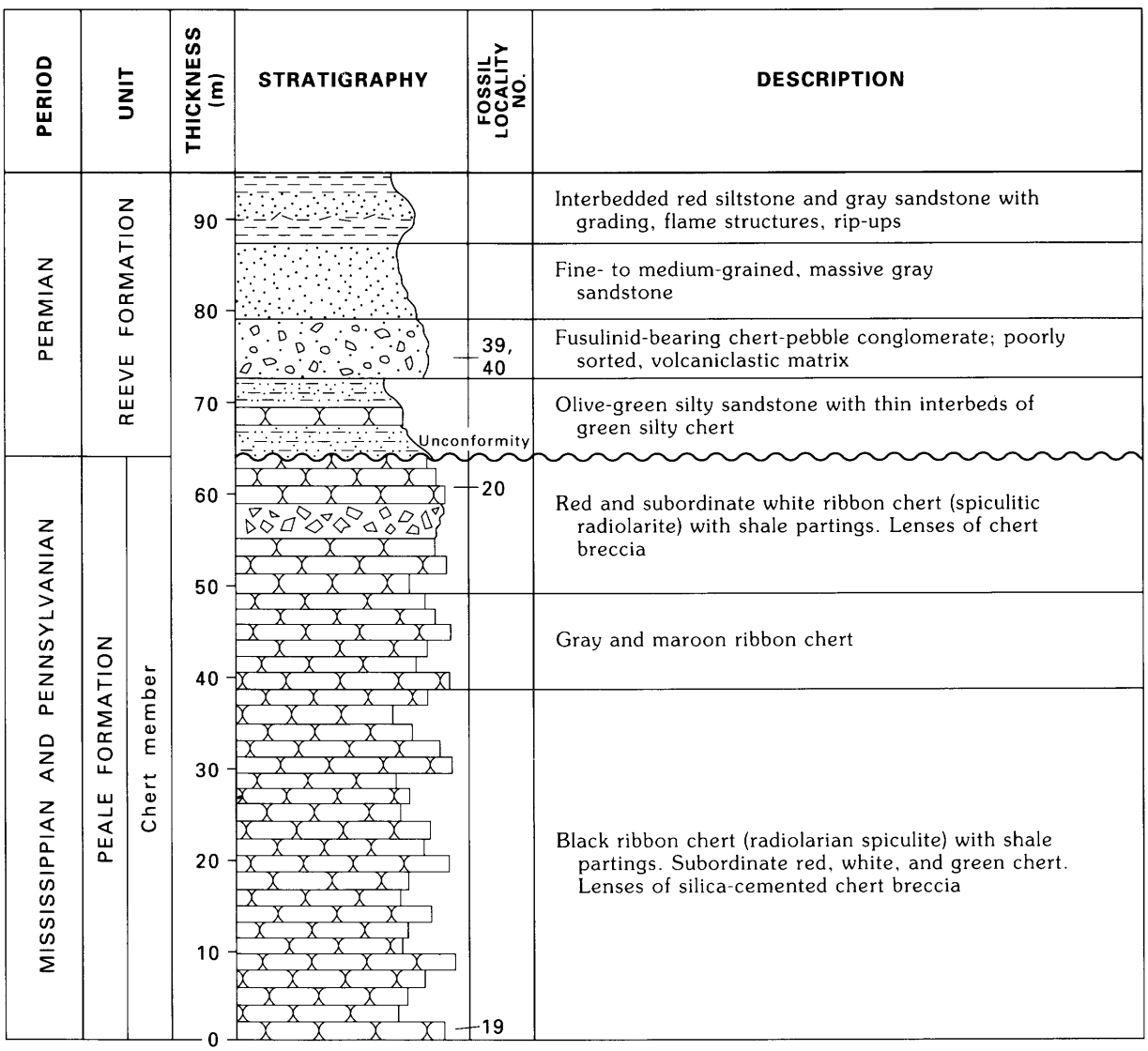
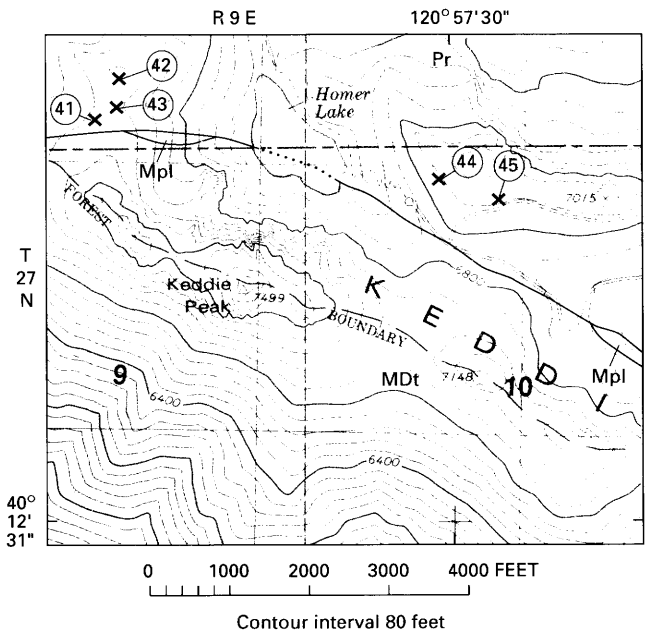


Figure 11. Stratigraphic column showing fossil localities in the chert member of the Peale Formation and in the Reeve Formation on Dyer Mountain, Calif. (modified from Hannah and Moores, 1986). Fossil locality numbers refer to "Catalog of fossil localities" and plate 1.

ribbon chert, signals a profound change in depositional environments and, by inference, tectonic regimes that should be marked by a line on a geologic map and a different formational unit.

Near Homer Lake (fig. 12), the Taylor Formation and discontinuous patches of volcanic rocks containing pink alkali-feldspar phenocrysts, typical of the lower member of the Peale Formation, are overlain by a heterogeneous sequence of volcaniclastic sandstone, tuffaceous siltstone, chert-pebble conglomerate and black, green, and gray chert. Chert forms less than 10 percent of the rocks and generally occurs as thin lenses interlayered with volcaniclastic sandstone and siltstone. Hannah (1980) and Hannah and Moores (1986) included the volcaniclastic rocks, chert, and conglomerate in their Peale Formation.



EXPLANATION

Pr	Reeve Formation (Permian)
	Peale Formation (Mississippian)—In this area, consists of:
Mpl	Lower member
MDt	Taylor Formation (Mississippian and (or) Devonian)
———	Contact—Dotted where concealed
(44) ×	Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 12. Geologic map of the Homer Lake area of Keddie Ridge, Calif., showing location of fossil localities in the Reeve Formation (modified from Hannah, 1980). Base from U.S. Geological Survey 1:24,000-scale Greenville 7.5-minute quadrangle, 1979.

However, radiolarians from the chert lenses (locs. 41, 42, 43, 45, fig. 12) are Early Permian (late Wolfcampian or early Leonardian) in age. Fragments of megafossils from the chert-pebble conglomerate (loc. 44, fig. 12) are indeterminate in age. On the basis of radiolarian data, the interbedded chert, volcaniclastic rocks, and conglomerate are here assigned to the Reeve Formation.

In Little Grizzly Creek about 10 km south of Genesee, Turner (1894) found a richly fossiliferous horizon in a sequence of hornfelsed calcareous tuff and volcaniclastic sandstone (locs. 48, 49, 50) that he included in the Robinson Formation as later defined by Diller (1908). Subsequent studies by McMath (1958, p. 125; 1966) and D'Allura (1977, p. 161) have identified the rocks at Little Grizzly Creek as the Reeve Formation. The fossil assemblage found here, which occurs about 100 m above the top of the Goodhue Formation (D'Allura, 1977), is characterized by abundant *Timaniella* specimens (loc. 48) that are suggestive of a late Early Permian (Wordian) age (J.T. Dutro, written commun., 1986), which is more or less equivalent to the age of the rocks of the Robinson Formation as defined by McMath (1958). On the basis of lithology, however, the sequence of rocks that contains the fossils is assigned to the Reeve in this report.

On the southwest slope of Fir Hill (loc. 52, pl. 1), D'Allura (1977) found poorly preserved fusulinids in the volcaniclastic sandstone matrix of chert- pebble conglomerate. C.A. Ross identified the Early Permian fusulinids and suggested a correlation with the middle part of the McCloud Limestone (C.A. Ross, written commun. to J.A. D'Allura, 1975, cited in D'Allura, 1977, p. 133–134). Following the definition of McMath (1958), D'Allura (1977) and D'Allura and others (1977) included the chert-rich conglomerate and volcaniclastic sandstone in the upper member of the Peale Formation. Schweickert (1981), however, found that the chert-rich conglomerate filled channels eroded 30 m deep into the chert member of the Peale and included the conglomerate in the lower part of the Reeve Formation. A few limestone blocks, 0.5×0.5×1.0-m in size, occur in the chert-rich conglomerate on the southwest slope of Fir Hill. The limestone blocks contain a rich, but not very age-diagnostic assemblage of bryozoans (loc. 53, pl. 1) that are indicative of a late Paleozoic, possibly Permian age. Conodonts from the bryozoan-rich limestone blocks (loc. 54, pl. 1) are definitive of a late Early Permian (middle to late Leonardian) age. Megafossils in the calcareous matrix surrounding the limestone blocks include the gastropod *Omphalotrochus* (loc. 55), which is indicative of an Early Permian age. On the basis of the conodonts from the limestone blocks and the fusulinids from the matrix of the conglomerate, the chert-rich conglomerate and volcaniclastic sandstone at Fir Hill are assigned here to the lower part of the Reeve Formation.

The chert-rich conglomerate and volcaniclastic sandstone on Fir Hill are lithologically identical to the lower,

conglomerate-rich part of the Arlington Formation, and these rocks probably will be mapped as the Arlington at some time in the future. It is interesting to note that the conodonts from limestone blocks at Fir Hill are younger than those from the limestone blocks in the Arlington at the principal reference locality (loc. 35), suggesting that local reef-forming conditions may have progressed southward with time through the Permian volcanic sequence.

South of Interstate Highway 80, D'Allura (1977), D'Allura and others (1977), and Harwood (1983) mapped a section of fine-grained, generally thin-bedded tuff and tuffaceous slate, which overlies the chert member of the Peale, as the Reeve Formation. From 3 to 10 m of chert-pebble conglomerate separate the fine-grained volcaniclastic rocks of the Reeve from ribbon chert of the Peale Formation. Harwood (1983) erroneously included the conglomerate with the chert member of the Peale. Harwood (1983) interpreted patches of coarsely recrystallized limestone associated with the chert-pebble conglomerate as olistoliths. Devonian echinoderm debris in one block of limestone (loc. 57) lends support to this interpretation, but the limestone is interbedded with chert-pebble conglomerate that appears to be part of the Reeve. Exactly where the block(s) of Devonian limestone, or possibly just the Devonian echinoid fragments, came from and how they were transported to this Reeve locale are unsolved mysteries at present. A debris-flow deposit of coarse-grained, feldspar-rich tuff about 30 m above the base of the Reeve near Big Valley (loc. 56, pl. 1) contains brachiopod fragments indicative of the mid-Permian (Roadian or Wordian) (M. Gordon, Jr., written commun., 1980). The brachiopods from Big Valley are equivalent in age to those reported in the Reeve by Durrell and D'Allura (1977) from Clio (loc. 51, pl. 1) and from the Little Grizzly Creek area (loc. 48, pl. 1). They are also approximately equivalent in age to conodonts extracted from a lens of limestone (loc. 59, pl. 1, fig. 10) interbedded with conglomerate and volcaniclastic sandstone that McMath (1958) mapped as the Robinson Formation near Genesee.

South of Interstate Highway 80, the Reeve Formation has a maximum thickness of 1,000 m. Chert-rich conglomerate and thin lenses or blocks of limestone in the lowermost part of the formation are overlain gradationally by thin-bedded, parallel-laminated to massive, bioturbated tuff and tuffaceous slate that contain locally abundant ichnofacies trace fossils. Lenses of gray sandy limestone and thick-bedded coarse-grained volcaniclastic sandstone are sporadically interbedded with the fine-grained tuff and tuffaceous slate. Lenses of thick-bedded to massive, matrix-supported volcaniclastic conglomerate with locally abundant chert clasts occur near the top of the formation. In this area, the Reeve is unconformably overlain by Upper Triassic conglomerate that overlaps the Reeve at Big Valley and progressively overlaps the chert member and the lower member of the Peale Formation farther south.

The base of the Reeve Formation is locally an erosional unconformity. At Big Valley Creek (loc. 56, pl. 1), mid-Permian (Roadian or Wordian) fossils near the base of the Reeve occur about 50 m above the chert member of the Peale that contains latest Late Mississippian to Early Pennsylvanian radiolarians (loc. 34, pl. 1). At Dyer Mountain (pl. 1) near the northernmost extent of the northern Sierra terrane, Early Permian (late Wolfcampian to middle Leonardian) fusulinids (loc. 39, pl. 1) occur near the base of a sequence of rocks assigned to the Reeve in this report and lie on the chert member of the Peale, which contains Pennsylvanian radiolarians (loc. 20, pl. 1). Locally, near Homer Lake (fig. 12), the Reeve lies on the Taylor Formation.

Robinson Formation of McMath (1958, 1966)

Diller (1908) gave the name "Robinson Formation" to interbedded volcaniclastic conglomerate, sandstone, and shale with lenses of limestone that occur with the Reeve Formation near Genesee (pl. 1, fig. 10). He attempted to separate the volcanic and volcaniclastic rocks into the Reeve and the Robinson, respectively, but the lithologies are interbedded on scales of a few meters to a few tens of meters and his original map units were greatly modified by McMath (1958). McMath (1958, 1966) retained the name "Robinson Formation" for two fairly restricted areas of conglomerate, sandstone, shale, and limestone (fig. 10), but he included all the other volcaniclastic rocks associated with plagioclase-rich tuff and tuff breccia in his redefined Reeve Formation. McMath (1958) designated the exposures on the northwest bank of Hosselkus Creek as the type section of the Robinson (fig. 10). The formation name was derived from the Robinson ranch (fig. 10) in Genesee Valley.

At the type section (sec. 33, T. 26 N., R. 11 E., Genesee Valley 7.5-minute quadrangle) the Robinson is about 200 m thick. Volcanic conglomerate forms about one-third of the section, and volcaniclastic sandstone and shale form the remainder. Shale is particularly abundant in the lower part of the section (McMath, 1958). Clasts in the conglomerate are primarily andesite, both massive and porphyritic, but gray and black chert clasts and fine-grained white quartzite clasts occur sporadically. The matrix ranges from fine- to medium-grained volcaniclastic sandstone to tuffaceous(?) siltstone. Most of the conglomerate is matrix supported. The clasts are subrounded to rounded and average about 6 cm in diameter, although they range in size from granules to boulders as much as 0.5 m in diameter. Conglomerate beds, which range in thickness from 0.5 to 1.5 m, are normally graded with medium- to fine-grained sandstone and siltstone tops. Cross laminations are common in the upper parts of the

individual conglomerate beds and in the sandstone beds. The conglomerate and sandstone are locally calcareous, particularly near lenses of limestone, and weather to a rough, rusty-brown surface. The limestone lenses, which are from 2 to 6 m thick, are calcarenites locally rich in crinoid and coral debris (McMath, 1958).

Of the five fossil localities included within the Robinson as mapped by Diller (1908, p. 28–29), only one (loc. 58, pl. 1, fig. 10) is within McMath's (1958, 1966) Robinson Formation; the remaining four localities occur in his redefined Reeve Formation. Conodonts extracted from a thin lens of limestone (loc. 59, pl. 1, fig. 10) are indicative of a mid-Permian (Wordian to Capitanian) age (K.E. Denkler and A.G. Harris, written commun., 1986). This lens of limestone is from the same general area as the coral-rich fauna reported by Diller (loc. 58, pl. 1, fig. 10). According to McMath (1958), this patch of the Robinson is separated from the underlying Reeve by a thrust fault. It is structurally overlain by upper Middle and Upper Triassic rocks (fig. 10).

At the type section on the west bank of Hosselkus Creek (fig. 10), McMath (1958, p. 123) reported a gradational, but not necessarily conformable, contact between the Reeve and Robinson Formations. His map contact at the base of the type Robinson strongly suggests that the contact is a disconformity. No fossils have been found, as yet, in the type section of the Robinson.

The age of the Robinson Formation is regarded as Early and Late Permian (Wordian to Capitanian) in this report.

Lake Tahoe Sequence

The Lake Tahoe sequence consists of predominantly quartz-chert-rich clastic rocks and carbonate rocks exposed on and near the Sierran crest west and northwest of Lake Tahoe (fig. 13). Lindgren (1897) originally correlated this sequence of rocks with the Jurassic Sailor Canyon Formation, which he had mapped farther to the west (Lindgren, 1900), and that interpretation has been shown on geologic maps of California since the turn of the century. New stratigraphic, structural, and paleontological data, however, suggest that part of the Lake Tahoe sequence is middle Paleozoic in age and correlative with Upper Devonian and Lower Mississippian volcanic rocks of the Taylorsville sequence. Part of the Lake Tahoe sequence is probably Mesozoic; no younger than Early Jurassic.

The Lake Tahoe sequence is well exposed east of the Talbot fault zone in the canyons of the North and Middle Forks of the American River, in Five Lakes Creek, on the south wall of Blackwood Creek canyon, and in the Rubicon River upstream from Hell Hole Reservoir (fig. 13). The rocks cannot be traced from canyon to canyon, however, because of intervening plutons and a thick cover of Tertiary volcanic rocks. The stratigraphic sequences in the Rubicon River and in the canyon of Blackwood Creek differ somewhat from those to the north, but Harwood (1988) integrated all of the lithologic units into one stratigraphic section of middle Paleozoic age. This age assignment was based, in large part, on poorly preserved ammonoids found in interbedded pelitic hornfels and limestone south of Blackwood Creek (loc. 60, pl. 1, fig. 13) that N.J. Silberling (written commun., 1983) suggested as "possibly late Devonian-Mississippian, but a Jurassic age cannot be ruled out." Additional specimens of ammonoids collected from this same locality currently "favor, but do not conclusively establish, an Early Jurassic age" (N.J. Silberling, oral commun., 1988) for this part of the Lake Tahoe sequence and the quartz arenite that stratigraphically overlies it. Therefore, it seems prudent to present separate generalized stratigraphic columns (fig. 14) for the northern and southern parts of the Lake Tahoe sequence.

The oldest rocks in the Lake Tahoe sequence are interbedded quartzite, pelite, and chert-rich conglomerate assigned to the Picayune Valley Formation (new). Along the North Fork of the American River (figs. 13, 14), the Picayune Valley Formation is overlain by metachert of the Serena Creek Formation (new) which, in turn, grades up into calc-silicate rock and marble of the Onion Creek Formation (new). Along the Rubicon River (fig. 13, 14), the Picayune Valley Formation is structurally overlain by interbedded black pelitic hornfels and gray sandy limestone that are assigned to the Blackwood Creek Formation (new). Well-bedded quartz arenite of the Ellis Peak Formation (new) overlies the Blackwood Creek Formation and is structurally overlain by an unnamed unit of rather nondescript black pelitic hornfels.

Picayune Valley Formation

The name "Picayune Valley Formation" is given here to the oldest unit in the Lake Tahoe sequence. It is composed primarily of interbedded quartzite and black pelite that contain abundant but scattered thin lenses of chert-rich conglomerate. Fine-grained felsic tuff, volcaniclastic rocks, and a few debris-flow deposits of andesitic tuff breccia are interbedded with the quartzite, pelite, and conglomerate in the western part of the formation. Mappable lenses or large blocks of recrystallized limestone occur in the formation near Big Spring (sec. 14, T. 15 N., R. 15 E., Granite Chief 7.5-minute quadrangle) and in Grouse Canyon (sec. 23, T. 15 N., R. 15 E., Granite Chief 7.5-minute quadrangle; loc. 62, fig. 13). The formational name is derived from Picayune Valley, and the open glaciated exposures there are designated as the type locality (NE¼ sec. 8, T. 15 N., R. 15 E., Granite Chief 7.5-minute quadrangle). The most accessible exposures of the felsic and andesitic volcanic rocks interbedded with the quartz-chert-rich rocks are found between the 5,640- and 5,840-ft contours in the

Middle Fork of the American River above Talbot Campground. These exposures are here designated as a reference section (center sec. 1, T. 15 N., R. 14 E., Granite Chief 7.5-minute quadrangle). Excellent exposures of the formation also occur in the canyon walls of the North Fork of the American River, along Five Lakes Creek and some of its major tributaries, and along the Rubicon River (fig. 13).

The formation is characterized by alternating quartzite-pelite sets that range from fine-grained, varve-like beds less than one centimeter thick (fig. 15*A*) to thicker bedded sets in which the quartzite is commonly graded and ranges in thickness from 10 to 25 cm. Parallel laminations are common in the arenaceous beds. Quartzite-pelite ratios range from 1:1 to 1:4, with the higher pelite content in the western part of the formation. Conglomerate lenses range in thickness from about 0.3 to 3 m and can be traced only a few tens of meters along strike in areas of abundant exposures. Black and white chert fragments are the dominant clasts and are associated with variable amounts of black pelite and both monocrystalline and polycrystalline quartz clasts. Larger clasts tend to be rounded to subrounded, whereas smaller clasts are commonly elongate. Matrix-supported chert-granule conglomerate (fig. 15*B*) is common in the western part of the formation. Clast size increases eastward in the formation so that clast-supported, rounded pebble and cobble conglomerate predominates in the eastern exposures. In addition to the conglomerate lenses, the formation contains local deposits of slump breccia (fig. 15*C*) composed primarily of angular pelite and quartzite rip-up clasts, some of which are folded, and variable amounts of white, tan, and gray quartzite, and sparse carbonate clasts as much as 3 cm in length set in a pelitic matrix. On the basis of bedding characteristics and lithologic variations, the quartz-chert-rich strata probably were deposited in a submarine-fan environment, where the coarser conglomerate lenses and slump deposits in the eastern part of the formation were laid down as inner-fan channel deposits or possibly more proximal deposits. Lenses of gray, recrystallized limestone, exposed in Grouse Canyon and at Big Spring, may be slump blocks in the more proximal siliciclastic deposits.

Felsic and andesitic volcaniclastic rocks, which are lithologically identical to rocks in the Sierra Buttes and Taylor Formations, are interbedded with each other and with pelite-quartzite turbidites in the lower part of the Picayune Valley Formation. Gray felsic volcanic rocks contain coarse grains of bipyramidal quartz and sparse intraclasts of phosphate-streaked black chert in a matrix of coarse-grained felsic tuff. They represent debris-flow deposits, 30 cm to 6 m thick, that grade into beds of very fine grained parallel-laminated tuffaceous siltstone. The andesitic rocks are dark-green debris-flow deposits, as thick as 8 m, that contain angular and rounded clasts of clinopyroxene-phyric andesite, as long as 10 cm, in a fine-grained andesitic tuff matrix. Felsic volcaniclastic rocks are more abundant along Five Lakes Creek, where they occur about 30 m above the base of the formation, whereas felsic and andesitic rocks occur in about equal proportions in the Middle Fork of the American River east of the Talbot fault zone where they occur about 100 m above the base of the formation. The volcaniclastic rocks represent submarine debris-flow deposits that were derived from a volcanic source or sources outboard of the provenance that was supplying the eastward coarsening quartz-chert-rich debris. Harwood (1988) suggested that protoliths of the volcaniclastic rocks were derived from the Late Devonian and Early Mississippian volcanic arc that produced the Taylorsville sequence and that they were deposited with quartz-chert-rich sediment derived from the evolving Antler orogenic highland. This interpretation still seems valid.

The Picayune Valley Formation overlies the Shoo Fly Complex east of the Talbot fault zone and along Five Lakes Creek. Jurassic faulting has impressed a high degree of strain on the Picayune Valley Formation and Shoo Fly Complex, but their contact, in both areas, appears to be a disconformity rather than a fault. In the North Fork of the American River drainage, the Picayune Valley Formation grades up into thin-bedded metachert of the Serena Creek Formation. The Picayune Valley Formation is multiply deformed by an early set of east-verging recumbent folds and a later set of northwest-trending upright folds so that its depositional thickness is unknown, but it is probably less than 600 m.

The only fossils recovered from the Picayune Valley Formation are echinoderm fragments found when a limestone sample from Grouse Canyon (loc. 62) was dissolved for conodonts. The fossil debris is suggestive of a Late Silurian to Late Devonian age (J.T. Dutro, Jr., written commun. 1988). Correlation of the volcanic rocks, especially the quartz-rich felsic deposits containing intraclasts of black chert, with the Sierra Buttes Formation seems reasonably certain. A 50-kg sample of felsic pyroclastic rocks from Five Lakes Creek was processed for zircons, but none were recovered. The limited fossil data and the lithologic correlation of the volcanic rocks suggest that the Picayune Valley Formation was deposited during the Late Devonian and Early Mississippian in a narrow basin between the Taylorsville arc and the evolving Antler orogenic highland.

Serena Creek Formation

The name "Serena Creek Formation" is given here to primarily thin bedded, tan metachert that gradationally overlies the Picayune Valley Formation. Exposures in the walls of Serena Creek (sec. 10, T. 16 N., R. 14 E., Soda Springs 7.5-minute quadrangle), from which the formation name is derived, are here designated as the type locality (fig. 13). Excellent exposures also occur in the upper reaches of the North Fork of the American River east and

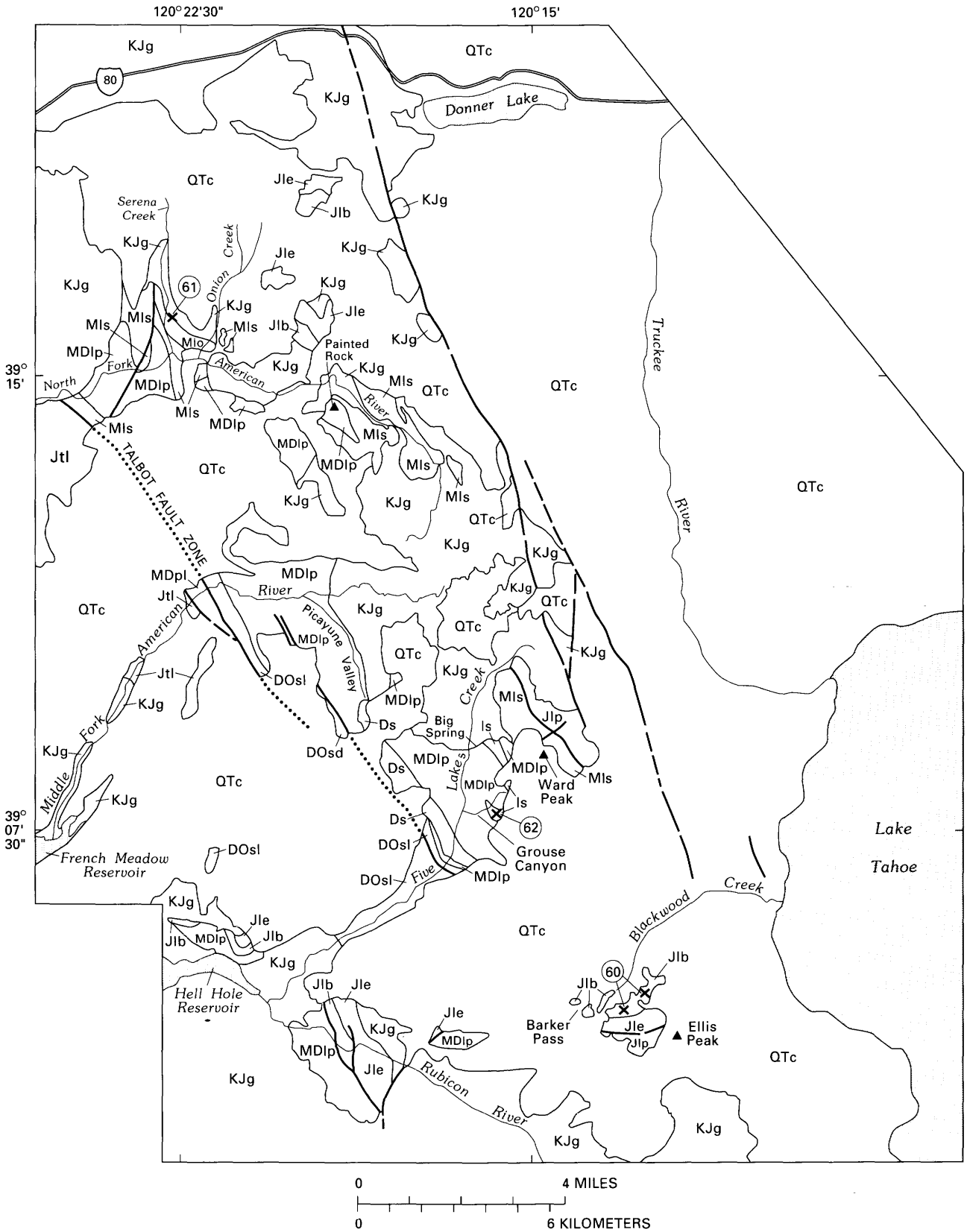


Figure 13. Geologic map of Middle Fork American River region, eastern Placer County, Calif., showing fossil localities in the Lake Tahoe sequence.

southeast of Painted Rock (secs. 15 and 16, T. 16 N., R. 15 E., Granite Chief 7.5-minute quadrangle) and east of the Sierran crest at Ward Peak (secs. 17 and 18, T. 16 N., R. 16 E., Tahoe City 7.5-minute quadrangle). Because of their accessibility, the exposures in the vicinity of Ward Peak are designated as a reference section.

Beds of light-tan, fine-grained metachert, 2 to 10 cm thick, with alternating beds of dark-gray siliceous argillite 1 to 3 cm thick, make up about 90 percent of the formation (fig. 16). The metachert is not graded, and parallel laminations are rare.

The lower contact of the Serena Creek Formation with the Picayune Valley Formation is sharply gradational. The Serena Creek Formation is about 300 m thick at the type locality.

No fossils have been found in the Serena Creek Formation; but bivalve fragments were found in quartzite interbedded with calc-silicate rocks and limestone in the lowermost part of the Onion Creek Formation (loc. 61) which gradationally overlies the Serena Creek Formation at the type locality. None of the shell fragments could be identified

EXPLANATION

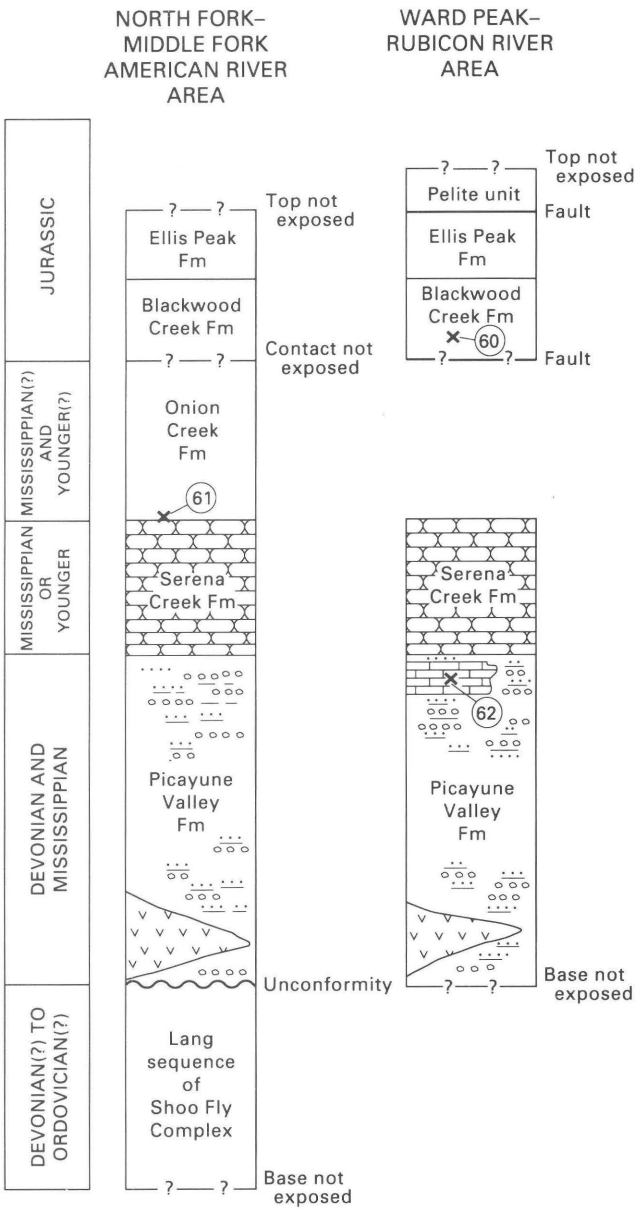
	QTc	Cover rocks (Quaternary and Tertiary)
	KJg	Granitic rocks (Cretaceous and Jurassic)
	Jtl	Tuttle Lake Formation (Jurassic)
Lake Tahoe sequence	Jlp	Pelite unit (Jurassic)—Provisional age assignment
	Jle	Ellis Peak Formation (Jurassic)
	Jlb	Blackwood Creek Formation (Jurassic)
	Mlo	Onion Creek Formation (Mississippian? and younger?)
	Mls	Serena Creek Formation (Mississippian or younger)
	MDlp	Picayune Valley Formation (Mississippian and Devonian)—Includes limestone lenses or blocks (ls)
	Ds	Sierra Buttes Formation (Devonian)
		Shoo Fly Complex—In this area, consists of:
	DOsd	Duncan Peak allochthon (Devonian? to Ordovician?)
	DOsl	Lang sequence (Devonian? to Ordovician?)

Contact

Fault—Dashed where approximately located; dotted where concealed

(62) Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 13. —Continued



EXPLANATION

Black slate, quartzite, and chert-rich conglomerate

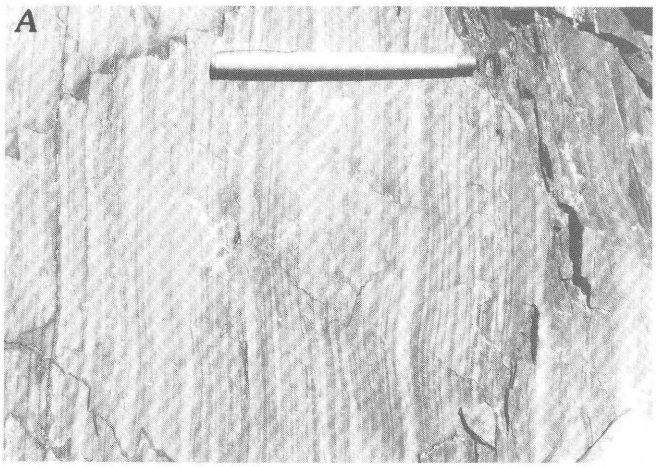
Metachert

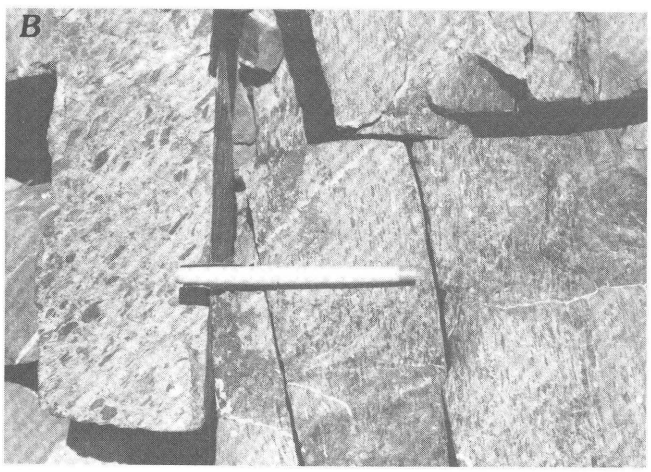
Limestone

Felsic and andesitic volcaniclastic rocks

(62) Fossil locality—Circled number refers to "Catalog of fossil localities"

Figure 14. Stratigraphic columns of the Lake Tahoe sequence west of Lake Tahoe, Calif.





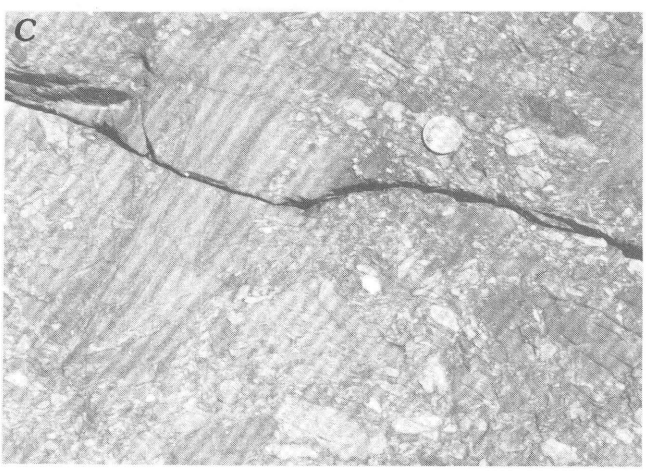


Figure 15. Picayune Valley Formation, northern California. *A*, Thin-bedded pelite-quartzite sets. *B*, Chert-granule conglomerate showing views parallel (right) and perpendicular (block to left) to foliation. *C*, Slump breccia with angular to subrounded fragments of chert and quartzite in pelite matrix and larger fragment of folded, thin-bedded quartzite and pelite.

specifically, but one fragment was suggestive of a nucleospirid brachiopod, which ranges in age from Late Silurian to Mississippian (J.H. Pojeta, Jr., written commun., 1984). On the basis of the large, coarse-ribbed character of the bivalve fragments, J.T. Dutro, Jr., (written commun., 1983) concluded that the age of this collection is definitely Paleozoic—and, more specifically, post-Early Ordovician. Because the Serena Creek Formation gradationally overlies the Picayune Valley Formation, which is considered to be no older than Late Devonian, the Serena Creek Formation is here provisionally assigned a Mississippian or younger age. On the basis of lithologic similarity, a correlation is possible with the chert member of the Peale Formation. If this correlation is correct the age of the Serena Creek Formation could span much of the Carboniferous.

Onion Creek Formation

The name "Onion Creek Formation" is given here to interbedded calc-silicate rock, limestone, and black pelite that gradationally overlie the Serena Creek Formation. Ex-

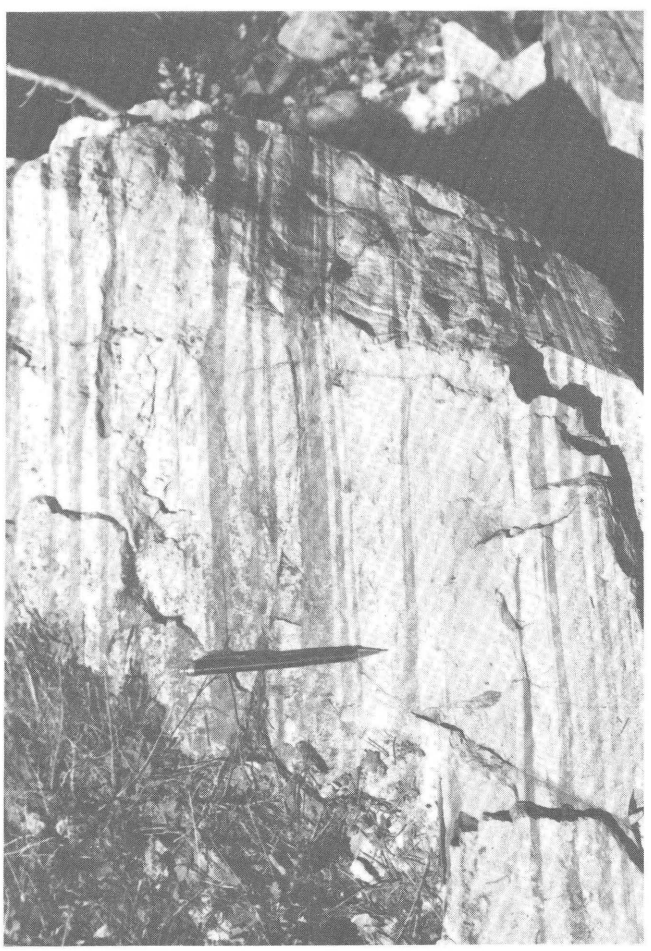


Figure 16. Metachert in the Serena Creek Formation, northern California.

posures along Onion Creek (SE¼ sec. 11, T. 16 N., R. 14 E., Norden 7.5-minute quadrangle), from which the formation name is derived, are here designated as the type locality (fig. 13). Other exposures of the formation occur east of Serena Creek and at the confluence of Serena Creek and the North Fork of the American River.

Limestone and argillaceous limestone, now recrystallized to marble and garnet-diopside-rich calc-silicate rock, are the dominant rock types in the formation. They are associated with black pelitic hornfels and calcareous quartzite composed predominantly of quartz with variable amounts of actinolite, epidote, and plagioclase. Beds of limestone, from 5 to 25 cm thick, locally alternate with quartzite beds to produce a typically banded rock. Massive pods and beds of mottled light- and dark-gray limestone, several meters thick, are interlayered with the quartzite-limestone-pelite sequences.

The Onion Creek Formation gradationally overlies the Serena Creek Formation. Neither the original total thickness of the Onion Creek Formation nor its complete compositional make-up are known because the upper part of the formation is intruded by granitoid plutons of the Sierra Nevada batholith. At the type locality, only 400 m of the formation are exposed.

No fossils have been found in the limestone strata of the Onion Creek Formation despite repeated efforts to extract conodonts from them. The limited fossil data discussed above under the Serena Creek Formation (loc. 61) suggest that the Onion Creek Formation is Paleozoic in age. On this basis, the Onion Creek Formation is here tentatively regarded as Mississippian(?) and younger(?) in age; however, there are no known lithologic correlatives of the Onion Creek Formation in the Taylorsville sequence.

Blackwood Creek Formation

The name "Blackwood Creek Formation" is given here to pelite and sandy limestone turbidites that overlie the Picayune Valley Formation. Exposures in and adjacent to the upper reaches of Blackwood Creek (fig. 13), from which the formation name is derived, are here designated as the type locality (sec. 9, T. 14 N., S. 16 E., Homewood 7.5-minute quadrangle).

The formation is characterized by metamorphosed gray sandy limestone and black pelite beds that range in thickness from 15 cm to 1 m. Medium-grained sandy limestone at the base of each bed is commonly graded and locally contains angular, randomly oriented rip-up clasts of black pelite. The sandy limestone grades upward into black pelite, either slate or pelitic hornfels, that is locally parallel laminated. Thin- to thick-bedded gray tuff and tuffaceous siltstone are interbedded with the black pelite. Punky-brown-weathering, massive debris-flow units, about 1.5 m thick, composed of medium-grained calcareous feldspathic sandstone are sparsely scattered throughout the pelite, sandy limestone, tuffaceous siltstone sequence.

The Blackwood Creek Formation is about 600 m thick in the Rubicon River canyon where the base and top of the formation can be located to within a few meters but the lower contact is a fault. The formation is about 750 m thick in Blackwood Creek, but its base is not exposed there.

Several kilograms of sandy limestone were processed for conodonts, but none were found. The calcareous feldspathic debris-flow units and adjacent hornfelsed pelite contain scattered molds of ammonites (loc. 60) that were studied by N.J. Silberling. Details of the ammonites are not well preserved, and, although no genera or species were identified, two different forms were noted. Material first studied led Silberling to the following discussion (written commun., 1983):

> One form is loosely coiled, discoidal and simply ribbed and the other form is more tightly coiled, fairly globose and smooth. Both forms are 2 to 3 cm in diameter and one specimen shows a simple 8-lobed suture that appears to be goniatitic. The ammonites can be no older than Late Devonian and may be Late Devonian or Mississippian, but a Jurassic age could not be ruled out.

Material collected from locality 60 in 1986 and 1987 (fig. 17), though not identifiable specifically, is suggestive of an Early Jurassic age (N.J. Silberling, oral commun., 1988).

Field relations don't help solve the age dilemma. Along the Rubicon River, the contact between the Picayune Valley and Blackwood Creek Formations, where exposed, is a fault of unknown displacement. Lithologically, the Blackwood Creek Formation is very similar to unnamed black pelite and limestone in Rockbound Valley, southeast of the study area, that contains "probable Early Jurassic" ammonites (N.J. Silberling, written commun.,

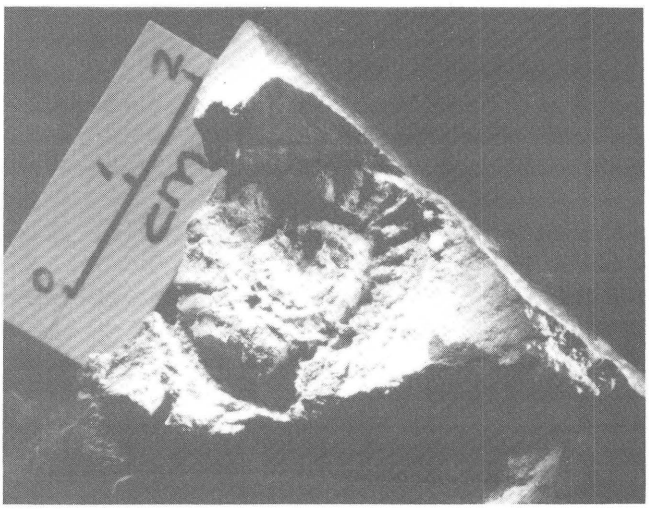


Figure 17. Ammonite from the Blackwood Creek Formation (loc. 60, "Catalog of fossil localities"), northern California.

1987, to Reid Fisher) and to a limestone-pelite horizon in the Sailor Canyon Formation, which has yielded Early Jurassic ammonites. An Early Jurassic age for the Blackwood Creek Formation is tentatively proposed here, but an older age—possibly even middle Paleozoic—cannot be unequivocally ruled out.

Ellis Peak Formation

The name "Ellis Peak Formation" is given here to a distinctive unit composed primarily of well-bedded, white quartz arenite and interbedded gray metasiltstone that gradationally overlies the Blackwood Creek Formation west of Lake Tahoe. Exposures on the northwest slope of Ellis Peak (fig. 13), from which the formation name is derived, are here designated as the type locality (secs. 9 and 10, T. 14 N., R. 16 E., Homewood 7.5-minute quadrangle).

At the type locality, the formation consists of graded, parallel-laminated and locally cross laminated, white quartz arenite beds interlayered with parallel-laminated, gray, quartzose metasiltstone beds (fig. 18*A*). The quartz arenite beds range in thickness from a few centimeters to about 1.5 m. Metasiltstone beds, which are generally a few centimeters thick, alternate regularly with quartz arenite beds to produce a white and light- to-dark-gray, thin-bedded, parallel-laminated rock that is characteristic of the Ellis Peak Formation. In the thin-bedded parts of the formation, quartz arenite beds locally form discontinuous, disc-shaped, channel-fill lenses with scoured bases overlapped by parallel-laminated metasiltstone (fig. 18*B*). The base of some quartz arenite beds truncates several quartz arenite-metasiltstone sets. Hummocky cross stratification, with a wavelength of 0.5 m or less, also characterizes some quartz arenite beds. Packets of thin-bedded quartz arenite and metasiltstone, several meters thick, grade upward into sets of thick-bedded quartz arenite, 10 to 50 cm thick, with relatively sparse siltstone interbeds. The bed forms in the thin-bedded part of the formation are indicative of a high-energy, shallow-water depositional regime.

At scattered localities in the upper reaches of the North Fork of the American River, the lowermost 20 m or so of the Ellis Peak Formation consists of quartzite-carbonate-chert breccia and poorly organized conglomerate (fig. 18*C*, *D*). Quartzite fragments are angular to subrounded and attain a maximum size of about 20 cm. The coarse clastic deposits are poorly sorted, generally matrix supported, and poorly bedded in their lower parts. Carbonate clasts, which are recrystallized to tremolite, show no primary bedding characteristics and the clasts range in shape from tabular to nearly rounded (fig. 18*C*). Clast angularity, poor sorting, and the lack of well-organized bedding all indicate short transport and relatively rapid deposition for the coarse clastic deposits.

At the type locality, the formation is 800 m thick, but its upper contact is a steeply south-dipping fault of unknown displacement.

No fossils have been found in the Ellis Peak Formation. It gradationally overlies the Blackwood Creek Formation. Therefore, an age assignment of Early Jurassic seems most appropriate for the unit at this time. Harwood (1988) earlier considered the metachert, herein assigned to the Serena Creek Formation, to be equivalent to the hereinnamed Ellis Peak Formation. Oxygen-isotope data clearly indicate that the silicic rocks of the Serena Creek Formation are metachert. The tentative Mississippian or younger age for the Serena Creek Formation and the current "best guess" Early Jurassic age for the Ellis Peak makes this previous interpretation untenable.

Pelite Unit

On the northwest slope of Ellis Peak, the Ellis Peak Formation is structurally overlain by rusty-weathering black pelite that is metamorphosed to a dense black hornfels. Thin, discontinuous beds of feldspathic quartzite are scattered throughout the pelitic hornfels, but they do not contain any recognizable internal stratigraphy or structure. The fault at the base of the pelite unit dips steeply south and is parallel to axial surfaces of isoclinal folds in the underlying Ellis Peak Formation. The movement pattern and age of the fault are unknown.

On the east slope of Ward Peak, the Serena Creek Formation is in fault contact with black pelite hornfels that contains feldspathic quartzite beds 10 to 30 cm thick and at least one lens of fine-grained tuff breccia or pebbly mudstone composed of intermediate to mafic volcanic fragments as much as 5 cm in diameter. Bedding and the axial trace of a mesoscopic fold in the pelite unit locally trend at a high angle into the basal fault, which dips steeply east parallel to bedding in the Ellis Peak Formation. The age and nature of the fault are unknown, but it is clear that the pelite unit was deformed independently of the Ellis Peak Formation.

An estimated 1,000 m of the pelite unit is exposed east of Ward Peak, but its total depositional thickness is impossible to determine due to its faulted lower contact and the presence of extensive Tertiary volcanic deposits. The age of the pelite unit is uncertain. It could be Paleozoic in age, but its lithologic character is more akin to the Mesozoic Sailor Canyon Formation than to any Paleozoic unit occurring in the area; the unit is thus provisionally assigned a Jurassic age in this report.

Permian-Triassic Unconformity

A profound angular unconformity separates the Paleozoic and Mesozoic rocks at the North Fork of the

American River (Lindgren, 1897; Clark and others 1962; Harwood, 1983; Harwood and others, in press). In this area the hiatus is bracketed by Upper Triassic (upper Karnian through Norian) conglomerate and limestone (loc. 85) and mid-Permian (Roadian or Wordian) fossils in the underlying Reeve Formation (loc. 56). The Upper Triassic rocks form a southward-transgressive onlap sequence of conglomerate, limestone, and andesitic tuff that truncates rocks of the Permian volcanic sequence and the Taylorsville sequence and locally lies unconformably on the Shoo Fly Complex (pl. 1). A northward-dipping paleoslope is indicated by the onlap assemblage. North of the American River, the Mesozoic rocks lie disconformably on Permian volcanic rocks at scattered localities throughout the eastern part of the northern Sierra terrane.

Mesozoic rocks lie with apparent unconformity on a variety of Permian volcanic rocks north of Genesee. However, in this general area, Jurassic thrust faulting locally interleaves Paleozoic and Mesozoic rocks, and the Permian-Triassic unconformity suggested by Diller (1908) and McMath (1958) is subject to alternative interpretations. Diller (1908) recognized two Upper Triassic units, the Hosselkus Limestone and the Swearinger Slate, and eventually concluded that the Hosselkus Limestone was the older unit and that it lay unconformably on the Permian volcanic rocks. McMath (1958) suggested that the unconformity at the base of the Hosselkus Limestone was "unglued" by subsequent, minor faulting. Neither Diller nor McMath recognized the gray-weathering black tuffaceous slate, which contains late Middle Triassic (middle Ladinian) ammonites (locs. 63, 64), below the Hosselkus Limestone. The tuffaceous slate is here assigned to the Pit Formation. To the southwest, the Pit and Hosselkus overlie the Reeve Formation, which contains

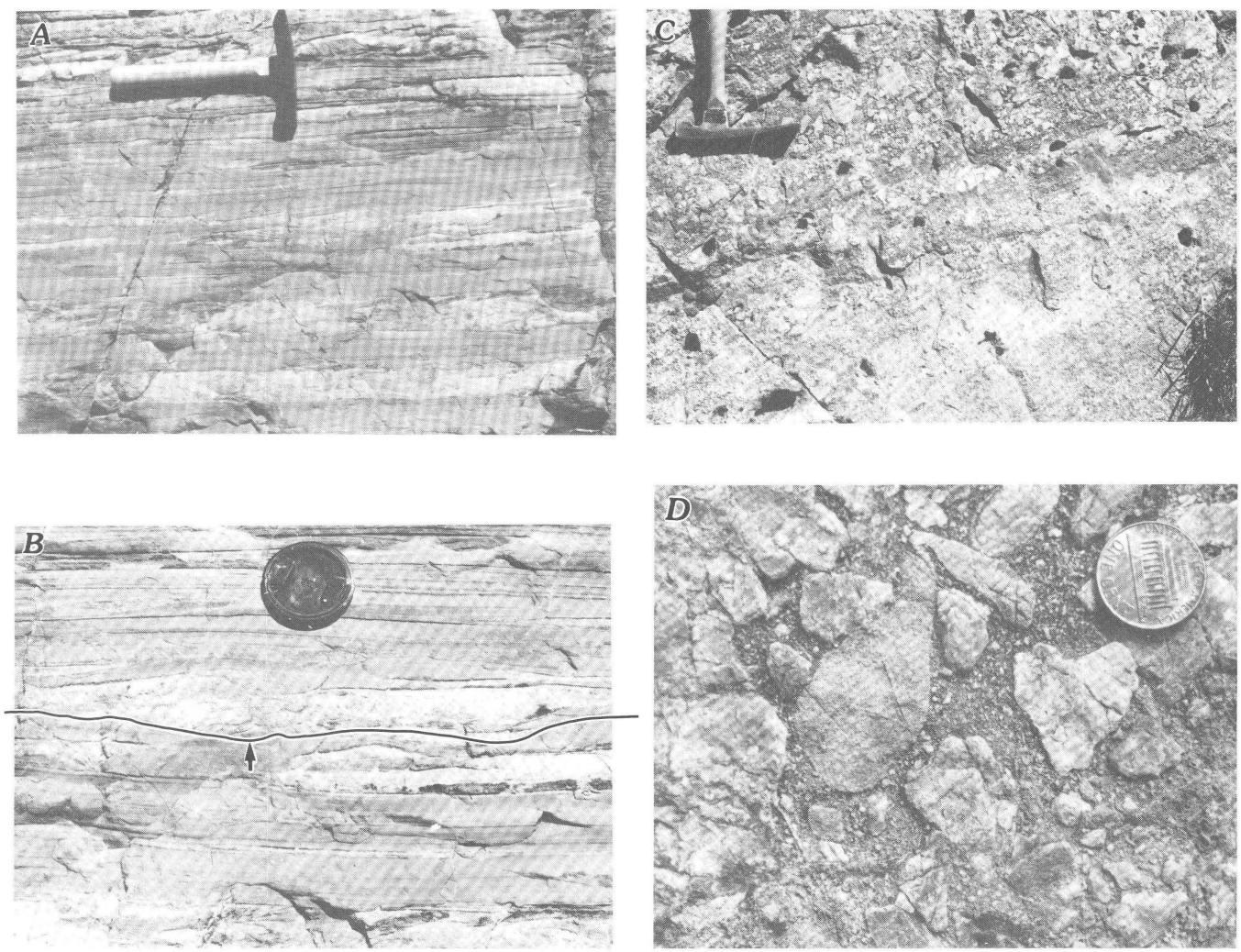


Figure 18. Ellis Peak Formation, northern California. *A*, Thin-bedded, parallel-laminated quartz arenite and pelite. *B*, Rippled cross-laminated quartz arenite bed with erosive base (arrow). *C*, Quartz arenite and carbonate-clast breccia showing crude bedding and poor sorting. *D*, Angular to subrounded, very poorly sorted quartz arenite fragments supported in metamorphosed calcareous mudstone matrix.

Early Permian (late Wolfcampian to early Leonardian) fusulinids (loc. 47, fig. 10) only a few tens of meters below the contact. That contact is interpreted to be the Permian-Triassic unconformity. The Reeve Formation structurally overlies the Robinson Formation, which contains early Late Permian (Capitanian) conodonts (loc. 59, fig. 10). Upper Middle Triassic slate of the Pit Formation also overlies the Robinson Formation, and that contact is interpreted to be part of the Ward Creek thrust fault (fig. 10). If the basal contact of the Pit is an unconformity throughout its length, then the underlying Reeve and Robinson were structurally inverted by either thrust faulting or recumbent folding prior to the late Middle Triassic. Exposures are not sufficient in this area to unequivocally establish whether the Permian rocks were inverted prior to Triassic time. In light of the abundant evidence for Jurassic thrusting in the Taylorsville area, it seems reasonable to postulate that the structural inversion of the Permian rocks occurred during the Late Jurassic and that the basal contact of the Triassic rocks north of Genesee is locally an unconformity and locally a thrust fault as shown in figure 10.

If this conclusion is correct, the Permian-Triassic hiatus near Genesee extends from the Late Permian to the Middle Triassic (middle Ladinian), whereas at the North Fork of the American River the hiatus spans the time between the late Early Permian (Wordian) and the Late Triassic (late Karnian through Norian).

Mesozoic Sequence

Mesozoic sedimentary and volcanic rocks are widely distributed in a belt along the eastern part of the northern Sierra terrane, and they occur locally in the western part of the terrane between the Shoo Fly Complex and the Feather River peridotite belt (pl. 1; Jayko and others, 1987; Harwood and others, 1988; Jayko, 1988, 1990). In the eastern belt, the Mesozoic rocks consist of upper Middle Triassic tuffaceous slate, Upper Triassic conglomerate, slate, and limestone, Lower and Middle Jurassic volcaniclastic sandstone, slate, and conglomerate interbedded with variable amounts of andesitic tuff and tuff breccia, and upper Middle Jurassic mafic flows and tuff breccia with variable amounts of volcaniclastic sandstone, slate, and conglomerate.

In the western part of the terrane, Mesozoic rocks occur as thin fault-bounded tectonic slivers generally caught between the Shoo Fly Complex and the Feather River peridotite belt. Southwest of Quincy, however, a tectonic sliver of Mesozoic rocks occurs wholly enclosed by the lower part of the Shoo Fly (Standlee, 1978). The largest area of Mesozoic rocks occurs southwest of Lake Almanor and consists of two tectonic slivers. The eastern sliver is composed of Upper Triassic conglomerate and limestone that overlies mafic volcanic rocks assigned to the Taylor Formation by Jayko (1988, 1990). The Upper Triassic rocks grade into slate, volcaniclastic sandstone, polymict conglomerate, and mafic-volcanic rocks of Late Triassic(?) and Early Jurassic age. This tectonic sliver of Triassic and Jurassic rocks is structurally juxtaposed on the west against black slate that contains blocks of Middle and Upper Triassic limestone as well as blocks of Lower Permian limestone.

D'Allura and others (1977) concluded that the limestone, graywacke, slate, and conglomerate southwest of Lake Almanor form a continuous, east-facing sequence ranging from Early Permian to Late Triassic in age, which they correlated with the Arlington Formation. However, new paleontologic and stratigraphic data, presented in this report, restrict the age of the Arlington at the principal reference locality to the Early Permian and rule out that correlation. Jayko and others (1987) suggested that the Mesozoic rocks southwest of Lake Almanor may be correlative with either the Pit Formation–Hosselkus Limestone–Brock Shale sequence in the Klamath Mountains or with the Hosselkus Limestone–Swearinger Slate sequence found in the eastern belt of Mesozoic rocks near Genesee (pl. 1). Subsequent mapping by Jayko (1988) and the discovery of probable Early Jurassic fossils near Butt Valley Reservoir indicate that the structural and stratigraphic relations in the Mesozoic tectonic slivers west of the Shoo Fly are far more complex than originally thought. The following discussion focuses first on the eastern belt of Mesozoic rocks near the North Fork of the American River area where the Mesozoic rocks form a relatively simple east-facing homoclinal sequence. It then focuses on Mesozoic rocks in the Taylorsville area and their structural relations to older rocks.

American River Area

Lindgren (1900) first recognized the angular unconformity between the Paleozoic and Mesozoic rocks exposed at the North Fork of the American River. This classic locality has figured prominently in tectonic interpretations of the Sierra Nevada since the turn of the century. Lindgren's original mapping above and below the Permian-Triassic unconformity has been modified by Clark and others (1962), Harwood (1983), and by my current work in the Duncan Peak and Cisco Grove 7.5-minute quadrangles (Harwood and others, in press). Stratigraphic relations in this area are shown in figure 19.

From the vicinity of Interstate Highway 80 south to the North Fork of the American River, the basal Mesozoic unit is a chert-rich polymict conglomerate that attains a maximum thickness of 200 m. In the northern part of the area, the conglomerate unit lies disconformably on upper Lower Permian (Wordian) volcaniclastic rocks of the Reeve Formation (loc. 56), but it progressively overlaps the Permian volcanic rocks and the Taylorsville sequence

toward the south and lies unconformably on the Shoo Fly Complex at the North Fork of the American River. Rounded to subrounded chert clasts, as much as 6 cm in diameter, commonly make up at least 50 percent of the conglomerate unit, and the composition of the remaining clasts generally reflect local detritus derived from the Paleozoic rocks directly below the unconformity. Between Big Valley and Sugar Pine Point (fig. 19), the conglomerate unit is composed almost entirely of volcanic detritus derived from the Reeve Formation. In Little Granite Creek (fig. 19), the conglomerate unit contains scattered granitoid boulders apparently derived from a small body of metagranodiorite that underlies the unconformity. From Cisco north to Fordyce Road (fig. 19), the conglomerate unit is a chaotic mixture of about equal amounts of rounded chert clasts and angular limestone fragments in a calcareous siltstone matrix. This part of the conglomerate unit represents a debris-flow deposit derived in part from the limestone unit that overlies the conglomerate unit at the American River.

The debris-flow deposit is chaotic and not bedded. The conglomerate is generally massive and clast supported. It locally contains interbeds of hummocky cross-stratified and trough-crossbedded chert-rich sandstone that indicate shallow-water deposition.

At the North Fork of the American River, the conglomerate unit, which is about 3 m thick and composed primarily of chert pebbles with scattered volcanic and quartzite pebbles, grades up into limestone and calcareous siltstone (herein referred to as the limestone unit) that contain Late Triassic (late Karnian through Norian) conodonts (loc. 85) (Harwood, 1983). In Little Granite Creek, the limestone unit contains thick beds of limestone breccia cemented with either calcareous siltstone or calcarenite. The calcareous siltstone cement locally contains abundant fossil fragments that have not been identified.

The limestone unit grades up into a volcanic and volcaniclastic unit of fine- to coarse-grained volcaniclastic sandstone, tuff, and lapilli tuff composed of andesite lapilli as much as 2 cm in diameter. Lenses of chert-rich pebble conglomerate occur in the uppermost part of the unit north of the American River and in the lower reaches of New York Canyon. This unit pinches out to the north, and the Upper Triassic conglomerate unit is abruptly overlain by black slate and feldspathic sandstone of the Sailor Canyon Formation north of Cisco. The volcanic and volcaniclastic rocks, which have a maximum thickness of 500 m, have not yielded any fossils, but they are considered to be Late Triassic and Early Jurassic(?) in age because of their stratigraphic position between the Upper Triassic limestone unit and the Sailor Canyon Formation.

The Sailor Canyon Formation (Lindgren, 1900) is composed of black slate, feldspathic sandstone, white-weathering, fine-grained calcareous tuff and siltstone, minor thin beds of gray sandy limestone, and lenses of volcaniclastic pebbly mudstone and polymict cobble conglomerate in its upper part. Its maximum thickness is about 3,500 m. Thin-bedded black slate and feldspathic sandstone within the lowermost 550 m of the formation have yielded Early Jurassic (late Sinemurian) ammonites (Clark and others 1962; Imlay, 1968; this report) at several localities (pl. 1, fig. 19, locs. 100, 101, 112, 115, 116). Pliensbachian ammonites also occur in that stratigraphic interval (pl. 1, fig. 19, locs. 102, 113). Late Pliensbachian and early Toarcian ammonites occur about 600 m above the base of the formation (Clark and others, 1962; Imlay, 1968; this report, pl. 1, fig. 19, locs. 103, 104, 106, 114), and early Middle Jurassic (early Bajocian) ammonites (Imlay, 1968) occur near the top of the formation (pl. 1, fig. 19, locs. 105, 108, 109).

The name "Tuttle Lake Formation" is given here to mafic tuff breccia, tuff, and minor volcaniclastic sandstone and conglomerate that overlie the Sailor Canyon Formation. The nearly continuous glaciated exposures on the east-trending ridge north of Tuttle Lake, from which the formation name is derived, are designated as the type locality of the unit (west-central sec. 21 and adjacent sec. 20, T. 17 N., R. 13 E., Cisco Grove 7.5-minute quadrangle). Massive tuff breccia makes up more than 90 percent of the formation, and andesitic tuff and volcaniclastic sandstone and conglomerate make up its remainder. Breccia fragments are angular and attain a maximum size of about 1 m, but the most common fragment size is between 20 and 30 cm. The tuff breccia is generally matrix supported and composed of polylithologic fragments, but large areas exist where the breccia fragments are dominantly plagioclase porphyry or clinopyroxene-phyric andesite. Epidote-rich clasts (metasiltstone? or metabasalt?) are abundant in parts of the formation and help to distinguish between individual tuff breccia deposits within the commonly massive breccia. The basal contact of the Tuttle Lake Formation is an unconformity that locally truncates beds in the underlying Sailor Canyon Formation. To the east the Tuttle Lake Formation is intruded by granitoid plutons or separated from the Lake Tahoe sequence by the Talbot fault zone. The maximum exposed thickness of the formation is 4,000 m.

Harwood and others (in press) suggest that the unconformity between the Sailor Canyon and Tuttle Lake Formations may have formed contemporaneously with the intrusion of the (informal) Emigrant Gap mafic complex of James (1971) (pl. 1), which they interpret to be one possible source of the parent magma of the Tuttle Lake rocks. Drake and others (1975) reported K/Ar ages ranging from 152 to 174 Ma for one phase of the Emigrant Gap mafic complex, and Snoke and others (1982) reported a U/Pb age of 163 Ma on zircon from the same pluton (I7, table 1, pl. 1) If the Emigrant Gap mafic complex is the parent-magma source of the Tuttle Lake Formation, the formation is

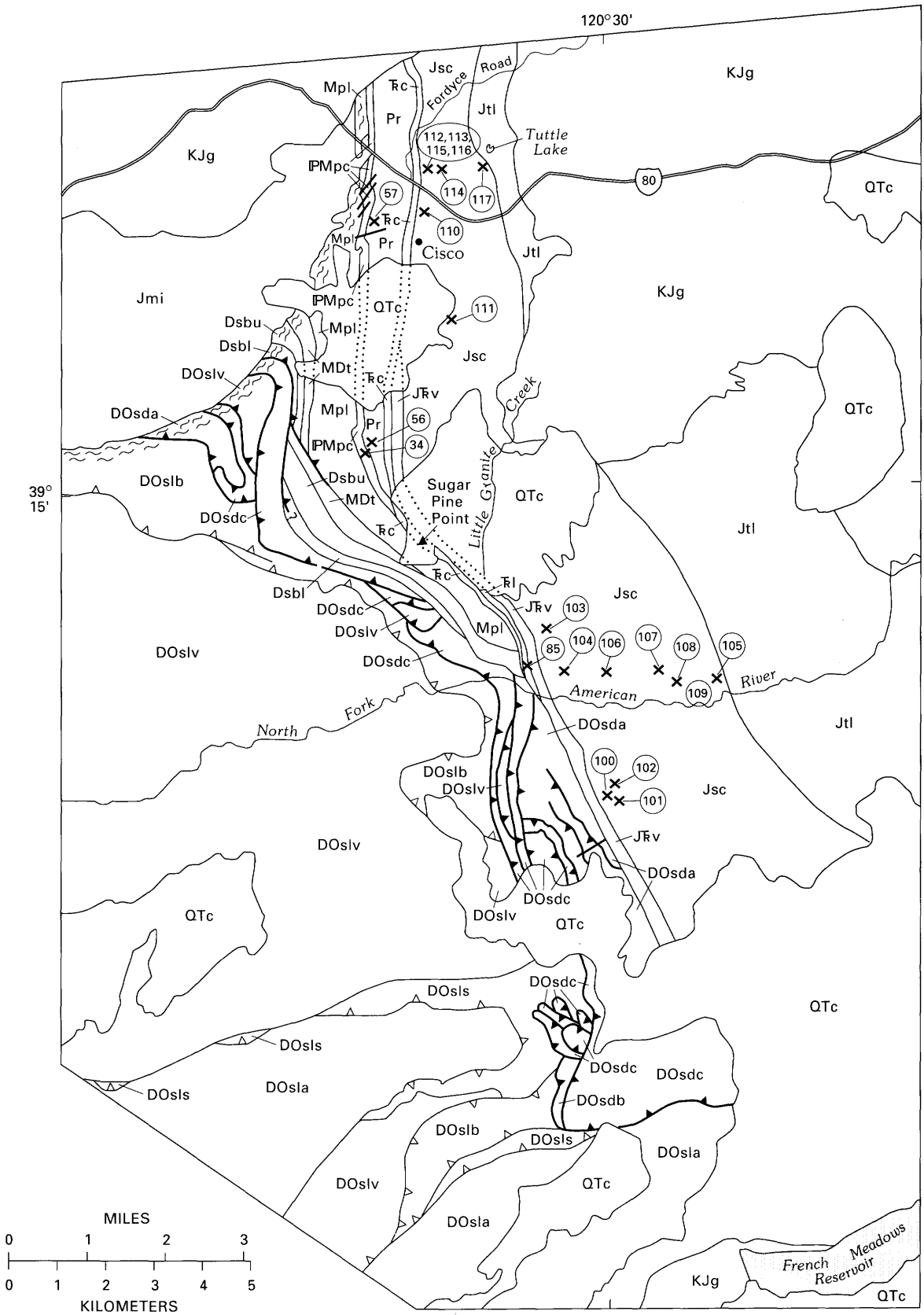


Figure 19. Geologic map of North Fork American River region of eastern Placer County, Calif., showing fossil localities and southward truncation of lithologic units below the Upper Triassic rocks.

EXPLANATION

QTc	Cover rocks (Quaternary and Tertiary)
KJg	Granitic rocks (Cretaceous and Jurassic)
Jmi	Mafic intrusive rocks (Jurassic)
Jtl	Tuttle Lake Formation (Jurassic)
Jsc	Sailor Canyon Formation (Jurassic)
JTRv	Volcanic and volcaniclastic rocks (Jurassic? and Triassic)
TRl	Limestone (Triassic)
TRc	Conglomerate (Triassic)
Pr	Reeve Formation (Permian)
	Peale Formation—Divided into:
PMpc	Chert member (Pennsylvanian and Mississippian)
Mpl	Lower member (Mississippian)
MDt	Taylor Formation (Mississippian and (or) Devonian)
	Sierra Buttes Formation (Devonian)—Divided into:
Dsbu	Upper member
Dsbl	Lower member
	Shoo Fly Complex (Devonian? to Ordovician?)—In this area, consists of:
	Duncan Peak allochthon—Divided into:
DOsdc	Chert
DOsdb	Chert breccia
DOsda	Argillite
	Lang sequence—In this area, divided into:
DOslb	Barney Cavanah Ridge Formation (Devonian? to Ordovician?)
DOslv	Big Valley Bluff Formation (Devonian? to Ordovician?)
DOsls	Screwauger Breccia (Devonian? to Ordovician?)
DOsla	Antoine Canyon Formation (Devonian? to Ordovician?)

Contact—Dotted where concealed

Soft-sediment slump contact—Sawteeth on upper deposits

Thrust fault—Sawteeth on upper plate; queried where uncertain

Normal fault

Shear zone

(102) Fossil locality—Number refers to "Catalog of fossil localities"

Figure 19. —Continued

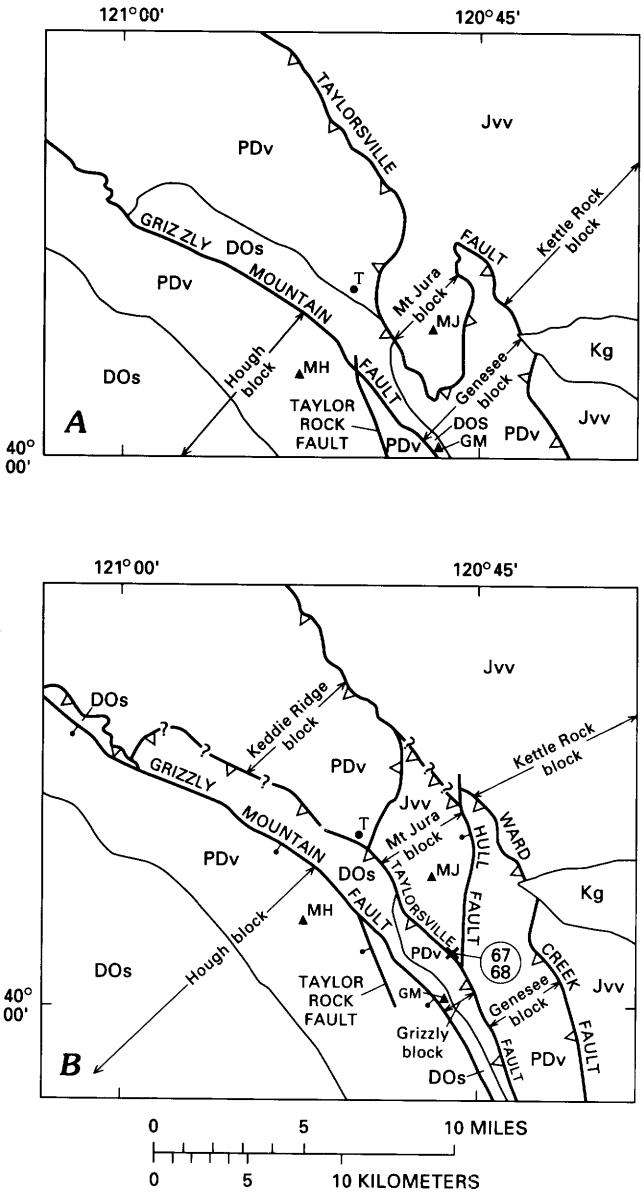
presumably Middle and Late(?) Jurassic in age. The formation can be no older than Bajocian, the age of the youngest fossils in the Sailor Canyon Formation. One specimen of the pelecypod *Posidonia*, which ranges in age from Early through Middle Jurassic, was found in volcaniclastic siltstone interbedded with andesitic tuff breccia on English Mountain (pl. 1, loc. 118). This tuff breccia overlies the Sailor Canyon Formation (Schweickert and others, 1984) and is probably correlative with at least part of the Tuttle Lake Formation.

Taylorsville Area

Diller (1892, 1908) first mapped and described the rocks in the Taylorsville area, and the specific ages of the Mesozoic rocks were determined by Hyatt (1892). Diller recognized that the area was cut by southwest-dipping thrust faults, but the extent of the faulting and the degree to which the thrusting repeated the Paleozoic section were not fully appreciated until McMath (1958) remapped the area. Because of this Late Jurassic faulting, stratigraphic relations are more complex here than they are in the American River area, and a discussion of the stratigraphy necessarily involves an outline of the structure as well.

McMath (1958) divided the Taylorsville area into four structural blocks, which are termed, from west to east: the Hough, Mount Jura, Genesee, and Kettle Rock blocks (fig. 20*A*). Each block contains an internally consistent stratigraphy, locally repeated by faults within some blocks, and is separated from adjacent blocks by major faults. McMath recognized that the Hough and Genesee blocks contain the same sequence of inverted Paleozoic rocks, a fact that had eluded Diller, and that the inverted sequence in the Genesee block is thrust over Jurassic rocks in the Kettle Rock block, which Diller (1908) had concluded earlier were Carboniferous in age.

Diller and McMath recognized that the area around Mount Jura was complicated by thrust faulting, but they made very different structural interpretations that were influenced primarily by the different ages they inferred for lenses of limestone that occur on the northeast slope of Grizzly Mountain. Diller correlated the limestone lenses with the Upper Triassic Hosselkus Limestone north of Genesee. He mapped the Taylorsville thrust fault on the southwest side of Mount Jura and extended the fault southeastward along the northeast slope of Grizzly Mountain in order to place Paleozoic rocks to the west in the upper plate over the inferred Upper Triassic limestone lenses and Jurassic rocks in the lower plate. East of Mount Jura, Diller mapped a zone of "distributive thrust faulting," referred to as the Hull fault (Diller, 1908, p. 100), that transposes Jurassic rocks on Mount Jura onto Paleozoic rocks to the east. Diller (1908, fig. 11) basically concluded that the Paleozoic and Mesozoic rocks around Mount Jura were structurally



EXPLANATION

Kg	Granite (Cretaceous)
Jvv	Volcanic and volcaniclastic rocks (Jurassic)
PDv	Volcanic rocks and chert (Permian to Devonian)
DOs	Shoo Fly Complex (Devonian? to Ordovician?)

Contact

Normal fault—Ball and bar on downthrown block

Thrust fault—Dashed where approximately located; querried where inferred; sawteeth on upper plate

67/68 Fossil locality—Circled numbers refer to "Catalog of fossil localities"

interlayered in imbricate thrust slices (fig. 20*B*). McMath (1958, p. 173–179), in contrast, concluded that the limestone lenses on the northeast slope of Grizzly Mountain were interbedded in the Taylor Formation and, thus, were Paleozoic in age. McMath mapped the Taylorsville fault along the southwest side of Mount Jura, but he extended the fault eastward around the south end of Mount Jura in a series of broad, upright folds (fig. 20*A*). In McMath's interpretation, the Taylorsville fault formed the structural base of the Genesee block and effectively separated Paleozoic and Triassic rocks in the upper plate from Jurassic rocks in the Mount Jura and Kettle Rock blocks in the lower plate.

To resolve this structural dilemma, samples of the limestone lenses on the northeast slope of Grizzly Mountain were collected for conodonts. They yielded Upper Triassic conodonts (locs. 67, 68) equivalent to those in the Hosselkus Limestone north of Genesee, thus verifying Diller's original lithologic correlation of the limestone lenses and adding support to his imbricate-thrust-slice interpretation for the Paleozoic and Mesozoic rocks around Mount Jura (fig. 20*B*). My reconnaissance mapping suggests that the Taylorsville thrust extends northwest of Taylorsville where it transposes the Sierra City melange over the Sierra Buttes Formation. Consequently, two other structural blocks, the Keddie Ridge and Grizzly blocks (fig. 20*B*), are added to the four originally recognized by McMath.

From the available data, it appears that Jurassic rocks make up all of the Kettle Rock and Mount Jura blocks. In the Kettle Rock block, the Jurassic rocks are predominantly andesitic and dacitic tuff breccia and tuff that form a southwest-dipping, upright stratigraphic sequence. The Genesee block, which contains rocks of the Taylorsville and Permian volcanic sequences overlain by upper Middle and Upper Triassic rocks, overlaps parts of the Kettle Rock block along the Ward Creek fault (fig. 20). The Mount Jura block lies on the west slope of the Genesee block along the Hull fault, and farther to the north it lies structurally above the Kettle Rock block. Thin lenses or tectonic slivers of Upper Triassic limestone (pl. 1, fig. 20, locs. 67, 68) occur along the Taylorsville thrust, which separates the Grizzly block from the Genesee and Mount Jura blocks. The Grizzly Mountain fault (McMath, 1958) places Upper Permian volcanic rocks in the Hough block against the Sierra City melange of the

◀**Figure 20.** Generalized geologic maps of the Taylorsville area, northern California. GM, Grizzly Mountain; MJ, Mount Jura; MH, Mount Hough; T, Taylorsville. *A*, Tectonic blocks and major faults as mapped by McMath (1958). In this tectonic interpretation, the folded Taylorsville thrust fault separates Paleozoic rocks in the upper plate from Mesozoic rocks in the lower plate. *B*, Tectonic blocks and major faults in imbricate-thrust-slice interpretation of this report.

Shoo Fly Complex in the Grizzly block. No Mesozoic rocks have been recognized in the Hough block.

The oldest known Mesozoic rocks in the Taylorsville area are gray tuff and tuffaceous slate of the Pit Formation. Recently discovered ammonites from the tuffaceous slate (pl. 1, fig. 10, loc. 63) are indicative of a late Middle Triassic (middle Ladinian) age. The slate lies beneath the Hosselkus Limestone with apparent conformity, but the contact is not exposed. The Hosselkus Limestone, which caps the ridge north of Genesee, has yielded a variety of megafossils as reported by Diller (1908) (pl. 1, fig. 10, loc. 65) and Late Triassic conodonts that are indicative of a probable late Karnian to early Norian age (loc. 66). The Swearinger Slate contains the pelecypod *Monotis subcircularis* (loc. 86) that is indicative of a Late Triassic (early late Norian) age somewhat younger than the age of the Hosselkus Limestone and significantly younger than the Pit beneath the Hosselkus. However, the Swearinger Slate occurs east of, and topographically below, the Hosselkus Limestone and Pit Formation (fig. 10). The west contact of the Swearinger Slate must be a fault, but whether it is a thrust or a high-angle normal fault is unknown; at this time a normal fault is favored.

Mount Jura Block

Jurassic rocks were first recognized in the Taylorsville area in 1863 when W.H. Brewer of Yale University and his field associate Clarence King collected fossils from red slate near Mormon Station (Whitney, 1865, p. 308). Mormon Station, a site name that does not appear on current topographic maps, was located in the alluvial valley of Indian Creek between Taylorsville and Genesee (SW¼ NE¼ sec. 12, T. 25 N., R. 10 E., Taylorsville 7.5-minute quadrangle). The fossil discovery site was located in the Hardgrave Sandstone (Diller, 1892) somewhere on the south slope of Mount Jura, which Diller named in 1890 (J.S. Diller, field notes). Since that original fossil discovery, the Jurassic rocks on Mount Jura have been the subject of repeated stratigraphic and biostratigraphic studies that have produced conflicting interpretations (Diller, 1892, 1908; Hyatt, 1892; Crickmay, 1933; McMath, 1958, 1966; Batten and Taylor, 1978).

Diller (1892, 1908) divided the Jurassic rocks into eight map units (fig. 21) that consist of volcanic tuff and tuff breccia interbedded with shallow-water marine volcaniclastic rocks and limestone. Hyatt (1892) identified Early, Middle, and Late Jurassic fossils in six of the eight map units recognized by Diller. On the basis of these paleontologic studies, Hyatt confirmed that the Jurassic rocks on Mount Jura were structurally inverted and tectonically repeated as Diller had proposed.

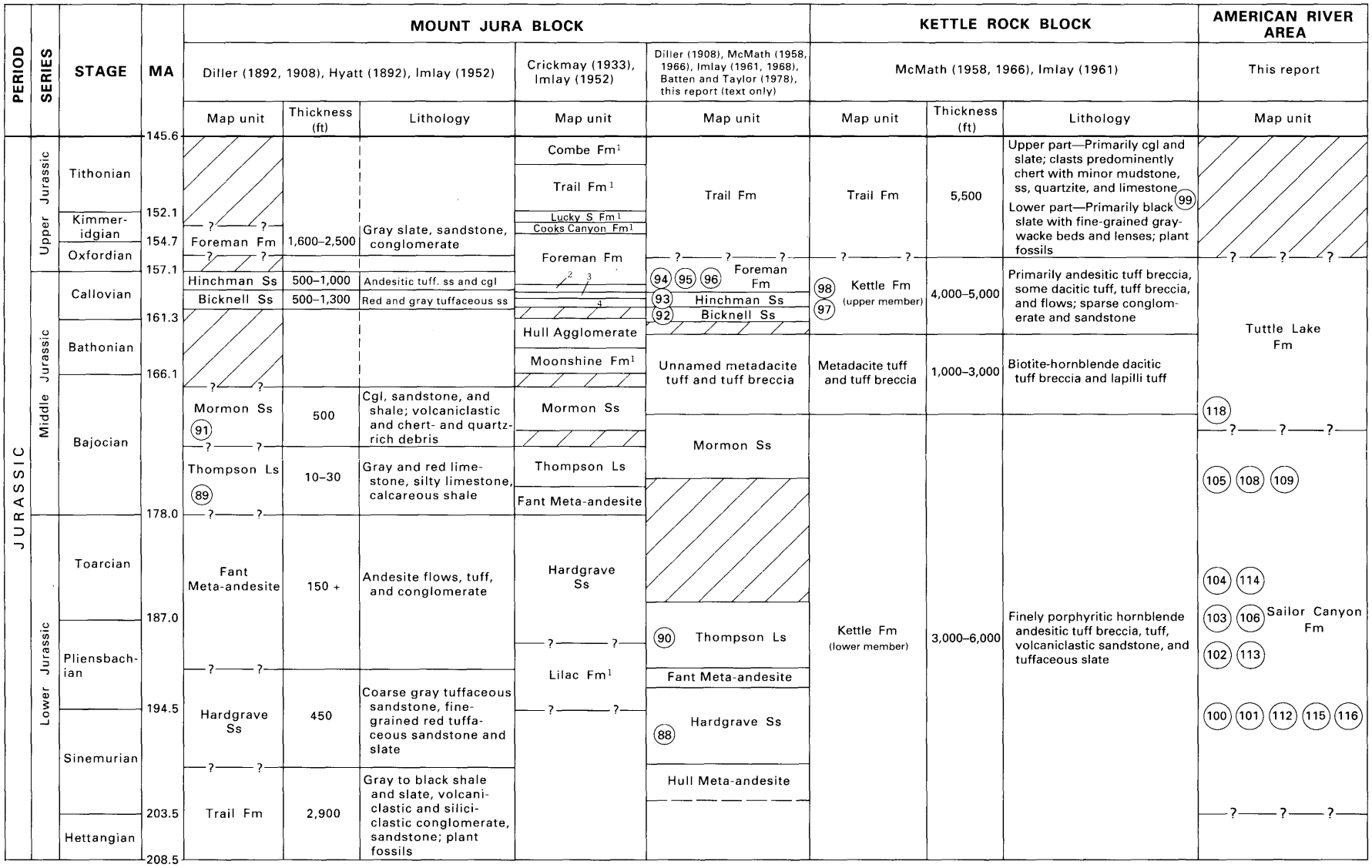
Crickmay (1933) restudied the Mount Jura section and, in a brief preliminary report, transposed Diller's (1908) Trail Formation from the base of the Jurassic sequence, where Diller had placed it, to the upper part of the section. This stratigraphic change was confirmed by McMath (1958). Crickmay (1933) also proposed fourteen map units in the Jurassic rocks (fig. 21), six of which have not been confirmed by subsequent mapping. Crickmay's studies produced new faunal lists for many of the Jurassic units, but he failed to give any locality descriptions and, unfortunately, none of his data could be used in this report.

McMath (1958) produced a detailed map of the south slope of Mount Jura, and he integrated the extrusive volcanic rocks, which Diller (1908) had treated separately, into the stratigraphic column (fig. 21). Furthermore, McMath recognized a distinctive unit of meta-dacite tuff and tuff breccia on Mount Jura that he correlated lithologically with a similar dacitic unit that he mapped in the middle part of his Kettle Formation (see McMath 1958, 1966) farther east. If this correlation is correct, it establishes an important stratigraphic link between the fossiliferous volcaniclastic rocks in the Mount Jura block and the sparsely fossiliferous volcanic and volcaniclastic rocks in the Kettle Rock block.

Imlay (1961) identified ammonites (loc. 97, 98) that established a late Middle Jurassic (Callovian) age for the upper part of McMath's (1958, 1966) Kettle Formation, and he refined the ages of some of the map units in the Mount Jura block (see also Imlay, 1952). Batten and Taylor (1978) presented evidence for an Early Jurassic (late Pliensbachian) age for the Thompson Limestone to which Hyatt (1892) had originally assigned an early Middle Jurassic (early Bajocian) age. They also suggested that the Mormon Sandstone is separated from the Thompson Limestone and other underlying units by a major disconformity that represents much of Toarcian and early Bajocian time.

Much work remains to be done on Mount Jura. However, until a definitive study is made, the stratigraphic sequence modified from Diller (1908) by the work of McMath (1958), Imlay (1952, 1961, 1968), and Batten and Taylor (1978) is used in this report (fig. 21). The distribution of the map units on Mount Jura has been shown by Diller (1908) and to a limited extent by McMath (1958), but a new detailed map of the area is needed.

Following the work of McMath (1958), Diller's (1908) Hull Meta-andesite is at the base of the exposed section on Mount Jura. The Hull is composed of fine- to medium-grained andesitic tuff breccia and tuff that contains augite- and plagioclase-phyric fragments set in a matrix of fine-grained plagioclase, epidote, calcite, chlorite, and magnetite(?). No fossils have been found in the Hull Meta-andesite, but it is older than the Hardgrave Sandstone, which contains late Sinemurian fossils (loc. 88). The Hardgrave Sandstone consists of gray and red, coarse- to fine-grained, locally calcareous volcaniclastic sandstone and shale with scattered lenses and beds of volcaniclastic conglomerate. Detrital feldspar grains and volcanic lithic fragments are common in the coarse-grained sandstone, but quartz is rare. Conglomerate



[1] Age unconfirmed
[2] North Ridge Fm
[3] Hinchman Fm
[4] Bicknell Ss

Figure 21. Comparative stratigraphic columns for Jurassic rocks of the Mount Jura block, Kettle Rock block, and North Fork American River area, California. Isotopic ages from Harland and others (1990). Circled numbers refer to "Catalog of fossil localities" and plate 1. Diagonal lines indicate hiatus.

beds are composed of rounded pebbles and cobbles of volcanic debris and intraclasts of volcaniclastic sandstone and shale. The Hardgrave Sandstone is richly fossiliferous; *Pecten acutiplicatus* is the most common form of the 42 species identified by Hyatt (1892) (loc. 88). On the basis of ammonites, Imlay (1968) considered the Hardgrave to be Early Jurassic (late Sinemurian) in age. The next younger unit in the inverted sequence is the Fant Meta-andesite (Diller, 1908), which is composed of massive andesitic tuff breccia and tuff composed of plagioclase- and clinopyroxene-phyric fragments generally less than 3 cm in diameter. The Fant Meta-andesite is succeeded stratigraphically by discontinuous lenses of the Thompson Limestone (Diller, 1892, 1908). The Thompson Limestone is composed of thin-bedded, blue-gray calcarenite and bioclastic limestone interbedded with red and gray calcareous shale. It is locally packed with the gastropod *Nerinea* (loc. 89) (Diller, 1908). Although Hyatt (1892) assigned an age of Middle Jurassic to the Thompson Limestone (inferior Oolite, in his terms), Batten and Taylor (1978) regarded the age of the Thompson as Early Jurassic on the basis of the rudist-like pelecypod *Plicatostylus* (loc. 90), which has been reported only in rocks of late Pliensbachian and early Toarcian age. Furthermore, they argued that the irregular distribution of the Thompson Limestone was due to the development of an erosional unconformity at the base of the overlying Mormon Sandstone. The Mormon Sandstone (Diller, 1892, 1908), though predominantly volcaniclastic, contains significant amounts of quartz in addition to volcanic-lithic fragments, plagioclase, and clinopyroxene grains. The sandstone grades into coarse polymict conglomerate, locally as thick as 50 m, composed of rounded pebbles, cobbles, and boulders of meta-andesite, metarhyolite, chert, quartzite, and limestone. Batten and Taylor (1978) found *Euhoploceras* 25 m above the base of the Mormon Sandstone and, on the basis of this ammonite, assigned the unit an early middle or late early Bajocian age. This age assignment refines Hyatt's (1892) original age determination for the Mormon (loc. 91) and indicates the presence of a major hiatus between the Mormon Sandstone and the Thompson Limestone that represents most of early Bajocian and at least part of Toarcian time (Batten and Taylor, 1978). East of and stratigraphically above the Mormon Sandstone, McMath (1958) mapped a unit of metadacite tuff that Diller (1908) had mapped as undivided volcanic rocks and patches of intrusive rhyolite of Late Jurassic or Early Cretaceous age. The metadacite tuff contains hornblende and biotite phenocrysts and was interpreted to be of pyroclastic origin by McMath (1958). The blue-gray metadacite tuff contrasts sharply with the andesitic units on Mount Jura, but it is lithologically similar to the middle member of McMath's (1958, 1966) Kettle Formation.

The metadacite tuff occurs at the top of the Jurassic section on the southwest slope of Mount Jura. To the east, it is in fault contact locally with the Hardgrave Sandstone and with the Hull Meta-andesite. Diller (1908) recognized that a fault repeats the section on Mount Jura, and he interpreted the fault to be an ancillary thrust related to the Taylorsville thrust fault.

East of this fault, McMath (1958) mapped the lower part of the Jurassic section up to and including the metadacite tuff on the south slope of Mount Jura. He showed the rocks above the metadacite tuff as undivided Jurassic rocks. Diller (1908), on the other hand, defined three map units—the (ascending) Bicknell Sandstone, Hinchman Sandstone, and Foreman Formation—on the east flank of Mount Jura. The Bicknell Sandstone is composed of reddish-brown and gray, locally calcareous, volcaniclastic sandstone and black shale. It contains widely scattered pelecypods and sparse ammonite fragments (loc. 92) that are indicative of a late Middle Jurassic (Callovian) age (Hyatt, 1892; Imlay, 1961). The Hinchman Sandstone gradationally overlies the Bicknell Sandstone and is distinguished from it primarily by its coarser grain size and associated fossils. The Hinchman Sandstone is dark-greenish gray and contains abundant feldspar and clinopyroxene grains. It also contains andesitic tuff breccia and lenses of conglomerate composed of rounded to subangular pebbles and cobbles of andesite and sparse limestone pebbles or nodules. Corals of the genus *Stylina* are the most abundant fossils in the Hinchman Sandstone, but gastropods, pelecypods, brachiopods, and ammonites also occur (loc. 93). On the basis of the ammonites, Imlay (1961) dated the unit as Callovian in age. The Foreman Formation occurs east of, and presumably above, the Hinchman Sandstone. It is composed of dark-gray to black shale, volcaniclastic sandstone and conglomerate interbedded in variable proportions; shale is predominant. Some sandstones are quartzose. Conglomerate occurs in thin beds and lenses and is composed of rounded pebbles of chert, meta-andesite, metarhyolite, and sparse limestone. The black shale locally contains fragments of plant fossils (loc. 96; Diller, 1908, p. 55). Fossils collected from the northeast slope of Mount Jura (locs. 94, 95; Diller, 1908) are indicative of a Callovian age (Imlay, 1961). Diller (1908) noted that the contact between the Foreman and the Hinchman is irregular and suggested that it might be a disconformity.

Kettle Rock Block

A thick sequence of andesitic and dacitic tuff breccia and tuff with interbedded volcaniclastic sandstone and conglomerate make up most of the Kettle Rock block (McMath, 1958), which is located in the northeastern part of the northern Sierra terrane. Diller (1908) named this predominantly volcanic sequence the "Kettle Meta-andesite" and correlated it with what he presumed were Carboniferous meta-andesite units (primarily the Taylor Formation) near Taylorsville. McMath (1958, 1966) renamed and revised Diller's Kettle Meta-andesite as the Kettle Formation (see also Lydon and others, 1960; Burnett and Jennings, 1962) to include

interbedded slate, sandstone, and conglomerate originally mapped by Diller as part of the "Trail beds." McMath established a late Middle Jurassic age for the upper part of the formation on the basis of ammonites. The formation name apparently was derived from extensive exposures at and near Kettle Rock (pl. 1), but neither McMath nor Diller designated a type area or type locality for the unit. These rocks are still too poorly known to establish a "type" locality for the Kettle.

McMath (1958, 1966) divided the Kettle Formation into three informal members. The upper and lower members are composed primarily of porphyritic hornblende andesite tuff breccia and tuff. Variable, but generally subordinate, amounts of volcaniclastic sandstone, conglomerate, and tuffaceous slate are interbedded with the fragmental andesitic deposits. The fragmental volcanic rocks are gray or green and contain locally abundant reddish clasts. Hornblende phenocrysts are more abundant than clinopyroxene phenocrysts, but both types tend to be small and sparsely distributed in a fine-grained matrix of plagioclase, chlorite, calcite, sericite, and indeterminate opaque dust. Locally, the volcanic rocks are contact metamorphosed to albite-epidote hornfels, and the more aluminous pelitic layers contain andalusite. Volcaniclastic sandstone and conglomerate beds are commonly graded, and channeling and cross bedding, typical of alluvial deposits, are present locally (Christe, 1987). McMath (1958) estimated the lower member to be 3,000 to 6,000 ft thick and the upper member to be 4,000 to 5,000 ft thick.

The middle member of the Kettle Formation is composed primarily of gray to bluish-gray dacitic tuff breccia and lapilli tuff. Quartz phenocrysts typically make up about 5 percent of the dacitic tuff breccia, and altered biotite phenocrysts compose about 10 percent of the rock. Saussuritized plagioclase phenocrysts constitute 35 to 65 percent of the rock. Hornblende occurs locally and is partially altered to pale-green calcic amphibole. McMath (1958) estimated the middle member to be 1,000 to 3,000 ft thick.

McMath (1958, p. 150; 1966) reported fossils near the middle of the upper member of the Kettle Formation (pl. 1, loc. 97), and Imlay (1961) reported the fauna from that locality and from a second locality several hundred feet stratigraphically lower in the upper member (pl. 1, loc. 98). Ammonites from these localities, identified by Imlay (1961), are indicative of a late Middle Jurassic (early or middle Callovian) age. Curiously, the occurrence of these fossils was apparently unknown to Christe and Hannah (1987) who concluded that the Kettle Formation was deposited subaerially during a period of continental-arc volcanism.

Mesozoic Tectonic Slivers

In the western part of the northern Sierra terrane, Mesozoic rocks occur in fault-bounded tectonic slivers caught between the Shoo Fly Complex and the Feather River peridotite belt. The largest area of Mesozoic rocks is located southwest of Lake Almanor and consists of two tectonic slivers. Jayko (1988) referred to the east sliver as the Butt Valley block and the west sliver as the Soda Ravine block. A smaller sliver, probably continuous with the Soda Ravine block, occurs west of Quincy, and a separate, totally isolated tectonic sliver occurs south of Interstate Highway 80 near Casa Loma (pl. 1). In addition to these tectonic slivers west of the Shoo Fly, Standlee (1978) mapped a lenticular unit of pelite-matrix melange within the lower part of the Shoo Fly southwest of Quincy, which is tentatively included here with the Mesozoic tectonic slivers. D'Allura and others (1977) also outlined an area of rocks that they designated as the Arlington Formation within the Shoo Fly west of Clio that may be part of another Mesozoic tectonic sliver. Harwood and others (1988) referred to the tectonic slivers as "fault slices of Permian and Triassic rocks," but subsequent mapping by Jayko (1988, 1990) and the discovery of probable Early Jurassic ammonites in the Butt Valley block indicate that the age and structure of the tectonic slivers are more complex than originally proposed.

Diller (1895) originally assigned the Mesozoic rocks southwest of Lake Almanor to the Cedar Formation, which he had also mapped in Shasta County. However, Smith (1894) and Willis (1912) referred to these same rocks as the combined Swearinger Slate and Hosselkus Limestone. Willis (1912) implied by his usage that the name "Cedar Formation" was superfluous and should be abandoned, but he did not make that formal proposal. Because the name "Cedar Formation" has never been widely accepted and has been used only rarely in the past 20 years, it is here formally abandoned everywhere that it has been previously mapped. Diller (1906), in fact, did not perpetuate (geographically extend) the name "Cedar Formation" in Shasta County but, rather, assigned stratigraphically equivalent rocks to the Modin and Potem Formations. Until more definitive lithologic, structural, and age data are available, it seems best to reassign the rocks previously mapped as the Cedar Formation in the northern Sierra terrane and Shasta County to unnamed lithologic units and to suggest correlation with named units as the data base evolves.

Robinson (1975) and D'Allura and others (1977) assigned the rocks mapped as the Cedar Formation by Diller (1895) to the Arlington Formation and concluded that the Arlington ranged in age from earliest Permian through the Triassic. Data previously presented in this report make this correlation untenable.

In the Butt Valley block, Upper Triassic conglomerate and limestone, which has yielded late Karnian to late Norian conodonts (locs. 77 to 82), unconformably overlies andesitic volcanic rocks assigned to the Taylor Formation by Jayko (1988). Over most of their outcrop length, these andesitic volcanic rocks are in thrust contact with the Lang sequence of the Shoo Fly Complex. North of the North Fork of the

Feather River, however, the andesitic volcanic rocks are separated from the Shoo Fly by a thin sliver of felsic volcanic rocks assigned to the Sierra Buttes Formation and a tectonic sliver of serpentinite (Jayko, 1988). Upper Triassic rocks in the Butt Valley block grade up into gray-weathering black tuffaceous slate and volcaniclastic sandstone that contain mappable lenses of chert-rich polymict conglomerate. Ammonites recovered from the tuffaceous slate (locs. 83, 84) are no older than Middle Triassic and are suggestive of an Early Jurassic age. The ammonites are associated with poorly preserved impressions of the pelecypod *Posidonia*. From available data, it appears that the Mesozoic rocks in the Butt Valley block range in age from Late Triassic to Early Jurassic and that they were deposited on a deeply eroded section of rocks belonging to the northern Sierra terrane (Jayko, 1988, 1990).

In contrast to the Butt Valley block, matrix rocks in the Soda Ravine block are undated black slate and argillite that contains tectonic blocks of Permian and Triassic bioclastic limestone. Permian limestone fragments in the Soda Ravine block and in the rocks west of Quincy have yielded Early Permian fusulinids (locs. 73, 74, 76) equivalent to zone A of the McCloud Limestone and poorly preserved Early Pennsylvanian to Early Permian conodonts (loc. 75). One fragment of Triassic limestone in the Soda Ravine block reportedly has yielded early Norian fossils (loc. 69), equivalent to those in the Hosselkus Limestone, and a second block produced ammonites indicative of a late Ladinian to Karnian age (loc. 71). The undated black slate that forms the matrix of the Soda Ravine block is lithologically similar to rocks in the Pit Formation and the Brock Shale mapped farther northwest in the eastern Klamath terrane. Jayko (1990) concluded that the Soda Ravine block is a dismembered slice of the eastern Klamath terrane containing rocks equivalent to the McCloud Limestone, Pit Formation, Hosselkus Limestone, and Brock Shale.

Lenses of polymict conglomerate and pebbly mudstone are common in the Butt Valley block and occur sporadically in the tectonic slivers west of Quincy and near Casa Loma. The conglomerate and pebbly mudstone lenses contain pebbles and cobbles of chert, quartzite, micaceous quartzite, quartz-mica schist, and a variety of volcanic fragments supported in variable amounts of mudstone matrix. Except in the Casa Loma sliver, the clasts are strongly deformed, but even the deformed clasts are rounded to subrounded suggesting significant transport at some time in their depositional history. However, the poor sorting and general lack of internal bed forms suggest rapid, chaotic deposition of the coarse debris in its present pelitic matrix. The micaceous quartzite and quartz-mica schist clasts contain a metamorphic foliation defined by oriented, coarse-grained biotite and muscovite suggestive of high-greenschist- or low-amphibolite-facies metamorphism. The matrix of the conglomerate, however, contains very fine grained sericite and chlorite indicative of, at most, low- greenschist-facies metamorphism. The depositional, structural, and metamorphic histories of the tectonic slivers are subjects of current study.

SUMMARY

Data from the "Catalog of fossil localities" have been used to refine and revise the ages and stratigraphic relations of Paleozoic and lower Mesozoic rocks in the northern Sierra terrane north of the 39th parallel. In some cases, the new fossil data dictate new structural interpretations for parts of the terrane.

Late Middle to Late Ordovician conodonts from a lens of limestone interbedded with quartzose turbidites of the Lang sequence provide the oldest depositional age obtained thus far for the lower Paleozoic Shoo Fly Complex. Conodonts and megafossils from limestone blocks in the Sierra City melange are Late Ordovician in age and have North American biogeographic affinities (Hannah and Moores, 1986; Potter and others, 1990). Zircons from a felsic tuff interbedded with the matrix of the Sierra City melange give a U/Pb age of $423^{+5}/_{-15}$ Ma. (Saleeby and others, 1987), which is the youngest depositional age obtained to date on rocks in the Shoo Fly Complex. This isotopic age and the biogeographic data on fossils from limestone blocks in the Sierra City melange provide important constraints on the time of deformation and on the paleogeography of the inferred accretionary wedge represented by the Shoo Fly Complex. The isotopic age indicates that at least the upper thrust slices of the Shoo Fly were structurally juxtaposed during or after the late Early Silurian, whereas the fossils in the limestone blocks establish that this accretionary tectonism occurred within the North American biogeographic province. Upper Devonian epiclastic and volcanic rocks of the Taylorsville sequence unconformably overlie the Shoo Fly and set a minimum age for deposition and early deformation in the Shoo Fly Complex.

Earliest deposition in the Taylorsville sequence is recorded by Frasnian fossils in a slump block of shallow-water limestone and interbedded sandstone contained in relatively deep water submarine-fan deposits of Famennian age in the Grizzly Formation. Arc volcanism, which began in the Famennian and continued into the late Kinderhookian (Early Mississippian), is recorded by rocks of the Sierra Buttes, Taylor, and lower member of the Peale Formations. By late Early Mississippian (Osagean) time, the volcanic arc had cooled and subsided to basinal depths and was overlapped by siliceous pelagic sediments recorded now in the thin but widespread chert member of the Peale Formation. Pelagic sedimentation continued at least until the Middle Pennsylvanian (Desmoinesian).

An erosional unconformity, spanning the Late Pennsylvanian and early Early Permian (early Wolfcampian), separates the Taylorsville sequence from the

Permian volcanic sequence. The Permian volcanic sequence consists of the Arlington, Goodhue, and Reeve Formations and the Robinson Formation of McMath (1958, 1966). Megafossils from the matrix of chert-rich conglomerate near the base of the Arlington Formation at its principal reference locality are indicative of a late Wolfcampian through Leonardian age. Conodonts from a limestone block in this conglomerate are early Leonardian, however, and indicate that the matrix of the conglomerate must also be Leonardian because it would be impossible for blocks of Leonardian limestone to have slumped into Wolfcampian deposits. Sparsely fossiliferous conglomerate on Peel Ridge, herein correlated with the Arlington Formation, gradationally underlies the Goodhue Formation and establishes a late Early Permian age for the lower part of the Goodhue rather than the Late Pennsylvanian age suggested by Durrell and D'Allura (1977) on the basis of *Helicoprion*. Conglomerate containing late Early Permian fusulinids that D'Allura and others (1977) and Hannah and Moores (1986) placed in the upper member of the Peale as defined by McMath (1958), is considered to be part of the Reeve Formation in this report. Fossil data and stratigraphic relations indicate that the Arlington, Goodhue, and Reeve Formations and the Robinson Formation of McMath (1958), 1966) are laterally equivalent facies deposited from late Wolfcampian(?) to Capitanian time. Fusulinids from the Reeve Formation have affinities with those in the McCloud Limestone of the eastern Klamath terrane.

In the vicinity of the North Fork of the American River, Upper Triassic conglomerate, limestone, and tuff form a southward-transgressive sequence that truncates folded and eroded Paleozoic rocks. This angular unconformity spans Late Permian to Late Triassic time and represents deformation considered to be related to the Sonoma orogeny. The Upper Triassic rocks are overlain by the Lower and Middle Jurassic Sailor Canyon Formation which, in turn, is overlain by Middle and lower Upper(?) Jurassic andesitic volcanic rocks of the Tuttle Lake Formation. The Tuttle Lake Formation is faulted on the east against presumably middle Paleozoic rocks of the Lake Tahoe sequence that are correlated with Upper Devonian and younger rocks in the Taylorsville sequence.

North of Genesee, the oldest Mesozoic rocks are upper Middle Triassic (middle Ladinian) tuffaceous slate assigned to the Pit Formation. The Pit locally underlies the Upper Triassic Hosselkus Limestone and rests disconformably on Permian rocks of the Reeve Formation. Lenses of Upper Triassic limestone lithologically equivalent to the Hosselkus occur on the northeast slope of Grizzly Mountain where they are interpreted to be tectonic slivers caught along the Taylorsville thrust fault as originally mapped by Diller (1908). On the basis of these Upper Triassic limestone slivers, Jurassic rocks on Mount Jura are inferred to lie in an imbricate thrust slice or slices structurally below Paleozoic rocks in the Grizzly block to the west and structurally above Paleozoic rocks in the Genesee block to the east.

Tectonic slices of Permian and Triassic rocks occur locally between the Feather River peridotite belt and the Shoo Fly Complex. Permian fusulinids from limestone blocks in these tectonic slivers have affinities to those in the McCloud Limestone. The tectonic evolution of these slivers is currently under study.

Other areas or geologic problems that need further study include the distribution of rocks on Mount Jura and their relation to rocks in the Kettle Rock block to the east, structural relations in the Taylorsville area, and the depositional and tectonic ages of the Shoo Fly Complex.

CATALOG OF FOSSIL LOCALITIES

The following catalog includes 118 fossil localities from the northern Sierra terrane. Collections date back to 1890, and faunal lists from the older studies have been available in widely scattered publications for nearly a century. Many of the published localities have been recollected, but some could not be found and others were not sought. For those localities that were not recollected, but for which approximate locations were published or were obtained from U.S. Geological Survey records, the original published faunal lists are given but no attempt was made to find or verify the material listed. Unfortunately, some published reports failed to give any geographic information on the localities, and those faunal lists are not included in this report.

Fossil localities in this catalog are shown on plate 1, and some are more precisely shown on text figures. The locality number in each bold heading is the same as that used on plate 1. Descriptions of fossil locations use many geographic names and triangulation features that cannot be shown on plate 1 because of the scale, but those places can be seen on the appropriate quadrangle map noted in the description.

Standard abbreviations have been used for fossil identifications. CAI refers to conodont alteration index (see Epstein and others, 1977; Rejebian and others, 1987).

Locality Number 1

Unit.—Lang sequence of the Shoo Fly Complex

Collector, year of collection, field No.—D.S. Harwood, 1987, BNM–87–1

U.S. Geological Survey locality No.—10692–CO

Location.—Blue Nose Mountain 7.5' quad., Plumas County, Calif.; SE¼NE¼ sec. 20, T. 22 N., R. 11 E.; lat 39°46'05" N., long 120°46'16" W. Low rubbly outcrop at 6,650-ft elevation, west side of road; 2,000 ft bearing 081° from BM 7308 on McRae Ridge.

Rock type/setting.—Dark-gray limestone with sparse, coarsely recrystallized megafossils (crinoid columnals?) interbedded with black slate and greenish gray chert. Associated with gray slate and quartzite, but contact relations are not exposed.

Fossils.—Conodonts:

1 Pa element fragment of *Amorphognathus* sp. indet.
3 simple coniform elements
5 indet. bar and blade fragments
1 pedicle valve of an acrotretid brachiopod

Fossil age.—middle Middle to Late Ordovician. CAI=5–5.5=300–350 °C. (A.G. Harris, written commun., 1987).

Locality Number 2

Unit.—Limestone block in the Sierra City melange of the Shoo Fly Complex (Schweickert and others, 1984)

Locality Number 2—Continued

Collector, year of collection, field No.—J.L. Hannah, 1984, GV–84–3H

U.S. Geological Survey locality No.—10009–CO

Location.—Greenville 15' quad., Plumas County, Calif.; center sec. 11, T. 25 N., R. 10 E.; lat 40°02'40" N., long 120°50' W. Outcrop in Montgomery Creek at elevation 4,040 ft.

Rock type/setting.—Lens of gray, recrystallized, bioclastic limestone in Sierra City melange of Shoo Fly Complex; originally mapped as (herein-abandoned) Montgomery Limestone by Diller (1908). Limestone block is associated with blocks of serpentinite, basalt, and limestone breccia in matrix of broken sandstone and pelite.

Fossils.—Conodonts:

Belodina sp.
Drepanoistodus suberectus (Branson and Mehl)
Panderodus gracilis (Branson and Mehl)
Protopanderodus insculptus (Branson and Mehl)
Indet. simple cone and bar elements

Fossil age.—late Late Ordovician (middle Maysvillian-Gamachian). "The species association is indicative of North American midcontinent faunas 12 and 13 (relatively warm-water biofacies) and deposition in generally warm shelfal or platformal settings. CAI=5.5–6=350–400 °C." (A.G. Harris, written commun., 1985).

Comment.—Diller (1908) considered this limestone block to be part of the (herein-abandoned) Montgomery Limestone to which he assigned a Middle Silurian age on basis of megafossils identified from a separate block (loc. 3) by C.D. Walcott.

Locality Number 3

Unit.—Limestone block in the Sierra City melange of the Shoo Fly Complex (Schweickert and others, 1984)

Collector, year of collection, field No.—Cooper Curtice, 1890, ?

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; NE¼NE¼SE¼ sec. 14, T. 25 N., R. 10 E.; lat 40°01'52" N., long 120°49'27" W. On ridge crest, about 6,740 ft elevation; 8,800 ft bearing 322° from BM 7711 on Grizzly Peak.

Rock type/setting.—Light-gray-weathering, dark-blue-gray limestone with minor chert knots; occurs as isolated block 60 ft thick and 200 ft long in serpentinite-bearing melange. Originally mapped as (herein-abandoned) Montgomery Limestone (Diller, 1908) and considered by him to be Silurian in age.

Fossils.—Corals:

(identified by C.D. Walcott in Diller, 1908, p. 16)
Stromatopora sp.(?)
Zaphrentis

Locality Number 3—Continued

Fossils.—Corals—Continued

(identified by C.D. Walcott in Diller, 1908)—Continued

Syringopora (like *S. serpens*)
Heliolites
Halysites catenulatus
Orthis (cf. *O. flabellum*)
Ormoceras (cf. *O. siphuncles*)

(identified by C.W. Merriam, 1972, p. 17)

Halysites (*Catenipora*) sp.
Plasmopora sp.
Dalmanophyllum? sp.
Palaeophyllum sp.

(identified by E.O. Ulrich in Diller, 1908, p. 17)

Halysites catenulatus
Heliolites cf. *H. interstinctus*
Heliolites cf. *H. elegans*
Favosites?
Cyathophyllum sp.

(identified by Potter and others, 1990)

Paleofavosites sp.
Propora sp.
Quepora sp.
Streptelasma or *Palaeophyllum*
Grewingkia penobscotensis

Brachiopods:

(identified by C.W. Merriam, 1972, p.17)

Hesperorthis
Schizoramma
Dicaelosia
Skenidioides

(identified by Boucot and Potter, 1977, p. 211)

Glypterina aff. *G. uniplicata*
glyptothinid
Phragmorthis sp.
n. gen. orthacean
Dicaelosia sp.
Epitomyonia? sp.
Diambonia

(identified by Potter and others, 1990)

Bimuria sp.
Diambonia sp.
Dicaelosia sp.
Diochthofera sp.
cf. *Elasmothyris*
Epitomyonia? sp.
Phragmorthis aff. *P. buttsi* Cooper, 1956
Ptychopleurella (*Glypterina*) aff. *G. uniplicata* Cooper, 1956
Skenidioides sp.

Sphinctozoan sponges:

(identified by Potter and others, 1990)

Amblysiphonella sp.
Pseudoimperatoria mega?

Locality Number 3—Continued

Fossils.—Sphinctozoan sponges—Continued

(identified by Potter and others, 1990)—Continued

Pseudoimperatoria? sp.
Corymbospongia cf. *C. adnata* Rigby and Potter, 1986
Cystothalamiella sp.
Girtycoella cf. *G. epiporata* Rigby and Potter, 1986
Rigbyetia obconica

Fossil age.—Faunal assemblages were considered to be early Middle Silurian (Niagaran) by Walcott and Ulrich, Early Silurian (Llandoverian) by Merriam (1972), and Late Ordovician (Ashgillian) by Boucot and Potter (1977) and Potter and others (1990).

Comment.—The limestone block is considered to be Late Ordovician (Ashgillian) in this report.

Locality Number 4

Unit.—Sierra City melange of the Shoo Fly Complex

Collector, year of collection, field No.—D.S. Harwood, 1986, MI–86–1C

U.S. Geological Survey locality No.—10519–CO

Location.—Mount Ingalls 7.5' quad., Plumas County, Calif.; SW¼NE¼ sec. 12, T. 23 N., R. 11 E.; lat 39°52'32" N., long 120°41'19" W. From 4,550-ft elevation in Little Long Valley Creek.

Rock type/setting.—Coarsely recrystallized, highly sheared, gray- and white-streaked limestone. Contact relations not exposed, but gray, quartz-rich felsic tuff breccia typical of Sierra Buttes Formation occurs 100 m east of the limestone; rocks to the west are covered by glacial drift.

Fossils.—Conodonts:

2 incomplete S elements of *Belodina* sp. indet.
14 largely incomplete elements of *Panderodus* sp.
2 indet. coniform fragments

Fossil age.—Middle to Late Ordovician. Relatively warm, shallow-water biofacies. CAI=5.5–6=350–400 °C. (K.E. Denkler and A.G. Harris, written commun., 1986).

Comment.—McMath (1958, p. 59) brought attention to this lens of limestone by indicating that Cordell Durrell had found crinoid stems and a fragmentary coral in it. Durrell and McMath considered the limestone to be in the Sierra Buttes Formation, but in the light of this conodont assemblage, and those from localities 1 and 2, it seems more likely that the limestone is a block in the Sierra City melange of the Shoo Fly Complex.

Locality Number 5

Unit.—Grizzly Formation

Collector, year of collection, field No.—R.E. Hanson, R.A. Schweickert, and G.C. Bond, 1980, 957

Locality Number 5—Continued

U.S. Geological Survey locality No.—10089–SD

Location.—Sierra City 15' quad., Plumas County, Calif.; SE¼NE¼ sec. 20, T. 20 N., R. 12 E.; lat 39°35'06" N., long 120°38'32" W. Southwest slope of Sierra Buttes, approximately 3,200 ft bearing 178° from lookout tower on Sierra Buttes.

Rock type/setting.—Limestone lens interbedded with calcareous sandstone. Limestone-sandstone assemblage is interpreted to be a large slump block of material deposited in shallow water and transported into association with submarine-fan deposits in deeper water (Hanson, 1983; Hanson and Schweickert, 1986).

Fossils.—Corals:

Alveolites sp.
Cladopora sp.
Thamnopora sp.
Disphyllum sp.
Haplothecia sp.
Macgeea sp.
Smithiphyllum imperfectum (Smith)
solitary rugose corals indet.

Fossil age.—Late Devonian (Frasnian) (W.A. Oliver, Jr., written commun. to R.E. Hanson, 1980).

Locality Number 6

Unit.—Grizzly Formation

Collector, year of collection, field No.—R.E. Hanson, R.A. Schweickert, and D.S. Harwood, 1981, G–2

U.S. Geological Survey locality No.—10384–SD

Location.—Sierra City 15' quad., Plumas County, Calif.; NW¼SE¼ sec. 20, T. 20 N., R. 12 E.; lat 39°35'06" N., long 120°38'32" W. Southwest slope of Sierra Buttes; 3,200 ft bearing 178° from lookout tower on Sierra Buttes.

Rock type/setting.—Bedded calcareous sandstone a few feet below lens of limestone at loc. 5.

Fossils.—Gastropods, corals, bryozoans:

solitary corals indet.
Fenestrate bryozoans indet.
Bellerophon (*Aglyoglypta*) sp.
"*Eunema*" sp.

Fossil age.—Late Devonian (Frasnian) (E.L. Yochelson, written commun. to D.S. Harwood, 1981).

Locality Number 7

Unit.—Grizzly Formation

Collector, year of collection, field No.—R.E. Hanson, 1982?, S–64

U.S. Geological Survey locality No.—?

Location.—Sierra City 7.5' quad., Sierra County, Calif.; NW¼NE¼ sec. 20, T. 20 N., R. 12 E.; lat 39°35'22" N., long 120°37'14" W. Southwest slope of Sierra Buttes.

Rock type/setting.—Chert from upper part of Grizzly Formation (Hanson, 1983; Hanson and Schweickert, 1986).

Locality Number 7—Continued

Fossils.—Conodonts:

Palmatolepis glabra
Palmatolepis sp.

Fossil age.—Late Devonian (middle Famennian) (B.R. Wardlaw, written commun. to R.E. Hanson, 1982).

Locality Number 8

Unit.—Grizzly Formation

Collector, year of collection, field No.—R.E. Hanson, 1982?, E–6

U.S. Geological Survey locality No.—?

Location.—Haypress Valley 7.5' quad., Sierra and Nevada Counties, Calif.; SW¼SW¼SW¼ sec. 11, T. 19 N., R. 12 E.; lat 39°31'14" N., long 120°34'30" W. in Middle Yuba River.

Rock type/setting.—Thick chert section in Grizzly Formation beneath lowest felsic pyroclastic rocks of member C of Sierra Buttes Formation of Hanson (1983) (see also Hanson and Schweickert, 1986).

Fossils.—Conodonts:

Palmatolepis glabra
Palmatolepis sp.

Fossil age.—Late Devonian (middle Famennian) (B.R. Wardlaw, written commun. to R.E. Hanson, 1982).

Locality Number 9

Unit.—Grizzly Formation; limestone clast in polymict conglomerate

Collector, year of collection, field No.—D.W. Klepacki and D.S. Harwood, 1984, SC–84–4B

U.S. Geological Survey locality No.—USGS Colln. 9898–CO (= USGS Colln. 10970–SD)

Location.—Sierra City 15' quad., Plumas County, Calif.; SE¼NE¼ sec. 20, T. 20 N., R. 12 E.; lat 39°35' N., long 120°37'28" W. At 7,200-ft elevation about 100 ft north of Pacific Crest Trail; 2,200 ft bearing 218° from lookout tower on Sierra Buttes.

Rock type/setting.—Limestone clast in coarse polymict conglomerate. Clast was probably derived from a lens of limestone in the Sierra City melange of the Shoo Fly Complex.

Fossils.—Corals:

solitary rugose corals indet. (W.A. Oliver, Jr., written commun., 1984) (USGS Colln. 10970–SD)

Conodonts:

Belodella sp. (post-Middle Ordovician morphotype)
Panderodus sp.
Protopanderodus sp. indet. (Middle to Late Ordovician morphotype)

Fossil age.—Late Ordovician, based on co-occurrence of morphotypes of *Protopanderodus* and *Belodella*. CAI= 5.5=350 °C. (A.G. Harris, written commun. to D.S. Harwood, 1985).

Locality Number 10

Unit.—Sierra Buttes Formation

Collector, year of collection, field No.—J.L. Hannah, 1979, ?

U.S. Geological Survey locality No.—None

Location.—Greenville 15' quad., Plumas County, Calif.; SW¼NE¼ sec. 16, T. 26 N., R. 10 E.; lat 40°06'48" N., long 120°51'37" W. Low road cut on east side of paved highway, east side of Indian Valley.

Rock type/setting.—Phosphate nodules in chert in lower part of Sierra Buttes Formation (Hannah, 1980, p. 39).

Fossils.—Radiolarians:

Family Entactiniidae (several species with spherical form and trigonal spines)

Haplentactinia (spicular form)

Family Paleoscenidiidae

Paleoscenidium cladophorum

Family Ceratoikiscidae (several species of *Ceratoikiscum*)

Fossil age.—Late Devonian (Frasnian to Famennian) (E. Stanley, oral commun. to J.L. Hannah, 1979; Hannah, 1980, p. 39).

Locality Number 11

Unit.—Sierra Buttes Formation

Collector, year of collection, field No.—T.B. Anderson and others, 1974(?), ?

U.S. Geological Survey locality No.—None

Location.—Sierra City 15' quad., Plumas County, Calif.; NE¼NE¼ sec. 1, T. 20 N., R. 12 E.; lat 39°36' N., long 120°39' W. On flank of low hill northwest of Dugan Pond.

Rock type/setting.—Anderson and others (1974) describe the host rock as quartzite, but Hanson (1983) concluded it was metachert or metatuff in the Sierra Buttes Formation about 420 ft below contact with the Taylor Formation.

Fossils.—Ammonites:

Platyclymenia aff. *P. ruedemanni*

Tornoceras aff. *T. crebriseptum*

Fossil age.—Late Devonian (Anderson and others, 1974); middle Famennian (D.L. Jones, oral commun., 1980).

Locality Number 12

Unit.—Elwell Formation of Durrell and D'Allura (1977)—included here as part of the Sierra Buttes Formation

Collector, year of collection, field No.—J.C. DeVay and E. Stanley, ?, ?

U.S. Geological Survey locality No.—None

Location.—Gold Lake 7.5' quad., Plumas County, Calif.; Lakes Basin area; T. 21 N., R. 11 E.

Rock type/setting.—Black phosphate-streaked chert.

Fossils.—Radiolarians:

Archocyrtium

Paleoscenidium

Ceratoikiscum

Locality Number 12—Continued

Fossils.—Radiolarians—Continued

Entactiniids with trigonal-bladed spines

Fossil age.—Late Devonian (Frasnian to Famennian) (DeVay and Stanley, 1979).

Locality Number 13

Unit.—Sierra Buttes Formation

Collector, year of collection, field No.—R.E. Hanson, ?, S–109

U.S. Geological Survey locality No.—?

Location.—Emigrant Gap 15' quad., Nevada County, Calif.; NE¼SE¼ sec. 3, T. 18 N., R. 12 E.; lat 39°27'31" N., long 120°36'06" W. 9,500 ft bearing 196° from BM 6955 on Fir Hill.

Rock type/setting.—Chert 100 m thick in uppermost part of member C of Sierra Buttes Formation of Hanson (1983) (see Hanson and Schweickert, 1986).

Fossils.—Conodonts:

Palmatolepis glabra

Fossil age.—Late Devonian (middle Famennian) (B.R. Wardlaw, written commun. to R.E. Hanson, 1982).

Locality Number 14

Unit.—Sierra Buttes Formation—member C of Hanson (1983)

Collector, year of collection, field No.—W. Snyder, 1978, 7829d (cited in Hanson, 1983; Hanson and Schweickert, 1986)

U.S. Geological Survey locality No.—?

Location.—Emigrant Gap 15' quad., Nevada County, Calif.; NW¼NE¼ sec. 22, T. 18 N., R. 12 E.; lat 39°25' N., long 120°35'24" W.; east of Culbertson Lake (see Hanson and Schweickert, 1986, fig. 1).

Rock type/setting.—Thick section of chert in upper part of member C of Sierra Buttes Formation of Hanson (1983), about 40 m below member D of Hanson (1983) (Hanson and Schweickert, 1986).

Fossils.—Conodonts:

Palmatolepis glabra

Fossil age.—Late Devonian (middle Famennian) (B.R. Wardlaw, written commun. to R.E. Hanson, 1982).

Locality Number 15

Unit.—Peale Formation

Collector, year of collection, field No.—T.W. Stanton, 1892, ?; J. Storrs and J.S. Diller, 1904, ?

U.S. Geological Survey locality No.—?

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SW¼SW¼ sec. 15, T. 25 N., R. 11 E.; about lat 40°02' N., long 120°44' W. Fossils discovered by T.W. Stanton along trail to the Peale diggings (see "Peale Formation" in text) at an elevation between 4,500 and 5,000 ft (Diller, 1908, p. 24); probably at or close to loc. 16.

Locality Number 15—Continued

Rock type/setting.—"The tuffaceous beds are well exposed and fossiliferous on the horse trail from Wards Creek to Peale diggings..." (Diller, 1908, p. 24). No fossils have been found in the volcanic rocks of the lower member, but lenses of limestone in keratophyric tuff contain corals, brachiopods, trilobites, and conodonts (loc. 16).

Fossils.—Identified by Charles Schuchert:

Orthis michelini
Streptorhynchus crenistria?
Ambocoelia planiconvexa
Spirifer striatus
Productus? sp.
Pelecypod like *Yoldia* or *Leda*
Phillipsia sp.
Lophophyllum profundum

Identified by G.H. Girty:

Fusulina sp.
Crinoid fragments
Fistulipora sp.
Meekopora sp.
Stenopora? sp.

Fossil age.—Carboniferous. Girty (cited in Diller, 1908, p. 25) likened the collections to those of the Baird Formation of the McCloud River section but was not prepared to make a positive correlation "because many of the characteristic Baird species are wanting."

Locality Number 16

Unit.—Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–8

U.S. Geological Survey locality No.—29638–PC

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SW¼SW¼ sec. 15, T. 25 N., R. 11 E.; lat 40°01'37" N., long 120°44'11" W. At 5,120-ft elevation on nose of spur ridge, northeast slope of Peel Ridge, 2,800 ft bearing 080° from BM 5733 at north end of Peel Ridge (fig. 8).

Rock type/setting.—Light-gray weathering, dark-gray crinoidal limestone with scattered, poorly preserved fragments of brachiopods and trilobites; occurs as lens about 1.5 m thick in green to purplish-green and gray tuff and lapilli tuff that contain small pink alkali-feldspar phenocrysts typical of the volcanic rocks in the lower member of Peale Formation. This probably is the locality mentioned by Diller (1908, p. 24–25; loc. 15, this report), and it appears to be locality where McMath collected brachiopods and trilobites dated as Early Mississippian by G.A. Cooper (McMath, 1966, p. 180). This limestone lens occurs about 150 m above base of the lower member of the Peale Formation.

Fossils.—Conodonts:

Bispathodus stabilis (Branson and Mehl)
Bispathodus n. sp.

Locality Number 16—Continued

Fossils.—Conodonts—Continued

Polygnathus triangulus triangulus (Voges)
Pseudopolygnathus sp. indet.
Siphonodella sp. indet. (late Kinderhookian morphotype)

Fossil age.—Early Mississippian (*Siphonodella isosticha*–Upper *S. crenulata* zone of late Kinderhookian age) CAI=5.5=350 °C (K.E. Denkler, written commun., 1985).

Locality Number 17

Unit.—Peale Formation

Collector, year of collection, field Nos.—R. Pietropaoli; 1983; F–18, F–25

U.S. Geological Survey locality Nos.—29211–PC (F–18); 29212–PC (F–25)

Location.—Sierra City 15' quad., Plumas County, Calif.; SE¼ sec. 5, T. 21 N., R. 12 E.; lat 39°43'30" N., long 120°39'06" W. At 6,000-ft elevation on west side of Fraizer Creek approximately 750 ft bearing 323° from Fraizer Falls.

Rock type/setting.—Light-weathering gray crinoidal limestone lenses approximately 3 m thick and several meters to tens of meters in length occur in green to greenish-purple tuff and calcareous tuff of the lower member of Peale Formation. The tuff and limestone are strongly deformed; it is unclear whether one limestone lens is repeated or whether several lenses occur in a thin stratigraphic interval. Lenses occur about 450 ft above the Taylor Formation.

Fossils.—Conodonts:

Gnathodus sp. indet.
Polygnathus communis communis (Branson and Mehl)
Polygnathus cf. *P. symmetricus* Branson
Pseudopolygnathus sp. indet.
Siphonodella sp. indet.

Fossil age.—Early Mississippian (*Siphonodella isosticha*–Upper *S. crenulata* zone of late Kinderhookian age) CAI=8=>600 °C (A.G. Harris, written commun. to D.S. Harwood, 1984).

Comment.—Conodont specimens are pictured in Rejebian and others (1987, fig. 2A+B, designated YY, ZZ, BBB, DDD).

Locality Number 18

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1984, GV–84–1

U.S. Geological Survey locality No.—MR–5602

Location.—Greenville 15' quad., Plumas County, Calif.; NW¼SE¼ sec. 8, T. 25 N., R. 10 E.; lat 40°02'30" N., long 120°52'16" W. Top of Mount Hough at lookout tower (fig. 9).

Locality Number 18—Continued

Rock type/setting.—Red, green, and gray chert approximately 30 ft above base of chert member.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Fossil age.—latest Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 19

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—J.L. Hannah, 1981, H–1

U.S. Geological Survey locality No.—MR–2425

Location.—Almanor 15' quad., Plumas County, Calif.; S½NW¼NW¼ sec. 31, T. 28 N., R. 9 E.; lat 40°14'50" N., long 121°01'10" W. Northern part of Keddie Ridge, northeast flank of Dyer Mountain.

Rock type/setting.—Black chert at base of chert member (Hannah and Moores, 1986, fig. 3, p. 793).

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Triactofenestrella sp.

Fossil age.—Late Mississippian (Chesterian) to Early Pennsylvanian (Morrowan), possibly as young as Middle Pennsylvanian (Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 20

Unit.—chert member of the Peale Formation

Collector, year of collection, field No—J.L. Hannah, 1981, H–2

U.S. Geological Survey locality No.—MR–2426

Location.—Almanor 15' quad., Plumas County, Calif.; S½NW¼NW¼ sec. 31, T. 28 N., R. 9 E.; lat 40°14'50" N., long 121°01'10" W. Northeast flank of Dyer Mountain.

Rock type/setting.—Red chert and subordinate white chert with shale partings, near top of chert member; occurs about 5 m above lenses of chert breccia (see Hannah and Moores, 1986, fig. 3, p. 793).

Fossils.—Radiolarians:

Triactofenestrella sp.

Paronaella? *triporosa* Holdsworth and Murchey, 1988

Fossil age.—Middle Pennsylvanian (Atokan to Desmoinesian) (B.L. Murchey, written commun., 1990).

Locality Number 21

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—J.L. Hannah, 1981, H–4

U.S. Geological Survey locality No.—MR–2428

Locality Number 21—Continued

Location.—Greenville 15' quad., Plumas County, Calif.; SE¼SW¼SE¼ sec. 17, T. 27 N., R. 10 E.; lat 40°11'33" N., long 120°52'40" W. Central part of Keddie Ridge.

Rock type/setting.—Gray chert about 100 m above base of chert member; stratigraphic position uncertain because chert is highly deformed.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Triactofenestrella sp.

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 22

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–38A

U.S. Geological Survey locality No.—MR–6640

Location.—Greenville 15' quad., Lassen County, Calif.; SE¼SW¼ sec. 17, T. 27 N., R. 10 E.; lat 40°11'35" N., long 120°52'53" W. On south-southeast-trending spur ridge between elevations of 5,800 ft and 6,100 ft, central Keddie Ridge. Localities 22 through 30 were collected on an east-northeast traverse approximately normal to strike across the chert member to determine stratigraphic continuity in a typical area of abundant but not continuous exposure.

Rock type/setting.—Red and green chert approximately 2 m above basal contact of the chert member; basal contact not exposed at this locality but is nearby at loc. 30; basal contact is a fault. Chert here is isoclinally folded.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Triactofenestrella sp.

Sponges:

oxyhexactine spicules

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1988).

Locality Number 23

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–39

U.S. Geological Survey locality No.—MR–6642

Location.—See loc. 22.

Rock type/setting.—Black radiolarian-bearing sponge spicule chert approximately 10 m above loc. 22.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Triactofenestrella sp.

Locality Number 23—Continued

Fossils.—Continued

Sponges:

hexactine and anatriaene spicules (abundant)

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 24

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–40

U.S. Geological Survey locality No.—MR–6643

Location.—See loc. 22.

Rock type/setting.—Red chert.

Fossils.—Radiolarians:

Pseudoalbaillella sp. G of Ishiga, 1982

Pseudoalbaillella sp. aff. *P.* sp. G of Ishiga, 1982

Triactofenestrella sp. (*T. nicolica*?)

Fossil age.—Middle Pennsylvanian (Atokan to Desmoinesian) (B.L. Murchey, written commun., 1990).

Locality Number 25

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–41

U.S. Geological Survey locality No.—MR–6644

Location.—See loc. 22.

Rock type/setting.—Red chert.

Fossils.—Radiolarians:

Pseudoalbaillella sp. G of Ishiga, 1982

Triactofenestrella sp. (*T. nicolica*?)

Fossil age.—Middle Pennsylvanian (Atokan to Desmoinesian) (B.L. Murchey, written commun., 1990).

Locality Number 26

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–42

U.S. Geological Survey locality No.—MR–6645

Location.—See loc. 22.

Rock type/setting.—Black chert.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Paleoxyphostylus variospina Won, 1983

Triactofenestrella sp.

Sponges:

oxyhexactine spicules

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 27

Unit.—chert member of the Peale Formation

Locality Number 27—Continued

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–43

U.S. Geological Survey locality No.—MR–6646

Location.—See loc. 22.

Rock type/setting.—Red and green chert.

Fossils.—Radiolarians:

Paronaella? sp. aff. *P.*? *triporosa* Holdsworth and Murchey, 1988

Triactofenestrella sp.

Fossil age.—Middle Pennsylvanian (Atokan) to Early Permian (Wolfcampian) (B.L. Murchey, written commun., 1990).

Locality Number 28

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–45

U.S. Geological Survey locality No.—MR–6648

Location.—See loc. 22.

Rock type/setting.—Gray-green chert approximately 10 ft below contact with Reeve Formation.

Fossils.—Radiolarians:

?*Triactofenestrella* sp.

?*Pseudoalbaillella* sp.

Fossil age.—probably Middle Pennsylvanian to Permian (B.L. Murchey, written commun., 1990).

Locality Number 29

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–46A

U.S. Geological Survey locality No.—MR–6649

Location.—See loc. 22.

Rock type/setting.—Contorted green chert in footwall of fault exposed on north side of road; hanging wall contains barren black chert with thin lenses of chalky gray-weathering tuffaceous slate.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Fossil age.—Late Mississippian to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 30

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–47

U.S. Geological Survey locality No.—MR–6651

Location.—See loc. 22.

Rock type/setting.—Green and greenish-gray chert, broken and sheared, abundant hematite smears and slickensides. Specimen taken 10 cm above contact with lower member of the Peale Formation on north side of road. Contact is a near-vertical, northwest-trending fault characterized by 1 to 2 m of brittle fractured chert.

Locality Number 30—Continued

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988 (long-rayed morphotypes)

Triactofenestrella sp.

Fossil age.—Late Mississippian to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 31

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GN–85–6

U.S. Geological Survey locality No.—MR–6630

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SE¼NW¼SW¼ sec. 15, T. 25 N., R. 11 E.; lat 40°01'39" N., long 120°44'07" W. At 4,900-ft elevation on east-trending spur ridge on east flank of Peel Ridge (fig. 8).

Rock type/setting.—Greenish-gray chert in uppermost part of chert member; disconformably overlain by polymict conglomerate of Arlington Formation that contains abundant chert and volcanic clasts as well as quartzite clasts probably derived from the Shoo Fly Complex.

Fossils.—Radiolarians:

Pseudoalbaillella sp. G of Ishiga, 1982

Pseudoalbaillella sp. aff. *P.* sp. G of Ishiga, 1982

Triactofenestrella sp.

Fossil age.—Middle Pennsylvanian (B.L. Murchey, written commun., 1990).

Locality Number 32

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GN–85–16

U.S. Geological Survey locality No.—MR–6634

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 15, T. 25 N., R. 11 E.; lat 40°01'33" N., long 120°44'05" W. At 4,700-ft elevation in ephemeral stream draining east slope of Peel Ridge (fig. 8).

Rock type/setting.—Black chert gradationally below barren red chert, approximately 20 m below top of chert member and loc. 31. Chert member is disconformably overlain by sandstone and minor conglomerate of the Arlington Formation.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Triactofenestrella sp.

?*Paleoxyphostylus variospina* Won, 1983

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 33

Unit.—chert member of the Peale Formation, principal reference locality

Collector, year of collection, field No.—D.S. Harwood, 1985, GN–85–18C

U.S. Geological Survey locality No.—MR–6638

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 15, T. 25 N., R. 11 E.; lat 40°01'32" N., long 120°44'06" W. At 4,890-ft elevation, in ephemeral stream draining east slope of Peel Ridge (fig. 8).

Rock type/setting.—Black chert 1.5 m above base of chert member. Between this locality and top of lower member of the Peale is 1.5 m of green chert that contains poorly preserved spheroidal spumellarians (B.L. Murchey, written commun., 1985).

Fossils.—Radiolarians:

Scharfenbergia impella (Ormiston and Lane) deformed spheroids

Fossil age.—Mississippian (Osagean to Chesterian?) (B.L. Murchey, written commun., 1990).

Comment.—About 30 m of folded black chert occur between locs. 32 and 33; stratigraphic thickness of this section of black chert is unknown but probably is no more than 15 m.

Locality Number 34

Unit.—chert member of the Peale Formation

Collector, year of collection, field No.—D.S. Harwood, 1980, V–10

U.S. Geological Survey locality No.—MR–1118

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; boundary between secs. 7 and 18, T. 16 N., R. 13 E.; lat 39°15'45" N., long 120°33'32" W. At 5,840-ft elevation on small southeast-trending spur ridge; 1,500 ft bearing 104° from BM 6364 on west side Big Valley Creek.

Rock type/setting.—Green chert approximately 10 m below top of chert member.

Fossils.—Radiolarians:

Scharfenbergia tailleurense Holdsworth and Murchey, 1988

Fossil age.—Late Mississippian (Chesterian) to Early or Middle Pennsylvanian (Morrowan or Atokan) (B.L. Murchey, written commun., 1990).

Locality Number 35

Unit.—Arlington Formation, principal reference locality

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–34

U.S. Geological Survey locality No.—29643–PC

Location.—Crescent Mills 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 5, T. 25 N., R. 10 E.; lat 40°03'12" N., long 120°53'28" W. At 6,600-ft elevation; 2,600 ft bearing 224° from BM 6924 at Arlington Heights (fig. 9).

Rock type/setting.—Block of gray crinoidal limestone (0.5×0.5×1.5 m) in conglomerate approximately 30 m

Locality Number 35—Continued

Rock type/setting.—Continued

stratigraphically above base of Arlington Formation.

Fossils.—Conodonts:

Hindeodus sp. indet.

Neogondolella idahoensis (Youngquist, Hawley, and Miller)

Neostreptognathus sp. indet. (early Leonardian morphotype)

Xaniognathus sp.

Fossil age.—late Early Permian (early Leonardian) (K.E. Denkler, written commun., 1985) CAI=5.5–6=350–400 °C.

Locality Number 36

Unit.—Arlington Formation, principal reference locality

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–35

U.S. Geological Survey locality No.—USNM 29849–PC

Location.—Crescent Mills 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 5, T. 25 N., R. 10 E.; lat 40°03'12" N., long 120°53'27" W. At 6,720-ft elevation on northwest-trending ridge; 1,300 ft bearing 226° from BM 6924 at Arlington Heights (see fig. 9).

Rock type/setting.—Thick-bedded, coarse-grained conglomerate and pebbly mudstone composed of chert and volcanic rock fragments with sparse blocks of gray crinoidal limestone (loc. 35). Fossils occur in matrix of the conglomerate about 30 m stratigraphically above base of Arlington Formation.

Fossils.—crinoid columnals, indet.

stenoporoid bryozoan, indet.

large orthotetid brachiopod

dictyoclostid brachiopod (perhaps *Penicularis*)

Neospirifer? sp.

Omphalotrochus? sp.

Fossil age.—Early Permian (late Wolfcampian or early Leonardian). "This appears to be an Early Permian assemblage; the most distinctive element is *Omphalotrochus*, a gastropod first described by Meek from the McCloud Formation of Shasta County. The possible age range is late Wolfcampian through Leonardian" (J.T. Dutro, Jr., written commun., 1986).

Comment.—It would be impossible to get Leonardian limestone blocks (loc. 35) slumped into a conglomerate of late Wolfcampian age; therefore the most reasonable age for this collection is Leonardian, probably early Leonardian.

Locality Number 37

Unit.—Arlington Formation, principal reference locality

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–31

U.S. Geological Survey locality No.—USGS 29851–PC

Location.—Crescent Mills 7.5' quad., Plumas County, Calif.; SW¼SE¼ sec. 5, T. 25 N., R. 10 E.; lat 40°03'13" N., long 120°53'16" W. At 6,800-ft elevation (fig. 9); 800 ft bearing 153° from BM 6924 at Arlington Heights.

Rock type/setting.—Interbedded pebble conglomerate, volcaniclastic sandstone, and slate near top of thick conglomerate and pebbly mudstone section in lower part of Arlington Formation; estimated to be about 245 m stratigraphically above base of Arlington Formation.

Fossils.—"collection contains only indeterminate productoid and spiriferoid brachiopod fragments. The extreme flattening and elongation of the large bivalved fossils makes it difficult to identify them even to phylum. They could be either brachiopods or pelecypods—or both" (J.T. Dutro, Jr., written commun., 1986).

Fossil age.—Early Permian(?).

Comment.—This locality occurs about 215 m above locality 36 and thus is no older than Early Permian; a Leonardian age seems reasonably certain on basis of stratigraphic and lithologic continuity with rocks at loc. 36.

Locality Number 38

Unit.—Arlington Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GN–85–36

U.S. Geological Survey locality No.—USGS 29850–PC

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NE¼SW¼ sec. 15, T. 25 N., R. 11 E.; lat 40°01'36" N., long 120°44' W. Elevation 4,500 ft, in ephemeral stream draining east slope of Peel Ridge; 3,350 ft bearing 020° from BM 5725 at south end of Peel Ridge (fig. 8).

Rock type/setting.—Pebble conglomerate lens in green and purple volcaniclastic sandstone and slate about 10 m stratigraphically below gradational contact with the Goodhue Formation.

Fossils.—echinoderm debris, indet. (includes large columnals)

echinoid plate, indet.

horn coral, indet.

Neospirifer? sp.

pelecypod fragments (perhaps pectenoid), indet.

gastropod, indet. (partial internal mold)

Fossil age.—"Nothing diagnostic to relate this very closely to GV–85–35" (loc. 36) (J.T. Dutro, Jr., written commun., 1986).

Comment.—Youngest fossils in underlying chert member of the Peale Formation are Middle Pennsylvanian radiolarians (loc. 31) (see fig. 8). Best guess about age of the conglomerate is Early Permian, probably Leonardian, on basis of *Neospirifer*(?) and lithologic similarity with the principal reference locality of the Arlington (locs. 35–37).

Locality Number 39

Unit.—Reeve Formation

Locality Number 39—Continued

Collector, year of collection, field No.—J.L. Hannah, ?, ?

U.S. Geological Survey locality No.—None

Location.—Almanor 15' quad., Plumas County, Calif.; S½NW¼NW¼ sec. 31, T. 28 N., R. 9 E.; lat 40°14'50" N., long 121°01'10" W. North part of Keddie Ridge on northeast flank of Dyer Mountain (Hannah, 1980).

Rock type/setting.—Poorly sorted chert-pebble conglomerate with volcaniclastic sandstone matrix; occurs 10 m above interbedded red and subordinate white chert of chert member of the Peale Formation that contains Middle Pennsylvanian radiolarians (loc. 20) (see Hannah and Moores, 1986, fig. 3, p. 793).

Fossils.—Fusulinids in matrix of conglomerate:

"Schwagerinidae, including probable *Schwagerina*, a possible very primitive *Parafusulina*, several biserial foraminifera, and other smaller foraminifers" (Hannah and Moores, 1986, p. 792).

Fossil age.—The "age of the fusulinids is fairly certainly Early Permian and probably late Wolfcampian to middle Leonardian as seen in the West Texas standard sections" (C.A. Ross, written commun., 1980, cited in Hannah and Moores, 1986, p. 792).

Comment.—Hannah and Moores (1986) included this locality in their Peale Formation and placed the lower contact of the Reeve Formation at the first occurrence of plagioclase-phyric volcanic rocks 300 m above this locality. The intervening 300 m contains fine-grained siltstone and feldspathic wacke (Hannah and Moores, 1986, p. 792), which are included here within the Reeve Formation.

Locality Number 40

Unit.—chert pebbles from conglomerate near base of the Reeve Formation

Collector, year of collection, field No.—J.L. Hannah, 1981, H-3

U.S. Geological Survey locality No.—MR-2427

Location.—same as loc. 39.

Rock type/setting.—Chert pebbles from conglomerate 10 m above red and white chert that contains Pennsylvanian radiolarians; separated from loc. 20 by olive-green silty sandstone with thin interbeds of green silty chert. Matrix of conglomerate contains Early Permian fusulinids (loc. 39) (see Hannah and Moores, 1986, p. 793).

Fossils.—Radiolarians:

Scharfenbergia impella (Ormiston and Lane) group

Albaillella sp.

Fossil age.—Mississippian (Osagean to Chesterian?) (B.L. Murchey, written commun., 1990).

Comment.—Hannah and Moores (1986) included the chert-pebble conglomerate in their Peale Formation even though they recognized that the chert pebbles contained radiolarians older than the oldest bedded chert in this

Locality Number 40—Continued

Comment.—Continued

section and that the bedded chert and the chert-pebble conglomerate were separated by a major hiatus spanning at least the Late Pennsylvanian. The chert-pebble conglomerate is included here within the lower part of the Reeve Formation.

Locality Number 41

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV-85-49

U.S. Geological Survey locality No.—MR-6652

Location.—Greenville 15' quad., Lassen County, Calif.; SW¼SE¼ sec. 4 (unmarked), T. 27 N., R. 9 E.; lat 40°13'30" N., long 120°59' W. North-trending saddle-and-knob spur ridge, elevation 7,160 to 7,200 ft; about 1,500 ft west of Homer Lake (fig. 12).

Rock type/setting.—Thin, discontinuous lenses of green, red, and black sponge-spicule chert interbedded with fine-grained, olive-green volcaniclastic sandstone and siltstone in lowermost 100 m of the Reeve Formation.

Fossils.—Radiolarians:

Pseudotormentus kamigoriensis DeWever and Caridroit, 1984

Quinqueremus robusta Nazarov and Ormiston, 1985

Q. sp. aff. *Q. robusta*

Polyfistula sp. (six-rayed form)

Fossil age.—Early Permian (Leonardian) (B.L. Murchey, written commun., 1990).

Comment.—Hannah (1980) mapped the chert-bearing volcaniclastic rocks as part of the chert member of the Peale Formation. Rocks at this locality, however, are primarily feldspar-rich volcaniclastic sandstones with only minor thin interbeds of chert that contrast sharply with the relatively thick sections of ribbon chert characteristic of the chert member of the Peale Formation elsewhere in the terrane; therefore, the rocks at locs. 41, 42, 43 are placed in the Reeve Formation.

Locality Number 42

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV-85-50

U.S. Geological Survey locality No.—MR-6653

Location.—See loc. 41 (fig. 12).

Rock type/setting.—Green chert interbedded with volcaniclastic sandstone and siltstone; minor volcaniclastic conglomerate; approximately 100 ft above base of Reeve Formation.

Fossils.—Radiolarians:

Pseudoalbaillella scalprata Holdsworth and Jones, 1980

Fossil age.—Early Permian (Leonardian) (B.L. Murchey, oral commun., 1990).

Locality Number 43

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–51A, B

U.S. Geological Survey locality No.—MR–6654

Location.—See loc. 41 and fig. 12. East slope of spur ridge, 12 m downhill from low part of saddle.

Rock type/setting.—Gray chert interbedded with volcaniclastic sandstone and siltstone; approximately 20 m above base of the Reeve Formation.

Fossils.—Radiolarians:

Ormistonella robusta DeWever and Caridroit, 1984
Quinqueremus sp. aff. *Q. robusta* Nazarov and Ormiston, 1985
Pseudoalbaillella scalprata Holdsworth and Jones, 1980
Pseudoalbaillella sakmarensis (Kozur, 1981)
Deflandrella sp.
Latentifistula patagilaterala Nazarov and Ormiston, 1985
Polyfistula sp. A (six-rayed form)
Pseudotormentus kamigoriensis DeWever and Caridroit, 1984

Fossil age.—Early Permian (Leonardian) (B.L. Murchey, written commun., 1990).

Locality Number 44

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1985, GV–85–52

U.S. Geological Survey locality No.—?

Location.—Greenville 7.5' quad., Plumas County, Calif.; NE¼NW¼ sec. 10, T. 27 N., R. 9 E.; lat 40°13'11" N., long 120°57'32" W. At 6,870-ft elevation on northwest-trending ridge east of Homer Lake; 3,250 ft bearing 062° from VABM 7499 on Keddie Ridge.

Rock type/setting.—Polymict conglomerate containing chert- and volcanic-rock pebbles interbedded with volcaniclastic sandstone. About 800 ft stratigraphically above top of Taylor Formation.

Fossils.—echinoderm debris, indet.
echinoid plate, indet.
ambocoelid brachiopod, indet.
pelecypod fragments, indet.

Fossil age.—indeterminate (J.T. Dutro, Jr., written commun., 1986).

Comment.—Although this locality produced no datable material, it is included to encourage additional searches. The conglomerate and sandstone apparently grade laterally into the rocks at loc. 45 and are thus most certainly Early Permian in age.

Locality Number 45

Unit.—Reeve Formation

Locality Number 45—Continued

Collector, year of collection, field No.—D.S. Harwood, 1983, HH–4

U.S. Geological Survey locality No.—

Location.—Greenville 15' quad., Lassen County, Calif.; sec. 10, T. 27 N., R. 9 E.; lat 40°12'40" N., long 120°57' W. At 6,880-ft elevation on south side of topographic saddle; 1,200 ft bearing 131° from 7,083 knob due east of Homer Lake.

Rock type/setting.—Poorly exposed rubble of black chert and feldspathic sandstone.

Fossils.—Radiolarians:

Pseudoalbaillella scalprata Holdsworth and Jones, 1980

Fossil age.—Early Permian (B.L. Murchey, oral commun., 1990).

Locality Number 46

Unit.—Reeve Formation; type locality (McMath, 1958, p. 115) (originally mapped as Robinson Formation by Diller, 1908)

Collector, year of collection, field Nos.—C. Curtice, 1890?, ?; J. Storrs, 1904?, ?

U.S. Geological Survey locality Nos.—6885, 6886

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; S½NW¼ sec. 10, T. 25 N., R. 11 E. (fig. 10).

Rock type/setting.—Reddish-brown sandstone and calcareous tuff.

Fossils.—Identified by C.D. Walcott (cited in Diller, 1908, p. 27):

Campophyllum ? sp.
Favosites sp.
Archaeocidaris
Fenestella 2 sp. undet.
Streptorhynchus crenistria
Productus semireticulatus
Spirifer lineatus?
Spirifer cameratus
Rhynchonella sp.
Meekella like *M. striaticostata* Cox
Aviculipecten 2 sp.
Aviculipecten interlineatus
Myalina
Edmondia sp.
Pleurotomaria sp.

Identified by G.H. Girty (cited in Diller, 1908, p. 27):

calcareous algae?
Fusulina elongata Shum
Lophophyllum n. sp.
Squamularia near *S. quadalupensis*
Dielasma? sp.
Actinostroma?? sp.
Stromatopora?? sp.

Fossil age.—Permian. G.H. Girty (cited in Diller, 1908,

Locality Number 46—Continued

Fossil age.—Continued

p. 28) considered the collection Carboniferous in age (which included the Permian) and suggested a correlation with the Nosoni Formation of the eastern Klamath sequence.

Locality Number 47

Unit.—Reeve Formation; type locality (McMath, 1958, p. 115). Originally mapped as Robinson Formation by Diller (1908)

Collector, year of collection, field No.—J. Storrs?, 1904?, ?; V.E. McMath, 1958?, ?; D.S. Harwood and C.H. Stevens, 1986, GV–86–3

U.S. Geological Survey locality No.—6749 (Storrs)

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NE¼SE¼ sec. 4, T. 25 N., R. 11 E.; lat 40°03'19" N., long 120°44'28" W. Southwest crest of hill (McMath, 1958) (fig. 10).

Rock type/setting.—Coarse-grained calcareous tuff and calcarenite in Reeve Formation as redefined by McMath (1958, 1966).

Fossils.—Diller (1908, p. 27, identified by G.H. Girty) reported:

Calcareous algae?
Fusulina sp.
Rugose coral?
Archaeocidaris sp.
Rhombopora, lepidodendroides group
Spirifer sp.
Squamularia cf. *S. guadalupensis*
Spiriferina n. sp.
Aviculipecten sp.
Pseudomonotis? sp.
Myoconcha? sp.

McMath (1958) reported:

large but specifically indeterminate fusulinids

Fusulinids (identified by C.H. Stevens):

Parafusulina mccloudensis Skinner and Wilde (zone H)
Parafusulina sp. aff. *P. nosonensis* (younger than zone H?)
Schwagerina? sp.

Fossil age.—late Early Permian (early Leonardian). "*Parafusulina mccloudensis* is a very distinctive McCloud Limestone fusulinid. The associated species of *Parafusulina* suggest a little younger age" (C.H. Stevens, written commun., 1989).

Locality Number 48

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood 1985, BN–85–1

U.S. Geological Survey locality No.—29852–PC

Location.—Mount Ingalls 7.5' quad., Plumas County, Calif.;

Locality Number 48—Continued

Location.—Continued

SE¼NW¼ sec. 12, T. 24 N., R. 11 E.; lat 39°57'41" N., long 120°41'46" W. Elevation 5,500 ft on east side of Little Grizzly Creek opposite confluence of Cascade Creek. Blocks and rubbly low outcrops of fossiliferous volcaniclastic siltstone occur at abandoned mine site and extend to southeast about 100 m.

Rock type/setting.—Light-rusty-tan-weathering volcaniclastic siltstone and fine-grained sandstone with locally abundant large molds of *Timaniella*; fossiliferous rocks occur about 100 m above top of the Goodhue Formation.

Fossils.—echinoderm debris, indet.

Chonetinella? sp.
Timaniella sp. (abundant)
punctate spiriferoid, indet.
pelecypod molds and casts, indet.

Fossil age.—late Early Permian or early Late Permian. "The abundant *Timaniella* specimens suggest a middle Permian (Wordian) equivalence, definitely younger than GV–85–35" (loc. 36, principal reference locality of Arlington Formation) (J.T. Dutro, Jr., written commun., 1986).

Comment.—Collection comes from same area but not necessarily same horizons as collections reported by Diller (1908, p. 28) (loc. 49) and D'Allura (1977, p. 170) (loc. 50).

Locality Number 49

Unit.—Reeve Formation (McMath, 1958). Originally mapped as Robinson Formation by Turner (1894) and Diller (1908, p. 28)

Collector, year of collection, field No.—Cooper Curtice, ?, ?; recollected by D.S. Harwood, 1985 (loc. 48)

U.S. Geological Survey locality No.—?

Location.—Probably same as loc. 48. Referred to as the Little Grizzly Creek locality by Diller (1908, p. 28).

Rock type/setting.—See loc. 48.

Fossils.—Identified by G.H. Girty:

crinoid stems
Archaeocidaris sp.
Crania sp.
Schizophoria sp.
Orthotetes? sp.
Meekella sp.
Chonetes n. sp.
Myalina sp.
Productus semireticulatus?
Marginifera n. sp.
Spirifer aff. *S. cameratus*
Spirifer sp.
Spiriferina aff. *S. pulchra*
Squamularia lineata
Pugnax? sp.
Rhynchonella sp.

Locality Number 49—Continued

Fossil age.—Permian. Diller (1908) considered the collection to be Carboniferous in age, which included the Permian at that time. G.H. Girty (cited in Diller, 1908) correlated the collection with that from the Nosoni Formation in the McCloud River section.

Locality Number 50

Unit.—Reeve Formation

Collector, year of collection, field No.—J.A. D'Allura, 1976?, ?

U.S. Geological Survey locality No.—None

Location.—Probably the same as loc. 48.

Rock type/setting.—See loc. 48.

Fossils.—Brachiopods (identified by R.E. Grant):

Chonetid indet.
Dyoros?
Derbyia sp.
Dictyoclostid productid (the *P. semireticulatus* of Schuchert?)
Megousia sp.
Neospirifer (another Permian indicator)
Xestotrema (common in the Leonardian and Guadalupian rocks of the Phosphoria Formation)

Fossil age.—late Early Permian to early Late Permian. The genus *Megousia* "ranges from the uppermost Wolfcampian into the Capitan, but is rare at both extremes of the range. It is abundant in rocks of Leonard and Word ages" (R.E. Grant, written commun. to J.A. D'Allura, 1975; cited by D'Allura, 1977, p. 170; Durrell and D'Allura, 1977, p. 851).

Locality Number 51

Unit.—Reeve Formation

Collector, year of collection, field No.—J.A. D'Allura, ?, ?

U.S. Geological Survey locality No.—None

Location.—Sierra City 15' quad., Plumas County, Calif.; SE¼ sec. 24, T. 22 N., R. 12 E.; approx. lat 39°45' N., long 120°34'40" W. Location uncertain. "East of the road trending north from Clio" (D'Allura, 1977, p. 170). "On the east side of the road near the NE¼ corner of sec. 25, T. 22 N., R. 12 E." (Durrell and D'Allura, 1977).

Rock type/setting.—Fossils occur in fine-grained calcareous tuff matrix of plagioclase-rich tuff breccia typical of the Reeve; overlain by 450 m of dark-gray, fine-grained, bedded unfossiliferous keratophyre tuff (Durrell and D'Allura, 1977, p. 851).

Fossils.—Brachiopods:

Megousia sp.
Neospirifer sp.

Fossil age.—late Early Permian or early Late Permian. "*Megousia* * * * ranges from uppermost Wolfcampian into the Capitan, is very rare at both extremes, and is most abundant in rocks of Leonard and Word age" (Durrell and D'Allura, 1977, p. 851, citing information from R.E. Grant, written commun., 1975).

Locality Number 51—Continued

Fossil age.—Continued

Locality Number 52

Unit.—Reeve Formation

Collector, year of collection, field No.—J.A. D'Allura, ?, ?

U.S. Geological Survey locality No.—None

Location.—English Mtn. 7.5' quad., Nevada County, Calif.; SW¼NW¼ sec. 35, T. 19 N., R. 12 E.; lat 39°28' N., long 120°35'24" W. Same general area as locs. 53–55.

Rock type/setting.—Volcaniclastic sandstone containing chert and volcaniclastic conglomerate; sparse blocks of bioclastic limestone. Fusulinids occur in matrix of dark-rusty-brown-weathering lenses of calcareous sandstone and granule conglomerate.

Fossils.—Fusulinids:

Schwagerina cf. *S. diversiformis*
Thompsonella(?)
a single specimen of *Triticites*

Fossil age.—Early Permian. "This combination of species suggests that the specimens are the same age as those in the lower and middle parts of the McCloud Limestone" (C.A. Ross, written commun., 1975, to J.A. D'Allura, cited in D'Allura and others, 1977, p. 133–134).

Comment.—D'Allura and others (1977) included this locality in their upper member of the Peale Formation, but Schweickert (1981) and Schweickert and others (1984) placed the fusulinid-bearing conglomerate in the lower part of the Reeve Formation, unconformably overlying the Peale. The chert-rich conglomerate and interbedded volcaniclastic sandstone are lithologically similar to those of the Arlington Formation.

Locality Number 53

Unit.—Reeve Formation

Collector, year of collection, field No.—R.A. Schweickert, 1982, PR–2

U.S. Geological Survey locality No.—?

Location.—English Mtn. 7.5' quad., Nevada County, Calif.; SW¼NW¼, sec. 35, T. 19 N., R. 12 E.; lat 39°28' N., long 120°35'24" W. Elevation 6,480 ft on southwest slope of Fir Hill; 2,500 ft bearing 225° from BM 6926 on Fir Hill.

Rock type/setting.—Limestone block in polymict conglomerate composed of chert and volcanic-rock fragments interbedded with volcaniclastic sandstone.

Fossils.—Bryozoans:

Fenestella
Fistuliporids
Girtyporids(?)
Polypora
Rhombotrypella(?)

Locality Number 53—Continued

Fossils.—Bryozoans—Continued

Tabulipora

Timanodictya(?)

Trepostomes, indet.

Fossil age.—late Paleozoic. "Most of these bryozoans are typical of Carboniferous and Permian ages. *Timanodictya* is known only from the Permian, but it could not be positively identified in this collection. In general this fauna appears to be of late Paleozoic age. It neither verifies nor contradicts a Permian age." (O.L. Karklins, written commun., 1982).

Locality Number 54

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1986, EM–86–1

U.S. Geological Survey locality No.—29941–PC

Location.—English Mtn. 7.5' quad., Nevada County, Calif.; SW¼NW¼ sec. 35, T. 19 N., R. 12 E.; lat 39°28' N., long 120°35'24" W. From 6,480-ft elevation on southwest slope of Fir Hill; 2,500 ft bearing 225° from BM 6926 on Fir Hill. Same locality as loc. 53 but may be from a different limestone block.

Rock type/setting.—See loc. 53.

Fossils.—Conodonts:

1 Pa element of *Hindeodus*? *excavatus* (Behnken)

1 incomplete Pa element of *Neostreptognathodus* sp. of middle-late Leonardian morphotype

1 juvenile Pa element aff. *Sweetognathus* sp.

Fossil age.—late Early Permian (middle to late Leonardian). CAI=7. Normal marine, relatively shallow water biofacies (K.E. Denkler and A.G. Harris, written commun., 1986).

Comment.—Occurrence of these limestone blocks in chert-rich conglomerate interbedded with volcaniclastic sandstone is identical to setting of limestone blocks at the principal reference locality of the Arlington Formation that contain early Leonardian conodonts (loc. 35). If age difference of these limestone blocks, which is based on morphotypes of *Neostreptognathodus* is significant, reef-forming conditions may have progressed southward through the terrane in Leonardian time.

Locality Number 55

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1986, EM–86–1

U.S. Geological Survey locality No.—30020–PC

Location.—Same as loc. 53.

Rock type/setting.—Calcareous, volcaniclastic sandstone and siltstone adjacent to bryozoan-rich blocks of limestone in lower part of Reeve Formation.

Locality Number 55—Continued

Fossils.—echinoderm debris, indet.

massive laminar bryozoan, undet.

Martinia sp.

Neophricadothyris? sp.

Omphalotrochus obtusispira (Shumard) (identified by E.L. Yochelson)

arcid pelecypod (large internal mold), undet.

pelecypod fragments, indet.

Fossil age.—Early Permian. "The large snail, *Omphalotrochus*, definitely places this collection in the Early Permian. It is like similar snails that were identified earlier from the Arlington Formation" (see loc. 36) (J.T. Dutro, Jr., written commun., 1987).

Locality Number 56

Unit.—Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1980, CG–1

U.S. Geological Survey locality No.—27785–PC

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NW¼SE¼ sec. 7, T. 16 N., R. 13 E.; lat 39°15'57" N., long 120°33'33" W. Elevation 5,760 ft in southeast-flowing tributary to Big Valley.

Rock type/setting.—Light-gray to tan, coarse-grained feldspathic tuff with abundant rusty-weathering casts of shell fragments and crinoid columnals; isolated outcrop surrounded by glacial drift about 30 m above base of Reeve Formation (Harwood, 1983).

Fossils.—Bryozoans, massive and ramose, indet.

Chonetinetes sp.

Megousia sp.

Neospirifer sp.

Aviculopecten sp.

Cyrtorosta? sp. indet.

gastropod? indet.

crinoid columnals

Fossil age.—"* * * a Permian age for this collection seems assured. The combination of *Chonetinetes*, *Megousia*, and *Cyrtorosta*? further suggests that this tuffaceous deposit was laid down sometime in the middle part of the Permian perhaps during the Roadian or Wordian Stage. In terms of the two-fold division of the Permian of current USGS usage, this collection is either late Early Permian (Leonardian) or early Late Permian (Guadalupian) in age" (M. Gordon, Jr., written commun., 1980).

Locality Number 57

Unit.—limestone block in the Reeve Formation

Collector, year of collection, field No.—D.S. Harwood, 1980, CG–1

U.S. Geological Survey locality No.—None

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; sec. 30, T. 17 N., R. 13 E.; lat 39°17'30" N., long 120°32'30" W. Under power line at northeast end of SP Lakes.

Locality Number 57—Continued

Rock type/setting.—Coarsely recrystallized limestone with interbedded chert-rich pebble conglomerate. At or very near base of thin-bedded feldspathic tuff and tuffaceous sandstone assigned to Reeve Formation.

Fossils.—Echinoderm debris:

"One specimen almost certainly a 'two-holer' of the kind known elsewhere to range from late Early Devonian into the Middle Devonian" (J.T. Dutro, Jr., written commun., 1988).

Fossil age.—late Early Devonian to Middle Devonian (Emsian to Givetian) (J.T. Dutro, Jr., written commun., 1988).

Comment.—If the age call is correct, either the limestone is an exotic block in the Permian volcanic rocks or the silicified echinoderm debris was redeposited from an unknown source. Field relations suggest the limestone is interbedded with volcaniclastic rocks of the Reeve.

Locality Number 58

Unit.—Robinson Formation (Diller, 1908; McMath, 1958)

Collector, year of collection, field Nos.—J. Storrs?, 1904?, ?

U.S. Geological Survey locality Nos.—6732–6734

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NE¼NW¼ sec. 10, T. 25 N., R. 11 E.; lat 40°03'06" N., long 120°44'12" W. Probably between 4,200- and 4,400-ft elevation on southeast-trending spur ridge (McMath, 1958, p. 124) (fig. 10).

Rock type/setting.—Calcareous chert- and volcanic-clast conglomerate interbedded with calcareous volcaniclastic sandstone and thin limestone lenses.

Fossils.—Identified by G.H. Girty (cited in Diller, 1908, p. 27):

Aulopora sp.
Striatopora n. sp.
Cystodictya sp.
Rhombopora, type of lepidodendroides
Lophophyllum? sp.
Streptorhynchoid brachiopod?

Fossil age.—Paleozoic; Permian(?).

Comment.—One of five localities originally reported in the Robinson Formation by Diller (1908, p. 27–28). McMath (1958, 1966) placed four of the five localities in his redefined Reeve Formation but left this locality in the Robinson. This original locality was not recovered during recent field work, but the calcareous conglomerate and volcaniclastic sandstone in the general area contain sparse scattered casts of shell fragments.

Locality Number 59

Unit.—Robinson Formation (McMath, 1958)

Collector, year of collection, field No.—D.S. Harwood, 1986, GV–86–1

U.S. Geological Survey locality No.—29942–PC

Locality Number 59—Continued

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; boundary of secs. 3 and 10, T. 25 N., R. 11 E., lat 40°03'10" N., long 120°44'16" W. Elevation 4,280 ft on southeast-trending spur ridge; 2,000 ft bearing 156° from BM 4806 (fig. 10).

Rock type/setting.—Lens of gray limestone 0.5 m thick in volcanic-clast pebble conglomerate, tuffaceous slate, and volcaniclastic sandstone.

Fossils.—Conodonts:

1 Pa element of *Neogondolella* cf. *N. rosenkrantzi* (Bender and Stoppel)
1 incomplete Pa element of *Neogondolella* sp. indet.
4 ichthyoliths

Fossil age.—early Late Permian (Wordian to Capitanian) (K.E. Denkler and A.G. Harris, written commun., 1986).

Comment.—The conglomerate, tuffaceous slate, and sandstone are more volcanic-rich than conglomerate in the Arlington Formation; conodont assemblage is significantly younger than conodonts recovered from limestone blocks in the Arlington (loc. 35) or the Reeve (loc. 54). Therefore, the name "Robinson Formation" is retained for these outcrops. Stratigraphic relations between this part of the Robinson and the Reeve are unknown because of poor exposures and complex thrust faulting (fig. 10); however, the conodont assemblage indicates a significantly younger age than the fusulinids in the nearby Reeve (loc. 47).

Locality Number 60

Unit.—Blackwood Creek Formation (this report)

Collector, year of collection, field Nos.—D.S. Harwood, 1983, HOM–1, HOM–2

U.S. Geological Survey locality Nos.—?

Location.—Homewood 7.5' quad., Placer County, Calif.; HOM–1—SE cor. sec. 4, T. 14 N., R. 16 E.; lat 39°05' N., long 120°12'30" W. Collected 50 ft from south end of large roadcut at 6,870-ft elevation on Blackwood Canyon–Barker Pass road. HOM–2—SW¼NE¼ sec. 9, T. 14 N., R. 16 E. Collected from large roadcut, south side of same road at elevation 7,040 ft; 5,400 ft due east of Barker Peak.

Rock type/setting.—Most of the fossils occur as molds in a calcareous, feldspathic sandstone debris-flow deposit interbedded with black pelite and sandy limestone turbidites; some fossil casts were found in black pelite and gray calcareous siltstone beds.

Fossils.—Ammonites:

No genera or species identified.

Two forms occur: one loosely coiled, discoidal, and simply ribbed; the other more tightly coiled, fairly globose, and smooth. Both forms are 2 to 3 cm in diameter. One specimen shows a simple 8-lobed suture that appears to be goniatitic.

Locality Number 60—Continued

Fossil age.—Uncertain. No older than Late Devonian. "Possibly Late Devonian–Mississippian, but a Jurassic age cannot be ruled out." (N.J. Silberling, written commun., 1983).

Comment.—New specimens (fig. 17) favor, but do not establish, an Early Jurassic age for the faunal assemblage (N.J. Silberling, oral commun., 1988).

Locality Number 61

Unit.—Onion Creek Formation (this report)

Collector, year of collection, field No.—D.S. Harwood and G.R. Fisher, 1983, RG(S)–28

U.S. Geological Survey locality No.—28783–PC

Location.—Soda Springs 7.5' quad., Placer County, Calif.; NE¼SE¼ sec. 10, T. 16 N., R. 14 E.; lat 39°15'53" N., long 120°43'53" W. Top of 6080 knob on east side of Serena Creek; 1,250 ft east of BM 6372.

Rock type/setting.—Tan to white calcareous quartzite containing sparse, scattered, ribbed, arcuate pits and holes. Quartzite overlies metachert of the Serena Creek Formation (new) and is interbedded with calc-silicate rock and minor calcarenite.

Fossils.—Bivalve shell fragments; some large with coarse ribs. One fragment suggestive of a nucleospirid brachiopod.

Fossil age.—Paleozoic; post-Early Ordovician (Canadian to Ibexian) based on large, coarse-ribbed bivalve fragments. Nucleospirids range from Late Silurian to Mississippian in age. Collection may be middle Paleozoic in age, (J.T. Dutro, Jr., written commun., 1983; J.H. Pojeta, Jr., written commun., 1984).

Locality Number 62

Unit.—Picayune Valley Formation (this report)

Collector, year of collection, field No.—D.S. Harwood, 1980, GC–1

U.S. Geological Survey locality No.—None

Location.—Granite Chief 7.5' quad., Placer County, Calif.; NE¼SE¼ sec. 23, T. 15 N., R. 15 E.; lat 39°07'30" N., long 120°15'05" W. Elevation 6,800 ft in Grouse Canyon.

Rock type/setting.—Limestone lens or block in black pelite, quartzite, and chert-rich cobble conglomerate.

Fossils.—Echinoderm fragments:

Lampterocrinus (?)

Fossil age.—Silurian to Devonian. "If these columnals are *Lampterocrinus*, a Silurian age is fairly certain. However, there is much distortion of these fragments and I opt simply for a Siluro-Devonian age range" (J.T. Dutro, Jr., written commun., 1988).

Locality Number 63

Unit.—Pit Formation

Locality Number 63—Continued

Collector, year of collection, field No.—D.S. Harwood, 1986, GV–86–4

U.S. Geological Survey locality No.—None

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; SW¼SW¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'16" N., long 120°44'14" W. On east side of ranch road in low rubbly cut bank at 4,480-ft elevation; 1,100 ft bearing 171° from BM 4806 in sec. 3 (fig. 10).

Rock type/setting.—Highly fissile, light-gray to yellow-tan, chalky-weathering, dark-gray tuffaceous slate with extremely abundant impressions of *Daonella* and sparse impressions of ammonites; occurs as narrow belt, no more than 200 ft thick, east and west of tongue of the Hosselkus Limestone.

Fossils.—Pelecypod:

Daonella cf. *D. degeeri* (abundant)

Ammonites:

Meginoceras meginae

Protrachyceras

Fossil age.—late Middle Triassic (middle Ladinian) (N.J. Silberling, written commun., 1987).

Comment.—Locality is probably part of the *Daonella* bed described by Hyatt (1892, p. 397) as "closely underlying the limestone," but this locality could also fit his poor locality description of the *Halobia* bed "near the top of the carboniferous spur" (Hyatt, 1892, p. 399). However, Hyatt recognized the large anterior ear characteristic of *Halobia* in his *Halobia* bed, and none of the flat clams at loc. 63 contain that diagnostic feature. Contact relations between the *Daonella*-bearing gray slate and the Hosselkus Limestone are not exposed, but conodonts from the Hosselkus Limestone (loc. 66) indicate the Hosselkus is younger (late Karnian to early Norian). A normal fault is inferred to juxtapose the tuffaceous slate and Hosselkus Limestone against *Monotis*-bearing black slate and limestone of the Swearinger Slate (Diller, 1908) to the east (loc. 86).

Locality Number 64

Unit.—Pit Formation

Collector, year of collection, field No.—D.S. Harwood, 1986, GV–86–3

U.S. Geological Survey locality No.—None

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼SW¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'21" N., long 120°44'15" W. At 4,670-ft elevation on north side of road about 1 m east of Hosselkus Limestone; 400 ft bearing 169° from BM 4806 in sec. 3 (fig. 10).

Rock type/setting.—See loc. 63.

Fossils.—Pelecypod:

Daonella cf. *D. degeeri*

Locality Number 64—Continued

Fossil age.—late Middle Triassic (middle Ladinian) on basis of ammonites associated with the abundant *Daonella* at loc. 63.

Locality Number 65

Unit.—Hosselkus Limestone (Diller, 1908; McMath, 1958)

Collector, year of collection, field No.—Alpheus Hyatt, ?, ?

U.S. Geological Survey locality No.—?

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼NW¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'40" N., long 120°44'10" W. Probably on or near ridge crest east of Hosselkus Creek (fig. 10).

Rock type/setting.—Gray limestone.

Fossils.—Identified by A. Hyatt:

Arcestes sp.
Badiolites cf. *B. eryx* Mojsis
Juvavites cf. *J. erlichi* Mojsis
Tropites
Atractites
Acrochordiceras
Balatonites cf. *B. waageni*

Fossil age.—Late Triassic (Diller, 1908, p. 31).

Locality Number 66

Unit.—Hosselkus Limestone (Diller, 1908)

Collector, year of collection, field No.—D.S. Harwood, 1987, GV–87–3

U.S. Geological Survey locality No.—Mes. colln. 33300

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼SW¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'16" N., long 120°44'16" W. At 4,680-ft elevation, north side of road; 600 ft bearing 189° from BM 4806 (fig. 10).

Rock type/setting.—Gray bioclastic limestone containing sparse, coarsely recrystallized megafossils; outcrops form prominent ledges on divide between Genesee Valley and Hosselkus Creek, a mile northwest of the old Robinson ranch (fig. 10).

Fossils.—Conodonts:

3 Pa elements of *Neogondolella polygnathiformis* (Budurov and Stefanov)
1 Pa element fragment of *Neogondolella* sp. indet.
2 ichthyoliths

Fossil age.—middle Late Triassic (Karnian to early Norian, very probably late Karnian to early Norian). CAI 5–5.5=300–350 °C (A.G. Harris, written commun., 1987).

Comment.—Limestone is in contact with gray tuffaceous slate that contains abundant *Daonella* impressions about 1 m east of easternmost limestone exposure. Contact is vertical, but fossil data indicate that the Hosselkus Limestone is younger than the tuffaceous slate.

Locality Number 67

Unit.—Hosselkus Limestone

Collector, year of collection, field No.—D.S. Harwood, 1986, GN–86–1

U.S. Geological Survey locality No.—Mes. colln. 33292

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; SE¼SE¼ sec. 18, T. 25 N., R. 11 E.; lat 40°01'36" N., long 120°46'42" W. Elevation 4,710 ft on ridge crest on northeast slope of Grizzly Mountain; 7,100 ft bearing 055° from BM 7711 at Grizzly Peak.

Rock type/setting.—Lens of medium-grained gray limestone with sparse small crinoid fragments. Sparse outcrops to the east are andesitic tuff breccia of unknown age, but contact with limestone was not observed.

Fossils.—Conodonts:

5 incomplete Pa elements of *Epigondolella* sp. indet. of middle-late Norian morphotype
1 *Xaniognathus* sp. element
4 indet. fragments

Fossil age.—middle Late Triassic (middle-late Norian). CAI=5–5.5 (K.E. Denkler and A.G. Harris, written commun., 1986).

Comment.—This limestone lens and the one at loc. 68 were originally mapped as the Hosselkus Limestone by Diller (1908). McMath (1958) mapped the associated andesitic volcanic rocks as the Taylor Formation and considered the limestone to be a lens in the Taylor. Stratigraphic and structural relations between the limestone and andesitic rocks are uncertain because of sparse exposures, but the limestone probably occurs as a tectonic sliver at the base of the Taylorsville thrust as originally mapped by Diller (1908).

Locality Number 68

Unit.—Hosselkus Limestone

Collector, year of collection, field No.—D.S. Harwood, 1986, GN–86–2

U.S. Geological Survey locality No.—Mes. colln. 33293

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; SW¼NW¼NW¼ sec. 20, T. 25 N., R. 11 E.; lat 40°01'15" N., long 120°46'28" W. From 4,800-ft elevation on northeast slope of Grizzly Mountain; 7,700 ft bearing 080° from BM 7704 at Grizzly Peak.

Rock type/setting.—Lens of gray limestone; adjacent rocks covered by glacial drift, but nearest outcrops are andesitic tuff breccia of unknown age.

Fossils.—Conodonts:

4 Pa elements of *Epigondolella* sp. of late Karnian to early Norian morphotype
1 Pa element of *Neogondolella* cf. *N. polygnathiformis* (Budurov and Stefanov)
1 incomplete Pa element of *Neogondolella* sp. indet.
4 indet. fragments
46 ichthyoliths

Locality Number 68—Continued

Fossil age.—middle Late Triassic (late Karnian to early Norian). CAI=5–5.5 (K.E. Denkler and A.G. Harris, written commun., 1986).

Comment.—Diller (1908) considered this limestone lens to be the Hosselkus Limestone, but McMath (1958) included it in his Taylor Formation. Stratigraphic and structural relations between the lens of limestone and surrounding rocks are not exposed, but the limestone probably occurs as a tectonic sliver at the base of the Taylorsville thrust as originally mapped by Diller (1908).

Locality Number 69

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—J.S. Diller, ?, 569

U.S. Geological Survey locality Nos.—Triassic locs. 1105, 2476

Location.—Caribou 7.5' quad., Plumas County, Calif.; SW¼NW¼ sec. 17, T. 26 N., R. 7 E.; lat 40°06'36" N., long 121°13'39" W. Approximate elevation 3,840 ft, at Soda Spring (see Jayko, 1988, loc. 14).

Rock type/setting.—Calcareous schist and slate(?).

Fossils.—Ammonites, belemnites, brachiopods, bryozoans, *Halobia*

Fossil age.—Late Triassic (early Norian) (Diller, 1892).

Locality Number 70

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—J.S. Diller, ?, 618

U.S. Geological Survey locality No.—?

Location.—Almanor 15' quad., Plumas County, Calif.; approximately on line between secs. 17 and 18, T. 26 N., R. 7 E.; lat 40°06'45" N., long 121°13'47"W. Elevation 4,200 ft on southwest slope of ridge; 900 ft bearing 315° from Soda Spring (see Jayko, 1988, loc. 22).

Rock type/setting.—Limestone and calcareous schist.

Fossils.—Pentagonal crinoid stems

Fossil age.—Unknown (Diller, 1892).

Locality Number 71

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—N.J. Silberling, 1987, 87–S–453; A.S. Jayko, ?, ?

U.S. Geological Survey locality No.—Mes. colln. 33276

Location.—Caribou 7.5' quad., Plumas County, Calif.; NE¼NE¼ sec. 18, T. 26 N., R. 7 E.; lat 40°06'53" N., long 121°13'54" W. Approximately 4,480-ft elevation, northeast side of road between Yellow Creek and Soda Ravine; 2,000 ft bearing 326° from Soda Spring (see Jayko, 1988, loc. 1).

Rock type/setting.—Dark-gray, dense, well-indurated ammonite-bearing limestone associated with calcareous schist, black slate, and massive porphyritic volcanic breccia (A.S. Jayko, oral commun., 1987).

Locality Number 71—Continued

Fossils.—Ammonites:

(1) *Megaphyllites* sp.
(2) indet. arcestids
(3) ornate forms that belong either to clionititids or arpaditinid trachyceratids

Conodonts:

Neospathodus homeri (Bender)
Xaniognathus sp. indet.
Neogondolella polygnathiformis
ichthyoliths

Fossil age.—late Middle to early Late Triassic. Ammonite "forms (1) and (2) are long ranging through much of the Middle and Upper Triassic; form (3) can't be older than late Ladinian and is probably no younger than Karnian. Although a late Karnian age is permissible, the common and characteristic late Karnian forms of the Hosselkus Limestone at Shasta Lake are not represented * * * if I had to guess how this limestone fit into the Shasta section, I'd place it in the Pit, perhaps in the upper part transitional into the Hosselkus." (N.J. Silberling, written commun., 1987). Conodonts are indicative of Ladinian to Karnian age (Jayko, 1988).

Locality Number 72

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—J.S. Diller, ?, 356

U.S. Geological Survey locality No.—Triassic loc. 2263

Location.—Caribou 7.5' quad., Plumas County, Calif.; NE¼NE¼ sec. 18, T. 26 N., R. 7 E.; lat 40°06'53" N., long 121°13'54" W. Approximately 4,480-ft elevation northeast of road between Yellow Creek and Soda Ravine; 2,000 ft bearing 326° from Soda Spring. Same as loc. 71.

Rock type/setting.—Calc-schist and limestone associated with black slate and massive porphyritic volcanic breccia (A.S. Jayko, oral commun., 1987).

Fossils.—*Pentacrinus californicus* (Clark)

Fossil age.—Unknown (Diller, 1908).

Locality Number 73

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—Larry Robinson, 1975(?), 348; recollected by A.S. Jayko, ?, ?

U.S. Geological Survey locality No.—None

Location.—Caribou 7.5' quad., Plumas County, Calif.; NE¼SE¼ sec. 19, T. 26 N., R. 7 E.; lat 40°05'38" N., long 121°13'54" W. Elevation about 4,720 ft, on ridge crest; 1,820 ft bearing 150° from BM 4363 on road immediately east of Yellow Creek (see Jayko, 1988, loc. 13).

Rock type/setting.—Gray limestone and calcareous schist in fault-bounded sliver, approximately 1,500 by 500 ft in size, in black slate (A.S. Jayko, oral commun., 1987).

Locality Number 73—Continued

Fossils.—Fusulinids:

(identified by G.L. Wilde)

Pseudofusulinella

Schwagerina

(identified by C.H. Stevens)

Triticites hermanni (Skinner and Wilde, zone A)

Triticites brevis (Skinner and Wilde)

Fossil age.—Early Permian, Zone A of the McCloud Limestone (G.L. Wilde, written commun., to L. Robinson 1974). Earliest Permian. "* * * similarity to Klamath fusulinids is so close, I feel it belongs to the same biogeographic province" (C.H. Stevens, written commun. to A.S. Jayko, 1985).

Locality Number 74

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—D.S. Harwood, 1987, C–87–1

U.S. Geological Survey locality No.—30149–PC

Location.—Caribou 7.5' quad., Plumas County, Calif.; NE¼SE¼ sec. 19, T. 26 N., R. 7 E.; lat 40°05'38" N., long 121°13'54" W. East slope of unnamed ridge between Yellow Creek and Mosquito Creek; 4,600 ft bearing 190° from Soda Spring.

Rock type/setting.—Gray bioclastic limestone with visible but scattered crinoid debris and fusulinid tests. Same limestone block as loc. 73.

Fossils.—Conodonts:

1 juvenile Pa element of *Streptognathodus* sp. indet.

1 unassigned Pb element

3 ichthyoliths

Fossil age.—Early Pennsylvanian to early Early Permian (Morrowan to Wolfcampian). CAI=6=>400 °C (A.G. Harris, written commun., 1987).

Locality Number 75

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—D.S. Harwood, 1987, MV–87–1

U.S. Geological Survey locality No.—30154–PC

Location.—Meadow Valley 7.5' quad., Plumas County, Calif.; SE¼NW¼ sec. 18, T. 24 N., R. 8 E.; lat 39°57'03" N., long 121°01'22" W. From north side of Spanish Creek at 3,600-ft elevation; 1,900 ft bearing 145° from BM 4012 on Gopher Hill.

Rock type/setting.—Mottled dark- and light-gray, highly sheared and recrystallized limestone associated with gray tuffaceous slate.

Fossils.—Conodonts:

3 Pa elements of *Streptognathodus* sp.

4 indet. bar, blade, and platform fragments

Locality Number 75—Continued

Fossil age.—Early Pennsylvanian to early Early Permian (Morrowan to Wolfcampian). CAI=5.5–6=350–400 °C. "These conodonts are fractured and deformed" (A.G. Harris, written commun., 1987).

Locality Number 76

Unit.—unnamed limestone block in Mesozoic tectonic sliver

Collector, year of collection, field No.—L.A. Standlee, 1978?, ?

U.S. Geological Survey locality No.—None

Location.—Quincy 7.5' quad., Plumas County, Calif.; S½SE¼ sec. 33, T. 24 N., R. 9 E.; lat 39°52'38" N., long 120°58'20" W. At elevation 5,160 ft on brushy slope, east side of logging road; 6,250 ft bearing 005° from BM 5584 at Cattle Springs mine.

Rock type/setting.—Gray limestone with sparse gray chert interbeds occurs as blocks in gray slate, tuff, and polymict conglomerate/pebbly mudstone.

Fossils.—Fusulinids:

(sample 1 submitted to C.H. Stevens)

Cuniculinella fusiformis? Skinner and Wilde, Zone F?

Pseudoschwagerina sp., Zone E?

Corals:

(sample 2 submitted to C.H. Stevens)

Heritschioides sp. aff. *H. carneyi* Wilson, Zone A?

Fossil age.—Early Permian. "These two samples (from different limestone blocks) contain typical McCloud Limestone fusulinids (sample 1) and a typical McCloud coral (sample 2)" (C.H. Stevens, written commun. to D.S. Harwood, 1989).

Locality Number 77

Unit.—unnamed conglomerate unit (Jayko, 1988)

Collector, year of collection, field No.—A.S. Jayko, 1985, 85CJ–21

U.S. Geological Survey locality No.—?

Location.—Almanor 15' quad., Plumas County, Calif.; NE¼NE¼ sec. 36, T. 26 N., R. 7 E.; lat 40°04'05" N., long 121°07'20" W. At 4,800-ft elevation; 2,450 ft bearing 339° from BM 5755 on Cherry Hill (see Jayko, 1988, loc. 2).

Rock type/setting.—Lenses of limestone in conglomerate.

Fossils.—Conodonts:

Neogondolella navicula (Huckriede)

Fossil age.—early Late Triassic (late Karnian through early Norian). CAI=5≅300 °C. (B.R. Wardlaw, written commun. to A.S. Jayko, 1986).

Locality Number 78

Unit.—unnamed limestone unit (Jayko, 1988)

Collector, year of collection, field No.—A.S. Jayko, 1985, 85CJ–22

Locality Number 78—Continued

U.S. Geological Survey locality No.—33278

Location.—Almanor 15' quad., Plumas County, Calif.; SE¼SE¼ sec. 36, T. 26 N., R. 7 E.; lat 40°03'35" N., long 121°07'05" W. At 5,520-ft elevation, southeast side of Spur Ridge; 550 ft bearing 025° from BM 5755 on Cherry Hill (see Jayko, 1988, loc. 3).

Rock type/setting.—Gray, schistose crinoidal limestone.

Fossils.—Conodonts:

Epigondolella abneptis (Huckriede)
Xaniognathus sp.

Fossil age.—early Late Triassic (early Norian). CAI=5≅300 °C. "This collection of conodonts has been tectonically deformed; many of the elements have 'flowed'" (B.R. Wardlaw, written commun. to A.S. Jayko, 1986).

Locality Number 79

Unit.—unnamed limestone unit (Jayko, 1988)

Collector, year of collection, field No.—A.S. Jayko, 1985, 85TJ–6

U.S. Geological Survey locality No.—?

Location.—Almanor 15' quad., Plumas County, Calif.; SW¼SE¼ sec. 8, T. 25 N., R. 8 E.; lat 40°02'15" N., long 121°06'40" W. Elevation 3,200 ft; 7,500 ft bearing 165° from BM 6283 at Eagle Rock (see Jayko, 1988, loc. 4).

Rock type/setting.—Gray limestone.

Fossils.—Conodonts:

Epigondolella primitia (Mosher)
Neogondolella navicula (Huckriede)

Fossil age.—early Late Triassic (late Karnian through early Norian). CAI=5≅300 °C (B.R. Wardlaw, written commun. to A.S. Jayko, 1986).

Locality Number 80

Unit.—unnamed limestone unit (Jayko, 1988)

Collector, year of collection, field No.—A.S. Jayko, 1986, 86AJ–10

U.S. Geological Survey locality No.—33299

Location.—Almanor 15' quad., Plumas County, Calif.; SE¼NE¼ sec. 26, T. 27 N., R. 7 E.; lat 40°10'06" N., long 121°09'24" W. At 5,600-ft elevation in saddle at end of secondary road (see Jayko, 1988, loc. 5).

Rock type/setting.—Schistose limestone.

Fossils.—Conodonts:

Epigondolella sp. indet. of late early to early late Norian age morphotype
ichthyoliths

Fossil age.—middle Late Triassic (late early to early late Norian). CAI=5.5=350 °C (K.E. Denkler, written commun. to A.S. Jayko, 1987).

Locality Number 81

Unit.—unnamed limestone unit (Jayko, 1988)

Locality Number 81—Continued

Collector, year of collection, field No.—A.S. Jayko, 1987, 87AJ–1

U.S. Geological Survey locality No.—33327

Location.—Almanor 15' quad., Plumas County, Calif.; SW¼NW¼ sec. 23, T. 27 N., R. 7 E.; lat 40°11'05" N., long 121°10'17" W. Elevation 5,080 ft; 2,050 ft due south of BM 4801 at NW cor. sec. 23 (see Jayko, 1988, loc. 7).

Rock type/setting.—Foliated gray limestone.

Fossils.—Conodonts:

Epigondolella abneptis (Huckriede)
Epigondolella sp.

Fossil age.—Late Triassic (Norian, possibly early to middle Norian). CAI=5.5–6≅350–400 °C (A.G. Harris, written commun. to A.S. Jayko, 1988).

Locality Number 82

Unit.—unnamed limestone unit (Jayko, 1988)

Collector, year of collection, field No.—A.S. Jayko, 1987, ?

U.S. Geological Survey locality No.—33328

Location.—Approximately 500 ft due south of loc. 81 (see Jayko, 1988, loc. 6).

Rock type/setting.—Foliated gray limestone.

Fossils.—Conodonts:

Epigondolella sp. indet.

Fossil age.—Late Triassic (late Karnian to late Norian). CAI=5.5–6≅350–400 °C (A.G. Harris, written commun. to A.S. Jayko, 1988).

Locality Number 83

Unit.—unnamed gray tuffaceous slate

Collector, year of collection, field No.—Larry Robinson, ?, 353a

U.S. Geological Survey locality No.—?

Location.—Almanor 15' quad., Plumas County, Calif.; NW¼NW¼ sec. 26, T. 27 N., R. 7 E.; lat 40°10'25" N., long 121°10'20" W. Elevation 5,160 ft on north side of gravelled road; 5,750 ft bearing 098° from powerhouse at head of Butt Valley Reservoir (see Jayko, 1988, loc. 16).

Rock type/setting.—Gray to greenish-gray tuff and tuffaceous slate, about 100 ft west of limestone and calcareous tuff.

Fossils.—Ammonites (no genus or species given)

Fossil age.—Middle Triassic to Early Jurassic(?) inclusive (N.J. Silberling, oral commun., 1974, cited in Robinson, 1975).

Locality Number 84

Unit.—unnamed Jurassic(?) and Triassic rocks

Collector, year of collection, field Nos.—V.E. McMath, ?, 772a; D.S. Harwood, 1988, BL–88–1; A.S. Jayko, 1989, ?

U.S. Geological Survey locality Nos.—None (UCLA locality No. 3964)

Locality Number 84—Continued

Location.—Almanor 15' quad., Plumas County, Calif.; NE¼NW¼ sec. 22, T. 27 N., R. 7 E.; lat 40°11'20" N., long 121°11'01" W. Elevation 4,660 ft on southeast side of main road from Prattville to Butt Valley Reservoir, approximately 100 ft southwest of intersection with logging road spur to the southeast.

Rock type/setting.—Black slate and siltstone with interbedded lenses of polymict conglomerate.

Fossils.—indeterminate ammonite impressions
imprints of a *Posidonia*-like pelecypod

Fossil age.—Mesozoic; possibly Early Jurassic (N.J. Silberling, written commun. to A.S. Jayko, 1989).

Locality Number 85

Unit.—unnamed limestone correlative with the Hosselkus Limestone

Collector, year of collection, field No.—D.S. Harwood, 1980, DP–1

U.S. Geological Survey locality No.—Mes. loc. No. 31871

Location.—Duncan Peak 7.5' quad., Placer County, Calif.; SW¼NE¼ sec. 28, T. 16 N., R. 13 E.; lat 39°13'20" N., long 120°31'07" W. Elevation 3,350 ft, north wall of North Fork American River canyon (fig. 19).

Rock type/setting.—Gray limestone with scattered, thin, chert-rich sandstone beds; approximately 25 ft above base of Mesozoic section.

Fossils.—Conodonts:
Epigondolella cf. *E. abneptis* (Huckriede)

Fossil age.—Late Triassic (late Karnian through Norian). CAI=8=>450 °C (A.G. Harris, written commun., 1981).

Locality Number 86

Unit.—Swearinger Slate (Diller, 1908) (*Monotis* bed of the Swearinger Slate of Hyatt, 1892)

Collector, year of collection, field No.—J.S. Diller, 1890(?), ?

U.S. Geological Survey locality Nos.—2460, 6757

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼SE¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'22" N., long 120°43'54" W. Low rubbly outcrops on southwest slope of low ridge at 4,160-ft elevation; 1,750 ft bearing 112° from BM 4806 in sec. 3 (fig. 10). Scattered rubble of fossiliferous black slate can be found along strike to the southeast between this locality and loc. 87.

Rock type/setting.—Black slate interlayered with dark-gray carbonaceous limestone beds as thick as 1.5 m; occurs east of, and presumably in tectonic contact with, the Hosselkus Limestone and gray slate of the Pit Formation (loc. 63).

Fossils.—Pelecypod:
Monotis subcircularis Gabb

Fossil age.—Late Triassic (early late Norian) (N.J. Silberling, oral commun., 1987).

Comment.—Locality was originally found in 1863 by Professor W.H. Brewer of Yale University and his field assistant Clarence King (Whitney, 1865). Diller (1892, 1908), Hyatt (1892), and McMath (1958) included the *Daonella*-bearing gray slate (locs. 63–64) with the *Monotis*-bearing black slate in the Swearinger Slate, which they considered to be Late Triassic in age. The *Daonella*-bearing slate is clearly older than the *Monotis*- bearing slate. Contact of the Swearinger Slate with the Hosselkus Limestone and *Daonella*-bearing slate of the Pit Formation is inferred to be a high-angle fault.

Locality Number 87

Unit.—Swearinger Slate (Diller, 1908)

Collector, year of collection, field No.—D.S. Harwood, 1987, GV–87–4

U.S. Geological Survey locality No.—Mes. colln. No. 33301

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼SE¼ sec. 3, T. 25 N., R. 11 E.; lat 40°03'19" N., long 120°43'49" W. Low outcrop and rubble on north side of ranch road 4,040-ft elevation; 2,300 ft bearing 112° from BM 4806 (fig. 10).

Rock type/setting.—Dark-gray to sooty black, fetid limestone beds as much as 30 cm thick interbedded with black slate containing locally abundant impressions of *Monotis subcircularis*. Slate and limestone dip steeply east and strike north-northwest uphill into the Hosselkus Limestone. Swearinger Slate–Hosselkus Limestone contact is inferred to be a high-angle fault.

Fossils.—Conodonts:
3 Pa elements of *Epigondolella* sp. indet.
4 indet. bar, blade, and platform fragments
3 phosphatized steinkerns

Fossil age.—Late Triassic (Karnian to Norian). CAI=5.5–6=350–400 °C (A.G. Harris, written commun., 1987).

Comment.—Black limestone was sampled to see if conodonts would differentiate ages of the Swearinger Slate and the Hosselkus Limestone; unfortunately, age range of these conodonts and those from the Hosselkus Limestone (loc. 68) are concurrent. The pelecypod *Monotis subcircularis* in slate interbedded with this limestone, however, restricts age of the Swearinger Slate to the early late Norian (N.J. Silberling, oral commun., 1987) and indicates that the Swearinger Slate is younger than the Hosselkus Limestone.

Locality Number 88

Unit.—Hardgrave Sandstone (Diller, 1892, 1908)

Collector, year of collection, field No.—J.S. Diller, 1890–1891, ?

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; NW¼NE¼ sec. 26, T. 26 N., R. 10 E.; lat 40°05'25" N., long 120°49'13" W. At 4,035-ft elevation on ranch road. The Hardgrave Sandstone is generally fossiliferous where it occurs on Mount Jura. Exact locations of collections

Locality Number 88—Continued

Location.—Continued

made by Diller and studied by Hyatt are unknown, but this is a representative and readily accessible fossiliferous exposure of the Hardgrave Sandstone.

Rock type/setting.—Commonly red, but locally gray, fine-grained calcareous volcaniclastic sandstone and slate with lenses of conglomerate (see Diller, 1908, for distribution of the Hardgrave Sandstone).

Fossils.—Determined by A. Hyatt (1892, p. 401–402):

Pecten acutiplicatus Meek (abundant)
Entolium meeki
Pinna expansa
Montlivaultia n. sp.(?)
Ostrea sp.
Anomia n. sp.
Modiola n. sp.
Mytilus n. sp.
Gervillia linearis n. sp.
Gervillia gigantia n. sp.
Lima n. sp.
Ctenostreon n. sp.
Goniomya n. sp.
Pholadomya n. sp.
Pleuromya n. sp.
Trigonia n. sp.
Cidaris n. sp.
Glyphaea punctata n. sp.

Fossil age.—Early Jurassic. Hyatt (1892) assigned the Hardgrave Sandstone to the upper Lias (which is equivalent to the Toarcian), but Imlay (1968) considered it to be late Sinemurian to early Pliensbachian in age on the basis of sparse ammonites (see fig. 21).

Comment.—Fossils listed undoubtedly are from several localities on Mount Jura.

Locality Number 89

Unit.—Thompson Limestone (Diller, 1892)

Collector, year of collection, field No.—J.S. Diller and A. Hyatt, 1890(?), ?

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 24, T. 26 N., R. 10 E.; lat 40°05'37" N., long 120°48'29" W. This is locality described by Diller (1908, p. 42) as the "most prominent and accessible exposures—near the north end [of Mount Jura] where it has been burned for lime." Probably same as loc. 90 recollected by Batten and Taylor (1978).

Rock type/setting.—Gray limestone interbedded with red shale, locally contains abundant "screw holes" (Diller, 1908, p. 41) where the long, slender gastropod *Nerinea* has weathered out.

Fossils.—*Nerinea* sp.

Opis sp. cf. *O. paradoxa* Buvignier
Terebratula sp.

Locality Number 89—Continued

Fossil age.—Early Jurassic. Hyatt (1892, p. 403) was uncertain of age of the Thompson Limestone but stated "it will probably be proved to be a member of the inferior Oolite" (roughly age equivalent to the Bajocian Stage of the lower Middle Jurassic).

Comment.—Batten and Taylor (1978) assigned an Early Jurassic (late Pliensbachian to early Toarcian) age to the Thompson Limestone, on basis of their discovery of *Plicatostylus* in the limestone at this locality (see loc. 90).

Locality Number 90

Unit.—Thompson Limestone (Diller, 1892)

Collector, year of collection, field No.—B.L. Batten and D.G. Taylor, ?, ?

U.S. Geological Survey locality No.—None

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; SE¼SW¼ sec. 24, T. 26 N., R. 10 E. North slope of Mount Jura (probably same place as loc. 89).

Rock type/setting.—Gray limestone.

Fossils.—Pelecypod:

Plicatostylus

Gastropod:

Nerinea sp.

Fossil age.—late Early Jurassic (late Pliensbachian to early Toarcian) (Batten and Taylor, 1978).

Comment.—Hyatt (1892) considered the Thompson Limestone to be part of the "inferior Oolite" (age equivalent to the Bajocian Stage) of early Middle Jurassic age. Batten and Taylor (1978) based their late Early Jurassic age for the unit on the occurrence of *Plicatostylus* in rocks of late Pliensbachian and Toarcian age in Oregon, Nevada, and Chile and its absence from rocks of demonstrable Middle Jurassic age. They proposed that an unconformity, spanning part of the Toarcian and the early Bajocian, separates the Thompson Limestone from the overlying Mormon Sandstone (Diller, 1892).

Locality Number 91

Unit.—Mormon Sandstone (Diller, 1892)

Collector, year of collection, field No.—J.S. Diller, 1890, ?

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif. Approximately on line between sec. 36, T. 26 N., R. 10 E., and sec. 1, T. 25 N., R. 10 E.; lat 40°03'45" N., long 120°48'35" W. Elevation 4,840 ft; 4,800 ft bearing 225° from BM 6274 on Mount Jura. This is "spur 8 of Mr. Diller's map" cited by Hyatt (1892) as containing well-preserved fossils. (Locations for the numerical designations of spurs and ravines on southwest and south slopes of Mount Jura were determined from Diller's original field notes.)

Locality Number 91—Continued

Rock type/setting.—Interbedded greenish-gray and red volcaniclastic sandstone and conglomerate of the Mormon Sandstone occurs above a thin lens of the Thompson Limestone and above the Fant Metaandesite (Diller, 1908) where the Thompson Limestone is missing.

Fossils.—Determined by A. Hyatt (1892, p. 404–405):

Terebratula
Rhynchonella n. sp.
Alectryonia n. sp.
Modiola subimbricata
Mytilus n. sp.
Pinna cuneiformis
Pteroperna n. sp.
Gervillia n. sp.
Lima dilleri n. sp.
Lima taylorensis n. sp.
Ctenostreon n. sp.
Pecten n. sp.
Pholadomya n. sp.
Trigonia n. sp.
Belemnites n. sp.
Sphaeroceras n. sp.
Grammoceras n. sp.

Fossil age.—Hyatt (1892) assigned fauna of the Mormon Sandstone to the upper part of the "inferior Oolite" (roughly age equivalent to the Bajocian Stage of the lower Middle Jurassic).

Comment.—The Mormon Sandstone is richly fossiliferous. It is unknown whether all fossils listed above occur at this locality or whether the faunal list is a composite of collections made throughout the Mount Jura area.

Locality Number 92

Unit.—Bicknell Sandstone (Diller, 1908, p. 49–50)

Collector, year of collection, field No.—J.S. Diller, 1891, 3512

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; SE¼NW¼NE¼ sec. 6, T. 25 N., R. 11 E.; lat 40°02'44" N., long 120°47' W. Approximately 4,080-ft elevation on west bank of Hinchman Ravine (J.S. Diller).

Rock type/setting.—Red and gray volcaniclastic sandstone, shale, and tuff.

Fossils.—Identified by A. Hyatt, (1892, p. 406–407):

Gryphaea bononiformis n. sp.
Entolium costatum n. sp.
Oxytoma n. sp.
Trigonia obliqua n. sp.
Trigonia plumasensis n. sp.
Rhacophyllites n. sp.
Reineckeia
Macrocephalites(?)
Perisphinctes

Locality Number 92—Continued

Fossil age.—early Late Jurassic (Callovian) (Diller, 1908, p. 50).

Comment.—Callovian is now considered to be late Middle Jurassic.

Locality Number 93

Unit.—Hinchman Sandstone (Diller, 1908)

Collector, year of collection, field No.—?

U.S. Geological Survey locality No.—?

Location.—Taylorsville 7.5' quad., Plumas County, Calif.; NE¼NW¼NE¼ sec. 6, T. 25 N., R. 11 E.; lat 40°03' N., long 120°47' W. Approximately 4,240-ft elevation on east bank of Hinchman Ravine. Curtice Cliff in lower part of Hinchman Ravine (Diller, 1908, p. 52).

Rock type/setting.—Volcaniclastic sandstone, shale, and conglomerate

Fossils.—Identified by A. Hyatt, (1892, p. 408):

Gryphaea curtici n. sp.
Camptonectes bellistriatus Meek
Chemnitzia
Rhacophyllites
Stylina tubulifera
Stylina subjecta n. sp.
Stylina alba n. sp.
Stylina minuta n. sp.
Stylina intermedia n. sp.
Stylina tertia n. sp.

Fossil age.—late Middle Jurassic (Callovian) (Imlay, 1961).

Comment.—Hyatt (1892) identified the fossils and assigned the Hinchman Sandstone to the "Corallian Stage" of the Late Jurassic, but Imlay (1961) considers unit to be Callovian on the basis of ammonites.

Locality Number 94

Unit.—Foreman Formation

Collector, year of collection, field No.—J. Storrs, 1904, ?

U.S. Geological Survey locality No.—6776

Location.—Greenville 15' quad., Plumas County, Calif.; approx. location NE¼NW¼ sec. 30, T. 26 N., R. 10 E.; lat 40°05'16" N., long 120°47'07" W. Approximately 4,200-ft elevation in southeast fork Foreman Ravine, 3 mi northeast of Taylorsville.

Rock type/setting.—Black shale.

Fossils.—Ammonites:

Reineckeia (*Reineckeites*) *dilleri*

Fossil age.—late Middle Jurassic (Callovian) (Imlay, 1961, p. D-9).

Comment.—Diller (1908, p. 55–56) listed several collections of plant fossils from the Foreman that have not been restudied. The Callovian age for the formation is based on ammonites originally collected by Storrs (cited in Diller, 1908, p. 56) and restudied by Imlay (1961).

Locality Number 95

Unit.—Foreman Formation

Collector, year of collection, field No.—J. Storrs, 1904, ?

U.S. Geological Survey locality No.—6776

Location.—Probably same as loc. 94

Rock type/setting.—Black slate, sandstone, and chert-rich pebble conglomerate.

Fossils.—*Pecten* sp.
Trigonia naviformis Hyatt?
Astarte sp.
Perisphinctes? sp.
Ammonites
Belemnites

Fossil age.—"Middle Jurassic or later" (Diller, 1908, p. 56, cites T.W. Stanton, unpublished report of 1/20/05).

Locality Number 96

Unit.—Foreman Formation

Collector, year of collection, field No.—Cooper Curtice, 1890, ?; J. Storrs, 1904, ?

U.S. Geological Survey locality No.—?

Location.—Greenville 15' quad., Plumas County, Calif.; near S. line of sec. 35, T. 27 N., R. 10 E. About 3 mi southeast of Evans Peak.

Rock type/setting.—Dark shale associated with sandstone, conglomerate, and thin bed of bluish limestone.

Fossils.—Plants:
F.H. Knowlton's 1904 report, based on W.M. Fontaine's 1891 identifications (Knowlton's 1905 reinterpretations in parentheses):
Acrostichites? *princeps* (*Gleichenia* or *Gleichenopsis*)
Acrostichites brevipennis
Sagenopteris? sp. (*Glossopteris*)
Equisetum munsteri
Podozamites? sp.? (*Pterophyllum*)
Conifer? fragments

Fossil age.—Jurassic (Diller, 1908, p. 55–56).

Comment.—The Foreman Formation was considered to be Late Triassic in age, on basis of plant fossils (fragments) (see Diller, 1908, p. 55), and subsequently considered as "Middle Jurassic or later", on basis of shelly fossils at loc. 95 (Diller, 1908, p. 56). Imlay (1961) later revised its age as Middle Jurassic (Callovian).

Locality Number 97

Unit.—Kettle Formation

Collector, year of collection, field Nos.—V.E. McMath, R.W. Imlay, 1957, ?

U.S. Geological Survey locality Nos.—26783, 26784

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NE¼SW¼ sec. 22, T. 26 N., R. 11 E.; lat 40°05'52" N., long 120°43'58" W. Near trail along Hosselkus Creek approximately at elevation 4,960 ft; collection 26784 is from several hundred feet stratigraphically below 26783.

Locality Number 97—Continued

Rock type/setting.—Host rock unknown. McMath (1958, p. 150) reports that locality is about in the middle of the upper member of the Kettle Formation. The upper member is composed of a variety of andesitic pyroclastic beds, shallow sills or flows, and minor conglomerate.

Fossils.—Ammonites:
Pseudocadoceras schmidti (Pompeckj)
Pseudocadoceras cf. *P. grewingki* (Pompeckj)
Choffatia sp.

Fossil age.—late Middle Jurassic (early or middle Callovian) (McMath, 1958, p. 150; Imlay, 1961, p. D-9).

Locality Number 98

Unit.—Kettle Formation

Collector, year of collection, field Nos.—V.E. McMath, R.W. Imlay, 1957, ?

U.S. Geological Survey locality Nos.—26785, 26786

Location.—Genesee Valley 7.5' quad., Plumas County, Calif.; NW¼NE¼ sec. 22, T. 26 N., R. 11 E.; approx. lat 40°06'13" N., long 120°43'34" W. Collection 26785 from 5,760-ft elevation, east side Hosselkus Creek; collection 26786 is from several hundred feet stratigraphically below 26785.

Rock type/setting.—Host rock unknown. Formation consists primarily of andesitic breccia, lapilli tuff, tuff, and minor conglomerate (McMath, 1958).

Fossils.—Ammonites:
Cadoceras sp. juv.
Xenocephalites? sp.
Paracadoceras? sp.
Pseudocadoceras cf. *P. grewingki* (Pompeckj)

Fossil age.—late Middle Jurassic (early or middle Callovian) (Imlay, 1961, p. D-9).

Locality Number 99

Unit.—Trail Formation

Collector, year of collection, field No.—D.S. Harwood, 1983, HH–6

U.S. Geological Survey locality No.—?

Location.—Greenville 15' quad., Plumas County, Calif.; NW¼SE¼ sec. 6, T. 27 N., R. 10 E.; lat 40°13' N., long 120°54' W. Elevation 5,280 ft on northwest-trending ridge crest; 1,900 ft bearing 149° from Strong Ranch.

Rock type/setting.—Silicified limestone pebble from polymict conglomerate interbedded with slate and sandstone in the Trail Formation. Locality is in western part of the unit near thrust contact with Paleozoic rocks to west (pl. 1).

Fossils.—Foraminifera:
Nankinella sp.
textularid suggesting *Climacammina* sp.
fusulinid suggesting *Profusulinella* sp.

Fossil age.—Age of fauna in the pebble is Middle Pennsylvanian; probably early Atokan (R.C. Douglass, written commun., 1984).

Locality Number 99—Continued

Comment.—Silicified limestone pebble was not derived from the Taylorsville sequence to the west because the chert member of the Peale Formation was being deposited at that time. An eastern source in the Great Basin or Inyo Mountains is possible.

Locality Number 100

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—N.J. Silberling, 1961, S–61–51

U.S. Geological Survey locality No.—Mes. colln. No. 28403

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; NW cor. sec. 2, T. 15 N., R. 13 E.; lat 39°11'53" N., long 120°29'56" W. Headwaters of tributary to New York Canyon near Oak Flat; 1,850 ft bearing 217° from Trinidad mine.

Rock type/setting.—Black slate interbedded with volcaniclastic sandstone; approximately 980 ft stratigraphically above base of Mesozoic rocks.

Fossils.—Ammonites:

Crucilobiceras? cf. *C. silviesi* (Hertlein)
Camptonectes (*Camptochlamys*) *semiplicatus* (Hyatt)

Fossil age.—Early Jurassic (late Sinemurian) (Imlay, 1968).

Locality Number 101

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—N.J. Silberling, 1961, S–61–50

U.S. Geological Survey locality No.—Mes. colln. No. 28404

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; NW cor. sec. 2, T. 15 N., R. 13 E.; lat 39°11'53" N., long 120°29'52" W. On Sailor Flat trail at Oak Flat on ridge between New York and Sailor Canyons; 1,600 ft bearing 219° from Trinidad mine (fig. 19).

Rock type/setting.—Black slate rubble approximately 1,200 ft stratigraphically above base of Mesozoic rocks.

Fossils.—Ammonite:

Crucilobiceras? cf. *C. silviesi* (Hertlein)

Fossil age.—Early Jurassic (late Sinemurian) (Imlay, 1968).

Locality Number 102

Unit.—Sailor Canyon Formation

Collector, year of collection, field Nos.—Waldemar Lindgren, 1890, ? (USGS No. 574); Cooper Curtice, 1891, ? (USGS No. 2464); L.D. Clark, 1961, LC–61–17 (USGS No. 28396).

U.S. Geological Survey locality Nos.—574, 2464, 28396

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; SE cor. sec. 34, T. 16 N., R. 13 E.; lat 39°12'06" N., long 120°29'51" W. On Sailor Flat trail at elevation 4,850 ft (fig. 19).

Locality Number 102—Continued

Rock type/setting.—Black slate rubble in trail contains abundant ammonite casts. Rubble derived from low outcrops of black slate and volcaniclastic sandstone west of trail; about 1,850 ft above base of Mesozoic rocks.

Fossils.—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.
Peronoceras? sp.
Aptychi undet.
Gryphaea sp. (found about 0.5 mi from ammonite bed)
"*Daonella*" *bochiformis* Hyatt
"*D.*" *cardinoides* Hyatt
"*D.*" sp. Hyatt (1894, p. 416)
Hemientolium? sp.

USGS Colln. No. 28396 (identified by R.W. 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.

Fossil age.—Early Jurassic (late Pliensbachian) (Imlay, 1968).

Comment.—All three collections probably came from the same locality or nearly so. All the fossil lists are from an unpublished report on referred fossils from R.W. Imlay to Lorin Clark dated 10/16/61 in which Imlay gave the age as early Toarcian (see Clark and others, 1962). Imlay (1968, p. C16–C17) apparently restudied the collections and noted the presence of *Reynesoceras* cf. *R. ragazzoni* (Hauer) in locs. 574, 2464, 28396; *Arieticeras* cf. *A. domarense* (Meneghini) in locs. 2464, 28396; *Harpoceras* (*Harpoceratoides*)? sp. in loc. 574; and *Fuciniceras* sp. in loc. 28396. On the basis of these fossils, he concluded that the collections were late Pliensbachian. About the pelecypods described as "*Daonella*" *bochiformis* and "*D.*" *cardinoides* by Hyatt (1894, p. 415, 416), Imlay noted similar pelecypods associated

Locality Number 102—Continued

Comment.—Continued

with the same ammonites in the Nicely Formation of eastern Oregon and stated, "the pelecypods resemble the Jurassic *Meleagrinella* and *Otapira* cf. *O. marshalli* (Trechmann)," but until better preserved material is found in the Sailor Canyon Formation he suggested referring to them as "*Daonella*."

Locality Number 103

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–7

U.S. Geological Survey locality No.—Mes. loc. 28395

Location.—Duncan Peak 7.5' quad., Placer County, Calif.; NW¼NE¼NE¼ sec. 28, T. 16 N., R. 13 E.; lat 39°13'40" N., long 120°30'55" W. Just north of ridge crest approximately at 4,520-ft elevation; about 1,600 ft bearing 068° from BM 4428 in sec. 28 (fig. 19).

Rock type/setting.—Black slate interbedded with volcaniclastic sandstone; approximately 1,150 ft above base of Mesozoic rocks.

Fossils.—Ammonites:

Dactylioceras sp.

Fossil age.—Early Jurassic (late Pliensbachian to early Toarcian) (Imlay, 1968).

Locality Number 104

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–12a

U.S. Geological Survey locality No.—Mes. loc. 28391

Location.—Duncan Peak 7.5' quad., Placer County, Calif.; NW¼SW¼ sec. 27, T. 16 N., R. 13 E.; lat 39°13'20" N., long 120°33'48" W. Approximately 3,500-ft elevation in ravine 1,100 to 1,300 ft north of North Fork American River (fig. 19).

Rock type/setting.—Black slate interbedded with volcaniclastic sandstone; approximately 2,400 ft stratigraphically above base of formation.

Fossils.—Ammonites:

Orthildaites? sp.
Hildaites sp.
Dactylioceras cf. *D. directum* (Buckman)
Protogrammoceras? sp.

Fossil age.—late Early Jurassic (early Toarcian) (Clark and others, 1962; R.W. Imlay, written commun. to L.D. Clark, 1961).

Locality Number 105

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—Cooper Curtice, 1891, ?

U.S. Geological Survey locality No.—Mes. loc. 2467

Locality Number 105—Continued

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; T. 16 N., R. 13 E.; approximately on line between secs. 25 and 26; lat 39°13'18" N., long 120°28'25" W.; elevation approximately 4,000 ft. Original description states, "American Canyon, Snow Mtn. opposite big canyon 800 to 1,000 ft elevation above canyon floor" (fig. 19).

Rock type/setting.—Black slate.

Fossils.—Ammonite:

Tmetoceras sp.

Fossil age.—Middle Jurassic (early Bajocian) (Imlay, 1968).

Locality Number 106

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–13

U.S. Geological Survey locality No.—Mes. loc. 28392

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; NW¼SE¼ sec. 27, T. 16 N., R. 13 E.; lat 39°13'20" N., long 120°29'58" W. About 3,800-ft elevation in ravine 2,100 ft north of North Fork American River (fig. 19).

Rock type/setting.—Black slate interbedded with feldspathic sandstone.

Fossils.—Ammonite:

cf. *Protogrammoceras*

Fossil age.—Early Jurassic (late Pliensbachian to early Toarcian) (R.W. Imlay, written commun. to L.D. Clark, 1961).

Locality Number 107

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–11

U.S. Geological Survey locality No.—Mes. loc. 28390

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; SE¼NW¼ sec. 26, T. 16 N., R. 13 N.; lat 39°13'20" N., long 120°29'10" W. About 3,800-ft elevation on west wall of intermittent tributary to North Fork American River (fig. 19).

Rock type/setting.—Black slate talus.

Fossils.—*Posidonia*? sp. (distorted)

Ammonite fragment undet.

Fossil age.—Early to Middle Jurassic (R.W. Imlay, written commun. to L.D. Clark, 1961).

Locality Number 108

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–10

U.S. Geological Survey locality No.—28389

Location.—Royal Gorge 7.5' quad., Placer County, Calif.; NW¼SE¼ sec. 26, T. 16 N., R. 13 E.; lat 39°13'08" N., long 120°28'51" W. Approximately 3,560-ft elevation in talus on north side of North Fork American River (fig. 19).

Locality Number 108—Continued
Rock type/setting.—Black slate talus.
Fossils.—*Tmetoceras* sp.
Erycites??
uncoiled ammonite undet.
Fossil age.—early Middle Jurassic (early Bajocian) (R.W. Imlay, written commun. to L.D. Clark, 1961).

Locality Number 109
Unit.—Sailor Canyon Formation
Collector, year of collection, field No.—L.D. Clark, 1961, LC–61–9
U.S. Geological Survey locality No.—Mes. loc. 28388
Location.—Royal Gorge 7.5' quad., Placer County, Calif.; NW¼SW¼ sec. 25, T. 16 N., R. 13 E.; lat 39°13'11" N., long 120°27'17" W. In talus from 3,600- to 3,800-ft elevation on north side of ephemeral stream north side of North Fork American River (fig. 19), at or very close to loc. 105.
Rock type/setting.—Black slate talus.
Fossils.—*Tmetoceras*? sp.
Ammonite undet.
Posidonia sp.
Fossil age.—early Middle Jurassic (early Bajocian) (R.W. Imlay, written commun. to L.D. Clark, 1961).

Locality Number 110
Unit.—Sailor Canyon Formation
Collector, year of collection, field No.—R.R. Compton, 1962, ?
U.S. Geological Survey locality No.—None
Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NE¼SW¼ sec. 29, T. 17 N., R. 13 E.; lat 39°18'25" N., long 120°32'36" W. Elevation approximately 5,750 ft on low ridge beneath power line; approximately 2,200 ft bearing 020° from BM 5923 on railroad at Cisco (fig. 19).
Rock type/setting.—Two-foot-thick bed of slate interbedded with feldspathic sandstone.
Fossils.—Ammonite:
Hildoceratid ammonite (identified by N.J. Silberling)
Arietidid ammonite (identified by S. Muller)
Fossil age.—late Early Jurassic (Toarcian) (N.J. Silberling, written commun. to D.E. Stuart-Alexander, 1967). Early Jurassic (Sinemurian) (S. Muller, written commun. to D.E. Stuart-Alexander, 1962).
Comment.—One poorly preserved impression of an ammonite was found that was first assigned to the family Arietidid by Muller and was later assigned to the family Hildoceratid by Silberling.

Locality Number 111
Unit.—Sailor Canyon Formation
Collector, year of collection, field No.—D.S. Harwood, 1986, CG–636

Locality Number 111—Continued
U.S. Geological Survey locality No.—None
Location.—Cisco Grove 7.5' quad., Placer County, Calif.; SW¼SE¼ sec. 32, T. 16 N., R. 13 E.; lat 39°17'13" N., long 120°32'11" W. Elevation 6,560 ft on east slope of low ridge immediately west of Huysink Lake (fig. 19).
Rock type/setting.—Black slate and thin-bedded white-weathering calcareous tuff(?) or tuffaceous siltstone approximately 2,600 ft above base of the Sailor Canyon Formation.
Fossils.—Highly deformed Hildoceratid(?) ammonites
Fossil age.—late Early Jurassic (J.W. Miller, written commun., 1987).

Locality Number 112
Unit.—Sailor Canyon Formation
Collector, year of collection, field No.—D.S. Harwood, 1986, CG–594
U.S. Geological Survey locality No.—?
Location.—Cisco Grove 7.5' quad., Placer County, Calif.; T. 17 N., R. 13 E.; lat 39°18'49" N., long 120°32'32" W. Elevation 5,800 ft on low ridge crest; 3,600 ft bearing 262° from BM 6959 on Rattlesnake Mtn. (fig. 19).
Rock type/setting.—Thin-bedded black slate and light-gray feldspathic sandstone 40 m above base of the Sailor Canyon Formation.
Fossils.—Ammonite:
?*Paltechioceras* spp.
Fossil age.—Early Jurassic (late Sinemurian) (D.G. Taylor, written commun., 1988).

Locality Number 113
Unit.—Sailor Canyon Formation
Collector, year of collection, field No.—D.S. Harwood, 1986, CG–544
U.S. Geological Survey locality No.—?
Location.—Cisco Grove 7.5' quad.; on Nevada-Placer County line, Calif.; NE¼NW¼ sec. 29, T. 17 N., R. 13 E.; lat 39°18'56" N., long 120°32'30" W. Elevation 5,950 ft on east side of small gully; 3,250 ft due west of BM 6959 ft on Rattlesnake Mtn. (fig. 19).
Rock type/setting.—Black slate and thin-bedded feldspathic sandstone. Approximately 100 m above base of the Sailor Canyon Formation.
Fossils.—Ammonites:
Reynesoceras cf. *R. ragazzoni* (Hauer)
Arieticeras sp.
Pelecypod:
Ostrea? sp.
Fossil age.—Early Jurassic (Pliensbachian) (J.W. Miller, written commun., 1987).

Locality Number 114
Unit.—Sailor Canyon Formation

Locality Number 114—Continued

Collector, year of collection, field No.—D.A. Davis, 1986, CG-8036–2

U.S. Geological Survey locality No.—None

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NE¼NW¼ sec. 29, T. 17 N., R. 13 E.; lat 39°18'44" N., long 120°32'40" W. Elevation 5,820 ft on low ridge crest; 3,600 ft bearing 262° from BM 6959 on Rattlesnake Mtn.; probably same outcrop area as loc. 112 (fig. 19).

Rock type/setting.—Black slate and thin-bedded feldspathic sandstone.

Fossils.—Ammonites:

Polyplectus sp. (identified by D.G. Taylor)

Paltarpites cf. *P. arqutus* (Buckman) (identified by J.W. Miller)

Fossil age.—Early Jurassic (late Pliensbachian to early Toarcian) (J.W. Miller, written commun., 1987); (Toarcian) (D.G. Taylor, written commun., 1988).

Locality Number 115

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—D.A. Davis, 1986, CG–6196–1

U.S. Geological Survey locality No.—None

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NE¼NW¼ sec. 29, T. 17 N., R. 13 E.; lat 39°18'08" N., long 120°32'31" W. Elevation 5,750 ft, beneath power line; 2,100 ft bearing 019° from BM 5923 on railroad at Cisco (fig. 19); at or very near loc. 110.

Rock type/setting.—Black slate and thin-bedded feldspathic sandstone.

Fossils.—Ammonites:

?*Paltechioceras* spp. (identified by D.G. Taylor)

Arieticeras sp. (identified by J.W. Miller)

Fossil age.—Early Jurassic (late Pliensbachian) (J.W. Miller, written commun., 1987); (late Sinemurian) (D.G. Taylor, written commun., 1988).

Locality Number 116

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—D.S. Harwood, 1986, CG–543

U.S. Geological Survey locality No.—None

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NE¼NW¼ sec. 29, T. 17 N., R. 13 E.; lat 39°18'54" N., long 120°32'32" W. Elevation 5,880 ft on low ridge crest east of Fordyce Road; 3,600 ft bearing 268° from BM 6959 on Rattlesnake Mtn. (fig. 19).

Rock type/setting.—Interbedded black slate and light-gray feldspathic sandstone 60 m above base of the Sailor Canyon Formation.

Fossils.—Ammonite:

?*Paltechioceras* spp.

Locality Number 116—Continued

Fossil age.—Early Jurassic (late Sinemurian) (D.G. Taylor, written commun., 1988).

Locality Number 117

Unit.—Sailor Canyon Formation

Collector, year of collection, field No.—D.A. Davis, 1986, CG–10136–1

U.S. Geological Survey locality No.—None

Location.—Cisco Grove 7.5' quad., Placer County, Calif.; NW¼NW¼ sec. 28, T. 17 N., R. 13 E.; lat 39°18'55" N., long 120°31'43" W. Elevation 6,880 ft on east slope of Rattlesnake Mtn. (fig. 19).

Rock type/setting.—Fine-grained, gray feldspathic siltstone interbedded with thick-bedded volcaniclastic sandstone and polymict conglomerate approximately 120 m below top of the Sailor Canyon Formation.

Fossils.—Ammonite indet.

Fossil age.—Early Jurassic. "The specimen is conceivably a heteromorph (what could be taken for uncoiling of the last whorl, however, is very likely the result of crushing), but it is not like any Middle Jurassic heteromorph or any other ammonite of that age. Could be referable to Late Triassic heteromorph genus *Choristoceras*, but not probable. The simple ribbing, concave costation profile and moderately rapid whorl expansion rate suggest any number of early Jurassic forms (but not an echioceratid) from late Hettangian to early Pliensbachian" (D.G. Taylor, written commun. to D.S. Harwood, 1988).

Locality Number 118

Unit.—unnamed volcaniclastic breccia

Collector, year of collection, field No.—D.E. Stuart-Alexander, 1965, L–1

U.S. Geological Survey locality No.—?

Location.—English Mtn. 7.5' quad., Nevada County, Calif.; center sec. 6, T. 18 N., R. 13 E.; lat 39°27'30" N., long 120°34' W. Exact location uncertain but approximately at 6,800-ft elevation on westernmost northwest-trending spur ridge of English Mountain due south of Jackson Lake.

Rock type/setting.—Volcaniclastic siltstone interbedded in andesitic volcanic breccia.

Fossils.—Pelecypod:

Posidonia cf. *P. ornati*

Fossil age.—late Early through Middle Jurassic. "This impression is that of *Posidonia* similar to the common mid-Jurassic species *P. ornati* which ranges from late Early Jurassic through the Middle Jurassic" (N.J. Silberling, written commun. to D.E. Stuart-Alexander, 1983).

Comment.—Unnamed volcanic and volcaniclastic rocks on English Mountain are probably correlative with the Tuttle Lake Formation to the south.

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