GEOLOGY AND PALEONTOLOGY OF THE SOUTHWEST QUARTER OF THE BIG BEND QUADRANGLE

SHASTA COUNTY, CALIFORNIA

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ABSTRACT

The area covered by this report is the southwest quarter of the Big Bend quadrangle in the vicinity of the town of Big Bend, Shasta County, California.

This region, which has been geologically unknown, contains sedimentary and volcanic strata of Mesozoic and Cenozoic ages.

The Mesozoic deposits are composed of pyroclastic rocks, lava flows, tuffaceous sandstone, argillite, and limestone. The Mesozoic formations, from the oldest to the youngest, are the Pit formation of Middle and Late Triassic age; the Hosselkus limestone, the Brock shale, and the Modin formation of Late Triassic age; the Arvison formation of Early Jurassic age; and the Bagley andesite and Potem formation of Early and Middle Jurassic age. Of the seven formations mapped, six are continuations of formations found in the contiguous Redding quadrangle. These formations, which have been only briefly described by other authors, were studied in detail in the field and laboratory.

The Modin formation is redefined and divided into three members, the lower or Hawkins Creek member, the middle or Devils Canyon member, and the upper or Kosk member. This division is based on lithologic differences observed in the field. This formation has previously been considered Early Jurassic. However, newly discovered fossils from the formation include the species *Spiriferina suessi* Winkler and *Choristoceras marshi* Hauer which are restricted to the uppermost Triassic of Europe. Thus, the Modin formation is Triassic rather than Jurassic. Marine strata of this stage of the Triassic have not been reported previously from California.

A new name, the Arvison formation, is proposed for strata of Early Jurassic age, which unconformably overlie the Modin formation and conformably underlie the Potem formation. This formation contains the ammonite genera *Arnioceras* and *Asteroceras,* which indicate a Sinemurian (Early Jurassic) age.

The Cenozoic rocks consist of fluviatile deposits of Eocene age, which unconformably overlie the Mesozoic strata and are capped by lavas and pyroclastic rocks associated with the Pliocene Cascade lavas.

INTRODUCTION

Location. The Big Bend region is a rectangular area of approximately 65 square miles located in north-central Shasta County, California. The region is situated in the southwest quarter of the Big Bend quadrangle U. S. Forest Service 15-minute planimetric map. The southwest corner of the region is at 41° north latitude and 122° west longitude.

The region may be reached by way of a county road which extends from Hillcrest, on United States Highway 299, northward a distance of 17 miles to the town of Big Bend.

Field Work and Methods. The field work was undertaken during the summers of 1950 and 1951. A total of 14 weeks was spent in the region.

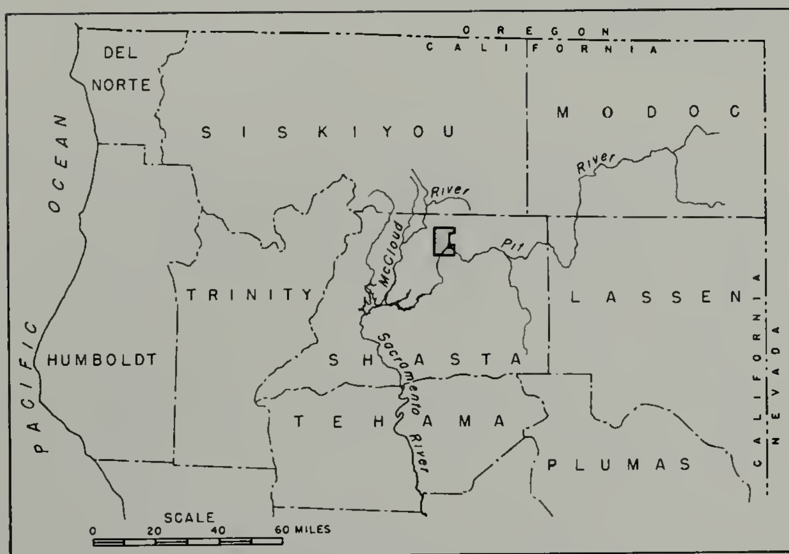


Figure 1. Index map showing location of the Big Bend area, Shasta County, California.

Geological data were plotted on aerial photographs with a scale of approximately 1:20,000. The U. S. Forest Service planimetric map of the Big Bend quadrangle (1:62,500), which was constructed from the same set of photographs used for this study, proved to be very satisfactory as a base map. Geologic sections were measured and estimated by pace and compass methods and by measurements on the aerial photographs where distortion of scale was thought to be at a minimum.

Topography. The greater part of the Big Bend area is drained by the Pit River and its tributaries. The Pit River, which is supplied with a large volume of water from the volcanic plateau east of the town of Burney, has cut a deep canyon into the volcanic rocks just east of Big Bend. The tributary streams, keeping pace with the rapidly downcutting Pit River, have cut deep, steep-sided canyons, giving sharp topographic relief to the region. Elevations in the area mapped range from 1,500 feet along the Pit River to about 4,800 feet along the highest ridge. Peaks immediately north of the area have elevations exceeding 6,000 feet. The area appears to be in the youthful stage of the fluvial erosion cycle.

Previous Work. The area around Big Bend appears as an unmapped region on the State Geologic Map of California (1938). Early workers, however, visited the region and collected fossils near the Pit River and Kosk Creek. A survey of previous work would not be complete without a brief discussion of early work carried on in adjacent regions, especially of the papers that deal with the stratigraphic units in the Big Bend area.

The first geologic account of sedimentary strata in Shasta County was by J. B. Trask (Whitney, 1865, p. 327), who collected fossils from limestone at Gray Rocks near Bayha in 1855 and determined their age as Carboniferous. A California Survey party under Whitney (1865, pp. 326-327) visited the same locality in 1863 and collected a number of fossils which were described by Meek (Meek and Gabb, 1864) also as Carboniferous. This limestone, now known as the McCloud limestone, lies to the west of the Big Bend area.

In 1883 J. S. Diller of the U. S. Geological Survey began a reconnaissance survey of northern California

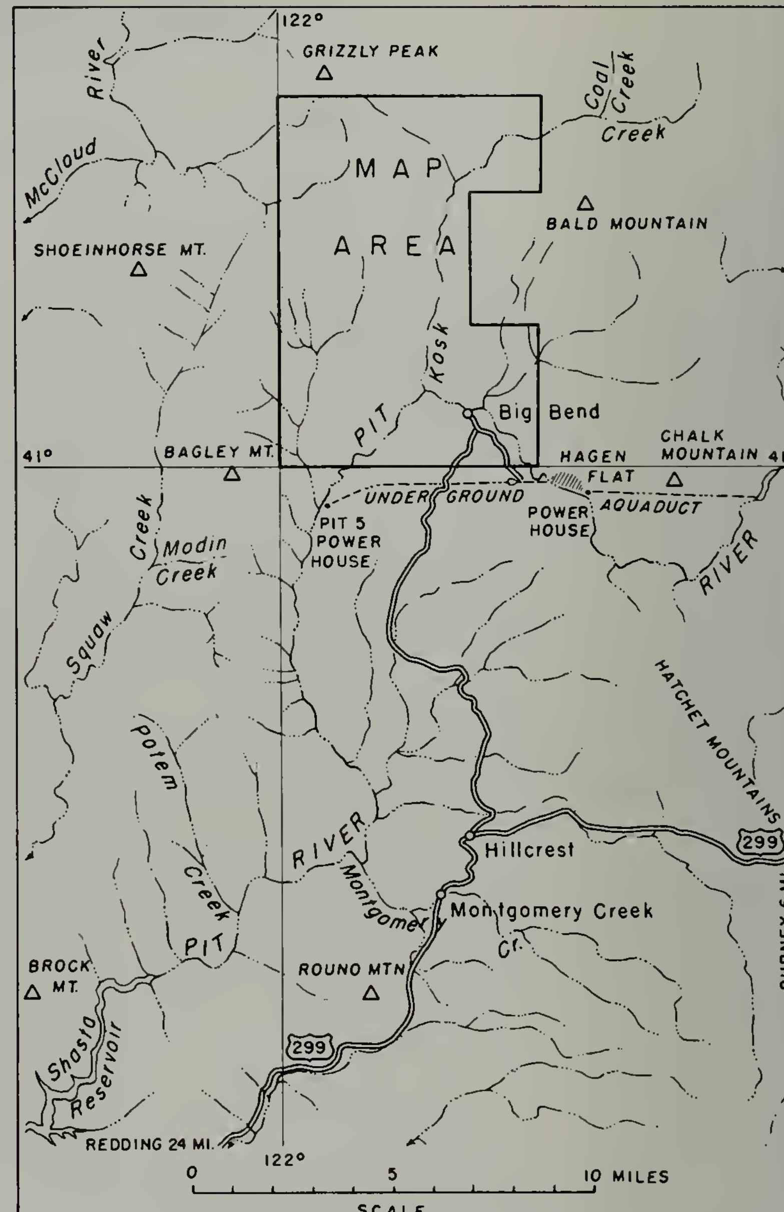


Figure 2. Index map showing local geographic setting of the Big Bend area, Shasta County, California.

and Oregon. In a paper on the geology of the Lassen Peak district, Diller (1889) first mentioned the presence of Mesozoic sediments older than Cretaceous in the vicinity of Pit River and Montgomery Creek. Diller also considered these rocks as part of the "Auriferous slate series."

Fairbanks (1893) wrote a general account of the geology of Shasta County which was published together with the first geologic map of the county. His account included some discussion of the rocks of the Big Bend area, with a description of a fossil locality in Big Canyon (now Iron Canyon) about 6 miles southwest of Big Bend. Of these rocks and the age of the contained fossils he wrote as follows:

> "Slates appear in Big Canyon. They strike very regularly a little west of north; dip almost vertical. The color is black to purplish. A few scattered fossils were found in them and in the washed boulders in the bed of the creek. . . . The most prominent fossil is a large-ribbed bivalve shell not found in place at this point. The character of these fossils indicates a Mesozoic age. Some of the fossils as well as the slates resemble the Triassic of Indian Valley, Plumas County. They are certainly younger than the Carboniferous and, according to our present accepted stratigraphy, must be older than Cretaceous."

The coal-bearing shales and conglomerates of the Big Bend area he considered Cretaceous.

> "Below Big Bend, Pit River flows for many miles in a deep, narrow canyon. Its course has been cut at the junction of the Chico conglomerates with the older series."

These beds are now considered Eocene in age.

Diller (1893) mentioned fossil localities near Big Bend and near Cedar Creek in the Redding quadrangle and stated that both Jurassic and Triassic of the Taylorsville region are well represented in the Pit River Valley. Of the Big Bend fauna, he quoted Hyatt's opinion that the age of the fossils is equivalent to those of the Mormon sandstone of Taylorsville. He mentioned the Bend and Cedar formations as new formations but did not outline their stratigraphic limits or distribution, as they were to be described in the text of the U. S. Geological Survey's Lassen Peak atlas sheet, which at that time was in proof.

Fairbanks (1894) published some supplementary notes on his geologic work in Shasta County. Fossils collected during the field studies had been sent to J. P. Smith for identification. Smith considered the fossils collected at Big Canyon to be contemporaneous with those of the Hardgrave sandstone of the Taylorsville area, Plumas County. The fossiliferous limestone west of the Big Canyon area near Squaw Creek was regarded as a correlative of the Hosselkus limestone of Taylorsville and the rocks at Diller's Cedar Creek locality, all three being of Karnian age.

Smith (1894) summarized the results of the study of fossil material from Shasta County and briefly described the various lithologic units of the region as then understood. Included with these were Diller's Upper Triassic Cedar formation and the Jurassic Bend formation, descriptions of which had apparently been published in 1892 in an advance copy of the Lassen Peak folio. Under the Cedar formation, Smith listed the fauna of the Swearinger slates (Brock shales), the age of which was placed as Late Norian. The first list of fauna from the Hosselkus limestone was also included, in a description of the Cedar formation. This limestone was considered to be Karnian in age, as previously reported by Fairbanks.

Diller (1906) revised the stratigraphy of this area in the Redding folio, which contains an excellent geologic description of the stratigraphic units of Shasta County. For the Upper Triassic and Jurassic rocks, Diller proposed several new formations. The previously used name, Cedar formation, was abandoned, and replaced by Hosselkus limestone for the strata of the lower part, and Brock shale for the overlying shale beds that previously had been referred to as the correlative of the Swearinger slates of the Taylorsville region. The Bend formation of the Lassen Peak quadrangle, which included all beds thought to be Jurassic in age, was abandoned because of prior use of the name on the Gulf Coast. The name Modin formation was proposed for the lower portion of the old Bend formation of the Lassen folio. Although many fossils were found in these beds, diagnostic forms were lacking and the formation was assigned to the Jurassic system on the basis of its stratigraphic position. The younger Jurassic beds were named the Potem formation. The Potem formation was thought to be the correlative of the Hardgrave and Mormon sandstones of the Taylorsville region. The lacustrine deposits which unconformably overlie the Jurassic beds near Big Bend and along Kosk Creek were considered an extension of the Ione formation and were assigned to the Miocene series on the basis of their flora.

Hinds (1933) published a report on the geologic formations of the Redding and Weaverville quadrangles. He suggested no changes of name for the geologic formations of the Mesozoic strata, but introduced the name Montgomery Creek formation for the rocks previously referred to the Ione formation by Diller.

Acknowledgments. Thanks are due Dr. Siemon W. Muller for guidance and advice during the field mapping and the preparation of this paper; to Dr. R. R. Compton for suggestions concerning the study of thin-sections of the representative rocks of the area; and to Drs. A. Myra Keen and J. J. Graham for many helpful suggestions.

It is a pleasure to acknowledge the innumerable courtesies extended by personnel of the United States Forest Service and residents of the vicinity of Big Bend.

GENERAL STRATIGRAPHY

Strata exposed in the Big Bend area are Mesozoic and Tertiary in age. A maximum thickness of 12,800 feet of Upper Triassic and Lower and Middle Jurassic strata is exposed above the Pit formation. The rocks are predominantly marine clastic sediments derived from the erosion of volcanic flows and associated pyroclastic material together with subordinate limestone deposits and considerable pyroclastic rocks and lavas.

These rocks are well indurated. They are locally metamorphosed by structural deformation, and some alteration of the pyroclastic rocks was observed. However, no obvious regional metamorphism has occurred in these sediments although the units outcropping in this area are shown as metasediments elsewhere in Shasta County on the California State Geologic Map of 1938.

Relatively unconsolidated fluvial shale, sandstone, and conglomerate of Eocene age unconformably overlie the Mesozoic strata. These beds in turn are unconformably capped by a thick layer of andesitic and basaltic flows and pyroclastic accumulations associated with the Pliocene Cascade lavas.

The formations in the Big Bend area are summarized in figure 3.

TRIASSIC SYSTEM

Pit Formation (Middle and Upper Triassic)

Definition and Lithologic Character. The Pit formation is the oldest formation (exposed) in the area studied. It was named by Fairbanks (1894), undoubtedly for exposures along the Pit River. However, no type locality was indicated. As originally defined, the Pit formation included all sediments younger than the McCloud limestone and older than the Hosselkus limestone. The lower part of the formation, which consisted of shales and pyroclastic material, called the McCloud shales, was considered Carboniferous in age. The upper beds were called the Pit shales and placed as the Lower or Middle Triassic. Diller (1906) restricted the Pit formation. The lower beds of the original Pit formation which were considered Carboniferous in age were assigned to the Nosoni formation. Certain extrusive and pyroclastic strata which overlie the Nosoni beds were placed in two formations, the Dekkas andesite and the

Series	Standard European stages	Formation	Estimated maximum thickness in feet
Pliocene?		Volcanic flows and associated pyroclasic deposits. (Shasta Lavas Highland)	3,000
. . . .		Unconformity	
Eocene		MONTGOMERY CREEK FORMATION	2,600—
. . . .		Unconformity	
Middle Jurassic	Bajocian	POTEM FORMATION	1,000
. . . .		BAGLEY ANDESITE	700
	Toarcian		
	. . . .		
	Pliensbachian		
Lower Jurassic	. . . .	ARVISON FORMATION	5,090
	Sinemurian		
	. . . . ?		
	Hettangian	. . . . ? . ? .	
. . . .		Unconformity	
	Rhaetian	MODIN FORMATION	5,500—
. . . . ?			
Upper Triassic	Norian	BROCK SHALE	400—
. . . .			
	Karnian	HOSSELKUS LIMESTONE	150—
. . . .			
Middle Triassic	Ladinian Anisian?	PIT FORMATION	

FIGURE 3. Geologic section in the Big Bend area.

GENERALIZED COLUMNAR SECTION OF BIG BEND AREA

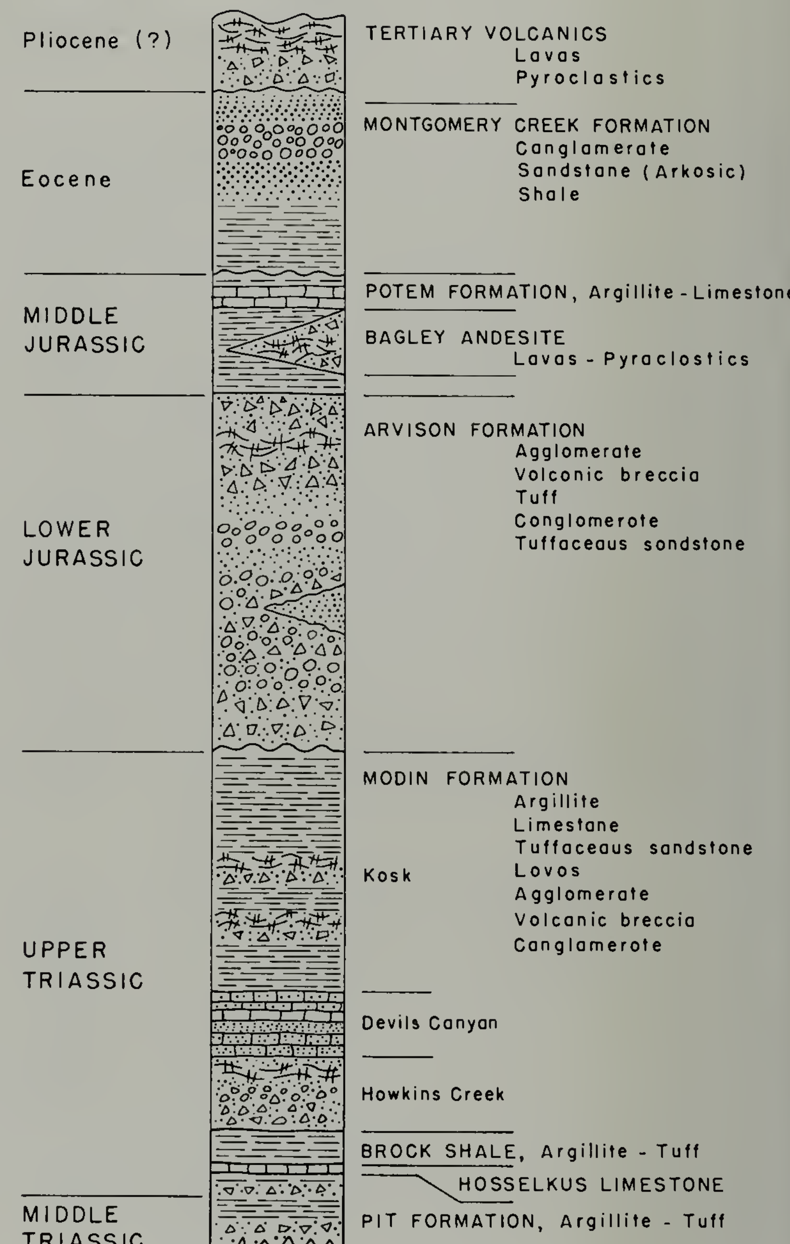


FIGURE 4.

Bully Hill rhyolite. The overlying interbedded shales and tuffs, largely the Pit shales described by Fairbanks, constituted the restricted Pit formation.

Field work in the Big Bend region was planned to include the investigation of rocks younger than the Pit formation. As a result, only exposures of the upper part of the Pit formation were examined. In Hawkins Creek the Pit formation consists of alternating dark gray to black argillites, light green to gray tuffs, and thin beds or lentils of gray limestone. The argillites predominate, comprising about 65 percent of the rock. Fresh outcrops are exposed only at intervals in the creek bed. Elsewhere, the nature of the bedrock can be judged only by the fragmental material present in the regolith. These weathered materials suggest a bedrock of interbedded argillite, volcanic breccia, and coarse-grained tuff.

Exposures of the Pit formation in upper Devils Canyon are similar to those on Hawkins Creek. However, tuffaceous and agglomeratic beds predominate and limestone is absent.

Thin-sections of samples from Devils Canyon show the tuffs to be composed mainly of subrounded to subangular fragments of volcanic origin and feldspar crystals encased in a fine-grained tuffaceous groundmass. Chlorite and leucoxene are common. The argillite is composed chiefly of silt to clay-sized particles of tuffaceous material together with about 20 percent black carbonaceous material. Numerous spherical to subspherical bodies composed of chalcedony are suggestive of radiolarian remains. However, no definite organic structures could be seen, as the silica has recrystallized, and any structures that may have been present have been destroyed.

Distribution and Age. The Pit formation is confined to the northwest corner of the Big Bend area. Best exposures are along Hawkins Creek and in the upper part of Devils Canyon below Grizzly Peak. Elsewhere, the Pit formation is deeply weathered and forms rolling hills and gentle slopes.

No fossils were found in the Pit formation in the Big Bend region. Smith (1927) reported the presence of *Halobia rugosa, Trachyceras, Ceratites* cf. *C. humboldtensis* and *Ptychites,* and placed the age of the formation as Middle and Late Triassic.

Hosselkus Limestone (Upper Triassic)

Definition and Lithologic Character. The Hosselkus limestone was the name given by Diller (1892) to limestone beds that form prominent ledges on the divide between Genessee Valley and Hosselkus Creek in the Taylorsville region, Plumas County, California. Limestones of similar age in the Redding quadrangle were at first included in the Cedar formation, a name proposed by Diller in the Lassen folio for those beds of the "Auriferous slate series," limestone and shale, containing fossils of the same age as the Hosselkus limestone and associated Triassic rocks of Genessee Valley. Smith (1894) treated the Hosselkus limestone of Shasta County as a member of the Cedar formation. In the Redding folio Diller (1906) discontinued the use of the name Cedar formation and considered the Hosselkus limestone of the Redding area as a formation correlative with the formation of the same name in the Taylorsville region.

Smith (1894) divided the limestone into three parts. The lower division is composed of rather hard, pure limestone and consists almost entirely of fossils; the middle division is hard, siliceous, prominently jointed limestone, which forms rugged ridges; the upper division is siliceous, massive gray limestone.

Smith (1894) later summarized his study of this limestone. He stated that the limestone is nearly continuous from the Cedar Creek locality northward to the Tertiary lavas but ranges in thickness from a thin edge to 400 feet on Brock Mountain where it is best developed. Smith gave a general section of the Hosselkus limestone from top to bottom as follows:

Spiriferina zone (hard siliceous limestone full of brachiopods)	100 feet
Coral zone; numerous reefs of *Astreidae*	
Tropites subbullatus zone	
Juvavites subzone (hard limestone that carries abundant ammonites)	50 feet
Trachyceras subzone (shaly limestone)	50 feet
Calcareous shales full of *Halobia*	100 feet

Distribution. The Hosselkus limestone in the Big Bend region crops out at two localities. One outcrop is on the trail from Stump Creek to Hawkins Creek, where a 20-foot bed of nearly pure, medium-gray limestone is exposed. This limestone weathers to a light blue-gray and is abundantly fractured, the resulting cracks being cemented with calcite. Although no fossils were found in this limestone, it lies below a weathered shale or argillite whose lithology and stratigraphic position are similar to that of the Brock shale at its type locality, and overlies a series of alternating, coarse tuffs and argillites typical of the Pit formation. For this reason this lenticular outcrop was mapped as Hosselkus limestone.

The second area of outcrop is in the upper part of Devils Canyon, where the estimated thickness is about 150 feet. The limestone is thin bedded and dark gray in color, weathering to light gray. Fossils are abundant. The Hosselkus limestone in Devils Canyon weathers easily and does not form the bold outcrops that characterize it elsewhere. This may be due to the fact that the silicified beds are missing in the Devils Canyon area.

A thin-section of the limestone shows it to be composed of about 95 percent calcite and about 5 percent black organic material. Many oval and circular areas of clear recrystallized calcite suggest the presence of microfossils; however, no definite organic structures were found.

Fossils and Correlation. The following fossils from the Devils Canyon locality were identified by the author:

Arcestes cf. A. shastensis Smith
Paratropites americanus Hyatt and Smith
Tropites sp.
Clionites aff. C. whitneyi Smith
Halobia austriaca Mojsisovics
Halobia cf. H. superba Mojsisovics
Halobia sp.

These forms indicate that this limestone represents the *Tropites subbullatus* zone of the Brock Mountain Hosselkus limestone as defined by Smith (1927) and is Karnian. Inasmuch as fossil material was gathered near the contact with the overlying Brock shale, it appears that all or most of the overlying Coral and *Spiriferina* zones are absent in this locality.

Field observations suggest a conformable relationship of the Hosselkus with the underlying Pit formation. Folding and some distortion of the beds obscure the relationship of the Hosselkus with the overlying Brock shale. Diller (1906) said of the Redding area that

> ". . . there is no doubt concerning the conformability of the Brock shale and the Hosselkus limestone."

If this be the case, the Hosselkus limestone is lenticular in nature, as it is not continuous either in the Redding quadrangle or in the Big Bend area.

Brock Shale (Upper Triassic)

Definition and Lithologic Description. The Brock shale was named by Diller (1906) in the descriptive text which accompanies the Redding folio, for the exposures on Brock Mountain, which lies between Squaw Creek and Pit River. He described the shale as being about 400 feet in thickness, of which the lower 300 feet are

> ". . . dark (shales) somewhat calcareous and frequently contain *Halobia*. Above these come sandy shales, gray and reddish in color and characterized locally by *Pseudomonotis subcircularis*."

The Brock shale exposures in the Big Bend area consist mainly of beds of dark gray to black argillite with interbedded layers of medium gray tuff or tuffaceous sandstone of medium grain size. The argillite is massive in fresh exposures but shows a parting parallel to the bedding in partially weathered exposures. They are also characteristically fractured by a joint system normal to the bedding plane which breaks up these partly weathered layers into small blocks which are about 1 to 2 inches thick. The fine grained material weathers a brown to reddish color. Thus the blocky fragments, coupled with a reddish color of the weathered material, are characteristic of the Brock exposures in this area.

Microscopic examination of a thin-section of Brock argillite shows that it is composed largely of silt- to

Photo 1. Brock shale outcrop in Devils Canyon.

clay-sized grains that are of volcanic origin. Black material constitutes about 10 percent of the rock. The carbonate content appears to be high, approximately 50 percent. Field examination of numerous hand specimens indicates, however, that although the argillite is usually somewhat calcareous, the carbonate content varies widely. No distinct bedding or micaceous laminae are present, but a certain rough alignment of elongate particles which appear to be shards was noted.

Distribution. Although the brushy terrain and deep regolith make it difficult to examine the contact throughout the area, characteristic Brock sediments were encountered below the basal member of the Modin formation and appear to be conformable with it wherever exposed in the Big Bend area. Thus, the Brock shale is probably continuous and varies but little in thickness. Diller reached a similar conclusion about the Brock shale in the Redding quadrangle.

An excellent exposure of the Brock shale is in Devils Canyon where the area of outcrop is increased by local folding. The estimated thickness is approximately 400 feet.

Age. No fossils were found in the Brock shale in the Big Bend area. Its age and correlation with the Brock shale at its type locality can only be determined on the basis of its stratigraphic position; i.e. that it overlies the Hosselkus limestone and immediately underlies the basal member of the Modin formation. Smith (1927) considered the Brock shale as part of the Upper Norian stage of the Triassic system.

Modin Formation (Upper Triassic)

Definition. The Modin formation derives its name from exposures near the mouth of Modin Creek at its confluence with Squaw Creek in the Redding quadrangle. The formation was defined by Diller (1906) who described it as

> " . . . an extensive succession of tuffaceous beds overlain by a greater mass of compact, fine gray shaley sandstones and shales, with a few lenses of limestone."

His basal "tuffaceous beds" are composed of volcanic conglomerate and pyroclastic material consisting mainly of volcanic debris but containing limestone fragments with fossils of Hosselkus age.

The writer, after examining the Modin formation along Squaw Creek near its type locality and tracing the basal beds from the Big Bend area to the northern part of the Redding quadrangle, concluded that the Modin formation is represented in the Big Bend area by an extensive accumulation of deposits reaching an estimated maximum thickness of about 5,500 feet. The Modin formation in the Big Bend region consists of all sediments overlying the Brock formation and underlying the extensive pyroclastic breccia, conglomerate, and tuff which are to be described below as the Arvison formation. Three lithologically distinct and readily mappable units are present within the formation. On this basis the author proposes a division of the Modin formation into three members: the basal pyroclastic and conglomeratic beds as the Hawkins Creek member; the intermediate tuffaceous limestones and fine sandstones as the Devils Canyon member; and the upper thin-bedded argillite as the Kosk Creek member.

Age. Diller (1906) originally placed the Modin formation at the base of the Jurassic system. Although his party had collected fossils from the Modin, the fossil material apparently did not include recognizable diagnostic forms and the age was judged Jurassic more on the basis of stratigraphic relationship than on faunal

Photo 2. Modin formation near head of Alder Creek. Line of trees on far slope is along the contact of the Hawkins Creek member (right) and the Devils Canyon member (left).

evidence. Diller quotes T. W. Stanton's opinion on the age of the Modin fossils:

> "Between the *Pseudomonotis subcircularis* horizon (Brock shale) and the beds yielding a well-characterized Jurassic fauna (Potem formation) comparable with that found at Taylorsville there is a broad belt in which a great thickness of rocks is represented and from which fossils were collected at many localities. In the field these were considered Jurassic and I still think that most if not all of them are of that period, but the palaeontologic evidence is not so complete as is desirable. The fossils at most localities belonged to few species and were either poorly preserved or belonged to persistent types that would not aid in discriminating Jurassic from Triassic."

The significance of the Modin fauna will be discussed in more detail below in the description of the members of the Modin formation. Included in the Modin fauna are three forms considered of stratigraphic significance: *Spiriferina* cf. *S. suessi* Winkler, *Plicatula perimbricata* Gabb, and *Choristoceras marshi* Hauer. *Spiriferina suessi* has been reported from Upper Norian and Rhaetian stages of the European Triassic section. The Modin *Spiriferina* has been compared with figures and descriptions of *Spiriferina suessi* and appears very similar if not conspecific with the European species, and also similar to a *Spiriferina* from the Upper Triassic Gabbs formation of Nevada. *Plicatula perimbricata* appears identical to topotypes from the Gabbs formation. *Choristoceras marshi* is characteristic of the *Choristoceras marshi* zone (=*Pteria contorta* zone) of the European Rhaetian stage of the Triassic. This faunal evidence, plus the fact that the Modin overlies beds of Norian age and, with apparent unconformity, underlies the Arvison beds whose tuffaceous strata yield fossils characteristic of the Sinemurian stage of the Lower Jurassic, points to the conclusion that the Modin formation is Late Triassic in age and probably a correlative with formations of the Upper Norian and Rhaetian stages of the European Triassic.

Lithologic Character. From the top to bottom, beginning at the contact with the overlying Arvison formation and ending at the contact with the Brock shale below, the Modin formation consists of the following units along Kosk Creek and Devils Canyon.

	Thickness in feet
Kosk member	
(10) Thin bedded dark gray argillites and fine grained tuffaceous sandstone. *Choristoceras marshi* Hauer	1000
(9) Andesite flows and volcanic breccia	300
(8) Thin bedded dark gray argillite	400
(7) Medium to fine grained tuff and agglomerate	285
(6) Andesite flows and volcanic breccia	165
(5) Coarse to medium gray tuff	250
(4) Thin bedded dark gray argillite and medium gray fine grained tuffaceous sandstone	1200
Devils Canyon member	
(3) Massive dark gray tuffaceous limestone, calcareous tuff, fine to medium grained calcareous sandstones and light gray limestone lenses. Very fossiliferous locally. *Spiriferina* cf. *S. suessi* Winkler and *Plicatula perimbricata* Gabb	1000
Hawkins Creek member	
(2) Andesite porphyry	200
(1) Medium gray agglomerate, volcanic breccia, tuff and conglomerate	700
Total thickness	5500

Hawkins Creek Member

Definition and Lithologic Character. The Hawkins Creek member derives its name from exposures near the head of Hawkins Creek in the vicinity of Little Meadows, at which place the conglomerate is extensively exposed. However, the type area is designated as that section in Devils Canyon beginning at the contact with the overlying Devils Canyon member approximately 1 mile west of the confluence of Devils Canyon and Alder Creek, extending west along Devils Canyon to the contact with the underlying Brock shale.

The member consists of a thick series of beds of volcanic material in the form of conglomerate, agglomerate, volcanic breccia, and tuff. The maximum thickness is approximately 900 feet. The character of the beds varies markedly along the strike. In the vicinity of the head of Hawkins Creek and Little Meadows the member is largely a polymictic conglomerate composed of well rounded pebbles of andesitic composition and a large proportion of well rounded quartz and chert pebbles enclosed in a groundmass of coarse sandstone or grit of approximately the same composition. Individual pebbles rarely exceed 1 inch in diameter, the average being about half an inch. Locally, with change in grain size, the conglomerate is interbedded with grits and coarse graywacke. The presence of the quartz and chert pebbles poses a problem as to their origin, for quartz and chert are otherwise completely foreign to the sediments of this area. In fact, the entire section from the Hosselkus formation through the Jurassic formations is remarkable for the paucity of silica in any form. A possible source could be the siliceous strata of the Hosselkus limestone.

Elsewhere in the member, the conglomerate occurs as thin layers and a larger proportion of volcanic breccia, agglomerate, and tuff is present. The size of the fragments of the breccia ranges from a fraction of an inch to 6 inches. Diller reported the presence of blocks up to 1 foot in diameter in the basal beds of the Modin formation in the Redding quadrangle. In general, the fragments are angular; however, many are slightly rounded and appear to have been subjected to erosion by water. The matrix material is composed of medium- to coarse-grained tuff.

In Devils Canyon the upper part of the member consists of approximately 200 feet of volcanic flows which appear to be andesite porphyry containing feldspar phenocrysts up to a quarter of an inch in length in an aphanitic greenish-gray groundmass.

Distribution and Age. The Hawkins Creek member overlies the Brock shale wherever the two units are exposed within the Big Bend area. The contact appears to be conformable. The transition from the deposition of fine-grained material in the Brock to coarse volcanic detritus in the Modin formation is abrupt, suggestive of a period of non-deposition between deposition of the Brock and the Modin formations. However, the consistent thickness of the relatively thin Brock formation for great distances suggests little or no erosion of the Brock prior to the deposition of the Modin. On the other hand, Hinds (1933, p. 101) suggested that a distinct erosional and slight angular discordance exists between the Brock and the Modin on the basis of evidence found on Bear Mountain in the Redding quadrangle. Diller (1906) reported fragments of limestone containing fossils of Hosselkus age from three areas of the lower Modin formation. He thought that the fragments had been dislodged from lower beds by volcanic action, but it seems possible that they could have been derived by ordinary processes of erosion. Thus there appears to be considerable evidence suggesting an unconformity between the Brock shale and the Modin formation, but as yet not enough evidence is available to confirm it.

Fossils were not found in this member, and the age is determined solely on the basis of its stratigraphic position. As the upper members of the formation contain fossils of Late Norian and Rhaetian ages, and the underlying Brock shale is of Norian age, this member represents part of the Norian stage of the Upper Triassic system.

The beginning of the time of Modin deposition in this area was a time of intense volcanic activity in which large deposits of volcanic material were accumulated on the fine-grained sediments of Brock shale, probably in a shallow sea.

Devils Canyon Member

Definition and Lithologic Character. The name Devils Canyon member is proposed for a series of massive fossiliferous limestones and calcareous sandstones overlying the Hawkins Creek member. The type sections is in Devils Canyon. Its upper contact is about a quarter of a mile west of the confluence of Devils Canyon and Alder Creek. From this point the member is well exposed to a point about three-quarters of a mile west at the contact with the underlying Hawkins Creek member.

The Devils Canyon member is composed principally of massive dark gray tuffaceous limestone, calcareous tuff, fine- to medium-grained calcareous sandstone, and nearly pure limestone lenses. The unweathered rock is a firmly indurated, tough rock that is difficult to chip with a hammer. The weathered material is tan or buff in color. As the weathering progresses, the leaching of calcareous material results in the formation of a porous, punky rock that has the appearance of a tuff.

A study of thin-sections of this rock shows that the carbonate content ranges from about 25 percent to 75 percent. Fine-grained sand- to silt-sized tuffaceous material and volcanic rock fragments which contain andesine compose the rest of the rock. Interbedded with this impure limestone and sandstone are a few lenses of nearly pure limestone. The lenses range from a few inches to about 10 feet in thickness and may be traced as far as one-quarter of a mile along strike. Microscopically, the limestone exhibits a very fine-grained granular texture with an apparent orientation of grains to a bedding plane. It appears to be a fine-grained calcarenite. Fossils were not found in these lenses but in thin-section this material is seen to contain occasional fossil fragments.

Weathering of this member tends to produce rounded hilltops and deep, steep-sided canyons. Fresh unweathered material is encountered only in the stream beds, with the exception of the more resistant pure limestone lenses which crop out in scattered localities on the hill slopes and ridges. Bedding is readily apparent in the relatively unweathered material near the bottom of stream canyons but usually is not discernible on higher slopes and ridges. Individual beds range from about 6 inches to several feet in thickness. Beds differ from one another in carbonate content and grain size of the volcanic detrital material.

Distribution. This member, which appears to be continuous across the northwest part of the area, ranges in thickness from about 430 feet along the ridge extending north from Smith Flat, to an estimated 1,000 feet in Devils Canyon, where the area of outcrop is increased somewhat by local folding. The best exposures are along Devils Canyon and Alder Creek. It also crops out in Live Oak Canyon and Bull Canyon in the northeast corner of the mapped area. Good exposures of the weathered material and limestone lenses occur along the trail from Stump Creek Butte to Little Meadows. The best fossil localities are along the Stump Creek-Little Meadows trail and in Alder Creek Canyon.

Fossils and Correlation. The Devils Canyon member yielded a rich, although poorly preserved, marine invertebrate fauna, consisting chiefly of pelecypods. Brachiopods, of which only a few genera are present, are fairly common. Pentagonal crinoid stem plates are common, and echinoid spines are rare.

The Devils Canyon assemblage includes the following:

Spiriferina cf. S. suessi Winkler
Rhynchonella richardsoni Smith
"Terebratula" piriformis Suess
Zugmayeria sp.
Pecten sp.
Myophoria? sp.
Lima sp.
Lima aff. L. costata Goldfuss
Lima cf. L. terquemi Tate
Plicatula perimbricata Gabb
Volsella sp.
Lopha sp.
Ostrea sp.
Philippiella sp.
Pinna cf. P. blanfordi Boettger

A comparison of this fauna with figured and described specimens of the Late Triassic faunas from Europe and Asia reveals that the Devils Canyon pelecypods are mainly forms that are not characteristic of a particular horizon in the Upper Triassic or Lower Jurassic systems. Apparently many new species are present in the Devils Canyon member, but the state of preservation is such that it appears impracticable to describe new species. It is hoped that further collection and study of fossils from this member will eventually provide fossil material suitable for the illustration and description of these new forms.

Spiriferina cf. *S. suessi* Winkler closely resembles *S. suessi* as described from the Rhaetian beds of the Alpine Triassic. H. Zugmayer (1882) reports that *S. suessi* appears exclusively in the Koessener facies of the Rhaetian stage and in the Starhemberger beds. The Devils Canyon *Spiriferina* has been compared with a *Spiriferina* collected from the Upper Triassic Gabbs formation of Nevada. The two forms appear to be very similar if not identical. Specimens identified as *Plicatula perimbricata* Gabb have been compared with topotype material from the Volcano Peak locality in Nevada. This species is a common and characteristic fossil in the Devils Canyon beds. Gabb (1870) originally described the species as a Jurassic fossil from Volcano Peak, Nevada. Subsequent study by S. W. Muller * has shown that the *Plicatula* locality is actually part of the Gabbs formation, of Late Triassic age.

Using the above comparisons and the stratigraphic position of the Devils Canyon member which overlies Norian beds and underlies Rhaetian *(Choristoceras marshi* horizon) strata, this member contains deposits that can be correlated with upper Norian and/or Rhaetian stages of the European section and with part of the Gabbs formation of Nevada.

The presence in the fauna of such forms as *Ostrea, Lopha, Plicatula, Volsella,* and *Pinna* are evidence that these fossiliferous layers were accumulated in a shallow-water, marine, upper neritic to littoral environment.

Kosk Member

Definition and Lithologic Character. The Kosk member derives its name from Kosk Creek. The type area is located along Kosk Creek and Devils Canyon from a point on Kosk Creek approximately 1 mile north of Arvison Flat, where the upper contact of the member is exposed, to its lower contact with the Devils Canyon member about a quarter of a mile west of the junction of Devils Canyon and Alder Creek.

The dominant lithology of the member is thin-bedded, dark gray to black argillite. In fresh exposure it is firmly indurated and appears massive but has a parting along the bedding plane. Partially weathered surfaces show a dark bluish-gray color. The weathered outcrops appear as thin-bedded calcareous argillite separated by shale partings. Generally the material is very fine grained but there are many 1- to 2-inch layers of fine to medium-grained tuff. Locally, the argillite is distinctly pyritiferous.

Microscopic examination of thin-sections of this member indicates that it is composed principally of clastic grains of volcanic origin, some of which appear to be water worn; others are angular glass shards. The clastic material ranges in size from fine sand to clay; most falls in the size-range of silt. Seen in thin-section the rock is a calcareous siltstone. Calcite constitutes about 25 to 30 per cent of the rock, carbonaceous material about 5 percent. A characteristic of this rock is the presence of subspherical bodies of calcite that suggest the presence of microfossils.

Two beds composed of andesitic flows, coarse tuffs, and agglomerates are present in the member. Both beds are approximately 300 feet in thickness. One of these volcanic beds is about a quarter of a mile south of the junction of Kosk Creek and Devils Canyon, and the other crosses Devils Canyon approximately a quarter of a mile west of Kosk Creek.

Distribution. The member is best developed and of maximum exposed thickness (approximately 3600 feet) at its type locality. Outcrops continue to the northeastern edge of the mapped area with less thickness exposed due mainly to the overlap of the Tertiary lavas on the east. West and south of the type area the member diminishes in thickness along the strike to a point just southwest of the Stump Creek-Little Meadow trail where it disappears completely. It is apparently absent from that point to the western edge of the area.

Fossils and Correlation. Diligent search of the outcrops of the Kosk member revealed the presence of impressions of highly evolute ammonites on weathered bedding planes. At two localities, better preserved material contained one species of ammonite identified as *Choristoceras marshi* Hauer. It is believed that the impression of ammonites throughout the beds of this member are probably of the same species or closely related forms. The specimens of *Choristoceras* are small in size and are either all young or dwarfed specimens. Casts and impression of somewhat larger, yet smaller than normal, forms were found at other localities. These latter could not be definitely identfied as *Choristoceras* but certainly were similar to the better-preserved material.

As *Choristoceras marshi* is characteristic of the Rhaetian beds of Europe this member is considered as a correlative of that stage. It is also correlated with the upper "member" of the Gabbs formation as defined by Muller and Ferguson (1939). These authors point out that prior to the time of their investigation, no marine beds of Rhaetian age had been reported from North America. Thus, the Kosk member of the Modin formation expands the known distribution of Rhaetian beds on this continent to northern California.

As to the environment of deposition of this member, three factors are noted. First, the meagerness of the fauna which consists almost entirely of cephalopods; secondly, the possible dwarfing of *Choristoceras marshi;* and lastly, the presence of a sediment made up of black organic silt locally containing abundant pyrite. These factors are suggestive of a restricted environment of deposition in a basin which did not allow free circulation of water at depth, thus producing an environment unfavorable to benthonic life. Pelagic forms such as ammonites would be expected to be the most common fossils to accumulate in a sediment formed in such an environment. Lack of oxygen at shallower depths might inhibit but not exclude a pelagic form, with the result that a dwarf fauna might be produced. Abundant organic material in the sediment and the common occurrence of pyrite are also results of accumulation of sediments in a stagnant environment.

JURASSIC SYSTEM

Arvison Formation (Lower Jurassic)

Definition and Lithologic Character. The Arvison formation is proposed for that series of dominantly pyroclastic beds with minor andesitic flows, which are intermediate between the Modin and Potem formations and which do not appear to be continuous with the Bagley andesite of Diller. The Bagley andesite as traced from its type area into the Big Bend region overlies and is interfingered with the basal beds of the Potem formation. Because the basal strata of the Potem formation appear to lie between the Bagley andesite and the Arvison pyroclastic accumulations, the author deems it fitting to propose a new formation for the lower beds. The name is taken from Arvison Flat on Kosk Creek where the beds are well developed. The type area can be considered as extending from a point on Kosk Creek approximately 1¾ miles south of Arvison Flat to a point about 1 mile north of Arvison Flat at the contact with the underlying Triassic beds. Unfortunately, at its type locality part of the section is lost because of faulting, but it is even more poorly exposed elsewhere.

* Personal communication.

Photo 3. Arvison formation conglomerate exposed at summit of Stump Creek Butte.

The bulk of the formation consists of extensive beds of agglomerate, volcanic breccia, and conglomerate. Interbedded with these are beds of fine to coarse tuff and tuffaceous sandstone. The lava flows constitute about 10 percent of the rock; tuff and sandstone 15 percent; and volcanic breccia and conglomerate 75 percent. The massive, coarsely jointed deposits of this breccia form prominent, rocky outcrops on hillsides and support only brushy vegetation; the breccia is composed entirely of fragments of volcanic rock, probably andesite, and colored medium gray on fresh and weathered surfaces. Constituents range in diameter from a quarter of an inch to 3 feet. No sorting is apparent. Some fragments are vesicular. A few small lenses of stratified, tuffaceous sandstone occur at intervals within the breccia. Matrix material is mainly tuff.

Conglomerate outcrops are well developed in the vicinity of Arvison Flat along Kosk Creek for more than half a mile. They weather to rounded slopes and support forest growth on the lower canyon slopes. The rock forms a 20-foot cliff along the stream bank of Kosk Creek. The conglomerate is composed mainly of fairly well rounded pebbles of volcanic material, with subordinate amounts of gray unfossiliferous limestone pebbles. The matrix is coarse tuffaceous sandstone. The gray calcarenite lenses of the Devils Canyon member of the Modin formation are a possible source for the limestone pebbles.

Along the Stump Creek trail, between Kosk Creek and Stump Creek Butte, a lenticular bed of blue-gray limestone occurs interbedded between tuff and conglomerate. The limestone is compact, crystalline, and contains intercalations of gray shale and impure limestone. There were fragments and casts of fossils but no recognizable forms were found. In thin-section the pure limestone layers appear to be calcarenite. The impure limestone is composed mainly of rounded fragments of volcanic rocks, broken shell fragments, some phosphatic material, and calcite cement.

The volcanic flows are basic igneous rocks. The flows occur intermittently throughout the formation but are not persistent along the strike. The lava is amygdaloidal in part and the more massive layers are commonly porphyritic. Under the microscope plagioclase phenocrysts are seen in a groundmass of volcanic glass with abundant microlites. Accessory minerals are largely altered to chlorite or sepentine minerals. The phenocrysts are so badly altered that no definite determination of the composition of the feldspar can be made, although it appears to be andesine.

Tuff, and more commonly tuffaceous sandstone, of a lenticular nature is common in the formation. One such accumulation is particularly important because it yielded fossil forms sufficiently well preserved to make possible the geologic dating of the formation. The fossil-bearing outcrop occurs along the east bank of Kosk Creek, north of the junction of Kosk and Shotgun Creeks. Here the fossiliferous beds are well exposed in a bold 385-foot outcrop of tuff and tuffaceous sandstone with minor layers of fine-grained tuff and shale. Elsewhere in this formation tuffaceous sediments weather more freely than the associated agglomerate and volcanic breccia, but this outcrop appears to be uncommonly resistant, probably due to the presence of calcareous cement in the sandstone. Casts and molds of fossils are abundant in certain layers. In general, fossils are poorly preserved but several recognizable forms were collected. Fragments of carbonized wood are abundant in some of these fossiliferous layers.

In the hand specimen, the rock is a greenish-gray, medium- to coarse-grained, tuffaceous sandstone. The color is the same on fresh and weathered surfaces.

A thin-section of a typical fossiliferous layer shows that the sandstone is composed of fragments derived

Photo 4. Arvison formation volcanic breccia exposed on Kosk Creek.

almost wholly from the erosion of volcanic rocks. The grains are medium to fine in size and subangular to subrounded. The cement is partly of clay, somewhat altered to chlorite, and partly of calcite. Volcanic rock fragments and tuff constitute about 75 percent of the rock, plagioclase grains about 10 percent, and calcite 5 percent. Minor constituents include chlorite, quartz, and magnetite.

From top to bottom the lithology of the Arvison formation as exposed at its type locality is as follows: (The upper contact of the Arvison formation is not exposed in Kosk Creek, and the uppermost beds shown below are at the north end of the large meadow which lies just above the mouth of Kosk Creek. The presence of this broad meadow suggests a change in lithology to a less resistant rock and may represent the area of transition to the overlying Potem beds.)

	Feet
(14) Dark gray volcanic breccia and volcanic flows	250
(13) Black hornfels, breccia zone (fault breccia?) with many small quartz veins	250
(12) Andesite porphyry	35
(11) Dark gray agglomerate and volcanic breccia	200
(10) No exposures (hillside talus suggests bedrock of tuff or tuffaceous sandstone)	750
(9) Dark gray agglomerate and volcanic breccia	200
(8) Greenish-gray medium- to coarse-grained calcareous, tuffaceous sandstone and tuff; very fossiliferous in certain strata. *Arnioceras* sp. *Asteroceras* sp. *Pecten* cf. *P. acutiplicatus* Meek, *Entolium meeki* Hyatt. *Pinna* cf. *P. expansa* Hyatt	385
(7) Medium gray, coarse volcanic agglomerate	800
(6) Fault zone—fine blue-gray fault breccia	100
(5) Medium gray conglomerate, well rounded volcanic and limestone pebbles	750
(4) Fine-grained medium gray tuff, weathers brown	70
(3) Medium gray conglomerate, agglomerate and volcanic breccia	950
(2) Dark gray volcanic flow, vesicular and amygdaloidal structure	100
(1) Medium gray conglomerate, agglomerate, and volcanic breccia	250
	5,090

Distribution. The Arvison formation occupies a large part of the Big Bend area. It is best exposed along Kosk Creek in its type area where an estimated thickness of 5,090 feet is exposed. East of Kosk Creek it is covered by the Tertiary lavas. West of Kosk Creek it occurs in a broad arcuate belt underlying most of the heavily forested, relatively flat region lying north and west of Smith Flat. With greatly diminished thickness and with a more southerly strike, its exposure is traceable into the adjacent Shoeinhorse Mountain quadrangle. Only isolated exposures of this formation are encountered to the west of the ridge west of Kosk Creek, where the streams are in weathered mantle material for the most part. The contact of the Arvison formation with the overlying Potem formation is not exposed, but can be inferred by examination of the mantle rock. This contact was placed at the uppermost limit of occurrence of fragments of volcanic breccia in the soil. The nature of the weathered material and talus leads to the belief that the contact is gradational.

Fossils and Correlation. Although many of the tuffaceous and sandstone layers contain fossil fragments, recognizable forms were found only in the Kosk Creek outcrop described above.

A list of recognized fossils from this locality follows:

Asteroceras sp.
Arnioceras sp.
Pecten sp.
Pecten cf. P. acutiplicatus Meek
Pinna cf. P. expansa Hyatt
Entolium meeki Hyatt
Pleurotomaria sp.
Lingula sp.
Stylophyllopsis sp.

The ammonite genera *Arnioceras* and *Asteroceras* have been reported occurring only in the Sinemurian stage of the European Jurassic.

Pecten acutiplicatus, Pinna expansa, and *Entolium meeki* were reported by Hyatt (Diller, 1908) from the Hardgrave sandstone of the Taylorsville region of California, but are not useful in precise dating of strata. The Arvison formation, on the basis of stratigraphic position as well as similar fossil content, may be correlated with the Hardgrave formation at Taylorsville. If so, the Hardgrave sandstone occupies a position somewhat lower in the stratigraphic column than that assigned to it by Crickmay (1933) who dated it as early Middle Jurassic.

Muller and Ferguson (1939) reported *Pecten acutiplicatus, Stylophyllopsis* and *Entolium* cf. *E. meeki* from the Sunrise formation (Lower Jurassic) of Nevada. Therefore the Arvison formation probably can be correlated with the middle and upper portions of the Sunrise formation, and possibly part of the Dunlap formation, also of Nevada. The Arvison is tentatively correlated with the Donovan formation of central Oregon as described by Lupher (1941) and with the Milton and Sailor Canyon formations of California.

The presence of marine fossils in the tuff and tuffaceous sandstone indicate that at least part of this formation was deposited in the sea. The volcanic breccia shows little or no effects of sorting or reworking by water; on the other hand the conglomerate shows the results of considerable reworking of volcanic material. The fauna and the presence of carbonized wood fragments suggest a shallow-water, near-shore environment. The Arvison formation, then, apparently accumulated in a shallow sea, in marked contrast to the deeper environment of deposition of sediments of the Kosk member of the

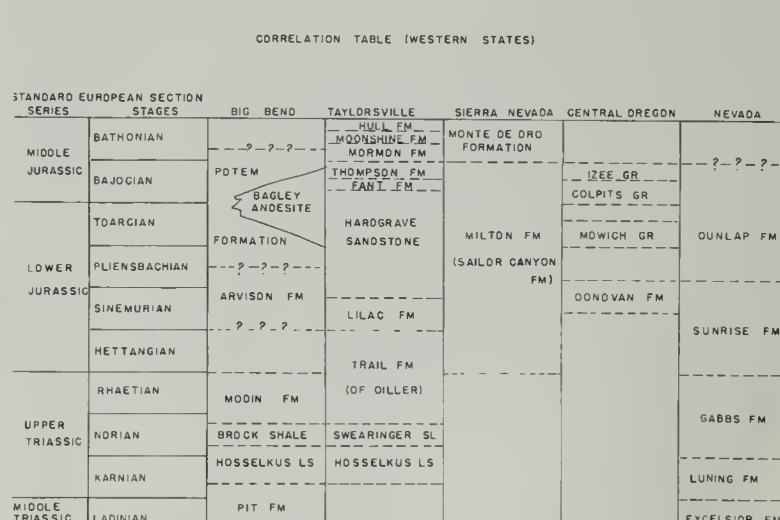


FIGURE 5.

underlying Modin formation. In the Taylorsville region the comparable beds, transitional between Triassic and Jurassic (Trail formation of Diller [1908, p. 36]), contain fresh or brackish water crustacean and plant remains.

Nature of the Contact of the Triassic and Jurassic Systems

The contact between the uppermost Triassic beds and the basal Jurassic strata appears to be unconformable. The contact is an abrupt division between fine-grained, relatively deep-water sediments and thick accumulations of coarse pyroclastic debris containing marine beds with a fauna characteristic of a shallow-water, near-shore environment.

Areal distribution of the Modin formation and the overlying Arvison formation also suggests an unconformable relationship. Muller and Ferguson (1939) report continuous sedimentation between Triassic and Jurassic beds in Nevada about 250 miles southeast of the Big Bend area. From this evidence and from Lupher's (1941) report of an angular unconformity between the Triassic and Jurassic systems in central Oregon, the shoreline of this transitional Triassic-Jurassic sea appears to have been to the southeast of the Big Bend area.

Bagley Andesite

Definition and Lithologic Character. Although the Bagley andesite overlies and is intercalated with part of the lower beds of the Potem formation in the Big Bend area, it is older than most of the Potem, which is here described as the next younger formation.

The Bagley andesite was originally described from the Redding area by Diller (1906) as follows:

> "The Bagley andesite includes the lavas and pyroclastics of a succession of volcanic eruptions of similar general character. It is commonly filled with an abundance of small phenocrysts of plagioclase, and rarely, also with dark grains in a greenish groundmass."

The type area is Bagley Mountain, located in the northeast corner of the Redding quadrangle about 1 mile from the southwest corner of the Big Bend area.

The Bagley andesite, in the Big Bend area, is best developed on Oak Mountain, where it reaches an estimated thickness of 700 feet. Here it forms a rugged mountain whose flanks are covered by a sparse, brushy vegetation, and whose summit area supports oak tree growth, whereas surrounding areas support fir and pine forests. Tuffaceous layers comprise about 30 percent of the beds, and agglomerate and volcanic breccia about 50 percent. Volcanic flows of andesite porphyry which occur near the ridge between Pit River and Iron Canyon, make up the remaining 20 percent of the formation.

A thin-section study of three of the lava flows shows the plagioclase to be andesine. The feldspars appear fresher, in general, than those of the Arvison formation. The phenocrysts are imbedded either in a groundmass of black devitrified volcanic glass containing feldspar microlites or in an almost holocrystalline groundmass of feldspar laths.

Occurrence. The Oak Mountain area comprises the largest occurrence of Bagley andesite in the mapped area. The western ridge of the west tributary of Iron Canyon is composed entirely of Bagley andesite lavas.

Porphyritic extrusive flows, 300 to 400 feet in thickness, mapped with the Bagley andesite, are interbedded with Potem strata that contain Middle Jurassic fossils. One such flow crosses the Pit River at Little Joe Flat where it causes a constriction in the river canyon and a sharp bend in the river.

An igneous rock that appears to be an intrusive dike or volcanic neck, crops out on both sides of the mouth of Kosk Creek and is shown as Bagley andesite on the map. This dike or neck is located stratigraphically and geographically in such a position that it could have contributed lava and debris to the Bagley accumulations. However, field relationships, and laboratory determinations showing that the intrusive rock contains a somewhat more calcic plagioclase than was observed in Bagley rocks, cast doubt on the correlation of this rock mass with the Bagley formation.

Age and Correlation. Since the Bagley andesite appears to be a volcanic facies of the Potem formation, its age and correlation is considered to be the same as that of the Potem formation in this area.

Potem Formation (Lower and Middle Jurassic)

Definition and Lithologic Character. The Potem formation in the Redding quadrangle was described by Diller (1906) from the Jurassic beds which overlie the Modin and Bagley formations. The type area is along Potem Creek. The Potem Creek exposures are essentially along the strike near the base of the formation; the Potem section is better exposed along the Pit River in the 15-minute Montgomery Creek quadrangle of the larger Redding sheet.

In the Big Bend region the Potem formation consists of argillites and fine-grained tuffaceous sandstone with small amounts of conglomerate, tuff, medium to coarse

Photo 5. Potem formation. Exposure of argillite near head of Iron Canyon.

tuffaceous sandstone, and a few beds of limestone and coarse pyroclastic material. These strata weather deeply and form rounded topography. They are exposed only in the deep canyons of streams and along the Pit River.

The argillite is massive with minor parting along bedding planes. The partly weathered exposures have a shaly appearance. The fresh rock is dark gray to black but weathers to a light gray or buff and occasionally reddish to purplish color. Much of the rock is calcareous. In outcrop this rock is similar in appearance to the Kosk member of the Modin formation. The argillite grades locally into dark gray, fine-grained tuffaceous sandstone which predominates in the lower part of the Potem formation. A few beds of tuff and volcanic breccia as much as 50 feet in thickness crop out along the eastern slope of the west branch of Iron Canyon.

In the Pit River Canyon north of Little Joe Flat the following beds crop out:

	Feet
(5) Interbedded dark gray clastic limestones and medium- to fine-grained sandstones, contain *Posidonia alpina, Trigonia, Rhynchonella*	210
(4) Dark gray, massive, fine-grained sandstone weathers lavender, contains *Lingula* sp. and *Posidonia alpina*	150
(3) Gray, coarse- to medium-grained, pebbly sandstone; weathers reddish	200
(2) Medium gray conglomerate, pebbles of volcanic origin, ½ to 2 inches in thickness. Matrix coarse-grained angular sandstone. Contains *Trigonia v-costata, T. undulata*	15
(1) Dark gray argillite, fine-grained tuffaceous sandstone and tuffs	410

The clastic limestone, and medium- to fine-grained sandstone beds listed as (5) above lie immediately below the thick andesite porphyry flow mapped as Bagley andesite, which crosses the Pit River at Little Joe Flat. The limestone is highly fossiliferous locally, but its massive character makes it difficult to obtain good specimens from the unweathered material.

Microscopic examination of this limestone showed it to be a calcarenite. Fine-grained particles of calcite, fossil fragments, microfossils, and calcite cement constitute about 75 percent of the rock; tuffaceous fragments 10 percent, quartz 5 percent, and black organic material 5 percent. Subspherical, recrystallized calcite bodies suggest the presence of microfossils.

Distribution. Only a portion of the lower beds of the Potem formation are within the mapped area of the Big Bend region.

Two general areas of Potem exposures occur in the Big Bend region. The first and larger area of exposure is that of Iron Canyon and its tributaries. Excellent exposures occur on the east slope of the west branch of Iron Canyon where the strata are relatively undisturbed and have a regular northerly strike and easterly dip. In Iron Canyon argillite predominates. The second area of Potem exposure lies along the Pit River and is connected with the first by exposures around the north end of Oak Mountain. In the Pit River section the strike is east and the dips are south, some dips are as low as 10°.

Fossils and Correlation. Poorly preserved fossils were found at many localities in the Potem formation. The fauna found in the Iron Canyon area is thought to be older than that along the Pit River. Included in this study is an assemblage collected in Iron Canyon some

PHOTO 6. Potem formation. *Posidonia alpina*-bearing argillite. Exposure in road cut near Pit River Power House No. 5.

years ago by S. W. Muller (L.S.J.U. fossil locality 2971). Fossils from these localities are listed below:

Lima sp.
Pecten sp.
Weyla aff. W. alata (Buch)
Entolium equabile Hyatt
Avicula sp.
Parallelodon sp.
Myacites depressus Meek
Volsella sp.

This assemblage lacks diagnostic forms but is listed separately because it comes from strata that appear to be stratigraphically lower than those collected from the Pit River. Specimens identified here as *Entolium equabile* were compared with the illustrated and described form credited to Hyatt by Crickmay (1933), who listed it from the Mormon sandstone in the Taylorsville region. *Weyla alata* is a common Liassic * form and is recorded from near the top of the Sunrise formation of Nevada by Muller and Ferguson who correlated that part of the Sunrise formation approximately with the Lilac formation described by Crickmay (1933, p. 396) and the Hardgrave sandstone in the region of Taylorsville. Inasmuch as these strata overlie the Arvison beds of Early Jurassic age and underlie deposits containing a fauna considered as Middle Jurassic, it seems probable that the lower Potem beds represent deposits of Early Jurassic age.

In the Pit River section fossils were found in many localities but at approximately the same horizon. This assemblage includes the following forms:

Posidonia alpina (Gras)
Trigonia v-costata Lycett
Trigonia undulata Fromherz
Trigonia cf. T. denticulata Agassiz
Trigonia cf. T. spinulosa Young and Bird
Trigonia sp.

* Lias is the oldest division of the European Jurassic system.

Entolium sp.
Astarte sp.
Gryphaea sp.
Pinna sp.
Ostrea sp.
Phylloceras sp.
Rhynchonella cf. R. varians Schlotheim
Lingula sp.
Orbiculoidea sp.
Astrocoenia sp.

Posidonia alpina is abundant in the fine sandstone and argillite in the Pit River section. Guillaume (1927) cited the European range of this fossil as Upper Toarcian to Lower Callovian. *Trigonia v-costata, T. undulata, T. spinulosa* and *T. denticulata* are all reported from the Jurassic beds of Great Britain and are restricted to the Inferior Oolite (Bajocian stage) of the Middle Jurassic epoch. *Rhynchonella varians* and related species are common in Lower and Middle Jurassic beds of Europe. In view of the above relationships it appears reasonable to regard those *Posidonia* and *Trigonia* bearing beds of the Potem formations as Middle Jurassic in age.

The Potem formation yielded little fossil evidence that would suggest correlation with beds in the Taylorsville region. However, on the basis of stratigraphic position and age assignment the formation can tentatively be correlated with the Thompson and Mormon formations and associated non-fossiliferous strata. Crickmay (1933) placed the Hardgrave as early Middle Jurassic, equal in age to part of the Potem formation. However, the author is of the opinion that the Hardgrave is better correlated with the Arvision formation, which appears to carry some fossils reported in the Hardgrave sandstone, whereas the younger Potem formation in the Big Bend area does not contain fossils characteristic of the Hardgrave. Muller and Ferguson (1939) approximately correlated the upper part of the Sunrise formation (lower Pliensbachian stage) with the Hardgrave sandstone, and also suggested an earlier age for the Hardgrave sandstone than that assigned by Crickmay.

The Potem formation is tentatively correlated with the Dunlap formation of Nevada, and the Mowich, Colpitts, and Izee groups of central Oregon as defined by Lupher (1941).

TERTIARY SYSTEM

Montgomery Creek Formation (Eocene)

Definition and Lithologic Character. The Montgomery Creek formation was first mentioned in the literature by Williams (1932, p. 215) and later by Hinds (1933, p. 114) Both authors credited the name to an unpublished manuscript by R. Dana Russell. The formation is extensively exposed along Montgomery Creek in the vicinity of the town of Montgomery Creek in the Burney quadrangle. Hinds discussed the formation as follows:

> "Along the southeast slopes of the Klamath Mountains in Kosk Creek and Pit River Canyon, farther to the south on Montgomery Creek and at a few other localities is a series of dominantly fluviatile brownish, arkosic sandstone, sandy shales, and conglomerates which Diller, in the Redding Folio, called the 'Ione' formation and dated Miocene on the basis of determination of fossil leaves made by Knowlton. These strata have been recently examined by R. Dana Russell . . . and will be described by him as the Montgomery Creek formation in a report now in preparation."

In the Big Bend area this formation is represented by non-marine conglomerate, arkosic sandstone, and shale. Its maximum thickness is approximately 2,600 feet.

The conglomerate, which appears to be in lens-like deposits, crops out along the road to Power House No. 5 on the Pit River. It is poorly consolidated, but forms a high, rounded ridge. It has been quarried for use as gravel in nearby dams on the Pit River. This conglomerate is composed of well rounded pebbles that range from 1 to 8 inches in diameter, the majority being about 2 inches in diameter. About 70 percent of the pebbles are derived from fine-grained igneous rocks, about 20 percent from hornfels, gneiss, and quartzite, and the remaining

Photo 7. Low hills in foreground underlain by Montgomery Creek sandstone. Oak Mountain in background composed of Bagley andesite.

10 percent from quartz. The matrix material is a coarse-grained arkosic sandstone cemented by clay and iron oxide. The outcrops are pale gray on fresh surfaces but the weathered material is reddish brown and the pebbles are coated with a red iron oxide stain.

The buff arkosic sandstone is the predominant lithologic type in the formation. This sandstone forms low, gently rolling hills, and the weathered surface characteristically contains large, calcareous, dark brown sandstone concretions 1 to 6 feet in diameter. The rock is fairly soft and friable. The grains are subangular to subrounded in shape and poorly sorted in size. The approximate composition is 40 percent feldspar, 50 percent quartz, 5 percent biotite, with clay cement.

The shale beds are brown on fresh exposures, and weather to a light brown or buff color. These beds are soft and incompetent, and form a typical hummocky land-slip topography. Plant remains are common in this shale and a few thin beds of carbonaceous shale and lignitic coal are present. The largest coal seam observed was 20 inches in thickness. The coal is too impure and soft for commercial use.

Photo 8. Montgomery Creek formation. Shale with beds of lignitic coal. Old coal prospect near head of Kosk Creek.

Distribution and Age. The Montgomery Creek formation has been exposed by the erosion of the Pit River and its tributaries, which have stripped off the covering Tertiary lava cap. South of the town of Big Bend the exposures are confined to an area east and south of the Pit River. Near the Pit River, in the south part of the mapped area, the Montgomery Creek strata have been eroded away, exposing the older rocks below. Exposures occur north of the Pit River along the east side of Kosk Creek south of the junction of Kosk and Shotgun Creeks, They are delimited on the west by Kosk Creek and on the east by the overlying Teritary volcanics.

As regards the age of the Montgomery Creek formation, Hinds (1933, p. 115) wrote:

> ". . . determination by R. W. Chaney of a flora discovered by Russell indicates a later middle Eocene age for the formation and Russell's field and laboratory studies prove that the formation is not the Ione formation as Allen has recently redefined it along the eastern margin of the Great Valley."

The Montgomery Creek formation overlies the older formations with distinct angular unconformity. Farther to the south in the Redding quadrangle the Upper Cretaceous ''Chico'' formation unconformably overlaps the older Mesozoic strata. If the Cretaceous sea extended over the Big Bend area, the sediments were completely eroded away before the Eocene sediments were deposited, as no trace of Cretaceous deposits was found in the area.

Tertiary Volcanic Rocks (Pliocene?)

A thick and extensive cover of basalt and andesite flows and pyroclastic deposits covers the eastern part of the Big Bend area. Peacock (1931) included the Big Bend area in the Shasta Lavas Highland and considered the age of the flows to be Pliocene(?) on the basis of their general similarity to the lavas regarded as Pliocene in the Cascade province. It appears that Kosk Creek and the Pit River marked the approximate western limit of this lava field. Only at one place in the Big Bend area do Tertiary lavas occur west of this line. This flow is on the ridge between Iron Canyon and its west branch. The lava is basalt, approximately 150 feet thick, and has an areal extent of about half a square mile. It was considered part of the Tertiary lavas because of its relative freshness, composition, and attitude.

Photo 9. Tertiary basalt dike cutting Eocene Montgomery Creek conglomerate.

Photo 10. Tertiary volcanic rocks in Pit River Canyon at Hagen Flat. Elevation of river 1,800 feet; that of the peak in background, 5,700 feet.

bratula" piriformis Suess, *Lima costata* Goldfuss, and *L. terqueni* Tate. Of the above only *Spiriferina suessi* is useful in the correlation of these beds with the Upper Triassic of Europe. *Plicatula perimbricata* Gabb is common to this member and the Upper Triassic Gabbs formation of Nevada. A diligent search of available literature on the Upper Triassic and Lower Jurassic series of other parts of the world failed to reveal other species similar to those found in the middle member of the Modin formation. The correlation and age of the member was made on the basis of the above similarities and on its stratigraphic position above beds of known Norian age and below the Kosk member which contains *Choristoceras marshi,* a species restricted to strata of Rhaetian age in Europe. The absence of ammonites in this fauna can be explained in two ways. Either this fauna accumulated in an isolated sea or ocean currents prevented the accumulation of the buoyant ammonite shells. The presence of the large percentage of forms not reported elsewhere suggests a rather isolated environment. However, it is probable that the fauna was incompletely preserved, as Muller and Ferguson (1939) reported that beds of approximately the same age in Nevada contain an abundant fauna, of which many species are identical with those of Europe. The genera *Lima, Plicatula, Volsella, Lopha, Ostrea, Phillippiella,* and *Pinna* indicate an upper neritic or littoral environment. *Lopha* is characteristic of warm water in the present seas. Thus, the Devils Canyon fauna probably lived in warm, shallow seas. Marine strata of the Upper Norian and Rhaetian stages (European Upper Triassic) have not previously been reported from California.

The Kosk member of the Modin formation yielded one species, *Choristoceras marshi* Hauer. This species is confined to the Rhaetian stage of the European Triassic. The lack of other fossils and the character of the enclosing sediments suggest a deep-water environment. Intercommunicating sea lanes with Europe apparently were present during the Rhaetian age to allow this species to exist both in Europe and on the west coast of North America.

The fauna of the Arvison formation shows that its environment is very similar to that of the Devils Canyon fauna. The Arvison fauna is composed mainly of pelecypods, many of which indicate upper neritic or littoral environments. The presence of carbonized wood fragments also suggests close proximity to land. Specimens of the cephalopod genera *Asteroceras* and *Arnioceras* were found in this formation. These genera are restricted to the Sinemurian stage of the Lower Jurassic in Europe and make it possible to correlate the fossil-bearing horizon of the Arvison formation with that stage. The presence of these genera, which are restricted to a narrow stratigraphic range indicates that the early Jurassic seas, like those of the late Triassic, were connected to the European region by east-west sea lanes.

The Arvison beds contain *Entolium meeki* Hyatt and forms very similar to *Pecten acutiplicatus* Meek and *Pinna expansa* Hyatt. The stratigraphic ranges of these species are not known but they were originally described as occurring in the Hardgrave sandstone of the Taylorsville region. *P. acutiplicatus* and *Entolium* cf. *E. meeki* are reported from the Sunrise formation (Lower Jurassic) of Nevada.

The Potem formation contains two distinct fossil horizons. The lower fauna yielded pelecypod forms that are not useful in dating the beds. However, *Entolium equabile* Hyatt, which was described from the Mormon sandstone of the Taylorsville area, is common in the lower Potem beds.

A younger horizon of the Potem formation yielded an abundant fauna which contains pelecypod species useful in the correlation of these beds with the European Jurassic. *Posidonia alpina* (Cras) occurs abundantly in the Potem formation along the Pit River. The European range of this species is Upper Toarcian to Lower Callovian. The genus Trigonia is well represented in local beds in the Potem formation. Forms similar to *Trigonia v-costata* Lycett, *T. undulata* Fromhertz, *T. spinulosa* Young and Bird, and *T. denticulata* Agassiz are recognized. These species are characteristic of the Bajocian stage of the European Middle Jurassic.

These pelecypods and the presence of the genera *Ostrea, Gryphaea* and *Pinna* again indicate shallow water conditions for the fauna of this horizon. The presence of *Lingula* and *Orbiculoidea* suggest brackish water conditions during a part of this time. Small coral reefs composed of *Astrocoenia* indicate a warm water enviroment.

From a survey of these faunas it appears that environmental conditions were remarkably similar in this area from late Triassic through the Middle Jurassic. Shallow, warm seas predominated and intercommunicating sea lanes which connected with the European area were probably continuous throughout this entire time. The movement which elevated the Shasta County Triassic rocks above the sea at the end of the Rhaetian stage apparently did not materially affect the distribution of these warm Mesozoic seas so as to create a barrier between western North America and the European areas.

SYSTEMATIC PALEONTOLOGY

Phylum BRACHIOPODA
Class ARTICULATA
Order TELOTREMATA
Family SUESSIIDAE Waagen
Genus SPIRIFERINA D'Orbigny, 1850
Spiriferina cf. *S. suessi* Winkler, 1882

Plate 2, Figures 7 and 8

Description. Shell inequivalved. Ventral valve pyramidal with median sinus extending from the beak to the anterior margin. Dorsal valve somewhat arcuate with median fold extending from the cardinal area to the anterior margin. Cardinal area high, with well developed delthyrium beginning near the beak of the ventral valve, widening and terminating at the hinge line. Valves radially striate. Fine growth lines more or less regularly spaced on both valves. Shell material coarsely punctate.

Dimensions.

Width	24 mm.
Length	22 mm.
Height	36 mm.
Height cardinal area	23 mm.

Locality. L.S.J.U. Localities 2970 and 2975. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian age, Late Triassic epoch.

Discussion. According to Zugmayer (1882), identification of the species depends in part on the character and arrangement of internal features. As the preservation of the fossil material from the Modin beds is too poor to permit observations of the internal parts, identification must depend on a comparison of the external features. Zugmayer states that *Spiriferina suessi* appears exclusively in the Koessener strata of the Rhaetian stage and in the

Starhemberger beds. Trechman (1918) has named a variety from New Zealand, *S. suessi* var. *australis*, which occurs in the *Halobia* beds of Karnian age.

Family RHYNCHONELLIDAE Gray
Genus RHYNCHONELLA Fisher, 1809
"Rhynchonella" richardsoni Smith, 1927

Plate 2, Figures 5 and 6

Description. Shell small; quadrangular in shape, biconvex; beak small, pointed and not prominent. Ornamentation of 8 subangular costae continuous from umbo to anterior margin. Dorsal valve with high ridge containing three plicae; ventral valve with deep sinus containing two plicae.

Dimensions.

Length	12 mm.
Width	13 mm.
Height	9 mm.

Locality. L.S.J.U. 2970. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian age, Late Triassic epoch.

Discussion. As the internal characters of this specimen could not be observed, definite identification of this form was not possible as to genus or species. However, this specimen appears to be identical in external features with topotype specimens of *R. richardsoni.*

Rhynchonella cf. *R. varians* Schlotheim, 1820

Plate 2, Figures 3 and 4

Description. Shell inequivalved; triangular to quadrangular in shape; biconvex; beak small, recurved toward umbo. Ornamentation consists of 18 to 26 subangular costae continuous from umbo to the anterior margin on both valves. The ventral valve with a prominent sinus containing three to six costae; seven to eight costae on each lateral slope. The dorsal valve with a strong medial fold containing two to five costae. Internal structures not preserved.

Dimensions.

Length	14-21 mm.
Width	16-22 mm.
Height	11-14 mm.

Locality. L.S.J.U. 2982. Potem formation.

Geologic age. Bajocian age, Middle Jurassic epoch.

Discussion. Definite specific identification was not possible because internal features were not preserved. This form closely resembles several Liassic and Middle Jurassic species including *Rhynchonella schopeni* Di Stefano, *R. plicatissima* Quenstedt, and *R. angulata* Sowerby. Thirty specimens were found at Locality 2982. The variability of characters is such that no two specimens are alike. There is considerable variation as to shape, number of costae on the valves and on the sinus and fold, and in convexity of the valves, although the latter may be due in part to compression. It appears that this form of *Rhynchonella* is extremely variable and individual specimens might be taken for different species. However, the intimate association of these forms in the rock, which in places is largely composed of these brachiopods, suggests that the various forms belong to one species.

Family TEREBRATULIDAE Gray
Genus "TEREBRATULA" Müller, 1776
"Terebratula" sp.

The Devils Canyon member of the Modin formation contains numerous *Terebratula*-like forms. The external features are clearly preserved. However, the preservation of the internal structures is so poor that sectioning failed to give sufficient information for generic as well as specific information. On the basis of external features alone, at least two distinct forms are recognizable.

The larger of the two is oval in shape, has a shallow sinus and fold confined to the anterior portion of the shell, contains fine but well defined growth lines. Both valves are strongly arched. The beak is prominent and curved slightly forward. This form closely resembles *"Terebratula" pyriformis* Suess, common in the Norian stage.

The second form is nearly circular in outline. Both valves are arched and show only slight plication or none along the margin. The juncture of the valves is slightly curved or straight. Growth lines are faint. This form resembles the genus *Zugmeyeria* Waagen, a Rhaetian form.

Phylum MOLLUSCA
Class CEPHALOPODA
Order AMMONOIDEA
Family AECOCERATIDAE Neumayr
Genus ARNIOCERAS Agassiz-Hyatt, 1867
Arnioceras sp.

Plate 2, Figures 1 and 2

Description. Shell discoidal, evolute; cross section of whorl subquadrate. Whorls increase in size gradually. Shell smooth in the initial three and one-half whorls. Outer whorls ornamented with radial ribs which number about thirty in the outer whorl at the diameter of 18 mm. Ribs flat and broad in earlier portion of shell but narrow and acute in the outer whorl. Ribs extending from the umbilical shoulder to the ventral shoulder, where they are abruptly terminated by turning orally to form well developed lateral keels. Venter broad, with well defined keel and shallow lateral furrows. Ventral shoulders sharply rounded; flanks nearly flat; umbilical shoulder sharply rounded overhanging the umbilical seam. Sutures not observed.

Dimensions.

Diameter of shell (DS)	18.0 mm.
Diameter of umbilicus (DU)	8.6 mm.
Height of outer whorl (HOW)	6.2 mm.
Width of outer whorl (WOW)	6.0 min.
Height of preceding whorl	3.2 mm.
Width of preceding whorl	3.0 mm.

Ratios.

$$\frac{HOW}{DS} = \frac{1}{3} \qquad \frac{DS}{DU} = \frac{2}{1} \qquad \frac{HOW}{WOW} = \frac{1}{1}$$

Locality. L.S.J.U. 2968. Arvison formation.

Geologic age. Sinemurian age, Early Jurassic epoch.

Discussion. Only a single specimen was found of this form, which closely resembles the figure and descriptions of *Arnioceras hartmanni* (Oppel) and *Arnioceras bodleyi* (Buckman) (Hyatt 1899). Identification as to species was not made because the suture could not be seen and, as the specimen was small, it was thought that this might be a juvenile form or the inner whorls of a broken specimen. The genus itself, however, is of such short geologic range that it serves as an excellent index fossil.

Genus ASTEROCERAS Hyatt, 1867
Asteroceras sp.

Plate 2, Figures 18 and 19

Description. Shell discoidal, somewhat involute. Last whorl covers about two-thirds of the preceding whorl. Whorls increasing in size rapidly. Flanks slightly convex, sloping toward the venter. Venter narrow with depressed keel and well developed lateral keels. Ventral shoulder rounded at lateral keel. Umbilical shoulders acutely rounded and overhanging the umbilical seam. Flanks nearly smooth in the body whorl but having rounded ribs in the chambered part of the shell. Suture not well defined.

Dimensions.

Diameter of the shell (DS) Approx.	43 mm.
Diameter of the umbilicus (DU) Approx.	12 mm.
Height of the outer whorl (HOW) Approx.	22 mm.
Width of the outer whorl (WOW) Approx.	18 mm.

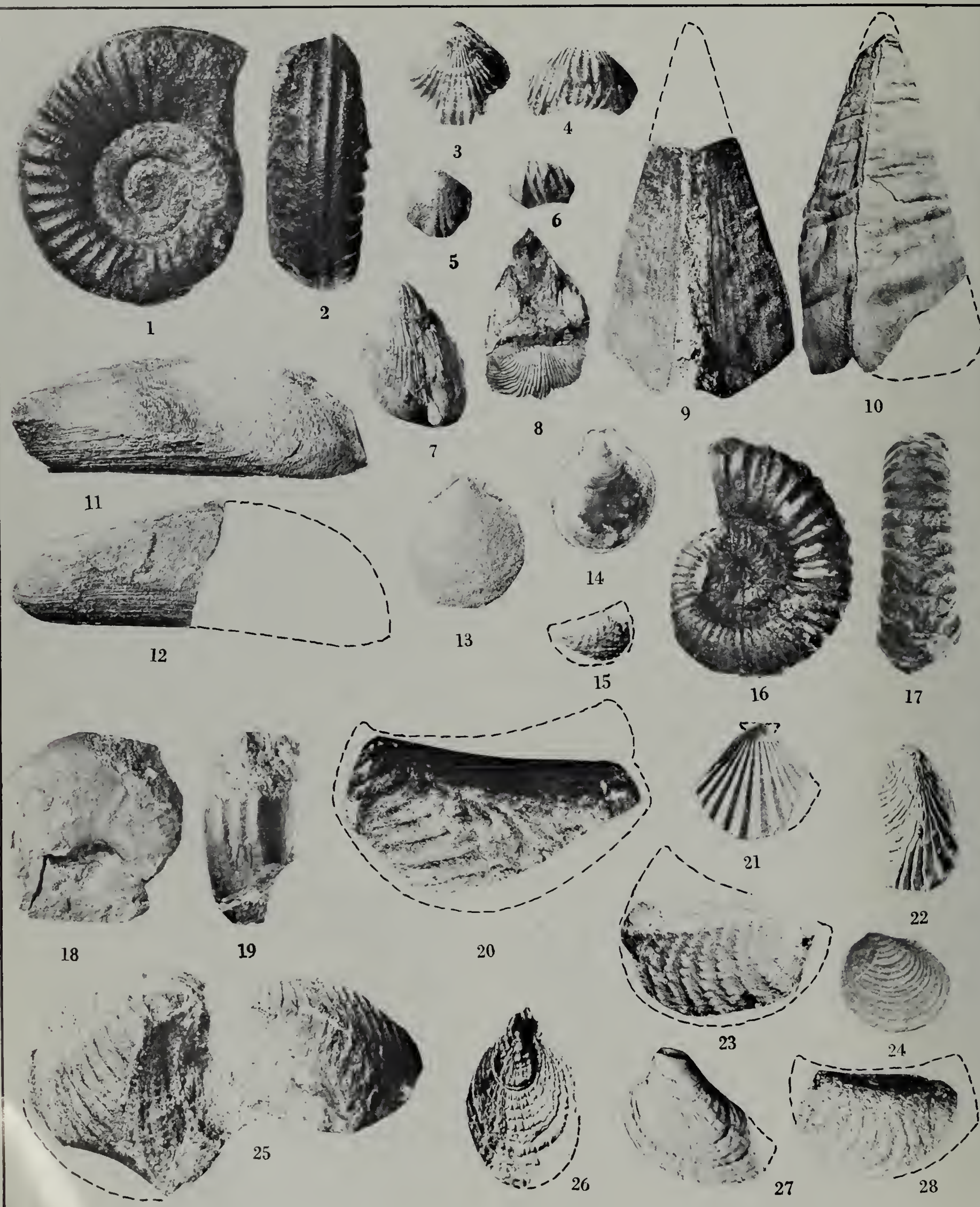
Ratios.

$$\frac{HOW}{DS} = \frac{1}{2} \qquad \frac{DS}{DU} = \frac{3.7}{1} \qquad \frac{HOW}{WOW} = \frac{11}{9}$$

Locality. L.S.J.U. 2968. Arvison formation.

Geologic age. Sinemurian age, Early Jurassic epoch.

Discussion. This specimen is a broken fragment. It has the general form, degree of involution, suture, and simplification of ornamentation of the outer whorls which are often characteristic of *Asteroceras.* It is very similar to *Asteroceras impendens* (Young and Bird), but the keel is more depressed in the Arvison specimen. (Wright 1881, plate XXIIA, Fig. 1–3.) It is also similar to *A. brooki* (Sowerby) and *A. turneri* (Sowerby) but differs in its smaller size, greater degree of involution, and early development of gerontic simplification of ribs in the body whorl.



FOSSILS

EXPLANATION OF PLATE 2

Figures 1 and 2.
Arnioceras sp. L.S.J.U. Loc. No. 2968.
Sinemurian Age, Early Jurassic.
Arvison formation.
Figure 1 Side view X3
Figure 2 Venter X3

Figures 3 and 4.
Rhynchonella cf. *R. varians* Schlotheim
L.S.J.U. Loc. No. 2982.
Bajocian Age, Middle Jurassic.
Potem formation.
Figure 3, Dorsal valve.
Figure 4, Anterior.

Figures 5 and 6.
"*Rhynchonella*" *richardsoni* Smith
L.S.J.U. Loc. No. 2970.
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
Figure 5, Dorsal valve.
Figure 6, Anterior.

Figures 7 and 8.
Spiriferina cf. *S. suessi* Winkler
L.S.J.U. Loc. No. 2970.
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
Figure 7, Ventral valve.
Figure 8, Posterior.

Figure 9.
Pinna cf. *P. expansa* "Hyatt" Crickmay
L.S.J.U. Loc. No. 2972.
Late Early Jurassic or Early Middle Jurassic.
Potem formation.
Side view, both valves.

Figure 10.
Pinna sp. L.S.J.U. Loc. 2970
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
Side view.

Figures 11 and 12.
Volsella sp.
L.S.J.U. Loc. No. 2970.
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
Left valves.

Figure 13.
Entolium meeki "Hyatt" Crickmay
L.S.J.U. Loc. No. 2968.
Sinemurian Age, Early Jurassic.
Arvison formation.
A single valve.

Figure 14.
Entolium equable "Hyatt" Crickmay.
L.S.J.U. Loc. No. 2568.
Late Early Jurassic or Early Middle Jurassic.
Potem formation.
A single valve.

Figures 16 and 17.
Choristoceras marshi Hauer
L.S.J.U. Loc. No. 2981.
Rhaetian Age, Late Triassic.
Kosk member, Modin formation.
Figure 17, Venter X4
Figure 16, side view X4

Figures 18 and 19.
Asteroceras sp.
L.S.J.U. Loc. No. 2968.
Sinemurian Age, Early Jurassic.
Arvison formation.
Figure 19, Venter.
Figure 18, Side view.

Figures 20 and 15.
Trigonia cf. *T. v-costata* Lycett
L.S.J.U. Loc. No. 2966.
Bajocian Age, Middle Jurassic.
Potem formation.
Figure 20, left valve.
Figure 15, right valve, young specimen.
Plaster cast.

Figure 21.
Pecten cf. *P. acutiplicatus* Meek.
L.S.J.U. Loc. No. 2968.
Sinemurian Age, Early Jurassic.
Arvison formation.
A single valve.

Figure 22.
Lopha sp. L.S.J.U. Loc. No. 2970.
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
A single valve.

Figure 23.
Trigonia cf. *T. spinulosa* Young and Bird.
L.S.J.U. Loc. No. 2982.
Bajocian Age, Middle Jurassic.
Potem formation.
Right valve.

Figure 24.
Posidonia alpina (Gras).
L.S.J.U. Loc. No. 2963.
Bajocian Age, Middle Jurassic.
Potem formation.
A single valve. X4

Figure 25.
Trigonia cf. *T. denticulata* Agassiz.
L.S.J.U. Loc. No. 2982.
Bajocian Age, Middle Jurassic.
Potem formation.
Both valves.

Figures 26 and 27.
Plicatula perimbricata Gabb.
L.S.J.U. Loc. No. 2970 and 2975.
Late Norian or Rhaetian Age, Late Triassic.
Devils Canyon member, Modin formation.
Figure 27, clay cast.

Figure 28.
Trigonia undulata Fromherz.
L.S.J.U. Loc. No. 2966.
Bajocian Age, Middle Jurassic.
Potem formation.
Left valve.

Family CERATITIDAE Mojsisovics
Genus CHORISTOCERAS Hauer, 1865
Choristoceras marshi Hauer, 1865

Plate 2, Figures 16 and 17

Description. Shell evolute, showing a tendency to uncoil in later whorls. Cross section of outer whorl subcircular. Whorls increasing in size gradually. Shell ornamented with coarse rounded ribs, about forty in the outer whorl at the diameter of 14.6 mm. Ribs characterized by the presence of two lateral nodes on the venter. Nodes forming two parallel lateral rows on the venter. Ribs nearly obsolete across venter between nodes. Suture not observed.

Dimensions.

Diameter of the shell (DS)	14.6 mm.
Diameter of the umbilicus (DU)	5.1 mm.
Height of the outer whorl (HOW)	4.8 mm.
Width of the outer whorl (WOW)	4.9 mm.

Ratios.

$\frac{HOW}{DS} = \frac{1}{3}$ $\quad \frac{DS}{DU} = \frac{3}{1}$ $\quad \frac{WOW}{HOW} = \frac{1}{1}$

Locality. L.S.J.U. localities 2981, 2969 and 2976. Kosk member, Modin formation.

Geologic age. Rhaetian age, Late Triassic epoch.

Discussion. This fossil was compared with descriptions and illustrations of Mojsisovics (1893) and, although the suture could not be observed, the external characters of the Kosk Creek specimen appear to be identical with those illustrated by Mojsisovics. Several specimens were obtained with ornamentation moderately well preserved. The amount of uncoiling is slight in these specimens. However, it is possible that the extended parts of the uncoiled whorl may have been very fragile and easily lost before preservation.

The genus *Choristoceras* is restricted to the upper Norian and Rhaetian stages of the European Triassic. *Choristoceras marshi* is a Rhaetian form reported from the clays and marly limestone of the Koessener beds in the northern Alps.

Class PELECYPODA
Order PRIONODESMACEA
Family OSTREIDAE Lamarck
Genus LOPHA Bolten, 1798
Lopha sp.

Plate 2, Figure 22

Description. Shell subquadrate in form; anterior margin convex; posterior margin concave. A long medial ridge extending from the umbonal area to the ventral margin. Supplementary ribs extending from the central ridge to anterior and posterior margins, the juncture with opposite valve being strongly plicate. Ribs smaller and more numerous on the posterior margin.

Dimensions.

Length	48 mm.
Width	26 mm.
Convexity of the right valve	21 mm.

Locality. L.S.J.U. 2975. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian ages of the Late Triassic epoch.

Discussion. The various species of this genus are difficult to distinguish even with well preserved material. Therefore, the stratigraphic value of poorly preserved specimens is questionable. However, the form is important as an indicator of environment. In the present seas it is characteristic of warm water and shallow depth and we may assume that the same relationship obtained in the past.

Family PECTINIDAE Lamarck
Genus ENTOLIUM Meek, 1864
Entolium meeki "Hyatt"-Crickmay, 1933

Plate 2, Figure 13

Description. Shell nearly circular with peripheral margin converging at the beak at an angle of 109°. The area near the umbo with several concentric ridges and the vicinity of the border marked by two concentric lines. Remaining portion of the shell smooth. Ears nearly equal, their dorsal margins meeting at an angle of approximately 180°.

Dimensions.

Length	34 mm.
Width	35 mm.
Convexity of one valve	2 mm.

Locality. L.S.J.U. 2968. Arvison formation.

Geologic age. These specimens are external molds in tuffaceous sandstone. The concentric ribbing near the umbo is nearly lost but can be recognized. This form has been reported from the Hardgrave sandstone of the Taylorsville area of Plumas County, by A. Hyatt (1892) and by Crickmay (1933). Although *Entolium meeki* was listed by Hyatt in 1892, it remained a *nomen nudum* until 1933 when it was described and illustrated by Crickmay from Hyatt's original collection. Crickmay credited the name to Hyatt.

Entolium equabile "Hyatt"-Crickmay, 1933

Plate 2, Figure 14

Description. Shell nearly circular in outline on the ventral two-thirds of the valve, above which point both margins converge in nearly straight lines to the umbo, forming an obtuse angle. Valves slightly inflated. Ears small, nearly symmetrical, extending above beak. Shell surface nearly smooth, marked only by very faint and closely spaced concentric striae.

Dimensions.

Length	25 mm.
Width	21 mm.
Convexity one valve	4 mm.
Apical angle 97°	

Locality. L.S.J.U. Localities 2563 and 2971. Potem formation.

Geologic age. Late Early Jurassic or Early Middle Jurassic.

Discussion. This form was reported by Hyatt (1892) and Crickmay (1933) from the Mormon sandstone of the Taylorsville area in Plumas County, California. *Entolium equabile* remained a *nomen nudum* from the time of its first mention by Hyatt until Crickmay included it among his descriptions of Hyatt's material. Crickmay (1933) credited the name to Hyatt.

Family MYTILIDAE Fleming
Genus VOLSELLA Scopoli, 1777
Volsella sp.

Plate 2, Figures 11 and 12

Description. Shell elongate, solenoid, inflated, becoming compressed posteriorly. Oblique ridge on both valves extending from the beak to posterior ventral border. Ventral border nearly straight, dorsal border arcuate, curving downward posteriorly to the junction with the ventral border. The junction of the valves forming an acute angle. Beak subterminal. Growth lines on the ventral part parallel to the ventral margin as far as the oblique ridge, thence curving back sharply to the dorsal border. The dorsal portion of the shell from the oblique ridge to the dorsal border covered with fine transverse striae which slightly overlap the ridge posteriorly but not extending to the ventral border. Striae immediately dorsal to the ridge, forming a slight chevron-shaped angle, with apex directed beakward.

Dimensions.

Length	72 mm.
Width	23 mm.
Convexity of one valve	15 mm.

Locality. L.S.J.U. 2970 and 2975. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian age of the Late Triassic epoch.

Discussion. This is an abundant and characteristic form from the middle of the Modin formation. Its presence suggests a shallow water, near-shore environment for the associated fauna. This fossil is similar to *Volsella sowerbyana* (D'Obigny) but differs in the fact that the concentric growth lines are less prominent and do not appear to bifurcate on passing the ridge. It also differs in the possession of transverse striae which gives the shell a cancellate ornamentation. This form also is similar to *Lithophaga verbeeki* Boettger.

Family PINNIDAE Meek
Genus PINNA Linnaeus, 1758
Pinna sp.
Plate 2, Figure 10

Description. Shell probably quadrate in cross section (most specimens deformed by compression). Compressed, the angle between the two margins approximately 90° near the beak and 45° near the posterior margin. Hinge line and ventral margin long and straight. Anterior extremity and the umbones not preserved. Ornamentation of radial ribs equally prominent on both valves and much fainter, irregularly spaced, concentric growth lines. Specimens characterized by rugose, irregular folding which is roughly normal to the radiating ornamentation, apparently a secondary feature possibly the result of compaction forces which squeezed and compressed the thin shell material while it still remained in its normal upright position in the sea-bottom muds.

Dimensions.
Length (reconstructed) ________________________ 79 mm.
Width varies from about 5 mm. at umbones to approximately 37 mm. at extremity.
Convexity varies from about 5 mm. at umbones to approximately 25 mm. at extremity.

Locality. L.S.J.U. Localities 2970 and 2975. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian age, of the late Triassic epoch.

Discussion. This form is probably a new species but the poor and incomplete preservation of the specimens prevented its recognition as such. The genus has a long stratigraphic range and may be regarded as a persistent one. Several descriptions and figures of this type of *Pinna*, ranging in age from Triassic to lower Tertiary, were studied. Few if any significant morphologic differences could be observed which would serve to distinguish these Modin specimens from others of earlier or later ages. This form compares very favorably with the *Pinna* cf. *P. blanfordi* Boettger described from the Rhaetian beds of Upper Burma (Healey, 1908).

Pinna cf. *P. expansa* "Hyatt" Crickmay, 1933
Plate 2, Figure 9

Description. Shell probably quadrate in cross section, compressed, angle between two margins approximately 120°. Fine line and ventral margin long and straight. Anterior extremity and umbones not preserved. Ornamentation consists of 14-16 radial ribs equally prominent on both valves.

Dimensions.
Length (reconstructed) ________________________ 85 mm.
Width varies from about 5 mm. at umbones to approximately 35 mm. at extremity.
Convexity varies from about 5 mm. at umbones to approximately 40 mm. at extremity.

Locality. L.S.J.U. locality 2072. Potem formation.

Geologic age. Late Early Jurassic or Early Middle Jurassic.

Discussion. This form was reported by Hyatt (1892) and Crickmay (1933) from the Hardgrave sandstone of the Taylorsville area of Plumas County, California. *Pinna expansa* remained a *nomen nudum* from the time of its first mention by Hyatt until Crickmay included it among his descriptions of Hyatt's material.

Family SPONDYLIDAE Fleming
Genus PLICATULA Lamarck, 1819
Plicatula perimbricata Gabb, 1870
Plate 2, Figures 26 and 27

Description. Shell inequivalved; larger valve convex and considerably inflated in the central portion of the shell; smaller valve flat or slightly concave or convex. Margins rounded but converging rapidly toward the beak in the dorsal half of the shell. Valves ornamented by well defined imbricating concentric ridges and somewhat less prominent radial plications. Beaks indistinct. Hinge with two strong teeth with resilifer pit between them. No attachment scar apparent.

Dimensions.
Length ______________________________________ 36 mm.
Width ______________________________________ 25 mm.
Convexity of larger valve______________________ 20 mm.

Locality. L.S.J.U. localities 2970 and 2975. Devils Canyon member of the Modin formation.

Geologic age. Late Norian or Rhaetian age of the Late Triassic epoch.

Discussion. This species is quite common in the middle of the Modin formation where a large number of specimens were collected. They are quite variable in size and shape but are constant in the characteristic imbrication of the concentric growth lines. No scar of attachment was observed on any of the specimens but this may be a local characteristic, as the original substratum was a soft calcareous mud. *Plicatula perimbricata* as originally described by Gabb (1870) was found at the "Jurassic" locality of Volcano, Nevada. Subsequent study by S. W. Muller (personal communication) has revealed that the *Plicatula perimbricata*-bearing strata at this locality are actually Upper Triassic. Comparison of the Modin specimens with a number of *P. perimbricata* collected by Muller at the type locality of the Triassic Gabbs formation show the California forms to be conspecific with the Nevada specimens.

Family PTERIIDAE Meek
Genus POSIDONIA Bronn, 1828
Posidonia alpina (Gras), 1852
Plate 2, Figure 24

Description. Shell thin, inequilateral, oval, compressed; periphery rounded to subquadrate; hinge line short, straight. Beak generally below the hinge line, rarely extending slightly above it, and anterior of the median line. Ornamentation of strong concentric costae which vary from coarse to fine. Costae rounded and wider than the interspaces, converging near the hinge line and generally coarser in the earlier portion of the shell, becoming progressively finer toward the periphery. Well preserved specimens with a posterior furrow from the umbilical region to the ventroposterior border.

Dimensions.
Length ___________________________________ 6–13 mm.
Width ___________________________________ 4– 9 mm.

Locality. L.S.J.U. localities 2963, 2964, 2977 and 2982. Potem formation.

Geologic age. Bajocian age of the Middle Jurassic epoch.

Discussion. This form is similar in size and shape to *Posidonia bronni* Voltz but differs in the anterior rather than the median location of the umbo. It is also very similar to *P. ornati* Quenstedt, *P. buchi* Roemer, *P. parkinsoni* Quenstedt, *P. opalina* Quenstedt and *P. suessi* Oppel. According to a study of *Posidonia* made by L. Guillaume (1927), the group named above are all conspecific with *P. alpina;* the described differences all fall well within the variation of the species *P. alpina* and the manner of preservation of the fossil material. Guillaume gives the geologic range of *P. alpina* as from Upper Toarcian to Lower Callovian stages.

Family TRIGONIIDAE Lamarck
Genus TRIGONIA Bruguiere, 1789
Trigonia cf. *T. spinulosa* Young and Bird, 1828
Plate 2, Figure 23

Description. Shell ovately triangular, convex, somewhat depressed. Area relatively broad, representing approximately one-half the area of the anterior portion, ornamented with fine, more or less regular striae which meet the carina at a right angle and give rise to small tubercles on the carina. Carina very slightly curved, rather prominent, tuberculated. The anterior portion ornamented with approximately fifteen tubercated costae of which ten appear on this broken specimen. Costae arranged concentrically, arising at the carina at an acute angle, and curving to the anterior border. Size of the costae and tubercles increasing to a maximum at a point about three-eighths of an inch from the carina and diminishing toward the anterior border. Details of the area and escutcheon not preserved.

Dimensions.
Length ______________________ approximately 48 mm.
Width ______________________________________ 53 mm.
Convexity one valve _________________________ 16 mm.

Locality. L.S.J.U. 2982. Potem formation.

Geologic age. Bajocian age of the Middle Jurassic epoch.

Discussion. This form is represented by a broken, incomplete portion of one valve. This fossil also shows similarities to *T. formosa* Lycett and *T. striata* Miller but differs from the former by the presence of fewer ribs and from the latter by the presence of a prominent carina. All three forms are confined to the Inferior Oolite (Bajocian stage-Middle Jurassic) of the British Isles.

Trigonia cf. *T. denticulata* Agassiz, 1840

Plate 2, Figure 25

Description. Shell ovately trigonal, convex. Umbones moderately pointed, incurved. Area ornamented by several rows of diverging denticulated costae extending from the umbones to the posterior border, at least one being much more prominent than the rest. Area flat near the umbones becoming somewhat convex near the border. Marginal carina curved, prominent, denticulate. Ribs about twenty in number, prominent, uniform, meeting the marginal carina at an acute angle directed toward the umbo and curving to the anterior border with a gentle undulation.

Dimensions.

Length	41 mm.
Width	37 mm.
Convexity one valve	17 mm.

Locality. L.S.J.U. 2982. Potem formation.

Geologic age. Bajocian age of the Middle Jurassic epoch.

Discussion. This member of the Costatae group resembles in part the following species; *T. costata* Sowerby, *T. tenuicosta* Lycett, and *T. bella* Lycett. All of the above, including *T. denticulata*, are reported from the Inferior Oolite (Bajocian stage-Middle Jurassic) of the British Isles.

Trigonia cf. *T. v-costata* Lycett, 1850

Plate 2, Figure 20

Description. Shell ovate, trigonal, moderately convex, anterior border curved, hinge border slightly concave. Area narrow, concave beneath the apices but flattened posteriorly. Anterior portion with 14-16 costae which are moderate in size, subtubercated near the point of greatest curvature. Costae commencing at the anterior border and curving obliquely downward, the six costate below the umbo curving upward to the marginal carina, those below less curved and more oblique, the anterior portions forming an acute angle with the posterior continuations of the costae.

Dimensions.

Length	45 mm.
Width	25 mm.
Convexity one valve	16 mm.

Locality. L.S.J.U. 2966. Potem formation.

Geologic age. Bajocian age of the Middle Jurassic epoch.

Discussion. This species differs from *T. v-costata* in the possession of fewer costae, but as the full description of *T. v-costata* allows for considerable variation of the species, this form could well fall into the species. *T. v-costata* is confined to the Inferior Oolite (Bajocian stage-Middle Jurassic) of the British Isles.

The genus *Vaugonia* set up by Crickmay (1930) contains two species, V. *veronica* and V. *mariajosephinae*, both of which would have fallen into Lycett's concept of *Trigonia v-costata*. This new genus includes the undulated trigoniae that are characterized by a break or interruption of the costae at the apex of the "V" on those forms that show V-shaped costae. The age assigned to the rocks which contain the genus *Vaugonia* is Middle Jurassic. The form described here differs from *Vaugonia* in its larger size, unbroken costae and number of curved costae below the beak that do not form a "V".

Trigonia undulata Fromherz, 1840

Plate 2, Figure 28

Description. Shell ovate-trigonal, convex. Anterier border curved sharply near the umbo, decreasing downward. Hinge border straight. Area narrow, costellae not preserved, marginal carina weak. Anterior portion with 12-14 costae of moderate size curving downward near the middle of the anterior portion, then upward to the marginal carina and joining the latter with an acute angle.

Dimensions.

Length	30 mm.
Width	20 mm.
Convexity one valve	8 mm.

Locality. L.S.J.U. 2966. Potem formation.

Geologic age. Bajocian age of the Middle Jurassic epoch.

Discussion. This species is a common and characteristic form of the Middle Jurassic of Europe.

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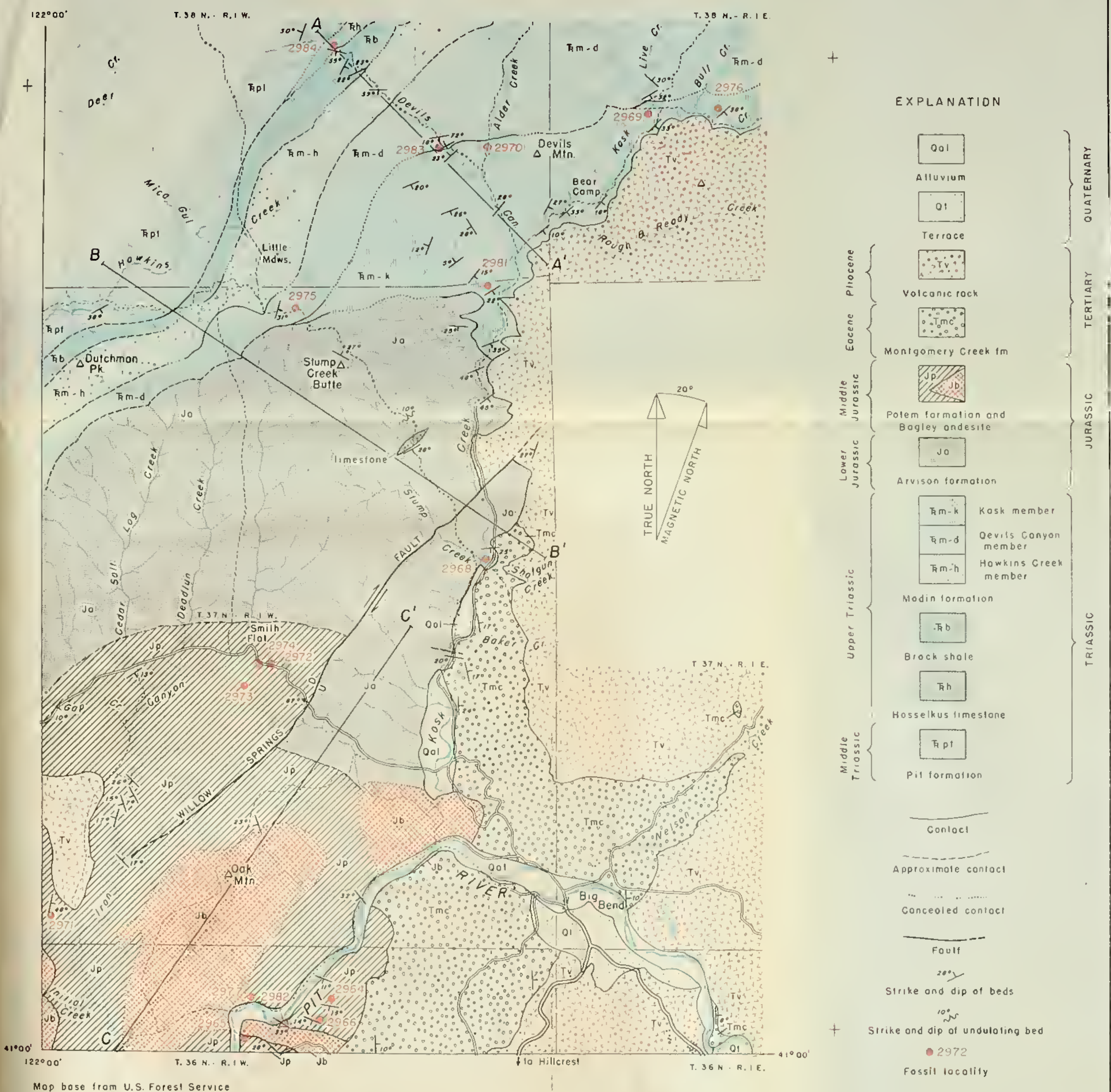

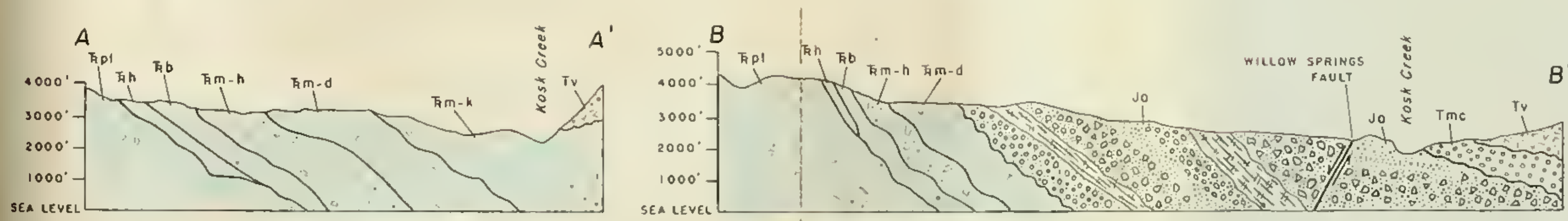

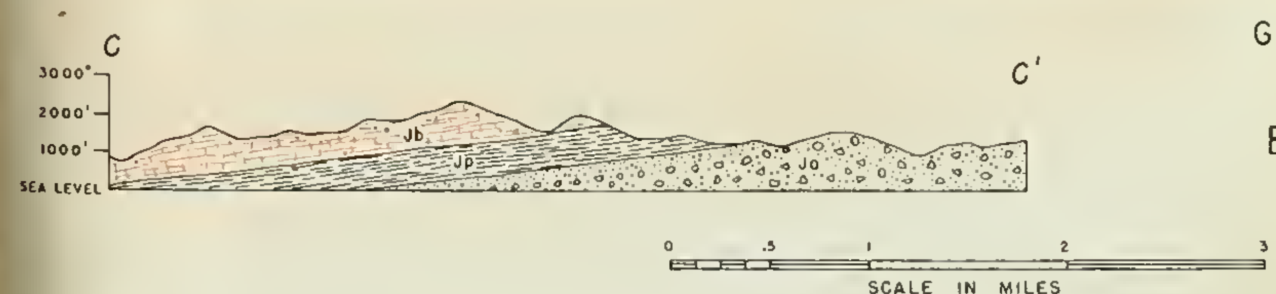

GEOLOGIC MAP AND SECTIONS OF PART OF THE BIG BEND QUADRANGLE SHASTA COUNTY, CALIFORNIA