Pre-Tertiary Stratigraphy and Upper Triassic Paleontology of the Union District Shoshone Mountains Nevada

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By N. J. SILBERLING

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A study of upper Paleozoic and lower Mesozoic marine sedimentary and volcanic rocks, with descriptions of Upper Triassic cephalopods and pelecypods

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PRE-TERTIARY STRATIGRAPHY AND UPPER TRIASSIC PALEONTOLOGY OF THE UNION DISTRICT, SHOSHONE MOUNTAINS, NEVADA

By N. J. Silberling

ABSTRACT

The pre-Tertiary rocks of the Union district are exposed in an elongate belt extending south from the town of Ione for about 12 miles along the west flank of the Shoshone Mountains in the northwest part of Nye County, Nev.

Within this area lies an exposure of a nearly complete sequence of stratigraphic units ranging in age from late Paleozoic to Middle Jurassic. At the base of this sequence is the predominantly volcanic Pablo formation of Permian(?) age in which three local members are recognized. The lowest member of the Pablo formation exposed in the Union district is composed of coarse- and fine-grained sedimentary rocks interstratified with andesitic volcanic rocks. Gradationally overlying this thick clastic member is a relatively thin limestone member which is in turn overlain by a thick greenstone member composed of altered andesitic flows and volcanic breccia.

The Grantsville formation, with little, if any, angular discordance, overlies the Pablo. It is about 700 feet thick and is composed of a lower clastic member, of siliceous conglomerate grading upward into sandstone and argillite, and an upper limestone member. The marine invertebrate fauna of the limestone member of the Grantsville is late Middle Triassic (Ladinian) in age, represents a biofacies of the Middle Triassic that is unique to North America, and is closely related to the fauna of the German Muschelkalk.

The overlying Luning formation of Late Triassic age rests with erosional disconformity upon the Grantsville formation. Four informal members are recognized within the Luning. In ascending order they are the clastic member, composed of siliceous conglomerate, sandstone, and argillite with a thickness of about 600 feet; the shaly limestone member, also about 600 feet thick; the calcareous shale member, about 550 feet thick; and the carbonate member, composed of massive limestone and dolomite with an exposed thickness of at least 2,000 feet. Three local faunal zones, characterized mainly by cephalopods, occur in the shaly limestone and calcareous shale members of the Luning formation. The stratigraphically lowest of these zones is tentatively correlated with the upper part of the *Tropites subbullatus* zone. Based on this correlation, the Karnian-Norian stage boundary is provisionally placed between the middle zone, characterized by new species of the ammonite genus *Tropites*, and the uppermost zone, the fauna of which is dominated by the lower Norian ammonite *Guembelites*.

The upper part of the Luning formation and strata equivalent to the lower part of the Gabbs formation of the Gabbs Valley Range are not exposed in the Union district. By analogy with the section in the Gabbs Valley Range, however, the contact between the Luning formation and the undifferentiated Gabbs and Sunrise formations in the Union district is presumably conformable. Although the rocks assigned to the undifferentiated Gabbs and Sunrise formations in the Union district agree in lithology and age with the type sections of these formations in the Gabbs Valley Range, the Gabbs and Sunrise formations are not differentiated because the minor lithologic change that marks their mutual boundary in the type area cannot be recognized in the Union district. The exposed section of the undifferentiated Gabbs and Sunrise formations is 2,700 feet thick in the Union district and is composed largely of argillaceous silty limestone and calcareous siltstone ranging from latest Triassic (Rhaetian) to at least late Early Jurassic (Toarcian) age. Several hundred feet of strata assigned to the Dunlap formation conformably overlie the undifferentiated Gabbs and Sunrise formations. The Dunlap formation in the Union district consists mainly of noncalcareous, possibly nonmarine, sandstone including two relatively thin dolomitic carbonate units near the top of the exposed section.

A thick unit of quartzite and an equally thick unit of dolomite, both of which are tentatively assigned to the Cambrian, occupy a small area east of Ione. The stratigraphic and structural relationship of these units to the upper Paleozoic and lower Mesozoic section is not known.

The generally eastward-dipping pre-Tertiary rocks in the northern two-thirds of the area are considered part of the upright limb of a large-scale overturned anticline, the axis of which strikes and plunges southeast. The complexly folded and thrust-faulted Mesozoic rocks in and south of Grantsville Canyon represent the axial region and overturned limb of this fold. Subsequent to folding and thrust faulting, an intricate pattern of normal faults developed. Most of the normal faulting preceded the deposition of Tertiary volcanic rocks, but some of the faults displace both pre-Tertiary and Cenozoic rocks.

The species of Late Triassic marine mollusks selected for description are those significant in recognizing the Karnian-Norian stage boundary. A total of 21 species, including 10 new species, are described and are assigned to the following genera: of ammonites, *Klamathites*, *Mojsisovicsites*, *Tropites*, *T.* (*Anatropites*), *Tropiceltites?*, *Guembelites*, and *Discophyllites;* of nautiloids, *Clydonautilus*, *Germanonautilus*, and *Phloioceras;* and of pelecypods, *Myophoria* and *Septocardia?*.

INTRODUCTION

Rocks of late Paleozoic and early Mesozoic age are present in many isolated localities in northwestern Nevada, geographically separated from one another by Cenozoic volcanic and sedimentary rocks. The geologic relationships between these areas of outcrop are generally obscured by the absence of continuity between them. Consequently, the regional stratigraphic history of the pre-Tertiary rocks exposed in northwestern Nevada must be obtained by gradually fitting together the information gained by the study of each isolated area of outcrop. In discussing some of the geologic features of the Great Basin region, C. R. Longwell (1950, p. 425) makes the very appropriate statement:

> * * * in any generalizing about the geology of the [Great Basin] province as a whole we have to deal with points of knowledge, separated by large areas of ignorance.

The principal purpose of the present study is to establish the Union district as a "point of knowledge" which may at some future date be fitted into a larger stratigraphic picture of the late Paleozoic and early Mesozoic of the Great Basin.

The Union district is well suited for stratigraphic studies of the pre-Tertiary rocks as they are neither greatly altered nor structurally deformed beyond understanding. Furthermore, they provide a nearly complete record of geologic events during the late Paleozoic and early Mesozoic. The nearest areas containing relatively unaltered sections of lower Mesozoic sedimentary rocks comparable in the time span represented to those exposed in the Union district are in the Pilot Mountains and Gabbs Valley Range about 35 miles to the southwest and in the New Pass Range about 50 miles to the north. The extensive exposures of pre-Tertiary rocks in the Paradise Range and Cedar Mountains, separated by the Ione Valley from the pre-Tertiary rocks described in this report, are for the most part structurally deformed and metamorphosed to the extent that detailed stratigraphic studies are not possible. Early Mesozoic sedimentary rocks are not present in the adjacent parts of central Nevada east of the Union district owing in part to nondeposition and in part to removal by erosion. As a result, the Union district occupies a critical position for the understanding of the early Mesozoic marine basin of deposition in northwestern Nevada.

LOCATION AND DESCRIPTION OF THE AREA

The Union district is situated on the west side of the Shoshone Mountains in the northwest part of Nye County, Nev., and is included in the U. S. Geological Survey Ione quadrangle (scale 1:62,500) and in the northeast part of the Tonopah quadrangle (scale 1:250,000). Parts of T. 12 N., R. 39 E., and T. 13 N., R. 39 E., are included within the district. The Union district is accessible from several different directions by way of unimproved or secondary roads. It is about 30 miles south of both Eastgate and Campbell Creek Ranch on U. S. Highway 50, about 50 miles southwest of Austin via Nevada State Highway 21, about 70 miles north of Tonopah by way of the Cloverdale Ranch, and about 40 miles east of Gabbs by way of Lodi Valley and Burnt Cabin Summit. The district is sparsely populated; Ione with about two dozen residents is the largest community.

The location of the Union district in relation to the geographic features in adjacent parts of Nevada is shown on figure 1.

The elevation of the edge of Ione Valley bordering the area mapped is about 6,600–6,800 feet above sea level, and the highest point in the immediate vicinity is Buffalo Mountain with an altitude of 9,036 feet. The altitude and climate supports a sparse forest of piñon and juniper trees which adds to the attractiveness of the area but results in somewhat poorer rock exposures than those in the more barren parts of Nevada.

With the exception of several small areas where pre-Tertiary rocks outcrop in "windows" through the overlying Tertiary volcanic rocks, the pre-Tertiary rocks of the Shoshone Mountains are exposed in a narrow belt, about 20 square miles in area, extending southward from Ione along the west front of the range bordering Ione Valley. As such, the principal pre-Tertiary area of outcrop roughly coincides with the Union mining district. All of the major mining activity of this district, excepting some of the mercury mines, has been restricted to the pre-Teritary rocks. A wide variety of mineral commodities has been produced from the Union district. Listed approximately in their order of decreasing economic importance they include silver, gold, mercury, lead, copper, zinc, fluorite, and tungsten. The gross yield of the district from 1866 to 1940 according to the available county records was $3,304,328 (Couch and Carpenter, 1943). Of this total production of about 3.3 million dollars, more than half was produced before 1900. Some information on the geologic setting of the various ore deposits in the district is included in the discussion of the stratigraphy and structure of the pre-Tertiary rocks.

PREVIOUS WORK

The Union district, which was organized in 1863, is one of the oldest mining districts in Nevada. Historical accounts of the mining activity and production of the district may be found in several of the early reports of the State Mineralogist of the State of Nevada and in Raymond (1869, p. 182). No published account concerned with the geology of the area appeared until Daggett (1905) described some of the structural features in the Berlin mine. The geology of the principal quicksilver deposits in the Union district, some of

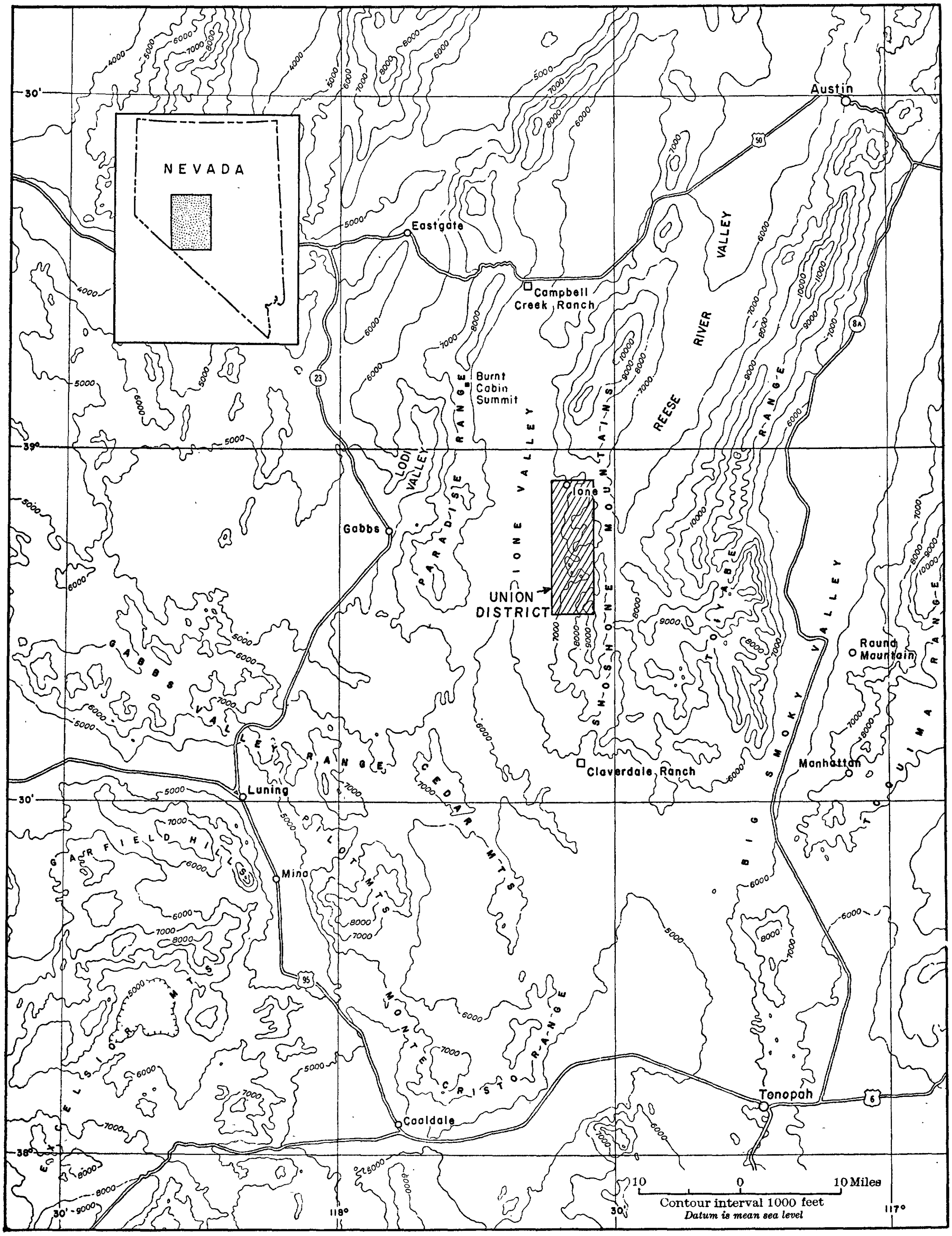

Figure 1.—Index map showing the location of the Union district, Nevada.

which are in the pre-Tertiary rocks, has been described by Bailey and Phoenix (1944, p. 148–154).

As a part of reconnaissance investigations in the Hawthorne and Tonopah quadrangles, the stratigraphy and structural relationships of the pre-Tertiary rocks in the Union district were studied in some detail by S. W. Muller and H. G. Ferguson. The stratigraphic results of these studies are included in the papers published in 1936 and 1939 (Muller and Ferguson), and the structural features were described in 1949 (Ferguson and Muller, p. 40–44). All of the formational names applied to the Mesozoic strata are those proposed by Muller and Ferguson in the two earlier publications. In general, the salient features described by these authors are confirmed by the present study, which serves mostly to provide further detail and interpretation beyond the scope of the previous work.

FIELDWORK AND ACKNOWLEDGMENTS

Fieldwork in the area was carried on during the summers of 1950 and 1953. The pre-Tertiary rocks were mapped at a scale of 1:12,000 on a topographic base enlarged from the Ione quadrangle. At least one section of each of the upper Paleozoic and Mesozoic units was measured by means of either the tape and compass method or a "Jacobs staff," and the faunas of each section were collected with as much stratigraphic control as surface exposures would permit.

The contribution made by Prof. Siemon W. Muller, of Stanford University, to the present study far exceeds that of supervisor and critic. Professor Muller was not only instrumental in starting this project but also provided a proper perspective by introducing the writer to many other comparable exposures of pre-Tertiary rocks in northwestern Nevada. Throughout the progress of this study, he gave generously of the information and materials accumulated during his nearly three decades of research on the lower Mesozoic rocks of the Great Basin. A large share of the paleontological collections on which part of this report is based were collected by Muller and Ferguson during the previous fieldwork in the area.

The writer is indebted to Mr. Philip A. Laylander, of Fallon, Nev. for the loan of an excellent set of large-scale colored aerial photographs, which were of considerable help in interpreting the complex structure in the southern part of the area.

Fieldwork in the area was made particularly pleasant by the hospitality shown by Mr. Harold P. Newman and his family of Berlin. Permission from Mr. J. G. Phelps Stokes, president of the Nevada Company, to utilize some of the buildings in the vicinity of Berlin as a field base is gratefully acknowledged.

STRATIGRAPHY

Pre-Tertiary rocks of both Paleozoic and Mesozoic ages are exposed in the Union district. Most of these rocks constitute a nearly complete depositional sequence that has an aggregate thickness of about 9,000 feet and represents a time span from the late Paleozoic to the early Middle Jurassic. A small part of the area is underlain by rocks tentatively assigned a Cambrian age, but the stratigraphic and structual relationship of these rocks to the younger pre-Tertiary section is indefinite.

Three periods of marine deposition separated by intervals of uplift and erosion are recorded in the late Paleozoic and early Mesozoic. A stratigraphic hiatus equivalent to most or all of the Early Triassic and the early Middle Triassic separates the dominantly volcanic Permian(?) rocks of the Pablo formation from the overlying Grantsville formation of late Middle Triassic age. A second period of nondeposition and erosion took place before the deposition of the Upper Triassic Luning formation. The sequence of the Luning, undifferentiated Gabbs (Triassic) and Sunrise (Jurassic), and Dunlap formations (Jurassic) appears to have been continuous and represents a complete cycle of marine transgressive deposition. The Dunlap formation, which is at least in part of early Middle Jurassic age, may be nonmarine and records the initial effects of the impending late Mesozoic orogeny and the obliteration of the early Mesozoic marine basin.

In describing the stratified rocks it was found useful to adopt quantitative terminology for the thickness of stratification and parting units. The system chosen is that proposed by Ingram (1954) and is reproduced for the reader's convenience.

Thickness of unit	*Terminology of stratification units*	*Terminology of parting units*
<0.1 in	Thin laminated	Super-thin parted
0.1–.4 in	Thick laminated	Extra-thin parted
.4–1.0 in	Very thin bedded	Very thin parted
1–4 in	Thin bedded	Thin parted
4–12 in	Medium bedded	Medium parted
1–3 ft	Thick bedded	Thick parted
>3 ft	Very thick bedded	Very thick parted

All references to the thickness of stratification and parting units are in accordance with the foregoing scheme except that the term "massive" is also used for sedimentary rocks which form homogenous, medium or thicker parting units and which upon weathering produce blocky debris. The terminology used for the particle size of clastic sediments is that originally proposed by Wentworth (1922).

CAMBRIAN(?) DOLOMITE AND QUARTZITE UNITS

The oldest rocks exposed in the Union district are represented by a thick dolomitic carbonate unit and an equally thick clastic unit of quartzite with a subordinate amount of argillaceous and conglomeratic sandstone. These rocks, which crop out over an area of about 1 square mile approximately 1 mile east of Ione, are adjacent; however, the nature of the contact between them is not definitely known. On the north and east they are bounded by Tertiary volcanic rocks, which are locally in fault contact with them; and on the southwest they are in fault contact with the greenstone member of the Pablo formation. Owing to the absence of fossils and the lack of stratigraphic continuity with units of known ages, these rocks cannot be definitely dated. However, lithologically, they are unlike any part of the established pre-Tertiary section within the area, and they appear to be older than the Pablo formation of Permian(?) age.

Neither the dolomite nor the quartzite is well stratified, and both are somewhat contorted, so that the attitude of the bedding is difficult to ascertain. Wherever observed, the strike is generally northwest with dips toward the northeast, and hence the quartzite, stratigraphically, appears to overlie the dolomite. Although the observed contact between the two units may not be a depositional one, they are considered to be depositionally related—not only because of the apparent conformance in attitude between them but also because of the presence of occasional lenticular quartzite beds at horizons within the dolomite. Ferguson and Muller (1949, p. 41) in discussing these rocks state that the carbonate rocks stratigraphically overlie the quartzite which is overlain in turn by greenstone. The attitude of the bedding in the dolomite and quartzite make the reverse of this relationship more probable—provided that they are not overturned. The relationship of the greenstone to the carbonate unit is definitely a fault, because elsewhere in the area the greenstone member of the Pablo is conformably underlain by the limestone and clastic members of the Pablo formation. Some brecciation and effects of hydrothermal alteration are present along the contact between the dolomite and quartzite; however, these features may be due to a minor amount of local slippage during deformation because of the different competency of the units rather than to a fault of large magnitude.

The dolomite unit consists of medium- to very thick-bedded generally grayish carbonate rocks, which, although dominantly dolomite, include some limestone. Most of these rocks have been intricately fractured and hydrothermally altered, so that they are usually somewhat recrystallized and irregularly veined with calcite. The relative proportions of primary dolomite and hydrothermal dolomite are not known. Some parts of this unit which appear to be the least altered consist of dense fine-grained slightly siliceous dolomite. The more coarsely crystalline carbonate rocks is almost invariably dolomitic.

In Ione Canyon a thick lens-shaped body of quartzite is included within the dolomite unit near its eastern contact with the orthoquartzite. This feature can be interpreted either as a fault sliver of the adjacent quartzite unit or as an original lenticular bed of quartzose sandstone within the dolomite. Near what appears to be the base of the dolomite unit, there are several thin lenticular beds of white fine-grained siliceous sandstone or siltstone. The total thickness of the exposed dolomite unit appears to be in excess of 1,000 feet. Several extensive zones of secondary silicification, oriented roughly parallel to the bedding, cut through the dolomite.

The quartzite unit, the exposed thickness of which appears to be in the order of 1,000 feet, is typically very thick bedded and only faintly stratified. The quartzite is pure white and sugary on freshly broken surfaces, and weathers dark yellowish brown or in places lavender brown. In thin-section the bedding is indicated by an indistinct alternation of medium- or coarse-grained subrounded quartz sand with layers of fine-grained quartz sand. The only allothigenic grains present in addition to the quartz are rare small rounded zircon crystals which also occur as inclusions in some of quartz grains. Authigenic overgrowths on the quartz grains are uncommon and, where visible, appear to be rounded, indicating an origin during a previous sedimentary cycle. The cement is predominantly microcrystalline quartz with some interstitial sericite, which probably represents original clay minerals. The boundaries between adjoining quartz grains are often sutured or "pressure welded," and most grains show strain shadows. These features and the presence of sericite indicate that the rock has undergone a low grade of metamorphism though a schistose texture has not been developed.

Locally, the quartzite becomes pebbly with a markedly poorer degree of sorting and with an increase in the amount of very fine-grained sand and silt composed of quartz. The amount of interstitial sericite and ferric oxides also increases, and the rock assumes a buff or lavender color on fresh surfaces in contrast with the white color of the pure quartzite. The coarse-grained detrital material is exclusively gray or pink chert granules and pebbles ranging in diameter from 2 to 20 millimeters. Under the microscope the boundaries of the chert grains are indistinct, the microcrystalline silica of the chert being more or less continuous with the cementing material. The rock type in the southeastern part of the area of outcrop, which may represent the top of the exposed section, is distinct from the typical quartzite of this unit and can be best described as a slightly metamorphosed pebbly and argillaceous quartzose fine-grained sandstone or siltstone.

Any attempt at correlating the Cambrian(?) dolomite and quartzite units of the Union district with the Paleozoic rocks of nearby areas is necessarily speculative. In addition to the absence of a means of assigning a definite age to these units, the problem of correlation is complicated by the lack of knowledge concerning the stratigraphic relationship between them. The field relations are not sufficient to establish whether or not their mutual contact is a depositional one, and the relative top and bottom of the section cannot be determined with certainty.

The distinctive lithologic character of the quartzite is the basis for tentatively assigning both the quartzite and the dolomite units to the Cambrian. Among the quartzitic formational units recognized in the Paleozoic section of the Great Basin, the quartzite unit is lithologically most similar to the Prospect Mountain quartzite of Early Cambrian age. The type locality of this formation is in the Eureka district approximately 100 miles northeast of the Union district. The Prospect Mountain has also been recognized throughout a large area in the eastern and southern part of the Great Basin region. Among the distinctive features of the Prospect Mountain quartzite which are also characteristic of the quartzite unit in the Union district are the thickness, the prevalent brownish and pinkish colors of weathered surfaces, the local relatively high content of argillaceous and ferruginous material in the cement, and the variable grain size with the presence of pebbly and conglomeratic beds. These features serve to distinguish the Prospect Mountain quartzite from the Eureka quartzite of Ordovician age and the Oxyoke Canyon member of the Nevada formation of Devonian age (C. W. Merriam, oral communication, 1954).

The quartzite in the Union district may be equivalent to part of the Gold Hill formation of Cambrian age described by Ferguson (1924) and Ferguson and Cathcart (1954) from the Toquima and Toiyabe Ranges. At Summit Creek, in the Toiyabe Range, the exposed section of the Gold Hill formation contains a higher proportion of quartzite than exposures farther south in the Toiyabe Range and in the Manhattan district and includes continuous sections of siliceous sedimentary rocks comparable in thickness to the quartzite unit in the Union district (H. G. Ferguson, written communication, 1956).

The dolomite unit in the Union district is also tentatively assigned to the Cambrian because of its apparent depositional relationship to the quartzite unit, but no obvious counterpart of the dolomite unit is present among the lower Paleozoic rocks of nearby areas. If the dolomite unit had originally overlain the quartzite unit, its stratigraphic position would be comparable to that of the dolomitic limestone beds in the upper part of the Gold Hill formation in the Toiyabe and Toquima Ranges (Ferguson and Cathcart, 1954) or that of the Eldorado dolomite of Cambrian age in the Eureka district which is separated from the underlying Prospect Mountain quartzite only by the relatively thin Pioche shale of Cambrian age. The possibility also exists that the so-called Cambrian(?) dolomite unit in the Union district is actually a down-faulted block of the carbonate member of the Luning formation of Late Triassic age to which the dolomite unit is lithologically similar if one interprets the infrequent quartzite lenses within it as fault slivers.

PABLO FORMATION (PERMIAN?)

A unit composed of greenstone, clastic, and tuffaceous sedimentary rocks and limestone of Permian(?) age forms the major share of the pre-Tertiary rocks that crop out north of Berlin Canyon. Greenstone beds belonging to this unit are also exposed along the western slope of Richmond Hill between West Union and Grantsville Canyons. This unit is correlated with the Pablo formation (Ferguson and Cathcart, 1954), the type locality of which is on the east side of the Toiyabe Range. The clastic sedimentary rocks, which, together with some greenstone beds, occupy a small erosional window in the Tertiary volcanic rocks about 4 miles northeast of Ione and another similar area several miles north of Ione, probably represent the lower part of the Pablo formation.

The Pablo formation has been divided into three cartographic units or informal members in the Union district. Listed in ascending order they are the clastic member, composed of stratified coarse- and fine-grained sedimentary rocks, largely volcanic debris and having a thickness in excess of 1,200 feet; the limestone member, whose thickness is variable but not more than 250 feet; and the greenstone member, composed of altered andesitic flows and volcanic breccias with a subordinate amount of clastic sedimentary rocks and with a total thickness of at least 1,000 feet but probably not exceeding 2,000 feet. The best exposed and least altered section of the clastic and limestone members forms the south wall of Knickerbocker Wash, but at this locality the section of the greenstone member is probably broken by faulting.

The base of the Pablo formation is not exposed in the Union district, and its relationship to the Cambrian(?) quartzite and dolomite units exposed east of Ione is not known. Structural complexities, combined with the homogeneous and unstratified nature of the greenstone member, preclude recognition of any variation in thickness of the Pablo formation owing to warping and erosion before deposition of the Middle Triassic Grantsville formation, which overlies the greenstone with little, if any, angular discordance. The contact between the Grantsville formation and the greenstone was reported by Ferguson and Muller (1949, p. 8, 41) to be an angular unconformity, and a period of pre-Middle Triassic folding in the Shoshone Mountains area was hypothesized. The results of detailed mapping do not bear out this supposed relationship.

LITHOLOGIC CHARACTER

The clastic member of the Pablo formation consists dominantly of volcanic material in the form of altered flows, tuffs, and clastic debris with a minor proportion of terrigenous sediment. Nevertheless, the term "clastic" serves well to distinguish this member from the younger greenstone member in which volcanic material predominates nearly to the exclusion of sediments. The relative proportions of the different rock types, which compose the clastic member in the vicinity of Knickerbocker Canyon, are approximately as follows:

Volcanic rocks (andesitic flows and tuffs of intermediate composition) ---percent--	45
Fine-grained clastic sedimentary desposits (tuffaceous argillite and sandstone with an abundance of volcanic debris) ---percent--	40
Coarse-grained clastic rocks (pebble and cobble conglomerates with clastic and volcanic matrices) ---percent--	15

These rock types form units of uniform lithology which usually do not exceed several tens of feet in thickness and which alternate and grade into one another at random throughout the section. The lithologic character of the clastic member is somewhat variable laterally, though its interstratified and heterogeneous nature is characteristic wherever it is exposed. The total thickness of the clastic member is not known, although approximately 1,150 feet of section is exposed along the south wall of Knickerbocker Canyon. These rocks have undergone a low degree of regional metamorphism, so that the finer grained rocks are commonly slaty, the matrix of the coarser clastic rocks contains abundant chlorite, and the interbedded andesitic flows are altered to greenstone.

None of the clastic sedimentary rocks are entirely free of volcanic material. The sandstone and tuffaceous argillite beds are generally dark gray or grayish green and are thinly interbedded, representing an alternation between the deposition of dominantly tuffaceous material and of clastic material largely of volcanic origin. In thin section the finer grained tuffaceous rocks are usually microscopically foliated aggregates of microcrystalline quartz and sericite with a variable amount of calcite and detrital plagioclase crystals, quartz, chert, and volcanic rock fragments. The bedding planes are commonly marked by a concentration of clastic grains, calcite pseudomorphs after plagioclase crystals, or layers relatively rich in ferric oxides. In hand specimen, a few of these rocks show elongate light-colored patches, which are oriented parallel to the stratification, suggesting crushed tuff lapilli.

With an increase in the amount of clastic material, these tuffaceous rocks grade into sandstone beds composed largely of material derived from intermediate or basic volcanic rocks that were probably deposited more or less contemporaneously with the sediment. The predominant clastic constituent of the sandstones consists of somewhat altered plagioclase crystals, which are secondarily albitic in composition, with the attendant development of calcite and minerals of the epidote group. Angular to subrounded grains of quartz, chert, and basic volcanic rock fragments make up the remainder of the clastic material. The matrix usually consists of a mixture of microcrystalline quartz and sericite with an abundance of opaque material and a variable amount of calcite and pale-green chlorite that has a striking anomalous blue extinction. The sandstone beds and finer grained tuffaceous sedimentary rocks are generally well stratified and moderately well sorted, indicating a subaqueous deposition.

Massive and very thick-bedded conglomerate units attaining thicknesses of several tens of feet occur at several horizons in the clastic member of the Pablo formation. Thinner conglomeratic units are locally present within the sandy and tuffaceous beds. The occurrence of abundant pebbles and cobbles of granitic igneous rocks is a significant feature in the conglomerate. Various compositions and textures of granitic rocks are represented and this coarse clastic material was evidently derived from a nearby plutonic complex. As these pebbles have been exposed to weathering both before and after they were subjected to a low grade of regional metamorphism, they are found in various stages of alteration, but some of them are sufficiently unaltered to permit recognition of their original lithology in thin section. Perhaps the most common intrusive rock represented is a porphyritic coarse-grained quartz-bearing granitic rock of granodioritic or quartz-monzonitic composition with large euhedral phenocrysts of potassic feldspar (microcline in part) set in a matrix of sodic plagioclase, quartz, and potassic feldspar. The original mafic mineral was biotite, which is usually almost entirely altered to chlorite. The provenance of these pebbles is a matter of speculation, though the possibility exists that granitic intrusions of Paleozoic age are present in central Nevada and that they may have been exposed to erosion during late Paleozoic time.

The coarsely porphyritic microcline granite described by Ferguson and Cathcart (1954) from the southern part of the Toquima Range (approximately 35 miles southeast from the exposures of the Pablo formation in the Union district) can be geologically dated only as post-Ordovician. This particular granitic intrusive rock, which bears a striking lithologic resemblance to the cobbles and pebbles described above, intrudes sedimentary rocks of Cambrian and Ordovician age but is not in contact with younger Paleozoic or Mesozoic rocks. In the Toiyabe Range, between the Toquima Range and the Shoshone Mountains, Cambrian and Ordovician strata are metamorphosed into mica schist and related rocks, and yet they are overlain with a pronounced angular discordance by only slightly metamorphosed sedimentary rocks of Permian age. This indicates deformation and metamorphism during the Paleozoic which could have been accompanied by granitic intrusions. Corals collected by C. W. Merriam and the writer from limestone pebbles and cobbles in the Permian Diablo formation at Jett Canyon in the Toiyabe Range include *Caninia*-like forms and *Triplophyllites*? of probable early Carboniferous age (C. W. Merriam, oral communication). These allochthonous fossils show that sediments derived from rocks of this age are represented in the Permian conglomerates, as well as coarse-grained detritus from the unconformably underlying Palmetto formation of Ordovician age. The age of these coarse-grained carbonate clastic rocks in the Diablo formation is significant in that a period of high topographic relief, representing a part of the post-Ordovician pre-Permian orogenic cycle which affected this area, can be tentatively dated as post-early Carboniferous.

The Paleozoic orogeny recognized in the Toquima and Toiyabe Ranges is probably related to the Antler orogeny described by Roberts (1949, 1951). This orogeny affected the Mississippian and older rocks of north-central Nevada before the Middle Pennsylvanian (R. J. Roberts, oral communication, 1956), although where the effects of the Antler orogeny have been recognized granitic intrusive rocks have not been associated with it. It is not the present author's intention to imply that the granitic pebbles and cobbles occurring in the Permian(?) rocks of the Shoshone Mountains were derived from the intrusive rocks now exposed in the Toquima Range but rather that there may have been Paleozoic granitic rocks in central Nevada which were the source of upper Paleozoic sediments.

In addition to the pebbles and cobbles of granitic rocks, the conglomerate units of the clastic member of the Pablo formation in the Union district contain a variety of other rock types. Moderately well-rounded cobbles of altered mafic volcanic rocks, which were probably derived from parts of the Pablo formation deposited earlier, are fairly abundant and locally predominate in thin, lenticular, conglomeratic beds. Chert pebbles are found everywhere in subordinate amounts throughout most of the coarse-grained clastic rocks; and a few sugary gray limestone cobbles, which are usually tabular, are present. The matrix of the massive conglomerate beds is usually a greenish-gray sandstone composed largely of volcanic debris.

Three andestitic flows, in the clastic member of the Pablo formation, the largest of which is about 100 feet thick, are recognized in the section along the south wall of Knickerbocker Canyon. The original texture of the rocks in these flows is usually preserved and appears to be that of a porphyritic, pilotaxitic andesite; however, the constituent minerals have been altered, so that the original plagioclase crystals are now albitic and partly replaced by calcite and the original ferromagnesian minerals are represented by chlorite and ferric oxides. A few hundred feet below the top of the clastic member in Knickerbocker Canyon a light-colored, aphanitic poorly stratified rock with a thickness of approximately 200 feet is present. This nondescript rock, which is composed of roughly equal amounts of microcrystalline quartz and calcite with a few crystals of plagioclase, may represent an original felsitic lava.

The abundance of relatively unstable minerals in the volcanic sedimentary rocks of the clastic member of the Pablo formation make this unit particularly susceptible to hydrothermal alteration. In the vicinity of the Good Luck mine, the original lithology of the clastic member cannot be recognized, owing to hydrothermal alteration. Here the rocks are uniformly dense and generally brown and have no megascopically visible textures or mineral grains except limonite pseudomorphs after secondary pyrite. An extensive aureole of tourmalinization surrounds a small granitic intrusive body on the south wall of Buffalo Canyon near its mouth, and crystals of schorlite are found along fractures in the volcanic sediments of the clastic member for a distance of half a mile south of Buffalo Canyon.

The contact between the clastic member and the overlying limestone member is gradational and interlensing. Thin lenticular bodies of brownish-gray impure limestone occur within the clastic member and a hundred feet or more beneath the main limestone body, and numerous lenses of greenish-gray banded cherty tuff and volcanic sandstone occur within the limestone member. In the vicinity of Knickerbocker Canyon, the basal beds of the limestone member contain abundant fragments of andesite.

The limestone is characteristically thick bedded, finely crystalline, and gray or buff, but locally it is impure and thin bedded. In the upper part, the limestone commonly has a mottled appearance that is caused by roughly equidimensional areas of gray approximately one-half an inch in length surrounded by buff limestone. In places these gray spots grade into recognizable fossils of the brachiopod genus *Composita*, and hence the mottled appearance is in part a primary feature. Locally, the limestone is bioclastic—composed largely of recrystallized and generally unidentifiable shell fragments. The thickness of the limestone member is usually about 200 feet. In some sections, tuffaceous, sandy, and conglomeratic lenses constitute about half of the total thickness. The occurrence of brachiopods in the limestone member indicates a marine environment, and the presence of bioclastic material points to shallow-water deposition.

The clastic and limestone members of the Pablo formation are thought to represent the recurrent rapid deposition in a shallow marine basin of primary volcanic tuffs and flows, reworked volcanic material, and clastic debris eroded from a nearby terrain of volcanic, granitic, and sedimentary rocks. At times the deposition of volcanic material was rapid enough to "flood out" the available terrigenous detritus and at other times the situation was reversed, producing a heterogeneous mixture of volcanic, terrigenous, bioclastic, and chemical sediments.

The upper contact of the limestone member with the overlying greenstone member is locally channeled, and the channels are filled with conglomeratic material originally of andesitic composition and lithologically similar to the basal part of the greenstone unit. Locally the upper few feet of the limestone are fragmental, forming an intraformational conglomerate of platy light-colored limestone fragments in a matrix of dense greenish-gray silicified limestone. On the north side of Buffalo Canyon structural features resembling pillow lavas occur in the greenstone member at its contact with the limestone.

The greenstone member of the Pablo formation, which is composed almost entirely of altered andesitic lavas and volcanic breccias, has a thickness of at least 1,000 feet, although the exact thickness is unknown because the homogeneous character of this unit and the absence of stratigraphic markers make it impossible to detect repetition or omission of the section that might be due to faulting. As the upper contact of the greenstone member with the Grantsville formation is an erosional disconformity, the thickness of the greenstone may be variable from place to place. The upper and lower parts of the greenstone can be distinquished by the greater amount of andesitic volcanic breccias present in the upper part, whereas sandy and pebbly beds are usually restricted to the basal part. However, water-worn pebbles and cobbles of chert, granitic rocks, and volcanic rocks occur sporadically throughout the greenstone member.

The greenstone is uniformly dark, with either a purplish or greenish tinge. Most thin sections show the remnants of an andesitic texture although the effects of local hydrothermal alteration superimposed on a low-grade regional metamorphism have changed the original mineralogy. Universal-stage measurements made on plagioclase phenocrysts of the andesitic greenstone from several different localities indicated compositions ranging from 2 to 5 percent of anorthite. The original ferromagnesian minerals are seldom preserved although a distinctive flow at about the middle of the unit contains conspicuous phenocrysts of only slightly altered hornblende. In the mineralized areas, such as in the vicinity of the Berlin mine and on the north side of Grantsville Canyon, the andesite is propylitized with the attendent formation of abundant calcite, minerals of the epidote group, chlorite, and ferric oxides.

The greenstone member of the Pablo formation forms the country rock for some of the more important mines in the area. Quartz veins carrying a small amount of free gold and various metallic sulfides, which are in part argentiferous, are the typical ore deposits present in the greenstone. These veins have been mined at the Berlin and Richmond mines and in the eastern part of the Shamrock diggings, where they occur within a dioritic intrusive rock as well as in the greenstone.

AGE AND CORRELATION

The only recognizable fossils obtained from the Pablo formation in the Union district occur in the limestone member and consist of poorly preserved and distorted brachiopods of the genus *Composita*, pelecypods tentatively referred to the genus *Schizodus*, and fragments of a small pectenoid pelecypod. These fossils suggest a late Paleozoic age for this part of the Pablo.

At its type locality on the east side of the Toiyabe Range, the Pablo formation consists of altered andesitic lavas and breccias, cherts interpreted as altered tuffs, and subordinate volcanic and terrigenous clastic sedimentary rocks. The Pablo in the Toiyabe Range gradationally overlies the dominantly conglomeratic Diablo formation from which a Permian fauna common to the Phosphoria formation is reported (Ferguson and Cathcart, 1954). Volcanic rocks are present only in the upper part of the Diablo that is transitional into the Pablo formation.

The exposures of the Pablo formation in the Union district, part of which can be dated as probable pre-Mesozoic, agree in lithologic composition with those in the Toiyabe Range where the Pablo overlies strata of known Permian age. These relationships strongly suggest a Permian age for the Pablo in the Union district. Nevertheless, correlations based on volcanic and coarse clastic rocks are of doubtful reliability, and the Pablo in the Union district could be correlative with both the Pablo and Diablo of the Toiyabe Range and include older rocks as well. Likewise, the Pablo in the Toiyabe Range and the upper part of the section in the Union district could conceivably extend into the Lower Triassic. For these reasons the Pablo in the Union district is only tentatively assigned to Permian.

The sequence of altered andesitic volcanic and sedimentary rocks which outcrop in the Paradise Range in the vicinity of Ellsworth are considered to be part of the Pablo formation. Here, as in the Shoshone Mountains, a thin limestone unit divides an overlying thick and more or less uniform section composed primarily of andesitic lavas and breccias from an underlying equally thick section of stratified volcanic, tuffaceous, and clastic sedimentary rocks.

The Pablo formation in the Toiyabe Range and the Darrough felsite, which is intrusive into the Pablo, are cited by Ferguson and Cathcart (1954) as possible equivalents of the Koipato formation. The volcanic rocks of the Koipato in the Humboldt Range are considered to be Permian in age on the basis of a *Helicoprion* found in them (Wheeler, 1937, p. 394; 1939, p. 107), and in the Sonoma Range quadrangle they are bracketed between rocks of early Permian and late Early Triassic age (Muller, Ferguson, and Roberts, 1951). The pre-Tertiary volcanic rocks of the Paradise Range, assigned here to the Pablo formation, have previously been compared to the Koipato formation by Wheeler (1939, p. 109).

GRANTSVILLE FORMATION (MIDDLE TRIASSIC)

The name Grantsville formation was proposed by Muller and Ferguson (1939, p. 1592) for the oldest clastic and carbonate sedimentary rocks of Mesozoic age present in the Shoshone Mountains. The discussion of this stratigraphic unit in the Union district by these authors in their report on the Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles is quite complete in as much as the only known area of outcrop for the Grantsville formation is in the Shoshone Mountains. The name of this unit is derived from the mining camp near the mouth of Grantsville Canyon. It is particularly appropriate since nearly the entire production at Grantsville was from pyrometasomatic ore deposits situated in the limestone member of the Grantsville formation.

The Grantsville formation is divided into two members. The lower member, referred to here as the clastic member, is composed of siliceous conglomerates and silty and sandy argillites. The upper member is predominantly limestone with a subordinate amount of shaly intercalations.

The type section of the Grantsville, as designated by Muller and Ferguson, is along the crest of the spur between Union Canyon and Berlin Canyon. Although the best exposed section in the area is at the type locality, the Grantsville formation crops out at the expected stratigraphic position in a discontinuous belt between Sheep Canyon and Grantsville Canyon. On the east flank of the Shoshone Mountains immediately east of Grantsville Summit, a small area of about one-half of a square mile, surrounded by Tertiary volcanic rocks and alluvium, is occupied by conglomerate and argillite beds overlain by contact-metamorphosed and altered limestone beds, all of which are assigned to the Grantsville formation on the basis of lithology. The possibility that rocks belonging to the Grantsville formation might be present in the vicinity of Germany Canyon in the northwestern part of the Paradise Range is mentioned by Muller and Ferguson (1939, p. 1592), but these rocks appear to represent part of the Pablo formation.

The clastic member of the Grantsville formation overlies the greenstone member of the Pablo formation with erosional disconformity but little if any angular discordance. The upper contact of the Grantsville formation is also an erosional disconformity, with only minor angular discordance between the limestone member and the overlying clastic member of the Luning formation.

LITHOLOGIC CHARACTER

The lithologic description of the Grantsville formation is based primarily on the section measured at the type locality, and despite local variation, the general sequence was the same wherever observed. The lower, or clastic member, consists of approximately equal amounts of conglomerate and slightly metamorphosed silty argillite with a progressive decrease in the grain size of the clastic sedimentary rocks towards the top of the member. At the type locality the clastic member has a thickness of about 400 feet. All of the clastic sedimentary rocks reflect a low grade of regional metamorphism, so that the original clay minerals of the argillites and the interstitial clayey material of the conglomerates have been recrystallized into sericite and microcrystalline quartz. The term "argillite" is used in this report for slightly metamorphosed and well-indurated claystones that lack slaty cleavage. The designation as the clastic member rather than the conglomerate member as used by Muller and Ferguson seems preferable because coarse-grained clastic rocks are restricted to the lower half of the member and do not characterize the entire section.

The basal beds of the clastic member of the Grantsville are typically dark-purple silty argillite. At the type locality the thickness of these basal beds is about 30 feet, though locally they are somewhat thinner or even absent. Similar purplish argillite also occurs in beds several feet in thickness and interbedded with siliceous conglomerate throughout the basal 100 feet of section. The purplish argillite is typically thick bedded and weathers into parting units of thin or medium thickness. The principal constituent, which composes about 75 percent of this altered argillite, is a fine-grained crudely foliated aggregate of sericite and microcrystalline quartz with an abundance of finely disseminated opaque material. Additional constituents are detrital quartz silt, which accounts for approximately 20 percent of the total volume, and the alteration products of other detrital material. Ragged patches of greenish chlorite constitute 5 or 10 percent of the rock. In thin section a specimen of the basal purple argillite from a sheared fault sliver in Grantsville Canyon shows a well-defined schistosity which parallels the surface of elliptical areas composed of calcite, chlorite, and sericite. These bodies, as much as several millimeters in diameter, are evidently a primary feature of the rock and are interpreted as altered clastic material—possibly volcanic rock fragments. The derivation of the basal purple argillite of the Grantsville formation from the volcanic rocks of the underlying Pablo formation, as suggested by Muller and Ferguson, seems reasonable because of the presence of chlorite and the abundance of fine-grained opaque material. However, no recognizable minerals or rock fragments of volcanic origin have been preserved.

Overlying the basal argillite are massive siliceous pebble conglomerate beds, which are restricted at the type locality to the lower 200 feet of the section. As mentioned above, purple argillite beds similar to the basal beds are interbedded with the conglomerate beds near their base. In the upper part of the conglomerate beds, these interbeds of purplish argillite are supplanted by a few thin beds of brownish silty argillite and chert sandstone. In the type section the thickest continuous section of conglomerate, uninterrupted by interbedded fine-grained sedimentary rocks is about 75 feet thick. The conglomerate is very thick bedded and poorly sorted, forming prominent blocky outcrops that weather dark reddish brown. The pebbles, which average about 1 inch in diameter, are exclusively of gray or grayish-brown chert. The largest of the chert cobbles are seldom over 3 inches in diameter. Many of the chert pebbles contain an appreciable amount of sericite in a roughly foliated arrangement similar to that of the fine-grained siliceous rocks in the Pablo formation that are interpreted as being altered volcanic tuffs. The matrix of the pebbles is a gritty chert sandstone with a small amount of sericitic interstitial material.

Above the uppermost conglomeratic beds, approximately 200 feet above the base of the section, and extending upward to the base of the limestone member is a continuous section of brownish silty and sandy argillite which at the type locality has a thickness of 200 feet. The composition of this argillite is similar to that of the basal argillaceous beds with a decrease in the amount of sparsely disseminated opaque material and an increase in the amount of detrital silt and sand. The silt comprises both quartz and chert, whereas the sand is almost exclusively chert. Like the basal argillite, these sediments are massive and thick bedded and weather at the surface into parting units of thin or medium thickness. Most of the silty and sandy argillite units are poorly stratified and separated into beds several feet in thickness by variations in the grain size of the quartz and chert detritus. A few thin sections taken from the lower part of the argillaceous beds show a sharply defined stratification, on a microscopic scale, that is due to an alternation of layers of silt and sand. Near the top of the clastic member, the amount of silt and sand decreases, and the typically massive argillite beds grade into a dark-greenish-gray finely fractured slate.

The limestone member of the Grantsville formation at the type locality has a thickness of 350 feet, but this section includes an igneous sill that accounts for approximately 60 feet of the total measurement. The thickness of the limestone member appears to decrease southward from the type locality towards Grantsville Canyon. This is most easily explained by postulating the existence of a small amount of angular discordance between the Grantsville formation and the disconformably overlying Luning formation. Locally, a marked channeling of the upper surface of the limestone member of the Grantsville can be observed; this could account for a considerable variation in the thickness of section.

The basal limestone beds are transitional with the argillites and slates of the underlying clastic member. The lower 60 feet of the limestone is argillaceous, silty, and sandy; thin and medium bedded; and weathers to a yellowish brown. Above these impure basal beds the limestone contains no terrigenous clastic material of silt or coarser grain size, and this transition evidently represents a continuing transgression of the sea. The middle and upper parts of the limestone are predominantly gray both on fresh and weathered surfaces and medium to very thickly bedded. Thin intercalations of dark-gray and greenish-gray slate are abundant in the lower part of the limestone member and become less abundant higher in the section. Shell fragments of marine mollusks are abundant throughout, and locally, particularly near the base, the limestone is bioclastic. In spite of the abundance of organic debris, well-preserved fossils are scarce. Some of the best fossils were obtained from the body chambers of large coiled nautiloid shells which occur rarely in the middle part of the limestone.

In the upper 100 feet of the section, the limestone becomes very massive and thick bedded and contains a few nodules of black chert that average about 2 inches in diameter. The uppermost part of the limestone, generally 20 feet or less in thickness, is characteristically fragmental and silicified, forming a dark-brown cherty breccia. This part of the section also exhibits cavernous weathering in some places. Several prospect pits, which were no doubt a disappointment to some hopeful prospector, were noticed in these silicified limestones. In view of the fact that the Luning formation overlies the limestone member of the Grantsville with erosional discordance, this broken and silicified material is interpreted as being of regolithic origin, as suggested by Muller and Ferguson (1939, p. 1593).

Although not sedimentary in origin, a characteristic feature of the limestone member of the Grantsville is a sill of distinctive lithology which is generally found in the middle part of this unit or, more rarely, near the top. This sill is sporadically present in the various fault segments of the limestone member from Sheep Canyon south to Richmond Hill, a distance of nearly 4½ miles, and yet no similar sills or dikes have been observed intruding any of the other pre-Tertiary formations in the area. Although these sills are not always present in the limestone member, some of them can be traced along the strike for several hundred feet and attain a maximum thickness of about 60 feet. In hand specimen the rock composing these sills is usually of a uniform buff and breaks with an uneven fracture like that of a granitic rock. However, none of the component minerals are megascopically recognizable with the exception of muscovite plates up to several millimeters in diameter. As seen in thin section, the original lithologic character usually has been considerably altered, so that the rock consists of a mosaic of ragged quartz crystals, which are clouded by abundant minute inclusion of sericite and opaque material, with an occasional flake of muscovite. At some localities alteration was less intense, and the original granitic texture and mineralogy has been partly preserved. The mineralogy suggests an original granodioritic composition with oligoclase in excess of the amount of potassium feldspar. Other constituents include a small amount of primary quartz, platy aggregates of sericite and iron oxides which suggest original biotite crystals, and abundant accessory apatite. The limestone of the Grantsville formation shows little effect of contact with the sill. A thin section of the limestone from only several inches above the upper contact of the sill contains no silicate minerals and little recrystallized limestone, so that the morphologic details of the included fossil-shell fragments are still well preserved.

The limestone member of the Grantsville Formation shows a propensity for mineralization by hydrothermal solutions, and from an economic standpoint it is the most important pre-Tertiary unit in the area. The contact ore deposits of silver, lead, and zinc at Grantsville were formed by the selective mineralization of this limestone by an igneous intrusive rock which is not exposed at the surface. A small amount of scheelite is also present in the Grantsville ore. A silicate skarn surrounds a small, dominantly dioritic intrusive rock in the limestone of the Grantsville exposed east of Grantsville Summit, though no contact ore mineralization is apparent at this locality. The principal ore bodies of the Mercury Mining Co. mine at the head of Shamrock Canyon, which produced several thousand flasks of quicksilver from two large glory-hole operations, were situated in the Grantsville limestone. Along the west front of the range, on either side of the mouth of West Union Canyon, fluorite mineralization is concentrated in the limestone member of the Grantsville. Fluorite occurs along the faults of both the northward-trending frontal range system and the northwestward-trending Union Canyon system where they transect the limestone. Fluorite also occurs as a replacement in the limestone, especially near the top of the unit where it is capped by the impervious siliceous conglomerates of the Luning formation. Similar occurrences of fluorite are also present on the west slope of Richmond Hill.

AGE AND CORRELATION

The fossils collected from the limestone member of the Grantsville formation are exclusively marine mollusks and spiriferid brachiopods including the following species:

Ceratites cf. *C. dorsoplanus* Philippi
  cf. *C. flexuosus* Philippi
  cf. *C. semipartitus* Montfort
Protrachyceras sp.
Germanonautilus cf. *G. bidorsatus* (Schlotheim)
Myophoria cf. *M. laevigata* Ziethen
Hoernesia cf. *H. socialis* (Schlotheim)
  aff. *H. joannis-austriae* (Klipstein)
Gervilleia cf. *G. incurvata* Lepsius
Edentula cf. *E. castelli* Wittenburg
Pecten (*Velopecten*) *albertii* Goldfuss
"*Pecten*" sp.
Spiriferina sp.

None of these forms are particularly abundant, owing largely to the type of preservation, and some sections are devoid of recognizable fossils. No stratigraphic separation of the various elements of the fauna is apparent, though, some of the forms are more commonly found in either the basal impure limestone beds or in the dominantly calcareous upper part of the limestone member. Perhaps the most common species above the basal beds is *Pecten* (*Velopecten*) *albertii*, which occurs with another indeterminate "*Pecten*" and *Myophoria* cf. *M. laevigata.* Lower in the section these forms are largely supplanted by an unidentified concavo-convex radially ribbed oysterlike pelecypod associated with occasional spiriferoids and fragments of *Hoernesia.* The best represented of the cephalopods are *Ceratites* cf. *C. flexuosus* and *C.* cf. *C. dorsoplanus*, of each of which only about half a dozen fragmentary specimens are in the available collections. Two or three specimens are assigned to *Ceratites* cf. *C. semipartitus* Monfort because their venters are more narrowly truncate than those of the specimens compared with *Ceratites dorsoplanus*, although not quite as narrow as those of the typical members of *Ceratites semipartitus.*

The species listed above are approximately the same as those listed by Muller and Ferguson (1939, p. 1593); the most important addition is the genus *Protrachyceras*, which is indicative of a late Middle Triassic or younger age. Three specimens that can be assigned to this genus despite their poor preservation were collected near the base of the limestone member in the type section.

The Grantsville fauna is not comparable to any Triassic assemblage reported from North America, as Muller and Ferguson have previously pointed out, and yet most of the forms recognized can be compared to species present in the Muschelkalk of Germany. The species of *Ceratites* recognized are restricted to the upper Muschelkalk, whereas *Pecten albertii*, *Hoernesia socialis*, and *Germanonautilus bidorsatus* range through the Muschelkalk. Although *Myophoria laevigata* typically occurs in the upper part of the German Lower Triassic, Diener (1925, p. 37) extends its range from the Röth (late Early Triassic) to the Grenzdolomit (Late Triassic). Two of the species to which the Grantsville forms are compared, *Gervilleia incurvata* and *Edentula castelli*, are recorded only from the upper part of the Tyrolian Lower Triassic, but the stratigraphic value of these species is questionable. In addition to *Hoernesia* cf. *H. socialis*, a strongly ridged *Hoernesia* is present that shows some resemblance to *H. joannis-austriae*, from the lower Upper Triassic of the Alps.

The elements of this fauna which might be expected to be the most restricted stratigraphically, particularly the ammonoids, indicate a Ladinian or late Middle Triassic age. This assignment is somewhat younger than that given by Muller and Ferguson (1939, p. 1593–4), who tentatively regarded the Grantsville fauna as of early Middle Triassic age because of the association of Campil (lower Triassic) species with the preponderant Muschelkalk species.

The Augusta Mountain formation in the New Pass Range, about 50 miles north of the Union district, includes marine sedimentary rocks correlative with the Grantsville formation. The lower part of the Augusta Mountain formation, the part that overlies the *Ceratites trinodosus* zone (upper Anisian) and is overlain by strata containing *Trachyceras* s. s. (lowest Karnian), is composed of about 1,600 feet of massive algal and coralline limestone with some conglomeratic and sandy beds near the base. Except for the colonial corals, the fauna of this "reeflike" section is impoverished and restricted to only a few beds, in which a large species of *Gervilleia* is fairly common associated with occasional nautiloids and species of *Protrachyceras.* The Middle Triassic is completely represented by marine strata in the New Pass Range; hence, this section may have been deposited seaward from the site of deposition of the Grantsville formation, where marine transgression and sedimentation did not commence until well after the beginning of the Middle Triassic. The occurrence of seaward reefs contemporaneous with the deposition of the Grantsville formation might have affected its depositional environment and may in part provide an explanation for the abnormal or "Germanic" character of its fauna.

An approximate correlation of the Grantsville with the Excelsior formation, or, more precisely, with the strata referred to the Excelsior that compose the upper plate of the Gillis thrust in the northwestern Gillis Range, has been suggested by Muller and Ferguson (1939, p. 1594). This correlation is based on a fauna which also shows a resemblance to that of the German Muschelkalk, although only the indefinitely identified species referred to *Hoernesia socialis* is common to both the so-called Excelsior of the Gillis Range and the Grantsville formation. As pointed out by Muller and Ferguson (1939, p. 1588), the age of the Excelsior at other localities, including the type area, is uncertain; and some exposures of the Excelsior may be correlative with the Pablo formation of Permian(?) age.

The beginning of deposition of the Grantsville formation in the Union district can be approximately dated as middle Middle or late Middle Triassic, but the duration of this period of marine sedimentation is indeterminate because the upper limit of the formation is truncated by an erosional disconformity. The oldest beds of the overlying Luning formation are of late Karnian age, and no sedimentary record of the early and middle Karnian is available in the area. Consequently, the Grantsville formation may have originally extended well into the Karnian, and its upper part may have been removed by erosion before deposition of the Luning formation. In this respect the Grantsville formation might be considered the result of a marine transgression preliminary to the prolonged Late Triassic and Early Jurassic transgression that began with the deposition of the Luning formation.

LUNING FORMATION (UPPER TRIASSIC)

The Luning formation constitutes most of the Triassic section in the Union district. Approximately 3,000 feet of Luning is exposed in the vicinity of West Union Canyon where the top of the section is obscured by Tertiary volcanic rocks. This section is considered here as continuous, but in the interpretation by Ferguson and Muller (1949, pl. 13), it is broken by a northern segment of the Shoshone thrust. According to these authors, the Upper Triassic section north of the Union Canyon fault includes two different facies of the Luning, brought together by the supposed thrust, as well as several hundred feet of Gabbs formation overlying the Luning in the lower plate of the thrust. Although the available evidence does not disprove the presence of this thrust, neither the age relations of the faunas above and below its supposed position nor the structural features within the section necessitate its existence. Furthermore, lithic correlation with the typical exposures of the Luning to the southwest and the paleogeographic interpretation of the Luning basin is enhanced if these strata in the Union district are assigned to a single continuous section of the Luning formation.

Four informal members of the Luning formation in the Union district are recognized in this report. From the base upward they are the clastic member, composed of coarse- and fine-grained noncalcareous sediments with a thickness of 550–650 feet; the shaly limestone member, also about 600 feet thick; the calcareous shale member, about 550 feet thick; and the carbonate member, with an exposed thickness of at least 2,000 feet. These members of the Luning more or less correspond respectively to the "slate and conglomerate member of the lower-plate facies of the Luning," the "limestone member of the lower-plate facies of the Luning," the "Gabbs formation," and the "upper-plate facies of the Luning formation" in the interpretation of Ferguson and Muller (1949, pl. 13).

The clastic member of the Luning overlies the Grantsville formation with erosional disconformity but with little, if any, angular discordance. The upper contact of the Luning is not exposed in the Union district. North of Grantsville Canyon the upper part of the section is either covered by Tertiary volcanic rocks or cut out by faulting. To the south the carbonate member of the Luning formation, the youngest member recognized, is thrust over the undifferentiated Gabbs and Sunrise formations.

LITHOLOGIC CHARACTER

The Luning formation deposited at this particular site represents a marine transgression accompanied by a more or less continuous progression of sedimentary processes. Commencing with conglomerate beds at the base of the section, the detrital sedimentary rocks become increasingly finer grained towards the top of the clastic member and ultimately grade into the impure limestones of the shaly limestone member. A continuing increase in the depth of water and distance to the shoreline during the deposition of the shaly limestone member is indicated by its lithologic character and fauna. Following this initial transgression, however, neither strong subsidence nor emergence of the sea floor is recorded by the sedimentary rocks of the Luning formation. The massive limestone and dolomite of the carbonate member at the top of the exposed section is probably the result of offshore, generally shallow-water deposition.

The clastic member, where measured along the north wall of West Union Canyon, is 645 feet thick. Here, the lower 360 feet of the member is predominantly conglomeratic. At most other localities, however, the clastic member is thinner, owing to a decrease of as much as 100 feet in the thickness of the basal conglomerate. This difference in thickness is the result of a broad channeling of the limestone member of the Grantsville which took place before the deposition of the Luning formation. Some of these channels, several tens of feet in width and about 20 feet in depth, may be observed at the base of the measured section of the Luning along the ridge north of the narrows in West Union Canyon about 1 mile from its mouth. The sedimentary rocks of the Luning which fill these local irregularities in the erosional surface of the Grantsville formation are poorly sorted crossbedded pebbly and gritty, chert sandstone with lenses of chert conglomerate like that which forms the immediately overlying beds. Locally, the pebbles and cobbles of the conglomerate have been derived largely from the silicified limestone found in the upper part of the Grantsville formation.

Except for the channel fillings just described, the basal part of the clastic member is composed of very thick-bedded chert pebble conglomerate which may attain a thickness of 250 feet and which is interrupted only by a few thin interbeds and lenses of gritty chert sandstone. Well-rounded cobbles several inches in diameter are common in this conglomerate, but the average grain size of the coarse-grained material is somewhat less than 2 inches. The largest boulder measured was 11 inches in its greatest dimension. Both the coarse-grained detritus and the sandy matrix of the conglomerate are composed exclusively of chert which ranges from light brownish gray to black, but is mostly light colored. The cement is microcrystalline silica; consequently, with the exception of a small amount of interstitial sericite and ferric oxide, the entire rock is siliceous. The conglomerate crops out as prominent brown-weathering ledges up to several tens of feet in thickness. Owing to its resistance to weathering, it commonly forms topographic highs, such as Richmond Hill.

Overlying the generally homogeneous basal conglomerate is a section about 200 feet thick that is composed of interbedded conglomerate, sandstone, and argillite. These rock types occur in intergrading beds, up to 30 feet in thickness, with no definite sequence. Except for a smaller average diameter of the pebbles, the conglomerate beds are identical in composition with the basal conglomerate. The sandstone beds are greenish gray and poorly sorted and commonly contain chert pebbles as well as an appreciable amount of sericitic interstitial material. The clastic grains of medium sand or larger are entirely of chert. Only a small percentage of quartz is present as grains of fine sand and silt. The argillite in this part of the section forms relatively thin and lenticular beds not exceeding several feet in thickness. It is dark gray, weathering greenish, and is thick bedded. Although the argillite is finely fractured, it lacks a slaty cleavage.

The upper 120 feet of the clastic member is devoid of conglomerate. The predominant rock type is massive-bedded, but very finely fractured, argillite. Like the argillaceous beds lower in the section, these rocks are usually dark greenish gray, locally weathering to reddish-brown. Some of the argillite beds are sandy or silty, and in places they are interbedded with unstratified dark chert sandstone. Bedding-plane laminae are, as a rule, not well developed in either the argillite beds or the more sandy sedimentary rocks.

The contact between the clastic member and shaly limestone member of the Luning formation is gradational. The upper beds of the clastic member consist of dark highly fractured argillite with a few lenses of impure brownish-weathering limestone, and the lower part of the shaly limestone member is dominantly calcareous but contains interbeds 2 or 3 feet in thickness of black highly fractured argillite. The transitional section between the 2 members is approximately 25 feet thick.

One can infer from the foregoing description that the various rock types present and their vertical distribution make the clastic member of the Luning formation an analog of the clastic member of the underlying Grantsville formation. These parts of the two formations apparently reflect successive marine transgressions under similar conditions. Although the calcareous rocks overlying the clastic members of the Grantsville and Luning formations are easily differentiated by their faunas and by the prevalence of argillaceous material in the shaly limestone member of the Luning, the lithologic features of the two clastic members differ only in degree, and limited exposures cannot be assigned to either clastic member with certainty. Where the sections are well exposed, in addition to the sequence of formations, the clastic member of the Luning formation can be differentiated from that of the Grantsville formation by the greater total thickness, the greater thickness of the basal conglomerate beds, the generally larger grain size of the conglomerate, the smaller grain size and resultant more intricate fracturing of the argillite beds, and the absence of purple argillite at the base.

The composition of the shaly limestone member of the Luning formation can be characterized as impure limestone and calcareous claystone in about equal proportions. Owing to its content, the designation of the member may be somewhat misleading, but it serves to distinguish this dominantly calcareous member from the underlying clastic member and from the overlying calcareous shale member, which is dominantly argillaceous.

The thickness of the shaly limestone member is approximately 570 feet in the section measured along the northwest wall of West Union Canyon above the narrows and continued along on the southeast side of the canyon north of the tributary leading to the Richmond mine.

Although the different stratigraphic horizons of the shaly limestone member are most easily recognized by their characteristic fossils, the lithologic character of the section shows some variation. Thin- or medium-bedded brownish-gray impure limestone beds with irregular stratification-surfaces characterize the basal part of the member. These rocks are dominantly bioclastic and are composed of recrystallized shell fragments in a matrix of yellowish-brown argillaceous silty or sandy microcrystalline calcite. The shell fragments are almost exclusively of various pelecypods, but the internal structure and shape of a few monocrystalline fragments seen in thin section suggest echinoid spines. Although impure bioclastic limestones are characteristic of the lower 200 feet of the member, there is an increasing tendency towards the top of this section for the argillaceous and calcareous components to be separated into alternating beds. Together with a decrease in the amount of terrigenous silt and the presence of unbroken molluscan shells, this indicates less agitation of the sea floor during deposition and probably increasing depth of water.

The middle and upper parts of the shaly limestone member consist of calcareous argillaceous rocks with limestone interbeds that are generally of medium thickness. Although limestone is the most conspicuous constituent on weathered slopes, it contributes only about one-fourth of the total thickness in the upper part of the section. The argillaceous sedimentary rocks compose uninterrupted beds up to 20 feet in thickness, whereas continuous sections of limestone are seldom more than 2 or 3 feet thick. Calcareous shale and calcareous claystone, which are gray on fresh surfaces and brownish where leached near the surface, make up most of the argillaceous rocks. A few relatively thin beds of dark-gray or black highly fractured noncalcareous argillite are present.

The limestones interbedded with the argillaceous rocks in the middle part of the member are crystalline and brownish-gray and weather brownish with irregular orange-brown, red, or lavender patches. Toward the top of the section, the limestones become increasingly dense and black. Dark-brown siliceous interior molds of minute gastropods and pelecypods, less than one-half a millimeter in diameter, are locally visible in abundance on the weathered surfaces of these dense black limestones. Other constituents of organic origin, visible only in thin section, are thin, flat shell (?) fragments and a few chambered foraminifera. The matrix is finely crystalline calcite clouded by carbonaceous (?) material with a few cubes of pyrite and patches of authigenic silica. Mature ammonite shells are fairly common, but their young stages are absent. Conversely, gastropods and pelecypods are not well represented in the megafauna although they are abundant in the microfauna. In general, the megafauna of these limestones appears to have been unrelated to the sediments during their deposition. This is in contrast to the limestones in the lower part of the section, in which shells and shell fragments representing all growth stages of the megafossils may locally compose the bulk of the rocks.

The shaly limestone member of the Luning formation is overlain by the calcareous shale member with only a subtle change in lithology. The calcareous shale member is best exposed in West Union Canyon north of the Union Canyon fault. Here the section is about 550 feet thick, though the uppermost beds, transitional to the dolomite member, are somewhat contorted, making accurate measurement of the thickness impossible.

The basal part of the calcareous shale member is dominantly calcareous shale with a few thin interbeds of dense black limestone. The calcareous shale, which is flaky and black or dark brownish gray on fresh exposures, weathers to a distinctive light reddish gray that serves to distinguish this member from the underlying shaly limestone member. Owing to the relative incompetence of the shaly beds, they are generally somewhat sheared and contorted. None of the terrigenous detrital sediment in this member is of silt or larger grain size.

The lowermost reddish-gray weathering calcareous shale in the section is arbitrarily recognized as the base of the calcareous shale member and provides a mappable boundary between this member and the shaly limestone member. This boundary is approximately at the same stratigraphic level as that between the cartographic units designated by Ferguson and Muller (1949, pl. 13) as the lower-plate facies of the Luning formation and the Gabbs formation.

Although calcareous shale exceeds the amount of bedded limestone by several times in the lower 300 feet, higher in the section medium- and thick-bedded limestone increases—eventually to the exclusion of argillaceous interbeds. Abundant spherical concretions of dark carbonaceous limestone, up to 1 inch in diameter and commonly containing shell fragments of *Halobia* as nuclei, are locally present in the calcareous shales about

300 feet above the base of the member. The limestone interbeds in the lower 400 feet of the section are usually of thin or medium thickness and are composed of dense black carbonaceous limestone. Higher in the section the limestone is thicker bedded and more crystalline, gradational upward with the massive limestone of the carbonate member.

The basal part of the carbonate member is exposed only in the vicinity of West Union Canyon where it consists of massive gray limestone with subordinate thick and very thick interbeds of brownish-weathering crystalline dolomite. As the contact between the calcareous shale and carbonate members is gradational, the lowest occurrence of dolomite is recognized as the base of the carbonate member. The strata transitional between the two members are locally contorted and broken, but this deformation is regarded as the result of minor readjustment between thick units of contrasting rock types and competency during the development of large folds, rather than the effect of a major thrust fault as interpreted by Ferguson and Muller (1949, pl. 13).

The part of the carbonate member cropping out in West Union Canyon is not as complicated structurally nor is as much altered hydrothermally as the carbonate member forming the upper plate of the Shoshone thrust south of Grantsville Canyon. On the southeast wall of West Union Canyon, northeast of the Union Canyon fault, an apparently continuous eastward-dipping section with a thickness of about 1,200 feet is exposed beneath the Tertiary volcanic rocks. The lower 600 feet of this section, which is the only part present in the other small exposures of the carbonate member in the vicinity of West Union Canyon, is predominantly massive dark-gray bluff-forming limestone irregularly veined with white calcite. The limestone is usually thick or very thick bedded, and the individual beds characteristically differ in thickness laterally and are thus separated by undulating stratification surfaces. Interbedded and intergrading with these massive limestone beds, particularly in the lower part of the section, are brownish-gray crystalline dolomites which commonly weather to a red. Although these dolomitic beds are thick bedded, they do not form prominent outcrops like the massive limestone beds with which they are associated. In a few places the dolomite beds include patches of gray limestone and at some places grade laterally into limestone, as if the dolomite had been produced by hydrothermal alteration of the limestone. Abundant terebratuloid and rhynchonellid brachiopods are present approximately 500 feet above the base of the carbonate member in the massive limestone bluffs near the crest of the ridge forming the southeast wall of West Union Canyon. When the brachiopod shells are examined in place, some of them are found to be filled partly by gray limestone like the matrix material and partly by white calcite. The gray limestone filling is nearly always in the part of the shell closest to the apparent base of the enclosing limestone bed indicating that this part of the carbonate member is in an upright position.

On the crest of the same ridge, approximately 200 feet of medium-bedded only slightly recrystallized black limestone with a red color on weathered surfaces overlies the massive cliff-forming limestone and dolomite. In a few places the limestone is shaly and include a few interbeds of flaky black reddish-weathering, calcareous slate. A variety of poorly preserved marine mollusks is present in the lower part of this stratigraphic interval. The section above these slightly shaly beds consists of about 400 feet of massive gray, reddish-weathering limestone which is poorly exposed beneath the capping of Tertiary volcanic rocks. The distinctive fauna of this part of the section shows that these rocks are not a repetition of the lithologically similar massive limestone beds exposed on the northwest-facing slope overlooking West Union Canyon.

South of Grantsville Canyon exposures of the carbonate member of the Luning formation occupy an area of over 2 square miles including most of Grantsville Ridge and extending southward with some interruption to the vicinity of Spanish Canyon. In this area neither the base nor top of the member is exposed. What appears to be the lower part of the section is in fault contact with fault slivers of the calcareous shale, shaly limestone, and clastic members of the Luning on the south wall of Grantsville Canyon, and to the south the apparent upper part of the section is carried over folded and partly overturned strata of the undifferentiated Gabbs and Sunrise formations by the Shoshone thrust. The prevailing dip of the massive limestone and dolomite beds which constitute Grantsville Ridge and the klippe in Spanish Canyon is to the east, and the structure of these rocks is interpreted as one or more overturned folds broken by subsidiary shears of the Shoshone thrust and subsequent normal faults. Owing to the absence of reliable marker horizons, the details of the structure could not be determined. Consequently, the maximum thickness of the carbonate member represented is unknown, but probably exceeds 2,000 feet. A monotonous succession of thick- and very thick-bedded generally somewhat crystalline gray dolomite and limestone constitutes most of this section.

The differentiation of limestone and dolomite units within the section is of doubtful stratigraphic significance because at least a part of the dolomite appears to have been formed by the hydrothermal alteration of the limestone. This is well shown at the north end of Grantsville Ridge where a zone of brownish-gray crystalline dolomite follows the fault separating the carbonate member from the older rocks. Away from the fault the dolomite may grade laterally into massive limestone, and as some beds are selectively dolomitized for greater distances than others, the result is an apparent interbedding of limestone and dolomite.

In a few places the massive carbonate beds are separated by platy-weathering limestone, but dominantly argillaceous beds are seldom present. At one locality, approximately 2,000 feet due north of the northern peak of Grantsville Ridge (elevation 7,906), hard, compacted calcareous slates with poorly preserved fossils are interbedded with the massive limestones. In the carbonate member of both the Grantsville Ridge and West Union Canyon areas, fossils (particularly mollusks) are associated with the more argillaceous rocks. This relationship may be due either to environmental factors or to the presence of argillaceous material that prevented the recrystallization of the carbonate sediments and the resulting obliteration of the fossils.

Prominent dark siliceous "reefs" are sporadically present along the plane of the Shoshone thrust and along subsidiary bedding plane shears in the carbonate member of the Luning on Grantsville Ridge and in the area to the south. Fluorite is associated with this silicification at several localities on Grantsville Ridge, and some of these deposits have been developed by small-scale mining operations.

AGE AND CORRELATION

Fossils of various kinds occur at a number of horizons, and locally are abundant, in the Luning formation of the Union district. Of particular interest because of their time-stratigraphic value are the three distinct cephalopod assemblages recognized in the shaly limestone and calcareous shale members. These are, in ascending order: the *Klamathites schucherti* fauna near the base of the shaly limestone member, the *Klamathites macrolobatus* fauna at the top of the shaly limestone member extending into the base of the calcareous shale member, and the *Guembelites* fauna in the upper part of the calcareous shale member. Each assemblage characterizes 100 feet or more of section, and careful collecting shows that a definite faunal succession exists within each of these fossiliferous sections. At most localities, however, the rocks are not well enough exposed to separate the various species of each assemblage stratigraphically. The absence or relative scarcity of fossils in the barren parts of the section between the fossiliferous beds is in part a primary feature, but is also due to unfavorable preservation.

The stratigraphically lowest of the cephalopod faunas occurs from about 125 to 250 feet above the base of the shaly limestone member. The faunal assemblage from these beds, which is referred to as the *Klamathites schucherti* fauna, includes the following species:

Klamathites schucherti Smith (including *K. kellyi* Smith)[1]
Juvavites (*Anatomites*) cf. *J.* (*A.*) *elegans* Gemmellaro
J. (*A.*) spp.
Discophyllites ebneri (Mojsisovics)[1]
Arcestes sp.
Germanonautilus kummeli Silberling, n. sp.[1]
Phloioceras mulleri Silberling, n. sp.[1]
Proclydonautilus sp.
"*Orthoceras*" sp.
Aulacoceras sp.
Myophoria shoshonensis Silberling, n. sp.[1]
Septocardia? sp.[1]
Pinna sp.

In addition to the fossils listed, several different species of unidentifiable pelecypods and gastropods are represented. Pelecypods tentatively assigned to the genus *Septocardia* are the most abundant fossils in this fauna; and locally, particularly in the lower part of this section, their shells make up much of the rock. These pelecypods were referred to as "*Cardium*" *arcaeformis* Gabb and "*Cardita*" by Muller and Ferguson (1936, p. 246; 1939, p. 1600). In the lower part of these beds and extending downward to the base of the shaly limestone member, where most of the fossils are fragmental and unrecognizable, various oysterlike pelecypods are abundant. *Klamathites schucherti* is well represented about 180–220 feet above the base of the member. At this same level as well as in the immediately overlying beds, *Juvavites* (*Anatomites*) cf. *J.* (*A.*) *elegans* is abundant. The species of *Arcestes* and *Discophyllites* occur only rarely. Of the nautiloids present, only *Germanonautilus kummeli* is common. Brachiopods and corals are absent.

This assemblage is referred to as the *Klamathites schucherti* fauna rather than the "*Carnites* fauna," used by Muller and Ferguson (1939, p. 1600), because none of the many discoidal ammonites examined can be assigned to *Carnites*. Furthermore, the elements of the fauna that provide information concerning its age indicate a position somewhat higher in the column than that at which *Carnites* is known to occur.

The *Klamathites schucherti* fauna has the species *Klamathites schucherti* (including *K. kellyi*) and *Discophyllites ebneri* (=*D. patens* of Smith, 1927) in common with the fauna described by Smith (1927) from the upper part, or "*Juvavites* subzone", of the *Tropites subbullatus* zone in Shasta County, Calif. The distinctive species of *Tropites* which characterize this Cal-

[1] Described in the paleontological part of this paper.

ifornia assemblage are not present in the fauna from the Union district, but their absence, providing that the two faunas are actually contemporaneous, might be explained by a difference in the environment of deposition in the two areas.

The second of the cephalopod assemblages, the *Klamathites macrolobatus* fauna, characterizes approximately 120 feet of section and extends from 500 feet above the base of the shaly limestone member into the lower part of the overlying calcareous shale member. Although several different pelecypods, mostly indeterminate forms, are present, this fauna is dominated by cephalopods as can be seen from the following list:

Tropites latiumbilicatus Silberling, n. sp.[1]
subquadratus Silberling, n sp.[1]
crassicostatus Silberling, n. sp.[1]
nodosus Silberling, n. sp.[1]
nevadanus Silberling, n. sp.[1]
(*Anatropites*) sp.[1]
Tropiceltites? densicostatus Silberling, n. sp.[1]
Klamathites macrolobatus Silberling, n. sp.[1]
Juvavites (*Anatomites*) cf. *J.* (*A.*) *inflatus* Gemmellaro
(*Griesbachites?*) cf. *J.* (*G.?*) *cornutus* Diener
spp.
Arcestes sp.
Clydonautilus sp.[1]
Paranaultilus sp.
Proclydonautilus sp.
Aulacoceras sp.
Septocardia? sp.[1]
Halobia sp.

This assemblage is designated the *Klamathites macrolobatus* fauna even though some of the other species of ammonites occur in greater numbers. This species appears to have been derived directly from *K. schucherti*, the faunal index of the immediately underlying fossiliferous beds, and it thus provides a genetic link between the two faunal assemblages in the shaly limestone member.

The beds containing the *Klamathites macrolobatus* fauna are distinguished throughout by the abundance of tropitids. For purposes of comparison it should be pointed out that the number of species of *Tropites* is small only because of the broad concept of a species adopted for this group. If all of the morphologic variations among the representatives of this genus were assigned specific names, several tens of species could be established which would agree more closely in scope with the species of this genus recognized by previous authors. The species of *Tropites*, like the other cephalopods present, are generally preserved only in limestone beds interstratified with the calcareous claystones and the different species are restricted in their stratigraphic distribution within the *Klamathites macrolobatus* beds. The abundant representatives of *Tropites nevadanus* along with *Juvavites* (*Griesbachites?*) cf. *J.* (*G.?*) *cornutus* are nearly confined to a 1-foot bed of limestone about 20 feet below the top of the shaly limestone member. *Tropites subquadratus*, *T. crassicostatus*, and *T. nodosus* occur approximately 30 feet lower in the section, and *T. latiumbilicatus* first occurs at least 10 feet below this, or about 60 feet below the top of the shaly limestone member. *Tropiceltites? densicostatus* Silberling, with which only poorly preserved specimens of *Anatropites* and *Halobia* are found, characterizes the lowermost 30 feet of the calcareous shale member and marks the upper extent of the *Klamathites macrolobatus* fauna.

Arcestes ranges throughout most of the *Klamathites macrolobatus* beds but is most abundant near the base where it is associated with several species of *Juvavites* including *J.* (*Anatomites*) cf. *J.* (*A.*) *inflatus*. Nautiloids are rare. A few stragglers of *Septocardia?* extend from the underlying part of the shaly limestone member into the lower part of this interval. As in the *Klamathites schucherti* fauna, brachiopods and corals are not represented.

The predominant elements of the *Klamathites macrolobatus* fauna consist of previously undescribed species, and consequently direct correlations with other faunas are not possible. The abundance of the genus *Tropites* suggests a rough equivalence to the *Tropites subbullatus* zone, but the species present are not characteristic of this zone, contrary to the statement by Muller and Ferguson (1939, p. 1601).

The well-preserved *Guembelites* fauna occurs in black carbonaceous limestone beds about 300–400 feet above the base of the calcerous shale member and includes the following forms:

Guembelites jandianus Mojsisovics[1]
philostrati Diener[1]
clavatus (McLearn)[1]
Mojsisovicsites robustus (McLearn)[1]
kerri (McLearn)[1]
cf. M. crassecostatus Gemmellaro[1]
Styrites cf. *S. subniger* Mojsisovics
cf. S. vermetus (Dittmar)
cf. *S. signatus* (Dittmar)
cf. *S. tropitoides* Gemmellaro
Dimorphites cf. *D. montis-ignei* Diener
Arcestes sp.
Paranautilus sp.
Cosmonautilus? cf. *C. pacificus* Smith
Halobia sp.

With the exception of *Halobia* the entire fauna is composed of cephalopods. Although a stratigraphic separation appears to exist between some of these forms

[1] Described in the paleontological part of this paper.

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within the interval of the *Guembelites* beds, the exposures at most localities do not allow detailed stratigraphic collecting. In general, the occurrence of the less ornamented species assigned to the genera *Guembelites* and *Mojsisovicsites*, like *G. clavatus* and *M.* cf. *M. crassecostatus*, tends to be higher in the section than the strongly ornamented species of the same genera. Although this trend may have genetic and hence time-stratigraphic significance, it could also simply reflect a gradual change in environmental conditions within this relatively thin section.

The species which these forms are assigned to, or compared to, have previously been reported from strata of both Karnian and Norian age and from widely different parts of the world. *Guembelites jandianus* was originally described from the "*Halorites* limestone" of India, which is considered to be "Lacic" or early Norian by Mojsisovics (1899, p. 132–134). *Guembelites philostrati* has previously been reported only from Timor where it occurs with a fauna, including *G. jandianus*, that is predominantly Norian in its affinities according to Diener (1923, p. 259) although it also contains several species indicative of the Karnian. The species described by Gemmellaro (1904) (*Mojsisovicsites crassecostatus* and *Styrites tropitoides*) are from the undifferentiated Neotrias of Sicily and hence are of little value in dating this assemblage. The other forms referred to the genus *Styrites* are compared to species known from the Karnian of the Alps. Nevertheless, the stratigraphic value of these small, relatively featureless and yet variable, degenerate tropitids is questionable. *Dimorphites montis-ignei* is also from the Karnian of the Alps, where it occurs in the *Tropites subbullatus* zone.

Mojsisovicsites robustus, *M. kerri*, and *Guembelites clavatus* were first described by McLearn from the Pardonet beds of the Peace River foothills in British Columbia. The two species of *Mojsisovicsites* were originally referred to the genus *Stikinoceras* and occur in the so-called *Stikinoceras* fauna while *Guembelites clavatus* was described as a *Juvavites* from the stratigraphically higher " '*Styrites*' *ireneanus* fauna." These two faunas in the Pardonet Hill section are separated by 1,600 feet of strata in which there is one intervening fauna containing an undescribed species of *Tropites* (McLearn, 1947, p. 3–5). In the Union district, however, *Mojsisovicsites robustus* and *M. kerri* are separated from *Guembelites clavatus* by not more than 100 feet of section, which bears out McLearn's belief that the three faunas in the Pardonet Hill section are closely related and "may merely be local phases of one fauna" (McLearn, 1947, p. 10), even though a considerable thickness of strata separates them. Nearly all of the species in the "*Stikinoceras*," "*Tropites*," and " '*Styrites*' *ireneanus*" faunas are described as new; but largely on the basis of the genera represented, the section containing these three faunas is assigned by McLearn (1947, p. 10) to the *Tropites subbullatus* zone of the upper Karnian. As this correlation is dependent upon the age significance of forms such as the undescribed species of *Tropites*, the new species of *Styrites*, and *Halobia ornatissima* Smith, it is questionable.

None of the specimens in the *Guembelites* fauna can be assigned to *Palicites mojsisovicsi* Gemmellaro or to the genus *Griesbachites*, included in the faunal list given by Muller and Ferguson (1939, p. 1602).

The foregoing more or less objective description of the *Klamathites schucherti*, *K. macrolobatus*, and *Guembelites* faunas leads to the conclusion that the part of the Luning formation containing these faunas can be assigned at least in part to the upper Karnian and may extend into the lower Norian.

Because of their potential utility, at least within the outcrop area of the Luning formation in Nevada, the beds characterized by these faunas are recognized as local faunal zones. A precise and objective age connotation cannot be assigned to these local zones. This is necessarily so because, if their relation to the standard Alpine faunal zonation (the ultimate basis for the Upper Triassic time scale) was clearly understood, the need for such local zones would be obviated. The lack of relationship is probably due in part to the geographic separation and possible environmental differences between the Nevada and Alpine sections. It seems likely, moveover, that a detailed sequence of faunal zones of worldwide utility for the part of the Upper Triassic that is transitional between the Karnian and Norian stages has not yet been formulated. The incompleteness of the existing zonation has been pointed out by Spath (1934, p. 39–40), who is of the opinion that the Tropitan age (the time equivalent of the *Tropites subbullatus* zone) can be subdivided and represents a considerable period. In the zonation set forth by Mojsisovics (1902, p. 339, 344), generally accepted as the standard for the Upper Triassic, the "lenses with *Thisbites agricolae*" at the top of the *Tropites subbullatus* zone and the basal Norian *Discophyllites patens* zone define the Karnian-Norian boundary in the Alps. These assemblages as described by Mojsisovics have not been recognized in North America possibly because they are relatively impoverished in the number of species present and consist largely of poorly developed forms, some of which appear to be dwarfed or immature.

A North American assemblage comparable to that listed by Mojsisovics (1893, p. 800–802; 1902, p.

338–339) from the *Tropites subbullatus* zone of the Hallstatt region in the Australian Alps occurs in the so-called Hosselkus limestone [2] of Shasta County, Calif. Thus the upper Karnian in terms of a European fauna can be recognized in North America, but the next youngest North American cephalopod fauna with an obvious counterpart in the standard Alpine section is the upper Norian *Pinacoceras metternichi* fauna from the middle part of the Gabbs formation in the Gabbs Valley Range, Nev. Even if the occurrence of *Sagenites* cf. *S. giebeli* in the lower part of the Gabbs formation (Muller and Ferguson, 1939, p. 1606) is considered indicative of the lower Norian *Sagenites giebeli* zone, the horizon of the Karnian-Norian stage boundary cannot be accurately defined by the faunal zones recognized in North America.

An indirect correlation of the *Klamathites schucherti* zone of the Union district with the European zonation may be provided by the *Tropites subbullatus* zone of Shasta County, Calif., in which two subzones, each with a distinctive fauna, are recognized. The name "*Tropites dilleri* subzone" has been recommended (Silberling, 1956, p. 1152) for the lower of these two subzones in preference to Smith's (1927, p. 4) original designation of "*Trachyceras* subzone" because the forms in this subzone assigned to *Trachyceras* by Smith are incorrectly placed in this genus and the use of this generic name as the subzonal index might cause confusion with the interregional lower Karnian zones of *Trachyceras aon* and *T. aonides*. Among the late Karnian faunas of North America, the fauna of the *Tropites dilleri* subzone shows the most agreement with the fauna of the Alpine *Tropites subbullatus* zone. *Tropites dilleri*, as redefined in this paper, is restricted to this subzone; and, of the North American species of *Tropites*, it appears to bear the closest relationship to *Tropites subbullatus*.

The name "*Tropites welleri* subzone" is proposed here in place of Smith's ambiguous name "*Juvavites* subzone" for the upper of the two subdivisions of the *Tropites subbullatus* zone in the so-called Hosselkus limestone. The fauna of this subzone includes some of the species indicative of the Alpine *Tropites subbullatus* zone but is characterized by species of *Tropites* and *Juvavites* different from those in the European section. An approximate correlation with the *Klamathites schucherti* zone of the Union district is suggested by the occurrence of *Klamathites schucherti* in the *Tropites welleri* subzone. As this species has a unique and highly modified suture pattern and it is replaced by a different species at a higher level in the Luning formation, it seems reasonable to assume that it is not a long-ranging form. *Discophyllites ebneri* (= *D. patens* of Smith, 1927) is also common to both faunas but may be a persistent species with less time-stratigraphic significance.

Based on this postulated correlation of the *Klamathites schucherti* zone of the Union district with the *Tropites welleri* subzone of the *Tropites subbullatus* zone in northern California, the Karnian-Norian stage boundary is tentatively drawn between the *Klamathites macrolobatus* and *Guembelites* zones in the Union district. An early Norian age assignment for the *Guembelites* zone is favored because of its stratigraphic position above the *Klamathites schucherti* zone and because *Guembelites* has been reported previously only from strata considered to be Norian in age by Diener and by Mojsisovics. Figure 2 illustrates the supposed age relationships of the upper Karnian and lower Norian faunas and formational units in California and Nevada according to the foregoing subjective line of reasoning.

Fossils have been found at only a few localities in the carbonate member of the Luning formation even though it covers a relatively large area of outcrops in the Union district. In general, the fauna of this member is poorly preserved and includes only forms with indefinite or lengthy stratigraphic ranges.

Three collections of fossils were obtained from the continuous section of the carbonate member north of the Union Canyon fault on the ridge southeast of West

[2] The Hosselkus limestone at its type locality in the Taylorsville area of Plumas County, Calif., was first described by Diller (1892, p. 374). At Taylorsville it overlies the Swearinger slate, in which the Upper Triassic pelecypod *Monotis* occurs. On the basis of a fauna at first thought to be equivalent in age to the *Monotis* fauna, Smith in 1894 (p. 604–609) adopted the name Swearinger in Shasta County for slates subsequently included in the Pit formation. Because of the seeming agreement with the Taylorsville section, Smith applied the name "Hosselkus" to the overlying limestone unit. Later, *Monotis* was discovered in Shasta County in the slates overlying the so-called Hosselkus limestone, for which the name Brock shale was eventually proposed by Diller (1906). Thus, the unit referred to the Hosselkus in Shasta County was apparently older than strata containing *Monotis*, whereas the type Hosselkus was younger. To make the section in the Taylorsville area containing the type Hosselkus limestone conform with the supposed formational sequence in Shasta County, Diller (1908, p. 33) decided that the Taylorsville section was overturned and that the Swearinger slate was stratigraphically above to the type Hosselkus limestone. Faunal correlations indicate only that the units assigned to the Hosselkus limestone in Plumas and Shasta Counties are both Late Triassic, but an equivalence in age has by no means been established. Stratigraphic features within the Swearinger slate of the Taylorsville region indicate that the section is upright as originally described by Diller, according to Vernon McMath (written communication, December 1955). If so, the type Hosselkus is younger than the Swearinger slate in Plumas County and the Brock shale in Shasta County. The Modin formation, which overlies the Brock shale in Shasta County, has been shown to be Late Triassic in age rather than Jurassic by A. F. Sanborn (Geology and paleontology of a part of the Big Bend quadrangle, Shasta County, Calif., unpublished doctoral dissertation, Stanford University, California, 1952). Consequently, the thick massive limestones of the Modin formation described by Sanborn may be more nearly correlative with the type Hosselkus than the late Karnian limestones lower in the Shasta County section for which the name "Hosselkus" has been used. For this reason the name "Hosselkus limestone" as used by Smith (1894, 1904, and 1927) and by Diller (1906) for the late Karnian limestones of Shasta County is referred to as the so-called Hosselkus limestone in this paper.

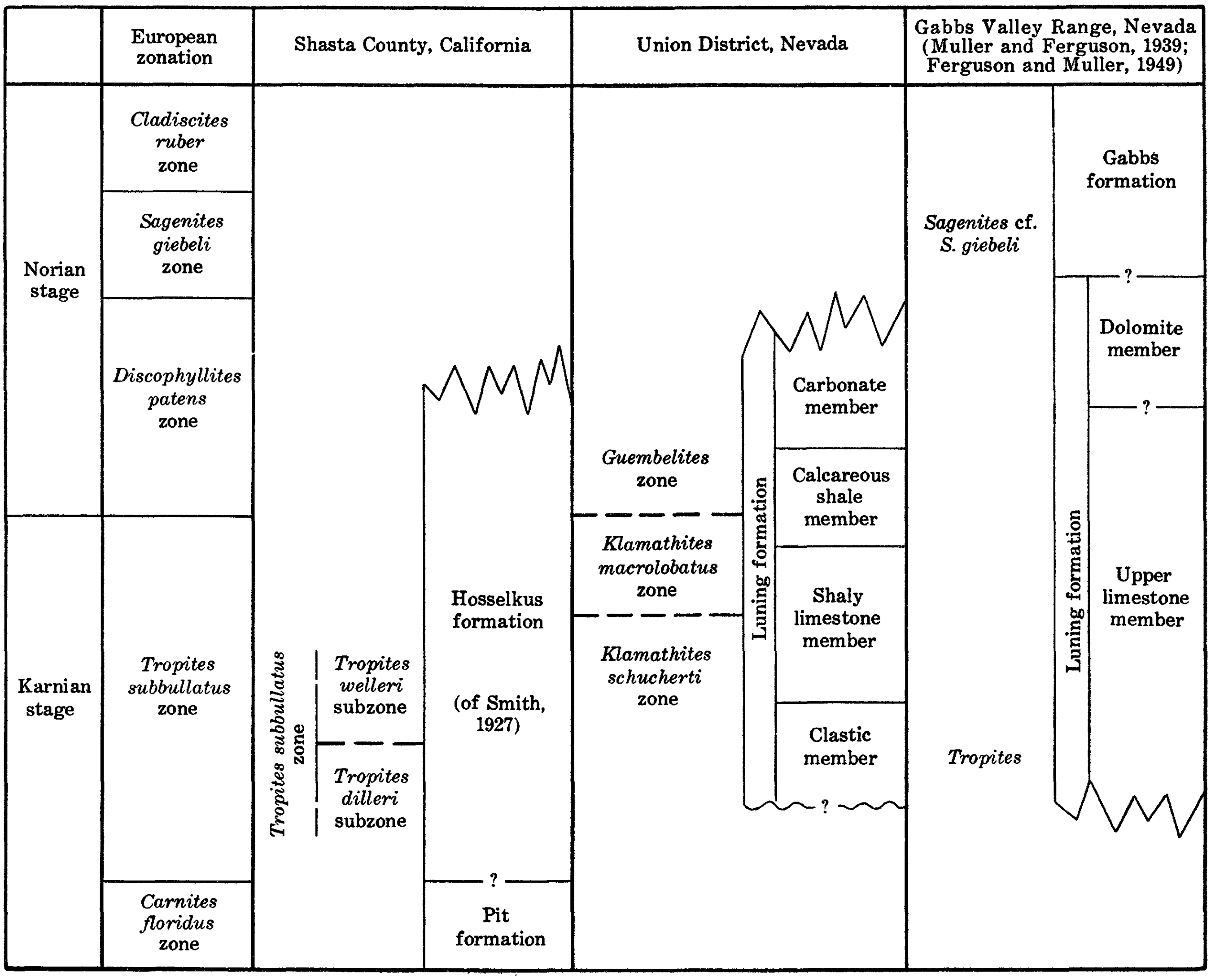

FIGURE 2.—Age relationships suggested for the upper Karnian and lower Norian faunal zones and rock units in California and Nevada. Thicknesses of stratigraphic units are not shown to scale.

Union Canyon. The lowest, about 500 feet stratigraphically above the base of the member, includes many kinds of terebratuloid and rhynchonellid brachiopods together with a few fragments of colonial corals and stromatoporoids, shell fragments of the pelecypod *Trichites*, and indeterminate gastropods.

The limestone beds associated with argillaceous sedimentary rocks on the crest of the ridge southeast of West Union Canyon contains the largest and most varied fauna observed in the carbonate member. Although brachiopods characterize the faunas occurring stratigraphically above and below, they are absent in these rocks. In addition to the many kinds of poorly preserved and generically indeterminate pelecypods and gastropods, the following mollusks are represented:

Alectryonia cf. *A. montis-caprilis* Emmrich
Myophoria sp.
Pinna sp.
Mysidioptera sp.
Germanonautilus? sp.

Abundant partly silicified brachiopods, assigned to *Plectoconcha* cf. *P. aequiplicata* (Gabb), occur in the red-weathering massive limestone beds on the eastern slope of this same ridge approximately 200 feet stratigraphically above the *Alectryonia* fauna. Associated with *Plectoconcha* and stratigraphically above it are *Trichites*, smooth terebratuloid brachiopods, and sponges.

In the carbonate member on the north spur of Grantsville ridge, poorly preserved pelecypods including *Alectryonia* cf. *A. montis-caprilis*, *Myophoria* spp., *Pinna* sp., and *Trichites* sp. were found in argillaceous beds intercalated with massive carbonate rocks. The lithologic character and molluscan fauna of these beds suggest a correlation with the part of the carbonate member containing the *Alectryonia* fauna on the ridge southeast of West Union Canyon.

A single specimen of *Plectoconcha* cf. *P. aequiplicata* was collected from the gravels at the base of the Tertiary volcanic sequence in Second Canyon, indicating the presence of this brachiopod in the carbonate member south of Grantsville Ridge and the continuation of these rocks to the south of their present exposures beneath the Tertiary volcanic rocks.

The fauna of the carbonate member cannot be used as the basis for an age assignment more precise than Late Triassic. Because of the occurrence of *Alectryonia* cf. *A. montis-caprilis*, known from the Karnian of Europe, and *Plectoconcha* cf. *P. aequiplicata*, which occurs in the Dun Glen and Osobb formations of the Sonoma Range quadrangle in Nevada, the carbonate member was originally regarded by Silberling (unpub. doctoral dissertation, Stanford University, California, 1957) as of Karnian age. It followed, therefore, that the rocks assigned here to the carbonate member had to be carried over the lower Norian *Guembelites* zone by the Shoshone thrust in the West Union Canyon section as interpreted by Ferguson and Muller (1949). More recently, similar or identical species of *Alectryonia* and *Plectoconcha* have been found by the writer in the Humboldt Range, Nev., in association with Norian ammonites. Hence, the supposed age-indicating fossils of the carbonate member are apparently long-ranging forms that have no significance in either proving or disproving the existence of the Shoshone thrust within the section of the Luning formation.

In addition to the marine mollusks, which have been discussed at length because of their age significance, several other types of fossils are present in the Luning formation of the Union district. Small foraminifers are occasionally visible in thin sections of the limestones, particularly those from near the top of the shaly limestone member. A 20-foot section of calcareous claystone about midway between the *Klamathites schucherti* and *Klamathites macrolobatus* zones was trenched and sampled for foraminifers without success. Several small smooth ovoid bodies recovered from this sample and interpreted as the interior molds of ostracodes suggested that the shells of any calcareous microfossils originally present may have been removed by the leaching action of ground water.

Petrified wood was collected from conglomerate of the clastic member northwest of the mouth of West Union Canyon. Although imperfectly preserved, this wood appears to have the microscopic structure of *Araucarioxylon*. The impression of a coniferous twig collected by S. W. Muller from argillites of this same member on Richmond Hill has been identified by Roland W. Brown as *Palissya*.

Skeletal remains of ichthyosaurs are characteristic of the shaly limestone member of the Luning formation. Although not restricted to any particular part of the member, the greatest concentration of bones occurs in the lower part of the *Klamathites macrolobatus* zone. A part of West Union Canyon has recently (1955) been set aside as the Nevada Ichthyosaur State Park, and the excavation and study of the vertebrate remains is being carried on under the direction of Prof. Charles L. Camp, of the University of California.

The rock types represented in the Luning formation of the Union district agree with those in the type section about 35 miles to the southwest in the north central Pilot Mountains. The thickness and sequence of rock types of the two sections, however, differ considerably. (See fig. 3.) The type section of the Luning, which may have an exposed thickness of as much as 8,000 feet, includes a thick lower limestone member at the base, a middle clastic member composed of coarse- and fine-grained noncalcareous rocks, and an upper limestone member (Muller and Ferguson, 1939, p. 1596). The lower limestone member is not represented in the Union district, and the slate and conglomerate member of the type section is several times thicker than the basal clastic member of the Luning in the Union district. The upper limestone member of the type section, the top of which is not exposed, resembles the carbonate member of the Union district.

If the upper part of the type section is correlated with the part of the section of the Luning nearby in the southwest Gabbs Valley Range, where the top of the formation is exposed, a total thickness in the type area on the order of 8,000 or 10,000 feet is deduced. The Luning formation in the Union district is roughly half this thick, assuming that only a relatively small part of the original thickness is cut out by the Shoshone thrust.

The age of the Luning formation in the Gabbs Valley Range-Pilot Mountains area, based on its fauna and relation to the overlying Gabbs formation, is transitional between Karnian and early Norian. Although the Luning in the Union district is approximately equivalent in age with the type Luning, the available faunal evidence is insufficient for detailed correlation between the local members of the formation recognized in the two areas.

The faunal description and age interpretation given by Muller and Ferguson (1939, p. 1598–1601) for the Luning of the Pilot Mountains and Gabbs Valley Range

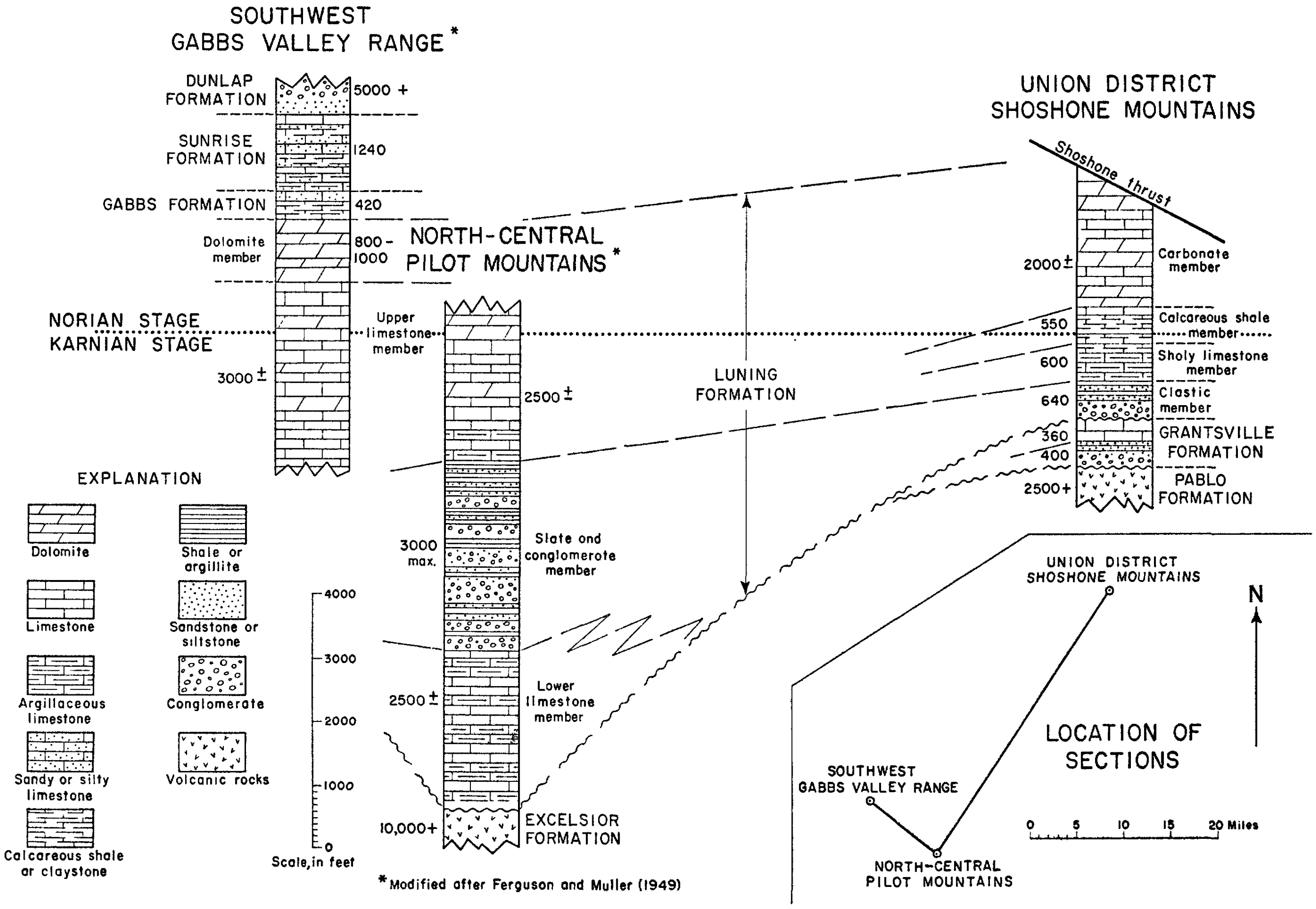

FIGURE 3.—Lithologic correlation of the Luning formation between the Union district, north central Pilot Mountains, and southwest Gabbs Valley Range. Datum (the dotted horizontal line) is the Karnian-Norian stage boundary.

suggests that several thousand feet of the type section was deposited before Luning deposition commenced in the Union district. These authors assign the coralline limestone of the lower limestone member to the middle or even lower Karnian, basing this assignment on the brachiopods associated with the reef-building corals and on the mollusks in the overlying beds. If correctly dated, this basal part of the type section is distinctly older than the Luning of the Union district. On the other hand the occurrence of *Tropites*, presumably in the upper limestone member, in the Gabbs Valley Range (Muller and Ferguson, 1939, p. 1601) may indicate an approximate age equivalence of the upper limestone of the type area with the shaly limestone member near the base of the Union district section.

The molluscan fauna near the base of the upper limestone member in the northern Pilot Mountains is characterized by smooth discoidal ammonites, *Septocardia?*, and *Myophoria*, and it bears a strong superficial resemblance to the *Klamathites schucherti* fauna of the Union district. The resemblance is further strengthened by the lithologic similarity between the clastic sedimentary rocks underlying the fossiliferous beds in both areas. If the two faunas are compared in more detail, however, the species of *Myophoria* present are seen to be different; and *Klamathites schucherti*, characteristic of the Union district fauna, is not represented among the discoidal ammonites in the Pilot Mountain fauna. Furthermore, the pelecypods assigned to "*Cardita*" (=*Septocardia?*) in the Pilot Mountains fauna show a small but constant difference in their shape and the details of their ribbing when compared with the similar forms from the *Klamathites schucherti* fauna of the Union district. Consequently, the resemblance between these faunas may be due to a similarity of environmental conditions rather than to an equivalence in age.

The Luning formation represents the initiation of sedimentation in the Luning embayment—a depositional basin defined by Ferguson and Muller (1949, p. 5) as "* * * an eastward embayment of a major Upper Triassic geosyncline that included a large part of the area of the present Sierra Nevada." By inference from the lateral variations observed within the Luning formation, the area of the type section and the Union district are respectively near the original southern and eastern limits of the Luning embayment. The variable composition and age of the lower part of the Luning is explained by transgression of the Luning sea during the Karnian into an area with appreciable topographic relief. By the late Karnian, however, the Luning sea had transgressed to the eastern part of the embayment and the effect of local irregularities was diminished. The upper part of the Luning, of late Karnian or early Norian age, throughout its outcrop area is composed of massive carbonate rocks like the upper limestone and dolomite members of the type area and the carbonate member of the Union district.

At present the lateral variation in the Luning formation is expressed by the use of different informal member names in the Union district and in the type area. It would be desirable to establish formal lithic subdivisions within the Luning and, where applicable, to recognize the same subdivisions between different areas. Nevertheless, this should be done only after further study of the region intervening between the Union district and the Gabbs Valley Range–Pilot Mountains area; that is, the Cedar Mountains and Paradise Range.

GABBS AND SUNRISE FORMATIONS UNDIFFERENTIATED (UPPER TRIASSIC AND LOWER JURASSIC)

The Gabbs and Sunrise formation are not differentiated here because the boundary between them at their type locality in the Gabbs Valley Range cannot be recognized in the Union district.

At its type locality the Gabbs formation has been separated into three members (Muller and Ferguson, 1939, p. 1604). The lower member represents a distinct lithologic entity, but the middle and upper so-called members are lithologically inseparable and are differentiated exclusively on the basis of fossils. The lower member, with a thickness of about 290 feet in the Gabbs Valley Range is described by Muller and Ferguson (1939, p. 1604) as follows:

> dark thinly bedded carbonaceous shale intercalated with beds of black impure limestone ranging in thickness from 4 inches to 2 feet. The shale and limestone in fresh exposures are dark gray to jet black but weather to a peculiar grayish purple which contrasts so strikingly with the color of the adjacent stratigraphic units as to render the lower member easily distinguishable even from a distance.

The middle and upper so-called members or the upper of the two natural lithologic subdivisions of the Gabbs formation in the type section are (Muller and Ferguson, 1939, p. 1604)—

> . . . composed predominatly of limestone, which is commonly brown and is shaly and even sandy. The individual layers of limestone range from 6 inches to 2 feet in thickness and are interstratified with thin seams of calcareous or sandy shale.

As such, the lithologic character of the upper part of the Gabbs formation resembles that of the overlying Sunrise formation. The nature of the boundary between these two formations is described by Muller and Ferguson (1936, p. 248–9) as follows:

> There is no lithologic change between the uppermost Triassic Gabbs formation and the lower part of the lowermost Jurassic Sunrise formation; the boundary between the two systems was therefore arbitrarily drawn in the 30 feet of nonfossiliferous shale which lies between the uppermost occurrence of the Upper Triassic fossils and the lowermost Lower Jurassic.

Although this statement would seemingly invalidate the utilization of this systemic boundary as a formational boundary, according to S. W. Muller (oral communication, 1955) the uppermost beds of the Triassic System in the Gabbs Valley Range are composed largely of silty or sandy limestone while the basal Jurassic beds are predominantly argillaceous and hence a local lithologic separation of the Gabbs and Sunrise formations nearly coincident with the boundary between the Triassic and the Jurrassic can be made in the type area.

The strata of latest Triassic and earliest Jurassic age in the Union district are like those in the Gabbs Valley Range being composed for the most part of silty limestone and calcareous siltstone interbedded with argillaceous silty limestone and calcareous silty shale. Subdivisions with this sequence can be recognized by means of relatively minor variations in composition such as the preponderance of either predominantly calcareous beds or argillaceous beds. Similar variations occur in the Gabbs and Sunrise formations at their type area, but unfortunately lithologic correlation of these minor variations is not possible between the Union district and the Gabbs Valley Range. In fact, the beds of latest Triassic age in the Union district are somewhat more argillaceous than those of earliest Jurassic age, which is the reverse of the situation in the Gabbs Valley Range.

Although it is not possible to separate the Gabbs and Sunrise formations in the Union district using the same minor lithologic change that marks their boundary in the Gabbs Valley Range, the gross lithologic character of these rocks corresponds to that of the typical sequence of the Gabbs and Sunrise. Accordingly, it is desirable to retain the original formational names. On the other hand, separation of the formations solely on the basis of fossils is not desirable, and therefore the Gabbs and Sunrise formations are not differentiated in the Union district.

The exposures of the undifferentiated Gabbs and Sunrise formations are restricted to the southern part of the Union district, where they occur in two areas of approximately equal size separated by Tertiary volcanic rocks and a klippe of the carbonate member of the Luning formation. In each of these areas the undifferentiated Gabbs and Sunrise formations are folded and partly overturned beneath the Shoshone thrust. The northern area of outcrop in the vicinity of Milton Canyon consists of a series of folds broken by at least one normal fault. The resulting structural repetition of some parts of this section and the omission of others makes this area unfavorable for study of the stratigraphic sequence. In the southern outcrop area, between First and Fourth Canyons, the undifferentiated Gabbs and Sunrise formations form part of the east limb of a partly overturned syncline, thrust over on the east by the Luning formation. Although this exposure is partly obscured by Tertiary volcanic rocks and is cut by high-angle tear faults, the section is continuous from the Late Triassic part of the undifferentiated Gabbs and Sunrise formations beneath the Shoshone thrust in First Canyon up into the overlying Dunlap formation south of the mouth of Second Canyon. At the stratigraphic top of this section the basal part of the Dunlap formation conformably overlies the undifferentiated Gabbs and Sunrise formations, and both units are thrust over discordant strata of the Dunlap formation. The conformable contact between the undifferentiated Gabbs and Sunrise and the Dunlap formations may also be observed immediately north of the mouth of Third Canyon where a small exposure of the uppermost undifferentiated Gabbs and Sunrise formations underlies the Dunlap formation in the west limb of a synclinal fold. This isolated patch of the undifferentiated Gabbs and Sunrise formations was mapped as a klippe of the Luning formation by Ferguson and Muller (1949, pl. 12).

Strata corresponding to the lower part of the Gabbs formation at its type area are not exposed in the Union district. Nevertheless, by analogy with the type area in the Gabbs Valley Range, the contact between the undifferentiated Gabbs and Sunrise formations and the underlying Luning formation is probably conformable. The massive carbonate rocks above the Shoshone thrust may represent the overturned limb of a large recumbent anticline and hence the upper part of the Luning formation. If so, the thickness of section missing between these rocks and the overturned lower part of the undifferentiated Gabbs and Sunrise formations as exposed beneath the thrust may amount to only several hundred feet.

LITHOLOGIC CHARACTER

The exposed thickness of the upper unit of the undifferentiated Gabbs and Sunrise formations is about 2,700 feet, of which approximately the upper 2,400 feet is Early Jurassic in age. For comparison, the thickness of the Sunrise formation, at its type locality in the Gabbs Valley Range, where it is exclusively Jurassic in age, is 1,245 feet (Muller and Ferguson 1939, p. 1611). The undifferentiated Gabbs and Sunrise and the Sunrise formations are conformably overlain in each place by the Dunlap formation. Several factors may be responsible for the considerably greater thickness of the lower Jurassic sedimentary rocks below the base of the Dunlap formation in the Union district. Of foremost importance, the base of the Dunlap formation appears to be at a somewhat younger horizon in the Union district than it is in the Gabbs Valley Range and hence the time span represented by the Early Jurassic part of the undifferentiated Gabbs and Sunrise is probably greater than that of the type Sunrise formation. The apparently higher proportion of silt and sand in the sedimentary rocks of the Jurassic part of the undifferentiated Gabbs and Sunrise formation in the Union district may also contribute to its greater thickness in comparison with the Sunrise formation of the Gabbs Valley Range. In addition some of the lateral variation in thickness may be due to minor interruptions in deposition which have not been recognized, but might be expected in these rocks, which are interpreted as the product of shallow-water deposition.

The lithologic composition of the undifferentiated Gabbs and Sunrise formations in the Union district consists for the most part of a repetitious succession of shaly calcareous siltstones and silty limestones. For convenience in description, this sequence has been divided into lithologic units of different thicknesses which, listed from top to bottom, are as follows:

	Thickness (Feet)
Dunlap formation:	
Sandstone, fine-grained and very fine-grained, grayish-brown, noncalcareous, thick-laminated but massive bedded.	
Gabbs and Sunrise formations:	
Unit L:	
Limestone, gray, crystalline, dolomitic. Weathers grayish brown to dark brown, thick- and very thick-bedded. Silicified in part, particularly near top. Abundant rhynchonellid brachiopods in silty or sandy brownish- and purplish-weathering oolitic limestone bed near base	80
Unit K:	
Limestone, medium- to thick-bedded, silty and sandy. Dolomitic in part. Weathers buff and brownish gray. Oolitic in a few places	About 150

Gabbs and Sunrise formations—Continued	*Thickness (in feet)*
Unit J:	
Limestone, pebbly conglomeratic. Granules and pebbles of limestone and gray chert in approximately equal proportions in matrix of sandy limestone. Thickness and stratigraphic horizon somewhat variable. A few reefs of rudistid pelecypods (*Plicatostylus*?)	About 30
Unit I:	
Limestone, silty or sandy; and calcareous siltstone to fine-grained calcareous sandstone. Predominantly massive and medium bedded. A few shaly partings, particularly near base. Gray; weathers buff and brownish gray, rarely grayish lavender. Large-sized *Weyla* and "*Uptonia*" near base	250
Unit H:	
Limestone, thin- and medium-bedded. Silty in part. Weathers predominantly grayish lavender, rarely brownish. A few argillaceous interbeds become strong reddish purple on weathering. *Polyplectus*, *Grammoceras*, and *Pholadomya* near top	270
Unit G:	
Limestone, very thinly parted, argillaceous, silty; and calcareous siltstone. Gray; weathers predominantly brownish gray with some purplish gray. Interbedded with and grading into subordinate thin- to medium-bedded gray, brownish-weathering silty and sandy limestone. Limestone is oolitic in places. Proportion of argillaceous, platy-weathering silty limestone and calcareous siltstone to massive-bedded silty limestone about 3:1. Abundant terebratuloid brachiopods and *Entolium*. *Weyla* cf. *W. alata* and "*Pecten*" *lycorrhynchus*	About 600
Unit F:	
Limestone, argillaceous, silty, and calcareous siltstone. Very thin- and extrathin-parted, black, predominantly purplish-weathering, with some orange-brown- and brown-weathering. A few interbeds of thin- and medium-bedded black, brownish-weathering silty limestone. Proportion of argillaceous platy-weathering silty limestone and calcareous siltstone to massive-bedded silty limestone about 10:1. Abundant generically unidentifiable impressions of arietid ammonites	About 700
Unit E:	
Limestone, medium-bedded, silty, brownish gray-weathering, with a few interbeds of lavender-weathering argillaceous silty limestone	45
Unit D:	
Limestone and calcareous siltstone, very thin- and extrathinly-parted, black, purplish-weathing, argillaceous, silty. Grades into and interbedded with subordinate medium-bedded black, brownish-weathering silty limestone	135
Unit C:	
Limestone, medium-bedded, silty, bioclastic, brownish-gray-weathering, with irregular stratification planes. Fossiliferous from 8 feet above base to top. *Velata*, *Arietites*, "*Pecten*" *pradoanus*, *Stylophyllopsis*, *Entolium*, and *Pleurotomaria* in lower part of fossiliferous interval. *Velata*, *Asteroceras*, and *Juraphyllites* in upper part	42
Unit B:	
Limestone, medium-bedded, gray-weathering; silty in part; a few lavender-weathering argillaceous limestone interbeds. *Caloceras* and *Phylloceras* approximately 10 feet from top	About 150
Unit A:	
Siltstone, very thin- and extrathin-parted, black, lavender- and brownish-weathering, dolomitic, calcareous. Interbedded with medium- to very thick-bedded black, orange-brown-weathering silty dolomitic limestone. *Choristoceras*, *Pteria* sp., and *Velopecten* sp. near base of exposed section. (Section truncated by Shoshone (thrust.)	About 250
Total exposed thickness	About 2,700

The separation of the undifferentiated Gabbs and Sunrise formations into the units listed above is based primarily on megascopic physical characteristics such as the thickness of stratification and parting units and the prevalent color of weathered surfaces, features which are in turn dependent on the relative proportions of the mineral components which are common to the entire section. With few exceptions the composition of all the sedimentary rocks of the section can be expressed in terms of the same three general types of constituents, namely, calcium carbonate, argillaceous material, and detrital silt including very fine and fine sand. As would be expected, the more calcareous sedimentary rocks are massive bedded while the abundance of argillaceous material results in thinness of parting. Each of the three major components imparts a characteristic weathering color to the rocks, and this in turn is a fairly reliable guide to their composition. The argillaceous sedimentary rocks weather purplish or reddish gray; the abundance of silty or sandy detrital material produces brown weathering; and the relatively pure limestones, which are usually black on fresh exposures, weather gray.

The massive-bedded and less contaminated limestones are commonly bioclastic, and their origin is probably due more to a rapid accumulation of calcareous material than to a decrease in the rate of deposition of argillaceous and terrigenous clastic sediment. Among the organic detritus in the limestones of unit C are abundant monocrystallic fragments with a radial meshlike interior structure, as seen in thin section, that are suggestive of echinoid spines. Oolites are present at several different horizons in the less argillaceous limestones, where they are often accompanied by the appearance of coarser detrital sand grains indicating a relationship between increased current action and the formation of the oolites. The dolomitic nature of the limestones near the base of the exposed section and near the top may be secondary in origin. The occurrence of small rhombs of dolomite scattered through the matrix of both the calcareous siltstone and the silty limestone of unit A may be due to hydrothermal action along the nearby Shoshone thrust. At the top of the section, the dolomitic limestone and dolomite are locally silicified; and the contact between the undifferentiated Gabbs and Sunrise and the Dunlap formations, though conformable, may represent an interruption in sedimentation, during which the calcareous sediments were exposed to surficial alteration.

Detrital silt in varying amounts is found everywhere throughout the undifferentiated Gabbs and Sunrise formations, whereas clastic material coarser than fine sand is rarely present, with the exception of the pebbly and conglomeratic limestones of unit J near the top of the section. The silt and sand is almost exclusively quartz, and detrital grains of chert, feldspar, magnetite, and zircon are present only in small amounts. Rare silt-sized grains of bluish-green tourmaline occur throughout the section. Detrital flakes of muscovite are fairly common, and in places in the argillaceous sediments of units D and F they amount to several percent of the rock. The detrital mica is distinct from the small amount of interstitial sericite produced by the recrystallization of the argillaceous material in the more sandy sediments. Although occurring in small amounts, the universal presence of tourmaline and muscovite, if not derived from a preexisting sedimentary rock, might suggest an igneous and metamorphic source area for a part of the clastic sediment. In contrast to the next younger Dunlap formation, the arenaceous sedimentary rocks of the undifferentiated Gabbs and Sunrise formations are predominantly well sorted and include only stable mineral grains.

AGE AND CORRELATION

The fossils from the undifferentiated Gabbs and Sunrise formations were not studied in detail, but their tentative identification is sufficient to establish the age of the section and its general correlation with the type sections of the Gabbs and Sunrise formations in the Gabbs Valley Range as described by Muller and Ferguson (1939).

Unit A contains a poorly preserved fauna composed of *Pteria* sp., *Velopecten* sp., and the characteristic Rhaetian (latest Triassic) ammonite *Choristoceras*. Thus, a correlation can be made between this unit and the strata assigned to the upper part of the type Gabbs formation, which also contain a Rhaetian fauna. About 300 feet higher in the section, *Caloceras* sp. occurs within a 2-foot thickness of strata along with isolated specimens of *Phylloceras* sp. and a species of *Velopecten* similar to that found in unit A. This fauna is of Hettangian age, the earliest subdivision of the Early Jurassic, but does not represent the lowermost Jurassic characterized by the genus *Psiloceras*. Hence, the boundary between the Triassic and Jurassic systems occurs at an indefinite horizon in the upper part of unit A or the lower part of unit B.

The beds of unit C from 18 feet above the occurrence of *Caloceras* to the top of the unit, within a stratigraphic interval of 35 feet, contain the most abundant and best preserved of the faunas collected from the undifferentiated Gabbs and Sunrise formations in the Union district. The assemblage from these beds includes several species of *Arietites*, "*Pecten*" *pradoanus* (closely related to "*P.*" *acutiplicatus* Meek), *Velata* sp. *Stylophyllopsis* sp., and a large species of *Pleurotomaria*. *Asteroceras* sp. and *Juraphyllites* sp. are also recognized in the upper part of this section. This fauna is closely related to that (Muller and Ferguson, 1939, p. 1611–1612) from 75 to 85 feet above the base of the type section of the Sunrise formation and is at least in part of Sinemurian age. As in the corresponding part of the type Sunrise section, more than one faunal zone may be represented in unit C.

Diagnostic fossils are absent in the overlying units D and F, mainly owing to the preponderance of argillaceous sediments, which result in poor preservation of the organic remains. Large pectenoid pelecypods from unit G, identified by S. W. Muller as *Weyla* cf. *W. alata* and "*Pecten*" *lycorrhyncus*, may indicate an equivalence with the fauna from "division 8" in the upper part of the type Sunrise section, which is assigned a late Sinemurian or early Pliensbachian (middle Early Jurassic) age (Muller and Ferguson, 1939, p. 1611–1612).

A Toarcian (late Early Jurassic) age is represented by a single specimen of *Grammoceras* sp. and another of *Polyplectus* sp. (identified by S. W. Muller) collected near the top of unit H. These beds, about 550 feet below the top of the undifferentiated Gabbs and Sunrise section in the Union district, are somewhat younger than the youngest fossils thus far obtained from the type section of the Sunrise formation in the Gabbs Valley Range (S. W. Muller, oral communication, 1956).

About 80–100 feet above the base of unit I, beds characterized by an abundance of *Weyla* sp. served as a useful datum (fossil zone Z, pl. 10) in interpreting the structure of the undifferentiated Gabbs and Sunrise formations. According to S. W. Muller (oral communication) this species of *Weyla* is undescribed and is not represented in the type Sunrise section. Fragments of a serpenticone ammonite tentatively referred to *Uptonia* sp. were also collected from these beds.

Undiagnostic brachiopods and rudistid pelecypods occur in the upper 400 feet of section above the "*Weyla* beds" in unit I. This part of the section may extend into the Bajocian (early Middle Jurassic). No fossils of any kind were observed in the overlying Dunlap formation, and hence there is no direct evidence for the age of the upper limit of the undifferentiated Gabbs and Sunrise formations.

DUNLAP FORMATION (MIDDLE JURASSIC)

The Dunlap formation is exposed only in the southernmost part of the area of pre-Tertiary outcrop in the Union district, where it occupies a continuous belt about 1 mile in length and not exceeding half a mile in breadth along the low hills bordering the Ione Valley south of Second Canyon. The exposed thickness assigned to the Dunlap formation and to a certain extent the lithologic description of the unit depend on the structural interpretation of its area of outcrop. On the east the exposures of the Dunlap formation are bounded by a thrust fault which has carried the undifferentiated Gabbs and Sunrise formations toward the west over the Dunlap formation. Parts of the same stratigraphic sections are present in both the lower and the upper plates of this thrust, indicating a comparatively small amount of displacement. For convenience this thrust will be referred to in the following discussion as the Third Canyon thrust.

The structure of the Dunlap formation within its area of outcrop is for the most part a syncline, which is partly overturned to the west and divided into three dislocated segments of unequal size by two westerly trending, high-angle faults. Although the structure of the Dunlap formation is predominantly synclinal, the east limb of this syncline in the middle one of its three faulted segments approaches an anticlinal axis adjacent to the Third Canyon thrust.

In the north segment the undifferentiated Gabbs and Sunrise formations forming the upper plate of the Third Canyon thrust are stratigraphically overlain by a few feet of the basal Dunlap formation, which is thrust over the Dunlap formation of the lower plate. Elsewhere, the Dunlap formation is restricted to the lower plate of the Third Canyon thrust. In the southern segment of the syncline, which is areally the most extensive and also the least deformed structurally, the synclinal axis bends sharply to the west as it is traced southward. In the west limb of the syncline north of the mouth of Third Canyon, the upper part of the undifferentiated Gabbs and formations is exposed beneath the base of the Dunlap formation.

The southern limit of the exposed Dunlap formation is an intrusive contact with an igneous body, only a small part of which can be seen beneath the Tertiary volcanic rocks. Although somewhat variable, the dominant component of this intrusive body, as exposed, is quartz monzonite porphyry. Contact alteration of the Dunlap formation adjacent to this igneous rock is not pronounced but does serve to prove its intrusive relationship. Impure sandstone containing volcanic rock fragments collected within several feet of the contact and examined in thin section is chloritized and clouded with finely disseminated alteration products but otherwise is not greatly altered.

Providing that the structural relations of the Dunlap formation described above are correct, the section is repeated in each limb of the synclinal fold which constitutes most of its outcrop area. Consequently, the actual thickness of section present is considerably less than the apparent thickness across the strike of the beds. The section of the west limb of the syncline measured along the north wall of "Third Canyon" from the conformable contact with the underlying undifferentiated Gabbs and Sunrise formations to the axial region of the syncline near the "Third Canyon" thrust has a thickness of approximately 800 feet. To work out the structural complexities, the exposed section of the Dunlap formation in the Union district has been divided into four units, three of which are relatively thin. Listed from bottom to top with their thicknesses they are the lower clastic unit, about 600 feet thick; the lower carbonate unit, about 50 feet thick; the upper clastic unit, 95± feet thick; and the upper carbonate unit. Throughout its area of outcrop, the upper carbonate unit occupies the axial region of the syncline in the Dunlap formation; and although the exposed thickness of this unit is only several tens of feet, its total thickness is not known. Both the structural and the stratigraphic interpretation of the Dunlap formation in this report are considerably different from that given by Ferguson and Muller (1949, p. 41) as a result of reconnaissance studies in the area.

The lithology of the Dunlap formation differs widely from one area to another within the region where it has been recognized (Muller and Ferguson, 1939, p. 1617). Consequently, the Dunlap formation of the Union district cannot be correlated with the type area of the formation in the Pilot Mountains solely on its lithologic composition. Furthermore, the original continuity of the Dunlap formation in the Union district with the exposures of the formation elsewhere cannot be established. Nevertheless, this formation is recognized as a genetic entity on a regional scale because its heterogenous lithologic character represents the initiation of folding of the older Mesozoic rocks and the eradication of the Luning embayment as a basin of marine deposition. The occurrence of sedimentary rocks indicative of rapid deposition, the abundance of unstable clastic material, and the appearance of volcanic rock in some areas serve to differentiate the Dunlap formation from the older formations characterized by carbonate and stable clastic sediments that were deposited in the Luning embayment during the Late Triassic and Early Jurassic. Although easily distinguished, the difference between the Dunlap formation, as exposed in the Union district, and the older formations of Mesozoic age is not nearly as pronounced as in some other localities. The Dunlap formation overlies the undifferentiated Gabbs and Sunrise formations with conformity, and no basal conglomerate is present. The base of the section is arbitrarily established at the beginning of a continuous thick section of noncalcareous fine-grained sandstone which becomes gritty and pebbly in its upper half. The impending orogeny in the region is suggested by the abrupt change from the marine carbonate rocks of the undifferentiated Gabbs and Sunrise formations to the dominantly clastic sedimentary rocks of the Dunlap formation and by the occurrence of volcanic detritus in the sandstones.

The part of the Dunlap formation exposed in the Union district is unfossiliferous, but might be assigned at least in part to the lower Middle Jurassic (Bajocian) owing to the absence of a marked stratigraphic break between it and the underlying undifferentiated Gabbs and Sunrise formations.

LITHOLOGIC CHARACTER

The lower clastic unit, with a thickness of about 600 feet, composes the major share of the exposed section of the Dunlap formation. In general, the grain size of the arenaceous sediment and the amount of unstable clastic material increases towards the top of the unit. The lower 250 feet of section is relatively homogeneous fine- and very fine-grained somewhat impure sandstone which is predominantly brown owing to the presence of interstitial ferric oxides. A poorly defined stratification is usually produced by variations in the amount of ferric oxides, so that the sandstone is commonly laminated although massive bedded. Quartz is the most abundant detrital constituent. However, chert grains and siliceous rock fragments make up about 25 percent of the rock, feldspars 5 to 10 percent, and a variety of accessory minerals, including magnetite, biotite, bluish-green tourmaline, apatite, and zircon, usually constitute about 5 percent. Most of the detrital grains are rimmed with sericite, representing the original argillaceous matrix material. A few small patches of calcite are present in the matrix, but calcareous cement is rarely present.

In contrast to the uniform nature of the lower part of the section, the remainder of the lower clastic unit is variable in grain size, with attendant variations in composition, texture, and color. A variety of arenaceous sediment ranging from impure fine-grained sandstone and siltstone to coarse-grained, gritty and pebbly lithic sandstones are present in interbedded and interlensing units from several feet to several tens of feet in thickness. The finer grained clastic rocks are usually a strong purple, whereas the coarser sandstones are greenish, giving the weathered slopes a variegated appearance when viewed from a distance.

The fine-grained sandstones and siltstones agree in composition and texture with those forming the basal part of the section, the most conspicuous difference being an abundance of detrital magnetite, commonly several percent, in addition to the interstitial ferric oxides. With an increase in grain size, volcanic detritus becomes an increasingly important constituent in the form of basic volcanic rock fragments, plagioclase crystals, and chloritic siliceous patches in the matrix which may either represent tuffaceous material or fine-grained sediment eroded from a volcanic terrain. None of the Dunlap rocks show unmistakable tuffaceous textures which would provide evidence that they were the product of contemporaneous volcanism rather than having been derived from the Pablo or some other preexisting volcanic formation. Most of the coarse-grained detritus in the coarse-grained sandstones and grits consists of lithic fragments, predominantly chert and siliceous, micaceous metasedimentary rocks in addition to the volcanic rock fragments and occasional limestone granules and pebbles. The matrix consists of a recrystallized mixture of sericite and of chlorite, which is apparently responsible for the characteristic green of these coarser grained arenaceous rocks. The pebbly sandstones commonly contain irregular fragments of purple argillite up to several inches in longest dimension and locally forming a sedimentary breccia.

The lower carbonate unit of the Dunlap formation, composed of relatively pure dolomitic limestone and dolomite, overlies the lower clastic member with an abrupt and sharply defined change in lithology. The carbonate rocks are nearly white on fresh exposures, weathering to a brownish gray or buff and are characterized by their distinctive stratification. Although they commonly crop out as medium- to thick-parted massive beds, the stratification is well defined by irregular and lenticular laminations about one-tenth of an inch in thickness. The individual laminae are composed of fine-grained dolomite with subordinate calcite in irregular, more coarsely crystalline patches. Separating the laminae from one another are thin seams of argillaceous material and ferric oxides. Little or no detrital quartz is present except at the top of the member near the transitional contact with the arenaceous sediments of the upper clastic unit. The stratification of the carbonate rocks is usually somewhat broken and contorted, and the thickness of 50 feet for this member in the measured section must be regarded as approximate.

The detrital sedimentary rocks of the upper clastic unit, which has a thickness of about 100 feet, are exclusively fine grained. The predominant rock type is very fine-grained laminated quartzose sandstone, which is somewhat feldspathic and contains the same suite of accessory detrital grains that are present in the lower clastic unit. The matrix contains an abundance of pigmented fine-grained detritus including ferric oxides, black carbonaceous (?) material, and chlorite, coloring the rock brownish or greenish black. The upper clastic unit is homogeneous except for a few thin interbeds of black slate in the lower part of the section. A small amount of calcareous cement is usually present, and at the base and top of the section the arenaceous sediments grade into the adjacent carbonate units.

The composition of the upper carbonate resembles that of the lower carbonate unit, but the laminated dolomite is generally less pure, commonly containing detrital quartz silt and sand and less commonly lenticular beds of quartzitic sandstone. The sandy dolomite consists of poorly defined layers of detrital quartz grains interlaminated with finely crystalline dolomite. Locally, small-scale crossbedding is developed. Near the quartz monzonite intrusive body south of Fourth Canyon, a variety of finely crystalline alteration products have developed in the matrix of these impure carbonate rocks and irregular microscopic crystals of secondary zoisite commonly occur along fractures. The lenticular beds of noncalcareous quartzitic sandstone consist almost exclusively of closely packed fine quartz sand with some interstitial micaceous material. In a specimen of quartzite collected near the Third Canyon thrust in Fourth Canyon, the quartz grains are rimmed with minute acicular crystals of "sericite" (illite?), some of which appear to penetrate the borders of the sand grains. Throughout its area of outcrop the upper carbonate unit of the Dunlap formation occupies the axial region of a synclinal fold, and consequently the rocks of this unit are usually somewhat brecciated and contorted.

The lithologic features of the Dunlap formation as exposed in the Union district reflect a definite change from the conditions of sedimentation which prevailed during the Late Triassic and earliest Jurassic. The homogeneous sandstone beds near the base of the lower clastic unit contain the same detrital materials as those that occur in the marine carbonate rocks of the underlying undifferentiated Gabbs and Sunrise formations. Higher in the section, however, clastic sedimentary rocks unique to the Mesozoic section in the area make their appearance. Although a part of the detrital volcanic material may have been derived from contemporaneous volcanism in nearby areas, the occurrence of volcanic detritus might also indicate the uplift and exposure to erosion of the Pablo formation. Some of the fine-grained greenish siliceous rock fragments in the coarse lithic sandstones closely resemble the altered tuffaceous rocks of the Pablo formation. The possible continued derivation of a part of the sediment from a granitic and metamorphic terrain is evidenced by the occurrence of feldspathic sands, detrital mica flakes, and the relative abundance of detrital accessory minerals such as magnetite and tourmaline.

The available evidence is inconclusive as to whether the sedimentary rocks of the Dunlap formation are marine or nonmarine in origin. The generally high degree of sorting and laminated stratification of the sandstone beds together with the absence of fossils may indicate strand-line conditions, and the peculiar aspect of the carbonate sedimentary rocks is suggestive of lagoonal or fresh-water deposition.

INTRUSIVE ROCKS

One of the factors that makes the Union district particularly favorable for pre-Tertiary stratigraphic studies is the relatively small part of the area underlain by igneous, intrusive rocks. Although igneous dikes and small intrusive bodies are scattered throughout the pre-Tertiary area, igneous activity has generally not resulted in strong thermal metamorphism of the older rocks.

The most extensive granitic body exposed in the Union district occupies an area of about 1 square mile along the front of the range from northwest of Ione south to Shamrock Canyon, where it forms the country rock of the Shamrock mine and the western part of the group of mining developments included in the "Shamrock diggings." On the north and east this granitic rock is in intrusive contact with the greenstone member of the Pablo formation, and on the south it is faulted against the Grantsville, Luning, and Pablo formations. Though the intrusive rock is predominantly quartz diorite, it grades in composition from diorite to granodiorite. Hornblende and its reaction product, biotite, are the most common ferromagnesian minerals present; but specimens from various parts of the intrusive body show a complete reaction series from clinopyroxene, through green or brown hornblende, to green biotite, and finally to brown biotite. Lath-shaped regularly zoned crystals of andesine or oligoclase are commonly included by the subordinate anhedral crystals of potassium feldspar. Quartz is present even in the samples most deficient in potassium feldspar. Accessory minerals, principally sphene, apatite, and "iron ores," are relatively abundant and are coarsely crystalline. A light-colored border zone of this intrusive body is exposed north of Ione.

From its intrusive relationships the age of this granitic body can be established only as post late Paleozoic. However, as the lower Mesozoic sedimentary rocks are metamorphosed and structurally deformed to about the same degree as the intruded upper Paleozoic rocks, the age of intrusive body is probably late Mesozoic or early Tertiary.

Two dikelike granitic intrusive bodies are present in the isolated exposure of the Grantsville formation on the east flank of the Shoshone Mountains near Grantsville Summit. The agreement in the range of composition and mineralogy, including the reaction series of the ferromagnesian minerals, with the granitic body exposed in the vicinity of Ione suggests a genetic relationship between these two disconnected intrusive bodies. The granodioritic sills in the segments of the Grantsville formation north of Richmond Hill, previously described in the discussion of the Grantsville formation, may also be related to the intrusive body near Ione, but they are generally too altered from their original composition for comparison.

The genetic relationships of the other scattered occurrences of igneous intrusive rocks in the Union district are indefinite, but most of them probably belong to the same general period of late Mesozoic or prevolcanic Tertiary intrusive activity. A possible exception is a small body of diorite, cropping out about 1,500 feet northwest of the Copper King mine between Knickerbocker and Sheep Canyons, which intrudes into the clastic member of the Pablo formation. This intrusive body is strongly propylitized like the meta-andesites of the Pablo formation and may represent a feeder dike of the rocks in the volcanic Pablo. In contrast to this occurrence, a relatively unaltered dike of granodiorite porphyry, composed of phenocrysts of plagioclase and chloritized biotite in an anhedral matrix of quartz and potassium feldspar is exposed along the access road to the Copper King mine in the clastic member of the Pablo formation immediately north of the mine workings.

Altered volcanic and sedimentary rocks of the Pablo, Grantsville, and Luning formations can be recognized within the area mapped as "aplite" in Grantsville Canyon by Ferguson and Muller (1949, pl. 12 and 13). Although no intrusive rocks were observed on the surface, the granitic rocks responsible for the contact metamorphism at Grantsville are said to occur in the underground mine workings.

No intrusive rocks are in evidence south of Grantsville Canyon except at the southernmost limit of the pre-Tertiary area of outcrop where a small exposure of quartz monzonite porphyry intrudes the Dunlap formation and is overlapped by Tertiary volcanic rocks.

STRUCTURE OF THE PRE-TERTIARY ROCKS

The structural features of the pre-Tertiary rocks exposed in the Union district are the result of normal faulting of the Basin and Range system superimposed on large-scale folds that are broken by thrust faults developed during folding. This interpretation differs somewhat from that of Ferguson and Muller (1949, p. 41–44), who called upon a major thrust fault to bring different facies of the Luning formation together in the area. All of the Luning is considered here as part of one continuous section, and hence thrusting of large magnitude is not required. In the present interpretation the folds and thrusts in the area are considered as interrelated local effects of widespread strong compressional deformation. The names applied by Ferguson and Muller to three of the more prominent structural features within the area, the Shoshone thrust, Richmond Hill fault, and Union Canyon fault, are adopted in this report.

No deformation before the early Middle Jurassic is recorded in the upper Paleozoic and Mesozoic section of the Union district. Although the Cambrian(?) quartzite and dolomite units exposed in the northern part of the area appear to be discordant with the younger formational sequence, they are not in stratigraphic contact with the younger rocks, and their structural relationship to the upper Paleozoic and Mesozoic section is not known. The Pablo formation of Permian(?) age is overlain with only erosional disconformity by the Middle Triassic Grantsville formation which is in turn disconformably overlain by the Upper Triassic Luning formation. The sequence of the Luning, undifferentiated Gabbs and Sunrise, and Dunlap formations is continuous and conformable, assuming that the contact between the Luning and the undifferentiated Gabbs and Sunrise formations, which is not exposed in the Union district, is conformable.

At some time after the deposition of the early Middle Jurassic Dunlap formation and before the emplacement of granitic intrusive rocks, the pre-Tertiary rocks were strongly deformed. The Permian (?) and Triassic rocks exposed north of Grantsville Canyon, which have a prevailing easterly dip, are considered part of the upright limb of a major overturned anticline whose axis strikes and plunges southeast. The axial region and the overturned limb of this fold are represented by the structurally complex Mesozoic rocks in Grantsville Canyon and the area to the south. The intricate system of high-angle faults in Grantsville Canyon and the Shoshone and Third Canyon thrust faults are interpreted as shears developed during the folding and overturning of these rocks. At the south end of the pre-Tertiary area, the Dunlap formation may occupy the axial region of a major overturned syncline coordinate with the anticline described above.

The Shoshone thrust carries massive carbonate rocks of the Luning formation over the undifferentiated Gabbs and Sunrise formations, cutting out the intervening part of the Triassic section. The thrust is well exposed where it crosses Milton Canyon and also crops out in the low hills between Milton and First Canyons where it bounds a down-faulted klippe of the Luning. In Milton Canyon the thrust strikes N. 35° W. and dips 45° NE., but beneath the klippe it becomes more nearly horizontal and may describe a shallow synclinal flexture. Owing to the lack of pronounced lithologic differences within the undifferentiated Gabbs and Sunrise formations and the generally poor exposures resulting from their low topographic relief, the structure of these rocks beneath the Shoshone thrust in Milton Canyon could not be worked out in detail. Nevertheless, a series of parallel folds, becoming overturned towards the southwest and adjacent to the thrust, are apparent in the Lower Jurassic rocks of the lower plate and clearly reflect a southwestward relative movement of the upper plate. South of the klippe of the Shoshone thrust the undifferentiated Gabbs and Sunrise formations between First and Fourth Canyons represent the east limb of a large synclinal fold which is also partly overturned towards the southwest. These rocks are in turn carried relatively southwestward over the folded and partly overturned Dunlap formation by the Third Canyon thrust. This thrust, which may be more or less subsidiary to the Shoshone thrust and of comparatively small displacement, has already been described in the discussion of the Dunlap formation.

The spectacular "spike" of massive dolomite belonging to the carbonate member of the Luning formation that protrudes from the plane of the Shoshone thrust on the south wall of Milton Canyon into the overturned calcareous siltstones of the undifferentiated Gabbs and Sunrise formations has previously been described and illustrated by Ferguson and Muller (1949, p. 42 pl. 10). The tip of the "spike," which has an overall apparent length of more than 200 feet, consists of an isoclinal anticline which is sheared along its lower surface. The individual beds of this fold can be traced eastward through subsidiary synclinal and anticlinal folds into the main mass of the Luning formation in the upper plate. As explained by Ferguson and Muller, a group of massive beds overlying the original plane of the Shoshone thrust evidently developed into a small drag fold and were forced into the relatively incompetent strata of the undifferentiated Gabbs and Sunrise formations. After this occurred, the thrust plane followed the lower surface of the drag fold and carried both the "spike" and the beds of the undifferentiated Gabbs and Sunrise formations caught between the spike and the main mass of the upper plate over the undifferentiated Gabbs and Sunrise formations of the lower plate. A similar anomaly is present along the plane of the Shoshone thrust on the north wall of Milton Canyon, where it is partly obscured by talus material from the Luning formation.

The complex system of northwest-trending faults in Grantsville Canyon was attributed by Ferguson and Muller (1949, p. 43) to reverse faulting that took place after movement on the Shoshone thrust, but an origin of both the Grantsville fault system and the Shoshone thrust during the folding of the area seems more plausible. Fault slivers of the Grantsville formation and the clastic, shaly limestone, and calcareous shale members of the Luning formation separate the Pablo formation on the north wall of the canyon from the carbonate member of the Luning on Grantsville Ridge. Where observed, the faults between the slivers of Triassic rock dip steeply, generally towards the southwest. Although a complete section of the various members of the Grantsville and Luning formations is not present and locally some members are faulted out entirely, the sequence of fault slivers is in the order of decreasing age from north to south across the canyon. Allowing for considerable contortion and breakage, these fault slivers can be traced to the east and north across Grantsville Canyon to Richmond Hill. Here the corresponding rock units are in a relatively undisturbed upright sequence, with a northerly strike and easterly dip. Thus the Grantsville Canyon area can be interpreted as the axial region of an asymetric anticline, the axis of which strikes and plunges southeast through the area of intensely altered greenstone of the Pablo formation on the north wall of Grantsville Canyon. During folding, the Triassic rocks in the steep southwestern limb of the anticline were sheared between the underlying greenstone member of the Pablo and the overlying carbonate member of the Luning formation, both of these units being relatively thick, homogenous, and competent. Dislocation may have taken place along some of the faults of the Grantsville system during the Tertiary block faulting of the region, but these structural features were originally formed before igneous intrusion and contact metamorphism at Grantsville.

Owing to the absence of lithologic markers and the scarcity of fossils, the structure of the carbonate member of the Luning formation that forms the upper plate of the Shoshone thrust south of Grantsville Canyon could not be adequately determined. The dip of the homogeneous massive dolomite and limestone on Grantsville Ridge is predominantly to the east, but isoclinal folding is apparent in the section. At the north end of Grantsville Ridge, the carbonate member of the Luning is evidently part of the sheared southwest limb of the asymmetric anticline described above. If so, and assuming the existence of an intervening synclinal fold, the part of the carbonate member carried over the undifferentiated Gabbs and Sunrise formations by the Shoshone thrust may represent a large recumbent anticline.

The maximum distance between outcrops of the Shoshone thrust, measured transverse to its strike, is about 1½ miles. If, however, the carbonate member of the Luning that forms the upper plate is interpreted as a recumbent anticline, the overturned limb of which is thrust over the overturned lower part of the undifferentiated Gabbs and Sunrise formations, the actual displacement on the thrust need be only a fraction of this distance. On the other hand, displacement of great magnitude on the thrust as suggested by Ferguson and Muller (1949, p. 42–43) cannot be precluded because the rocks of the upper and lower plates are of different ages, and hence a similarity of facies in the rocks above and below the thrust cannot be demonstrated.

North of Grantsville Canyon the outcrop pattern of the generally eastward-dipping pre-Tertiary rocks is due primarily to faulting. The intricate arrangement of normal faults between Richmond Hill and Berlin is separated into two systems, the Union Canyon fault system and the Richmond Hill fault system.

The Union Canyon fault can be traced from a point about 3,000 feet east of the Richmond mine, where it is lost beneath the Tertiary volcanic rocks, westward into West Union Canyon. About 1 mile from the mouth of the canyon at its intersection with the Richmond Hill fault, the Union Canyon fault appears to branch into many divergent normal faults that trend northwestward and westward and dissect the pre-Tertiary rocks between West Union Canyon and the ridge north of Berlin Canyon. Although the greenstone member of the Pablo formation, as mapped in this area, appears to be devoid of these faults, this is only because faults are unrecognizable on the surface where they cross the thick and relatively homogeneous greenstone unit. Actually, only the more conspicuous of the faults of the Union Canyon system could be plotted on the scale at which they were mapped. Where exposures are good, as in the workings of the Berlin mine, the faults are seen to be more closely spaced (Dagget, 1908). Most of the faults of the Union Canyon fault system on the north side of West Union Canyon dip steeply southwest and show relatively small displacements with the apparent downthrow to the south or southwest. The displacement on a few of these faults is in the opposite direction; but as they dip to the northeast, they are also normal faults. In contrast, east of its intersection with the Richmond Hill fault, the Union Canyon fault is more or less vertical and causes a displacement of several thousand feet owing to either relative downthrow of the northern block or left lateral strike-slip movement. As rotational movement on the Union Canyon fault system does not seem to have taken place, more than one period of displacement is indicated.

Although at least some dislocation along the Union Canyon fault system took place during the Tertiary block faulting of the Union district, this fault system may have originally formed during an earlier period of deformation, as pointed out by Ferguson and Muller (1949, p. 43–44). Faulting before the intrusion of granitic rocks is suggested by the occurrence of a small body of altered granodioritic dike rock ("aplite" of Ferguson and Muller), identical with that which is present locally as sills in the Grantsville formation, along the Union Canyon fault immediately northeast of the Richmond mine. Unfortunately, the field relations are inconclusive as to whether this occurrence is actually an igneous intrusive body along the plane of the fault or simply a fault sliver derived from a sill in the nearby Grantsville formation. The absence of contact alteration associated with this dike rock does not necessarily disprove the possibility of its intrusive nature because little, if any, contact effect has been caused by the intrusion of sills with similar lithology into the limestone of the Grantsville formation. On the other hand, the small amount of shearing observed at the contact of the dike rock with the carbonate member of the Luning formation might be attributed to renewed movement along the Union Canyon fault after the intrusion of a dike rather than to the emplacement of the dike rock as a fault sliver.

Between West Union Canyon and Grantsville Canyon, a displacement of large magnitude has taken place along the Richmond Hill fault that borders the west side of Richmond Hill. This fault separates the greenstone member of the Pablo on the east from the Triassic rocks on the west. Both the dip and the relative downdrop are to the west, and the throw, providing that the original feature was more or less homoclinal, is in excess of 3,000 feet. Where the fault surface is exposed about midway along its trace, separating a sliver of conglomerate of the Luning on the west from the greenstone of the Pablo on the east, the plane strikes N. 20° E., dips 50° west, and shows striae that plunge 40° SW. The branching normal faults dislocating the Triassic rocks west of the Richmond Hill fault are apparently subsidiary to it and belong to the same system of faulting.

The Richmond Hill fault terminates at its north end against the southernmost fault of the Union Canyon system, but is not truncated by it because no extension of the Richmond Hill fault is present in the area north of West Union Canyon. This suggests that displacement along the Richmond Hill fault system was accommodated to the north of West Union Canyon by part of the Union Canyon fault system.

As pointed out by Ferguson and Muller (1949, p. 43–44), the faulting that occurred after mineralization in the Berlin mine, described by Daggett (1908), may confirm contemporaneous normal faulting in two directions. In the Berlin mine, normal faults that strike northwest and are parallel to the Union Canyon system, and northward trending normal faults, which may be part of the range front system, offset one another, and both fault systems displace the Berlin vein, which strikes northeast and dips southeast. In the Berlin mine the faults referable to the Union Canyon system, termed "faults" by Daggett in distinction to the "breaks" of the range front system, have a dip and relative downdrop to the northeast and seem to be the northwestern extensions of the faults that cross the ridge between West Union and Berlin Canyons to the southeast of Berlin and have the same relative displaceplacement. The fact that the direction of displacement on these faults is opposite to that observed on most of the branches of the Union Canyon fault system might be an important consideration in attempting to find the northeast and southwest extensions of the Berlin vein.

The sequence of events suggested by Ferguson and Muller (1949, p. 43–44) is that the original movement on the Union Canyon fault was horizontal and shifted the northern block relatively westward. This was followed by relative uplift of the block bounded on the west by the Richmond Hill fault and on the north by the eastern segment of the Union Canyon fault. In this sequence of events the faults of the Union Canyon system, diverging from the intersection of the two major faults, represent "adjustment in the downthrown block at the point of major stress."

An alternate interpretation is that original dislocation on the Richmond Hill fault was accompanied by distributed displacements on the faults of the Union Canyon system, which possibly follows a preexisting fracture pattern. The result of this movement was relative downthrow of the block bounded respectively on the east and north by the Richmond Hill and Union Canyon fault systems. Subsequent dislocation along the east segment of the Union Canyon fault and a few of its western branches then resulted in relative downdrop of the block north of the Union Canyon fault system. As geologic mapping does not show which, if either, is the older among the northeast- and southwest-dipping normal faults of the Union Canyon system, the sequence of faulting remains unsolved.

The structure of the dissected pediment south of West Union Canyon and west of Richmond Hill was considered to be a broad broken syncline by Ferguson and Muller (1949, p. 43–44) but is better described as a series of step-faulted blocks formed by displacements on the Richmond Hill fault system with the only folding being minor drag folds adjacent to the faults.

Throughout most of the Union district the Tertiary volcanic rocks are in depositional contact with the pre-Tertiary rocks and are unaffected by the structural features of the older rocks. Possible exceptions to this relationship are the patches of Tertiary lavas west of Richmond Hill and those near the mouth of Milton Canyon which may have been downdropped respectively by the Richmond Hill fault and the normal fault that crosses Milton Canyon and offsets the Shoshone thrust. However, because the Tertiary volcanic rocks were deposited on a preexisting topography, the difference in elevation between these isolated patches of volcanic rocks and those higher in the range is not necessarily due to a late stage of faulting.

The most striking fault relationship between the Tertiary volcanic rocks and the older rocks is the northward-trending normal fault, here named "the Mercury Mine fault", that separates the pre-Tertiary rocks in the northeast part of the area from the Tertiary rocks along the crest of the Shoshone Mountains. This fault can be traced from the drainage of Ione Canyon southward for nearly 2 miles to the Mercury Mining Co. mine at the head of Shamrock Canyon. South of the

Mercury Mining Co. mine, the Mercury Mine fault appears to die out in the Tertiary volcanic rocks (C. J. Vitaliano, written communication, 1956), indicating that its displacement is not large. Patches of volcanic rocks are present on the relatively uplifted west side of the fault and these rocks belong to the same Tertiary volcanic unit that has been downdropped to the east of the fault. A short segment of a similar fault between the pre-Tertiary and Tertiary rocks is also exposed near the southward bend in Sheep Canyon, north of the Nevada Cinnabar mine.

Where the Mercury Mine fault crosses Shamrock Canyon, it is displaced by a younger, westward-trending, normal fault. This transverse fault may be related to several other approximately parallel faults exposed near the front of the range between Shamrock and Sheep Canyons. The relative downthrow of these transverse faults is uniformly toward the north.

The Mercury Mine fault and the younger transverse fault system displacing it represent one of the controlling factors in the localization of the quicksilver mineralization in this part of the Union district. The ore of the Mercury Mining Co. mine, the largest producer of quicksilver in the Union district, occurs in both the pre-Tertiary sedimentary rocks and the Tertiary volcanic rocks in the zone of the Mercury Mine fault (Bailey and Phoenix, 1944, p. 149–151). North of the Mercury Mining Co. mine, small quicksilver mines and prospects are situated in either the pre-Tertiary or Tertiary volcanic rocks on both sides of the fault. To the south, the Nevada Cinnabar mine, at the head of Sheep Canyon, and the prospect locally known as the King claim, at the head of East Union Canyon are along a southward extension of this north-trending belt of mercury mineralization. However, both of these deposits are in Tertiary volcanic rocks at some distance from the pre-Tertiary area of outcrop, and they cannot be directly related to the Mercury Mine fault.

The Indian Johnnie Dick and Two Injun quicksilver properties, on the ridge between Shamrock and Sheep Canyons and nearly a mile west of the Mercury Mining Co. mine, are along one of the faults of the transverse fault system which displaces the Mercury Mine fault. Thus, the younger transverse fault system may provide a connection between these seemingly isolated occurrences of mercury and the main north-trending zone of mineralization along the Mercury Mine fault. The mercury mineralization in the northern part of the Union district seems to be associated only with the structural features of the pre-Tertiary rocks which also involve the Tertiary volcanic rocks.

Both the Mercury Mine fault and the transverse fault offsetting it are younger than the beginning of Tertiary volcanism, but the age relationship of these faults with the other normal faults in the area is indeterminate. The faults of the transverse system in Sheep Canyon and on the ridge north of Sheep Canyon offset three northward-trending normal faults that may be related to the range front faulting because their relative downthrow is toward the west. This at least shows that these northward-trending faults as well as the Mercury Mine fault are older than the transverse faults. The northward-trending fault crossing Buffalo Canyon, which has the same direction of displacement as the Mercury Mine fault, is truncated at its south end by faults of the Union Canyon fault system. However, a genetic connection between this northward-trending fault and the Mercury Mine fault cannot be established.

The Mercury Mine fault downdrops the present crest of the Shoshone Mountains in relation to the parts of the range west of the fault. This suggests that the Mercury Mine fault may be related to the relative downdrop of the Reese River valley, which separates the northern part of the Shoshone Mountains from the Toiyabe Range to the east.

Although the west front of the Shoshone Mountains probably represents the eroded scarp of a range front fault system, evidence of relatively modern faulting along the range front in the Union district is scarce. Fault-line scarps are visible at the edge of the alluvium near the mouth of West Union Canyon and along the front of Grantsville Ridge.

PALEONTOLOGY

GENERAL FEATURES

A comparatively small number of the marine invertebrates from the pre-Tertiary rocks exposed in the Union district have been selected for description. The species described are all of Late Triassic age and include either those which were found to have the greatest stratigraphic value or previously little-known forms, the description of which is desirable to increase the knowledge of their biologic relationships and stratigraphic occurrence. The emphasis is placed on the paleontology of the Upper Triassic strata because this part of the pre-Tertiary section exposed in the Union district provides the best opportunity for biostratigraphic studies and contains the most abundant fauna. The forms selected for description are so indicated in the lists of the marine invertebrates provided in the stratigraphic discussion of each of the Upper Triassic formational units.

The locality numbers used in the paleontologic descriptions are recorded at the Menlo Park, Calif., laboratory of the Paleontology and Stratigraphy Branch of the U. S. Geological Survey. As all the fossils described are from the Luning formation in the vicinity of West Union Canyon, the locality numbers serve primarily to denote the stratigraphic level within this formation. The locality numbers used are as follows:

M71. Shaly limestone member of the Luning formation. *Klamathites schucherti* zone. About 125–250 feet stratigraphically above the base of the member.

M72. Upper part of the shaly limestone member and basal part of the overlying calcareous shale member of the Luning formation. *Klamathites macrolobatus* zone, with the stratigraphic position within the zone undifferentiated. About 100 feet stratigraphically below to 30 feet above the base of the calcareous shale member of the Luning formation.

M72a. Lower subdivision of the *Klamathites macrolobatus* zone. About 100–30 feet below the base of the calcareous shale member of the Luning formation.

M72b. Middle subdivision of the *Klamathites macrolobatus* zone. About 30–0 feet below the base of the calcareous shale member of the Luning formation.

M72c. Upper subdivision of the *Klamathites macrolobatus* zone. About 0–30 feet above the base of the calcareous shale member of the Luning formation.

M73. Calcareous shale member of the Luning formation. *Guembelites* zone. About 300–400 feet stratigraphically above the base of the member.

The primary type specimens of all of the species described are deposited in the U. S. National Museum. Topotypes for as many species as possible are stored in the paleontological collections of the Menlo Park, Calif., laboratory of the U. S. Geological Survey, and at Stanford University.

None of the fossils collected from the rocks of Paleozoic age in the Union district are sufficiently well preserved to warrant description. The most diagnostic forms from the Middle Triassic Grantsville formation can be adequately characterized, considering their generally poor preservation, by referring them to previously described genera and species. Some of the ammonoids from the Lower Jurassic undifferentiated Gabbs and Sunrise formations are well enough preserved to allow generic identification, which is generally sufficient for stratigraphic purposes, owing to the narrow vertical range of these genera. The pectenoid pelecypods are among the best represented fossils from the Lower Jurassic strata of the Union district and are being currently (1956) studied by S. W. Muller.

Representatives of three groups of Upper Triassic ammonoids, namely, juvavitids, arcestids, and *Styrites*, are not described although they are fairly well represented in the Union district and in some places are useful as stratigraphic markers. Several species of *Juvavites*, and the closely related generic groups of *Anatomites* and *Dimorphites*, occur in the Luning formation. Wherever possible in the faunal lists, these forms have been assigned to or compared to previously described species. The juvavitids are a group in which a large number of specific names have been proposed, and yet the distinction between the species and their assignment to the established genera is doubtful. Many of the taxonomic problems associated with this group are due to the considerable amount of morphologic change which commonly takes place during the growth of their shells, so that the biologic identity of the different growth stages is in some species unknown or difficult to establish. Furthermore, one may question whether the criteria used for the separation of species and genera among the juvavitids, such as the variations in whorl shape, the presence of paulostome furrows or marginal tubercles, the occurrence of excentrumbilication, and the stage of maturity at which these features are developed, have any genetic significance. A complete review of the existing species and genera of the juvavitids would be desirable both to define the existing taxonomic units more precisely and to evaluate their stratigraphic utility. However, a comprehensive revision of this group is not warranted by the material from the Union district, and such a study is beyond the scope of this report. Rather than expand the definitions of previously described species which have doubtful affinities or burden the literature with additional specific names for forms which cannot be positively compared to previously described species, the description of the juvavitids from the Union district is being postponed pending further study of this group.

The taxonomy of the arcestids is based largely on the features of the body chamber and aperture of the shell. These ammonoids occur in all three of the faunal zones recognized in the Luning formation, and they are fairly abundant in the *Klamathites macrolobatus* zone, but they are not sufficiently well preserved to justify specific determination. The occurrence of *Styrites* in the *Guembelites* zone, which is here assigned to the lower Norian, might be considered anomalous because this genus has previously been reported only from strata of late Karnian age or older. However, being small degenerate forms seemingly derived from a *Tropites*-like ancestor, the members of this genus are relatively featureless and may have a long stratigraphic range. The morphology of the *Styrites* from the Union district can be adequately characterized by comparing them to species previously described from the Karnian of the Alps.

The only fossils previously described from the Union district are two nautiloids, which Kummel (1953) described and identified generically from the early collections made in the area by Geological Survey geologists. One of these is included in the new species *Germanonautilus kummeli*, based on specimens from later collections. Only a few additional fragmentary specimens of the other form described by Kummel as *Paranautilus* sp. were collected, and Kummel's description cannot be enlarged upon. The locality (USGS 11773) of the specimen described by Kummel corresponds to that of the early collections from the *Guembelites* zone, and hence this specimen is from the calcareous shale member of the Luning formation in the formational terminology adopted in this report, and its age is considered to be early Norian.

The locality of three species of lower Middle Triassic ammonites collected by the Whitney expedition and subsequently assigned to *Acrochordiceras hyatti* Meek, *Balatonites kingi* Smith, and *B. shoshonensis* Hyatt and Smith, by Hyatt and Smith (1905) and Smith (1914) is given as "the Shoshone Mountains, Nevada" and in addition, for the last species listed above, "from longitude 117° W." This might give the impression that these forms are from the Union district, the only known occurrence of Triassic rocks in the Shoshone Mountains. However, besides the different longitude of the Union district no lower Middle Triassic fossiliferous marine sedimentary rocks are present in the Union district. The Whitney expedition locality is probably in the New Pass Range, as suggested by Smith (1914, p. 239), where the easternmost strata of that facies and age are known to occur.

SYSTEMATIC DESCRIPTIONS

Class CEPHALOPODA
Order AMMONOIDEA
Suborder CERATITINA Hyatt, 1884
Superfamily CERATITACEAE Mojsisovics, 1879
Family CARNITIDAE Arthaber, 1911
Genus KLAMATHITES Smith, 1927

Klamathites schucherti Smith

Plate 1, figures 15, 17–19

Klamathites schucherti Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 74, pl. 62, figs. 14–17.

Klamathites kellyi Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 74, pl. 63, figs. 1–5.

This species is represented by about 50 specimens in the collections from the Union district. The shell is strongly compressed and discoidal, with a narrow venter, which is biangular and flat or shallowly furrowed on the inner whorls, becoming convex and bluntly rounded on the outer whorls. The flanks are flattened, with a very gentle convexity. The outer whorls completely embrace the earlier whorls, so that the umbilicus is closed. Except for weak sigmoidal folds, which are best developed on the inner whorls, the surface of the flanks is smooth. With the aid of a hand lens, a fine radial vermicular pattern can be observed on the outer shell material, when preserved.

The suture line is the most distinctive feature of this species. The ventral lobe is extremely broad, extending across almost the entire outer half of the flanks, and is characteristically subdivided into three prominent adventitious saddles on either side of a small ventral saddle. The adventitious saddles and lobes, which develop by division of the juvenile ventral saddle, are usually individualized by the time the whorls attain 10 mm in height. A prominent spur is always present on the inner side of the second adventitious saddle, the largest of the adventitious saddles. The adventitious lobes usually terminate in several serrations, and the corresponding saddles are sometimes slightly crenulate. The principal lateral saddles are rounded, with some crenulation; and the lateral lobes are lanceolate or ceratitic. Following the principal elements of the suture is a long and somewhat crenulate auxiliary series.

The dimensions of the figured plesiotype are as follows: Diameter, 74 mm; width, 18.5 mm. The greatest whorl height of the largest specimen collected is about 60 mm compared with 44 mm for the plesiotype.

The examples of this species from the Union district are identical with those originally described by Smith from the so-called Hosselkus limestone of Shasta County, Calif. *Klamathites kellyi* described by Smith from the same locality and horizon is placed in synonomy with *K. schucherti*, which was originally designated by Smith as the type of the genus. According to Smith, *Klamathites kellyi* can be distinguished from *K. schucherti* by a slightly larger size and a greater complexity of the septa. Although the suture of the specimen illustrating the "early mature stage" of *K. kellyi* is somewhat more crenulate (Smith, 1927, pl. 63, fig. 5), the septation of the holotype (Smith 1927, fig. 3) is nearly identical with that of *K. schucherti*. Both forms appear to lie within the range of variation of a single stratigraphically restricted species for which the name *Klamathites schucherti* is applicable.

Plesiotypes, USNM 128249, 128315.

Occurrence.—Union district, Shoshone Mountains, Nev. This species is fairly common in the lower part of the shaly limestone member of the Luning formation about 180–220 feet above the base of the member. USGS locality M71.

Klamathites macrolobatus Silberling, n. sp.

Plate 1, figures 16, 20–22

The name of this species, of which about 30 specimens are available for study, has been adopted for the faunal zone included in the upper part of the shaly limestone member and basal calcareous shale member of the Luning formation. The shape of the shell of *Klamathites macrolobatus* is compressed and discoidal, with a narrow venter. On the inner whorls at whorl heights of less than about 25 mm, the venter is biangular and flattened. On the outer whorls the venter loses its angular margins but remains narrow and acutely terminated. The whorls are entirely embracing, and consequently, the shell is completely involute. The flanks are flattened and nearly smooth except for weak sigmoidal folds on the inner whorls.

The suture line contains the same number and disposition of principal and adventitious elements as that of *Klamathites schucherti*, but the subdivision and proportions of these elements is more extreme. The three adventitious saddles and their corresponding lobes are extremely long and slender, and their length equal to 3 or 4 times their breadth. The second adventitious lobe is completely crenulate and includes a prominent spur or secondary saddle on its inner side. The first lateral saddles and lobes are prominent and subdivided, respectively, by brachyphyllic crenulations and dolichophyllic serrations. The second lateral saddles and lobes are individualized but are not much subdivided and are followed by a series of low auxiliary lobes and saddles.

The dimensions of the holotype, which is among the largest of the well-preserved specimens, are as follows: Diameter, 86 mm; width, 21 mm; and the greatest height of the final whorl, 53 mm.

Klamathites macrolobatus occurs at a higher stratigraphic level than *K. schucherti* and is distinguished by the generally greater complexity and digitation of the septa and particularly by the extreme length of the adventitious lobes and saddles. Whereas the venter of *K. schucherti* becomes bluntly rounded on the outer whorls, that of *K. macrolobatus* remains sharp after losing the biangular flattened shape characteristic of the inner whorls of both species.

Holotype, USNM 128252; paratype, USNM 128251.

Occurrence.—Union district, Shoshone Mountains, Nev. This species occurs sparingly throughout the upper part of the shaly limestone member of the Luning formation. The specimen representing the lowest stratigraphic occurrence was collected 430 feet above the base of the member, and the highest known occurrence is about 165 feet above this level or just below the top of the member. The greatest number of specimens was collected, along with *Tropites nevadanus*, from the measured section of the Luning formation on the east side of West Union Canyon from the beds about 20 feet below the top of the member. USGS locality M72.

Superfamily CLYDONITACEAE Mojsisovics, 1879
Family TIBETITIDAE Hyatt, 1900

Genus MOJSISOVICSITES Gemmellaro, 1904

Mojsisovicsites Gemmellaro, 1904, Gior. Sci. nat. econ., Palermo, v. 24, p. 57. [Type species *Mojsisovicsites crassecostatus* Gemmellaro, 1904, by original designation.]

Stikinoceras McLearn, 1930, Canada Royal Soc. Trans., 3d ser., sec. 4, v. 24, p. 17. [Type species *Stikinoceras kerri*, McLearn, 1930, by monotypy.]

McLearn, 1937, Canadian Field Naturalist, v. 51, p. 98.
McLearn, 1947, Canada Geol. Survey Paper 47–14, p. 13.
McLearn, 1953, Canada Geol. Survey Paper 53–21, p. 5.

The representatives of this group from the *Guembelites* zone of the Union district show a continuous morphologic gradation from coarsely sculptured forms, like those included by McLearn in his genus *Stikinoceras*, to nearly smooth forms like the species originally assigned to *Mojsisovicsites* by Gemmellaro. Consequently, *Stikinoceras* McLearn, 1930, is here placed in synonomy with *Mojsisovicsites* Gemmellaro, 1904. As a complete gradation exists between the three species recognized from the Union district, their separation is necessarily arbitrary. Nevertheless, their distinction is useful because the coarsely ornamented forms like *Mojsisovicsites robustus* (McLearn) are the first to appear in the section, whereas progressively smoother forms occur at higher levels within a stratigraphic thickness of about 100 feet.

All of the members of this genus have a laterally compressed moderately evolute shell, which, at least at some stage of growth, has a flattened venter and a narrow subtrapezoidal cross-sectional whorl outline. At this growth stage the flanks are ornamented with sigmoidal radial ribs bearing both ventral and ventrolateral tubercles which are elongate parallel to the venter. A swelling of the ribs towards their umbilical ends may also produce radially elongate umbilical tubercles on the strongly ornamented species. The whorl shape and ornament of the coarsely sculptured species persists on the body chamber, but on the more delicately ornamented species like *Mosjsisovicsites crassecostatus*, the characteristic ornamentation and whorl shape of the inner whorls gives way to a nearly smooth body chamber without tubercles and with a rounded venter.

The suture line is ceratitic, becoming nearly clydonitic in the least ornamented species. The ventral lobe is simply divided into two prongs by a low rounded ventral saddle. The first and second lateral saddles are entire and separated by a deep first lateral lobe that is serrate across its base. Simple subdivision of the second lateral lobe occurs only in the more coarsely ornamented species. One or two auxiliary saddles complete the external suture line.

The coarsely ornamented species here assigned to *Mojsisovicsites* bear some resemblance to *Palicites mojsisovicsi* Gemmellaro, 1904. The single species referred to *Palicites* is more involute, however; and through both ventral and ventrolateral tubercles occur on the inner whorls, they coalesce into a single row of prominent lateral tubercles on the body chamber. Moreover, the septa of *Palicites*, having both the first and the second lateral lobes serrate in addition to incipient digitation of the ventral lobe, are more complex than those of *Mojsisovicsites*. McLearn (1939a, p. 70) reports the occurrence of "'*Palicites*'" from a stratigraphic level considerably above that at which *Mojsisovicsites kerri* and *M. robustus* occur in the Pardonet Hill section of the Peace River Foothills of British Columbia. Providing McLearn's identification is correct, this indicates that *Palicites* is not the coarsely ornamented end member of the series from *Mojsisovicsites robustus* to *M.* cf. *M. crassecostatus*, as this series shows a gradation upward in the Union district section from coarsely sculptured forms to forms with progressively more subdued ornamentation and simpler septa.

Mojsisovicsites robustus (McLearn)

Plate 1, figures 1, 2

Stikinoceras robustum McLearn, 1937, Canadian Field Naturalist, v. 51, p. 98, pl. 1, fig. 4.

This species is represented in the collections from the lower part of the *Guembelites* zone in the Union district by about 15 well-preserved specimens and 2 or 3 times this number of fragmentary specimens. Some of these are externally identical with those described and illustrated by McLearn, but others show a transition to *Mojsisovicsites kerri* (McLearn), which may occur slightly higher in the Nevada section.

The shell is laterally compressed and evolute with a quadrate cross-sectional outline of the whorls. The flanks are flattened and slightly convergent toward the rows of ventrolateral tubercles, and the venter is also flattened between the rows of ventral tubercles. The The umbilical walls slope gradually inward to the umbilical seam. Coarse weakly sigmoidal radial primary ribs extend from the umbilical walls to the edges of the venter. A swelling towards their umbilical ends produces radially elongate tubercles, which have their greatest elevation about one-third of the distance up the flanks. A secondary rib is inserted between each pair of primary ribs and branches from the preceding primary rib, although the connection between them is barely visible. In all, about 16 ribs are present on the apertural half of the outer whorl, which is in agreement with the density of ribbing on the holotype. Both a ventrolateral and a ventral tubercle is developed at the ventral end of each rib, forming two closely spaced longitudinal rows of tubercles on either side of the shell. In comparison with the ventrolateral tubercles, the ventral tubercles are slightly more prominent and more elongate parallel to the venter. A threadlike ventral keel is present on the otherwise smooth venter. No decrease in the strength of the ornamentation with increasing maturity takes place on any of the available specimens.

The suture line agrees with that of *M. kerri* and has entire saddles with a deep, narrow, crenulate first lateral lobe. The second lateral lobe is either singly or doubly pointed, and the single auxiliary lobe terminates in a single point. The otherwise undivided ventral lobe is bisected by a low ventral saddle.

The outer whorl of the plesiotype is largely broken away, but it had an estimated original diameter of about 40 mm. The greatest height of the outer whorl is 18 mm, the corresponding width, 15 mm, and the width of the umbilicus, 14 mm.

This species differs from *M. kerri* only in the greater strength of its ornamentation and its thicker whorls. Although a complete gradation appears to exist between them, they are recognized as distinct species because the typical forms of each appear to be slightly separated stratigraphically. Some of the forms assigned to *M. robustus* have a narrower venter than the plesiotype in addition to a tendency for the ventrolateral and ventral tubercles to coalesce on the outer whorls, and thus they resemble *Palicites mojsisovicsi* Grumellaro; however, the latter species is more involute and has a more subdivided suture line.

Plesiotype, USNM 128253.

Occurrence.—Union district, Shoshone Mountains, Nev. About 300 feet above the base of the calcareous shale member of the Luning formation in the lower part of the *Guembelites* zone. USGS locality M73.

Mojsisovicsites kerri (McLearn)

Plate 1, figure 3–5

Stikinoceras kerri McLearn, 1930, Canada Royal Soc. Trans., 3d ser., sec. 4, v. 24, p. 17, pl. 1, fig. 2.

McLearn, 1947, Canada Geol. Survey Paper 47–14, pl. 2, figs. 1, 2.

About 30 specimens that closely resemble the holotype of this species in their external morphology were collected from the Union district. The whorls of the evolute laterally compressed shells are narrowly subtrapezoidal in cross-sectional outline with flattened flanks sightly convergent towards the flat or slightly arched venter. The ventrolateral and ventral shoulders are angular by virtue of their coincidence with longitudinal rows of tubercles. A poorly defined umbilical shoulder separates the flanks from the umbilical walls, which slope gradually inward to the umbilical seam.

On the outer part of the flanks 45–50 evenly spaced primary and secondary sigmoidal radial ribs are present per volution. The primary ribs extend from the umbilical walls to the rows of ventral tubercles, and a secondary rib branches from the apertural side of each primary rib at the umbilical shoulder, where the primary ribs are slightly swollen. On each rib is a ventrolateral and a somewhat stronger ventral tubercle forming two closely spaced longitudinal rows of tubercles on either side of the smooth venter. A threadlike ventral keel is visible on the interior mold. No modification of the sculpture takes place with increasing maturity.

The suture line is nearly clydonitic in its simplicity. The first and second lateral saddles are entire and separated by a deep, narrow first lateral lobe, which is digitate across its flattened base. On larger specimens the second lateral lobe may show an incipient similar type of subdivision. Two undivided auxiliary saddles are present external to the umbilical seam. The ventral lobe is not crenulate but is divided into two points by a low rounded ventral saddle.

The dimensions of the plesiotype, measured in the plane of the greatest diameter, are as follows: Diameter, 38 mm; width, 13 mm; height of the final whorl, 15 mm; width of the umbilicus, 12 mm. The largest specimen collected has a diameter of 52 mm.

Except for a slightly greater width of the venter, a feature that is somewhat variable in the specimens from Nevada, the plesiotype is externally identical with the holotype, a cast of which was provided the writer by Dr. E. T. Tozer, of the Geological Survey of Canada. McLearn's (1953, p. 5) written description of the suture of *Mojsisovicsites kerri* (McLearn) applies equally well to the suture lines of the Nevada specimens.

Plesiotype, USNM 128254.

Occurrence.—Union district, Shoshone Mountains, Nev. In the *Guembelites* zone, about 300 feet above the base of the calcareous shale member of the Luning formation and slightly higher in the section than the occurrence of *M. robustus.* USGS locality M73.

Mojsisovicsites cf. M. crassecostatus Gemmellaro

Plate 1, figure 6–14

Mojsisovicsites crassecostatus Gemmellaro, 1904, Gior. sci. nat. econ., Palermo, 24, p. 59, pl. 28, figs. 5–9, 14, 15.

About 40 specimens from the *Guembelites* zone of the Union district are tentatively referred to *Mojsisovicsites crassecostatus* Gemmellaro although their range of variation probably exceeds the scope of this species as originally defined. Gemmellaro (1904) originally recognized five species of his genus *Mojsisovicsites*, for which *M. crassecostatus* served as the type species. These species were distinguished from one another by minor differences in ornamentation, degree of involution, and the configuration of the first lateral lobes of their suture lines. Although it would appear that the scope of Gemmellaro's species is excessively narrow, a reevaluation of his species cannot be attempted without knowledge of the variations and stratigraphic occurrence of the type material. Except for a possible slight decrease in the strength of their ornamentation upwards in the section, the morphologic variations of the specimens from the Union district do not appear to have either systematic or stratigraphic value, and consequently, all these forms are considered a single species.

The shells are laterally compressed, with a moderately narrow umbilicus equal to about one-fourth or one-fifth of their diameter. The cross-sectional outline of the nearly smooth mature whorls is ovate, with a smoothly rounded venter. The inner whorls, however, retain some of the ornamentation and shape of *M. kerri* and have a flattened venter and flanks separated by angular ventral and ventrolateral shoulders. The umbilical shoulders are not well defined at any growth stage, and the umbilical walls slope gradually inward to the umbilical seam.

The strength of the ornamentation on the inner whorls and its persistence on the mature shell appears to be inversely proportional to the relative elevation of the specimens in the stratigraphic section. A longitudinal row of ventral tubercles, elongate parallel to the venter, and a row of somewhat less prominent ventrolateral tubercles are present on either side of the smooth venter. Sigmoidal primary radial ribs extend from the umbilical walls to the rows of ventral tubercles, and the presence of 1 or 2 secondary ribs between each pair of primary ribs is indicated by their corresponding tubercles, although the extensions of the secondary ribs on the flanks are barely visible. The umbilical ends of the primary ribs may be somewhat enlarged but are not tuberculate. In general, the ornamentation on the inner whorls is best developed on the outer part of the flanks. With increasing maturity the ornamentation becomes obsolescent, so that the body chamber of the characteristic specimens is nearly smooth, with only weak sigmoidal radial folds. In some specimens the position of the prominent rows of ventral tubercles present on the inner whorls is marked by very weak longitudinal ridges on the smooth mature shell. A complete transition appears to exist between forms gradational in sculpture with *M. kerri* to those with no trace of ribbing or tubercles on the outer whorls.

The suture line is ceratitic and simple, with only the prominent first lateral lobe digitate. The saddles are entire, with a low ventral saddle bisecting the ventral lobe. Only one auxiliary saddle is present exterior to the umbilical seam, and hence, the suture contains fewer elements than that of *M. kerri* though the suture line of the latter species illustrated represents a somewhat greater whorl height.

All the specimens referred to this species are small, with a maximum diameter of about 40 mm. The greatest dimensions of the largest plesiotype showing a loss of ornamentation on the outer whorl are as follows: Diameter, 31 mm; width, 10.5 mm; height of the final whorl, 15 mm; and width of the umbilicus, 7 mm.

Plesiotypes, USNM 128255, 128256, 128257.

Occurrence.—Union district, Shoshone Mountains, Nev. In the *Guembelites* zone about 350–400 feet above the base of the calcareous shale member of the Luning formation and higher in the section than *M. kerri*. USGS locality M73.

Superfamily TROPITACEAE Mojsisovics, 1875
Family TROPITIDAE Mojsisovics, 1875
Genus TROPITES Mojsisovics, 1875

The type species is *Ammonites subbullatus* Hauer, 1850, (p. 19, pl. 4, fig. 1–2; lectotype selected by Mojsisovics, 1893, p. 187), and subsequent designation as type species was by Mojsisovics (1893, p. 184).

The original description of this genus (Mojsisovics, 1875, p. 889) is quite vague by modern standards. Of the original heterogenous group of eleven species cited as examples, only one, *Tropites subbullatus*, was retained in the genus *Tropites* (subgenus *Tropites*) by Mojsisovics in 1893. This species was considered to be typical of *Tropites* s. s. by Mojsisovics who referred to this subgenus as the group of "*Tropites bullati.*" Although not actually designated by name as the type species, *Tropites subbullatus* has been accepted as the generic type by all subsequent authors.

The morphologic characteristics of the genus are those exemplified by *Tropites subbullatus* and qualified to include the variations shown by the many other species assigned to the genus. The proportions of the shell in the various species are widely variable, but the typical representatives, at least during their earlier growth stages, possess robust whorls with broadly rounded venters taking the place of lateral flanks. On these robust forms the umbilicus is open and funnel shaped. The greatest width of the shell occurs at the umbilical edge. An egression of the final whorl accompanied by modifications of the sculpture is typical. A ventral keel is invariably present, often separated from the surface sculpture by bordering furrows. Transverse ribs, usually originating from umbilical nodes, provide an important criterion for the separation of species by variations in their strength, curvature, bifurcation, and association with lateral nodes. In addition to the ribbing, the typical species have closely spaced longitudinal striations on the outer shell material. The suture pattern is fairly constant for all members of the genus. Characteristically, the first and second lateral saddles are prominent and separated by an equally broad first lateral lobe. Although ammonitic, the lobes and saddles are not deeply divided. An auxiliary saddle is usually present between the second lateral lobe and the umbilical shoulder. The ventral lobe is divided by a short bluntly terminated ventral saddle.

Although the genus *Tropites* is characterized by these typical morphologic features, the limits of the genus are indefinite and doubt may exist in differentiating between *Tropites* s. s. and related generic groups, particularly *Paratropites* and *Anatropites*. *Paratropites* Mojsisovics, 1893, established as a subgenus of *Tropites* but given generic rank by some subsequent authors, was proposed to include forms with compressed, relatively involute whorls which do not change appreciably in shape during the various growth stages. This characterization is not sufficient to set this generic group apart from forms transitional with the type of the genus *Tropites*. A diagnostic feature of primary importance appears to be the nature of the ribbing, the ribs of *Paratropites* being flattened and wide in relation to the interspaces and commonly more elevated on their anterior sides, giving the ornamentation a shingle aspect. Some confusion exists in the literature as to whether the type species of *Paratropites* is *P. bidichotomous* Mojsisovics, 1893 (see Hyatt and Smith, 1905, p. 53; Spath, 1951, p. 89), or *P. saturnus* (Dittmar, 1866) (see Diener, 1916, p. 104); however, this characteristic type of ribbing is exhibited by both of these closely related species. Considered in terms of either candidate for the type species, *Paratropites* includes a well-defined group of species with stratigraphic significance. *Paratropites* is not represented in the collections from the Union district.

The subgenus *Anatropites* was established by Mojsisovics (1893, p. 184) for tropitids with prominent spines in place of umbilical nodes and a tendency toward developing low evolute whorls. This subgenus, treated as a genus by some authors, was originally designated as the group of "*Tropites spinosi*," and hence *Tropites* (*Anatropites*) *spinosus* Mojsisovics, 1893, (p. 225, pl. 110, fig. 2), has been accepted as the type species. Although a morphologic distinction can be made between typical examples of *Anatropites* and *Tropites* s. s., some forms appear to have equal affinities to both groups. The close relationship between them was pointed out by Mojsisovics in the original description of *Anatropites*, where the similarity in the development of their young stages was described. Even though it appears to be gradational with *Tropites* s. s., *Anatropites* is a useful designation for forms closely agreeing with its type species, and it is employed for tropitids from the Union district in its original status as a subgenus.

The characteristic features of *Anatropites* are relatively narrow and low whorls, a tendency toward evolute coiling, and an obsolescene of the ribbing on the outer part of the flanks and venter. In the original description of this subgenus, Mojsisovics does not mention the presence of longitudinal striations on the outer shell. Judging from his figures of the typical forms as well as the descriptions of other species assigned to this group by subsequent authors, they are absent. Prominent umbilical spines are exhibited by some forms properly assigned to *Tropites* s. s.; consequently, they cannot be considered peculiar to *Anatropites*. Also, some forms which are best assigned to *Anatropites* on the basis of the agreement of their general morphology with the type species of this subgenus lack well-defined umbilical spines, at least on their mature whorls.

Tropites *from the Union district.*—More than 1,000 specimens of *Tropites*, sufficiently well preserved for specific assignment, were collected from the upper part of the shaly limestone member of the Luning formation during the course of fieldwork in the Union district by the writer and on previous occasions by S. W. Muller, H. G. Ferguson, and others. Of this large amount of material, obtained from a limited geographic area and a stratigraphic thickness of about 100 feet, no two specimens are identical in all respects. This wide variation permits, if not necessitates, distinguishing between genetic groups of specific rank and morphologic variations of intraspecific or nontaxonomic significance. Three different aspects of the shell morphology of these variable forms can be recognized; namely, the ornamentation, whorl shape, and proportions of the shell. If the latter variable is considered to be secondary in importance, a grouping based on the ornamentation and shape of the whorls allows all of the available specimens to be placed in one of several groups which are treated as species. In doing this, however, the morphologic changes accompanying the ontogenetic development of the individual specimens must be taken into account as well as the variation in the rate of maturity of different individuals. Also the variations in proportion, i. e., the amount of compression or depression, which is not considered to be of specific importance, is accompanied to some degree by other morphologic changes such as variations in the degree of evolution and the strength of the ornamentation.

Although the end members of some of the species are considerably different in appearance, a complete gradation in morphology occurs within each species between one extreme and the other. Conversely, well-defined transitions do not exist between the different species. A further indication of the genetic equivalence of the widely variable forms included in the different species is their stratigraphic isolation. Each of the species, delineated as outlined above, occupies a particular part of the stratigraphic interval characterized by the occurrence of *Tropites*. The species of *Tropites* from the Union district do not include previously described forms, and consequently their taxonomy is not complicated by prior names for morphologic entities of narrower scope.

Comparison with Tropites *from the so-called Hosselkus limestone, Shasta County, Calif.*—Representatives of the genus *Tropites* are abundant in the so-called Hosselkus limestone of Shasta County, Calif., and some of the same forms have also been collected from central Oregon and from Sonora, Mexico (USGS loc. 18950). None of these specimens are conspecific with the *Tropites* from the Union district, and correlations based on other elements of the two faunas indicate that the species of *Tropites* from the Union district are somewhat younger than those from the so-called Hosselkus limestone. Smith (1927) has divided the forms assigned to *Tropites* from the so-called Hosselkus limestone into 30 species assembled into six groups and subgroups. Although Spath (1951, p. 89) suggests that Smith's groups might some day be elevated to subgeneric rank, their reduction with some minor changes to specific rank seems preferable in order to express the close relationship of their members and to increase their stratigraphic utility. From a study of Smith's type specimens, the writer advocates a grouping, based primarily on ornamentation and whorl shape, of Smith's species of *Tropites*, into five stratigraphically restricted species comparable in scope with the species of *Tropites* recognized from the Union district. Each of these species includes a group of closely related variants centered around one particularly well-represented form, though the affinities of several of the less commonly occurring of Smith's "species" are doubtful. For these uncommon forms, the only specimens available for study besides the holotypes are 1 or 2 homeotypes of each of Smith's species in the collections of Stanford University. For convenient reference the grouping of the forms described by Smith from the so-called Hosselkus limestone of Shasta County, Calif., is given below.

Tropites dilleri *Smith, 1904, revised*

Tropites discobullatus, Smith, 1927 (not Mojsisovics, 1893)
torquillus, Smith, 1927 (not Mojsisovics, 1893)
dilleri Smith, 1904
subbullatus, Hyatt and Smith, 1905 (not Hauer, 1850)
armatus Smith, 1927
morloti, Smith, 1927 (not Mojsisovics, 1893)
occidentalis Smith, 1927

Tropites welleri *Smith, 1927, revised*

Tropites keili, Smith, 1927 (not Mojsisovics, 1893)
wodani, Smith, 1927 (not Mojsisovics, 1893)
ursensis Smith, 1927
welleri Smith, 1927
shastensis Smith, 1927
kellyi Smith, 1927
schellwieni Smith, 1927
fusobullatus, Smith, 1927 (not Mojsisovics, 1893)
?brockensis Smith, 1927
?rotatorius Smith, 1927

Tropites reticulatus *Smith, 1927, revised*

Tropites reticulatus Smith, 1927
dieneri Smith, 1927
kokeni Smith, 1927

Tropites johnsoni *Smith, 1927, revised*

Tropites traski Smith, 1927
phillippii Smith, 1927
johnsoni Smith, 1927
boehmi Smith, 1927
?T. mojsvarensis Smith, 1927

Tropites morani *Smith, 1927, revised*

Tropites morani Smith, 1927
hessi Smith, 1927
rothpletzi Smith, 1927
arthaberi Smith, 1927
stearnsi Smith, 1927

The salient features of the emended species are given in the following table.

Morphology of the species of Tropites *originally described from the so-called Hosselkus limestone, Shasta County, Calif., by Smith (1927), as revised in this report*

	Proportion (ratio of diameter to width)	Involution	Ventral shoulders	Umbilical knots	Strength of ribbing	Bifurcation of ribs	Angle between ribs and ventral keel	Spiral striae
T. dilleri	1.7 to 1.0	Widely variable; proportional to depression.	Absent on robust forms.	Present; proportional in strength to depression.	Weak	On lower flanks	50°–70°	Well developed relative to ribbing.
T. welleri	>2.0 to about 1.0	do	do	do	Moderate to strong; proportional to depression.	On flanks	20°–30°	Well developed.
T. reticulatus	2.3 to 2.0	Involute	Rounded but distinct.	Weak	Moderate	On flanks and at ventral shoulders.	60°–70°	Well developed relative to ribbing.
T. johnsoni	2.0 to 1.5	Variable; proportional to depression.	Rounded to subangular.	Weak to strong	Moderate to strong; proportional to depression.	On ventral shoulders with nodes and on flanks.	20°–60°	Weak relative to ribbing.
T. morani	2.5 to 1.0	Involute	Absent	Absent	Moderate	On flanks	Large. >60°	Weak.

The specific names proposed by Smith and placed in synonomy according to the foregoing scheme represent morphologic variations which were neither geographically nor temporarlly isolated and hence cannot be recognized as subspecies. If a useful purpose exists for these names, it is suggested that they be adopted as varietal names.

The wide morphologic latitude attributed to the species of *Tropites* known from the Western United States implies that a grouping of the Alpine species of this genus described by Mojsisovics (1893) from the Hallstatt limestone could be undertaken without decreasing their significance as biologic units. Even Smith (1927, p. 28) remarks on the exceedingly narrow interpretation of the species described by Mojsisovics. Nevertheless, a redefinition of Mojsisovics' species should not be attempted without study of the type material and knowledge of their typical occurrence.

Considered as a group, the species of *Tropites* from the so-called Hosselkus limestone of Shasta County, Calif., appear to be more closely related to the typical European representatives of this genus than are the new species described here from the Union district. The forms from the so-called Hosselkus limestone agree with the typical species by having longitudinal striations on the outer shell material, branching ribs which are generally closely spaced and cover the ventral surface of the shell, and generally weak umbilical tubercles. In contrast the *Tropites* from the Union district, when considered as a group, lack longitudinal striations, are usually simply ribbed with a tendency for the ribs to fade out before crossing the venter, and have spinose umbilical tubercles. Although these forms are assigned to *Tropites* s. s. by virtue of their whorl shapes, their ornamentation is in better agreement with that of the subgenus *Anatropites.* If the absence of longitudinal striae, combined with the other morphologic generalities mentioned above, can be considered as significant genetic characteristics, it is suggested that the new species of *Tropites* described here from Nevada were derived separately from a persistent ancestral form like *Anatropites* and are not the result of geographic or temporal modifications of the more typical members of *Tropites.*

Tropites dilleri Smith, 1904, revised

Tropites dilleri Smith, 1904, California Acad. Sci. Proc., 3d ser., v. 1, p. 393, pl. 46, figs. 3, 4, pl. 47, fig. 3.
Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 29, pl. 68, fig. 13.
Tropites subbullatus Hauer. Hyatt and Smith, 1905, U. S. Geol. Survey Prof. Paper 40, p. 67, pl. 34, figs. 1–14, pl. 79, figs. 1–10.
Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 29, pl. 34 figs. 1–14, pl. 79, figs. 1–10.
Tropites discobullatus Mojsisovics. Smith, 1927, op cit., p. 28, pl. 68, figs. 32–34.
Tropites torquillus Mojsisovics. Smith, 1927, op. cit., p. 28, pl. 68, figs. 1–31.
Tropites armatus Smith, 1927, op. cit., p. 31, pl. 33, figs. 1–7, pl. 69, figs. 1–12.
Tropites morloti Mojsisovics. Smith, 1927, op. cit., p. 31, pl. 69, figs. 13–24.
Tropites occidentalis Smith, 1927, op. cit., p. 31, pl. 70, figs. 1–20.

A redefinition of this species is proposed to include most of the forms originally assigned to Smith's group I. ("group of *Tropites subbullatus*"). The following statement by Smith (1904, p. 394), made before the introduction of additional specific names for some of the intermediate forms, illustrates the close relationship between the members of the "group of *Tropites subbullatus*," redefined here as the species *T. dilleri:*

* * * the distinction of species in the group of *Tropites subbullatus* must be entirely artificial when one has any great quantity of material. The writer has what appears to be an unbroken series, grading through *Tropites torquillus, T. dilleri, T. subbullatus, T. fusobullatus, to T. morloti*, represented, not by a few, but by a large number of specimens of each. As these all occur in the same beds, the species have no stratigraphic value, and do not mark stages in evolution.

Tropites dilleri, as redefined, is characterized by delicate ribbing which is commonly not much stronger than the spiral striae. The ribs are curved forward towards the aperture making an angle with the ventral keel of about 70° in the most compressed forms to about 50° in the depressed forms. The degree of evolution and the prominence of the umbilical knots is proportional to the degree of depression. The outer part of the whorls is smoothly rounded without well-defined ventral shoulders. The ratio of the diameter to the width ranges from about 1.7 to 1.0.

Tropites fusobullatus, Smith, 1927 (not Mojsisovics, 1893), originally included by Smith in "group I," has relatively strong ribbing; and, regardless of Smith's viewpoint to the contrary (1927, p. 34), it is considered here as a variant of the single species proposed for Smith's "group III." The mature plesiotype of "*T. fusobullatus*" figured by Smith is very similar to the holotype of *T. schellwieni* Smith, 1927, the most robust member of "group III."

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Some of the forms included in the emended species *Tropites dilleri* were originally assigned by Smith to species described from the Alps. Although the morphologic entities for which Smith used the names *Tropites subbullatus*, *T. morloti*, *T. torquillus*, and *T. discobullatus* agree in most respects with the type specimens of these Alpine species, as described and figured by Hauer and by Mojsisovics, there is a consistent difference in the nature of the ribbing. On the Alpine species the transverse ribs curve forward from the umbilical shoulders, but as they approach the venter they bend back making a curve convex toward the aperture, intersecting the ventral keel at nearly right angles, and appearing to be continuous with the ribs on the opposite side of the keel. This is not found on the forms from California described by Smith; consequently they are separated from the the Alpine species and considered as variants of a single species with distinctive ornamentation.

The holotype of *Tropites dilleri* (Smith, 1927, pl. 68, fig. 1–2), which is representative of the average shell proportions shown by the members of the expanded species, is suitable as the type of the revised species.

Tropites welleri Smith, 1927, revised

Tropites welleri Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 33, pl. 78, figs. 5–17.
Tropites keili Mojsisovics. Smith, 1927, op. cit., p. 33, pl. 72, figs. 24–28.
Tropites wodani Mojsisovics. Smith, 1927, op. cit., p. 33, pl. 72, figs. 29, 31.
Tropites ursensis Smith, 1927, op. cit., p. 33, pl. 78, figs. 18–26.
Tropites shastensis Smith, 1927, op. cit., p. 34, pl. 78, figs. 1–4.
Tropites kellyi Smith, 1927, op. cit., p. 34, pl. 77, figs. 12–15.
Tropites schellwieni Smith, 1927, op. cit., p. 34, pl. 77, figs. 1–11.
Tropites fusobullatus Mojsisovics. Smith, 1927, op. cit., p. 32, pl. 70, figs. 21–28.
?*Tropites brockensis* Smith, 1927, op. cit., p. 32, pl. 74, figs. 1–6.
?*Tropites rotatorius* Smith, 1927, op. cit., p. 32, pl. 71, figs. 1–3.

All of Smith's species of "group III" are placed in synonmy with *Tropites welleri*, the most representative and abundant member of this group. The resulting expanded species is characterized primarily by its ribbing, which is regular and moderately strong. The ribs curve forward sharply from umbilical knots, commonly bifurcate on the outer part of the flanks, and continue to the furrows bordering the ventral keel, which they intersect at an angle of 20 to 30°. Spiral striae are usually well developed. The ratio of the shell diameter to the width ranges from more than 2.0 in the compressed members to about 1.0 in the depressed members. An increase in the degree of evolution, the strength of the umbilical knots, and to a lesser extent the strength of the ribbing accompanies an increase in the degree of depression.

The small, compressed form assigned by Smith to "*Tropites keili*" differs from the other forms included here in *Tropites welleri* by having much weaker ornamentation, but in other respects it agrees better with *T. welleri*, as revised, than with any of the other species established from the tropitids described by Smith. "*Tropites fusobullatus*" of Smith, originally included in his "group I," is included here because of its strong similarity to the depressed end members of *T. welleri*. *Tropites brockensis* Smith, 1927, and *T. rotatorius* Smith, 1927, each based on a single large specimen and placed by Smith in a separate group with *T. mojsvarensis* Smith, 1927, are apparently variants of the expanded species *T. welleri*. However, without knowledge of their early growth stages, their inclusion with the typical forms of this group can only be tentatively suggested.

As with the revised species *Tropites dilleri*, some of the forms included here in *T. welleri* were originally assigned to species described from the Alps by Mojsisovics in 1893. Nevertheless, the ornamentation of the forms from California which Smith assigned to *Tropites keili*, *T. wodani*, and *T. fusobullatus* is distinct from that shown by the illustrations of the Alpine type specimens. Allowing for some variation, these forms show better agreement with the group of Smith's species typified by the holotype of *Tropites welleri* (Smith, 1927, pl. 78, figs. 5–7). The strong similarity between the intermediate forms of *T. welleri* as revised and *T. laestrigonus* Gemmellaro, 1904, has already been pointed out by Smith.

Tropites reticulatus Smith 1927, revised

Tropites reticulatus Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 34, pl. 76, figs. 8–18.
Tropites dieneri Smith, 1927, op. cit., p. 35, pl. 76, figs. 19–28.
Tropites kokeni Smith, 1927, op. cit., p. 35, pl. 76, figs. 1–7.

This species is expanded to include the three species described by Smith and assigned to "subgroup 1" of his "group IV" (the "group of *Tropites reticulatus*"). *Tropites reticulatus*, as revised, is characterized by involute laterally compressed whorls with rounded, but distinct, ventral shoulders. The diameter is more than twice the width even in the least compressed forms. The closely spaced dichotomous ribs, dividing either on the flanks or at the ventral shoulders, are not strongly bent forward and meet the ventral keel at an angle of 60°–70°. A reticulate pattern is produced on the outer shell by the intersection of spiral striae with the ribs.

Tropites johnsoni Smith, 1927, revised

Tropites johnsoni Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 36, pl. 74, figs. 10–15.
Tropites traski Smith, 1927, op. cit., p. 35, pl. 75, figs. 1, 2.
Tropites phillippii Smith, 1927, op. cit., p. 36, pl. 75, figs. 12–16.
Tropites boehmi Smith, 1927, op. cit., p. 36, pl. 75, figs. 3–11.
?*Tropites mojsvarensis* Smith, 1927, op. cit., p. 32, pl. 74, figs. 7–9.

The species originally included in "subgroup 2" of Smith's "group IV" are considered here as variations of a single species for which the name of the most abundant and representative of the species placed in synonomy is retained. *T. johnsoni*, as revised, includes forms which range widely in shape from those with relatively involute, compressed whorls and rounded ventral shoulders to those with evolute, depressed whorls and subangular ventral shoulders. The ratio of the shell diameter to the width ranges from over 2.0 to about 1.5. Strong ribs originate from umbilical knots and curve forward to the ventral keel and bifurcate at the ventral shoulders. The development of nodes or spines at the bifurcation as well as the tendency for a swelling of the ventral ends of the ribs is diagnostic of this species. The spiral striae are weak in comparison with the ribbing. The degree of evolution, amount of forward curvature of the ribs, and strength of the ribs and nodes is proportional to the degree of compression.

The more compressed members of *T. johnsoni*, as redefined, are apparently transitional with the depressed forms of the expanded species *T. reticulatus*, as expressed by the grouping of Smith's original species. Nevertheless, two distinct species are established from this seemingly continuous series of variations because in freqency of occurrence the morphologic variations group themselves around the two forms selected as typical.

Tropites mojsvarensis Smith, 1927, a rare occurrence in the so-called Hosselkus limestone of Shasta County, Calif., was included by Smith in a group by itself ("group II") along with *Tropites brockensis* and *T. rotatorius*, forms with which it has little in common. The position of *T. mojsvarensis* in terms of the five variable species recognized here is indefinite, but it was compared by Smith with his species *T. traski*, one of the forms included in *T. johnsoni* as revised. Although the flattened venter and rounded, but distinct, ventral shoulders of *T. mojsvarensis* suggest a relationship with the compressed varieties of *T. johnsoni*, bifurcation of the ribs at the ventral shoulders rarely occurs on the holotype and is not accompanied by the development of nodes.

Tropites morani Smith, 1927, revised

Tropites morani Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 36, pl. 73, figs. 7–18.
Tropites hessi Smith, 1927, op. cit., p. 37, pl. 73, figs. 1–6.
Tropites rothpletzi Smith, 1927, op. cit., p. 37, pl. 71, figs. 4–8.
Tropites arthaberi Smith, 1927, op. cit., p. 37, pl. 72, figs. 13–23.
Tropites stearnsi Smith, 1927, op. cit., p. 37, pl. 72, figs. 1–12.

With one exception the species of Smith's "group V" (the "group of *Tropites morani*") are grouped together as variations of the form chosen by Smith as representative of this group. The principal difference between the members of the expanded species is the degree of compression, which expressed as the ratio of the diameter to the width ranges from about 2.5 to nearly 1.0. All the members of this species, regardless of their whorl proportions, are relatively involute and have rounded venters. Although the flanks of the more compressed forms are flattened, the ventral shoulders are broadly rounded, and the depressed forms are subspherical. The dichotomous ribs are distinct but typically closely spaced. The ribs are not strongly bent forward and have a tendency towards being sigmoidal with a reverse curve on the venter, so that they meet the ventral keel at an angle greater than 60°. In this respect the ribbing resembles that of *T. subbullatus*. Umbilical knots are absent even in the most depressed members. Spiral striae are only weakly developed.

Tropites stantoni Smith, 1927, described from the Nizina district, Alaska, was originally assigned to this group of forms by Smith, but it is not included here because the nature of its ribbing, which is peculiar to the tropitids from the so-called Hosselkus limestone of Shasta County, Calif., suggests that it may belong to a stratigraphically, as well as geographically, distinct group of varieties.

Tropites latiumbilicatus Silberling, n. sp.

Plate 2, figures 1–10

This species is the least well represented of the tropitids from the Luning formation, possibly owing to its occurrence among the first members of this group to appear in the section. Only 12 specimens were collected, three of which have the outer whorls preserved and show a striking modification of the whorl shape with growth. The shape of the whorls and the proportions of the shell at different stages of development are nearly identical with that of the type species of *Tropites*, as can be seen by comparing the figure showing the cross-sectional outline of the holotype with the cross section of *T. subbullatus* illustrated by Mojsisovics (1893, pl. 108, fig. 3). The width of the inner whorls is 2 or 3 times their height and approximately equal to or greater than the shell diameter. Flanks are absent, and the broadly arched venter extends to the umbilical edges which represent the widest part of the whorls. The body chamber whorl of the mature shell shows a strong egression resulting in a narrower, helmet-shaped cross-sectional outline. On the holotype the ratio of the diameter to the whorl width of the final whorl near the aperture at a diameter of 70 mm is about 2.0 in comparison with about 1.1 for the penultimate whorl measured in the same plane of cross section. The umbilical walls of all but the final whorl are slightly convex and slope inward to join the venter of the preceding whorl a short distance outside of its umbilical edge. The funnel-shaped umbilicus is open with an angle of about 60° between its walls as seen in cross section. With maturity the relative width of the umbilicus increases in response to the egression of the final whorl and equals about one-half of the shell diameter.

In addition to the ventral keel, strong umbilical spines, usually between 15 and 20 per volution, are the most prominent feature of the ornamentation. The spines tend to be flattened parallel to the umbilical edge and flare out from the sides of the whorls following the curve of the umbilical walls. Weak forward-curving ribs originate in pairs from the umbilical spines and gradually fade out as they cross the venter. Distinct furrows, approximately equal in width to the ventral keel, border the keel and are better developed than in the other species of *Tropites* recognized from the Luning formation. On the outer shell, striations paralleling the ribs intersect the keel furrows at a small angle of about 30°. Spiral striae are absent.

Owing to the broad venter and the absence of lateral flanks, the suture line has fewer elements outside the umbilical edge than the other species of *Tropites* from the same locality. In addition to the ventral lobe, which is divided by a blunt ventral saddle, and the prominent first lateral saddles and lobes, only the second lateral saddles are present on the ventral surface. The saddles are typically brachyphyllic, and the lobes, dolichophyllic.

The holotype with a diameter of 70 mm is a nearly complete mature specimen which has been sectioned to show the ontogenetic development of the whorl shape. The dimensions of the outermost 5 whorls of the holotype listed in the order of shell diameter, width of the whorl toward the apertural end, and width of the umbilicus, are as follows: 70 mm, 34 mm, 33.5 mm; 45 mm, 40 mm, 19 mm; 27 mm, 29 mm, 11.5 mm; 16 mm, 17 mm, 5 mm; and 9 mm, 8 mm, 2.5 mm. The two smaller paratypes illustrate the extremes in proportions of the young growth stages.

Among the species of *Tropites* from the Luning formation, this species bears the closest apparent relationship to the European representatives of the genus. The proportions and development of the whorl shape agree with those of *Tropites subbullatus*, but the nature of the ribbing, absence of spiral striae, and strong umbilical spines are not in agreement. *Tropites dilleri*, as redefined, differs from *T. subbullatus* primarily in the nature of its ribbing; hence, it is also a species to which *T. latiumbilicatus* is similar. Nevertheless, the distinction between *Tropites latiumbilicatus* and *T. subbullatus* also holds true for *T. dilleri*. Whereas the ribbing of *T. dilleri* is more or less constant in strength across the venter, that of *T. latiumbilicatus* tends to fade out about midway between the umbilical edge and the ventral keel and thus resembles the ribbing characteristic of *Anatropites.*

The resemblance to *Anatropites* appears to be more than superficial because a gradation takes place in the collections from the Luning formation from these robust forms assigned to *Tropites* to forms with the same ornamentation but with shell proportions typical of *Anatropites.* As mentioned previously, the distinction between *Tropites* and *Anatropites* appears to be gradational and, although treated here as of subgeneric importance, may be of only specific significance.

Holotype, USNM 128258; paratypes, USNM 128259, 128260.

Occurrence.—Union district, Shoshone Mountains, Nev. Shaly limestone member of the Luning formation. This species occurs near the base of the *Klamathites macrolobatus* zone at a stratigraphic level with the lowermost occurrence of *Tropites subquadratus.* Most of the specimens were collected about 1 mile from the mouth of West Union Canyon, where these beds are exposed on both sides of the canyon. USGS locality M72a.

Tropites subquadratus Silberling, n. sp.

Plate 2, figures 11–19; plate 3, figures 1–6

This species is represented in the collections by over 200 specimens showing a wide range of variation, particularly in the proportions of the shells. The ratio of the diameter to the width ranges from about 1.6 in the compressed end members to about 0.8 in the most depressed specimen measured. Although a continuous series exists between these extremes, by far the greatest number of specimens agree in amount of compression with the holotype (ratio of diameter to width about 1.3). The members of this species are characterized by a quadrate cross-sectional outline of the whorls produced by flattened flanks, which in the compressed forms are nearly parallel, separated from a broad flat venter by rounded, but distinct, ventral shoulders. The umbilicus is narrow, its width being only about one-seventh of the diameter of the compressed specimens, increasing in the more depressed specimens to about one-third of the diameter. In the involute, compressed forms, the whorls enclose more than half of the flanks of the preceding whorl, but in the depressed forms they enclose only the venter and ventral shoulders.

The lateral ribs are well developed on the flanks, but after bending sharply forward at the ventral shoulders, they fade out on the flattened venter, so that the intersection of their ventral ends with the ventral keel is barely visible. Two ribs usually originate from each umbilical knot with an additional 1 or 2 ribs inserted between each pair of primary ribs. The number of ribs so produced is about 25–30 per volution. The keel is bordered by depressions on either side, but well-defined keel furrows are absent. Spiral striae, typical of forms closely related to the genotype, *Tropites subbullatus*, are not apparent, but the outer shell is seldom preserved on the available specimens.

The suture agrees with that of other species of *Tropites* by having prominent dolichophyllic first and second lateral saddles separated by a lateral lobe equal in size to the first lateral saddle. A blunt, low ventral saddle divides the ventral lobe. Besides the principal elements of the suture, only part of a single auxiliary saddle is present between the second lateral saddle and the umbilical shoulder.

The dimensions of the holotype are as follows: Diameter, 40 mm; width, 29 mm; and width of umbilicus, 9.0 mm. The largest specimens represented in the collections with a diameter of about 60 mm have a body chamber more than 1 whorl in length. Although these large specimens may represent mature individuals, the ornamentation and shape of the unchambered part of their shells is the same as that of their inner whorls, except for a slight decrease in the involution.

The diagnostic feature of this species at all growth stages beyond the fourth whorl is the quadrate whorl shape with a subsidence of the ribbing on the broad flattened venter. A variation from the typical morphology of this species is shown by some relatively depressed individuals whose outer whorls become strongly involute with an attendant rounding of the ventral shoulders and arching of the venter. The specimen selected to illustrate this variation (pl. 3, figs. 3–6) with a diameter of 43 mm and a width of 35 mm has an umbilicus only 4 mm in width.

Holotype USNM 128263; paratypes, USNM 128261, 128262, 128264, 128265, 128266, 128267.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation, 40–60 feet below the top of the shaly limestone member. This species is particularly abundant where these beds are exposed on the north and the south walls of West Union Canyon about 1 mile from its mouth. USGS locality M72a.

Tropites crassicostatus Silberling, n. sp.

Plate 3, figures 7–16; plate 4, figures 1–7

About 60 well-preserved specimens of this species are available for study. The proportion and shape of their shells is less variable than in some related species from the same locality. The specimens of this species are generally depressed, more or less equidimensional, and subquadrate in cross-sectional outline. The ratio of the diameter to the width ranges from 1.3 to 0.7, the extremely depressed forms being small, immature specimens. The whorl shape in cross section is similar to that of *Tropites subquadratus*, with low, flattened lateral flanks about equal in height to the umbilical walls. A broad, flat venter is separated from the flanks by rounded ventral shoulders. The whorls are not deeply embracing and do not enclose the flanks of the preceding whorl. In response to the depressed shape of the shell, the umbilicus is open and amounts to about one-third of the shell diameter. The body chamber includes all of the final whorl and about half of the penultimate whorl. The complete body chamber is preserved on 1 premature specimen 57 mm in diameter and exhibits a prominent rostrum on the ventral margin of the aperture approximately equal in length to the greatest width of the shell.

The ribs are very strong and relatively few. They are uniform in strength from the umbilical shoulders to the venter, where they die out before intersecting the ventral keel and in doing so produce depressions along either side of the keel. The ribs are strongly curved forward making an angle with the keel of 20°–30°. Approximately 15–20 nonbifurcating ribs, originating for the most part either singly or in pairs from about 12 umbilical spines, are present per volution. Only in a few places are ribs inserted between the primary ribs. The ribbing on the body chamber of the mature shell decreases in strength and becomes irregular, while the umbilical spines are replaced by elongate nodes, and weak folds paralleling the margin of the aperture cross the venter and the keel. Spiral striae are apparently absent.

The suture consists of a broad dolichophyllic or brachyphyllic first lateral saddle and lobe and a somewhat smaller second lateral saddle and lobe. The ventral lobe is divided by a blunt ventral saddle.

The specimen selected as the holotype is somewhat broken, but is representative of the average morphology. The dimensions of the holotype are as follows: Diameter, 44 mm; width, 39 mm; and width of the umbilicus 13 mm. This species attains a large size, the largest specimen collected, which is not fully mature, has a diameter of over 90 mm.

Tropites crassicostatus is distinguished by its coarse ribbing and large robust subquadrate whorls. A few smaller specimens with somewhat smaller and more numerous ribs suggest a transition with the robust members of *T. nevadanus*.

Holotype, USNM 128268; paratypes, USNM 128269, 128270, 128271, 128272, 128273, 128274, 128275.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation, 40–60 feet below the top of the shaly limestone member, where it is associated with *T. subquadratus*. USGS locality M72a.

Tropites nodosus Silberling, n. sp.

Plate 4, figures 8–13

This species is represented by 24 specimens which show a relatively small amount of variation in their shape and ornamentation. The shells are robust, and the diameter of the septate part is about 1½ times the width. They become more compressed with maturity, owing to an increase in the height of the final whorl. In cross section the shape of the whorls, excepting the final whorl, is quadrate with angular ventral shoulders separating a broad flattened venter from flat parallel flanks, which are approximately equal in height to half the width of the venter. On the mature body chamber whorl, the venter gradually becomes arched, so that the ventral shoulders are less pronounced and the resulting cross-sectional outline is helmet shaped. The umbilicus is open and equal in width to about one-fourth of the shell diameter. The dorsal side of each whorl encloses only the ventral surface of the preceding whorl.

The presence of nodes or tubercles at the ventral shoulders in addition to umbilical tubercles is the most distinctive feature of this species. Approximately 10 umbilical tubercles are present per volution; this gives rise to widely spaced slightly forward-bending ribs on the flanks. Normally, 2 ribs originate from each umbilical tubercle; hence, there are about 20 ribs per volution. On the inner whorls the umbilical tubercles are not situated on the umbilical shoulders but occur about one-third of the distance up on the low flanks. At the ventral shoulders the lateral ribs form prominent tubercles or spines which grade into strong forward-curving ribs crossing the adjacent part of the venter. Only rarely do the ribs bifurcate at the ventral shoulders. The ribs extend across the venter about two-thirds of the distance from the ventral shoulder to the keel before they fade out, leaving smooth, slightly depressed areas bordering the median keel on either side. The angle betwen the ribs at their ventral ends and the keel is about 30°. At maturity the ribbing on the body chamber becomes somewhat irregular, and both the umbilical and the ventrolateral tubercles become less pointed and more elongate parallel to the ribbing. Spiral striae are not apparent.

The elements of the suture exposed on the venter are prominent first lateral saddles and lobes in addition to a ventral lobe which is bisected by a low, blunt ventral saddle. Somewhat smaller second lateral saddles and lobes are on the flanks, and a single auxiliary saddle is present on the umbilical shoulders.

The dimensions of the holotype are as follows: Diameter, 42 mm; width, 28 mm; and the width of the umbilicus, 11 mm. The largest specimen collected is not complete but has a diameter of 73 mm.

Tropites nodosus is easily distinguished by the presence of nodes or tubercles on the ventral shoulders at all diameters greater than about 15 mm. *Tropites johnsoni*, as revised in this report, from the so-called Hosselkus limestone of Shasta County, Calif., also has ventrolateral nodes but differs in the bifurcation of the ribs at the ventral shoulders, the nature of the ribbing on the venter, the whorl shape, and the presence of spiral striae. *Tropites nodosus* is not included among the nodose tropitids assigned to the genus *Hoplotropites* Spath, 1929 (="*Margarites*" Mojsisovics, 1889) because the flanks are developed from the ventral surface during growth rather than from the umbilical walls as in *Hoplotropites* (Mojsisovics, 1893, p. 184).

Holotype, USNM 128276; paratypes, USNM 128277, 128278, 128279.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation about 40 feet below the top of the shaly limestone member in the lower part of the *Klamathites macrolobatus* zone. Most of the specimens of this species were collected from the dissected pediment forming the south wall of West Union Canyon, where they were associated with *Tropites subquadratus*. USGS locality M72a.

Tropites nevadanus Silberling, n. sp.

Plate 4, figures 14–16; plate 5, figures 1–11

Although stratigraphically restricted, this species includes the largest number of tropitids from the Union district and is represented by several hundred specimens. Included in this species are forms with an extremely wide variation in shell proportions—from compressed, subquadrate, involute forms to depressed, evolute forms with the venter extending to the umbilical shoulders. The smaller representatives with diameters of about 30 mm show a continuous gradation in the ratio of the diameter to the width—from 2.0 to 0.75. However, most specimens fall within the range of 1.5 to 1.3, and the extremely compressed or depressed forms are rare. Larger specimens are more uniform in proportions owing to a relative increase in the whorl height at maturity. The chambered part of the shell in all but the more depressed forms has flattened nearly parallel flanks which grade into broadly rounded ventral shoulders and ultimately into a flat venter. With maturity the shape of the body chamber whorls becomes higher and helmet shaped while the umbilicus becomes wider. The width of the umbilicus on the average specimens is about ⅕–⅓ of the diameter and increases proportionally with the degree of depression. The umbilicus of the most depressed forms, on which lateral flanks are absent, amounts to about two-thirds of the diameter.

The ribs are closely spaced but well developed and of the same strength from the umbilical shoulder to the depressions bordering the ventral keel. On the lower part of the flanks, the primary ribs are directed posteriorly but curve smoothly forward, so that they are approximately transverse to the whorls about one-third of the distance up the flanks and eventually meet the ventral keel at an angle of less than 30°. On the holotype a tangent to one of the ribs rotates through about 100° of arc as the point of tangency is traced along the the rib from the umbilical shoulder to the keel. About 30–35 (in a few specimens as few as 25 or as many as 40) ribs are present per volution. The primary ribs originate in pairs from spinose umbilical nodes that average about 10 per volution. The additional ribs are inserted between the primary ribs or rarely branch from them on the lower flanks. On the depressed, widely umbilicate members, short ribs are visible on the umbilical walls extending anteriorly from the umbilical nodes. The ribbing on the body chamber of mature individuals decreases in strength, and the curvature of the ribs becomes irregular.

The suture has an equally broad first lateral saddle and lobe and a somewhat smaller, but prominent, second lateral saddle. The lobes are brachyphyllic, and the saddles, dolichophyllic. An auxiliary saddle is present on the umbilical shoulder. The ventral lobe is divided by a blunt ventral saddle about one-third of the height of the first lateral saddle.

The dimensions of the holotype are as follows: Diameter, 49 mm; width, 26 mm; and width of the umbilicus, 9.5 mm. The largest specimens collected, which have nearly complete body chambers, are about 90 mm in diameter and approximately agree in proportions with the holotype.

The numerous and persistent ribs extending from the umbilical shoulders to the ventral keel distinguish this species from the other tropitids with which it is associated. *Tropites nevadanus* resembles *T. welleri* Smith from the so-called Hosselkus limestone of Shasta

County, Calif., but lacks the prominent bifurcation of the ribs on the flanks and the spiral striae.

Holotype, USNM 128280; paratypes, USNM 128281, 128282, 128283, 128284, 128285, 128286, 128287.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation, 20–30 feet below the top of the shaly limestone member in the upper part of the *Klamathites macrolobatus* zone. This species is well represented in the measured section of the Luning formation on the east side of West Union Canyon northwest of the Richmond mine. USGS locality M72b.

Subgenus ANATROPITES Mojsisovics, 1893

Tropites (Anatropites) sp.

Plate 5, figures 12–15, 18–21

Included in this subgenus are about 100 specimens which are grouped together because of their whorl shape and ornamentation, but yet show a fairly wide range of variation. Although more than one biologic entity of specific rank may be represented in this group of forms, well-defined and consistent criteria for subdividing them are not apparent from the available material. With the exception of *Styrites*, both the stratigraphically lowest and the highest occurrences of tropitids from the Luning formation in the Union district are forms belonging to this group. While each species assigned to *Tropites* s. s. occurs at a particular level within the strata characterized by tropitids, these forms extend through these beds without consistent change in morphology.

The shape of the shells is compressed, with the diameter usually about twice the width, although a continuous variation in the ratio of the diameter to the width takes place from about 1.5 to 2.5. The coiling is relatively evolute, considering the compression of the shells; and each whorl encloses about half of the height of the preceding whorl. In cross section the whorls are helmet shaped without a distinct separation between the venter and the flanks. At maturity the final whorl shows a slight egression, resulting in an increase of the whorl height accompanied by a contraction of the width.

Forward-curving lateral ribs, originating in pairs or in a few places singly from umbilical tubercles or nodes, are well developed on the lower flanks but gradually fade out until they disappear about midway between the umbilical edges and the ventral keel. In a few places additional ribs are inserted between the primary ribs or bifurcate from them, so that 25–30 ribs are usually present per volution, whereas the corresponding number of umbilical tubercles or nodes is about 12. Small but distinct umbilical spines are present at least on the inner whorls. The ventral part of the shell adjacent to the keel is smooth except on the outer shell material, where faint striations parallel the ribs and intersect the keel at a small angle. Spiral striae are absent. The ventral keel is bordered by well-defined furrows. On the body chamber of mature individuals, the ribs decrease in strength and are more closely spaced, whereas the umbilical spines are reduced to elongate swellings on the umbilical ends of the ribs. Some of the specimens collected from the upper part of the stratigraphic range of this subgenus are somewhat smaller and tend to resemble the mature morphology of the forms from lower in the section rather than that of their inner whorls at comparable diameters. However, as the outer whorls of these specimens are unchambered, they may simply have attained maturity at a smaller diameter and are not genetically distinct.

The suture agrees with that of *Tropites* in having broad brachyphyllic first lateral saddles and dolichophyllic first lateral lobes. The second lateral saddle is somewhat smaller and extends to the umbilical shoulder. The ventral lobe is divided by a blunt, low ventral saddle.

Specimens showing modifications of their morphology indicating maturity average about 40 mm in diameter. The largest specimen collected has a diameter of 75 mm, including an incomplete body chamber 1½ whorls in length.

These forms differ from the type of the subgenus, *Tropites* (*Anatropites*) *spinosus* Mojsisovics, 1893, and the closely related species described by Mojsisovics, by having stronger, better defined, ribs and weaker umbilical spines. The closest agreement with previously described species is with *T.* (*Anatropites*) *nihalensis* Diener, 1906, described from the Upper Triassic of the Himalayas.

Plesiotypes, USNM 128288, 128289, 128290, 128291.

Occurrence.—Union district, Shoshone Mountains, Nev. Upper part of the shaly limestone member and base of the calcareous shale member of the Luning formation. USGS locality M72.

Family TROPICELTITIDAE Spath, 1951

Genus TROPICELTITES Mojsisovics, 1893

Tropiceltites? densicostatus Silberling, n. sp.

Plate 5, figures 16–17

This species is represented in the available collections by 18 broken and distorted specimens. Although the available specimens are poorly preserved, they are described here because of their value as stratigraphic markers in the Union district. The shell is compressed, the diameter being about three times the width, and evolute, with the umbilicus nearly equal to half of the diameter. In cross-sectional outline the whorl shape is ovate, without well-defined umbilical shoulders and with low umbilical walls. The height of the whorls is about equal to their greatest width, which is approximately at the umbilical shoulders. The dorsal side of the whorl is only slightly indented to accommodate the venter of the preceding whorl. The shell wall is abnormally thick and amounts to about one-tenth of the whorl width.

The ornamentation is distinctive even on small fragments. Closely spaced rounded ribs separated by deep interspaces run without bifurcation from the umbilical seam to the venter. The ribs, about 60 per volution, are nearly straight on the flanks but curve forward slightly on the venter making a large angle of about 70°–80° with the ventral keel. The keel is approximately the same height and width as any one of the ribs and is bordered by deep, narrow furrows produced by the abrupt termination of the ribs a short distance from the keel. A few of the ventral ends of the ribs are slightly enlarged, but no nodes are present on the shell. No change in the morphology with increasing maturity is apparent.

Unfortunately, the suture line is not well preserved on any of the available specimens. Judging from the surface of a septum exposed at the broken end of a whorl, the general plan of the suture agrees with that of *Tropites* but is somewhat simpler. The first lateral lobe is definitely digitate, and the equally prominent first lateral saddle may be slightly crenulate. A smaller second lateral saddle and lobe extend to the umbilical shoulder. The ventral lobe is not as deep as the first lateral lobe and may be divided by a small ventral saddle.

The holotype, which is among the largest of the unbroken specimens, is somewhat distorted but has the following approximate dimensions: Diameter, 32 mm: width, 11 mm; and width of the umbilicus, 13 mm.

The generic assignment of this species is somewhat doubtful particularly since the sutures are at least ceratitic in their development, whereas *Tropiceltites*, restricted by subsequent authors to Mojsisovics' original group of *T. costatus*, has clydonitic sutures insofar as known. Nevertheless, the closely related genus *Arietoceltites* Diener, 1916, has ceratitic sutures. *Arietoceltites* presumably includes the species of Mojsisovics' original group of *Tropiceltites arietitiformis*, for Spath (1951, p. 94) has selected *Tropiceltites laevis* as the type species of *Arnioceltites*, the subgeneric name applied by Mojsisovics to both the groups of *Tropiceltites laevis* and *T. arietitiformis*. The type species of *Arietoceltites*, *A. arietitoides* (Diener, 1906), has a tricarinate venter; consequently, this name does not seem applicable to the new species from Nevada. A resemblance exists with some of the species assigned to *Thisbites* Mojsisovics, 1893, but the type species of this genus, *T. agricolae* Mojsisovics, 1893, has a trachyceratid type of venter not consistent with *Tropiceltites? densicostatus*, which is interpreted as a degenerate tropitid.

Holotype, USNM 128292; paratype (a septate fragment), USNM 128293.

Occurrence.—Union district, Shoshone Mountains, Nev. Restricted to the calcareous shales weathering light reddish gray about 10–20 feet above the base of the calcareous shale member of the Luning formation. USGS locality M72c.

Family HALORITIDAE Mojsisovics, 1893
Genus GUEMBELITES Mojsisovics, 1896
Guembelites clavatus (McLearn)

Plate 6, figures 9–13

Juvavites clavatus McLearn, 1939, Canada Royal Soc. Trans., 3d ser., sec. 4, v. 33, p. 51, pl. 1, fig. 6.

This species is represented in the collections from the Union district by 14 specimens of various sizes and stages of maturity. The shell is compressed and involute, with deeply embracing ovate whorls that are widest near the umbilical shoulders. At maturity the venter is flattened by modifications of the sculpture giving the whorls a narrow, subtrapezoidal cross-sectional outline. The umbilical shoulders are rounded but distinct and grade abruptly into low, steep umbilical walls.

On the inner whorls the flanks are covered by numerous weak radial ribs which develop from primary ribs by both bifurcation and intercalation. The ribs are nearly straight on the flanks, curving sharply forward at their ventral ends. Numerous striations, differing in strength and spacing, parallel the ribs on the outer shell material. On the surface of the mature shell, the ribs and striae decrease in strength until they are barely perceptible as weak radial folds. The ventral ends of the ribs terminate in tubercles or "fins" that alternate on either side of the narrow smooth venter. On the inner whorls the tubercles are low and roughly equidimensional, but with increasing maturity they become stronger and elongate parallel to the forward-curving tips of the ribs and eventually develop into prominent elongate "fins" parallel to the venter of the nearly smooth mature shell. About 60 tubercles and "fins," each of which usually corresponds to 2 of the weak, indistinct ribs, are present on the outer whorl of the largest plesiotype. At diameters of less than about

10 mm 3 or 4 paulostome furrows are present on each volution.

The suture line, which is not well enough preserved on any of the available specimens to be figured, consists of long dolichophyllic first and second lateral saddles and lobes plus two auxiliary lobes exterior to the umbilical shoulder. The ventral lobe is divided by a blunt ventral saddle.

The dimensions of the largest plesiotype are as follows: Diameter, 92 mm; width, 34 mm; and width of the umbilicus, 6 mm.

The morphology of the mature representatives of this species closely agrees with that of the holotype, a cast of which was provided the writer by Dr. E. T. Tozer, of the Geological Survey of Canada. The ontogenetic development and morphologic variations exhibited by the specimens from Nevada establish the assignment of this species in the genus *Guembelites.* McLearn originally discarded this generic assignment because *Guembelites*, including only 2 previously described species represented by a total of 4 specimens, has "stout and thick, not compressed, whorls and has tubercles at the ends of the ribs, which are smaller, not 'ear'-like in form and are more numerous" (McLearn, 1939b, p. 51–52). Because of these differences and the lack of affinity with other genera, McLearn tentatively assigned this species to *Juvavites* with the stipulation that the erection of a new genus or subgenus for it might be necessary. This indefinite original assignment illustrates the difficulties in attempting to compare isolated specimens which represent different stages of ontogenetic development in a group of ammonoids in which increasing maturity is accompanied by considerable changes in shell morphology. In the collections from the Union district, the weakly ribbed compressed forms assigned to *Guembelites clavatus* represent one end member of the wide morphologic variation shown by the representatives of this genus. Although a continuous gradation may take place from *Guembelites clavatus* to forms assigned to *G. jandianus*, both species are recognized as being distinct because the former may represent a slightly higher stratigraphic horizon than the latter. Unfortunately, however, the stratigraphic control of the collections from the *Guembelites* zone in the Union district is not sufficient to establish whether or not such a stratigraphic separation actually exists.

Plesiotypes, USNM 128294, 128295.

Occurrence.—Union district, Shoshone Mountains, Nev. Calcareous shale member of the Luning formation, in the *Guembelites* zone about 300–400 feet above the base of the member. USGS locality M73.

Guembelites jandianus Mojsisovics

Plate 6, figures 1–8; plate 7, figures 4–10

Heraclites (*Gümbelites*) *jandianus* Mojsisovics, 1896, K. Akad. Wiss. Wien, Math.-naturw. Kl., Denkschr., v. 63, p. 634, pl. 10, fig. 1.

Heraclites (*Guembelites*) *jandianus* Mojsisovics, 1899, Paleontologia Indica, ser. 15, v. 3, pt. 1, p. 74, pl. 10, fig. 1.

Guembelites jandianus Mojsisovics. Diener, 1923, Jaarb. mijnwezen Ned.-Indie, v. 49 (1920) verh. 4, p. 149, pl. 30, fig. 1.

Approximately 80 well-preserved specimens from the Union district, showing a fairly wide range of variation, are assigned to this species. The shell is involute and somewhat compressed; the diameter ranges from 1¾ to 2 times the width. The deeply embracing whorls are inflated and ovate in cross-sectional outline, with their greatest width between the umbilical shoulders. The walls of the narrow umbilicus are steep and separated from the flanks by abruptly rounded umbilical shoulders. At maturity the development of rows of prominent "fins" along either side of the ventral margin produces a flattening of the narrow venter.

On the chambered part of the shell, the transverse ribs are moderately strong and terminate at their ventral ends in tubercles that alternate on either side of the smooth venter. The density of the ribbing on the flanks is maintained by the bifurcation and intercalation of the ribs at random outward from the umbilicus. On the lower flanks the ribs are nearly straight, but toward their ventral ends they curve forward abruptly and commonly bifurcate at the point of curvature. The ribs decrease in strength on the mature outer whorl, so that the flanks of the body chamber are nearly smooth. Numerous fine striae parallel the ribs on the outer shell material. The marginal tubercles originate on the early whorls as swellings on the ventral ends of the ribs, which with increasing maturity become stronger and elongate parallel to the forward-curving tips of the ribs. This stage of growth approximately corresponds to that of the holotype as illustrated and described by Mojsisovics and shows the same peculiar nature of the ribbing, whereby short offshoots from the ventral ends of the ribs may connect them with two successive marginal tubercles or "fins." On the mature body chamber the tubercles ultimately develop into laterally flattended pointed "fins" which are elongated nearly parallel to the venter and bear no obvious relationship to the obsolescent lateral sculpture. On the inner whorls the ventral tip of each rib bears a tubercle, but as the tubercles become increasingly elongate, they eventually correspond to about two of the lateral ribs. Very weak spiral folds are visible on the flanks of the nearly smooth body chamber in a few specimens.

Paulostome furrows are restricted to the inner whorls at diameters of less than 15 mm, on which they provide the dominant sculpture.

Exterior to the umbilical shoulder, the suture line includes 2 principal lateral saddles and 3 auxiliary saddles separated from one another by the appropriate lobes. The first lateral lobe is prominent and exceeds the second lateral lobe in both depth and breadth. Both the lobes and the saddles are dolichophyllically subdivided. The ventral lobe agrees in depth with the first lateral lobe and is divided into two points by a crenulate bluntly terminated ventral saddle equal in height to half that of the first lateral saddle.

The dimensions of the largest plesiotype, which represents a nearly mature specimen with the unbroken part of the body chamber extending for three-fourths of the final whorl, are as follows: Diameter, 85 mm; width, 41 mm; and width of the umbilicus, 7 mm. This species attains a large size. The estimated diameter of the largest specimen collected, represented by a fragment of the ventral part of the body chamber, is about 150 mm. The "fins" bordering the venter of this fragment are nearly 20 mm in length and rise about 5 mm above the smooth ventral region.

A considerable variation in morphology is shown by the representatives of this species from the Union district. Although the various specimens agree in their proportions and ornamentation at comparable growth stages, the morphologic changes accompanying maturity take place at widely different shell diameters. Specimens of a given size may represent various growth stages and consequently exhibit widely different morphologies. The transition with increasing maturity from the occurrence of tubercles to "fins" along the ventral margins is accompanied by an increase in the breadth of the ribs as well as a decrease in the strength of the ribbing. As a result the number of marginal tubercles and "fins" per volution among specimens of 40–50 mm in diameter ranges from less than 20 to about 40, with a corresponding variation in the number of the ribs. Whether or not this variation in the rate of maturity has a stratigraphic significance is indefinite because the relatively poor exposures of the stratigraphic interval characterized by the genus *Guembelites* prevented a stratigraphic separation of the collections.

Plesiotypes, USNM 128296, 128297, 128298, 128299, 128300, 128301.

Occurrence.—Union district, Shoshone Mountains, Nev. Calcareous shale member of the Luning formation, in the *Guembelites* zone about 300–400 feet above the base of the member. USGS locality M73.

Guembelites philostrati Diener

Plate 7, figures 1–3

Guembelites philostrati Diener, 1923, Jaarb, mijnwezen Ned.-Indië, v. 49 (1920) verh. 4, p. 150, pl. 29, fig. 6.

Among the members of the genus *Guembelites* collected from the Union district, 10 specimens can be assigned to this species on the basis of their ornamentation and robust shape. The shell is globose with the width of the inner whorls equal to three-quarters or more of the diameter. The exterior of the whorls is broadly rounded without a distinct separation between the flanks and venter. The coiling is involute, but the width of the umbilicus is relatively greater than that of the more compressed members of this genus. The umbilical shoulders are abruptly rounded, and the walls of the umbilicus are high and steep.

The lateral ribs are well developed and, apparently owing to the robust shape of the whorls, are nearly straight. As a result of the lack of curvature of the ribs, the tubercles at their ventral ends are equidimensional and do not become elongate on any of the specimens examined. The primary ribs usually bifurcate near the umbilicus and often branch again farther up on the flanks. In a few places, additional ribs are inserted between the primary ribs and their branches. As with the other species of *Guembelites*, the marginal tubercles alternate on either side of the smooth ventral region. Although the tubercles do not become elongate as the whorls mature, they increase in size at a faster rate than that of the increasing coarseness of the ribs, so that on larger specimens 1 tubercle may correspond to 2 ribs. About 30–35 tubercles are present per volution.

The suture line is not well preserved on any of the available specimens but agrees in the configuration of its principal elements with that of *Guembelites jandianus*. The foreshortening of the flanks, resulting from the robust shape of the whorls, causes a reduction in the number of auxiliary elements on the flanks, so that the second auxiliary saddle is situated on the umbilical shoulder.

The dimensions of the plesiotype, which although immature agrees in morphology with the larger fragmentary specimens, are as follows: Diameter, 29 mm; width, 24 mm; and width of the umbilicus, 5 mm. None of the examples are fully mature, and the largest specimen with an estimated original diameter of about 70 mm shows neither a reduction of the lateral sculpture nor a tendency for the marginal tubercles to develop into elongate "fins."

This species, characterized by robust whorls, straight ribs, and equidimensional marginal tubercles, may be gradational with forms assigned to *Guembelites jandianus*. However, as with *G. clavatus* it is recognized as a distinct species because a gradation cannot be demonstrated from the available material, and the distinctive morphology may have a stratigraphic significance.

Plesiotypes, USNM 128302, 128303.

Occurrence.—Union district, Shoshone Mountains, Nev. Calcarous shale member of the Luning formation in the *Guembelites* zone about 300–400 feet above the base of the member. USGS locality M73.

Suborder PHYLLOCERATINA Arkell, 1950
Superfamily PHYLLOCERATACEAE Zittel, 1884
Family DISCOPHYLLITIDAE Spath, 1927
Genus DISCOPHYLLITES Hyatt, 1900

Discophyllites ebneri (Mojsisovics)

Plate 8, figures 1–4

Phylloceras (*Mojsvarites*) *ebneri* Mojsisovics, 1896, K. akad. Wiss. Wien, Math.-naturw. Kl., Denkschr., v. 63, p. 668, pl. 19, fig. 6.

Mojsisovics, 1899, Paleontologia Indica, ser. 15, v. 3, pt. 1, p. 116, pl. 19, fig. 6.

Discophyllites cf. *D. ebneri* Mojsisovics. Welter, 1914, Paläontologie von Timor, Lief. 1, p. 202, pl. 30, fig. 10, 11.

Discophyllites ebneri (Mojsisovics) Spath, 1934, Catalogue of the fossil cephalopods in the British Museum (Natural History), pt. 4, The Ammonoidea of the Trias, (I), p. 318, figs. 107 e–d, 108.

Rhacophyllites (*Discophyllites*) *patens* (Mojsisovics). Smith, 1927, U. S. Geol. Survey Prof. Paper 141, p. 100, pl. 62, figs. 1–13, pl. 103, figs. 4–6.

[not] *Discophyllites ebneri* Mojsisovics. Diener, 1906, Palaeontologia Indica, ser. 15, v. 5, mem. 1, p. 173, pl. 5, fig. 5. (=*Phylloceras* (*Discophyllites*) *joharense* Diener, 1915. Fossilium Catalogus, pt. 8, p. 219).

[not] *Rhacophyllites* (*Discophyllites*) cf. *R.* (*D.*) *ebneri* Mojsisovics. Trechmann, 1917, Geol. Soc. London Quart. Jour., v. 73, p. 184, pl. 17, fig. 7.

This species is represented in the collections from the Union district by six fragmentary specimens, all of which possess a consistent and characteristic cross-sectional whorl shape. The shell is evolute, formed by slowly enlarging, little-embracing whorls. The ovate cross-sectional outline of the whorls is considered to be the most diagnostic feature of this species. The umbilical shoulders are gently rounded, grading into steep umbilical walls that overhang slightly at the umbilical seams. The greatest width of the whorls is at about one-third of the distance up from their umbilical margins to their venters and corresponds to about three-fourths of the whorl height. The surface of the whorls is smooth except for closely spaced, nearly straight, striae on the outer shell material extending from the flanks across the venter.

The suture line agrees with that which is characteristic of *Discophyllites.* The first lateral saddle ("external saddle" of Mojsisovics, Spath, and others) is unsymmetrically monophyllitic with a prominent asymmetric terminal leaf convex towards the umbilicus and a lower, less prominent leaf on the wall of the shallow ventral lobe. This subordinate outer leaf extends somewhat higher in the sutures of the outer whorls than it does on those of the inner whorls, hence, the tendency towards a diphyllic subdivision of the first lateral saddle appears to increase with growth of the shell. The first lateral lobe is divided into three first-order subdivisions, each of which shows at least a tendency for a further second-order threefold division and eventually a third-order trifid subdivision. At a whorl height of about 60 mm, all 3 orders of subdivision of the first lateral lobe are trifid only on the middle and deepest of the first-order divisions. The terminal leaf of the second lateral saddle is convex ventrally with the next subordinate leaf on the side toward the umbilicus. A slightly greater tendency toward diphyllic subdivision is shown by the second lateral saddle in comparison with the first lateral saddle. The second lateral lobe and the third lateral saddle agree in plan with the corresponding ventrally preceding elements but are less subdivided. An additional lobe and saddle are present exterior to the umbilical shoulder.

The dimensions of the smaller plesiotype, measured in the same plane of cross section, are as follows: Diameter, 100 mm; greatest height of the outer whorl, 41 mm; greatest width of the outer whorl, 32 mm; and width of the umbilicus, 33 mm. The larger plesiotype is a chambered whorl segment with a maximum height of about 65 mm.

The specific name *Discophyllites ebneri* has had a varied application owing to the lack of agreement among paleontologists as to what features of the shell morphology should be considered diagnostic. In the original description, Mojsisovics (1896) stated that this species is distinguished from *D. patens* only by very slight differences in outward appearance that are due to a somewhat different transverse section of the whorls caused by their lesser height. Also, the details of the lobes and lower parts of the saddles were said to differ from those of *D. patens.* In applying this specific name to examples from the Himalayas, Diener (1906, p. 174) considered only the suture pattern to be significant for the separation of the two species. However, the suture line of these examples described by Diener also differs from that of Mojsisovics' original specimen, as pointed out by Welter (1914, p. 202) and subsequently Diener (1915, p. 219) placed these forms, which he had originally assigned to *D. ebneri*, in a new species, *Phylloceras* (*Discophyllites*) *joharense*, which later was correctly assigned to the genus *Diphyllites* Jullien, 1911, an objective synonym of *Rhacophyllites* Zittel, by Spath (1934, p. 322). Welter (1914) attempted to enlarge upon Mojsisovics' original distinction between *Disco-*

phyllites ebneri and *D. patens* on the basis of differences in the details of the lobes, but the differences in the sutures shown by otherwise identical specimens from the same locality lend doubt to the reliability of these minor distinctions. Diener (1920) in describing examples of *D. patens* from the Karnian-Norian "Mischfauna" of the Hallstatt Kalk states that if *D. patens* and *D. ebneri* are to be recognized as separate species, they can be distinguished only on the basis of the relatively minor differences in the shapes of their whorl cross sections. He did not, however, consider the two species to be synonomous, as stated by Smith (1927, p. 100), who ventured the opinion that *D. patens*, *D. ebneri*, and *D. insignis* Gemmellaro are all specifically identical. The writer accepts the usage of *D. ebneri* adopted by Spath (1934, p. 318–319), whose diagnosis of this species is " * * * like *D. patens*, but with a whorl-section with [the] greatest thickness closer to [the] umbilical border" and who considered " * * * this species [to be] intermediate in whorl-section between the more regularly elliptical *D. patens* and the cordiform *D. insignis.*" Occurrences of these three species have been geographically isolated, and the suggestion that the forms with a more cordiform whorl shape characterize somewhat older strata than those with elliptical whorls has not been demonstrated. Nevertheless, the recognition of these species as distinguished by the cross-sectional shape of their whorls is considered to be desirable, at least until the stratigraphic utility of such a distinction is ascertained. For this reason, the forms described by Smith (1927) from the so-called Hosselkus limestone of Shasta County, Calif., as *Discophyllites patens* are transferred here to *D. ebneri.* Although the shape of the whorl section is not clearly shown by Smith's figures, additional specimens from the upper Karnian of Shasta County, Calif., in the collections of Stanford University show a consistently greater agreement in whorl shape with the holotype of *D. ebneri* than with that of *D. patens.*

Plesiotypes, USNM 128313, 128314.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation in the *Klamathites schucherti* zone in the lower part of the shaly limestone member. USGS locality M71.

Order NAUTILOIDEA
Family TAINOCERATIDAE Hyatt, 1833
Genus GERMANONAUTILUS Mojsisovics, 1902
Germanonautilus kummeli Silberling, n. sp.

Plate 8, figures 7–11

About 10 reasonably complete specimens, mostly immature, and about twice this number of fragmentary specimens, most of which are the internal molds of chambers, of this species were collected from the *Klamathites schucherti* zone in the Luning formation. The specimen (USNM 107090) described by Kummel (1953, p. 31) as *Germanonautilus* sp. from West Union Canyon agrees in morphology with this species and is unmistakably from the same zone, as shown by the lithologic character of its matrix and the characteristic pelecypod shell fragments (*Septocardia?*) imbedded in the matrix.

The trapezoidal shape of the mature whorls is illustrated by the part of the body chamber preserved on the holotype. The venter is broad and flattened, and its median area is depressed slightly below the part of the venter adjacent to the ventrolateral shoulders. The flanks are flattened, but somewhat convex, and slope inward towards the venter, so that the greatest width of the whorls is at the umbilical shoulders. Both the ventrolateral and umbilical shoulders are smoothly rounded, and the latter grade into steep umbilical walls which are slightly overhanging at the umbilical seam. The umbilicus is open but relatively narrow, its width being about one-sixth of the shell diameter. The preceding growth stage finds the venter equally broad, but gently arched with the ventrolateral shoulders less distinct. At still earlier immature stages, during approximately the first 1½ whorls, the external outline of the transverse whorl section is semicircular with the flanks and venter not yet individualized. The surface of the shell is devoid of ornamentation except for coarse growth lines that describe a broad sinus on the venter. The suture line is nearly straight, with shallow lateral lobes and equally shallow, but narrower, ventral and dorsal lobes.

The siphuncle intercepts the septa about one-third of the distance up from the venter of the preceding whorl. In longitudinal section the siphuncle is seen to be suborthochoanitic with the septal necks sometimes slightly recurved, particularly on their dorsal sides. The connecting rings expand in each chamber, so that their maximum diameter is nearly twice that of the adjacent septal necks. This results in a beaded appearance of the siphuncle as viewed in longitudinal sections. No siphonal deposits can be observed at any growth stage.

An appreciable variation in the rate of maturity takes place giving specimens of the same size, but representing different ontogenetic stages of development, a different outward appearance. The holotype, the outer one-fourth whorl of which is unchambered, is apparently a premature individual. Its adoral cross-sectional whorl shape at a height of 33 mm agrees with that of larger fragmentary whorls of nearly twice this height. Other specimens of about the same diameter as the holotype show a less trapezoidal whorl cross section and have broadly rounded venters. A correlation appears to exist between the rate of maturity and the relatively minor variations in the relative whorl thickness, as individuals with more compressed inner whorls appear to have matured at a slower rate. The other dimensions of the holotype are as follows: Diameter, about 52 mm (venter partly eroded); and the maximum width, 44 mm.

This species is similar in shape to *Germanonautilus breunneri* Mojsisovics from the lower Karnian of the Alps, but it differs by having less angular ventral and umbilical shoulders. The whorls of *G. brooksi* Smith from the Karnian of Alaska are more compressed at comparable sizes and appear to expand in width more slowly.

This new species is named for Dr. Bernhard Kummel, of Harvard University, who previously described a fragmentary specimen of this species in his recent (1953) monograph on the American Triassic coiled nautiloids.

Holotype, USNM 128304; paratype, USNM 128305.

Occurrence.—Union District, Shoshone Mountains, Nev. Luning formation in the *Klamathites schucherti* zone in the lower part of the shaly limestone member. USGS locality M71.

Genus PHLOIOCERAS Hyatt, 1883

Phloioceras mulleri Silberling, n. sp.

Plate 9, figures 11–14

This new species is based on a single specimen from the *Klamathites schucherti* zone of the Luning formation. Although the holotype consists of a complete phragmocone, it is figured without the 13 adoral chambers, which are crushed and distorted. Only a few patches of the shell material are retained on the outer whorls, so that the specimen consists mostly of an internal mold.

The shell is evolute and composed of little-embracing wide subtrapezoidal whorls. On the mature shell the venter is broad and only slightly arched, with a median depression. The flanks are slightly convex and convergent towards the umbilicus. The ventral shoulders are subangular, by virtue of the exterior ornamentation, whereas the umbilical shoulders are less distinct and round gradually into steep umbilical walls. The cross-sectional shape of the outer whorls remains fairly constant at heights exceeding 12 mm, but the shape of the first whorl differs strikingly by having a prominent continuous keel along the median line of the rather highly arched venter. In addition to the ventral keel, ventrolateral and lateral longitudinal ridges are also present on the first whorl; however, these correspond to the most prominent ridges on the outer whorls, but no counterpart of the ventral keel is present at later growth stages on which the median part of the venter is characterized instead by a broad depression.

The surface of the whorls is highly ornamented by longitudinal ridges of different strengths composed of rows of coalescing elongate nodes in addition to both longitudinal and transverse striations on the outer shell material. Three parallel, but somewhat sinuous, ridges are present on the venter on either side of the median furrow. There are also some indications, on the internal mold, of additional smaller ridges, which may have been better exhibited on the outer shell material, between the prominent ridges on either side of the venter. The ventrolateral shoulders are marked by strong ridges second only in strength to the adjacent ridges on the outer flanks. Besides an inconspicuous ridge on the umbilical shoulders, an additional low ridge occurs on the flanks. Three small ridges are present on the umbilical walls. Not counting the possible occurrence of small interridges on the outer shell material, a total of 20 longitudinal ridges can be observed on the surface of the interior mold of the outer whorls; the ridges are arranged as follows: 3 ridges on either side of the venter, 1 at the ventrolateral shoulder, 2 on the flanks, 1 at the umbilical shoulder, and 3 on each umbilical wall. The fine transverse growth striae, which together with the longitudinal striae produce a reticulate pattern on the outer shell material as preserved on the first whorl, describe a shallow ventral sinus. The suture line is nearly straight, with shallow ventral, lateral, and dorsal lobes.

The siphuncle is dorsal to the center of the whorls and intercepts the septa about one-fourth of the distance up from the venter of the preceding whorl. The siphuncle was examined in a longitudinal median section from the crushed adoral part of the phragmocone at a whorl height of about 40 mm and is suborthochoanitic, with a "beaded" appearance like that of *Germanonautilus kummeli*. At least at this growth stage, no siphonal deposits are present.

The maximum dimensions of the uncrushed phragmocone at a diameter of 51 mm are as follows: Width of whorl, 36 mm; height of the whorl, 22 mm; and width of the umbilicus, 26 mm. The estimated original greatest diameter of the phragmocone including the crushed adoral part is about 120 mm.

Besides the holotype of this new species, only one other specimen belonging to the genus *Phloioceras* has been described from North America. This other specimen, *Phloioceras* sp. from Alaska, described by Kummel (1953, p. 44), differs from *P. mulleri* at comparable growth stages by having 4 instead of 6 longitudinal ridges or rows of nodes on the venter, only half as many ridges in all, and a different cross-sectional whorl shape. *Phloioceras welteri* Kieslinger, 1924, and "*Phloioceras* nov. spec. ind. ex. aff. *gemmati* Mojsisovics" (Welter, 1914) both agree with *P. mulleri* by having six prominent ridges on the venter in addition to ventrolateral ridges, but *P. welteri* has only a single median ridge on the flanks, and the form described by Welter has two low ridges on the flanks, a prominent ridge on the angular umbilical shoulders, and smooth umbilical walls. All these forms differ from the two other previously described species of this genus, *Phloioceras deliciosum* Diener, 1908, and the genotype *P. gemmatum* (Mojsisovics, 1873), on which the longitudinal ridges are much more numerous and more consistent in strength.

This new species is named in honor of Prof. Siemon Wm. Muller, of Stanford University, who provided the writer with the opportunity of undertaking the present study.

Holotype, USNM 128306.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation in the *Klamathites schucherti* zone in the lower part of the shaly limestone member. USGS locality M71.

Family CLYDONAUTILIDAE Hyatt, 1900
Genus CLYDONAUTILUS Mojsisovics, 1882

Clydonautilus sp.

Plate 8, figures 5, 6

A single fragmentary specimen from the *Klamathites macrolobus* zone in the Luning formation can be assigned to this genus and represents the first reported occurrence of *Clydonautilus* in North America. The specimen consists of the internal mold of a whorl segment approximately 90 mm in length as measured along the venter, half of which is part of the living chamber and is separated from the adoral chamber by the final septum. The configuration of the suture line establishes the generic assignment, but the specimen is not well enough preserved for specific identification.

Judging from the available segment of one whorl, the shape of the shell was laterally compressed and involute. The cross-sectional shape of the whorl is subtrigonal with high flattened slightly concave flanks which are strongly convergent towards the narrow rounded venter. The umbilical shoulder is abruptly rounded, and the umbilical wall overhangs. The maximum height of the whorl is about 62 mm, and the corresponding greatest width is about 52 mm. The estimated width of the umbilicus is about 10 mm. A small patch of shell material on the venter of the living chamber part of the specimen shows fairly coarse transverse growth lines that describe a shallow ventral sinus.

The suture line is strongly sinuous with a long, narrow first lateral saddle and lobe and a shorter and broader second lateral saddle which extends to the umbilical margin. The ventral lobe is divided by a ventral saddle about two-thirds the height of the first lateral saddle. The extremities of the lobes and saddles are sharply rounded. On the dorsal side of the whorl a very weak, barely perceptible, annular lobe is present.

The siphuncle is located in the center, where it intercepts the final septum. Unfortunately, the structure of the siphuncle could not be observed, owing to the incompleteness of the specimen.

The structure of the siphuncles of specimens assigned to the closely related genus *Proclydonautilus*, examined in longitudinal median sections, warrant a digression from the present description. Several specimens from both the *Klamathites schucherti* and the *K. macrolobatus* zones of the Luning formation with a suture pattern and external morphology characteristic of *Proclydonautilus* show a consistent structure and ontogenetic development of the siphuncle. In the outer septate whorls of these specimens and beyond about the second whorl, the siphuncle is suborthochoanitic with straight septal necks and connecting rings that expand slightly in the chambers, so that the gross aspect of the siphuncle resembles a string of sausage. At earlier growth stages, in the second whorl and the outer part of the first whorl, annulosiphonate deposits are developed at the tips of the septal necks. These deposits are apparently ringlike in shape, convex inward, and somewhat thicker on the ventral side. In thin section they show a lamellar structure. In the innermost 1½ whorls of the shell, the annulosiphonate rings increase in width adapically until they form a continuous lining inside of the connecting rings, reducing the siphuncle to about half of its unfilled inside diameter. At the same early stage of growth, the relative length of the septal necks is greater and the siphuncle shows a tendency toward being holochoanitic. The siphuncle of a single specimen of *Proclydonautilus triadicus* (Mojsisovics) from the so-called Hosselkus limestone of Shasta County, Calif., was examined in longitudinal section and found to agree in structure and development with the specimens of the same genus from the Luning formation of the Union district. These features of the siphuncles are described here because they have not previously been recognized in Triassic coiled nautiloids, and yet they would appear to have considerable taxonomic and phylogenetic significance.

Returning to the discussion of *Clydonautilus* sp. from the Union district, among the previously described species of this genus, the suture pattern agrees most closely with that of *C. quenstedti* (Hauer), particularly the suture line of a large example of this species as figured by Mojsisovics (1873, pl. 9, fig. 3).

Plesiotype, USNM 128307.

Occurrence.—Union district, Shoshone Mountains, Nev. Luning formation in the *Klamathites macrolobatus* zone in the upper part of the shaly limestone member. USGS locality M72b.

Class **PELECYPODA**
Order **PRIONODESMACEA**
Suborder **SCHIZODONTA**
Family **TRIGONIIDAE**
Genus **MYOPHORIA** Bronn, 1834

Myophoria shoshonensis Silberling, n. sp.

Plate 9, figures 9, 10

This species is represented in the collections from the Luning formation by several dozen specimens, most of which are preserved only as interior molds. Although generally poorly preserved, these specimens are described as a new species because of their distinctive and consistent morphology and their potential stratigraphic value.

The shell is equivalved and inequilateral with a trigonal lateral outline produced by the truncation of the posterior margin. A prominent carinate umbonal radial ridge extends ventrally from the beak, forming a protuberance from the posterolateral margin. The surface posterior to the umbonal ridge is smooth and slopes steeply to the commissure of the valves. The lateral sculpture consists of radial ribs, one of which, extending from the beak to the ventral margin, is usually more prominent than the others and approximately bisects the area anterior to the umbonal ridge. Each of the 3 or 4 ribs posterior to this median rib commences at a progressively greater distance from the beak, so that a smooth area of constant width is formed between the posterior umbonal ridge and the ribbed part of the shell. Anterior to the median rib, but confined to the lateral surface, are between 6 and 8 radial ribs extending from the beak to the ventral margin. Counted along the ventral margin the radial ribs total 10–14, usually 11 or 12. The radial ribs are crenulated on the outer shell material by coarse concentric lines which are continuous with those that ornament the area adjacent to the anterior margin, where radial ribs are absent.

The structure of the hinge line is known only from a partly weathered right valve which shows the two strong divergent cardinal teeth characteristic of this group of pelecypods.

The dimensions of the holotype, which is representative in size and proportions, are as follows: height, 32 mm; length, 35 mm; and width, 23 mm.

The forms assigned to this new species represent those referred by Muller and Ferguson (1939, p. 1601) in the faunal list of the *Klamathites schucherti* zone to *Myophoria* cf. *M. decussata* Münster, with which they agree in the major elements of their sculpture. However, the outline of *M. shoshonensis* is more trigonal, because the posterior margin is abruptly truncated, the radial ribs are more pronounced, and the concentric ornamentation is weaker.

Holotype, USNM 128308.

Occurrence.—Union district, Shoshone Mountains, Nev. This species is most abundant in the *Klamathites schucherti* zone of the Luning formation about 200–250 feet above the base of the shaly limestone member (USGS locality M71), but it also occurs somewhat higher in the section, up to about 430 feet above the base of the member.

Order **TELEODESMACEA**
Family **CARDITIDAE**

Genus **SEPTOCARDIA** Hall and Whitfield, 1877

Septocardia Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Par. Rept., v. 4. Paleontology, pt. 2, p. 294. [Type species *Septocardia typica* Hall and Whitfield, 1877, by original designation.]

?*Pascoella* Cox, 1949, Inst. Geol. Peru, Bol. 12, p. 33. [Type species *Pascoella peruviana* Cox, 1949, by original designation.]

The application of this generic name is subject to doubt because of the inferior quality of the original specimens on which it is based. The syntypes of the type species, *Septocardia typica* (USNM 12538), consist of two right valves and one left valve which are small, probably immature, silicified specimens not nearly as well preserved as Hall and Whitfield's illustrations (1877, pl. 7, figs. 26–29) indicate. Besides the type species, Hall and Whitfield described one other species of this genus, *Septocardia carditoidea*, based on a single relatively large (about 1½ inches in height) poorly preserved specimen (USNM 12549). Here again Hall and Whitfield's illustration (1877, pl. 7, fig. 25) is considerably more artistic than authentic, as the holotype barely shows the original outline of the shell and only parts of several of the ribs on each valve are visible. Externally this specimen generally agrees with the syntypes of *S. typica*, differing, according to Hall and Whitfield, by having more angular ribs and interspaces, a different style of transverse ornamentation, and a proportionally longer shell. However, owing to its considerably (about 10 times) larger size, the distinction between the two species cannot be demonstrated, and the single specimen of *Septocardia carditoides* might well represent the mature shell of the small forms on which *S. typica* is based.

Hall and Whitfield's original description of *Septocardia* describes the morphology shown by the syntypes of the type species fairly adequately, but it is supplemented here to some extent as a result of the writer's study of these specimens. In summary, the shells are equivalved, inequilateral, and cardiaform, with the surface ornamented by radial ribs marked by transverse growth lines. A deep anterior muscle scar cavity, separated from the interior of the shell by a partition, is present in the anterior cardinal margin of both valves. On the right valve between the anterior muscle scar pit and the cardinal tooth is an elongate socket which is somewhat greater in length than as shown in Hall and Whitfield's figure 27. The cardinal tooth, slightly anterior to the beak of the right valve, is triangular and may have been somewhat hooked but not curved posteriorly as shown in the original figure. A relatively small socket is immediately posterior and slightly dorsal to the cardinal tooth. Intersecting the cardinal margin posteriorly to this socket is the external ligament groove. The posterior cardinal margin is preserved only on the small (height about 4 mm) right valve corresponding to Hall and Whitfield's figures 26 and 27. As stated by the original authors, no posterior lateral teeth can be observed. However, as the absence of a posterior lateral tooth is of considerable importance, it should be noted that the granularity of the silicified shell material is nearly equal in coarseness to the thickness of the shell, and consequently it is difficult to appraise the quality of the preservation. Also, as will be brought out later, the probable immaturity of this specimen alone may be responsible for the absence of a posterior lateral tooth. Both the anterior and the posterior extremities of the cardinal margin of the left valve, which appears to be that illustrated by Hall and Whitfield's figure 28, are broken away, and apparently there is no basis for the original illustration of these parts. The anteriormost structure preserved on the cardinal margin of the left valve is a prominent socket that is slightly anterior to the beak and that corresponds to the cardinal tooth of the right valve. Immediately posterior to the cardinal socket and curved slightly over it is a posterior tooth. Posterior to this tooth is a notch in the outer edge of the cardinal margin which may represent the ligament groove. The remainder of the posterior margin is not preserved.

In an attempt to collect more definitive material, the type locality of *Septocardia* in Shoshone Canyon in the northwestern Clan Alpine Mountains (or the southwestern Augusta Mountains), Nev., was visited by S. W. Muller and the writer in 1952 and again in 1953. A few cardiaform pelecypods about 20 mm in height, which agree with the external morphology of *Septocardia typica*, considering their larger size, were collected on the north side of the canyon in the vicinity of Shoshone Springs. These pelecypods occur near the base of the exposed pre-Tertiary section and at a stratigraphic horizon somewhat below the occurrence of characteristic Norian mollusks such as *Steinmannites* and *Monotis*. All the pre-Tertiary rocks exposed at the type locality appear to be Late Triassic in age rather than Jurassic as they were thought to be by Hall and Whitfield. The hinge structures of these pelecypods generally agree with those shown by the considerably smaller syntypes of *Septocardia typica*, except for the presence of a prominent elongate, and yet tubercular, posterior lateral tooth on the left valve.

The hinge structure as well as the external morphology of the specimens from the type locality of *Septocardia* resembles in all essential characteristics that of the genus *Pascoella* Cox, 1949, described from the Norian of Peru. The arrangement of the hinge teeth, the nature of the ligament groove, and the conspicuous anterior muscle scar pit of *Pascoella* all agree with the corresponding structures shown by the small syntypes of *Septocardia typica*. The most significant difference is the presence of a prominent tuberculiform posterior lateral tooth in the left valve of the specimens of *Pascoella*. The young stages of *Pascoella* from the well-preserved silicified Peruvian material were recently compared with photographs of the syntypes of *Septocardia typica* by Dr. L. R. Cox, who found them to be very similar. Concerning two small right valves of *Pascoella peruviana*, the genotype of *Pascoella*, Dr. Cox writes (written communication, May 19, 1955):

> They are so similar to [the] photographs of the smaller and better preserved syntype [of *Septocardia typica*] that I have changed my opinion based on the published figures of *Septocardia*, and have come to the conclusion that the species is probably the same. The specimens seem to be identical in outline, and the small posterior lateral tooth present in the larger right valves [of *Pascoella*] . . . can scarcely be detected at this early growth stage, although the socket below the tooth can just be seen in my specimens. Other details of dentition which seem so characteristic of the full-grown shell have not become differentiated in the young shell, and the latter is relatively more elongated than the full-grown shell.

Because of these similarities of the young shells, Dr. Cox concludes that his genus *Pascoella* will apparently have to be suppressed as a synonym of *Septocardia*. Dr. Cox's permission to quote these findings is gratefully acknowledged.

As the hinge line elements of immature specimens of *Pascoella peruviana* differ from those of the mature shells of the same species by being less differentiated and in particular by lacking the prominent posterior lateral tooth and socket of the mature shell, it seems probable that the mature specimens from the type locality of *Septocardia*, which agree with *Pascoella*, are simply mature individuals of *Septocardia typica*. However, even though the small shells of both genera are similar, it remains to be demonstrated that the presumed mature topotypes of *Septocardia typica* actually represent the same biologic entity as the small syntypes of this species. This can only be established by enlarging the collections of *Septocardia* from the type locality and demonstrating the ontogenetic development. For this reason the forms from the Upper Triassic of the Union district and elsewhere in Nevada which agree with *Pascoella* are only tentatively assigned to *Septocardia* and the establishment of this generic name as a senior synonym of *Pascoella* is only tentative. A generic separation of the Peruvian forms from the similar forms occurring in Nevada on the basis of geographic isolation cannot be made because specimens from the Norian or possibly Rhaetian strata of the Gabbs Valley Range, Nev., collected and prepared by S. W. Muller, are conspecific in all respects with *Pascoella peruviana* Cox.

Septocardia? sp.

Plate 9, figures 1–8

Although these forms are extremely abundant in the Union district in the lower part of the Luning formation, their shells are seldom well preserved and the structure of the hinge line could not be developed on any of the available specimens. The external morphology and the general features of the dentition as observed in sections and internal molds allow a tentative generic assignment, but without more detailed knowledge of the hinge line, specific identification cannot be attempted.

The shell is equivalved and strongly biconvex, with prominent recurved beaks located anteriorly. The lateral outline is subtrigonal with a tendency towards the truncation of the posterior margin producing an assymetric subquadrate outline. Approximately 25–30 radial ribs, counting those on the posterior cardinal surface, are present in each valve. In cross section the ribs and interspaces have a rounded V-shape. Closely spaced concentric growth lines produce a chevron pattern on the ribs, which near the ventral margin becomes pronounced as wavy wrinkles.

The structure of the hinge line is known only from interior molds and serial sections from specimens on which the original shell was retained. A deep anterior adductor scar cavity, incurved towards the beak, is present in the dorsal margin of both valves and is separated from the interior of the shell by a partition. These muscle scar pits are well shown on interior molds. Anterior to the umbo in the left valve is a tooth that is elongate parallel to the cardinal margin, with a corresponding socket in the right valve. A prominent cardinal tooth is present in the right valve beneath the beak. The ligament groove is exterior, short, and oblique, intersecting the cardinal margin immediately posterior to the umbo. A well-defined posterior lateral tooth is present in the left valve at some distance posterior to the ligament groove.

The dimensions of representative mature specimens are as follows: Height, 15–25 mm; length, 20–30 mm; and width, 15–30 mm.

A specimen probably belonging to this species from "Uniontown," the mining community located in West Union Canyon during the later part of the 19th century, was referred by Gabb (1870, p. 12) to his species *Cardium arcaeformis* Gabb (1870, p. 11, pl. 3, fig. 9). This species was described from "Volcano," another early mining camp, located near Volcano Peak in the southwestern Gabbs Valley Range and distinct from the district of the same name in the Monitor Range. Because Gabb failed to find other fossils in the vicinity of "Uniontown," he concluded that the single specimen obtained had been brought in from the Volcano district. However, pelecypods answering the general description of Gabb's inadequately characterized species are present at both localities, but in strata of different age. In this case Gabb's collecting was surpassed by that of the small boys in the former community of "Uniontown," who according to local legend highly prized the abundant equidimensional interior molds of *Septocardia?* as sling-shot ammunition, without regard to the possibility of stratigraphic admixtures.

Plesiotypes, USNM 128309, 128310, 128311, 128312.

Occurrence.—Union district, Shoshone Mountains, Nev. Distributed throughout the shaly limestone member of the Luning formation, but most abundant in the lower part of the member, where it dominates the fauna of the *Klamathites schucherti* zone. USGS localities M71 and M72a.

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INDEX

[Italic numbers indicate descriptions]

PLATES 1–9

PLATE 1

[All figures natural size except as indicated below]

FIGURES 1, 2. *Mojsisovicsites robustus* (McLearn) (p. 40).
Plesiotype, USNM 128253. From USGS loc. M73, calcareous shale member of the Luning formation.

3–5. *Mojsisovicsites kerri* (McLearn) (p. 40).
Plesiotype, USNM 128254. 5, suture line near beginning of body chamber, × 2. All from USGS loc. M73, calcareous shale member of the Luning formation.

6–14. *Mojsisovicsites* cf. *M. crassecostatus* Gemmellaro (p. 41).
6–8. Plesiotype, USNM 128255. 6, suture line about one-fourth of whorl from body chamber, × 2.
9–11. Plesiotype, USNM 128256. 9, suture line at beginning of body chamber, × 2.
12–14. Plesiotype, USNM 128257. 12, suture line at beginning of body chamber, × 2.
All from USGS loc. M73, calcareous shale member of the Luning formation.

15, 17–19. *Klamathites schucherti* Smith (p. 38).
15. Plesiotype, USNM 128315. Suture line at whorl height of 42 mm.
17–19. Plesiotype, USNM 128249. 17, suture line of third septum from body chamber.
All from USGS loc. M71, shaly limestone member of the Luning formation.

16, 20–22. *Klamathites macrolobatus* Silberling, n. sp. (p. 38).
16. Paratype, USNM 128251. Suture line at whorl height of 42 mm, × 1¼. Specimen representing lowest occurrence of this species from about 430 feet above the base of the shaly limestone member of the Luning formation, USGS loc. M72a.
20–22. Holotype, USNM 128252. 20, suture line at whorl height of 39 mm. From USGS loc. M72, shaly limestone member of the Luning formation.

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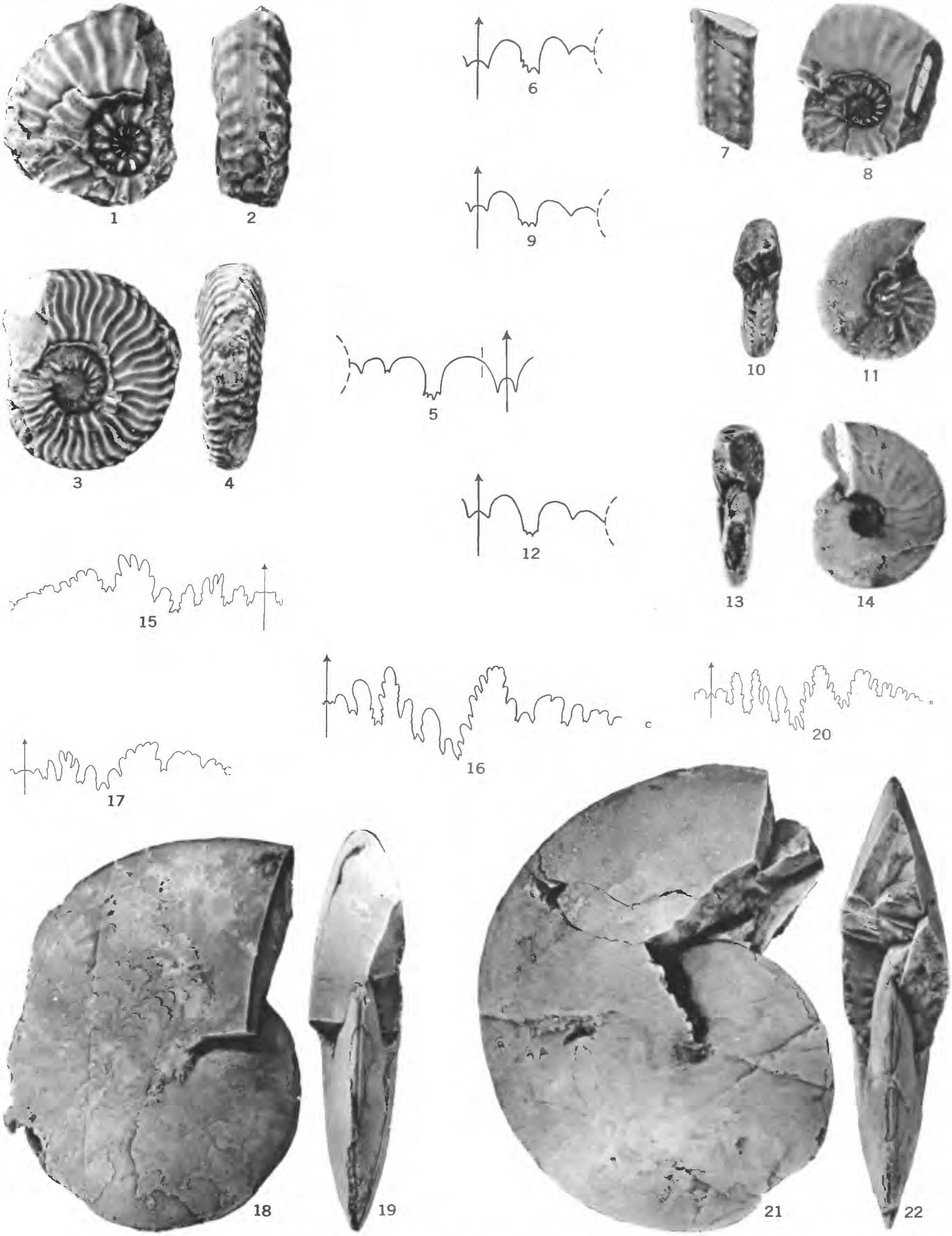
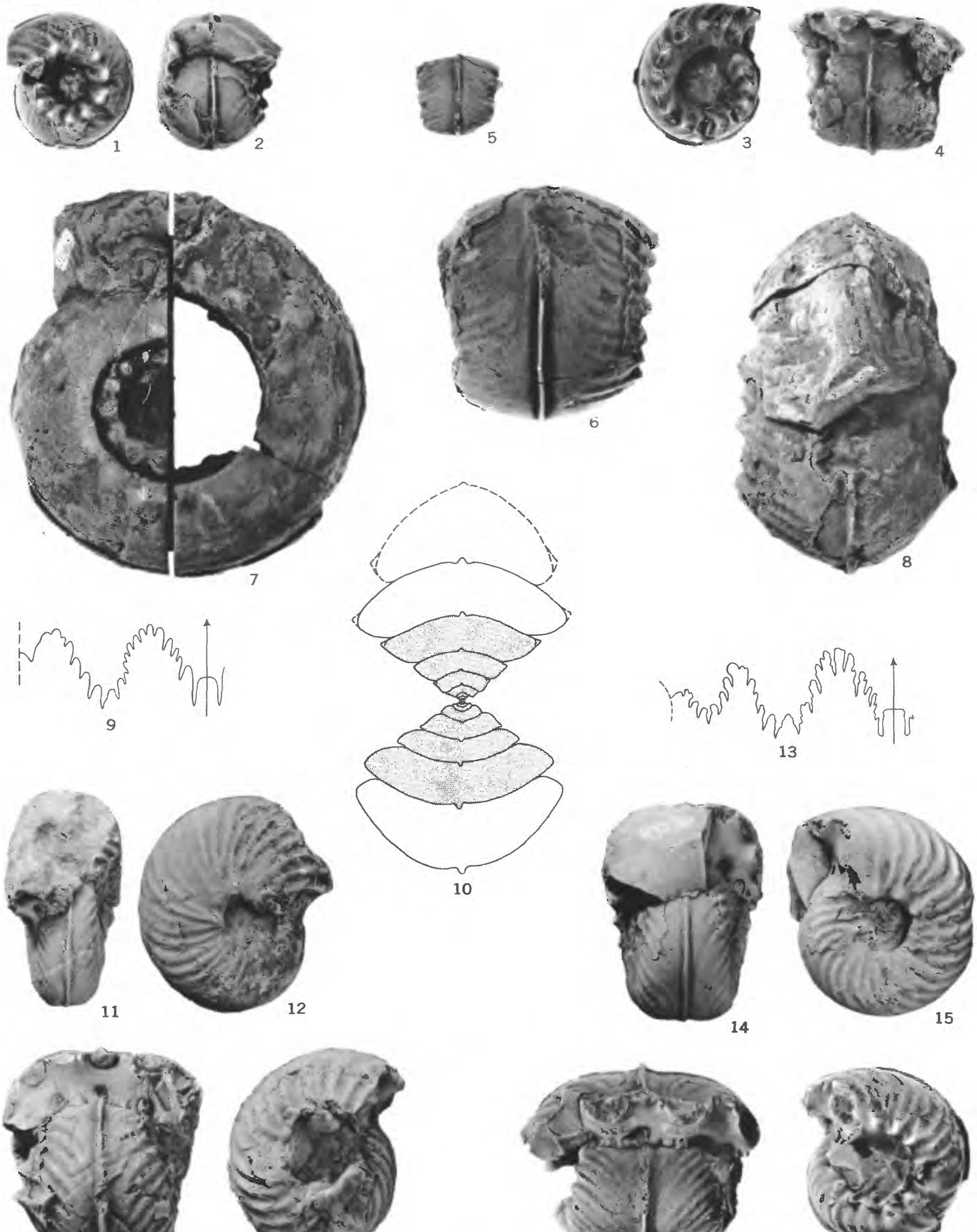


MOJSISOVICSITES AND *KLAMATHITES*



TROPITES

PLATE 2

[All figures natural size except as indicated below]

FIGURES 1–10. *Tropites latiumbilicatus* Silberling, n. sp. (p. 47).

1, 2. Paratype, USNM 128259.

3, 4. Paratype, USNM 128260.

5–10. Holotype, USNM 128258. Umbilical spines on outer whorl eroded away. 5, 6, ventral views of inner whorls at diameters of 16 mm and 35 mm, respectively. 9, final suture line 1½ whorls from aperture, × 1½. 10, diagrammatic cross section prepared from a cellulose peel.

All from USGS loc. M72a, shaly limestone member of the Luning formation.

11–19. *Tropites subquadratus* Silberling, n. sp. (p. 48).

11, 12. Paratype, USNM 128262, a compressed variant.

13–15. Holotype, USNM 128263. 13, suture line at whorl height of 17 mm. × 1½.

16, 17. Paratype, USNM 128264, a robust variant.

18, 19. Paratype, USNM 128265, illustrating the extreme in depression of the shell.

All from USGS loc. M72a, shaly limestone member of the Luning formation.

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PLATE 3

[All figures natural size except as indicated below]

FIGURES 1–6. *Tropites subquadratus* Silberling, n. sp. (p. 48).

1, 2. Paratype, USNM 128261, comparable in proportions to holotype. 1, diagrammatic cross section prepared from a cellulose peel. 2, suture line at a diameter of about 50 mm at the beginning of the body chamber, × 1½.

3, 4, 6. Paratype, USNM 128266. An involute variant, compare with plate 2, figures 16, 17. 6, final suture line at whorl height of 37 mm, × 1½.

5. Paratype, USNM 128267. Diagrammatic cross section of an involute variant prepared from a cellulose peel.

All from USGS loc. M72a, shaly limestone member of the Luning formation.

7–16. *Tropites crassicostatus* Silberling, n. sp. (p. 49).

7, 8. Paratype, USNM 128272.

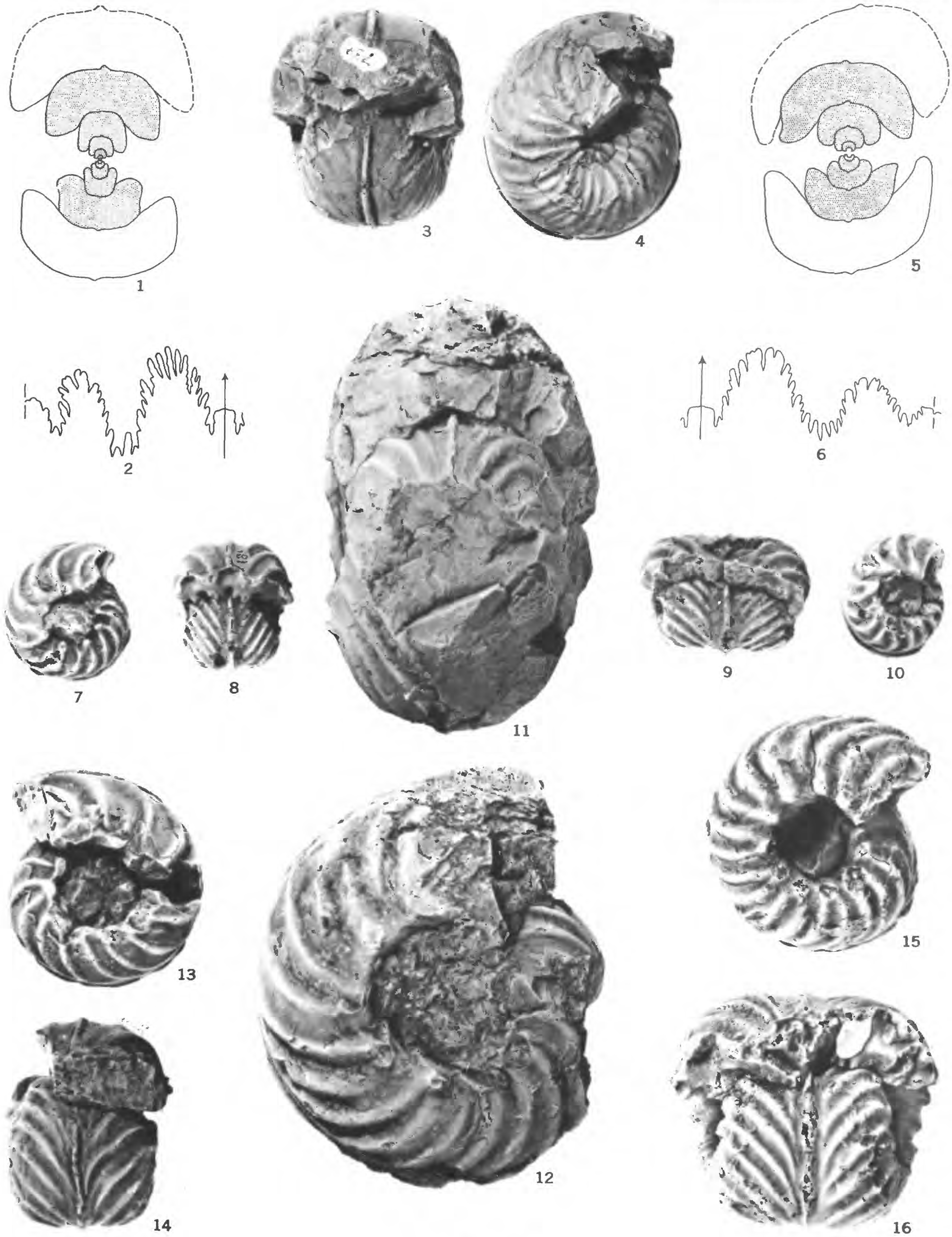
9, 10. Paratype, USNM 128271.

11, 12. Paratype, USNM 128273.

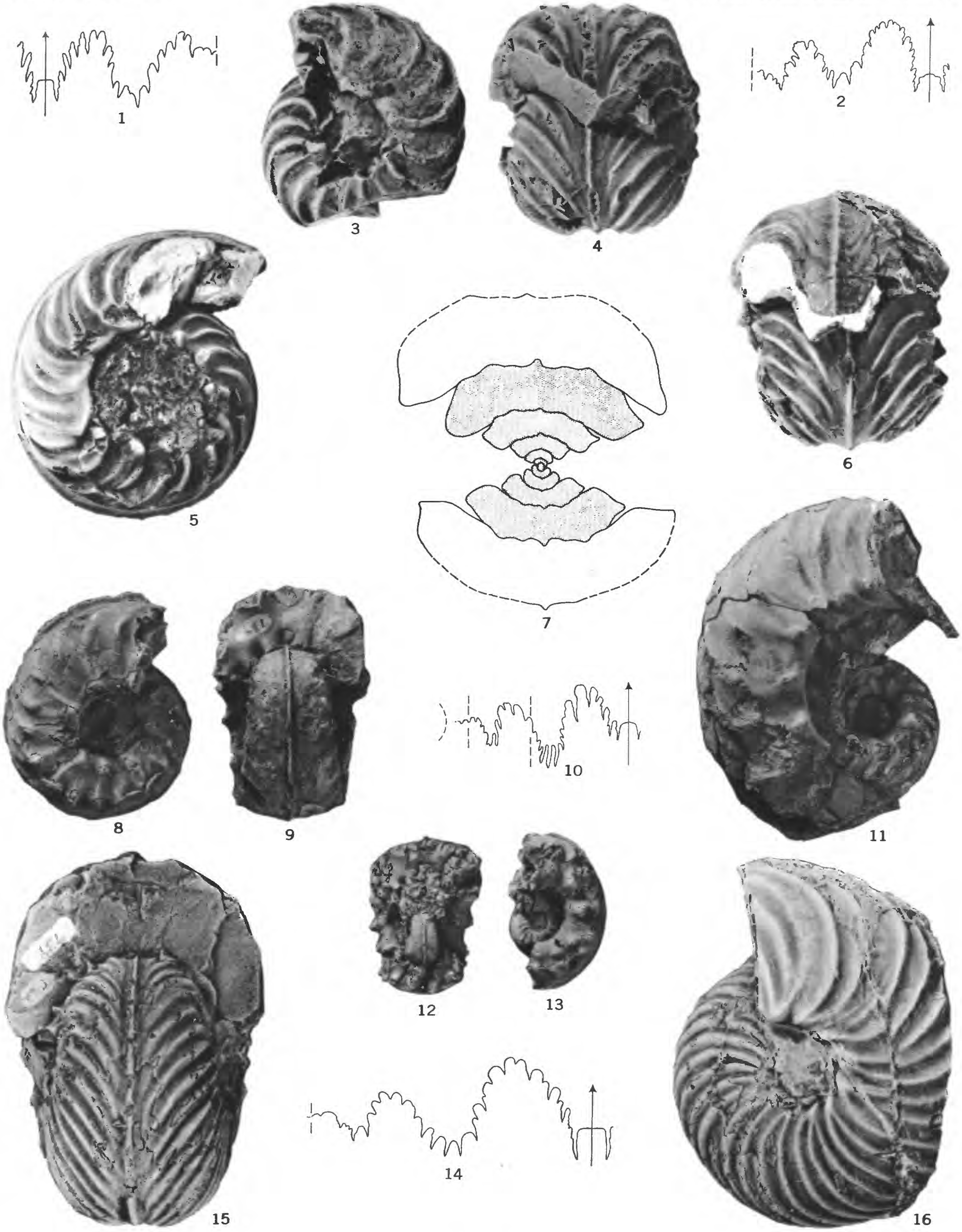
13, 14. Paratype, USNM 128269.

15, 16. Paratype, USNM 128270.

All from USGS loc. M72a, shaly limestone member of the Luning formation.



TROPITES



TROPITES

PLATE 4

[All figures natural size except as indicated below]

FIGURES 1–7. *Tropites crassicostatus* Silberling, n. sp. (p. 49).

1. Paratype, USNM 128269. Suture line of the specimen illustrated on plate 3, figures 13 and 14, near the beginning of the body chamber at a diameter of 35 mm, × 1½.

2–4. Holotype, USNM 128268. 2, suture line near the beginning of the body chamber at a diameter of 36 mm, × 1½.

5, 6. Paratype, USNM 128275, a premature specimen showing the configuration of the aperture.

7. Paratype, USNM 128274. Diagrammatic cross section prepared from a cellulose peel.

All from USGS loc. M72a, shaly limestone member of the Luning formation.

8–13. *Tropites nodosus* Silberling, n. sp. (p. 49).

8, 9. Holotype, USNM 128276.

10. Paratype USNM 128279. Final suture line of a specimen nearly identical with the holotype at a diameter of about 40 mm.

11. Paratype, USNM 128277.

12, 13. Paratype, USNM 128278, a broken specimen showing the shape of the inner whorls.

All from USGS loc. M72a, shaly limestone member of the Luning formation.

14–16. *Tropites nevadanus* Silberling, n. sp. (p. 50).

Paratype, USNM 128286. 14, final suture line at a whorl height of 21 mm, × 1½. From USGS loc. M72b, shaly limestone member of the Luning formation.

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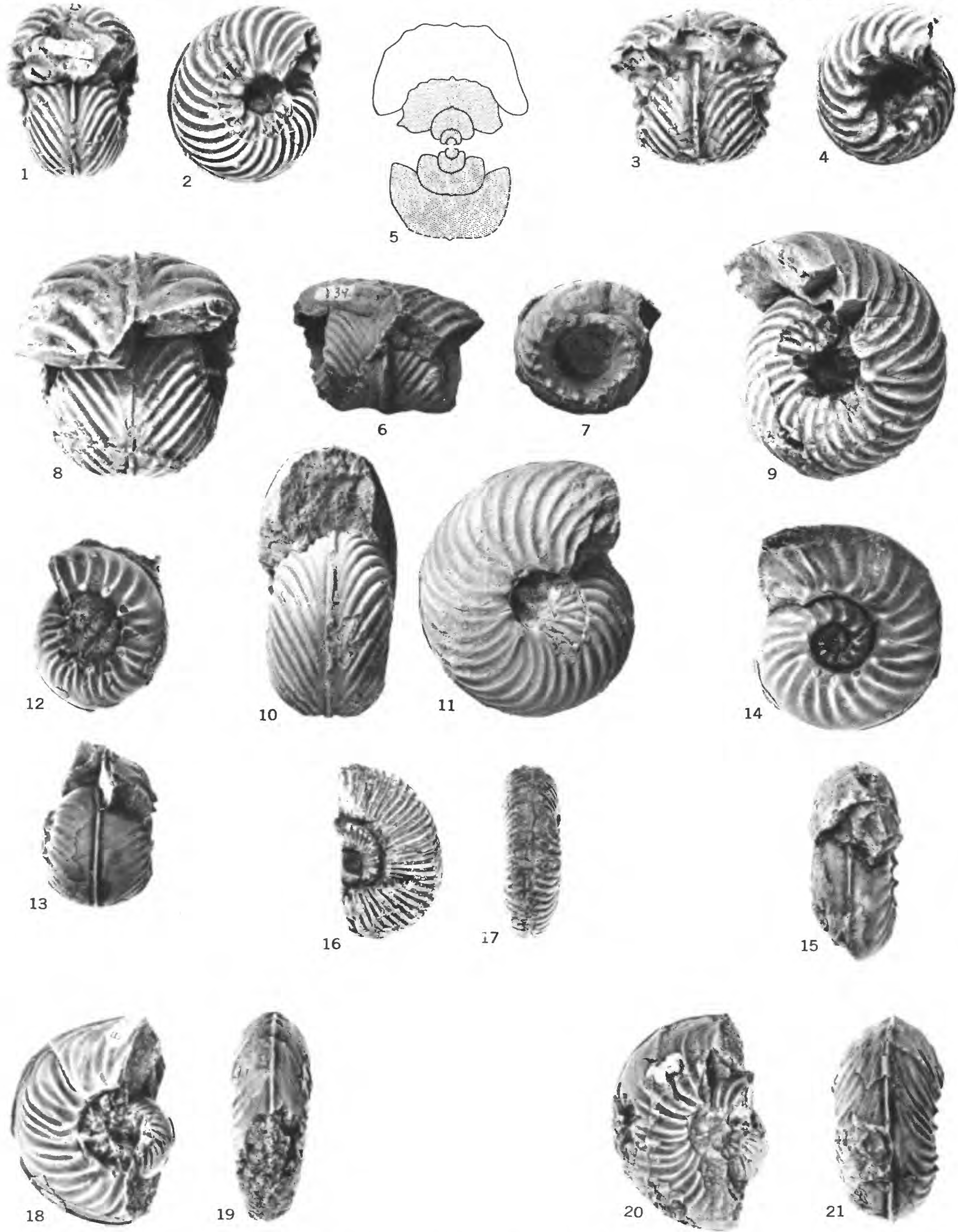
PLATE 5

[All figures natural size]

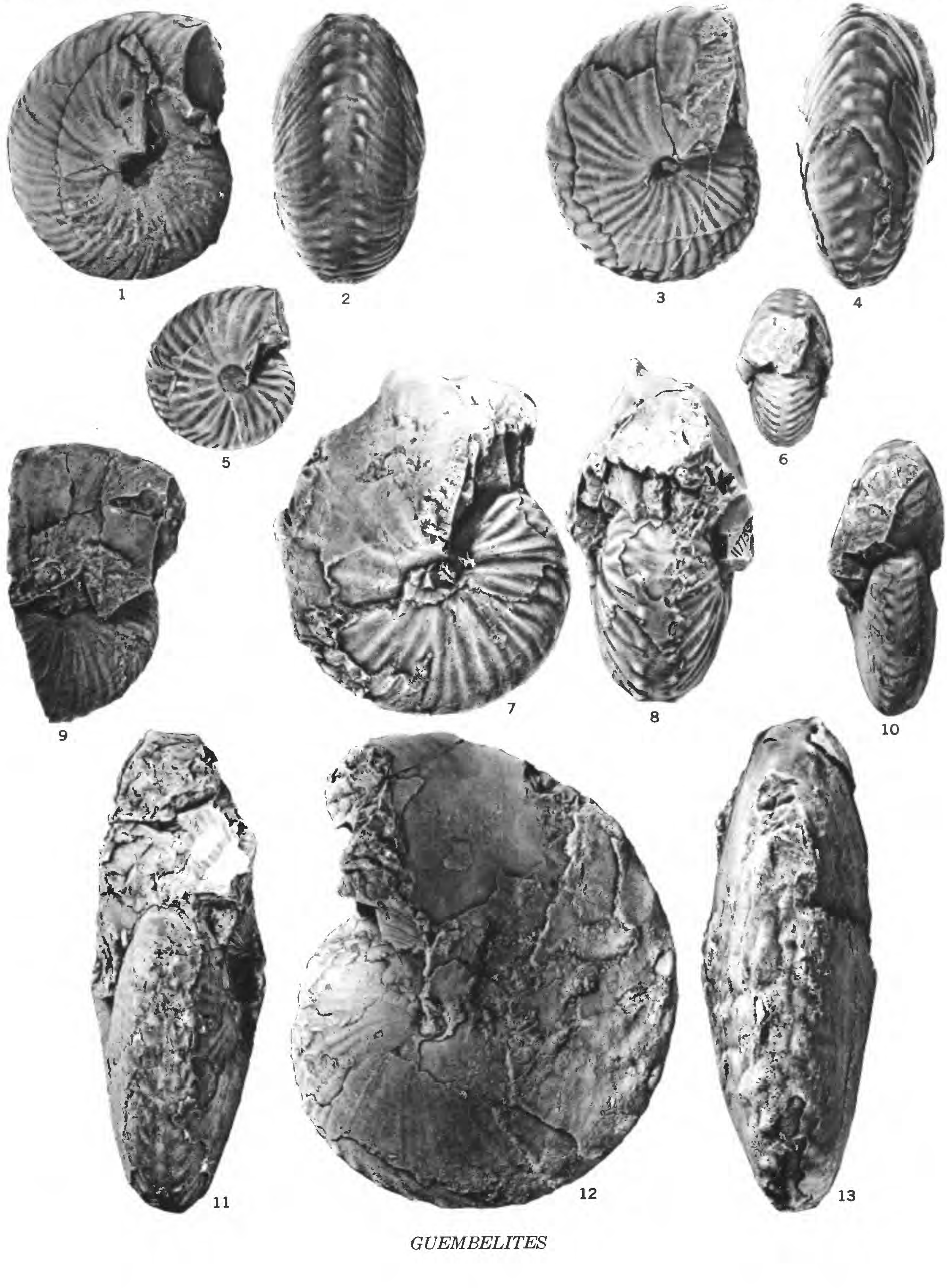
FIGURES 1–11. *Tropites nevadanus* Silberling, n. sp. (p. 50).
1, 2. Paratype, USNM 128282, illustrating the average proportions of immature individuals.
3, 4. Paratype, USNM 128283, a robust immature specimen.
5. Paratype, USNM 128287. Diagrammatic cross-sectional outline prepared from a cellulose peel.
6, 7. Paratype USNM 128284, illustrating the extreme in depression of the shell.
8, 9. Paratype, USNM 128285, a robust larger individual.
10, 11. Holotype, USNM 128280.
All from USGS loc. M72b, shaly limestone member of the Luning formation.

12–15, 18–21. *Tropites* (*Anatropites*) sp. (p. 51).
12, 13. USNM 128288.
14, 15. USNM 128289.
18, 19. USNM 128290.
20, 21. USNM 128291.
All from USGS loc. M72, shaly limestone member of the Luning formation. The specimens illustrated by figures 18–21 are from USGS loc. M72b where they were collected with *Tropites nevadanus*.

16–17. *Tropiceltites*? *densicostatus* Silberling, n. sp. (p. 51).
Holotype, USNM 128292. From USGS loc. M72c, basal calcareous shale member of the Luning formation.



TROPITES, T. (ANATROPITES), AND *TROPICELTITES?*



GUEMBELITES

PLATE 6

[All figures natural size]

FIGURES 1–8. *Guembelites jandianus* Mojsisovics (p. 53).

1, 2. Plesiotype, USNM 128298, a somewhat robust and densely ribbed example.

3, 4. Plesiotype, USNM 128297, illustrating the average morphology of the immature shell.

5, 6. Plesiotype, USNM 128299, an immature specimen.

7, 8. Plesiotype, USNM 128300, a premature individual developing prominent ventral fins at a smaller diameter than usual.

All from USGS loc. M73, calcareous shale member of the Luning formation.

9–13. *Guembelites clavatus* (McLearn) (p. 52).

9, 10. Plesiotype, USNM 128295, an immature specimen illustrating the relatively compressed shape and delicate ornamentation.

11–13. Plesiotype, USNM 128294, a mature specimen comparable in size to the holotype (Canada Geol. Survey coll., cat. no. 9408).

Both specimens from USGS loc. M73, calcareous shale member of the Luning formation.

PLATE 7

[All figures natural size except as indicated below]

FIGURES 1–3. *Guembelites philostrati* Diener (p. 54).

1–2. Plesiotype, USNM 128302, an immature specimen.

3. Plesiotype, USNM 128303.

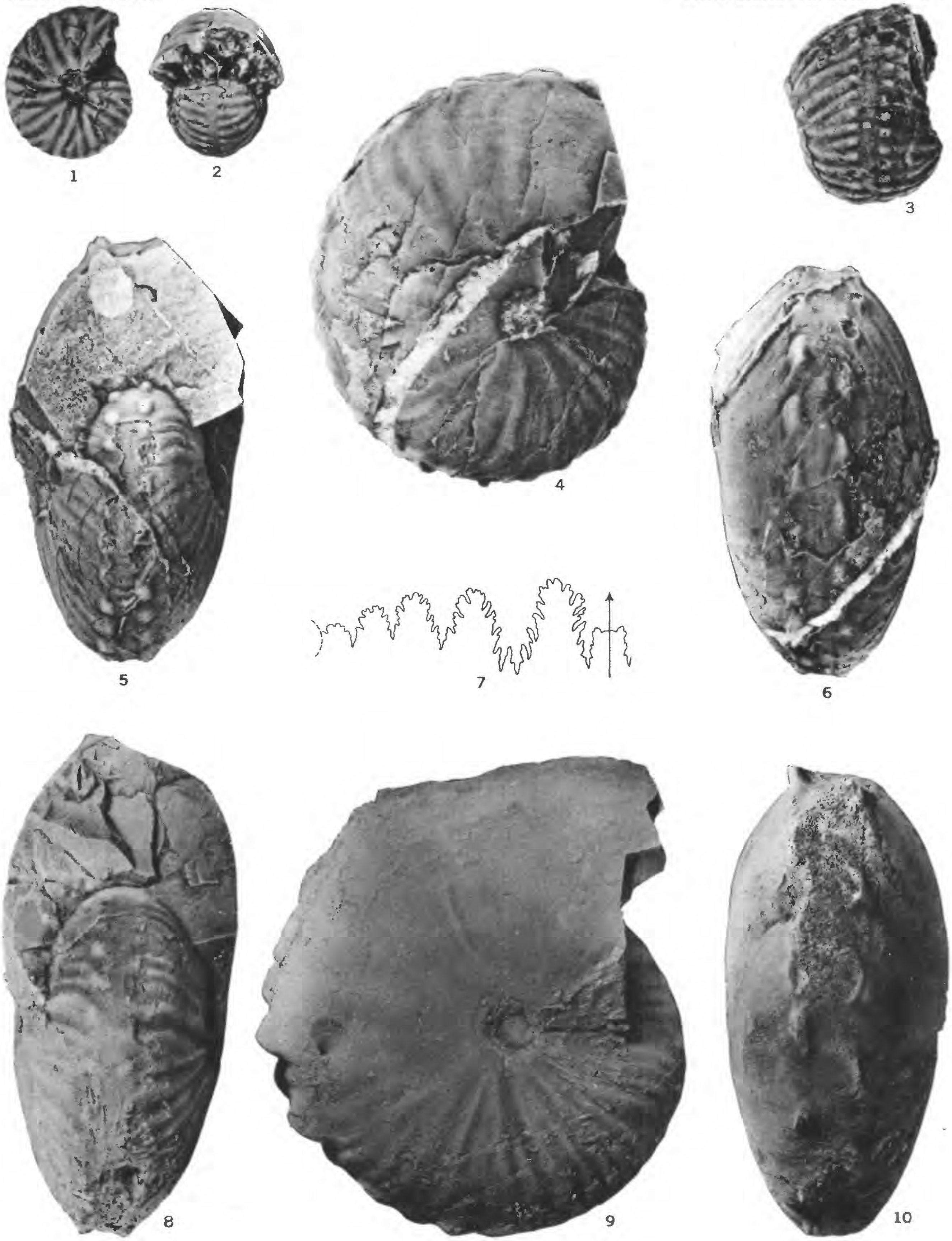
Both specimens from USGS loc. M73 calcareous shale member of the Luning formation.

4–10. *Guembelites jandianus* Mojsisovics (p. 53).

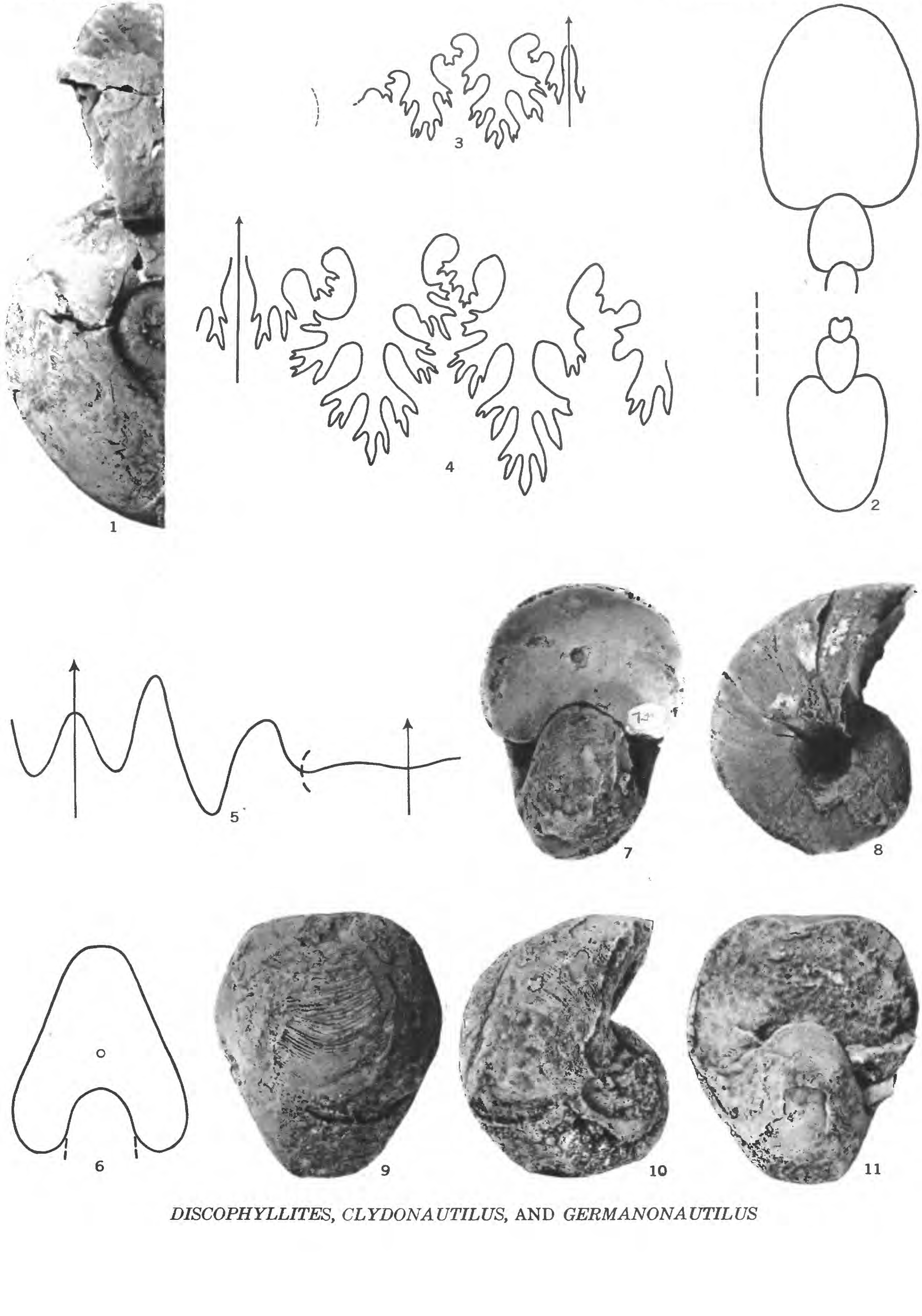
4–6. Plesiotype, USNM 128301.

7–10. Plesiotype, USNM 128296, a nearly complete mature specimen showing the smooth body chamber. 7, final suture line at whorl height of 29 mm, × 1½.

Both specimens from USGS loc. M73, calcareous shale member of the Luning formation.



GUEMBELITES



DISCOPHYLLITES, CLYDONAUTILUS, AND *GERMANONAUTILUS*

PLATE 8

[All figures natural size except as indicated below]

FIGURES 1–4. *Discophyllites ebneri* (Mojsisovics) (p. 55).

1–3. Plesiotype, USNM 128313, a completely septate specimen. 2, diagrammatic cross section prepared from a cellulose peel. 3, suture line at a whorl height of about 26 mm, × 1½.

4. Plesiotype, USNM 128314. Suture line at whorl height of about 60 mm, × 1½

Both specimens from USGS loc. M71, shaly limestone member of the Luning formation.

5, 6. *Clydonautilus* sp. (p. 58).

USNM 128307. 5, suture line of final septum at a whorl height of about 50 mm, × ¾. 6, diagrammatic outline at the final septum, × ¾. From USGS loc. M72, shaly limestone member of the Luning formation.

7–11. *Germanonautilus kummeli* Silberling, n. sp. (p. 56).

7, 8. Paratype, USNM 128305, an average completely septate specimen.

9–11. Holotype, USNM 128304, a somewhat premature specimen illustrating the shape of the body chamber.

Both specimens from USGS loc. M71, shaly limestone member of the Luning formation.

PLATE 9

[All figures natural size]

FIGURES 1–8. *Septocardia*? sp. (p. 61).

1–3. USNM 128309, a representative specimen. Note the ligament groove immediately posterior to the beak in figure 2.

4, 5. USNM 128311, a somewhat longer and narrower than average specimen.

6, 7. USNM 128310, a relatively flat specimen.

8. USNM 128312, dorsal view of an interior mold showing the mold of the anterior muscle scar cavities.

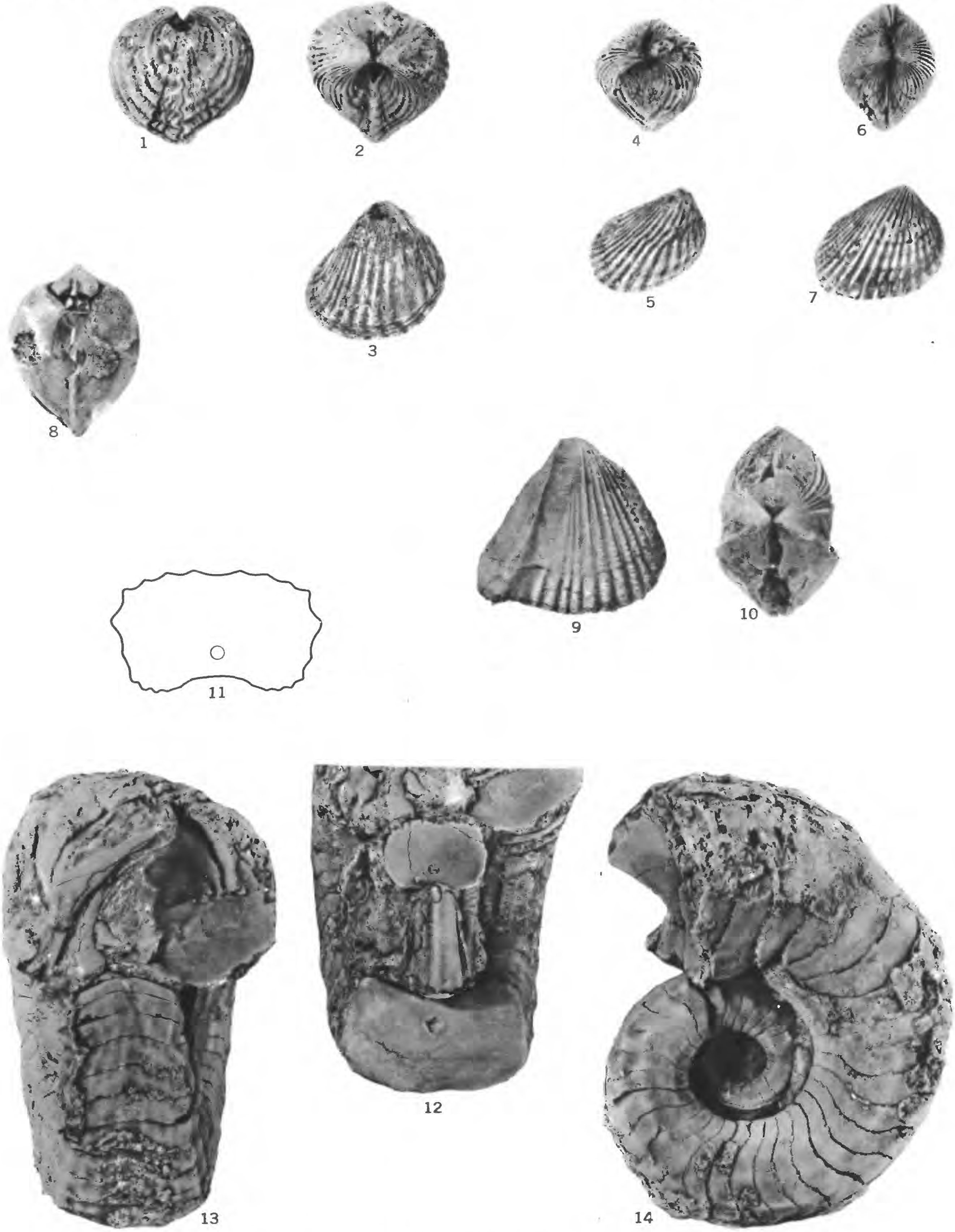
All from USGS loc. M71, shaly limestone member of the Luning formation.

9–10. *Myophoria shoshonensis* Silberling, n. sp. (p. 59).

Holotype, USNM 128308. From USGS loc. M71, shaly limestone member of the Luning formation.

11–14. *Phloioceras mulleri* Silberling, n. sp. (p. 57).

Holotype, USNM 128306. 11, diagrammatic outline at a whorl height of 21 mm. 12, same view as figure 13 with outer whorl removed. From USGS loc. M71, shaly limestone member of the Luning formation.



SEPTOCARDIA?, *MYOPHORIA*, AND *PHLOIOCERAS*