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Biostratigraphy of the type Weberg Member, Snowshoe Formation, Grant County, Oregon

David G. Taylor
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Thirty three species of ammonites are recorded from the composite type section of the Weberg Member of the Snowshoe Formation in the Suplee area, Grant County, Oregon. *Holcophylloceras burkei*, *Euholoploceras vesti*, *E. tuberculosum* and *Strigoceras taylori* are described as new, while four new species belonging to the genera *Soninia* [?], *Bradfordia*, *Pseudotoites* and *Witchellia* are not formally named. Three ammonite zonules characterize the ammonite sequence of the type Weberg composite section. The sequence correlates with parts of the standard lower and middle Bajocian (Jurassic) of northwestern Europe. In addition, four associations (paleo-communities) of benthic megainvertebrates, the *Gervillia*, *Protocardia*, *Isocyprina* and *Bositra*
**bouchii** associations are delineated.

The type Weberg composite section is a record of a local marine transgression westward onto an island system. The section also represents sedimentation over an irregular pre-Snowshoe tographic high, and indicates a progressive change from proximal to distal source of pre-Snowshoe sediments, from high to low energy conditions, and perhaps a slight deepening of the ocean bottom.

Ammonites are rare in the lower division of the Weberg Member, locally present in fine sandy limestones of the lower part of the upper division, abundant and most diverse in silt-rich, clay-poor limestones of the upper part of the upper division, and locally abundant in mudstones of the Warm Springs Member. Recurrent associations of certain ammonite species, strong correlation of the associations with lithofacies and biofacies, and pervasive faunal differences of ammonites between facies indicate in general that the distributional patterns of the ammonites reflect spatial life-habitats. The spotty yet widespread geographic occurrence of several ammonite species suggest they had undergone extensive planktic dispersal, thus ocean currents probably played an important role in their distributional patterns.
BIOSTRATIGRAPHY OF THE TYPE WEBERG MEMBER,
SNOWSHOE FORMATION, GRANT COUNTY, OREGON

by

DAVID G. TAYLOR

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University
1977
TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

The members of the Committee approve the thesis of David G. Taylor presented August 25, 1977.

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Ammonite species from the type Weberg composite section showing biological relationships and number of specimens available for study
INTRODUCTION

LOCATION AND TERRAIN

The Suplee area (Dickinson and Vigrass, 1965) lies in the southwestern part of the Blue Mountains geomorphic division (Baldwin, 1964), a complex mountain system comprising much of northeastern Oregon (fig. 1). In Crook and Grant Counties, south of the defunct town of Suplee, the type Weberg Member of the Snowshoe Formation is well exposed in small draws on the east side of Warm Springs Creek Valley. Warm Springs Creek is a northward-flowing tributary of the south fork of Beaver Creek; both creeks are part of the Crooked River drainage system.

The type area of the Weberg Member (also type area for Warm Springs Member) varies in elevation from 1,460 to 1,700 m. The climate is cool and semi-arid. The study area supports sagebrush and bunchgrass, some junipers, and occasional aspen groves along creek bottoms. The valley bottoms are cultivated for winter hay, while higher ground is utilized for cattle-grazing.

GEOLOGIC SETTING

The Snowshoe Formation is part of an extensive Mesozoic and Paleozoic terrain in the southwestern Blue Mountains. The formation is thickest and most widely cropped out in the Izee and Seneca areas (Lupher, 1941; Dickinson and Vigrass, 1965). Near Izee itself three
Figure 1. Location map
informal members are recognized, the lower, middle and upper. In the eastern part of the Izee area the middle member is replaced by the Silvies Member.

In the Izee and Seneca areas the Snowshoe Formation is entirely clastic and represents more offshore deposition than in the Suplee area to the west. The Mowich upwarp separates the Snowshoe Formation in the Suplee area from the unit in the Izee and Seneca areas. In the Suplee area the formation is divided into the Weberg, Warm Springs, and Basey Members in ascending stratigraphic order. Although the Warm Springs and Basey Members are wholly clastic, the Weberg is highly calcareous.

PURPOSE AND SCOPE

In this report the paleontology and stratigraphy of the type Weberg section, and basal beds of the type Warm Springs Member are described. Ammonite paleontology is emphasized.

The Snowshoe Formation was deposited in a tectonically unstable region associated with extensive andesitic volcanism. This study was undertaken to examine the potential for conducting detailed biostratigraphic investigations in such terrain. The study area was selected for the following reasons: (a) it has been mapped in detail by Dickinson and Vigrass (1965), and Buddenhagen (unpublished geologic map), (b) Imlay (1973a) laid the groundwork for detailed biostratigraphic studies, (c) the type Weberg composite section is well exposed, and (d) it yields a well preserved, diverse, and rich
ammonite fauna.

The Weberg Member is one of several rock units of the Jurassic terrain that contain diverse mega-invertebrates. Thus the study of the type Weberg is an example of the kind of detailed biostratigraphic projects that can be conducted, all of which may lead to a refined Jurassic biochronology in the northeastern Pacific. A similar study made by Paul Smith (1977) in the Snowshoe Formation in the Izee area supports this interpretation.

METHODS

The field investigation was conducted over a period of six weeks during the summer of 1972. Six stratigraphic sections making up the type Weberg composite section are described in detail. Stratigraphic sections through the Warm Springs Member were generally made using a brunton compass and tape, whereas sections through the Weberg Member were made by clearing off the surface rubble and measuring stratigraphic thicknesses bed by bed.

Only the ammonites were collected systematically. Collections were generally made from stratigraphic intervals of 20 cm or less. An attempt was made to collect along respective beds over an interval of 1 m or less. In some cases, where ammonites are rare, they were sought for up to 10 m laterally along a bed. All in situ specimens encountered were collected so that the approximate relative proportions of ammonite species are represented.

Lithological analysis is based on hand specimens, acetate peels,
and thin sections. The rock color terminology is derived from the G.S.A. color chart by Goddard, et al (1963). Color designations in parentheses are informal. Sandstone and limestone classification, grain size and other textural terms follow those of Folk (1968). Staining procedures for determining carbonate constituents follow those of Friedman (1959). Potassium feldspar, plagioclase feldspar, and quartz were differentiated by examining their optical properties in thin section under the petrographic microscope. Plagioclase composition was ascertained by measuring extinction angles of albite twins on grains oriented approximately normal to (010).

Relative abundances of various mineralogical components were estimated from thin sections with the aid of charts for estimating percentage composition (Compton, 1962). However, several sections were point counted (300 to 500 grains per slide) to ensure that the qualitative estimates were reasonable. For grain size analysis, diameters of terrigenous grains were measured by examining thin sections under the petrographic microscope. Counts of 100 to 200 grains were made from several samples to ensure that estimates of median diameters were reliable.

Zeolite and clay composition of certain tuff beds were determined by x-ray diffraction methods. Clays for x-ray diffraction analysis were sized to less than 2 microns. Samples which yielded a peak of approximately 14 Å were glycolated to test for presence of smectites. Samples for which sepiolite was suspected were heated to 200°C for 2 hours to determine if the 12.26 Å peak shifts.
GEOLOGY

GENERAL

The Snowshoe Formation is part of an areally extensive and tremendously thick Jurassic sequence in east central Oregon (fig. 2,3). Marine strata temporally equivalent to the Weberg Member can be traced over 160 km to the east of Suplee, to the Huntington area (Imlay, 1973a), not far west of the Oregon-Idaho border. The Snowshoe Formation is best exposed in the Seneca and Izee areas (Lupher, 1941; Dickinson and Vigrass, 1965; Imlay, 1973a) where it is conformably overlain by the upper Jurassic Trowbridge Formation. Here the Snowshoe Formation is entirely clastic, and represents deposition in a relatively deeper basin than its shallower water facies to the west, in the Suplee area (Dickinson and Vigrass, 1965). The outcrops of the Snowshoe Formation in the Suplee area are separated from the exposures in the Izee area by the Mowich upwarp.

In the Suplee area the Snowshoe Formation progressively overlaps older strata toward the west. Thus the formation truncates the lower Jurassic Mowich Group, upper Triassic Begg and Brisbois Formations, and finally Paleozoic strata, going in a westerly direction. The Snowshoe Formation contacts all these subjacent units with angular unconformity. In the Suplee area the basal Snowshoe Formation transgresses to the west (Dickinson and Vigrass, 1965). The upper two members of the formation, the Warm Springs and
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Figure 3. Generalized geologic column of Triassic and Jurassic formations in the Suplee area.
Basey, are much like the facies developments to the east but the lowest member, the Weberg, is quite thin, highly irregular in thickness, and has much limestone.

The outcrop distribution of the Snowshoe Formation in the Suplee area is delimited by geologic structures. The four major structural features in the Suplee area are (a) Mowich upwarp, (b) Pine Creek downwarp, (c) an unnamed upwarp to the northwest of the Pine Creek downwarp, and (d) the Camp Creek fault (fig. 2). The synclinorium and two anticlinoria trend northeasterly. The anticlinoria are cored by the upper Triassic Begg and Brisbois Formations. Jurassic strata comprise most of the Pine Creek downwarp, and are exposed to the south of the Mowich upwarp up to where they are covered by Tertiary volcanics. The Camp Creek fault marks the western terminus of the principal exposures of the Jurassic rocks, although they are locally present west of it. The Weberg Member occurs principally around the periphery of the Pine Creek downwarp, and around part of the southern terminus of the Mowich upwarp.

The type Weberg and Warm Springs Members are situated on the southwestern flank of the Mowich upwarp. In the area of the type section of the Weberg, the member strikes northwesterly, has southwesterly dips of 30 to 35 degrees, and laps onto the subjacent Begg Formation, which at this locality has a northerly strike, and westerly dips of 60 to 80 degrees. At other localities in the type area of the Weberg, the member overlaps with angular discordance the Brisbois and Nicely Formations.
ROCK UNITS

On the following pages rock units of the Mesozoic terrain in the Suplee area are described (fig. 3). First units subjacent and superjacent to the Snowshoe Formation are described, then the salient characteristics of the Snowshoe Formation are outlined, and finally the Weberg Member is discussed in detail.

Subjacent units

The Begg Formation is composed of resistant sandstone, conglomerate, sedimentary breccia, altered tuff beds, minor flows of porphyro-aphanitic pyroxene keratophyre, and less resistant, volumetrically predominant argillaceous mudstone and siltstone. Approximately 25 percent of the coarse clastic detritus is composed of chert-grain sandstone and chert-pebble conglomerate, 10 percent volcaniclastic rocks and minor lava, 5 percent polymictic conglomerate and sedimentary breccia, and occasional thin bioclastic or biostromal limestone units (Dickinson and Vigrass, 1965, p. 18). Argillaceous mudstone and siltstone comprise about 50 to 70 percent of the formation. Estimated total thickness of the Begg Formation is 2,280 m. In the Suplee area the Formation comprises most of the exposures of the Mowich upwarp and the unnamed upwarp. The unit is considered to be Karnian in age.

The Brisbois Formation consists of "black, gray" and "green" mudstone and siltstone with intercalations of calcareous chert-grain lithic sandstone and calcarenite. Volcaniclastic rocks and silitic
lavas occur locally. The formation is intricately folded, but is estimated to be to 1,525 m in stratigraphic thickness. The unit is exposed in the Mowich upwarp, the more northerly unnamed upwarp, at the southern end of the Pine Creek downwarp, and around Suplee itself. The formation conformably overlies the Begg Formation. Ammonites from the Brisbois are assigned to the Tropites subullatus Zone (uppermost Karnian Stage).

The Mowich Group is a lower Jurassic unit with four formations, the Robertson, Suplee, Nicely, and Hyde, in ascending stratigraphic order.

The Robertson Formation consists of a locally developed basal member of massive, sometimes imbricated and bedded, sandy pebble-conglomerate from 3 to 30 m thick, and an upper part comprised chiefly of volcanic sandstone and lesser amounts of limestone. The sandstone is a massive, locally cross-laminated, well sorted volcanic arenite composed dominantly of subangular to subrounded grains of volcanic plagioclase, originally glassy volcanic rock fragments of hyalopilitic to pilotaxitic texture, and minor crystals of volcanic augite (Dickinson and Vigrass, 1965, p. 34). The limestone units are as much as 9 m thick; they are biostromal, reefoid limestone made up of the rudist-like pelecypod Plicatostylus gregarius Lupher and Packard (1930), and massive bioclastic limestone. The Robertson Formation crops out along the southern and western borders of the Mowich upwarp. The unit is provisionally correlated with the Pliensbachian Stage. The formation rests unconformably on older rocks and is conformably overlain by the Suplee Formation, the next higher
formation of the Mowich Group.

The Suplee Formation consists principally of calcareous sandstone and sandy limestone. It varies in thickness from less than 10 m to 25 m, and is correlated with the Pliensbachian Stage (Imlay, 1968). The formation is found along the southern border of the Mowich upwarp.

In the Suplee area the Nicely Formation is less than 30 m thick, and is made up of black mudstone with minor intercalations of volcanic litharenite. It conformably overlies the Suplee Formation and is found along the southern border of the Mowich upwarp. Ammonites allow correlation of the unit with the upper Pliensbachian.

The Hyde Formation is composed of massive, thick-bedded, altered, andesitic tuff and volcanic litharenite. In the Izee area this formation generally is 300 to 365 m thick, but is much thinner in the Suplee area where it is exposed along the southern margin of the Mowich upwarp. In that area the formation is truncated and unconformably overlain by the Snowshoe Formation.

Superjacent Units

The "Shaw Member" as described by Dickinson and Vigrass (1965, p. 57) is composed mostly of "gray" to "dark brownish gray" shale. It is poorly exposed and nonresistant to erosion. The maximum exposed thickness is less than 300 m, however, the top of the unit has never been observed. The unit is locally exposed in the Pine Creek downwarp and a short distance southwest of the Mowich upwarp.

The "Shaw Member" was placed by Dickinson and Vigrass as the
fourth and highest member of the Snowshoe Formation in the Suplee area. Following Imlay (1973a, p. 9), who cited unpublished evidence by Buddenhagen, that usage is tentatively abandoned because the unit in its type area, along Shaw Creek, is in part lithologically identical to the Trowbridge Formation, and ammonites from the unit in the southern part of the Suplee area indicate temporal equivalence to the Trowbridge.

The Snowshoe Formation

The Snowshoe Formation most extensively crops out in the Izee area. The type area for the formation is at the south fork of the John Day River at Izee, where it is about 840 m thick. Dickinson and Vigrass recognized three members, the lower, middle, and upper. The lower member consists of approximately 180 m of nonresistant "dark gray" mudstone, shale and siltstone. The lithology is like that of the Warm Springs Member of the Suplee area. The middle member consists of approximately 300 m of dark gray lutite, interlaminated with "gray" to "green" volcanic siltstone and litharenite. The "laminae" are 1 to 10 mm thick. Fresh plagioclase is andesine, but is commonly altered to albite. The upper member is approximately 380 m thick and consists of thin-bedded, dark mudstone and siltstone with thick intercalated beds of "gray", calcareous sandstone.

The Snowshoe Formation in the Suplee area is comprised of three members, which in ascending order are: Weberg, Warm Springs, and Basey.

The Weberg Member is composed of sandy to pebbly biosparite,
calcareous lithic arkose, chert litharenite, and chert-felsite pebble conglomerate. For detailed lithologic descriptions of the type section of the member see appendix A. Limestone beds are a conspicuous feature of the member and locally make up over 50 percent of the section. At most localities the Weberg Member is separable into a lower and upper division (Dickinson and Vigrass, 1965). In gross appearance, the lower division looks thick-bedded, and has coarse terrigenous detritus. Sand size particles predominate, but the coarsest few percent of the grains fall in the granule or coarser size range. The upper division is essentially a sequence of very fine sandstone to sandy siltstone with numerous, thin intercalations of fine sandy biosparite. The type area for the Weberg, as well as Warm Springs Member, is on the east side of Warm Springs Creek Valley in sections 19, 20, 29 and 30, T. 18S., R. 26E. The member is thin and variable in thickness, ranging from 15 to 65 m.

The Warm Springs Member is a mudstone unit which is generally sandy near the base. Sometimes it is medium bedded, particularly in its lower part, but is usually laminated, particularly high in the section. Following Buddenhagen (unpublished geologic map) the Warm Springs Member is considered to include the "blue-green" strata of the Basey Member of Dickinson and Vigrass (1965). The "blue-green" strata occur locally, mostly in the western and southern parts of the Supplee area, and always are restricted to the upper part of the member. An augite-andesite flow up to 65 m thick separates the upper and lower parts of the member on the west side of Pine Creek downwarp.
This local, upper part of the member is differentiated from the "brown-gray" colored lower Warm Springs Member by its distinctive "blue-green" coloration, owing to high chlorite content. The member varies in thickness from 100 to over 275 m. Contacts with the subjacent Weberg and superjacent Basey Members are conformable.

The type area for the Basey Member is in sections 1, 12 and 13, T. 18S., R. 25E. The member is characterized as follows (Dickinson and Vigrass, 1965, p. 56).

The most characteristic and abundant strata in Basey Member are hard, massive marine volcaniclastic rocks, with median size in the sand range, that are devoid of bedding for thicknesses as great as 200 feet [66 m]. The strata are dark gray or blue-gray on fresh surfaces, but weather gray-green, green, or rust brown. The beds are composed of the following constituents: (a) 30 to 50 percent plagioclase grains, clear labradorite or albite clouded with pumpellyite inclusions; (b) 40 to 70 percent rock fragments of originally hyalopilitic or vitrophyric texture but now zeolitized and chloritized; (c) 3 to 6 percent augite grains; (d) 1 to 3 percent fragmental calcite grains; and (e) 0 to 1 percent admixtures of quartz grains. Most grains are subangular to subrounded, although a few lithic fragments have the shapes of blocky andesitic shards. Many of the strata are probably only slightly reworked marine tuffs, but they grade laterally to softer tuffaceous andesitic sandstones, some of which contain abundant chert, quartz, and calcite grains and all of which display more distinct stratification.

An augite andesite flow about 31 m thick occurs in the western part of the area. The Basey is probably about 450 to 610 m thick in its type area.

The interpretation of the facies relationships of the Snowshoe Formation between the Supplee and Izee areas, made by Dickinson and Vigrass (1965), is followed here in part.

The lower member of the Snowshoe Formation near Izee is
considered to be the lateral equivalent of the Weberg and Warm Springs Members. The Weberg differs from the lower member (which is composed of dark lutites) in that it is a basal, thin, transgressive highly calcareous sandstone unit. The Warm Springs Member is lithologically like the lower member and is thought to be a westward extending tongue of that unit. The "blue-green" strata of the Warm Springs Member (assigned by Dickinson and Vigrass to the Basey Member) are confined mostly to the western part of the Suplee area, and pass laterally into dark lutites of the Warm Springs Member, so are interpreted herein to be laterally equivalent to the lower member.

The middle member, composed of interlaminated "black" lutite, and "gray" to "green" volcaniclastic siltstone and sandstone, is considered to be laterally equivalent to the Basey Member, which is composed of "gray to green" volcaniclastic sandstone. Augite-andesite flows in the Warm Springs and Basey Members are not known in the Izee area. The precise lateral equivalence of the Basey and middle members is complicated because the presumed intergradation of the facies has been removed by erosion over the Mowich upwarp, where the transition is expected to have occurred, and because the relative contribution of volcaniclastic strata to the middle member by the inferred laterally equivalent Silvies Member in the eastern part of the Izee area is not well understood. The supposed lateral equivalence of the "Shaw" and upper member of the Snowshoe Formation needs further investigation.
Type Composite Section of the Weberg Member

General. Several stratigraphic sections were made in the type area of the Weberg Member (fig. 4). The type section is at Lupher Draw. However, the type section and certain others, 490 m northwest of Lupher Draw, Vigrass Draw, 230 m south of Lupher Draw, Washburn Draw, and 320 m south of Washburn Draw are hereinafter referred to collectively as the type Weberg composite section, because of their similar stratigraphic sequence and close geographic proximity. It is the type Weberg composite section that is dealt with in detail in this report. The lower division is well exposed only at Lupher and Washburn Draws. The division is essentially the same at those two localities, but differs in particulars. At Washburn Draw it is thinner and less calcareous. At that locality bed B is not present but the unit has several feet of calcareous litharenite at its base, and the lower part of unit D is less strongly calcareous.

Units E and F 490 m northwest of Lupher Draw, at Washburn Draw and 320 m south of Washburn Draw are variable in thickness, but the sequence of the beds is the same. A pebbly chert arenite (unit E) is overlain by unit F which is characterized by a thick limestone bed of granular biosparite at its top. The last mentioned bed marks the top of the lower division of the Weberg Member. The section 320 m south of Washburn Draw differs only in that unit F grades upsection to a calcareous chert arenite which is not granular or pebbly.

The upper division of the Weberg at various sections is lithologically similar, but the sequence is not identical because the
limestone beds do not usually persist laterally more than a couple hundred meters. However, a very reliable marker unit is a sandy crinoidal biosparite and a superjacent 46 to 60 cm thick fine to coarse sandstone bed, which are very resistant to erosion and form a conspicuous narrow rib on south-facing hillsides. The marker unit is situated at about the middle of the upper division; at Lupher Draw it occurs 40.2 to 41.5 m above the base of the Weberg Member. The sandstone bed 4.6 m higher at Lupher Draw is finer-grained and not very resistant to erosion.

The fossil localities from each of the stratigraphic sections of the type Weberg composite are arranged in one sequence (fig. 5). The localities from the lower division of the Weberg are easy to position, but those from the upper division are numerous and closely spaced, so the superpositional relationships of the localities between sections are not always clear. For the lower part of the upper division the stratigraphical distance between the top of unit F and the sandstone-limestone marker unit in the middle of the upper division was examined to infer the relative rates of sedimentation at Washburn Draw with respect to the unit at Lupher Draw. With this in mind the relative positions of the fossil collections are simply estimated.

To position localities in the upper part of the upper division, the sandstone-limestone marker was used as a datum and localities from Vigrass Draw, Lupher Draw, Washburn Draw, and 320 m south of Washburn Draw were arranged in order by their distance above the base
of the lithological datum. Occasionally, some limestone beds which 
are thought to be correlative between sections were also used as 
points of reference.

Paleotopography. An attempt is made to reconstruct the pre-
Snowshoe topography in the type area of the Weberg Member to help 
provide a framework for paleo-environmental interpretations. In 
lining up the various stratigraphic sections (fig. 4) with respect to 
their vertical dimension an assumption is made that, disregarding 
other factors, as sedimentation progresses in a given area the bottom 
topography tends to become progressively more uniform. Therefore the 
sandstone-limestone unit from the middle of the upper division of the 
type Weberg composite is considered to have been deposited over a more 
nearly uniform surface than beds lower in the member, and is regarded 
as a point of reference for topographical reconstruction.

When the datum in the upper division is used, by examination the 
Weberg at Lupher Draw indicates deposition in a topographic low 
relative to the member at Washburn Draw. Note that the lower division 
at Lupher Draw is relatively expanded. By inference the much expanded 
top of the lower division 320 m south of Lupher Draw is thought to 
represent deposition over a topographic low. The section 490 m north-
west of Lupher Draw shows an expanded sequence of the top of the lower 
division with respect to the Lupher and Washburn Draw sections, but the 
measured distance from the top of the lower division to its base at 
that locality is relatively short, indicating a minor high. Either 
the high was present, but was very local in areal extent; the lower
division is faulted, giving a false impression a high was present, or a high was present, but its crest was not at the immediate site of the section.

The stratigraphic sections 1,130 and 1,430 m northwest of Lupher Draw are inferred to represent deposition in a topographic low because, (a) they were deposited over the Brisbois Formation, which being composed chiefly of nonresistant mudstone was likely to have been more deeply eroded than the nearby Begg Formation when the pre-Snowshoe topography was developed, (b) because the nearby Begg conglomerate certainly tended to shed detritus into lows, which probably accounts for the abundance of conglomerate in the lower division of the Weberg Member in the two stratigraphic sections, and (c) because the lower division 1,430 m northwest of Lupher Draw is expanded relative to the section at Lupher Draw.

The stratigraphic section 1,950 m northwest of Lupher Draw is much thinner and has finer-grained terrigenous detritus than the section made just 335 m further south (section 1,430 m northwest of Lupher Draw), suggesting that faulting brought these two very different sections of the Weberg Member into close geographic proximity.

Examining the relative thickness of the upper division of the Weberg Member also gives indications of the paleotopography. The upper division at Washburn Draw is much thicker and extends higher upsection, over a topographic high, than at Lupher Draw. By inference the low stratigraphic position of the top of the Weberg Member 320 m south of Washburn Draw suggests deposition over a low, and the stratigraphically high Warm Springs-Weberg contact at Vigrass Draw
indicates deposition over a topographic high, but one which was not so pronounced as at Washburn Draw. Finally the very short stratigraphic thickness of the upper division 1,430 m northwest of Lupher Draw may be taken as evidence indicating that section was deposited over a topographic low in comparison to the type Weberg composite column.

In general the type Weberg Member was deposited over a pre-Snowshoe terrain of considerable topographic complexity. The stratigraphic sections in the northern part of the area indicate deposition over the non-resistant Brisbois Formation in a local basin, while the type Weberg composite section was deposited over the Begg Formation, on a variable but generally higher topography. In the area of the type Weberg composite section the Begg Formation probably had very high dips prior to deposition of the Weberg Member, so the most resistant, strongly dipping conglomerates of the Begg Formation probably stood out as narrow ridges, accounting for the irregular topographic high.

Environment of Deposition. The varied lithology of the Weberg and basal Warm Springs Members in the vicinity of the type Weberg composite section suggests deposition under a range of energy conditions and basinal environments. As follows, starting with the lower Weberg Member, the environment of sedimentation is interpreted.

Paucity of clay, common occurrence of granules to fine gravels, internal lamination and thin bedding, and cross and lenticular bedding in the lower division indicates that this unit was deposited under conditions of strong bottom traction currents probably in combination
with shallow, strongly wave agitated waters. The angularity of the sand-size detritus and poor sorting indicates no prolonged reworking of sediment at the site of deposition.

A regional examination of the lower division of the Weberg Member shows that its stratigraphic development and composition were strongly controlled by the lithology of subjacent units. In the study area the chert, quartz, and felsite-rich terrigenous detritus closely matches that of the subjacent Begg Formation, which is a potential source rock. Based on inferences from stratigraphic sections at numerous localities around the study area, the Weberg to the immediate south, southeast, north and northeast of the type Weberg composite section was deposited in topographic lows, precluding coarse clastic supply from those directions. Reworked sedimentary detritus may have had a local source, but may also have come directly from the west, from Paleozaic to lower Mesozoic strata, and/or a short distance from the east, from the Begg Formation.

The change in deposition from lower to upper division sediments is thought to have occurred when the local pre-Snowshoe terrain was entirely blanketed. Like the lower Weberg Member, the upper division generally has angular to subangular sand-size particles, but it differs in many respects. Terrigenous detritus commonly ranges from medium silt to fine sand, while coarser detritus is rare. The unit is mostly well sorted. In contrast to the lower division, the upper division contains many beds which are exceptionally rich in fresh andesitic detritus. Finally, undisturbed tuff beds are commonly present in the upper division, but are never found lower in the
Weberg Member.

The transition to finer-grained terrigenous detritus in the upper division may not only indicate a shift in supply of reworked terrigenous detritus to a more distal source, but may also indicate lower energy conditions. Certainly the abundance of andesitic debris, presence of undisturbed tuff beds, and greater abundance of silt-size particles indicate less intensive reworking in the upper division. However, paucity of clay and fine silt suggests agitated water strong enough to winnow out the fines. Also, in limestone beds shells to 1 cm in diameter are commonly concentrated into thin lentils, indicating some reworking. In general the upper division was formed in more offshore lower energy conditions than the lower division, but apparently experienced persistent, moderately strong traction currents and/or wave activity.

The upper division grades both laterally and upsection into sandy mudstone (Warm Springs Member) which in turn grades to pure mudstone. The Warm Springs Member was deposited in slightly deeper water and under lower energy conditions than the upper division of the Weberg Member. As previously indicated the upper division in the vicinity of the type Weberg composite section is thought to have been deposited on a subtle high. The numerous limestone beds of the upper division probably reflect local, periodic episodes of reduced terrigenous supply, also suggesting continuation of a high.

Whereas the reduction of topographic irregularities during deposition of the lower division was accomplished by concentrating coarse as well as fine detritus into lows, further reduction of highs
during deposition of the upper division was brought about by continuous winnowing of fines, which were eventually carried into slightly deeper water not sufficiently agitated to keep them in suspension. Thus the upper division Weberg lithology gave way upsection to muds only when the bottom was sufficiently deepened, and local topography entirely reduced, allowing mud to accumulate evenly across the sea floor.

**Tuffs, Pyrogenic Minerals, and Diagenesis**

During the course of the field investigation numerous tuff beds were noted. In the area of the type Weberg composite section two tuff beds, one 26.9 to 27.1 m and the other 36.2 to 36.6 m above the base of the Weberg Member, were found at Washburn Draw. At Vigrass Draw tuff beds occur 1.7 to 1.9 m, 2.0 to 2.4, and 3.8 to 3.9 m below the top of the Weberg Member. From an examination of the Snowshoe Formation throughout the Suplee area, it was found that several tuff beds appear to have the same stratigraphic relationship to each other at several different localities, though occurring in varied facies, and that they appear to have the same relationships to the biostratigraphic sequence at the various localities. Because the tuff beds transgress several facies, and single tuff units represent essentially synchronous events, these beds may be invaluable for future, more detailed biostratigraphic studies planned for the Snowshoe Formation in the Suplee area. For example, correlation of ash-fall tuffs may be used to test and refine biostratigraphic correlations between several facies. The markers should provide
refinement in temporal correlation not permissible strictly through biochronologic analysis, and may allow correlation to areas for which there is little or no faunal control. If correlations can be made using tuff beds, they should serve to demonstrate that a volcaniclastic terrain may be an ideal area for conducting refined biostratigraphic studies.

Some representative samples of altered tuffs, exemplifying the various stages of diagenetic alteration found in these beds in the study area, are described in detail below, in part to aid in recognizing the tuffs in the field and laboratory, and in part to infer sequence and process of diagenetic alterations undergone by strata of the Snowshoe Formation.

Diagenetic changes in some way related to deep burial are pervasive in the pre-Cretaceous rocks of the Suplee-Izee area. A textural result of deep burial is that the framework grains of the sediments are tightly compacted. Depending partly upon the chemical stability of the component grains, boundaries are variably dissolved and molded against neighboring grains: grain boundary contacts are commonly sutured.

Diagenetic characteristics of Jurassic strata in the Suplee area are brought out as isolated remarks in lithological descriptions by Dickinson and Vigrass (1965), and in more detail for the Buck Creek Tuff in the Izee area (Dickinson 1962a, p. 249-66; 1962b, p. 481-500). The chief chemical diagenetic alterations of the rocks in the Izee area have been summarized as follows by Dickinson (1962b, p. 485) and apply equally well to the Snowshoe Formation in the Suplee area.
Plagioclase, the most abundant of the pyrogenetic minerals, was largely decomposed to albite plus one or more of several hydrous Ca-bearing minerals, of which pumpellyite is the most abundant, although prehnite, laumontite, and minor calcite also occur. However, no concurrent breakdown of igneous augite or hornblende could be detected in any thin sections that were examined. The glasses in volcanic rock fragments and shards altered readily to an assemblage of chlorite, celadonite, and zeolite, chiefly heulandite. Portions of the rocks interstitial to frameworks of clastic fragments are occupied either by a murky detrital matrix that has recrystallized to dominantly chloritic and celadonitic material or by clear, chemically precipitated cements, which are either calcite or celadonite and chlorite.

In a general statement earlier on the same page Dickinson states that:

In clay-rich mudstones, no diagenetic changes other than those normally associated with compaction and lithification of muddy sediments are manifest. Nor are there any diagenetic effects, beyond those that commonly accompany cementation, in the rare nonvolcanic calcareous sandstone rich in quartz and chert grains. The condition of these argillaceous and quartzose rocks associated with the clastic volcanic strata suggests that diagenesis took place under physical conditions no more rigorous than those that have existed during lithification and burial of many less reactive assemblages of sedimentary particles.

Dickinson noted that the rock textures and fabrics are mostly preserved, and there are no patterns of alteration related to structural features. Consequently the above diagenetic alterations are interpreted by him to have taken place sometime from post-Callovian to Early Cretaceous time, before folding and deep erosion of the middle Cretaceous Bernard Formation.

Dickinson (1962b, p. 498) following Coombs (1954, p. 93) considered that abundant connate water produced a strong catalytic effect on what otherwise would be slow reactions on some silicates.
at low temperature. Dickinson stated that (1962b, p. 498):

Unequal distribution of interstitial water might have impeded nucleation and reaction in water-poor regions while promoting nucleation and speeding reaction rates in water-rich regions. Chance variations in porosity or location of channels for fluid access might thus have caused the intricate variations in degree of alteration seen on a microscopic scale.

The last statement resulted from the observation that the fresh and albitized grains are often found to be intimately associated in individual thin sections. However, the above conditions probably account for differences in degree of reaction on a megascopic scale as well.

Dickinson (1926b, p. 491) inferred from his extensive studies the following order of diagenetic reaction of the andesitic rocks of the Izee area: (a) First glass was altered to heulandite and associated minerals, maybe in part concurrently and shortly after detrital matrix was altered to celadonite and chlorite, as both "depositional fillings of open space, and as replacement bodies in originally glassy groundmass of rock fragments." Consequently glass altered to an early diagenetic assemblage of heulandite, celadonite, and chlorite. (b) Later glass was albitized. Associated alteration minerals include pumpellyite and prehnite. The earlier diagenetic alteration products of glass remained unchanged through this stage and augite and hornblende remained unaltered. However, laumontite developed locally in tuffs and in the terrain in general this alteration appears to have been concomitant with albitization of plagioclase, but appears to have preceded albitization, on occasion.

Observations of thin sections and x-ray diffraction data of
rocks from the Suplee area for this study serve to support the observations made by Dickinson for rocks of the Izee area. The following are short descriptions of altered tuff beds from the Suplee area which on one hand illustrate very nicely some of Dickinson's observations, and on the other hand point out some interesting but minor differences in the Suplee area.

Sample 1 (from 3 cm thick tuff 183 m above the top of the Weberg Member at Mowich Spring) (fig. 2). That sample is from a slightly reworked tuff unit that occurs in the "blue-green" strata high in the Warm Springs Member. The basal centimeter of the bed is a volcanic litharenite which contains about 15 percent altered glass. Relative abundances of the major constituents are as follows:

<table>
<thead>
<tr>
<th>component</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>hornblende (green)</td>
<td>trace</td>
</tr>
<tr>
<td>augite</td>
<td>2-3</td>
</tr>
<tr>
<td>plagioclase</td>
<td>20</td>
</tr>
<tr>
<td>volcanic rock fragments</td>
<td>50-60</td>
</tr>
<tr>
<td>chlorite</td>
<td>12</td>
</tr>
<tr>
<td>zeolite</td>
<td>3</td>
</tr>
<tr>
<td>pyrite</td>
<td>2-4</td>
</tr>
<tr>
<td>magnetite</td>
<td>1</td>
</tr>
<tr>
<td>undetermined matrix</td>
<td>5</td>
</tr>
</tbody>
</table>

The terrigenous detritus is medium to coarse sandy, angular to subangular, and tightly compacted. Less than 25 percent of the plagioclase is albitized. Plagioclase twin extinction angles on relatively fresh grains indicates andesine to labradorite composition. Chlorite and minor amounts of a zeolite replaced the shards, with the zeolite occurring principally in the vesicles, along with chlorite and minor amounts of pyrite. Pyrite is abundant and is both disseminated throughout the rock and concentrated as linings around
detrital grains. The angularity of the rock fragments and relatively large, subhedral augite grains suggest that the volcanic detritus was reworked very little prior to burial. The original volcanic rock probably was an augite andesite.

The upper two centimeters consists of a chloritic, zeolitic, andesitic tuff with the following components:

<table>
<thead>
<tr>
<th>component</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>augite</td>
<td>2-10</td>
</tr>
<tr>
<td>plagioclase</td>
<td>5</td>
</tr>
<tr>
<td>volcanic rock fragments</td>
<td>1-3</td>
</tr>
<tr>
<td>pyrite</td>
<td>trace</td>
</tr>
<tr>
<td>magnetite</td>
<td>20-30</td>
</tr>
<tr>
<td>calcite</td>
<td>25-40</td>
</tr>
<tr>
<td>chlorite</td>
<td>15-25</td>
</tr>
</tbody>
</table>

The fresh plagioclase is andesine to labradorite. At the base of the bed the coarsest 1 percent of the alloogenic components (including altered glass) is 0.9 to 1.2 mm in diam.; median clast size is 0.16 mm. At least 18 mm upsection this bed is graded so that near the top only rare glass bubbles to 1.0 mm in diam. are encountered; median clast size is 0.07 mm.

The volcanic detritus is uncompacted and cemented by coarsely crystalline calcite spar; individual calcite crystals are commonly 1.0 to 1.5 mm long and encompass several detrital grains. The glass is replaced principally by chlorite along with minor amounts of zeolite. Most of the zeolite is concentrated in the glass vesicles.

The shard morphology is complex. The walls may be thin but the junctures between bubbles are usually thick. Original porosity of pumice was high, probably about 60 to 80 percent. Toward the top of the ash-fall bed the shards are nearly entirely fragmented. They
are both flat and arcuate, but tend to be stubby, or nearly equant.

Of particular interest in the sample just described is the fresh condition of much of the plagioclase, and lack of pumpellyite and prehnite. In siltstone and minor sandstone beds in this part of the formation albitization of plagioclase is usually complete, and pumpellyite and prehnite are ubiquitous although minor authigenic components.

Sample 2 (from a 1.5 m thick clayey, altered tuff 3.0 to 4.5 m below the top of the Weberg Member at the stratigraphic section 1,950 m northwest of Lupher Draw). The bed consists mainly of clay. X-ray diffraction results indicate the clay to be made up of vermiculite, sepiolite and a minor amount of chlorite. No other alteration products were noted.

Sample 3 (from a 23 cm thick zeolitic tuff 24.77 to 25 m above the base of the Weberg Member at Washburn Draw). In hand specimen the rock is "dark green" to "greenish brown", dense and with splintery to blocky fracture. Sample 3 has the following mineralogical components:

<table>
<thead>
<tr>
<th>component</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>biotite</td>
<td>0.5-2.0</td>
</tr>
<tr>
<td>celadonite</td>
<td>trace</td>
</tr>
<tr>
<td>undetermined phyllosilicate</td>
<td>4-6</td>
</tr>
<tr>
<td>limonite</td>
<td>1</td>
</tr>
<tr>
<td>calcite</td>
<td>47</td>
</tr>
<tr>
<td>heulandite (may include finely divided crystalline quartz)</td>
<td>40</td>
</tr>
<tr>
<td>plagioclase</td>
<td>3</td>
</tr>
<tr>
<td>quartz</td>
<td>2</td>
</tr>
</tbody>
</table>

The albitized feldspar and quartz grains are angular. The larger grains are commonly 0.03 to 0.015 mm in diam.; the largest grains attain 0.04 mm in diam. Biotite grains are typically 0.05-0.07 mm in
diam.; coarsest 1 percent is 0.075-0.1 mm in diam.

There is no primary internal stratification in the tuffs; however, there are closely spaced fe-stained partings, probably diagenetically produced, which are clay-rich and parallel to the bedding. Clay is also disseminated throughout the rock, oriented in lenticular anastomosing stringers in two directions. One direction is parallel to the parting; the other transects the partings at about a 40 degree angle. The calcite is in two forms. Biogenic clasts of crinoidal columnals 0.012 to 0.025 mm in diam. comprise less than 0.5 percent of the rock. The remaining calcite is authigenic sparry cement. Over 50 percent of spars are 0.008 to 0.02 mm in diam., but the remainder grades to coarse spar, as much as 0.2 mm in diam. The calcite cement is concentrated in randomly distributed generally ovoid patches 0.08 to 0.2 mm in diam. Vitric texture is not preserved where calcite has developed.

Heulandite (and quartz?) replaced the shards. The shards reach 0.08 to 0.1 mm in length. The fragments range from subequant to flattened and gently curved plates with a width-length ratio of 1:5 to 1:6. Small shards appear to comprise at least 20 to 30 percent of the finely crystalline zeolitic matrix. The zeolite in the larger shards is in the form of fibrous tufts, or sheaves, 0.005 to 0.01 mm in diam., and form a mosaic pattern.

Sample 4 (from a 30 cm thick altered tuff situated 19.5 to 19.8 m above the top of the Weberg Member near Mowich Spring) (fig. 2). In hand specimen the rock is "light tan" and fairly soft. It is composed of the following constituents:
component | percent  
--- | ---  
albite | 1-3  
biotite | 0.5-1.5  
phyllosilicates | 1  
limonite | 0.5-2.0  
laumontite | 95

In thin section the laumontite is distinguished from heulandite by its coarser crystals, mass extinction of groups of crystals, and somewhat greater birefringence. The vitric texture is not as prevalent as in the heulanditic rocks. The shard morphology is similar to the shards described for the above heulanditic tuff (sample 3). The largest shards are 0.16 mm long. Albite and biotite grains commonly reach 0.1-0.13 mm in diam. The tuff bed displays an interesting zeolitic zonation at its base. The basal 9 mm of the tuff gives a very strong x-ray diffraction pattern for laumontite, and a lesser one for quartz. In sharp contact is an overlying 5 mm thick heulandite-rich zone which grades over 4 to 5 mm at its top into clay-rich heulanditic tuff. The clay, which comprises 8 to 20 percent of the rock, is composed of a probable sepiolite and a clay which gives a 14 Å peak.

The coexistence of heulandite, laumontite and albitized plagioclase in rocks in the Suplee area is like the association reported by Dickinson (1962b) for the Buck Creek Tuff at a higher stratigraphic interval several miles to the east of the study area. Unlike that association described by Dickinson, one of the tuffs in the Suplee area shows a well ordered zonation from laumontite to clay-rich heulandite. Also, an examination of tuff beds throughout the
Snowshoe Formation in the Izee area, many of which do not appear to be reworked, shows them to be completely zeolitized. The presence of clay-rich tuff beds in the Snowshoe Formation in the Suplee area indicates less pervasive diagenetic alteration. The Formation had probably not been as deeply buried in the Suplee area as in the Izee area. The principal difference in burial depth may have been caused by the absence of the upper Jurassic Lonesome Formation in the Suplee area, which in the Izee area reaches a thickness of over 3,000 m. If the Lonesome Formation was present in the Suplee area, it had probably been entirely removed by the upper Cretaceous (prior to deposition of the Bernard Formation).
PALEONTOLOGY

The type Weberg composite section yields a diverse and abundant ammonite fauna. The 1,112 specimens used for this report are distributed amongst 33 species referable to 16 genera and subgenera, 7 families and subfamilies (Table I), and were obtained from about 80 localities (Appendix B). The ammonites are numerically dominated by the Sonniniidae and Grammatoceratinae, whereas the remaining families and subfamilies constitute less than 3 percent of the fauna.

Ammonites are rare in the lower division of the Weberg Member, are abundant and occur in greatest diversity in the upper division, and are locally abundant in the Warm Springs Member. Well preserved, uncrushed specimens come mostly from the limestone beds in the upper division of the Weberg and basal Warm Springs Members. They are compressed molds when occurring in mudstone, and are uncrushed but usually crudely preserved in the lower division of the Weberg Member.

The Weberg Member contains a rich and generally well preserved benthic megainvertebrate fauna. Pelecypods are most diverse, abundant and ubiquitous. Terebratulid and rhynchonellid brachiopods are locally abundant, but rhynchonellids are more widespread. Very few specimens of gastropods have been found.

Most of the lower division of the Weberg was not sampled, but
<table>
<thead>
<tr>
<th>Family and Subfamily</th>
<th>Genus and Subgenus</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phylloceratidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phylloceratinae</td>
<td>Phylloceras sp.</td>
<td>1</td>
</tr>
<tr>
<td>Calliphylloceratinae</td>
<td>Partschloceras sp.</td>
<td>6</td>
</tr>
<tr>
<td>Hildoceratidae</td>
<td>Holophylloceras burkei</td>
<td>13</td>
</tr>
<tr>
<td>Grammoceratinae</td>
<td>Asthenoceras boreale</td>
<td>512</td>
</tr>
<tr>
<td></td>
<td></td>
<td>290</td>
</tr>
<tr>
<td></td>
<td>Pontamussia grantiensie</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>cf. luculenta 17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aff. luculenta 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>spp. 4</td>
<td></td>
</tr>
<tr>
<td>Sonninidae</td>
<td>Sonninia spp. n. sp.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Papilloceras cf. blackwelderi</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>cf. Juramontanum 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>spp. 4</td>
<td></td>
</tr>
<tr>
<td>Euhoploceras</td>
<td>acanthodes 16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. crassimun 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aff. densicostatum 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>dominans 18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>marginatum 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. modestum 58</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. polyacanthum 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>revirescens 7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>tuberculun 55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>westi 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cf. westi 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>spp. 6</td>
<td></td>
</tr>
<tr>
<td>Witchellia</td>
<td>n. sp. 3</td>
<td></td>
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<tr>
<td></td>
<td>sp. undet. 1</td>
<td></td>
</tr>
<tr>
<td>Strigoceratidae</td>
<td>Alaskoceras evolutum</td>
<td>43</td>
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<td>Oppellidae</td>
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<td>4</td>
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<tr>
<td>Oppellitea</td>
<td>Bradfordia n. sp.</td>
<td>1</td>
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<tr>
<td></td>
<td>Hebesoxyites cf. hebes</td>
<td>2</td>
</tr>
<tr>
<td>Stephanoceratidae</td>
<td>Docidoceras lapheri</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>paucinodoseum 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>warmspringsense 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Docidoceras aff. camachoi</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pseudoctidoceras sparsicostatum</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Pseudotoites n. sp.</td>
<td>1</td>
</tr>
</tbody>
</table>
Yielded the following taxa, mostly very near the base of the division:

**Pelecypoda**
- *Entolium* sp. A
- *Gryphaea* spp.
- *Lopha* sp. A
- *Modiolus* sp. A
- *Myophorella* sp. A

**Coelenterata**
- undetermined coral

**Brachiopoda**
- *Terebratulid* sp. A
- *Rhynchonellid* spp.

A list of the highly diverse fauna collected from lithological unit C of the lower division of the Weberg Member is given below:

**Gastropoda**
- *Neritid* nerinea *sp.*

**Pelecypoda**
- *Anomia* sp. A
- *Anomia* sp. B
- *Anomia* sp. C
- *Astarte* spp.
- *Camptoneetes* sp.
- *Catinula* sp. A
- *Ceratomya* sp.
- *Chlamys* sp. A
- *Chlamys* sp. B
- *Chlamys* sp. C
- *Chlamys* sp. D
- *Entolium* sp. A
- *Entolium* sp. B
- *Entolium* sp. C
- *Gervillia* sp.
- *Goniomya* sp.
- *Grammatodon* sp. A
- *Grammatodon* sp. B
- *Grammatodon* sp. C
- *Grammatodon* sp. D
- *Gryphaea* spp.
- *Liostraea* sp. A
- *Lopha* sp. A
- *Lopha* sp. B
- *Lucina* sp.
- *Modiolus* sp.
- *Myophorella* sp.
- *Mytilid* sp. A
- *Mytilid* sp. B
The above assemblage is termed the *Gervillia* association; *Gervillia* commonly occurs in the lower division, but is rarely found in higher strata. The faunal change between this association and the super-jacent one from the upper division is marked and occurs within a couple of meters. The following is a list of those species from the top of the lower division which range into the upper division lithology:

**Brachiopoda**
- *rhynchonellid spp.*

**Pelecypoda**
- *Campionectes* sp.
- *Catinula* sp. A
- *Ceratomya* sp.
- *Entolium* sp. A
- *Gervillia* sp.
- *Goniomya* sp.
- *Grammatodon* sp. D
- *Gryphaea* spp.
- *Lucina* sp.
- *Modiolus* sp.
- *Mysophoria* sp.
- *Pleuromya* sp. A
- *Pleuromya* sp. B
- *Protocardia* sp.

In addition several species are found in the upper division, but do not range lower:

**Gastropoda**
- *Patella* sp.
- *Pleurotomaria* sp. A
- *Pleurotomaria* sp. B
- *gastropods* spp.

**Pelecypoda**
- *Inoceramus* sp.
- *Isozyprina* sp.
The two pelecypods Protocardia and Isocyprina are usually numerically predominant in the upper division. Below the sandstone-limestone marker unit in the middle of the upper division Protocardia is usually numerically predominant over Isocyprina, while above the marker Isocyprina is more abundant. Also Inoceramus is not found below the marker. The fauna from the upper division occurring below the marker is termed the Protocardida association, while the one above the marker is called the Isocyprina association.

Only Inoceramus ranges upsection into the Warm Springs Member where it is commonly associated with multitudes of Bositra buchii. The fauna from the Warm Springs Member is called the Bositra buchii association.

Other fossils from the type Weberg composite section include the nautilus Cenoceras imlayi Kummel, which is locally common in the lower division, rare in the upper division, and has not been found in the Warm Springs Member. Belemnite guards are nearly ubiquitous, are rarely abundant, but are perhaps most common in the lower division. Crudely preserved foraminifera, sponge spicules, pollen, and other disseminated plant remains were noted. Sponge spicules occur only in the upper division of the Weberg Member. Rare disarticulated ichthyosaur elements were collected from the basal Warm Springs Member. Material belonging to a new crocodilian genus, a primitive thalattosuchian, is locally present in the Weberg Member, but has not been found in the type Warm Springs Member. Disarticulated fish elements are ubiquitous and particularly abundant in the Warm Springs Member.
BIOSTRATIGRAPHY

ZONULES

Analysis of the ranges of ammonite species from the type Weberg composite section permits a subdivision of the faunal sequence into three principal units. They are designated zonules 1, 2, and 3 in ascending stratigraphic order (fig. 5). These zonules are purely descriptive; they are intended to carry no formal chronostratigraphic connotation, nor are they necessarily expected to comprise or form any subdivision of formal biostratigraphic units should any eventually be recognized. The terms faunule and zonule follow the definitions by Fenton and Fenton (1928).

Zonule 1 is recognized on the basis of ammonites from three localities (A-0551, A-0628, and A-0635) spanning most of the lower division of the Weberg Member at Washburn Draw. The three species which occur in the zonule are also restricted to it. They are *Dociodoceras* (Pseudodoceras) *sparsiocostatum*, *D. (P.)* aff. *D. (P.) camaahoi*, and *D. (Dociodoceras) paucinodosum*. Each species is represented by one specimen.

Zonule 2 encompasses the top of the lower division and the upper division of the Weberg Member. It is recognizable in each of the sections comprising the type Weberg composite. The species found in zonule 2 (fig. 5) constitute the zonule as all are restricted to it.
Zonule 3 is represented by the basal strata of the Warm Springs Member, where Holophyllumoceras burkei, Asthenoceras boreale, and Papilliceras cf. P. juramentatum, occur.

AGE AND CORRELATION

General

Ammonite genera are typically short ranging; most Jurassic genera have ranges in magnitude encompassing less than three ammonite zones. Because many ammonite genera are both short-ranging and nearly cosmopolitan in distribution, most ammonite workers, especially when making long range correlations, have preferred to correlate at the generic level.

In general aspect the stratigraphic relationships of the genera from the type Weberg composite section appear similar to the better known ammonitiferous sections in Europe. Nevertheless the species is herein regarded as the basic unit in taxonomy and systematics, and accordingly the basic unit for correlation. Thus correlation at the species level is emphasized, and resort to generic level correlation is made only when other kinds of evidence is lacking. Correlations are made first within Oregon, then with Europe, and finally with areas outside Oregon bordering the eastern Pacific.

Oregon

The type Weberg and basal Warm Springs Members are correlative with part of the lower member of the Snowshoe Formation in the Izee area. None of the ammonites Imlay (1973a) found in the lower member
occur also in the Weberg, while *Asthenoceras boreale* is the only species he recorded from the lower member which also is found in the basal type Warm Springs Member. He inferred that a c. 7 m interval in the lower member 69 to 76 m above its base is temporally equivalent to the upper two thirds of the Weberg as well as the lower part of the Warm Springs Member. The 7 m interval inferred by Imlay is surprising because it corresponds to about 137 m in the Suplee area based on a stratigraphic section made near Mowich Spring (fig. 2).

Smith (1977) recorded 2 specimens of *Euhoploceras* (one of which is *E. westi* from about 30 m above the base of the lower member from his section 3) and *Euhoploceras* spp. from a little over 60 m above the base of the member in his section 5. These specimens indicate a correlation with zonule 2. The only other species common between the Suplee and Izee areas for the interval in question is *Alaskoceras evolutum*.

The occurrence of *A. boreale* and *Fontannesia* in the Clover Creek and Juniper Mountain areas (Imlay, 1973a) suggests correlation with zonules 2 and 3.

**Other Areas**

In order to make correlations with formations outside Oregon, something must be said about usage of the northwest European ammonite succession, because most Jurassic ammonite-bearing strata are ultimately correlated to it, and many authors apply the standard terminology to their respective areas.

The type Weberg and Warm Springs Members are correlative with
the standard Bajocian Stage. But the Bajocian, as well as any other
standard Jurassic Stage, has not yet been demonstrated in North
America. Morton (1971b) notes that the distinction between the
*calensis* Subzone of the *lavesequei* Zone (top of the Toarcian Stage)
and the *Leioceras opalinum* Zone (base of superjacent Bajocian Stage)
is based on the evolution of *Pleydellia*, a genus which is not known
in North America. Also the *Leioceras opalinum* Zone is usually recog-
nized by the occurrence of *Leioceras*, a genus known in North America
only from the Canadian Arctic (Frebold, 1957; 1964). But the lower
to middle Jurassic transition described by Imlay (1968) and Smith
(1977) is similar to Europe, indicating a potential for recognizing
the boundary in North America, even though it is not recognized by
taxa usually taken to define the transition in Europe. In contrast
a fossiliferous Bajocian-Bathonian correlative transition (Imlay,
1973a) can not be demonstrated in Oregon. The closest, fossiliferous
biostratigraphic correlatives of the interval under consideration, in
Canada and Alaska (Frebold, 1957, 1973; Imlay, 1965, 1973b) belong to
the Boreal Realm, where ammonites are mostly different at the generic
level from European forms, making correlations, sometimes at the stage
level, extremely difficult. Because of the difficulty in defining the
Bajocian in the northeastern Pacific, particularly the upper boundary,
that stage name is not used here for the correlative strata of the
Snowshoe Formation.

For purposes of correlation only, zonule 2 is subdivided into
three units 2a, 2b and 2c (fig. 5). These subdivisions are defined
only by taxa which allow correlation with European forms. 2a applies
to that part of the zonule yielding the joint occurrence of
Euhoploceras dominans, E. marginatum, Fontannesia cf. F. luculenta,
F. aff. F. luculenta, and E. grantensis. Unit 2b is defined on the
basis of the occurrence of Euhoploceras acanthodes, E. cf. E.
modestum, E. cf. E. orassinudum, E. dominans, E. cf. E. polyacanthum,
and Alaskoceras evolutum, below Witchellia. Interval 2c is defined
on the basis of the first occurrence of Witchellia (at A-0565), and
extends as far upsection as strata which yield Euhoploceras.

Most precise correlation with Europe can be made with the
succession from southern England because of the several species of
Euhoploceras found there which also occur in Oregon. Euhoploceras
acanthodes, E. dominans, E. aff. E. densecostatum, E. marginatum,
E. revirescens, E. cf. E. orassinudum, E. cf. E. modestum, Fontannesia
cf F. luculenta, and Hebetoxytes cf. H. hebes are species from Oregon
that are conspecific or very close to those described by Buckman
(1887-1907; 1909-1930). Unfortunately much of Buckman's material
was derived from private collectors and his hemeral scheme is largely
hypothetical with no foundation in actual stratigraphic occurrence.
Thus detailed correlations can not be made based on his studies.

Euhoploceras spans the lower to middle Bajocian transition. In
England this transition is defined using graphoceratids which do
not occur in North America. Correlation is further hampered in that
the Bajocian sequence in southern England, as well as in most of
Europe, is condensed, and fossils are commonly found in thin, isolated
pockets, making it difficult to establish superpositional control of
faunas,

Buckman (1887-1907) considered the assemblage of *Euhoploceras* from southern England to be middle Bajocian in age, but this is not immediately clear, because he assigned it to the *Concavum* beds. The *Graphoceras concavum* Zone belongs to the lower Bajocian. An explanation of this apparent dilemma is resolved in Buckman's *(op. cit.; explanation opposite plt.xlvi)* statement: "It has been thought advisable to call this horizon definitely "Concavum-Zone." It is the same horizon which was described as 'Sowerbyi Zone' or 'Sowerbyi Zone (Concavum beds)' until Pl. XIV, and afterwards 'Concavum beds.' These terms may be altered to Concavum Zone." The *Sonninia sowerbyi* Zone was erected by Oppel (1862-63) and allocated to the basal middle Bajocian. The ambiguous terminology used by Buckman, and resulting confusion, was discussed by Arkell (1956), who regarded the *Euhoploceras* fauna from southern England to belong to the "Discites Hemera" of the *S. sowerbyi* Zone.

It turns out that *S. sowerbyi* appears to be the inner whorls of *Papilliaceras mesacanthum* or a closely related species. In Europe the *P. mesacanthum* group is not found lower than the *Emileia sausei* Zone. This finding resulted in the recent abandonment of the term *S. sowerbyi* Zone and its replacement by another terminology (Parsons, 1974). The European zonal terminology follows that of Parsons (fig. 6). In this scheme the old *S. sowerbyi* Zone spans the *Hyperlioceras discites* and *Witchellia laeviuscula* Zones. With this background correlations with English faunas, based on sections recently made by Parsons (1974) in the Dorset area, and Morton (1976) in Skye, Scotland are permissible.
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Figure 6. Zonal schemes for parts of the British Bajocian. (after Parsons, 1974)
The faunule from zonule 1 provides little basis for correlation with Europe. *Dociodiceras* has never been found below the upper part of the lower Bajocian. The position of zonule 1 below zonule 2 indicates its correlation with pre-middle Bajocian strata.

Recently Parsons (op. cit.) collected ammonites at three levels at the Bradford Abbas Railway cutting in southern England. His age assignments of the three beds are based mainly on graphoceratids. The lowest bed yielded *E. acanthodes* (=*E. crassiformis*), and the next higher one in which *E. acanthodes* and *E. dominans* were collected, were allocated to the *G. concavum* Zone, suggesting a correlation with some part of zonule 2b-c. The highest collection, yielding *E. acanthodes* and *E. dominans* (=*E. submarginatum*), was allocated to the *H. discites* Zone, indicating a correlation with some part of zonule 2b-c.

Correlation of 2c with the *Fissilobiceras ovatis* Subzone of the *Witchellia laeviuscula* Zone is indicated by a fauna collected by Parsons at Barns Spinny, yielding questionably identified *Euhoploceras* as well as *Witchellia*.

In Skye, Scotland, Morton (1976) records *Euhoploceras* (?)*dominans* and *E. marginatum* 17 m above the base of the Udairn Shales in the Bearreraig Burn. Based on a fragment of *Hyperlioceras* 1-2 m higher in the section he allocates the occurrence of *Euhoploceras* to the *H. discites* Zone or top of *G. concavum* Zone. Thus zonule 2a is correlated with this occurrence of *Euhoploceras*.

Correlation of zonule 2b-c is made with the strata 27 to 29 m below the top of the Udairn Shales, where *E. sp.* (? cf. *modestum*) was collected, which Morton allocated to the *H. discites* Zone.
A fauna 29 m below the superjacent Holm Sandstone was assigned to the *W. laeviuscula* Zone, and tentatively allocated to the *W. laeviuscula* Subzone. Zonule 2 may be correlative with the bed yielding that assemblage based on the occurrence there of *Euhoplooceras* and *Witchellia*.

Correlative deposits in Germany are generally condensed and poorly fossiliferous. There is no basis for correlating zonule 2 with deposits described by Dorn (1935) and Oechsle (1958). *E. marginatum* is recorded from Germany but misidentified. A specimen figured under *Sonninia mayeri* Waagen by Dorn (1935, p. 42, pl. 3, fig. 1; text-fig. pl. e, fig. 8,9), was later described as *Sonninia polyacantha marginata* by Oechsle (1958). Oechsle is correct in assigning the specimen to *E. polyacanthum*, but incorrect in the subspecific designation *marginatum*. The specimen is clearly distinguished from *E. marginatum* by the apparent lack of the wide, shallow sulcae, the adult umbilical shoulder is only incipient, and the shell possesses strongly reclined costation. The last character is developed in a style present in other examples of *E. polyacanthum*, notably the one figured by Dorn (1935, pl. 17, fig. 1). The former two characters are found in *E. polyacanthum* as well.

Dorn (*op. cit.*, p. 120) reports *E. polyacanthum* (also=E. *mayeri*) from the *Witchellia pinquis* and *Emileia sausei* Zones. He admits that little reliability can be attached to his zonal compilation, in part because of the paucity of ammonites at individual localities, and partly because many museum specimens were assigned to a stratigraphic interval (and given a temporal designation) solely by
examining adhering matrix. Dorn's age assignments are suspect, so no correlations based on his work will be made here.

Correlation of zonule 2\textsubscript{b-c} with the "Sowerbyi Bank" and "Sand Mergal" (Oechsle, 1958) is provided via the occurrence in those units of *E. polyacanthum* (=*Sonninia polyacantha polyacantha*; *Sonninia polyacantha marginata*) and *E. modestum* (=*Sonninia modesta modesta*) reported only from the "Sand Mergal").

Correlation of zonule 2 with the *Sonninia* strata from Hellern is provided through the occurrence there of *Fontannesia* and *E. modestum* (=*Sonninia modesta modesta*) (Hiltermann, 1939).

Maubeuge (1951) described taxa which are conspecific with material from Oregon, but he supplied no stratigraphic sections and the locality information is minimal. Thus his temporal allocations are probably often arbitrary and suspect. Nevertheless *E. revirescens* provides a means for correlating zonule 2\textsubscript{a} with his occurrence of that species (=*Soninina* (Euhoploceras) *mussonense*), which he allocates to the *G. concavum* Zone. *E. acaenodes* (=*Sonninia cf. acaenodes*; *Sonninia pseudogibbera*) is allocated to the *H. discites* Zone and tentatively to the *S. sowerbyi* Zone. *E. cf. E. crassinudum* (=*Sonninia luciusi* Maubeuge) is assigned by Maubeuge to the *S. sowerbyi* to *W. laeviuscula* Zone interval. In Oregon *E. cf. E. crassinudum* is confined to zonule 2\textsubscript{b}.

The Mormon Sandstone of Diller (1892), in the Taylorsville region at Mount Jura, Plumas County, California, is in part a correlative of the type Weberg and basal Warm Springs Members. Crickmay (1933) defined 11 successive faunas, some of which contain
ammonites, to delineate the faunal sequence of the Mormon Sandstone.

It would seem that *Papilliceras* cf. *blackwelderi* from zonule 2 would provide correlation with strata in California yielding *P. blackwelderi* Crickman (unit 7), but that species is associated with stephanoceratids which suggests a substantially younger age. In the course of this study *P. blackwelderi* has been found in sections in Oregon occurring with stephanoceratids and other ammonites in the Warm Springs Member which correlate best with unit 7 in California.

Lower in the section at Mount Jura (unit 4) Crickmey reports *E. cf. E. crassinudum* (= *Stiphromorphites schucherti* Crickmey, 1933, p. 909, pl. 28, figs. 1-3), which indicates correlation with zonule 2. Occurrences of *E. n. sp. aff. E. modestum* from 23 m above the base of the Mormon Sandstone, and one *ex situ* example of *E. acanthodes* which came from the basal Mormon Sandstone, both from a stratigraphic section made by the author on the south side of Mount Jura, allow correlation of the lower part of the Mormon Sandstone with zonule 2.

Correlation of zonules 2 and 3 with part of the Rock Creek Member of the Fernie Group at a locality 4.8 km north of the east end of Lake Minnewanka in Western Alberta, Canada, is afforded by *Astenioceras boreale* (= *Schloenbachia borealis* (Whiteaves) 1886; *Grammoceras ? boreale* (Whiteaves) Frebold, 1964) and *Euhoploceras cf. E. marginatum* (= *Sonninia div. sp. indet.* p. 49, pl. 19, fig. 2a, b, Frebold, 1957.)

Correlation of part of the Smithers Formation of the Hazelton Group in British Columbia, Canada, is provided through *Fontannesia* spp. (Tipper and Richards, 1976). There are several records of
poorly preserved sonniniids and stephanoceratids from isolated localities in the Hazelton Group that may suggest correlation with the type Webberg composite, but the faunas from British Columbia are poorly known.

*Asthenoaeras boreale* (=*G. ? boreale*) is recorded (Frebold, 1964) from the Labe,rge Group at two localities in the Southern Yukon. An upper Toarcian assignment was based on the species' supposed close relationship to *Grammoceras ? doertense* (Denkmann) and a wrong identification of some poorly preserved ammonites referred to *G. aff. fallioeum*. The latter specimens may belong to *Turgurites*. Since *Asthenoaeras* has never been recorded from the lower Jurassic, it is suggested that the strata yielding the examples of *A. boreale* described by Frebold (1964) be correlated with the lower to lower middle Bajocian.

Westermann (1964, 1969b) described an interesting ammonite sequence from the Kialagvik Formation at Wide Bay, Alaska. Correlation with his *Amplexctens* or lower *Pseudocidoceras "Zonule"* is tenuous and is based on the presence of *Docidoceras* (*Docidoceras*) *paucinodontum*, and *D. (Pseudocidoceras) aff. D. (P.) camachoi* in *zonule 1*. Correlation of his *Pseudocidoceras "Zonule"* with *zonule 2* from Oregon is provided through the joint occurrence in both areas of *Euhoploceras, Asthenoceras, Alaskoceras, Docidoceras (D.), and Pseudotoites*. Excepting possibly for *A. costulum* (*may = A. aff. A. nomnodes* Buckman), none of the species are common between the two areas.

Correlation of *zonule 2* with strata in Argentina that
Westermann and Riccardi (1972) correlate with the G. concavum Zone or S. aowerbyi Zone is suggested by the presence of Pontannesia, and E. aff. E. acoanthodes (=Soninia (Euhoplloceras) cf. adicra (Waagen)) near Paso del Espinacite, San Juan Province suggests zonule 2b-c may be correlative with some Jurassic strata there.
PALEOECOLOGY

The strand of the sea in which the Weberg fauna thrived was at least as far east as Idaho. In the Suplee area the lower Snowshoe Formation was deposited on a shallow platform which was part of an island system. The Weberg and its contained fauna represents the history of inundation of the platform by a sea which locally transgressed toward the west. The type Weberg and Warm Springs Members represent a local development of this record, where a topography of irregular relief was covered, and indicate a progressive change from proximal to distal source of pre-Snowshoe sediments, from high to low energy conditions, and perhaps a slight deepening of the platform.

Normal salinity throughout that history is attested by the abundance of the normally stenohaline taxa, articulate brachiopods, cephalopods, and crinoids. Hallam (1975) reviewed the evidence for equable and warm paleoclimates over much of the globe during the Jurassic, but even rough estimates of paleotemperature in the study area are not possible from the data gathered thus far.

Ammonite paleoecology is stressed here, so the remaining invertebrates are discussed only insofar as they contribute to that topic. Based on a regional examination, most ammonites appear to be very spotty in geographical distribution. Of the ammonites found in the Weberg Member only rare Euhoplooceras and Alaskoceras evolutum have been collected from temporally equivalent strata in the Izee
area. Similar marked differences in faunal composition occur within 
the type area of the Weberg and Warm Springs Member as well. Warm 
Springs strata lateral to the upper division of the Weberg Member 
yield *A. boreale* to the near exclusion of other ammonites. For 
example, locality A-0626 yields densely packed *A. boreale*, but no 
other ammonites. Note that the lateral distance between the two 
facies where fossils have been found is only a few hundred meters 
and also that *A. boreale* has not been found in the Weberg Member at 
the type Weberg composite section (fig. 4,5).

*Euhoplloceras* is persistently common only in the vicinity of the 
type Weberg composite section, in silty biosparite beds of the upper 
part of the upper division containing the *Isocyprina* association. 
*Euhoplloceras* becomes less common in the lower upper division, in 
limestone beds which have principally sand size terrigenous detritus 
and yield the *Protocardia* association. *Euhoplloceras* is uncommon in 
the top of the lower division where granule size terrigenous detritus 
is common and the *Gervillia* association is well developed, and is not 
found lower in the Weberg Member. At localities outside the type 
Weberg composite section the limestone beds of the upper division 
are usually less calcareous, commonly have mainly sand size detritus, 
and often yield the *Protocardia* association. At those localities 
*Euhoplloceras* occurs in the most calcite-rich beds, fine sandy beds, 
and is usually found only in one or two levels. *Euhoplloceras* is 
early excluded from other facies. For example, it is found only at 
two localities in the Warm Springs Member. Both of these localities 
are from sandy mudstone closely associated with silty biosparites of
the upper division of the Weberg Member. As already noted, the genus is exceptionally rare in the Snowshoe Formation in the Izee area (Smith, 1977), while Imlay (1973) records no occurrences in the formation outside the Suplee area.

*Fontannesia* has a distributional pattern closely paralleling that of *Euhoploceras*, but its telzzone does not extend as high. *Asthenoceras costulum* occurs abundantly in the upper part of the upper division of the type Weberg composite section, but otherwise is locally present only in the basal Warm Springs Member in the vicinity of Mowich Springs (fig. 2).

The species is restricted to sediments in which over 50 percent of the terrigenous component is silt and clay.

Each species from the type Weberg composite section has a unique distributional pattern reflecting post-mortem drifting, life habitats, or a combination of both. The common association of certain ammonite species, close correlation of ammonites with certain biofacies as well as lithofacies, and regional observation of pervasive changes in taxonomic composition of ammonites between facies suggests that many ammonites died in their approximate life-habitats. Neither whole nor fragmentary ammonites were found in the basal beds of the Weberg where it was examined, where one might expect to find fragments if the shells of ammonites floated extensively after death and became stranded at the high water line (Reyment, 1958). The strong similarity of sonniniid faunas between southern England and Oregon may be owing in part to similar ecological conditions in both areas. The species of *Euhoploceras* described by Buckman (1887-1907) were derived
from Bajocian strata which were deposited on a submarine high (Ian Penn, Institute of Geological Sciences, London, England, personal communication, 1976). The broad distributional patterns of the ammonites in the Snowshoe Formation probably reflect the spatial life habitats of the organisms rather than distribution by post-mortem drifting.

The extreme rarity of ammonites from the lower division may be owing to their inability to inhabit the area when the unit was being deposited, perhaps because currents were too strong for them to live there. Reports that ammonites did not occur in inferred high energy environments are widespread; Arkell (1933) and Young (1972) have excellent discussions. Ammonites have poorly developed retractor muscle scars, hence were probably poor swimmers, unable to cope with strong currents (Kennedy and Cobban, 1976). Too little is known of the distributional patterns of the three species of Doidoceras from the lower division to assess whether they are autochthonous.

In contrast to ammonites, Cenoceras imlayi is most common in the lower division of the Weberg Member. It may be argued that shells of the species drifted posthumously from offshore areas, but not a single specimen has been found in the Snowshoe Formation outside the Suplee area. It is possible that shells of Cenoceras drifted from areas where the Snowshoe is not presently exposed, or from an entirely different region, and it is conceivable that the few shells one would expect to encounter in basinal sediments like those from the Snowshoe Formation in the Izee area have not been found because of collection failure. But the lower Weberg Member may represent its preferred
life habitat, because, like Recent *Nautilus, Cenoceras* was probably a good swimmer and better able to inhabit high energy environments, from which most ammonites were excluded.

The much greater abundance of ammonites in the upper division correlates with inferred lower energy conditions. But the upper division lithology indicates some current activity or wave agitation, perhaps strong enough that the ammonites had to deal with currents and/or wave activity. The ammonite fauna from the upper division is characterized by species with widely varying morphologies. Included are serpenticones (*Alaskoceras* and *Docidoceras*), oxycones (*Strigoceras*), compressed, involute forms (*Hebetoxyites, Bradfordia, Phylloceras*) several planulates (*Asthenoceras, Fontannesia, Papilliceras, Witchellia, Sominia*) as well as other morphologies. For the most part, these ammonites appear to have exploited approximately the same spatial habitat, perhaps by different means.

*Asthenoceras costulum* is the most common ammonite high in the upper division. The lower termination of the range of the species, well above the base of the upper division, correlates closely with the coarsening downsection of terrigenous detritus and appearance of the *Protocardia* association. The lowest occurrence of *A. costulum* is certainly facies controlled because it is found in slightly older beds near Mowich Spring (fig. 2). Possibly *A. costulum* did not tolerate the slightly higher energy conditions required to deposit the strata in which the *Protocardia* association is found.

The morphology of *A. costulum* may give clues to its ability to
cope with currents. The shell is evolute but has a very shallow umbilicus. Ribbing is weak, the whorl section is strongly compressed, gently convex, and the venter is narrow. An ammonite shell with these characters in common should have a low drag coefficient (Westermann and Chamberlin, 1976) thus the organism may have been capable of swimming with relatively little expenditure of energy. The exceptionally high keel could act to control directional movement; the moderate whorl expansion rate and body chamber comprising only 3/4 solution may have acted to separate centers of gravity and buoyancy (Raup, 1967). The animal may have been a relatively efficient swimmer for an ammonite, but the high keel and strongly compressed, evolute shell are characters not to be expected in an animal suited for a benthic life-mode. An inability to stabilize itself on the substrate may have restricted the animal from areas experiencing all but low current and/or wave activity.

_Euhoplo ceras_ is the next most common ammonite from the upper division, and is characterized by a very low keel, broad venter, strong ornamentation, locally thick shell, and relatively deep umbilicus. These characters suggest an animal which was not an efficient swimmer, and one which may have preferred at least a partly benthic life-mode. This ammonite appears much lower in the section, and thus was apparently able to live under somewhat higher energy conditions than was _A. costulum_. The apparent ability of _Euhoplo ceras_ to stabilize itself on the bottom may have been crucial to its withstanding relatively strong currents.
In the Warm Springs Member there is a marked decrease in species diversity, and absence of coarsely ornate forms like *Euhoploceras*. Instead of *Euhoploceras* a closely related genus *Papilliceras* is represented. *Papilliceras* characteristically has a fairly high keel, shallow umbilicus, compressed whorls, acute venter, and very fine ornamentation; like *A. costulum* it may have been a relatively efficient swimmer. Other ammonites in the Warm Springs Member include the numerically predominant *A. boreale* which is morphologically similar to *A. costulum*, and *Holophylloceras hydei*, a phylloceratid. Phylloceratids have long been taken to have a predominantly offshore distribution.

The ammonites from the Warm Springs Member have morphologies which may be suited to a swimming mode of life, whereas those from the Weberg show more varied morphologies, some of which most certainly were poorly constructed for efficient swimming activities.

The above discussion is certainly not rigorous and is intended only to point out that a paradigm approach (Rudwich 1964) relating morphology and function of ammonites may be especially applicable when comparisons can be made with ammonites from units with rapid and complex facies changes, such as exist in the Snowshoe Formation. The paradigm models can be tested with observed distributional patterns of the ammonites with regard to lithological facies and biofacies as well as by experimental methods.

The spotty distribution and at the same time geographically widespread range of many ammonites indicates very strongly that, like most molluscs (Thorson, 1950, 1966), many ammonites probably had
a "larval" stage (Spath, 1933; Kennedy and Cobban, 1976) and probably spent long periods of time in the plankton. Consequently, currents may have played a prominent role in ammonite dispersal. If this is correct the "larvae" could have passed over extensive areas not suitable to their adult life and may have, like many molluscs, delayed settling up to several weeks until a suitable substrate or proper environmental conditions promoted adult development (Thorson, 1966).
SYSTEMATIC CATALOGUE

In general the systematic section follows that of Arkell (1957), but there are several differences. Following Westermann and Getty (1970) *Fontannesia* is removed from the Sonniniidae and placed in the Grammatoceratinae of the Hildoceratidae. *Asthenoeceraceras* was considered to be a subgenus of *Grammoceras* by Arkell who thought that *Asthenoeceraceras* differs only in its smaller size. Full generic status is given *Asthenoeceraceras* on account of its laterally sulcate adult keel. *Euhoploceraceras* is removed from *Sonninia* and given full generic status because of its much coarser ornamentation, tendency to possess relatively coarse ribbing on the adoral part of the body chamber, and stouter whorls. The subgenus *Euhoploceraceras* (Alaskoceraceras) of Westermann is given full generic status. It differs from *Euhoploceraceras* in its much smaller adult size, strongly bisulcate venter, serpentine-coiling, collared aperture, and prominent ventro-lateral ornamentation. At the generic level classification of the Stephanoeceratidae closely follows that of Morton (1971a). Within the family the subgenus *Docidoceraceras* (Pseudodocidoceraceras) of Westermann is recognized. Within the Haplocerataceae, *Hebetoxyites* is removed from the Strigoceratidae and placed in the Oppelidae. *Hebetoxyites* differs from other strigoceratids by lacking a keel, and presence of a simple suture. The mid-lateral spiral ridge and non-suspensive umbilical lobe of *Hebetoxyites* are characters of *Bradfordia*, a genus of the Oppelidae.
Following Westermann (1964; 1969 a,b; 1972) as well as many other authors, a neontological approach is taken herein by classifying dimorphic counterparts, whenever possible, under the same species. In order to avoid designating sex of dimorphs the larger form with the simple aperture is designated the macroconch (M), while the smaller, lappeted form is designated the microconch (m). In cases where the microconch can not be matched with its counterpart, open nomenclature is used.

Thus material assigned to Pelekodites, which Arkell classified as a genus of the Sonniniidae is herein assigned to various macroconchiate sonniniid genera as well as Fontannesia. In this report Pelekodites is abandoned.

Some parameters measured on ammonite specimens are listed and figured below (fig. 7).

D = diam. of shell
U = diam. of umbilicus
H = whorl height
W = whorl width
Rd = rib count per one half volution
U/D = a measure of the degree of involution
Rh = rib height
Tb = tubercle height
H/W = a measure of whorl compression

Measures of shell diameter and whorl height exclude the keel. Rib density is counted in the ventro-lateral area, and the corresponding shell diameter represents the largest shell diameter at which each count was made.

The localities prefixed with an A refers to material catalogued into the Earth Sciences Museum, Portland State University; localities prefixed with a D belong to the Museum of Paleontology, University of
Figure 7. Ammonite measurements.
California, Berkeley. C.A.S. numbers refer to the California Academy of Sciences, San Francisco, California, and U.S.N.M. numbers refer to the U.S. National Museum, Washington D.C.

SYSTEMATIC DESCRIPTIONS

Phylum MOLLUSCA

Class CEPHALOPODA Cuvier, 1797

Order AMMONOIDEA Zittel, 1884

Family PHYLLOCERATIDAE Zittel, 1884

Subfamily PHYLLOCERATINAE Zittel, 1884

Genus Phylooceras Suess, 1865

Phylloceras sp.

Discussion: One partly crushed shell belonging to Phylloceras was found at A-0621. The specimen appears identical to the more coarsely ornate example of Phylloceras sp. figured by Imlay (1973a, p. 54, pl. 52, fig. 9).

Genus Partschiceras Fucini, 1923

Partschiceras sp.

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
<th>D</th>
<th>H</th>
<th>W</th>
<th>H/W</th>
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<tbody>
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<td>A-0573-1</td>
<td>end phragmocone</td>
<td>56</td>
<td>33</td>
<td>22</td>
<td>1.5</td>
</tr>
<tr>
<td>A-0628-1</td>
<td>phragmocone</td>
<td>28.2</td>
<td>16</td>
<td>10</td>
<td>1.6</td>
</tr>
<tr>
<td>A-0628-1</td>
<td>end phragmocone</td>
<td>39.9</td>
<td>22.5</td>
<td>14.7</td>
<td>1.53</td>
</tr>
<tr>
<td>A-0831</td>
<td>end phragmocone</td>
<td>22</td>
<td>12.8</td>
<td>9.3</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Description: The hypodigm consists of the above measured specimens from the Washburn Draw section. The shell is strongly involute; the whorls are moderately compressed, subovate in section.
The shell is nearly devoid of ornamentation, but the example from A-0573 shows incipient plicae (c. 8/cm) on the externside at 30 mm shell diam., and the specimen from A-0582 exhibits very weak, dense lirae on the umbilical wall and in the ventro-lateral area (where there are 6 lirae/cm at 55 mm shell diam.). The suture shows a graded series of diphylllic saddles.

Subfamily CALLIPHYLLOCERATINAe Spath, 1927

Genus Holocophylloceras Spath, 1927

Holocophylloceras burkei Taylor, n. sp.

Pl. 1, fig. 1a, b

Holocophylloceras sp., Imlay, 1973a, p. 54 [in part], pl. 1, figs. 18-21.

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
<th>D</th>
<th>H</th>
<th>W</th>
<th>H/W</th>
<th>No. constrictions per 1/4 whorl</th>
</tr>
</thead>
<tbody>
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<td>A-0606</td>
<td>end phragmocone</td>
<td>32</td>
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<td>14.5</td>
<td>1.14</td>
<td>a.6</td>
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<tr>
<td>A-0631</td>
<td>end phragmocone</td>
<td>31</td>
<td>17</td>
<td>16</td>
<td>1.06</td>
<td>6</td>
</tr>
<tr>
<td>D-6753-1</td>
<td>end phragmocone</td>
<td>31</td>
<td>16</td>
<td>15.5</td>
<td>1.03</td>
<td>7</td>
</tr>
<tr>
<td>D-6753-1</td>
<td>aperture</td>
<td>44</td>
<td>22.3</td>
<td>19</td>
<td>1.19</td>
<td>7</td>
</tr>
<tr>
<td>13329 U.S.N.M.</td>
<td>end phragmocone</td>
<td>26</td>
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<td>7</td>
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<td>10</td>
<td>1.02</td>
<td>-</td>
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<tr>
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<td>end phragmocone</td>
<td>23</td>
<td>12.5</td>
<td>11</td>
<td>1.14</td>
<td>a.6</td>
</tr>
<tr>
<td>A-0735</td>
<td>aperture</td>
<td>43.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>8</td>
</tr>
</tbody>
</table>

Holotype: pl. 1, fig. 1a, b; complete shell with most of test.

Repository: University of California, Berkeley, Museum of Paleontology D-6753-1.

Locus typicus: University of California, Berkeley, Museum of Paleontology, locality D-6753; Scott Ranch Section.

Stratum typicum: Weberg Member, Snowshoe Formation, from limestone concretion in silty litharenite unit 16.46 - 16.67 m strati-
graphically above base of Weberg Member.

**Derivatio nominis:** In memoriam of Bernard W. Burke, son of Mrs. Chris Burke, former preparatory assistant at the Earth Sciences Museum, Portland State University.

**Diagnosis:** Shell weakly compressed; constrictions strongly sigmoidal, moderately strongly convex over venter.

**Description:** This species is very involute. The whorl section of the adult shell is subovate, weakly compressed, but on the body chamber a very weak ventro-lateral shoulder is present. The body chamber comprises one half volution. The aperture is strongly sigmoidal in outline, with a broad lateral and a short ventral lappet.

On the adult phragmocone are six fairly strongly sigmoidal constrictions per whorl. The adoral half of the body chamber bears three somewhat approximated constrictions, accounting for the counts of 7-8 constrictions per whorl on specimens D-6753-1, 13329, and A-0735. The constrictions are moderately strongly convex over the venter. Faint ribbing is most noticeable at largest shell diameters, and on the upper parts of the flanks. Ribbing is subparallel to the trend of the constrictions.

**Discussion:** *H. burkei* is distinguished from *H. costisparsum* Imlay in that the constrictions are somewhat more strongly sigmoidal, and that they are more acutely convex over the venter. The new species may also be less compressed and differ by having the approximated constrictions on the body chamber. *H. burkei* is very close to *H. ultramontanum*, and is differentiated only in that the
constrictions are less acutely convex over the venter. Consequently
H. burkei is morphologically intermediate between H. cf. H.
ultramontanum and H. costisparsum. The morphological trend does not
necessarily imply a simple lineage because H. costisparsum
(Westermann, 1969b) is reported from beds approximately equivalent to
the northwest European H. discites to W. laevivscola Zone interval.

H. cf. H. ultramontanum (Westermann, op. cit.) differs markedly
from the figures of H. ultramontanum by Zittel (1869) by being stouter
whorled, and by bearing denser constrictions which are much more
strongly sigmoidal and which are much more strongly convex over the
venter. Zittel's example is also more evolute. The examples of H.
ultramontanum described by Vacek (1886) seem to be more stoutly
whorled than the type (Vacek, op. cit., pl. 5, fig. 20), but they also
bear very sparse constrictions. As a result neither the taxon from
the Eryitoides howelli Zone of southern Alaska, nor the new species
from Oregon appears to be very closely related to H. ultramontanum.

Family HILDOCERATIDAE Hyatt, 1867
Subfamily GRAMMOCERATINAE Buckman, 1904
Genus Asthenoceras Buckman, 1899
Asthenoceras boreale (Whiteaves)
Schloenbachia borealis Whiteaves, 1889, p. 160, pl. 21, fig. 5;
p. 171.
Grammoceras ? boreale (Whiteaves); Frebold, 1964, p. 18, pl. 7,
fig. 3,4.
Asthenoceras delicatum Imlay, 1973a, p. 55, pl. 3, fig. 1-32;
pl. 4, fig. 3-6.
Asthenoceras cf. A. delicatum Imlay, 1973a, pl. 4, fig. 1, 2.
**Wichellioides connata** (Buckman); Imlay 1973a, p. 69 [in part] pl. 20, fig. 4.

*Asthenoceras ?* sp., Imlay, 1973a, p. 55, pl. 35, fig. 10.

**Macroconch**

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
<th>D</th>
<th>H</th>
<th>W</th>
<th>U</th>
<th>H/W</th>
<th>U/D</th>
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<td>A-0606-1</td>
<td>phragmocone</td>
<td>c.32</td>
<td>12</td>
<td>---</td>
<td>12</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>A-0606-1</td>
<td>end phragmocone</td>
<td>50</td>
<td>17.5</td>
<td>13</td>
<td>19.7</td>
<td>1.35</td>
<td>0.38</td>
</tr>
<tr>
<td>A-0853-1</td>
<td>phragmocone</td>
<td>c.31.5</td>
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<td>8.5</td>
<td>13</td>
<td>1.31</td>
<td>c.0.39</td>
</tr>
<tr>
<td>A-0853-1</td>
<td>end phragmocone</td>
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<td>16</td>
<td>11.5</td>
<td>20</td>
<td>1.39</td>
<td>0.41</td>
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<tr>
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<td>7.5</td>
<td>7.0</td>
<td>1.01</td>
<td>c.0.43</td>
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<td>12.4</td>
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<td>12</td>
<td>1.08</td>
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<tr>
<td>A-0631-1</td>
<td>body chamber</td>
<td>c.53</td>
<td>16.8</td>
<td>---</td>
<td>26.5</td>
<td>---</td>
<td>c.0.36</td>
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<td>13</td>
<td>---</td>
<td>21.5</td>
<td>---</td>
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<tr>
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<td>18.4</td>
<td>---</td>
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<td>0.39</td>
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</table>

**Microconch**

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
<th>D</th>
<th>H</th>
<th>W</th>
<th>U</th>
<th>H/W</th>
<th>U/D</th>
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<tr>
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<td>c.7</td>
<td>---</td>
<td>12</td>
<td>---</td>
<td>0.50</td>
</tr>
<tr>
<td>A-0735-1</td>
<td>end phragmocone</td>
<td>20.2</td>
<td>7.0</td>
<td>6.3</td>
<td>9</td>
<td>1.11</td>
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<td>8</td>
<td>---</td>
<td>8.1</td>
<td>---</td>
<td>0.28</td>
</tr>
<tr>
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<td>0.99</td>
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<tr>
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<td>c.8</td>
<td>---</td>
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<td>0.48</td>
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<td>---</td>
<td>10.3</td>
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<td>0.43</td>
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**Description, macroconch:** The inner two and one half whorls (shell diam. to 2 mm) of the nucleus bear a strongly depressed ovate whorl section, becoming less strongly depressed on the remaining whorls of the juvenile stage (juvenile stage ends at 6.5-8.0 mm diam.). The earliest adult whorl may possess a subcircular, slightly compressed whorl section, but the section is usually depressed to a shell diam. of 20 mm. Range of variation of the whorl section at 17-22 mm diam. is (H/W; 0.35-0.45). The umbilical wall is vertical or nearly so at its base and rounds gently onto the flanks which are widest about one third height and converge gently to the broadly
rounded venter which supports a low, solid keel. The outer whorls of the phragmocone become more strongly compressed, and the widest part of the whorl section migrates toward mid-flank adorally. At the end of the phragmocone (diam. 33-52 mm) the whorl section varies from (H/W) c.1.1-1.4, and evolution is usually strong (U/D=0.39-0.44), but is moderate in one finely ornate specimen (U/D=0.36). Most complete specimens of the hypodigm exhibit an incomplete body chamber (=2/5 to 1/2 volution). Imlay (1973a, op. cit.) described a body chamber of just over one half whorl for Asthenoceras delicatum and for his Asthenoceras sp. (Imlay, 1973a, op. cit.) three fifths of a whorl for the body chamber was reported. The body chamber possesses somewhat flattened flanks and egresses rapidly over the penultimate whorl.

The keel first develops as a very low, solid structure on the late juvenile whorls, becomes hollow, floored on the late first or second adult whorl, and attains the high laterally sulcate cross-section on the outermost whorl of the phragmocone. Concurrent with the appearance of the keel are narrow, slightly flattened areas bordering the keel which become clearly delimited on the outer whorls. On a few inflated and/or coarsely ornate specimens these flattened areas become distinctly sulcate on the outer whorls.

Beginning on the inner juvenile whorls are faint mid-flank swellings, and surficial striae are noticeable at the late juvenile stage. On the adult phragmocone the low plicae, which are strongest at greatest whorl width, may persist as low swellings (6-10 per one half whorl), or become obsolete. Commonly more acute adorally convex, somewhat buliate plicae, also most prominent at greatest whorl width,
over-ride in strength the low broad swellings, if present.

The remaining ornamentation consists of growth striae and acutely crested or sharply rounded moderately to strongly falcoid fine ribs. Ribbing on the upper one half of the flanks of the phragmocone varies considerably in density (22 to about 45 ribs per one half whorl), but is usually 30-34 ribs per one half whorl. This ornamentation begins as faint, dense striae, rarely as ribs, at the umbilical seam. Uncommonly specimens exhibit only obsolete ornamentation on the lower one half of the flanks. But, generally on the umbilical shoulder, a few of the striae rapidly increase in strength to fine ribs. When well defined, the ribbing passes over low undulations, if present, and becomes strongest on the ventro-lateral shoulder where it is most strongly concave. The adorally convex, bullate plicae, when present, are the result of inflation of commonly one to two and sometimes more ribs per bulla. Costation may be fasciculate (commonly with 3—6 secondaries per swelling), mixed, simple or bifurcate-fasciculate where bullate swellings are absent. Costation strength may be regular, or irregular in which case there is an admixture of striae and acute ribbing.

On the venter ornamentation is strongly projected and diminishes rapidly in strength against the tabulated areas. Especially where the keel is low on the inner whorls, striae and fine ribs pass over it, often giving the keel a chorded appearance.

On the adoral one half of the outer septate whorl costation immediately becomes blunt, less dense, strongly falcoid, and moderately or strongly rursiradiate. At this stage ribbing consists
of primaries and incipiently attached intercalatories, but is sometimes distinctly bifurcate. Adorally on the body chamber costation of the outer whorls remains fairly dense and becomes only weakly rursiradiate.

Microconch: The adult ranges in size from 21-30 mm in shell diameter (mean = 24 mm). Shell dimensions are similar to the macroconch at corresponding shell diameters, and the microconch seems to differ only in that it may be more evolute. The body chamber is crushed on all specimens, but it appears to have been only weakly compressed. The keel remains low and is similar to the macroconch at corresponding shell diameters. The body chamber comprises one half to two thirds volution.

Particularly for the microconch ornamentation is variably developed. The complex ornamentation is a function of differential expression of several sets of ornamentation. The finest ornamentation consists of dense surficial growth striae which may occur at any shell diameter. Fine acute, dense ribs, which have been measured in the ventro-lateral area on the microconchs, most commonly at shell diameters between 7-22 mm, have a density of 40-60 ribs per cm. This rib style, herein termed "first order" ribbing, appears to be very regularly spaced and even in strength when it occurs to the exclusion of the other rib sets. A second order of ribbing is coarser in strength and is usually half as dense. It may be regular or irregular in strength and spacing. Bullate swellings which have already been described for the macroconch, occur also in the microconch. Lastly the microconch body chamber sometimes displays
widely spaced (6-7 ribs per cm) mid-flank, convex plicae.

The ornamentation of the microconch consists principally of first order costation. Dense growth striae are often present, and second order ribbing often occurs for short intervals during the ontogeny of the individual. A specimen figured by Imlay (1973a, pl. 3, fig. 28-30) is probably a microconch which exhibits regular development of the first order ribbing. The microconch figured by Imlay (1973a, pl. 3, fig. 31) displays an admixture of first and second order ribbing. The supposed microconch figured by Imlay (1973a, pl. 3, fig. 5-7), which possesses exclusively second order ribbing, is very rare. Most microconchs compare favorably with another example figured by Imlay (1973a, pl. 3, fig. 32), which displays an admixture of first and second order ribbing, with the first order accounting for most of the ornamentation.

Discussion: The different ornamentation densities are usually quite distinct, and appear to have developed independently of the other. For this reason it was possible to plot first and second order rib densities for both microconchs and macroconchs (fig. 8). The graph suggests similar development of second order rib density for both dimorphs with increasing shell diameter. First order density is based upon meager information, but the trend appears similar to that of the coarser ribbing. The differences in fineness of ornamentation for the macroconch and microconch therefore is a function of relative predominance of the two rib orders. First order ribbing is uncommon in macroconchs, whereas that costation predominates in the microconch. Also, of the juvenile specimens,
Figure 8. Rib density distribution in *Asthenoceras boreale* (Whiteaves).
which usually account for the vast majority of specimens of *A. boreale* which have been found, 70-90 percent are finely ornate and are probably microconchs.

The hypodigm available to me is highly variable morphologically. No reasonable criteria have been devised to split the sample since there appears to be continuous morphic variation between coarsely and finely ornate material for each dimorph. Moreover the specimens from nearly all the localities, where reasonably well preserved and large samples have been taken, (A-0853, A-0631, A-0606, A-0619), exhibit a similar range of morphic variation.

Most of the hypodigm available to Imlay (1973a) was derived from localities in the type area of the Warm Springs Member, where specimens are well preserved, but are mostly inner whorls. Therefore it is not surprising that the macroconchs figured by him under *Witchellia connata* (Imlay, 1973a, pl. 20, fig. 4) and *Asthenoaeras* ? sp. (Imlay, 1973a, pl. 35, fig. 10), were not identified as the macroconch of his *Asthenoaeras delicatum*. A latex mold of the latter specimen was kindly sent to the author. The reported lappet on that specimen is the external mold of another small ammonite, perhaps a microconch. A keel and dense ribbing can be seen on the mold of the supposed lappet.

The holotype for *A. boreale* (and additional figured specimens) were refigured and redescribed under *Grammoaeras* by Frebold (1964, pl. 18, pl. 7, fig. 3,4) and are virtually identical to macroconchiate material from Oregon.

*Asthenoaeras boreale* may have a similar rib density, profile
and strength to the type species (Buckman, 1888, p. 49, pl. 3, fig. 28; 1890, p. 213, pl. 33, fig. 13-16), but the English species differs by having a much more compressed whorl section.

**Asthenceras costulum (Imlay)**

*Fontannesia costula* Imlay, 1973a, p. 57, pl. 4, fig. 16-26.

*Fontannesia intermedia* Imlay, 1973a, p. 57, pl. 4, fig. 7-15.

*Pelekodites weberti* Imlay, 1973a, p. 73, pl. 34, fig. 19-34.

### Macroconch

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### Microconch

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**Description, macroconch:** The adult phragmocone attains a diameter of 30-60 mm, while the entire shell attains a diameter of approximately 50-70 mm. The shell is evolute. Umbilical whorls overlap one half, and at 10 mm diameter juvenile whorls overlap one third to one quarter. The whorls egress gradually, with an involution of one seventh to one tenth on the body chamber (adoral end). Imlay records somewhat more than one half of a whorl for the body chamber...
and an aperture which is gently sinuous with broken ventral lappet (Imlay, 1973a, p. 57). The whorl section is subovate, much higher than wide, with gently rounded sides becoming somewhat flattened on the body chamber. The umbilicus is shallow, with a low wall, nearly vertical at its base and rounding gently onto the flanks. The venter is narrow, fastigate on the outer whorls, and has a narrow non-sulcate flattened area on the venter which is an extension of the sulcae on the keel. The keel is hollow, floored, low, and blunt on the inner whorls, and by 25 mm shell diameter becomes typically high, narrow and laterally sulcate.

The ornamentation varies considerably in strength. On intermediate whorls the weakest ribbed specimens have nearly smooth lower flanks and faint to weakly ribbed upper flanks. The strongest ribbed specimens have costation on the whorl sides which becomes strongest on the upper two thirds of the flanks. The outer whorls vary similarly in costation strength; although, on the body chamber costation is always weak to moderately strong on the upper flanks. All whorls greater than about 4 mm shell diameter have densely spaced striae which continue over the keel. The whorl at 2 mm shell diameter bears low, broad swellings and may be faintly striate. At a shell diameter greater than 7 mm, dense ornamentation is moderately to strongly sigmoid depending upon the convexity of the mid-lateral obscure to weak plications which bear striae. Some of the striae are fasciculate. By 20-25 mm shell diameter the ribbing is usually well developed and gently flexuous, nearly upright and biconcave.

The simplest ribbed specimens have essentially the same ornamentation
on the outer whorls excepting for the presence of numerous costae arising mainly by intercalation on the upper one third of the flanks. The ribbing usually maintains the partly fasciculate striae as on the earlier whorls.

Several specimens develop bifurcate and intercalatory ribbing mostly on the adoral half of the last septate whorl, although it may begin at the juvenile stage. The low primaries give way to sharper, fairly dense ribbing by intercalation and bifurcation about at mid-flank as well as high on the whorl sides. On the body whorl the primaries are low, broad, gently flexed, widely spaced, irregular in strength, and project nearly radially. Ribbing may be moderately strongly falcoid.

Microconch: The complete shell of the microconch is between 22 and 26 mm in diameter. Material with finer ribbing bears essentially the same ornamentation and whorl section of the macroconch at corresponding shell diameters. However, the whorls egress rapidly at 6 to 10 mm shell diameter where the involution changes from one half to one third or one fourth in one quarter volution. The keel is low, blunt and rarely attains a high, laterally sulcate section on the body chamber. The body chamber is about three fifths of a whorl and ends in elongate lateral lappets and a shorter v-shaped ventral projection. Most strongly ornamented specimens undergo rapid whorl egression at 10-12 mm shell diameter, after which the septate whorls bear low, prominent, fairly widely spaced, gently convex costae which may become rursiradiate, and are strongest on the ventro-lateral edge where they terminate abruptly. The whorl section thus becomes
subquadrate. Specimens with a moderately falcoid rib profile have costae originating by bifurcation near mid-flank and by intercalation primarily high on the whorl sides. Specimens with gently falcoid ribbing have simple costation. Striae are not prominent. The body chamber often has adorally increasingly convex mid-lateral plicae.

Description of a deformed specimen: A single specimen 18 mm in shell diameter possesses a body chamber which has a subquadrate whorl section, and incipient keel, and coarse convex folds which pass over the venter. On the outer part of the phragmocone whorl dimensions and shell proportions are identical to *A. costulum*, and the keel is low but distinct. The venter is flattened at the adoral end of the phragmocone. It is possible that this is an injury site which initiated the development of the deformed body chamber.

Discussion: The abundant material from the type area of the Weberg Member yielded several specimens intermediate in rib strength between Imlay's two species *Fontannesia costula*, and *F. intermedia* (Imlay, 1973a), which are herein considered junior synonyms of *A. costulum*. Many of the microconchs have ornamentation identical to the macroconchs at corresponding shell diameters, making identification of dimorphic counterparts difficult for several incomplete specimens. There is an intergradation in the microconchiate form of the more finely ornamented specimens with those which are more coarsely ribbed. It is possible that the shells with the more inflated whorl section, which are also the rursiradiate, simple ribbed specimens, merely retain to larger shell diameters, ornamentation equivalent to an earlier growth stage of the more finely ribbed
microconchs. The shift in ornamentation from a simple and coarsely ribbed, to a complex and finely ribbed style usually accompanies the rapid whorl egression of the juvenile whorls.

_A. boreale_ differs from _A. costulum_ by having more inflated inner whorls, greater shell evolution, stronger costation, by possessing fasciculate ribbing low on the flanks, sharper striae and ribs on the inner and intermediate whorls, and by having much denser and more strongly falcoid ribbing. _A. costulum_ has ornamentation identical to the material described by Westermann (1969b) under _A. sp. aff. A. nannodes_ (Buckman). The Oregon material is differentiated for the time being, however, as the specimens of _A. costulum_ are much larger. None of the specimens of _A. costulum_ have the same regularly developed, simple, thin and sharp ribs as does _A. nannodes_ (Buckman, 1899, p. 49; 1889, p. 213, pl. 33, fig. 13-16).

Genus _Fontannesia_ Buckman, 1902

*Fontannesia grantensis* Taylor, n. sp.

Pl. 1, fig. 3a, b; 4

*Fontannesia cf. F. luculentia* (Buckman); Imlay, 1973a, p. 58. [in part], pl. 5, fig. 14-17.

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
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<th>H</th>
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_Holotype_: Pl. 1, fig. 3a, b; internal mold, parts of two adult whorls. _Repository_: University of California, Berkeley, Museum of Paleontology no. D-6744-7.

_Locus typicus_: University of California, Berkeley, Museum of
Paleontology, locality D-6744: Packard Draw section.

*Stratum typicum:* Webberg Member, Snowshoe Formation, from a 0.23 m thick crinoidal biosparite bed 22.22 - 22.45 mm stratigraphically above base of Webberg Member.

*Derivatio nominis:* Name taken from Grant County, Oregon.

*Diagnosis:* Shell strongly evolute; whorl section of phragmocone subcircular to subovate, weakly compressed; section of body chamber weakly to moderately compressed; no ventro-lateral nodose ornamentation on outer whorls.

*Description:* The nucleus is poorly preserved but is probably depressed and subovate to subcircular. The weakly compressed whorl section of the adult is subovate to subcircular. The umbilical wall arises nearly vertically from the umbilical seam and is fairly high, however, an umbilical shoulder, if at all present, is very gently rounded. The whorl flanks are gently or moderately convex and the venter is broadly rounded but has no distinctly flattened areas. Adorally the whorl section becomes somewhat compressed, thus the body chamber is never subcircular. The shell is moderately evolute.

The ribbing of the nucleus (to 26 mm shell diam.) is fairly strongly falcoid; the costae first become strong at mid-flank where the rib profile is convex. The upper part of the flanks have not been observed. The ribbing on the outer whorls is also sigmoidal. Ribs are at first prorsiradiate where they begin low on the flanks, are convex just below mid-flank and usually trend backwardly or radially most of the remaining distance up the whorl sides, curve forward on the ventro-lateral area, and terminate before reaching the keel.
The ribs first become strong where the rib profile is convex, but usually are strongest high on the flanks where the rib profile is concave. Ventro-lateral nodose ornamentation is at most incipient, at least on the outer whorls. Costation is predominantly simple to fasciculate, but many ribs arise also by intercalation low on the flanks. A few ribs arise by bifurcation on the lower half of the whorl sides, temporarily altering the trajectory of the secondary ribbing.

Discussion: An example of this species illustrated under *F. cf. F. luculenta* by Imlay (1973a, p. 58, pl. 5, fig. 14-17) appears to have slightly less concave flanks on the body chamber than most examples. However, the specimen figured by Imlay actually has a stout whorl section, excepting on the adoral part of the body chamber. The rounded and inflated whorl section, coupled with relatively weak ventro-lateral ornamentation, are quite distinctive, so the taxon is not likely to be confused with most other species of *Fontannesia*. This species is not much different from *F. cf. F. luculenta* in development and strength of ornamentation, but the whorl section is very dissimilar.

*Fontannesia cf. F. luculenta* Buckman

cf. *Fontannesia luculenta* Buckman, 1905, p. 189; 1892, pl. 46, fig. 4,5,8; pl. 47, fig. 1-12.

*Fontannesia cf. F. evoluta* Buckman; Imlay, 1973a, p. 59, pl. 5, fig. 1-3.

*Fontannesia cf. F. carinata* Buckman; Imlay, 1973a, p. 58 [in part], pl. 5, fig. 4-6, 9-13.

Description: The whorl section of the nucleus is subovate, and
a ventro-lateral shoulder may be defined as early as 7 mm shell diameter. The whorl section of the adult phragmocone is subovate to subquadrate. The umbilical shoulder is variably conspicuous, but is always quite gently rounded. The flanks are flattened or gently convex; a ventro-lateral shoulder is usually present and the venter is fastigate. Whorl sides meet at the carina at an angle of about 120 degrees. On the outer whorls the ventro-lateral shoulder, though present, usually becomes less well defined.

The ornamentation of the nucleus first becomes prominent on the upper part of the flanks at a shell diameter of 7 mm or more, and may remain obsolete on the lower part of the flanks to a shell diameter of at least 24 mm. On most specimens are ventro-lateral subnodose or nodose protuberances. On the inner whorls the rib profile is typically falcoid, however, the most coarsely ornate specimens, which have ventro-lateral nodes, bear ribbing on the lower part of the flanks which is gently convex but nearly straight. On the outer adult whorls the ventro-lateral nodose ornamentation diminishes in strength concomitantly with rounding of the ventro-lateral area. The ribs at this stage are also falcoid; they first become prominent near the ventro-lateral convexity, and are often strongest in the ventro-lateral area.

Discussion: The material from Oregon shows no significant differences from *F. luculenta* and may belong to that species.

*Fontaminesia* aff. *F. luculenta* Buckman

Pl. 1, fig. 2 a,b

Description: This species has a strongly evolute shell. The
inner whorls are not well preserved, but the whorl section of the last volution is subquadrate. The umbilical wall is steep but low, and rounds onto flattened, subparallel flanks. A ventro-lateral shoulder is present and the fastigate venter is moderately broad; it may be nearly flattened, or the two sides may meet at the carina at an angle as acute as 120 degrees.

The costation is widely spaced, strong, prorsiradiate or radially trending, and is usually straight, but may be gently falcoid. Occasionally incipient nodes are present on the umbilical shoulder. Ribbing is slightly inflated to subbullate just below mid-flank. The ventro-lateral shoulder bears strong nodes that weaken but persist to the latest preserved shell diameters.

Family SONNINIIDAE Buckman, 1892

Genus Soninia Bayle, 1879

*Sorninia* [?] n. sp.

Pl. 8, fig. 2

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Description: Two partially crushed specimens from the upper division of the Webberg Member from Washburn Draw (localities A-0565, A-0552) comprise the hypodigm for this species. The largest example, which is from A-0565, does not show the end of the phragmocone, but the body chamber is represented by shell diameters of approximately 110-170 mm. The smaller specimen is septate to about 80 mm shell.
diameter.

The nucleus is strongly evolute and the inner adult whorls gradually increase in involution so that the body chamber at large shell diameters appears to be fairly involute. The nucleus appears to have had a subcircular whorl section, which rapidly becomes strongly compressed adorally. An umbilical shoulder first appears at about 30-40 mm shell diameter, and remains gently rounded adorally. The body chamber of the large specimen has a low umbilical wall and a subacute umbilical shoulder at an estimated shell diameter of 115 mm. The venter of the adult phragmocone is slightly bisulcate, and supports a fairly prominent keel (keel height at 75 mm shell diameter is about 1.75 mm).

The nucleus is spinose to about 25 mm shell diameter. Adorally on the adult phragmocone are dense, gently flexed, biconcave, gently prorsiradiate, fasciculate to subfasciculate ribs with a density on the outer flank of 28-30 ribs per one half volution at 70 mm shell diameter. At an estimated shell diameter of 150 mm the rib density is about 14 costae per one quarter volution. The conspicuous but only moderately strong ribs of the adult phragmocone are mostly strongest at mid-flank, but are noticeable and even conspicuous high on the flanks, and expire before reaching the vague sulcae. At large shell diameters the ribbing is very weak, strongest at mid-flank, and expires in the ventro-lateral area.

Discussion: There is no evidence of papillae on the available specimens, thus precluding an assignment to Papilliceras. Since this
species occurs well below the established range of *Soninia s. s.*, and since the species is not well represented, the assignment to *Soninia* remains tentative.

Genus *Papilliceras* Buckman, 1920

*Papilliceras* cf. *P. blackwelder* Crickmay


Discussion: This form differs from typical *Papilliceras blackwelderi* in that it has very coarse, high conical or bullate nodes on the body chamber at large shell diameters.

*Papilliceras* cf. *P. juramontanum* Crickmay

cf. *Papilliceras juramontanum* Crickmay, p. 911, pl. 31, fig. 1.

*Soninia* (*Papilliceras*) cf. *P. (S.) juramontana* (Crickmay); Imlay, 1973a, p. 69, pl. 27, fig. 1.

*Soninia* (*Papilliceras*) cf. *S. (P.) espinazitensis* Tornquist; Imlay, 1973a, p. 69, pl. 27, fig. 4-6.

Description: This species is fairly evolute (*U/D=0.34-0.42*) while the whorl section is usually moderately compressed (at shell diameters greater than 75 mm, *H/W=1.37-1.44*), but rarely is strongly compressed (*H/W* to 1.87). The inner whorls are subcircular in cross section, and become subovate at 25-35 mm shell diameter. Adorally the umbilicus is gently rounded, but is well defined. The umbilical wall is vertical or steeply inclined on the inner adult whorls, but always slanted on the outer whorls.

The adult whorl section is nearly ogival. The flanks are parallel, quite gently convex, and round gently onto a moderately broadened venter which supports a low keel (110 mm shell diam., *H=1.52 mm; W=2.0 mm*), and very shallowly grooved sulcae. The sulcae are
evident only in the internal mold; where shell is present the venter is narrowly tabulated.

To a shell diameter of 7-10 mm the nucleate whorls are smooth or bear obsolete undulations on the lower part of the flanks. Adorally on the most finely ornate specimens the undulations (5-6 per one half whorl) may be well developed on the remaining juvenile whorls (or to 25 mm shell diam.), and form bundles from which up to 6 falcoid ribs may arise by fasciculation. The juvenile may lack these prominent undulations, in which case the nucleus may exhibit only subfasciculate to simple, gently falcoid costation. Adorally the ribbing remains gently falcoid, convex and swollen at mid-flank. If the ribbing of the inner adult whorls is fasciculate the ribs may arise in pairs on the lower one half of the flanks, however, costation may be nearly simple. Rib density is estimated to range from 16-28 costae per one half whorl.

More coarsely ornate specimens bear costation on the inner adult whorls which is stronger, less dense (about 14-22 ribs per one half whorl) and more irregular in strength; in one coarsely ornate specimen the ribbing appears to be nearly straight. On the outer juvenile and inner adult whorls the ribbing is fasciculate. The costae which arise in pairs are usually more strongly inflated near mid-flank than those which are simple; those which bifurcate at mid-flank may be distinctly bullate. All the ribs are strongest near mid-flank and are weak to obsolete on the upper one half of the whorl sides.

On the outer whorl of the phragmocone the ribbing becomes widely
and evenly spaced, much stronger, nearly straight and radial, and papillate. Between shell diameters of 60-80 mm this transition usually occurs quickly, within one quarter volution. On most coarsely ornate specimens the transition is gradual, but may be completed by 50 mm shell diameter.

Although density of papillate costation ranges from 10-20 ribs per one half whorl, most examples have 10-12 costae per one half whorl. The ribs begin on or just above the umbilical shoulder, become fairly strong and trend radially to the mid-flank papillae. Above mid-flank they immediately become weak or obsolete, they trend radially or slightly backwardly just above the papillae, are gently concave, and swing forward on the ventro-lateral area where they are no longer traceable; however, the growth striae of some specimens were observed to be fairly strongly projected on the venter. On fragments of body chambers of large individuals the ribbing is less sharp and begins above the umbilical shoulder.

Discussion: *P. juramontanum* is close to the densely papillate material from Oregon, but is more strongly costate than most of those specimens. Topotypic material recently collected by the author at Mount Jura indicates that *P. juramontanum* exhibits a similar range of morphic variation as the hypodigm from Oregon, but until the Mount Jura material is described, the sample from Oregon is considered to compare favorably with *P. juramontanum*.

*P. cf. P. juramontanum* differs from *P. espinasitensis* (Tornquist) (see: Westermann and Riccardi, 1972) by usually being more evolute, by possessing a more reclined umbilical wall, a more acutely rounded
umbilical shoulder, and by having nearly radial instead of prossi-
radiate costation. Also, the nucleus of the specimens from Oregon is
never spinose. Some specimens from Oregon are virtually identical to
*Euhoploceras costatum* (Buckman, 1892, p. 338, pl. 74, fig. 1) except-
ing, of course, for the absence of papillae in that species.

Genus *Euhoploceras* Buckman, 1913

*Euhoploceras acanthodes* (Buckman)

[?] *Sonninia multispinata* Buckman, 1892, p. 317, pl. 50, fig. 11-13.

*Sonninia crassispinata* Buckman, 1892, p. 317 [in part], pl. 48, 
fig. 16, 17; pl. 50, fig. 16-18; pl. 57, 65.

*Sonninia acanthodes* Buckman, 1892, p. 319, pl. 58-60; pl. 63, 
fig. 1.

*Sonninia irregularis* Buckman, 1892, p. 320, pl. 61.

*Sonninia ptycta* Buckman, 1892, p. 332, pl. 73, fig. 1.

*Sonninia cymatera* Buckman, 1892, p. 332, pl. 73, fig. 2,3.

*Sonninia magnispinata* Buckman, p. 341, pl. 76, fig. 1-6.

*Sonninia biplicata* Buckman, 1893, p. 346 [in part], pl. 78, fig. 
4,5.

*Sonninia crassiformis* Buckman, 1893, p. 348, pl. 79, fig. 1-6.

*Sonninia euromphalica* Buckman, 1893, p. 362, pl. 85, fig. 1-3.

*Sonninia omphalica* Buckman, 1893, p. 363, pl. 83, fig. 5-7.

*Sonninia nodata* Buckman, 1893, p. 369, pl. 89, fig. 1-3.

*Sonninia abnormis* Buckman, 1894, p. 377, pl. 85, fig. 4-6.

*Sonninia regularis* Buckman, 1894, p. 395, pl. 96, fig. 3-5. 
(1892, *S. marginata* Buckman, this mon. pl. 64 only).

*Sonninia duplicata* Buckman, 1894, p. 402, pl. 99, fig. 1-3.

*Sonninia magnispinata* Buckman, 1894, p. 413, pl. 98, fig. 1-3.
Sonninia mutans Buckman, 1894, p. 414, pl. 91, fig. 4-6.
Sonninia biplicata Buckman, 1894, p. 417, pl. 103, fig. 16.
Sonninia acanthes Buckman, 1894, p. 419, pl. 100, fig. 8.
Sonninia ptycta Buckman, 1894, p. 420, pl. 96, fig. 7.
Sonninia realinans Buckman, 1894, p. 421, pl. 98, fig. 7; pl. 103, fig. 21, (1892, Sonninia crassispinata (in part) (this mon., pl. 48, fig. 16-17; pl. 65. fig. 3,4, p. 318 (pars.)).
Sonninia gibbera Buckman, 1894, p. 421, pl. 87, fig. 4,5.
Sonninia multispinata Buckman, 1894, p. 425, pl. 103, fig. 3.
Sonninia crassispinata Buckman, 1894, p. 425, pl. 93, fig. 7.
Sonninia subirregularis Buckman, 1894, p. 426, pl. 98, fig. 4,5; pl. 77, fig. 6,7 pl. 88, fig. 4.
Sonninia lueoples Buckman, 1894, p. 431, pl. 92, fig. 1-4; pl. 103, fig. 4.
Sonninia reformata Buckman, 1894, p. 434, pl. 89, fig. 6-8.
Sonninia cf. crassiformis Buckman; Maubegue, 1951, p. 17, pl. 9, fig. 3.
Sonninia (Eunoplaceras) adara (Waagen); Imlay, 1973a, p. 65, fig. 7-12; pl. 14, fig. 1,2,5; pl. 15, fig. 1,2,3,5; pl. 17.

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**Diagnosis:** Coiling moderately to strongly evolute, whorl section of outer whorls subcircular, subovate or subogival; whorl flanks moderately to strongly convex, umbilical shoulder not present to well developed on adult whorls; inner whorls bear regular series of rounded tubercles to at least 25 mm shell diameter; tubercles become irregular in occurrence and usually are bullate on intermediate whorls, and generally expire on outer whorls; costae weakly to strongly concave, radial to strongly reclined, strongest at mid-flank, usually prominent on upper flanks, irregularly strong on intermediate whorls, fairly regular in strength on outer whorls.

**Description:** The coiling of this species is moderately to strongly evolute. The inner whorls to a shell diameter of at least 30 mm bear a subcircular whorl section. Adorally the whorl section may remain strongly inflated and subcircular, or subogival, or may become moderately compressed and subovate or subogival. A distinct but gently rounded umbilical shoulder may develop on the adult whorls irrespective of the whorl compression. The flanks are rarely nearly flattened, but are moderately to strongly convex. The incomplete body chamber of A-0555-30 comprises three-quarters of a volution. The venter is often weakly sulcate.

The inner whorls, to at least 25 mm shell diameter, possess a regular series of strong, rounded tubercles (5-8 per one half whorl). These tubercles are borne on concave costae. Costation of the adult phragmocone is characteristically irregular in strength and the tubercles generally become bullate and sporadic in their occurrence as
they become less common adorally. Tuberculated costae may be simple, but generally possess associated secondaries and intercalatories. Rib strength becomes strong only as it approaches mid-flank, is highest at mid-flank, and commonly remains well developed on the upper flanks, but expires before reaching the keel. Costation profile on the adult whorls may be weakly to strongly concave, and is strongly reclined to radially projected on the lower flanks. The costae become forwardly projected on the upper flanks.

**Discussion:** Most of the examples of *E. acaanthodes* from Oregon are either identical to or are very similar to species of *Euhoplo ceras* described by Buckman (see above synonymy). As herein understood *E. acaanthodes* exhibits a wide range in morphology with respect to the compression of the whorl section, convexity of flanks, development of umbilical shoulder, concavity of rib profile, re- inclination of ribbing, strength and persistence of spinose ornamentation, and a moderate degree of variation in coiling, and costation strength and density. These characteristics, which in other species of *Euhoplo ceras* generally vary interdependently, vary independently of each other in *E. acaanthodes*. The amount of morphic variability realized by the species is tremendous. Consequently, each of the specimens available for study differs from the other to a variable degree. No morphological subgroups can be clearly delimited. Clearly it will only be possible to determine whether more than one species should be recognized for *E. acaanthodes* by having available for study large collections of specimens from many stratigraphic
levels. From England the sample is sufficiently large, but there is no stratigraphic control. From Oregon the stratigraphic control may be sufficient, but unfortunately, although this taxon is not rare, it is never locally abundant. Although at present it is not possible to demonstrate with any degree of satisfaction whether *E. acanthodes* as herein understood is a single species, it is at least a morphological entity which, excepting for a few transitional specimens, is easily separable from other species of *Euhoplloceras*. Therefore, the material from Oregon is referred to a single species, *E. acanthodes*, since any attempt to split the hypodigm would be purely arbitrary, and because it does comprise a coherent albeit phenotypically variable taxon. Where preservation permits, each of the available specimens is compared with a previously illustrated example.

Specimen A-0560-23 has an estimated shell diameter of 75 mm; it resembles *E. duplicatum* (Buckman, 1894, pl. 99, fig. 1) particularly bearing gibbous-sided inner adult whorls with long, slender spines. The whorl section is depressed and subcircular, and by the largest shell diameter is depressed subogival.

Specimen A-0550-22 has an estimated shell diameter of 125 mm. In ornamentation it is nearly identical to *E. acanthodes* (Buckman, 1892, pl. 57). The ribs of A-0550-22 are more prominent high on the flanks, and the tuberculated costae are not as prominent just below the nodes. The whorl section from about 85 mm shell diameter is moderately compressed, and the umbilical shoulder is rather tightly rounded.
Specimen A-0625-25 has an estimated maximum shell diameter of 115 mm. It is nearly identical to *Euhoploceras cymatera* (Buckman, 1892, pl. 73, fig. 2,3). The spines on A-0625-25 are coarser and persist to a greater shell diameter than on the English form. Also, the whorl section of the last one half voluteion on A-0625-25 has subparallel flanks, the umbilical wall is vertical, and the umbilical shoulder is rather tightly rounded.

D-6744-27 has a maximum shell diameter of 86 mm. The specimen is nearly identical to *E. biplicatum* (Buckman, 1893, pl. 78, fig. 4,5). The specimen is also very much like the inner whorls of *E. acanthodes* (Imaly, 1973a, pl. 16). The irregularly nodose stage persists to the largest preserved shell diameter.

A-0970-26 has a maximum preserved shell diameter of 70 mm. It is also like *E. biplicatum* (Buckman, 1893, pl. 78, fig. 4,5).

A-0975-29 has an estimated maximum shell diameter of 107 mm. It is essentially identical to *E. crassiformis* (Buckman, 1893, pl. 79, fig. 3,4). The outer preserved whorl is weakly bisulcate.

A-0563-33 has an estimated maximum shell diameter of 160 mm. It compares favorably with *E. duplicatum* (Buckman, 1894, pl. 99, fig. 1,2). However, the long and slender spines leave the umbilical seam earlier. Regularly spaced, coarse spines persist to about 70 mm shell diameter, and bullate nodes continue to the largest preserved shell diameters. The whorl section is subcircular to over 70 mm shell diameter, and the body chamber has a compressed, nearly subquadrate section. The rib height is strong high on the flanks of the
outer whorl. Striae and costae of the inner whorls are strongly concave in profile.

The nearly complete shell of A-0555-30 has a maximum preserved shell diameter of 100 mm. It is very close in appearance to *E. acanthodes* (Buckman, 1892, pl. 48, fig. 16, 17). The whorl section of the phragmocone is subcircular; the body chamber whorl section is compressed and subovate, the umbilical shoulder is at most incipient. High, slender, conical spines increase in strength to the maximum preserved shell diameter.

*Euhoploceras* cf. *E. crassirudum* (Buckman)

Pl. 2, fig. 1a, b, 2.

cf. *Sonninia crassirudata* Buckman, 1893, p. 351, pl. 81, fig. 1-4.

cf. *Sonninia crassibullata* Buckman, 1893, p. 353, pl. 80, fig. 1-3.

cf. *Sonninia crassicostata* Buckman, 1893, p. 354, pl. 80, fig. 4,5.

cf. *Sonninia diversa* Buckman, 1893, p. 355, pl. 83, fig. 1, 2; pl. 81, fig. 5, 6.

cf. *Sonninia laevigata* Buckman, 1893, p. 356, pl. 82, fig. 5, 6.

cf. *Sonninia paucinodosa* Buckman, 1893, p. 370, pl. 91, fig. 7-9.

cf. *Sonninia crassicostata* Buckman, 1894, p. 398, pl. 103, fig. 18.

cf. *Sonninia diversa* Buckman, 1894, p. 399, pl. 103, fig. 8.

cf. *Sonninia crassibullata* Buckman, 1894, p. 400, pl. 103, fig. 17.

cf. *Stiphromorphites schucherti* Crickmay, 1933, p. 909, pl. 28, fig. 1-3.

cf. *Sonninia luciusi* Maubeuge, 1951, p. 14, pl. 3; pl. 14, fig. 5; text-fig. 2-4.
Specimen no. | Place measured | D  | H  | W  | U  | H/W | U/D  
---|---|---|---|---|---|---|---
A-0571-31 | phragmocone | 107 | 37 | 27 | 45 | 1.37 | 0.42  
A-0571-31 | body chamber | 190 | 68 | 55 | 70 | 1.24 | 0.37  
A-0556-32 | phragmocone | 47  | 17 | 17 | 16.5 | 1.00 | 0.35  
A-0556-32 | phragmocone | 68  | 24 | 24 | 24 | 1.00 | 0.35  

**Description:** Two examples of this species from A-0571 and A0556 are moderately strongly evolute. The ogival whorl section of the adult is attained by 20 mm shell diameter. The umbilical wall is nearly vertical, the shoulder is subacute, and the flanks are nearly flattened and round gently onto a very broad venter which bears no indication of sulcae.

The nucleus of A-0556-32 is fairly densely costate and appears to be non-tuberculated at least to a shell diameter of 17 mm. On the inner adult phragmocone are about six spines per one half whorl, and intervening costae of irregular strength. Costation strength is greatest at mid-flank. Adorally on the phragmocone only the widely spaced coarse tubercles are conspicuous, as most costation drops out. Ribbing on the upper flanks arises by bifurcation, trifurcation, and intercalation, is weak or obsolete, and is fairly strongly projected on the venter. On A-0556-32 one eighth of the last whorl is non-septate. The body chamber of the example from A-0571 encompasses nearly three quarters of a volution. The tuberculate costation of the phragmocone is replaced on the body chamber by fairly dense (c.11 costae per one half whorl), simple, radial, and bullate ribs.

A small specimen from A-0615 differs from the two above described examples by having much more involute and compressed whorls, and by possessing denser and weaker ornamentation.
Discussion: The two examples from A-0571 and A-0556 are nearly identical to *E. crassinudum* (forma *crassibullatum*), although the specimen from A-0556 differs from the English material in that it has a costate instead of a tuberculate nucleus. The example from A-0616 is closest to *E. crassinudum* (forma *crassinudum*), but differs by possessing a more compressed whorl section, and the moderate involution and weaker ornamentation begins at an earlier growth stage.

*Euhoploceras* aff. *E. densicostatum* (Buckman)

Pl. 3, fig. a,b; Pl. 4, fig. 1

aff. *Sonninia densicostata* Buckman, 1893, p. 375, pl. 88, fig. 8,9,9a.

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Description: The nucleus of this species possesses a sub-circular whorl section, and by 10-15 mm shell diameter the subogival whorl section which characterizes the adult shell is present. The umbilical wall is vertical, the distinct umbilical shoulder is gently rounded, and the very gently convex, subparallel flanks round evenly onto a venter which is not particularly wide. Shallow, narrow sulcae are present on the body chamber. The keel is narrower than on most species of *Euhoploceras*. A-0570-34 bears a keel that is 2 mm high and 1.7 mm wide at 85 mm shell diameter.

The nucleus is non-spinose. The ornamentation of the phragmocone is gently falcoid or biconcave in profile, and the ribs may be swollen but are not nodose or pointed on the middle one third of the
flanks. On the inner whorls of the phragmocone costation is fasciculate, it arises mostly from low undulations, and it becomes subfasciculate adorally. The primaries usually arise low on the flanks; several secondaries arise by fasciculation further up the flanks, commonly at the mid-flank swelling. Ribbing is gently projected on the venter and expires close to the keel. The fasciculate and subfasciculate costation of the phragmocone on A-0570-34 differs in that none of the ribs branch above the base of the flanks, and the whorls are also densely striate.

On the body chamber ribbing becomes more distantly spaced and stronger. A-0570-34 bears about 12 costae per one half whorl on the incomplete (?) body chamber of three quarters volution. The ribs begin on or just above the umbilical shoulder, and trend backwardly across most of the flanks. The ribs are inflated at mid-flank; no distinct nodes are present, but some of the ribs have pointed swellings. The ribbing remains strong on the ventro-lateral area where it bends sharply forward and expires only a short distance from the keel.

Discussion: E. aff. E. densicostatum is morphologically closest to E. densicostatum, although it differs from that form in that its ribbing is finer, more strongly falcoid, and is usually less simple, at least on the phragmocone.

*Sonminia dominans* (Buckman)

*Sonminia dominans* Buckman, 1892, p. 322, pl. 66, pl. 67, fig. 1, 2; pl. 69.

*Sonminia submarginata* Buckman, 1892, p. 329, pl. 71, fig. 1-3.
Sonninia subcostata Buckman, 1892, p. 330, pl. 71, fig. 4,5.

Sonninia multicostata Buckman, 1894, p. 410, pl. 86, fig. 1-3.

Sonninia dominans Buckman, 1894, p. 435, pl. 94, fig. 1, 2; pl. 95, fig. 1; pl. 97, fig. 4.

Sonninia (Euhoploceras) dominans Buckman. Imlay, 1973a, p. 63 [in part], pl. 12, fig. 1, 2, 4, 5.

Euhoploceras (Euhoploceras) adiara (Waagen). Imlay, 1973a, p. 65 [in part], pl. 15, fig. 4.

Euhoploceras (Euhoploceras) ? dominans (Buckman). Morton, 1975, p. 48, pl. 7, fig. 1, 2.

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<td>--</td>
<td>1.33</td>
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**Diagnosis:** Inner whorls usually tuberculate, subovate in section; adult whorl section ogival, umbilical shoulder well defined, flanks very gently convex, venter moderately to broadly rounded; ventral sulcae absent or weak, present only on internal mold; costation nearly radial, weak to moderate in strength, strongest at mid-flank.

**Description:** The inner whorls pass from a subcircular to a subovate section at a shell diameter of 20-25 mm. Adorally the umbilical wall increases in height and becomes vertical, so that by 40-45 mm shell diameter there is a gently rounded but pronounced umbilical shoulder which within another one half whorl becomes sharply rounded. At the same time the flanks pass from gently convex to nearly flattened. The nearly parallel sides round gently onto a
broad venter which supports a low keel that may be bordered by incipient sulcae, seen only on the internal mold. Thus the whorl section of the adult is characteristically ogival (H/W=1.19-1.33). The moderate involution of the adult shell (U/D=0.33-0.36) varies within fairly narrow limits.

The inner whorls bear regularly developed and spaced, rounded and small tubercles (5-7 per one half volition). Beginning at 15-22 mm shell diameter the tubercles become increasingly distantly spaced for about the next one half to one and three quarters whorls (or to a shell diameter of 40-55 mm); they alternate with 1-4 simple to fasciculate, sometimes bullate costae. The tubercles also are borne either on simple or on two fasciculating costae. Costae on the tuberculate whorls are strongest at mid-flank and are nearly radial, excepting on the most coarsely spinose specimen (specimen from A-0974) where the costae are concave to 35 mm shell diameter. Adoral to the last tubercles, ribbing of highly irregular strength may continue for about one half whorl; the costae are usually simple, but are sometimes subfasciculate. Costation on the adult whorls is very gently biconcave in profile.

On the outer whorls ribs are weak to moderate in strength (1-1.5 mm in height at mid-flank), and are essentially radial, though they may either be slightly reclined or gently prorsiradiate (projected about 2-5 degrees). The costae become pronounced at mid-flank, where incipient papillae are usually developed beyond 120 mm shell diameter. The ribs remain relatively strong only a short
distance above mid-flank or may be nearly as prominent on the ventro-
lateral area, but on the venter itself they are expressed only as
diffuse undulations which fade entirely against the sulcae.
Costation density on the outer whorls is usually 18-21 ribs per one
half whorl; but, one finely ornate specimen (at A-0974) possesses
27-28 costae per one half whorl. Specimens from A-0616 differ from
the rest of the hypodigm in that the ribs on the outer whorls are
less dense (13-14 costae per one half whorl); the whorl section is
more compressed (H/W=1.32-1.64), the umbilical shoulder is sharper
(somewhat angulated), and the venter is more narrowly rounded.

Discussion: The type of *E. dominans* differs from the material
in Oregon assigned to that species in that it possesses more strongly
prorsiradiate ribs; but, numerous specimens of *E. dominans* from
England have the more nearly rectiradiate costae. Since several
specimens from England appear morphologically intermediate between
the rectiradiate and prorsiradiate character states, the differ­
ences in rib trajectory are attributed to intraspecific variation.

*Euhoploceras marginatum* (Buckman)

Pl. 5, fig. a,b.

*Sonninia marginata* Buckman, 1892, p. 321, pl. 62; pl. 63, fig. 2;
pl. 64; pl. 65, fig. 1, 2.

<table>
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<th>Specimen no.</th>
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Diagnosis: Adult whorl section subquadrate, umbilical shoulder
gently rounded, whorl sides gently to moderately convex; venter
moderately broad, bears two wide sulcae which are shallow; costation moderate in strength on inner adult whorls becoming strong on outer whorl; strongest at mid-flank, weakly flexed or nearly straight on inner adult whorls, nearly straight or gently concave of outermost whorl.

**Description:** The nucleus is partly preserved on two specimens, and appears to be subovate in section at least by 20-25 mm shell diameter. Beginning at a shell diameter of 55-65 mm, an umbilical shoulder becomes conspicuous. On the moderately evolute adult phragmocone the umbilical wall is steep or vertical, and rounds gently onto moderately convex flanks. The venter, particularly on the outer whorls, usually bears conspicuously wide, shallow sulcae bordering a low, broad keel, producing a somewhat flattened, moderately broad venter. The whorl section is fairly compressed (H/W= 1.25-1.95; mean 1.4) and nearly subrectangular. On the body chamber the flanks become a little more inflated.

Tubercles are restricted to a shell diameter of 40-45 mm. Costae to this diameter are fasciculate to subfasciculate and are nearly straight to gently falcoid. A few ribs bifurcate near mid-flank. Ribbing is moderately strong on the phragmocone, irregular in height, and is gently falcoid, incipiently biconcave, concave or nearly straight in profile and is variably rursiradiate or prorsiradiate, as much as 10 degrees from the radial, depending upon the costation strength. The more finely and densely ribbed examples have prorsiradiate ribbing. On the outer whorl of the phragmocone the costae pass from subfasciculate to simple and rib density passes
from 15-19 ribs per one half whorl on the inner whorls to 11-13 on
the last whorl. On the outer-most whorl ribbing becomes strong at
mid-flank, and is slightly prorsiradiate. Ribs on all the whorls
are initially reclined where they arise from vague undulations on
the umbilical shoulder. Costae become sharpest and highest at mid-
flank, and above mid-flank they again fade into diffuse undulations
upon the low, lateral, ventral carinae. The ribs of the highest
part of the whorl sides are gently projected. Ribbing, especially
on the outer whorls where the biconcave profile disappears, may be
nearly straight, but is generally concave.

Discussion: The Oregon material agrees very closely with
Buckman's concept of the species. This species is distinguished from
E. acanthodes by lacking a conspicuous spinose stage on the adult
whorls, by having a less evolute adult phragmocone, and in that the
costae of at least the inner whorls are generally less strongly
concave.

Euhoploceras cf. E. modestum (Buckman)

cf. Sonninia modesta Buckman, 1892, p. 325, pl. 68, pl. 70, fig. 5;
1894, pl. 95, fig. 3-5 (holotype).

cf. Sonninia subsimplex Buckman, 1894, p. 427, pl. 95, fig. 6-8.

cf. Sonninia modesta Buckman, Hiltermann, 1939, p. 153, pl. 10,
fig. 5,6, pl. 11, fig. 1.

cf. Sonninia (Euhoploceras) modesta Buckman; Imlay, 1973a, p. 62,
pl. 7-10.
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**Description:** The innermost 1-1.5 juvenile whorls (shell diameter of 1-1.5 mm) are depressed ovate in section becoming subcircular by a shell diameter of 2 mm. The remaining juvenile whorls (to a shell diameter of 13-18 mm) retain the subcircular section. At 15-20 mm shell diameter the whorl section becomes subovate, compressed, and between 10-20 mm shell diameter a rounded but distinct umbilical shoulder is developed. Involution of the outer juvenile whorls varies from about 26-30 percent.

The inner adult whorls rapidly develop compressed sides yielding an ogival section, with the development of a low, overhanging,
vertical or steeply inclined umbilical wall, a tightly rounded to acute shoulder, compressed and very gently convex to flat flanks, and a broad to narrowly rounded externside supporting a keel moderate in height and width (H=1.1 mm; W=0.75 mm).

At 45-50 mm diameter the shell is moderately involute (U/D=0.20=0.33) and the whorl section (H/W=1.25-1.42) is weakly to moderately compressed. By 100 mm shell diameter the whorl overlap varies considerably (0.20-0.64), involution remains similar (U/D=0.24-0.31), but the whorl section may become more compressed (H/W=1.25-1.67). The keel remains constant in height (1 mm) but increases in breadth as much as three times, thus becoming a low, rounded structure.

Usually commencing near the end of the phragmocone (150-210 mm) the outer whorl egresses rapidly so that near the aperture the shell is moderately evolute (U/D=0.30-0.36) and the whorl section becomes moderately to strongly compressed (H/W=1.66-2.22). The umbilical shoulder, which is most acute on the adult phragmocone, becomes somewhat more rounded on the body chamber. The body chamber of A-0552-59 (the specimen has a maximum shell diameter of 182 mm) comprises seven eighths of a whorl, and appears to possess a slightly constricted and gently sinuous aperture. Two other apparently complete specimens (A-0552-57, maximum shell diameter 268 mm; A-0552-58, maximum shell diameter 284 mm) possess a body chamber of five eighths evolution.

Ornamentation of the nucleus (5-15 mm shell diameter) on the lower one half of the flanks is obsolete, or consists of 4-5 low,
broad, bullate plications per one half whorl. A few specimens possess a weakly tuberculate nucleus; the tubercles persist only to 10-15 mm shell diameter. The upper one half of the flanks are not well known, but are costate by a shell diameter of 5-10 mm. The remaining juvenile whorls are characterized by the low, broad, sometimes bullate swellings on the lower part of the flanks. At this stage the costation of the upper one half of the flanks is borne by fasciculation, commonly 5-6 ribs arising per bulla. A few specimens may possess simple to fasciculate-bifurcate costation by this stage. Strongly fasciculate ornamentation may continue on the young adult phragmocone, in which case a few specimens exhibit low, broad undulations (4-5 per on half whorl) on otherwise smooth or densely striate lower flanks. The bundles yield 5-9 secondaries on the upper one half of the flanks. Rarely the undulations may simply disappear adorally as they are over-ridden in strength by the secondary costation. Most commonly the undulate primary ornamentation becomes more dense within one quarter volution, with as many as 15 distinct bullate primaries per one half whorl. However, due to the weak ornamentation, which is sometimes obsolete, and because several specimens have ornamentation which consists of mixed simple, long intercalatory and fasciculate bundles, counts of primary costation are sometimes meaningless. Secondary ribbing of the young adult whorls (counts made to 45-50 mm shell diameter) ranges from 28-45 costae per one half volution. Although in detail there is no precise correlation between rib density, volution and whorl section, usually the specimens which are most evolute and have the broadest whorl
sections have a secondary rib density of 28-32 costae per one half whorl, and the more involute specimens with compressed whorl sections possess 32 or more secondaries per one half whorl. Costation on the outer whorls of the phragmocone becomes broader, less distinct, and somewhat less dense, and usually by 65 mm shell diameter it becomes simple. Least densely ribbed specimens may pass from sub-fasciculate to simple costation by 35-45 mm shell diameter. A few individuals may possess nearly entirely smooth (only striate) flanks or have low, nearly obsolete, distant plications on the outer whorls of the phragmocone (to at least 120 mm shell diameter).

On the last septate whorl, as early as 90-100 mm shell diameter, the ribbing becomes low, broad, more widely spaced, and distinctly simple. Costation becomes well developed on the body chamber, where in the compressed variants it may only reach moderate strength near the aperture, whereas the more inflated variant possesses conspicuous costation over the entire body chamber and may be moderately strong near the aperture. The density of ribbing on the body chamber of the two nearly complete specimens is 17-18 ribs per one half volution. Two specimens develop distant primaries on the outer whorls (about 10 per one half whorl) and have 18-21 ribs on the outer flank, commonly formed by bifurcation and by intercalation. The sites of the bifurcations may be slightly nodose.

Ribbing and striation may be very gently falcoid but are usually incipiently biconcave. Ribs are faint where they begin on or a short distance above the umbilical shoulder, often become slightly swollen at the mid-flank adoral convexity, and are strongest in the ventro-
lateral area where they become projected on the venter and expire before reaching the keel. On the inner adult whorls the ribs expire about 1-2 mm before reaching the keel, whereas on the body chamber they die out 5-8 mm from the keel. The conspicuous simple costation of the outer whorls may be slightly bullate at the mid-flank convexity, and only on the adoral part of the body chamber will exceed the rib height of the ventro-lateral area.

Ribbing up to the stage of simple costation may be nearly upright, but is characteristically prorsiradiate, inclined 5-10 degrees. The simple costation of the outer whorls is nearly upright on the lower one half of the flanks, but on the upper part of the flanks is fairly strongly projected.

Discussion: Although the Oregon material appears to be conspecific with E. modestum, the sample from Oregon differs in that many specimens develop coarser ornamentation which is more noticeably stronger in the ventro-lateral area, especially on the body chamber.

_Euhoploceeras_ cf. _E. polyacanthum_ (Waagen)

Pl. 4, fig. 2

cf. _Ammonites polyacanthus_ Waagen, 1867, p. 592, pl. 29, fig. 1a, b.

cf. _Sonninia renovata_ Buckman, 1894, p. 433, pl. 93, fig. 1-3.

cf. _Sonninia mayeri_ Waagen. Dorn, 1935, p. 42, pl. 3, fig. 1; text-fig. pl. 3, fig. 8, 9.

cf. _Sonninia polyacantha_ Waagen. Dorn, 1935, p. 44, pl. 9, fig. 1; pl. 17, fig. 1; text-fig. pl. 4, fig. 2.

_Sonninia (Euhoploceeras) arassispinata_ Buckman. Imlay, 1973a, p. 67 [in part], pl. 23, fig. 2.
Description: The hypodigm consists of one specimen. The adult phragmocone is evolute. The whorl section of the adult phragmocone is subovate to at least 40 mm shell diameter. Adorally on the phragmocone the umbilical wall becomes more tightly rounded. The convex flanks round evenly only a moderately rounded venter. On the body chamber the section becomes nearly subrectangular as the flanks between the nodes flatten a little. Very shallow and narrow sulcae are present on the internal mold on the body chamber.

The nucleus is non-tuberculate, and the costae on the adult phragmocone are fairly dense and irregular in strength. Rib profile is biconcave; the strongest ribs originate on the umbilical shoulder and are slightly bullate or pointed at mid-flank. Sometimes from them arise 2 or more secondaries. The remaining ribs, of which there are 1-4 between the stronger costae, arise a variable distance up the flanks, and also may split into secondaries. Ribbing is strongest at mid-flank.

On the body chamber costation is much stronger, more widely spaced, and is simple. The ribs arise at the umbilical shoulder, trend radially or are gently rursiradiate, and develop strong, bullate tubercles at mid-flank. The ribs remain strong on the ventro-lateral shoulder where they bend sharply forward and expire against the narrow sulcae.

Discussion: This specimen differs from the type of *E. polyacanthum* in that the nucleus is non-spinose, the costae of the inner whorls are finer, some are branched, and the nodes of the outer whorls are a little stronger and begin sooner. The whorl section
is essentially the same. In general the specimen from Oregon is most like \textit{E. renovatum}. Like Oechsle (1958), I feel that \textit{E. renovatum} should be synonymized under \textit{E. polyacanthum}.

The falcoid, rursiradiate ribbing on the outer whorl of a specimen figured by Imlay (1973a, pl. 23, fig. 1) indicates it's close relationship with \textit{E. polyacanthum}. The example figured by Imlay is separable from \textit{E. westi} by its distinctly subquadrate whorl section, by the ribs which are strong on the ventro-lateral shoulder, and possibly by its principally simple costation on the outer whorls. The rib strength on the ventro-lateral shoulder is much too strong for \textit{E. crassinudum} and related species. The examples of \textit{E. cf. E. polyacanthum} from Oregon differ from \textit{E. aff. E. densicostatum} by lacking tubercles on the outer whorls; otherwise, the two taxa are nearly identical.

\textit{Euohoploceras revirescens} (Buckman)

\textit{Sonninia revirescens} Buckman, 1892, p. 324, pl. 70, fig. 1.

\textit{Sonninia subcostata} Buckman, 1892, p. 330, pl. 71, fig. 4, 5.

\textit{Sonninia substriata} Buckman, 1892, p. 330, pl. 70, fig. 6, 7; pl. 71, fig. 6-8, and intermediate form, pl. 72, fig. 1, 2.

\textit{Sonninia papillonacea} Buckman, 1893, p. 367, pl. 90, fig. 1-3.

\textit{Euohoploceras mussonense} Buckman. Maubeuge, 1951, p. 25, pl. 2, fig. 3.

\textit{Sonninia (Euohoploceras) dominans} Buckman. Imlay, 1973a, p. 63 [in part], pl. 12, fig. 1, 4.

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Diagnosis: Inner adult whorls fairly involute, flanks flattened, umbilical shoulder subacute, costation weak, fairly dense, weakly to strongly prorsiradiate; body chamber evolute, flanks gently convex, umbilical shoulder gently rounded, venter narrowly to moderately rounded; costation widely spaced, strong, highest at mid-flank, gently concave.

Description: The inner adult whorls are moderately involute (U/D=0.30). The whorl section is compressed; the umbilical shoulder is fairly sharply rounded and the whorl sides are flattened. The outermost whorl egresses so that evolution of the body chamber may be as much as 40 percent. The umbilical wall is steep or vertical, and the shoulder is gently rounded. The whorl flanks are gently or moderately convex and the venter is fairly narrowly or moderately rounded. Wide, very shallow sulcae may border the low keel.

Costation on the inner adult whorls is moderately dense and weakly to strongly prorsiradiate, often inclined as much as 10-20 degrees. On the outer whorls ribs become distantly spaced, become somewhat more upright, and at first are very irregular in height. The ribs of the body chamber may be strong and gently concave, in which case they may arise from the umbilical shoulders where they are at first backwardly inclined, but then trend nearly radially and become strong at mid-flank. The costae remain strong until they bend forward in the ventro-lateral area. On the venter the costae are fairly strongly projected and fade quickly against the weak lateral carinae. There are generally 12-13 costae per one half whorl on the body chamber.
Discussion: The material from Oregon differs from Buckman's figured specimens (see synonymy) in that the phragmocone of the type is slightly less strongly prorsiradiate and the ribs are a little more widely spaced. These differences are slight and are herein attributed to individual variation.

*Euhoploceras tuberculoseum* Taylor, n. sp.

Pl. 6, fig. a, b.

*Sorninia (Euhoploceras) polyacantha* (Waagen). Imlay, 1973a, p. 64, pl. 18, 19; pl. 20, fig. 1, 5-7; pl. 21, fig. 8, 9.

<table>
<thead>
<tr>
<th>Specimen no.</th>
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<th>W</th>
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<th>H/W</th>
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*Holotype:* Pl. 6, fig. a, b; most of shell with nearly complete body chamber of three quarters volution. Repository: University of California, Berkeley, Museum of Paleontology D-7072-63.

*Locus typicus:* University of California, Berkeley, Museum of Paleontology, locality D-7072; Washburn Draw section.

*Stratum typicum:* Weberg Member, Snowshoe Formation, from an 18.3 cm thick crinoidal biosparite bed 24.35-24.53 m above datum for the Washburn Draw section.

*Derivatio nominis:* The name is taken from the coarse tubercles on the body chamber of the species.

*Diagnosis:* Whorl section of adult phragmocone ogival, becoming subrectangular on the body chamber; umbilical shoulder gently rounded, very shallow sulcae may be present on body chamber; nucleus costate or spinose, spines may persist to 25 m shell diameter; costation of
adult shell weakly to strongly prorsiradiate, on inner adult whorls secondary costation density 26-34 ribs per one half volution; body chamber bears strong bullate nodes.

**Description:** This species possesses inner whorls (to shell diam. of 15-25 mm) which are subcircular in cross section, later becoming subovate, higher than wide. With the development during growth of moderately compressed whorl sides, a vertical or steep umbilical wall and distinct but rounded umbilical shoulder appear.

On the adult phragmocone the umbilical shoulder varies from gently to acutely rounded. The whorl flanks are very gently convex and the venter is moderately to narrowly rounded. The whorl section varies from ogival to subrectangular. The young adult phragmocone (at 45 mm shell diam.) is moderately involute (U/D=0.25-0.31) and the whorl section is weakly compressed (H/W=1.15-1.32; mostly 1.16-1.19). The outer whorls on most specimens are too crushed for meaningful measurements. Apparently on the adult phragmocone whorl width and height increase at a very slow rate. At the end of the phragmocone (120-152 mm shell diameter) involution is moderate (U/D=0.28-0.34) and the whorl section is moderately compressed (H/W=1.30-1.38); however, some fragments indicate greater compression, perhaps as much as (H/W) 2.0. Near the aperture of A-0556-64 the whorl section is weakly compressed (H/W=1.12), which seems to be typical for the species, and is subquadrate. The umbilical wall is vertical and rounds evenly onto the very gently convex or flat flanks which in turn round onto the venter high on the flanks, producing a distinct but gently rounded
ventro-lateral shoulder. The venter is broad and may bear wide, shallow sulcaes bordering the keel. The keel on the inner-most adult whorl is moderate in height and width (H=1 mm; W=0.75-1.0 mm), becomes blunt on the adoral part of the phragmocone (H=1 mm; W=2.5 mm) and on the adoral part of the body chamber is very low and rounded (H=1.5 mm; W=4 mm).

Weak tubercles or node-like projections (5-10 per one half whorl) occur in the nucleus of a small number of specimens, and may persist to a shell diameter of 25 mm. Otherwise, the nucleus bears broad undulations or low bullate primary bundles which vary in density from 4-8 per one half whorl. Maximum density of the undulations or bundles is attained on the inner-most adult whorl (at a shell diameter of 20-60 mm), where there may be 5-12 primaries per one half whorl. Also, at 20-60 mm shell diameter secondary costation varies from 26-34 ribs per one half whorl, after which diameter the density begins to decrease. Adorally, the undulations of the lower parts of the flanks become stronger, broader and more distant. Within about one half whorl either adorally or adapically of the last-formed septum, the undulate costation becomes bullate, and adorally on the body chamber the costae develop coarse tubercles at mid-flank. On the body chamber there are generally 7-10 bullate primaries per one half whorl and 14-20 ribs on the outer flanks, most of which are secondaries borne by bifurcation, although some are detached and intercalatory. Costation of the outer whorls is highly variable in strength and pattern.
Specimen A-0556-64 exhibits a gently flexed aperture which is concave on the lower part of the whorl sides, convex and with a narrow lip on the upper part of the flank, and gently projected over the venter. Apparently, there is a trend toward simple costation near the aperture, which has a slight subterminal constriction. There is no collar or condensed bundles of growth striae at the aperture.

Ribbing is very gently falcoid and may be incipiently biconcave. Costae begin on or just above the umbilical shoulder, are usually slightly swollen near mid-flank, and on the ventro-lateral shoulder may again increase in strength. On the more coarsely ornate specimens rib height is often prominent near mid-flank and costation may be strongly inclined (inclined as much as 20-25 degrees). Most finely ornate specimens usually bear costae which are strongest on the ventro-lateral area. These specimens have costation of the phragmocone inclined 10-20 degrees. On the body chamber costation on the upper flanks is always relatively strong.

Discussion: The phragmocone of finely ornate specimens closely resembles that of E. cf. E. modestum. The inner whorls of E. tuberculosum are distinguished by their possession of a more gently rounded umbilical shoulder, the more strongly prorsiradiate costation, and less dense ribbing. Each of the attributes are intergradational between the two taxa and decisive identification sometimes requires recognizing the tuberculate costation of the body chamber of E. tuberculosum. The phragmocone of E. tuberculosum is more often nearly identical to E. revirescens; likewise, the tuberculate body
chamber of the former species is sometimes the only means of distinguishing the two species.

*Euhoploceras westi* Taylor, n. sp.

Pl. 7, fig. a-c.

*Sonninia (Euhoploceras) crassispinata* Buckman. Imlay, 1973a, p. 67 [in part], pl. 22, fig. 1, 2; pl. 23, fig. 2-4; pl. 24, fig. 1, 4; pl. 25, fig. 17-19.

<table>
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<th>Specimen no.</th>
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<th>W</th>
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<th>H/W</th>
<th>U/D</th>
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<td>37</td>
<td>52</td>
<td>1.16</td>
<td>0.43</td>
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Holotype: Pl. 7, fig. a, b; shell with partly compressed phragmocone and partial body chamber of nearly one half volution.

Repository: Earth Sciences Museum, Portland State University

A-0977-66.

*Locus typicus:* Earth Sciences Museum, Portland State University locality A-0977; Robertson Draw section.

*Stratum typicum:* Weberg Member, Snowshoe Formation, from a crinoidal biosparite bed 7.56-9.30 m stratigraphically above datum for Robertson Draw section.

*Derivatio nominis:* In memorium of Roy West, a former field assistant.

*Diagnosis:* Shell moderately to strongly evolute, whorl section subcircular to nearly subquadrate; body chamber bears coarse tubercles (5-11 per one half whorl) usually distantly spaced.

*Description:* This species is moderately to strongly evolute. Involution is 40-45 percent for well preserved specimens of the
hypodigm; however, several incomplete examples appear to be more involute. The phragmocone possesses a subcircular to subovate whorl section; the flanks are strongly or moderately convex and round gently onto the venter. The flanks flatten somewhat on the body chamber as a conspicuous but gently rounded umbilical shoulder develops. The converging upper flanks may terminate at low lateral carinae distal to wide and very shallow sulcae which border the low keel. Thus the venter on the body chamber is well defined and the whorl section is usually subrectangular.

The juvenile whorls, observed only on A-0977-66, are poorly preserved, but are costate and may in part be tuberculate. The costae of the remaining whorls of the phragmocone are nearly radial and are gently falcoid, biconcave, or concave, depending upon the strength of the ornamentation.

Between 35-60 mm shell diameter the specimen at A-0977 has approximately 19-20 costae per one half whorl, and there are 4-5 tubercles per one half whorl. Most of the non-tuberculated ribs on this specimen arise in pairs low on the flanks, or bifurcate near mid-flank. Other specimens appear to be less costate and bear coarse, widely spaced tubercles.

Adorally on the phragmocone or body chamber costation drops out and the flanks between the widely spaced tubercles (5-7 per one half volition) are nearly smooth. The tubercles rest on low, broad costae which are no more than undulations. At the base of the flanks they appear at first to trend backwardly or radially, and above the mid-
flank tubercles the ribbing is radial or prorsiradiate. The secondary costation arises by bifurcation, trifurcation, or by intercalation. These ribs are weak in strength or are obsolete.

Discussion: Euhoploceras westi differs markedly from all examples of E. adicorum in that the tuberculate ornamentation of the phragmocone increases in strength adorally and that the extremely coarse and widely spaced spines on the body chamber are clearly a continuation of the same trend which begins at an early stage of growth. In contrast the tuberculate ornamentation on the phragmocone of E. adicorum decreases in intensity or expires adorally. The renewed development of bullate ornamentation on the body chamber in examples of E. adicorum is more densely spaced than for typical examples of E. westi, and rarely produces well developed tubercles as in E. westi. Two examples of E. adicorum, one by Dorn (1935, p. 38, pl. 6, fig. 1) and Hiltermann (1939, p. 142, pl. 9, fig. 2) superficially resemble E. westi by having fairly strong tuberculate ornamentation on the body chamber. The form figured by Hiltermann appears closest by its persistence of tuberculate ornamentation; although it becomes a little denser with growth, it remains widely spaced. The tubercles on the body chamber of that form decrease in strength adorally.

The nucleus and inner adult whorls of E westi are more commonly less spinose than in E. adicorum. Euhoploceras adicorum never develops the distinctly subquadrate whorl section present in E. westi. In addition the shallow and wide sulcae, present on the examples of E. westi with the subquadrate whorl section, are not reported to occur in E. adicorum.
Europloceras cf. E. westi Taylor, n. sp.

Pl. 8, fig. 1a, b.

Specimen no. Place measured D H W U H/W U/D
A-0559-67 phragmocone  a.118 38 28 44 1.36 a.0.37

Description: This form is represented by one internal mold which on the outer one sixth whorl bears part of the body chamber. The adult phragmocone possesses a subquadrate whorl section; the venter is very broad and weakly sulcate.

The inner discernible part of the phragmocone (50-70 mm shell diameter) is characterized by tubercles and bullate costae of irregular strength. The adoral part of the phragmocone bears coarse and widely spaced tubercles, secondaries which are bifurcate and trifurcate and intercalatory costation which is weak or moderate in strength.

Discussion: The form is close to E. westi, but differs by bearing a more pronounced subquadrate whorl section to smaller shell diameters. This specimen may well be a variant; however, since it occurs above the established teilzone for E. westi, it is desirable for the time being to exclude the specimen from that species.

Genus Witchellia Buckman, 1889

Witchellia n. sp.

Pl. 9, fig. 1a, b; 2a, b.

Specimen no. Place measured D H W U H/W U/D
A-0827-68 phragmocone  30 13.5 10.1 8.5 1.34 0.28
A-0827-68 body chamber  46.5 19 15.1 14.4 1.26 0.31
A-0827-69 end phragmocone  38.5 14 11.6 12.5 1.21 0.33
A-0827-69 body chamber  50 a.18.5 --- 19 --- 0.38
Description: On A-0827-68 the inner-most observed whorls (3-6 mm shell diameter) bear ornamentation consisting of sharply bullate, fine costae (7-8 costae per one half volution) that adorally on the inner adult whorls grade to weak but stronger sinuate prosiradiate plicae (10-12 per one half whorl). On the adoral one third of the last septate whorl the costation becomes obsolete, conspicuous only under oblique illumination, and is strongest at mid-flank. Beginning with the body chamber the costation becomes adorally increasingly swollen and convex at mid-flank. There are 15 plicae on the incomplete body chamber of one half volution. These costae usually bifurcate at the swellings, yielding extremely weak secondaries which are strongly projected on the venter and expire before reaching the sulcae. Involution is moderate (at shell diameter of 30 mm U/D=0.28) on the outer adult phragmocone. The body chamber egresses slightly over the penultimate whorl (at shell diameter of 46.5 mm U/D=0.31) where whorl inclusion is just over one third. The outer whorls are characterized by a quadrate whorl section; the umbilical wall is steep, and rounds onto flattened flanks which in turn round rather abruptly onto a gently convex, broad venter. Whorl compression is moderate (at shell diameter of 30 mm H/W=1.34) on the outer septate whorl and becomes slightly more depressed on the body chamber (at shell diameter of 46.5 mm H/W=1.26). The keel is low, thin and bordered by narrow, deeply set sulcae, producing a bisulcate-tricarinate venter. One partial specimen from A-0562 is identical to A-0827-68.
Another specimen assigned to this species bears, on its juvenile whorls, non-bullate, flexuous, adorally convex costae. There are as many as 16 costae per one half whorl. The weak costae are strongest at mid-flank and become obsolete on the adoral one third of the last septate whorl. Ornamentation is identical in style, strength and density to A-0827-68, as developed on the body chamber, excepting for the near absence of observable secondary costation (only one primary yields two nearly equally strong and broad secondaries). The whorl section, at least beyond the juvenile stage, is compressed subovate, with very low, gently rounded inner flanks (at shell diameter of 38 mm H/W=1.21). The shell is moderately evolute at the adoral end of the phragmocone (at shell diameter of 38 mm U/D=0.32). The body chamber egresses and becomes strongly evolute (at shell diameter of 50 mm U/D=0.38) and encompasses the preceding whorl about one sixth. The venter is moderately broad and shallowly bisulcate.

Discussion: Closest similarity of A-0827-68 and the example from A-0562 are with Witchellia spatians (Buckman, 1928, p. 12, pl. 765, vol. 7) in involution, whorl section and style of ornamentation. The examples from Oregon differ markedly through the weak ornamentation of the inner adult whorls and relative increase of strength of plicae on the body chamber.

Locality A-0827 represents a bed of shelly concretions from an indeterminate position high in the Weberg Member near the section 320 m south of Washburn Draw. Four specimens belonging to this species and Alaskoceras were collected from the locality. Two are
typical examples of *A. evolutum*. The other two are the examples just described. A-0827-69 is just slightly less evolute than *A. evolutum*, and in shell proportions looks like that species, but it bears the ornamentation of A-0827-68. A-0827-69 is morphologically intermediate between A-0827-68 and *A. evolutum*, indicating that *Witchellia* n. sp. and *A. evolutum* are closely affiliated. Consequently, it is suggested that *Witchellia* n. sp. is a derivative of *A. evolutum* that differs by being more involute, possessing a more compressed whorl section, and by having much weaker ornamentation.

*Witchellia* sp. undet.

*Description:* One small specimen (maximum shell diameter 30 mm) is moderately involute and has a moderately compressed whorl section. The umbilical wall is vertical, the umbilical shoulder is gently rounded and the flanks are gently convex. The venter bears a small, thin keel bordered by very narrow, distinct sulcae.

The costation is gently prorsiradiate, very gently falcoid, and is commonly bifurcate near mid-flank, or fasciculate low on the flanks.

*Discussion:* This specimen has narrower sulcae, but otherwise resembles *Witchellia* sp. (Imlay, 1973a, p. 70, pl. 20, fig. 2, 3).

**Genus Alaskoceras** Westermann, 1969b

*Type species:* *Alaskoceras alaskense* Westermann, 1969b.

*Species of Alaskoceras:*

*Alaskoceras alaskense* Westermann

*Sominiia (Alaskoceras) alaskensis* Westermann, 1969b, p. 103, pl. 27, fig. 2-7, text-fig. 32-33.
Alaskoceras aff. A. alaskense Westermann


Alaskoceras evolutum (Imlay)

Witchellia (Latiswitchellia) evoluta Imlay, 1973a, p. 70, pl. 31-33.

Alaskoceras graiile

Schloenbachia gracilis Whiteaves, 1889, p. 171, pl. 23, fig. 2, 2a.
Sonninia gracilis (Whiteaves). Frebold, 1957, p. 48, pl. 19, fig. 1a, b.

Alaskoceras n. sp.

Sonninia? n. sp. undet. Imlay, 1964, p. B33, pl. 4, fig. 5, 6; 10-12.

Diagnosis: Shell medium size, strongly evolute to serpentically coiled; collared aperture may be present; venter weakly to strongly bisulcate; whorl section subovate, subrectangular, trapezoidal; ribbing commonly bifurcate low on flanks, usually strongly reclined, falcoid in profile; subnodose to spinose ornamentation commonly developed in ventro-lateral area.

Discussion: The derived characters small adult shell size, serpentic coiling, collared aperture, strongly bisulcate venter, trapezoidal whorl section and subnodose to spinose ventro-lateral ornamentation clearly distinguishes this species group from Euhoploceras, indicating generic status for Alaskoceras is warranted.

Westermann (1969b, p. 107) recognized the close affinities of Imlay's (1964, p. B33) Sonninia cf. S. nodata with A. alaskense. Westermann (op. cit.) also noted the close morphological similarity.
of *A. alaskense* and *A. gracile*. *A. gracile* differs from other members of *Alaskoceras* only in that it possesses more consistently radial and straight ribbing; in these respects the ornamentation is similar to *E. crassiradium* and *E. adiutum*.

*Alaskoceras evolutum* (Imlay)

Discussion: *A. evolutum* possesses similar adult size, coiling, rib profile, and position of nodose ornamentation on the whorl as *A. alaskense*. *A. evolutum* differs by having less well developed ventro-lateral shoulders (subquadrate instead of trapezoidal whorl section), no prominent spines, much more pronounced ventral sulci, and possessing a collared aperture and subterminal constriction.

The examples of *Alaskoceras* sp. undet. (Imlay, 1964) appear to be close to *A. evolutum*; but, they differ by being more involute and possessing mid-lateral nodes on the inner adult whorls.

Family STRIGOCERATIDAE Buckman, 1924

Genus *Strigoceras* Quenstedt, 1886

*Strigoceras taylori* Taylor, n. sp.

Pl. 9, fig. 3a, b.

*Strigoceras* sp. undet., Imlay, 1973a, p. 76, pl. 36, fig. 14-16.


Holotype: Pl. 9, fig. 3a, b; complete phragmocone with most of test. Repository: Earth Sciences Museum, Portland State University A-0581-70.

Locus typicus: Earth Sciences Museum, Portland State University, locality A-0581; Washburn Draw section.
Stratum typicum: Weberg Member, Snowshoe Formation, from a limestone bed 24.9-26.4 m stratigraphically above datum for Washburn Draw section.

Derivatio nominis: In memorium of my father Clyde C. Taylor.

Diagnosis: Shell strongly compressed, with low keel and low, dense ribbing of irregular strength and branching.

Description: This species possesses a compressed, discoidal whorl section and a low, hollow floored keel. The umbilicus is very narrow, with nearly vertical sides and rounded, raised shoulders. The holotype exhibits 3 low striations at intervals approximately one quarter the distance up the whorl sides, producing shallow fluting on the lower three quarters of the flanks. The most ventral stria­tion is faint and is visible only on the last two thirds preserved whorl.

The ribbing is falcoid. Ribs are prorsiradiate low on the flanks, become rursiradiate a short distance above mid-flank, and are projected near the venter where they terminate as low, broad swell­ings against the keel. Ribbing is generally weak low on the flanks, and on the upper one half of the whorl sides is fairly dense on the inner whorls, becoming broader and somewhat more widely spaced adorally. A few ribs, sporadically spaced, and generally originating low on the flanks, are stronger than the other ribs. Ribs may arise at any distance up the flanks by intercalation or furcation. Many arise from the mid-lateral strigation.

The suture is moderately complex but is not deeply incised. E/L is broad. E is slightly shorter than L. L is trifid and has a
wide base. U2 is two thirds the height of L, and is also fairly broad based. The remaining umbilical elements are slightly oblique, have a nearly straight saddle boundary, and form an essentially evenly declining series. Each of the inner umbilical saddles are broad and are divided by a narrow secondary lobe.

Discussion: The worn specimen figured by Imlay (1973a, pl. 35, fig. 11, 12, 14) under Praestrigites cf. P. denticus possesses a distinct lateral ridge and bears the ornamentation and suture of S. tayleri. Strigoceras tayleri differs from S. strigifer Buckman (1924, pl. 469) and S. septicarinatus Buckman (1924, pl. 470) by having much finer ribbing and less pronounced fluting, and has much finer ribbing than S. symplectus Buckman (1924, pl. 471). The new species appears morphologically more similar to S. languidum Buckman (1924) than any of the other described species of Strigoceras, but differs from that species by having a slightly lower keel, ribbing that is weaker, denser and more irregular in strength, and by having ribs that branch well above mid-flank. The whorl section may also be slightly more compressed. The irregularly branched ribbing is reminiscent of Praestrigites, as exhibited by P. praenutia.

Family OPPELIIDAE Bonarelli, 1894
Subfamily OPPELIINAE Bonarelli, 1894
Genus Bradfordia Buckman 1910

Bradfordia n. sp.

Pl. 10, fig. a, b.

Description: This species is represented by one nearly complete
individual with most of the shell. The body chamber is broken and is shortened approximately 2 cm where the adoral part of the chamber was pushed into the first part of the body chamber.

The shell is strongly compressed and appears to be strongly involute. The umbilical margin apparently is rounded and not raised. The body chamber comprises one half volution.

Spiral ornamentation consists of a pronounced, low ridge situated just above mid-flank (it becomes obsolete on the adoral end of the body chamber) and possibly another faint ridge just over three quarters the distance up the flanks. The upper-flank strigation is perceptible only on the phragmocone.

On the phragmocone growth striae are nearly radial on the lower flanks, but are gently concave; they are deflected backwardly at the prominent ridge, again become gently concave higher on the flanks, and have not been observed in the ventro-lateral area. On the adoral half of the body chamber the mid-lateral strigation is obsolete and the growth striae are more gently falccid, but follow the same sort of course as on earlier whorls. The striae are rursiradiate high on the flanks and are slightly rursiradiate or radial where they pass over the venter. Very near the aperture growth proceeded at a faster rate on the upper one half of the flanks so that the striae become progressively more strongly falccid toward the adoral end of the body chamber. Thus, the aperture is strongly falccid in outline as it is extended on the upper one half of the whorl.

Ribbing is conspicuous only on the outer three quarters of the flanks, where it follows the trend of the striae. On the phragmocone
the ribs are moderately spaced; the strongest ribs, which are irregularly spaced but somewhat distant, arise at the lateral ridge. Other ribs arise higher on the flanks by intercalation and furcation. The costae are rursiradiate to slightly projected in the ventro-lateral area, and are entirely absent over the venter itself. Costation on the inner adult whorls is very irregular in strength. On the adoral part of the phragmocone and body chamber the ribbing becomes simple, fairly uniform in strength, and moderately spaced; but, adorally on the body chamber the plicae rapidly become progressively distant, low and broad until they are to be seen no more on the last one eighth volvation.

The septal suture is fairly complex for the genus, but is not deeply incised. E is not completely drawn (fig. 9) but it is shorter than L. L is trifid and is very broad based. E/L is wide and is divided by a prominent subcentral assessor lobe. The L/U saddle is as high as but somewhat narrower than E/L. U2 is shorter than L and is extremely broad based. The U2/U3 saddle is very shallow and the remaining umbilical elements diminish in a graded series.

Discussion: This species differs from most described members of the genus in that the ribbing, which in combination with being confined mostly to the outer flanks, is partly bifurcate and intercalatory and highly irregular in strength. With respect to the costation being irregular in strength and consisting partly of widely spaced strong plicae, the ornamentation is reminiscent of Oppelia subradiata (Sowerby) var A (Favre, 1912, p. 11, pl. 1, fig. 1a).
Figure 9. Septal suture of Bradfordia n. sp., drawn at about 60 mm shell diameter; X2.75.
Genus *Hebetoxytes* Buckman, 1924

*Hebetoxytes* cf. *H. hebes* Buckman


**Description:** The following remarks are intended to supplement Imlay's (1973a, p. 76) description. Usually at 55-60 mm shell diameter, with the commencement of the body chamber, the outer-flank ribs may remain weakly rursiradiate, but usually become strongly reclined, and the costation becomes distantly spaced as intervening ribs become obsolete. No lower-flank costation has been observed on the specimens collected for this study.

**Discussion:** The apparent lack of lower-flank ribbing may be due in part to preservation, but the example figured by Imlay (1973a, pl. 36, fig. 10) has stronger primaries than could have existed on the specimens collected by me. That specimen figured by Imlay also bears denser outer-flank costation. For the time being these differences in ornamentation are considered to be intraspecific. Additional collections at different stratigraphic levels are needed to understand possible temporal changes in the morphology of this taxon.

Family *STEPHANOCERATIDAE* Neumayr, 1875

Genus *Docidoceras* Buckman, 1919

*Docidoceras* (Docidoceras) Buckman, 1919

*Docidoceras* (Docidoceras) *lupheri* Imlay

*Docidoceras lupheri* Imlay, 1973a, p. 78, pl. 38, fig. 8, 9, 12, 14-17.
Docidoeceras (Docidoeceras) paucinodosum Westermann


[?] Docidoeceras (?) (Pseudoaidoeceras or n. subgen.) n. sp. indet. B Westermann, 1969b, p. 515, pl. 43, fig. 1a, b; text-fig. 50.

Stephanoceras aff. S. nodosum (Quenstedt). Imlay, 1973a, p. 87, pl. 44, fig. 12, 13.

Discussion: The example of this species from A-0628 at the Washburn Draw section is identical to material described by Westermann.

Westermann's placement of the species in both the genus Docidoeceras and subgenus Pseudoaidoeceras was tentative. It is herein assigned to the subgenus Docidoeceras (Docidoeceras) because the collared aperture is only weakly inclined, and ventral ribbing gently projected. Certainly the widely spaced, pointed nodes on the outer whorls have no parallel in other members of Docidoeceras, but in all other respects the morphology is like that of Docidoeceras (Docidoeceras). The inner whorls are identical to those of Docidoeceras (D.) liebi Maubeuge. Creation of a new genus for D. (D.) paucinodosum, if warranted, should await a clear understanding of the evolution of Docidoeceras and precise phylogenetic relationship of that genus to Pseudotoites.

Docidoeceras (Docidoeceras) warmspinsense Imlay

Docidoeceras warmspinsense Imlay, 1973a, p. 78, pl. 38, fig. 1-7, 13.

Subgenus Docidoeceras (Pseudoaidoeceras) Westermann, 1969b

Docidoeceras (Pseudoaidoeceras) aff. D. (P.) camacho Westermann

Pl. 11, fig. 1.

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>Place measured</th>
<th>D</th>
<th>H</th>
<th>W</th>
<th>U</th>
<th>H/W</th>
<th>U/D</th>
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<tr>
<td>A-0635-72</td>
<td>body chamber</td>
<td>60</td>
<td>15</td>
<td>23.5</td>
<td>29.5</td>
<td>0.64</td>
<td>0.49</td>
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</tbody>
</table>

**Description:** This taxon is represented by one crudely preserved internal mold which bears an incomplete body chamber of nearly one volution. The phragmocone ends at 54 mm shell diameter, and the maximum preserved diameter is 80.5 mm. The shell is strongly evolute. The whorls of the phragmocone are strongly depressed and lenticular in cross section, becoming less depressed and developing rounded whorl sides on the body chamber.

The primaries are gently prorsiradiate and are moderately densely spaced. Secondary costation on the phragmocone is very strongly projected and fairly coarse; there are 21 secondaries to the half whorl at 47.5 mm shell diameter. On the adapical part of the body chamber the secondaries are only moderately projected and become weaker and denser. No ornamentation remains on most of the body chamber.

**Discussion** The style of ornamentation of the phragmocone is closest to *D. (P.) widebayense* (Westermann, 1969b, p. 137), excepting perhaps for the less strongly projected primaries. It differs markedly from *D. (P.) widebayense* by being more evolute, and developing finer instead of coarser ornamentation on the body chamber. With respect to the last characteristic the specimen is closest to *D. (P.) aamaohoi*, which is reported by Westermann to have a phragmo-
cone which may be identical to *D. (P.) widebayense*. The specimen from Oregon is also more evolute than *D. (P.) oamahoi*.

**Docidoceras (Pseudodicoceras) sparingostatum** Imlay

*Docidoceras sparingostatum* Imlay, 1973a, p. 79, pl. 37, fig. 1–3, 5–12, 15, 16.

**Discussion:** This species is placed in *Docidoceras (Pseudodicoceras)* because of the strongly prorsiradiate costation, and presence of a strongly oblique peristome. The peristome is strongly concave in profile along the whorl sides, and is strongly projected as a broad ventral lappet. An incipient to weak, strongly oblique constriction is present just behind the peristome.

**Genus Pseudotoites** Spath, 1939

*Pseudotoites* n. sp.

Pl. 11, fig. 2a, b.

**Description:** This species is represented by one specimen (119 mm maximum preserved shell diameter) from A-0571 which exhibits an incomplete body chamber of onevolution. The whorls of the adult phragmocone have a depressed, lenticular section. The primary costation of the phragmocone is gently prorsiradiate and terminates in fairly closely spaced, fine tubercles. Three to four secondaries arise from each primary (as seen at an estimated shell diameter of 45 mm). These secondaries are gently projected over the venter.

The body chamber is subovate (*H*=37 mm; *W*=47 mm; *H/W*=0.79) and only moderately depressed. The primaries are rursiradiate where they first arise from the umbilical seam, are concave in profile and give rise to distinctly bullate nodes. The secondary ornamentation,
which is moderately strongly projected over the venter, consists of fine fasciculate rib bundles, the individual costae of which usually become obsolete over the venter. The body chamber is conspicuously densely striate.

Discussion: *Pseudotoites* n. sp. has a phragmocone which is identical in all observable respects to that of *Docidoceeras* (*Docidoceeras*) *liebi* Maubuge. The ornamentation on the body chamber is similar to that of *Emileia crater* (Buckman, 1924, vol. 3, pl. 414), but differs from that species by possessing whorl sides on the body chamber which are evenly rounded, by being more involute, possessing denser bullae on the body chamber, and in that the primaries on the body chamber are much shorter. The last character indicates that the specimen from Oregon belongs to *Pseudotoites*. Also like *Pseudotoites* (unlike *Emileia*) primary ribbing first appears well above the umbilical seam. The new species is perhaps closest to *P. championensis* (Crick) (Arkell and Playford, 1956, p. 574, pl. 32, fig. 4; pl. 33, fig. 1). It differs from that species in that on the body chamber the bullae are weaker and slightly higher on the flanks, the umbilical wall is not quite so steep, and the secondary ribbing is entirely reduced. *Pseudotoites* n. sp. differs from any previously described species of the genus by lacking distinct secondary ribbing on the body chamber.
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DORN, P.

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WESTERMANN, G. E. G. AND T. A. GETTY

WESTERMANN, G. E. G. AND A. C. RICCARDI

WHITEAVES, J. F.

YOUNG, K.
ZITTEL, K. A.
PLATE 1

[All figures are natural size. All specimens are from the upper division of the Weberg Member, Snowshoe Formation.]

Figures 1a, b. *Holoophylloceras burkei* Taylor n. sp.
Holotype, University of California, Berkeley, Museum of Paleontology, no. D-6753-1; Scott Ranch section; p. 63.

2a, b. *Fontannesia* aff. *F. luculenta* Buckman.
University of California, Berkeley, Museum of Paleontology, no. D-6744-6; Scott Ranch section; p. 80.

3a, b. *Fontannesia grantensis* Taylor n. sp.
Holotype, University of California, Berkeley, Museum of Paleontology, no. D-6744-7; Scott Ranch section; p. 77.

4. Paratype, University of California, Berkeley, Museum of Paleontology, no. D-6744-8; Scott Ranch section; p. 77.
PLATE 2

[All figures are natural size. All specimens are from the upper division of the Weberg Member, Snowshoe Formation.]

Earth Sciences Museum, Portland State University, no. A-0556-32; Lupher Draw section; p. 92.

2. Earth Sciences Museum, Portland State University, no. A-0571-31; Lupher Draw section; p. 92.
PLATE 3

[Figures are natural size. The figured specimen is from the upper division of the Weberg Member, Snowshoe Formation.]

PLATE 4

[Figures are natural size. Both specimens are from the upper division of the Weberg Member, Snowshoe Formation.]

Earth Sciences Museum, Portland State University, no. A-0570-34; Vigrass Draw section; p. 94.

Earth Sciences Museum, Portland State University, no. A-0825-1; Lupher Draw section; p. 105.
PLATE 5

[Figures are x0.7 natural size. The figured specimen is from the upper division of the Weberg Member, Snowshoe Formation.]

Figures a, b. *Euhoploceras marginatum* (Buckman).
Hypotype, Earth Sciences Museum, Portland State University, no. 0571-1; p. 98.
Figures are natural size. The figured specimen is from the upper division of the Weberg Member, Snowshoe Formation.

Figures a, b. *Euhoploceras tuberculosum* Taylor n. sp.
Holotype, University of California, Berkeley, Museum of Paleontology, no. D-7072-63; Washburn Draw section; p. 109.
PLATE 7

[Figures are natural size. The figured specimen is from the upper division of the Weberg Member, Snowshoe Formation.]

Figures a–c. *Euhoploceras westi* Taylor n. sp.
I. PLATE 8

[Figures are natural size. Both figured specimens are from the upper division of the Weberg Member, Snowshoe Formation.]

Figures 1a, b. **Euhoploceras cf. E. westi** Taylor n. sp.

2. **Soninia (?)** n. sp.
Earth Sciences Museum, Portland State University, no. A-0552-20; Washburn Draw section; p. 81.
PLATE 9

[Figures are natural size. All figured specimens are from the upper division of the Weberg Member, Snowshoe Formation.]

Figures 1a, b. *Witchellia n. sp.*

2a, b. *Witchellia n. sp.*

3a, b. *Strigoceras taylori* Taylor n. sp.
Holotype, Earth Sciences Museum, Portland State University, no. A-0581-70; Washburn Draw section; p. 121.
PLATE 10

[Figures are natural size. The figured specimen is from the upper division of the Weberg Member, Snowshoe Formation.]

Figures a, b. *Bradfordia* n. sp.
Earth Sciences Museum, Portland State University, no. A-0550-71; Washburn Draw section; p. 123.
PLATE 11

[Figures are natural size. Both figured specimens are from the upper
division of the Weberg Member, Snowshoe Formation.]

Figures 1. Docidoceras (Pseudocidoceras) aff. D. (P.) camachoi
Westermann. Earth Sciences Museum, Portland
State University, no. A-0635-72; Washburn
Draw section; p. 128.

2a, b. Pseudotoites n. sp.
Earth Sciences Museum, Portland State University,
no. A-0571-73; Lupher Draw section; p. 130.
APPENDIX A

LITHOLOGIC DESCRIPTIONS OF TYPE WEBERG COMPOSITE SECTION

Begg Formation

Unit A

**Conglomerate;** sandy chert-felsite conglomerate.

**Sandstone;** pebbly chert-felsite arenite.

The Begg Formation at this locality is composed mainly of resistant, thick and massive-bedded granule-cobble conglomerate with intercalations of pebbly chert-felsite arenite. The weathered surface is light olive gray in color. Sand size terrigenous detritus is angular to subangular, while coarser detritus is subangular to subrounded.

- angular unconformity-

Weberg Member, lower division

Unit B

**Limestone;** pebbly sandy shelly biosparite.

The unit is gray on fresh exposure; its weathered color is not known. It is very resistant, 1m thick, and the basal limestone bed of the Weberg Member at Lupher Draw. Abundant broken shelly detritus is subparallel to bedding, and terrigenous grains form thin to medium, sometimes lenticular internal bedding.

The rock is submature and poorly sorted. Terrigenous grain size distribution is essentially medium sand through small pebbles. Median
diameter is probably in the coarse sand size range. Grains are sub-
angular to subrounded. The terrigenous component is 35 percent of
the rock. Of that 35 percent, chert and felsite rock fragments com-
prise about 93 percent, quartz about 5 percent, albite about 1 percent,
and interstitial phyllosilicates about 1 percent.

Calcite comprises about 65 percent of the rock. Microfibular
molluscan shell fragments make up perhaps 40 percent of that percen-
tage, but crinoidal elements also occur in abundance. A couple of
coral fragments were noticed in thin section. Authigenic medium
crystalline sparry calcite accounts for about 50 percent of the car-bonate material. The coarsest 1 percent is coarsely crystalline,
while less than 10 percent is finely crystalline. Overgrowths of
sparry calcite (0.01 to 0.05 mm thick) are present on some allochems
and terrigenous detritus.

Unit C

Sandstone: granular calcareous (crinoidal) submature chert arenite.

The unit is texturally and compositionally much like the super-
jacent limestones and sandstones of the lower Weberg. This unit
differs in that it is less calcareous and in that the terrigenous
detritus is coarser.

The most calcite-rich chert arenite occurs in the upper part of
the unit, is brown gray when fresh and weathers to a yellowish orange
color. It is not strongly resistant to erosion. The less calcareous
chert arenite in the lower part of the unit is largely light brownish
gray (5 YR 6/1), but has a pale red matrix (10 R 6/2) upon fresh
exposure. The rock weathers to a pale yellow brown and olive gray.
The unit has beds which are very resistant to erosion and form prominent ribs on hillsides. The entire unit appears thick-bedded but is faintly thin to medium-bedded in many places.

The following description is based upon a hand specimen and thin section from a resistant sandstone bed in the lower part of the sequence. The rock is submature and poorly sorted. Size range of terrigenous detritus is from very fine sand (0.09 mm diam.) to granules. The coarsest 1 percent is 3 mm in diam. Median diameter is in the medium sand size range. The detritus is angular to subangular, and only occasional larger grains have subrounded boundaries. The terrigenous components comprise 71 percent of the rock and occur in the following relative abundances:

<table>
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<th>Component</th>
<th>Percent</th>
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<tbody>
<tr>
<td>albite</td>
<td>6</td>
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<tr>
<td>quartz</td>
<td>15</td>
</tr>
<tr>
<td>chert</td>
<td>75</td>
</tr>
<tr>
<td>coarsely crystalline volcanic rock fragments</td>
<td>5</td>
</tr>
<tr>
<td>interstitial phyllosilicates</td>
<td>1</td>
</tr>
</tbody>
</table>

The calcite is made up of about 10 percent microfibular molluscan shell fragments, and about 75 percent crinoidal elements which are so intimately intergrown with the terrigenous grains as to superficially look like coarsely crystalline spar cement. Fine to medium crystalline blocky spar comprises the remaining 15 percent of the calcite. Interstitial calcite is mostly finely crystalline spar.

Unit D

Limestone: coarse silty-granular crinoidal sparite.

Sandstone: granular calcareous submature albite-bearing chert arenite.
The rock is gray on fresh exposure, and weathers light olive gray and yellowish gray. It is resistant and medium to thick-bedded. The limestone is well exposed, particularly in its upper part. The calcareous (40 percent calcite) sandstone in the lower third of the unit differs in that it weathers a yellowish orange color and that it is not resistant to erosion. A minor sandy intercalation near the top of the unit is lithologically much like unit F.

The entire unit is submature and poorly sorted. Grain size distribution is from coarse silt through coarse sand. Coarsest 1 percent of terrigenous detritus ranges from coarse sand (0.65 mm) near the top of the unit to finest granules (2 mm diam.) at the base. Median diameter for the terrigenous detritus is in the fine sand size class. Terrigenous grains are angular to subangular, and only occasionally large grains may be subrounded. The interstitial phyllosilicates, which are partly chlorite, are mostly a yellow-brown clay. The yellow-brown clay may be detrital. Phyllosilicates occur in abundances of 1 to 4 percent.

The terrigenous components of the limestone (excluding clay) comprise about 21-27 percent of the rock. Their approximate relative abundances are:

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<tr>
<th>Component</th>
<th>Percent</th>
</tr>
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<tr>
<td>quartz</td>
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<tr>
<td>chert</td>
<td>21-52</td>
</tr>
<tr>
<td>albite</td>
<td>8-18</td>
</tr>
<tr>
<td>coarsely crystalline volcanic rock fragments</td>
<td>5</td>
</tr>
<tr>
<td>undetermined altered rock fragments</td>
<td>5</td>
</tr>
<tr>
<td>felsitic rock fragments</td>
<td>18-35</td>
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</table>
The carbonate fraction comprises 69 to 75 percent of the limestone. Over 75 percent of the calcite is in the form of poorly sorted abraded allochems. Most of them are crinoidal elements, and a large minority are microfibular shell fragments. Interstitial calcite is mostly finely crystalline spar.

Unit E

**Sandstone:** pebbly calcareous submature albite-rich chert arenite.

The color of the rock when fresh is medium light gray; it weathers brownish gray to dark yellowish orange. The unit is not very resistant to erosion. There appears to be no internal bedding. Texturally, the rock is submature and poorly sorted. The grain size distribution (excluding clays) is mainly from coarse silt to fine pebbles (20 mm maximum diam.), however, it is conspicuously bimodal. Granules comprise less than 5 percent of the rock but small pebbles, mostly 7 to 10 mm diam. make up 20 to 40 percent of the rock. The size fraction coarser than sand consists of subangular to subrounded grains. The coarse silty through sand size fraction makes up 20 to 40 percent of the rock; median diameter of this size group is in the fine sand size class. Nearly all material through fine sand is angular. Medium and coarse through very coarse sand has a mixture of grains which are angular to subrounded. The detritus coarser than sand is composed of rock fragments which are mostly chert, but perhaps 5 percent are volcanic in composition. The terrigenous coarse silt through sand size fraction consists of the following components:
The carbonate fraction comprises 20 to 60 percent of the rock. Well over half of the allochems are poorly sorted, abraded crinoidal elements, and the remaining ones are mostly molluscan shell fragments replaced by coarse spar. The outlines of many of the crinoidal elements are vague as their boundaries are dissolved and often conform to the neighboring detrital grain boundaries. It is impossible to accurately estimate the percentage of interstitial calcite or calcite cement, but it probably comprises not over 25 percent of the carbonate fraction. Calcite tends to be finely crystalline in the terrigenous sandy matrix, but in places, especially where pebbles are tightly packed, coarsely crystalline sparry cement is present.

Unit F

Sandstone; granular calcareous submature chert arenite.

When fresh the rock is pale yellowish brown and weathers to a medium grayish to pale reddish brown and dark yellowish brown. These beds are a little more resistant to erosion than the superjacent sandy mudstones. The lithology is transitional between lower and upper Webber lithology.

No internal bedding was observed; some horizons are concretionary. Medium sand and coarser material commonly forms ill-defined congregations. Close inspection of the rock shows it is faintly mottled because of the irregular distribution of relatively silty and

<table>
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<tbody>
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<tr>
<td>albite</td>
<td>37</td>
</tr>
<tr>
<td>chert</td>
<td>31</td>
</tr>
<tr>
<td>volcanic rock fragments</td>
<td>7</td>
</tr>
<tr>
<td>phyllosilicates</td>
<td>1-4</td>
</tr>
</tbody>
</table>
relatively sandy parts of the rock. Some shelly detritus is parallel to the bedding but much is also randomly oriented. The mottled nature of the matrix and random shell orientation indicate the rock is bioturbated. The lithology near the base of the sequence has 2 to 5 percent medium sand and coarser grains, but this size fraction becomes less conspicuous toward the top of the unit.

The rock is poorly sorted; size range of the terrigenous component (excluding clay) is from coarse silt through granules. Subangular chert granules locally comprise the coarsest 1 percent of the rock, but coarse through very coarse subangular to subrounded chert sand is ubiquitous and comprises 2 to 20 percent of the rock. Median diameter is in the fine sand size class. The terrigenous detritus up through medium sand size is angular to subangular. Carbonate content, excluding the calcite concretions, probably does not exceed 20 percent. In some sections the top of the unit is marked by a bed of granular-sandy biosparite.

- conformable contact -

Weberg Member, upper division

Unit G

The upper division of the member is composed of relatively non-resistant silty sandstone with numerous thin, resistant, tabular intercalations of limestone, each 6 to 60 cm thick. The two principal lithologies are as follows.

Sandstone; siltstone; silty, calcareous submature plagioclase arkose, and silty calcareous submature arenite.
The rock is "medium" to "tan gray" when fresh and weathers "tan gray." It is relatively non-resistant to erosion and weathers to fine blocky rubble. Besides abundant disarticulated fish bones, uncommon ostreids and belemnites are the only fossils encountered. No internal bedding features are evident.

The terrigenous detritus ranges from medium silt through medium sand, and is well to moderately well sorted. Grain outlines are angular to subangular. Phyllosilicates probably comprise a very few percent of the rock (2 to 4 percent). Variable percentages of calcite are present.

These rocks border on being sandstones and siltstones. Rocks with slightly over 50 percent sand size detritus are prevalent in the part of the division below the sandstone-limestone marker unit in the middle of the upper division, while very sandy siltstone predominates above the marker. This textural trend occurs also in the associated limestone beds.

Limestone; medium silty to medium sandy crinoidal sparite.

The color of the limestone beds is medium light gray, tan gray and medium gray on fresh exposure; the weathered surface is light gray, tan gray but more typically grayish orange. The beds are best exposed as blocky rubble on minor ribs on south-facing hillsides.

Internally, beds may show faint indications of bedding, lamination and usually bioturbation, but are structureless in gross appearance. Shell debris is commonly randomly oriented, presumably due to bioturbation, but may be concentrated into lentils, and around or in large objects like the body chamber of an ammonite where a shelly
layer may be found in the side of the body chamber which fell against the substrate when the animal died. The infaunal burrowing pelecypod *Pleuronyx* is commonly found in living position.

The rock is well to moderately sorted; size range of the terrigenous component (excluding clay) ranges from medium silt to medium sand. Median diameter of grains is in the very fine sand size class lower in the unit, but above the sandstone-limestone marker it is generally in the coarse silt size class. Terrigenous detritus is mostly angular to occasionally subangular. There are a couple beds of well sorted medium to coarse arenite. One of them is the marker bed in the middle of the upper division, which with the underlying limestone bed, crops out as a conspicuous rib on south-facing hill-sides.

The carbonate fraction is mostly recrystallized crinoidal elements which, along with the terrigenous component, forms the framework of the rock. A few ossicles have sharp boundaries, but these are usually dissolved to varying degrees. Their identity is usually revealed because they are often recrystallized by medium to coarsely crystalline spar which is clearer and coarser than the finely crystalline blocky interstitial calcite. The crinoidal elements are well to moderately sorted and have a similar but somewhat coarser size range than the terrigenous component. The ossicles are not usually in the silt size range; particles up to medium sand size are not infrequent.

The terrigenous component comprises 10 to 35 percent of the rock. Both volcanic and sedimentary detritus is present in various degrees of mixing. Beds with abundant volcanic detritus are most
common high in the unit. Here albite grains may comprise up to 75 or 80 percent, altered volcanic rocks up to 20 to 25 percent, and reworked quartz and chert may make up just a few percent of the rock.

Biotite is a very common accessory mineral. Beds with abundant sedimentary detritus are most common low in the unit. Here individual beds may have up to 40 to 45 percent quartz, and may have little volcanic detritus. Clay is probably not present in abundance greater than 1 to 3 percent. A brown phyllosilicate is concentrated into vague patches and occurs around detritual grains.

Recrystallized crinoidal ossicles comprise approximately 25 to 30 percent of the rock; molluscan shell detritus, which is recrystallized to coarsely blocky spar, accounts for 1 to 25 percent of the rock. Interstitial calcite matrix probably does not comprise more than 20 to 25 percent of the rock.

Warm Springs Member

Unit H

Mudstone; sandy mudstone.

The sandy mudstone of the lower part of the Warm Springs Member is dark gray to dark yellowish brown in color when fresh and weathers a dark yellowish brown. It is laminated to medium-bedded. Occasional thin beds of concretionary limestone occur near the base of the member.
APPENDIX B

SECTION AND LOCALITY DESCRIPTIONS

Stratigraphic Section 490 m Northwest of Lupher Draw Section

Lower division of Weberg Member
Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon
W1/2SE1/4SW1/4 sec. 19, T. 18 S., R. 26 E.

The northern terminus of this section, at the contact of the
Snowshoe and Brisbois Formations, is 157 m north of the southern
boundary of section 19, and 279 m east of the western boundary of the
same section. The southeastern terminus of the stratigraphic section
is 116 m north of the southern boundary of section 19, and 335 m east
of the western boundary of the same section. The stratigraphic sec-
tion was measured and fossil collections were made from road cuts
along the northeastern side of a county road.

The stratigraphic datum is a 0.37 m thick bed of coarse sandy
crinoidal biosparite; it is underlain by several feet of silty lith-
arenite.

Locality A-0607: Weberg Member; medium to thick-bedded silty
litharenite, 0 to 0.46 m stratigraphically below datum.

Locality A-0616: Weberg Member; medium to thick-bedded silty
litharenite, 0 to 1.52 m stratigraphically below datum; specimens
are float.

Locality A-0641: Weberg Member; medium-bedded silty lith-
arenite, 2.13 to 2.44 m stratigraphically below datum.
**Vigrass Draw Section**

Upper part of Weberg Member and lower part of Warm Springs Member.

Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon E1/2SE1/4SW1/4 sec. 19, T. 18 S., R. 26 E.

The southern terminus of the stratigraphic section, which is within the Warm Springs Member, is 85 m north of the southern boundary of section 19, and 53 m west of the eastern boundary of the same section. The northern terminus of the stratigraphic section, which is within the upper division of the Weberg Member, is 210 m north of the southern boundary of section 19, and 482 m west of the eastern boundary of the same section. The stratigraphic section was run parallel to and 30 to 60 m northeast of a northeast-southwest trending valley herein designated Vigrass Draw, after Lawrence Vigrass, a geologist who mapped the Suplee area. The northeastern two-thirds of the stratigraphic section was run on the south-facing hillside of the draw, while the southwestern one-third of the stratigraphic section was run through a bulldozer cut down a gently sloping southwesterly-facing hillside.

The stratigraphic datum for the Vigrass Draw section is the base of a 0.31 m thick resistant, calcareous litharenite. The base of this bed occurs 15.24 m stratigraphically below the top of the Weberg Member.

**Locality A-0978:** Warm Springs Member; calcareous mudstone concretions in medium-bedded mudstone, 45.11 to 45.42 m stratigraphically above datum.
Locality A-0979: Warm Springs Member; medium-bedded mudstone, 44.20 to 44.50 m stratigraphically above datum.

Locality A-0980: Warm Springs Member; calcareous mudstone concretions in medium-bedded mudstone, 38.56 to 38.77 m stratigraphically above datum.

Locality A-0606: Warm Springs Member; calcilutite concretions in medium-bedded mudstone, about 20 m stratigraphically above datum.

Locality A-0583: Weberg Member; crinoidal biosparite, 0.06 m thick bed 9.45 to 9.51 m stratigraphically above datum.

Locality A-0623: Weberg Member; crinoidal biosparite, 0.12 m thick bed 7.86 to 7.98 m stratigraphically above datum.

Locality A-0625: Weberg Member; crinoidal biosparite, 0.09 m thick bed 7.01 to 7.10 m stratigraphically above datum.

Locality A-0597: Weberg Member; crinoidal biosparite, 0.21 m thick bed 6.86 to 7.07 m stratigraphically above datum.

Locality A-0579: Weberg Member; crinoidal biosparite, 0.30 m thick bed 4.18 to 4.48 m stratigraphically above datum.

Locality A-0600: Equivalent to A-0579.

Locality A-0634: Weberg Member; mudstone, 0.46 m thick bed 3.78 to 4.24 m stratigraphically above datum.

Locality A-0594: Weberg Member; crinoidal biosparite, 0.18 m thick bed 3.60 to 3.78 m stratigraphically above datum.

Locality A-0578: Weberg Member; mudstone, 0.25 m thick bed 3.35 to 3.60 m stratigraphically above datum.

Locality A-0570: Weberg Member; crinoidal biosparite, 0.24 m thick bed 3.11 to 3.35 m stratigraphically above datum.
Locality A-0533: Weberg Member; crinoidal biosparite, 0.12 m thick bed 2.38 to 2.50 m stratigraphically above datum.

Locality A-0615: Weberg Member; calcareous silty litharenite, 0.18 m thick bed 0.55 to 0.73 m stratigraphically above datum.

Lupher Draw Section (Type Weberg Section)

Weberg Member.
Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon
SW1/4SE1/4 sec. 19, T. 18 S., R. 26 E.

The southwestern terminus of the stratigraphic section, which is at the contact of the Weberg and Warm Springs Members, is 15 m north of the southern border of section 19, and 420 m west of the eastern border of the same section. The northeastern terminus, which is at the contact of the Snowshoe and Begg Formations, is 113 m north of the southern boundary of section 19, and 293 m west of the eastern border of the same section. The stratigraphic section runs horizontally on a south-facing hillside of Lupher Draw, herein named for the geologist Ralph Lupher, who was the first person to describe in detail the Jurassic rocks of the area.

The stratigraphic datum for the section is the base of the 0.91 m thick sandy, pebbly biosparudite which is the lower contact of the Snowshoe Formation at the locality. The bed is underlain by conglomerate of the Begg Formation.

Locality A-0752: Weberg Member; crinoidal biosparite, 0.21 m thick bed 47.61 to 47.82 m stratigraphically above datum.

Locality A-0554: Weberg Member; silty litharenite, 0.61 m thick bed 46.94 to 47.55 m stratigraphically above datum.
Locality A-0591: Weberg Member; silty litharenite, 0.49 m thick bed 46.21 to 46.70 m stratigraphically above datum.

Locality A-0555: Weberg Member; crinoidal biosparite, 0.21 m thick bed 43.80 to 44.01 m stratigraphically above datum.

Locality A-0564: Weberg Member; silty litharenite, 0.12 m thick bed 43.68 to 43.80 m stratigraphically above datum.

Locality A-0556: Weberg Member; crinoidal biosparite, 0.25 m thick bed 43.43 to 43.68 m stratigraphically above datum.

Locality A-0601: Weberg Member; limestone nodule in silty litharenite, 0.18 m thick bed 43.04 to 43.22 m stratigraphically above datum.

Locality A-0563: Weberg Member; crinoidal biosparite, 0.21 m thick bed 41.79 to 42.00 m stratigraphically above datum.

Locality A-0557: Weberg Member; crinoidal biosparite, 0.31 m thick bed 41.39 to 41.7 m stratigraphically above datum.

Locality A-0640: Equivalent to A-0557, upper part of bed.

Locality A-0766: Equivalent to A-0557.

Locality A-0560: Weberg Member; crinoidal biosparite, 0.40 m thick bed 40.17 to 40.57 m stratigraphically above datum.

Locality A-0825: Weberg Member; crinoidal biosparite, 0.31 m thick bed 39.11 to 39.41 m stratigraphically above datum.

Locality A-0571: Weberg Member; crinoidal biosparite, 0.12 m thick bed 37.86 to 37.98 m stratigraphically above datum.

Locality A-0575: Weberg Member; crinoidal biosparite, 0.18 m thick bed 34.87 to 35.05 m stratigraphically above datum.
**Locality A-0566:** Weberg Member; crinoidal biosparite, 0.1 m thick bed 34.9 to 40.0 m stratigraphically above datum.

**Locality A-0568:** Weberg Member; silty litharenite, 0.12 m thick bed 34.63 to 34.75 m stratigraphically above datum.

**Locality A-0553:** Weberg Member; crinoidal biosparite, 0.27 m thick bed 30.33 to 30.60 m stratigraphically above datum.

**Locality A-0580:** Weberg Member; litharenite, 29.5 m stratigraphically above datum.

**Lupher Draw Section (a)**

Warm Springs Member.
Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon NE1/4NW1/4NW1/4NE1/4 sec. 30, T. 18 S., R. 26 E.

This stratigraphic section begins at the contact of the Warm Springs and Weberg Members 15 m south of the northern boundary of section 30, and 381 m west of the eastern boundary of the same section. It continues upsection, down a fairly steep west-facing hillside to low roadcuts on the east side of a county road. Then the stratigraphic section continues southeast and ends in the Warm Springs Member 61 m south of the northern boundary of sec. 30, and 381 m west of the eastern boundary of the same section.

The stratigraphic datum for the section is the top of the highest limestone bed which demarks the top of the Weberg Member. The thickness of the limestone bed was not measured. The stratigraphic section, designated Lupher Draw section (a), is situated on the south side of Lupher Draw.
Locality A-0784: Warm Springs Member; mudstone, 32.37 to 32.46 m stratigraphically above datum.

Locality A-0783: Warm Springs Member; mudstone, 32 m stratigraphically above datum.

Locality A-0782: Warm Springs Member; mudstone, 31.70 m stratigraphically above datum.

Locality A-0954: Warm Springs Member; mudstone, 25.15 to 25.33 m stratigraphically above datum.

Washburn Draw Section

Weberg Member
Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon NE1/4NE1/4 sec. 30, T. 18 S., R. 26 E.

The western terminus of the stratigraphic section is 175 m south of the northern boundary of section 30, and 213 m west of the eastern boundary of the same section. The eastern terminus, which is at the contact of the Snowshoe and Begg Formations, is 152 m south of the northern boundary of section 30, and 110 m west of the eastern boundary of the same section. The stratigraphic section was run approximately horizontally across a steep south-facing slope at Washburn Draw. The stratigraphic section is situated about 60 m upslope from the trough of the draw. The draw is named for the Old Washburn Homestead, located a couple hundred meters west of the locality for this stratigraphic section.

The stratigraphic datum for the Washburn Draw section is the base of a resistant 1.22 m thick medium-bedded, granular-sandy biosparudite. This unit is overlain by 1.83 m of calcareous litharenite,
and underlain by 1.22 m of calcareous litharenite. The base of the
Weberg Member, which is rather poorly exposed at this locality, is
7 m stratigraphically below the base of the datum.

**Locality A-0612:** Weberg Member; crinoidal biosparite, 0.52 m
thick bed 26.82 to 27.34 m stratigraphically above datum.

**Locality A-0550:** Weberg Member; crinoidal biosparite, 0.49 m
thick bed 25.91 to 26.40 m stratigraphically above datum.

**Locality A-0552:** Equivalent to A-0550.

**Locality A-0565:** Weberg Member; crinoidal biosparite, 0.23 m
thick bed 24.90 to 25.13 m stratigraphically above datum.

**Locality A-0581:** Equivalent to localities A-0550 or A-0565.

**Locality A-0573:** Weberg Member; from upper part of member,
probably equivalent to locality A-0550 or A-0565.

**Locality D-7072:** Weberg Member; crinoidal biosparite, 0.18 m
thick bed 24.35 to 24.53 m stratigraphically above datum.

**Locality A-0572:** Weberg Member; crinoidal biosparite, 0.17 m
thick bed 22.46 to 22.63 m stratigraphically above datum.

**Locality D-6774:** Equivalent to A-0572.

**Locality A-0559:** Weberg Member; crinoidal biosparite, top 0.1 m
of 0.2 m thick bed 20.95 to 21.15 m stratigraphically above datum.

**Locality A-0558:** Weberg Member; crinoidal biosparite, bottom
0.1 m of 0.2 m thick bed 20.75 to 20.95 m stratigraphically above
datum.

**Locality A-0574:** Equivalent to A-0558, but specimens are float.

**Locality A-0576:** Weberg Member; crinoidal biosparite, 0.46 m
thick bed 19.44 to 19.90 m stratigraphically above datum.
Locality D-6781: Weberg Member; silty litharenite, from near middle of 0.15 m thick bed, 14.82 to 14.97 m stratigraphically above datum.

Locality A-0569: Weberg Member; concretions of crinoidal biosparite in silty litharenite, 0.21 m thick bed 14.97 to 15.18 m stratigraphically above datum.

Locality A-0637: Equivalent to A-0569, specimens are float.

Locality A-0636: Weberg Member; crinoidal biosparite, 0.16 m thick bed 13.72 to 13.88 m stratigraphically above datum.

Locality D-6780: Weberg Member; silty litharenite, 0.76 m thick bed 12.96 to 13.72 m stratigraphically above datum.

Locality A-0562: Weberg Member; litharenite, 12.2 to 12.4 m stratigraphically above datum.

Locality A-0635: Weberg Member; litharenite, 12.0 to 12.4 m stratigraphically above datum.

Locality A-0639: Equivalent to A-0635, specimens are float.

Locality A-0628: Weberg Member; stratigraphically equivalent to A-0551 or higher, perhaps as high as 7.3 m stratigraphically above base of datum; specimens are float.

Locality A-0551: Weberg Member; litharenite, 1.16 to 1.31 m stratigraphically above datum.

Locality A-0582: Weberg Member, upper division.

Locality A-0970: Weberg Member, upper part of upper division.

Locality A-0975: Weberg Member, upper division (probably Washburn Draw).
Stratigraphic Section 320 m South of Washburn Draw

Upper part of Weberg and Lower part of Warm Springs Members. Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon SE1/4NE1/4 sec. 30, T. 18 S., R. 26 E.

The southern terminus of this section is 348 m south of the northern boundary of section 30 and 116 m west of the eastern boundary of the same section. The northeastern terminus, which is in the upper division of the Weberg Member, is 282 m south of the northern boundary of section 30, and on the eastern boundary of the same section.

The stratigraphic datum of the section is the top of a 0.48 m thick crinoidal biosparite which demarks the top of the Weberg Member.

Locality A-0619: Warm Springs Member; crinoidal biosparite, 0.15 m thick bed 15.94 to 16.09 m stratigraphically above datum.

Locality A-0631: Stratigraphically equivalent to A-0619, but about 60 m to the north of that locality.

Locality A-0583: Stratigraphically equivalent to A-0619, but 30 m to the south of that locality.

Locality A-0602: Weberg Member; crinoidal biosparite, 0.24 m thick bed 2.04 to 2.28 m stratigraphically below datum.

Locality A-0974: Weberg Member; crinoidal biosparite, 0.16 m thick bed 3.11 to 3.26 m stratigraphically below datum.

Locality A-0603: Weberg Member; crinoidal biosparite, 0.15 m thick bed 3.75 to 3.90 m stratigraphically below datum.

Locality A-0620: Weberg Member; silty litharenite, 3.50 m thick bed 22.56 to 26.06 m stratigraphically below datum.
Locality A-0746: Stratigraphically equivalent to A-0620, but specimens are float.

Locality A-0621: Weberg Member; granular litharenite, 0.60 m thick bed 26.06 to 26.66 m stratigraphically below datum.

Locality A-0827: Weberg Member; upper part of upper division.

Locality A-0735: Weberg Member; upper division; somewhere from area of type Weberg composite section.

Robertson Draw Section

Middle part of Weberg Member.
Delintment Lake Quadrangle, 1:62,500, 1961; Grant County, Oregon S1/2NW1/4NW1/4 sec. 29, T. 18 S., R. 26 E.

The stratigraphic section was measured approximately horizontally across a small draw herein designated Robertson Draw, after Les Robertson, a local rancher of the area. The measured section runs from 60 m west of the draw, at the stratigraphically lower part of the section, to about 30 m east of it. The section is a composite and parts were measured from 45 m south to 150 m south of the brow of the hill at the north head of the draw. A small, generally north-trending dirt road goes through the locality and ends approximately 90 m to the northeast of where the stratigraphic section was measured.

The stratigraphic datum for the section is the base of a 0.31 m thick "light gray" sandy-granular crinoidal biosparite. This bed is very distinctive in its light coloration.

Locality A-0977: Weberg Member; crinoidal biosparite, 7.56 to 9.30 m stratigraphically above datum.
Scott Ranch Section

Weberg Member
Dayville Quadrangle, 1:125,000, 1932; Crook County, Oregon
E. central border of NW1/4 sec. 1, T. 18 S., R. 25 E.

The Scott Ranch section is located 6,248 m southwest, and 122.25 degrees from the summit of Funny Butte. It is also located 183 m southwest of the summit of a small hill. The section is situated on the north side of an east-west trending tributary which enters into Camp Creek. The tributary is named Scott Draw for the property owner. The stratigraphic section runs approximately horizontally. It begins at the contact of the Snowshoe and Brisbois Formations on a west-facing hillside 213 m east of Camp Creek and about 76 m north of the trough of Scott Draw. It trends south for about 38 m then trends northeast along an east-facing hillside, finally crosses Scott Draw and ends in the lower part of the Warm Springs Member about 183 m northeast of the beginning of the section.

The stratigraphic datum for the section is the base of a 0.21 m thick calcareous litharenite which is the base of the Weberg Member. The bed is overlain by a 1.83 m thick unit of calcareous litharenite. The top of the Brisbois Formation underlies the Snowshoe Formation at this locality, and very near the contact is composed of mudstone with calcilutite concretions.

Locality A-0676: Weberg Member; biosparite concretions in silty litharenite, 16.46 to 16.67 m stratigraphically above datum.

Locality D-6753: Equivalent to A-0676.
Packard Draw Section

Weberg and lower part of Warm Spring Members.
Dayville Quadrangle, 1:125,000, 1932; Grant County, Oregon
W central part of sec. 3, T. 18 S., R. 26 E.

The Packard Draw section is located 3,900 m south-southeast and 188 degrees from the summit of Funny Butte, and is situated on a southwest-facing hillside on the northeast side of a draw herein designated Packard Draw, for Earl Packard, a geologist who worked in the area. The stratigraphic section was run approximately horizontally from the southeast terminus at the contact of the Snowshoe and Robertson Formations. The section trends northwest into the basal bed of the Warm Springs Member.

The stratigraphic datum for the section is the base of a 0.24 m thick bed of crinoidal biosparite which demarks the base of the Snowshoe Formation at this locality. The Snowshoe Formation here is underlain by volcanic litharenite of the Robertson Formation.

Locality D-5744: Weberg Member; crinoidal biosparite, 0.23 m thick bed 22.22 to 22.45 m stratigraphically above datum.

Mowich Spring Section

Parts of Weberg and Warm Spring Members.
Delintment Lake Quadrangle, 1:62,500, 1961; Harney County, Oregon E1/2 of sec. 3, T. 19 S., R. 26 E.

A line trending 101 degrees in a southwesterly direction from the southeasterly summit of Big Mowich Mountain meets the southern terminus (or stratigraphically highest point) of the Mowich Spring section at a distance of 1,920 m from the summit of the mountain. The stratigraphic section was started in the Warm Springs Member on the east
side of Ochoco National Forest service road 1843, and continued along the same side of the road for a distance of about 1,060 m in a northeasterly direction, and terminated at a point where the Weberg Member becomes covered by regolith. The northern terminus of the section is 524 m from, and 356 degrees north-northeast of Mowich Spring. Fossil collections were made in roadcuts and in the road ditch.