

BIOSTRATIGRAPHY AND AMMONOID FAUNA  
OF THE LOWER JURASSIC  
(SINEMURIAN, PLEINSBACHIAN AND LOWEST TOARCIAN)  
OF EASTERN OREGON AND WESTERN NEVADA



By

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## ABSTRACT

Over 2000 ammonite specimens from the Lower Jurassic of Oregon and Nevada are identified, described, and their stratigraphic ranges determined. At least 66 species are represented, distributed amongst 32 genera or subgenera and 9 families. *Luningiceras* is erected as a new subgenus of *Acanthopleuroceras* (type species *A. (L.) pinnaforme* n. sp.). *Paltechioceras depressum*, *P. gettyi* and *Acanthopleuroceras (A.) mulleri*, are described as new. *Hyperderoceras* and *Asteroceras (Eparietites)* are also probably represented by new species but the nature of the material does not warrant the establishment of new names.

The following assemblage zones are erected spanning the Sinemurian (excluding the lowest Sinemurian), Pliensbachian, and lowest Toarcian Stages: *A. ceratitoides*, *P. harbledownense*, *P. rothpletzi*, *Acanthopleuroceras (Luningiceras) pinnaforme*, *D. dayiceroides*, *R. fannini*, and *Tiltoniceras propinquum*. The zones are used to correlate the contrasted facies of Oregon and Nevada which are respectively eugeosynclinal and miogeosynclinal in aspect. The age of all the lithostratigraphic units

discussed is either refined or revised. In the southern part of the Nevada study area, a regression occurred during the late Carixian and early Domerian which correlates with a time of transgression in the Suplee-Izee area of east-central Oregon. The Lower Jurassic sequences of the two states accumulated on separate microplates but the coincidence of regression and transgression suggests microplate interaction and hence, geographic proximity. Marine deposition was continuous at Westgate, Nevada but the presence of vertically imbedded ammonites and other lines of evidence suggest a shallow water environment of deposition. Analysis of the orientation of ammonite planes of bilateral symmetry indicate a palaeocurrent from the northwest.

The Lower Jurassic ammonites of Oregon and Nevada show Tethyan affinities. The Pliensbachian faunas of the northeast Pacific show a tripartite division into Boreal, mixed, and Tethyan faunas as in Europe but the transition is from west to east, rather than from south to north. This pattern is caused by a northward transportation of the Wrangellia terrane relative to the North American plate since the Early Jurassic.



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*Gleviceras ex gr. victoris* (DUMORTIER)
8. *Hyperderoceras* n. sp.  
*Crucilobiceras (Metaderoceras) evolutum* (FUCINI)  
*Crucilobiceras (Metaderoceras) beirense* MOUTERDE

9. *Crucilobicerias* (*Metaderoceras*) cf. *muticum* (D'ORBIGNY)
10. *Crucilobicerias* (*Metaderoceras*) cf. *muticum* (D'ORBIGNY)  
*Microderoceras* cf. *birchiades* ROSENBERG  
*Phricodoceras* sp.  
*Tropidoceras actaeon* (D'ORBIGNY)  
*Acanthopleuroceras* (*Acanthopleuroceras*) spp.  
*Acanthopleuroceras* (*Acanthopleuroceras*)  
cf. *valdani* (D'ORBIGNY)
11. *Crucilobicerias* (*Metaderoceras*) *silviesi* (HERTLEIN)
12. *Acanthopleuroceras* (*Acanthopleuroceras*) *mulleri* n. sp.  
*Dayicerias dayiceroides* (MOUTERDE)
13. *Acanthopleuroceras* (*Luningicerias*) *pinnaforme* n. sp.
14. *Acanthopleuroceras* (*Luningicerias*) *pinnaforme* n. sp.
15. *Oistoceras* ? sp.  
*Coeloceras* (*Coeloceras* ?) cf. *depressum* ROSENBERG  
*Coeloceras* (*Coeloceras* ?) spp.  
*Coeloceras* (*Reynesocoeloceras*) cf. *baconicum* GECZY  
*Coeloceras* (*Reynesocoeloceras*) *incertum* FUCINI
16. *Prodactylioceras* (*Prodactylioceras*) cf. *davoei* (SOWERBY)  
*Prodactylioceras* (*Aveyronicerias*) *colubriforme* (BETTONI)  
*Prodactylioceras* (*Aveyronicerias*) spp.  
*Prodactylioceras* (*Aveyronicerias*) cf. *inaequiornatum*  
(BETTONI)  
*Protogrammoceras paltum toyoranum* (MATSUMOTO)
17. *Arieticerias* cf. *algovianum* (OPPEL)  
*Protogrammoceras* cf. *lusitanicum* (CHOFFAT)  
*Lioceratoides* cf. *matsumotoi* HIRANO  
*Protogrammoceras argutum* (BUCKMAN)
18. *Protogrammoceras* cf. *nipponicum* (MATSUMOTO)  
*Protogrammoceras varicostatum* (FUCINI)  
*Fucinicerias* sp.  
*Fontanellicerias* cf. *fontanellense* (GEMMELLARO)  
*Harpoceras* cf. *maurelli* McLEARN
19. *Tiltonicerias propinquum* (WHITEAVES)

## CHAPTER 1

### INTRODUCTION

#### 1.1 Previous Work

In 1865 a U. S. Cavalry expedition led by Captain Drake returned from Oregon with collections of fossils proving the occurrence of marine Mesozoic rocks in the Upper Crooked River region, the geographic centre of the state. Seventy-five years were to pass before the first systematic accounts were published describing the general extent and nature of the Jurassic rocks of the western United States. Lupper's (1941) pioneering work on the Jurassic stratigraphy of central Oregon and Muller and Ferguson's (1939) mapping of the Hawthorne and Tonopah quadrangles in Nevada laid the foundation for all subsequent work in those states. Further discoveries of Lower Jurassic rocks in Oregon (Nolf, 1966; Brown and Thayer, 1966) and Nevada (Silberling, 1959; Corvalan, 1962) have been made relatively recently and there are almost certainly further discoveries waiting to be made. In fact as this was being written, geologic maps of the Rastus Mountain and Bull Run quadrangles in east-central Oregon became available showing a new and extensive unit named the Weatherby

Formation (Brooks and Ferns, 1979; Brooks *et al.*, 1979).

No details are available as yet but this unit is reported to contain early Sinemurian ammonites. Also, an unlocalised specimen of *Arnioceras* recorded from Humboldt County by Hyatt (1889, p. 173) indicates the presence of marine Lower Jurassic rocks somewhere in northern Nevada.

Although there is hope that the situation will improve marginally in the future, the fact remains that the Lower Jurassic rocks of the western United States crop out as small, isolated inliers surrounded by vast expanses of mostly Tertiary units. In addition, the lithology of the rocks indicates that a diverse suite of depositional environments existed during the Early Jurassic and that the present pattern of outcrop is the result of a complex tectonic history.

If a realistic picture of Early Jurassic history is to emerge, a maximal amount of evidence must be wrung from the sparse data points available. Detailed correlation is perhaps nowhere more important than in a mobile belt and detailed correlation is the primary aim of this thesis. Ammonoids have, with the possible exception of the Foraminiferida, been the most widely and successfully utilised organisms in zonal correlation. An immense body of knowledge has grown in Europe concerning the nature of the evolutionary turnover of Lower Jurassic ammonites

( ) and this forms the standard of reference for the division of Jurassic time. More importantly, the lateral distribution of temporally equivalent ammonoid faunas of Italy (Fischer, 1971, 1972; Wiedenmayer, 1977), Turkey (Bremer, 1965), the Iberian Peninsula (Mouterde, 1971), and Morocco (Dresnay, 1963; Dubar and Mouterde, 1978) have placed the Tethyan sequences on a sounder footing *vis a vis* the standard scheme of the northwest European Province. This is of great importance with respect to the American faunas because, at certain levels, a greater affinity to the Tethyan rather than the Boreal Realm is evident.

The relatively recent acquisition of knowledge concerning the Lower Jurassic biostratigraphy of the Tethyan Realm is not sufficient to explain the dearth of published information on the Lower Jurassic of the conterminous United States. Imlay's work on the Pliensbachian and Toarcian of California and Oregon remains the only major work (Imlay, 1968). A single specimen from the Donovan Formation of Oregon was described by Hertlein (1925); a new echioceratid species from California was described by Crickmay (1933) but no published palaeontologic account of the Lower Jurassic of Nevada exists at present. During the course of his geologic mapping of the Hawthorne and Tonopah quadrangles, Muller made extensive ammonite collections but the promise of a detailed account was never realised. Unfortunately,

Muller's collection has been poorly curated and locality information, if present at all, is often geographically and stratigraphically vague. With the exception of Imlay's work (1968) for part of the Oregon succession, the palaeontologic data for the Lower Jurassic of Oregon and Nevada consists of incomplete faunal lists for large stratigraphic intervals together with discussions of their broad age connotations based on the northwest European succession (Hallam, 1965). As such, it remains a major gap in our knowledge of the Lower Jurassic world.

## 1.2 Location of the Study Areas

The Jurassic localities that form the subject of this thesis are isolated points in a narrow area spanning almost eight degrees of latitude, a distance of approximately 800 km from the southern to the northernmost exposures (Fig. 1-1). The outcrops in Nevada are restricted to a series of upfaulted mountain ranges to the east and southeast of Reno in the west-central part of the state. These localities are separated by a distance of approximately 450 km from exposures of the Donovan Formation, the most southerly Lower Jurassic rocks in Oregon. It is not until the various ranges of the Western Blue Mountains are reached that exposures of the Jurassic are common. This region, stretching from the area around the abandoned towns



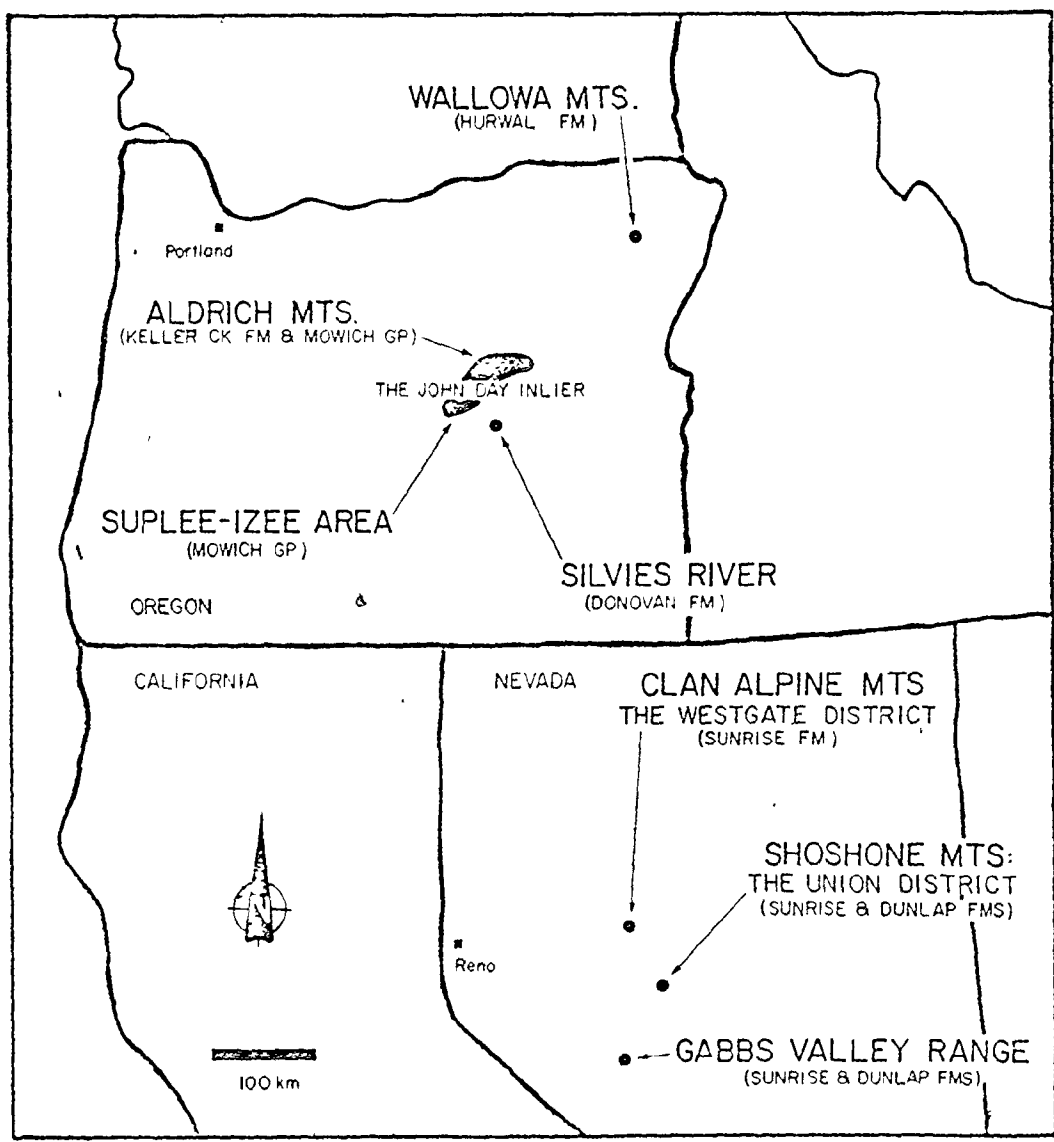


FIGURE 1-1 Location of the areas and lithostratigraphic units of study in Oregon and Nevada.

of Suplee and Izee in the south to the Aldrich Mountains in the north, has been called the John Day inlier. It has been, and is being, intensively studied as the most important source of data on the Jurassic Period in the western United States. The inlier is separated from the Wallowa Mountains in the northeastern corner of the state by a structurally chaotic region termed the central mélangé area (Dickinson and Thayer, 1978).

Coverage is inevitably uneven if for no other reason than that Nevada and Oregon present such contrasts in climate and hence erosion and vegetation cover. From the dryer parts of a very dry state to the wetter parts of a very wet state, exposure varies respectively from total to very modest indeed.

### 1.3 Purpose and Scope

The purpose and scope of this thesis is as follows:

- 1) to describe the stratigraphic units of Lower Jurassic age exposed in Oregon and Nevada and provide a comprehensive list of references published to date dealing with their lithology, environment of deposition and fossil content;
- 2) to give a full taxonomic treatment of the ammonites collected from these units;
- 3) to establish the stratigraphic ranges of the

taxa described;

4) to delimit the stages and erect a sequence of ammonite zones for the conterminous United States;

5) to use these zones to correlate between the contrasted Lower Jurassic facies of the two states dating major geologic events such as regression and transgression; the zonal scheme will also be of use in correlating Jurassic sequences that might be discovered in the future;

6) to compare from a biogeographic viewpoint the ammonite fauna of the United States with faunas elsewhere in the world, particularly in Europe; this aspect of the work sheds light on the interplay between palaeogeography, plate tectonics and palaeobiogeography;

7) to examine the fossilisation of ammonites in shallow water environments of deposition.

#### 1.4 Methods

Six months were spent in the field during the summers of 1977 and 1978, during which time all the areas of Jurassic exposure in both states were visited.

Stratigraphic sections in the Lower Jurassic rocks were measured wherever the beds were fossiliferous, exposure was adequate, the area was well mapped geologically and topographically and where tectonic complications were minimal. The sections were measured using the Brunton

and tape technique (Compton, 1962) and each fossil collected was accurately located stratigraphically. To facilitate the handling of such enormous quantities of stratigraphic data, a Fortran IV computer programme has been written which provides the position of every fossil locality with respect to some stratigraphic base line, such as a formation or member contact (Smith, 1976). Although this study is concerned primarily with ammonoids, specimens were taken of all other fossil organisms encountered together with lithologic samples for micropalaeontological analyses. These specimens will be the springboard for future research.

The taxonomy has been approached quantitatively wherever preservation permits. The systematic part of the study was greatly facilitated by access to many museum and university ammonoid collections in England, Germany, France, Italy, and particularly the United States. Some of the material studied herein was made available by the United States National Museum in Washington, the Department of Palaeontology at the University of California at Berkeley, and the Geology Department of Stanford University (see acknowledgements).

## CHAPTER 2

### GENERAL GEOLOGY

#### 2.1 Introduction

The purpose of this chapter is fourfold:

1) to list the lithostratigraphic units dealt with in this thesis at the same time providing bibliographic information on original descriptions of the stratotypes;

2) to summarise the lithologic character of each unit and its stratigraphic relationship with subjacent and superjacent units;

3) to list the fauna of each unit (excluding ammonites which will be dealt with in Chapter 3);

4) to synthesize these data by discussing the environments of deposition and geologic events that are represented thus providing the necessary backdrop for the next chapter dealing with biochronologic correlation.

Treatment is arranged geographically beginning with the stratigraphy of the southernmost areas and moving northwards. For each area, treatment is arranged stratigraphically beginning with the lowest units.

## 2.2 Nevada

### 2.2.1 The Sunrise Formation

#### 2.2.1a The Gabbs Valley Range

The Sunrise Formation was named after Sunrise Flat in the Gabbs Valley Range by Muller and Ferguson (1936, p. 249, and 1939, p. 1609). They designated as type section a homoclinal sequence exposed in a still unsurveyed area to the east of the New York Canyon Road where it veers northwards (Fig. 2-1). The Sunrise Formation conformably overlies the Gabbs Formation which is similar lithologically; there is some question as to whether the two formations should be combined under the name Gabbs Formation as discussed on p. 22. The Sunrise Formation is conformably overlain by the Dunlap Formation.

Muller (*in* Ferguson and Muller, 1949) divided the type section into five informal units numbered 1-5 and this format is followed here. Unit 1 has yielded Hettangian fossils and is presently being studied by Jean Guex of the University of Lausanne in Switzerland. Unit 2 and its equivalents elsewhere have yielded an extremely rich and well preserved fauna representing the Bucklandi Zone of the lowest Sinemurian. This unit is being studied by David Taylor of the University of California at Berkeley. The scope of this present study is therefore limited to the post Bucklandi Zone beds, that is, units 3-5 inclusive.

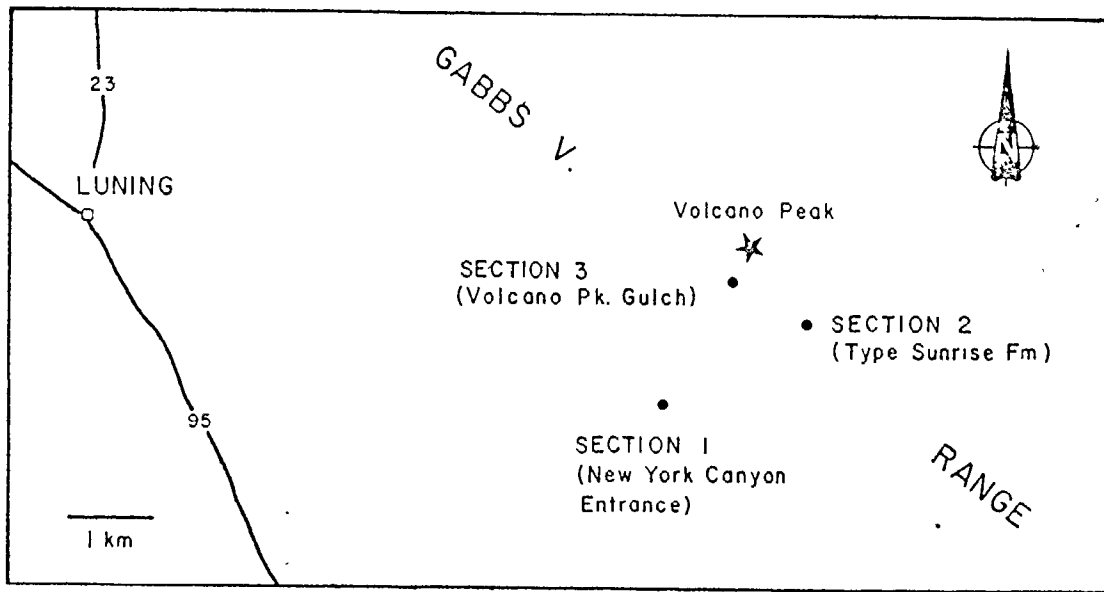










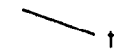


FIGURE 2-1 Location of the measured sections of the Sunrise Formation in the Gabbs Valley Range.

The type section has been remeasured by Stanley (1971) (section 2 of this report; Fig. 2-2); I also measured sections at the entrance to New York Canyon (section 1; Fig. 2-3) and in the gulch to the southwest of Volcano Peak which is here named Volcano Peak Gulch (section 3; Fig. 2-4; see also Pl. 5 in Ferguson and Muller, 1949). The post Bucklandi Zone part of the sequence varies in thickness from approximately 125 m at Volcano Peak Gulch to 275 m at the type locality.

Unit 3 consists of black and dark grey shales and siltstones that weather brown and light grey. Thin limestone beds occur intermittently and the upper part of the unit locally consists of bright red and purple siltstones.

	Rudaceous rocks with some sandstone	
	Sandstone	
	Mudstone, siltstone, and shale	
	Limestone (biocalcarenite)	
	Dolomite, or dolomite with some limestone	
	Sill	} Basic intrusives
	Dyke	
	Concealed	
	Hardground surface	
	Normal fault	
	Thrust fault	

Symbols used for measured sections (1-7) illustrated in Figs. 2-2; 2-3; 2-4; 2-7; 2-8; 2-10; 2-13.



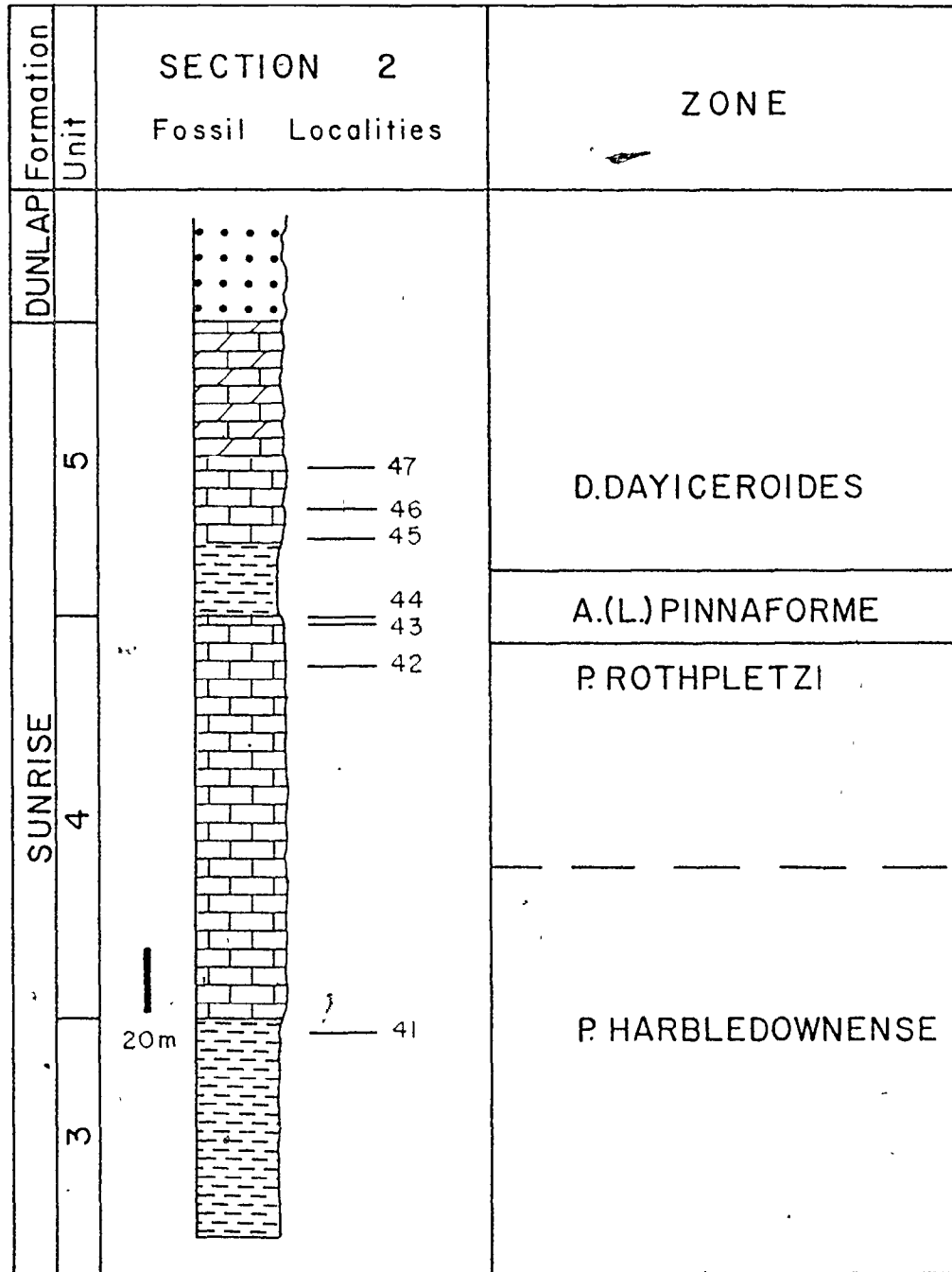


FIGURE 2-2 Measured section and fossil localities of the type Sunrise Formation (section 2). For explanation of symbols see page 12.

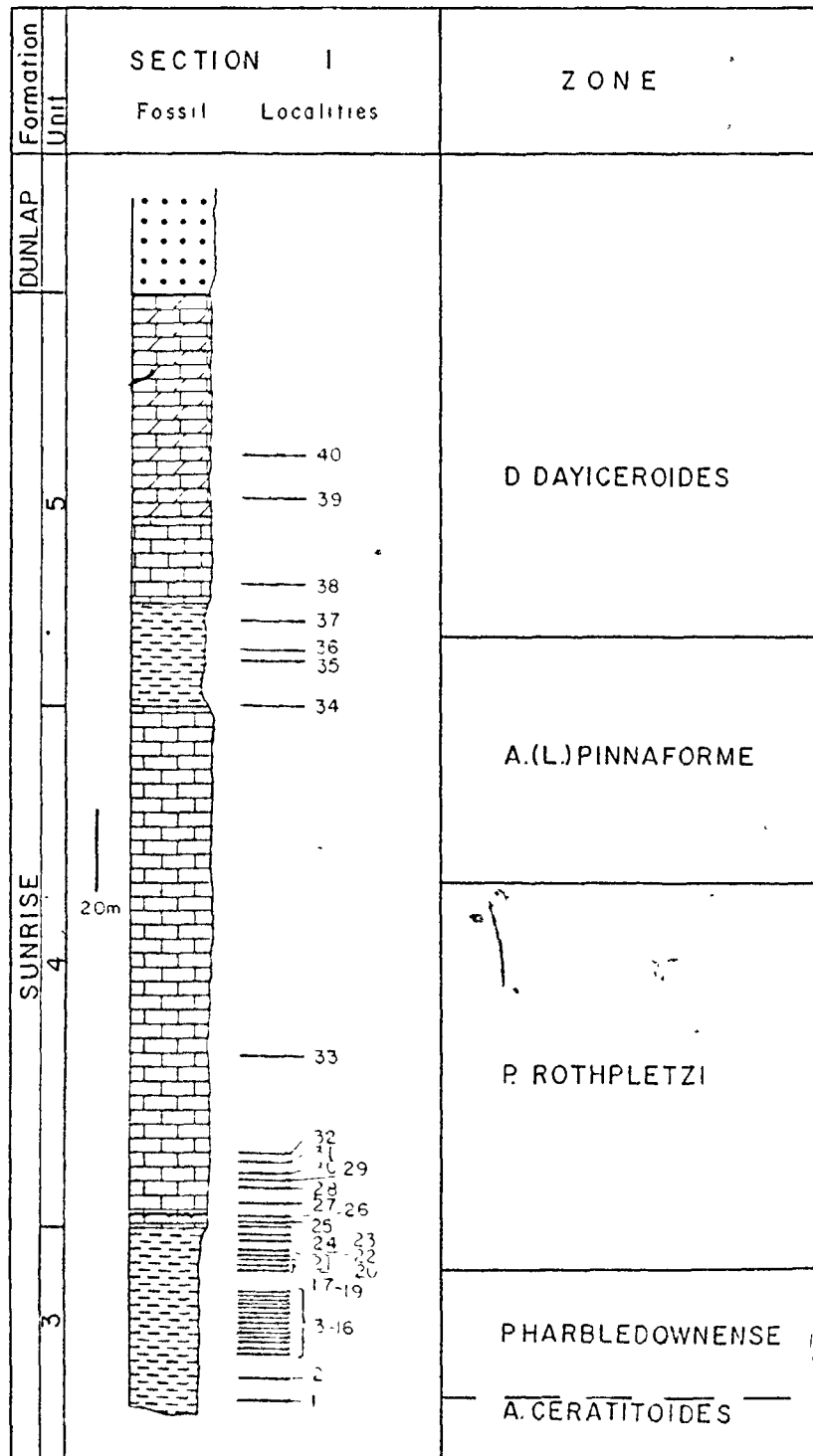


FIGURE 2-3 Measured section and fossil localities at the Sunrise Formation at the entrance to New York Canyon (section 1). For explanation of symbols see page 12.

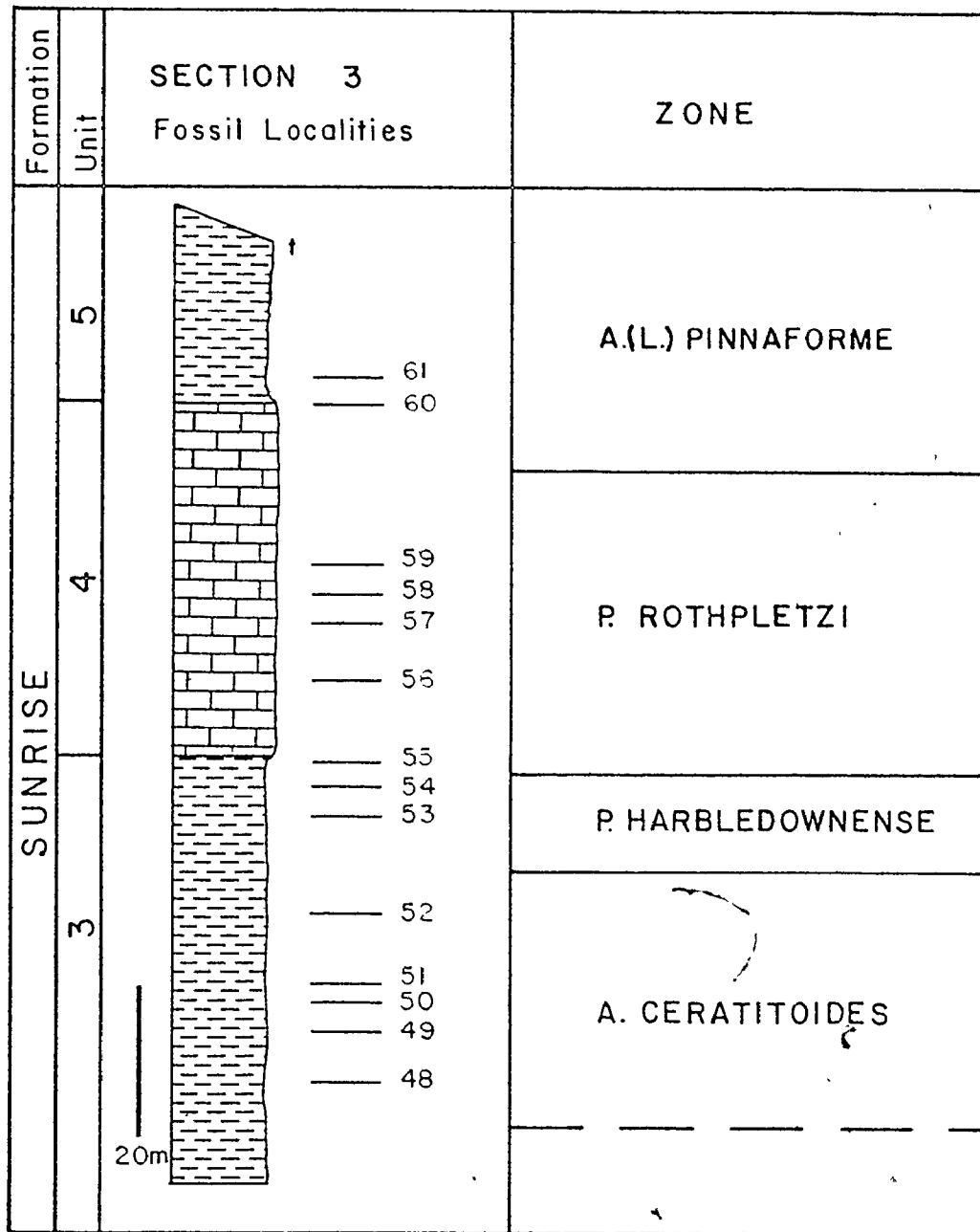


FIGURE 2-4 Measured section and fossil localities of the Sunrise Formation exposed at Volcano Peak Gulch (section 3). For explanation of symbols see page 12.

Nineteen and a half metres above the base of the unit at Volcano Peak Gulch there occurs a thin bed of light grey tuff which probably correlates with the tuff bed reported by Stanley (1971) approximately 27 m above the base of unit 3 in the type section. The bed does not appear to be exposed in the entrance to New York Canyon but this reflects non-exposure of the pertinent stratigraphic interval rather than a lateral pinching out of the bed. The difference of 7.5 m in stratigraphic position of the tuff above unit 2 (which is probably an isochronous unit) represents a condensing of section 3 with respect to section 2. Condensing between sections 3 and 1 is also evident from the relative ranges of the ammonites but this will be discussed in more detail in Chapter 3. Ammonites, mostly preserved as impressions, are common in this unit, particularly in the upper parts; the only other fossil collected was a pectinid bivalve.

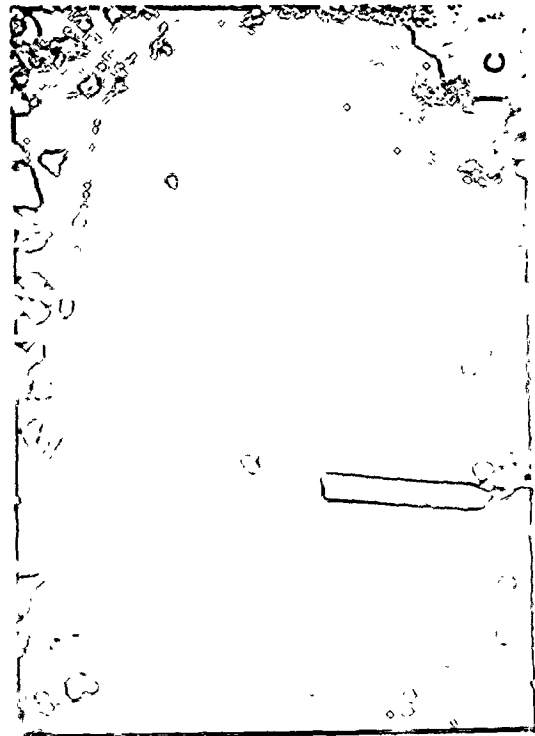
Unit 4 is a carbonate unit that has been described in detail by Stanley (1971) using Dunham's classification (1962). Biocalcarenite wackestone is the predominant lithology. In outcrop the beds are thin to thickly bedded and appear blue grey in colour. Grey and brown mottling at some levels is believed by Stanley (1971, p. 458) to be secondary. Local silicification in the upper part of the unit is common.

3.7 m above the base of unit 4 in section 3 occurs

a previously unrecognized, although laterally extensive hardground surface (Fig. 2-5) developed on a grey brown stained, 1.2 m thick limestone bed that overlies 1.5 m of bright purple siltstone. This is the first Jurassic hardground to be discovered in North America and it will be the subject of a detailed study at a later date. In the meantime, its main features are described below and its significance in terms of interpreting the environment of deposition will be discussed at the end of the chapter.

The surface is stained dark and light brown with hematite and its weathering products. Hematite occurs within boreholes as euhedral crystals commonly lining the inner surface but also scattered throughout the borehole infill which consists of a light grey limestone of identical lithology to the overlying beds. The boreholes are simple, single entrance, pouch-like borings assignable to the ichnogenus *Trypanites*. They vary in diameter from less than 1 mm to 7 mm and in length from 5 mm to 5 cm with most examples falling within a 1.5 to 2 cm range. The entrances are round-edged, the boreholes parallel-sided, sometimes curved, and often surrounded by a halo. The haloes differ from the surrounding rock in being lighter in colour and more porous. With one exception (Fig. 2-5e), the boreholes are unlined. The hardground surface is not planar but bears very shallow depressions (Fig. 2-5b). Radiating

FIGURE 2-5 Synsedimentary lithification surface (hardground), Sunrise Formation. a) Unit 4 and uppermost unit 3 of the Sunrise Formation, New York Canyon entrance (section 3), Gabbs Valley Range, Nevada. b) Hardground surface (from above) showing a depression with radially disposed grooves. c) Close-up of area to the upper right of the Brunton compass seen in (b) above. Centre of depression to the bottom left. Note borehole entrances and grooves infilled with rock from the overlying bed. d) Polished slab. Hardground surface at the top. Note rounded edges of borehole entrance, hematite infilling of *Trypanites* boreholes, and haloes. Natural size. e) X-ray photograph of Fig. 2-5d showing more clearly the hematite infilling and haloes. The *Trypanites* in the centre of the slab differs from all other boreholes seen in its exceptional length, its possession of a lining, and in the absence of both a halo and hematite infilling. Natural size.



from the centre of these depressions are a series of grooves whose radial nature is illustrated in Fig. 2-6. The grooves in the best exposed depression that was selected for detailed study reach a maximum length of 15.3 cm with an average length of 4. cm; none reaches the centre of the depression. The grooves are shallow with a tendency to be shallowest and more tapered at their distal ends (see Fig. 2-5d); the groove edges are not sharp. The depressions possess central hollows that seem to be superficial structures. Their rims are barely below the general level of the hardground surface and they do not exceed 5 cm in depth. They are not presently infilled; their bottoms are planar and apparently neither stained nor mineralized. No fauna, encrusting or otherwise, was found associated with the hardground.

The uppermost beds of unit 4 are composed of phosphatic oolite and pellet grains and this interval has been the subject of debate by Stanley (1971) and Hallam (1965) as to whether a period of non-deposition or erosion is represented. It will be discussed in more detail in Chapter 3.

Unit 4 contains a diverse and, at some levels, abundant benthonic fauna. Muller and Ferguson (1939) list the following:

*Weyla alata* (BUCH)      *W. cf. bodenbenderi* (BEHRENDSEN)



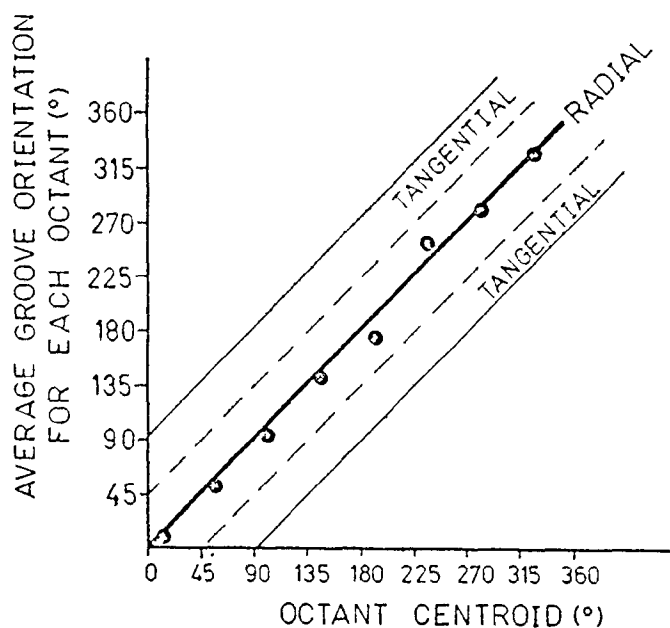


FIGURE 2-6 A plot of the average groove orientation for each octant against the octant centroid. Points falling on the thick line indicate perfectly radial arrangement with respect to the centre of the depression; points deviating far enough from this line to fall within the shaded areas indicate tangential groove orientation.

*Trigonia* aff. *clavellata* SOWERBY *T. sp.*

*Pholadomya nevadana* GABB *P. multilineata* GABB

*Entolium* cf. *meeki* HYATT *Rhynchonella sp.*

To this list may also be added *Nerinea* sp. and unidentified gastropods. At one locality in the middle of unit 4 at Volcano Peak Gulch, weathering has revealed a variety of trace fossils on a bedding plane. Similar trace fossils are evident in unit 5 and in the Shoshone Mountains as discussed below. The nautiloid genus *Cenoceras*, which

reaches a considerable size, has been collected from the lower and middle part of the unit in section 3.

The uppermost unit (unit 5), which varies in thickness from 90 to 96 m in the Gabbs Valley Range, may be divided into two sub-units. The lower third consists of black shale and siltstone. Just above the unit 4/5 contact, the shales are commonly red and thin limestone beds are present, yielding ammonites, rhynchonellid brachiopods and *Trigonia* fragments. The upper two-thirds of unit 5, in contrast, consists of biocalcarenite grainstone and packstone interbedded with subordinate black shales; dolomite and dolomitic limestone are common near the Sunrise-Dunlap contact (Stanley, 1971). This part of the sequence is very sparsely fossiliferous. Ammonite impressions and occasional fragments of internal moulds are most common; benthonic forms include *Trigonia* sp., *Pleuromya* sp., and fragments of terebratulid brachiopods. A horizontal burrow (? *Planolites*) was discovered at the base of the sub-unit in the type section. This burrow is identical to forms discovered at localities bearing echioceratid ammonites in the middle of unit 4 exposed in the entrance to New York Canyon.

#### 2.2.1b The Shoshone Mountains (Union District)

The Sunrise Formation exposed in the Shoshone

Mountains of the Union District was mapped by Silberling (1959). The most continuous exposures occur from First Canyon southwesterly to Third Canyon (sections 20 and 21, T. 11 N, R 39 E, presently unsurveyed), where Silberling measured 823 m of rocks that he attributed to the "undifferentiated Gabbs/Sunrise Formations". This terminology stems from the problem of defining the contact between these two units as mentioned in the previous section. In the Shoshone Mountains and Gabbs Valley Range, there is no major lithologic difference between the Gabbs and the Sunrise Formations which were initially differentiated palaeontologically, the former yielding Triassic, the latter Jurassic fossils (Muller and Ferguson, 1936, p. 248). This is poor stratigraphic practice and in contravention of the recommendations of the International Subcommission on Stratigraphic Classification (Hedberg *et al.*, 1976). However, Muller (oral communication to Silberling, 1955) seems to have retracted earlier statements concerning the lithologic identity of the two units in the type area. Should further study of the contact (a problem beyond the scope of this thesis) confirm his earlier statements, however, the name Sunrise Formation should probably be suppressed in favour of the Gabbs Formation which has page priority (Muller and Ferguson, 1936).

The Shoshone Mountain section, which is conformably

overlain by the Dunlap Formation, is divided into 12 lithologic units (labelled A to L, see Fig. 2-7). These units are predominantly limestones with various amounts of clastic material incorporated. They are often difficult to separate in the field differing primarily in bedding characteristics and the colour of weathered surfaces. Silberling's descriptions of units D to L, the subject of this report, are summarised and in some cases supplemented below.

Unit D consists of calcareous siltstones and subordinate silty limestones that are black or dark grey when fresh but weather purple. The unit, which is very thinly bedded, reaches a thickness of 41 m. The overlying unit (E) is only 13.7 m thick. It is differentiated from unit D by its medium bed thickness. It is composed of silty limestone with minor interbeds of lavender weathering siltstone. Both D and E have yielded ammonites but they are apparently devoid of benthonic fossils.

Unit F is identical to unit D in both composition and bedding characteristics. It differs only in yielding abundant ammonites (mostly impressions) and trace fossils in the upper 15 m of its 213 m total thickness. The trace fossils are of uncertain taxonomic affinities. They consist of horseshoe-shaped trails on weathered bedding planes and seem to be identical to those observed in the middle of

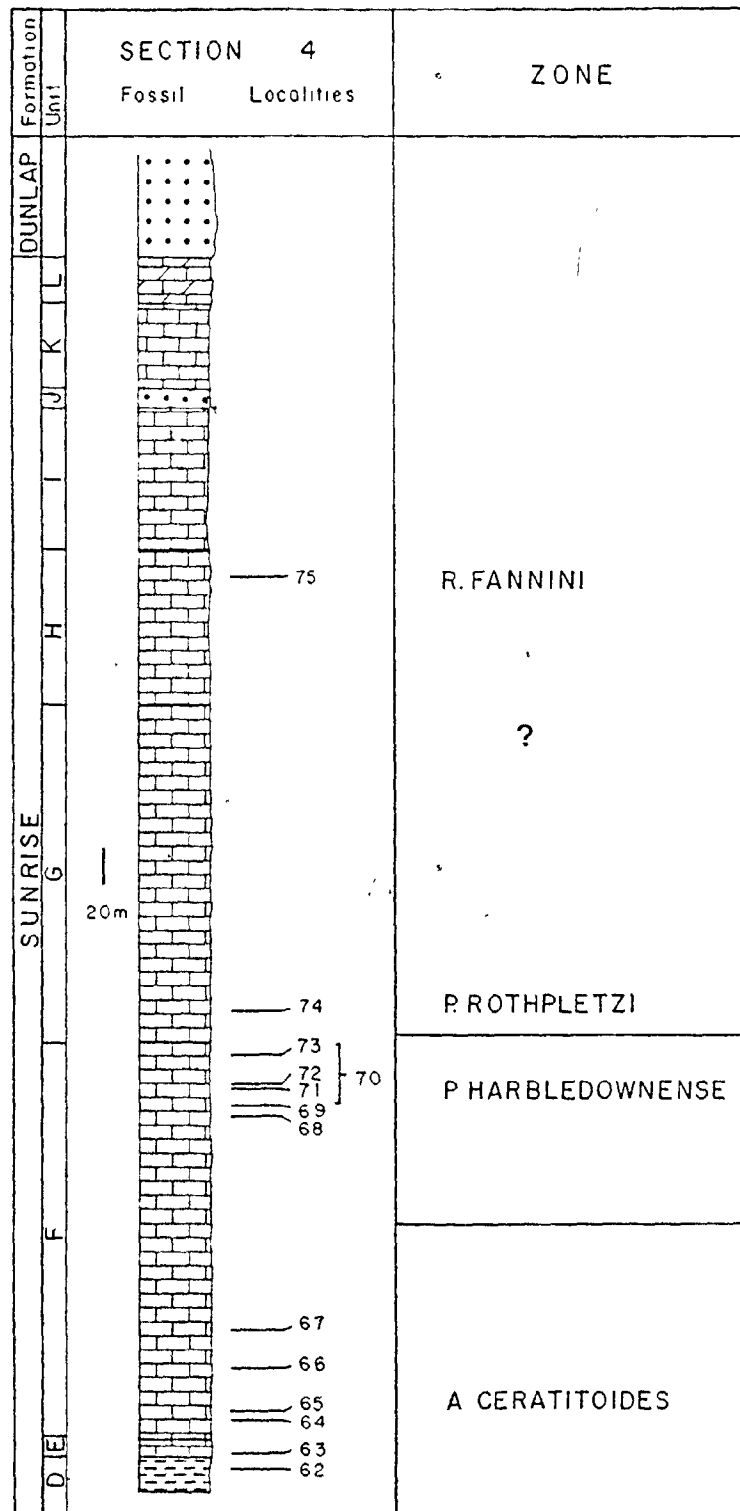


FIGURE 2-7 Measured section and fossil localities of the Sunrise Formation exposed in the Shoshone Mountains (section 4). For explanation of symbols see page 12.

unit 4 in the Gabbs Valley Range. In the Shoshone Mountains the curved traces are crosscut by straight traces.

Unit G consists of 183 m of very thinly bedded limestone. It differs from the underlying unit in being slightly less dark in colour when fresh, in containing minor oolitic horizons and in containing a benthonic fauna which at some levels is quite prolific. *Entolium* sp., *Weyla* cf. *alata*, *Pholadomya* sp., and terebratuloid brachiopods are recorded.

Unit H is 82.3 m thick. It is more massively bedded than the underlying unit; it has yielded ammonites as well as a meagre benthonic fauna (*Pholadomya* sp., and terebratuloid brachiopods). Unit I is slightly thinner than H (76.2), contains a high proportion of sandy limestone and is much more thickly bedded. Large specimens of *Weyla* are common near the base.

Overlying unit I are 9 m of limestone and chert clasts set in a sandy matrix; rudistid pelecypod (probably *Plicatostylus*) reefs are developed locally.

The upper 70 m (units K and L) of the Sunrise Formation directly beneath the Dunlap Formation are lithologically similar to their counterparts in the Gabbs Valley Range in consisting of limestones that are in part oolitic and in part dolomitic. Bedding is thicker

than in most of the underlying beds. The only fossils reported are rhynchonellid brachiopods from the 24.4 m thick upper unit (unit L).

#### 2.2.1c The Clan Alpine Mountains (Westgate District)

The exposures of the Sunrise Formation in the Clan Alpine Range were mapped by Corvalan (1962) who divided the formation into seven units labelled A-G. Units B-E inclusive, the subject of the present study, are described below (section 5; Fig. 2-8).

Unit B is an easily eroded argillaceous unit reaching a thickness of 82 m. It is composed of dark shales and thin-bedded mudstones that weather grey in the lower part and brown, purple or red in the upper part of the unit. The lower contact with the limestones of unit A is abrupt and easily defined although thin, persistent limestone beds are sporadically intercalated into the lower 15 m of unit B. The upper contact with the resistant, hill-capping limestone of unit C is equally sharp.

In marked contrast to unit B which is richly ammonitiferous, unit C contains a rich benthonic fauna but no ammonites. Taxa recorded (Corvalan, 1962, and my observations) are:

<i>Weyla</i> cf. <i>bodenbenderi</i> (BEHRENDSEN)	<i>W. unca</i> (BUCH)
<i>Terebratula</i> sp.	<i>Entolium</i> sp.
unidentifiable gastropod fragments	rhynchonellid brachiopods

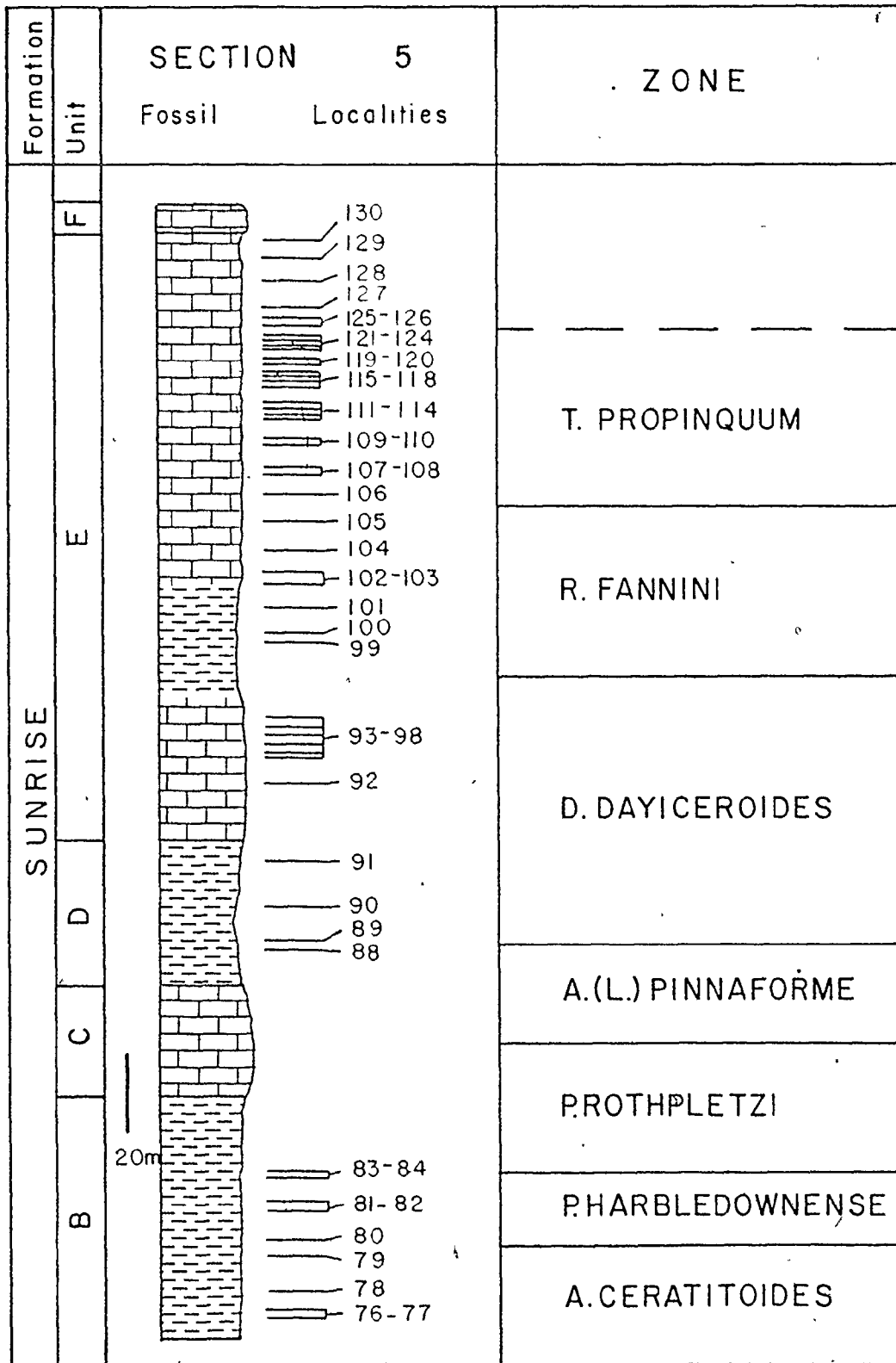


FIGURE 2-8 Measured section and fossil localities of the Sunrise Formation exposed in the Clan Alpine Mountains (section 5). For explanation of symbols see page 12.



This benthonic fauna is identical to that collected from unit 4 of the Sunrise Formation in the Gabbs Valley Range. There is also lithological similarity; unit C consists of 33.5 m of thin to medium-bedded, dark grey biocalcarenites that weather brown. Silicification is evident in some beds.

Except for sporadic beds of sandy limestone in its lowermost parts, the entire 30.5 m of unit D consists of black and grey shales and some siltstone beds. The dark colour is attributed to abundant, finely disseminated organic matter. The unit is much less resistant to erosion than superjacent and subjacent units so that it is easily delineated in the field. Apart from rare impressions of Pliensbachian ammonites, unit D has yielded a few specimens of the pelecypods *Pholadomya* and *Entolium* ?; the archaeogastropod *Pleurotomaria* becomes locally abundant at the top of the unit.

The thickness of the superjacent unit, unit E, has been grossly underestimated in the past. Reports of a total thickness of 360 feet (110 m) by Corvalan (1962) are erroneous. Measurement using Brunton and tape methods shows that the unit reaches a thickness of 189 m. The lower part of unit E consists of medium bedded grey and blue-grey sandy limestone; beds of conglomerate reaching medium thickness also occur. An horizon of phosphate nodules occurs 30 m above the base of the unit. Some nodules are

spherical with an average diameter of 0.5 cm, others are elongate with long axes reaching 1.5 cm. A locally rich benthonic fauna is dominated by the trigonid pelecypod genus *Myophorella* and its subgenus *Vaugonia*; large specimens of *Pleurotomaria* have also been collected as well as *Dosinia* sp. and *Weyla dufrenoyi* (d'ORB.). Belemnites and extremely large individuals of the nautiloid *Cenoceras* are also present.

The middle part of unit E, although still composed of limestones, is more argillaceous and shale units are also present. *Pleurotomaria* sp., *Dosinia* sp., and the belemnites persist; *ex situ* specimens of rare *Plicatostylus* and several articulated ichthyosaur vertebrae were also collected at this level. The vertebrae are presently being studied by specialists at the University of California, Berkeley. The lithology of the upper part of the unit is described in some detail in Chapter 5 (p. 115). *Gryphaea*, *Myophorella*, and rhynchonellids occur sporadically with *Gryphaea* becoming more frequent in the uppermost part of the unit beneath the coquina limestone of unit F.

### 2.2.2 The Dunlap Formation

The Dunlap Formation is a largely unfossiliferous, predominantly terrestrial unit that conformably overlies the Sunrise Formation in the Gabbs Valley Range and the

Shoshone Mountains (Figs. 2-2; 2-3; 2-7). It is absent from the Clan Alpine Mountains where the Sunrise Formation is conformably overlain by the Middle Jurassic Westgate Formation. To the south and southwest of the area of study in the Pilot Mountains and Garfield Hills respectively, the Dunlap Formation has overlapped the Sunrise Formation to rest directly on Triassic and Permian rocks with marked angular unconformity (Hallam, 1965; Stanley, 1971).

The Dunlap Formation, which reaches a maximum thickness of 1524 m, has been studied in detail by Stanley (1971) who records four basic facies:

- 1) quartz sandstone texturally and compositionally like the Aztec-Navajo-Nugget complex to the east (see p. 46).
- 2) carbonates of shallow marine and intertidal origin;
- 3) locally derived breccias, conglomerates and sandstones;
- 4) volcanoclastic sediments derived from Lower Jurassic and Triassic andesitic lava flows and pyroclastics.

There seems to be little discernible stratigraphic or lateral pattern to the distribution of these four facies and the Dunlap Formation is distinguished by its heterogeneity. Even the basal beds vary considerably in lithology. Where the Dunlap conformably overlies the Sunrise Formation the contact is invariably gradational and the basal Dunlap

rocks may be composed of quartz or volcanic sandstone, volcaniclastic or limestone conglomerate. Where the Dunlap rests with angular unconformity on much older rocks, however, the basal beds reflect the composition of the subunconformity rocks (Stanley, 1971).

To the southwest of the Gabbs Valley Range the Dunlap Formation is exposed in the tectonically complex Garfield Hills. Here there are several marine intercalations in the lower part of the Dunlap that have yielded pelecypods closely resembling *Plicatostylus gregarius* LUPHER and PACKARD, as well as a single ammonite specimen; the vast bulk of the formation is, however, devoid of fossils.

## 2.3 Oregon

### 2.3.1 The Donovan Formation

Around the junction of sections 5 to 8 (T. 20 S., R. 30 E., West Myrtle Butte 15 minute quadrangle) in east-central Oregon, the Silvies River drainage system has breached the Tertiary volcanic cover to expose a small (1.3 square km) inlier of marine Jurassic rocks (Fig. 2-9). The entire sequence, which is predominantly clastic in origin, was named the Donovan Formation by Luper (1941, p. 229) who pointed to previous confusion with the lithologically similar Hardgrave Formation of California (Hyatt, 1894; see also Crickmay, 1928). The Donovan

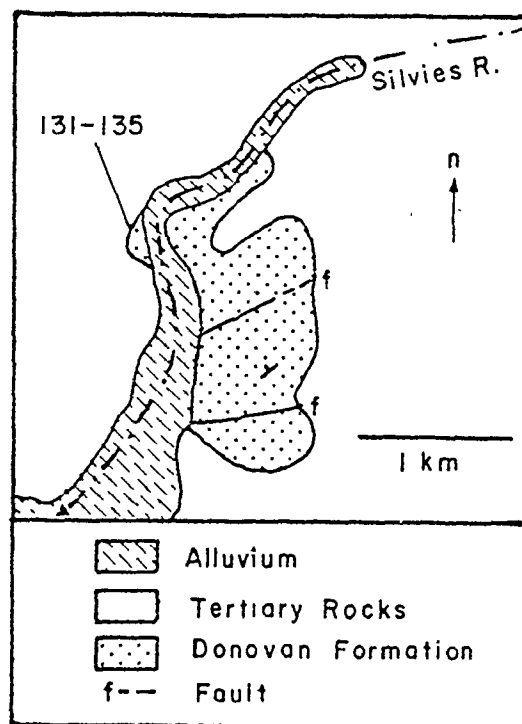


FIGURE 2-9 Geologic map and fossil localities of the Donovan Formation. Modified from Buddenhagen (unpublished).

Formation has been little studied. Beaulieu (1972) summarised the original description of Luper whilst detailed mapping by Buddenhagen remains unpublished.

The section as measured by Luper is 800 m thick (section 6; Fig. 2-10) but there is evidence of faulting particularly in the lower third of the sequence along Coral Creek where basic Tertiary sills intruded into the Donovan Formation are truncated. Luper's suggestion of an angular unconformity to explain the sudden change in dip at this level is therefore unfounded. The lower 110 m of the section

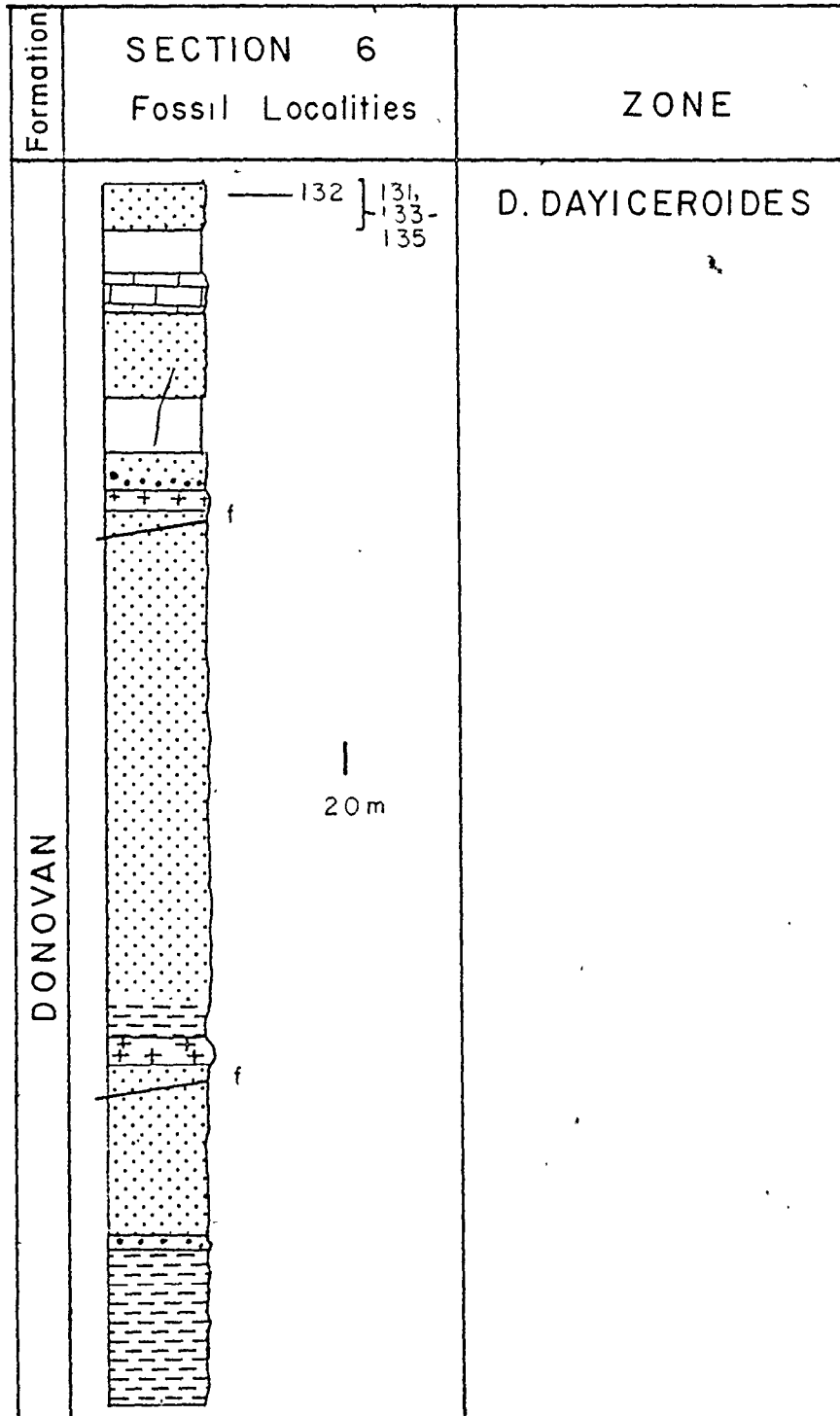


FIGURE 2-10 Measured section and fossil localities of the Donovan Formation exposed in the Silvies River Valley (section 6). For explanation of symbols see page 12.

are composed of argillaceous rocks containing pods of sparsely fossiliferous, sometimes silicified limestones, that are sheared. The fossils are difficult to identify because of their poor state of preservation but the pelecypods resemble juvenile *Weyla* and the coelenterates *Oppelismilia* (= *Stylophylloopsis* auct.) which are so common in the Lower Jurassic of Nevada. The remainder of the section is composed of grey, green, and red sandstone of medium to coarse grain size containing intercalations of conglomerate up to 2 m thick. This part of the unit is abundantly fossiliferous yielding well preserved specimens of infaunal and semi-infaunal pelecypods at most levels but, particularly in the higher beds exposed in Red Gulch.

The following species, based on my own observations and those of Hallam (1965), are present:

*Camptonectes* cf. *lohbergensis* (EMERSON)

*Cardinia concinna* (SOWERBY)

*Ceromya gibbosa* GABB

*Chlamys textoria* (SCHLOTHEIM)

*Gervillia* sp.

*Goniomya aperta* GABB

*Gryphaea* cf. *cymbium* LAMARCK

*Hippopodium* sp.

*Homomya* cf. *ventricosa* AGASSIZ

*Lima gigantea* (SOWERBY)

*Mactromya* sp.

*Pholadomya multilineata* GABB

*Pleuromya* cf. *striatula* AGASSIZ

*Plicatostylus gregarius* LUPHER and PACKARD

*Pinna* sp.

*Rollieria* sp.

*Weyla* spp.

The aberrant pelecypod *Plicatostylus* was first described from Oregon by Luper and Packard (1930) and it is now recognised widely along the east Pacific margin but nowhere else (Hallam, 1977). In the Donovan Formation *Plicatostylus* occurs in dense concentrations forming part of a 23-m thick limestone lens that was long ago worked as a source of lime. The ruins of the kilns may still be found in the headwaters of Lime Gulch.

Nearly all the ammonites collected from the Donovan Formation originate from the uppermost part of the formation as exposed in isolated outcrops on the west bank of the Silvies River. The sudden appearance of abundant ammonites does not appear to coincide with any change in the number or diversity of the benthonic fauna nor with any discernible change in the lithology.

### 2.3.2 The Mowich Group

The Robertson, Suplee, Nicely, and Hyde Formations



comprise the Mowich Group which has been studied in some detail stratigraphically by Lupper (1941) who defined the group and its formations, and Dickinson and Vigrass (1965). A palaeontological study followed (Imley, 1968). In that the Mowich Group is correlative in part with the units dealt with in this thesis, it is included and briefly described here for the sake of completeness. Some new fossil material has been collected from part of this group by D. Taylor of the University of California at Berkeley. Reference to this material, which will be the subject of a later joint study, is made in the biochronologic and systematic sections of this thesis (Chapters 3 and 6).

The Mowich Group crops out in a wide arc from the Izee area to the Bear Valley Basin in the Aldrich Mountains where it conformably overlies the Keller Creek Shale (Fig. 1-1). It overlaps the Keller Creek near Izee, coming to rest with marked angular unconformity on Triassic and Palaeozoic rocks in the Suplee area (Fig. 2-11). This sub-Mowich unconformity is considered a major event in the Early Jurassic history of the John Day inlier. The diastrophism responsible for this event has been named the Ochoco Orogeny by Dickinson and Vigrass (1965, p. 80).

The Robertson Formation is well developed in the Suplee area but it thins in an easterly direction, pinching out beneath and partly interdigitating with the Suplee

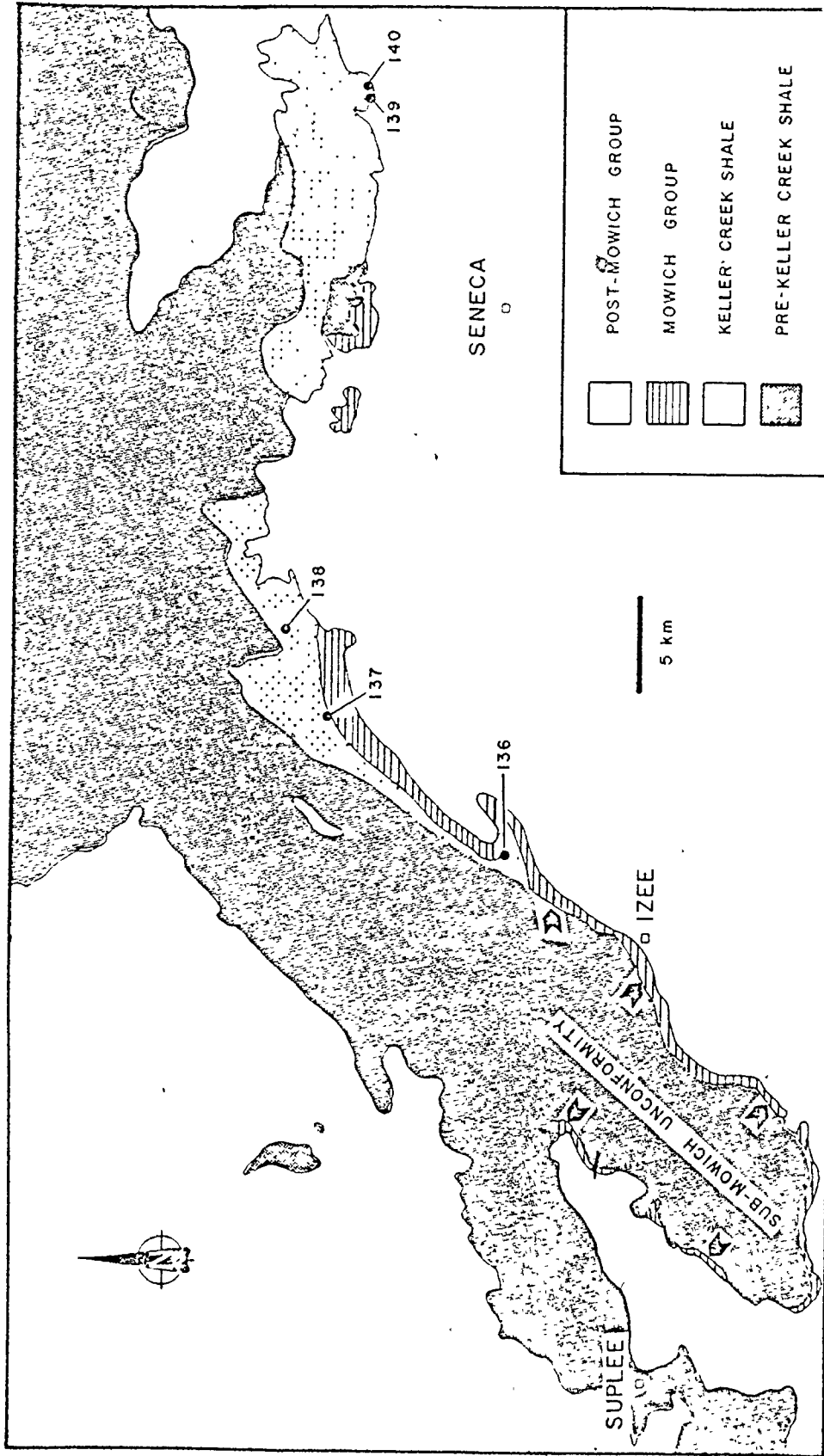


FIGURE 2-11 Fossil localities of the Keller Creek Shale and the sub-Mowich unconformity in the John Day inlier.

Formation so that it is not present in the Izee area.

The unit consists of conglomerates, volcanoclastic (andesitic) sandstone and extensive bioherms of the pelecypod *Plicatostylus gregarious*. A complete list of the fauna from the Robertson Formation, which unfortunately does not contain ammonites, is given below (from Dickinson and Vigrass, 1965):

<i>Nerinea</i> sp.	<i>Ostrea</i> sp.
<i>Astarte</i> sp.	<i>Pholadomya</i> sp.
<i>Camptonectes</i> sp.	<i>Pinna</i> sp.
<i>Coelastarte</i> sp.	<i>Pleuromya</i> sp.
<i>Isocyprina</i> sp.	<i>Plicatostylus gregarious</i> L. and P.
<i>Lima</i> sp.	<i>Trigonia</i> sp.
<i>Lucina</i> sp.	<i>Weyla</i> cf. <i>unca</i> (BUCH)
<i>Modiolus</i> sp.	

The Suplee Formation is a transgressive unit consisting of up to 23 m of fossiliferous grey calcareous sandstone and sandy limestone. It has a rich benthonic fauna listed below with *Weyla* being present in nearly every outcrop. Ammonites are present in the upper part of the unit (Imlay, 1968). The benthonic fauna includes:

<i>Astarte</i> sp.	<i>Gryphaea</i> sp.
<i>Camptonectes</i> sp.	<i>G.</i> cf. <i>cymbium</i> LAMARCK
<i>Gardinia</i> sp.	<i>Homomya</i> sp.
<i>Gervillia</i> sp.	<i>Lima</i> sp.
<i>Goniomya</i> sp.	<i>Lucina</i> sp.

<i>Mactromya</i> sp.	<i>Phacooides</i> sp.
<i>Meleagrinnella</i> sp.	<i>Pinna</i> sp.
<i>Modiolus</i> sp.	<i>Pleuromya</i> sp.
<i>Ostrea</i> sp.	<i>Trigonia</i> sp.
<i>Plicatostylus gregarius</i> L. and P.?	<i>Weyla</i> sp.
<i>Parallelodon</i> sp.	<i>Nerinea</i> sp.

The Nicely Formation conformably overlies the Suplee Formation. It consists of up to 91 m of black mudstone and shale with common black spheroidal limestone concretions. An andesitic submarine lava flow approximately 15.3 m thick occurs in the middle part of one unit to the southwest of Izee. The Nicely Formation has yielded a rich ammonite fauna (Imlay, 1968); the remainder of the fauna consists of:

<i>Camptonectes</i> sp.	<i>Lupherella boechiformis</i> (HYATT)
<i>Entolium</i> sp.	rhynchonellid brachiopods
<i>Modiolus</i> sp.	ichthysaur vertebrae
<i>Oxytoma</i> sp.	indeterminate gastropods
<i>Pinna</i> sp.	belemnites

The Hyde Formation consists of up to 365 m of andesitic marine tuff and tuffaceous greywacke. Its stratigraphic position and very sparse fossil content, *Phymatoceras* sp. and *Dumortieria* ?, indicate a Late Toarcian age placing it beyond the scope of this thesis.

### 2.3.3 The Keller Creek Shale

The Keller Creek Shale was defined by Brown and Thayer (1966) who designated exposures in the headwaters of Keller Creek in the northwest corner of the Logdell quadrangle as the type locality. Here the base is not truncated tectonically but rests conformably on the Murderer's Creek Graywacke of Late Triassic age; it is overlain by Lower Jurassic deposits of the Mowich Group and the nature of this upper contact will be discussed in Chapter 3. The formation occupies part of the southern limb of the Aldrich Mountain anticline extending some 35 km in an east-west direction as far west as Keller Creek (Fig. 2-11). The strike of the formation then veers southwestwards toward the Izee area where it crops out in the headwaters of Rosebud Creek. Here it was provisionally and informally named the Caps Creek Beds by Dickinson and Vigrass (1965), a name that should now be abandoned.

Of all the lithostratigraphic units dealt with in this thesis, the Keller Creek Formation is the most poorly exposed and sporadically fossiliferous. At the type locality Brown and Thayer (1966) record a thickness of 1525 m. The lower 610 to 760 m consist of massive to well-bedded, coarse to fine grained tuffaceous greywacke. Lenses of conglomerate and subordinate amounts of shale are also present. The upper part of the formation consists of

grey to black shale interbedded with thin beds of greywacke and siltstone. Massive greywacke predominates again near the top of the formation.

It was not possible to measure continuous fossiliferous sequences through the Keller Creek Shale during the course of this study. Isolated fossil localities yielded impressions of ammonites, the pelecypod *Lupherella boechiformis* (HYATT) and the trace fossil *Chondrites*. *L. boechiformis* sometimes occurred associated with Pliensbachian ammonites but often occurred as the only fossil crowding single bedding planes; *Chondrites* was always found alone. A large ichthyosaur skeleton has been collected near the top of the formation; beneath the Suplee Formation in the headwaters of Rosebud Creek, by D. G. Taylor.

#### 2.3.4 The Hurwal Formation

In the Wallowa Mountains of the eastern Blue Mountain Geologic Province, isolated Mesozoic inliers are exposed along the major divide separating the Hurricane Creek and Lostine River Valleys (Enterprise 15 minute quadrangle). The name Hurwal Formation was established by Smith and Allen (1941) for argillaceous beds conformably overlying the Martin Bridge Formation in the northern Wallowa Mountains. Much of the Hurwal Formation is of Triassic age but Nolf (1966) included four sequences that

have yielded Lower Jurassic fossils. These four sequences are geographically isolated from the Triassic rocks and stratigraphic continuity cannot be demonstrated in the field; the age relationships and identical lithology justify the application of the name Hurwal Formation to all these exposures. The location of the four fossiliferous localities is shown in Fig. 2-12. Contact metamorphism by Tertiary intrusives and lava flows is common; in addition, the beds exposed at Ed Smith Creek and Frances Lake are complexly folded.

By far the most important sequence occurs along a small gulch on the north side of Sheep Ridge where nearly 300 m of the Hurwal Formation are exposed beneath a caprock of Columbia River Basalt. The sequence is uncomplicated tectonically although it is intruded by three basic sills which range in thickness from 6 to 20 m; thinner basic dykes are also common at the base. The lithology which typifies the upper Hurwal Formation consists of black or dark brown, thin-bedded siltstones and mudstones. As noted by Nolf (1966), the dark colour is due to a high content of fine organic material. Bedding planes are usually sharp and persistent and, at some levels, are crowded with fossils.

Late Pliensbachian ammonites from the Hurwal Formation have been studied previously by Imlay (1968)

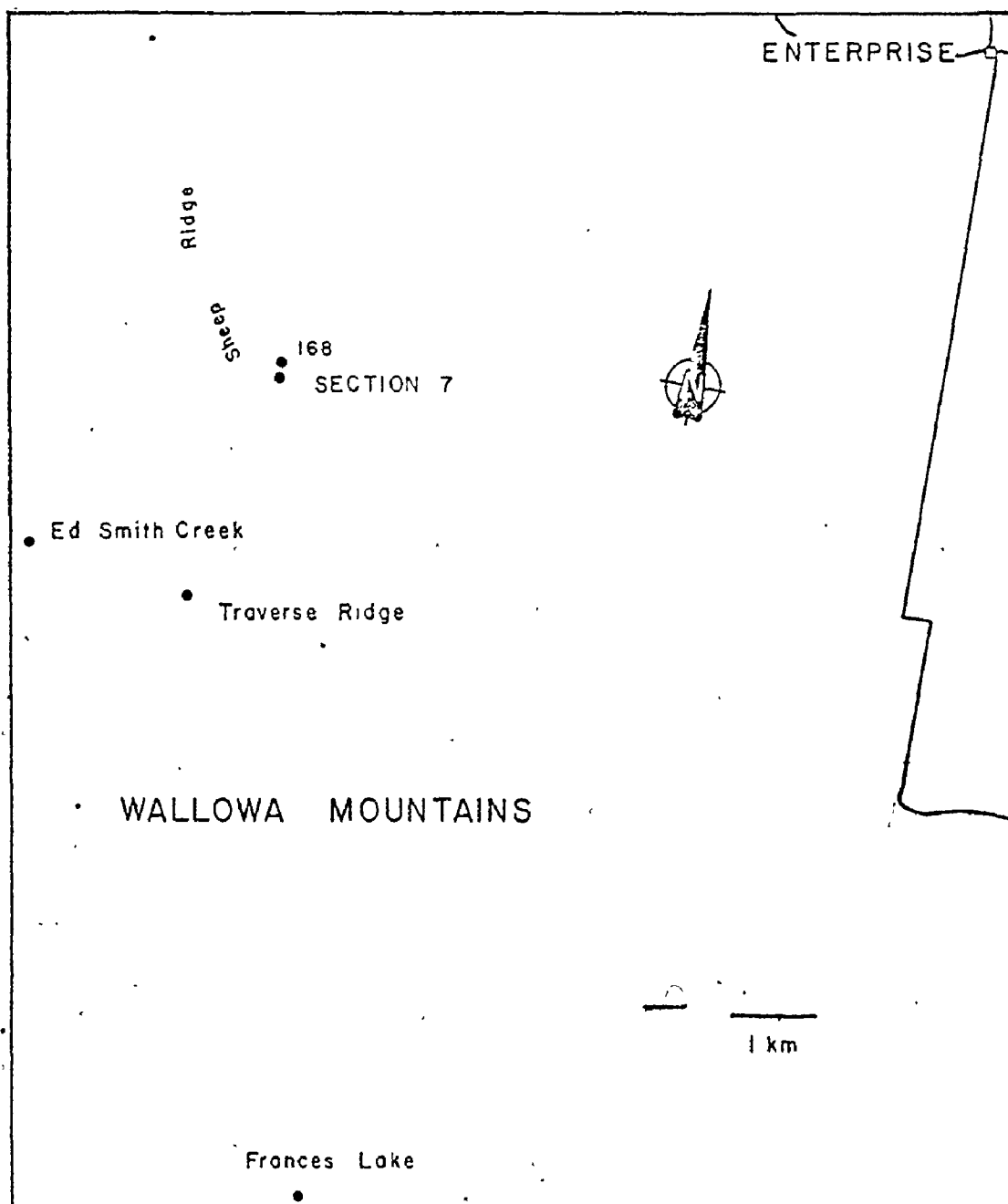


FIGURE 2-12 Location of measured section (7) and fossil localities in the Wallowa Mountains, northeastern Oregon.



who correlated the beds above the middle sill (the upper 189 m) with the Suplee and Nicely Formations of east-central Oregon. The subject of the present study concerns the fauna and age of the lowest 110 m beneath the middle sill at Sheep Ridge (section 7; Fig. 2-13). The beds exposed at Ed Smith Creek, Frances Lake and Traverse Ridge have yielded lowermost Sinemurian fossils (see p. 70) and are beyond the scope of this thesis.

Ammonites are usually preserved as external moulds. Often whorl fragments are present, sometimes bearing long and delicate, unbroken spines. It is difficult to imagine an environment of deposition where clays and silts are accumulating, suggesting low energy conditions, and yet large ammonites could be fragmented whilst delicate ornament escapes unscathed. A possible explanation is the presence of predators, perhaps large vertebrates, that break up the shells before they reach the substrate. Megafossils other than ammonites are quite scarce. Belemnites attaining a guard diameter of up to 4 cm are sporadically present, particularly in the lowest part of the exposures. Pelecypods are scarce and diversity low; *Entolium*, *Eopecten*, and *Lupherella* are present (Imlay, 1968) but only *Lupherella* is moderately common.

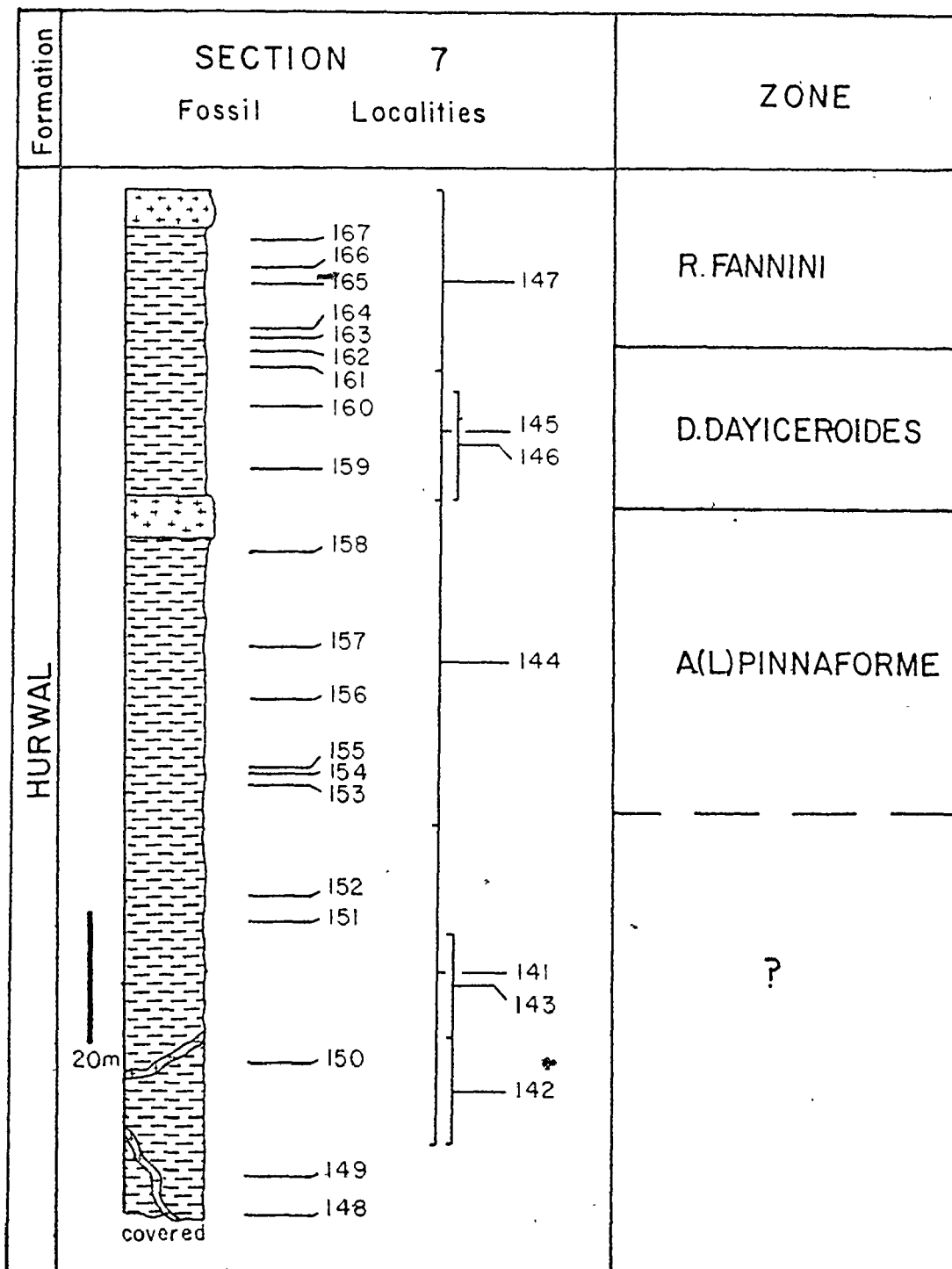


FIGURE 2-13 Measured section and fossil localities of the Hurwal Formation exposed in the Wallowa Mountains (section 7). For explanation of symbols see page 12.

## 2.4 Conclusions

The marginal position of the Early Jurassic sea in Nevada has been established for some time although the position of the strand line has evoked considerable debate. The coeval Aztec-Navajo-Nugget complex was, and in most quarters still is, regarded as eolian (see Freeman and Visher, 1975; and a series of papers in the 1977 Journal of Sedimentary Petrology by Picard; Folk; Steidtmann; Ruzyla; and Visher and Freeman). The complex stretches from eastern Idaho and western Wyoming across Utah into the southernmost parts of Nevada where it crops out as the Aztec sandstone. Stanley (1971) has argued that the quartz arenites of the Dunlap Formation are the distal correlatives of the Aztec-Navajo-Nugget complex which in turn had a northerly source in Montana and Alberta. If this interpretation is correct it has important ramifications.

1) It argues against the existence of a large Mesocordilleran Geanticline stretching across Nevada during the Early Jurassic, a point emphasized by Stanley (1971; Stanley *et al.*, 1971). This positive area originated in the Devonian (Noland, 1928) and was thought to have dominated the palaeogeography of this part of the world well into the Mesozoic.

2) More importantly in terms of the present study, it argues against the large scale displacement of the Jurassic

rocks (and their fossils) of Nevada by right-lateral transcurrent faulting which has occurred, for example, with Jurassic sequences in western Canada (see Chapter 4). There is no doubt that the Aztec-Navajo-Nugget complex was deposited on an autochthonous basement since palaeomagnetic pole positions for the Kayenta and Carmel Formations, which occur stratigraphically below and above the complex respectively, cluster in northern Siberia along with other palaeopole positions for North America (Collinson and Runcorn, 1960; Steiner and Helsley, 1972; Packer and Stone, 1974).

The close lateral proximity of the marine Lower Jurassic rocks of Nevada to a vast complex of continental origin at least provides a palaeographic setting where a shallow water environment of deposition might be expected. Such an environment of deposition is born out by other lines of independent evidence.

The Sunrise-Dunlap sequence in the Gabbs Valley Range and the Shoshone Mountains is a classic example of a shallowing upward (shoaling upward or regressive) sequence (see James, 1979 for a discussion of the shallowing upward facies model). The Sunrise Formation is interpreted as a shallow water carbonate sequence characterising the miogeosynclinal nature of the Lower Jurassic of western Nevada. Hardgrounds develop in shallow water and there is evidence

that the hardground developed in the lower part of unit 4 in the Gabbs Valley Range (section 1) indicates a period of emergence, perhaps into the littoral zone. The hardground was relatively short-lived since Sinemurian ammonites of the same zone were collected from 1 m beneath and 2.5 m above the hardground. Also, the marine influence was never far removed since cephalopods are marine and stenohaline. The radial arrangement of the grooves around the depressions in the hardground surface and the morphology of the grooves themselves, however, are reminiscent of karstic features developed on modern subaerial limestone surfaces (Gascoyne, personal communication, 1980). Solution and etching are effected by a combination of seawater, rainwater, and acids from an algal cover. The possible presence of algae and the presence of *Trypanites* boreholes (probably attributable to polychaete or sipunculid worms (Kobluk *et al*, 1977) would suggest a littoral rather than a totally emergent situation. High energy conditions did not favour the development of an encrusting fauna.

The Sunrise Formation passes up into the Dunlap Formation which represents the accumulation of tidal flat, intertidal and alluvial fan deposits (Stanley, 1971). This regression sees a termination of Jurassic marine sedimentation in the Gabbs Valley Range and Shoshone Mountains; arguments based on bioherm accumulations and

cephalopod orientations are presented later (Chapter 5, p. 105) indicating a shallow water setting at Westgate.

It is worthy to note that just prior to the regression, *Plicatostylus* established itself in the area. It seems likely that this bivalve was in fact restricted to shallow water when its North American occurrences are reviewed. It invariably occurs as bioherms or biostromes in the uppermost parts of regressive sequences (Dunlap and Sunrise Formations) or in the lowermost parts of transgressive sequences (Robertson and Suplee Formations). The other major occurrence in the study area is in the Donovan Formation which was probably also laid down in shallow water, high energy conditions.

The Lower Jurassic sediments deposited in Oregon differ from the Nevada sequence in being dominantly clastic in origin. Furthermore, Dickinson (1962) and Dickinson and Vigrass (1964, 1965) have demonstrated that constituent particles were derived predominantly from andesitic, pyroclastic eruptions and the weathering of andesitic extrusive rocks. Although andesitic volcanic activity is locally evident in Nevada it is not as pervasive as in Oregon where the setting is dominated by island arc activity.

A shallow water shelf, termed the Suplee shelf by Dickinson and Vigrass (1965) was the site of sediment

accumulating in a transgressing sea (Robertson and Suplee Formations) in the western part of the Oregon study area. To the east of this area lay an extensive fault-bounded basin in which the Aldrich Mountains Group (to which the Keller Creek Shale belongs) was deposited. The relationship between the deposits of east-central Oregon and those of northeastern Oregon is uncertain in that the two areas are separated by a central mélangé terrain where stratigraphy is chaotic (Dickinson and Thayer, 1978). Nonetheless, the Hurwal Formation is eugeosynclinal in its setting, forming part of the Wallowa Mountains-Seven Devils Mountains volcanic arc terrain (Brooks and Vallier, 1978).

In summary, the Nevada region may be described as miogeosynclinal in aspect where shallow shelf carbonates are overlain by continental deposits indicating regression. The Oregon rocks are eugeosynclinal in aspect with a transgression evident in the western part of the area. The questions are posed:

1) Is it possible to correlate between these markedly contrasted eugeosynclinal and miogeosynclinal facies?

2) When did regression begin in Nevada?

3) When did transgression begin in Oregon?

## CHAPTER 3

### BIOCHRONOLOGY

#### 3.1 Introduction

Evolution is a nonreversible process, a tenet sometimes referred to as Dollo's Law, and the evolutionary turnover of species is the foundation of any zonal scheme. The scheme developed for northwest Europe was initiated by Quenstedt and his student, Oppel, working at the University of Tübingen during the first half of the nineteenth century, several years before the publication of Darwin's "The Origin of Species". Consequently, their's was a pragmatic approach, an embellishment of Smith's Law of Faunal Succession. They recognised vertically arranged rock units in the Jurassic that were characterised by overlapping ranges of numerous ammonite taxa. The units were unique, independent of lithology and, in the light of the theory of evolution, held to be of temporal significance. In selecting ammonites as index fossils Quenstedt and Oppel had fortunately chosen a group that evolved rapidly and was geographically widespread. The lateral limits to the distribution of ammonites that have since been recognised are discussed in some detail in the succeeding chapter.



The concern of the present chapter is the establishment of a zonal scheme for the Sinemurian, Pliensbachian, and lowest Toarcian of Oregon and Nevada that will hopefully find application in the rest of North America and perhaps South America.

### 3.2 The Northwest European Zonal Scheme

The work of Quenstedt and Oppel led to the establishment of what would be called assemblage zones in modern terminology. These assemblage zones have undergone three modifications with the passage of time and the zones defined below for the United States will probably be modified in a similar fashion.

1) Faunas that were not initially included because of collection failure or local nonsequence have been inserted into the zonal scheme.

2) Larger zones have been subdivided.

3) Zonal boundaries are being marked in type sections and an attempt is being made to define these boundaries using evolutionary events that are considered unique in time. Ideally, the species of an evolutionary lineage are used as "indices" and the zones bear their names. It should be emphasized that not all zonal boundaries are defined in such a manner and also that it is possible to recognise a zone when the index species is absent but

other members of the zonal assemblage are present.

The Lower Jurassic zonal scheme for northwest Europe for the interval of interest is illustrated in Fig. 3-1. The criteria used for its erection and the details of the zone definitions are discussed by Dean *et al.* (1961), and Mouterde *et al.* (1971).

### 3.3 The Proposed American Zonal Scheme

As stated above (p. 44) the correlative of the Bucklandi Zone in the United States is beyond the scope of this report but it will be discussed briefly when the age of the lithostratigraphic units is considered. The remainder of the Sinemurian is divided into three zones, the Pliensbachian is also divided into three zones, and a single zone equivalent to the basal Toarcian is erected (Fig. 3-1). A consideration of ammonite evolution at the family and generic levels permits an approximate correlation of the northwest European and United States ammonite schemes as illustrated in Fig. 3-1. In the section dealing with systematic palaeontology (Chapter 6) the age of every non-endemic taxon is given in terms of the European as well as the American zonal scheme and this also facilitates intercontinental correlation.

The scheme described below is derived from the data shown in Fig. 3-2 which, combined with the stratigraphic

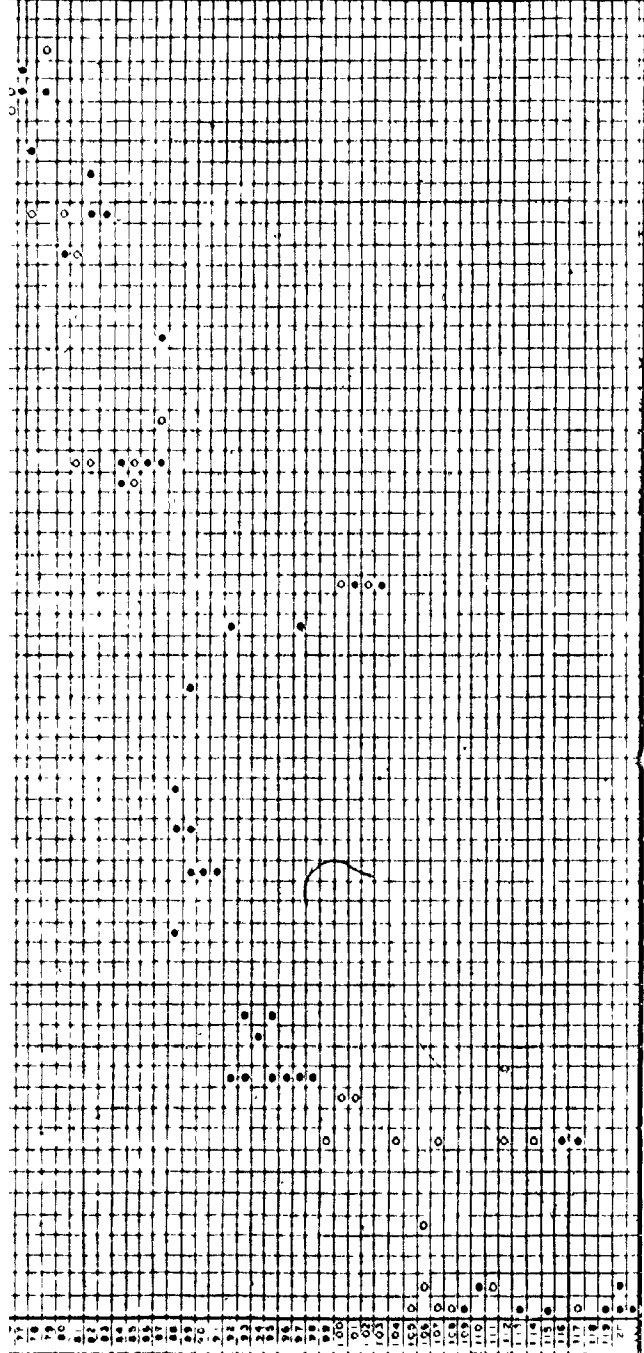
STAGE	SUBSTAGE	EUROPEAN ZONE	UNITED STATES ZONE
TOARCIAN	WHITBIAN	TENUICOSTATUM	T PROPINQUUM
PLIENSCHACHIAN	DOMERIAN	SPINATUM	R FANNINI
		MARGARITATUS	
	CARIXIAN	DAVOEI	D. DAYICEROIDES
		IBEX	A(L) PINNAFORME
		JAMESONI	
SINEMURIAN	LOTHARINGIAN	RARICOSTATUM	P. ROTHPLETZI
		OXYNOTUM	
		OBTUSUM	P. HARBLEDOWNENSE
		TURNERI	
		SEMICOSTATUM	A. CERATITOIDES

FIGURE 3-1 Approximate correlation of the European Standard Zones and the proposed American Assemblage Zones.

columns presented in Chapter 2, illustrate the stratigraphic distribution in Oregon and Nevada of all the ammonites dealt with in this study. Only the *in situ* fauna is considered. The scheme is founded on the overlapping range principle, that is, the zones are belts of rock defined by the joint occurrence of ammonite taxa. Taxa are confined to a zone, may first appear in a zone, or may range upwards from the preceding zone to become extinct within a zone.



R P D H R P D C H R P C H R P D F Pr



Distribution in Oregon and  
sites dealt with in this study.

Abbreviations

- P = *Acanthopleuroceras*
- se (Luningiceras) pinnaforme
- F = *Radstockiceras fannini*
- Pr = *Tiltoniceras propinquum*

20f

fat



3 of 3

Only the lower boundary of each zone is delimited, with the top automatically being drawn at the lower boundary of the superjacent zone. From the base upwards, the scheme is as follows:

### 3.3.1 Arnioceras ceratitoides Assemblage Zone

Taxa Restricted to the Zone: *Arnioceras ceratitoides*  
*A. miserabile*  
*A. cf. oppeli*  
*A. sp.*

First Occurrence: *Epophioceras cf. carinatum*  
*E. aff. carinatum*  
*E. sp.*  
*Asteroceras (Eparietites) n. sp.*  
*A. (E.) sp.*

Last Occurrence: *Arnioceras arnouldi*

Lower Boundary: The base of the zone is presently left undefined pending the results of other workers.

*A. arnouldi* occurs abundantly in the upper part of unit 2 of the Sunrise Formation in the Gabbs Valley Range (Taylor, *in litt.*, 1979), unit 2 being approximately correlative with the Bucklandi Zone of the European succession. The lower part of the range of species of *Epophioceras* overlaps the upper part of the range of representatives of *Arnioceras* and this interval marks the incoming of rare specimens of *Asteroceras (Eparietites)*.

### 3.3.2 Paltechioceras harbledownense Assemblage Zone

First Occurrence: *Paltechioceras harbledownense*

Last Occurrence: *Epophioceras* cf. *carinatum*  
*E.* aff. *carinatum*  
*E.* ? sp.  
*Asteroceras* (*Eparietites*) n. sp. ?  
*A.* (*E.*) sp.

Lower Boundary: Drawn above the last occurrence of the genus *Arnioceras*.

The lower part of this zone is characterised by the presence of species of *Epophioceras* and immediately above the range of this genus, *Paltechioceras harbledownense* appears. The latter is generally found alone for a stratigraphic interval until the echioceratids appear in abundance, the first species often being *P. rothpletzi*.

### 3.3.3 *Paltechioceras rothpletzi* Assemblage Zone

Taxa Restricted to the Zone: *Palaeoechioceras spirale*  
*P.* aff. *spirale*  
*Orthechioceras edmundi*  
*Paltechioceras boehmi*  
*P. depressum*  
*P.* aff. *depressum*  
*P. gettyi*  
*P. oosteri*  
*P. rothpletzi*  
*P. tardecrescens*  
*Microderoceras* cf. *birchiades*  
*Oxynoticeras* cf. *simpsoni*  
*Gleviceras* ex gr. *victoris*

Last Occurrence: *Paltechioceras harbledownense*

Lower Boundary: Drawn beneath the incoming of the echioceratids in abundance.

The upper limit of this zone approximately corresponds with the boundary between the Sinemurian and Pliensbachian



Stages which marks the demise of the Echioceratidae.

3.3.4 Acanthopleuroceras (Luningiceras) pinnaforme

Assemblage Zone

Taxa Restricted to the Zone: *Acanthopleuroceras (Luningiceras)*  
*pinnaforme*  
*A. (Acanthopleuroceras) mulleri*  
*A. (A.) cf. valdani*  
*A. (A.) spp.*  
*Tropidoceras actaeon*  
*Crucilobiceras (Metaderoceras)*  
*evolutum*  
 ? *Coeloceras (C. ?) cf. depressum*

First Occurrence: *Crucilobiceras (Metaderoceras) cf. muticum*  
*C. (M.) silviesi*

Lower Boundary: Drawn above the last occurrence of the family Echioceratidae.

3.3.5 Dayiceras dayiceroides Assemblage Zone

Taxa Restricted to the Zone: *Dayiceras dayiceroides*  
*Prodactylioceras (Prodactylioceras)*  
*cf. davoei*  
*P. (Aveyroniceras) colubriforme*  
*P. (A.) cf. inaequioratum*  
*P. (A.) spp.*  
*Hyperderoceras n. sp.*  
*Lioceratoides cf. matsumotoi*  
 ? *Crucilobiceras (Metaderoceras)*  
*beirense*  
 ? *Coeloceras (Reynesocoeloceras)*  
*cf. baconicum*  
 ? *C. (R.) incertum*

First Occurrence: *Radstockiceras fannini*

Last Occurrence: *Crucilobiceras (Metaderoceras) cf. muticum*  
*C. (M.) silviesi*  
*Acanthopleuroceras (A.) spp.*

Lower Boundary: Drawn beneath the first occurrence of *Dayiceras dayiceroides*.

*D. dayiceroides* is most abundant in the lower part of the zone, being replaced by species of *Proactylioceras* (*Aveyroniceras*) and *P. (P.)* at higher levels. The precise stratigraphic position of some of the species of *Coeloceras* (*Reynesocoeloceras*) is uncertain as discussed below under the Donovan Formation. *Radstockiceras* makes its first appearance in the highest part of this zone but it is very rare.

### 3.3.6 *Radstockiceras fannini* Assemblage Zone

Taxa Restricted to the Zone: *Radstockiceras gemellaroi*  
*R. cf. kuae*  
*Arietoceras cf. algovianum*  
*Protogrammoceras cf. lusitanicum*  
*P. cf. nipponicum*  
*P. paltum toyoranum*  
*P. varicostatum*

First Occurrence: ? *Protogrammoceras argutum*

Last Occurrence: *Radstockiceras fannini*  
 ? *Proactylioceras (Aveyroniceras) spp.*

Lower Boundary: Drawn beneath the appearance of *Radstockiceras* and hildoceratids in abundance.

### 3.3.7 *Tiltoniceras propinquum* Assemblage Zone

Taxa Restricted to the Zone: *Tiltoniceras propinquum*

First Occurrence: *Harpoceras cf. maurelli*

Last Occurrence: *Protogrammoceras argutum*

Lower Boundary: Drawn beneath the first occurrence of *T. propinquum*.

In Europe the genus *Tiltoniceras* appears at the base of the Toarcian Stage and it is used in the present study to define the upper limit of the Pliensbachian for the United States. As in Europe, this boundary is also marked by the demise of many hildoceratids such as *Arietoceras*, and most species of *Protogrammoceras*.

The upper limit of this zone is left undefined for the present pending the completion of further work. The zone as used here is restricted to the range of *T. propinquum* which occurs beneath the first *Dactylioceras* in the Westgate area.

### 3.4 Age and Correlation

#### 3.4.1 The Sunrise Formation

##### 3.4.1a The Gabbs Valley Range

A single *ex situ* specimen of *Arnioceras* cf. *oppeli* collected from the base of the section exposed in the entrance to New York Canyon (Fig. 2-3 and 3-2) suggests that the *A. ceratitoides* Zone may be present here but it is not well developed. A rich *P. harbledownense* Zone fauna is present in much of the upper part of unit 3 but the *Echioceratidae* appear in force at locality 18 marking the

base of the *P. rothpletzi* Zone. The *P. rothpletzi* Zone assemblage ranges from the upper part of unit 3 into the lower half of unit 4 but the upper half of this predominantly carbonate unit has proved barren of ammonites in this area. A rich benthonic fauna is present, however, dominated by pelecypods and gastropods. The uppermost beds of unit 4 and the lower argillaceous portion of unit 5 have yielded *Crucilobicerias* (*Metaderoceras*) cf. *muticum* which in the upper half of unit 5 overlaps with the lower part of the range of *Dayiceras dayiceroides* of the *D. dayiceroides* Zone. The age of the Sunrise Formation at this locality therefore ranges from the Lower Sinemurian to the middle of the Pliensbachian with the highest ammonite fauna beneath the Dunlap-Sunrise contact correlating with the *D. dayiceroides* Zone.

The type section of the Sunrise Formation to the east of New York Canyon has yielded relatively few fossils (Fig. 2-1; 2-2; 3-2). *P. harbledownense* at the top of unit 3 suggests a correlation with the *P. harbledownense* Zone, the same age as determined at New York Canyon entrance. Not far beneath the contact between units 4 and 5 *Oxynticeras* cf. *simpsoni* of *P. rothpletzi* Zone age occurs whereas at the top of unit 4 a fairly diverse *A. (L.) pinnaforme* Zone fauna is recorded. The upper part of unit 5 has yielded an association of *Prodactylioceras* (*Aveyroniceras*) sp. and

*Lioceratoides cf. matsumotoi* indicating a *D. dayiceroides* Zone age. The range in age of the Sunrise Formation at this locality is therefore identical to that recorded at New York Canyon entrance.

Almost the same age range is recorded at Volcano Peak Gulch just to the north (Fig. 2-1; 2-4; 3-2) except that the upper part of the sequence is truncated by a thrust fault. There appears to have been some condensing as the units are much thinner than in other exposures and ammonites that are stratigraphically separated in section 1, occur together in section 3. The highest fauna, which occurs in the lower part of unit 5, is attributable to the *A. (L.) pinnaforme* Zone. At this locality, unit 2 of the Sunrise Formation is exposed which has yielded a very rich ammonite fauna correlative with the Bucklandi Zone of the European succession (Taylor, *in litt.*, 1979). The following taxa are provisionally identified by Mr. Taylor:

<i>Arnioceras arnouldi</i>	<i>Arietites</i> sp.
<i>Tmaegoceras cf. crassiceps</i>	<i>Coroniceras (Coroniceras)</i>
<i>T. n. sp.</i>	<i>C. (Primarietites) sp.</i>
<i>Arietites cf. bisulcatus</i>	new genus

Throughout the Gabbs Valley Range there does not appear to be any diachronism within the Sunrise Formation. Facies are approximately co-eval but it should be born in mind that the sections are less than a kilometre or so apart and diachronism would probably not be resolvable over such short distances.

### 3.4.1b The Shoshone Mountains

A Bucklandi Zone fauna is also present in the lower part of the Sunrise Formation in the Shoshone Mountains. Above it in section 4 (Fig. 2-7; 3-2) an *A. ceratitoides* Zone fauna ranges through 75 m of rock (upper unit D to lower unit F). This fauna is separated from an abundant *P. harbledownense* fauna by 115 m of beds that have not yielded any ammonites. A single locality in the lower part of unit G has yielded a small *P. rothpletzi* Zone fauna whilst the highest ammonites, representing the *R. fannini* Zone, occur near the top of unit H. When the area was first mapped, Silberling (1959, p. 59) found a serenticone ammonite in the lowest part of unit I that he tentatively referred to *Uptonia* and this name was used by Hallam (1965). This identification is considered most unlikely since this would mark one of the latest records of *Uptonia* in the world. Also, *Uptonia* is not known from anywhere else in the Sunrise Formation or, for that matter, in the conterminous United States. It could possibly represent a species of *Prodactylioceras* (*Aveyroniceras*) but unfortunately the specimen is now lost (Silberling, *in litt.*, 1980) so that the matter cannot be resolved until more material is collected.

### 3.4.1c The Clan Alpine Mountains

Above the Bucklandi Zone fauna of unit A and the

lowest part of unit B at Westgate (Fig. 2-8; 3-2) occurs an *A. ceratitoides* and *P. rothpletzi* Zone fauna in the remainder of unit B whilst unit C has not yielded any ammonites. Unit D is assigned to the *A. (L.) pinnaforme* and *D. dayiceroides* Zones on the basis of a sparse fauna. A specimen identified as *Xipheroceras* from this interval (Corvalan, 1962) was referred to as an indeterminate "deroceratid" by Hallam (1965) who used it, nonetheless, as an indicator of a Sinemurian age. I agree with Hallam that the fragment is indeterminate but it certainly cannot be used as evidence of a Sinemurian age since the "deroceratids" range up into the Carixian in Europe. Also, Hallam's arguments as to a Toarcian rather than a Pliensbachian age of *Arietoceras* (which is present about one-third of the way up unit E, higher than indicated by Corvalan, 1962) have already been refuted by Imlay (1968). Hallam was attempting to demonstrate the absence of the Pliensbachian both here and elsewhere in North America in an attempt to bolster his theories concerning eustatic changes of sea level during the Jurassic. The Pliensbachian is now known to be widely present in North America as shown here and by Imlay (1968, in press) and Frebold (e.g. 1970).

Unit E yielded an abundant fauna ranging from the *D. dayiceroides* Zone of the Carixian to the lowest Toarcian although the Domerian is not richly fossiliferous in terms

of ammonites. The Lower Toarcian fauna of unit E is unique in the western United States, and the Sunrise Formation at Westgate serves as a section for defining the boundary between the Pliensbachian and the Toarcian Stages for North America.

#### 3.4.2 The Dunlap Formation

The meagre evidence used for previously determining the age of the Dunlap Formation can be summarised as follows:

1) The age of the upper part of the Sunrise Formation in the Gabbs Valley Range was believed to be Toarcian based on the occurrence of an "indeterminate harpoceratid about halfway up unit H (= 5)" (Hallam, 1965, p. 1486). The Dunlap Formation conformably overlies the Sunrise Formation in this area. Conformity is evident in the Shoshone Mountains where the age of the highest fauna in the Sunrise Formation was previously thought to be Toarcian (Silberling, 1959) or Lower Pliensbachian (Hallam, 1965).

2) In the basal part of the Dunlap Formation in the Garfield Hills the pelecypod *Plicatostylus gregarius* and an ammonite determined as *Harpoceras* have been found (Muller and Ferguson, 1939; Hallam, 1965).

3) The Dunlap Formation consists principally of fanglomerates which were, according to Stanley (1971), probably deposited rapidly in a short period of time.



The age of the Dunlap Formation based on all or part of this evidence has been interpreted as possibly Middle Jurassic (Silberling, 1959); Pliensbachian and Toarcian (Muller and Ferguson, 1939); and Lower Jurassic (Hallam, 1965; Stanley, 1971).

No ammonites were found in the Dunlap Formation during the course of this study but the upper part of the Sunrise Formation in the Gabbs Valley Range and the Shoshone Mountains is now conclusively shown to be Pliensbachian (*D. dayiceroides* and *R. fannini* Zones respectively).

Hallam's statement (1965) that an "indeterminate harpoceratid" is unequivocal evidence of a Toarcian age is unwarranted.

Firstly, the subfamily Harpoceratinae arises in the Pliensbachian and secondly, there are a variety of Tethyan Pliensbachian forms (many of them only recently described) which could be confused with *Harpoceras* of the northwest European Toarcian. The same holds true of the *Harpoceras* mentioned by Muller and Ferguson (1939) and Corvalan (1962). Nearly all this material now appears to be lost but Corvalan's specimen of *Harpoceras* is definitely a Pliensbachian *Protogrammoceras* (*P. cf. hungaricum* GECZY).

Although the stratigraphic distribution of *Plicatostylus gregarius* has not been studied in detail, I know of no report of a post-Pliensbachian occurrence in western North America. The bioherms of the Robertson

Formation in Oregon are Pliensbachian (or earlier) in age; the specimens from the Donovan Formation occur beneath a Lower Pliensbachian fauna and I have found an *ex situ* specimen that probably originates from the Pliensbachian at Westgate.

The weight of the evidence therefore suggests a Pliensbachian (probably early Domerian) age for the regression that resulted in the deposition of the terrestrial Dunlap Formation.

### 3.4.3 The Donovan Formation

The ammonites described below have previously been listed from the Donovan Formation by Luper (1941). Several of Luper's ammonites are described in this thesis but his specimens are no longer accompanied by museum labels showing his original identifications. I have attempted to match his published list with the surviving specimens and my revisions are shown in brackets. Nonetheless, there must remain an element of doubt.

<i>Coeloceras</i> cf. <i>pettos</i>	[ <i>Coeloceras</i> ( <i>Reynesocoeloceras</i> ) <i>incertum</i> ]
<i>Deroceras</i> cf. <i>impavidum</i>	[? <i>Cruciloboceras</i> ( <i>Metaderoceras</i> ) <i>beinense</i> ]
" <i>Uptonia</i> " <i>silviesi</i>	[ <i>Cruciloboceras</i> ( <i>Metaderoceras</i> ) <i>silviesi</i> ]
" <i>Metechioceras</i> "	[ <i>Paltechioceras</i> ]

All except the last represent the Carixian assemblage of the *D. dayiceroides* Zone. Most of these specimens probably originated (together with the other

specimens listed in Fig. 3-2) from the upper part of the formation exposed on the west bank of the Silvies River but their relative stratigraphic positions within this 30 m or less of rock are not known. The "*Metechioceras*" cannot now be traced (Imlay, *in litt.*, 1980) although Dickinson and Vigrass (1965, p. 36) mention the presence of echioceratids 145 m beneath the *Plicatostylus* beds of the Donovan Formation, *i.e.* well beneath the *D. dayiceroides* Zone assemblage. This would be most interesting if it could be confirmed since the echioceratidae are so very abundant in Nevada at an identical stratigraphic level.

#### 3.4.4 The Mowich Group

The ammonites of the Suplee and Nicely Formations have been studied by Imlay (1968) who assigned the whole assemblage to the upper Pliensbachian (*R. fannini* Zone of this report). The Mowich Group is part of a transgressive sequence and it would be very interesting to undertake a detailed study establishing the stratigraphic distribution of ammonites in several stratigraphic sections to see if any diachronism can be determined (see a similar study of the Middle Jurassic Snowshoe Formation by Smith, *in press*). The Suplee and Nicely Formations are almost certainly partially correlative and some of the ammonites present suggest the Carixian might also be represented as well as

the Domerian. Not only could such a study provide valuable information concerning the timing of the transgression which is related to deep-seated (plate tectonic) controls but the Suplee-Nicely ammonite fauna is very diverse and abundant and could be used as a basis for subdividing the rather large *R. fannini* Zone.

#### 3.4.5 The Keller Creek Shale

It is not possible to measure a stratigraphic section in the Keller Creek Shale so that the age of the unit as a whole can only be described in gross terms. At one locality not included in this thesis (U. S. G. S. 28363), an association of *Coroniceras pseudolyra* ERBEN, *Arnioceras arnouldi* (DUMORTIER), and *Vermiceras* ? sp. indicates that the earliest Sinemurian (equivalent of the Bucklandi Zone) is represented.

The *A. ceratitoides* Zone (Fig. 3-2) is represented by an association of *Asteroceras (Eparietites)* sp., *Arnioceras ceratitoides*, and *A. arnouldi*. The *A. (L.) pinnaforme* Zone of the lowest Carixian is represented at three localities. The Keller Creek Shale, therefore, represents the entire Sinemurian as well as the lowest Pliensbachian and as such, it is the correlative of the Sunrise Formation of Nevada.



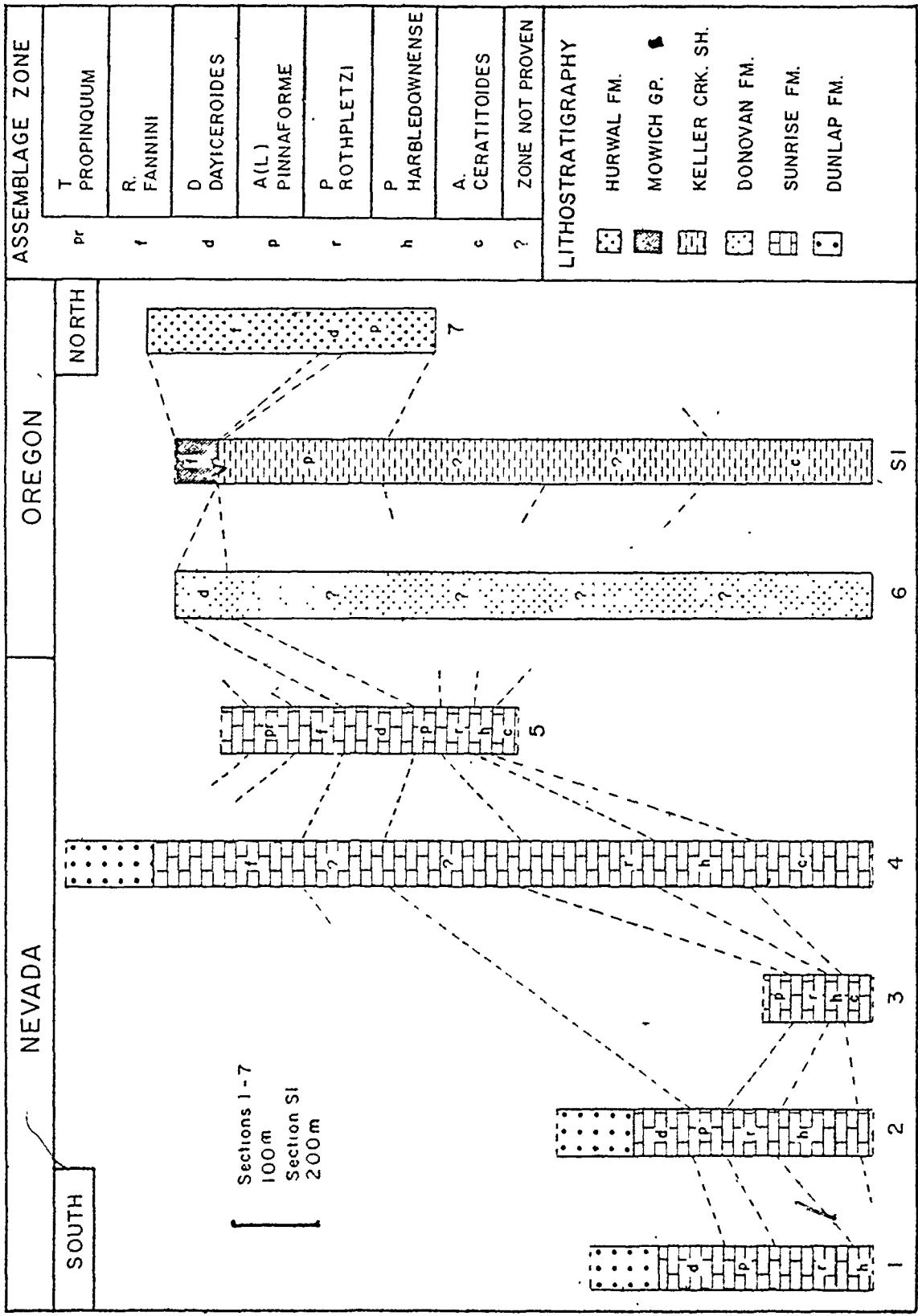


FIGURE 3-3 Correlation of the measured sections (1-7) of Nevada and Oregon.

are schematic and the estimated thickness given by Brown and Thayer (1966) is shown at half scale. The Mowich Group does not include the Robertson or the Hyde Formations. The following points are suggested by this figure.

1) In Nevada, the Shoshone Mountain section (section 4) was relatively closest to the source of clastic input as shown by the maximum thickness of the zones.

2) The Pliensbachian Dunlap regression began slightly earlier in the Gabbs Valley Range (sections 1 and 2) than in the Shoshone Mountains.

3) The Westgate District (section 5) was the site of slow, continuous deposition as shown by the condensing of the zones northwards and the continuation of marine sedimentation into the Toarcian (and, in fact, later).

4) The period of transgression represented by the sub-Mowich unconformity in the John Day inlier (the stratigraphic column SI, Fig. 3-3) approximately correlates with the period of regression represented by the Dunlap Formation in Nevada. In very recent years it has been realised that the western Cordillera consist of a mosaic of microplates that have undergone complex histories, often isolated from each other, later to be accreted to the western margin of the North American plate. The Lower Jurassic miogeosynclinal rocks of Nevada, for example, were laid down in the Sonoma microplate whereas the Oregon correlatives were deposited on the Blue Mountains microplate (Beck *et al.*,

1980). One of the major tasks facing west coast geologists in the future is to accurately define these plates in terms of their extent and their geologic histories. The evidence of synchronous geologic events (in this case, transgression and regression) strongly suggests that these two plates were interacting and *ipso facto* in close proximity to each other during the Lower Jurassic.



## CHAPTER 4

### PALAEOBIOGEOGRAPHY

#### 4.1 Introduction

Palaeobiogeographic studies suffer the weakness of absence of evidence not being evidence of absence; to say that a particular taxon has not been collected in a given region obviously does not preclude it being collected there in the future. Palaeobiogeographic studies are also complicated by the species problem in palaeontology (Sylvester-Bradley, 1956). Excessive taxonomic splitting applied unevenly from area to area masks biogeographical relationships. Conversely, excessive lumping leads to an over-simplified picture. Fortunately there is closer agreement amongst taxonomists at the generic and higher taxonomic levels and, as a consequence, the genus is the common, basic unit of biogeographic study. It is to be hoped that the availability of computer facilities for handling and storing large amounts of quantitative data will eventually lead to a synthesis at the specific level but this is for the future. Bearing these limitations in mind, the arrangement of coeval fossil organisms in space can throw light on problems of palaeoclimate, former land or marine connections,

and large-scale tectonic displacement of terranes subsequent to the fossilisation of the animals.

The Jurassic of Europe has been the subject of meticulous biostratigraphic study for almost 150 years. The coverage has been far from even but nonetheless, a reasonably complete picture has emerged of the extent of ammonite endemism and by virtue of this, it is Europe that serves as a model for the rest of the world. The northwestern and northeastern Pacific margins are the two other areas of importance in that they are the sites of transition between the major palaeobiogeographic units described below. The following treatment is therefore arranged geographically proceeding from Europe to the northwestern Pacific, and finally to the northeastern Pacific and the more detailed treatment of the Nevada and Oregon ammonites. In drawing comparisons between these three regions, the following questions are addressed:

- 1) What palaeobiogeographic units can be recognised, and how are they faunally distinct?

- 2) What is the nature of the boundary between the palaeobiogeographic units?

- 3) What ecologic factors might have caused the differentiation?

- 4) To what extent have the present distributional patterns been caused by subsequent plate tectonic displacement

and, conversely, to what extent can present patterns be used as a source of corroborative evidence in constructing plate tectonic models based on palaeomagnetic and other data?

#### 4.2 Europe

Neumayr (1883) was the first to point to a large scale spatial change in the composition of synchronous Jurassic faunas. Two faunal realms are presently recognised. The Boreal Realm, of which the Northwest European Province is a subdivision, occupies the northern part of the northern hemisphere whereas all areas of the world to the south of this region comprise the Tethyan Realm. This bipartite division occurred at various times during the Jurassic but it became very marked in the Upper Jurassic, and extreme in the Early Cretaceous where separate zonal schemes and even stages are necessary for the two realms.

Arkell's belief that all Lower Jurassic ammonites were cosmopolitan has proved to be unfounded (Arkell, 1956). Figure 4-1 is a compilation of faunal data by stage and substage presented by Donovan (1967) together with absolute ages (modified from Van Hinte, 1976). Ammonite genera fall into three categories: those with a chiefly northern distribution (Boreal); those with a chiefly southern distribution (Tethyan), and unrestricted. It is

## EUROPEAN LOWER JURASSIC AMMONITE PROVINCIALISM

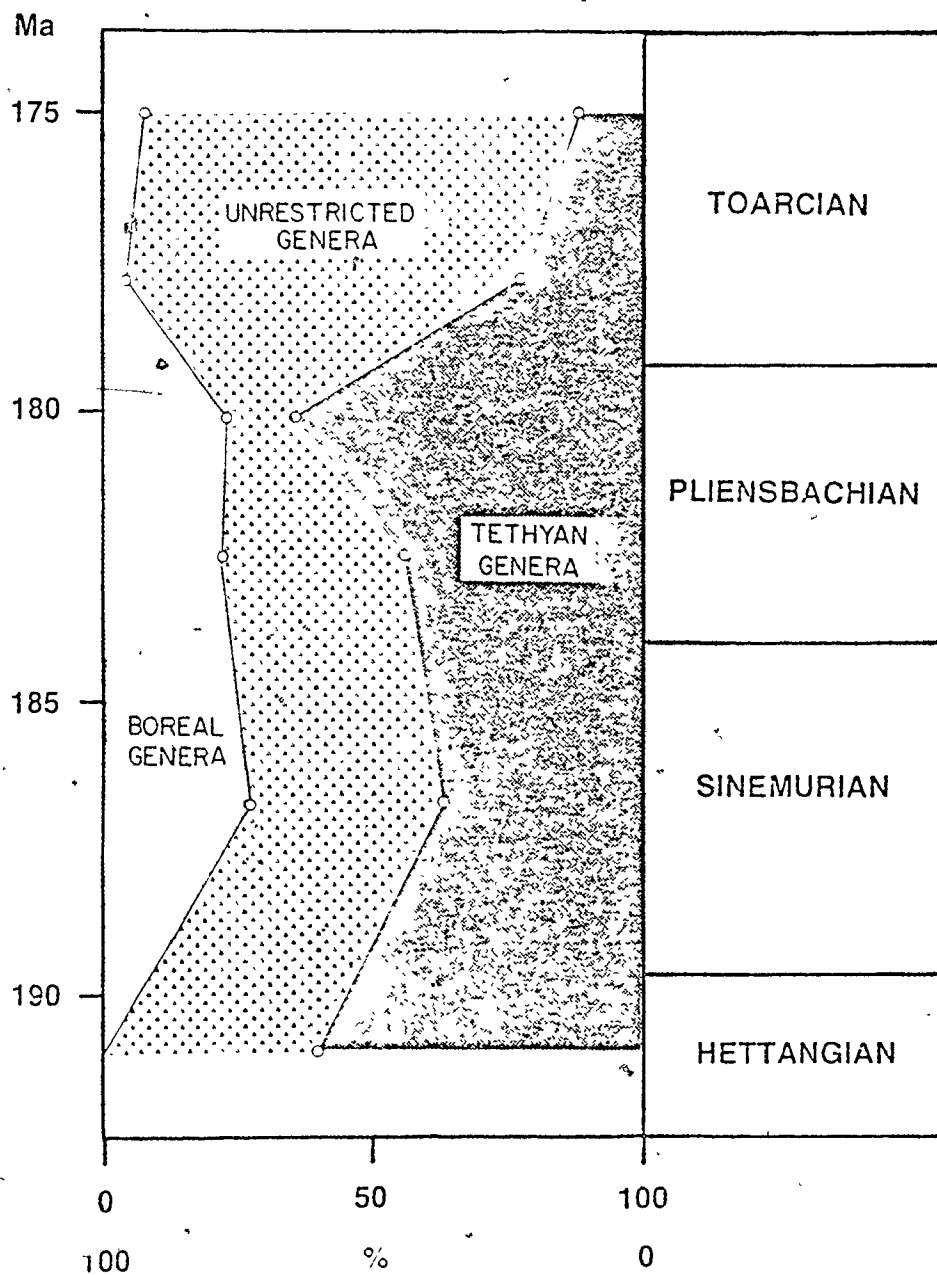


FIGURE 4-1 Ammonite provincialism by Stage for the Lower Jurassic of Europe. Modified from Donovan (1967), and Van Hinte (1976).

immediately apparent that there is a decreasing northward diversity gradient in that the number of Tethyan genera far exceeds the number of Boreal genera for any given time interval. During the part of the Lower Jurassic of interest here (Sinemurian to earliest Toarcian), the Tethyan Realm was the site of the proliferation of several ammonoid families, namely, the Discophyllitidae, the Phylloceratidae, the Ectocentritidae, and the Lytoceratidae. Many of the genera belonging to these families never reached northwest Europe whilst others gradually migrated northwards making a late appearance in the Early Jurassic.

It is also evident from the proportion of unrestricted genera (Fig. 4-1) that the degree of faunal differentiation fluctuated with time. A maximum was reached during the Late Pliensbachian when the Liparoceratidae and Amaltheidae are characteristic of, and the latter restricted to, the Boreal Realm whilst the families Hildoceratidae and Dactylioceratidae are characteristically Tethyan (Donovan, 1967; Hallam, 1969a, 1969b).

Boreal genera may occur in the Tethyan Realm and *vice versa* but such occurrences are rare and would be presumably in part the result of post-mortem drift. These specimens serve as a useful link between the different zonal schemes erected for each realm but the area including southern France (the Causses), and the Iberian Peninsula

is much more important in this respect. This is a region of complete intermixing of the two faunas which allows a direct interfingering of the zonal schemes, making it possible to use northwest European standard zonal names in the Tethyan Realm. The area occupied by the mixed fauna shifted with time but only within fairly narrow limits. Its position in Europe when plotted on a palaeocontinental map for the Pliensbachian (Fig. 4-2) is seen to be fairly close and approximately parallel to the  $30^{\circ}$  palaeolatitude.

The scissor-like closure of the Tethyan Ocean during the formation of the Alpine Belt has juxtaposed crustal blocks that during the Jurassic were widely separated. Consequently, the nature of the boundary between the Tethyan and Boreal Provinces changes as it is traced in present day Europe from the Iberian Peninsula, through southern France, and into the Alpine region. In the Iberian Peninsula, as already mentioned, a complete intermixing of faunas is apparent whereas in the Alpine region the boundary is faunally much sharper although its trend is more difficult to place geographically because of the complex subsequent tectonic history.

Speculation as to the causes of the Boreal-Tethyan division has a long history beginning with Neumayr himself (Neumayr, 1883). Of the hypotheses that have been proposed, that of physical barriers may be dismissed out of hand

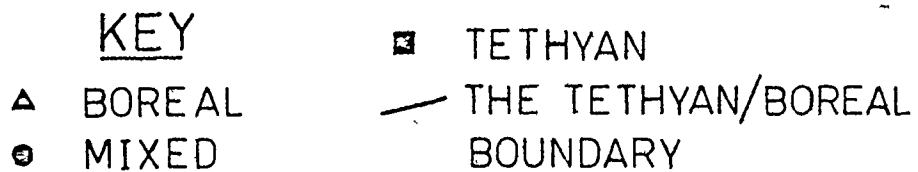
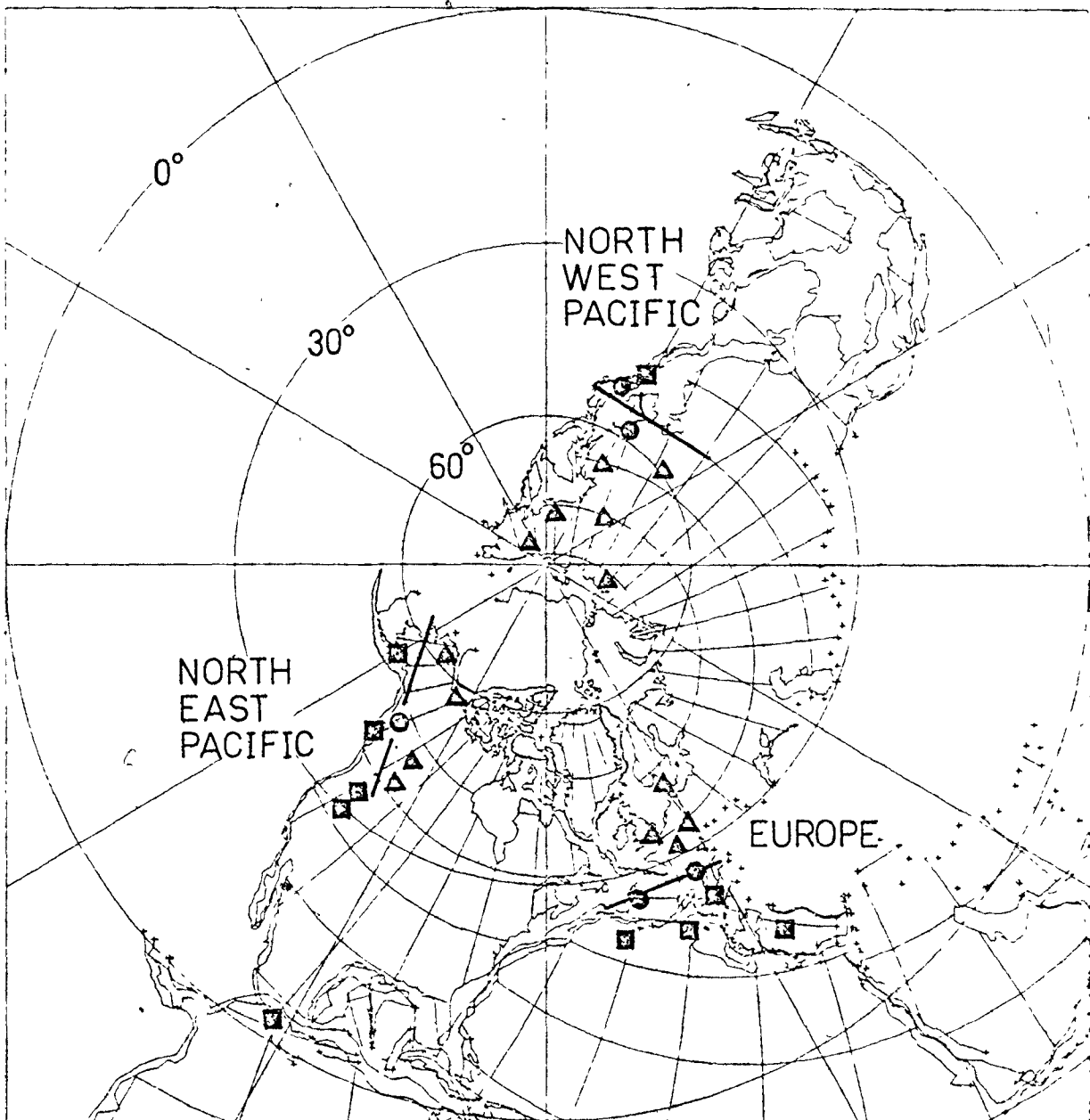


FIGURE 4-2. The distribution of Boreal, Tethyan, and mixed ammonoid faunas during the Pliensbachian. Base map from Smith and Briden (1977).

because of the unrestricted distribution of some genera whilst the rest may be grouped into three categories.

1) Temperature: Many workers but more recently Donovan (1967), and Gordan (1976), have concluded that the distribution of Liassic ammonites can best be explained by assuming that some ammonites were tolerant of wide temperature ranges whilst others were not. This accounts for the north-south transition of the faunas in Europe.

2) Salinity: Hallam (1969a, 1969b) has levelled several arguments at the hypothesis of temperature control. Firstly, the transition from Boreal to Tethyan which occurs with many other groups apart from the ammonoids, takes place over fairly narrow palaeolatitudinal intervals. This would suggest a marked climatic gradient. This contradicts the evidence available from Jurassic plant distributions which apparently show a world-wide uniformity and suggest a more equable climate than the present day. Secondly, he points to a broad correlation between sedimentary facies and faunal realms. Three facies associations are defined: terrigenous clastic, intermediate, and calcareous, with the calcareous facies corresponding approximately with the region of the Mediterranean countries (Tethys) and the two other facies with the Boreal Realm. Hallam equates the pattern of sedimentary change from south to north with a passage from open oceanic towards more enclosed marine



conditions. The rivers transporting clastic material to the enclosed northern sea would, Hallam argues, reduce the salinity thus explaining the northward reduction in faunal diversity.

3) Environmental stability: Ecologic studies of faunal benthonic diversity in all marine environments have led to the emergence of the stability-time hypothesis (Sanders, 1969). In stable environments such as tropical and deep sea, the physical and chemical constancy allows niche partitioning to occur over long periods of time leading to high diversity. As the gradient of environmental stress increases, as it does with increasing latitude, diversity decreases as the organisms are forced to adapt to the increasing and fluctuating physiological stress. This environmental stability hypothesis, which incorporates the temperature and to some extent the salinity hypotheses, explains the ammonite distribution data the most adequately as realised indirectly by Reid (1973) and also by Hallam himself (Hallam, 1973).

To summarise the brief outline of the Lower Jurassic palaeobiogeography of Europe given above, a division into a northern Boreal Realm and a southern Tethyan Realm is evident. Both were characterised by their own endemic ammonite families particularly in the Pliensbachian, with the Tethyan Realm being further characterised by high

diversity. The boundary between the two realms is gradational and has been affected by subsequent plate tectonic movements. The most likely cause of the biogeographic division is seen as being changes in environmental stability and temperature, related to latitude. The effect on the ammonites could have been both direct and indirect through the food chain.

#### 4.3 The Northwestern Pacific

The Lower Jurassic of the northwest Pacific crops out sporadically in Japan and the eastern U. S. S. R. where there is still much work to be done. Some of the studies described below have been published in the last decade, and in some cases during the last few months, so that the palaeobiogeographic picture will inevitably be clarified as work progresses.

The Lower Jurassic of Japan is restricted to the island of Honshu where it is exposed at five localities stretching from the southwest tip to the northeast coast of the island (Fig. 4-3). Exposures at Yamaoku and Iwamuro are dated as Early Jurassic on the basis of their plant remains and pelecypod faunas whereas the Schizukawa Group has yielded only one species of the cosmopolitan genus *Arnioceras* of Sinemurian age (Sato, 1957, 1962). Attention is therefore confined to the ammonitiferous beds

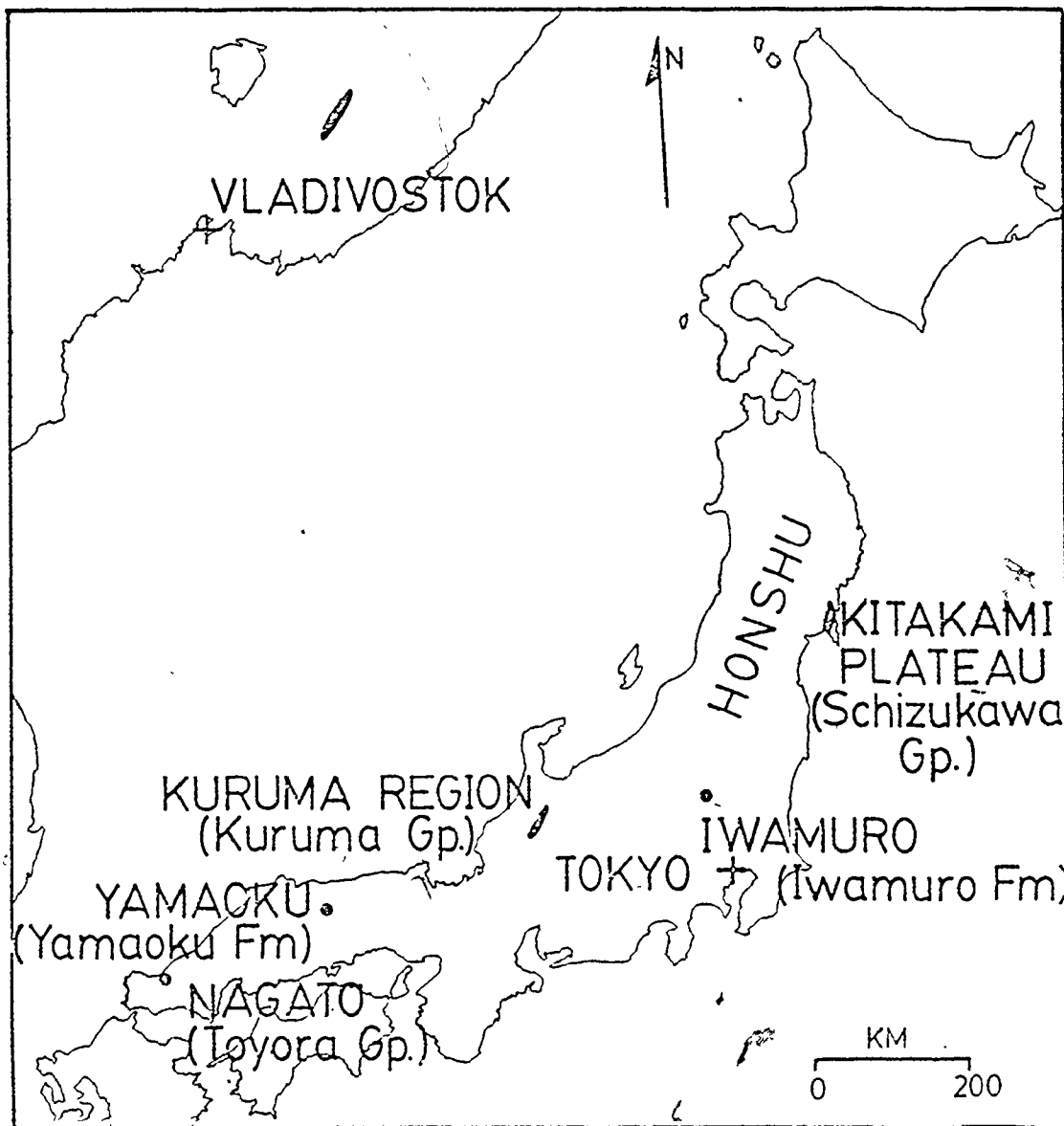


FIGURE 4-3 The Lower Jurassic ammonite localities of the U. S. S. R. and Japan discussed in the text.

of the Nagato and Kuruma regions.

The Toyora Group of the Nagato region was the subject of a preliminary biostratigraphic study by Matsumoto and Ono (1947) whose conclusions are discussed at some length by Arkell (1956). More recently, Hirano (1971, 1973a, 1973b) has published a series of elegant papers in which he proposes a local Liassic zonal scheme and also statistically analyses his faunas from a biogeographic viewpoint. The Sinemurian and Lower Pliensbachian are not represented, while the Upper Pliensbachian is dominated by Tethyan forms. Several species of the Tethyan hildoceratids *Arieticeras*, *Canavaria*, *Paltarpites*, *Lioceratoides*, *Fuciniceris*, and *Protogrammoceras* are present, together with *Fontanelliceras fontanellense* (GEMMELLARO), which is exclusively Tethyan. Dactylioceratids also occur whereas the Boreal Realm is only represented by a single fragment of *Amaltheus stokesi* (SOWERBY). In the Whitbian Substage (Lower Toarcian) the Tethyan connection is more equivocal and the fauna takes on a more mixed Tethyan-Boreal aspect. Some 75 km due east of Nagato, Hirano *et al.* (1978) have recently discovered a small Domerian fauna that consists entirely of Tethyan elements.

Moving to the north, the Kuruma region presents a rather different picture. Here only the Upper Pliensbachian occurs. The Boreal fauna is represented by numerous

*Amaltheus* sp. whereas *Canavaria* ex. gr. *geyeriana* (HAAS) is typically Tethyan. The boundary between the Tethyan and Boreal Realms, therefore, probably stretched across Honshu, at least during the Late Pliensbachian.

Insufficient information is available on the Sinemurian and Early Pliensbachian of the U. S. S. R. to make any detailed biogeographic analysis. Occurrences of the Late Pliensbachian Boreal family Amaltheidae, however, are widespread in northeastern Siberia, from a palaeolatitude of approximately 60° to the Early Jurassic North Pole (Fig. 4-2) (Howarth, 1973; Dagens, 1976). Recently a fauna has been described from outcrops just north of Vladivostok where amaltheids occur together with the characteristically Tethyan forms *Arietoceras* aff. *algovianum* (OPPEL), *A. japonicum* MATSUMOTO, *Fontanelliceras* cf. *fontanellense* (GEMM.), *Protogrammoceras* cf. *serotinum* (BETTONI), and various dactyloceratids compared with forms from Italy (Sey and Kalacheva, 1980).

The northwest Pacific region therefore mirrors the European situation in that a south to north transition from Tethyan to Boreal, with an intervening mixed fauna, is evident. The transition appears to occur at a higher palaeolatitude than in Europe (Fig. 4-2).

#### 4.4 The Northeastern Pacific

##### 4.4.1 Nevada and Oregon

The ammonite fauna from Oregon and Nevada is investigated at two taxonomic levels. At the species level, and at the generic (or subgeneric) level. The histograms shown in Fig. 4-4 show, by state, the number of ammonite species for the Sinemurian, Carixian, and Domerian described herein. Each taxon is allotted to one of the following groups based on the discussion of its occurrence given in the systematic section (Chapter 6):

- 1) endemic: found in Oregon and Nevada or restricted to the western Americas;
- 2) cosmopolitan: found in northwest Europe, the Mediterranean countries, and other parts of the world;
- 3) Tethyan: most abundant in, or restricted to lands bordering the Mediterranean;
- 4) Boreal: most abundant in, or restricted to the high palaeolatitude; characteristic of northwest Europe.

Tables 4-1 to 4-3 show the Simpson and Dice Coefficients comparing the ammonite genera or subgenera from the United States (including those described by Imlay, 1968) with those of Portugal, Hungary, southwest Germany, and Great Britain. The coefficients are defined as follows:

$$\text{Simpson Coefficient (S)} = \frac{C}{N_1} \cdot 100$$

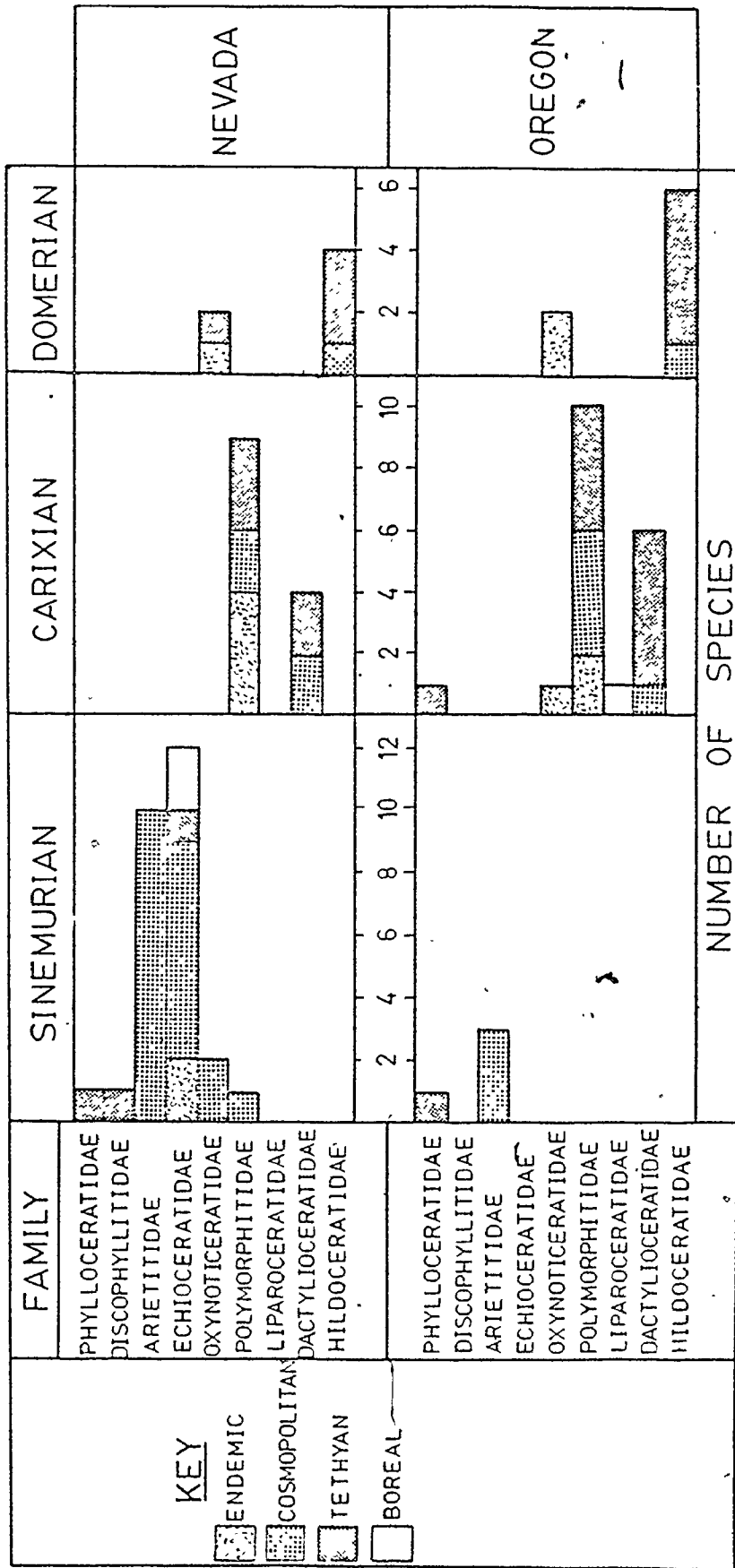


FIGURE 4-4 The composition and biogeographic affinity of the Lower Jurassic ammonite fauna of Oregon and Nevada.

Portugal	Hungary	SW Germany	G. B.	
$N_2=13$ $N_1=11$ $C=3$ $S=27$ $D=25$	$N_2=28$ $N_1=11$ $C=10$ $S=91$ $D=51$	$N_2=23$ $N_1=11$ $C=7$ $S=64$ $D=41$	$N_2=28$ $N_1=11$ $C=9$ $S=82$ $D=46$	United States
	$N_2=28$ $N_1=13$ $C=9$ $S=69$ $D=44$	$N_2=23$ $N_1=13$ $C=8$ $S=62$ $D=44$	$N_2=28$ $N_1=13$ $C=11$ $S=85$ $D=54$	Portugal
		$N_2=28$ $N_1=33$ $C=14$ $S=42$ $D=46$	$N_2=28$ $N_1=28$ $C=16$ $S=57$ $D=57$	Hungary
			$N_2=28$ $N_1=23$ $C=21$ $S=91$ $D=82$	Germany SW

TABLE 4-1 Regional comparison of Sinemurian ammonite faunas at the generic level.



Portugal	Hungary	SW Germany	G. B.	
$N_2=22$ $N_1=16$ C=8 S=50 D=42	$N_2=38$ $N_1=16$ C=13 S=81 D=48	$N_2=29$ $N_1=16$ C=11 S=69 D=49	$N_2=17$ $N_1=16$ C=8 S=50 D=48	United States
	$N_2=38$ $N_1=22$ C=18 S=82 D=72	$N_2=29$ $N_1=22$ C=16 S=73 D=63	$N_2=22$ $N_1=17$ C=12 S=71 D=62	Portugal
		$N_2=38$ $N_1=29$ C=22 S=76 D=66	$N_2=38$ $N_1=17$ C=15 S=88 D=55	Hungary
			$N_2=29$ $N_1=17$ C=15 S=88 D=65	SW Germany

TABLE 4-2 Regional comparison of Carixian ammonite faunas at the generic level.

Portugal	Hungary	SW Germany	G. B.	
$N_2=19$ $N_1=11$ C=8 S=73 D=53	$N_2=19$ $N_1=11$ C=8 S=73 D=53	$N_2=19$ $N_1=11$ C=5 S=45 D=33	$N_2=19$ $N_1=14$ C=9 S=64 D=55	United States
	$N_2=11$ $N_1=11$ C=8 S=73 D=73	$N_2=11$ $N_1=11$ C=6 S=55 D=55	$N_2=14$ $N_1=11$ C=6 S=55 D=48	Portugal
		$N_2=11$ $N_1=11$ C=6 S=55 D=55	$N_2=14$ $N_1=11^o$ C=7 S=64 D=56	Hungary
			$N_2=14$ $N_1=11$ C=7 S=64 D=56	SW Germany

TABLE 4-3 Regional comparison of Domerian ammonite faunas at the generic level.

$$\text{Dice Coefficient (D)} = \frac{2C}{N_1 + N_2} \cdot 100$$

where  $N_1$  = the number of taxa in one area  
 $N_2$  = the number of taxa in the second area  
 $N_1 \leq N_2$   
 $C$  = the number of taxa common to both areas.

These coefficients are the most commonly used in biogeographic studies but the Simpson Coefficient has the shortcoming of ignoring large differences in the size of the faunas, *i.e.* differences in diversity (Westermann and Riccardi, 1976). Also, both coefficients, being based on presence-absence data, are not particularly suited to the study of ammonites where the post-mortem drift of endemic forms into adjacent biogeographic regions is always a possibility. However, in the absence of any statistically meaningful figures as to the relative abundance of every genus in each area, the coefficients, combined with the more subjective classification at the species level, must suffice for the present.

The four areas selected for comparison were chosen for two reasons:

1) Their faunas are generally well described and illustrated. The exceptions are Portugal, where only faunal lists are available for the Sinemurian (which is not very well developed) and the Domerian, and Hungary,

where a monograph on the Domerian fauna is pending.

2) The faunas serve as examples of predominantly Tethyan (Hungary), mixed (Portugal, and to a lesser extent southwest Germany), and Boreal (Great Britain) types.

The data, which are presented in Appendix 2, are based on the following works:

Portugal: Courbouleix, Mouterde, and Ruget, 1974; Mouterde, 1967; Mouterde *et al.*, 1971; Mouterde, Rocha, and Ruget, 1978.

Hungary: Geczy, 1970, 1971a, b, 1972, 1976.

Southwest Germany: Quenstedt, 1884; Schlegelmilch, 1976.

Great Britain: Wright, 1878-1884; Donovan, 1958; Howarth, 1955, 1957, 1958, 1962.

#### 4.4.1a The Sinemurian

The Sinemurian fauna was collected primarily from Nevada where a diverse suite of ammonites representing four families is recognised (Fig. 4-4). The Oregon fauna, by contrast, includes only two families. This should not necessarily be interpreted as a northward decrease in diversity, however, since the Keller Creek Shale in Oregon is very poorly exposed and only yields an *A. ceratitoides* Zone and an *A. (L.) pinnaforme* Zone fauna.

The intervening *P. rothpletzi* Zone is not represented and the Echioceratidae are presently unknown in Oregon. This is probably a result of collection failure rather than any ecological factor although it is interesting to note that the majority of echioceratids in Europe are only known from condensed or remanié beds deposited in shallow water bordering ancient massifs (Getty, 1972). The environment of deposition in Nevada was probably quite similar (see Chapters 2 and 5).

Most of the Sinemurian species found in Oregon and Nevada are cosmopolitan forms with the notable exception of the Tethyan Discophyllitidae in Nevada and very early records of the Phylloceratidae in both states. A comparison of the United States fauna as a whole with the European localities (Table 4-1) indicates that there is closest affinity with the Tethyan faunas of Hungary.

#### 4.4.1b The Carixian

The Carixian is approximately equally represented in both states in terms of the amount of exposure, and Fig. 4-4 indicates that the diversity is quite similar. There is an increase in the number of endemic species compared to the Sinemurian and a reduction in the number of cosmopolitan forms. Tethyan species are common in both states whereas a single specimen of the Boreal family

Liparoceratidae is known from Oregon.

The similarity coefficients (Table 4-2) indicate that there is closest affinity with the Tethyan fauna of Hungary although the values for the Dice Coefficient are more equivocal.

#### 4.4.1c The Domerian

A comparison of the Domerian faunas of the Sunrise Formation of Nevada and the Hurwal Formation of Oregon (Fig. 4-4) shows a similar number of species. The Oregon histograms do not include the many species from the Suplee-Izee area described by Imlay (1968), however, which would give a higher diversity from the Oregon fauna. The Domerian of Nevada is a time of regression so that only one locality with marine rocks is known. In contrast, the Domerian of Oregon marked a time of transgression and a broadening of the shallow shelf seas. The Tethyan influence is still prevalent as already noted for Oregon by Imlay (1968). Rare fragments of Boreal Liparoceratids are known from the Mowich Group in east-central Oregon but not in Nevada. The Boreal family Amaltheidae has never been recorded from the conterminous United States although it is known in Canada (Frebald, 1964, 1966; Frebald and Tipper, 1970). The Simpson Coefficient indicates that the United States fauna as a whole is most similar to those of Portugal and

Hungary whereas the Dice Coefficient is more equivocal, showing similar values for all the areas except southwest Germany (Table 4-3).

#### 4.4.1d The Whitbian

Only the lowest part of the Whitbian Substage (Lower Toarcian) is dealt with in this study and it is only exposed in the Clan Alpine Mountains of western Nevada. A numerical comparison for this restricted interval has not been attempted but the species described are either cosmopolitan or are known from localities to the north in Canada, Alaska, and also northeastern Siberia.

In summary, the Lower Jurassic ammonite fauna of Oregon and Nevada is generally of Tethyan aspect with occasional appearances of members of the Boreal family Liparoceratidae in the Pliensbachian of Oregon. This family is not recorded in Nevada, and the Boreal family Amaltheidae is not represented in either of the states. In the Lower Pliensbachian the subgenus *Crucilobiceras* (*Metaderoceras*) is considered as a Tethyan marker since it is restricted to and very abundant in areas of Tethyan aspect in Europe and North Africa, principally those lands bordering the Mediterranean. The subgenus is abundant in both Nevada and Oregon, together with the polymorphitid

species *Dayiceras dayiceroides*. *D. dayiceroides* is only known elsewhere from Portugal where it also occurs with species of *Crucilobiceras* (*Metaderoceras*), several of which are known in the western United States.

#### 4.4.2 Western Canada and Alaska

The discussion of this region and its Lower Jurassic faunas in relation to those of Oregon and Nevada will focus on the Pliensbachian since the Sinemurian is relatively poorly documented. Figure 4-5 is an amplification of the information presented in Fig. 4-1 showing the nature and distribution of Lower and Upper Pliensbachian faunas of western North America. The data are compiled from my own information and the works of Imlay (1968, 1980, in press), Imlay and Detterman (1973), Frebold (1966, 1967, 1970, 1975, and many other works summarised in Frebold and Tipper, 1970).

The Lower Pliensbachian Tethyan association of *Dayiceras dayiceroides* and *Crucilobiceras* (*Metaderoceras*) spp. is evident northwards from Oregon and Nevada to the insular belt of western British Columbia and as far as the Wrangell Mountains of southern Alaska. The Lower Pliensbachian fauna of the Talkeetna Mountains has yielded several species of the subgenus *Metaderoceras* but *D. dayiceroides* is absent. It is not certain whether the Upper Pliensbachian is represented on Vancouver Island and the Queen Charlotte Islands.



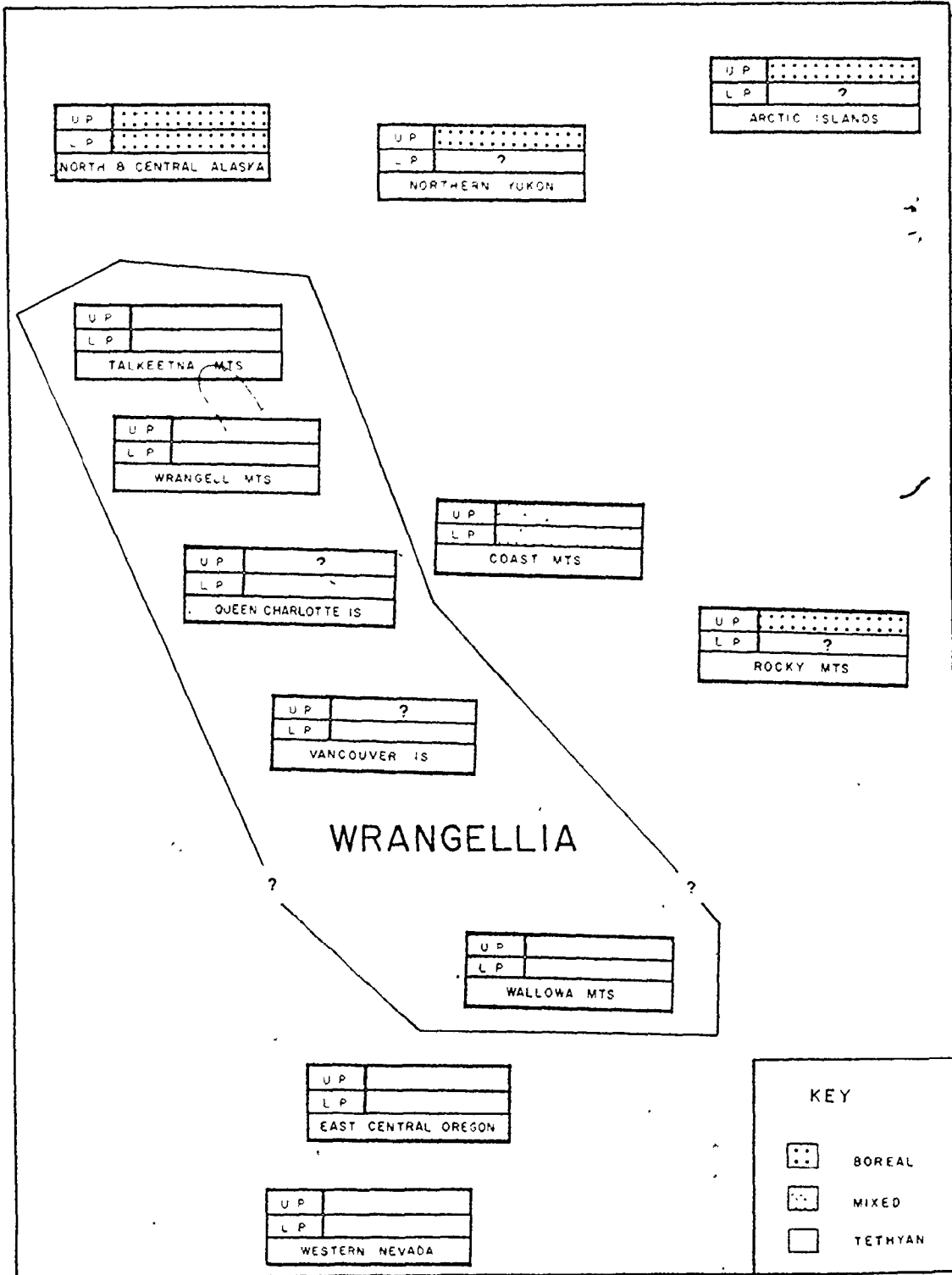


FIGURE 4-5 Pliensbachian ammonoid faunas of North America (L.P. = Lower Pliensbachian; U.P. = Upper Pliensbachian.)

Frebold (1967) reports a typical *A. (L.) pinnaforme* Zone assemblage from the Queen Charlotte Islands and above this locality occurs *Radstockiceras* [= "*Fanninoceras*"] but no other ammonites are present. Either a *D. dayiceroides* or a *R. fannini* Zone age is therefore possible although the latter is more likely. The Domerian fauna of the Wrangell Mountains is represented by several records of Tethyan hildoceratids, and the same is true of the Talkeetna Mountains except that two specimens of *Amaltheus* are recorded from a single locality (Imlay, in press).

The Coast Mountains of western Canada by contrast have yielded a completely mixed fauna for all the Pliensbachian. *Prodactylioceras (Aveyroniceras) inaequicornatum* (BETTONI), *Cruciloboceras (Metaderoceras) spp.*, *Dayiceras dayiceroides*, and *Liparoceras (Becheiceras) cf. bechei* occur in the Carixian whereas the Domerian is represented by a mixture of hildoceratids and amaltheids (Frebold, 1964; Frebold and Tipper, 1970; Tipper and Richards, 1976).

The hildoceratids are absent from the Rocky Mountains, however, where *Amaltheus* is reported almost as far south as Banff, Alberta (Frebold, 1966).

The northeastern Pacific is similar to the northwestern Pacific and western Europe in the separation of Pliensbachian faunas into two distinct but overlapping biogeographic regions. A major difference is to be found in the approximate

trend of the boundary between these two realms. In Europe and the northwestern Pacific the trend approximately parallels the palaeolatitudes whereas in western North America it runs at a very high angle to the palaeolatitudes (Fig. 4-2). This suggests two possibilities.

1) The hypothesis that differences in diversity and the areal restriction of certain ammonite families is not a function of palaeolatitude and that the European situation, so clearly showing a north-south transition, is fortuitous.

2) The distribution of faunas in the northeastern Pacific has been affected by Post Jurassic plate tectonic movements that have transported Tethyan, and perhaps mixed, faunas northwards. Right lateral transcurrent faulting has a long history in the western mobile belt and of course continues today. Jones *et al.* (1977), and Hillhouse (1977) have delineated an extensive terrane named Wrangellia that is defined by a consistent sequence of Triassic rocks. Palaeomagnetic data from basalts show that the terrane occupied a more southerly position during the Triassic relative to the North American continent and has subsequently been transported to its present position. Interestingly, the Lower Jurassic Tethyan faunas collected from the insular belt and southern Alaska are all positioned on Wrangellia (Fig. 4-5), so that the possibility of the Wrangellian

faunas being fossilized at much lower palaeolatitudes is quite feasible. During the Triassic, Wrangellia was positioned within  $15^{\circ}$  of the palaeo-equator.

#### 4.5 The Central Atlantic Seaway

Many ammonite species that are common in the European Tethys are also found in Oregon and Nevada, and this raises the question of how genetic continuity was maintained between the two separated populations. A postulated marine connection running approximately from Morocco through the present Caribbean and Mexico to the Pacific has been termed the central Atlantic seaway (Hallam, 1977) and there has been much debate as to when this seaway was established. Such a marine connection would serve as a barrier isolating terrestrial faunas of Gondwanaland from those of North America, leading to a faunal dissimilarity. Although rich Lower Jurassic dinosaur faunas are known from North America, unfortunately none are known from South America (Charig, 1973) so that this line of approach cannot be adopted. In the converse situation, however, the absence of a marine connection would result in the isolation and divergence of the marine faunas of western Tethys and the eastern Pacific. Ideally, one would like to compare benthonic faunas of the same age from the two areas to assess the degree of similarity. Rapidly migrating, pelagic forms

such as the ammonites would not be suitable in this respect because more circuitous migration routes can be used. It is the evolution of these rapidly migrating forms, however, that provides the basis for intercontinental correlation. The work of detailed intercontinental correlation is in its early stages at present but this work is a prerequisite to the comparison of benthonic faunas.

The distribution of *Dayiceras dayiceroides* in the Carixian is an excellent example of disjunct endemism, *i.e.* two populations of a species widely separated geographically. The species is common in rocks of Tethyan aspect throughout western North America and it is also known from Portugal where it was first described. Furthermore, the Portuguese population is "hemmed in" at the western end of Tethys. It has never been recorded from the intensively studied Carixian rocks of the Mediterranean region or northwest Europe. The southern Atlantic was not open before the mid-Cretaceous so that it could not have acted as a Lower Jurassic migration route. Also, the species is not known from the Carixian of the southeast Pacific although this region is not well studied. The most likely connection between the two populations, therefore, seems to be via a central Atlantic seaway. The existence of such a seaway during the Pliensbachian has been suggested by Damborena and Manceñido (1979) who studied the distribution of the pectinid bivalve

*Weyla*. The earliest records of *Weyla* are probably from the Hettangian of Canada, and it was abundant in the eastern Pacific during the Sinemurian, Pliensbachian, and Toarcian. It is also known along the northern shores of Gondwanaland from northwest India, East Africa, the Middle East, Morocco, southern France, and the Iberian Peninsula. The earliest occurrences on this northern "shoreline" are from the Pliensbachian of the western end of Tethys (Morocco, the Iberian Peninsula, southern France); *Weyla* did not reach India until the Toarcian. This argues for a central Atlantic migration route for *Weyla* rather than a southerly migration route via Antarctica and Australia. A southerly route would require an earlier appearance in the east, with the western Tethyan occurrences being the youngest. Since the western Tethys fauna is found to be the oldest, a central Atlantic connection is strongly indicated.

## CHAPTER 5

### BIOSTRATINOMY

#### 5.1 Introduction

Biostratinomy (or biostratonomy) is that part of taphonomy concerned with the lot of a fossil organism after its death and prior to the onset of diagenesis following final burial. Interest in the post-mortem history of ammonoids had been confined to speculations on the possibilities of dispersal by drifting (*e.g.* Reyment, 1958) until a paper by Reyment (1970) opened a new line of inquiry. The majority of planispirally coiled fossil cephalopods are preserved in a horizontal position, that is, with the plane of bilateral symmetry parallel to the bedding plane. However, Reyment observed that vertical preservation was not as uncommon as the lack of observations in the literature might suggest. He cites examples from the Triassic of Germany, the Jurassic of England and Scotland, and the Cretaceous of Romania and Russia. A further example from the Ordovician of Canada has since been added by Collins (1978). The shingling of cephalopod shells drifting into a strand line, or the sinking of a depressed shell with a broad, flat venter could lead to a vertical

orientation but the examples cited above include relatively compressed shells preserved in open water sediments. It is the physical conditions implied by such circumstances that have been the subject of continuing research.

## 5.2 Bathymetric Implications of Vertically Imbedded Shells

The extant pearly *Nautilus*, whose chambered shell acts as a buoyancy apparatus, serves as a model for extinct fossil ectocochliates. The fundamental morphological differences between *Nautilus* and the ammonites include the overall curvature of the septa (concave adorally in *Nautilus*, and convex in the ammonites); the marginal frilling of the ammonite septa (suture), and the position of the siphuncle (central or subcentral in *Nautilus*, ventral in the ammonites). Nonetheless, the conchs are fundamentally similar and were undoubtedly analogous in terms of their buoyancy function. Examples of ammonite "touch-down" marks in fine grained limestones and their implication that ammonites were at least partly pelagic are well known (Rothpletz, 1909). Buoyancy control in ammonoids to compensate for the weight of encrusting oysters has also been suggested by Heptonstall (1970) (see also Westermann, 1971).

Surprisingly, buoyancy control in *Nautilus* has only been studied in detail relatively recently (Denton and Gilpin-Brown, 1966; Ward and Martin, 1978). Chambers in



the *Nautilus* phragmocone contain air or both air and a watery fluid, and buoyancy during growth is controlled by adjusting fluid volume. By actively transporting salt ions across the siphuncular membrane; thus rendering the sea water in the chambers watery, an osmotic differential is established causing the chamber fluid to be withdrawn through the permeable siphuncle and air to be passively diffused into the chamber. There are two points of importance to arguments that follow:

- 1) The pressure exerted by the osmotic pump, as it is sometimes called, is in opposition to the ambient hydrostatic pressure which tends to force sea water into the chambers.

- 2) Air passively diffused into the chambers after withdrawal of fluid by the osmotic pump is at less than one atmosphere pressure and its pressure is not a function of water depth. This is a direct result of water being incompressible, and dissolved gasses consequently being at pressure equilibrium with the atmosphere regardless of depth. (Chamber gas pressure is usually slightly less than one atmosphere as a result of a drop in the partial pressure of oxygen due to respiration.) On the death of the animal and the failure of the osmotic pump, hydrostatic pressure forces sea water into the chambers compressing the cameral gas causing a buoyancy loss. Cameral gas volume will be

linearly and inversely proportional to water pressure (Boyle's Law).

Raup (1973) suggested that it should be possible to determine the maximum water depth at which a vertical orientation remains stable and he approached the problem empirically by simulating *Nautilus* chamber flooding in the laboratory. His experiments indicated a maximum water depth of less than about 10 m and he went on to calculate a similar depth limit for several ammonite species.

In his experiments Raup assumed the passage of sea water into the chambers would not be greatly impeded by the siphuncular sheath. Weaver and Chamberlain (1976) derived equations of motion for this situation as well as for a sinking situation involving slow phragmocone filling where the permeable siphuncle is undamaged. In both cases Raup's conclusion that vertical preservation implies shallow water conditions was upheld. In the case where the siphuncle remains intact, the shell could sink to great depths in an upright position but after one or two days resting vertically on the substrate, continued filling would cause it to topple. This, of course, assumes that the venter of the shell is not flat, in which case a vertical orientation would be stable in the absence of any trapped gas. Weaver and Chamberlain also concluded that the terminal velocity for a sinking shell whatever the mode of waterlogging was too

low to make embedding by impact likely although the consistency of the substrate would certainly influence this.

### 5.3 Palaeocurrent Analysis

Reyment (1970) first suggested that the axial orientation of the plane of bilateral symmetry of vertically preserved forms might be a source of palaeocurrent information. Since the occurrence of a single vertically preserved cephalopod specimen is worthy of special report (Collins, 1978), the prospects of quantitatively analysing axial orientations at any one locality seem remote.

During his experiments with *Nautilus*, Raup (1973) noted that the shell tilted at an increasing angle from the vertical during progressive artificial flooding of the chambers. This was probably due to the inhomogenous distribution of the water within the phragmocone and would be expected in a real situation. In addition, breaches of parts of the shell by corrosion (Reyment, 1958) or minor impact would cause local flooding of camerae, contributing both to buoyancy loss and inhomogeneity of the mass distribution within the conch.

In the presence of a bottom current, a cephalopod shell will be in a stable position when the forces are symmetrically dispersed about the shell resulting in zero

torque. For a vertical shell there might be a weather-vane type of alignment as envisaged by Reyment but any disturbance in the fluid flow would cause a couple to come into effect, causing the shell to turn to a more stable position dipping broadside into the current. Shells already leaning and dipping in the same direction as the current as in Fig. 5-1a would experience a pressure build-up between the shell and the substrate, such that the shell would be flipped over to adopt the more stable attitude dipping into the current (Fig. 5-1b). The stability of this attitude is the result of three factors:

- 1) the current itself;
- 2) movement of water within the shell shifting its centre of gravity;
- 3) an undermining of the leading, ventral edge of the cephalopod as the current is diverted around the shell.

Undermining of the leading edge of an object being subjected to a persistent current is responsible for the orientation of sediment particles, even those of considerable size (G. Middleton, personal communication) whereby all the particles dip into the current. The possibility of such an alignment of ammonites would be enhanced by the buoyant effect of the gas trapped in the phragmocone. It therefore seems a reasonable hypothesis that the attitudes of cephalopod bilateral symmetry planes could, under the

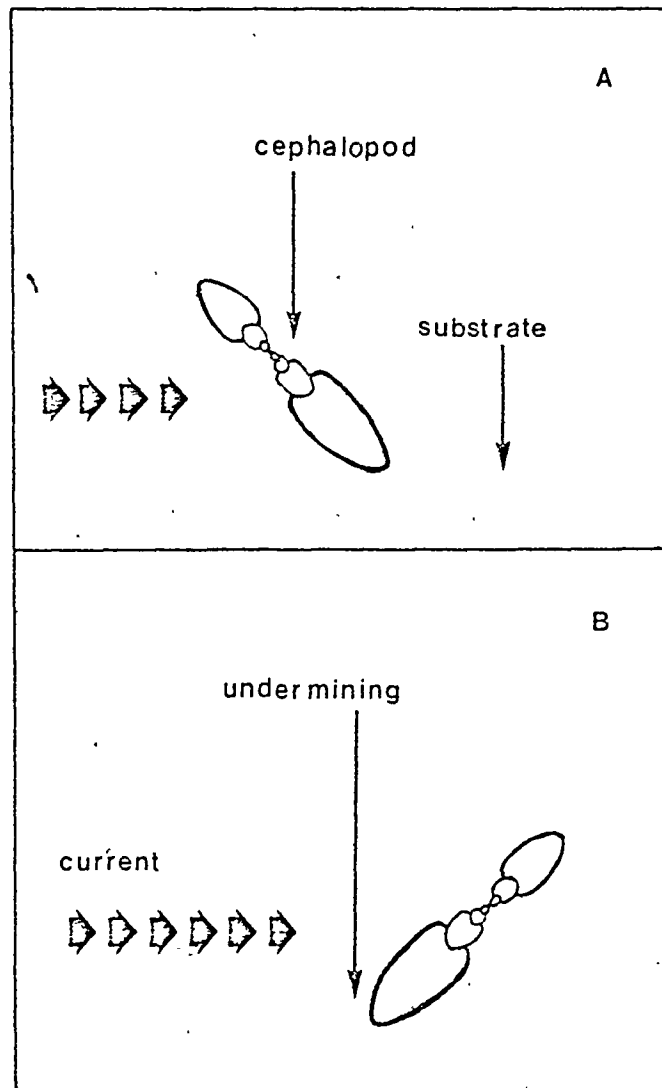


FIGURE 5-1 The effect of bottom currents on inclined ammonites.

circumstances described above, be a valuable source of palaeocurrent information.

The study of fossil orientations as a source of palaeocurrent data had its beginning with the work of Hall (1843) on brachiopods. Subsequent work involved many

different animal groups (see the treatment of Potter and Pettijohn, 1977) but, to the best of my knowledge, only two papers have been published based on the analysis of planispirally coiled cephalopod orientations. The most recent (Brenner, 1976) concerns a study of the Toarcian Posidonia shales in Germany where, unlike the situation encountered during the present study, the cephalopods were all horizontal. Brenner measured the orientation of the peristomes and found a consistent clustering that coincided with the orientation of the long axes of belemnite guards found in the same beds. The other study (Wendt, 1973) involved Triassic cephalopods from Yugoslavia and Greece. Here there was strong evidence for reworking of the shells that had been redeposited in a shallow water environment of deposition, the shells stacked one against the other. Wendt quantified the inclination of the symmetry planes but he did not analyse the horizontal components of the attitudes, relying instead on the alignment of straight-shelled orthoceratids and atractids for palaeocurrent data. No information is therefore available from the literature on the attitude of inclined bilateral symmetry planes; this is probably due, in part, to difficulties of *in situ* measurement.

An orientation measuring technique was developed during the course of this study that is applicable when

the fossil is small or the amount exposed is limited making the direct use of a compass and clinometer either inaccurate or impossible (Smith, in press). The method is essentially that of solving a three point problem as described in many introductory textbooks on structural geology (*e.g.* Billings, 1972, p. 559). The datum of sea level is replaced by a horizontal datum plane positioned at some convenient distance either above or below the specimen and represented by points drawn on the outcrop with a felt-tipped pen (illustrated diagrammatically in Fig. 5-2. A horizontal plane is used rather than a plane representing the local tectonic dip. This avoids the problem of establishing apparent dips in exposures whose trends deviate from the direction of tectonic strike or dip.

Given three exposed points anywhere on the plane of bilateral symmetry that are separated three-dimensionally, it is necessary to measure:

- 1) the distance between each point (calipers are most suitable);
- 2) a bearing from one arbitrarily chosen point to another, noting the cardinal direction of the third;
- 3) the vertical distance of each point beneath (or above) the datum plane.

The distances between the three points must be projected onto a horizontal plane using the Pythagorean

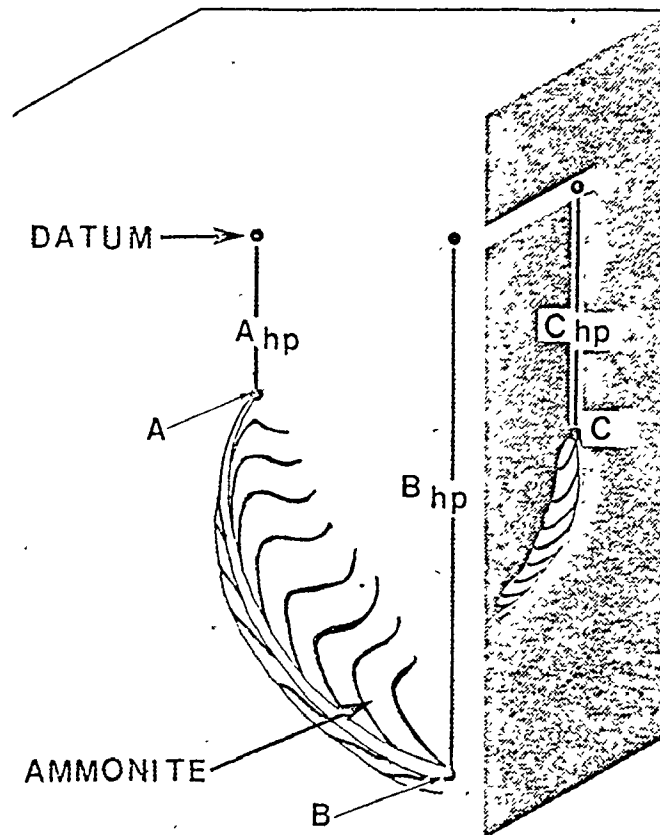
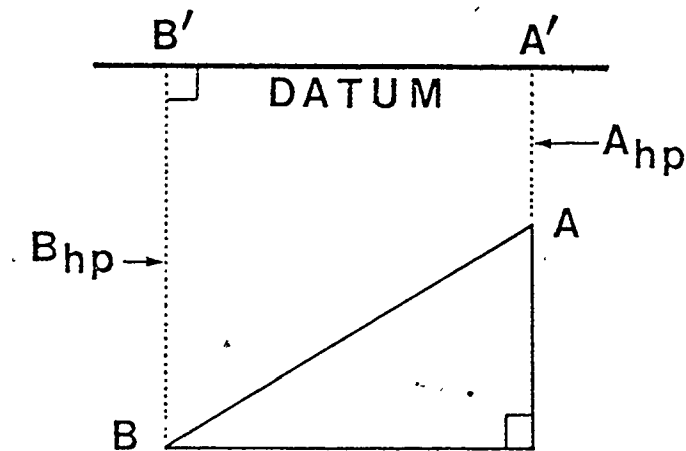


FIGURE 5-2 Block diagram showing points A, B, and C on the plane of bilateral symmetry separated from the horizontal datum plane by distances  $A_{hp}$ ,  $B_{hp}$ , and  $C_{hp}$  respectively.

relationship (Fig. 5-3). Descriptive geometry may then be applied to solve the three point problem using the calculated projected distances and the distances of each point from the datum plane (Billings, 1972). The resulting strike and dip must be rotated stereographically to account for the tectonic dip as is commonly done during the analysis of cross-bedding (Potter and Pettijohn, 1977, p. 371-374).

The accuracy of this technique was tested in the





$$A'B' = \sqrt{AB^2 - (A_{hp} - B_{hp})^2}$$

FIGURE 5-3 Projection of distance AB onto the horizontal datum. Similarly for distances AC and BC.

laboratory by measuring the orientation of ten partial saw cuts made at various angles in clamped rock samples. After applying the three point method, the saw cuts were completed in order that the orientation of the cut surface could be measured directly with a compass-clinometer. The two methods yield the same results. The mean difference between the measured and calculated values for the strike was  $1.2^\circ$  ( $\sigma = 4.5^\circ$ ) and for the dip  $-0.9^\circ$  ( $\sigma = 3.4^\circ$ ).

#### 5.4 The Westgate Study

##### 5.4.1 Introduction

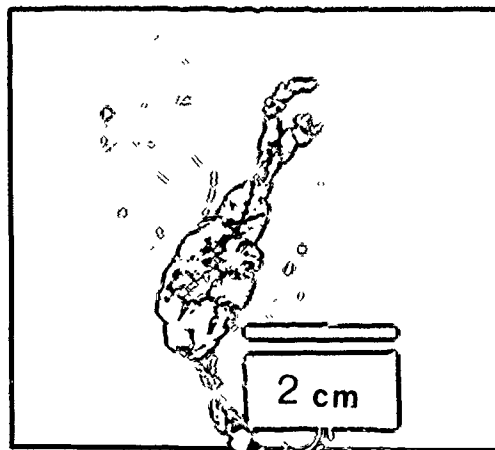
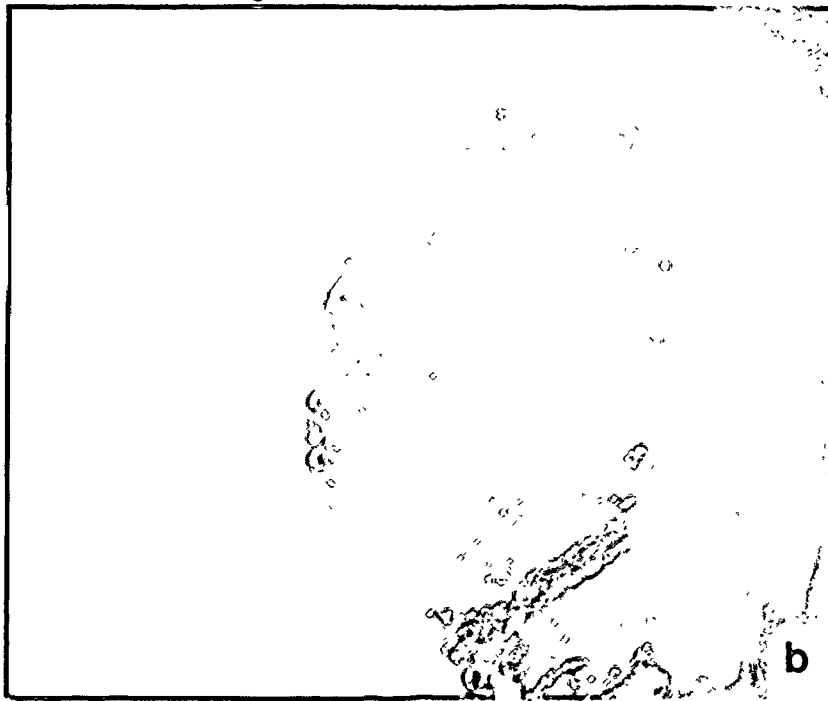
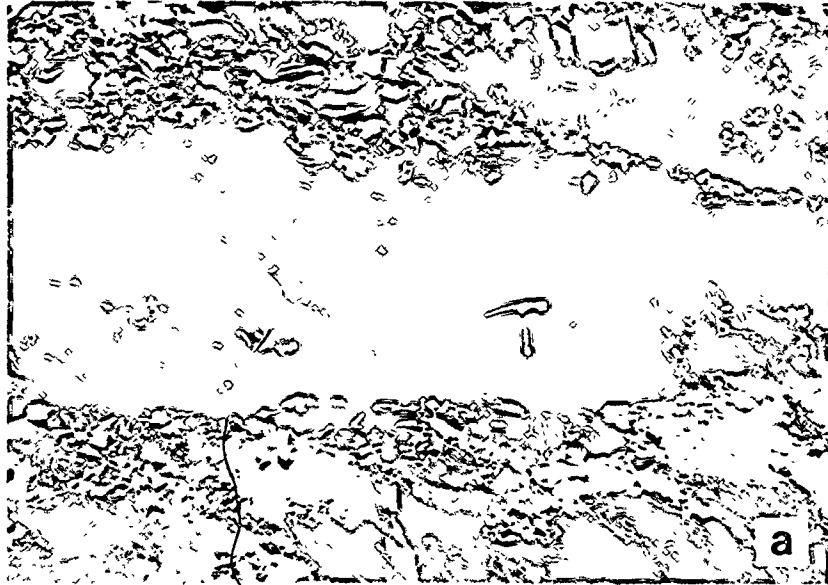
Two superposed beds, 40 m beneath the upper contact of unit 5 in the Sunrise Formation of the Westgate District,

yielded vertical ammonites (Fig. 5-4a). This ammonitiferous interval was selected for a detailed study using the three point problem technique to assess the variability of bilateral symmetry plane dip and direction of dip that might reflect the influence of bottom currents.

The two beds are well exposed along strike for a distance of 30 m. The lower bed has an average thickness of 34 cm and the upper is slightly thinner at 30 cm (Fig. 5-5b). The lower contact of bed 1 and the upper contact of bed 2 are sharp and planar whilst the bedding plane separating the two is gently undulatory in places and sometimes indistinct.

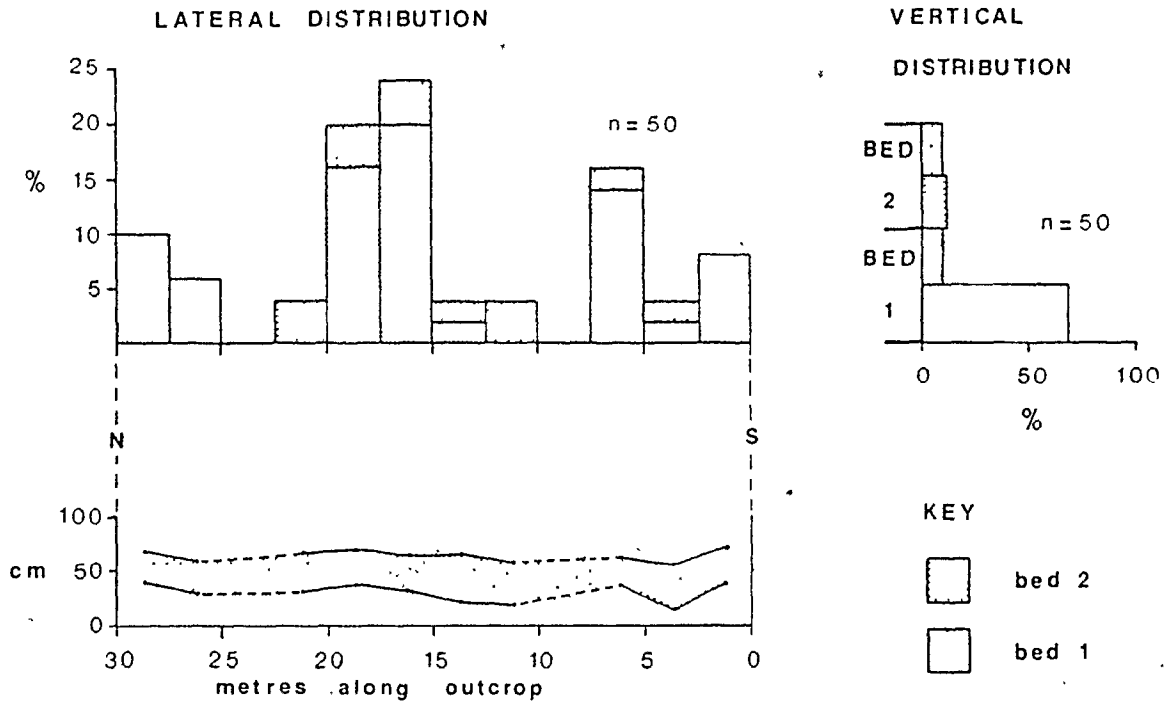
Thin-section examination shows the rock to be a sandy biomicrosparite (classification of Folk, 1974). Sparry calcite forms approximately 40% of the rock but much of it may originate from recrystallised micrite which constitutes only 10% of the rock. Black and brownish organic material (up to 15%) occurs throughout, giving the rock its dark colour in outcrop. Fossil allochems include the ammonites discussed below and fragments of pelecypod shells (including *Trigonia* sp.) which average 2 mm in length but may reach up to 6 mm. The margins of the pelecypod shell fragments are irregular and no structure is visible, the shells being composed of coarse, recrystallised spar. Up to 10% of the rock consists of very fine (3-4  $\phi$ )

FIGURE 5-4 a) The two beds of unit E of the Sunrise Formation yielding highly inclined ammonites. b) Vertically embedded specimen of *Tiltoniceras propinquum* (WHITEAVES). Diameter of shell approximately 45 mm. c) Polished section of a highly inclined specimen showing complete infill by drusy calcite.



c

a) AMMONITE FAUNA



b) BED THICKNESS

FIGURE 5-5 Distribution of the ammonite fauna measured during the analysis of plane of bilateral symmetry orientation.

subangular (0.3 on the Powers Scale) quartz grains. Ammonites are not common. Fifty specimens are widely distributed along the 30 m of outcrop with local concentrations in the intervals 5 to 7.5 m, and 15 to 20 m. As can be gleaned from Fig. 5-5, there is a weak (but statistically insignificant) positive linear correlation between average bed thickness and the number of ammonites per 2.5 m lateral interval of the lower bed. Also, it is the lower bed, in

fact the lower half of the lower bed, that yielded the majority of the ammonite specimens. However, no two ammonites are in physical contact.

The ammonites, which are assigned to *Tiltoniceras propinquum* (WHITEAVES) (see Pl. 19), average 50 mm in diameter and show a consistent mode of preservation. Phragmocones are completely infilled with large crystals of sparry calcite (Fig. 5-4c) and the body chambers contain limestone of the same lithology as the surrounding rock. This is consistent with the envisaged mode of deposition. Cephalopods that lie flat on the substrate for any length of time usually become "draught infilled" (Seilacher, 1968) whereby sediment gradually works its way into the camerae via the siphuncle. In most fossil cephalopods the siphuncle is frequently breached and in the last few chambers often completely destroyed (Trueman, 1920; Westermann, 1971). The partial sediment infill with its upper horizontal surface has been used as a "spirit level" (geopetal structure) in determining the preservational history of cephalopods that have undergone reworking (Seilacher, 1971).

In the case of the Westgate specimens, the integrity of the siphuncle and the absence of a sediment infill indicate that the shells were empty when interred, that burial was fairly rapid, and that reworking did not occur.

#### 5.4.2 Bathymetric Implications

If the conclusion of Raup (1973) and Weaver and Chamberlain (1976) concerning high angle preservation is correct, the Sunrise Formation in the Westgate District, at least in its upper parts, was deposited in 10 m of water or less.

It has been demonstrated elsewhere (Chapter 2) that the Sunrise Formation exposed in the Gabbs Valley Range and the Shoshone Mountains to the south of Westgate represents a shoaling upwards or regressive sequence. A shallow water setting for the Westgate District would therefore be in keeping with these findings although there is no doubt that marine deposition continued well into the Middle Jurassic in this area. 40 m above the vertical ammonite locality at Westgate occurs a 12 m thick resistant, coquinal limestone (unit 6) composed of shells of the pelecypod genera *Gryphaea* and *Ostrea* and, as noted by Corvalan (1962), most of the valves appear complete and articulated. Unit 6 therefore represents the *in situ* accumulation of gregarious organisms in a shallow water, marine environment. Evidence for a shallow water setting based on the vertical preservation of ammonites is therefore not contradicted by the other, independent sources of evidence.

#### 5.4.3 Palaeocurrent Analysis

Of the 50 ammonites exposed, only 6 could not be measured because too little of the specimen remained as a result of weathering. The inclinations of the bilateral symmetry planes of the remaining 44 specimens were stereographically corrected to allow for tectonic dip and then plotted as a histogram (Fig. 5-6). The frequency distribution is unimodal, the peak number of inclinations falling within the 15-30 degree class interval. Angles of repose of this magnitude are commonly encountered in studies of arenaceous and rudaceous sediment particles under unidirectional flow conditions (Rusnak, 1957; Wendt, 1973). To be meaningful, this phenomenon of imbrication must be accompanied by a two dimensional orientation.

Plotting the direction of dip of all the bilateral symmetry planes yields a mode of the class interval centred on  $315^{\circ}$  (Fig. 5-7a). Figure 5-7b shows the orientations for the lower half of bed 1 which yielded most of the ammonites and here a concentration of readings in the northwest quadrant is even more evident. Too few measurements are available to present rose diagrams for the remaining stratigraphic interval. To assess the validity of these data more rigorously, a vectoral analysis was undertaken, yielding the Tukey vector resultant and Chi square value (Middleton, 1965, 1967). Small Tukey Chi square values



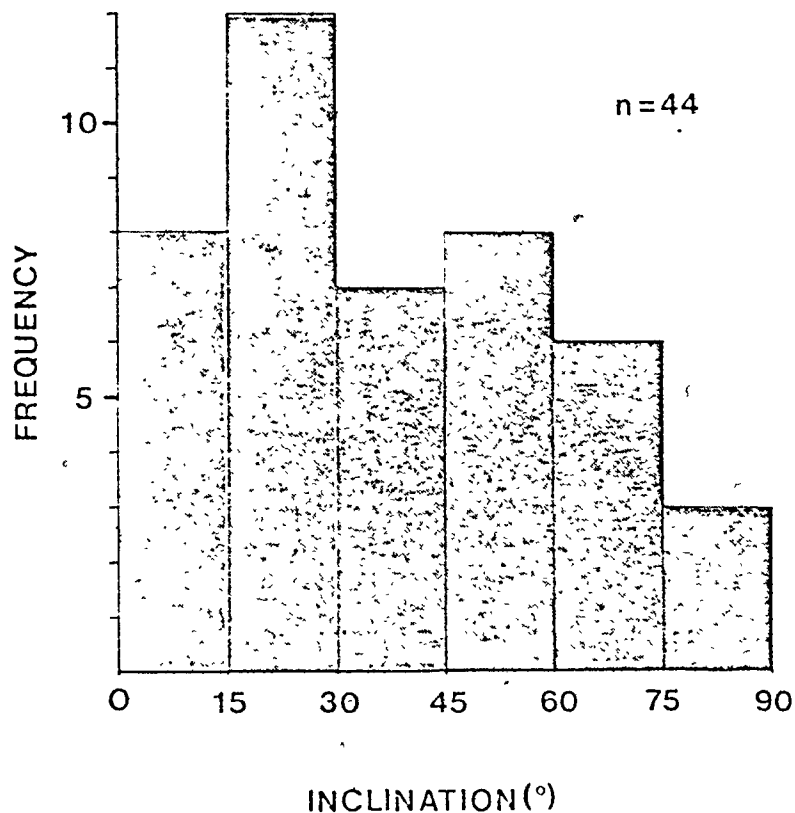


FIGURE 5-6 Inclination from horizontal of the planes of bilateral symmetry of all the ammonites studied.

indicate an even dispersal of the data. Conversely, the higher the value, the higher the probability that the vector resultant is real (Table 5-1).

<u>Data</u>	<u>N</u>	<u>Tukey Vector Resultant</u>	<u>Tukey Chi Square Value</u>	<u>Level of Significance</u>
All data	44	340	3.7	<90
Lower half of bed 1	31	308	5.7	90-95

TABLE 5-1 Tukey vector resultants and Chi square values for the Westgate data.

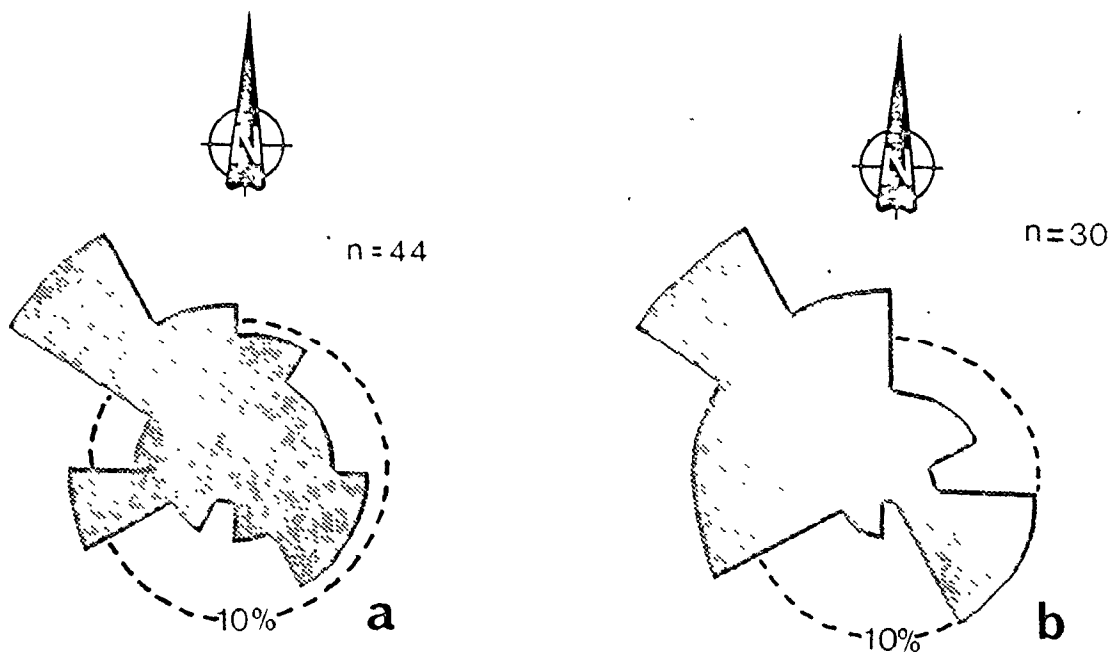


FIGURE 5-7 Orientation of the planes of bilateral symmetry of: a) all the specimens from both beds; b) specimens from the lower half of the lower bed.

Both data groups show vector resultants in the northwest quadrant indicating a northwest-southeast flow direction. The Chi square value for all the data is low but comparable with those encountered in planar cross-stratification studies. High and Picard (1974) analysed cross-stratification in seven fluvial rock units ranging in age from Jurassic to Oligocene. They found an average Chi square value for planar cross-stratification of 3.4 although they emphasized the unreliability of planar *vis-a-vis* trough cross-stratification (average Chi square value 27.6) in reconstructing palaeocurrent systems. The

data for the lower half of bed 1 show a Tukey Chi square value significant at the 90-95% level.

Unfortunately there are no independent sources of palaeocurrent (sedimentary structures, alignment of other fossils) for the Sunrise Formation at Westgate that can be compared with the cephalopod data.

### 5.5 Conclusions

This study indicates that ammonite orientation may be a valuable source of palaeobathymetric and palaeocurrent data. Two lines of inquiry should be pursued to place the subject on a sounder footing:

- 1) Internment of partially buoyant cephalopod shells (either models or *Nautilus*) should be studied using a flume in order to establish the interplay of current velocity, substrate lithology, and amount of chamber flooding in determining the final angles of shell repose and orientation.

- 2) The three point problem technique should be applied to inclined cephalopods in other areas, particularly where sedimentary structures or alignment of other fossils might serve as corroborative evidence.

## CHAPTER 6

### SYSTEMATIC PALAEOLOGY

#### 6.1 Introduction

The classification of the ammonoids is currently being revised for the new edition of the Treatise on the Ammonoidea which will replace that of Arkell *et al.* (1957). Donovan and Forsey (1973) published a preliminary and partial classification of the Liassic Ammonitina but more recently, many workers (*e.g.* Schlegelmilch, 1976; Geczy, 1976; Wiedenmayer, 1977) have adopted the classification of Schindewolf (1961-1968) which places emphasis on sutural development rather than morphology of the shell in determining phylogenetic relationships. The classification of Donovan and Forsey is adopted here for the present, with the exception of the Eoderoceratidae and Polymorphitidae where the revisions of Schindewolf are followed. Schindewolf is also followed in the case of the Hildoceratidae and Dactylioceratidae which were beyond the scope of Donovan and Forsey's work.

An impression of the ammonite diversity and the abundance of families is given in Fig. 6-1. The relative abundance of each family as expressed by the number of

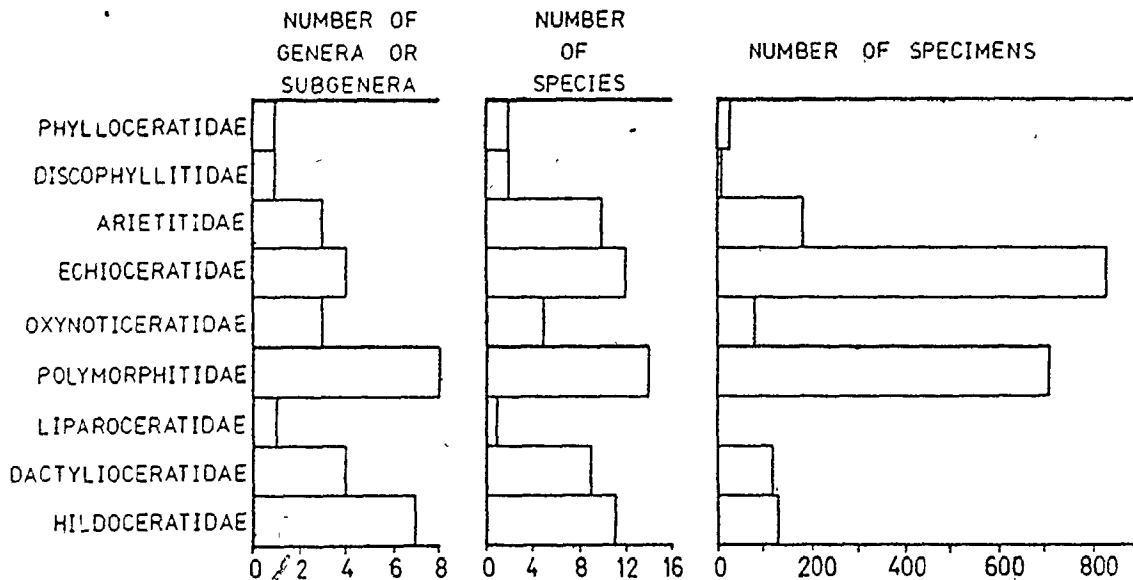


FIGURE 6-1 The Lower Jurassic ammonite fauna of Oregon and Nevada: approximate abundance and diversity.

specimens available for study is very approximate since the sample is not a random, unbiased sample in the statistical sense. These figures are discussed in more detail in the chapter dealing with palaeobiogeography where the data are divided on a temporal basis (Chapter 4). It can be seen, however, that the Upper Sinemurian to lowest Toarcian fauna for Oregon and Nevada combined is dominated both in terms of abundance and diversity by the families Echioceratidae (which is restricted to Nevada), and Polymorphitidae, followed by the Arietitidae, Dactylioceratidae, and Hildoceratidae. The Phylloceratidae, Discophyllitidae, and to some extent the Oxynoticeratidae are minor constituents whilst the Liparoceratidae are virtually absent from the

western United States.

## 6.2 Measurements and Abbreviations

All measurements for the following parameters are in millimetres:

*c* = *circa*

D = shell diameter

est. = estimated

P = primary ribs per half whorl

S = secondary ribs per half whorl

T = tubercles per half whorl

U =  $U_d/D \cdot 100$

$U_d$  = umbilical diameter

Wh = whorl height

WS =  $W_w/Wh \cdot 100$

Ww = whorl width

\* = the holotype in a synonymy list

Figures in parentheses represent the value concerned expressed as a percentage of the diameter.

## 6.3 Systematic Descriptions

ORDER AMMONOIDEA ZITTEL, 1884

SUBORDER PHYLLOCERATINA ARKELL, 1950

SUPERFAMILY PHYLLOCERATACEAE ZITTEL, 1884

FAMILY PHYLLOCERATIDAE ZITTEL, 1884

GENUS *Phylloceras* SUESS, 1865

Type-Species: *Ammonites heterophyllus* J. SOWERBY, 1820,  
by subsequent designation.

Remarks: Involute, compressed forms with fine radial lirae on test but smooth on interal moulds. Complex sutures with triphyllic saddles.

Age and Distribution: The first record of *Phylloceras* is from the Lower Sinemurian of the eastern Mediterranean. Donovan (1967, p. 114) records a gradual northwesterly spread until the end of the Pliensbachian but it is not until the Toarcian that *Phylloceras* became widespread in northwest Europe.

*Phylloceras* spp.

Pl. 1, Fig. 1

Material: Approximately 30 specimens. Two fragments preserved in limestone, three in mudstone, one in fine grained sandstone, and the remainder in greywacke.

Discussion: The material is too fragmentary for any meaningful measurements but all the specimens are involute, compressed, have a high expansion rate, and in many cases display the characteristic suture line with triphyllic

saddles. One fragment of a fairly large whorl (Wh  $\approx$  25 mm) shows an indistinct constriction suggesting that the Calliphylloceratinae might be represented. Variation in the whorl shape in the rest of the specimens indicate that more than one species is present but the nature of the preservation does not warrant a detailed treatment.

Occurrence: Rare specimens occur in units 3 and 4 of the Sunrise Formation in the Gabbs Valley Range, Nevada, and the Hurwal Formation of northeastern Oregon but most of the material originates from the Keller Creek Shale, Oregon.

Localities: 33, 52, 56, 136, 138, 140, 144, 168.

Age: Sinemurian and Pliensbachian (*A. ceratitoides*, *P. rothpletzi*, and *A. (L.) pinnaforme* Zones).

FAMILY DISCOPHYLLITIDAE SPATH, 1927

GENUS *Juraphyllites* MULLER, 1939

Type-Species: *Phylloceras diopsis* GEMMELLARO, 1884 (p. 170, pl. 2, fig. 6-8; pl. 6, fig. 1, 2), by original designation.

Remarks: Fairly evolute compressed forms showing egression at various diameters accompanied by the appearance of coarse ribbing on the upper flanks and venter. No keel.

Synonyms: *Ryacophyllites*, auct. (non ZITTEL, 1884).



Age and Distribution: The earliest representatives of *Juraphyllites* occur in Lower Sinemurian rocks but the genus became more common and widespread during the Late Sinemurian and Pliensbachian. *Juraphyllites* is a Tethyan form that reached only as far north as the Fleckenmergel facies of the German Alps (Schröder, 1927).

*Juraphyllites* cf. *dorsocurvata* (FUCINI, 1901)

Pl. 1, Fig. 2

? 1901 *Rhacophyllites transylvanicus* HAUER var. *dorsocurvata*  
FUCINI (p. 53, pl. 8, fig. 7a-c).

Material: 1 specimen.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>
J2050	32	7	22	10.9(34)	15(47)	73

Description: A small, mature individual that is moderately involute but shows a marked egression of the last half whorl. The whorl section is compressed; the umbilical wall is steep, rounding rapidly into the flanks that are sub-parallel until just above the middle of the flank where they curve rapidly to the narrowly rounded venter. No keel is present.

The inner whorls are smooth. The last 150° of the body chamber bears 15 coarse, simple ribs that arise near the middle of the flank at first but closer to the umbilical wall nearer the peristome. These ribs are prorsiradiate and project over the venter where they are also thickened. The peristome parallels the ribbing and is slightly flared as if it were a partially grown rib; in fact the line of the peristome is continued as a projected rib onto the rostrum. The rostrum is parallel-sided and at its adoral end broadly rounded and unornamented. No septa are visible.

Discussion: This is a mature specimen as indicated by its variocostate ornament, the egression of the body chamber, and the presence of an apertural modification in the form of a rostrum. This is an exceptional individual in that most species of *Juraphyllites* do not develop strong ribbing or show egression until they reach a much larger size. Also, no specimens have previously been figured showing a rostrum with the possible exception of *J. quadri* MENECHINI (Fucini, 1901, pl. 9, fig. 6). Some specimens of *J. lunensis* (DE STEFANI) from the extensive collection of juraphyllitids (mostly collected by Fucini) housed at the University of Florence show a constricted aperture at mature growth stages (see Fucini, 1901, pl. 11), and there is some

discrepancy in the diameters at which maturity is reached. These casual observations suggest that it might be possible to recognise dimorphism in *Juraphyllites* but a statistical study of a large number of mature individuals from one locality is necessary.

The closest species comparable to the Nevada specimen is *J. dorsocurvata* (FUCINI, 1901, *Rhacophyllites transylvanicus* HAUER var. *dorsocurvata*, p. 53, pl. 8, fig. 7a-c) which has a similar whorl shape, style of volution, and ornamentation. It differs in the absence of a rostrum, the ribbing being sharper, and in reaching a mature stage at diameters approximately twice that of the specimen from Nevada. If they are conspecific, the Nevada specimen would be considered a microconch or male dimorph.

Occurrence: From unit 4 of the Sunrise Formation exposed in the entrance to New York Canyon, Gabbs Valley Range.

Localities: 33.

Age: Sinemurian (*P. rothpletzi* Zone).

*Juraphyllites* ? sp.

Material: Five moulds of small individuals and one fragment. Preservation mediocre.

Description: Evolute forms ( $U \approx 40$ ; maximum  $D \approx 26$  mm)

whose whorl shape cannot be determined with certainty because of the state of preservation; it was probably somewhat compressed with a low umbilical wall and gently rounded flanks. The venter does not have a keel.

The inner whorls are smooth but at an umbilical diameter of approximately 5 mm coarse, simple, slightly prorsiradiate ribs appear. The ribs arise in the middle third of the flank and gain strength toward the venter where they are projected slightly. No suture line is available for study.

Discussion: These specimens are tentatively assigned to *Juraphyllites* on the basis of the late development and unusual style of the ribbing. They are quite small for this genus (the onset of ornamentation marks the approach of maturity), and also rather evolute. They are not juveniles of *Arnioceras* in that the venter is unkeeled and the ribbing, when it appears, is coarse and restricted to the upper flank. It is possible that they represent a species of *Lytoceras* but in the absence of a suture this is difficult to judge. A definite assignment must await the discovery of better preserved material.

Occurrence: From the middle and lower parts of unit 3 of the Sunrise Formation exposed at New York Canyon and Volcano

Peak Gulch in the Gabbs Valley Range, and from the middle of unit B of the Sunrise Formation at Westgate, Nevada.

Localities: 11, 48, 79.

Age: Sinemurian (*A. ceratitoides* and *P. harbledownense* Zones).

SUBORDER AMMONITINA HYATT, 1889

SUPERFAMILY PSILO CERATAEAE HYATT, 1867

FAMILY ARIETITIDAE HYATT, 1874

SUBFAMILY ARIETITINAE HYATT, 1874

GENUS *Arnioceras* HYATT, 1867

Type-Species: *Arnioceras cuneiform* HYATT, 1867 (p. 73)

by subsequent designation (Arkell, 1951, p. 217).

Remarks: Evolute forms with whorl sections that are higher than wide, mostly quadrate but sometimes oval (e.g. *A. kridioides* (HYATT)), or even subrounded (e.g. *A. miserabile* (QUENSTEDT)).

The earliest whorls are characteristically smooth. In some species, particularly those figured by Fucini (e.g. *A. mendax* FUCINI, 1902), the smooth stage is barely discernible whereas at the other extreme, the small *A. miserabile* (QU.) is almost unribbed. Costation is simple, sharp, rectiradiate to rursiradiate with the ribs swinging forward onto the venter to abut against the lateral sulci

of the keel or fade before reaching the keel if sulci are not present.

The peristome is rarely preserved, a fact which may be concealing the presence of dimorphism since rare examples of apertural modifications are known in some small species. *A. falcares* (QU.), for example, possesses a rostrum (Quenstedt, 1884, pl. 13, fig. 13), whereas *A. miserabile* (QU.), the unribbed form, has a constricted and lipped aperture (Quenstedt, 1884, pl. 13, fig. 27). Another rare phenomenon, believed to be abnormal, is that of uncoiling (e.g. Reynes, 1879, pl. 19, fig. 20-22).

The suture line is extremely simple, almost ceratitic in some cases, with a deep lateral lobe. Detailed treatments of *Arnioceras* are given by Jaworski (1931) and Guerin-Franiette (1966, p. 252).

Synonyms: *Arniotites* WHITEAVES, 1889; *Amioceras* SPATH, 1919, *nom null.*; *Eparnioceras* SPATH, 1924; *Burkhardticerias* LOPEZ, 1967.

Age and Distribution: *Arnioceras* is a cosmopolitan genus. Many of the occurrences from Europe and the eastern Pacific are discussed below whilst occurrences from the west and southwest Pacific are listed by Sato (1957, 1975). The genus is known most frequently from the Semicostatum Zone

but the earliest occurrence is at the top of the Bucklandi Zone, and the genus does not become extinct until the Obtusum Zone (Dean *et al.*, 1961; Mouterde *et al.*, 1971). The most detailed documentation of the succession of species is given by Spath (1956, p. 161) based on his study of the Stowell Park borehole in England but, with the exception of the work of Blind (1963), information of this sort is lacking at most localities.

*Arnioceras arnouldi* (DUMORTIER, 1867)

Pl. 1, Fig. 3-5; Text:-fig. 6-2

- \*1867 *Ammonites arnouldi* DUMORTIER, p. 27, pl. 5, fig. 1, 2; pl. 6, fig. 1-6.
- 1878 *Arietites douvillei* BAYLE, pl. 76, fig. 2, 3.
- 1934 *Arnioceras* n. sp. near *humboldti* HYATT - LEES, p. 46, pl. 6, fig. 5-8.
- 1956 *Arnioceras arnouldi* (DUM.) - ERBEN, p. 272, pl. 32, fig. 1.
- non 1960 *A. arnouldi* (DUM.) - POZZI, p. 471, pl. 42, fig. 3.
- 1966 *A. arnouldi* (DUM.) - GUERIN-FRANIATTE, p. 279, pl. 150-152.
- 1967 *A. arnouldi* (DUM.) - CASSINIS and CANTALUPPI, p. 60, pl. 7, fig. 2, 3.
- non 1979 *A. cf. arnouldi* (DUM.) - GEYER, p. 208, fig. 5d.



FIGURE 6-2 Septal suture of *Arnioceras arnouldi* (DUMORTIER)  
at Wh  $\approx$  13 mm. Specimen J2052.

Material: Approximately 60 specimens including many fragments, preserved as internal and external moulds in siltstone and thin-bedded limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Wh</u>	<u>P</u>
J2051	c 30 --	15 10	50 --	8.7 (29) --	16 16
J2052	c 97 -- --	c 52 29 15	54 -- --	c 25 (26) -- --	21 16 16
P33 (6)	-- --	15 10	-- --	c 10 --	c 19 20
P34 (5)	-- c 41 -- --	c 35 24 15 11	-- c 59 -- --	-- c 10 (24) -- --	c 18 15 15 15
P34 (7)	-- -- --	19 15 11	-- -- --	c 10 c 8 --	17 17 15
p34 (8)	est 49 est 40 --	25 20 15	c 51 c 50 --	c 13 (27) -- --	18 16 16



P34(9)	--	c 15	--	--	17
P34(10)	--	14	--	--	15
	c 24	10	42	c 7.5(31)	15
P34(11)	c 21	10	48	c 6.5(31)	16
P34(12)	--	11	--	--	c 16
P34(13)	c 19.5	c 9	46	c 6(31)	15
P34(14)	c 21.5	10	47	c 7(33)	18
P36(1)	c 87	c 45	52	c 28(32)	20
	--	c 23	--	--	c 17
30397(1)	--	15	--	c 7.5	19
	--	10	--	--	17
30397(2)	--	10	--	--	19
D6909(4)	--	c 36	--	--	c 20
	--	c 15	--	--	c 17
	--	c 11	--	--	c 16
D6909(3)	--	c 10	--	--	c 17

Descriptions: Large, evolute forms with a compressed whorl section. The umbilical wall is very low, the flanks very gently concave and the flattened venter bears a pronounced, sharp, laterally sulcate keel.

The earliest whorls are smooth to an umbilical diameter of 5-7 mm at which point dense, sharp, straight, rectiradiate ribs arise. Ribbing has a tendency to become rursiradiate with growth and at whorl heights greater than 20 mm the line of the ribbing becomes slightly concave adorally. The ribs swing sharply forward onto the ventral surface.

The suture (Fig. 6-2) has a broad first lateral saddle that is divided by an accessory lobe. The first lateral lobe is broad and notched with sharp lobules at its adapical end.

Discussion: The lectotype and paralectotypes of *A. arnouldi* were subsequently designated by Guerin-Franiette (1966) who refigures the type material of Dumortier (1867). The differences between *A. arnouldi* and *A. ceratitoides* are discussed under *A. ceratitoides*. *A. cf. oppeli* is less densely ribbed and *A. sp.* has a more rounded whorl section.

Occurrences: *A. arnouldi* is characteristic of the upper Bucklandi and the Semicostatum Zones of northwest and southern Europe but it also ranges up into the Obtusum Zone according to Cassinis and Cantaluppi (1967). Apart from Europe, the species is also recorded from Mexico and Canada.

In the United States, *A. arnouldi* is recorded from the Sunrise Formation at Volcano Peak Gulch in the Gabbs Valley Range (middle of unit 3); at Westgate (lower half of unit B), and in the Union District (upper part of units D, E, and the lower half of unit F), Nevada, and from the Keller Creek Shale, Oregon.

Localities: 51, 63, 64, 65, 66, 67, 71, 77, 138.

Age: Sinemurian (*A. ceratitoides* Zone).

*Arnioceras ceratitoides* (QUENSTEDT, 1848)

Pl. 1, Fig. 6, 7; Text-fig. 6-3

- \*1848 *Ammonites ceratitoides* QUENSTEDT, p. 239, pl. 19,  
fig. 13.
- 1856 *Amm. ceras* GIEBEL - VON HAUER, p. 25, pl. 6, fig. 4-6.
- 1885 *Amm. ceratitoides* QUENSTEDT, p. 105, pl. 13, fig. 23  
'only.
- 1886 *Amm. ceratitoides* var. *densicosta* STEFANI, p. 66,  
pl. 4; fig. 8, 9.
- 1889 *Arnioceras humboldti* HYATT, p. 173, fig. 31-33.
- 1889 *A. ceratitoides* (QU.) - BONARELLI, p. 61, pl. 8,  
fig. 4, 5.
- 1902 *A. ceratitoides* (QU.) - FUCINI, p. 164, pl. 14;  
fig. 13; pl. 15.
- 1917 *A. ceratitoides* (QU.) - TILMANN, p. 661, pl. 21, fig. 3.
- ?1956 *A. ceratitoides mexicanum* ERBEN, p. 254, pl. 24,  
fig. 3; pl. 25, fig. 16; pl. 29, fig. 3-7; pl. 30,  
fig. 1, 2.
- 1963 *Arietites ceratitoides* (QU.) - WILLARD, p. 213,  
fig. 1, lower specimen.
- 1967 *Arnioceras ceratitoides* (QU.) - CASSINIS and CANTALUPPI,  
p. 60, pl. 7, fig. 4, 5.
- 1971 *A. ceratitoides* (QU.) - GECZY, p. 31, fig. 2.
- 1973 *A. sp. ex gr. ceratitoides* (QU.) - GEYER, p. 50,  
pl. 3, fig. 4; pl. 4, fig. 1, 2.

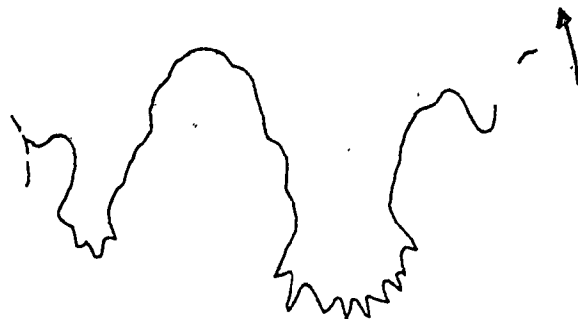


FIGURE 6-3 Septal suture of *Arnioceras ceratitoides* (QUENSTEDT) at Wh  $\approx$  15 mm. Specimen J2055.

- ?1974 *A. sp. ex gr. ceratitoides* (QU.) - GEYER, p. 537, fig. 6.
- 1976 *A. ceratitoides* (QU.) - SCHLEGELMILCH, p. 48, pl. 20, fig. 6.
- 1979 *A. sp. ex gr. ceratitoides* (QU.) - GEYER, p. 208, fig. 5c.

Material: Twenty-nine specimens preserved in siltstone, mudstone, and limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Wh</u>	<u>P</u>
J2054	c 61 --	26 c 11	43 --	c 20 (33) --	c 19 c 18
J2055	--	c 11	--	--	c 20
P4(2)	c 79 -- --	35 16 10	44 -- --	c 27 (34) -- --	22 21 22

P4(4)	--	31	--	c 17	22
	--	15	--	--	22
	--	10	--	--	c 20
P14(3)	e 32	15	47	c 11(34)	17
P14(4)	--	11	--	c 10.5	17
P14(5)	--	10	--	--	c 20
P33(1)	--	20	--	--	21
	e 32	15	47	c 9.5(30)	22
P33(2)	e 32	15	47	c 9.5(30)	18
	--	11	--	--	c 18
P33(4)	--	c 28	--	c 18	c 20
	--	c 14	--	--	c 20
W3-13(1)	--	c 21	--	--	c 24
	--	11	--	--	22

Description: Evolute forms with a compressed whorl section. The umbilical wall is low, the flanks flat, and the flattened venter bears a marked, rounded keel flanked by sulci.

The whorls are smooth to an umbilical diameter of approximately 5 mm at which point dense, sharp, rectiradiate ribs arise. Ribbing is sharper on internal moulds. The ribs are slightly swollen ventrally and cross the venter transversely to slightly prorsiradiately, to abut against the later sulci of the keel.

The suture is typical for *Arnioceras* (Fig. 6-3), that is, simple with long, broad elements. The first lateral saddle is divided by an accessory lobe and the first lateral

lobe is ceratite-like with adapical serrations.

Discussion: *A. ceratitoides* differs from *A. arnouldi* in its higher expansion rate, sharper, straighter and more densely spaced ribs which do not project markedly onto the venter, and in its keel which is less sharp. It differs from *A. cf. oppeli* which has stronger and sparser ribs. *A. sp.* has a more rounded whorl section and fewer ribs per whorl.

Occurrence: *A. ceratitoides* is characteristic of the Semicostatum Zone in Europe but there are reports of its occurrence as high as the Obtusum Zone (Cassinis and Cantaluppi, 1967; Ferretti, 1975). The species is cosmopolitan. It is recorded from northwest, eastern, and southern Europe, Peru, Colombia, and possibly Mexico and Ecuador. Hillebrandt (1973) lists an occurrence from Chile but the material is not figured. Sato (1962, p. 43) notes a possible occurrence from Japan.

The American specimens originate from the Keller Creek Shale, and the following units of the Sunrise Formation: the middle and lower parts of unit 3 at Volcano Peak Gulch; from unit E and the lowest parts of unit F in the Shoshone Mountains, and the lowest part of unit B at Westgate. Hyatt (1889) indicates an unlocalised occurrence (under

the name *Arnioceras humboldti* HYATT) from Humboldt County in northern Nevada. This is of great interest since, if the locality information is correct, it would mark the most northerly occurrence of marine Lower Jurassic rocks in Nevada.

Localities: 48, 49, 50, 51, 52, 63, 64, 66, 76, 77, 79, 138.

Age: Sinemurian (*A. ceratitoides* Zone).

*Arnioceras miserabile* (QUENSTEDT, 1858)

Pl. 2, Fig. 2, 3

- \*1858 *Ammonites miserabilis* QUENSTEDT, p. 71, pl. 8, fig. 7.
- 1879 *Amm. geometricus* var. *hartmanni* OPPEL - REYNES, pl. 15, fig. 3, 4.
- 1884 *Amm. miserabilis* QUENSTEDT, p. 106, pl. 13, fig. 27-29.
- 1889 *Arnioceras miserabilis* var. *acutidorsale* HYATT, p. 162, pl. 2, fig. 4-6.
- 1902 *A. miserabile* QU. - FUCINI, p. 162, pl. 16, fig. 10.
- ?1917 *Arietites* (*Arnioceras*) cf. *miserabilis* QU. - TILMANN, p. 661.
- 1955 *Arnioceras miserabile* (QU.) - DONOVAN, p. 28.
- ?1956 *A. cf. miserabile* (QU.) - ERBEN, p. 273, pl. 37, fig. 18.
- 1966 *A. miserabile* (QU.) - GUERIN-FRANIATTE, p. 254, pl. 136, fig. 1-4.
- 1973 *A. cf. miserabile* (QU.) - GEYER, p. 52, pl. 4, fig. 6.

1976 *A. miserabile* (QU.) - SCHLEGELMILCH, p. 49, pl. 21,  
fig. 5.

?1979 *A. cf. miserabile* (QU.) - GEYER, p. 208.

Material: Three internal moulds with some shell material  
adhering, and six external moulds.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Wh</u>
J2056	36	15	42	11.5(32)
	<i>c</i> 26	10	38	<i>c</i> 9.7(37)
J2057	25	11	44	8(32)
P5(2)	<i>c</i> 24.5	10	41	<i>c</i> 7.5(31)
P34(1)	<i>c</i> 22	10	45	<i>c</i> 6(27)

Description: Small evolute shells with an ovate, higher  
than wide whorl section. The venter is acute and on one  
specimen at a diameter of approximately 22 mm a low, sharp  
non-sulcate keel can be distinguished. The shell has no  
ribs but in oblique lighting lirae can be distinguished  
and on some specimens slight wrinkles are evident.

Discussion: The inner whorls of the genus *Arnioceras* are  
characteristically smooth but ribbing usually appears at  
very small diameters. In the case of the specimens of



*Arnioceras* from the United States, ribbing appears at umbilical diameters ranging from 4 to 7 mm. *A. miserabile* in contrast is unornamented, even at umbilical diameters of 15 mm. It may also be distinguished by its narrowly arched keel-less, or non-sulcate keeled venter.

Occurrence: In Europe, *A. miserabile* is restricted to the Semicostatum Zone. It has been collected from both northwest Europe and the Mediterranean countries as well as Colombia and possibly Mexico and Peru.

The specimens from the United States originate from the middle of unit 3 at Volcano Peak Gulch; from the lowest part of unit F in the Shoshone Mountains, and from the lowest part of unit 6 at Westgate; all units of the Sunrise Formation, Nevada.

Localities: 50, 51, 64, 65, 76.

Age: Sinemurian (*A. ceratitoides* Zone).

*Arnioceras* cf. *oppeli* GUERIN-FRANIATTE, 1966

Pl. 2, Fig. 1, 4

- ?1856 *Ammonites geometricus* (non Phill.) OPPEL, p. 79.
- ?1865 *Amm. geometricus* OPPEL - SCHLOENBACH, p. 155,  
pl. 26, fig. 3.
- ?1867 *Amm. geometricus* (OPPEL) - DUMORTIER, p. 31, pl. 7,  
fig. 3-5.

- ?1878, 1881 *Arietites semicostatus* YOUNG and BIRD, - WRIGHT,  
p. 284, pl. 1, fig. 4-6.
- ?1884 *Ammonites ceratitoides* QUENSTEDT, p. 100, pl. 13,  
fig. 8, 10, 11.
- ?1884 *Amm. falcaries* QUENSTEDT, p. 104, pl. 13, fig. 21.
- ?1889 *Arnioceras hartmanni* HYATT, p. 167, pl. 2, fig. 17, 18.
- ?1902 *A. geometricum* OPPEL - FUCINI, p. 208, pl. 23, fig. 1.
- ?\*1931 *A. geometricum* OPPEL - JAWORSKI, p. 84, pl. 2, fig. 1-3.
- ?1931 *A. subgeometricum* JAWORSKI, p. 97, pl. 3, fig. 1-4;  
pl. 4, fig. 1-3.
- ?1966 *A. oppeli* GUERIN-FRANIATTE, p. 267, pl. 143, fig. 1-3;  
text-fig. 132-134.
- ?1976 *A. oppeli* G.-F. - SCHLEGELMILCH, p. 48, pl. 20,  
fig. 5.

Material: Two internal moulds and nine fragments of  
internal moulds preserved in limestone, siltstone, and fine  
grained sandstone.

Measurements:

Specimen

D6863 (5)	e	55	26	47	e	16 (29)	12
		--	15	--		--	13
		--	10	--		--	12
D6863 (6)	e	33	15	45		11 (33)	13
P34 (18)	e	27	--	--	e	7 (26)	--
		--	8.5	--		--	e 13

P35(18)	e	37.5	16	43	e	11.5(31)	13
	--		10	--	--		13
P35(19)	e	42	21	50	e	12(29)	13
	--		10	--	--		e 12

Description: An evolute form with a compressed whorl section.

The umbilical wall is low and the flanks flat. No clear view of the venter is available but it appears to bear a high keel with no, or at the most very weak sulci.

The inner whorls are smooth to a diameter of approximately lcm at which point sharp, rectiradiate to slightly rursiradiate ribs arise. The ribs are sparse, straight, and swollen at their ventral ends where they swing abruptly forward onto the venter. The suture line is simple with incised lobes.

Discussion: *A. oppeli* has been described and discussed in some detail by Guérin-Franiatte (1966) who named the species and designated the holotype from material figured by Jaworski (1931). The American material is very similar to *A. oppeli* as far as preservation allows comparison. The ribbing style is identical and the rib frequency, although low compared to the holotype, falls within the range of variation evident in the paratypes and synonymised material (Guérin-Franiatte, 1966, text-fig. 133). The sparse nature of the ribbing together with the ventral geniculation of

the ribs serve to readily distinguish *A. cf. oppeli* from all other species of *Arnioceras* found in Oregon and Nevada.

This species may also be represented by a poorly preserved fragment from Chile figured as *A. semicostatum* (Escobar, 1980, p. 72, pl. 2, fig. 3).

Occurrence: *A. oppeli* is a cosmopolitan species characteristic of the Semicostatum Zone.

The American material was collected from the lower parts of unit 3 and unit F of the Sunrise Formation exposed in the New York Canyon entrance and the Union District respectively.

Localities: 2, 64, 65, 66.

Age: Sinemurian (*A. ceratitoides* Zone).

*Arnioceras* sp.

Material: Two large specimens, one secondarily compressed and the other an external mould only. No view of the venter is available.

Measurements:

<u>Specimen</u>	<u>Ud</u>	<u>P</u>	<u>Specimen</u>	<u>Ud</u>	<u>P</u>
W3-12(1)	40	17	P3(2)	25	17
	35	17		20	16
	20	16		15	17
e 16	16	16		10	17

Description: The largest specimen reaches a maximum measurable diameter of approximately 95 mm. Fragments of the outer whorl are present at least half a revolution past the point of measurement, however. The shell is evolute ( $U \approx 55$ ). Details of the whorl section and venter are obscured by the state of preservation but the flanks are quite convex relative to the other species of *Arnioceras* described herein.

The smooth stage persists to an umbilical diameter of approximately 5 mm. The ribs are sharp, persistently straight, and rectiradiate to slightly rursiradiate. No suture line is visible.

Discussion: These specimens have a ribbing density comparable to *A. arnouldi* but the ribs do not become arcuate at large diameters, their straightness being more comparable to *A. ceratitoides*. They differ from both these species in the relative convexity of their flanks.

Occurrence: Both specimens are *ex situ* and originate from the Sunrise Formation of Nevada (from the middle of unit 3 at Volcano Peak Gulch, Gabbs Valley Range, and from the lower part of unit B at Westgate).

Localities: 51, 78.

—Age: Sinemurian (*A. ceratitoides* Zone).

## SUBFAMILY ASTEROCERATINAE SPATH, 1946

GENUS *Asteroceras* HYATT, 1867Type-Species: *Ammonites stellaris* J. SOWERBY, 1815

(p. 211, pl. 93) by subsequent designation (Buckman, 1911, p. 5).

Remarks: Moderately involute to evolute forms with a high expansion rate; whorl section higher than wide; flanks converge above middle; keel well defined and often laterally sulcate. Ribbing strong, simple, prorsiradiate; sutural elements broad, shallow, and little incised. The most comprehensive treatment of the genus is given by Guerin-Franiette (1966).

Age and Distribution: *Asteroceras* is cosmopolitan. It is particularly abundant in Europe (see for example Fucini, 1903; Guerin-Franiette, 1966; Schlegelmilch, 1976) but it has also been recorded from the western Pacific (Wanner and Jaworski, 1931; Matsumoto and Ono, 1947) and the eastern Pacific (Tilmann, 1917; Frebold, 1951, 1964; Hillebrandt, 1973; Tipper and Richards, 1976). Sandborn (1960) records a possible occurrence from California.

*Asteroceras* is characteristic of the Obtusum Zone of the Lower Sinemurian but it has representatives in the preceding Turneri Zone.

SUBGENUS *Eparietites* SPATH, 1924

Type-species: *Ammonites tenellus* SIMPSON, 1855 (p. 97)

figured by Buckman (1912, pl. 54).

Remarks: Involute, compressed forms with a prominent keel and irregular ribbing that fades at large diameters (Arkell *et al.*, 1957).

Age and Distribution: The type species was collected from Robin Hood's Bay, Yorkshire (Howarth, 1962) but the subgenus is not known from the Dorset coast (Spath, 1925). It is quite common on the Continent, however, (Guerin-Franjatte, 1966; Schlegelmilch, 1976) and it has also been recorded from South America (Hillebrandt, 1973; Geyer, 1979) and possibly Russia (Efimova *et al.*, 1968). It is characteristic of the upper Obtusum Zone.

*Asteroceras (Eparietites) n. sp. ?*

Pl. 2, Fig. 6, 8

Material: Three internal moulds of whorl fragments, two with some shell material attached, and five external moulds.

Description: The largest fragment has a whorl height of approximately 40 mm indicating that the species reaches a large size. The shell is moderately involute, probably

with a compressed whorl section. The umbilical wall is low and steep; the flanks are flat and the narrow, somewhat flattened venter bears a non-sulcate keel.

Ribbing is strong, simple and quite dense ( $P = 14$  at  $Ud. \approx 30$  mm). The ribs are weak on the umbilical wall where their trend is slightly rursiradiate; they gain strength at the umbilical shoulder and swing prorsiradiately across the flanks. Ventrally the ribs broaden and become slightly projected before they fade. There is no loss in ribbing strength with growth. One large whorl fragment shows a little incised suture on its lower flank but only a small part is visible.

Discussion: These specimens are placed in *Eparietites* rather than *Asteroceras* s. s. because they are fairly involute, the whorl section appears to be quite compressed, and the venter bears a non-sulcate keel. Of the species of *Eparietites* that resemble the American material in overall morphology, none have an identical style of ornamentation. The closest comparison that may be drawn is with *A. (E.) fowleri* (J. BUCKMAN) (Guerin-Franjatte, 1966, pl. 197) and *A. (E.) impendens* (YOUNG and BIRD) (Buckman, 1919, pl. 120). In the former, the ribbing is much sharper and in the latter, the ribbing is less dense and becomes obsolete with growth. The full description of this species



must await the discovery of more complete material.

This species differs from *Asteroceras* (*Eparietites*) sp. described below which has denser, sharper, irregular ribbing.

Occurrence: From the middle and upper parts of unit 3, and from the middle part of unit B of the Sunrise Formation exposed in the Gabbs Valley Range and the Clan Alpine Range respectively.

Localities: 1, 9, 15, 16, 49, 56, 82.

Age: Sinemurian (*A. ceratitoides* and *P. harbledownense* Zones).

*Asteroceras* (*Eparietites*) sp.

Pl. 2, Fig. 5

Material: One poorly preserved partly external and partly internal mould preserved in mudstone, and a very poorly preserved external mould in siltstone.

Description: Much of the lower flank on the outer whorl is destroyed on the figured specimen but it is apparently an involute form. The expansion rate is high and the whorl section probably quite compressed. A high keel is evident. Ribs are numerous, simple, and irregularly sharp. They arise at the umbilical wall, pass rectiradiately across

the flank, and are slightly projected ventrally.

Discussion: These poorly preserved specimens are assigned to *A. (Eparietites)* on the basis of their narrow umbilicus, irregular ribbing, and prominent keel. They cannot confidently be assigned to a species at this point although they are somewhat similar to the type species.

Occurrence: Collected from the Keller Creek Shale in Oregon, and unit 3 of the Sunrise Formation exposed in Volcano Peak Gulch, Gabbs Valley Range, Nevada. In both cases these ammonites are associated with *Arnioceras*.

Localities: 51, 138.

Age: Sinemurian (*A. ceratitoides* Zone).

GENUS *Epophioceras* SPATH, 1924

Type-Species: *Ammonites landrioti* D'ORBIGNY, 1850 (p. 213, *nomen dubium*). Type figured by Reynes (1879, pl. 29, fig. 2-5); clarified by Thevenin (1907, p. 22, pl. 7, fig. 4, 5) and refigured by Guerin-Franiette (1966, pl. 217). Original designation by Spath (1924, p. 204).

Remarks: Large, very evolute forms with a subcircular (slightly compressed) whorl section. Venter smooth with a weak or indistinct keel. Ribbing is dense, simple, and

rectiradiate or prorsiradiate. Suture as in *Asteroceras*. The external lateral saddle is broad and the lateral lobe fairly narrow and short. A major treatment of the genus is given by Guerin-Franiette (1966).

Age and Distribution: In northwest Europe *Epophioceras* is characteristic of the Obtusum Zone and is considered the root stock of the Echioceratidae, so common in the succeeding Oxynotum and Raricostatum Zones (Getty, 1973). The genus is well represented in the Mediterranean countries (see, for example, Fucini, 1902) and has been recorded from Peru (Geyer, 1979) and Chile (Hillebrandt, 1973).

*Epophioceras* cf. *carinatum* SPATH, 1924

Pl. 2, Fig. 7, 9; Pl. 3, Fig. 1, 3; Text-fig. 6-4

?\*1867 *Ammonites landrioti* (D'ORBIGNY) - DUMORTIER, p. 128, pl. 23, fig. 1, 2.

? 1924 *Epophioceras carinatum* SPATH, p. 204.

? 1956 *Arnioceras ? mongeslopezi* ERBEN, p. 274, pl. 31, fig. 5, 6 (nomen correctum).

? 1966 *Epophioceras carinatum* SPATH - GUERIN-FRANIATTE, p. 333, pl. 222, 223.

? 1979 *Epophioceras* sp. ex gr. *carinatum* SPATH - GEYER, p. 209, fig. 5e.

Material: Fifty-eight specimens, mostly fragments of external moulds in siltstone and calcareous mudstone.

Measurements: See Fig. 6-4.

Description: Very evolute forms ( $U \approx 58$  in small, and up to 68 in large individuals) that reach a maximum measurable umbilical diameter of almost 90 mm. The flanks are convex and the venter gently arched to slightly flattened bearing a keel that is sharp at small diameters and weakens with growth.

The ribs are strong, simple, moderately dense (see Fig. 6-4), prorsiradiate, and very gently concave adorally in some specimens. The ribs fade before reaching the ventral surface.

A moderately incised septal suture is preserved on one fragment ( $Wh \approx 20$  mm). The saddles are broad and the lobes short and relatively narrow (Fig. 6-5).

Discussion: As far as the preservation allows comparison, these specimens are conspecific with *Epophioceras carinatum*

SPATH: They are also tentatively compared with material figured by Erben (1956) under the name of *Arnioceras ? monges-lopezi* ERBEN (*nomen correctum* A. ? *mongeslopezi* ERBEN). This problematical material was collected from

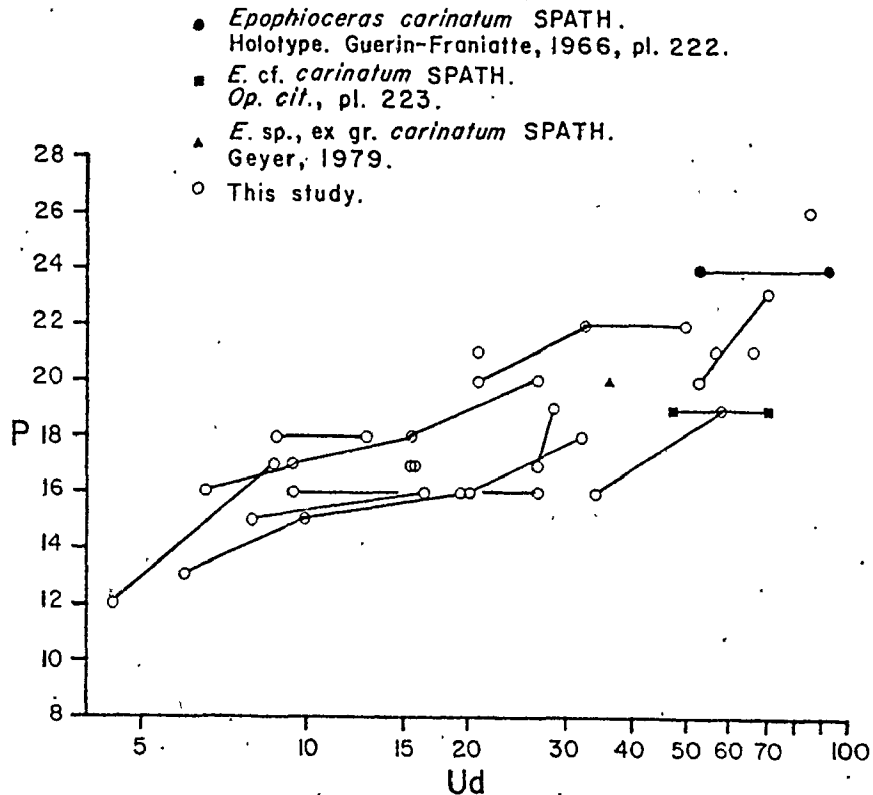


FIGURE 6-4 Rib density plot for *Epophioceras cf. carinatum* SPATH.

units of the Totolapa and Huaycocotla Formations that are correlative, at least in part, with the Obtusum Zone of northwest Europe. An assignment to the genus *Epophioceras* would therefore be more reasonable although Erben describes the presence of sulci which cannot be seen on the figured specimens, and also the ribbing is a little denser than that exhibited by the material described here.

Occurrence: *E. carinatum* has been described from the Obtusum Zone of France and recorded from Sinemurian rocks of northern Peru. Erben's material discussed above was

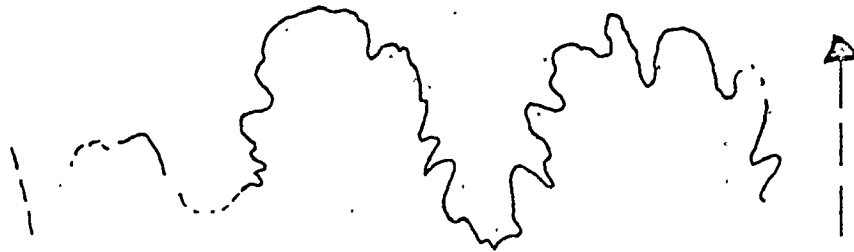


FIGURE 6-5 Septal suture of *Epophioceras* cf. *carinatum* SPATH at Wh  $\approx$  22 mm. Specimen P100(1).

collected from western Veracruz State, east-central Mexico.

The material from the United States was collected from the following units of the Sunrise Formation, Nevada: the middle and upper parts of unit 3, Volcano Peak Gulch; the lower part of section 1 (unit 3), New York Canyon entrance, and the middle part of unit B at Westgate.

Localities: 2, 3, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15, 49, 50, 51, 53, 78, 80, 82, 83.

Age: Sinemurian (*A. ceratitoides* and *P. harbledownense* Zones).

*Epophioceras* aff. *carinatum* SPATH, 1924

Pl. 3, Fig. 4

Material: One slightly distorted internal mould in limestone and three external moulds.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>D</u>	<u>Wh</u>	<u>P</u>
J2036	87	56	64	c 16(18)	17
	--	36	---	--	19
	--	22	--	--	19
N1-1-15(2)	--	37	--	--	14
	--	23	--	--	15
P35(7)	--	25	--	14	--
	--	17.5	--	--	13
	--	11	--	--	18
	--	8	--	--	18

Description: ~~Evolute~~, fairly large forms with convex flanks and an arched venter bearing a low keel.

Ribs are simple, prorsiradiate and strong, fading ventrally. The species is characterised by a low ribbing density with the number of ribs per half whorl tending to decrease with growth. No septal suture is available for study.

Discussion: These specimens are closely related to *E. carinatum* as indicated by their volution and whorl shape, but they differ in the ribbing being less dense with a tendency for the number of ribs to decrease rather than increase with growth.

Occurrence: Collected from the following units of the Sunrise Formation, Nevada: the middle of unit 3, Volcano

Peak Gulch; the lower part of section 1 in unit 3, New York Canyon Entrance, the lowest part of unit F, the Union District.

Localities: 8, 15, 49, 64.

Age: Sinemurian (*A. ceratitoides* and *P. harbledownense* Zones).

*Epophioceras* ? sp.

Pl. 3, Fig. 2

Material: Two poorly preserved moulds (one contact metamorphosed external and one internal mould), and three fragments of external moulds preserved in siltstone and calcareous mudstone.

Description: Very evolute forms with a low expansion rate. The nature of the whorl section is difficult to observe because of the state of preservation but the umbilical wall is low and the flanks gently convex. The ventral surface cannot be clearly seen although a weak keel is evident.

The ribbing is sparse ( $P \approx 10$  at  $Ud = 10$ ;  $P \approx 13$  at  $Ud = 20$ ), simple, and gently prorsiradiate.

Discussion: This material is difficult to identify with confidence because of the small number of specimens and the



poor state of preservation , but it is tentatively assigned to *Epophioceras* on the basis of the volution, ornamentation, and stratigraphic position. The material differs from other species of *Epophioceras* described herein by being consistently more sparsely ribbed.

Occurrence: Collected from the following units of the Sunrise Formation, Nevada: the lowest part of section 1 (unit 3, *ex situ*), New York Canyon entrance; the middle to unit 3 at Volcano Peak Gulch, and the middle of unit B at Westgate.

Localities: 2, 50, 80, 81.

Age: Sinemurian (*A. ceratitoides* and *P. harbledownense* Zones).

#### FAMILY ECHIOCERATIDAE BUCKMAN, 1913

##### 6.3.1 The Echioceratidae

##### 6.3.1a Introduction

Genera of the family Echioceratidae are widely distributed geographically but narrowly restricted stratigraphically. Consequently, they form ideal index fossils and are used as both characterising and defining taxa (*sensu* Murphy, 1977) for the Oxynotum and Raricostatum Zones (Upper Sinemurian) of northwest Europe. There are two important shortcomings in the present knowledge of

this family:

1) Detailed stratigraphic information is only known from Britain and Germany (Getty, 1972). Successions have been studied in east-central Mexico (Erben, 1956) but they cannot be described as detailed since the stratigraphic units to which the ammonites were referred range in thickness from 20 to 60 m. The relative positions of the localities within these units is unknown and the picture is further clouded by the poor preservation of the fossils.

2) The family has been the subject of unbridled taxonomic splitting. The morphology of the group is quite simple, consisting of evolute forms with a quadrate or subcircular whorl section becoming depressed or compressed in some genera. The venter may be featureless or, more commonly, bear a low keel often flanked by sulci. The ribs are simple, usually straight, and sometimes projected onto the venter. Notwithstanding this simple morphology, 109 species have been erected since Buckman established the family in 1913, most of them originating from the taxonomic study of Trueman and Williams (1925) based on the Biogenetic Law (recapitulation) (Donovan, 1973). The echioceratid genera have recently been comprehensively revised by Getty (1973) and the excessive number of species approximately halved in a presently unpublished study of the family by the same author (Getty, 1972). Nonetheless, echioceratid

taxonomy is still a difficult subject in that many of the taxa are poorly defined or too much weight is given to one morphologic feature at the expense of others. Consequently, a multivariate statistical approach has been adopted in the present study.

### 6.3.1b The Multivariate Approach

Principal components analysis has become a powerful aid to taxonomic work in biology and botany. Not only can an array of variables be considered simultaneously but sometimes covariation between variables is detected which may lead to important insights into functional morphology. There are, however, three problems faced in the application of multivariate techniques at a general level, and to the study of the American Echioceratidae in particular.

1) Weighting: all the variables are treated equally in multivariate analysis whereas the taxonomist usually weights variables according to experience. Furthermore, if a morphologic feature shows no measurable variability, it cannot, by definition, be used and yet such morphologic constancy is the very stuff of classification. In addition, the variables model the ammonite shell at a very crude level so that multivariate analysis can only be used as an adjunct in the identification procedure.

2) Preservation: distortion of fossils can be

caused by tectonic stresses or compaction resulting from lithification of the enclosing sediment, and such specimens must obviously be avoided. Fortunately there are three localities (locality 30 and 33 of section 1, and locality 56 of section 3) in the sandy limestone of unit 4 of the Sunrise Formation where enough well preserved specimens could be collected from one bed to yield sufficient data.

3) Ontogeny: an ammonite often undergoes morphologic change during the course of its development so that it is necessary to compare specimens at the same growth stage. Ideally, this would be at maturity but the echioceratids do not show features that normally point to a mature condition (whorl egression, sutural approximation, and apertural modifications). Consequently, it is necessary, by way of compromise, to standardise one parameter of size and then assess the variability in the other parameters. In this study, all measurements were taken as closely as possible to a specific umbilical diameter (11.5 mm). Hirano (1971, 1973a, b) has demonstrated the practicality of this approach in his biostratigraphic study of the Toyora Group in Japan. He showed that for any given species, ribbing density was normally distributed at a standardised shell diameter.

### 6.3.1c The Variables

The variables selected are drawn from those commonly used in studies of ammonite taxonomy but relatively few are needed because of the simple morphology of the Echioceratidae:

1) U = the umbilical diameter (Ud) expressed as a percentage of the diameter (D);

2) WS = the ratio of whorl width (Ww) to whorl height (Wh);

3) P = the number of ribs per half whorl at a given umbilical diameter;

4) K = keel height.

Since the measurement of keel height in polished section would be destructive to the specimens and unnecessarily tedious, the following scale was used:

0 = no keel      1 = weak keel      2 = strong keel;

5) S = depth of sulci;

0 = no sulci      1 = weak sulci      2 = deep sulci.

### 6.3.1d The Analysis

Detailed treatments of principal component analysis are given in many texts dealing with multivariate analysis *e.g.* Seal (1964), Morrison (1967), and Blackith and Reyment (1971). Computer programme documentation is given by Dixon (1977, p. 193).

Forty specimens were measured, 19 from locality 56, 10 from locality 33, and 9 from locality 30. Locality 56 occurs in section 3 whereas the two other localities occur in the same section, section 1, separated by approximately 28 stratigraphic metres.

The first and second principal components explain 61% of the total variance. The loading of individual variables onto each component is shown by the bar scale in Fig. 6-6. High values on the first component are achieved by those specimens that are densely ribbed, keeled, sulcate forms whereas low values are achieved by evolute, more sparsely ribbed forms with a low keel or featureless venter. High values on the second component are achieved by more depressed or sulcate forms whereas low values indicate evolute forms with a more compressed whorl section and a non-sulcate keel.

Plots of scores on the components (Fig. 6-6) show a broad separation of the three localities with locality 56 (triangles) clustering in the left half of the field; locality 33 (dots) in the upper right, and locality 30 (squares) in the lower right quadrant. Locality 56 represents a condensed sequence yielding ammonites that are only found beneath the lower locality in section 1, together with ammonites that are common to all three localities.

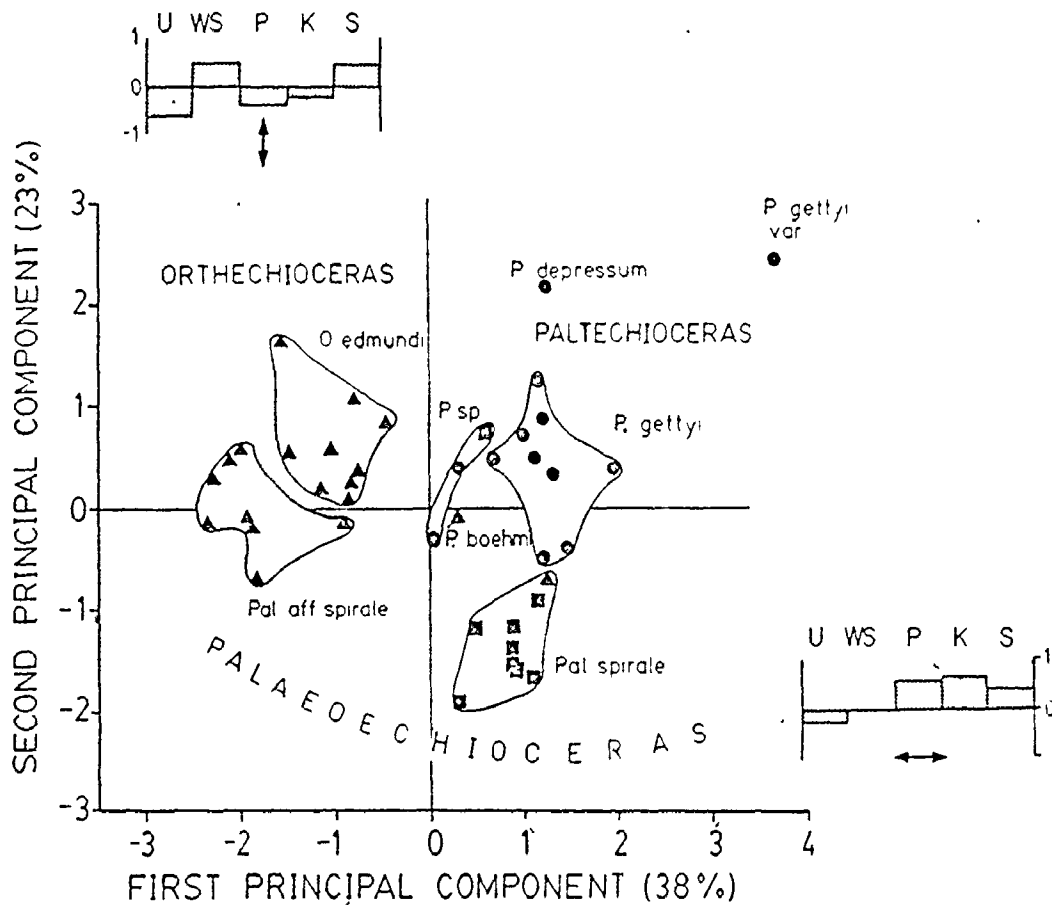


FIGURE 6-6 Echioceratids from the Sunrise Formation:  
scores on the first two principal components.

Examination of the specimens shows that the upper left quadrant describes specimens that can be assigned to the genus *Orthechioceras*; the upper right quadrant describes forms assignable to *Paltechioceras*, and the lower half of the field describes forms assignable to *Palaeoechioceras*. This information provided invaluable taxonomic nuclei which greatly facilitated the initial splitting of the echioceratid collection. Furthermore, individual clusters could be

delineated that corresponded closely with groupings that were eventually accorded specific status. It is also considered feasible that *Palaeoechioceras spirale* gave rise to *Paltechioceras gettyi* by a depression of the whorl section and the acquisition of sulci. Such a possibility is also suggested in Fig. 6-6 where the fields for each species almost overlap and both are elongated along the second principal component.

GENUS *Palaeoechioceras* SPATH, 1929

Type-Species: *Protechioceras spirale* TRUEMAN and WILLIAMS, 1927 (p. 248, pl. 28, fig. 6). Refigured by Getty (1973, pl. 1, fig. 2).

Remarks: Evolute forms possibly derived from *Epophioceras*. The whorl section is depressed in the nucleus but it rapidly becomes compressed with a slightly fastigate or tabulate venter usually bearing a weak keel that is subsulcate on rare occasions and sometimes crenulate. The depressed nucleus is smooth, followed by a stage of blunt, widely spaced ribs to a diameter of 5 mm after which the ribbing becomes dense. Ribs are projected onto the venter where they fade rapidly or sometimes continue, meeting to form chevrons:



Synonyms: *Hypechioceras* SPATH, 1956; *Protechioceras* TRUEMAN and WILLIAMS, 1927.

Age and Distribution: The type species is of uncertain age since the type material was not collected *in situ* but other finds in England indicate an Oxynotum Zone age. The genus has previously been recorded from Britain and Austria (Getty, 1972). A record of a fragment of *Palaeoechioceras* from Spain (Behmel and Geyer, 1966) is probably a misidentification since it came from the Jamesoni Zone (Getty, 1972). The specimen was not figured and is probably lost (Behmel, personal communication, 1979).

*Palaeoechioceras spirale* (TRUEMAN and WILLIAMS, 1927)

Pl. 3, Fig. 5

- \* 1927 *Protechioceras spirale* TRUEMAN and WILLIAMS,  
p. 248, pl. 38, fig. 6.
- 1941 *Echioceras* (*Plesechioceras*) cf. *typus* BUCKMAN -  
KELLAWAY and WILSON, p. 164, pl. 9, fig. 4, 5.
- 1956 *Hypechioceras pierrei* SPATH, p. 149, pl. 9, fig. 13.
- 1973 *Palaeoechioceras spirale* (T. and W.) - GETTY,  
p. 9, pl. 1, fig. 2 (holotype refigured).
- 1973 *Palaeoechioceras pierrei* (SPATH) - GETTY, pl. 1,  
fig. 6 (holotype refigured).

Material: Nineteen specimens preserved in limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
D6908(1)	29 --	16 9	55 --	6.3(22) --	7.1(24) --	89 --	28 25
D6908(35)	23.6 --	13.5 7	57 --	4.6(19) --	5.3(22) --	87 --	30 26
D6908(46)	23.5 -- --	13.5 9 4.5	57 -- --	6.2(26) -- --	5.5(22) -- --	113 -- --	30 26 22
P52(1)	22.1 --	13 6	59 --	5.2(24) --	5.4(24) --	96 --	32 22
P52(3)	20.3 --	11 6	54 --	5.5(27) --	5.5(27) --	100 --	30 24
P52(4)	20.6 --	11 6	53 --	4.4(21) --	5.5(27) --	80 --	25 18
P52(5)	21	11.5	55	4.9(22)	5.4(26)	91	31
P52(6)	19.9 --	11.5 6	58 --	5.6(28) --	5.1(26) --	110 --	31 24
P52(12)	20.8	11.5	55	4.9(24)	5(24)	98	29
P52(14)	22	12	55	5.1(23)	5.4(25)	94	29
P52(16)	20.4 --	11.5 6.5	56 --	4(20) --	4.9(24) --	82 --	26 20

Description: Evolute form with a quadrate whorl section.

The somewhat flattened venter bears a weak, non-sulcate keel that is irregular. After a short initial smooth stage, ribbing is rectiradiate, fine, and dense throughout.

Discussion: Examination of the holotypes of *P. spirale* and

*P. pierrei* held in the Geological Survey Museum, London shows them to be conspecific. Ribbing density and volution are identical and the only difference to be noted is that *P. pierrei* is slightly compressed whereas the much smaller *P. spirale* is slightly depressed. This difference is small, however, and *P. spirale* has a square whorl section on its outermost whorl suggesting an ontogenetic trend from a depressed to a square to a slightly compressed whorl section. The two species are therefore synonymised.

Occurrence: *P. spirale* was previously only known from England where it is recorded from the Oxynotum Zone of the Upper Sinemurian.

The American specimens were collected from the lowest parts of unit 4 of the Sunrise Formation exposed in Volcano Peak Gulch, and the entrance to New York Canyon, Gabbs Valley Range, Nevada.

Localities: 30, 32, 56.

Age: Sinemurian (*A. rothpletzi* Zone).

*Palaeoechioceras* aff. *spirale* (TRUEMAN and WILLIAMS, 1927)

Pl. 3, Fig. 6

1886 *Arietites doricus* SAVI and MENEGHINI - GEYER, p. 247,  
pl. 3, fig. 3 (non Savi and Meneghini, 1851).

Material: Eighty-three specimens preserved in limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>W</u>	<u>P</u>
D6908 (4)	20.2 --	11 6	54 --	4.6 (23) --	4.8 (24) --	96 --	18 17
D6908 (8)	21.1 --	11.5 6	55 --	5.6 (27) --	5.3 (25) --	106 --	19 e 18
D6908 (9)	21 --	11.5 6	55 --	4.4 (21) --	5.3 (25) --	83 --	e 21 17
D6908 (11)	16.3 --	8 4	49 --	4.3 (26) --	4.6 (28) --	93 --	20 16
D6908 (15)	20.2 --	11 6	54 --	4.3 (21) --	5 (25) --	86 --	20 18
D6908 (18)	19.3 --	11 6	57 --	4.4 (23) --	4.4 (23) --	100 --	18 15
D6908 (22)	20 --	11 6	55 --	4.8 (24) --	5.1 (26) --	94 --	20 15
D6908 (29)	15.4	8.5	55	3.7 (24)	4 (26)	93	18
D6908 (32)	18.1 --	9 4	50 --	3.8 (21) --	4.6 (25) --	83 --	18 15
D6908 (39)	15.6	8.5	54	3.7 (24)	3.5 (22)	106	19
D6908 (44)	23.4 --	13.5 6	58 --	5.1 (22) --	5.3 (23) --	96 --	19 16
D6908 (47)	20.8 --	11.5 6	55 --	4.8 (23) --	4.7 (23) --	102 --	22 21
P20 (23)	16.2	8.5	52	3.8 (23)	e 4.1 (25)	93	18
P20 (29)	13.8	6.5	47	4.2 (30)	4 (29)	105	26
P20 (32)	11.7	5.5	47	3.3 (28)	3.9 (33)	85	20
P20 (42)	17 --	9 4	53 --	4 (24) --	4.2 (25) --	95 --	29 20

N1-4-4(2)	16.9	9	53	4(24)	4.4(26)	91	28
	--	4	--	--	--	--	18
N1-4-4(8)	17.4	9	52	4.1(24)	4.6(26)	89	24
	--	4	--	--	--	--	c 18
N1-4-4(16)	16.1	8.5	53	3.9(24)	4.3(27)	91	c 26
N1-4-4(25)	11.7	5.5	47	3.4(29)	3.7(32)	92	22
P52(8)	19.5	10	51	4.8(25)	5.3(27)	91	25
	--	6	--	--	--	--	18
P52(9)	16	8.5	53	4.9(31)	4.6(29)	107	26
P52(15)	15.5	9	58	4.1(26)	4.4(28)	93	28
	--	4	--	--	--	--	18
P52(17)	17.9	9.5	53	4.4(25)	4.6(26)	96	25
	--	4	--	--	--	--	15
P52(19)	17.1	9	53	3.5(20)	4.3(25)	81	22
	--	5.5	--	--	--	--	12

Description: Evolute forms with a quadrate to slightly compressed whorl section. The venter varies from tabulate to slightly fastigate. The non-sulcate keel is very weak, particularly on the internal moulds, and has a crenulate appearance on some specimens.

The nuclei are smooth to an umbilical diameter of approximately 2 mm at which point stout ribbing arises which rapidly gives way to finer, more densely spaced ribs. Ribbing is rectiradiate to prorsiradiate. The ribs swing forward onto the venter where they rapidly lose strength although faint traces of the ribs can often be seen in oblique lighting forming chevrons, and the high points in

the irregular keel are marked by the meeting of the ribs. The figured specimen (Pl. 3, Fig. 6) has a slightly flared aperture.

Discussion: These specimens are similar to *Arietoceras doricus* as figured by Geyer, 1886, a specimen which is closely related to *Palaeoechioceras spirale*. Geyer's specimen differs in the ribbing not being quite as dense and in the whorl section being a little more compressed but there are specimens from the American material which, at the extreme range of variation in ribbing density, are very close to *P. spirale* indeed. The fact that they occur in the same bed as *P. spirale* suggest that they could represent a variant of *P. spirale* rather than a new subspecies. They are retained as *P. aff. spirale* at present but should *P. aff. spirale* be found in Britain, or *P. spirale* be found in Austria, the two should be synonymised. *Echioceras* cf. *lepidum*, collected from Somerset in England (Kellaway and Wilson, 1941), has been compared to Geyer's material in the past (Getty, 1972) but it differs substantially in having a very low expansion rate, in fact one of the lowest expansion rates exhibited by an echioceratid.

Occurrence: The age of the specimen from Austria is not known with any precision but it is undoubtedly Late Sinemurian.

The American material was collected from the lower part of unit 4 of the Sunrise Formation exposed in Volcano Peak Gulch and the entrance to New York Canyon, Gabbs Valley Range, Nevada.

Localities: 30, 33, 56, 57.

Age: Sinemurian (*P. rothpletzi* Zone).

GENUS *Paltechioceras* BUCKMAN, 1924

Type-Species: *Paltechioceras elicatum* BUCKMAN, 1924 (pl. 483).

Remarks: Evolute forms with a compressed whorl section and a characteristic bisulcate, carinate venter. Ribbing is dense and may be locally interrupted or, in some species, looped.

Synonyms: *Epechioceras*, *Euechioceras*, *Kamptechioceras*, *Metechioceras*, *Plesechioceras*, *Vobstericeras*, all erected by TRUEMAN and WILLIAMS, 1925; *Stenechioceras* BUCKMAN, 1927; *Tmaegophioceras* BUCKMAN, 1925.

Age and Distribution: The genus appears to be restricted to the upper Raricostatum Zone in Europe but the stratigraphic relationships between many of the species of *Paltechioceras* are unknown because they have only been collected from remanié or condensed beds.

*Paltechioceras* is the most widely distributed echioceratid, having been recorded throughout northwest Europe and the Mediterranean countries as well as from Mexico. It is not, according to Getty (1973), known from the East Indies, as previously believed.

*Paltechioceras boehmi* (HUG, 1899)

Pl. 4, Fig. 1, 2

- \* 1899 *Arietites boehmi* HUG, p. 16, pl. 12, fig. 8.  
 ? 1902 *Vermiceras boehmi* (HUG) - FUCINI, p. 141, pl. 12, fig. 13.  
 1914 *Echioceras boehmi* (HUG) - BUCKMAN, p. 96c.  
 1925 *Euechioceras boehmi* (HUG) - TRUEMAN AND WILLIAMS, p. 726.  
 1958 *Paltechioceras boehmi* (HUG) - DONOVAN, p. 26, pl. 2, fig. 5 (?), 6.

Material: Ninety-five specimens preserved in limestone and grey and purple siltstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
D6908 (7)	30.9 24.8	16.5 13.5	53 54	7 (23) 6.2 (25)	8.2 (27) 6.5 (26)	85 95	22 21
D6909 (16)	28.4 22.5 --	16 12 6	56 53 --	7.3 (26) 4.9 (22) --	7.1 (25) c4.9 (22) --	103 100 --	23 23 21
D6908 (17)	33.9 -- --	18.5 11 6	55 -- --	8.7 (26) -- --	8.9 (26) -- --	98 -- --	23 21 18



D6908(34)	e32	19	59	7.1(22)	7.3(23)	97	24
D6908(36)	23.5	13	55	5.5(23)	6.2(26)	89	22
	--	6	--	--	--	--	20
D6908(40)	31.1	16.5	53	7(23)	8.8(28)	80	--
	e23	12.5	54	6.6(29)	6.4(28)	103	21
	--	6.5	--	--	--	--	18
P20(44)	27.3	14	51	e6.5(24)	7(26)	93	23
	--	8	--	--	--	--	22
P20(48)	26.6	15.5	58	6.4(24)	6.7(25)	96	18
J2041	--	27	--	9.8	10.5	93	--
	--	17.5	--	--	--	--	22
	--	10.5	--	--	--	--	24
	--	6.2	--	--	--	--	21
J2042	46	27	59	10(22)	11.1(24)	90	21
	--	15.5	--	--	--	--	22
	--	9	--	--	--	--	23
	--	5.3	--	--	--	--	20

Description: Evolute form with a compressed whorl section. The flanks are flat and the venter is either tabulate or very gently arched. The keel is weak and does not develop sulci until quite a large diameter is reached. The specimen figured of Pl. 4, Fig. 2 shows a strengthening of the keel and an appearance of the sulci on the outer whorl whereas the outer quarter whorl of the other figured specimen (Pl. 4, Fig. 1) is still non-sulcate.

Ribbing is dense and the density increases steadily to an umbilical diameter of approximately 10 mm after which there is a gradual decrease.

Discussion: The dense ribbing on the inner whorls with a gradual increase in density followed by a gradual decrease serve to distinguish this species from other species of *Paltechioceras*. The late development of the sulci also seems to be characteristic.

Occurrence: *P. boehmi* is recorded from the Upper Sinemurian of Switzerland and Great Britain. It has been recognised in boreholes in southern England where it occurs in the Macdonnelli Subzone of the Upper Raricostatum Zone. The upper part of its range overlaps with the lower part of the range of *P. tardecrescens*.

The stratigraphic separation of *P. boehmi* and *P. tardecrescens* is also evident in the United States. *P. boehmi* is recorded from the uppermost part of unit 4 of the Sunrise Formation exposed in the Gabbs Valley Range, and from the uppermost part of unit B of the Sunrise Formation exposed at Westgate.

Localities: 23, 24, 25, 26, 33, 56, 87.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras depressum* n. sp.

Pl. 4, Fig. 3, 4; Text-fig. 6-7

Derivation of Name: In reference to the depressed whorl section.



FIGURE 6-7 Sketch of the whorl section of the holotype of *Paltechioceras depressum* n. sp. (Natural size)

Diagnosis: Fairly evolute forms; whorl section rectangular, depressed at all growth stages. Venter with a pronounced laterally sulcate keel.

Holotype: McMaster Catalogue Number J2043, Pl. 4, Fig. 3. From the Sinemurian (*P. rothpletzi* Zone), locality 33 of the Sunrise Formation (unit 4) exposed in the entrance to New York Canyon, Gabbs Valley Range, Nevada. The paratype (McMaster Catalogue Number J2044), also from locality 33 and illustrated on Pl. 4, Fig. 4, is selected to show the features of the inner whorls which are poorly preserved in the holotype.

Material: In addition to the type material, 32 other specimens, some of them whorl fragments, are available for study. All the material is preserved in sandy limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
J2043	40.6	22.5	55	10.7(26)	10(25)	107	21
Holotype	34.8	19	55	9.7(28)	8.3(24)	117	20

J2044'	19.8	9.5	48	6.1(31)	5.7(29)	107	e	19
Paratype est 14	6	6	43	e 4.1(29)	4.5(32)	91		17
N1-3-10(6)	--	--	--	8.7	8.2	94		--
	--	9	--	--	--	--		23
	--	5	--	--	--	--		19
P20(13)	29.1	16	55	8.6(30)	7.3(25)	118	e	26
P20(45)	22.1	11.5	52	7.1(32)	5.8(26)	122		22
	17.1	9.5	56	6(35)	5.1(30)	118		22
P52(11)	36.6	19.5	53	10.3(28)	9.3(25)	111		22
	--	11	--	--	--	--	e	24
P52(13)	17.2	9	52	5.4(31)	4.6(27)	117		21

Description: Evolute forms with a rectangular whorl section that is considerably depressed at all growth stages. The venter bears a pronounced keel flanked by deep sulci.

Ribbing is simple, sharp, and fairly sparse for the genus, particularly at larger diameters. The ribs are rectiradiate to gently prorsiradiate, project onto the ventral surface and abut against the sulci.

Discussion: This species is erected for the combination of depressed whorl section and a strong keel flanked by deep lateral sulci, a combination of features not shown by any other echioceratid species. The features of the venter are characteristic of the genus *Paltechioceras* whilst a depressed whorl section, although known in *Paltechioceras* e.g. Bremer, 1965, is somewhat atypical.

Occurrence: *P. depressum* is found in the middle parts of unit 4 of the Sunrise Formation exposed in the Gabbs Valley Range. It is one of the last echioceratids found in Nevada.

Localities: 30, 31, 32, 33, 58.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras* aff. *depressum* n. sp.

Pl. 6, Fig. 5-8

Material: Approximately 130 specimens preserved in sandy limestone.

Measurements:

Specimen

P20(1E)	13.6	7	51	3.7(27)	3.7(27)	100	17
	--	4	--	--	--	--	c 12
P20(22)	16.8	8	48	3.9(23)	4.1(24)	95	17
	--	4	--	--	--	--	15
P20(26)	16.3	8	49	5.1(31)	4.8(29)	106	18
	--	4	--	--	--	--	15
P20(28)	19	11	58	4.5(24)	4.8(25)	94	19
	--	4	--	--	--	--	12
P20(47)	19.4	11	57	5(26)	4.7(24)	106	20
	--	3.5	--	--	--	--	16
P52(7)	21.3	11.5	54	5.2(24)	5.3(25)	98	c 20
J2054	27.7	14.5	52	7.3(26)	7.7(28)	95	22
	--	6.5	--	--	--	--	c 19

Description: Evolute forms with a square to slightly compressed whorl section. A marked keel is flanked by narrow, fairly shallow sulci. Ribbing is sharp, rectiradiate, and projects strongly onto the ventral surface. Four specimens show ribbing on one side only whilst the other side is smooth except for faint lirae (Pl. 6, Fig. 7, 8).

Discussion: These specimens are closely related, if not conspecific with *P. depressum* with which they are always associated. *P. aff. depressum* never reaches the very depressed whorl shape characteristic of *P. depressum*, the lateral sulci are never as deep, and the density of the ribbing is less. *P. aff. depressum* is also similar to a form from Turkey described under the subspecific name of *P. romanicum anatolicum* (Bremer, 1965, p. 141, pl. 13, fig. 2). The backwardly inclined ribs on the inner whorls described by Bremer are not evident in the American material, however.

The four "semi-costate" specimens range in size from diameters of 13 to 28 mm. Either side seems prone to becoming smooth, and smoothness is always achieved by an inflation of the intercostal regions rather than a contraction of the ribs. One specimen shows an obliteration of the ventral features whereby the much reduced non- (or semi- ?) sulcate keel runs along the ventro-lateral shoulder of the

smooth side. These specimens are interpreted as being pathogenic. The echioceratids as a whole, but particularly *Paltechioceras*, seem prone to ribbing disruption, irregularities, and the development of smooth areas that are usually interpreted as malfunctions of the mantle. This is the first record of "semi-costation", however, although an almost completely smooth individual is known from Austria (Geyer, 1886, pl. 3, fig. 10). This single individual was used by Spath (1925) to erect the genus *Tmaegophioceras* which Getty (1973), in his revision of the Echioceratidae, considered as *incertae sedis*. Based on the present discovery it is here suggested that *Arietites laevis* GEYER represents a diseased *Paltechioceras*, and that the generic name of *Tmaegophioceras* should be abandoned.

Occurrence: From the lower and middle part of unit 4 of the Sunrise Formation exposed in the Gabbs Valley Range, Nevada.

Localities: 23, 30, 32, 33, 58.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras gettyi* n. sp.

Pl. 4, Fig. 5-8

1886 *Arietites hierlatzicus* (VON HAUER) - GEYER, p. 246, pl. 3, fig. 1 only (non von Hauer).

- ? 1915 *Vermiceras hierlatzicum* HAUER - (ONETTI, p. 77,  
pl. 3, fig. 8.
- ? 1956 *Arnioceras harpoides* ERBEN, p. 245, pl. , fig. 11-14.
- cf. 1965 *Paltechioceras* cf. *hierlatzicum* (HAUER) - BREMER,  
p. 144, pl. 13, fig. 3a, b.

Diagnosis: Moderately evolute; whorl section quadrate;  
pronounced, weakly sulcate keel. Nucleus smooth, ribbing  
simple, dense, and projecting onto the venter.

Holotype: McMaster Catalogue Number J2047, figured on  
Pl. 4, Fig. 7. An internal mould from the Sinemurian  
(*P. rothpletzi* Zone), locality 33, of the Sunrise Formation  
(unit 4) exposed in the entrance to New York Canyon,  
Gabbs Valley Range, Nevada. Preserved in sandy limestone.

The paratypes (McMaster Catalogue Numbers J2045,  
J2048; Pl. 4, Fig. 5, 8 respectively) are from the same  
locality as the holotype and are selected to show the  
variation in whorl inflation and ribbing density.

Material: Apart from the type material, 95 specimens,  
all preserved in sandy limestone, are available for study.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
J2047	21.5	11	51	6(28)	5.5(26)	109	27
Holotype	--	6	--	--	--	--	22



J2045	25.2	12	48	7.2(29)	7.1(28)	101	31
Paratype	19.9	9.5	48	6.1(31)	5.8(29)	105	c30
	--	5.5	--	--	--	--	c24
J2048	15.2	7.5	49	4.6(30)	4.2(28)	110	27
Paratype							
J2046	24	11.5	48	6.1(25)	6.8(28)	90	27
	--	6	--	--	--	--	22
P20(18)	24	13.5	56	5(21)	5.9(25)	85	28
	--	6	--	--	--	--	c21
P20(35)	22.3	11	49	6.2(28)	6.2(28)	100	25
	--	6	--	--	--	--	21
P20(43)	22.7	11.5	51	5.6(25)	6.3(28)	89	28
N1-4-4(1)	20	10.5	53	5.9(30)	5.1(26)	116	25
	15.5	6.5	42	4.4(28)	4.1(26)	107	c22
N1-4-4(5)	19.5	11	56	5.3(27)	4.4(23)	120	c31
N1-4-4(6)	15.9	7	44	4.4(28)	5.2(33)	85	27
	--	3.5	--	--	--	--	19
N1-4-4(7)	24.7	14	57	5(20)	5.9(24)	85	c31
	--	9	--	--	--	--	26
N1-4-4(36)	23.5	13	55	5.5(23)	6(26)	92	23
	--	9	--	--	--	--	c21
	--	4	--	--	--	--	c15
N1-4-4(46)	19.6	10.5	54	5.2(27)	4.8(24)	108	24
	12.3	6	49	3.9(32)	4.0(33)	98	19
P52(2)	24	13.5	56	6.8(28)	6.8(28)	100	c31
	--	7	--	--	--	--	26
	--	4	--	--	--	--	20
Geyer, 1886	24	12.5	52	6.1(25)	7(29)	87	c26
Pl. 3, Fig. 1	--	6.2	--	--	--	--	20
Bremer, 1965	17.5	8.8	50	5.8(33)	6(34)	97	c16
Pl. 13, Fig. 3							

Description: Moderately evolute forms with a whorl section

that is compressed or sometimes quadrate. The flattened venter bears a pronounced keel that is weakly sulcate at larger diameters. The nucleus is smooth to an umbilical diameter of approximately 1 mm at which point simple, fairly dense ribs arise that project onto the venter where they quickly fade. The more inflated forms tend to be more densely ribbed.

Discussion: *Ammonites hierlatzicus* was established by von Hauer (1856, p. 28, pl. 7, fig. 4-6) for a form that Getty (1972, 1973, and *in litt.*) has argued is not an echioceratid but a hildoceratid, based on his examination of the type material. Consequently, a new name must be established for Geyer's material (1886) which he incorrectly identified with von Hauer's form. The name proposed is in honour of Dr. Getty but Geyer's specimens cannot be used as type material since his collection was destroyed during World War II. Types are therefore selected from the American collection. The holotype is very similar to Geyer's material whereas some of the paratypes differ in being slightly more inflated and more densely ribbed.

This species seems to be transitional between *Paltechioceras* and *Orthechioceras* since the dense ribbing and early sulci are features of the former, and the stout whorl section and smooth nucleus are features of the latter

genus.

Consideration of rib frequency plots (Getty, 1972, fig. 19) shows that *P. gettyi* is more densely ribbed than all other species of *Paltechioceras* with the exception of *P. boehmi* and *P. rothpletzi*. It differs from the former in being sulcate at small diameters and from the latter in having rectiradiate rather than prorsiradiate ribs.

Occurrence: Known from the Upper Sinemurian (? Oxynotum and Raricostatum Zones) of Austria and Turkey and possibly present in Italy, Mexico, and Hungary.

The American material was collected from the lower half of unit 4 of the Sunrise Formation exposed in Volcano Peak Gulch and the entrance to New York Canyon, Gabbs Valley Range, Nevada.

Localities: 30, 31, 32, 33, 56.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras harbledownense* (CRICKMAY, 1928)

Pl. 4, Fig. 9, 10; Pl. 5, Fig. 1, 4

? 1913 *Celtites* ? *vancouverensis* (MEEK) - BANCROFT, p. 75, pl. 9b (non Meek).

\* 1928 *Melanhippites harbledownensis* CRICKMAY, p. 61, pl. 3, 4.

? in press *Paltechioceras* cf. *harbledownense* (CRICKMAY) -

IMLAY, pl. 4, fig. 15, 17, 22 (non 16, 18-21).

Material: Approximately 200 specimens, mostly fragments preserved as moulds in siltstones, mudstones, and occasionally thin-bedded limestones.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Wh</u>	<u>P</u>
D6812(4) est	134	86	64	c23.3(17)	--
	--	80	--	--	36
	--	48	--	--	c38
	--	30	--	--	c34
	--	19	--	--	c28
J2037	--	39	--	c16	38
	--	23	--	--	31
J2050 est	69	41	59	c16(23)	39
	--	21	--	--	33
	--	14	--	--	28

Description: Evolute, compressed forms with a laterally sulcate keel that becomes non-sulcate at large diameters. Ribbing also changes with growth from dense and straight to less dense and more arcuate.

Discussion: This species was used as the type of a genus named *Melanhippites* by Crickmay (1928). The state of preservation leaves a lot to be desired; the holotype (Crickmay, 1928, pl. 3), the largest specimen, is crushed and distorted and its inner whorls are not visible. It

has subsequently been lost so that Getty (1973) designated Crickmay's paratype 1 (1928, pl. 4, fig. d) as the neotype. It is hardly surprising that this poorly defined genus has generated controversy in the past, particularly as its stratigraphic position and morphology suggests it could occupy an important intermediate position between the arietitids and the echioceratids.

In the most detailed discussion of "*Melanhippites*" *harbledownensis* to date, Getty (1973) points to the similarities with both *Paltechioceras* and *Arnioceras*; he suggests that the weight of the evidence favours an affinity with *Arnioceras* (see also Donovan and Forsey, 1973) but concludes that *Melanhippites* is best regarded as *nomen dubium* and abandoned. Bremer (1965) considered including *Melanhippites* as a subgenus of *Paltechioceras*, even suggesting several other species that might be included, but eventually he abandoned *Melanhippites*, including all the forms in *Paltechioceras*.

Frebold (*in* Frebold and Little, 1962) initially agreed with Arkell (1957) in tentatively synonymising *Melanhippites* with *Arniotites* [= *Arnioceras*] but he later rescinded his decision (*in* Frebold and Tipper, 1970) in order to support the contention of Crickmay (1962) that *Melanhippites* is a synonym of *Echioceras*. Presently in North America, Imlay (preprint) synonymises *Melanhippites*

with *Paltechioceras*. This practice has also been adopted by the Canadian Geologic Survey (Tipper, personal communication, 1980), and such an approach is also adopted here since it seems most reasonable on both morphologic and stratigraphic grounds.

*Palaeoechioceras* is the earliest echioceratid in northwest Europe whereas *Paltechioceras harbledownense* is the earliest in North America. Whenever it has been accurately located stratigraphically, *P. harbledownense* is separated by a considerable stratigraphic interval from the last *Arnioceras*. In the present study, the stratigraphic interval between the last *Arnioceras* and the first *P. harbledownense* has yielded *Epophioceras*, and this lends weight to the suggestion of Getty (1973) and others that *Epophioceras* is the arietitid root stock of the Echioceratidae rather than *Arnioceras* as suggested by Bremer (1965).

Occurrence: The type material was collected from the Harbledown Formation at Parson Bay, British Columbia, three metres beneath an unfigured oxynoticeratid (resembling *Gleviceras* according to Crickmay), approximately 150 metres above a locality yielding "*Arniotites*" [= *Arnioceras*]. Based on its stratigraphic position and associated ammonite fragments, Crickmay suggested an "Asterocheratan date" for

*P. harbledownense*, that is, the Obtusum Zone of modern terminology. This is corroborated by an association of "*Melanippites*" (*sic*) *harbledownensis* and *Asteroceras* cf. *obtusum* reported from Vancouver Island by Frebold and Tipper (1970). Imlay (preprint) has tentatively recognised *Paltechioceras harbledownense* at a much higher stratigraphic level from the Sinemurian of Alaska. His smaller specimens (pl. 4, fig. 18-21), which occur with several eoderoceratids, have a high nonsulcate keel, a somewhat florid suture, and small, sharp tubercles on the ventral ends of rursiradiate ribs. These are not echioceratid features and the specimens probably represent *Acanthopleuroceras* sp. described herein. Figure 16, on the other hand, could be an *Arnioceras* (see for example Geyer, 1886, pl. 3, fig. 17).

Apart from the occurrences listed below, *P. harbledownense* is recorded from western Canada and possibly Alaska (Frebold and Tipper, 1970; Imlay, preprint).

The specimens from Nevada originate from the following units of the Sunrise Formation: the upper part of unit 3 in the Gabbs Valley Range; the upper part of unit F in the Shoshone Mountains, and the upper part of unit B in the Clan Alpine Range.

Localities: 16, 17, 18, 19, 20, 21, 54, 68, 69, 70, 72, 73, 87.

Age: Sinemurian (*P. harbledownense* and *P. rothpletzi* Zones).

*Paltechioceras oosteri* (DUMORTIER, 1867)

Pl. 5, Fig. 2, 3

- 1860 *Ammonites sinemuriensis* D'ORBIGNY - OOSTER, p. 13, pl. 13, fig. 3-5 (non d'Orbigny).
- \*1867 *Amm. oosteri* DUMORTIER, p. 164, pl. 30, fig. 3, 4.
- 1879 *Amm. oosteri* DUM. - REYNES, pl. 45, fig. 12-14.
- 1899 *Arietites bonnardi* D'ORB. var. *oosteri* DUM. - HUG, p. 13, pl. 12, fig. 7.
- 1902 *Vermiceras oosteri* DUM. - FUCINI, p. 143, pl. 13, fig. 3, 3a.
- 1925 *Paltechioceras ebriolum* TRUEMAN and WILLIAMS, p. 729, pl. 4, fig. 5.
- 1956 *P. ? aberrans* ERBEN, p. 344, pl. 41, fig. 1 (?), 2.
- ? 1958 *P. cf. oosteri* (DUM.) - DONOVAN, p. 30, pl. 2, fig. 2.
- 1965 *P. oosteri* (DUM.) - ZEISS, p. 38, pl. 2, fig. 3a-c.

Material: Five incomplete specimens and one whorl fragment preserved in limestone.

Description: Evolute forms with a whorl section that is quadrate at small diameters ( $W \approx 1.08$  at  $D \approx 27$ ) becoming compressed in the outer whorls ( $W \approx 0.83$  at  $D \approx 46$ ).

The venter bears a marked, rounded keel flanked by weak sulci or flattened areas in larger whorls.

Discussion: The lectotype for this species (Dumortier, 1867)



was designated by Donovan (1958, p. 30). The species is characterised by its irregular, periodically looped ribs, and it is closely related to *P. studeri* (HUG) which differs in the marked sparseness of its costation (Donovan, 1958).

Occurrence: The age of the species in Europe is uncertain. The lectotype cannot be dated precisely because it was collected from a condensed sequence but a specimen of *P. cf. oosteri*, collected just below *P. tardecrescens* in the Upton borehole of England, suggests a Raricostatum Zone age (Getty, 1972).

The material from the United States originates from the lower part of unit 4 of the Sunrise Formation exposed at Volcano Peak Gulch, and the entrance to New York Canyon, Gabbs Valley Range, Nevada.

Localities: 31, 32, 33, 56.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras rothpletzi* (BÖSE, 1894)

Pl. 5, Fig. 5, 6; Pl. 6, Fig. 1

- 1867 *Ammonites tardecrescens* HAUER - DUMORTIER, p. 170, pl. 31, fig. 3-5 (non Hauer).
- \*1894 *Arietites rothpletzi* BÖSE, p. 730, pl. 56, fig. 5.
- 1902 *Vermiceras rothpletzi* (BÖSE) - FUCINI, p. 139, pl. 12, fig. 12.

- 1914 *Echioceras delicatum* BUCKMAN, p. 96c.
- 1927 *Plesechioceras typus* BUCKMAN, pl. 694.
- 1956 *Vermiceras* cf. *bavaricum* (BOESE) *stuebli* TILMANN -  
ERBEN, p. 209, pl. 34, fig. 10.
- non 1956 *Vermiceras* aff. *rothpletzi* (BOESE) - ERBEN, pl. 25,  
fig. 23; pl. 36, fig. 8, 9.
- 1961 *Plesechioceras typum* BUCKMAN - BLAISON, pl. 1,  
fig. 5a, b; non pl. 3, fig. 3.
- 1962 *Vermiceras* sp. CORVALAN, p. 171, pl. 2, fig. 4.
- 1965 *Paltechioceras rothpletzi* (BÖSE) - BREMER, p. 143,  
pl. 13, fig. 4.
- 1972 *Paltechioceras delicatum* (BUCKMAN) - GETTY, p. 63,  
pl. 2, fig. 5a-c (holotype of Dumortier, 1867  
refigured).

Material: Ninety-four specimens preserved in limestone  
and siltstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>P</u>	
D6908(13)	33.3	18.5	56	8.6(26)	8.3(25)	104	c28
	--	14	--	--	--	--	c25
	--	8.5	--	--	--	--	22
P20(41)	16.9	9	53	4.1(24)	4.2(25)	98	31
	--	4	--	--	--	--	17
N1-4-4(10)	18.6	9.5	51	4.4(24)	5(27)	88	31
	--	6	--	--	--	--	23
N1-4-4(24)	26.1	14.5	56	5(19)	5.1(20)	98	c24
	--	6	--	--	--	--	22

P52(10)	39.1	23.5	60	9.5(24)	9(23)	106	e 31
	34.8	19.5	56	7.2(21)	8.3(24)	87	29
	28.1	15.5	55	6(21)	7.4(26)	81	e 29
	--	9	--	--	--	--	25
P52(18)	11	5.5	50	3.4(31)	3.1(28)	110	26

Description: Evolute forms with a subquadrate, slightly compressed whorl section. The flanks are gently convex, and the flattened venter bears a keel flanked by sulci that are often weak.

The ribbing is dense throughout ontogeny and regularly prorsiradiate. The ribs project onto the venter but fade before reaching the sulci.

Discussion: *P. rothpletzi* may be distinguished from all other species of *Paltechioceras* by its dense, prorsiradiate ribbing. The variability in ribbing density exhibited by the specimens listed in the synonymy (e.g. Fucini, 1902; Bremer, 1965) is also evident in the material collected from Nevada as shown by the figured specimens.

Occurrence: The specimens from Europe are from the Upper Sinemurian but of uncertain position with respect to the zonal scheme since most of the material was collected from condensed or remanié beds. The species occurs in northwest Europe but is particularly common in the Mediterranean region, having been recorded as far east as Turkey.

The American specimens were collected from the following units of the Sunrise Formation: the lowest part of unit 4 exposed at Volcano Peak Gulch; the lower half of unit 4 exposed in the entrance to New York Canyon, and from the upper third of unit B at Westgate.

Localities: 18, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, 56, 74, 81, 82, 84, 85, 86, 87.

Age: Sinemurian (*P. rothpletzi* Zone).

*Paltechioceras tardecrescens* (HAUER, 1856)

Pl. 6, Fig. 2-4; Text-fig. 6-8

- \*1856 *Ammonites tardecrescens* HAUER, p. 20, pl. 13, fig. 10-12.
- 1876 *Arietites tardecrescens* (HAUER) - BLAKE, p. 285, pl. 5, fig. 5.
- 1879 *Ammonites tardecrescens* HAUER - REYNES, pl. 13, fig. 8-10 (Hauer's material refigured).
- ? 1899 *Arietites* cf. *conybeari* SOWERBY - HUG, p. 11, pl. 12, fig. 3, 4 (non Sowerby).
- ? 1914 *Echioceras subquadratum* BUCKMAN, p. 96c (new name for *Arietites* cf. *conybeari* SOWERBY - HUG, 1899).
- 1924 *Leptechioceras aplanatum* (HYATT) - BUCKMAN, pl. 482 (non Hyatt).
- 1925 *Euechioceras nobile* TRUEMAN and WILLIAMS, p. 725.
- ? 1925 *Euechioceras angustilobatum* T. and W., p. 726.



FIGURE 6-8 Septal suture of *Paltechioceras tardecrescens* (HAUER) at  $Wh \approx 11$  mm. Specimen N1-2-6(89).

- 1925 *Euechioceras insigne* T. and W., p. 727, pl. 3, fig. 3.  
 ? 1927 *Stenechioceras angustilobatum* (T. and W.) -  
 BUCKMAN, pl. 697.

Material: Thirty-seven specimens preserved in limestone and siltstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
J2053	54.6	33.5	61	9.7(18)	11.2(21)	87	25
	--	21	--	--	--	--	22
P20(14)	32.8	18.5	56	7.4(23)	8.1(25)	91	30
	26.9	14	52	6.2(23)	6.3(23)	98	29
	--	10.5	--	--	--	--	c 25
P20(40)	51.7	29.5	57	9.1(18)	12.1(23)	75	c 25
N1-4-4(50)	41.9	24	57	8.2(20)	9.1(22)	90	31
	--	14	--	--	--	--	c 25
	--	6	--	--	--	--	c 20

Description: A large serpentine with a compressed whorl section. The flanks are gently convex and the

narrow, somewhat flattened venter bears a high, median keel flanked by strong sulci which in turn are flanked by weak lateral keels.

The ribbing is quite dense throughout. The ribs are rectiradiate and straight becoming gently convex apically at larger diameters. The suture line is simple with a broad, wide based, ceratite-like first lateral lobe (Fig. 6-8).

Discussion: *P. tardecrescens* is closely related to *P. aplanatum* as noted by Getty (1972, 1973) but the latter has a more rectangular, flat-sided whorl section.

Occurrence: In Europe *P. tardecrescens* is one of the last echioceratids and it is widely distributed geographically, having been recorded from as far north as Britain; as far south as Portugal (Mouterde, 1967), and as far east as Austria (Hug, 1899).

Similarly, in the United States *P. tardecrescens* is amongst the last echioceratids. It was collected from the middle and upper parts of unit 4 of the Sunrise Formation at Volcano Peak Gulch and New York Canyon entrance, as well as from the upper part of unit B of the Sunrise Formation exposed at Westgate.

Localities: 19, 29, 30, 32, 33, 59, 84.

Age: Sinemurian (*P. rothpletzi* Zone).

SUBGENUS *Orthechioceras* TRUEMAN and WILLIAMS, 1925

Type-Species: *Orthechioceras recticostatum* TRUEMAN and WILLIAMS, 1925 (p. 723, pl. 3, fig. 1).

Remarks: Forms that are similar to *Paltechioceras* except for the greater breadth of their quadrate whorls, their less dense ribbing, and the absence of sulci (Getty, 1973). *Orthechioceras* was considered a synonym of *Paltechioceras* by Arkell *et al.* (1957) in the Treatise whilst Donovan and Forsey (1973) include it as a subgenus.

Synonym: *Homechioceras* TRUEMAN and WILLIAMS *in* BUCKMAN, 1925.

Age and Distribution: *Orthechioceras* is known from the Raricostatum Zone of England, and the Upper Sinemurian of France and Mexico (Getty, 1973; Dumortier, 1867; Erben, 1956).

*Paltechioceras (Orthechioceras) edmundi* (DUMORTIER, 1867)

Pl. 3, Fig. 7, 8

\*1867 *Ammonites edmundi* DUMORTIER, p. 163, pl. 39,  
fig. 3, 4.

- 1879 *Amm. edmundi* DUM. - REYNES, pl. 45, fig. 19, 20.
- ? 1880 *Arietites raricostatus* ZIETEN - WRIGHT, pl. 26,  
fig. 12 (and see comments of Donovan, 1954, p. 34).
- ? 1902, *Vermiceras* cf. *edmundi* (DUM.) - FUCINI, p. 153,  
pl. 13, fig. 9.
- 1925 *Echioceras elegans* TRUEMAN and WILLIAMS, p. 717,  
pl. 1, fig. 9.
- 1925 *Neurechioceras congruens* T. and W., p. 720, pl. 4  
fig. 4.
- ? 1925 *Orthechioceras recticostatum* T. and W., p. 723,  
pl. 3, fig. 1.
- 1925 *O. radiatum* T. and W., p. 724, pl. 2, fig. 9.
- 1925 *Homechioceras simile* T. and W. in BUCKMAN, pl. 609.
- ? 1956 *Vermiceras edmundi* (DUM.) - ERBEN, p. 204, pl. 33,  
fig. 12.
- ? 1961 *Paltechioceras edmundi* (DUM.) - BLAISON, p. 103,  
pl. 3, fig. 1.
- 1972 *Paltechioceras (Orthechioceras) edmundi* (DUM.) -  
GETTY, p. 247, pl. 13, fig. 5, 6?, pl. 14, fig. 1-11.
- 1973 *Orthechioceras radiatum* T. and W. - GETTY, pl. 5,  
fig. 1, 2.
- 1975 *Echioceras arcticum* FREBOLD, p. 9, pl. 3, fig. 1-6.

Material: Eighty-eight specimens preserved in limestone.



Measurements:

<u>Specimen</u>	<u>U</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>W</u>	<u>P</u>
D6908 (2)	18.5	9	49	5 (27)	5.5 (30)	91	21
	--	6	--	--	--	--	17
	--	3.5	--	--	--	--	13
D6908 (3)	26.2	14	53	8.2 (31)	7.3 (28)	112	20
	--	9	--	--	--	--	19
	--	4	--	--	--	--	15
D6908 (5)	16	8	50	4.2 (26)	4.7 (29)	89	15
	--	4	--	--	--	--	13
D6908 (6)	20.9	11.5	55	5.8 (28)	5.1 (24)	114	20
	--	4	--	--	--	--	15
D6908 (10)	33	19	58	8.3 (25)	7.7 (23)	108	19
	--	14	--	--	--	--	18
	--	6.5	--	--	--	--	17
D6908 (12)	20.3	10.5	52	5 (25)	5.4 (27)	93	21
	--	6	--	--	--	--	16
D6908 (14)	52	31.5	61	10.2 (20)	12.3 (24)	83	21
	34	19	56	7.8 (23)	8.1 (24)	96	22
	--	10.5	--	--	--	--	23
est	14.5	6.5	45	4 (28)	4 (28)	100	23
D6908 (19)	21.7	11	51	6.5 (30)	5.9 (27)	110	19
	--	6	--	--	--	--	18
D6908 (20)	26.1	14.5	56	6.4 (25)	6.6 (25)	97	22
	--	9	--	--	--	--	22
	--	4	--	--	--	--	18
D6908 (23)	25.1	13.5	54	6.5 (26)	6.5 (26)	100	19
	--	9	--	--	--	--	21
D6908 (24)	57.7	31	54	11.7 (20)	14.2 (25)	82	20
	47.1	26	55	11.3 (24)	11.3 (24)	100	19
	--	16	--	--	--	--	19
	--	11	--	--	--	--	18
D6908 (25)	19.4	10.5	54	5.2 (27)	5.3 (27)	98	19
	--	6	--	--	--	--	16
D6908 (26)	21.5	11.5	53	6.4 (30)	5.6 (26)	114	23
	--	6	--	--	--	--	21

D6908(27)	est 30	--	--	8.8(29)	7(23)	126	--
	c20	9.5	48	--	--	--	17
	--	4.5	--	--	--	--	17
D6908(28)	13	6	46	4.3(33)	3.6(28)	119	17
D6908(30)	15.3	8	52	4.2(27)	3.6(24)	117	22
D6908(31)	24.2	12.5	52	5.4(22)	6.2(26)	87	20
	--	4	--	--	--	--	13
D6908(37)	c32	19	59	8.2(26)	7.5(23)	109	c22
	--	11.5	--	--	--	--	20
D6908(38)	20.8	11	53	5.8(28)	5.1(25)	114	20
	--	6	--	--	--	--	17
D6908(41)	15.3	8	52	4.3(28)	3.7(24)	116	18
	--	4	--	--	--	--	17
D6908(42)	est 49	21.5	44	c10.4(21)	c11.8(24)	88	c18
	c30	16	53	7.8(26)	7.1(24)	110	17
	--	9	--	--	--	--	17
	--	4	--	--	--	--	15
D6908(43)	c28.5	15.5	54	6.8(24)	7.4(26)	92	22
	--	11	--	--	--	--	22
D6908(45)	24.7	13	53	c7.1(29)	6.7(27)	106	18

Description: An evolute form with a subquadrate whorl section that is slightly wider than high at small diameters becoming slightly compressed with growth. The flanks are gently convex and the widest part of the whorl is nearer the venter in the outer whorls. The venter is flat and featureless on most specimens to a maximum diameter of approximately 30 mm whereas others show a very weak, non-sulcate keel. Larger specimens develop a low keel flanked by smooth, flat zones that develop into subsulci on the largest whorl fragments (Wh  $\approx$  15 mm).

Ribbing is strong and rectiradiate or sometimes gently prorsiradiate. The ribs begin to project onto the venter but fade very quickly.

Discussion: The synonymy given above is a revised version of that presented by Getty (1972) who discusses the species in some detail. Dumortier's (1867) specimen, which was one of several syntypes, is now lost but Dr. Getty hopes presently to designate a lectotype from the type material still in existence.

*Echioceras arcticum* was established by Frebold (1975) for material collected from Borden Island in the Canadian Arctic. The whorl section is described as depressed at small diameters becoming quadrate, with rounded flanks and a venter bearing a subsulcate keel. These features suggest an assignment to *Orthechioceras* rather than *Echioceras* since the latter usually has a depressed whorl section throughout ontogeny and the keel is never sulcate (Getty, 1972, 1973). Although there is some variation in both external morphology and suture, as discussed by Frebold, the Canadian specimens seem to fall within the range of variation of *P. (O.) edmundi* and its synonyms.

Occurrence: *P. (O.) edmundi* is reported from the Upper Sinemurian (Raricostatum Zone) of Britain, France, Canada,

and possibly Italy and Mexico.

The American specimens originate from the lowest part of unit 4 of the Sunrise Formation exposed in Volcano Peak Gulch, Gabbs Valley Range, Nevada.

Localities: 56.

Age: Sinemurian (*P. rothpletzi* Zone).

Echioceratidae gen. and sp. indet.

Pl. 6, Fig. 9, 10

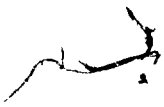
- ? 1867 *Ammonites armentalis* DUMORTIER, p. 162, pl. 29, fig. 1, 2.
- ? 1879 *Amm. armentalis* DUM. - REYNES, pl. 41, fig. 22, 23 (Dumortier's material refigured).
- ? 1955 *Echioceras ? armentale* (DUM.) - DONOVAN, p. 34.
- ? 1972 *Echioceras ? aff. E. ? armentale* (DUM.) - GETTY, p. 255, pl. 15, fig. 7.

Material: Four small, incomplete specimens preserved in limestone.

Description: Shell evolute with an almost circular whorl section. Ribbing is quite dense but a count per half whorl cannot be given because of the incomplete nature of the material. The venter bears no keel or sulci. In three specimens (see Pl. 6, Fig. 10) the ribs pass uninterrupted

across the venter whereas in the largest specimen, which reaches a whorl height of approximately 6 mm, the ribbing is irregular with some ribs being uninterrupted whilst others pass across one flank and the venter but become obsolete high on the opposite flank (Pl. 6, Fig. 9).

Discussion: These specimens are similar to *E. ? armentale* (DUMORTIER), the type of which is a very large individual making comparison difficult. A specimen from Charmouth, in England figured by Getty (1972) is much smaller ( $D \approx 32$  mm) and is very similar to the American material. The taxonomic position of *Ammonites armentalis* is very uncertain. It has been referred to *Echioceras* but the ventrally uninterrupted costation is a unique feature and not characteristic of this genus. Spath (1945) and Getty (1972) considered this species as "crippled", and this might be feasible bearing in mind that pathologic echioceratids have been collected from Nevada (see p. 182). A specimen of unknown stratigraphic position from the Liassic of Turkey is similar to *E. ? armentale* in whorl shape and ventrally uninterrupted ribbing but the costation is more dense. Bremer (1965, p. 176, pl. 16, fig. 7) referred to the specimen as *Polymorphites ?* sp. indet.



Occurrence: *E. ? armentale* is known from France and

England but its stratigraphic position is uncertain. The English specimen was not found in place but it possibly originated from the Raricostatum Zone (Getty, 1972).

The American specimens were collected from the lower half of unit 4 of the Sunrise Formation exposed at Volcano Peak Gulch and the entrance to New York Canyon, Gabbs Valley Range, Nevada.

Localities: 33, 56, 57.

Age: Sinemurian (*P. rothpletzi* Zone).

FAMILY OXYNOTICERATIDAE HYATT, 1875

GENUS *Oxynoticeras* HYATT, 1875

Type-Species: *Ammonites oxynotus* QUENSTEDT, 1843 (p. 161) by subsequent designation (Buckman, 1909, p. 2).

Remarks: *Oxynoticeras* is characterised by a fairly narrow umbilicus; a highly compressed, oval to lanceolate whorl section with a sharp venter, and radial ribs restricted to the lower part of the flanks.

Synonyms: *Hypoxynoticeras* SPATH, 1925; *Oxynotoceras* BUCKMAN, 1894.

Age and Distribution: *Oxynoticeras* is cosmopolitan and characteristic of the Upper Sinemurian, particularly the

Oxynotum Zone. The last representative of the genus is recorded from the lower Carixian (Jamesoni Zone) of Hungary (Geczy, 1976). In the Americas, the genus is known from the Andes (Hillebrandt, 1973), Mexico (Erben, 1956), and Arctic Canada (Fredold, 1960); it has not previously been reported from the United States.

*Oxynoticeras cf. simpsoni* (SIMPSON, 1843)

Pl. 7, Fig. 1, 2

- ? 1843 *Ammonites simpsoni* SIMPSON, p. 37.
- ? 1876 *Amaltheus simpsoni* SIMPSON - TATE and BLAKE, p. 291, pl. 8, fig. 4.
- ? 1886 *Oxynoticeras oxynotum* (QUENSTEDT) - GEYER, p. 231, pl. 2, fig. 12, 13.
- ?\*1912 *Aetomoceras simpsoni* BEAN-SIMPSON - BUCKMAN, pl. 66A and B (holotype refigured).
- ? 1956 *Oxynoticeras praecursor* SÖLL, p. 394, pl. 18, fig. 3-7.
- ? 1961 *O. simpsoni* (SIMPSON) - DEAN, DONOVAN and HOWARTH, pl. 67, fig. 4.
- 1965 *O. sp.* HALLAM, p. 1486.
- ? 1976 *O. simpsoni* (SIMPSON) - SCHLEGELMILCH, p. 53, pl. 22, fig. 11.

Material: One external mould, in tuffaceous siltstone and

four internal moulds (three of them fragments) in silty limestone.

Measurements: (All measurements are approximate.)

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>
N1-2-6(1)	31	6	19	--	9.2(30)	--
J2060	18	4.5	25	--	--	--
	14	3.1	22	3.3(24)	5.8(42)	57
714D(- (25-50'))	--	--	--	--	15	--
D7899(1)	106	17	16	c 24.5(23)	62.5(59)	39

Description: The mode of preservation hinders confident identification of this material to specific level and the discrepancy in size is a further complication.

The smallest two individuals are moderately involute and very compressed with a knife-edged venter. These two specimens together with the fragment from Muller's collection (specimen number 714D (-25-50')) are identical in general morphology and in the possession at whorl heights greater than 5 mm of broad, low, widely spaced ribs that are confined to the lower half of the flanks.

The largest specimen (D7899(1)) is tentatively included here because it was found at the same level and locality as specimen J2060, although direct comparisons are impossible in the absence of the inner whorls of the large specimen. It is certainly an *Oxynoticeras* on the



basis of its narrow, rather deep umbilicus, its very compressed whorl section, and sharp venter. The lower part of the flanks are gently convex. No ribbing is evident.

Discussion: These specimens are comparable to material from Austria figured by Geyer (1886, p. 231, pl. 2, fig. 12 and 13 only) as *O. oxynotum* (QU.). They differ in the ribs on the smaller specimens (cf. Geyer, 1886, pl. 2, fig. 12) being broader and more distantly spaced, and in the larger specimen having a slightly less acute venter. Geyer's material has been referred to as *O. oxynotum* var. *hierlatzicum* by Pia (1914), and more recently as *O. simpsoni* by Getty (1973). The style of ribbing on the smaller whorls is similar to that shown by *O. praecursor* which is a probable synonym of *O. simpsoni* (Dean *et al.*, 1961).

Occurrence: *O. simpsoni* occurs in the lower Oxynotum Zone of northwest Europe. The specimens from the United States were collected from the upper part of unit 3 and most of unit 4 of the Sunrise Formation exposed in the Gabbs Valley Range, Nevada where they occur with abundant echioceratids.

Localities: 19, 42, 56, 58.

Age: Sinemurian (*P. rothpletzi* Zone).

GENUS *Gleviceras* BUCKMAN, 1918

Type-Species: *Gleviceras glevense* BUCKMAN, 1918 (p. 289) by original designation. *G. glevense* is a subjective junior synonym of *G. subguibalianum* (VON PIA, 1914) (Bremer, 1965; Donovan and Forsey, 1973; Geczy, 1976).

Remarks: Large forms closely related to *Oxynoticeras*. Venter rounded with a sharp keel that is often lost on outer whorls. Whorl egression and coarsening of the ornament marks the mature stage. Septal suture complex.

Synonyms: *Glevumites*, *Victoriceras*, and *Guibaliceras*, BUCKMAN, 1918; *Tutchericeras* BUCKMAN, 1919; *Glevumnites* SPATH, 1926 *nom null.*; *Riparioceras* SCHINDEWOLF, 1962.

Age and Distribution: Reported from all Europe and also South America (Geczy, 1976). The record described below is the first from North America. Upper Sinemurian to Jamesoni Zone; most common in the the Oxynotum and lowest Raricostatum Zones.

*Gleviceras ex gr. victoris* (DUMORTIER, 1867)

Pl. 7, Fig. 6

Material: Two specimens: a large, somewhat corroded and

oyster-encrusted whorl fragment, and the internal mould of a partially septate individual.

Description: The large fragment (Wh = 112 mm) was part of a fairly evolute shell with an ovate whorl section (WS = 59). Ribbing is sparse. Broad, low primary ribs arise near the umbilical wall and trend radially across the flanks to the narrowly arched venter where they swing gently forward before fading. At one point an intercalated secondary rib arises just above the mid-point of the flank. The fragment is completely septate indicating that the individual must have reached a gigantic size but septa are too corroded to be traced accurately.

The second specimen is also fairly evolute but it has been secondarily compressed so that precise information on the whorl shape is not available although the umbilical wall is fairly high and convex. Also, only the dorsal part of the outer whorl is present. The part of the septate whorl that is visible appears to be smooth whilst the body chamber bears low, broad, simple ribs that arise near the umbilical shoulder in a manner similar to that described above. The suture is strongly incised although too little is available to present a meaningful trace.

Discussion: These specimens are included in *Gleviceras* on

the basis of the whorl section, volution, and style of ribbing on the outer whorls. Species identification, however, must await the discovery of better preserved material. They compare most favourably with the giant forms with a compressed, ovate whorl section such as the Oxynotum Zone form *Gleviceras subguibalianum* (PIA) (see especially Donovan, 1958, p. 12, pl. 1) although this particular species is more involute. *Gleviceras victoris* (DUMORTIER) (cf. Buckman, 1919, pl. 536A, B) has similar volution and, on the outer whorl, similar whorl section and ornamentation but the inner whorls are strongly ribbed.

Occurrence: Both specimens originate from the lower part of unit 4 of the Sunrise Formation exposed in Volcano Peak Gulch, Gabbs Valley Range, Nevada.

Localities: 55, 58.

Age: Sinemurian (*P. rothpletzi* Zone).

GENUS *Radstockiceras* BUCKMAN, 1918

Type-Species: *Radstockiceras complicatum* BUCKMAN, 1918, p. 287, pl. 27, fig. 1.

Remarks: The relation of *Fanninoceras* to *Radstockiceras* is one of controversy and importance. *Fanninoceras* has

been recorded only from the western Americas, implying the evolution of an endemic stock recorded from Alaska (Imlay, in press) and as far south as Argentina (Blasco *et al.*, 1978). Opinions are divided into two schools, the American school (Frebold, 1967; Imlay, in press) in favour of retaining *Fanninoceras*, and the European school (Donovan and Forsey, 1973) in favour of synonymising *Fanninoceras* with *Radstockiceras*. Fundamental similarities between the two genera are obvious and widely accepted; the arguments forwarded in support of retaining *Fanninoceras* may be summarised as follows:

- 1) *Fanninoceras* has narrower whorls than *Radstockiceras*.
- 2) The umbilical wall of *Fanninoceras* is undercut.
- 3) The external saddle of the suture of *Fanninoceras* is wider than in *Radstockiceras*. Consequently, the lateral lobe occupies a position nearer the middle of the flank in *Fanninoceras*.

- 4) *Fanninoceras* ranges into the Late Pliensbachian whereas *Radstockiceras* is restricted to the Early Pliensbachian.

As pointed out by Frebold (1967, p. 1146), there is some difficulty in comparing figured specimens of *Radstockiceras* with those of *Fanninoceras* in that species of *Radstockiceras* tend to be considerably larger. However, this should not be construed as indicating a size difference between the two genera. The holotype of *Fanninoceras carlottense*

McLEARN, for example, is septate to the end and it must have been at least 100 mm in diameter (based on an expansion rate of 2.5 and a conservative estimate of body chamber length of half a whorl). This is quite comparable with sizes attained by *Radstockiceras*.

Recent work by Geczy (1976) and Wiedenmayer (1977) has brought to light established European species of *Radstockiceras* that possess all the characters normally attributed to *Fanninoceras* including narrower whorls, a wide external saddle, and an undercut umbilical wall (Geczy, 1976, fig. 18; Wiedenmayer, 1977, fig. 11). Both taxa are therefore synonymised.

Synonyms: *Carixiceras* SPATH, 1925; *Fanninoceras* McLEARN, 1930; *Fastigiceras* BUCKMAN, 1919; *Homoxynticeras* BUCKMAN, 1925; *Kleistoxynticeras* BUCKMAN, 1925; *Metoxynticeras* SPATH, 1922; *Phylloxyntites* BUCKMAN, 1924; *Retenticeras* BUCKMAN, 1920.

Age and Distribution: The only objection that could be raised against synonymising *Fanninoceras* with *Radstockiceras* is that of the difference in age but this is not sufficient. Frebold (1967, p. 1147) has already suggested an Early Pliensbachian age for the type locality of *Fanninoceras* on Maude Island. In Oregon *Fanninoceras* occurs in beds

equivalent in age to the early Domerian (Imlay, 1968) whereas in Europe the latest representatives of *Radstockiceras* occur in the Davoei Zone (upper Carixian). All that is required therefore is an extension of the range of *Radstockiceras*, its revised range now being from the Jamesoni Zone (Carixian) to the Margaritatus Zone (Domerian).

*Radstockiceras fannini* (McLEARN, 1930)

Pl. 7, Fig. 5

- \*1930 *Fanninoceras fannini* McLEARN, p. 4, pl. 1, fig. 3.
- 1932 *F. fannini* McLEARN - McLEARN, p. 72, pl. 7, fig. 7, 8; pl. 8, fig. 1-8.
- 1959 *Polyplectus* sp. SILBERLING, p. 28.
- 1965 *Oxynoticeras* sp. HALLAM, p. 1488.
- 1967 *F. fannini* McLEARN - FREBOLD, pl. 1, fig. 2, 3 (holotype and one paratype refigured).
- 1970 *F. fannini* McLEARN - FREBOLD, pl. 2, fig. 5 (paratype refigured).
- 1978 *F. fannini* McLEARN - BLASCO, LEVY and NULLO, p. 424, pl. 1, fig. 7.

Material: Approximately 40 external moulds in mudstone, and one internal mould preserved in limestone.

Description: The shell is involute ( $\bar{U} \approx 14$ ) and oxyconic except for an internal stage up to a diameter of approximately 6 mm where the venter is somewhat rounded. The umbilical wall is always steep and undercut in some specimens. The ornamentation consists of broad, low, radial to slightly prorsiradiate straight ribs that fade just before reaching the venter.

The ribbing becomes obsolete at diameters greater than 20 mm with the exception of the figured specimen (Pl. 7, Fig. 5) which has ribs up to a diameter of 40 mm. The last half whorl of this specimen is a body chamber with a suture evident at its adapical end. The septal suture shows a fairly broad lateral lobe but no details can be seen because it is corroded.

Discussion: These specimens are conspecific with the type material figured by McLearn (1932) (e.g. pl. 7, fig. 7, 8). The range of *R. fannini* overlaps the lower part of the range of *R. kunae* (McLEARN) which differs in the sharper ribs that are projected ventrally and do not disappear with growth. *R. gemmellaroi* (POMPECKJ) differs in being much more involute.

Occurrence: *R. fannini* is reported from the Pliensbachian of the Queen Charlotte Islands, and the Province of Chubut



in Argentina (Frebald, 1967; Blasco *et al.*, 1978).

In the United States it occurs in the uppermost parts of section 7 (Hurwal Formation) in the Wallowa Mountains of Oregon, and in unit H of the Sunrise Formation exposed in the Shoshone Mountains, Nevada.

Localities: 75, 141, 144, 147, 159, 160, 161, 162, 164, 165, 167.

Age: Pliensbachian (Uppermost *D. dayiceroides* Zone and *R. fannini* Zone).

*Radstockiceras gemmellaroi* (POMPECKJ, 1906)

Pl. 7, Fig. 3; Text-fig. 6-9

- \*1884 *Amaltheus* n. sp. GEMMELLARO, p. 209, pl. 1; fig. 18, 19.
- 1884 *Sphenodiscus requienianus* ? D'ORBIGNY - WHITEAVES, p. 248, pl. 22, fig. 4, 4a (*non* d'Orbigny).
- 1906 *Oxynoticeras gemmellaroi* POMPECKJ, p. 283.
- 1930 *Fanninoceras carlottense* McLEARN, p. 4.
- 1932 *F. carlottense* McLEARN - McLEARN, p. 76, pl. 8, fig. 9, 10.
- 1967 *F. carlottense* McLEARN - FREBOLD, pl. 1, fig. 1 (holotype refigured).
- 1968 *F. cf. carlottense* McLEARN - Imlay, p. C44, pl. 8, fig. 23, 24.
- 1970 *F. carlottense* McLEARN - FREBOLD, p. 435, pl. 2, fig. 3 (holotype refigured).

- 1972 *Metoxynoticeras* cf. *involutum* (POMPECKJ, 1907) -  
GECZY, pl. 3, fig. 1.
- 1976 *Radstockiceras involutum aequisellatum* n. ssp. GECZY,  
p. 37, pl. 4, fig. 1.
- 1977 *R. gemmellaroi* (POMPECKJ) - WIEDENMAYER, p. 55,  
pl. 12, fig. 1-5, 10-12; text-fig. 11a, b.
- 1978 *Fanninoceras carlottense* McLEARN - BLASCO, LEVY and  
NULLO, p. 425, pl. 1, fig. 4a, b.
- ? in press *F.* cf. *carlottense* McLEARN - IMLAY, not figured.

Material: Eight specimens preserved in limestone.

Measurements: See Fig. 6-9.

Description: The complete specimen, which does not appear to be septate, reaches a diameter of 73 mm. Larger diameters are reached, however, as evidenced by one of the fragments which has a maximum measurable whorl height of 60 mm. This species is extremely involute, the umbilicus barely discernible at all growth stages. The shell is oxyconic, with a sub-vertical umbilical wall, very gently curved flanks, and knife-edge venter. The earliest whorls bear weak, densely spaced, flexuous ribs that arise a short distance from the umbilical wall and fade near the ventral area where they project slightly. All ribbing is

See synonymy for full references

- Gemmellaro, 1884  
Holotype of *R. gemmellaro* (GEMM)
- △ Whiteaves, 1884
- McLearn, 1932  
Holotype of *F. carlottense* (McLEARN)
- Geczy, 1976
- ▲ Wiedenmayer, 1977
- This study

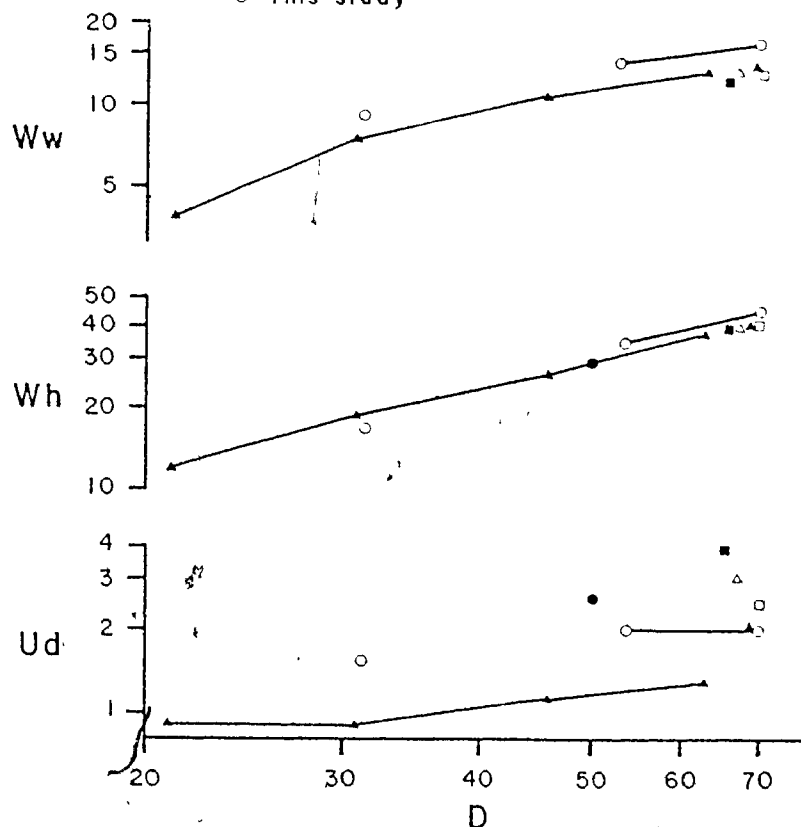


FIGURE 6-9 Double logarithmic plot of whorl height, whorl width, and umbilical diameter against diameter for *Radstockiceras gemmellaro* (POMPECKJ). Measurements in millimetres.

lost at diameters greater than approximately 30 mm.

One small individual (D = 14) shows that at this stage the shell is not as compressed and the venter has not developed its acute form evident in later whorls. A suture line is also evident on this specimen (Wl-11-6(1));

it shows a fairly broad first lateral saddle notched by a marked accessory lobe, and a deep, fairly narrow first lateral lobe.

Discussion: Although no sutures of large individuals are available for study on the Nevada material, conspecific large specimens collected from the Nicely Shale of Oregon by D. Taylor and now on loan to me from the University of California at Berkeley show excellent sutures. These have a broad external saddle and a trifid lateral lobe as encountered in "*Fanninoceras*" and *Radstockiceras gemmellaroi*. The Canadian "*Fanninoceras*" *carlottense* cannot be distinguished from *R. gemmellaroi* (Fig. 6-9).

Occurrence: Age as for the genus. *R. gemmellaroi* is reported from Alaska, British Columbia, Oregon, Argentina, Italy, Switzerland, and Hungary.

In this study, it is recorded for the first time from Nevada. All the specimens originate from the middle part of unit E of the Sunrise Formation exposed at Westgate in the Clan Alpine Mountains.

Localities: 100, 101, 102, 103.

Age: Pliensbachian (*R. fannini* Zone).

*Radstockiceras* cf. *kunae* (McLEARN, 1930)

## Pl. 7, Fig. 4

- ?\*1930 *Fanninoceras kunae* McLEARN, p. 5, pl. 2, fig. 4.
- ? 1930 *F. kunae* var. *latum* McLEARN, p. 5, pl. 2, fig. 3.
- ? 1932 *F. kunae* McLEARN - McLEARN, p. 77, pl. 8, fig. 11, 12.
- ? 1932 *F. kunae* var. *crassum* McLEARN, p. 78, pl. 9,  
fig. 1-4.
- ? 1932 *F. kunae* var. *latum* McLEARN - McLEARN, p. 78,  
pl. 9, fig. 5, 6.
- ? 1967 *F. kunae* McLEARN - FREBOLD, fig. 4 (holotype  
refigured).
- ? 1968 *F. kunae* McLEARN - IMLAY, p. C44, pl. 8, fig. 25-32.
- ? in press *F. kunae* McLEARN - IMLAY, pl. 7, fig. 11.

Material: Six poorly preserved external moulds of small individuals, and a number of fragments.

Description: The maximum diameter of the largest available specimen is approximately 25 mm. The specimens are fairly evolute compared with other closely related species ( $U \approx 24$ ). The shell is oxyconic and is ornamented with persistent bold ribs that are somewhat prorsiradiate and projected ventrally.

Discussion: *R. kunae* was first named by McLearn in 1930

but not adequately figured until 1932. McLearn recognised two varieties as well as the species itself which differ only in the coarseness of the ribs, and by slight differences in the width of the umbilicus. These differences are not clear cut and there seems little point in retaining these varietal names.

Since McLearn's original descriptions, *R. kunae* has been collected in Oregon from the Nicely Formation, and the upper part of the Hurwal Formation (Imlay, 1968). Imlay only figured material from the Nicely Formation and the larger specimens (pl. 8, fig. 28-32) are somewhat unusual in the coarseness of their ornament and in the roundness of their venters. The latter feature in particular is not characteristic of *R. kunae* and these specimens seem to be comparable to a specimen from the Pliensbachian of Austria figured by Rosenberg (1909, p. 282, pl. 14, fig. 15a-c) under the name of *Oxynoticeras haueri* FUCINI (non Fucini, 1909, p. 8, pl. 1, fig. 3, 4).

*R. kunae* differs from *R. fannini* and *R. gemmellaroi* in its ribbing which is sharper, persists to larger diameters, and projects forward ventrally. My specimens cannot be identified specifically with certainty, however, because of incomplete preservation.

Occurrence: *R. kunae* is reported from the Pliensbachian

6

of the Queen Charlotte Islands, Oregon, and Alaska (see synonymy for references). Judging from its stratigraphic position within the Nicely and Hurwal Formations (Imlay, 1968), it is characteristic of the Upper Pliensbachian. During this study it was collected from the Hurwal Formation exposed in the uppermost part of section 7, Wallowa Mountains, Oregon.

Localities: 147, 165, 166.

Age: Pliensbachian (*R. fannini* Zone).

FAMILY POLYMORPHITIDAE HAUG, 1887

SUBFAMILY XIPHEROCERATINAE SPATH, 1925

GENUS *Hyperderoceras* SPATH, 1926

Type-Species: *Ammonites armatus ruga* QUENSTEDT, 1884 (p. 206, pl. 25, fig. 9, 10; pl. 26, fig. 1) by original designation (Spath, 1926, p. 47). The presumed holotype (Quenstedt, pl. 25, fig. 9) is now lost; Schlegelmilch (1976, pl. 76, fig. 4) refigures one of the other type specimens.

Remarks: When Spath erected this genus he provided no description and included no other species apart from the type. Donovan and Forsey (1973, p. 15) make the following diagnosis: "Evolute, strongly ribbed eoderoceratids, in which certain ribs at irregular intervals are flared and

bear tubercles (about 5-12 per whorl on the septate whorls). The tuberculate ribs bifurcate; the others pass over the venter without interruption, and without loss of strength. Body chamber unknown."

Age and Distribution: *Hyperderoceras* is rare, and the record below is the first from outside Europe. It is known from the lower Carixian of Germany (Quenstedt, 1884); England (Howarth, 1962), and Hungary (Geczy, 1976).

*Hyperderoceras* n. sp.

Pl. 8, Fig. 1

Material: One quite well preserved fragment cut by a calcite vein, and one contact metamorphosed, poorly preserved whorl fragment.

Description: A large, fairly evolute form with a depressed whorl section (WS = 133). The flanks are strongly convex and the venter gently arched.

The ribs vary in strength, are somewhat prorsiradiate, and cross the venter almost transversely without being interrupted. Most of the ribs are simple and wirey, often gaining strength on the upper flank. At irregular intervals on the inner two whorls, but at approximately every fourth rib on the outer two whorls, a rib is thickened



and flares into a large, radially elongate tubercle from which two secondary ribs arise. No suture line is visible.

Discussion: This material agrees very well with the diagnosis for the genus but it cannot be matched exactly with any of the known species. Perhaps the morphologically closest is the type species *H. ruga* (QUENSTEDT, 1884) which differs in having a narrower whorl section, thicker ribs, and more rounded tubercles. *H. lina* (QUENSTEDT, 1884) and *H. fila* (QUENSTEDT, 1884) differ in ribbing and tuberculation style as well as in the form of the whorl section. *H. bimaecula* (QUENSTEDT, 1884), assigned to this genus by Dubar and Mouterde (1961), and Geczy (1976), has two rows of tubercles. Two species have been recognised from England but the neotype of *H. mamillatum* (SIMPSON) (see Howarth, 1962, pl. 15, fig. 6) is impossible to interpret. It consists of less than one whorl of a small, badly preserved individual; the inner whorls are not visible. *H. nativum* (SIMPSON), the holotype of which has been figured by Buckman (1913, pl. 84), is quite close to the American specimen but the whorl section is circular rather than depressed. *H. hungaricum* and *H. sp.* from Hungary (Geczy, 1976) both have much weaker ornamentation and more circular whorls than the American specimen.

Although the specimen represents a new species, it is not named because it is not considered adequate as a holotype.

Occurrence: From the lower part of unit E of the Sunrise Formation exposed in the Westgate District, Nevada.

Localities: 92, 97.

Age: Pliensbachian (*D. dayiceroides* Zone).

GENUS *Crucilobicerias* BUCKMAN, 1920

SUBGENUS *Metaderoceras* SPATH, 1925

Type-Species: *Ammonites muticus* D'ORBIGNY, 1844 (p. 274, pl. 80) by original designation.

Remarks: *Metaderoceras* was created as a genus by Spath (1925, p. 363) for a group of ammonites previously referred to *Crucilobicerias*. Spath gave no description of this new genus nor stated which species were to be referred to it. He did designate a type species (see above) but Donovan and Forsey (1973) have pointed out that d'Orbigny's figure of the type specimen is idealised, having been drawn from nine whorl fragments. Also, the width of the venter is exaggerated in the drawing. Donovan and Forsey refrained from designating a lectotype, pointed to the need for revising the species, and concluded, in keeping

with the Treatise (Arkell *et al.*, 1957), that *Metaderoceras* was a junior subjective synonym of *Cruciloboceras*. Bearing in mind that the inaccuracies of the type figure may have over-emphasised the differences in ventral width, it still seems inappropriate to synonymise the two genera; *Metaderoceras muticum* possesses a single row of tubercles situated along the ventral shoulder whereas the type species of *Cruciloboceras*, *C. crucilobatum* BUCKMAN, 1920 (pl. 178), has a second row low on the flank near the umbilical shoulder. Furthermore, as detailed stratigraphic work has progressed, particularly in southern Europe, a difference in age between the two genera has become apparent (see below). Mouterde (1970) consequently advocated the revival of *Metaderoceras* in which he included the species *Ammonites submuticus* OPPEL, *Amm. gemellaroi* LEVI, and *Deroceras venarense* OPPEL, as well as the new species *Metaderoceras beirense* MOUTERDE. This approach has been accepted by many authorities working on Tethyan Jurassic but there remains a seemingly overlooked problem best expressed by Mouterde (1976, p. 181). "In using the generic name *Metaderoceras* [in 1970], I wanted to avoid creating a new taxon before a complete study of the family Eoderoceratidae. In fact, '*M.*' *beirense* as well as '*M.*' *venarense* diverge notably from the type of the genus *Metaderoceras* by the trapezoidal (whorl) section, wider ventrally, and the strong ornamentation. The single

row of tubercles on the ventral shoulder, well marked in early ontogeny and often persistent up to the end of the body chamber, could indicate an affinity with the true *Eoderoceras*. Assignment to the genus '*Metaderoceras*' is not therefore considered as entirely satisfactory but provisional" (translation from French). The affinity of *M. beirense* with *Eoderoceras* has also been commented on by Wiedenmayer (1977, p. 58).

It seems probable that *Eoderoceras* and *Crucilobiceras* form the end members of a morphological spectrum bridged by *Metaderoceras*, and that a detailed statistical study of the group as a whole will be necessary before this taxonomic problem can be satisfactorily resolved. A start in gathering the data has been made by Rocha (1977). In the meantime, *Metaderoceras* will be provisionally retained as a subgenus of *Crucilobiceras*.

Age and Distribution: *Crucilobiceras* (*Metaderoceras*) as understood here is characteristic of the Carixian, particularly the Ibex Zone, although it ranges into the lower Domerian. The nominate subgenus *C. (Crucilobiceras)*, in contrast, is confined to the Upper Sinemurian. *C. (Metaderoceras)*, with the possible exception of *C. (M.) venarense*, is so prevalent in the Tethyan faunal realm during the Lower Pliensbachian that it should be regarded as a Tethyan marker.

It appears only briefly in the southern part of the Northwest European Province during the Lower Pliensbachian, e.g. at Cottard in central France (Dommergues and Mouterde, 1978). A single specimen of uncertain age collected from the Dorset coast and named *Deroceras eusculptum* by Spath (Lang and Spath, 1926) almost certainly belongs to this subgenus and as such, represents its most northerly occurrence.

*Cruciloboceras (Metaderoceras) beirense* MOUTERDE, 1970

Pl. 8, Fig. 4

- \*1970 *Metaderoceras beirense* MOUTERDE, p. 50, pl. 2, fig. 2a-c, 3, 4.
- 1972 *Metaderoceras beirense* MOUTERDE - GECZY, pl. 3, fig. 2; pl. 5, fig. 3; non pl. 4, fig. 4  
(= *Cruciloboceras evolutum brutum*, see Wiedenmayer, 1977, p. 59).
- 1976 "*Metaderoceras*" ? *beirense* MOUTERDE - MOUTERDE, pl. 1, fig. 1-5.
- 1976 *Metaderoceras beirense* MOUTERDE - GECZY, p. 58, pl. 11, fig. 7-9.

Material: One slightly distorted specimen. The internal whorls are replaced by calcite whereas almost the whole outer whorl consists of an internal mould formed by fine

grained sandstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>T</u>
L48(1)	43	21	49	11.2(26)	13.2(31)	85	6

Description: Coiling is evolute and the whorl section slightly compressed although there has been some secondary compaction. The widest part of the whorl is at the ventral margin. The umbilical wall is low and rounds rapidly into the very gently convex flanks. The flanks slowly diverge ventrally, the ventro-lateral margin is angular, and the venter is broad and gently arched.

The inner whorls are smooth. Low, broad, weakly prorsiradiate ribs terminating in spirally elongate tubercles arise at an umbilical diameter of approximately 2 mm. Ribbing becomes weaker whilst the tubercles become more marked adorally. On the outer whorls the ribs become looped and lirae are evident. The tubercles are off-set across the venter which is smooth.

No sutures are evident on the outer seven-eighths of a whorl which probably represents the body chamber whereas sutures on the inner whorls are too poorly preserved for further comment.

Discussion: *C. (M.) beirence* is noted for its polymorphism whereby specimens from the same bed possess identical inner whorls but differ in the (? mature) body chamber at larger diameters (Mouterde, 1976). The specimen under discussion here, however, is fairly small and shows the characters of the earlier whorls well, comparing most favourably with Mouterde's paratype from Pentelheira, Portugal (Mouterde, 1970, pl. 2, fig. 4).

This species differs considerably from other species of the subgenus *Metaderoceras*, particularly in the sparseness of the ribbing.

Occurrence: *C. (M.) beirence* has been collected from the Ibex Zone in Portugal and Hungary (Mouterde, 1970; Geczy, 1976). The specimen from the United States originates from the upper part of the Donovan Formation in east-central Oregon.

Localities: 131.

Age: Pliensbachian (? *D. dayiceroides* Zone).

*Cruciloboceras (Metaderoceras) evolutum* (FUCINI, 1921)

Pl. 8, Fig. 2, 3, 5; Text-fig. 6-10

1899 *Deroceras gemmellaroi* LEVI - FUCINI, p. 16,  
pl. 3, fig. 1, 2 (non Levi).

1909 *Deroceras muticum* D'ORBIGNY - ROSENBERG, p. 265,  
pl. 13, fig. 7.

- \*1921 *Deroceras evolutum* FUCINI, p. 50, pl. 1, fig. 14a, b.
- 1963 *Crucilobiceras* aff. *evolutum* (FUCINI) - DU DRESNAY,  
p. 147, pl. 2, fig. 2, 3.
- 1970 *C. pacificum* FREBOLD, p. 435, pl. 1, fig. 4,  
6-8 (non fig. 5); pl. 2, fig. 10.
- ? 1972 *Metaderoceras* gr. *gemmellaroi* (LEVI) - *evolutum*  
(FUCINI) - FERRETTI, pl. 13, fig. 1.
- 1975 *M. gemmellaroi* (LEVI) - FERRETTI, pl. 24, fig. 4,  
(non Levi).
- 1977 *Crucilobiceras evolutum* <sup>4</sup>*evolutum* (FUCINI) -  
WIEDENMAYER, p. 59, pl. 13, fig. 3 (original of  
Rosenberg, 1909, pl. 13, fig. 7 refigured).
- 1978 *Metaderoceras evolutum* (FUCINI) - DUBAR and  
MOUTERDE, p. 44, pl. 2, fig. 1.
- non 1978 *Metaderoceras* sp. 3 (gr. *M. evolutum* FUCINI) -  
COLERA *et al.*, p. 314, pl. 1, fig. 2; pl. 2, fig. 2  
(? = *M. atlantis* DUBAR and MOUTERDE).

Material: Two specimens and four fragments from Nevada;  
approximately 53 impressions from Oregon, mostly fragments.

Measurements: See Fig. 6-10.

Description: This species reaches a large size. It is  
characterised by evolute coiling and a compressed whorl  
section. The umbilical wall is low and rounds gently



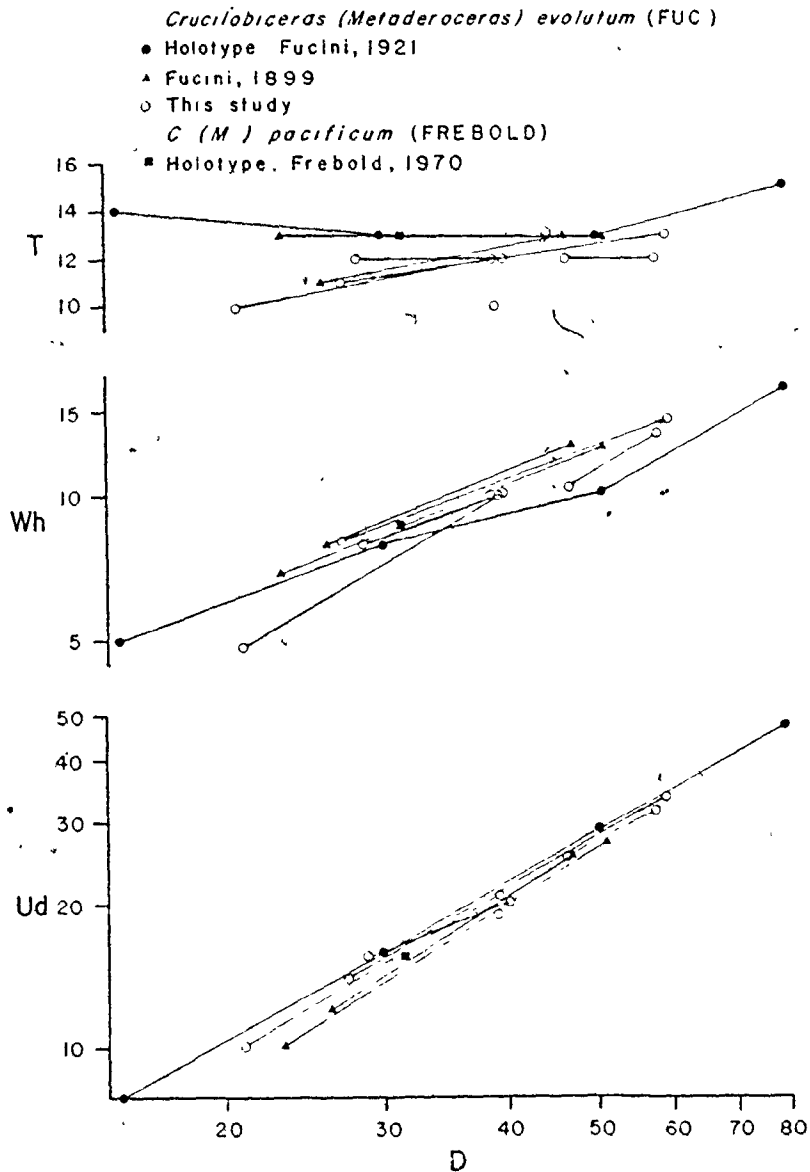


FIGURE 6-10 Plot of umbilical diameter, whorl height, and number of tubercles per half whorl for *Crucilobicerus (Metaderoceras) evolutum* (FUCINI).

into the slightly convex flanks. The venter is tabulate and unornamented. On internal moulds (in limestones) the ornamentation is seen to consist of both weak and moderately strong, simple ribs and sometimes faint lirae that are radial to slightly prorsiradiate in trend. Each major

primary rib terminates in a strong, rounded tubercle (11 to 13 per half whorl) at the angular ventro-lateral shoulder. On external moulds the lirae are more marked and the intercalated ribs are more evident showing a tendency toward fibulation, particularly on larger whorls. Also, tubercles are seen to be the base of long (up to 1 cm at a whorl height of 1.5 cm), hollow, sharp spines that are directed ventrally.

Discussion: These specimens match most closely with *C. (M.) evolutum* and its synonyms. Included is *C. pacificum* FREBOLD which is common in the insular belt of western British Columbia. Frebold compared this species with *C. evolutum* but stated that Fucini's (1921) and du Dresnay's (1963) material was considerably larger, and that the whorls of the Queen Charlotte Island specimens increase faster in height and thickness. On the first point, Frebold notes that the holotype is septate to the end of the last whorl, and his material almost certainly represents juveniles. In fact specimens of this species collected from the Maude Formation of Graham Island (Queen Charlotte Islands) and now in the collections of the University of California at Berkeley reach diameters in excess of 10 cm. With regard to the second point, the expansion rate (Raup, 1967) of *C. pacificum* is approximately 1.9 whereas the range of the

expansion rate for *C. (M.) evolutum* and its synonyms is 1.8 to 2.0. This is reflected in Fig. 6-10 where, at identical diameters, a plot of the whorl height of the holotype for *C. pacificum* falls on the line for "*Deroceras gemmellaroi* LEVI" of FUCINI (1899, pl. 3, fig. 1) but between the lines for the holotype and "*D. gemmellaroi* LEVI" of FUCINI (*op. cit.*, fig. 2). An inclusion of *C. pacificum* in *C. (M.) evolutum* therefore seems fully justified.

*C. (M.) gemmellaroi* LEVI, 1896 is closely related to *C. (M.) evolutum* showing similarities in evolution, whorl shape, and the presence of lirae. It differs in possessing slightly more tubercles per whorl and in lacking fibulated ribs.

Occurrence: This species ranges through the Carixian (from the upper Jamesoni Zone) and Domerian in rocks of Tethyan aspect in Europe. It has been recorded from Morocco (where it is restricted to the Ibex Zone), Italy, and Austria. Subspecies or closely related forms have also been recorded from Spain (Colera *et al.*, 1978), and Hungary (Geczy, 1976).

In North America it is now recorded from Nevada to the Queen Charlotte Islands and probably the Wrangell Mountains of southern Alaska (Imlay, in press).

Localities: 139, 141, 143, 153, 154, 155.

Age: Pliensbachian (A. (L.) pinnaforme Zone).

*Crucilobicerast* (*Metaderoceras*) cf. *muticum* (D'ORBIGNY, 1844)

Pl. 9, Fig. 1, 2; Pl. 10, Fig. 1

- ?\*1844 *Ammonites muticus* D'ORBIGNY, p. 274, pl. 80.
- non 1909 *Deroceras muticum* D'ORB. - ROSENBERG, p. 265,  
pl. 13, fig. 7 (= *C. (M.) evolutum*).
- non 1958 *Crucilobicerast* cf. *muticum* (D'ORB.) - DONOVAN, p. 36,  
pl. 3, fig. 2 (? = *C. (M.) submuticum* (OPPEL)).
- ? 1965 *C.* cf. *muticum* (D'ORB.) - BREMER, p. 155.
- ? 1970 *Acanthopleuroceras sutherlandbrowni* FREBOLD, p. 440,  
pl. 1, fig. 1.
- ? 1971 *Metaderoceras muticum* (D'ORB.) - CANTALUPPI and  
MONTANARI, p. 21, pl. 12, fig. 1a, b.
- ? 1976 *M. muticum* (D'ORB.) - GECZY, pl. 11, fig. 3, 4.
- in press *Crucilobicerast* cf. *muticum* (D'ORB.) - IMLAY,  
pl. 7, fig. 6-10, 12-15.

Material: Approximately 200 specimens, most of them fragments, preserved in phosphatic limestone, mudstone, siltstone, and fine grained red sandstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
1-0-7 D-10' (2)	70	30	43	--	22(31)	--	--
L48(14)	e100	e56	56	e21.9(22)	e23.5(24)	.93	17
J2067	130	70	54	--	--	--	19
	109	48	53	34.6(32)	31(28)	1.12	17

Description: A fairly evolute form with a whorl section that is subquadrate, slightly higher than wide to diameters of approximately 10 cm after which it becomes depressed. The umbilical wall is rounded and the flanks and venter gently arched except at larger diameters where the whorl section is more inflated.

The ribbing is quite dense on the earlier whorls but it quickly becomes more sparse, coarser, and somewhat prorsiradiate. Each rib terminates ventrally in a sharp, tangentially elongate tubercle. The ribs begin to project forward from the tubercles but they quickly fade, leaving the ventral surface smooth.

Discussion: These specimens are identical to material collected from southern Alaska and named *Crucilobiceras* cf. *muticum* (Imlay, preprint). They are similar to *C. muticum* in the volution and overall ornamentation but they differ in the ribbing being a little more dense at small diameters, and in the whorl section being less compressed, particularly at larger diameters. It is difficult to comment on whorl

shape since the diameter at which the change occurs in the American material is in excess of the maximum diameter of the holotype. It could, in fact, mark the advent of maturity since a change in whorl shape is quite common at this stage.

The only other North American species that might be confused with this form is *C. (M.) silviesi* which differs in its much denser, more prorsiradiate ribbing, and in its whorl section which remains compressed throughout.

Occurrence: *C. (M.) muticum* is characteristically a Carixian form (Jamesoni Zone) although there are possible occurrences from the Upper Sinemurian (Bremer, 1965). The specimens from Alaska are assigned to the Sinemurian on the basis of their joint occurrence with echioceratids (Imlay, in press), but the latter are here considered as misidentified polymorphitids (probably *Acanthopleuroceras*) so that a Carixian age for the species is also apparent in North America.

The specimens from Nevada and Oregon were collected from unit 5 of the Sunrise Formation in the Gabbs Valley Range; unit D of the Sunrise Formation at Westgate; the Donovan Formation; the Keller Creek Shale, and the Hurwal Formation.

Localities: 34, 35, 36, 37, 38, 61, 89, 131, 132,

134, 139, 141, 144, 148, 149, 151, 152, 153, 156, 157, 158,  
162, 168.

Age: Pliensbachian (A. (L.) *pinnaforme* and *D.*  
*dayiceroides* Zones).

*Crucilobiceras* (*Metaderoceras*) *silviesi* (HERTLEIN, 1925)

Pl. 11, Fig. 1

\*1925 *Uptonia silviesi* HERTLEIN, p. 39, pl. 3, fig. 1,  
2, 5.

Material: Approximately 50 specimens, mostly fragments,  
preserved in sandstone and siltstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
Plaster cast	--	--	--	27.6	40	.69	--
of holotype	155	89	57	28.8(19)	37.7(24)	.76	34
SU99(1)	--	c41	--	--	--	--	27
(distorted)	--	c19	--	--	--	--	24

Description: An evolute form that reaches a very large  
size (one whorl fragment reaching a height of 46 mm).

The whorl section is subquadrate, higher than wide. The  
ornamentation consists of densely spaced, strong, simple  
prorsiradiate ribs that are marked at the ventro-lateral  
shoulder by sharp, rounded tubercles. The ribs project  
forward from the tubercles onto the ventral surface and

quickly reduce in strength to form weak chevrons.

Discussion: "*Uptonia*" *silviesi* is the only Carixian ammonite ever to have been described from the conterminous United States. The original figure of the holotype was quite poor, however, and the journal in which it was published is somewhat difficult to obtain so that a plaster cast of the holotype is figured here (Pl. 11, Fig. 1). The species is assigned to *Cruciloboceras* (*Metaderoceras*) rather than *Uptonia* because it is tuberculate.

Occurrence: Collected from the top of unit 4 of the type Sunrise Formation (Gabbs Valley Range); the Donovan Formation of south-central Oregon, and the Hurwal Formation exposed in the Wallowa Mountains, northeastern Oregon.

Localities: 44, 131, 132, 133, 135, 141, 144, 146, 148, 149, 150, 153, 156, 168.

Age: Pliensbachian (A. (L.) *pinnaforme* Zone).

GENUS *Microderoceras* HYATT, 1871

Type-Species: *Ammonites birchi* J. SOWERBY, 1820 (p. 121) by subsequent designation (Spath, 1926, p. 171).

Lectotype designated by Donovan and Forsey (1973, p. 10, pl. 1, fig. 1a, b).



Remarks: Evolute form with two persistent rows of tubercles.

Age and Distribution: A cosmopolitan genus ranging from the Sinemurian (Turneri Zone) to the Pliensbachian (Jamesoni Zone).

*Microderoceras* cf. *birchiades* ROSENBERG, 1909  
Pl. 10, Fig. 2

- ? 1867 *Ammonites birchi* SOWERBY - DUMORTIER, p. 130,  
pl. 41, fig. 1, 2.
- ? 1899 *Microderoceras* cf. *herberti* OPPEL - FUCINI,  
p. 161, pl. 21, fig. 3.
- ?\*1909 *M. birchiades* ROSENBERG, p. 262, pl. 13,  
fig. 5a, b.
- ? 1927 *M. birchiades* ROSENBERG - SCHRÖDER, p. 204.
- ? 1975 *M. aff. birchiades* ROSENBERG - FERRETTI, pl. 23,  
fig. 1.

Material: One crushed quarter-whorl.

Description: The fragment from the Shoshone Mountains is from a large, evolute individual (Wh  $\approx$  3.5 cm) which had an unkeeled venter. The umbilical slope is gently rounded and the flat flanks bear two rows of strong tubercles

connected by broad, simple ribs. Ten pairs of tubercles can be counted on this quarter whorl. The ribs and their tubercles are sometimes irregularly spaced, and faint lirae running parallel to the ribs are present throughout.

Discussion: On the basis of its ornamentation, this specimen is confidently assigned to the genus *Microderoceras* although its preservation leaves doubt as to its specific affinities. This specimen is identical with a much larger specimen collected from the Maude Formation of the Queen Charlotte Islands and now held in the collection of the University of California at Berkeley. Both specimens were associated with echioceratids suggesting a Late Sinemurian age. Similar but even more poorly preserved specimens of this have been recorded from Mexico (Erben, 1956, pl. 41, fig. 10 and ? 12).

Occurrence: *M. birchiades* has been collected from France, Austria, southern Germany, Italy, and possibly Mexico. This species is characteristically found in the Oxynotum Zone of the Upper Sinemurian but it probably ranges into the Pliensbachian.

In western Nevada this similar form is found in the Shoshone Mountains associated with echioceratid ammonites.

Localities: 71.

Age: Sinemurian ( *P. harbledownense* Zone).

SUBFAMILY PHRICODOCERATINAE SPATH, 1938

GENUS *Phricodoceras* HYATT, 1900

Type-Species: *Ammonites taylori* SOWERBY, 1826 (pl. 514, fig. 1, 2) by original designation.

Remarks: Early stages depressed or rounded, strongly ribbed, and bearing marked median lateral and paired ventral tubercles. Outer whorls compressed with ribbing becoming weak or obsolete and the tubercles dying out. Relatively few species of this distinct genus have been recognised despite a wide geographic and stratigraphic range (Geczy, 1976, p. 77).

Synonyms: *Hemiparinodoceras* GECZY, 1959.

Age and Distribution: The earliest *Phricodoceras* is known from the Jamesoni Zone (Pliensbachian) of the Northwest European Province where *P. taylori* is a subzonal index (Dean *et al.*, 1961) in spite of the fact that it is quite rare in France and Britain. During the course of the Pliensbachian its distribution seems to have spread to the south where *Phricodoceras* existed for a much longer

period in the Tethyan Province. Species are known from the Ibex and Davoei Zones of Hungary (Geczy, 1976), with the last representatives occurring in the Margaritatus Zone of Italy (Sestini, 1978). *Phricodoceras* was present along the northern margin of Gondwanaland from Morocco (Dubar and Mouterde, 1978), to Turkey (Bremer, 1965). It is also recorded from the Lodgepole area, south of Fernie, British Columbia (Frebold, 1970).

*Phricodoceras* sp.

Pl. 10, Fig. 3

Material: Two specimens: a poorly preserved outer whorl, and an external mould of a smaller individual with part of a whorl attached.

Description: As far as can be ascertained, the species was fairly involute, and the whorl section rounded. On the inner whorls the ribs are densely spaced and bear four tubercles, two on the middle of the flanks and two ventrally. The mid-flank tubercles are soon lost but the ventral tubercles which are radially elongate persist.

Discussion: There is no doubt in the assignment of these specimens to the genus *Phricodoceras* although the state of preservation does not permit designation to species

level. They are similar in some respects to *P. taylori* which has been tentatively recognised in British Columbia (Frebold, 1970) but they also compare with a specimen from Morocco figured by Dubar and Mouterde as *P. cf. lamellosum* (1978, pl. 3, fig. 3). A confident species identification must await the discovery of better preserved material.

Occurrence: From the lowermost Hurwal Formation, Sheep Ridge, in the Wallowa Mountains, Oregon.

Localities: 148, 150.

Age: Pliensbachian (*ex situ*, ? *A. (L.) pinnaforme* Zone).

#### SUBFAMILY ACANTHOPLEUROCERATINAE ARKELL, 1950

Remarks: The classification of the Treatise (Arkell *et al.*, 1957), which agrees with that of Schindewolf (1962) based on sutural studies, is followed here in that *Tropidoceras* and *Acanthopleuroceras* are included within the Acanthopleuroceratinae as a subfamily of the Polymorphitidae. The distinction between *Tropidoceras* and *Acanthopleuroceras* is sometimes difficult (see discussion below) but they are distinct from all other polymorphitids in possessing a keel. The abandonment of the subfamily as proposed by Donovan and Forsey (1973, for the new edition of the

Treatise) does not, therefore, seem justified.

GENUS *Tropidoceras* HYATT, 1867

Type-Species: *Ammonites masseanum* D'ORBIGNY, 1844,  
by subsequent designation (Haug, 1885, p. 606).

Remarks: Fairly evolute forms with a compressed lanceolate whorl section bearing a keel. Ribbing may be differentiated into primaries and secondaries but tubercles are characteristically absent. It differs from *Acanthopleuroceras* to which it is closely related (Dommergues and Mouterde, 1978) in its whorl section, which is more depressed in *Acanthopleuroceras*, often with a fastigate venter; in its keel, which is blunt or absent in *Acanthopleuroceras*, and in the lack of tuberculation, *Acanthopleuroceras* being characteristically bituberculate (Spath, 1928).

Age and Distribution: *Tropidoceras* is a cosmopolitan genus that is particularly abundant in faunas of Tethyan aspect. It possibly arises in the Late Sinemurian, reaches its acme in the Ibex Zone, and ranges upward into the Davoei Zone (Donovan, 1958; Geczy, 1976). As already noted by Spath (1928, p. 225), *Tropidoceras* was the root stock for the Upper Pliensbachian and characteristically Tethyan genus *Arietoceras* which is well represented in the Americas.

*Tropidoceras actaeon* (D'ORBIGNY, 1844)

Pl. 10, Fig. 4-8; Text-fig. 6-11.

- \*1844 *Ammonites actaeon* D'ORBIGNY, p. 232, pl. 61,  
fig. 1-3.
- 1893 *Cycloceras actaeon* FUTTERER, p. 329, pl. 12,  
fig. 2.
- 1928 *Tropidoceras* aff. *T. actaeon* (D'ORB.) - SPATH,  
p. 228, pl. 16, fig. 7a, b.
- 1928 *T. actaeon* (D'ORB.) - SPATH, p. 229, pl. 17, fig. 9a, b.
- 1965 *T. actaeon orientale* (D'ORB.) - BREMER, p. 189,  
pl. 16, fig. 9a, b; text-fig. 3.
- 1970 *T. actaeon* (D'ORB.) - FREBOLD, p. 440, pl. 2,  
fig. 13a, b, 14a, b, 15a, b.
- 1976 *T. actaeon* (D'ORB.) - SCHLEGELMILCH, p. 65, pl. 31,  
fig. 1.
- 1978 *Acanthopleruoceras actaeon* (D'ORB.) - MOUTERDE  
and DOMMARGUES, fig. 25a, b.
- 1978 *A. actaeon* (D'ORB.) - DOMMARGUES and MOUTERDE,  
fig. 2, no. 6; pl. 3, fig. 6a-c, 7a-c, 8a-c.
- in press *Tropidoceras actaeon* (D'ORB.) - IMLAY, pl. 8,  
fig. 1-9.

Measurements: See Fig. 6-11.

Material: Eighteen external and internal moulds preserved

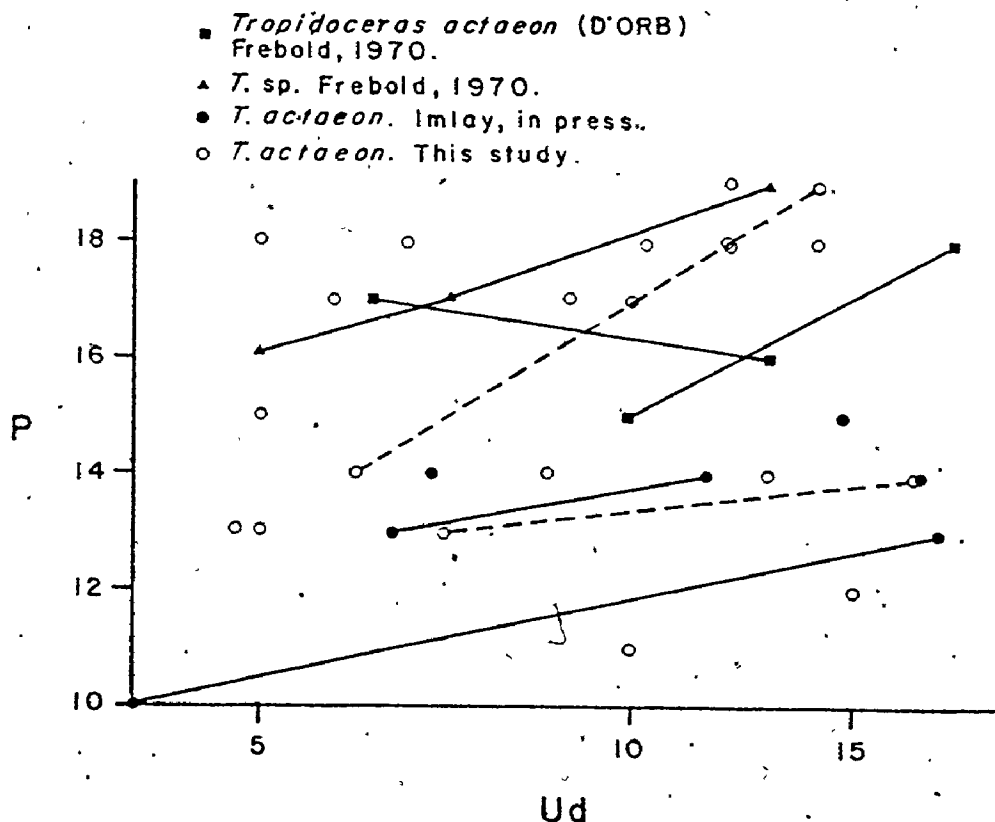


FIGURE 6-11 Rib density plot for *Tropidoceras actaeon* (D'ORB.)

in mudstones and siltstones; approximately 40 small individuals preserved in greywacke.

Description: This is an evolute form ( $U \approx 40$ ) with a compressed, ovate whorl section. On early whorls the venter is narrowly rounded but it sharpens to a low keel in later whorls. The ribs are simple, very gently signoid, and narrow with wide interspaces although ribbing density varies as discussed below. The ribs arise on the umbilical wall, maintain their strength across the flank, and then fade quickly as they swing forward onto the venter.



Discussion: The specimens of *T. actaeon* reported from Canada (Frebold, 1970) and Alaska (Imlay, in press) differ somewhat in the density of their ribbing, which on the Alaska specimens is consistently lower. Variability in this character has already been noted by Frebold, however, who separated some particularly densely ribbed forms as *Tropidoceras* sp., stating that they may represent either a variant or a new species (Frebold, 1970, p. 441). The specimens available here show a range in ribbing density which spans that exhibited by the Alaskan and Canadian specimens assigned to *T. actaeon* as well as one of the forms of *T. sp.* described by Frebold (1970, pl. 2, fig. 17). Since the material occurs at the same localities (as does Frebold's material), the ribbing density is here considered a variable feature.

Occurrence: *T. actaeon* is cosmopolitan but particularly common in the Carixian of Tethys, and is characteristic of the Ibex Zone. The specimens described here originate from the lower part of section 7 measured in the Hurwal Formation, and the Keller Creek Shale, Oregon.

Localities: 136, 141, 142, 143, 144, 154, 168.

Age: Pliensbachian (A. (L.) pinnaforme Zone).

GENUS *Acanthopleuroceras* HYATT, 1900

Type-Species: *Ammonites valdani* D'ORBIGNY, 1844, by subsequent designation (below). Hyatt (1900, p. 578) designated *Ammonites natrix* SCHLOTHEIM as the type species but he based this on Zieten's illustration (1830, pl. 4, fig. 5) of *Ammonites natrix*, the only representation of the species available at the time. As pointed out by Quenstedt (1843) and later Jaworski (1931) who was the first to figure the holotype, Schlotheim's species is in fact an echioceratid. *Acanthopleuroceras* was therefore based on a misidentified type-species. Bremer (1965, p. 185) renamed *Ammonites natrix sensu* ZIETEN, as *Acanthopleuroceras pseudonatrix*, and this was accepted as the type-species by Frebold (1970, p. 439) although Bremer had pointed out its unsuitability in this respect. The type material is lost and there is some doubt as to the accuracy of Zieten's figure so that Getty (1970) finally proposed *Ammonites binotatus* OPPEL, 1862 as the type-species. Getty considered *Amm. binotatus* as the new name for *Ammonites valdani* D'ORBIGNY, 1844, a homonym of *Ammonites* ["*Turrilites*"] *valdani* D'ORBIGNY, 1842. D'Orbigny's 1844 species was upheld (ICZN Opinion 996, 1973), however; and it now becomes the type-species of *Acanthopleuroceras*.

Remarks: The lectotype of *Amm. valdani* (Getty, 1970,

pl. 3) is fairly evolute with a compressed whorl section and a fastigate venter bearing a conspicuous keel. Ribbing is simple, characteristically bituberculate, and swings forward onto the venter. Some species of *Acanthopleuroceras* show a tendency toward a square whorl section and rursiradiate ribbing.

*Acanthopleuroceras* is held to be closely related to *Tropidoceras* by most workers (see Dommergues and Mouterde, 1978) whereas Wiedenmayer (1977) believes they represent separate lineages. *Acanthopleuroceras* differs from *Tropidoceras* in its less compressed whorl section, the blunt keel, and the bituberculate ornamentation. Unlike *Acanthopleuroceras* s. s., *Tropidoceras* often bears secondary ribs.

Age and Distribution: *Acanthopleuroceras* is found throughout Europe and the Mediterranean countries, and is also reported from British Columbia. It is characteristic of the Ibex Zone, particularly its middle parts.

SUBGENUS *Acanthopleuroceras* HYATT, 1900

*Acanthopleuroceras* (*Acanthopleuroceras*)

cf. *valdani* (D'ORBIGNY, 1844)

Pl. 10, Fig. 11

?\*1844 *Ammonites valdani* D'ORBIGNY, pl. 71 (refigured by

Getty, 1970, pl. 3).

Material: One poorly preserved external mould of a large individual.

Description: The specimen, which is not complete, has a diameter of approximately 120 mm. It is an evolute form with a low expansion rate. The exact nature of the whorl section is not known because of the state of preservation but the umbilical wall is fairly steep, and the flanks almost flat.

The ribbing is simple, rursiradiate, and dense (P = 19 at Ud = 45 mm). Little may be said of the inner whorls since the mould is quite corroded here but at an umbilical diameter of approximately 25 mm, sharp, round tubercles are evident on the umbilical shoulder at the dorsal end of each rib. Swelling of the ribs near the umbilical seam suggests a second row of tubercles positioned near the ventro-lateral shoulder.

Discussion: The state of preservation precludes a confident assignment to specific level, particularly as the lectotype and most other specimens figured in the literature are relatively small, and it is the inner whorls of the specimen from Nevada that are most poorly preserved. Consequently,

it was felt that a complete synonymy would serve little purpose. A large fragment of *A. (A.) valdani* figured by Wright (1880, pl. 38, fig. 3; Donovan, 1954) compares most favourably with the American specimen although the ribbing is not quite as rursiradiate. *A. (A.) cf. valdani* differs from *A. (A.) mulleri* in its sharper, more rursiradiate ribbing; its greater expansion rate, and in its sharper tuberculation. It is similar to *A. (A.)* sp. described herein but differs in possessing a dorsal row of tubercles.

Occurrence: *A. (A.) valdani* is widespread in Europe where it is characteristic of the Ibex Zone. The specimen from Nevada originated from the top of unit 4 of the Sunrise Formation exposed in the Gabbs Valley Range.

Localities: 44.

Age: Pliensbachian (*A. (L.) pinnaforme* Zone).

*Acanthopleuroceras (Acanthopleuroceras) mulleri* n. sp.

Pl. 12, Fig. 1-3; Text-fig. 6-12

Derivation of Name: In honour of the late Professor Simon Muller of Stanford University.

Diagnosis: Evolute; compressed, subquadrate whorls; weakly sulcate, rounded keel; rectiradiate to rursiradiate, bituberculate ribs.

Holotype: Catalogue Number D-10'(1), Pl. 12, Fig. 1.

From locality 60 in the Sunrise Formation exposed in Volcano Peak Gulch, Gabbs Valley Range, Nevada.

Material: The holotype, four other specimens, and three fragments, preserved in sandstone and mudstone.

Measurements: See Fig. 6-12.

Description: Evolute ( $\bar{U} = 53$ ) form with a whorl section that is slightly higher than wide, and a flattened venter bearing a rounded keel bordered by weak sulci. The umbilical wall is low and rounds rapidly into the flat flanks. The ribbing is simple, quite dense (see Fig. 6-12), and gently rursiradiate to radial. The ventral ends of the ribs are swollen and at umbilical diameters greater than approximately 1 cm small, rounded tubercles appear, accompanied by similar tubercles on the dorsal end of the ribs. The ribs project sharply onto the ventral surface but soon fade, particularly on the outer whorls. No septal suture is available for study.

Discussion: The whorl section of *A. (A.) mulleri* is not as compressed (WS = 92) as in other species of *Acanthopleuroceras* with the exception of *A. (A.) pseudonatrix*

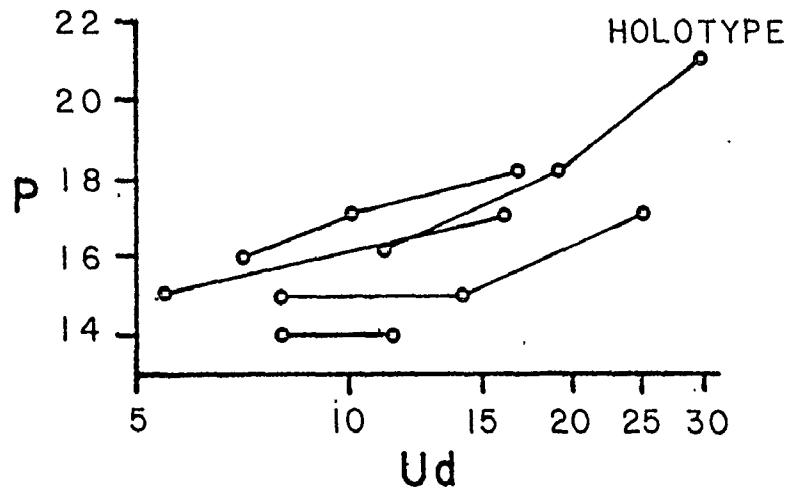


FIGURE 6-12 Rib density plot for *Acanthopleuroceras mulleri* n. sp.

BREMER (Bremer, 1965, fig. 3x; see also Schlegelmilch, 1976, pl. 29, fig. 7) (WS = 1). The presence of a weakly sulcate keel is distinctive. *A. arietiforme* (OPPEL) (Schlegelmilch, 1976, pl. 30, fig. 4 and references; Dommergues and Mouterde, 1978, pl. 1, fig. 19) is also sulcate but differs from *A. (A.) mulleri* in the compressed whorl section and less dense ribbing. Other sulcate species are *A. ?* sp. aff. *arietiforme* (OPPEL) (Geczy, 1976, p. 93, pl. 18, fig. 2), and *A. subarietiforme* (FUTTERER) (Geczy, 1976, p. 94, pl. 18, fig. 3). Both species differ from *A. (A.) mulleri* in their greater expansion rates.

Occurrence: The lower part of unit 5 of the Sunrise Formation in Volcano Peak Gulch, Gabbs Valley Range;

lower part of unit D, Sunrise Formation at Westgate, Nevada, and the Keller Creek Shale, Oregon.

Localities: 60, 88, 137.

Age: Pliensbachian (A. (L.) *pinnaforme* Zone).

*Acanthopleuroceras* (*Acanthopleuroceras*) spp.

Pl. 10, Fig. 9, 10

? 1970 *Pleuroceras* ? spp. indet. FREBOLD, p. 441, pl. 3, fig. 5-9.

? 1978 *Arieticeras* sp. HIRANO, MIKAMI and MIYAGAWA, p. 414, pl. 51, fig. 1a, b.

? in press *Paltechioceras* cf. *harbledownense* (CRICKMAY) - IMLAY, pl. 4, fig. 18-21 only.

Material: Approximately 35 specimens and fragments preserved as external moulds in siltstone and mudstone.

Description: Evolute forms ( $U \approx 45-50$ ) whose whorl section cannot be studied due to the mode of preservation. The umbilical wall is low and rounds rapidly into the gently convex flanks. One fragment shows that the venter is fastigate and bears a low, rounded keel.

Ribbing is simple and dense, approximately 20 per half whorl on early whorls decreasing slightly on outer whorls. The ribs are rursiradate and bear small



tubercles on their ventral ends. From the tubercles the ribs reduce in strength and project onto the venter to abut against the keel. On some forms the ribbing is wirey whereas on others it is consistently coarser, suggesting that more than one species might be represented.

Discussion: The preservation of this material is poor, making comparisons difficult. Frebold (1970) has figured similar material collected from the Halfway River area of northeastern British Columbia. His specimens are associated with *Proactylioceras* at some localities and *Amaltheus* at others, suggesting a late rather than an early Carixian age, the age of the material described here. Frebold tentatively assigned his specimens to the Late Pliensbachian genus *Pleuroceras* but this genus is very distinctive in having a tabulate venter bearing a crenulated keel. Such a keel is not readily apparent from Frebold's figures, and the keels on the American material are definitely unornamented. A closer comparison may be drawn with the unituberculate forms of the genus *Acanthopleuroceras* rather than *Pleuroceras*. Schröder (1927, p. 6, pl. 1, fig. 1) figured a specimen from the Fleckenmergel facies of southern Germany that he referred to *A. sella* SCHAFFHAUTL. It is very similar to the North American material except that the ribs are sparser on the inner whorls. Geczy (1976, p. 96) considers

Schröder's specimen to be closely related to *A. stahli* (OPPEL) and this too is similar to the North American material. A conclusion must await the discovery of better preserved North American material but if both the Canadian and the American material does prove to belong to *Acanthopleuroceras*, then the genus existed for a longer period in the eastern Pacific than it did in Europe.

A recently described fragment from the Higuchi Group of southwestern Japan (Hirano *et al.*, 1978) is also tentatively compared with the material from the United States. Not only is the Japanese specimen poorly preserved but it is also *ex situ*, having been collected from the gravel of a river bed. The volution and particularly the style of ribbing is very similar to the American material. The Japanese workers assigned the specimen to *Arieticeras* but the ventral ends of the ribs appear swollen (if not tuberculate), suggesting that an assignment to *Acanthopleuroceras* would be more appropriate.

The material from Alaska assigned to *Paltechioceras* cf. *harbledownense* by Imlay (preprint) includes specimens that are not echioceratids and that are assignable to *Acanthopleuroceras* as discussed on p. 191.

Occurrence: From the middle and lower parts of section 7 measured in the Hurwal Formation of the Wallowa Mountains,

Oregon, and from the lower half of unit D of the Sunrise Formation exposed in the Westgate District of Nevada.

Localities: 88, 89, 141, 143, 144, 149, 150, 151, 168.

Age: Pliensbachian (A. (*L.*) *pinnaforme* and *D. dayiceroides* Zones).

SUBGENUS *Luningiceras* n. subgen.

Derivation of Name: After the town of Luning, Mineral County, Nevada.

Type-Species: *Acanthopleuroceras* (*Luningiceras*) *pinnaforme* n. sp.

Diagnosis: Large, evolute forms; whorl section subquadrate to slightly compressed with a gently arched venter bearing a low keel. Primary ribs tending to be rursiradiate; bituberculate at large diameters with more prominent ventral tubercles. Dense, strongly projected secondaries.

Discussion: The distinction between the two genera of the subfamily Acanthopleuroceratinae has been dealt with above under the discussion of *Acanthopleuroceras*. *Luningiceras* possesses characters that are common to both genera but it shows greater affinity to *Acanthopleuroceras* in the tuberculation, and the nature of the keel. The whorl

section is also reminiscent of *Acanthopleuroceras* although *Tropidoceras zitteli* FUCINI (Fucini, 1899; Geczy, 1976; Dubar and Mouterde, 1978) has a similar form to the type-species of *Luningiceras*. The presence of numerous secondary ribs is common to the type-species and several other species of *Tropidoceras*.

*Acanthopleuroceras rursicosta* BUCKMAN (1918, p. 286, pl. 26, fig. 4a-c) is included in this subgenus as is *Ammonites valdani sensu* QUENSTEDT (1884, pl. 35, fig. 4 only) which Buckman considered to be conspecific with *A. rursicosta*. A large fragment of a body chamber held in the collections of the British Museum of Natural History (number C22346) is also a representative of this subgenus. It was referred to *A. rursicosta* BUCKMAN by Spath (1922, p. 124) but it differs from this species in the coarseness of its ribbing and the strength of its ventrally placed tubercles. It was labelled as coming from Vancouver Island and included in a collection of Cretaceous age. Spath (1922) believed the specimen misplaced and suggested that it originated, like Buckman's specimen of *A. rursicosta*, from the Carixian of Gloucestershire. This specimen is closely related to, and perhaps conspecific with *A. (Luningiceras) pinnaforme* described below. It differs only in being slightly more compressed and in the ribbing being more rursiradiate. The possibility of it

originating from the insular belt of British Columbia cannot be discounted, particularly as the Lower Jurassic faunas collected from this area at the end of the last century were often confused with Cretaceous forms (see Whiteaves, 1884).

Occurrence: The subgenus is represented in the Carixian (Ibex Zone and equivalents) of Gloucestershire, England, Swabia, Germany, Nevada, Oregon, and possibly British Columbia.

*Acanthopleuroceras (Luningiceras) pinnaforme* n. sp.

Pl. 13, 14; Text-fig. 6-13

Derivation of Name: Latin, *Pinna* = feather in reference to the pattern formed on the ventral surface by the keel and secondary ribs.

Diagnosis: Giant form; evolute; whorl section compressed. Primary ribs strong, weakly bituberculate; secondaries dense and projected.

Holotype: Catalogue number LSJU 714D(1); Pl. 13 and 14. From the collection of S. Muller (to be deposited in the U. S. National Museum). Collected from the highest beds of unit 4 of the type Sunrise Formation, Gabbs Valley

Range, Nevada. The holotype is a large internal mould with much of the shell material intact.

Material: In addition to the holotype there are five fragments of external moulds preserved in mudstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
LSJU 714D(1)	327	157	48	c85(54)	c94(60)	c90	--
Holotype	188	91	48	47(52)	53(58)	89	23
	--	86	--	--	--	--	21
	--	68	--	--	--	--	21
	--	33	--	--	--	--	21
	--	20	--	--	--	--	20
	--	12	--	--	--	--	18

Description: The shell is fairly evolute. The whorl section is slightly compressed (Fig. 6-13); the umbilical wall is high but rounds evenly into the flanks which are gently inflated on the inner whorls, becoming flatter in the outer whorls. The flanks are weakly convergent toward the gently arched venter. The primary ribs are dense and interrupted in two places at umbilical diameters of 18 mm and 52 mm. On the umbilical wall the ribs are weak and trend rursiradiately to the umbilical shoulder where, on the inner whorls, there may be weak swellings. From the umbilical shoulder the ribs become strong and only gently rursiradiate to radial. Where the ventral ends of the

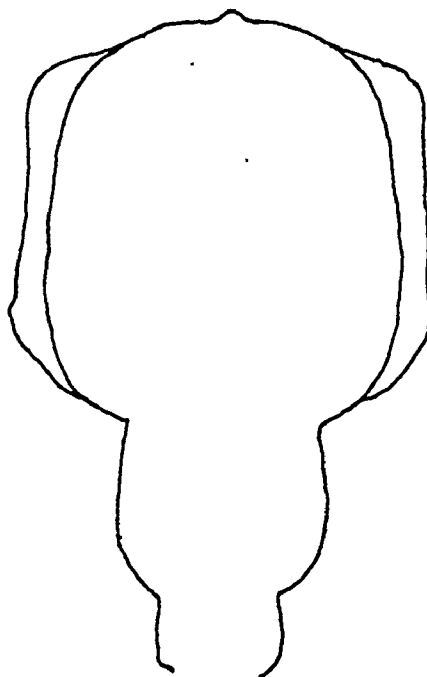


FIGURE 6-13 Whorl section of holotype of *Acanthopleuroceras* (*Luningiceras*) *pinnaforme* n. sp. Natural size, outer whorl excluded.

primary ribs are exposed on the outer whorl they bear low, rounded tubercles which are stronger than the more dorsal tubercles although these become persistent and increase in strength during growth. From just above the ventral tubercles, secondary ribs arise (4-5 per primary) that swing forward onto the ventral surface. The secondary ribs are rounded in cross section. They are interrupted by a low, broad, and rounded keel; the acute angle between the secondaries and the keel is  $50^{\circ}$ .

Discussion: This species differs from *A. (L.) rursicosta*

BUCKMAN, the only other species of the subgenus recognised, in its stronger, less rursiradiate ribbing.

Occurrence: From the upper part of unit 4, Sunrise Formation, Nevada, and silty shales cropping out in the eastern Bear Valley Basin of Oregon (either the Keller Creek Shale or Murderer's Creek Greywacke).

Localities: 43, 139.

Age: Pliensbachian (*A. (L.) pinnaforme* Zone).

#### SUBFAMILY POLYMORPHITINAE HAUG, 1887

##### GENUS *Dayiceras* SPATH, 1920

Type-Species: *D. polymorphoides* SPATH, 1920 (p. 539, pl. 15, fig. 1-4) by original designation.

Remarks: A moderately evolute polymorphitid genus with very dense ribs that are markedly rursiradiate near the umbilical slope, flexuous across the flanks, and that project onto the venter. Each rib with ventral, radially elongate swelling or tubercle. A median row of indistinct (at least on internal moulds) tubercles present on the venter. Septal suture very complex.

Age and Distribution: The type material is from the Ibex Zone of southern England (Dorset), but the genus is unknown



from the rest of northwest Europe. *Dayiceras* is recorded from the Ibex Zone of Portugal (Meister, 1913; Mouterde, 1951, 1970); the Ibex Zone of northern Tunisia (Rakus, 1972), and a whorl fragment has been collected from northern Italy (Wiedenmayer, 1977).

In the Americas, apart from the occurrences described below, it is known from the equivalent of the Ibex Zone in the Queen Charlotte Islands of British Columbia (Frebald, 1970), and from the Carixian (equivalent of the Davoei Zone ?) of the Wrangell Mountains in Alaska (Imlay, in press).

*Dayiceras dayiceroides* (MOUTERDE, 1951)

Pl. 12, Fig. 4-8; Text-fig. 6-14

- \*1951 *Uptonia* ? *dayiceroides* MOUTERDE, p. 9, pl. 1, fig. 4-6.
- 1970 *Uptonia* cf. *dayiceroides* MOUTERDE - FREBOLD, p. 438, pl. 1, fig. 9.
- in press *Uptonia* cf. *dayiceroides* MOUTERDE - IMLAY, pl. 9, fig. 1-4, 8, 12-16.

Material: One hundred and seventy-two specimens, many of them fragments, plus countless numbers of juveniles crowding a bedding plane at locality 162. / Most are external moulds in mudstones and siltstones with rarer

impressions in phosphatic limestone, and internal moulds in fine grained red sandstone.

Measurements: See Fig. 6-14.

Description: The shell is ~~is~~ evolute (U = 40-50, increasing slightly with growth), large (D maximum = 115 mm), and has compressed whorls. The umbilical wall is abrupt, the flanks concave, and the venter flattened. On the smaller whorls there appear to be traces of an impersistent, weak, and slightly beaded keel, but on larger whorls the venter is featureless.

Ribbing is very dense, particularly on nine of the specimens (Text-fig. 6-14; Pl. 12, Fig. 7). They are here interpreted as variants since they always occur with typical *D. dayicerooides* and are similar to them in all other respects. The ribs arise near the umbilical seam, trend rursiradiately up the umbilical wall, and become gently sinuous on the flanks. The ribs are terminated ventrally by sharp tubercles which become weaker, radially elongate swellings in later ontogeny. The ribs project forward onto the venter from the tubercles.

The specimen figured on Pl. 12, Fig. 8 is septate except for the last one-eighth of a whorl indicating that the species reached a considerable size. The suture is

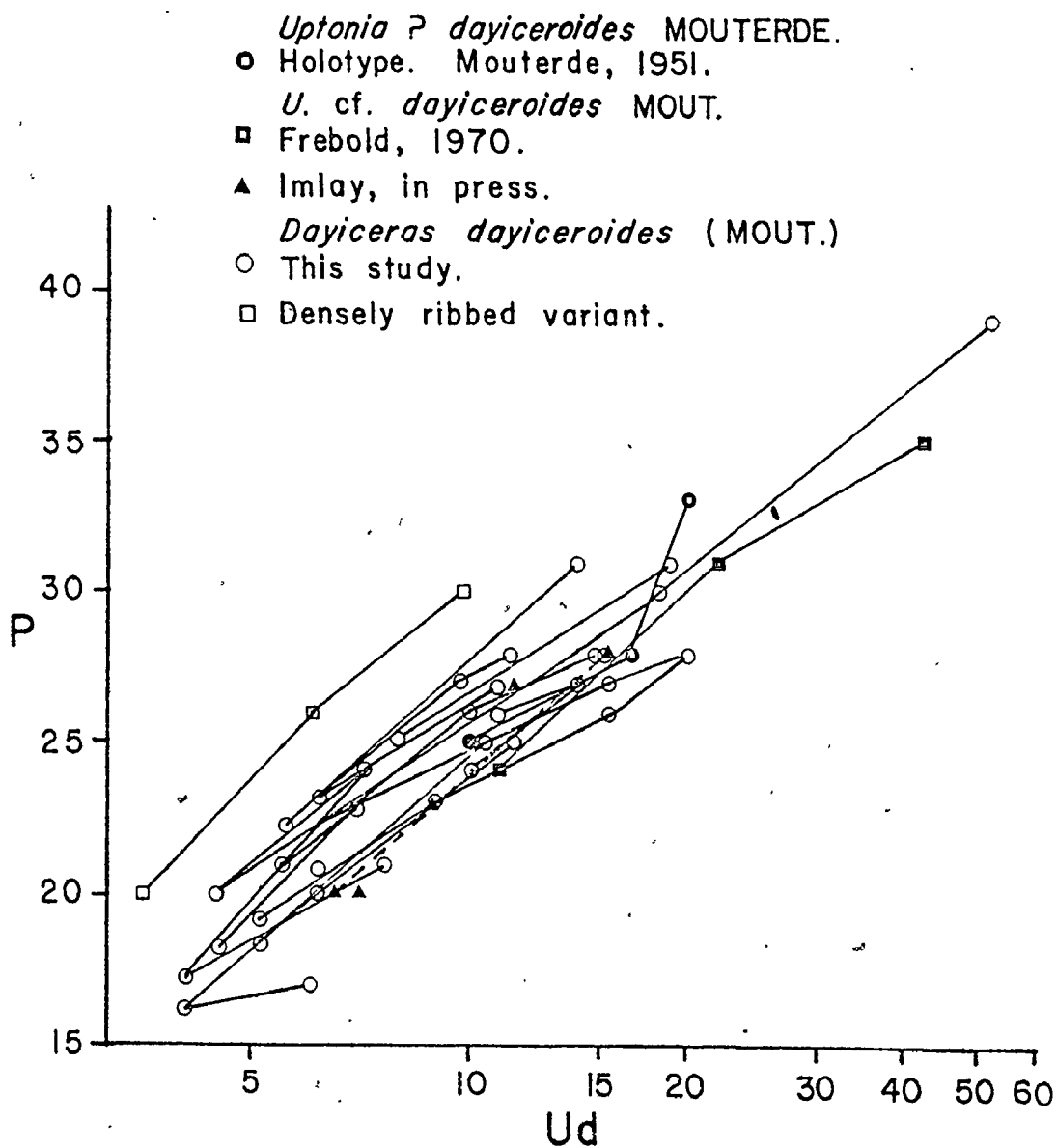


FIGURE 6-14-Rib density plot for some specimens of *Dayiceras dayiceroides* (MOUTERDE).

very complex with a bifid external saddle and a deep, narrow trifold lateral lobe.

Discussion: When Mouterde erected this species he had doubts as to its generic affinities. He tentatively

placed it in *Uptonia* because of its resemblance to certain species of that genus, e.g. *U. argusta*, and presumably because of its stratigraphic position (upper Jamesoni Zone). Mouterde considered the species as transitional between *Uptonia* and *Dayiceras*, however, and he indicated this by the name he chose. It is here considered more appropriate to assign this species to *Dayiceras* because the ventral tubercles on the ribs, and the weak median tubercles (at least at smaller diameters) are characteristic of this genus. Also, the very dense ribbing is much closer to the type-species of *Dayiceras* than that of *Uptonia* (see Donovan and Forsey, 1973, pl. 4, fig 3), as is the backward bend of the ribs on the umbilical wall, a feature which Spath was at some pains to point out (Spath, 1920, pl. 15, fig. 4). The age of the species as discussed below also lends credence to this assignment.

The presence of a finer ribbed variant as noted in Oregon and Nevada is also indicated in Portugal (Mouterde, 1951, p. 10).

Occurrence: The type section is the uppermost Jamesoni Zone at Sao Pedro Muel, Portugal, beneath beds containing specimens that Mouterde assigned unequivocally to *Dayiceras* (Ibex Zone) (Mouterde, 1951). The specimens from the Queen Charlotte Islands, British Columbia originate from

beds equivalent to the Ibex Zone (Frebold, 1970) although Tipper (personal communication, 1980) suggests it probably ranges higher. The material from Alaska could also range as high as the upper Carixian (Imlay, in press). The distribution of this species is a classic example of disjunct endemism as discussed in the section on palaeobiogeography (Chapter 4).

In Nevada and Oregon the species was collected from the Sunrise Formation (from the upper half of unit 5 at New York Canyon; from the upper two-thirds of unit D at Westgate), the upper Donovan Formation, and the upper part of section 7 measured in the Hurwal Formation of the Wallowa Mountains.

Localities: 37, 38, 39, 40, 89, 90, 91, 131, 145, 146, 148, 158, 159, 160, 161, 162, 168.

Age: Pliensbachian (*D. dayiceroides* Zone).

#### FAMILY LIPAROCERATIDAE HYATT, 1867

#### GENUS *Oistoceras* BUCKMAN, 1911

Type-Species: *Ammonites figulinus* SIMPSON, 1855 by original designation.

Remarks: Serpenticonic capricorns similar to *Androgymoceras* but with the ribs forming chevrons on the venter. Donovan (in Dean *et al.*, 1961, p. 465) considers *Beaniceras*,

*Androgynoceras*, and *Oistoceras* as subgenera marking successive stages in the evolution of *Androgynoceras*.

Age and Distribution: The Liparoceratidae are characteristically Boreal in distribution where *Oistoceras* is restricted to the upper part of the Davoei Zone, the Margaritatus, and possibly the Spinatum Zones (Maubeuge, 1951, 1957). The family does make rare appearances in Tethys, however, and two, possibly three, specimens of *Oistoceras* are reported from the Bakony Mountains of Hungary where they are restricted to the Davoei Zone (Geczy, 1976).

*Oistoceras* ? sp.

Pl. 15, Fig. 1

Material: One distorted fragment of an external mould in tuffaceous siltstone.

Description: A moderately evolute form with a fairly low umbilical wall and flat flanks. The venter appears to be tabulate and keel-less but a clear view is not available because of the mode of preservation. The ribbing is strong, simple, sparse, rectiradiate, and projects onto the ventral surface where it begins to fade.

Discussion: This specimen is tentatively placed in *Oistoceras* on the basis of its subquadrate whorl section and ornamentation. The absence of a complete ventral view precludes a definite assignment but in lateral view the specimen shows considerable resemblance to a specimen from the Bakony Mountains of Hungary figured as *Oistoceras* cf. *sinuosiforme* SPATH by Geczy (1976, p. 115, pl. 20, fig. 6).

Occurrence: The specimen was collected from the Wallowa Mountains in northeastern Oregon.

Localities: 144.

Age: *Ex situ*, with a Pliensbachian fauna.

FAMILY DACTYLIOCERATIDAE HYATT, 1867

SUBFAMILY COELOCERATINAE HAUG, 1910\*

GENUS *Coeloceras* HYATT, 1867

Type-Species: *Ammonites pettos* QUENSTEDT, 1843 (p. 178) by subsequent designation (Buckman, 1898, p. 454). When Quenstedt first described *Amm. pettos* he did not figure it but he included in his hypodigm *Ammonites crenatus sensu* ZIETEN (1830, p. 1, pl. 1, fig. 4a-d) (non Reinecke). Zieten's specimen was designated lectotype and refigured by Donovan and Forsey (1973, p. 10, pl. 2, fig. 2a, b).

Remarks: Morphology can be variable during ontogeny but all forms show a stage with a crater-like umbilicus, depressed whorls with a wide venter, and tubercles at the angular ventro-lateral shoulder. Recent treatments of the genus are given by Fischer (1971), Schmidt-Effing (1972), Donovan and Forsey (1973), Geczy (1976), and Wiedenmayer (1977).

Occurrence: *Coeloceras* is a cosmopolitan genus which ranges from the Upper Sinemurian to the Lower Toarcian according to Schmidt-Effing (1972).

SUBGENUS *Coeloceras* HYATT, 1867

Remarks: Forms that do not show a change in morphology with growth.

*Coeloceras* (*Coeloceras* ?) cf. *depressum* ROSENBERG, 1909

Pl. 15, Fig. 2

?\*1909 *Coeloceras sellae* var. *depressa* ROSENBERG,

p. 315, pl. 16, fig. 9a-c.

? 1934 *Coeloceras depressum* ROSENBERG - FUCINI, p. 92,

pl. 10, fig. 10.

Material: Approximately 60 fragments preserved as internal and external moulds in greywacke, and one specimen in



siltstone.

Description: (Composited from many fragments): The shell is fairly evolute. The compressed whorls have a low, abrupt umbilical wall, flat, subparallel flanks, and a broadly arched, keel-less venter. The ornamentation consists of fairly closely spaced primaries that are gently prorsiradiate and terminate in small, rounded tubercles quite high on the flank. From each tubercle arise approximately five much weaker secondary ribs that arch very gently across the venter. No septal suture is available for study.

Discussion: As far as the state of preservation allows comparison, these specimens are close to *C. depressum* ROSENBERG. They differ in the line of tubercles being marginally lower on the flank. The type and the American material are quite small but the specimen from Sicily figured by Fucini (1934) reaches a diameter of approximately 46 mm without a change in morphology or ornamentation, suggesting that an assignment to *Coeloceras* rather than *Reynesocoeloceras* is most appropriate.

Occurrence: In Europe *C. depressum* is only known from the Carixian and lowermost Domerian of the Tethyan region.

In the United States it is found in the upper Keller Creek Shale in east-central Oregon, and the Hurwal Formation in northeastern Oregon.

Localities: 136, 151.

Age: Pliensbachian (A. (L.) *pinnaforme* Zone).

*Coeloceras* (*Coeloceras* ?) spp.

Pl. 15, Fig. 3, 5, 7

Material: One poorly preserved internal mould, and eleven whorl fragments preserved in siltstone, mudstone, and greywacke.

Discussion: The nature of the preservation of this material does not warrant a full treatment. More than one species appear to be represented as indicated by the range in ribbing and tubercle densities.

Occurrence: Collected from unit D of the Sunrise Formation exposed at Westgate; the Keller Creek Shale of east-central Oregon, and the Hurwal Formation of northeastern Oregon.

Localities: 88, 136, 141, 143, 144, 148, 149, 153, 168.

Age: Pliensbachian (A. (L.) *pinnaforme* Zone).

SUBGENUS *Reynesocoeloceras* GECZY, 1976

Type-Species: *Ammonites (Stephanoceras) crassus* YOUNG and BIRD var. *indunensis* MENEHINI, 1881 (p. 72, pl. 16) by original designation.

Remarks: Internal whorls cadiconic, tuberculate, with bi- or trifurcating ribs. Outer whorls serpenticonic, ribs simple and non-tuberculate. For a full discussion of the subgenus see Geczy (1976, p. 123) and Wiedenmayer (1977, p. 75).

Synonyms: *Indunoceras* WIEDENMAYER, 1977; *Cetanoceras* WIEDENMAYER, 1977.

Occurrence: *Reynesocoeloceras* is restricted to the Tethyan Realm. In Hungary the first representative is recorded from the Ibex Zone but the acme is reached in the Davoei Zone (Geczy, 1976). Wiedenmayer (1977, Table 3) records an Obtusum to Davoei Zone range inclusive but this incorporates information presented by Fischer (1971). Wiedenmayer (*in litt.*) now traces the Lotharingian-Carixian boundary in unit 16a of Fischer (1971, p. 121). Consequently, none of the species assignable to *Reynesocoeloceras* occurs in Sinemurian strata.

*Coeloceras* (*Reynesocoeloceras*) cf. *baconicum* GECZY, 1976

Pl. 15, Fig. 4

- ?\*1971 *Coeloceras* ? n. sp. aff. *obesum* FUCINI - GECZY,  
p. 45, text-fig. 12a, b.
- ?\*1976 *Coeloceras* (*Reynesocoeloceras*) *baconicum* (FUCINI) -  
GECZY, p. 123, pl. 23, fig. 7, 8.
- ? 1977 *Indunoceras* (*Indunoceras*) *obesum* (FUCINI) -  
WIEDENMAYER, p. 78, pl. 16, fig. 6.

Material: One specimen: only the outer one and a half whorls are well preserved, slightly distorted tectonically.

Description: The shell is evolute and the whorl section depressed; the flanks are almost parallel, the ventro-lateral shoulder angular, and the venter very gently arched.

The flanks bear prorsiradiate primary ribs whose appearance varies during ontogeny. On the last part of the penultimate whorl and the first eighth of the last whorl, they are closely spaced, broad, and terminate in very large, round, blunt nodes. On the next quarter whorl the ribs sharpen, the nodes are reduced, and a slight constriction is evident. On the last half whorl the ribbing becomes sparser and the tubercles decrease steadily in strength; some ribs do not bear tubercles. Up to the

constriction, each primary gives rise to two secondaries that arch gently forward across the venter. After the constriction, on the last half whorl, some tuberculate primary ribs cross the ventral surface without dividing. These ribs are followed adorally by a simple, non-tuberculate primary rib. On the last half whorl, secondaries that divide from a single tubercle on one ventro-lateral shoulder do not always unite in a single tubercle on the opposite shoulder. No septal suture is available for study.

Discussion: This specimen, as far as the state of preservation allows comparison, seems similar to *C. (R.) baconicum* but it differs in the ribbing being a little less dense. The specimen from Italy assigned to *Indunoceras (I.) obesum* (FUCINI) by Wiedenmayer (1977) appears to be conspecific with *C. (R.) baconicum*. It differs from *C. (R.) obesum* (FUCINI) (1905, p. 137, pl. 10, fig. 9-12) in the position of the line of tubercles being closer to the middle of the flank rather than on the more angular ventro-lateral shoulder as in *C. (R.) baconicum*.

Occurrence: The holotype was collected from the Ibex Zone of the Bakony Mountains of Hungary. The *Coeloceras* cf. *obesum* reported from the high Cordillera of Chile and

Argentina may also represent this species (Hillebrandt, 1973); it is indicated as Raricostatum Zone but the listed fauna suggest an assignment to the Early Pliensbachian.

The specimen described here was collected from the upper Donovan Formation in east-central Oregon.

Localities: 133.

Age: Pliensbachian (? *D. Qyiceroides* Zone).

*Coeloceras* (*Reynesocoeloceras*) *incertum* FUCINI, 1905

Pl. 15, Fig. 6, 8; Text-fig. 6-15

\*1905 *Coeloceras incertum* FUCINI, p. 140, pl. 11, fig. 4-7.

1971 *Coeloceras* (*Coeloceras*) *incertum incertum* FUCINI - FISCHER, p. 110, text-fig. 5j.

1976 *Coeloceras* (*Reynesocoeloceras*) *incertum* FUCINI - GECZY, p. 131, pl. 23, fig. 4, 5.

Material: One large, slightly distorted internal mould partially infilled with calcite; one smaller, distorted internal mould, and one weathered fragment of an external mould showing the inner whorls. All preserved in red sandstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>S</u>
L48(3)	61	36	59	c27.5(45)	c13.5(22)	49	c39

Description: This evolute form reaches a diameter in excess of 90 mm. The whorl section is very depressed with divergent, convex flanks on the inner whorls (becoming subparallel on the outer whorl), and a flattened venter.

The style of ribbing changes during ontogeny. On the inner whorls the dense, somewhat prorsiradiate primary ribs give rise to two secondary ribs from prominent tubercles which represent the bases of spines up to 5 mm in length. Some primaries miss tubercles and cross the venter without bifurcating; the density of secondaries is high. On the outer half-whorl the ribbing is much coarser, and the frequency of furcation is lower so that the density of secondary ribs is much reduced.

Septation is evident to an umbilical diameter of approximately 34 mm suggesting a body chamber length of at least one and one-eighth whorls. The last septal suture has a bifid external lobe that is considerably longer than the lateral lobe (Fig. 6-15).

The distorted small specimen figured on Pl. 15, Fig. 6 is tentatively included in this species. It differs from the larger specimen in that its outer whorl shows a weakening of the ribs which become approximated and are interrupted just before the aperture by a deep constriction. Although no sutures are evident, the mode of preservation suggests a body chamber length of one and a half whorls;

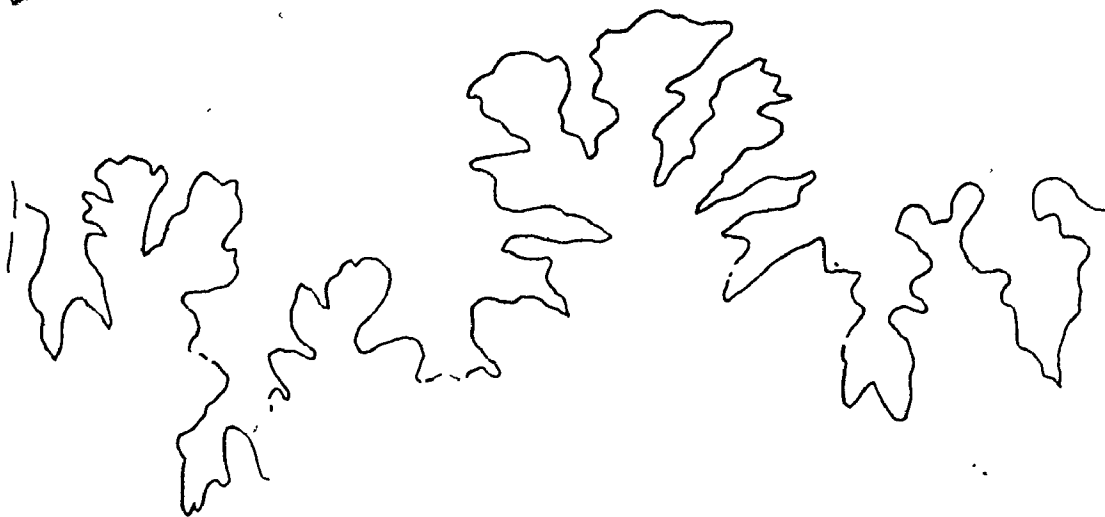


FIGURE 6-15. Septal suture of *Coeloceras* (*Reynesocoeloceras*) *incertum* FUCINI at Ud = 32 mm. Specimen L48(3).

these whorls are internal moulds of sandstone whereas the inner whorls are replaced by calcite. The change in ribbing style almost certainly indicates the early onset of maturity, and this specimen is considered a microconch of *C. (R.) incertum*. The size ratio is a little less than three to one.

Discussion: This material agrees well with the holotype except that the American material reaches larger diameters. All the material described here is from the Lupper collection and probably represents "*Coeloceras* cf. *pettos* QUENSTEDT" referred to in Lupper's list of taxa from the Donovan Formation (Lupper, 1941, p. 235).



Occurrence: This species is known from the Lower Pliensbachian of Italy and Hungary. The Hungarian material is restricted to the Davoei Zone.

The American specimens were collected from the upper part of the Donovan Formation, south-central Oregon.

Localities: 131.

Age: Pliensbachian (? *D. dayiceroides* Zone).

*Coeloceras* (*Reynesocoeloceras* ?) sp.

Material: Four poorly preserved external moulds of small specimens preserved in mudstone.

Description: An extremely evolute form; whorl section very depressed with a broad, gently arched (?) venter.

The narrow flanks bear strong, prorsiradiate ribs that terminate in prominent tubercles. On the inner whorls approximately five very fine secondary ribs (lirae) per primary cross the venter arching slightly forward; on the outer whorls there are apparently no secondaries although the primary ribs are expressed weakly on the venter.

Discussion: The nature of evolution, whorl section, and ribbing suggest an assignment to *Coeloceras* although much better preserved material must be collected

before a specific identification may be attempted. The style of ribbing suggests an assignment to the subgenus *Reynesocoeloceras*.

The high degree of evolution and low expansion rate are worthy of note. In these respects there is a similarity with a specimen collected from the Fernie Group and figured by Frebold (1969, 1970). Frebold indicates an Upper Sinemurian or Lower Pliensbachian age for this specimen and this is in keeping with the age of the material described here.

Occurrence: Lower part of the Hurwal Formation in the Wallowa Mountains of northeastern Oregon. The species is also represented in the Lodgepole area of British Columbia as discussed above.

Localities: 141, 153, 158.

Age: Pliensbachian (A. (L.) *pinnaforme* Zone).

GENUS *Prodactylioceras* SPATH, 1923

Type-Species: *Ammonites davoei* J. SOWERBY, 1822 (p. 71, pl. 350) by original designation (Spath, 1923, p. 10).

Remarks: Serpenticonic forms with a subrounded whorl section. Ribbing fine and usually simple, except for sporadic ventro-lateral tubercles giving rise to several

secondary ribs. Suture complex.

Synonyms: *Paralytoceras* FREBOLD, 1922 (non Frech, 1902);  
*Praedactylioceras* FRENTZEN, 1937.

Age and Distribution: *Prodactylioceras* is known throughout the Pliensbachian; it reaches its greatest development in the Davoei Zone for which the type-species is the index. The genus is cosmopolitan (Schmidt-Effing, 1972).

SUBGENUS *Prodactylioceras* SPATH, 1923

Remarks: No ontogenetic change in morphology and ornamentation.

*Prodactylioceras* (*Prodactylioceras*)

cf. *davoei* (J. SOWERBY, 1822)

Pl. 16, Fig. 1

- ?\*1822 *Ammonites davoei* J. SOWERBY, p. 71, pl. 350.  
? 1844 *Amm. davoei* J. SOW. - D'ORBIGNY, p. 276, pl. 81.  
? 1880 *Aegoceras davoei* J. SOW. - WRIGHT, p. 346, pl. 31,  
fig. 1, 2.  
? 1884 *Amm. davoei* J. SOW. - QUENSTEDT, p. 298, pl. 38,  
fig. 6-9.  
? 1933 *Prodactylioceras davoei* (J. SOW.) - ARKELL,  
pl. 31, fig. 3.

- ? 1956 *P. davoei* (J. SOW.) - ARKELL, pl. 32, fig. 3.  
 ? 1961 *P. davoei* (J. SOW.) - DEAN, DONOVAN and HOWARTH,  
 pl. 70, fig. 1.  
 ? 1976 *P. davoei* (J. SOW.) - GECZY, p. 150, pl. 27,  
 fig. 3, 4.

Material: One partly crushed specimen infilled with  
 drusy calcite, and one external mould.

Measurements:

<u>Specimen</u>	<u>Ud</u>	<u>P</u>	<u>T</u>
J2074	28	c52	1
	16	--	5

Description: The shell is evolute and the whorl section subrounded, although the exact whorl shape cannot be determined. The ribbing is sharp and very dense, particularly on the inner whorls. Most of the ribs are simple but the large, irregularly spaced, ventro-lateral tubercles give rise to three or, more often, four secondary ribs. The prorsiradiate ribs arch back to cross the venter transversely. No septal suture is evident.

Discussion: As far as the preservation permits comparison, these specimens resemble *P. (P.) davoei*. They differ in the ribs being somewhat sharper and more distantly spaced

on the outer whorls.

Occurrence: *P. davoei* is the index species for the Davoei Zone of the northwest European zonal scheme. It is most common in the southern part of the Northwest European Province, only rarely occurring as far north as England (Schmidt-Effing, 1972). It is also recorded from the faunas of Tethyan aspect (Geczy, 1976).

The well preserved specimen from Nevada was *ex situ* but could only have originated from the lower part of unit E of the Sunrise Formation exposed at Westgate where an external mould was found in place.

Localities: 93, 95.

Age: Pliensbachian (*D. dayiceroides* Zone).

SUBGENUS *Aveyroniceras* PINNA and LEVI-SETTI, 1971

Type-Species: *Ammonites acanthoides* REYNES, 1868 (p. 91, pl. 1, fig. 3) by original designation.

Remarks: The subgenus *Aveyroniceras* is characterised by a change in ornamentation from an early stage with spinose bifurcating ribs to a stage of simple, very dense, non-tuberculate ribbing. As pointed out by Geczy (1976), *Aveyroniceras* and *Prodactylioceras* are closely allied so that *Aveyroniceras* is best relegated to subgeneric

rank. *Aveyronicerias* differs from *Prodactylioceras* in lacking tubercles at large diameters but there are exceptions, in that *P. (A.) mortilleti* (MENECHINI) occasionally shows tubercles where *P. (P.) enode* (QUENSTEDT) shows a marked reduction in tuberculation.

Synonyms: *Bettonicerias* WIEDENMAYER, 1977

Age and Distribution: *Prodactylioceras (Aveyronicerias)* is a Tethyan form found in North Africa (Dubar and Mouterde, 1978), southern France, Italy, and the Alps (Geczy, 1976). It ranges from the Ibex to the Margaritatus Zone with a maximum development in the Davoei Zone.

*Prodactylioceras (Aveyronicerias) colubriforme* (BETTONI, 1900)

Pl. 16, Fig. 2; Text-Fig. 6-16

\*1900 *Coeloceras colubriforme* BETTONI, p. 75, pl. 7, fig. 10.

1905 *Coeloceras colubriforme* BETT. - FUCINI, p. 122, pl. 7, fig. 13, 14.

? 1962 *Catacoeloceras* cf. *crassoides* (SIMPSON) - CORVALAN, p. 184, pl. 3, fig. 1, 2.

1963 *Reynesoceras* aff. *fallax* (FUCINI) - DU DRESNAY, p. 151, pl. 2, fig. 1.

1966 *Prodactylioceras* cf. *colubriforme* (BETT.) - PINNA, p. 348, pl. 10, fig. 6.

- 1971 *Prodactylioceras colubriforme* (BETT.) - FISCHER,  
p. 112, pl. 2, fig 10; text-fig. 5m.
- 1971 *P. colubriforme* (BETT.) - CANTALUPPI and MONTANARI,  
p. 65, pl. 12, fig. 2.
- 1977 *Indunoceras (Bettoniceras) colubriforme* (BETT.) -  
WIEDENMAYER, p. 81, pl. 16, fig. 8-10, text-fig. 15e.

Material: Two small internal moulds with some shell material adhering, preserved in sandy limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>
J2075	45	21	47	16(26)	13(29)	123

Description: An evolute form with depressed, *Coeloceras*-like inner whorls, becoming more rounded and moderately depressed in the outer whorl (Fig. 6-16).

The innermost whorls to an umbilical diameter of approximately 4mm bear simple, prorsiradiate ribs terminated by weak, rounded tubercles. At larger umbilical diameters the ribs are non-tuberculate and more densely spaced. At all growth stages the ribs cross the venter transversely and are uninterrupted.

Discussion: This specimen is identical to *P. (A.) colubriforme*

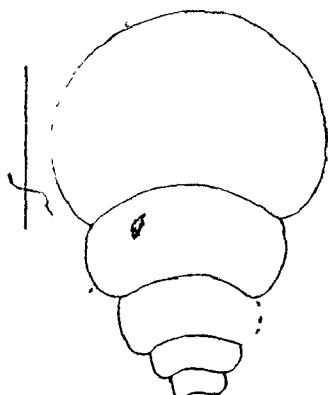


FIGURE 6-16 Whorl section of  
*Prodactylioceras*  
(*Aveyronicerias*)  
*colubriforme*  
(BETTONI).  
Bar. = 1 cm.  
Specimen J2075.

particularly the specimen from northern Italy figured by Wiedenmayer (1977).

Occurrence: This is a Tethyan form possibly arising in the Ibex Zone and ranging through the Davoei and lower Margaritatus Zones.

The American material was collected from the lower part of unit E of the Sunrise Formation exposed at Westgate.

Localities: 94.

Age: Pliensbachian (*D. dayiceroides* Zone).

*Prodactylioceras* (*Aveyronicerias*).

cf. *inaequiornatum* (BETTONI, 1900)

Pl. 16, Fig. 5, 6

? 1900 *Coeloceras inaequiornatum* BETTONI, p. 75, pl. 7,  
fig. 11.



- ? 1964 *Prodactylioceras davoei* (J. SOW.) - FREBOLD,  
p. 10, pl. 3, fig. 2.
- ? 1968 *Dactylioceras* cf. *D. acanthus* BUCKMAN (non D'Orbigny) -  
IMLAY, p. C30, pl. 3, fig. 13-16.
- ? 1968 *Dactylioceras* (*Orthodactylites*) cf. *D. (O.)*  
*tenuicostatum* (YOUNG and BIRD) - IMLAY, p. C30,  
pl. 3, fig. 1, 2, 8, 9.
- ? 1968 *Dactylioceras* (*Orthodactylites*) cf. *D. (O.) verme*  
(SIMPSON) - IMLAY, p. C31, pl. 3, fig. 7, 10.
- ? in press *Bettoniceras inaequioratum* (BETTONI) - WIEDENMAYER,  
pl. 5, fig. 11 (plates not seen).

Material: Seven poorly preserved specimens, mostly  
fragments of external moulds, preserved in siltstone.

Description: Evolute forms of unknown whorl section. On  
the inner whorls the dense primaries are terminated by  
rounded tubercles near the umbilical seam. The simple  
ribs of the larger whorls are non-tuberculate and even  
more dense and wiry in appearance. One specimen shows a  
coarsening of the ribs at large diameters. As far as  
preservation permits comparison, these specimens are  
identical to material from California and east-central  
Oregon (Imlay, 1968), and northeastern British Columbia  
(Frebald, 1964) that Wiedenmayer (in press) includes in

① *B. inaequiornatum*.

Occurrence: This is a typically Tethyan form which according to Wiedenmayer (preprint) ranges from the Davoei to the lower Spinatum Zones of the Pliensbachian.

The material described here was collected from the upper part of the Hurwal Formation exposed in the Wallowa Mountains of northeastern Oregon.

Localities: 145, 147, 162.

Age: Pliensbachian (*D. dayiceroides* Zone).

*Prodactylioceras (Aveyroniceras) spp.*

Pl. 16, Fig. 3, 4

Material: Nine specimens: fragments and internal moulds very poorly preserved as a result of contact metamorphism.

Description: All the forms present reach a large size, are evolute, and densely ribbed. In one group the ribs are mostly simple but occasionally two primary ribs coalesce and become swollen (Pl. 16, Fig. 3). A second group shows dense primary ribs that remain simple and in some specimens, at large diameters, begin to coarsen.

Discussion: The first group appears to be similar to

*P. (A.) mortilleti* (MENEHINI) which is known from the John Day inlier (Imlay, 1968) whilst the second group is comparable to *P. (A.) italicum* which is widespread in the Mediterranean and northern circum-Pacific regions, having been reported from Japan (Hirano, 1971), Alaska (Imlay, preprint), possibly British Columbia (Frebold, 1970, pl. 4, fig. 1), and Oregon (Imlay, 1968). However, the nature of the preservation precludes a confident assignments to species.

Occurrence: Collected from the upper part of unit 5 of the type Sunrise Formation in the Gabbs Valley Range, and from the lower part of unit E of the Sunrise Formation exposed at Westgate.

Localities: 45, 47, 92, 93, 95, 96, 97, 98.

Age: Pliensbachian (*D. dayiceroides* Zone).

SUPERFAMILY HILDOCERATACEAE HYATT, 1867

FAMILY HILDOCERATIDAE HYATT, 1867

SUBFAMILY ARIETICERATINAE HOWARTH, 1955

GENUS *Arieticeras* SEGUENZA, 1885

Type-Species: *Ammonites algovianus* OPPEL, 1862, by original designation.

Remarks: Fairly evolute with quadrate to compressed

whorl section, unicarinate venter, and simple, straight to gently falcoid ribs. Closely related to the earlier *Tropidoceras*.

Age and Distribution: *Arietoceras* characterises the Domerian of Tethys. In the Pacific region it is recorded from the Andes of Chile and Argentina (Hillebrandt, 1973), Mexico (Erben, 1954), Canada (Frebold, 1964), southern Alaska (Imlay, in press), Japan (Hirano, 1973), and eastern Siberia (Sey and Kalacheva, 1980).

*Arietoceras* cf. *algovianum* (OPPEL, 1862)

Pl. 17, Fig. 1, 2

- ?\*1853 *Ammonites radians amalthei* OPPEL, p. 51, pl. 3, fig. 1.
- ? 1862 *Amm. algovianus* OPPEL, p. 137.
- ? 1868 *Amm. algovianus* OPPEL - REYNES, p. 92, pl. 2, fig. 1.
- ? 1900 *Hildoceras (Arietoceras) algovianum* (OPPEL) - BETTONI, p. 53, pl. 4, fig. 8, 10, 11.
- ? 1908 *Hildoceras algovianum* (OPPEL) - FUCINI, p. 54, pl. 2, fig. 5, 6.
- ? 1908 *Hildoceras reynési* FUCINI, p. 55, pl. 2, fig. 7-9.
- ? 1909 *Sequeniceras algovianum* (OPPEL) - ROSENBERG, p. 288, pl. 14, fig. 18-20.

- ? 1931 *Arieticerias reynesi* FUCINI, p. 103, pl. 7,  
fig. 15-19.
- ? 1934 *A. algovianum* (OPPEL) - MONESTIER, p. 55, pl. 7,  
fig. 1-4.
- ? 1936 *Segueniceras algovianum* (OPPEL) cf. var. *reynesei*  
FUCINI - TERMIER, p. 1284, pl. 22, fig. 10, 11.
- ? 1954 *Arieticerias algovianum* (OPPEL) *guerreresense* ERBEN  
p. 5, pl. 1, fig. 4, 5.
- ? 1962 *A. algovianum* (OPPEL) - SESTINI, p. 516, pl. 38,  
fig. 15.
- 1962 *A. sp.* CORVALAN, p. 187, pl. 3, fig. 6.
- ? 1964 *A. algovianum* (OPPEL) - FREBOLD, p. 13, pl. 3,  
fig. 4, 5; pl. 4, fig. 2.
- 1965 *A. cf. algovianum* (OPPEL) - HALLAM, p. 1488.
- ? 1968 *A. algovianum* (OPPEL) - CANTALUPPI and BRAMBILLA,  
p. 294, pl. 27, fig. 2, 3.
- ? 1968 *A. algovianum* (OPPEL) - CANTALUPPI and SAVI,  
p. 240, pl. 20, fig. 9-11.
- 1968 *A. cf. algovianum* (OPPEL) - IMLAY, p. C34, pl. 4,  
fig. 1-8.
- ? 1970 *A. algovianum* (OPPEL) - FREBOLD, pl. 2, fig. 1.
- preprint *A. cf. algovianum* (OPPEL) - IMLAY, pl. 10, fig. 16-20.

Material: One large, poorly preserved specimen, and a  
fragment of an internal mould.

Description: The larger specimen attains a diameter of approximately 65 mm. The specimen is fairly evolute but little can be said of the whorl shape because of the state of preservation. A keel is evident. The ribbing is strong, simple, and gently sigmoidal, projected, particularly on the outer whorl.



Discussion: These specimens are tentatively considered conspecific with *A. algovianum* as far as preservation permits comparison. They compare particularly favourably with similarly preserved material from the Laberge Group of southern Yukon (Frebold, 1964, pl. 4, fig. 2) which was assigned to *A. algovianum*.

Occurrence: *A. algovianum* is restricted to the Domerian, and is characteristic of southern Europe and North Africa, *i.e.* the Tethyan area. It has previously also been recorded from Mexico, western Canada, and Alaska (see synonymy).

The specimens described here were collected from the highest beds of section 7 measured in the Hurwal Formation, northeastern Oregon. During field work a few unextractable fragments of what appeared to be this species were seen in the lower half of unit E of the Sunrise Formation exposed at Westgate, Nevada. I have

carefully examined the unpublished plate of *Arieticerias* sp. of Corvalan (1962) which was collected from the same interval, and I agree with Hallam (1965) that this specimen should be compared with *A. algovianum*.

Localities: 159, 166.

Age: Pliensbachian (*R. fannini* Zone).

GENUS *Fontanelliceras* FUCINI, 1931

Type-Species: *Harpoceras fontanellense* GEMMELLARO, 1885 (p. 12, pl. 2, fig. 1, 2) by subsequent designation (Vecchia, 1949). The type material has been refigured by Fucini (1931, pl. 8, fig. 21, 22).

Remarks: Evolute forms with slowly enlarging subquadrate whorls, a tricarinate, bisulcate venter, and straight, strong, distant ribs.

Age and Distribution: As for *F. cf. fontanellense* below.

*Fontanelliceras cf. fontanellense* (GEMMELLARO, 1885)

Pl. 18, Fig. 7

- ?\*1885 *Harpoceras fontanellense* GEMMELLARO, p. 12, pl. 2, fig. 1, 2.
- ? 1900 *Harpoceras (Arieticerias) fontanellense* (GEMM.) - BETTONI, p. 58, pl. 5, fig. 10-12.

- ? 1908 *Hildoceras fontanellense* (GEMM.) - FUCINI, p. 69,  
pl. 2, fig. 41-45.
- ? 1913 *Arietoceras (Vermiceras) fontanellense* (GEMM.) -  
HAAS, p. 42, pl. 5, fig. 1, 2.
- ? 1931 *Fontanelliceras fontanellense* (GEMM.) - FUCINI,  
p. 110, pl. 8, fig. 21-26.
- non 1934 *Arietoceras fontanellense* (GEMM.) - MONESTIER,  
p. 68, pl. 10, fig. 48-52; pl. 11, fig. 9.
- 1968 *Fontanelliceras cf. F. fontanellense* (GEMM.) -  
IMLAY, p. C36, pl. 5, fig. 16-18.
- ? 1968 *F. cf. fontanellense* (GEMM.) - CANTALUPPI and SAVI,  
p. 251, pl. 22, fig. 4a, b.
- ? 1968 *F. fontanellense* (GEMM.) - CANTALUPPI and  
BRAMBILLA, p. 393, pl. 28, fig. 4, 5.
- ? 1971 *F. fontanellense* (GEMM.) - HIRANO, p. 111, pl. 16,  
fig. 1-4.
- ? 1973 *F. fontanellense* (GEMM.) - GÜEX, p. 507, pl. 6,  
fig. 2.
- ? 1977 *F. fontanellense* (GEMM.) - SESTINI, p. 736,  
pl. 33, fig. 5, 6.
- 1978 *F. cf. fontanellense* (GEMM.) - HIRANO, MIKAMI, and  
MIYAGAWA, p. 412, pl. 51, fig. 4-7.
- 1980 *F. cf. fontanellense* (GEMM.) - SEY and KALACHEVA,  
p. 78, pl. 2, fig. 15-17, 19.



Material: Three *ex situ* specimens preserved in siltstone, two as external moulds and one as an internal mould.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>P</u>
29423(3)	18	9	50	13
29424(1)	17.5	9	51	15
31742(1)	10.8	5.6	52	11

Description: A serenticone with a low expansion rate, a low umbilical wall, and gently concave flanks. A low keel is evident but a clear view of the venter is not available. The ribs are strong, simple, straight, widely spaced, and rectiradiate to slightly rursiradiate. They arise low on the umbilical wall, maintain their strength across the flanks, and end abruptly on the ventro-lateral shoulder.

Discussion: The small size of these specimens, and the nature of the preservation does not permit a confident assignment to species, but they appear to be identical with similarly preserved material from eastern Oregon, Japan, and Russia which has also been compared with *F. fontanellense* on the basis of the style of coiling and ornamentation.

Occurrence: *F. fontanellense* occurs in Domerian rocks of Tethyan aspect. It is particularly abundant in southern Europe but has also been recorded from Morocco where it may range upward into the Toarcian, as well as from Far Eastern U.S.S.R., and Japan. A single specimen has been collected from the Upper Pliensbachian Nicely Shale of Oregon (Imlay, 1968) but, interestingly, the species is not known from Alaska or western Canada.

The specimens described here originate from the lower and middle part of section 7 measured in the Hurwal Formation of northeastern Oregon. Unfortunately they are all *ex situ* so that no significance can be attached to their association with Early rather than Late Pliensbachian assemblages.

Localities: 143, 144, 168.

Age: *Ex situ*, with a lower Carixian fauna.

SUBFAMILY HARPOCERATINAE NEUMAYR, 1875

GENUS *Protogrammoceras* SPATH, 1913

Type-Species: *Grammoceras bassanii* FUCINI, 1900 (p. 46, pl. 10, fig. 6) by subsequent designation (Spath, 1919). The type material has been refigured by Cantaluppi (1972).

Remarks: In his paper dealing with Jurassic ammonites from Tunisia Spath (1913, p. 550) recognised two hildoceratid

genera viz. *Segueniceras* [= *Arietoceras*] and *Protogrammoceras*. The latter included one group whose ribbing projected onto the venter and a second group lacking projection. Unbeknownst to Spath, this latter group had independently been recognised and named *Fuciniceras* (as a subgenus of *Harpoceras*) by Haas (1913, p. 75). Brief excursions of *Protogrammoceras*, a predominantly Tethyan genus, into the Liassic sea covering England subsequently afforded Buckman the opportunity of erecting several genera. I agree with Howarth (1973, p. 265), who has pointed out that there is no difference worthy of generic distinction between the type material of *Protogrammoceras* and *Paltarpites*.

Synonyms: *Paltarpites* BUCKMAN, 1922; *Argutarpites* BUCKMAN, 1923; *Platyharpites* BUCKMAN, 1927; *Bassaniceras* FUCINI, 1923; *Eoprotogrammoceras* CANTALUPPI, 1970; *Neoprotogrammoceras* CANTALUPPI, 1970.

Age and Distribution: This genus has a wide distribution but is prolific in the Tethyan region where it is found in the Carixian and particularly the Domerian. In England it makes a sparse appearance in both the Domerian (Buckman, 1922) and the earliest Toarcian (Howarth, 1973). The migration of *Protogrammoceras* from northern Tethys into southern Germany in the Carixian and finally into northern

Germany during the Domerian is documented by Fischer (1975). In the western Pacific, *Protogrammoceras* is reported from western Siberia (Sey and Kalacheva, 1980), and Japan (Sato, 1960, 1962; Hirano, 1971), and in the eastern Pacific from Domerian rocks as far north as southern Alaska (Imlay, in press).

*Protogrammoceras argutum* (BUCKMAN, 1923)

Pl. 17, Fig. 7

- \*1923 *Argutarpites argutus* BUCKMAN, pl. 363.
- ? 1921 *Harpoceras densecapillatum* FUCINI, p. 11, pl. 1, fig. 12, 13.
- ? 1959 *Harpoceras* aff. *exaratum* YOUNG and BIRD - FREBOLD, p. 7, pl. 3, fig. 1 only (non Young and Bird).
- 1962 *Harpoceras* sp. CORVALAN, p. 189, pl. 3, fig. 8.
- 1965 *Harpoceras* HALLAM, p. 1487.
- 1968 *Paltarpites* cf. *P. argutus* (BUCK.) - IMLAY, p. C37, pl. 5, fig. 20-22, 24, 25.
- 1970 *Paltarpites argutus* (BUCK.) - FREBOLD, p. 444, pl. 4, fig. 8-10.
- 1976 *Paltarpites* sp. indet. KALACHEVA, p. 90, pl. 2, fig. 1, 2.
- 1980 *Paltarpites* sp. indet. SEY and KALACHEVA, p. 79, pl. 3, fig. 1, 2 (refigured from Kalacheva, 1976).
- in press *Protogrammoceras* cf. *P. argutum* (BUCK.) - IMLAY, pl. 11, fig. 14.

Material: Twelve specimens, mostly fragments, preserved in sandy limestone.

Description: This species reaches a large size since the largest whorl fragment (Pl. 17, Fig. 7) still has a siphuncle along its entire length. The species is of intermediate volution ( $U \approx 32$ ) with a compressed whorl section. The umbilical wall is steep, the flanks convex, and the venter bears a narrow, flat-topped, very high keel at all stages of growth.

The ornamentation consists of dense, flat-topped, falcoid ribs whose strength sometimes varies on one and the same specimen, and over narrow growth intervals. The projection of the ribs onto the venter appears to become more marked with growth.

Discussion: This species is closely related to *P. paltus* as indicated by several workers (Howarth, 1973; Frebold, 1970; Imlay, in press). On the whole, it tends to be more densely ribbed although, as pointed out above, this character is variable.

Occurrence: *P. argutus* is reported from the Domerian of Europe, Russia, Alaska, and Canada.

In the United States it occurs in the upper part

of unit E of the Sunrise Formation exposed at Westgate, Nevada.

Localities: 99, 104, 107, 112, 114, 116, 118, 123, 126, 127.

Age: Pliensbachian and Lower Toarcian (? R. *fannini*, and *T. propinquum* Zones.

*Protogrammoceras* cf. *lusitanicum* (CHOFFAT, 1880)

Pl. 17, Fig. 3-5

? 1880 *Ammonites lusitanicus* CHOFFAT, p. 15, 29.

? 1908 *Harpoceras lusitanicum* CHOFFAT, p. 147, 150.

1909 *Grammoceras fallaciosum* BAYLE - ROSENBERG, p. 299, pl. 15, fig. 11 (non Bayle).

?\*1970 *Protogrammoceras lusitanicum* CHOFFAT - MOUTERDE, p. 40, pl. 1, fig. 1-5; pl. 2, fig. 1; pl. 7, fig. 9, 10.

Material: Twelve external moulds, most of them incomplete, in tuffaceous mudstone and siltstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>P</u>
28805 (24)	c50	21	42	38
28806 (20)	c33	15	45	28
P68 (4)	38	12.5	33	32

Description: Moderately evolute forms with a compressed whorl section. The umbilical wall is low, the flanks fairly flat, and the narrow venter bears a tall, thin, non-sulcate keel. Ribbing is dense throughout and quite sharp. The ribs arise at the umbilical shoulder, are falcoid on the flanks, and project strongly forward onto the venter to parallel the keel.

Discussion: This species name was first used by Choffat (1880) for forms collected in Portugal, but he neither figured nor described the specimens. This deficiency was corrected by Mouterde (1970).

Occurrence: The material from Portugal is from the lower Margaratatus Zone but the precise age of the material from Austria (Rosenberg, 1909) is not known, although it is undoubtedly Pliensbachian.

The American material was collected from the Hurwal Formation exposed in the Wallowa Mountains of northeastern Oregon.

Localities: 141, 144, 159, 160, 163, 165.

Age: Pliensbachian (*R. fannini* Zone).

*Protogrammoceras* cf. *nipponicum* (MATSUMOTO, 1947)

Pl. 18, Fig. 1-3

- ?\*1947 *Grammoceras* (s. s.) *nipponicum* MATSUMOTO, in  
MATSUMOTO and ONO, p. 27, pl. 2, fig. 3.
- ? 1947 *G.* (s. s.) *nipponicum* var. *tenuicostata* MATSUMOTO,  
*loc. cit.*
- ? 1947 *G.* (s. s.) *nipponicum* var. *paucicosta* MATSUMOTO,  
*loc. cit.*
- non 1968 *Protogrammoceras* sp. cf. *P. nipponicum* (MATSUMOTO) -  
IMLAY, p. C38, pl. 6, fig. 12-20.

Material: Fifteen external moulds preserved in siltstone  
and mudstone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>P</u>
28806(21)	c30	c14	47	38
31741(13)	c34	c12	35	34
J2085	c20	8	40	34
P90(1)	17	8	47	28

Description: The whorl section was probably compressed  
with a low umbilical wall and fairly flat flanks. The  
venter bears a low keel. The ribbing is very fine and  
dense, with the ribs arising near the umbilical seam,  
swinging forward across the lower flank, then backward to  
a more rectiradiate trend on the upper flank, and finally



forward again onto the ventral surface.

Discussion: The American specimens are comparable with *P. nipponicum* from Japan, both in morphology and nature of the preservation. They differ from all other species of *Protogrammoceras* found in Oregon and Nevada in the more evolute whorls, and denser ribbing. There is some doubt as to whether the type material should be referred to *Fuciniceras* rather than *Protogrammoceras* since projection of ribbing onto the ventral surface is not very marked. In this respect they compare with some of the densely ribbed, more evolute species of *Fuciniceras* occurring in Hungary (Geczy, 1976). In the absence of well preserved material, however, it seems prudent to retain this species under its present name for the time being.

Occurrence: The Japanese material is from the upper Domerian and Lower Toarcian of southwestern Honshu (Hirano, 1973). The American material was collected from the Hurwal Formation exposed in the Willowa Mountains, northeastern Oregon.

Localities: 141, 144, 147, 151, 152, 165.

Age: Pliensbachian (*R. fannini* Zone).

*Protogrammoceras paltum* (BUCKMAN, 1922)

Discussion: *Paltarpites paltum* BUCKMAN (1922, pl. 362A, holotype; pl. 362B, paratype) has been studied in detail by Gabiilly (1976) who provides an extensive synonymy. The species is widespread, having been reported from the uppermost Pliensbachian and the Lower Toarcian of much of Europe as well as Japan (Hirano, 1971), Alaska (Imlay, in press), and Canada (Friebold, 1970).

*Protogrammoceras paltum toyoranum* (MATSUMOTO, 1947)

Pl. 16, Fig. 7

\*1947 *Harpoceras* (s. l.) (*Nagatoceras*) *toyoranum*MATSUMOTO - in MATSUMOTO and ONO, p. 28, pl. 1,  
fig. 6.1947 *H.* (s. l.) (*N.*) *toyoranum* var. *costata* MATSUMOTO,  
*loc. cit.*1971 *Paltarpites toyoranum* (MATSUMOTO) - HIRANO, p. 114,  
pl. 19, fig. 1-5.

Material: Six secondarily compressed external moulds in sandstone.

Description: The figured specimen is the largest, reaching an estimated diameter of 90 mm. The specimens are fairly evolute ( $U \approx 34$  mm); probably with a compressed whorl

section. The umbilical wall is abrupt, the flanks gently convex, and the venter bears a tall, narrow, rounded keel.

The style of ornamentation is variable during ontogeny. The earlier whorls bear quite strong, densely spaced ribs (between 20 and 25 per half whorl). Ribs are gently falcoid, ventrally projected, and relatively sharp, becoming stronger and more rounded at later stages. The ribbing ultimately gives way to striations that appear first on the lower part of the flank and spread dorsally.

Discussion: These specimens compare with material collected from southwestern Honshu, Japan, particularly the paralectotype designated by Hirano (1971, pl. 19, fig. 1). This individual is morphologically similar to the holotype of *Protogrammoceras paltus* (Buckman, 1922, pl. 362A) of which it is here considered a subspecies. It differs only in the ribs being somewhat more flexuous, and in the presence of striae rather than fine ribs on larger whorls.

Occurrence: *P. paltum toyoranum* is reported from part of the Fontanellense Zone of Japan which is approximately equivalent to the lower Spinatum Zone of Europe (Hirano, 1973).

The American specimens were all collected from

the highest part of section 7 measured in the Hurwal Formation, Wallowa Mountains, northeastern Oregon.

Localities: 160, 164, 165, 166, 167.

Age: Pliensbachian (*R. fannini* Zone).

*Protogrammoceras varicostatum* (FUCINI, 1900)

Pl. 18, Fig. 4, 5

\*1900 *Grammoceras varicostatum* FUCINI, p. 32, pl. 8, fig. 6.

1967 *Protogrammoceras varicostatum* (FUCINI) - GECZY,  
p. 117, pl. 38, fig. 1.

Material: Six internal moulds, two in limestone and four fragments in siltstone. Six external moulds in siltstone. Preservation fair.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Ww</u>	<u>Wh</u>	<u>WS</u>	<u>P</u>
LSJU 2950(2)	c58	23	40	11.2(19)	23(40)	49	c33
J2086	c52	21	40	--	c18(35)	--	c27
	--	10	--	--	--	--	c18

Description: A fairly evolute form with a compressed whorl section, the umbilical wall is steep and low, the flanks flat and parallel, and the narrow, somewhat fastigate venter bears a low keel.

The strength of the ribbing varies during growth and according to preservation, with ornamentation being sharpest on external moulds. Ribbing is weakest and prorsiradiate on the lower third of the flank at which point it strengthens and flexes backwards to approach the ventro-lateral shoulder almost radially, finally projecting weakly onto the venter where it fades just before reaching the keel. No suture line is available for study.

Discussion: This species is similar to *P. normanianum* (D'ORBIGNY, 1844, p. 291, pl. 88) which differs in having convergent flanks and a more evenly rounded umbilical shoulder.

*P. varicostatum* differs from *P. paltum toyoranum* (MATSUMOTO) in the absence of a striate stage, its flatter flanks, and lower, sharper keel. *P. argutum* has denser ribs that project much more strongly onto the venter.

Occurrence: *P. varicostatum* is a rare species previously recorded from the Pliensbachian of Italy, Hungary, and possibly North Africa (Termier, 1936, p. 1281).

The specimens from the United States originate from the Sunrise Formation exposed in the Shoshone and Clan Alpine Mountains, Nevada (unit H and unit E respectively),

and the Hurwal Formation of the Wallowa Mountains in northeastern Oregon.

Localities: 75, 106 144, 157, 160, 162, 164, 165, 166.

Age: Pliensbachian (*R. fannini* Zone).

GENUS *Fuciniceras* HAAS, 1913

Type-Species: *Harpoceras lavinianum* MENEGHINI in FUCINI, 1900 by original designation.

Remarks: Planulates with flat-sided whorls, variable venter, and gently falcoid ribbing that is not markedly projected ventrally.

Age and Distribution: A typically Tethyan form recorded from the Mediterranean countries, Baluchistan, Indonesia, and Japan (Arkell *et al.*, 1957). The genus is known from the Carixian and the Domerian.

*Fuciniceras* sp.

Pl. 18, Fig. 6

Material: Two small internal moulds of calcite with parts of the outer whorl (body chamber ?) infilled with sediment. Both preserved in fine grained red sandstone.

Description: Fairly evolute ( $U \approx 41$ ) form with a compressed whorl section and a narrow venter bearing a high, non-sulcate keel. The umbilical wall is low, and the flanks gently arched to flat. Ribbing is simple and dense throughout. The ribs arise at the umbilical shoulder, are very gently flexuous on the flanks, and project slightly onto the venter. No septal suture is available for study.

Discussion: The nature of the preservation and particularly the small size of these specimens do not permit specific assignment. They are fairly evolute and densely ribbed for the genus and in this respect compare with such forms as *F. detractum portisiforme* GECZY (1976, p. 180) and *F. costicillatum* (FUCINI, 1900).

Occurrence: From the upper part of the Donovan Formation in south-central Oregon.

Localities: 131, 132.

Age: Pliensbachian (? *D. dayiceroides* Zone).

GENUS *Lioceratoides* SPATH, 1919

Type-Species: *Lioceras ? grecoi* FUCINI, 1900 (p. 65, pl. 11, fig. 4) by original designation.

Remarks: Forms of intermediate coiling, compressed whorl

section, and a fastigate or tabulate venter bearing a keel. Ribbing somewhat variable in strength, often in one and the same specimen, generally falcoïd and sometimes fasciculate; secondaries may arise by intercalation or, less commonly, by bifurcation.

Synonyms: *Praelioceras* FUCINI, 1927.

Age and Distribution: A Tethyan form characteristic of the Domerian and basal Toarcian.

*Lioceratoides* cf. *matsumotoi* HIRANO, 1971

Pl. 17, Fig. 6

?\*1971 *Lioceratoides matsumotoi* HIRANO, p. 118, pl. 15, fig. 8, 11-13.

Material: One slightly weathered specimen preserved in limestone.

Measurements:

<u>Specimen</u>	<u>D</u>	<u>Ud</u>	<u>U</u>	<u>Wh</u>
J2083	c30	4	13	c16(53)

Description: An involute, compressed form with a high expansion rate. The umbilical wall is steep and low, the



flanks almost flat, and the narrow, flattened venter bears a fairly high keel. The ribbing is dense, sinuous, and prorsiradiate. The secondaries arise by intercalation and rarely by bifurcation. The ribbing is reduced to striations on the outer quarter-whorl.

Discussion: This specimen is comparable to *L. matsumotoi* from southern Honshu, Japan in shape and style of ornamentation but it differs in the trend of the ribbing being somewhat less sinuous. Differences between *L. matsumotoi* and other species of *Lioceratoides* are discussed in some detail by Hirano (1971).

Occurrence: The Japanese material ranges from the Domerian into the Lower Toarcian. The American material originates from the upper part of unit 5 of the type Sunrise Formation exposed in the Gabbs Valley Range, Nevada.

Localities: 46.

Age: Pliensbachian (*D. dayiceroides* Zone).

GENUS *Harpoceras* WAAGEN, 1869

Type-Species: *Ammonites falcifer* J. SOWERBY, 1820 by original designation.

Remarks: Compressed, with flat flanks and unicarinate

venter. Ribbing simple, falcate, strongest (on) the outer part of the whorl, and projected on venter.

Synonyms: *Falciferites* BREISTROFFER, 1947; *Tardarpoceras* BUCKMAN, 1927; *Phaularpites* BUCKMAN, 1928.

Age and Distribution: *Harpoceras* is cosmopolitan and restricted to the Lower Toarcian Falciferum and Bifrons Zones (Gabilly, 1976).

*Harpoceras* cf. *maurelli* MCLEARN, 1930

Pl. 18, Fig. 8

?\*1930 *Harpoceras maurelli* MCLEARN, p. 4, pl. I, fig. 5.

? 1932 *H. maurelli* MCLEARN - MCLEARN, p. 63, pl. 7, fig. 4-6.

Material: One crushed, weathered, *ex situ* specimen, and several poorly preserved fragments, all preserved in sandy limestone.

Description: The figured specimen probably reached a diameter of 9 cm, although one septate whorl fragment (Wh = 8cm) indicates the species must have reached a considerable size. The shell is involute and compressed. The umbilical wall is abrupt, the flanks flat, and the narrow venter bears an exceptionally prominent keel.

Ornamentation is simple and falcoid. The ribs are broad, flat-topped on larger whorls, and strongly projected onto the venter. No septal suture is available for study.

Discussion: The specimens are poorly preserved but they compare most favourable with a large species first figured as a sketch by McLearn and described two years later (McLearn, 1930, 1932).

Occurrence: The type material was collected from the Lower Toarcian of the Queen Charlotte Islands, British Columbia. The American specimens all originate from the upper part of unit E of the Sunrise Formation exposed at Westgate, Nevada.

Localities: 106, 110, 111, 120, 122, 130.

Age: Lower Toarcian (*T. propinquum* Zone).

GENUS *Tiltoniceras* BUCKMAN, 1913

Type-Species: *Tiltoniceras costatum* BUCKMAN, 1914

(pl. 97, fig. 1-4, [= *Tiltoniceras antiquum* (WRIGHT, 1882), (pl. 57, fig. 1-4)]).

Remarks: Compressed, fairly involute forms with rounded umbilical wall and keel. Ornament varies in strength but

is often faint, consisting of flexuous lirae projecting on venter.

Age and Distribution: *Tiltoniceras* is recorded from the basal Toarcian Tenuicostatum Zone of Britain, Germany, France, Hungary, Bulgaria (?), and northeast Siberia. The specimens reported as *Eleganticeras* sp. from Alaska (Imlay, in press) may also represent this genus.

*Tiltoniceras propinquum* (WHITEAVES, 1884)

Pl. 19, Fig. 1-6; Text-fig. 6-17

- \*1884 *Schloenbachia propinqua* WHITEAVES, p. 247, pl. 33, fig. 2, 2a.
- 1930 *Harpoceras propinquum* (WH.) - McLEARN, p. 4.
- 1932 *H. propinquum* (WH.) - McLEARN, p. 66, pl. 6, fig. 1-4; pl. 7, fig. 3.
- 1944 *H. propinquum* (WH.) - SHIMER and SHROCK, pl. 240, fig. 13, 14.
- 1964 *H. propinquum* (WH.) - FREBOLD, pl. 8, fig. 4, 5, 7 (McLearn's (1932) material refigured.)
- 1966 *Ovaticeras facetum* POLUBOTKO and REPIN, p. 45, pl. 1, fig. 4, 5, 8.
- 1968 *O. facetum* POLUBOTKO and REPIN - REPIN, p. 45, pl. 46, fig. 1, 2, 4, 5.
- 1968 *O. propinquum* (WH.) - REPIN, p. 116, pl. 44,

- fig. 1; pl. 45, fig. 1.
- 1971 *Tiltoniceras propinquum* (WH.) - DAGIS, pl. 4,  
fig. 4, 5.
- 1974 *T. propinquum* (WH.) - DAGIS, p. 21, pl. 1,  
fig. 1-4; pl. 2, fig. 1. }

Material: Forty-nine specimens in various states of preservation occurring as both internal and external moulds in limestone.

Measurements: See Fig. 6-17

Specimen

J2088	c61	17.9	29	c16(26)	24(39)	c67
J2090	45.7	11.5	25	13.3(29)	17.3(38)	77
J2091	40.4	12	30	10.3(25)	15.4(38)	67
J2093	38	10.3	27	10.3(27)	17.1(45)	60
W1-8-15(1)	48.5	15.5	32	12.1(25)	c21(43)	58
W1-8-15(2)	c28	c8	29	c9(32)	c12(43)	75
W1-10-1(1)	58	18.9	33	16.4(28)	22.9(39)	72
W1-10-9(1)	c42	c10	c24	--	c20(48)	--
W1-10-14(I)	42.3	13.3	31	c9.1(22)	c17.2(41)	53
Sec.50 52m	c34	10.4	31	c9.1(27)	12.9(38)	71
50 52m(1)	52	12	23	--	c22(42)	--
50 52m(2)	37	10	27	--	c16(43)	--
50 52m(3)	39.5	11.5	29	10.8(27)	15.4(39)	70
50 52m(4)	c49	13.5	28	--	20(41)	--

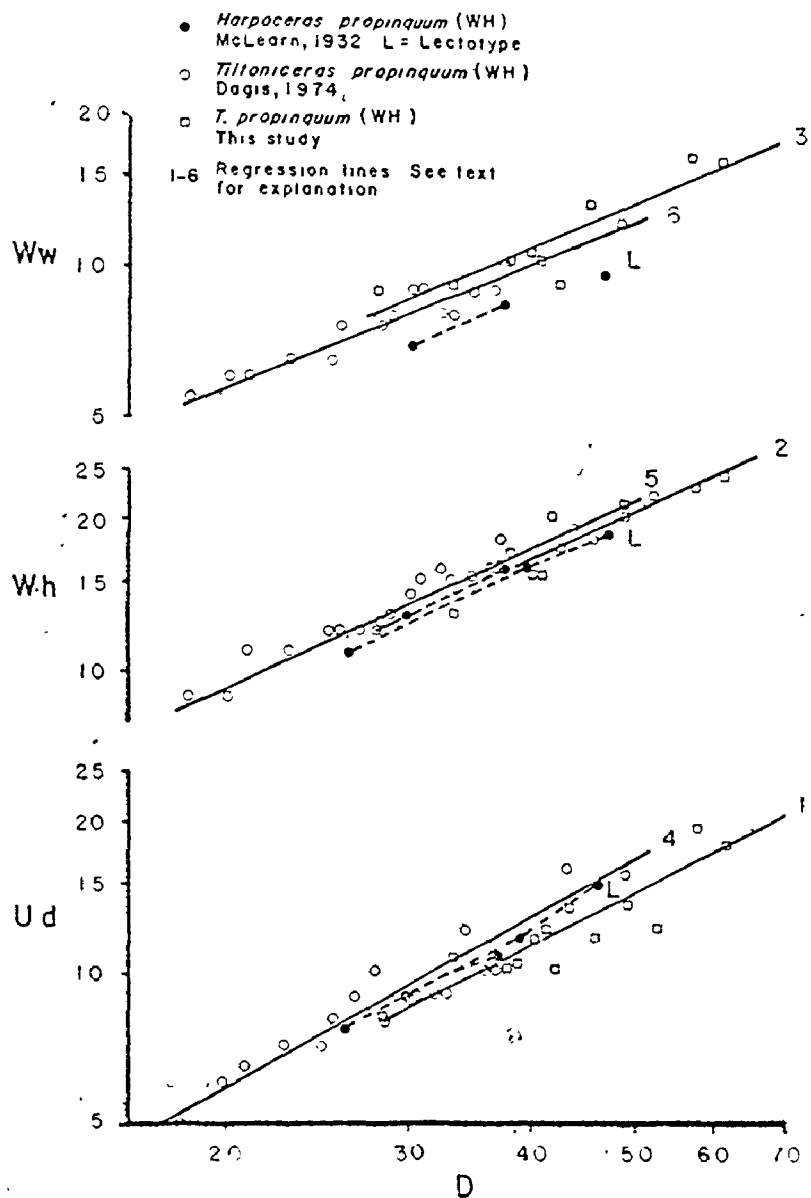


FIGURE 6-17 Double logarithmic plot of umbilical diameter, whorl width, and height against diameter for *Tiltoniceras propinquum* (WHITEAVES). Measurements in millimetres.

Description: Compressed with rounded umbilical shoulder, gently convex flanks, and a narrow, fastigate venter bearing a keel. At larger diameters the umbilical wall becomes a little steeper but the shoulder remains rounded.

Ornamentation is weak throughout and variable on the inner whorls which may be smooth or bear broad, low, falcoïd ribs. Ribbing may sometimes persist to a diameter of 45 mm but it generally becomes obsolete at much smaller diameters, giving way to a smooth test or dense, falcoïd lirae. The external lobe of the suture line is shallow, the external saddle fairly broad, and the first lateral lobe deep, narrow, and trifid.

Discussion: The material from Canada (Whiteaves, 1884; McLearn, 1932; Frebold, 1964) was assigned to the genus *Harpoceras* although McLearn indicated that he was using this name in a loose sense, pointing to similarities between the several species of *Harpoceras* he described and the hildoceratid genera *Tiltoniceras* and *Ovaticeras* (McLearn, 1932, p. 62, 63). When "*H.*" *propinquum* was discovered in northeast Siberia it was assigned to *Ovaticeras* by Polubotko and Repin (1966), and Repin (1968). In discussing these specimens Howarth (1973, p. 273) concluded that they represented the genus *Tiltoniceras* and he even drew comparisons with the English species *T. antiquum* (WRIGHT). Dagis (1971, 1974) described more specimens from Siberia under *Tiltoniceras propinquum*, in which he included Repin's *O. propinquum* and *O. facetum* (Dagis, 1974, p. 21). The assignment of *T. propinquum* to

*Tiltoniceras* rather than *Harpoceras* seems fully justified. There are many resemblances but *Harpoceras* differs consistently from *Tiltoniceras* in its strong, falcate ornamentation.

In the U.S.S.R., *T. propinquum* occurs with two other species of *Tiltoniceras*, *T. capillatum* and *T. costatum* (Dagis, 1974). These two forms, which are probably conspecific with *T. antiquum* (WRIGHT) (Howarth, 1973), are common in Europe perhaps as far east as Hungary (Hoffmann and Martin, 1970; Geczy, 1967; Hoffmann, 1968; Lehmann, 1968). *T. propinquum* differs from *T. antiquum* only in being a little more compressed at similar diameters.

Figure 6-17 is a double logarithmic plot of diameter against umbilical diameter, whorl height, and whorl width for *T. propinquum*. Regression lines are plotted for the material from the United States (lines 1-3) and, for the Russian and Canadian material combined (lines 4-6). Slope (m), Y-intercept (b), correlation coefficient (r), and t-statistic (t) for the regression equations, as well as the number of data pairs (N) used are shown in Table 6-1a. Correlation coefficients are high and statistically significant at the .001% level.

The null hypotheses of no difference in slope or position of regression line may be tested using the  $F$  statistic whereby the hypotheses are rejected if  $F$  is



<b>A</b>								
<u>Source of Data</u>	<u>Regression Line</u>			<u>N</u>	<u>m</u>	<u>b</u>	<u>r</u>	<u>t</u>
	<u>Number</u>							
This Study	1	14	1.02	-0.58	0.90	6.98		
	2	14	0.94	-0.28	0.95	10.24		
	3	10	0.85	-0.33	0.90	5.71		
McLearn, 1932 and Dagis, 1974	4	29	1.12	-0.69	0.99	40.37		
	5	29	0.90	-0.20	0.99	49.14		
	6	27	0.82	-0.31	0.99	36.96		

<b>B</b>		
<u>Comparison</u>	<u>Z Statistic for Slope</u>	<u>Z Statistic for Position</u>
lines 1 and 4	0.82	7.83
lines 2 and 5	0.45	7.02
lines 3 and 6	0.26	10.39

TABLE 6-1 Regression coefficients and statistics for analysis of *Tiltoniceras propinquum* (WHITEAVES). See text for explanation.

greater than 1.96 ( $P < 0.05$ ) (Imbrie, 1956). These data, which are presented in Table 6-1b, indicate identical slopes and different positions in all cases tested. In other words, the expansion rates for the two groups of ammonites are identical but inspection of the graphs shows that the whorl shape of the American specimens is somewhat

less compressed than the Russian and Canadian material. In fact the average value for the ratio of whorl width to whorl height expressed as a percentage (WS) for the former is 67 ( $\sigma = 7.7$ ) compared to 58.8 ( $\sigma = 4.8$ ) for the latter. The taxonomic weight that should be attached to this is open to debate, bearing in mind that these data do not take into account morphologic features such as ornament and suture line, which are identical. Separation at the subspecific level could be argued but this would serve little purpose.

Occurrence: *T. propinquum* is recorded from the lowest Toarcian of the Queen Charlotte Islands, and the lowest Toarcian (Tenuicostatum Zone) of northeast Siberia. Howarth's tentative suggestion of a Falciferum Zone age for the Canadian material (Howarth, 1973, p. 274) does not seem warranted in view of the imprecise nature of the stratigraphic data presently available.

All the specimens from the United States were collected from the upper third of unit E of the Sunrise Formation exposed at Westgate, Nevada.

Localities: 105, 107, 108, 109, 113, 115, 117, 119, 120, 121, 122, 123, 124, 125, 128, 129.

Age: Lower Toarcian (*T. propinquum* Zone).

## CHAPTER 7

### SUMMARY AND CONCLUSIONS

This work represents the first study of the Sinemurian ammonites of Nevada and Oregon, and the Pliensbachian and Toarcian ammonites of Nevada. At least 66 taxa are represented, distributed amongst 32 genera or subgenera. *Luningiceras* is erected as a new subgenus of *Acanthopleuroceras*. *Paltechioceras depressum*, *P. gettyi*, *Acanthopleuroceras* (*A.*) *mulleri*, and *A.* (*Luningiceras*) *pinnaforme* are established as new species whilst *Asteroceras* (*Eparietites*) and *Hyperderoceras* are probably represented by new species, although the state of preservation or the paucity of material does not warrant the establishment of new names.

The vertical distribution of the ammonites is used to divide the Sinemurian (excluding the lowest Sinemurian), the Pliensbachian, and the lowest Toarcian into seven assemblage zones: the *Arnioceras ceratitoides*, *Paltechioceras harbledownense*, *P. rothpletzi*, *Acanthopleuroceras* (*Luningiceras*) *pinnaforme*, *Dayiceras dayiceroides*, *Radstockiceras fannini*, and *Tiltoniceras propinquum* Zones. Most of these zones are recognised in both Nevada

and Oregon, and are used to correlate the markedly contrasted facies consisting of predominantly carbonate, miogeosynclinal rocks in Nevada compared to predominantly volcanoclastic, eugeosynclinal rocks in Oregon. The previous understanding of the ages of the formations studied is revised. The Sunrise Formation is dated at the zonal level for the first time and is shown not to range into the Toarcian Stage except at Westgate. The Dunlap Formation is considered to be of Late Pliensbachian age, and the Donovan Formation is shown to range into the Lower Pliensbachian as suggested but never conclusively demonstrated by other workers (Lupher, 1941). The Keller Creek Shale, on the other hand, was previously believed to be exclusively of Sinemurian age. Its fauna is described here for the first time, and the uppermost part of the formation is shown to be of Early Pliensbachian age. It is overlain by the transgressive Mowich Group of Late Pliensbachian age. The part of the Hurwal Formation described in detail herein is shown to be restricted to the Early Pliensbachian, with the Late Sinemurian not represented.

The regression and deposition of the Dunlap Formation in Nevada began in the late Early or the Late Pliensbachian. In Oregon, the overlap of the Keller Creek Shale by the Mowich Group, and the transgression onto the Suplee shelf of the sea in which the Mowich Group

was deposited occurred at approximately the same time as the regression in Nevada. Thus shallow seas were present in both states during the Pliensbachian and Toarcian although the lowest Toarcian is not yet proven faunally in Oregon. An abundant benthonic fauna flourished in these seas, and reefs of the aberrant pelecypod *Plicatostylus gregarius* were common. A shallow water environment of deposition is also suggested by the development of a hardground during *P. rothpletzi* Zone times at New York Canyon, and by the occurrence of vertical and highly inclined ammonites in the *T. propinquum* Zone at Westgate. Analysis of the direction of dip of the ammonite planes of bilateral symmetry indicates a palaeocurrent from the northwest at Westgate.

The reasons for the synchronicity of transgression and regression in Oregon and Nevada are not yet clear. The Jurassic rocks of the two states were believed to have been deposited on separate microplates, and the synchronicity of these events suggest microplate interaction and consequently, the proximity of the two microplates.

A review of the Lower Jurassic ammonite distributions of Europe and the northwest Pacific shows (most clearly for the Pliensbachian) a division into a northern Boreal and a southern Tethyan Realm, separated by an area yielding a mixed fauna. Diversity also decreases towards the

palaeonorth, and the biogeographic division is considered a function of environmental stability and temperature which are a reflection of latitude. The boundary between the two realms in Europe has been radically affected by subsequent plate tectonic movements.

As is the case in Europe, the Sinemurian ammonite fauna of Nevada and Oregon contains a high percentage of cosmopolitan forms whereas the Pliensbachian fauna is dominated by Tethyan forms, and a similar Tethyan fauna occurs as far north as southern Alaska. The same tripartite division into a Boreal, mixed, and Tethyan fauna is evident in the northeast Pacific but, in contrast to the other areas, the transition is east-west rather than north-south. It is suggested that this pattern is caused by subsequent plate tectonic motions which have resulted in the northward transportation of a coherent terrane (Wrangellia) relative to the North American continent since the Triassic and Early Jurassic.

#### 7.1 Future Research

In the last fifteen years plate tectonics has revolutionized geology and nowhere has the revolution been more strongly felt than in the study of the world's mobile belts. The western Cordillera seem to be a collage of allochthonous terranes whose limits, histories, and

interactions are very poorly understood. Ammonite biochronology promises to be a useful tool in helping to decipher at least the Jurassic portion of this part of the world's history. The next step is to apply the zonal scheme to other regions of the Cordillera and in so doing, refine the scheme still further. A knowledge of the ammonite sequences in Nevada and Oregon should prove most useful in areas where exposure is poor or where tectonic complications are severe.

No attempt has been made to study microfossils during the course of this work. A linking of a microfossil zonal scheme with the ammonite scheme could prove to be tremendously important, however, since the precise ages of the extensive *mélange* terranes in the western Cordillera are often impossible to determine because of the absence of megafossils and the poor knowledge of microfossil sequences.

Another major problem that remains to be faced is the existence or nonexistence of the central Atlantic seaway during the Lower Jurassic. As indicated in Chapter 4, the most fruitful line of approach is considered to be a comparison of coeval benthonic faunas from western Tethys and the eastern Pacific to determine the degree of genetic similarity and hence, geographic isolation. The prerequisite of dating the eastern Pacific Sinemurian to

lowest Toarcian benthonic faunas in terms of the standard zonal scheme of northwest Europe has now been fulfilled.



APPENDIX 1 - LOCALITY DESCRIPTIONS AND  
FOSSILS NUMBERS

Section 1 (Sunrise Formation)

Localities 1-40.

The entrance to New York Canyon, Gabbs Valley Range, Nevada. Area unsurveyed. See Ferguson and Muller, 1949, pl. 5.

Section 2 (Type Sunrise Formation)

Localities 41-47.

The type section of the Sunrise Formation. To the east of the New York Canyon Road as shown in Ferguson and Muller, 1949, pl. 5.

Section 3 (Sunrise Formation)

Localities 48-61.

Volcano Peak Gulch. To the southwest of Volcano Peak. See Ferguson and Muller, 1949, pl. 5.

Section 4 (Sunrise Formation)

Localities 62-75.

The Shoshone Mountains, section 21, T.11 N, R.39, T.15 N, R.35 E, Westgate 7.5 minute quadrangle.

Section 5 (Sunrise Formation)

Localities 76-130.

Clan Alpine Mountains, W $\frac{1}{2}$  section 20, E $\frac{1}{2}$  section 19, T.17 N, R.35 E, Westgate 7.5 minute quadrangle.

## APPENDIX 1 (CONT'D)

Section 6 (Donovan Formation)

Localities 131-135.

SE $\frac{1}{4}$  of section 6, T.20 S, R.30 E, West Myrtle  
Butte 15 minute Quadrangle.

Section 7 (Hurwal Formation)

Localities 141-167.

Unsurveyed area south of section 18, T.2 S,  
R.44 E, Enterprise 15 minute quadrangle.

Locality 136 (Keller Creek Shale)

SE SW section 35, T.16 S, R.28 E, Grant County,  
Oregon. Location is roadcut.

Locality 137 (Keller Creek Shale)

NE $\frac{1}{4}$  section 4, T.16 S, R.29 E. Locality is small  
roadcut just west of road intersection. Cut is on north  
side of road.

Locality 138 (Keller Creek Shale)

On Forest Road. East central part of SE $\frac{1}{4}$  section 25,  
15S 29E, Logdell quadrangle, Grant County, Oregon.

Locality 139 (Keller Creek Shale)

SE $\frac{1}{4}$  SE  $\frac{1}{4}$  section 11, T.16 S, R.32 E, Grant County,  
Big Canyon, Seneca quadrangle. Fossils in silty-grey  
shale.

Locality 140 (Keller Creek Shale)

Centre SW $\frac{1}{4}$  section 12, T.16 S, R.32 E, Big Canyon,  
Seneca quadrangle.

## APPENDIX 1 (CONT'D)

Locality 168 (Hurwal Formation)

Elevation c. 6600 feet, E central part NW $\frac{1}{2}$  NW $\frac{1}{2}$ , section 19 (unsurveyed), T.2 S, R.44 E, Enterprise quadrangle, Wallowa Mountains, NE Oregon.

The geographic and, where possible, the precise stratigraphic position of each fossil locality is shown on the maps and stratigraphic columns presented in Chapter 2 (Fig. 2-2, 2-3, 2-4, 2-7, 2-8, 2-10, 2-12, 2-13.) Each specimen, however, bears the original locality number rather than the locality number designated in this report, and these numbers are used to identify specimens when measurements are presented. The tables below list the thesis locality numbers against the collection's locality number, and *vice versa*, so that no confusion can arise.

<u>Locality Number</u> used in <u>This Report</u>	<u>Collector's</u> <u>Number</u>	<u>Locality Number</u> used in <u>This Report</u>	<u>Collector's</u> <u>Number</u>
1	N1	13	N1-1-25
2	N1	14	N1-1-31
	Lower 50'	15	N1-2-1
3	N1-1-1	16	N1-2-3
4	N1-1-4	17	N1-2-4
5	N1-1-12	18	N1-2-5
6	N1-1-13	19	N1-2-6
7	N1-1-14	20	N1-2-7
8	N1-1-15	21	N1-2-8
9	N1-1-16	22	N1-2-9
10	N1-1-18	23	N1-2-10
11	N1-1-21	24	N1-3-5
12	N1-1-22	25	N1-2-11

## APPENDIX 1 (CONT'D)

<u>Locality Number</u> <u>used in</u> <u>This Report</u>	<u>Collector's</u> <u>Number</u>	<u>Locality Number</u> <u>used in</u> <u>This Report</u>	<u>Collector's</u> <u>Number</u>
26	N1-2-13	66	D6863
27	N1-3-8	67	P36
28	N1-3-9	68	D6813
29	N1-2-19	69	D6812
30	P52	70	P37, D6808
31	N1-3-10	71	D6865
32	N1-3-11	72	D6809
33	N1-4-4, P20	73	D6807
34	N1-8-1	74	P31
35	N1-9-1	75	LSJU 2950
36	P51	76	P43
37	N1-10-1	77	P50,
38	N1-11-2	78	W3-13
39	N1-10-3	79	W3-12
40	P99	80	W3-11
41	P29	81	W3-10
42	714D(-(25-50'))	82	W3-9
43	LSJU 714D	83	W3-8
44	D-Top JS4	84	W3-5
45	P25	85	P44
46	P27	86	W3-4
47	P28	87	W3-3
48	P2	88	W3-2
49	P14	89	P46
50	P5	90	P47, P48
51	P3, P4	91	W4-4
52	D7033	92	W1-13A-0
53	D7034, P100	93	P49
54	D7035	94	W1-13B-9
55	D7036	95	W1-13B-7
56	P6, D6908, D7899	96	W1-13B-6,
57	P10	97	W1-13A-4
58	P11, P16	98	W1-13B-5
59	P15	99	W1-13A-3
60	1-0-7 D-10'	100	W1-13B-2
61	P13, LSJU 890	101	Sec. 50 Coll. 1
62	D6851	102	W1-11-12
63	P33	103	W1-11-9
64	P35	104	W1-11-8
65	P34	105	W1-11-6
		106	W1-11-3
		107	W1-11-2
			Sec. 50 27 m
			W1-10-14

## APPENDIX 1 (CONT'D)

<u>Locality Number</u> <u>used in</u> <u>This Report</u>	<u>Collector's</u> <u>Number</u>	<u>Locality Number</u> <u>used in</u> <u>This Report</u>	<u>Collector's</u> <u>Number</u>
108	W1-10-13	149	P92
109	W1-10-9	150	P91
110	Sec. 50 36 m	151	P90
111	W1-10-7	152	P89
112	W1-10-6	153	P81
113	Sec. 50 52 m	154	P80
114	W1-10-4	155	P79
115	W1-10-1	156	P87
116	W1-9-1	157	P85
117	W1-8-18	158	P75, P76,
118	W1-8-16		P77, P78
119	W1-8-15	159	P71, P72,
120	W1-8-14		P73
121	W1-8-12	160	P67, P68,
122	W1-8-11		P69, P70
123	W1-8-10	161	P65, P66
124	W1-8-9	162	P63, P64
125	W1-8-7	163	P62
126	W1-8-6	164	P60, P61
127	W1-8-4	165	P56, P57,
128	W1-8-2		P58, P59
129	W1-8-1	166	P55
130	W1-7-9	167	P54
131	L48	168	P82, P83,
132	D11		31742
133	BUD 90		
134	Donovan Fm.		
135	SU 99		
136	P98, 28367	<u>My Collection</u>	
137	D6911	<u>Numbers</u>	<u>This Report</u>
138	D6909,		
	30397	D11	132
139	28361	N1	1
140	28358	N1	2
141	28805	Lower 50'	
142	29422	N1-1-1	3
143	29423	N1-1-4	4
144	28806,	N1-1-12	5
	29424	N1-1-13	6
145	28811	N1-1-14	7
146	29425	N1-1-15	8
147	31741	N1-1-16	9
148	P93	N1-1-18	10

## APPENDIX 1 (CONT'D)

<u>My Collection</u> <u>Numbers</u>	<u>This Report</u>	<u>My Collection</u> <u>Numbers</u>	<u>This Report</u>
N1-1-21	11	W1-10-4	114
N1-1-22	12	W1-10-6	112
N1-1-25	13	W1-10-7	111
N1-1-31	14	W1-10-9	109
N1-2-1	15	W1-10-13	108
N1-2-3	16	W1-10-14	107
N1-2-4	17	W1-11-2	105
N1-2-5	18	W1-11-3	104
N1-2-6	19	W1-11-6	103
N1-2-7	20	W1-11-8	102
N1-2-8	21	W1-11-9	101
N1-2-9	22	W1-11-12	100
N1-2-10	23	W1-13A-0	91
N1-2-11	25	W1-13A-3	97
N1-2-13	26	W1-13A-4	95
N1-2-19	29	W1-13B-2	98
N1-3-5	24	W1-13B-5	96
N1-3-8	27	W1-13B-6	95
N1-3-9	28	W1-13B-7	94
N1-3-10	31	W1-13B-9	93
N1-3-11	32	W3-2	87
N1-4-4	33	W3-3	86
N1-8-1	34	W3-4	85
N1-9-1	35	W3-5	83
N1-10-1	37	W3-8	82
N1-10-3	39	W3-9	81
N1-11-2	38	W3-10	80
		W3-11	79
W1-7-9	130	W3-12	78
W1-8-1	129	W3-13	77
W1-8-2	128	W4-4	90
W1-8-4	127		
W1-8-6	126	P2	48
W1-8-7	125	P3	51
W1-8-9	124	P4	51
W1-8-10	123	P5	50
W1-8-11	122	P6	56
W1-8-12	121	P10	57
W1-8-14	120	P11	58
W1-8-15	119	P13	61
W1-8-16	118	P14	49
W1-8-18	117	P15	59
W1-9-1	116	P16	58
W1-10-1	115	P20	33

## APPENDIX 1 (CONT'D)

<u>My Collection</u> <u>Numbers</u>	<u>This Report</u>	<u>My Collection</u> <u>Numbers</u>	<u>This Report</u>
P25	45	P81	153
P27	46	P82	168
P28	47	P83	168
P29	41	P85	157
P31	74	P87	156
P33	63	P89	152
P34	65	P90	151
P35	64	P91	150
P36	67	P92	149
P37	70	P93	148
P43	76	P98	136
P44	84	P99	40
P46	88	P100	53
P47	89		
P48	89		
P49	92		
P50	77		
P51	36	<u>United States</u>	
P52	30	<u>Geological</u>	
P54	167	<u>Survey</u>	<u>This Report</u>
P55	166	BUD 90	133
P56	165	Donovan Fm.	134
P57	165	L48	131
P58	165	SU 99	135
P59	165	28358	140
P60	164	28361	139
P61	164	28367	136
P62	163	28805	141
P63	162	28806	144
P64	162	28811	145
P65	161	29422	142
P66	161	29423	143
P67	160	29424	144
P68	160	29425	146
P69	160	30397	138
P70	160	31741	147
P71	159	31742	168
P72	159		
P73	159		
P75	158		
P76	158		
P77	158		
P78	158		
P79	155		
P80	154		

## APPENDIX 1 (CONT'D)

<u>University of California, Berekely</u>	<u>This Report</u>	<u>Stanford University</u>	<u>This Report</u>
D-Top JS4	44	1-0-7 D-10'	60
Sec. 50 Coll. 1	99	LSJU 714D	42
Sec. 50 27 m	106	(-(25-50'))	
Sec. 50 36 m	110	LSJU 714D	43
Sec. 50 52 m	113	LSJU 890	61
D6807	73	LSJU 2950	75
D6808	70		
D6909	72		
D6812	69		
D6813	68		
D6851	62		
D6863	66		
D6865	71		
D6908	56		
D6909	138		
D6911	137		
D7033	52		
D7034	53		
D7035	54		
D7036	55		
D7899	56		



APPENDIX 2 - DISTRIBUTION OF LOWER JURASSIC  
AMMONITE GENERA (See Chapter 4)

Sinemurian (excluding the Bucklandi and  
basal Semicostatum Zones)

	<u>United States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW Germany</u>	<u>Great Britain</u>
<i>Aegasteroceras</i>		x	x	x	x
<i>Angulaticeras</i>			x	x	x
<i>Agassiceras</i>				x	x
<i>Apoderoceras</i>		x	x		x
<i>Arnioceras</i>	x		x	x	x
<i>Asteroceras</i>		x	x	x	x
<i>Audaxyltoceras</i>			x		
<i>Bifericeras</i>				x	x
<i>Caenisites</i>					x
<i>Cheltonia</i>				x	x
<i>Coeloderoceras</i>			x	x	
<i>Crucilobiceras</i>			x	x	x
<i>Cymbites</i>		x		x	x
<i>Echioceras</i>		x	x	x	x
<i>Ectocentrites</i>			x		
<i>Eoderoceras</i>		x			x
<i>Eparietites</i>	x		x	x	x

## APPENDIX 2. - SINEMURIAN (CONT'D)

	<u>United States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW Germany</u>	<u>Great Britain</u>
<i>Epideroceras</i>		x	x		x
<i>Epophioceras</i>	x	x	x	x	x
<i>Euagassiceras</i>				x	x
<i>Gagaticeras</i>				x	x
<i>Gemellaroceras</i>		x	x		
<i>Geyerocheras</i>			x		
<i>Gleviceras</i>	x		x	x	x
<i>Juraphyllites</i>	x		x		
<i>Leptechioceras</i>		x		x	x
<i>Lytoceras</i>			x		
<i>Microderoceras</i>	x		x	x	x
<i>Orthechioceras</i>	x				x
<i>Oxynoticeras</i>	x	x	x	x	x
<i>Paroxynoticeras</i>			x		
<i>Partschiceras</i>			x		
<i>Palaeoechioceras</i>	x		x		x
<i>Paltephioceras</i>	x	x	x	x	x
<i>Phylloceras</i>	x		x		
<i>Pompeckioceras</i>		x			
<i>Promicroceras</i>				x	x
<i>Riparioceras</i>				x	
<i>Slatterites</i>					x

## APPENDIX 2 - SINEMURIAN (CONT'D)

	<u>United</u> <u>States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW</u> <u>Germany</u>	<u>Great</u> <u>Britain</u>
<i>Tropidoceras</i>			x		
<i>Tmaegophioceras</i>	?		x		
<i>Xipheroceras</i>			x	x	x

## APPENDIX 2 (CONT'D)

	<u>Carixian</u>				
	<u>United States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW Germany</u>	<u>Great Britain</u>
<i>Acanthopleuroceras</i>	x	x	x	x	x
<i>Aegolytoceras</i>			x		
<i>Androgymoceras</i>		x	x	x	x
<i>Apoderoceras</i>			x	x	
<i>Aveyroniceras</i>	x		x		
<i>Beaniceras</i>		x	x	x	x
<i>Becheiceras</i>			x	x	x
<i>Calliphylloceras</i>			x		
<i>Coeloceras</i>	x	x	x	x	x
<i>Coeloderoceras</i>		x		x	
<i>Cymbites</i>		x		x	
<i>Dayiceras</i>	x	x			
<i>Epideroceras</i>				x	
<i>Fuciniceras</i>	x		x	x	
<i>Gemmelloceras</i>		x	x		x
<i>Gleviceras</i>			x	x	
<i>Harpophylloceras</i>			x		
<i>Hyperderoceras</i>	x		x	x	x
<i>Holcolytoceras</i>			x	x	
<i>Juraphyllites</i>		x	x		
<i>Lioceratoides</i>	x				

## APPENDIX 2 - CARIXIAN (CONT'D)

	<u>United</u> <u>States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW</u> <u>Germany</u>	<u>Great</u> <u>Britain</u>
<i>Liparoceras</i>		x	x	x	x
<i>Luningiceras</i>	x			x	x
<i>Lytoceras</i>		x	x	x	
<i>Meneghiniceras</i>			x		
<i>Metaderoceras</i>	x	x	x	x	
<i>Microderoceras</i>				x	
<i>Oistoceras</i>	x	x	x	x	x
<i>Oxynoticeras</i>		x	x		
<i>Parinodiceras</i>			x	x	
<i>Paroxynoticeras</i>			x		
<i>Partschiceras</i>			x		
<i>Peripleuroceras</i>			?		x
<i>Phricodoceras</i>	x	x	x	x	x
<i>Phylloceras</i>	x	x	x		
<i>Platypleuroceras</i>		x	x	x	
<i>Prodactylioceras</i>	x	x	x	x	x
<i>Protogrammoceras</i>		x	x		
<i>Polymorphites</i>		x	x	x	x
<i>Radstockiceras</i>	x		x	x	x
<i>Reynesoceras</i>			x		
<i>Reynesocoeloceras</i>	x		x		
<i>Tetraspidoceras</i>			x		
<i>Uptonia</i>		x	x	x	x
<i>Xipheroceras</i>				x	

## APPENDIX 2 (CONT'D)

	<u>Domerian</u>				
	<u>United States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW Germany</u>	<u>Great Britain</u>
<i>Amaltheus</i>		x	x	x	x
<i>Amauroceras</i>					x
<i>Arieticeras</i>	x	x	x	x	x
<i>Aveyroniceras</i>	x		x		
<i>Becheiceras</i>	x				x
<i>Calliphylloceras</i>			x		
<i>Canavaria</i>	x	x			
<i>Dactylioceras</i>	x				x
<i>Derolytoceras</i>				x	
<i>Fontanelliceras</i>	x				
<i>Fucinigeras</i>	x	x	x	x	
<i>Harpoceras</i>	x				
<i>Holcophylloceras</i>	x				
<i>Leptaleoceras</i>	x		x		x
<i>Lioceratoides</i>	x	x	x		
<i>Lytoceras</i>	x	x	x	x	
<i>Metacymbites</i>	x			x	x
<i>Oistoceras</i>					x
<i>Partschiceras</i>	x				

## APPENDIX 2 - DOMERIAN (CONT'D)

	<u>United States</u>	<u>Portugal</u>	<u>Hungary</u>	<u>SW Germany</u>	<u>Great Britain</u>
<i>Phylloceras</i>	x	x	x		x
<i>Pleuroceras</i>		x	x	x	x
<i>Prodactylioceras</i>			x		
<i>Protogrammoceras</i>	x	x	x	x	x
<i>Pseudoamaltheus</i>				x	x
<i>Radstockiceras</i>	x				
<i>Reynesoceras</i>	x	x			
<i>Reynesocoeloceras</i>		x			
<i>Sowerbyceras</i>				x	
<i>Tragyphylloceras</i>	x				x
<i>Zetoceras</i>				x	

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EXPLANATION OF PLATE 1

[All figures natural size unless otherwise indicated.]

Fig. 1      *Phylloceras* spp.

Specimen D7033(5); internal mould from  
locality 52 (*A. ceratitoides* Zone),  
Sunrise Formation, Gabbs Valley Range.

Fig. 2.      *Surphyllites* cf. *dorsocurvata* (FUCINI)

McM J2050; internal mould from locality  
33 (*P. rothpletzi* Zone), Sunrise  
Formation, Gabbs Valley Range.

Fig. 3-5.    *Arnioceras arnouldi* (DUMORTIER)

3. McM J2051; latex cast of external  
mould from locality 65 (*A. ceratitoides*  
Zone), Sunrise Formation, Shoshone  
Mountains.

4. McM J2052; internal mould from  
locality 65, age and formation as for  
figure 3.

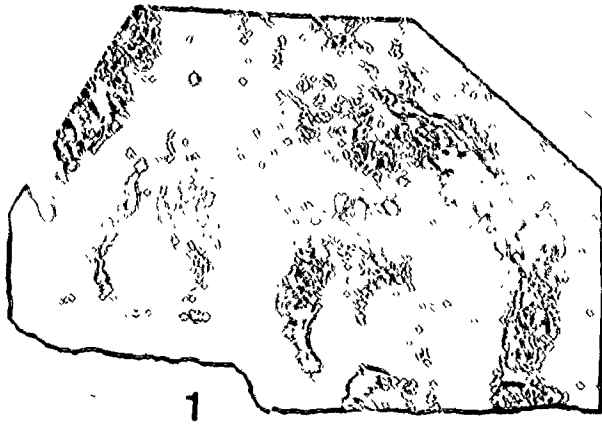
5. McM J2053; internal mould from  
locality 63 (*A. ceratitoides* Zone),  
Sunrise Formation, Shoshone Mountains.

Fig. 6, 7.    *Arnioceras ceratitoides* (QUENSTEDT)

6. McM J2054; internal mould from  
locality 51 (*A. ceratitoides* Zone),  
Sunrise Formation, Gabbs Valley Range.

7. McM J2055; internal mould from  
locality 63, age and formation as for  
figure 5.

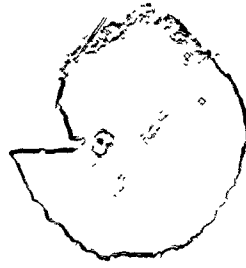
PLATE I



1



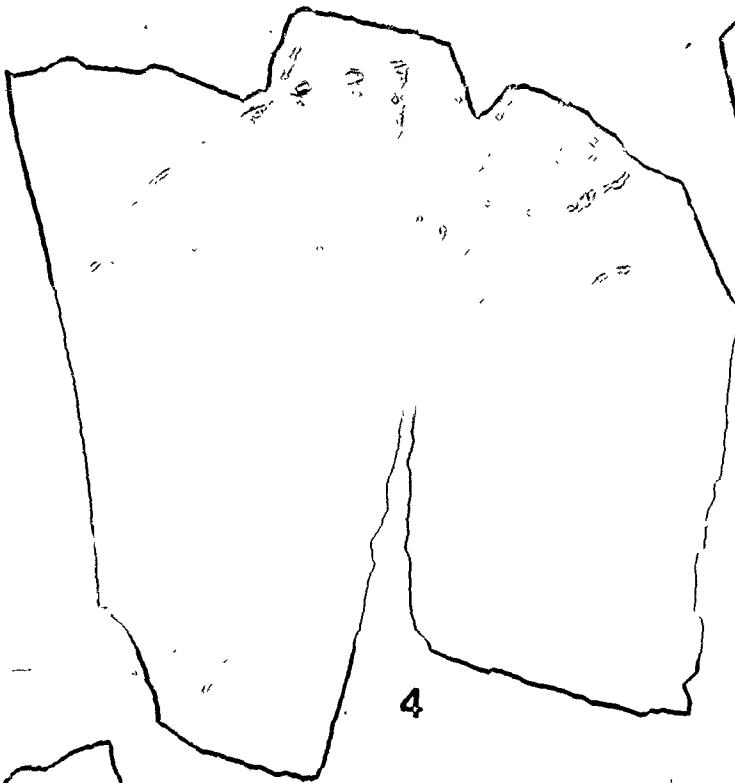
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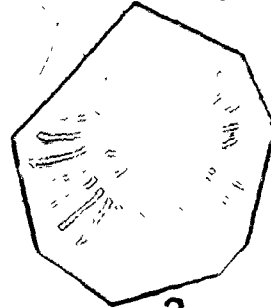
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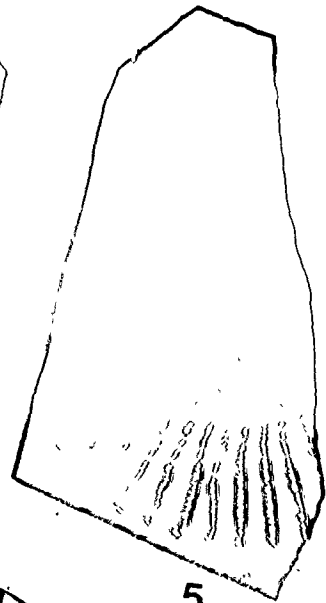
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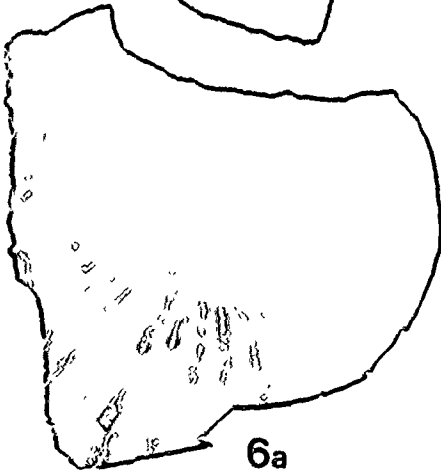
4



3



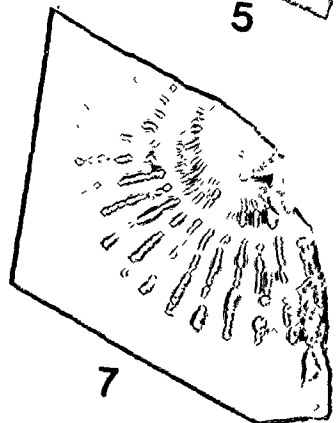
5



6a



6b



7

EXPLANATION OF PLATE 2

[All figures natural size unless otherwise indicated.]

Fig. 1, 4. *Arnioceras* cf. *oppeli* GUERIN-FRANIATTE

1. Specimen D6863(5); internal mould from locality 66 (*A. ceratitoides* Zone), Sunrise Formation, Shoshone Mountains.
4. McM J2058; internal mould from locality 64 (*A. ceratitoides* Zone), Sunrise Formation, Shoshone Mountains.

Fig. 2, 3. *Arnioceras miserabile* (QUENSTEDT)

2. McM J2056; internal mould from locality 59 (*A. ceratitoides* Zone), Sunrise Formation, Gabbs Valley Range.
3. McM J2057; internal mould from locality 51 (*A. ceratitoides* Zone), Sunrise Formation, Gabbs Valley Range.

Fig. 5. *Asteroceras (Eparietites)* sp.

Specimen D6909(1); internal mould from locality 138 (*A. ceratitoides* Zone), the Keller Creek Shale.

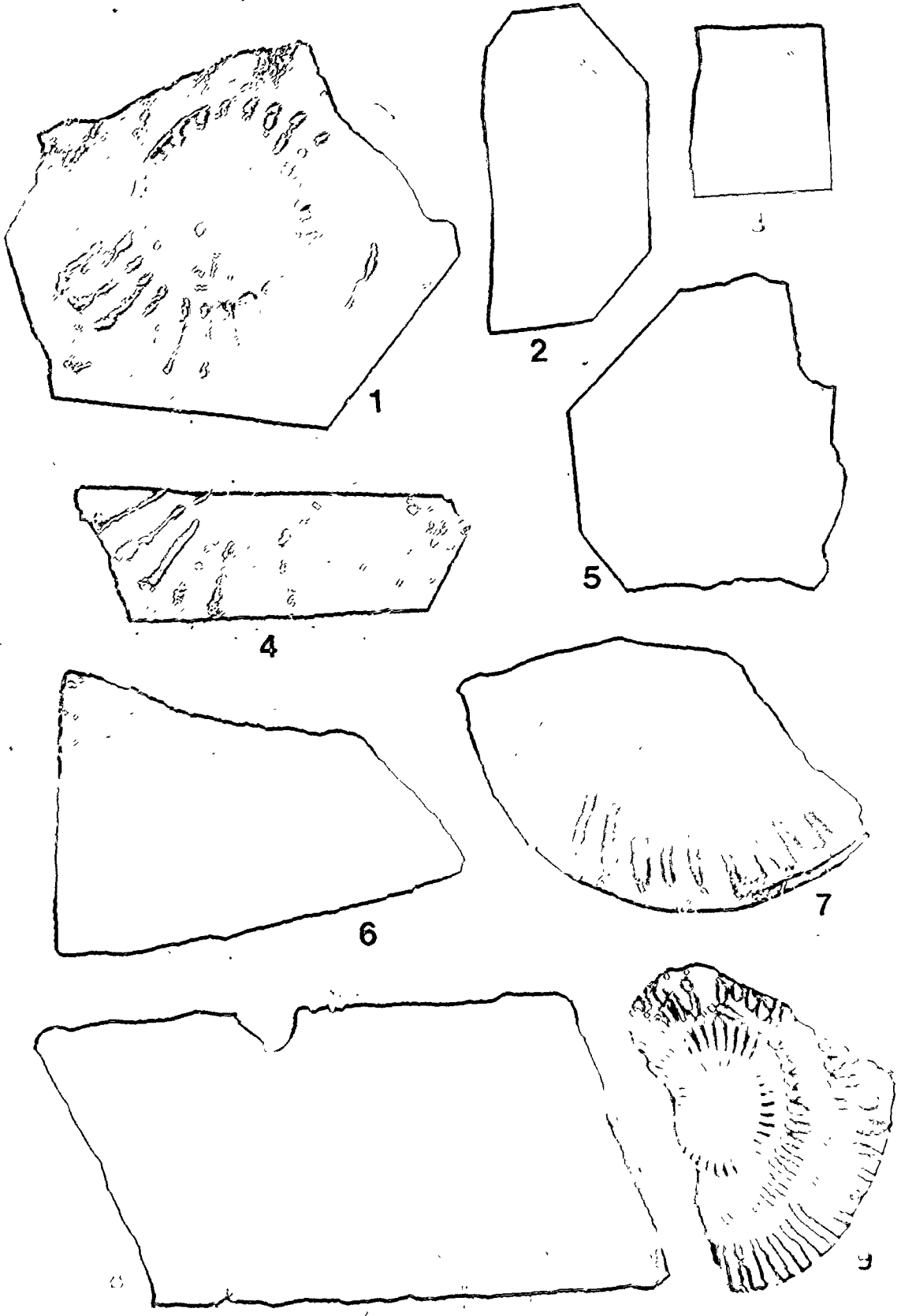
Fig. 6, 8. *Asteroceras (Eparietites)* n. sp. ?

6. McM J2059; internal mould from locality 56 (*ex situ*, ? *P. harbledownense* Zone), Sunrise Formation, Gabbs Valley Range.
8. McM J2031; internal mould from locality 1 (*A. ceratitoides* Zone), Sunrise Formation, Gabbs Valley Range.

Fig. 7, 9. *Epophioceras* cf. *carinatum* SPATH

7. McM J2030; latex cast of external mould from locality 7 (*P. harbledownense* Zone), Sunrise Formation, Gabbs Valley Range.
9. McM J2032; internal mould from locality 51, age and formation as for figure 3.

PLATE 2



EXPLANATION OF PLATE 3

[All figures natural size unless otherwise indicated.]

Fig. 1, 3. *Epophioceras* cf. *carinatum* SPATH

1. McM J2033; latex cast of external mould from locality 7 (*P. harbledownense* Zone), Sunrise Formation, Gabbs Valley Range.
3. McM J2035; latex cast of external mould from locality 82 (*P. harbledownense* Zone), Sunrise Formation, Clan Alpine Mountains.

Fig. 2. *Epophioceras* ? sp.

McM J2034; latex cast of external mould from locality 80 (*P. harbledownense* Zone), Sunrise Formation, Clan Alpine Mountains.

Fig. 4. *Epophioceras* aff. *carinatum* SPATH

McM J2036; internal mould from locality 15 (*P. harbledownense* Zone) Sunrise Formation, Gabbs Valley Range.

Fig. 5. *Palaeoehioceras spirale* (TRUEMAN & WILLIAMS)

Specimen D6908(46); internal mould from locality 56 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.

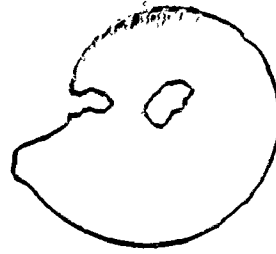
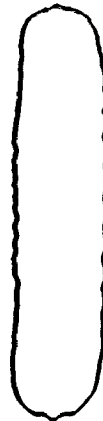
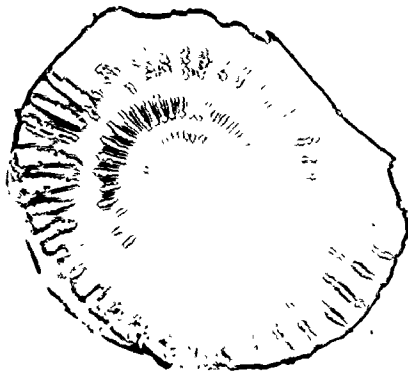
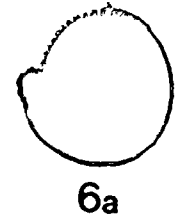
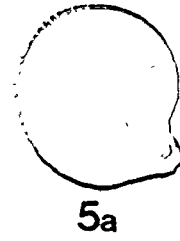
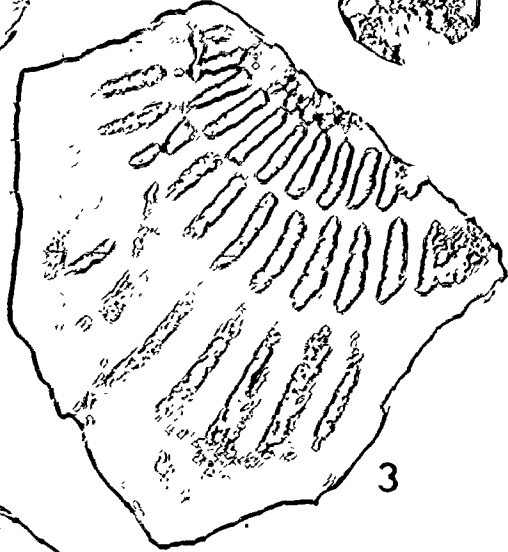
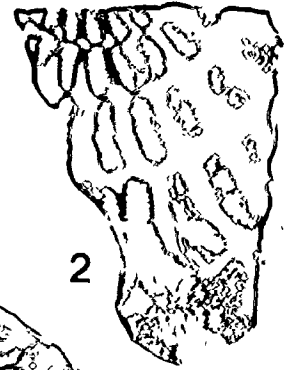
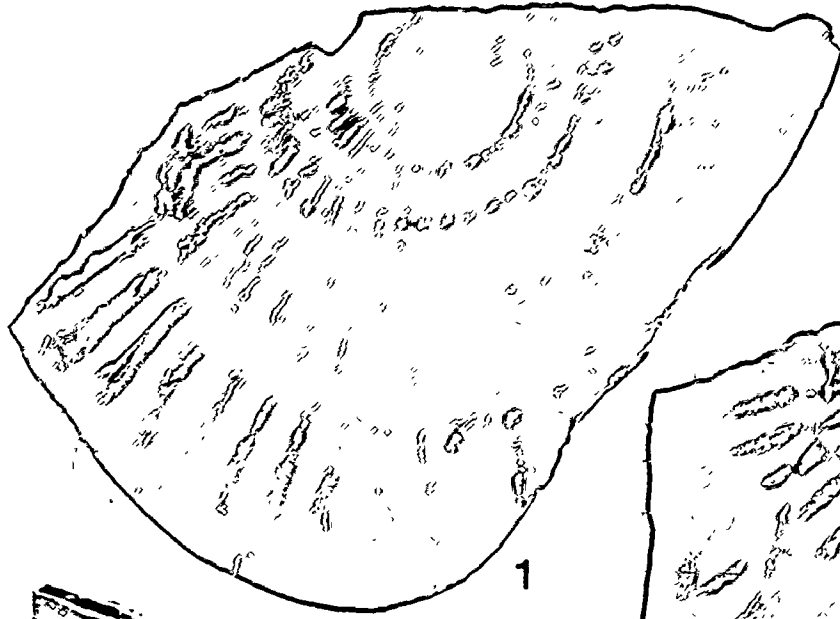
Fig. 6. *Palaeoehioceras* aff. *spirale* (T. and W.)

Specimen D6908(47); internal mould from locality 56, age and formation as for figure 5.

Fig. 7, 8. *Paltechioceras* (*Orthechioceras*) *edmundi* (DUMORTIER)

7. Specimen D6908(24); (a), (c) internal mould; (c) latex cast of external mould from locality 56, age and formation as for figure 5.
8. Specimen D6908(10); internal mould from locality 56, age and formation as for figure 5.

PLATE 3



EXPLANATION OF PLATE 4

[All figures natural size unless otherwise indicated.]

Fig. 1, 2. *Paltechioceras boehmi* (HUG).

1. McM J2041; internal mould from locality 56 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
2. McM J2042; internal mould, locality and age as for figure 1.

Fig. 3, 4. *Paltechioceras depressum* n. sp.

3. Holotype, McM J2043; internal mould from locality 33 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
4. Paratype, McM J2044; internal mould, locality and age as for figure 3.

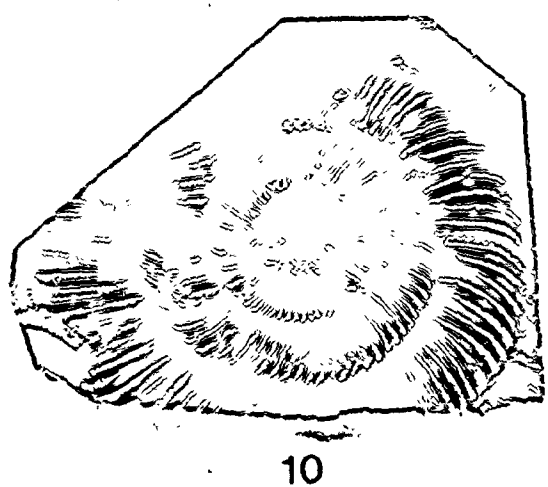
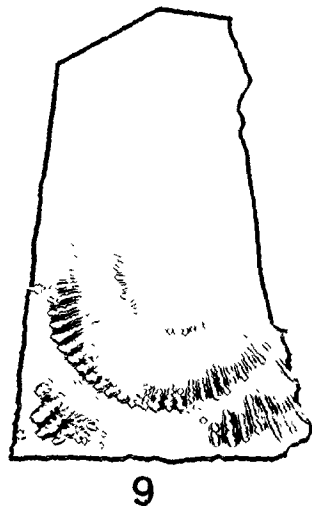
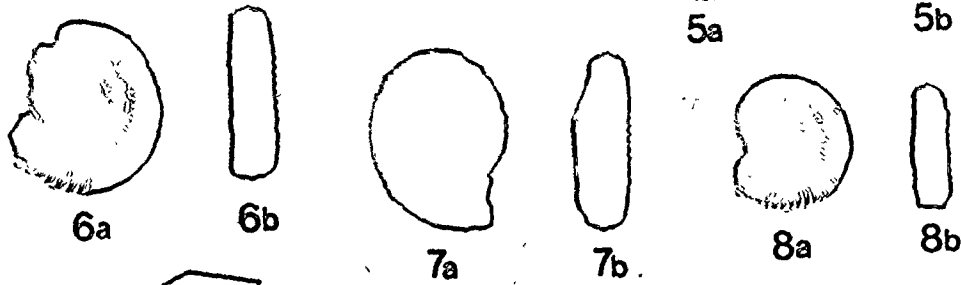
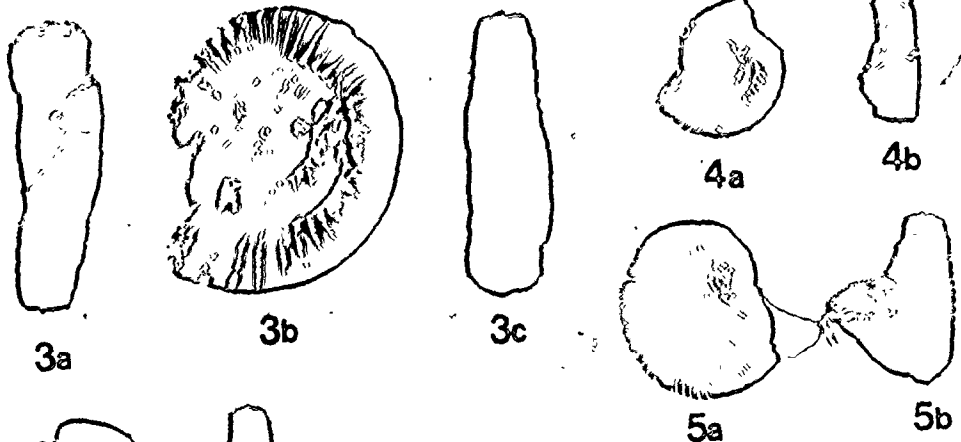
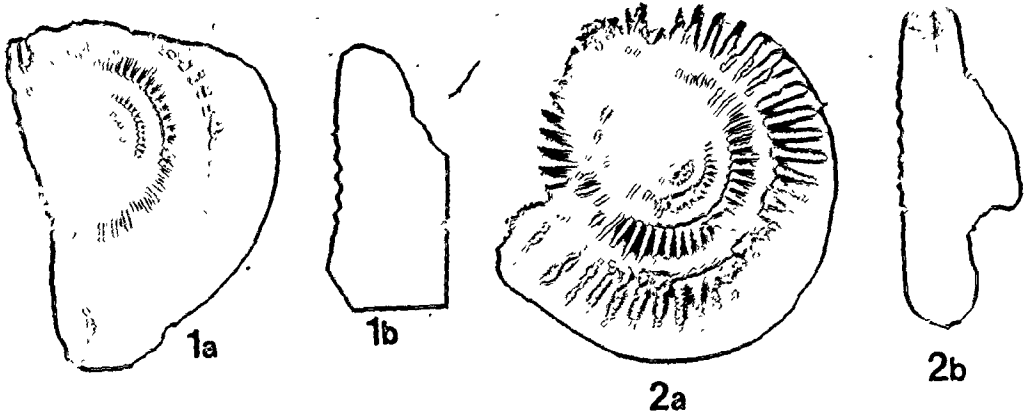
Fig. 5-8. *Paltechioceras gettyi* n. sp.

5. Paratype, McM J2045; internal mould, locality and age as for figure 3.
6. McM J2046; internal mould, locality and age as for figure 3.
7. Holotype, McM J2047; internal mould, locality and age as for figure 3.
8. Paratype, McM J2048; internal mould, locality and age as for figure 3.

Fig. 9, 10. *Paltechioceras harbledownense* CRICKMAY

9. McM J2049; latex cast of external mould from locality 87 (*ex situ*, ? *P. rothpletzi* Zone), Sunrise Formation, Clan Alpine Mountains.
10. McM J2050; internal mould from locality 18 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.

PLATE 4





EXPLANATION OF PLATE 5

[All figures natural size unless otherwise indicated.]

Fig. 1, 4. *Paltechioceras harbledownense* (CRICKMAY)

1. McM J2037; internal mould from locality 19 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
4. Specimen D6812(4); external and partial internal mould from locality 69 (*P. harbledownense* Zone), Sunrise Formation, Shoshone Mountains.

Fig. 2, 3. *Paltechioceras oosteri* (DUMORTIER)

2. Specimen D6908(48); internal mould from locality 56 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
3. McM J2038; internal mould from locality 57 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.

Fig. 5, 6. *Paltechioceras rothpletzi* (BÖSE)

5. McM J2039; internal mould from locality 31 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
6. McM J2040; internal mould, locality and age as for figure 5.

PLATE 5



EXPLANATION OF PLATE 6

[All figures natural size unless otherwise indicated.]

Fig. 1.

*Paltechioceras rothpletzi* (BÖSE)

Specimen D6908(13); internal mould  
from locality 56 (*P. rothpletzi* Zone),  
Sunrise Formation, Gabbs Valley Range.

Fig. 2-4.

*Paltechioceras tardecrescens* (HAUER)

2. McM J2051; internal mould from  
locality 33 (*P. rothpletzi* Zone),  
Sunrise Formation, Gabbs Valley Range.

3. McM J2052; internal mould, locality  
and age as for figure 2.

4. McM J2053; internal mould, locality  
and age as for figure 2.

Fig. 5-8.

*Paltechioceras* aff. *depressum* n. sp.

5. McM J2054; internal mould, locality  
and age as for figure 2.

6. McM J2055; internal mould from  
locality 31 (*P. rothpletzi* Zone),  
Sunrise Formation, Gabbs Valley Range.

7. McM J2056; internal mould, locality  
and age as for figure 6. Note the  
"semi-costation".

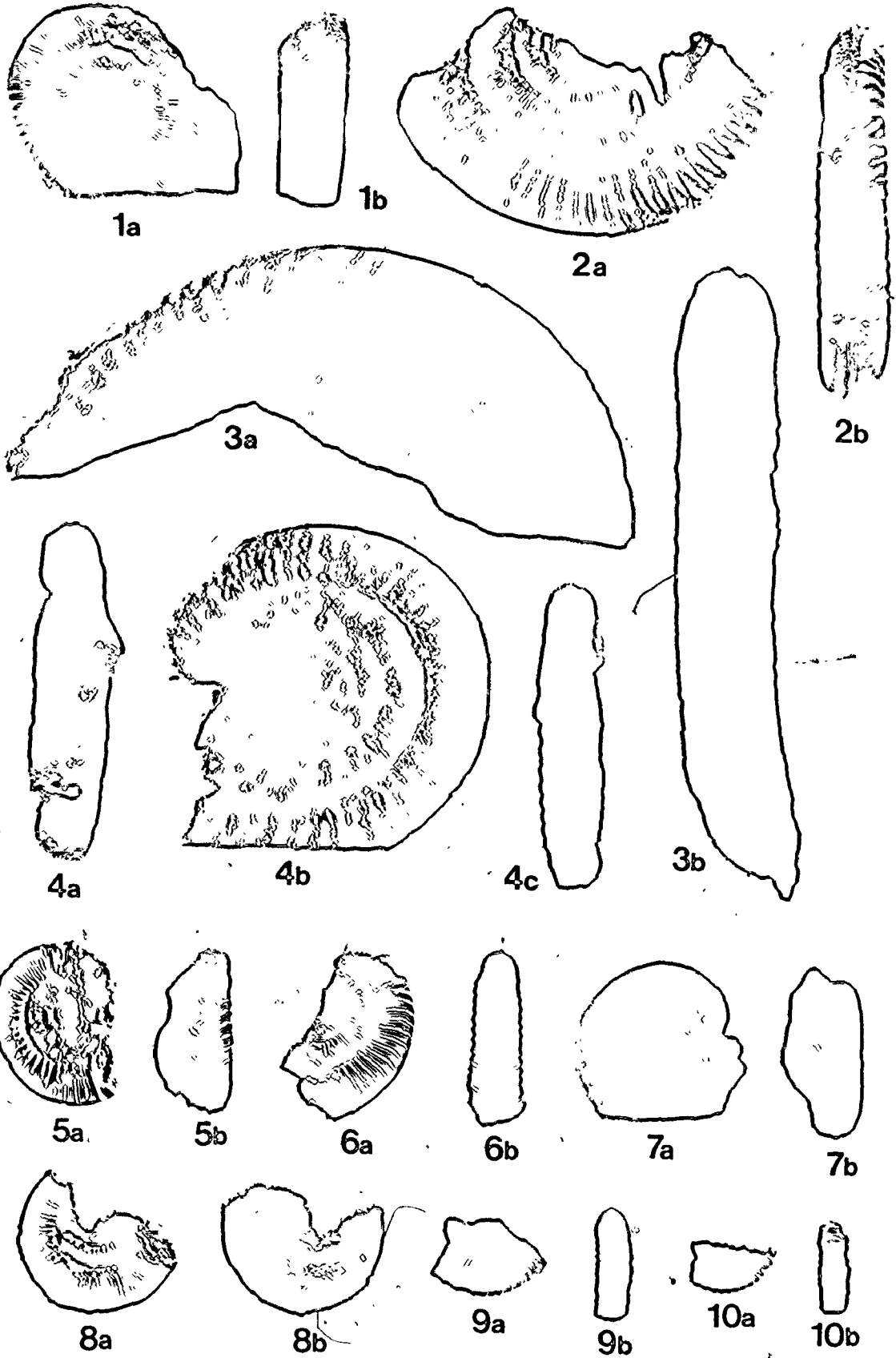
8. McM 2057; internal mould from  
locality 30 (*P. rothpletzi* Zone),  
Sunrise Formation, Gabbs Valley Range.  
Note "semi-costation". x 2

Fig. 9, 10. Echioceratidae gen. and sp. indet.

9. McM J2058; internal mould from  
locality 57 (*P. rothpletzi* Zone),  
Sunrise Formation, Gabbs Valley Range.

10. Specimen D6908(49); internal mould,  
locality and age as for figure 1.

PLATE 6



EXPLANATION OF PLATE 7

[All figures natural size unless otherwise indicated.]

-Fig. 1, 2. *Oxynoticeras* cf. *simpsoni* (SIMPSON)

1. Specimen D7899(1); internal mould from locality 56 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.
2. McM J2060; internal mould from locality 58 (*P. rothpletzi* Zone), Sunrise Formation, Gabbs Valley Range.

Fig. 3. *Radstockiceras gemmellaroi* (POMPECKJ)

McM J2059; internal mould from locality 100 (*R. fannini* Zone), Sunrise Formation, Clan Alpine Mountains.

Fig. 4. *Radstockiceras* cf. *kunae* (McLEARN)

McM J2061; internal and partial external mould from locality 165 (*R. fannini* Zone), Hurwal Formation, Wallowa Mountains.

Fig. 5. *Radstockiceras fannini* (McLEARN)

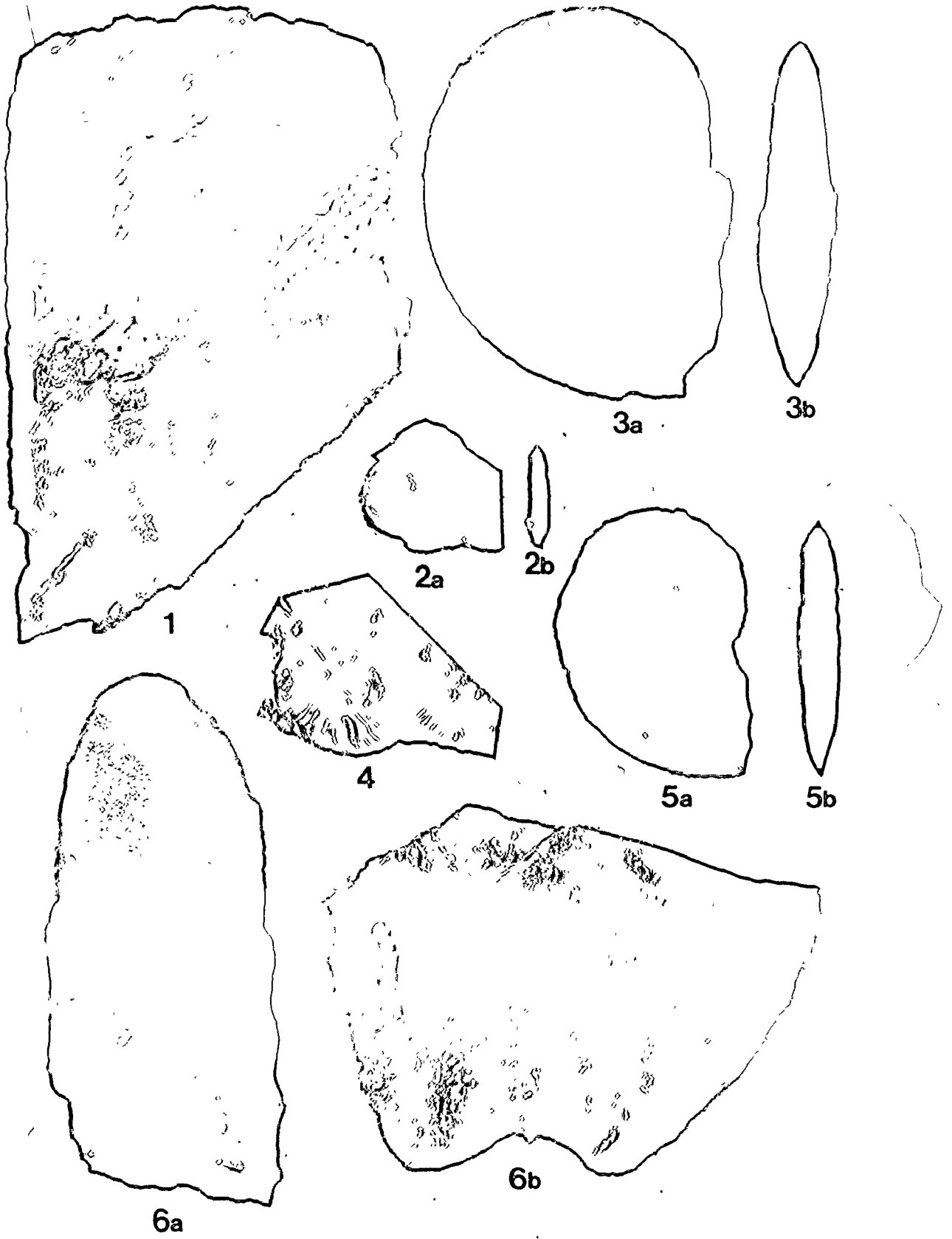
Specimen LSJU 2905(1); internal mould from locality 75 (*R. fannini* Zone), Sunrise Formation, Shoshone Mountains.

Fig. 6. *Gleviceras* ex gr. *victoris* (DUMORTIER)

McM J2062; internal mould, locality and age as for figure 2. x  $\frac{1}{2}$ .

6

PLATE 7



EXPLANATION OF PLATE 8

[All figures natural size unless otherwise indicated.]

Fig. 1. *Hyperderoceras* n. sp.

McM J2063; internal mould from locality 97 (*D. dayiceroides* Zone), Sunrise Formation, Clan Alpine Mountains.

Fig. 2,3,5. *Crucilobiceras* (*Metaderoceras*) *evolutum* (FUCINI)

2. McM J2064; latex cast of external mould from locality 153 (*A. (L.) pinnaforme* Zone), Hurwal Formation, Wallowa Mountains.

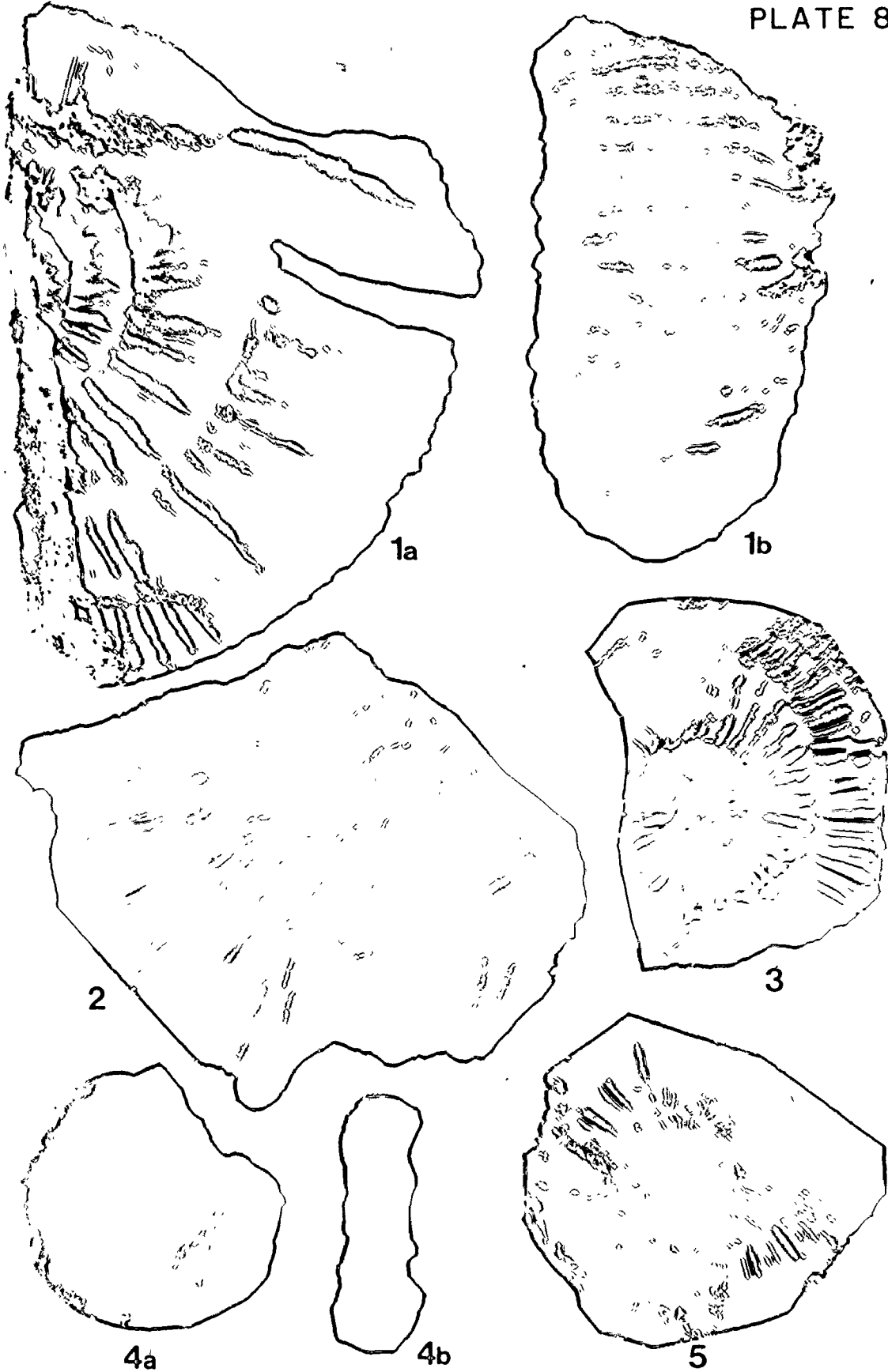
3. McM J2065; latex cast of external mould from locality 155 (*A. (L.) pinnaforme* Zone), Hurwal Formation, Wallowa Mountains.

5. McM J2066; latex cast of external mould, locality and age as for figure 2.

Fig. 4. *Crucilobiceras* (*Metaderoceras*) *beirense* MOUTERDE

USGS L48(1); internal mould from locality 131 (*ex situ*, ? *D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.

PLATE 8



e



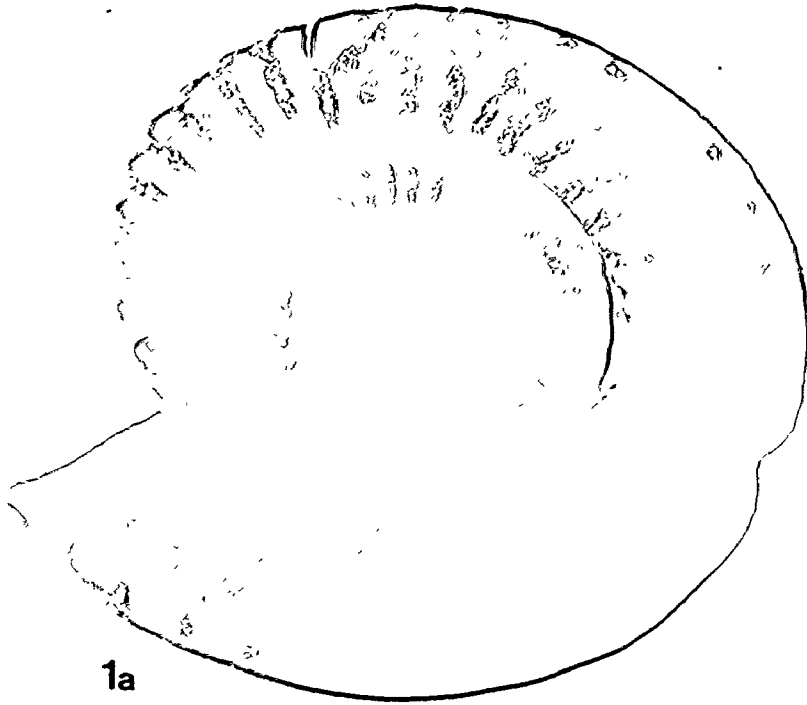
EXPLANATION OF PLATE 9

[All figures natural size unless otherwise indicated.]

Fig. 1, 2. *Crucilobicerias* (*Metaderoceras*) cf. *muticum*  
(D'ORBIGNY)

1. USGS L48(14); internal mould from locality 131 (*ex situ*, ? *D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.
2. McM J2067; internal mould from locality 132 (*D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.

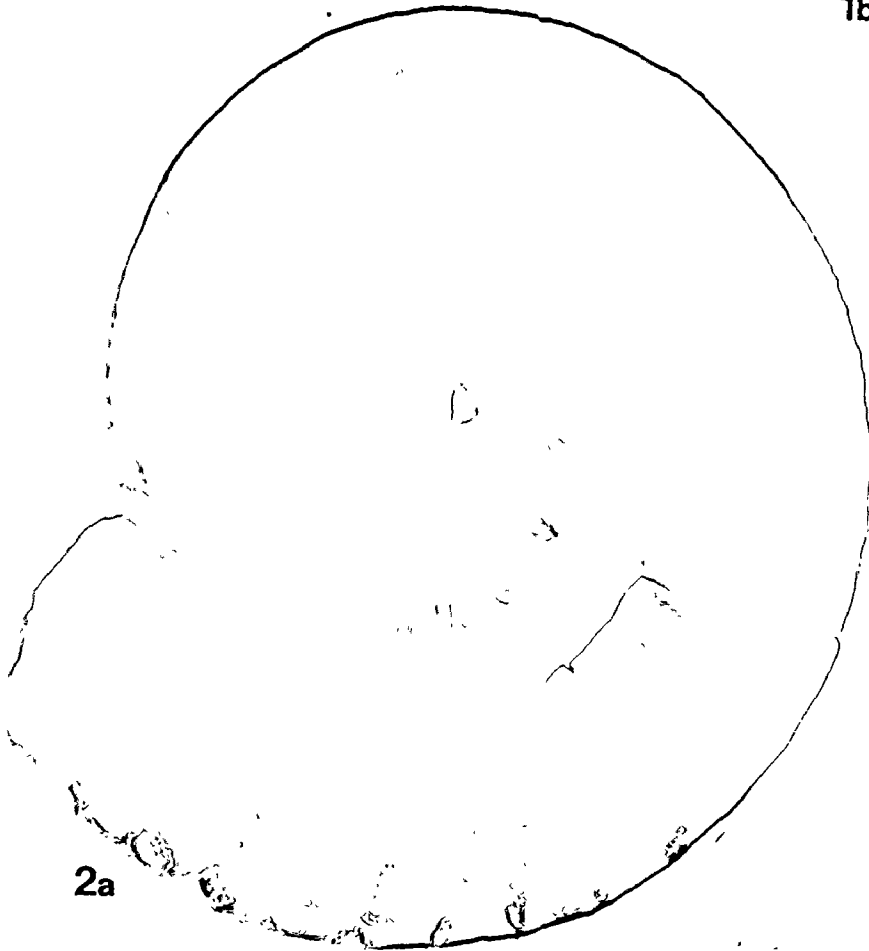
PLATE 9



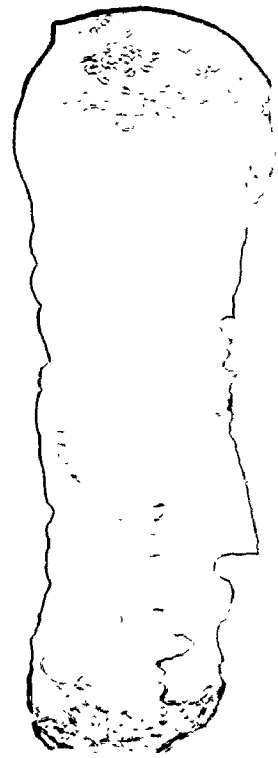
1a



1b



2a



2b

EXPLANATION OF PLATE 10

[All figures natural size unless otherwise indicated.]

Fig. 1. *Cruciloboceras* (*Metaderoceras*) cf. *muticum*  
(D'ORBIGNY)

McM J2068; latex cast of external  
mould from locality 149 (*ex situ*, ?),  
Hurwal Formation, Wallowa Mountains.

Fig. 2. *Microderoceras* cf. *birchiades* (ROSENBERG)

Specimen D6865(1); internal mould from  
locality 71 (*P. harbledownense* Zone),  
Sunrise Formation, Shoshone Mountains.

Fig. 3. *Phricodoceras* sp.

McM J2069; latex cast of external  
mould from locality 148 (*ex situ*,  
? *A. (L.) pinnaforme* Zone), Hurwal  
Formation, Wallowa Mountains. x2

Fig. 4-8. *Tropidoceras agtaeon* (D'ORBIGNY)

4. McM J2070; latex cast of external  
mould from locality 168 (*ex situ*,  
? *A. (L.) pinnaforme* Zone), Hurwal  
Formation, Wallowa Mountains.

5. USGS 31742(2); latex cast of external  
mould, locality and age as for figure 4.

6. USGS 31742(3); latex cast of external  
mould, locality and age as for figure 4.

7. USGS 28805(8); latex cast of external  
mould from locality 141 (*ex situ*, ?  
*A. (L.) pinnaforme* Zone), Hurwal  
Formation, Wallowa Mountains.

8. USGS 28367(21); latex cast of external  
mould from locality 136 (*ex situ*,  
? *A. (L.) pinnaforme* Zone), the Keller  
Creek Shale.

EXPLANATION OF PLATE 10 (cont'd)

Fig. 9, 10. *Acanthopleuroceras* (*Acanthopleuroceras*) spp.

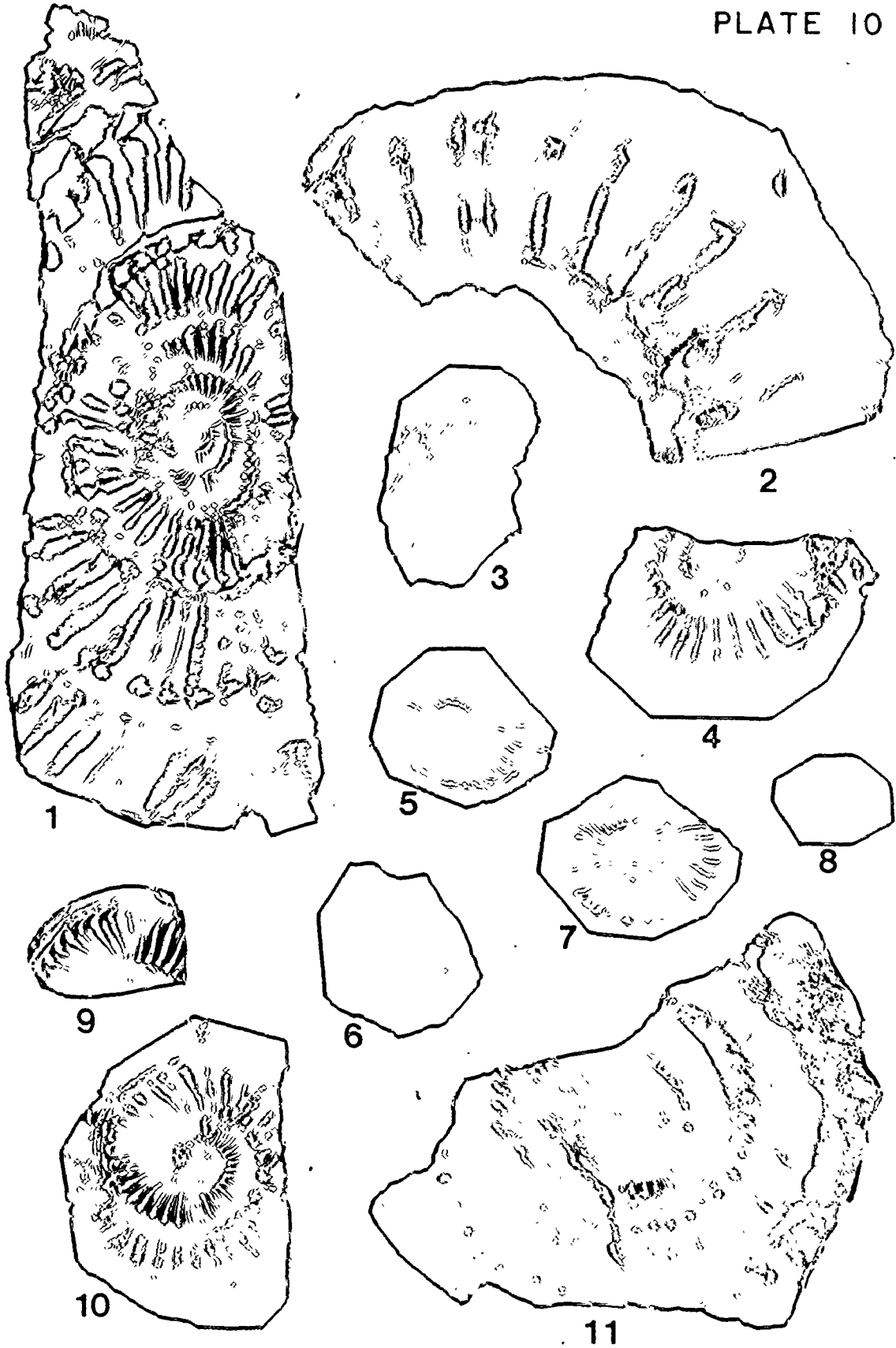
9. McM J2071, latex cast of external mould from locality 149 (*ex situ*), Hurwal Formation, Wallowa Mountains.

10. USGS 28805(11); latex cast of external mould, locality and age as for figure 7.

Fig. 11. *Acanthopleuroceras* (*Acanthopleuroceras*)  
cf. *valdani* (D'ORBIGNY)

Specimen D-Top JS4(1); latex cast of external mould from locality 44 (*A. (L.) pinnaforme* Zone), Sunrise Formation, Gabbs Valley Range.

PLATE 10



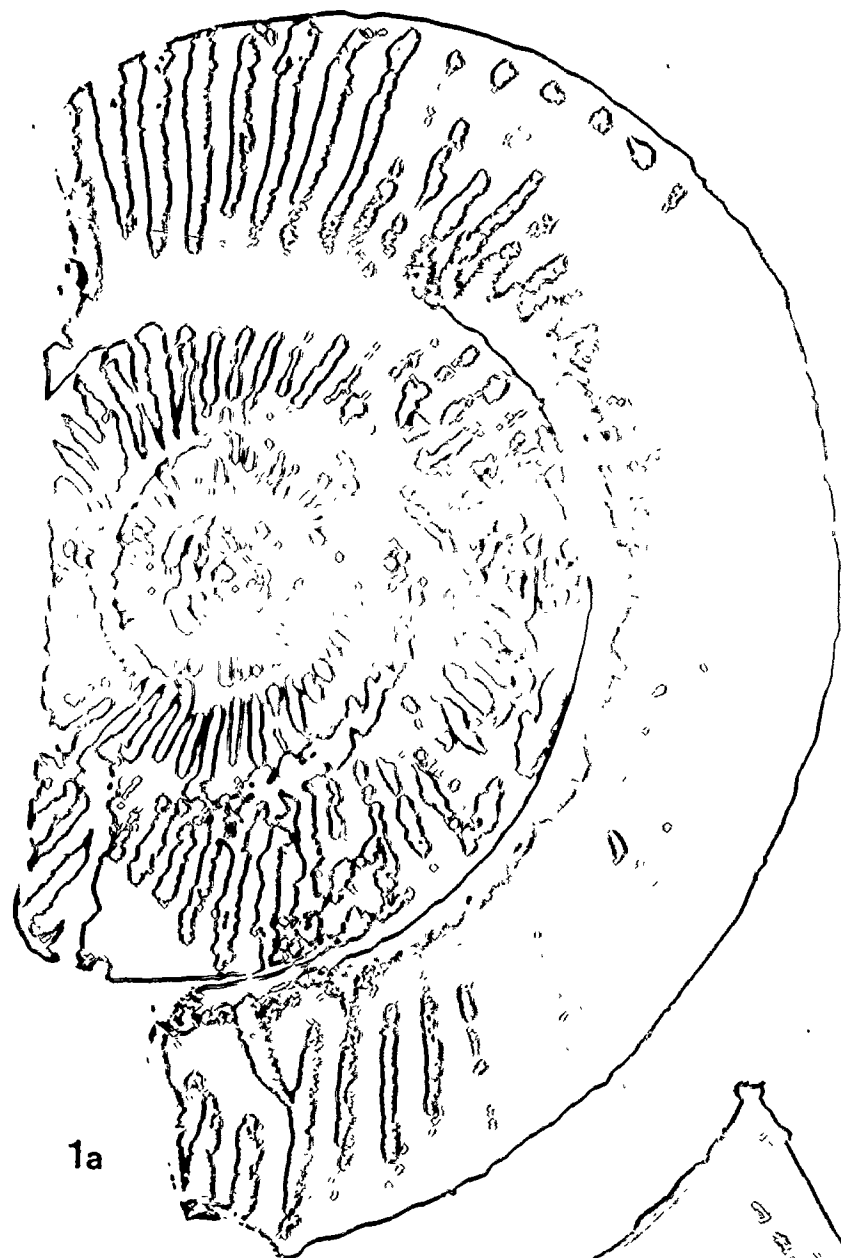
EXPLANATION OF PLATE 11

[All figures natural size unless otherwise indicated.]

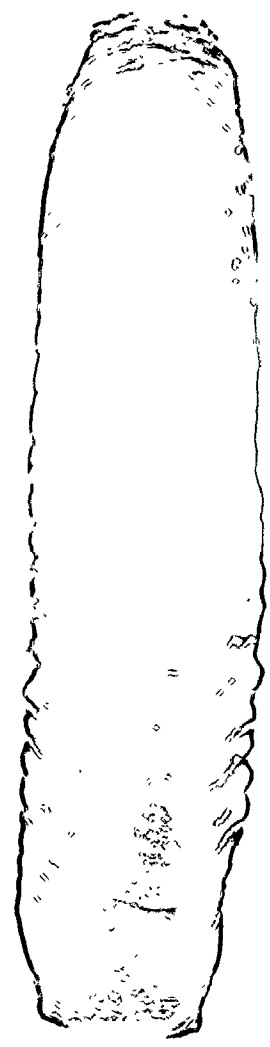
Fig. 1. *Cruciloboceras (Metaderoceras) silviesi*  
(HERTLEIN)

Holotype, USGS SU 99(1); plaster copy,  
from locality 135 (A. (L) *pinnaforme*  
Zone), Donovan Formation, Silvies  
River Valley.

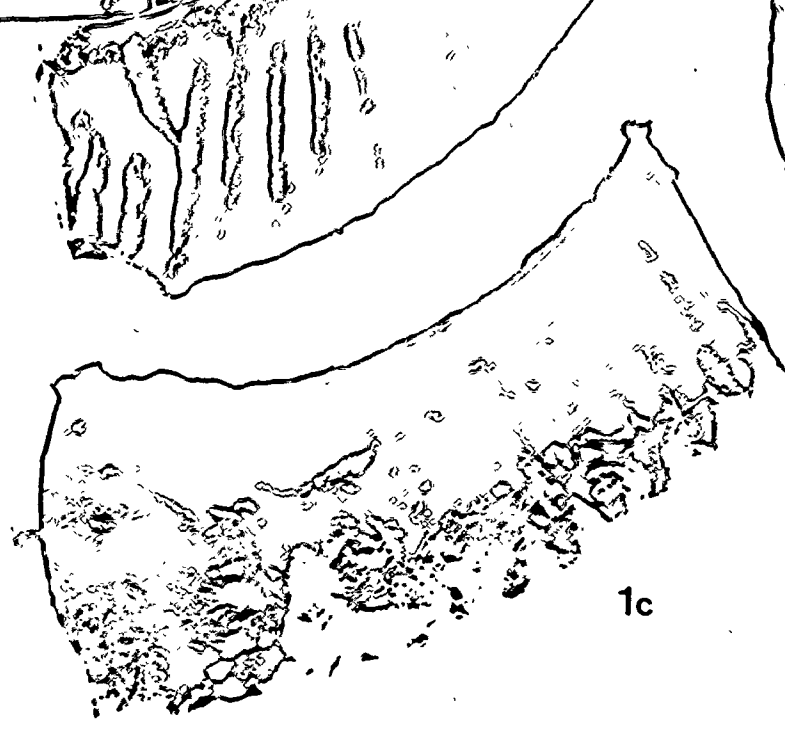
PLATE II



1a



1b



1c

EXPLANATION OF PLATE 12

[All figures natural size unless otherwise indicated.]

Fig. 1-3. *Acanthopleuroceras (Acanthopleuroceras) mulleri* n. sp.

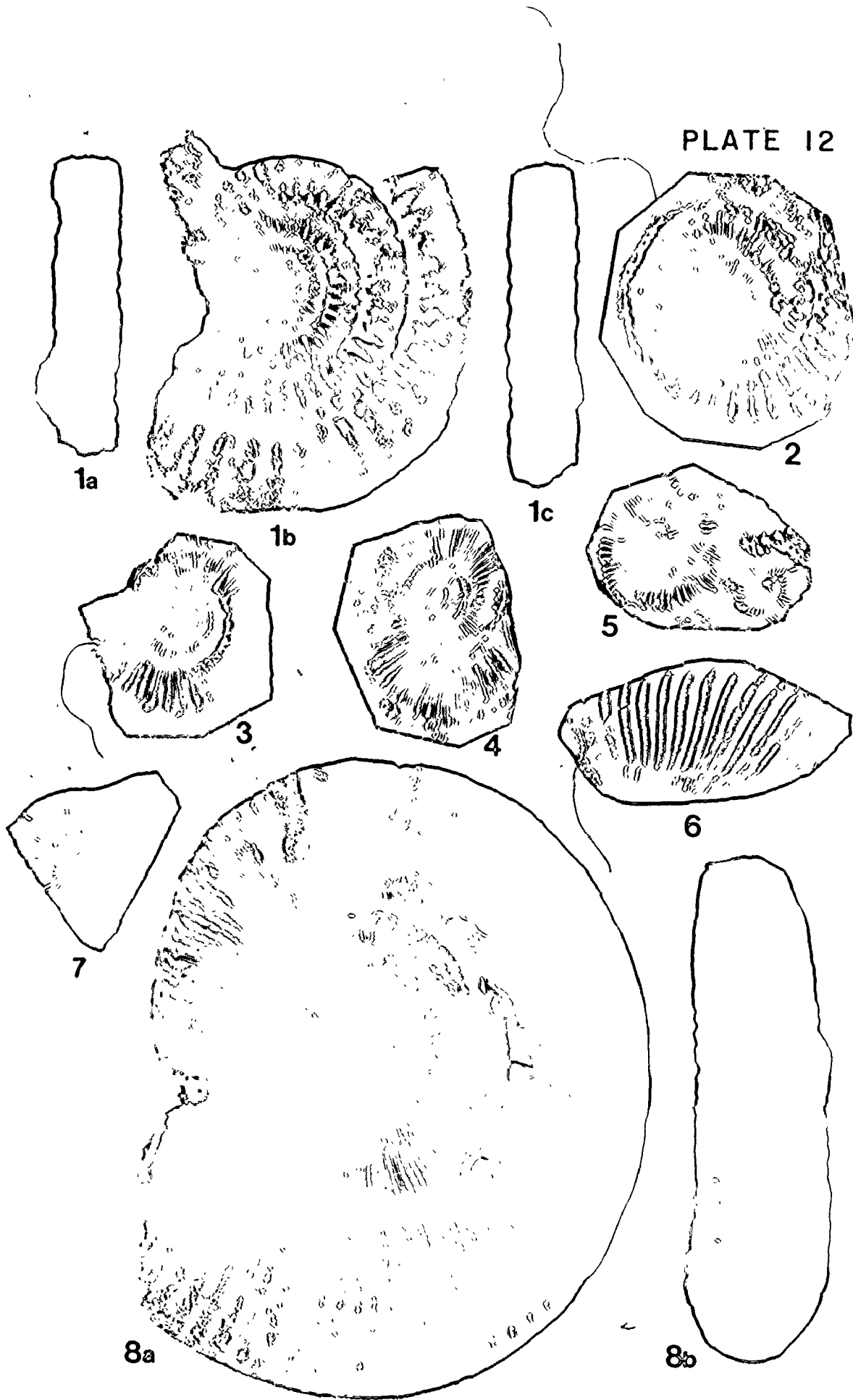
1. Holotype, specimen 1-0-7 D-10' (1); internal mould from locality 60 (*A. (L.) pinnaforme* Zone), Sunrise Formation, Gabbs Valley Range.
2. Specimen D6911(1); latex cast of external mould from locality 137 (*A. (L.) pinnaforme* Zone), the Keller Creek Shale.
3. Specimen D6911(5); internal mould, locality and age as for figure 2.

Fig. 4-8. *Dayiceras dayiceroides* (MOUTERDE)

4. USGS 28811(2); latex cast of external mould from locality 145 (*ex situ*, ? *D. dayiceroides* Zone), Hurwal Formation, Wallowa Mountains.
5. McM J2072; latex cast of external mould from locality 158 (*D. dayiceroides* Zone), Hurwal Formation, Wallowa Mountains.
6. USGS 29425(7); latex cast of external mould from locality 146 (*ex situ*, ? *D. dayiceroides* Zone), Hurwal Formation, Wallowa Mountains.
7. USGS 29425(13); latex cast of external mould, locality and age as for figure 6.
8. USGS L48(2); internal mould from locality 131 (*D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.



PLATE 12

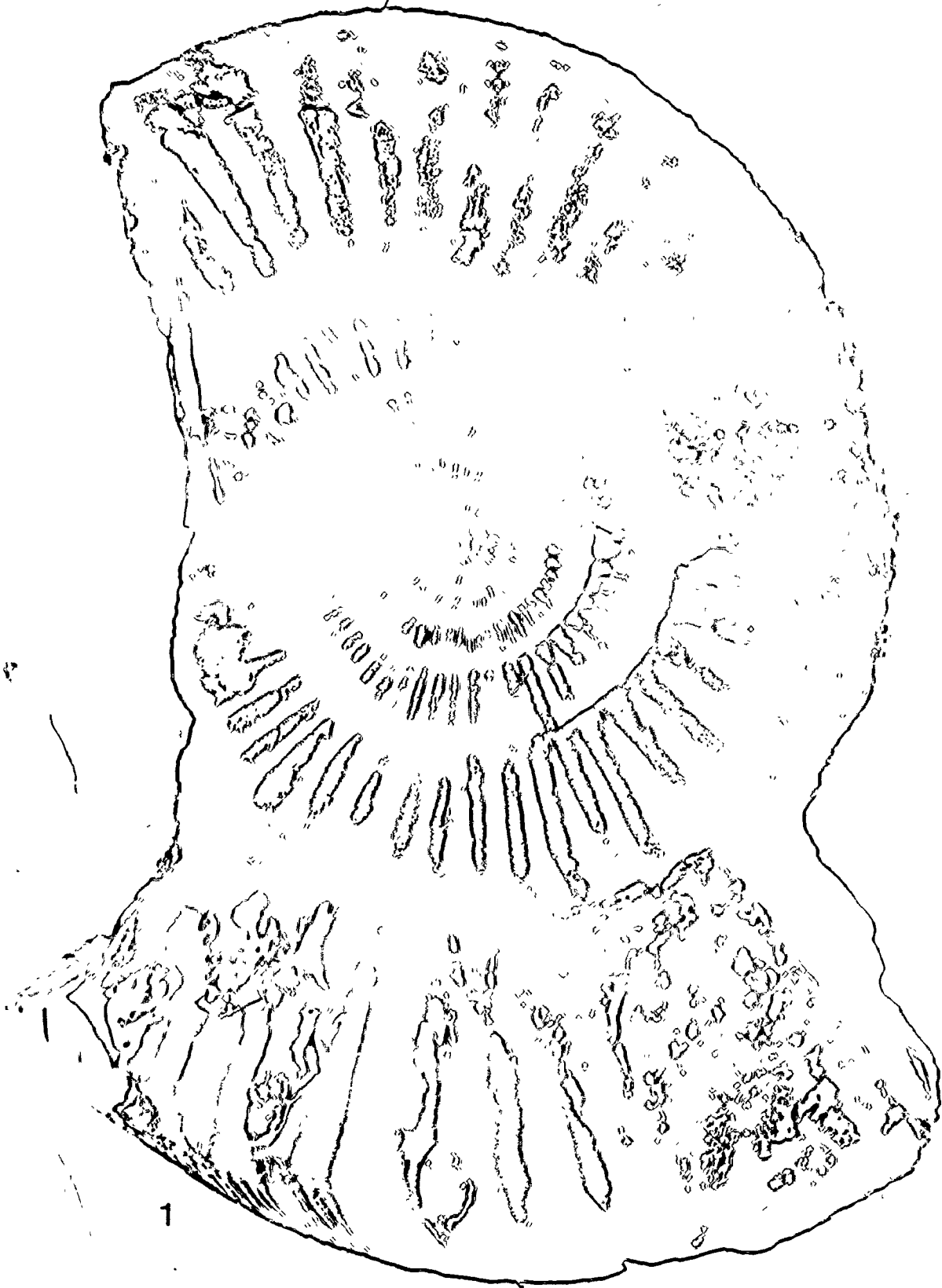


EXPLANATION OF PLATE 13

Fig. 1. *Acanthopleuroceras (Luningiceras) pinnaforme*  
n. sp.

Holotype, specimen LSJU 714D(1);  
internal mould with shell material  
adhering, from locality 43 (A. (L.)  
*pinnaforme* Zone), Sunrise Formation,  
Gabbs Valley Range. x 3/4

See also plate 14.

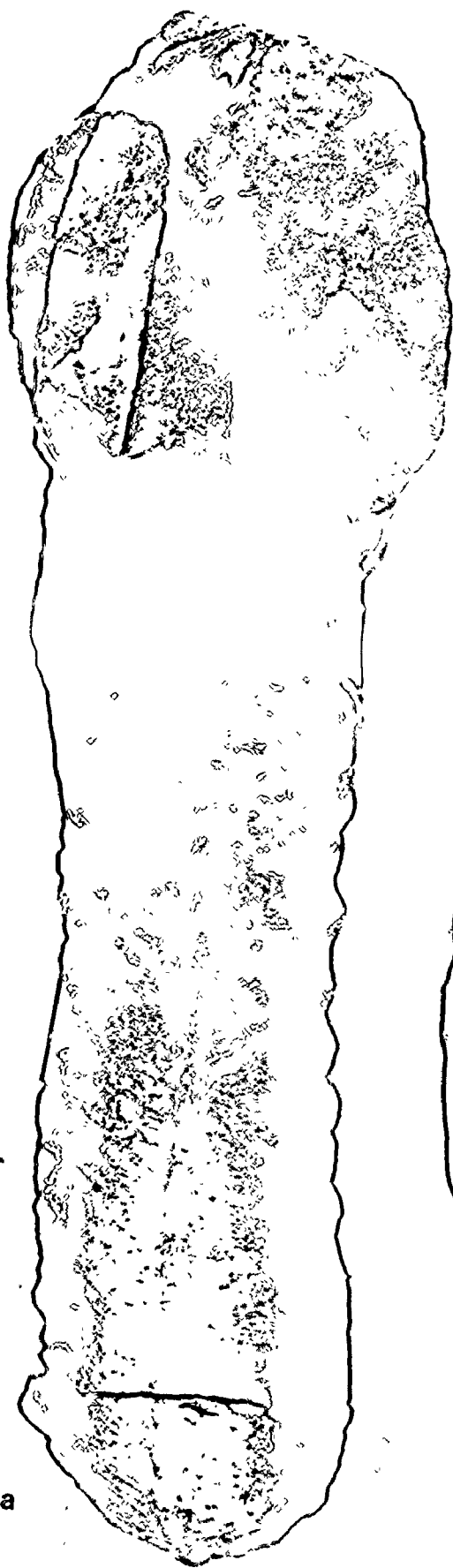


EXPLANATION OF PLATE 14

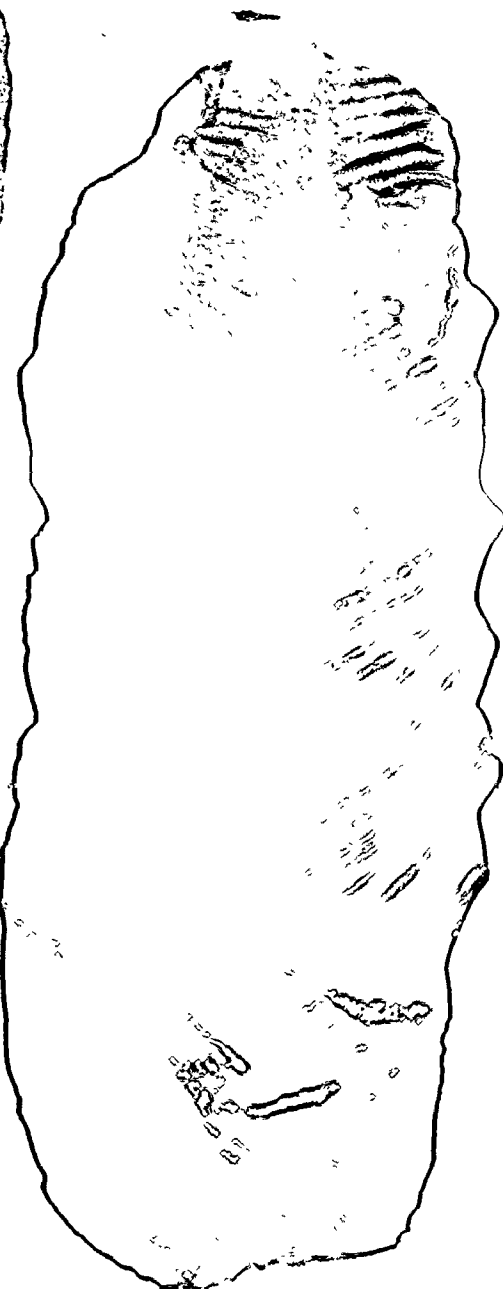
Fig. 1. *Acanthopleuroceras* (*Luningiceras*) *pinnaforme*  
n. sp.

Holotype, specimen LSJU 714D(1);  
see plate 13 for locality and age.  
x 3/4

PLATE 14



1a



1b

EXPLANATION OF PLATE 15

[All figures natural size unless otherwise indicated.]

Fig. 1. *Oistoceras* ? sp.

USGS 29424(5); latex cast of external mould from locality 144 (*ex situ*, with a Pliensbachian fauna), Hurwal Formation, Wallowa Mountains.

Fig. 2. *Coeloceras* (*Coeloceras* ?) cf. *depressum* (ROSENBERG)

USGS 28367(1); internal mould from locality 139 (*ex situ*, ? *A. (L.) pinnaforme* Zone); the Keller Creek Shale.

Fig. 3,5,7. *Coeloceras* (*Coeloceras* ?) spp.

3. USGS 31742(15); latex cast of external mould from locality 168 (*ex situ*, ? *A. (L.) pinnaforme* Zone), Hurwal Formation, Wallowa Mountains.

5. McM J2073; latex cast of external mould from locality 148 (*ex situ*, ? *A. (L.) pinnaforme* Zone), Hurwal Formation, Wallowa Mountains.

7. USGS 28367(25); latex cast of external mould, locality and age as for figure 2.

Fig. 4. *Coeloceras* (*Reynesocoeloceras*) cf. *baconicum* GECZY

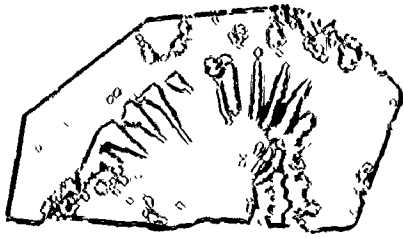
USGS Bud 90(1); internal mould from locality 133 (*ex situ*, ? *D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.

Fig. 6, 8. *Coeloceras* (*Reynesocoeloceras*) *incertum* FUCINI

6. USGS L48(4); internal mould from locality 131 (*ex situ*, ? *D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.

8. USGS L48(3); internal mould, locality and age as for figure 6.

PLATE 15



1



2a



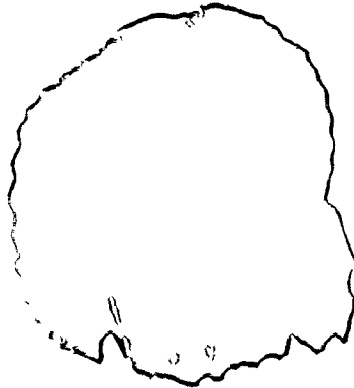
2b



3



4a



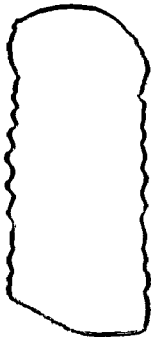
4b



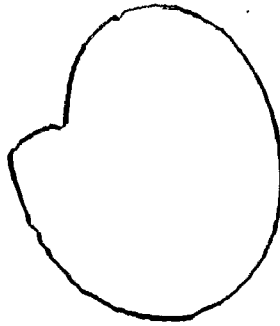
4c



5



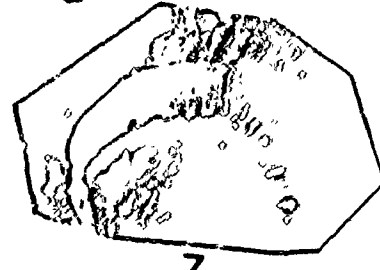
6a



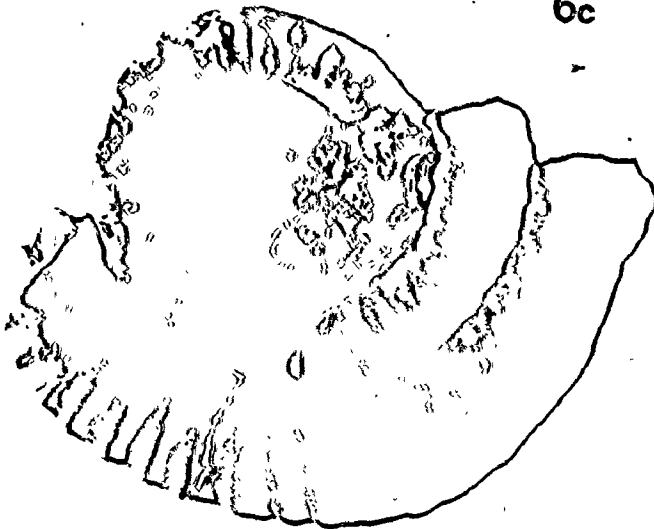
6b



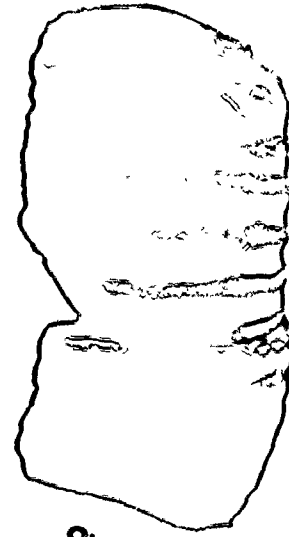
6c



7



8a



8b

EXPLANATION OF PLATE 16

[All figures natural size unless otherwise indicated.]

Fig. 1. *Prodictyloceras (Prodictyloceras) cf. davoëi*  
(SOWERBY)

McM J2074; internal mould from locality  
93 (*D. dayiceroides* Zone), Sunrise  
Formation, Clan Alpine Mountains.

Fig. 2. *Prodictyloceras (Aveyroniceras) colubriforme*  
(BETTONI)

McM J2075; internal mould from locality  
94 (*D. dayiceroides* Zone), Sunrise  
Formation, Clan Alpine Mountains.

Fig. 3, 4. *Prodictyloceras (Aveyroniceras) spp.*

3. McM J2076; latex cast of external  
mould from locality 45 (*D. dayiceroides*  
Zone), Sunrise Formation, Gabbs Valley  
Range.

4. McM J2077; latex cast of external  
mould from locality 96 (*D. dayiceroides*  
Zone), Sunrise Formation, Clan Alpine  
Mountains.

Fig. 5, 6. *Prodictyloceras (Aveyroniceras) cf.*  
*inaequiornatum* (BETTONI)

5. McM J2078; latex cast of external  
mould from locality 162 (*D. dayiceroides*  
Zone), Hurwal Formation, Wallowa  
Mountains.

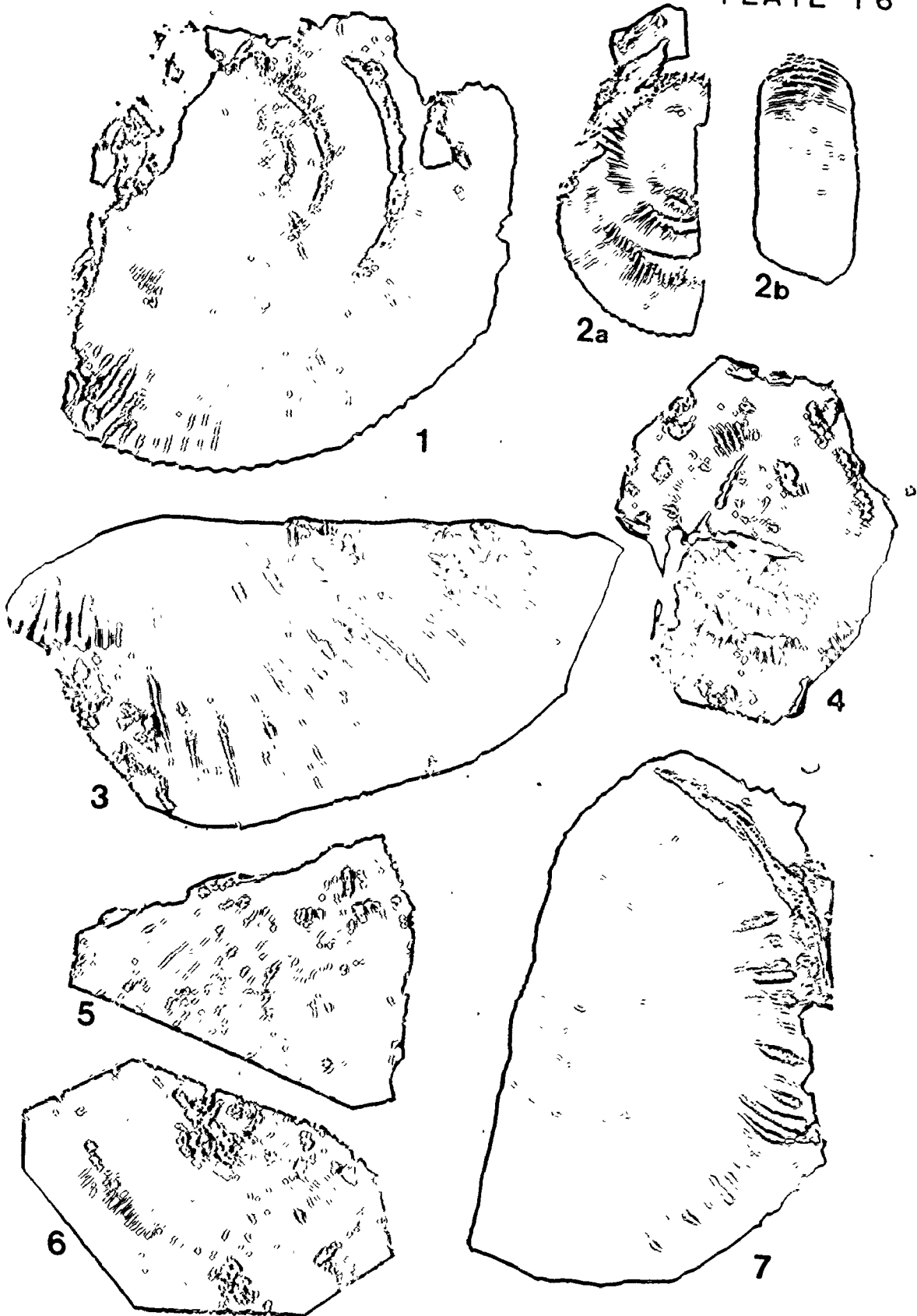
6. USGS 31741(2); latex cast of  
external mould from locality 147  
(*ex situ*, ? *D. dayiceroides* Zone)  
Hurwal Formation, Wallowa Mountains.

Fig. 7. *Protogrammoceras paltum toyoranum* (MATSUMOTO)

McM J2079; latex cast of external  
mould from locality 167 (*R. fannini*  
Zone), Hurwal Formation, Wallowa Mountains.



PLATE 16



EXPLANATION OF PLATE 17

[All figures natural size unless otherwise indicated.]

Fig. 1, 2. *Arieticerias* cf. *algovianum* (OPPEL)

1. McM J2080; internal mould and partial external mould from locality 159 (*ex situ*, ? *R. fannini* Zone), Hurwal Formation, Wallowa Mountains.
2. McM J2081; internal mould from locality 166 (*R. fannini* Zone), Hurwal Formation, Wallowa Mountains.

Fig. 3-5. *Protogrammoceras* cf. *lusitanicum* (CHOFFAT)

3. USGS 28805(24); latex cast of external mould from locality 141 (*ex situ*, ? *R. fannini* Zone), Hurwal Formation, Wallowa Mountains.
4. USGS 28806(19); latex cast of external mould from locality 144 (*ex situ*, ? *R. fannini* Zone), Hurwal Formation, Wallowa Mountains.
5. McM J2082; latex cast of external mould from locality 165 (*R. fannini* Zone), Hurwal Formation, Wallowa Mountains.

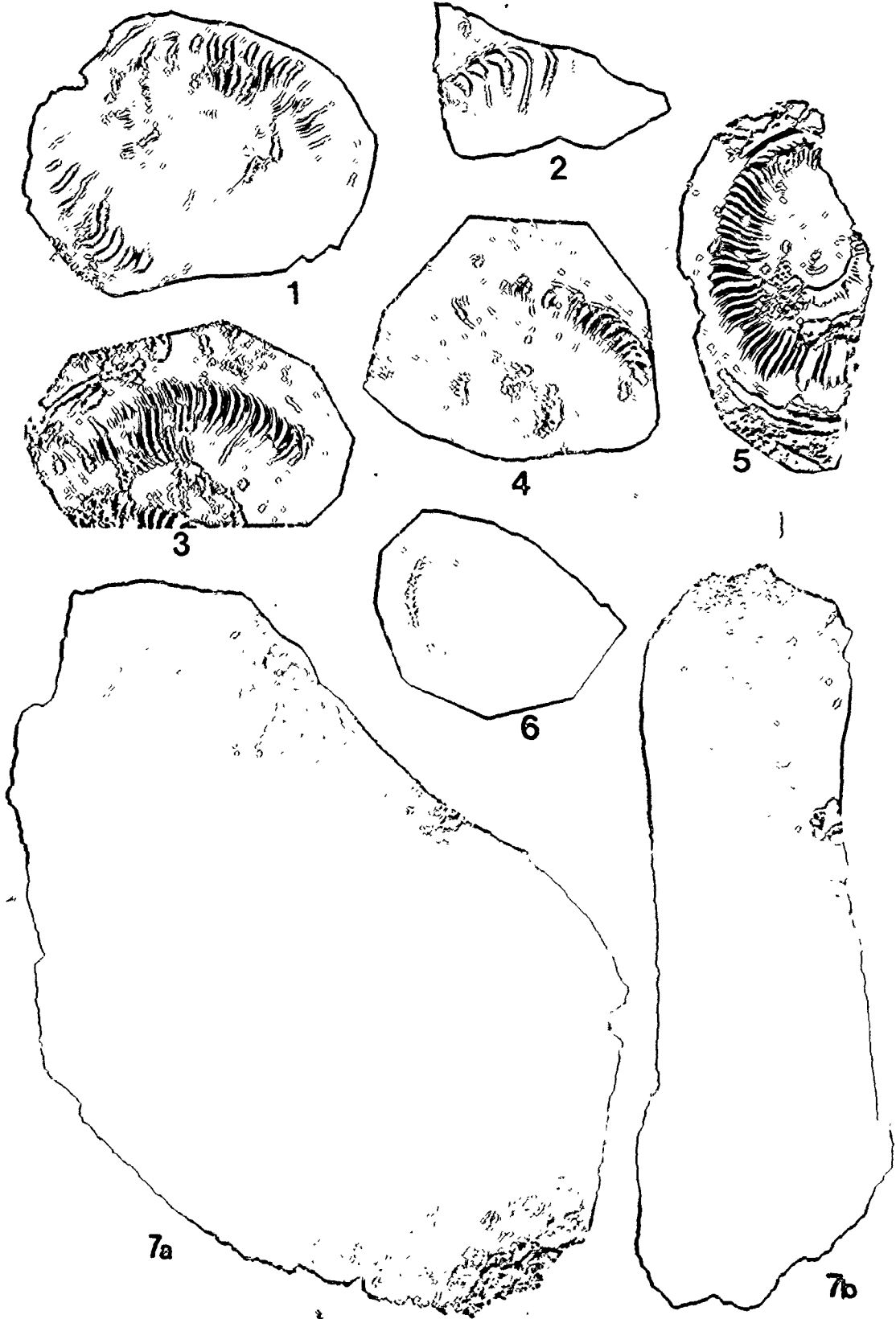
Fig. 6. *Lioceratoides* cf. *matsumotoi* HIRANO

McM J2083; internal mould from locality 46 (*D. dayiceroides* Zone), Sunrise Formation, Gabbs Valley Range.

Fig. 7. *Protogrammoceras* *argutum* (BUCKMAN)

McM J2084; internal mould from locality 112 (*T. propinquum* Zone), Sunrise Formation, Clan Alpine Mountains.

PLATE 17



EXPLANATION OF PLATE 18

All figures natural size unless otherwise indicated.

Fig. 1-3. *Protogrammoceras* cf. *nipponicum* (MATSUMOTO)

1. USGS 28806(21); latex cast of external mould from locality 144 (*ex situ*, ? *R. fannini* Zone), Hurwal Formation, Wallowa Mountains.
2. McM J2085; latex cast of external mould from locality 165 (*R. fannini* Zone), Hurwal Formation, Wallowa Mountains.
3. USGS 31741(3); latex cast of external mould from locality 147 (*ex situ*, ? *R. fannini* Zone), Hurwal Formation, Wallowa Mountains.

Fig. 4, 5. *Protogrammoceras varicostatum* (FUCINI)

4. Specimen LSJU 2950(2); internal mould from locality 75 (*R. fannini* Zone), Sunrise Formation, Shoshone Mountains.
5. McM J2086; latex cast of external mould, locality and age as for figure 2.

Fig. 6. *Fuciniceras* sp.

McM J2087; internal mould from locality 132 (*D. dayiceroides* Zone), Donovan Formation, Silvies River Valley.

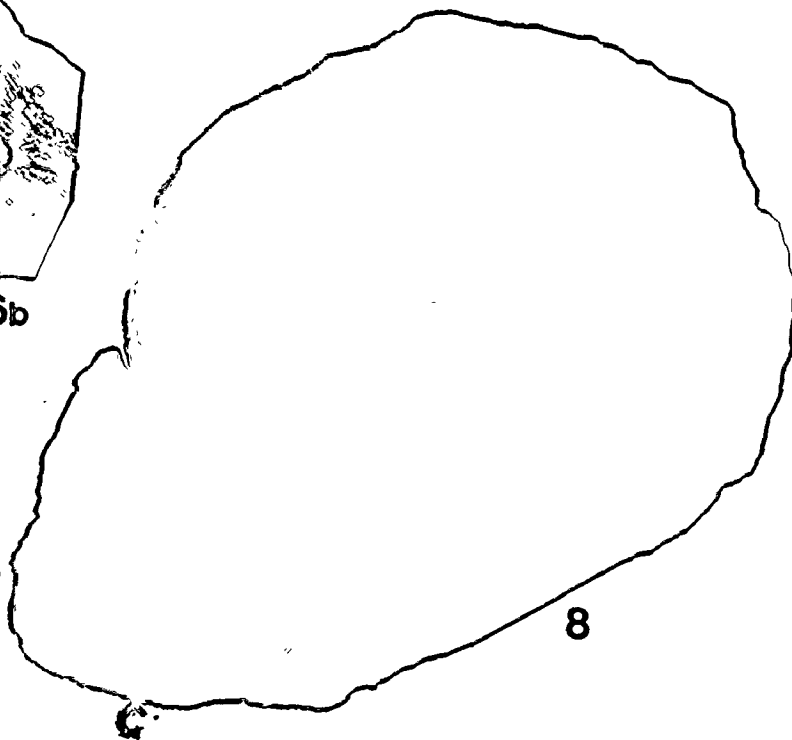
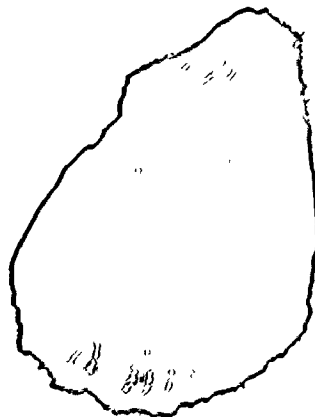
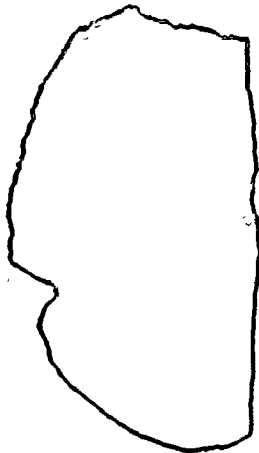
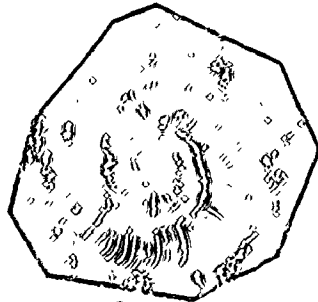
Fig. 7. *Fontanelliceras* cf. *fontanellense* (GEMMELLARO)

USGS 29424(1); latex cast of external mould from locality 144 (*ex situ*, with a lower Carixian fauna), Hurwal Formation, Wallowa Mountains.

Fig. 8. *Harpoceras* cf. *maurelli* McLEARN

Specimen Sec. 50 27m(1); internal mould from locality 106 (*T. propinquum* Zone), Sunrise Formation, Clan Alpine Mountains.

PLATE 18



EXPLANATION OF PLATE 19

All figures natural size unless otherwise indicated.

Fig. 1-6. *Tiltoniceras propinquum* (WHITEAVES)

1. McM J2088; internal mould from locality 128 (*T. propinquum* Zone), Sunrise Formation, Clan Alpine Mountains.
2. McM J2089; latex cast of external mould from locality 119, age and formation as for figure 1.
3. McM J2090; internal mould from locality 107, age and formation as for figure 1.
4. McM J2091; internal mould from locality 120, age and formation as for figure 1.
5. McM J2092; latex cast of external mould, age and locality as for figure 4.
6. McM J2093; internal mould, age and locality as for figure 4.

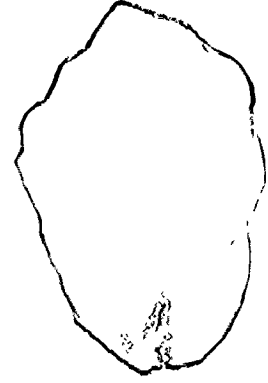
PLATE 19



1a



1b



2



3a



3b



4a



4b



5



6a



6b