

LOWER TO MIDDLE JURASSIC (PLIENSBACHIAN TO BAJOCIAN) STRATIGRAPHY  
AND PLIENSBACHIAN AMMONITE FAUNA OF THE NORTHERN SPATSI AREA,  
NORTH CENTRAL BRITISH COLUMBIA

by

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B.Sc., UNIVERSITY OF ALBERTA, 1981

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF  
MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES  
DEPARTMENT OF GEOLOGICAL SCIENCES

We accept this thesis as conforming  
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OCTOBER, 1985

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## Abstract

The lithostratigraphy and Pliensbachian ammonite fauna of a sequence of Pliensbachian to Bajocian sedimentary rocks, informally referred to here as the Spatsizi Group, from the Spatsizi map-area (104 H) in north-central British Columbia are examined in this thesis. Twenty five species of ammonites representing fifteen genera from Pliensbachian rocks of the Spatsizi Group are described and their stratigraphic ranges in the thesis area determined. The Spatsizi fauna is comprised primarily of ammonites of Tethyan aspect and also contains elements endemic to the East Pacific faunal realm. The Spatsizi fauna is located on the northern half of the Stikine terrane of the western Cordilleran eugeocline, and is surrounded by biogeographically related faunas containing ammonites of Boreal affinity in addition to Tethyan and East Pacific forms, indicating that northern Stikinia occupied a position within the mixed Boreal/Tethyan zone of the eastern Pacific region during the Pliensbachian. Subsequent tectonic displacement of Stikinia transported it northward to its present position.

The Spatsizi Group is informally defined and is divided into five informal formations; the Joan, Eaglenest, Gladys, Groves, and Walker Formations. Each formation reflects deposition in a different sedimentary environment affected by varying degrees of volcanic (epiclastic or pyroclastic) input. Rocks of the Spatsizi Group represent the basinward sedimentary equivalents to the coeval Toodoggone volcanics that formed along the southern flank of the Stikine Arch. Facies transitions from the Stikine Arch in the north to the sedimentary basin in the south are best developed in sediments deposited during Pliensbachian and Early Toarcian times, when epiclastic sands and conglomerates accumulating on the southern flank of the arch graded southward into silts and muds in the basin.

Two phases of non-coaxial deformation folded and faulted the rocks in the thesis map area. Deformation was probably related to interaction between the Stikinia and the North American continental margin during accretion.

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## ACKNOWLEDGEMENTS

The realization of this thesis is due, in large part, to the valuable guidance, generosity, and sense of humour of my thesis advisor, Dr. P. L. Smith. Of equal importance to the accomplishment of this work was the constructive "Devil's advocacy" provided by Dr. H. W. Tipper of the Geological Survey of Canada. My sincerest thanks go to both of these people for their confidence and encouragement.

This study was supported by grants to P. L. Smith from the Natural Science and Engineering Research Council and Chevron Canada Limited. The Cordilleran Section of the Geological Survey of Canada is gratefully acknowledged for logistical support while in the field, and for provision of work and storage space for the fossil collections used in this study. Thanks go to M. Akehurst, head librarian of the Geological Survey, for her uncanny ability to procure the obscurest of journals in the shortest possible time, and for her patience with one so negligent of library due dates.

Parts of this thesis were critically reviewed by Drs. W. C. Barnes, R. M. Bustin, and J. V. Ross. Their help is greatly appreciated, as are the many useful discussions with I. W. Moffat on the structure and stratigraphy of the Spatsizi region. J. R. Montgomery helped untangle many computer problems encountered during the textforming of this work. The drafting services of G. Hodge and the photographic services of E. Montgomery were invaluable to the illustration of this thesis.

The moral support needed to complete this thesis was abundantly supplied by my parents and by E. Gauthier.

## 1. INTRODUCTION

### 1.1 INTRODUCTORY STATEMENT

The Stikine River region of north-central British Columbia has received comparatively little study because of its isolated location, rugged terrain, and complex stratigraphy and structure. Recent work in the area (Tipper and Richards, 1976; Smith et al., 1984) has shown that paleontology, and in particular ammonite biostratigraphy, can be useful in unravelling the lithostratigraphy of the area. Previously undivided rock units have now been subdivided and correlated with other units of markedly different facies.

The objects of the present study are:

- 1) to describe and illustrate the Pliensbachian ammonites from the study area and to determine their stratigraphic range;
- 2) to describe the Pliensbachian to Bajocian lithostratigraphy and to map the distribution and structure of the rock units within the study area;
- 3) to analyze the facies relationships based on bio- and lithostratigraphic data and to relate these data to a regional geologic framework; and
- 4) to describe the paleobiogeographic implications of the fauna in view of contemporary theories concerning ammonite provinciality and the tectonic evolution of the Western Cordillera.

### 1.2 LOCATION AND METHODS

The study area is in the Spatsizi Plateau Wilderness Park in north-central British Columbia. Detailed field mapping and most of the fossil collecting were carried out in an area roughly 80 square kilometres in the Eaglenest Range, about 65 km southeast of the confluence of the Stikine and Klappan Rivers (NTS map area 104 H (Spatsizi), fig. 1.1 and 1.2, in map pouch). Field work was conducted from June to August, 1983, from a helicopter supported camp near a small unnamed alpine lake near the centre of the thesis

area (fig. 1.1).

Fossils were collected from four measured sections and from scattered localities in the thesis area. The sections were measured using the Brunton and tape technique (Compton, 1962). Fossils were recorded in ascending stratigraphic order, and collections from localities less than 50 m distant were tied into the sections where possible. True stratigraphic thicknesses and the position of the fossil collections within the sequences were calculated from field data using the Fortran IV programme STRAT (Smith, 1976).

In addition to the collections from the thesis map area, three fossil collections were made from localities outside the thesis area but within the Eaglenest Range (figure 1, localities 131-134, 138, and 142; see also appendix 2). Although these sections were not measured, the relative stratigraphic position of the fossils within each section was recorded.

In this study, both quantitative and qualitative morphologic characters of the ammonites, as well as stratigraphic and systematic data have been entered into a pre-existing ammonite data base. This data base, managed by TAXIR (Brill, 1983), is one of the University of British Columbia's computer data base systems. The ammonite database was initiated by Dr. P.L. Smith to facilitate the storage and retrieval of Lower Jurassic ammonite data from North America and Europe (Smith, *in press*). Once entered, this data can quickly and easily be statistically examined by interfacing with the computer's statistical programmes. The various parameters that can be entered into the database are listed in Appendix 1, along with computer print-outs of the Spatsizi data that has been entered. It is hoped that application of this ongoing computer work to Lower Jurassic paleontologic and biostratigraphic problems in western North America will demonstrate its potential for more widespread use.

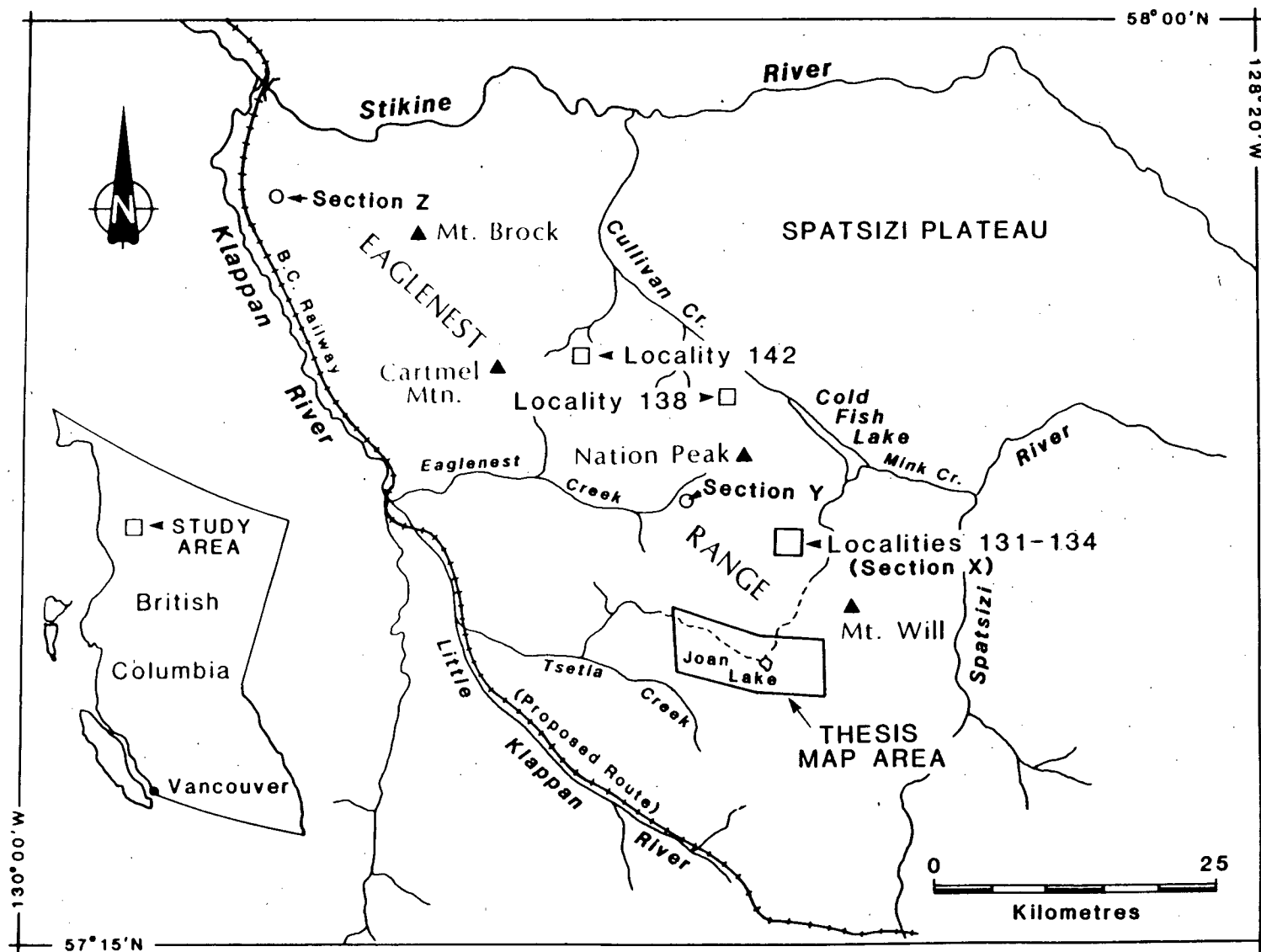


FIGURE 1.1 Location map.



### 1.3 PREVIOUS WORK

The first references to Lower Jurassic rocks in north-central British Columbia are scattered. Kerr (1948) reported the occurrence of Lower Jurassic rocks in the Telegraph Creek area (fig. 1.3) based on fossils collected from an unnamed group of volcanic and sedimentary rocks. To the southeast of the thesis area, in the Hazelton and Smithers map areas, Armstrong (1944a, b) and Kindle (1954) reported the occurrence of Lower Jurassic rocks which they included in the lowermost unit of the Hazelton Group. Lord (1948) defined the upper division of the Takla Group in the McConnell Creek area as being of Early to middle Late Jurassic age. Current usage restricts the Takla Group to the Late Triassic, and therefore at least part of the upper division of Lord's Takla Group would now be considered as Hazelton Group.

"Operation Stikine" was the code-name under which the Geological Survey of Canada, in 1956, carried out the first regional geologic study of an area including the northern part of the Bowser Basin and other map areas to the north (fig. 1.3). In the following year a 1:250,000 map with accompanying descriptive notes was published (G.S.C., 1957). Reference to the Lower Jurassic rocks of the area was made in this report, and although not formally named, the nature and extent of the Bowser Basin was first commented upon.

In 1966, Souther and Armstrong published a comprehensive geologic and tectonic synthesis of north-central British Columbia and first applied the name "Bowser Basin" to the large sedimentary basin delineated by Operation Stikine (G.S.C., 1957). Souther and Armstrong (1966) constructed a Lower Jurassic paleogeographic map for the entire northwest portion of the province and from this made a cross-section of the area to the south of Spatsizi illustrating the relations between volcanic, sedimentary and basement rocks.

Systematic mapping by the G.S.C., and the detailed documentation of the Lower Jurassic rocks and fossils of the Spatsizi and surrounding map areas did not begin until

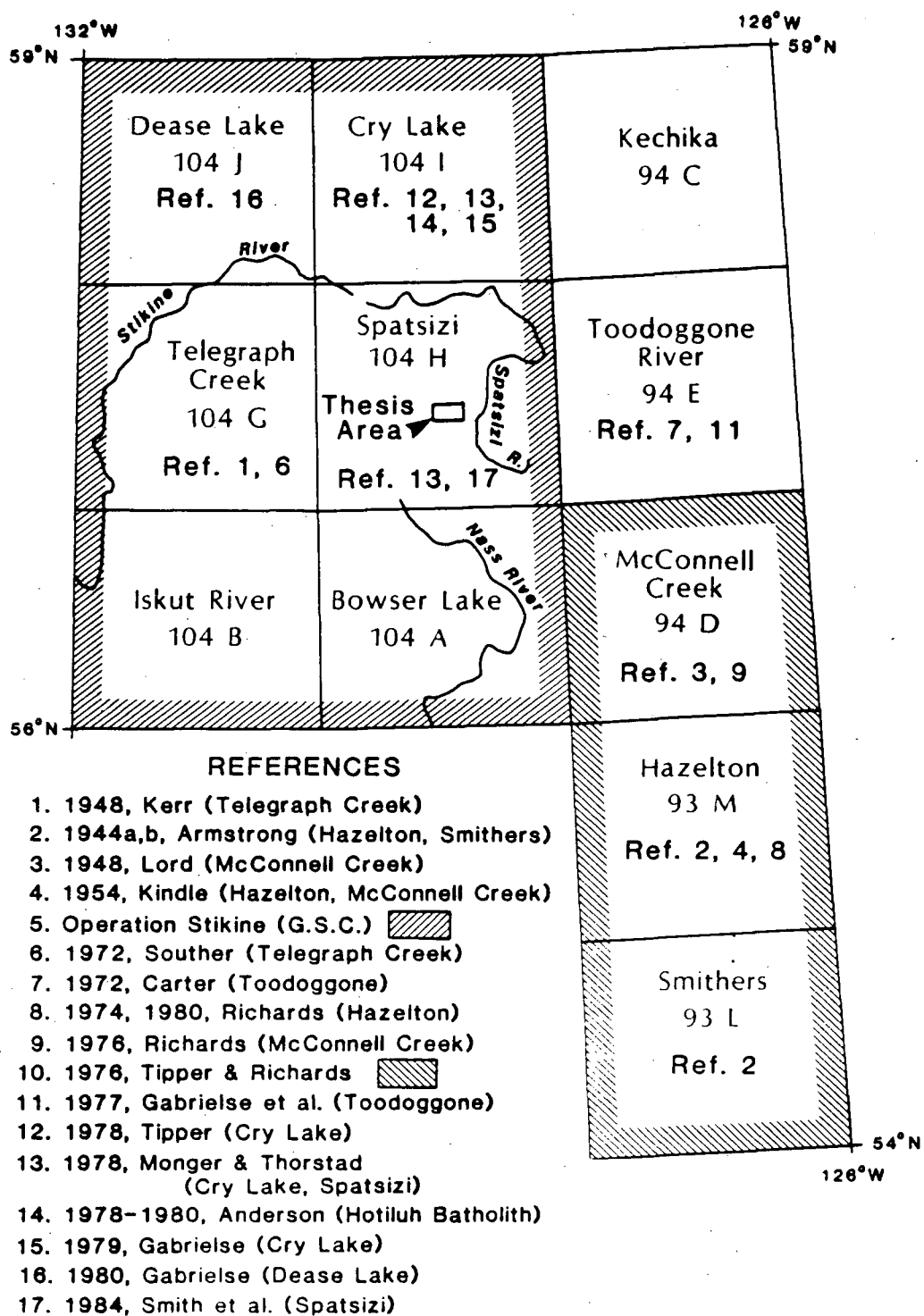


FIGURE 1.3 Map illustrating the location of previous studies on the Lower Jurassic of the Spatsizi and surrounding NTS map areas.

the 1960's. Frebold (1964, 1970) published the only detailed systematics on the Early Jurassic ammonoid faunas of northern British Columbia and southern Yukon, and most of the ages of rock units published in subsequent geologic reports on north-central British Columbia were determined based on Frebold's work. In 1972, the Telegraph Creek map (104 G) was published (Souther, 1972). Lower Jurassic ammonites and bivalves found in the Telegraph Creek area demonstrated the presence of Hettangian (now thought to be Sinemurian), Upper Pliensbachian and Upper Toarcian sediments.

In 1974 an open file map of the Hazelton map area (93 M) was published (Richards, 1974), showing the distribution of Sinemurian to Bajocian volcanic and sedimentary rocks. Just to the north of the Hazelton area, in the McConnell Creek map area (94 D), abundant Lower to Middle Jurassic sediments and volcanics, correlative with the volcanics and sediments in the Hazelton area, yielded a rich Sinemurian to Bajocian fauna (Tipper, 1976).

The Lower and Middle Jurassic fauna and stratigraphy of the Smithers, Hazelton, and McConnell Creek map areas was documented by Tipper and Richards (1976). This is the most comprehensive publication on the Jurassic fauna and stratigraphy for any part of north-central British Columbia. The reader is also referred to this paper for an excellent summary of the development of the Mesozoic stratigraphic nomenclature for north-central British Columbia.

A thick and areally extensive volcanic pile in the Toodoggone map area (94 E), east of the thesis area, was mapped as Lower Jurassic by Carter (1972) and later by Gabrielse et al. (1977) as Lower to Upper Jurassic. These volcanics, informally referred to as the Toodoggone volcanics, mark the northern margin of the Bowser Basin and have been dated isotopically (Gabrielse et al., 1980) and paleontologically (Smith et al., 1984) as Pliensbachian to Bajocian. Toodoggone volcanics of Pliensbachian age are exposed in the thesis area in the core of an anticline.

To the north of the Spatsizi map area, in the Cry Lake map area (104 I) Tipper (1978) and Gabrielse (1979) report sediments of the Upper Sinemurian Inklin Formation, the Pliensbachian Takwahoni Formation, and Toarcian through Bajocian volcanics and sediments. West of the Cry Lake map area, in the Dease Lake map area (104 J), Gabrielse (1980) reports further occurrences of the Inklin and Takwahoni Formations.

Recent detailed studies by Anderson (1978, 1979, 1980) on the distribution and time of emplacement of the various phases of the Hotailuh Batholith, located north of the thesis area, indicate that the intrusions were emplaced during Late Triassic and Early Jurassic time. The Hotailuh Batholith and related igneous bodies form the backbone of the Stikine Arch and exerted a fundamental control on the Lower Jurassic volcanic and sedimentary stratigraphy in the Spatsizi area.

In summary, Lower Jurassic rocks have been found in almost all the areas surrounding the thesis area. It was not until 1981 that Lower Jurassic sediments, replete with ammonites, were discovered below Middle to Upper Jurassic Bowser Lake Group sediments in the Spatsizi area. The aim of this thesis is to document, for the first time, the Pliensbachian and Toarcian elements of this fauna.

#### 1.4 GEOLOGICAL SETTING

The Canadian Cordillera can be divided into five physiographically and geologically distinct belts that are parallel to the northwest-southeast grain of the Cordillera (fig. 1.4). Three of these belts, the Insular, Intermontane, and Rocky Mountain Belts consist of low-grade metamorphic or unmetamorphosed rocks of varying structural style. The Insular, Intermontane, and Rocky Mountain Belts are separated from one another by the Coast Plutonic Complex and by the Omineca Crystalline Belt which consist of intensely deformed, high-grade metamorphic and plutonic rocks, and have been described by Monger et al. (1982) as major tectonic welts within the Cordillera.

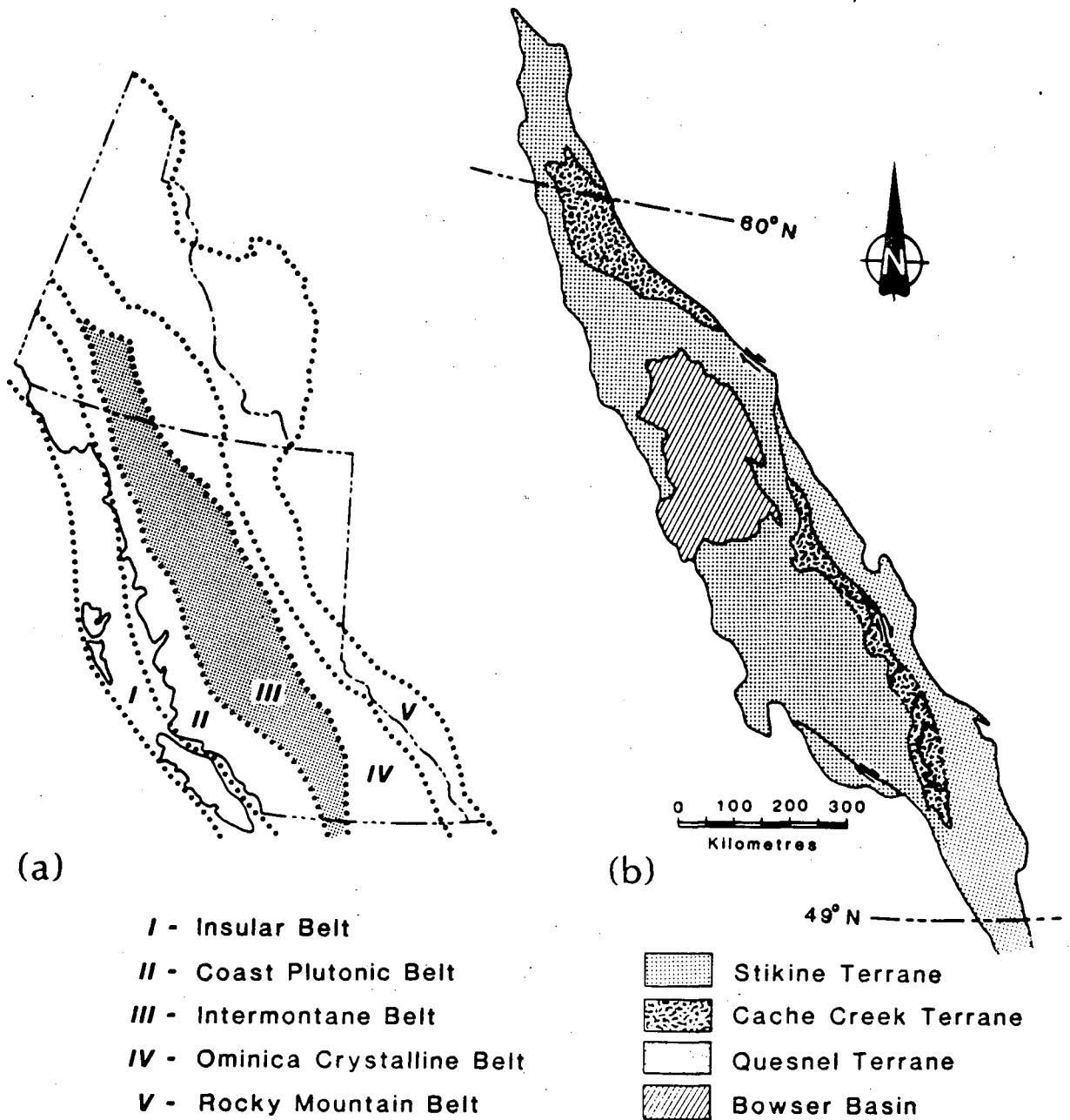


FIGURE 1.4 Location of the Intermontane belt within the Canadian Cordillera (fig. 1.4a) and the position of the tectono-stratigraphic terranes comprising the Intermontane belt (fig. 1.4b; modified from Tipper *et al.*, 1981).

The Insular and Intermontane Belts are both composed of smaller, geologically distinct crustal fragments or terranes. Each terrane is characterized by an internally consistent tectono-stratigraphic assemblage that differs from those of surrounding terranes and is characteristic of a particular tectonic setting. The terranes are separated by major faults or structurally complex zones which are often marked by plutons or covered by younger rocks. The history of the amalgamation of these terranes and of their accretion to, and interaction with, the North American continental margin is complex and is described by Coney *et al.* (1980), Monger *et al.* (1982), and Monger (1984). The effects of terrane displacement on the distribution of Early Jurassic ammonites is discussed in chapter 5 (paleobiogeography).

The Intermontane Belt includes parts of three major tectono-stratigraphic terranes; the Stikine terrane or Stikinia, Quesnellia, and the Cache Creek terrane. The Stikine terrane, of which the thesis area is a part, was formed in the Late Paleozoic-Early Mesozoic eugeocline of the Canadian Cordillera and consists mainly of sedimentary and volcanic rocks. The Bowser Basin, a major geologic feature superimposed on the Stikine terrane, is not technically part of the Stikine terrane because it formed as a successor basin during the Middle and Late Jurassic and therefore post-dates the eugeoclinal origin of Stikinia. Sediments of the Bowser Lake Group were deposited in the basin during the Middle and Upper Jurassic, and their present day distribution delineates the basin (fig. 1.5).

The Lower Jurassic rocks analyzed in this study are exposed below Bowser Lake Group sediments in an erosional/structural window. The geologic events leading to the formation of the thesis rocks, and to the subsequent formation of the Bowser Basin are outlined in the following discussion.

During the Late Triassic, the Stikine terrane was the site of considerable volcanic activity. In the Stikine River region of the Stikine terrane, the Triassic, calc-alkaline Stuhini volcanics were deposited and formed the basement to subsequent volcanism and

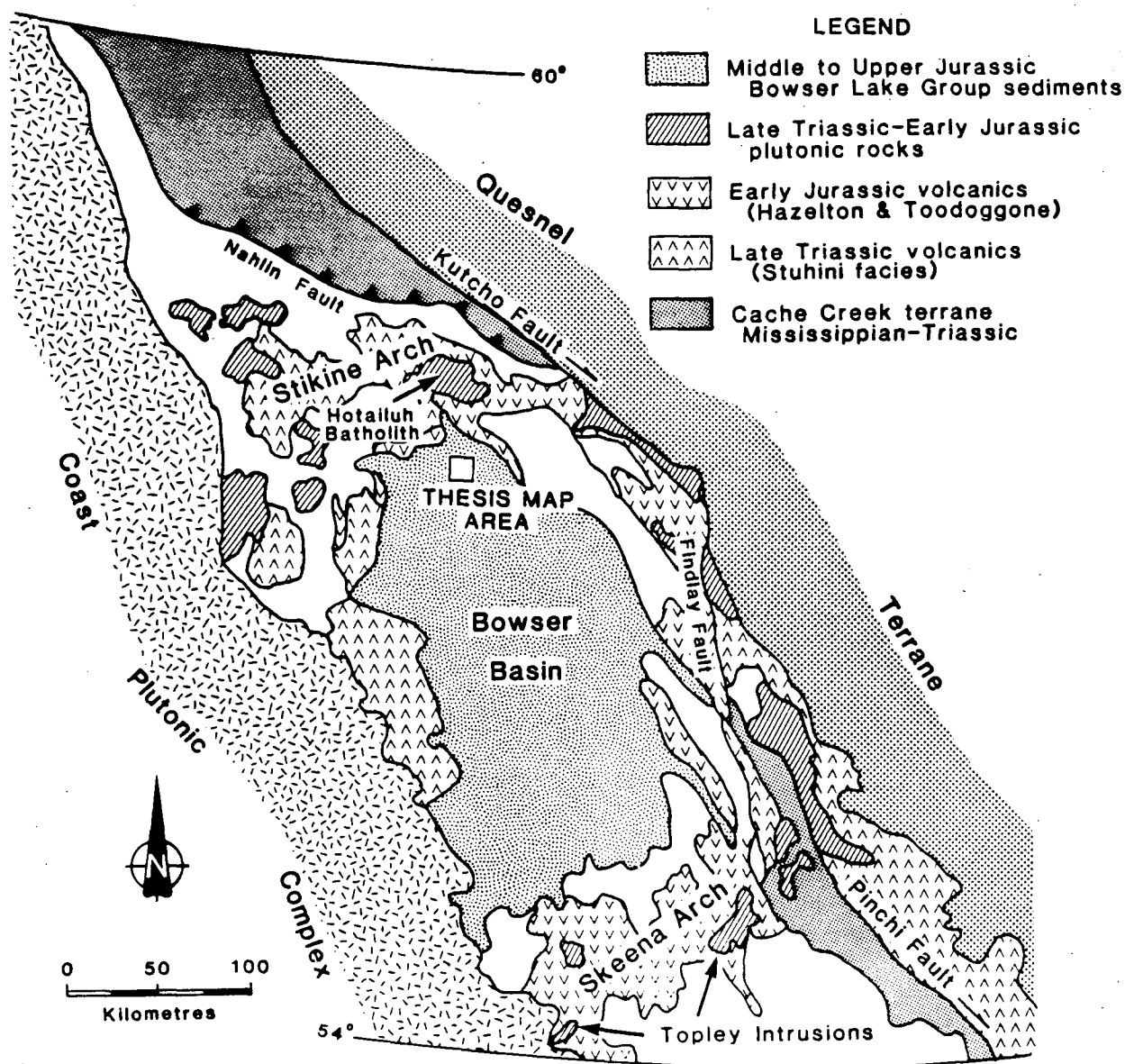


FIGURE 1.5 Geological map of the north-central British Columbia outlining the distribution of major Triassic and Jurassic rock groups, tectonic features, and terrane boundaries (modified from Tipper *et al.*, 1981).

sedimentation in the Stikine River and Hazelton regions. The Stikine Arch also began to rise during the Late Triassic (Anderson, 1978, 1980; Tipper and Richards, 1976). Some of the intrusions that make up the arch are thought to be comagmatic with the Stuhini volcanics (Souther, 1976).

At the close of the Late Triassic and possibly the earliest Jurassic, the Cache Creek terrane, located along the northwest-southeast boundary between the Intermontane and Omineca Crystalline Belts, also began to rise (Tipper and Richards, 1976). Uplift along the Stikine Arch and the Cache Creek terrane resulted in the division of the Triassic eugeocline into distinct basins; the dominantly volcanogenic Hazelton Trough to the west and southwest, the sedimentary Whitehorse Trough to the north, and the Quesnel Trough to the east. The Hazelton Trough extended from the Stikine Arch in the north to the Chilcotin area in southwestern British Columbia where it is now truncated by the Yalakom fault. This was the site of all Lower to early Middle Jurassic sedimentation and volcanism which formed the rocks of the Hazelton Group of southwestern and central British Columbia. The Hazelton Trough was also the locus of deposition of the sediments and volcanics, analyzed in this study, that are distributed along the southern flank of the Stikine Arch. Although these northern Hazelton Trough rocks are coeval with the Hazelton Group farther to the south, they are considered to be of different origin and therefore not strictly equivalent to the Hazelton Group for the following reasons:

- 1) the two rock units, although partly time equivalent, are geographically separate from one another; and
- 2) the volcanics in the northern part of the trough are related to the Stikine Arch (Souther, 1977), whereas the Hazelton volcanics are genetically related to the plutonic core of the ancestral Skeena Arch (Tipper and Richards, 1976).

In view of the foregoing, and following the precedent set by Smith et al. (1984), the volcanics and sediments deposited in the Stikine River region of the Hazelton Trough are referred to in this study as the Toodoggone volcanics and Spatsizi Group, respectively.



Volcanism and related sedimentation continued in the Hazelton Trough until Early Bajocian time when the northeasterly trending Skeena Arch, cored by the Topley intrusions, was uplifted, dividing the Hazelton Trough into two successor basins, the Bowser Basin to the north and the Nechako Basin to the south. The Bajocian uplift of the Skeena Arch, manifested in the Stikine region by a major volcanic pulse, marked the end to eugeoclinal conditions in the Hazelton Trough, and the beginning of molasse sedimentation in the resultant successor basins.

## 2. STRATIGRAPHY

### 2.1 GENERAL GEOLOGY AND STRATIGRAPHY OF THE SPATSIZI AREA

The Lower Pliensbachian to Lower Bajocian sediments examined in this study are part of a complex package of early Mesozoic plutonic, volcanic, and sedimentary rocks that crop out along the southern flank of the Stikine Arch. Informal designation of these sediments as the Spatsizi Group, the relationship between the Spatsizi Group and the volcanic rocks of the area, the nature of the sediments, and their depositional history are discussed in this chapter.

The distribution of Triassic and Jurassic rocks in the Spatsizi area is shown in fig. 2.1 and a diagrammatic cross-section illustrating their stratigraphic relationships is shown in fig. 2.2. Triassic volcanics of the Stuhini Group are the oldest rocks exposed in the area and, as mentioned in the preceeding chapter, form the basement to all subsequent volcanic and sedimentary rock units in the Spatsizi area. Rocks of Hettangian and Sinemurian age have not been found in the Spatsizi area, although to the north of the Stikine Arch, in the Cry Lake map area, Sinemurian sediments rest unconformably on Triassic limestones of the Sinwa Formation (Tipper, 1978). Also, to the southeast of Spatsizi in the McConnell Creek, Hazelton, and Smithers map areas, Sinemurian volcanics and sediments of the Telkwa Formation (Hazelton Group) are abundant (Tipper and Richards, 1976).

Rocks of Pliensbachian age are well represented in Spatsizi, although their distribution is discontinuous. Extensive Pliensbachian flows and breccias of the Toodoggone volcanics are exposed along the southern flank of the Stikine Arch (fig. 2.1). Southward from the Stikine Arch these volcanics are replaced by Pliensbachian sediments of the Spatsizi Group (fig. 2.2). The nature of the southward transition from volcanic to sedimentary rocks is not clearly understood. Whether the volcanics thin and grade basinward into sediments, or if the volcanics end abruptly is not known, however, the

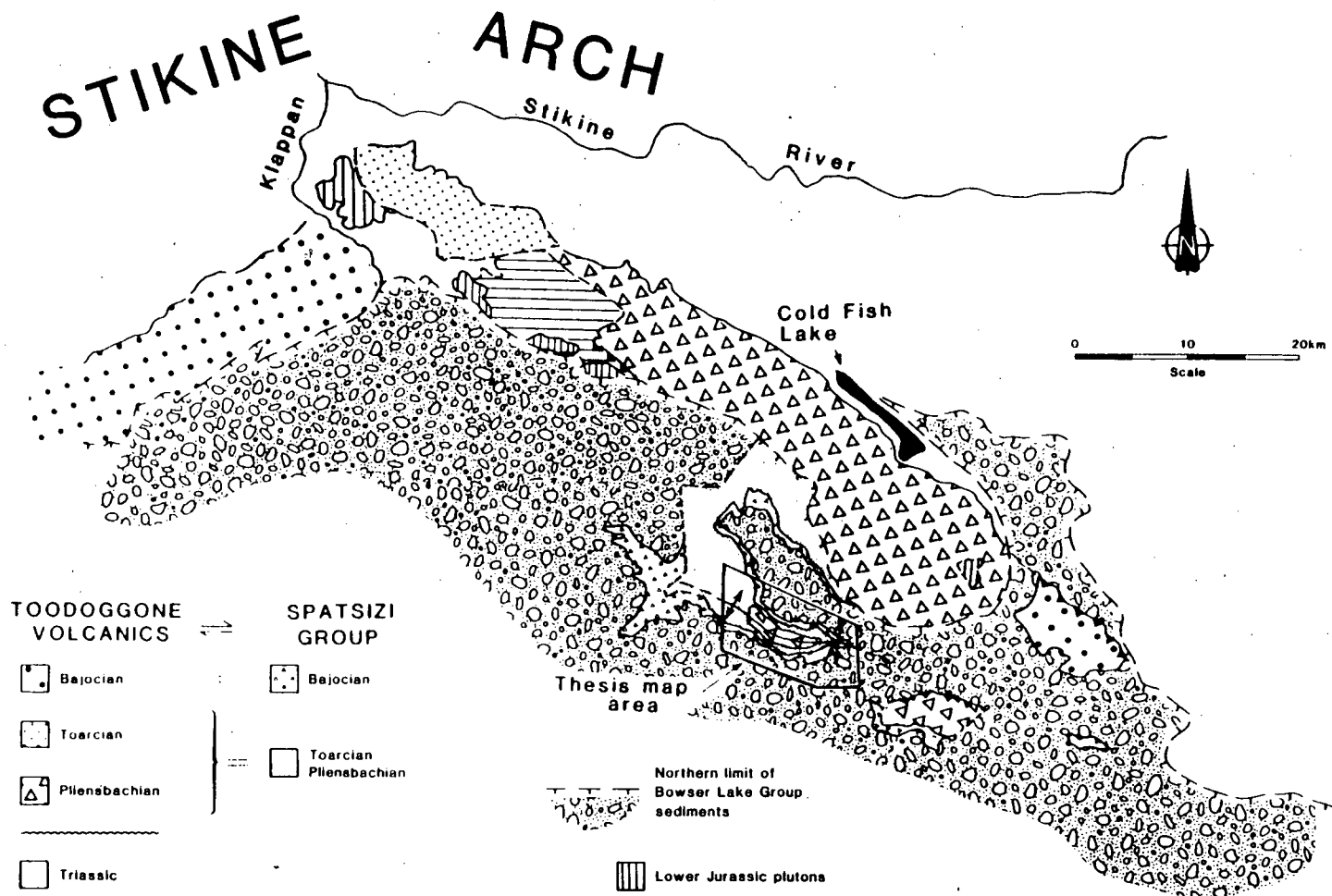


FIGURE 2.1 Geological map of the upper Stikine region showing the distribution of the Toodoggone volcanics and their basinward sedimentary equivalents of the Spatsizi Group (modified from Gabrielse and Tipper, 1984, and Smith *et al.*, 1984).

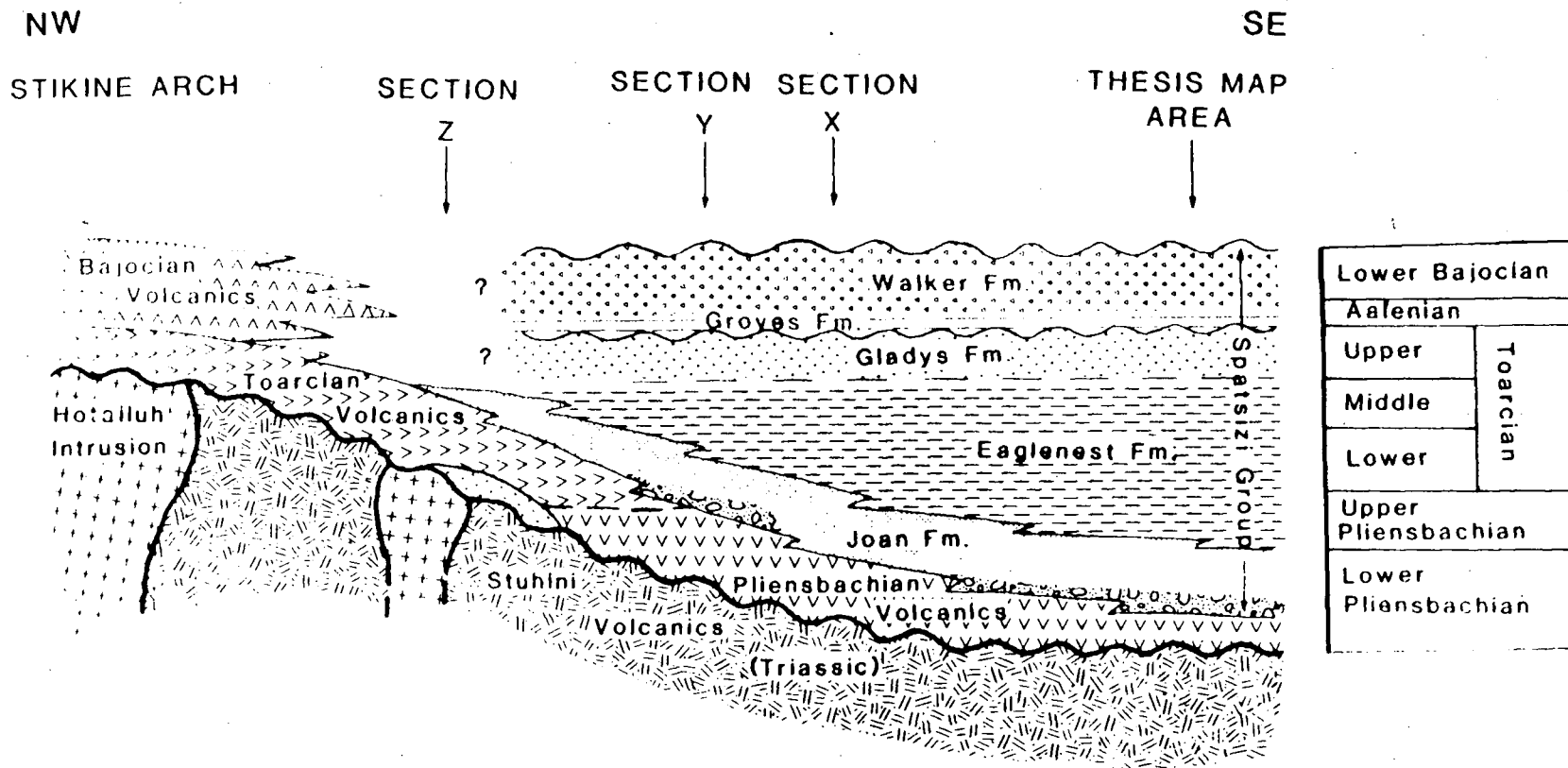


FIGURE 2.2 Diagrammatic cross-section showing the inferred stratigraphic relationships of the Toodoggone volcanics and the Spatsizi Group sediments along the southern margin of the Stikine Arch. Note that the time scale on the right applies only to rocks of the Spatsizi Group and Toodoggone volcanics and not to the underlying Stuhini and Hotailuh rocks.

transition probably represents a facies change from a volcanic arc environment to a sedimentary basin environment (Smith *et al.*, 1984). Pliensbachian volcanics are abundant on the southern flank of the Stikine Arch but are not present on top of the arch. Rather, Toarcian volcanics and minor sediments lie directly on Stuhini volcanics and on intrusions of the Hotailuh Batholith (Smith *et al.*, 1984; Henderson and Perry, 1981; Anderson, 1980). North of the Stikine Arch, Pliensbachian sediments of the Laberge Group (Takwahoni facies) are present in the Cry Lake area (Tipper, 1978).

The distribution of Toarcian rocks in the Spatsizi area is more continuous than the Pliensbachian rocks. As mentioned, Toarcian volcanics and minor sediments rest unconformably on Triassic rocks on the upper flanks and top of the Stikine Arch. As with the Pliensbachian volcanics, the Toarcian volcanics are replaced basinward (*i.e.*, southward) by sediments of the Spatsizi Group.

Early Bajocian rocks of the Spatsizi area have a similar distribution pattern as the Pliensbachian and Toarcian rocks; Bajocian volcanics outcropping along the southern flank of the Stikine Arch give way to sediments of the Spatsizi Group to the south. It should be noted that the Bajocian sediments of the Spatsizi Group (*i.e.*, rocks belonging to the Walker Formation described below in section 2.2) have a greater volcanogenic component than either the Toarcian or the Pliensbachian sediments, perhaps indicating a difference in the type of volcanism, a shift in the centre(s) of volcanism, or a change in the general tectonic environment during the Bajocian. The Bajocian sediments are the youngest rocks of the Spatsizi Group and are unconformably overlain by clastic sediments of the Middle and Upper Jurassic Bowser Lake Group.

The total extent of the Spatsizi Group is unknown due to the almost unbroken cover of the overlying Bowser Lake Group south of the Stikine Arch. It is assumed that the Spatsizi sediments continue for a considerable distance below this cover where they become shalier and their volcanogenic component diminishes southward towards the centre of the basin of deposition as implied by Smith *et al.* (1984), and Tipper and Richards

(1976) for the Hazelton Group.

## 2.2 THE SPATSIZI GROUP

The area underlain by the Pliensbachian to Lower Bajocian sediments examined in this study was, prior to the first close examination in 1981 by the Geological Survey of Canada, thought to have been underlain by Middle to Upper Jurassic Bowser Lake Group sediments. Since 1981, however, the Pliensbachian to Lower Bajocian rocks have been recognized as comprising a distinct lithostratigraphic unit that is informally referred to in this study as the Spatsizi Group. It is the author's intention to formalize the Spatsizi Group and its component formations (described below) in forthcoming publications.

The name of the Spatsizi Group is derived from the Spatsizi Plateau Wilderness Park in which the sediments outcrop. The total areal extent of the Spatsizi Group is shown in fig. 2.1. Four stratigraphic sections of the Spatsizi Group were measured (figs. 2.3–2.9), one of which (section 1, figs. 2.3 and 2.4) is here designated as the group stratotype, or type section. The description of an incomplete section examined about 10 km north of the thesis map area (Section X, fig. 1.1) is given in fig. 2.10. In the thesis map area the base of the section is marked by a disconformable contact with underlying flows of the Toodoggone volcanics, and the upper boundary is defined by a slight ( $<5^\circ$ ) angular unconformity with the overlying Ashman Formation of the Bowser Lake Group.

Five formations of the Spatsizi Group, together attaining a thickness of up to 900 m, were delineated in the field and mapped at a scale of 1:25000 (fig. 1.2). These five formations are described below in ascending stratigraphic order. Note that the Joan and Eaglenest Formations were studied in greater detail than Gladys, Groves, and Walker Formations due to the sparsity of fossils (particularly ammonites) in the latter three units.

### LEGEND FOR FIGURES 2.3-2.10



**Tuffaceous shale**



**Siltstones and fine sandstones**



**Shale**



**Limestone**



**Siltstone**



**Conglomerate**



**Volcanic flows and breccias**

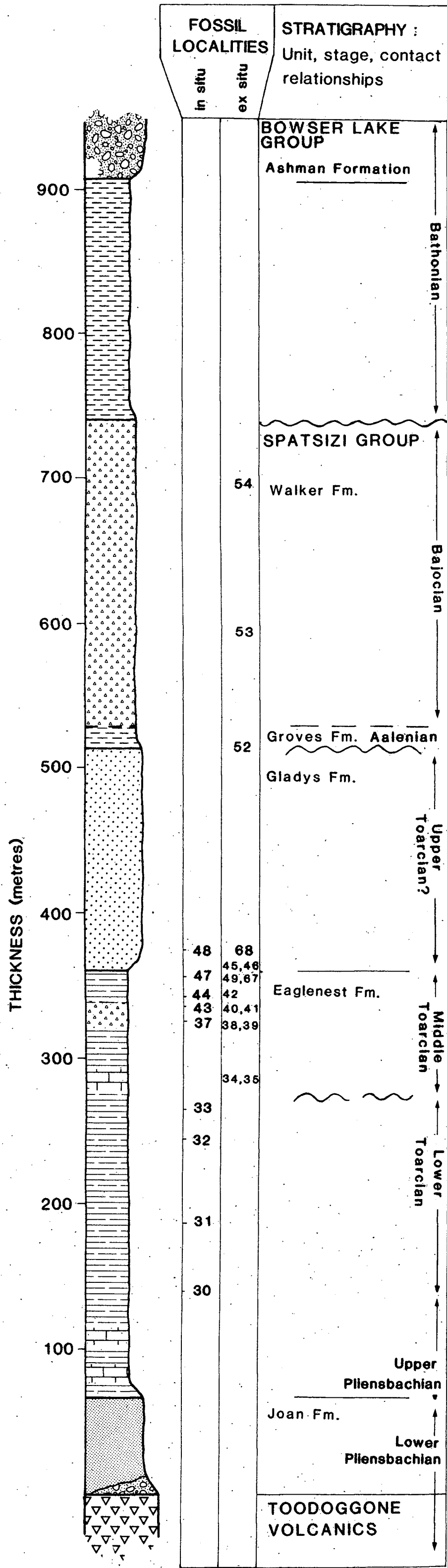
(See legend of figure 1.2 for description of Formations)

○ ● Fossil localities (ex situ, in situ)

— — — — — Conformable contact (defined, assumed)

~~~~~ Unconformable contact (defined, assumed)

See figure 1.2 for location of sections 1-4,  
and figure 1.1 for location of section X.



19B

FIGURE 2.3 Section 1, lithostratigraphy



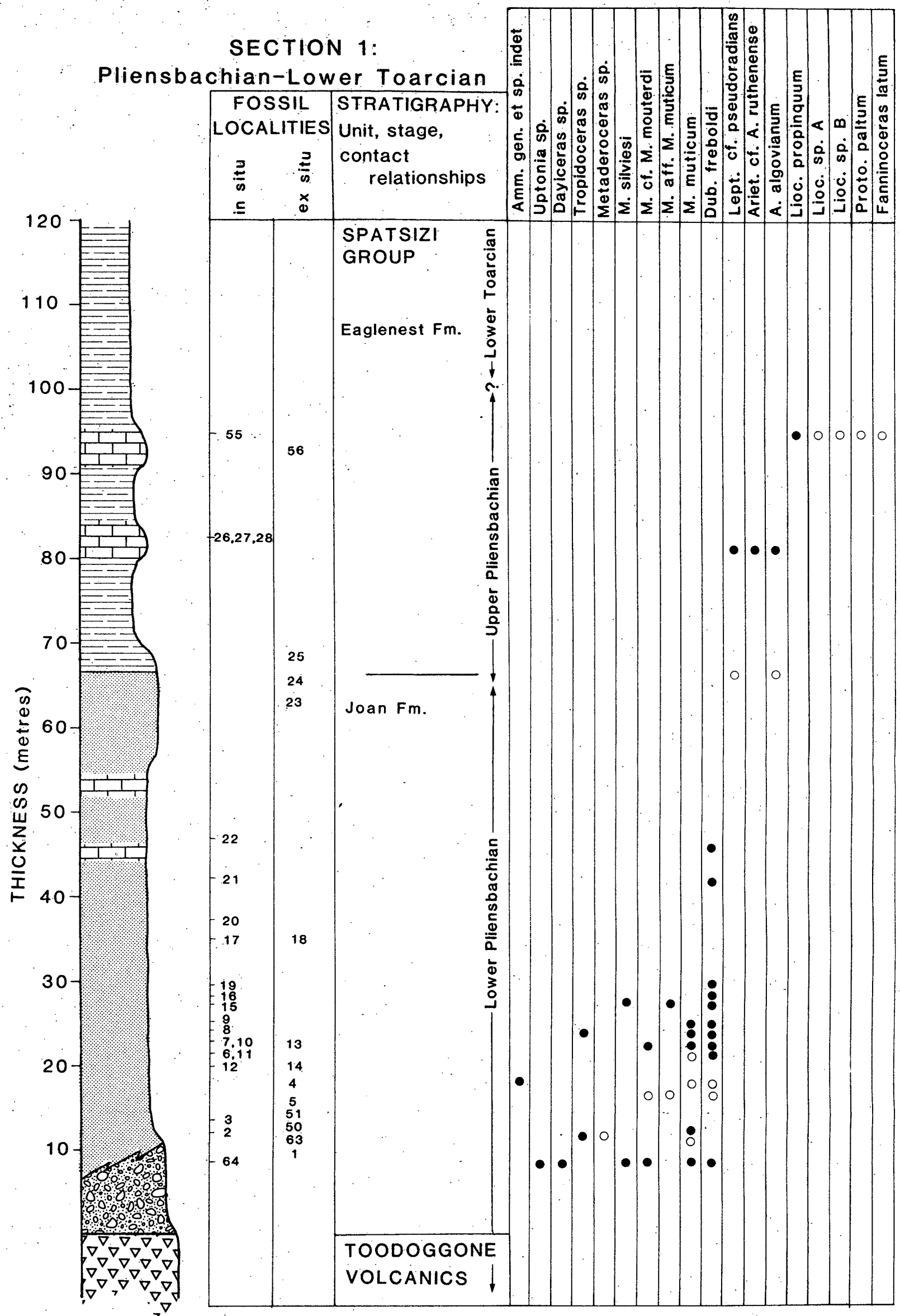


FIGURE 2.4 Section 1, Pliensbachian biostratigraphy and lithostratigraphy

## 21

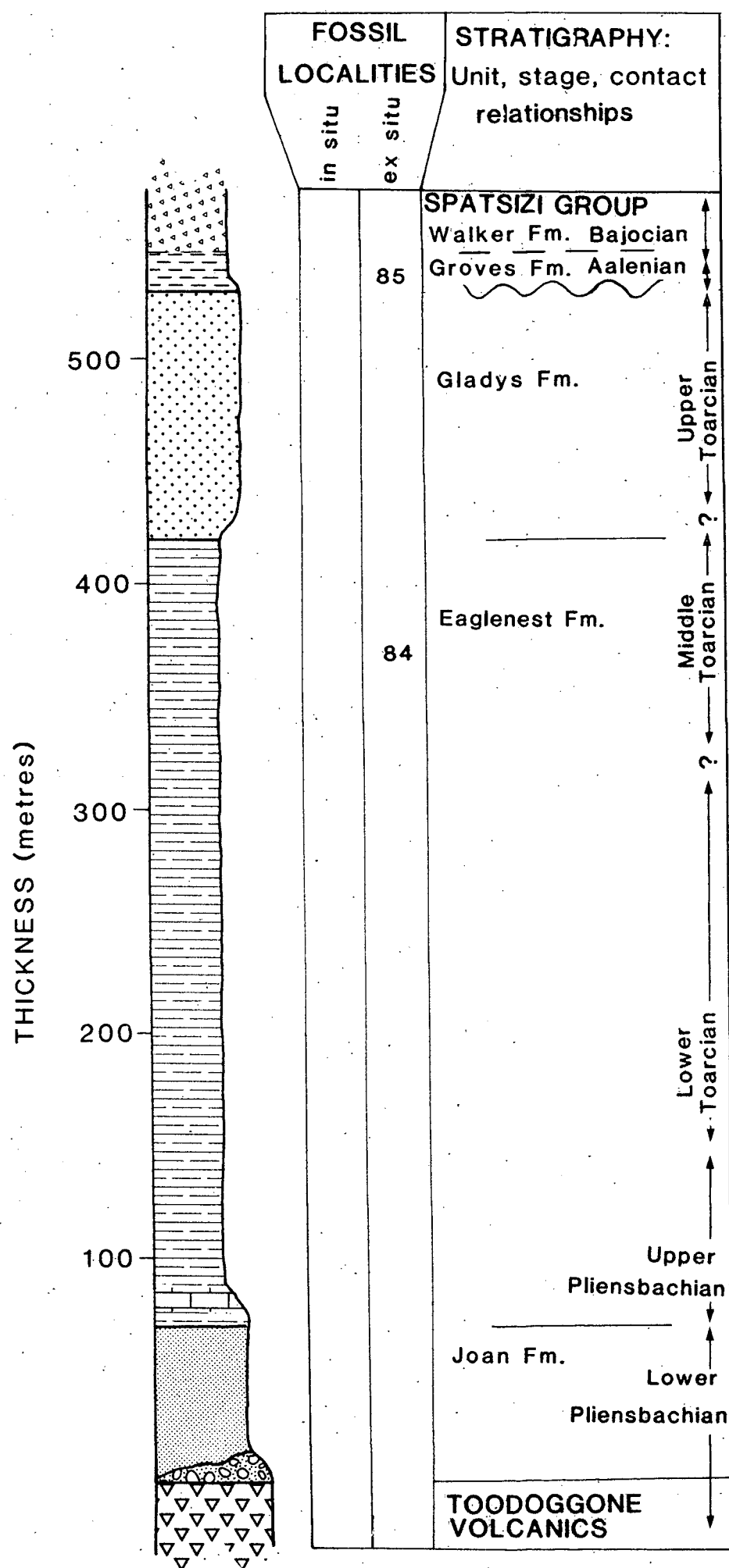


FIGURE 2.5 Section 2, lithostratigraphy

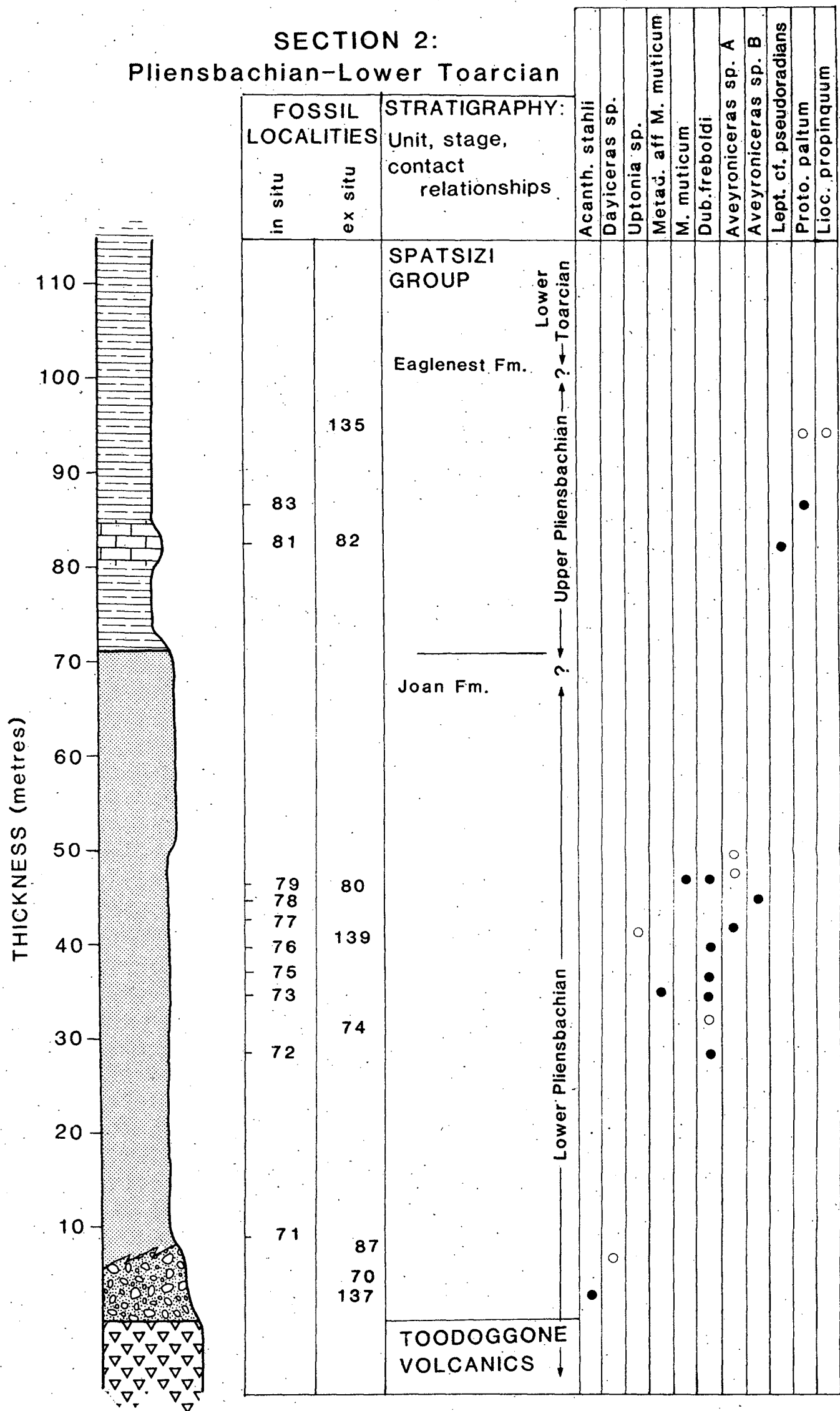


FIGURE 2.6

Section 2 Pliensbachian biostratigraphy and lithostratigraphy

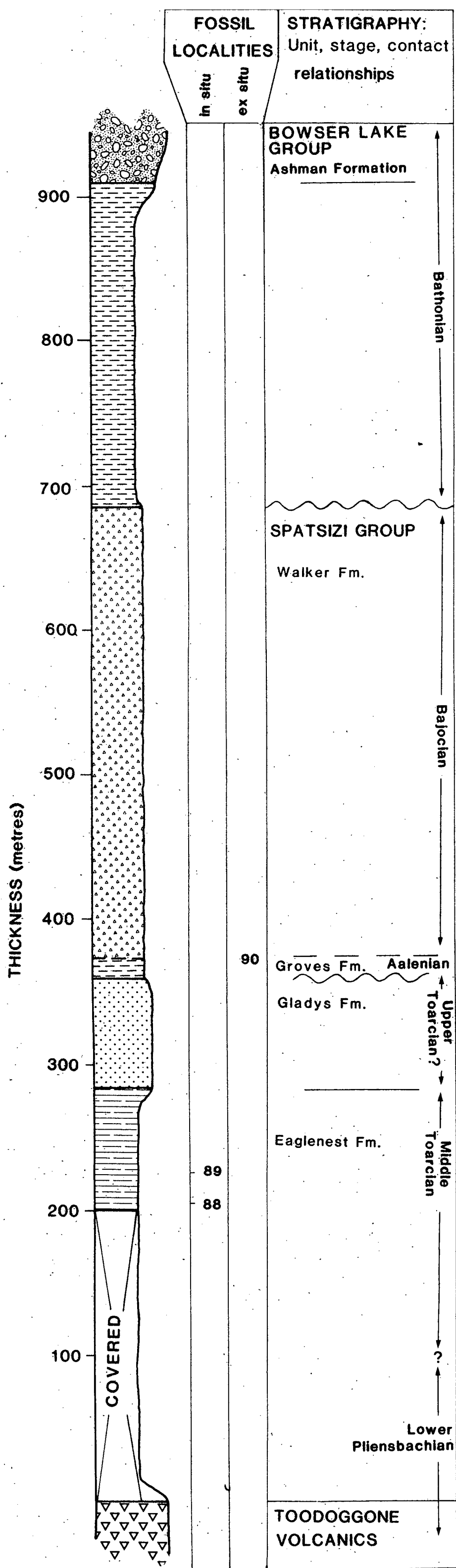


FIGURE 2.7 Section 3, lithostratigraphy

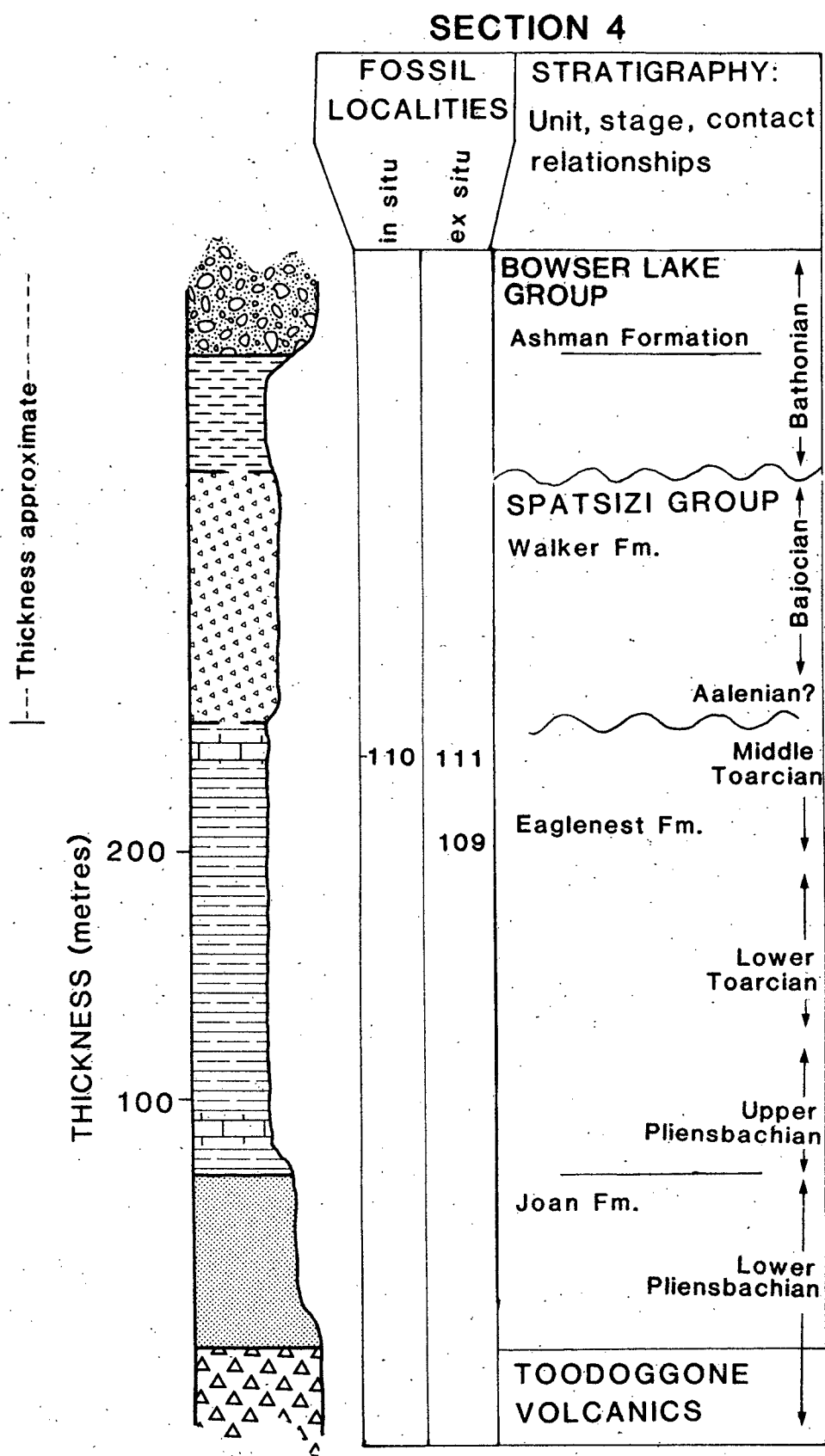


FIGURE 2.8 Section 4, lithostratigraphy

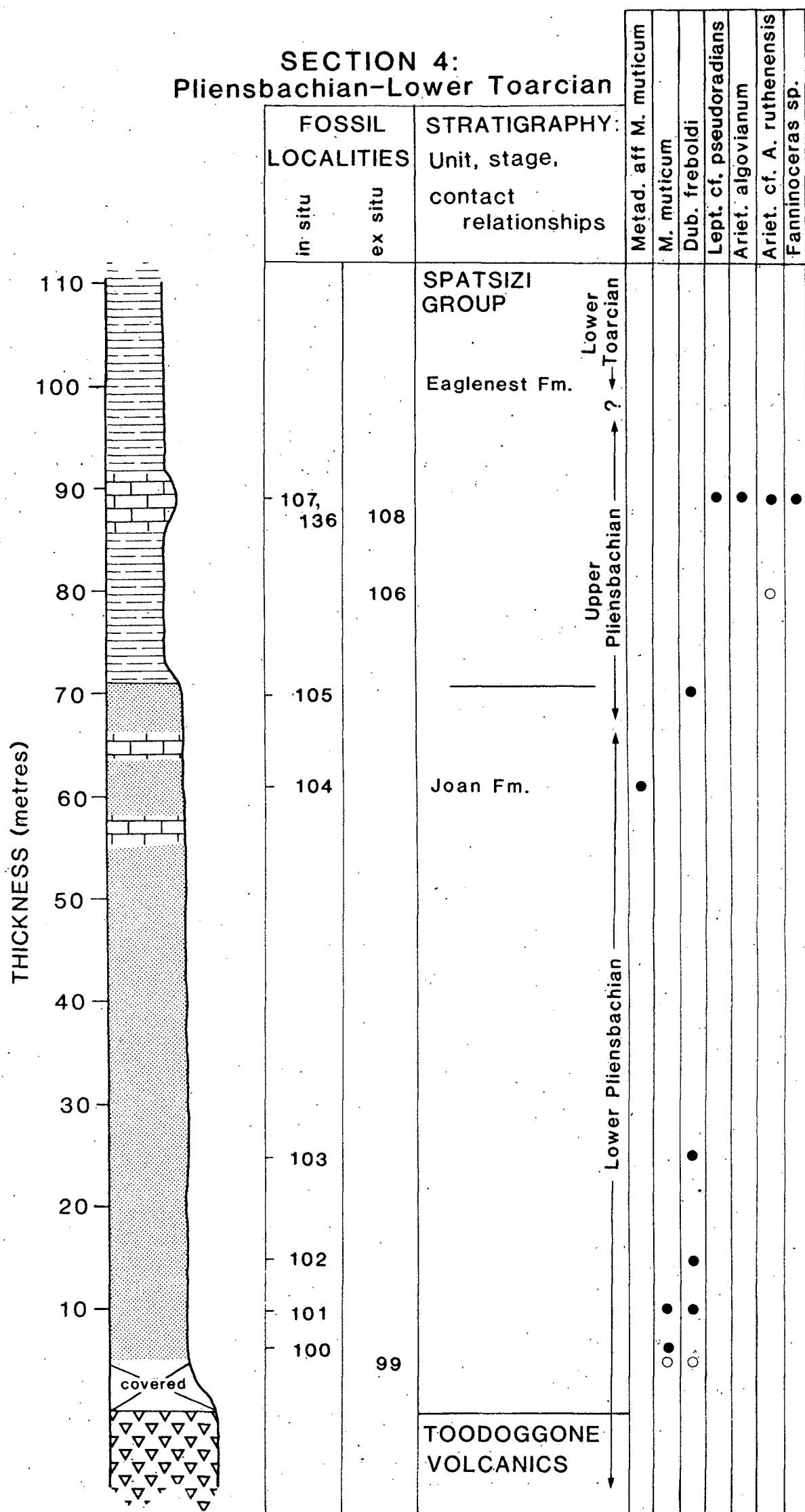


FIGURE 2.9 Section 4, Pliensbachian biostratigraphy and lithostratigraphy

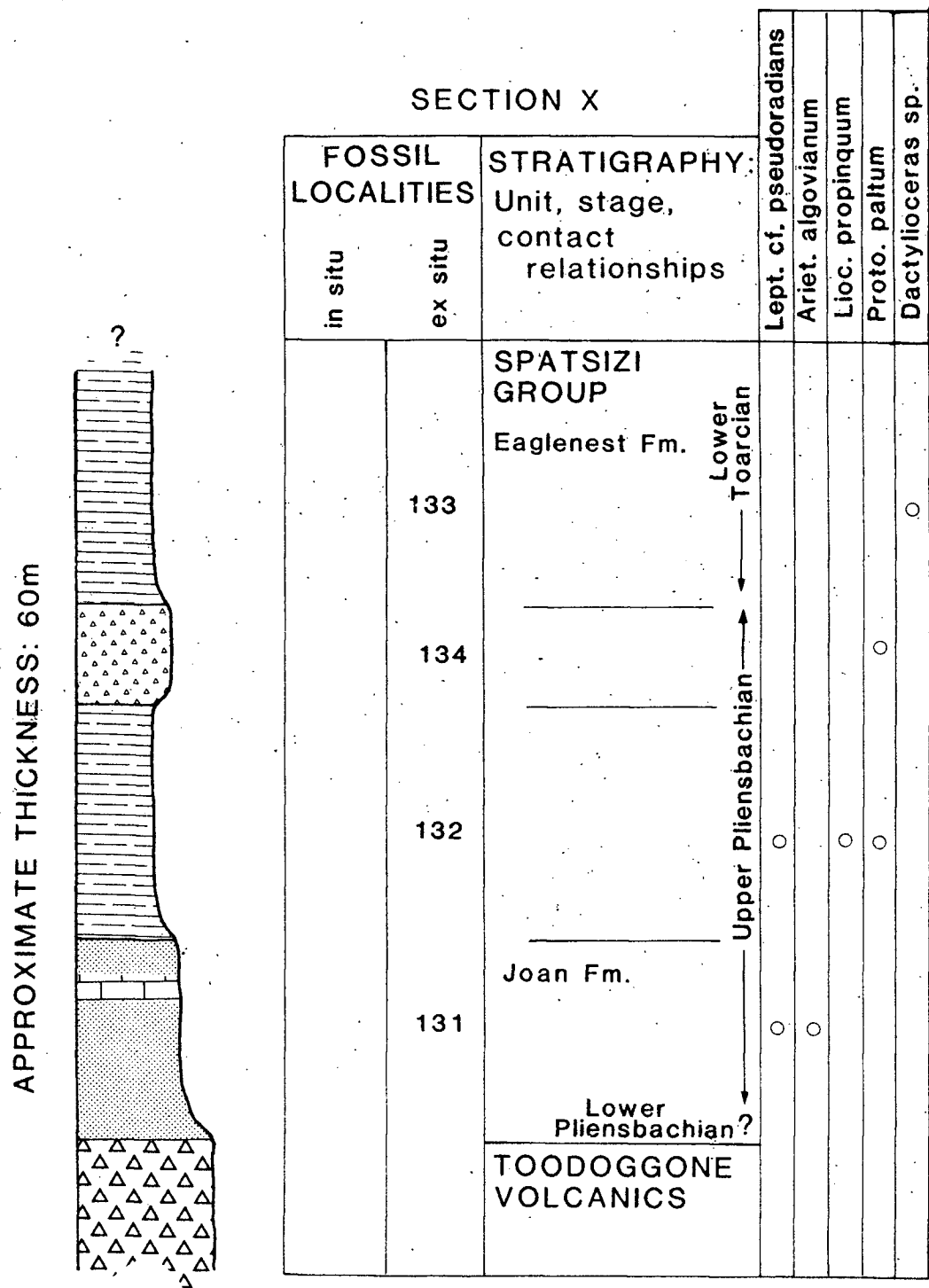


FIGURE 2.10 Section X, Pliensbachian biostratigraphy and lithostratigraphy

### 2.2.1 THE JOAN FORMATION:

The Joan Formation is named for exposures examined in its type locality, around the southern shore of Joan Lake in the thesis map area (fig. 1.2). The type section of the Joan Formation, about 200 m east of the south end of Joan Lake, is illustrated in figs. 2.3 and 2.4. The Joan Formation is discontinuously exposed above the uppermost flow of the Toodoggone Volcanics in the thesis map area and attains a maximum thickness of about 60 m. It consists primarily of medium bedded (10–30 cm thick beds) siltstone with minor interbeds of mudstone and silty limestone, and a thin (<10 m), locally developed basal conglomerate that grades laterally to pebbly sandstone and possibly silty shale. The basal conglomerate is poorly sorted and consists of rounded to angular grains ranging in size from fine sand to cobbles. There does not appear to be any relationship between grain size and degree of rounding. Volcanic rock fragments make up about 50% of the grains, and about 20% of the grains are chert. The remainder of the grains are predominantly quartz (about 20%), and feldspar (chiefly plagioclase; about 5%). The average size of the rock fragments is greater than that of the mineral grains. The conglomerate is clast supported; less than 5% of the rock is made up of fine sand-size or smaller grains (1/4 mm or less). Veins less than 1 mm wide are common and are filled with calcite, quartz, or both. Pore space is filled with calcite or less commonly with chlorite. The source of much of the volcanic material was from the underlying flows. In hand specimen, many of the clasts are indistinguishable from the subjacent flow rocks. Fossils are rare or absent in the coarser facies of the conglomerate, but the occasional ammonites and bivalves were found in the finer sediments, indicating a marine setting. Sedimentary structures other than poorly defined massive bedding (>1 m thick) are absent.

The upper contact of the conglomerate is abrupt and is overlain by fine sandstones that grade rapidly upward into the siltstones that comprise the bulk of the Joan Formation. The lower siltstones are medium bedded, medium grey and weather to



medium grey-brown. They are compositionally less mature than siltstones higher in the unit due to higher organic and clay content. The lower siltstones are made up of about 40% angular to sub-angular monocrystalline quartz grains with less common (10–20%) chert grains. Plagioclase grains make up about 10% of the rock, and volcanic rock fragments, often of fine sand size comprise about 5% of the rock. Less than 5% of the rock consists of skeletal carbonate grains, opaque minerals, and chlorite. The matrix consists of organic matter, clay minerals, and fine grained chlorite. The rock has a high percentage of matrix (about 25–35%) but is clast supported.

Siltstones higher in the unit are more siliceous and compositionally more mature. They tend to be more brittle than the lower siltstones and commonly show a polygonal or columnar jointing pattern perpendicular to the medium (10–30 cm thick) bedding. The amount of organic matter and clay in the matrix is less than that seen in the lower siltstones, however, there is an appreciable amount of cherty groundmass in the matrix that gives the higher siltstones their brittle nature. Patches and vein fillings of calcite are common.

Fossil content varies throughout the siltstone sequence. The lower siltstones and fine sandstones contain abundant ammonites and bivalves, particularly the large, thick-shelled bivalve genus *Weyla*. Higher in the section the specimens of *Weyla* tend to be smaller, trigonid bivalves are more common, and ammonite frequency remains the same. Near the top of the siltstone section the rocks are either unfossiliferous or contain mainly terebratulid brachiopods which are locally very abundant.

Thin carbonate interbeds in the upper siltstones consist of medium to coarsely crystalline calcarenite containing 80–85% calcite spar, less than 10% shell fragments and 5–10% silt-size quartz grains. The boundaries with the sub- and superjacent siltstones are fairly sharp but show slight gradation in thin section. Ammonites are uncommon in the calcarenite beds but colonial and solitary corals, bivalves, gastropods, brachiopods, rare echinoids and bryozoans are found.

Fining upward grading observed in the sandstones and conglomerates in the lower part of the Joan Formation is the only sedimentary structure seen in the formation.

The lower contact of the Joan Formation with subjacent flows of the Toodoggone Volcanics is erosional as indicated by the basal conglomerate, but this erosional contact surface does not represent a significant time gap, however, as the same ammonite, *Acanthopleuroceras* cf. *A. stahli*, has been found in the lowest sediments of the Joan Formation and from sediment interbeds in the highest volcanics in an area about 20 km north of the thesis map area (locality 138, fig. 1.1; H. W. Tipper, *pers. comm.*, 1985). Deposition of the Joan Formation in the thesis map area began early in the Carixian (Lower Pliensbachian) as indicated by *A. cf. A. stahli*, and continued to the end of the Carixian as indicated by the ammonites *Dubariceras freboldi* and *Aveyroniceras* (see also chapter 4, biochronology).

About 1 km to the northwest of the westernmost exposure of volcanic rocks in the core of the anticline that dominates the thesis map area (localities 129–130, fig. 1.2), Lower Pliensbachian rocks of markedly different lithology to that described above were found. Here the Joan Formation is a dark grey to black shale comprising 90–95% organic matter and clays with about 5% very fine quartz silt, minor (<1%) plagioclase silt grains, and minor calcite in the form of veinlet fillings and calcispheres. This shale is strongly fissile although this may, in large part, be due to tectonic shearing rather than sedimentary laminations as suggested by the distorted preservation of fossils in these shales. Pyrite is uncommon. Ammonites found in the shale allowed for correlation with the Pliensbachian siltstones described above.

### 2.2.2 THE EAGLENEST FORMATION:

The Eaglenest Formation is named for exposures examined at Section Y, near the headwaters of Eaglenest Creek (fig. 1.1). The type section, however, is located in the thesis map area, in Section 1 (fig. 2.3). The Eaglenest Formation is widely distributed in

the thesis map area and to the northwest (fig. 2.1), and attains a thickness of 280 m in the thesis map area.

The Eaglenest Formation comprises mainly dark grey to black, fissile to blocky weathering shale with three concretionary beds and minor tuffaceous beds or lenses. The shales are composed of 80–90% clay particles and organic matter. Quartz silt and minor carbonate and chert make up about 10–15% of the rock, and silt-size botryoidal and/or cubic pyrite grains may make up to 0.5% of the rock.

The shales are largely structureless. Bedding, where exposed in creek beds and gullies, is poorly defined and is on the order of 40 to 100 cm thick. Lamination was not readily observed in outcrop but the shales separate along closely spaced (approximately 1 cm) surfaces parallel to bedding. According to Spears (1980), fissility results from the separation of laminae in weathered surface exposures of shale. In thin section, faint colour lamination and concentration of grains along lamellar planes can be seen. Blocky or flakey weathering shales characterized by strong, closely spaced (1–3 cm) fractures indicate the presence of non-fissile mudstones in the section.

Three levels of calcareous concretions are present within the shales of the type section. The lowermost bed occurs at about 15 m from the base of the shales (fig. 2.2) and contains the Upper Pliensbachian ammonite genera *Arietoceras*, *Leptaleoceras*, and *Protogrammoceras*. At 30 m the second concretionary bed contains the Upper Pliensbachian ammonite *Lioceratoides propinquum*. In neither of these concretionary beds do the ammonites appear to form the nuclei of the concretions, and original shell material is rarely preserved.

The *L. propinquum* concretion bed locally contains trace fossils referable to the ichnogenus *Chondrites*. These traces are definitely burrows rather than borings; they are infilled with sediment identical to the matrix, and the walls of the traces are irregular and do not cut across grain boundaries.

Concretions in the two lowermost concretionary beds maximum dimensions, usually parallel to bedding, of about 1 m, but average about 0.5–0.75 m. In thin section the rock is fairly homogeneous and consists of fine grained calcite spar with silt-sized pyrite cubes making up about 1 to 2% of the rock. Abundant unwalled calcispheres infilled with calcite spar of a slightly coarser texture than the matrix may represent infilled microfossil moulds (Scholle, 1978). Rarely, remnants of the original wall structure of the microfossil can be seen; these remnants appear to be of radiolarian tests. Thus in thin section there is some evidence for the replacement of radiolarian tests by calcite.

The third and highest concretion bed is found about 200 m above the base of the shale sequence and contains Middle Toarcian ammonites including *Peronoceras* and *Haugia*. These concretions are different than those just described. They are smaller (less than 40 cm) than the lower concretions and weather to a light brown colour as opposed to the dark grey colour of the lower concretions. They appear to have formed around fossil nuclei, and some concretions consist entirely of large, severely recrystallized ammonites. Shell material is quite commonly preserved in these concretions, whereas pyrite is rare.

In thin section the rock consists of partly recrystallized remains of ammonites and some small spherical structures infilled with calcite spar that probably represent microfossil moulds. Patches of coarse calcite spar make up about 25% of the rock and may be infillings of dissolved macrofossils but evidence of the original structure has been obliterated.

About 20 m above the *Peronoceras* concretion bed, a resistant, medium to light grey-brown weathering lenticular bed of siliceous mudstone containing Middle Toarcian ammonites crops out. The lens is 3–4 m thick and can be traced no more than about 60 m along strike. Ten to fifteen percent of the rock consists of angular silt-size quartz and minor plagioclase grains. Unwalled calcispheres and microcrystalline silica spheres about 0.1–0.5 mm in diameter are common (1–2%). The matrix consists of a cherty groundmass

with a high content of organic matter giving the rock a medium-dark grey colour on fresh surfaces. The high silica content in this bed is probably due to both pelagic (radiolarian?) sedimentation and a moderate influx of volcanoclastic material. The microcrystalline silica spheres provide evidence for the pelagic source of silica, while the angular quartz and feldspar grains indicate a volcanic input.

The lower contact of the Eaglenest Formation is structurally conformable but lithologically abrupt with the underlying siltstones of the Joan Formation. The stratigraphic juxtaposition of these two markedly different formations suggests that a hiatus, or paraconformity of unknown extent may exist, but fossil control is poor in this portion of the section. The age of the lowest shales in the Eaglenest Formation is Late Plienbachian as indicated by the ammonites *Arietoceras* and *Leptaleoceras*, and the ammonites *Haugia* and *Peronoceras* suggest a late Middle Toarcian age for the top of the formation in the type section.

About 15 km to the northwest of the thesis map area, on a hillside referred to in figs. 1.1 and 2.2 as Section Y, a sequence of Lower to Middle Toarcian shales, siltstones, sandstones and pebbly sandstones was examined. This sequence probably represents a more proximal facies than the shales in the thesis map area, the significance of which is discussed in section 2.3 of this chapter. Also discussed in section 2.3 is a sequence of Lower Toarcian siltstones, sandstones and volcanic breccias described by Smith *et al.* (1984) from an area referred to in figs. 1.1 and 2.2 as Section Z (section 1 of Smith *et al.*), about 40 km northwest of the thesis map area.

### 2.2.3 THE GLADYS FORMATION:

Resistant beds of the Gladys Formation are well exposed and form a series of small waterfalls in Gladys Creek which has cut a channel perpendicular to strike through the thesis map area and for which the formation is named (fig. 1.2). The type section of the Gladys Formation is located in Section 1 (fig. 2.3). Thickness of the Gladys

Formation is variable; the formation attains a maximum thickness of about 130 m, and is well exposed in the thesis map area where its resistant beds underlie prominent ridges.

The Gladys Formation consists of medium bedded (10–30 cm), siliceous to calcareous siltstones and fine sandstones with minor silty calcarenite beds. Fine, medium grey–brown weathering sandstone in the lower portion of the unit is calcareous and shows fine ripple lamination whereas the siltstones show parallel lamination, tend to be non–calcareous, are darker in colour and have a more rusty weathering, probably due to a higher content of organic matter and oxidized pyrite. Carbonate content decreases upsection and the dominantly fine sandstones become more resistant and siliceous. Fossil content of the Gladys Formation is restricted to dicoelitid belemnites that are sparse except in a few beds where they are abundant. In the western portion of the thesis map area rocks of the Gladys Formation become less siliceous and finer grained.

The lower contact of the Gladys Formation with the underlying shales of the Eaglenest Formation is conformable. The gradational contact is marked by a 5–8 m zone of interbedded shale and siltstone; the formation boundary is arbitrarily placed above the last shale interbed. The age of the Gladys Formation is not well constrained due to the absence of ammonites. The presence of late Middle Toarcian ammonites (*Haugia* and *Peronoceras* in shales underlying the Gladys Formation, and dicoelitid belemnites within the Gladys Formation suggest a Late Toarcian age.

#### 2.2.4 THE GROVES FORMATION:

The Groves Formation is named for the abundance of float material of this unit found in the cirque southeast of Groves Mountain (fig. 1.2). The type locality of the Groves Formation is situated just south of the westernmost exposure of the Toodoggone Volcanics in the thesis map area (around locality 122, fig. 1.2). Thickness probably does not exceed 20–25 m, although this is difficult to determine due to the poor exposure of the formation. The presence of the Groves Formation can usually only be inferred by

characteristic pieces of light grey weathering, platy (<1 cm thick) siliceous shale found in float at the base of the more resistant and distinctive Walker Formation (described below). Fragments of the Groves Formation commonly contain external moulds of small (.5–1.5 cm) bivalves that may or may not be superimposed onto external moulds of ammonites, most notably of the genus *Tmetoceras*. The lower contact of the Groves Formation is an erosional unconformity. In places, the entire thickness of the underlying the Gladys Formation was completely eroded away before the deposition of the Groves and Walker Formations took place. This unconformity is discussed further in section 2.4 of this chapter. The ammonite *Tmetoceras* commonly found in the Groves Formation indicates an Aalenian age for the formation.

#### 2.2.5 THE WALKER FORMATION:

The Walker Formation is named for exposures examined on the slopes of Walker Mountain in the thesis map area (fig. 1.2), where the type section is located (Section 1, fig. 2.3). It is widely exposed in the thesis map area and to the west (fig. 2.1), and reaches about 200 m in thickness in the thesis map area. The Walker Formation is a thinly bedded to laminated (<10 cm) siliceous shale that is easily recognized in the field by its distinctive banding and reddish-brown weathering. Bed thickness is 0.5 to 3.0 cm normally, reaching a maximum of 5 cm. The beds are fairly continuous and maintain their thickness laterally for up to a few tens of metres. The darker beds owe their colour to a high clay mineral and organic content, and are notably thinner (<1 cm) than the lighter coloured beds. About 5% of the dark beds consists of polycrystalline quartz spheres (.1–.2 mm diameter) that probably represent recrystallized microfossils (radiolaria?). The lower contacts of the dark beds are sharp, the upper contacts are distinct but irregular and almost convoluted in places. The lighter coloured beds consist almost entirely of a microcrystalline quartz groundmass containing about 10% angular, silt-size quartz and plagioclase grains that grade upward from the irregular upper contact of the dark beds.

Besides the fining upward observed in thin section, some fine grained calcareous sandstone and siltstone beds occasionally found in more southerly exposures of the Walker Formation display fining upward grading. Soft sediment deformation of the beds is manifest by convolute slump structures.

The lower contact of the Walker Formation is conformable, and probably gradational with the underlying Groves Formation. At its base in the type section, the Walker Formation is Late Aalenian or Early Bajocian in age, although faunal control is poor at this contact. The ammonites *Stephanoceras* and *Teloceras* found near the top of the formation indicate a late Early Bajocian age.

### 2.3 FACIES CHANGES AND DIACHRONISM

In the preceding sections of this chapter the lateral variations in the rock units of the Spatsizi Group have been described. In this section a summary and analysis of the facies changes in the Spatsizi area is presented. It should be noted here that recognition of facies changes in Spatsizi was made possible through correlations based on the ammonite faunas collected during the course of this study and during earlier field work in the area by the Geological Survey of Canada.

The most profound lateral variation in lithology is seen in the transition from the Pliensbachian-Bajocian Toodoggone volcanics on the southern flank of the Stikine Arch to the basinward sedimentary Spatsizi Group equivalents to the south (figs. 2.1 and 2.2). This southward change from an active volcanic region to a marine sedimentary environment is also reflected in the sedimentary units themselves in that the volcanogenic and coarse clastic components of the units decreases southward into what is believed to be a shale basin now covered by Bowser Lake Group sediments.

The northward transition from fine to coarse sediments is best seen in sediments of Late Pliensbachian to Middle Toarcian age. In the thesis map area the Upper Pliensbachian comprises the lowermost shales and concretionary shales of the Eaglenest



Formation, and is directly underlain by Lower Pliensbachian siltstones of the Joan Formation. Ammonites found in float at Section X, 10 km north of the thesis map area (fig. 1.1), indicate that the Upper Pliensbachian there consists of strata identical to the Lower Pliensbachian (Joan Formation siltstones) in the thesis map area, thus indicating a northward coarsening of the Upper Pliensbachian sediments. The Lower to Middle Toarcian shales of the Eaglenest Formation in the thesis map area are replaced farther northwest at Section Y by epiclastic siltstones, sandstones, and pebbly sandstones that represent a more proximal environment, but are dominantly marine as indicated by their faunas. Still farther to the northwest at Section Z, siltstones, sandstones, and volcanic breccias interbedded in volcanic flow rocks yielded a Late Pliensbachian–Early Toarcian fauna including *Lioceratoides propinquum* and *Dactylioceras* sp. (Smith *et al.*, 1984).

From the foregoing discussion it appears that the Joan Formation, as defined lithologically in the thesis map area, is a diachronous unit. In its southernmost exposure in the thesis map area it is Early Pliensbachian in age. It is Late Pliensbachian in age at Section X, 10 km to the north, and is Early to Mid Toarcian in age farther northwest at Section Y, although it has not been firmly established that the Joan Formation of the thesis map area and the sandstone/siltstone sequence at Section Y are the same rock unit. Similarly, it is uncertain whether the Joan Formation of the thesis map area and the mixed clastic/volcanic sequence at Section Z represent distal and proximal variations, respectively, of the same rock unit. The diachronism and northward shallowing facies trends outlined above all indicate an overall rise in sea-level (or basin subsidence) that resulted in a northward transgression of marine waters onto the Stikine Arch and the establishment of a shale basin south of the Stikine Arch.

A similar sequence of events was reported by Tipper and Richards (1976) for the southeastern portion of the Bowser Basin where Sinemurian and Early Pliensbachian subaerial volcanics of the Telkwa Formation are conformably to disconformably overlain by volcanogenic marine sediments and minor volcanics of the Pliensbachian to Bajocian

Hazelton Group. Lithologies of the Hazelton rocks do not necessarily correspond to lithologies of age equivalent rocks of the Spatsizi Group, but a few of the overall facies trends are common to both sequences. The Pliensbachian to Mid Toarcian Nilkitkwa Formation, for example, consists of volcanogenic sediments, tuffs, volcanic flows and breccias that lose their volcanic character and grade northwestward (*i.e.*, basinward) into more shaly sediments (Tipper and Richards, 1976). The initiation of Nilkitkwa sedimentation was a result of an Early Pliensbachian transgression, as was the initiation of the Joan Formation sedimentation in the thesis map area (see also section 2.5).

## 2.4 UNCONFORMITIES

The Stikine Arch was the dominant tectonic element in the Spatsizi area during the Early and Middle Jurassic and had a profound influence on the volcanic and sedimentologic history of the area. In the preceding section of this chapter, facies changes and the distribution of units within the Spatsizi Group were discussed with respect to the Stikine Arch. In this section several hiatuses that have been recognized in the Spatsizi Group, and whose origins were also related to the tectonic mobility of the arch, are detailed.

The oldest hiatus in the thesis map area is the erosional contact between the uppermost flows of the Toodoggone volcanics and the Lower Pliensbachian siltstones of the Joan Formation. As previously mentioned, faunal evidence indicates that this erosional surface does not represent a significant time gap and is referred here considered to be a disconformity. The basal conglomerate developed at the contact is discontinuous and grades laterally into finer clastics. The conglomerate was presumably deposited in depressions in the upper surface of the volcanics and the finer clastics collected on the higher areas. The paleotopography of the volcanics is not believed to be the result of a significant pre-Spatsizi Group deformational event, but rather, was due to differential erosion of, and deposition on an originally irregular volcanic terrane. Evidence contrary to a pre-Spatsizi

Group deformational event is twofold:

- 1) There is no significant time gap, if any, between the volcanics and the sediments, therefore a structural event would have had to have been very short-lived.
- 2) The volcanics and overlying Pliensbachian siltstones appear to be structurally concordant. Had there been a pre-Spatsizi Group deformational event, evidence of an angular discordance should be apparent.

A disconformity is inferred to exist within the shales of the Eaglenest Formation, approximately at the Lower/Middle Toarcian boundary. Evidence for this is found in the southwest portion of the thesis map area (near localities 124-128, fig. 1.2) where Middle Toarcian shales appear to rest on Toodoggone flows, although the contact is covered or inaccessible. No trace of intervening Pliensbachian or Lower Toarcian strata was found, but the possibility remains that they are present, at least in part or in stratigraphically condensed form. This disconformity is only recognized in the southwest part of the map area and may represent a local erosional event or very slow deposition on a topographically high feature on the sea floor.

A hiatus of regional extent has been recognized at the base of the Groves Formation in the thesis map area, and is here referred to as the sub-Aalenian paraconformity. The sub-Aalenian paraconformity is manifest in the thesis map area by the variable thickness and even absence of the subjacent Gladys Formation which had been partly or completely removed by erosion prior to the deposition of the Groves and Walker Formations. Within the thesis map area, the Groves and Walker Formations have been found resting directly on Lower Toarcian shales of the Eaglenest Formation, and about 7 km to the southeast of the thesis map area (fig. 2.1) the Walker Formation overlies Lower Pliensbachian flows of the Toodoggone volcanics, indicating the erosion of all the underlying units of the Spatsizi Group prior to the deposition of the Groves and Walker Formations. Clearly, the sub-Aalenian disconformity had more far-reaching effects than any of the older breaks in the Spatsizi Group record. In the vicinity of the Skeena

Arch in the southeastern Bowser Basin, the contact between the Pliensbachian–Middle Toarcian Nilkitkwa Formation and the overlying Smithers Formation (the base of which varies in age from late Middle Toarcian to Early Bajocian) is also disconformable in many of the sections examined by Tipper and Richards (1976).

The top of the Spatsizi group is defined by a slight ( $<5^\circ$ ) angular discordance with the overlying black shales and conglomerates of the Bathonian Ashman Formation (Bowser Lake Group). This discordance is visible from a distance on a few hillsides within the thesis map area and is seen at several other localities outside the thesis map area (H. W. Tipper, *pers. comm.*, 1984).

## 2.5 DEPOSITIONAL HISTORY OF THE SPATSIZI GROUP

### 2.5.1 INTERPRETATION: THE JOAN FORMATION

Deposition of the Lower Pliensbachian basal conglomerate of the Joan Formation resulted from a transgression that covered the upper flow surface of the Toodoggone volcanics. Whether the upper flow surface was subareally exposed or covered by shallow marine waters prior to transgression is uncertain. Deposition of coarse and fine sediments of the basal unit in depressions and more elevated areas of the upper flow surface, from which most of the detritus was derived, was followed by the deposition of the fine sandstones and lower siltstones of the Joan Formation. The abrupt contact between the basal conglomerate and the overlying fine sandstones, together with the rapid fining-upward transition from the fine sandstones to the lower siltstones indicates a fairly sudden transgression. The environment changed from a shallow (possibly nearshore) environment with conglomerate deposition and low faunal diversity to a deeper water environment of fine sand and silt deposition in which abundant, large sized specimens of the bivalve *Weyla* and frequent ammonites were present. Water depth continued to increase with the deposition of the upper siltstones of the Joan Formation. The finer

grained and more mature sediments of the upper siltstones indicate that the source of the detrital material was farther away or that the sediment was undergoing more intense sorting and reworking before deposition. Thin limestone interbeds in the upper siltstones reflect periods of reduced clastic influx and may also indicate a distant or low lying clastic source area. A deeper water environment of deposition for the upper siltstones is also suggested by the smaller size of the few specimens of *Weyla* found in these rocks, together with the higher incidence of infaunal bivalves such as *Pholadomya*, *Trigonia*, and *Myophorella*. Near the top of the Joan Formation the fauna becomes either very sparse or is dominated by abundant terebratulid brachiopods. According to Taylor (1982), an abundance of terebratulids indicates a nearshore shallow water setting usually comprising coarser grained sediments. The terebratulid beds at the top of the Joan Formation, however, are dominantly siltstones as described above, and may represent shallowing in an offshore area not subject to coarse clastic influx, or nearshore deposition close to a low source area. The depositional and environmental patterns described here correspond to those outlined for the Joan Formation by Steel (1984).

#### 2.5.2 INTERPRETATION: THE EAGLENEST FORMATION

The contact between the shales of the Eaglenest Formation and the underlying siltstones of the Joan Formation is abrupt and is structurally conformable. Whether or not the contact represents a stratigraphic break is unknown. In any case, the transition from Joan Formation siltstones to the Eaglenest shales represents a significant water depth increase and an associated change in depositional environment. In order to determine the nature of the environment of deposition of the the Eaglenest shales, factors such as sediment composition, sedimentary structures, and fossil content (including macrofossils, microfossils, and trace fossils) are considered. The fauna of the Eaglenest Formation is examined here first.

Modern marine environments have been divided into three generalized biofacies according to the amount of dissolved oxygen is present in the sediment pore waters. The three biofacies are; aerobic ( $>1.0$  ml dissolved  $O_2$ /l sediment), dysaerobic (0.1–1.0 ml dissolved  $O_2$ /l sediment), and anaerobic ( $<0.1$  ml dissolved  $O_2$ /l sediment; (Savrda et al., 1984). These biofacies can be recognized in the rock record based on sediment fabric, faunal composition, and species richness. The low diversity fauna, the dark colour, and pyrite content of the Eaglenest shales suggest deposition in an anaerobic to dysaerobic environment. Field observations and micropalaeontological analysis of the shale show that infaunal or epifaunal macro- or microfossils are rare; a toxic bottom environment would preclude their existence in these muds. A few poorly preserved radiolaria and a single dinoflagellate cyst found in the shales would not have been affected by bottom conditions.

Apart from the fossils found in the concretion beds, several poorly preserved ammonite impressions were found in the shales. Near the 190 m level in the shale sequence (fig. 2), below the *Peronoceras* concretion bed, a sample of dark grey, fissile and pyritic shale was collected containing a single indeterminate ammonite mould associated with numerous small (3–7mm) bivalves. The bivalve impressions are both superimposed onto and scattered around the ammonite mould, and all the fossils are concentrated along a single bedding surface. Isolated specimens of the same bivalve were also found in shale samples devoid of any larger fossils. The bivalves closely resemble those found in the Toarcian Posidonienschiefer in Germany, including the genera *Bositra* (or *Posidonia*) and *Pseudomytiloides*. It is widely accepted that the Posidonienschiefer were deposited under dominantly anaerobic to dysaerobic conditions (Brenner and Seilacher, 1978; Kauffman, 1978). In southern British Columbia, certain facies of the Fernie Formation deposited under dysaerobic conditions also contain these bivalves (Hall and Stronach, 1982). It follows, then, that the presence of these bivalves in the Eaglenest shales indicates deposition in an anareobic to dysaerobic bottom environment.

The mode of life of these bivalves is a subject of some debate (Tenabe, 1983; Brenner and Seilacher, 1978; Jeffries and Minton, 1965). Pseudoplanktonic, planktonic, and epibyssate-benthic (or benthic island) modes of life have all been proposed. In any case, these bivalves are not thought to have lived in the anaerobic bottom environment represented by the Eaglenest shales, the Posidonienschiefer, and the Fernie Formation, but rather, they lived above the stagnant bottom. It is likely that they could tolerate dysaerobic conditions. The observed association between bivalve and ammonite impressions in the Eaglenest shales could indicate either a pseudoplanktonic or benthic island mode of life. However, common 'stray' bivalve fossils found isolated from any larger fossil would seem to favour the pseudoplanktonic model. These 'strays' may represent individuals that became dislodged from their host (possibly a floating piece of wood or algae) and subsequently sank into the poisonous depths below. However, none of the common pieces of silicified wood found in the section show any sign of colonization by epizoan bivalves. The life mode controversy cannot be solved based on the Spatsizi collections, but the evidence does support the interpretation of an anoxic depositional environment.

The trace fossil *Chondrites* which is found in some of the concretions may indicate a somewhat more oxygenated environment of deposition for that particular horizon. Brenner and Seilacher (1981) report several levels within the Posidonienschiefer that contain abundant *Chondrites*. They interpret these as representing periodic oxygenation events during which colonization of the sediment by *Chondrites* forming organisms occurred. This interpretation is supported by the work of Savrda *et al.* (1984) who describe trace fossil gradients from aerobic to anaerobic sediments in the Santa Barbara, Santa Monica, and San Pedro basins off the coast of California. The sediments classified as anaerobic (*i.e.*, less than 0.1 ml dissolved O<sub>2</sub>/l sediment) contain no trace fossils. The first appearance of trace fossils created by infaunal burrowers occurs in dysaerobic sediments of slightly higher (0.1–1.0 ml O<sub>2</sub>/l sediment) oxygen content. Bromley and Eckdale (1984), however, consider that *Chondrites* is found in all environments, including

anaerobic environments. The view that *Chondrites* is not found in true anaerobic sediments is maintained here in light of the impressive data presented by Svarda *et al.* (1984). In summary, the apparently limited occurrence of *Chondrites* to certain levels in the Spatsizi shales is probably a result of short-lived oxygenation events that punctuated the dominantly anoxic depositional environment represented by the Eaglenest shales.

Sedimentary evidence supporting the anoxic interpretation of the Eaglenest shales includes the dark colour, pyrite content, the fissility of some of the shales, and the faint colour lamination and concentration of grains along lamellar planes as seen in thin section. The dark colour is imparted by organic matter preserved in the rock. Accumulation of organic matter in the shales was possibly facilitated by anoxic bottom conditions which prevented the destruction of organics on the seafloor by deposit feeders and bacteria. Faint colour lamination and the concentration of grains parallel to lamination seen in thin section suggest an absence of bioturbating infauna, presumably due to inimical bottom waters.

Although similar in many respects to classic black shale sequences such as the Fernie Formation and the Posidonienschiefer, the Eaglenest shales appear to have been deposited fairly rapidly with respect to these other sequences. For example, the thickness of the Fernie Formation ranges between 67 and 400 m and deposition spanned much of Jurassic time (Hall and Stronach, 1982). More specifically, the Toarcian Poker Chip, or Paper Shale division of the Fernie Formation, consisting of thin bedded, dark grey to black shale, ranges between 10 and 30 m thick (Frebold, 1969). The thickness of the Upper Pliensbachian to Middle Toarcian portion of the Spatsizi shales is on the order of 150 m. Accumulation of this thickness of sediment over this short period of time indicates that the sedimentation rate for the Spatsizi shales was perhaps an order of magnitude greater than in the Fernie Basin. It is possible that rapid sedimentation of the Eaglenest shale was due to sedimentation in a tectonically active eugeocline, and that the poorly developed lamination in these shales was the result of rapid burial under anoxic



conditons.

According to Curtis (1980), bituminous shales undergo intense diagenetic alteration in the upper 10–15 m of the sediment column, in the sulphate reduction diagenetic zone, and experience continued alteration below this in the fermentation diagenetic zone where the presence of 'aggressive' solutions dissolves unstable minerals in the sediments. The pyrite in the Eaglenest shales probably formed in the sulphate reduction zone where bacterially reduced sulphate in the pore waters may react with any ferric iron present to form pyrite. Fluctuations in the pH of the pore waters resulting from the metabolic activity of the bacteria were probably responsible for the dissolution of calcareous skeletal material as well as, conversely, for the formation of the calcareous concretions. The poor preservation of radiolarian tests in these shales may, in part, be due to this pH fluctuation, however the 'aggressive' solutions of the fermentation diagenetic zone may have been more effective in their destruction.

The anoxic condition inferred from sedimentologic and faunal evidence in the Eaglenest shales is consistent with data indicating a world wide eustatic sea-level rise and anoxic event during the Toarcian (Hallam, 1981; Sellwood, 1978). Although local tectonics had some influence on facies development, an absolute rise in sea-level is thought to have been responsible for the deposition of bituminous facies around the globe. The Posidonienschiefer and the Fernie Formation are two examples of bituminous Toarcian sediments. The Toarcian event is just one transgressive phase in an overall Lower Jurassic sea-level rise (Hallam, 1981). Sellwood (1978) attributes the Jurassic eustatic events to rifting and dispersal of Pangea; increased seafloor spreading rates and growth of mid-oceanic ridges resulted in the displacement of ocean water out of the ocean basins and onto continental areas.

The relationship between anoxic events and transgression is linked to local bathymetric configuration (for example, the flooding of a silled basin) and to the position and magnitude of the oxygen minimum layer. According to Jenkyns (1980), transgression

leads to increased organic productivity in epeiric and shelf seas, which in turn leads to greater bacterial oxidation below the photic zone. Vertical and lateral spreading of the oxygen minimum layer, formed by bacterial oxidation, would cause a general anoxic event in the worlds oceans. The absence of polar ice caps and the equable climate inferred for the Early Jurassic (see chapter 5) would have augmented the effects of transgression by minimizing the flow of cold, oxygen-rich polar density currents along the worlds sea floors (Sellwood, 1978; Jenkyns, 1980). The combined effects of an expanded oxygen-minimum layer and an absence of oxygenating bottom currents resulted in wide spread anoxic conditions.

In summary, the faunal and sedimentologic character of the Eaglenest shales together with well documented evidence of a worldwide Toarcian transgressive/anoxic event all point towards a dominantly anaerobic to dysaerobic environment of deposition. The overall anoxicity was probably punctuated by short lived oxygenation events. The absence of a benthic fauna is largely due to anoxicity whereas the scarcity and poor preservation of planktonic forms is attributed to post-depositional diagenetic factors.

### 2.5.3 INTERPRETATION: THE GLADYS FORMATION

The ripple laminations and relatively coarse grain size of the Gladys Formation, with respect to the Eaglenest Formation, indicates a shoaling event in the basin of deposition during the Late Toarcian. In the absence of all fossil types except for the belemnites, little can be said of the environment of deposition based on faunal evidence. However, according to the faunal and lithologic distribution data presented by Taylor (1982), the association of belemnites with fine sandstone, together with an absence of ammonites indicates a fairly nearshore or shallow water environment.

As discussed previously in this chapter, the upper contact of the Gladys Formation is an erosional unconformity of regional extent. The shoaling event that effectively ended the deposition of the deeper marine shales of the Eaglenest Formation and led to the

deposition of the Gladys Formation may also have ultimately led to the erosion of the Gladys Formation and, in some cases, older units, prior to the deposition of the Groves and Walker Formations. Tipper and Richards (1976) and Carter (1985) have also reported major regressive phases recorded in sequences in the southern Hazelton Trough area and the Queen Charlotte Islands, respectively. It is possible that this shoaling event is related to a global sea-level drop postulated by Hallam (1981) for the Late Toarcian.

#### 2.5.4 INTERPRETATION: THE GROVES AND WALKER FORMATIONS

Subsequent to the erosional period represented by the sub Aalenian paraconformity, renewed marine transgression initiated the deposition of the Groves and Walker Formations of Aalenian to Early Bajocian age. This Aalenian transgression, like the Late Toarcian regression discussed above, has been reported by Tipper and Richards (1976), Carter (1985), and Hallam (1981), and probably reflects global sea-level change. The Early Bajocian stage in the Spatsizi area was a time of both explosive volcanism and shale sedimentation as recorded in the bedded tuffaceous shales of the Walker Formation. The dark beds of the Walker Formation were formed in a quiet basinal setting where clay-sized particles (and radiolarian tests?) accumulated in an anoxic environment undisturbed by a bioturbating infauna. This sedimentation was frequently interrupted by ash falls and density currents resulting from volcanic activity probably centred along the southern flank of the Stikine Arch. The irregular upper surfaces of the dark shale beds and the fining upward grading in the light coloured tuff beds indicate that the tuffaceous material settled out quickly. Soft sediment convolute slump structures in the Walker Formation rocks were probably formed by movement of semi-coherent sediment down shallow slopes in the sedimentary basin. Movement may have been triggered by volcanic and seismic activity in the area.

Toodoggone volcanism and Spatsizi Group sedimentation came to a close in the Middle Bajocian. Regional uplift subsequently resulted in the angular discordance observed

between the Walker Formation of the Spatsizi Group and the Bowser Lake Group. The molasse-type sedimentation of the Bowser Lake Group was in marked contrast to the eugeoclinal volcanism and sedimentation previously active in the region, and marked the beginning of a new tectonic regime for the northern part of the Stikine terrane.

### 3. STRUCTURAL GEOLOGY

#### 3.1 FOLDS

Structure in the thesis map area is dominated by a large, west-northwest trending, open to close, upright anticline whose axial plane dips steeply to the northeast. The axial trace of the anticline transects the map area and can be traced farther to the northwest and southeast for a total distance of about 40 km (fig. 3.1). Within the map area the anticline is doubly plunging and is cored by flows of the Toodoggone volcanics.

The Toodoggone volcanics and the overlying Spatsizi sediments behaved differently during the formation of the anticline, due to the viscosity contrast between the volcanics and overlying sediments. Because of their relatively competent, rigid nature, deformation of the volcanics resulted in the development of a broad, open fold. The dominantly shaly and tuffaceous sediments of the overlying Spatsizi and Bowser Lake Groups are more complexly deformed than the volcanics. Development of tight minor folds in the sediments is common on both limbs of the anticline.

Folds in the map area have a parallel form, that is, there is no appreciable thickening or thinning of the units in the core or limbs of the folds. Much of the strain has been taken up through flexural slip primarily along surfaces separating the different lithologic units. The best developed examples of this can be seen between the Toodoggone volcanics and the overlying Lower Pliensbachian conglomerates and siltstones of the Joan Formation, and between the resistant Upper Toarcian siltstones (Gladys Formation) and the overlying Aalenian to Bajocian tuffaceous shales of the Groves and Walker Formations. These contacts are conspicuous in the field and are manifest by prominent dip slopes of the underlying unit. Flexural slip occurred along these dip slope surfaces as evidenced by local preservation of slickensides and minor brecciation. Exposure of these dip slopes is due to the erosion of the less resistant, overlying units above the flexural slip (dip slope) surface. Flexural slip also resulted in the development of slickensides on the more

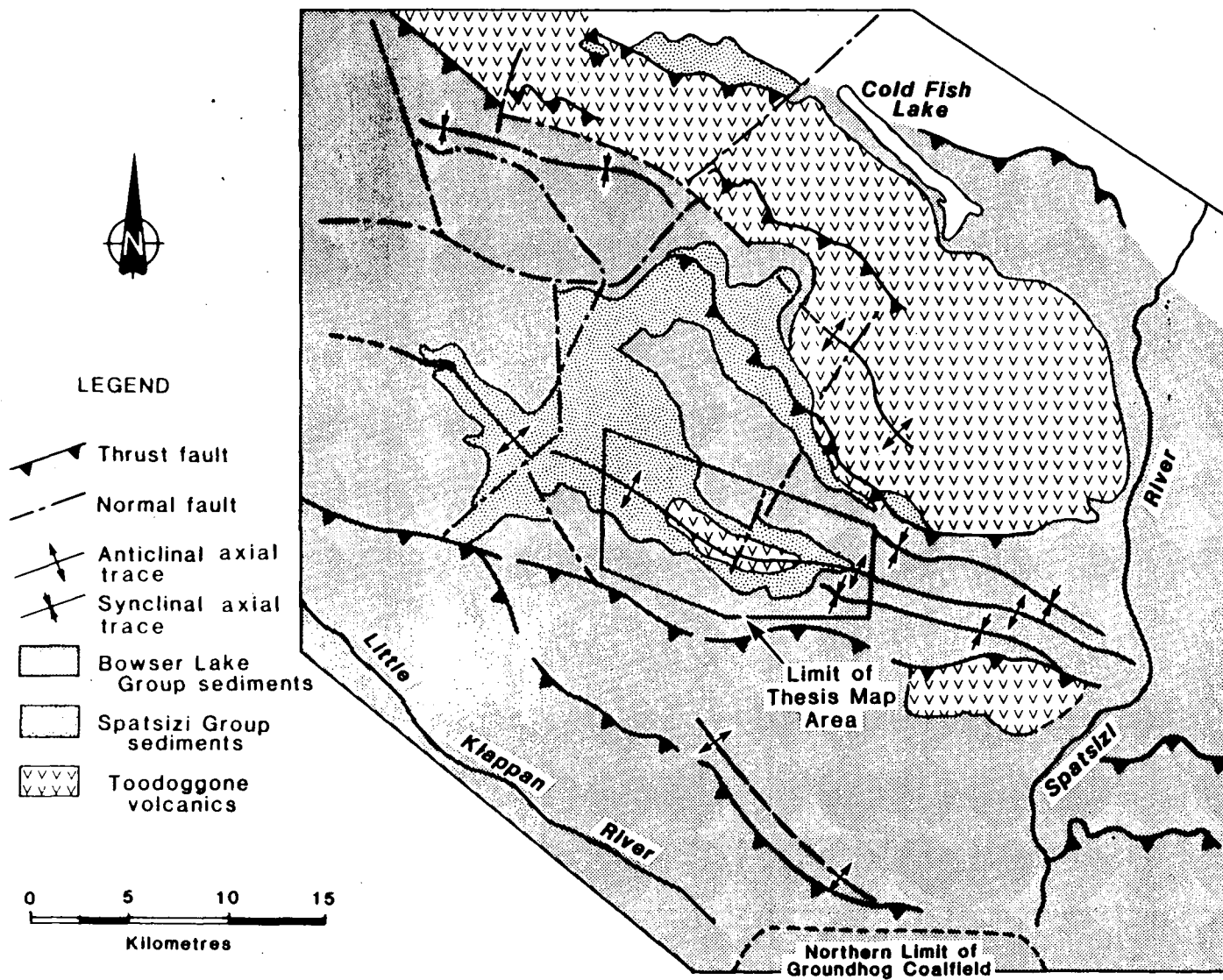


FIGURE 3.1 Map showing the major rock units and structures in the region surrounding the thesis map area (modified from Gabrielse and Tipper, 1984).

resistant, and generally more calcareous beds within the Toarcian shales of the Eaglenest Formation.

A series of cross-sections through the anticline (fig. 3.2a, c, and e) illustrates the structural relationships between the units present in the area. The anticline becomes progressively tighter from the northwest to the southeast within the map area. The axial plane of the anticline appears to be steeply dipping ( $75^{\circ}$ – $90^{\circ}$ ) to the northeast as evidenced by field relations of the axial trace with topography and analysis of stereoplots of bedding plane intersections ( $\rho$  diagrams) constructed from field data in the vicinity of each section line (figs. 3.3b, d, and f). A more accurate determination of the orientation of the axial plane is beyond the scope of this thesis.

Bustin and Moffat (1983) and Moffat and Bustin (1984) have described in detail the stratigraphy and structure of the Groundhog coalfield 20 to 40 km to the south of the thesis map area. The Groundhog coalfield is underlain by Middle to Upper Jurassic/Lower Cretaceous (Callovian to Albian) marine and non-marine sediments. This sedimentary sequence, referred to as the Gunanoot assemblage, is correlative with the Bowser Lake Group sediments that overlie the Spatsizi sediments in the thesis map area (Bustin and Moffat, 1983). Structural analysis of the Gunanoot assemblage has shown that these rocks have undergone two phases of deformation (Moffat and Bustin, 1984). Analysis of structural data from the Spatsizi sediments in the thesis map area indicates that this stratigraphically lower sequence of rocks has experienced the same deformational history as the younger Gunanoot assemblage.

A contoured stereoplot ( $\rho$  diagram) of the Spatsizi data shows that originally northwest trending first phase lineations (bedding intersection lineations) have been rotated about a second phase fold axis oriented approximately perpendicular to the first phase fold axis, resulting in the fanning out of these lineations along a small circle in the storeoplot (fig. 3.3a). This relationship between first and second phase folding is similar to that outlined for the Gunanoot assemblage (Moffat and Bustin, 1984; fig. 3.3b).

### 3.2 FAULTS

Faulting played a significant rôle in the structural development of the Spatsizi area as a whole, but only one fault of more than a few tens of metres displacement has been found exposed in the map area itself. Traces of large thrust faults in areas surrounding the thesis map area are indicated on the bedrock geology map of Spatsizi (Gabrielse and Tipper, 1984) and thrusts of similar magnitude (generally less than 1 km displacement) have been mapped in the Groundhog coalfield (Moffat and Bustin, 1984). Tipper and Gabrielse (1984) have mapped thrust traces immediately to the south and to the north of the thesis map area (fig. 3.1), although no thrust traces were found in the thesis map area itself. This suggests that the thesis area is part of a larger thrust sheet whose trace does not come to surface anywhere within the thesis map area. Interpretive cross sections constructed by Moffat (*in prep.*) for the Groundhog coalfield show that the coalfield consists of imbricate, dominantly southwest dipping thrust sheets. Moffat calculates the detachment surface of the thrusts to be stratigraphically below the Toodoggone volcanics. A similar thrust surface is assumed to be present at some depth below the volcanics exposed in the thesis map area.

North-south trending, steeply dipping faults with vertical displacements ranging between a few metres to a maximum of about 100 m are recognized in the map area. The western block of these faults has been downthrown, but the dips of the fault planes have not been determined. Small scale, north-south trending faults of about 3-10 m displacement have been observed cutting the uppermost surface of the highest flow of the volcanics. These faults die out rapidly in the overlying sediments, the strain presumably being taken up through deformation in these less rigid rocks.

Trending perpendicular to the fold axis of the anticline is a single fault whose western block has dropped on the order of 100 m. This fault has displaced all the stratigraphic units present in the area, from the Toodoggone volcanics up to the lower conglomerate of the Ashman Formation. Movement on this fault therefore occurred later



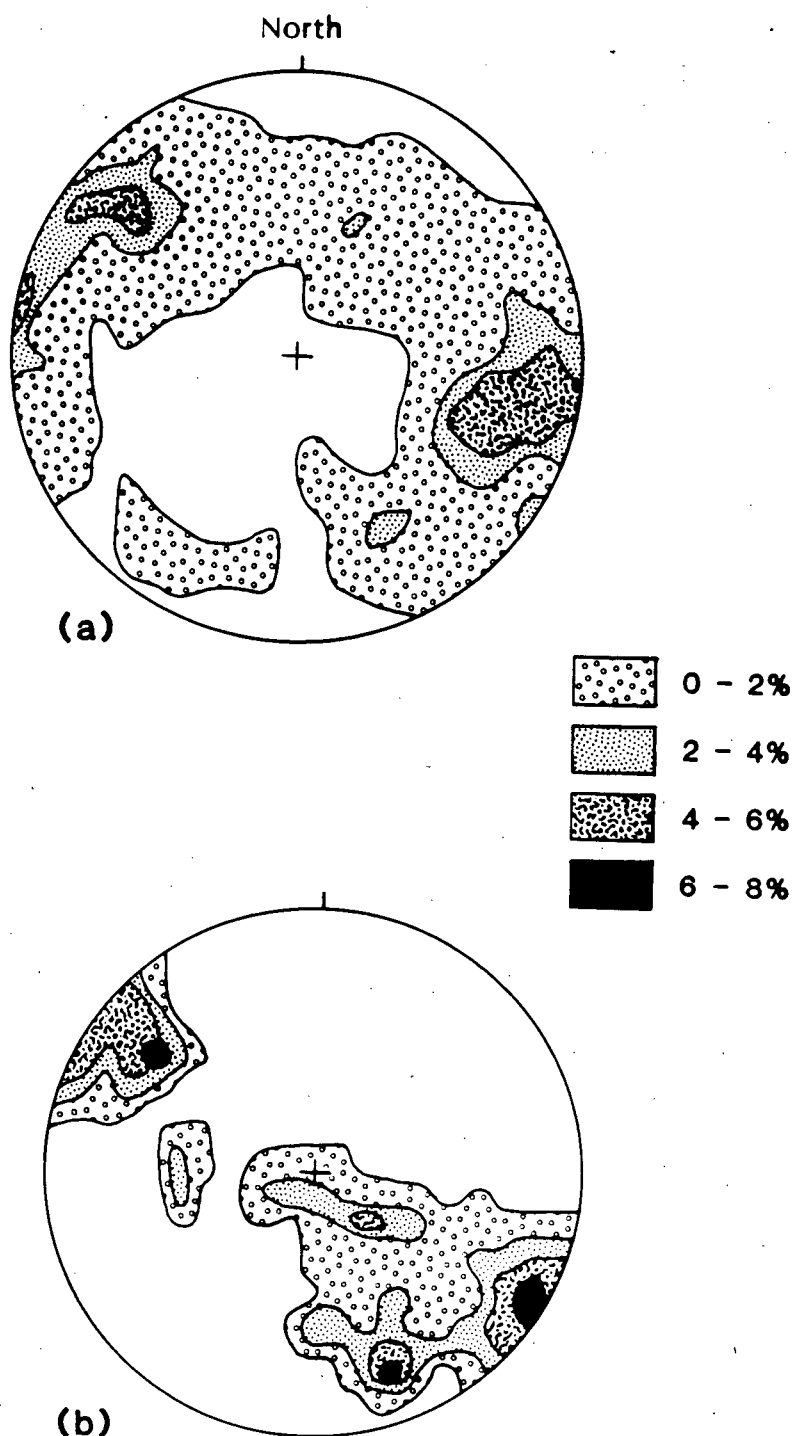


FIGURE 3.3 Comparison of structural data from the thesis map area (fig. 3.3a) with the northern Groundhog coal field (fig. 3.3b; from Moffat and Bustin, 1984). Fig. 3.3a is a contoured stereoplot of bedding plane intersection lineations ( $\beta$  diagram) from the entire thesis map area; fig. 3.3b illustrates bedding to first phase cleavage intersections from the Groundhog coal field.

than Bathonian time. The orientation of this fault is parallel to the inferred trend of the second phase fold axis, suggesting that it may be related to the second phase of folding. Outer arc extension perpendicular to the second phase fold axis could conceivably have resulted in the formation of this fault. In the Groundhog coalfield, the formation of extension faults of similar orientation and displacement to that of the large scale high angle fault in the thesis map area is also attributed to outer arc extension during the second phase of deformation (Moffat and Bustin, 1984).

### 3.3 DISCUSSION

The exposure of the Toodoggone volcanics below the overlying Spatsizi and Bowser Lake Group sediments in the core of the doubly plunging anticline may be an expression of a structural interference pattern resulting from the superposition of two sets of folds on the rock sequence in the area. In Spatsizi, the overprinting of first phase upright buckle folds by a second phase of upright buckle folds trending approximately perpendicular to the original folds seems to have led to the development of the dome-like anticline in the centre of the thesis map area. This dome probably represents a structural culmination resulting from the superposition of a second phase anticline on a first phase anticline. The interference pattern developed in Spatsizi is geometrically similar to the Type I interference pattern of Ramsay (1967), although Ramsay's Type I pattern applies to folds formed by simple shear rather than buckling. The large scale high-angle fault that cuts through the high point of the dome in the thesis map area may have formed as a result of high tensions present at the apices of such structures.

#### 4. BIOCHRONOLOGY

##### 4.1 INTRODUCTION: ZONAL SCHEMES AND AMMONITE PROVINCIALITY

Of all fossil organisms used in biostratigraphy, Jurassic and Cretaceous ammonites have provided geologists with one of the most detailed and easily utilized zonal standards known. The concept of biostratigraphy itself was, in large part, developed in light of the rich Jurassic ammonite faunas of Germany and Great Britain. The subsequent application of these early ideas throughout what has come to be known as the northwest European Liassic ammonite province led to the development of increasingly refined zonal schemes culminating in the standard of Liassic ammonite zones and subzones of the northwest European province by Dean *et al.* (1961). This standard has served as a frame of reference to all subsequent zonal work in other parts of the world. However, due to the provincial nature of Early Jurassic ammonite distribution, application of the northwest European standard is limited outside of the northwest European province. Dean *et al.* (1961, p. 438) state that the standard cannot be directly applied to other parts of the world ". . . on account of the absence or rarity of many of the index species, apart from the question of the relative time ranges of ammonite species in (different) provinces.". The creation of zonal tables unique to the different ammonite provinces, and a means of correlating between the different provinces is an area of active research. It is the problem that shall be addressed in this chapter with specific reference to the Spatsizi fauna.

The restriction on the application of the northwest European standard is of particular importance in view of the division of Early Jurassic ammonite distribution into distinct realms. The Lower Jurassic, and particularly the Pliensbachian, was characterized by two dominant faunal realms; the northern Boreal realm, of which the northwest European province was a part, and the southern Tethyan realm that included the European Alpine belt and areas to the south and southeast (Donovan, 1967; Hallam,

1969; Howarth, 1973b; fig. 5.1). The boundary between the two realms was roughly parallel to latitude and is marked by a narrow zone of overlap running through the European Mediterranean region. The origin and nature of these faunal realms is discussed in the following chapter on paleobiogeography.

Because the two realms were occupied by significantly different faunas during the Early Jurassic, the zonal standard derived from successions in the northwest European province (of the Boreal realm) cannot be directly applied to the Tethyan realm, that is, a zonal standard pertaining to the Tethyan realm itself is needed. Zonal schemes for parts of the Tethyan Lias have been proposed, but a comprehensive standard of Liassic zones and subzones for the Tethyan realm has not yet been compiled.

Correlation of contemporaneous faunas between the Boreal and Tethyan realms has been achieved through studies of the mixed Boreal/Tethyan fauna in the narrow overlap zone, where zonal index fossils of both realms have been found together. Further evidence of correlation is provided by ammonites of pandemic distribution.

#### 4.2 ZONATION OF NORTH AMERICAN FAUNAS

Lower Jurassic stratigraphic data from western North America have traditionally been analyzed with respect to the northwest European standard. More recently, however, workers have come to realize that not all of the western North American faunas are of northwest European derivation, and that the same division into a Boreal, mixed, and Tethyan fauna seen in Europe can be distinguished in western North America (Imlay, 1968; Howarth, 1973b; Smith, 1981, 1983; Tipper, 1981). As a result, application of the northwest European zonal standard to the entire western North American fauna is in question, and the need has arisen for a revised zonal scheme pertaining to the Tethyan elements of the western North American fauna and associated forms endemic to western North America. Based on ammonites of Tethyan aspect collected from Oregon and Nevada, Smith (1981) has proposed a zonal scheme for the mid Lower Sinemurian to the

Lower Toarcian (fig. 4.1). In view of subsequent taxonomic and zonal work, two changes need to be made to this zonal scheme. Firstly, North American specimens previously assigned to *Dayiceras dayiceroides* (Frebold, 1970; Smith, 1981, 1983; Imlay, 1981) have been placed into the new genus *Dubariceras*, and the species renamed to *freboldi* (Dommergues *et al.*, 1984). Thus, the *Dayiceras dayiceroides* Zone is now the *Dubariceras freboldi* Zone. Secondly, as explained in the discussion of *Lioceratoides propinquum* and in the following section (4.4) on the Pliensbachian/Toarcian boundary, the *Tiltoniceras propinquum* Zone has been renamed as the *Lioceratoides propinquum* Zone, and is considered to represent the uppermost Pliensbachian rather than the lowest Toarcian (Smith *et al.*, *in prep.*). In short, the species *propinquum* is no longer considered to belong to the genus *Tiltoniceras*, which in northwest Europe (and possibly Siberia) occurs near the top of the *Tenuicostatum* Zone. In western North America, *Lioceratoides propinquum* is found below the first appearance of *Dactylioceras*, which is here considered to mark the Pliensbachian/Toarcian boundary. The *L. propinquum* Zone is probably roughly equivalent to the northwest European *Spinatum* Zone, although precise correlation with European zonal standards will require further work.

#### 4.3 ZONATION OF THE SPATSIZI FAUNA

The Spatsizi fauna is considered to be of mixed Tethyan/Boreal affinity, although Boreal elements, particularly the Upper Pliensbachian genus *Amaltheus*, were not found in the thesis map area. *Amaltheus*, however, is found in biogeographically related faunas from areas surrounding the thesis map area on northern Stikinia, including the Cry Lake map area (104 I; Tipper, 1978), the Telegraph Creek map area (104 G; Frebold, 1964; Souther, 1972), and in the McConnell Creek (94 D), Hazelton (93 M), and Smithers (93 L) map areas (Tipper and Richards, 1976; fig. 1.3; see also Chapter 5, section 5.2). Thus the Spatsizi fauna, comprising mainly Tethyan and unrestricted forms is, by association, considered to be a mixed Boreal/Tethyan fauna. The absence of *Amaltheus* from the

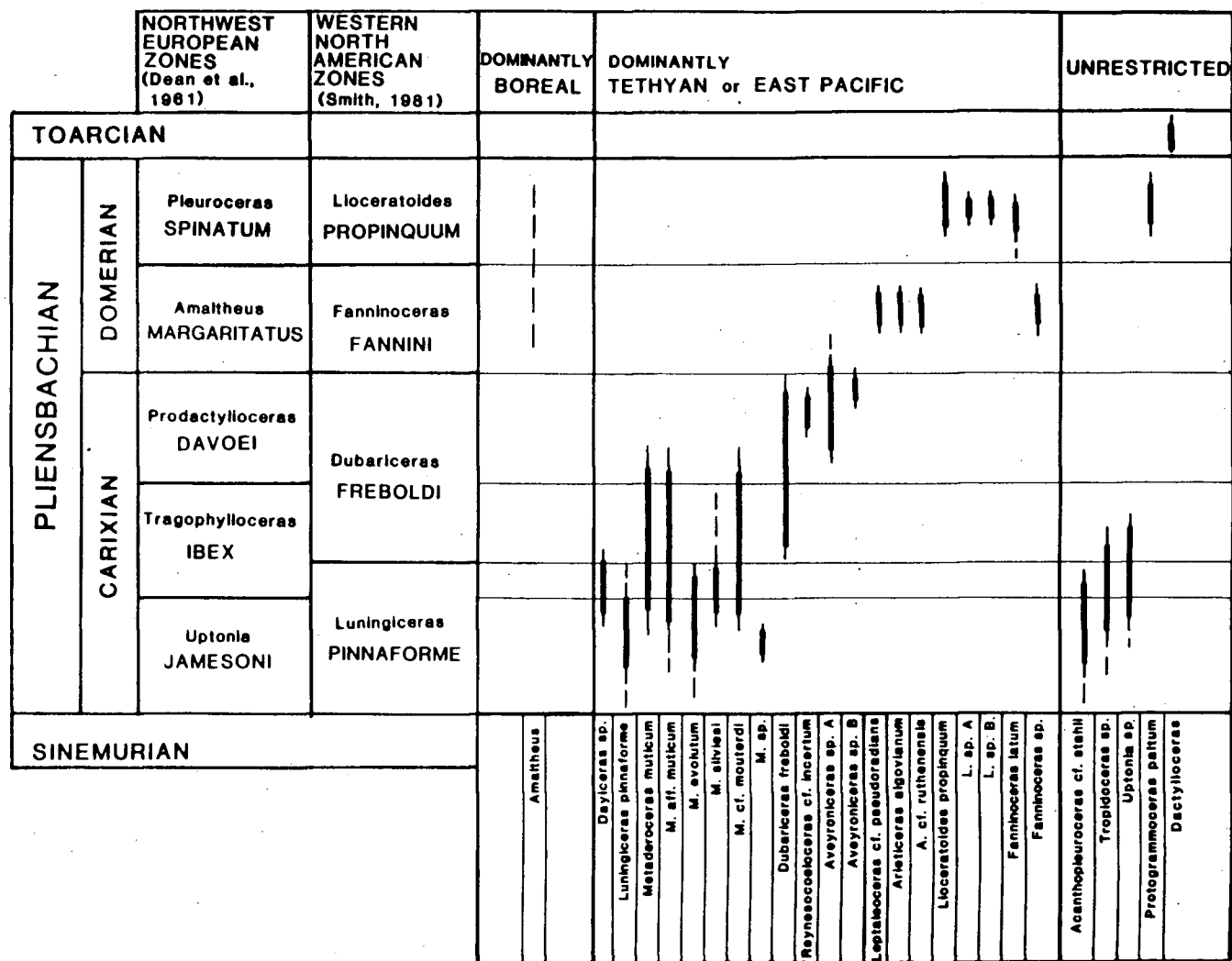


FIGURE 4.1 Range chart including all the species of the Spatsizi fauna. Both the standard of northwest European zones and the western North American zonal scheme of Smith (1981) are shown, along with the paleobiogeographic affinity of each faunal element.

Spatsizi fauna may be explained by the fact that, while in Europe *Amaltheus* is present throughout the Upper Pliensbachian, it appears to have a much narrower stratigraphic range in the Upper Pliensbachian of western British Columbia (H. W. Tipper, *pers. comm.*, 1985). Collection failure, poor preservation potential, and/or a slight stratigraphic break in the Upper Pliensbachian shales in the thesis map area at the level of *Amaltheus* may account for its absence.

Correlation of the Spatsizi fauna to both the northwest European standard and to the scheme proposed by Smith (1981) has been made where possible. The ranges of all the Spatsizi species are summarized in fig. 4.1. Because the zone ammonite *Dubariceras freboldi* is found in such great abundance in the Spatsizi sections, its range is often used in this study as a reference with which to compare the occurrence of many of the other Early Pliensbachian species.

Observations on the stratigraphic ranges of certain genera in the Spatsizi fauna indicate that the northwest European standard can, in general aspect, be applied to Boreal elements of the western North American faunas. However, the details of the northwest European standard have become 'out of focus' over the distance between northwest Europe and Spatsizi. As a case in point, the ranges of the Spatsizi representatives of the genera *Acanthopleuroceras*, *Tropidoceras*, and *Uptonia* are compared to their ranges in northwest Europe. In Spatsizi, *Uptonia* sp. first appears in association with *Tropidoceras* sp.. At this level *Uptonia* sp. is above the last occurrence of *Acanthopleuroceras* cf. *A. stahli*. *Uptonia* sp. ranges up to about the middle of the range of *Dubariceras freboldi* which is above the last occurrence of *Tropidoceras* sp.. This range roughly corresponds to the Upper *Jamesoni* to Middle *Ibex* Zones of northwest Europe. The genus *Uptonia*, however, is not found in strata above the *Jamesoni* Zone in northwest Europe, i.e., it is found below the range of both *Acanthopleuroceras* and *Tropidoceras*. The fact that *Uptonia* sp. ranges higher in the sequence in Spatsizi than do other species of *Uptonia* in northwest Europe is consistent with von Hillebrandt's (1981a) observation that *Uptonia* persisted into the *Ibex*

Zone in the Tethyan realm. The reason for this extended range in Tethys may be related to the generally more stable environment that was prevalent in the deeper Tethys ocean than was present in the shallower, epicontinental seas of northwest Europe (Ziegler, 1981; Hallam, 1971).

#### 4.4 THE PLIENSBACHIAN/TOARCIAN BOUNDARY

The stratigraphic position of the Pliensbachian/Toarcian boundary in the Spatsizi sections is not readily apparent due to the scarcity of fossils at this level. From the faunal information available from Spatsizi, and from work in more fossiliferous sections on the Queen Charlotte Islands (see discussion of *Lioceratoides propinquum*), it seems appropriate to place the Pliensbachian/Toarcian boundary at the first appearance of *Dactylioceras*, as suggested by Dean et al. (1961) for the northwest European Province. More recently, however, Howarth (1973a) has divided the lowermost zone of the Toarcian, the *Tenuicostatum* Zone, into four subzones at its type section in Yorkshire. The lowest subzone proposed by Howarth, the *Protogrammoceras paltum* Subzone, was placed in the Toarcian due to the occurrence of rare *Dactylioceras* within the subzone. In Spatsizi however, the *P. paltum* subzone is not recognizable based on available field data, so the lower limit of *Dactylioceras* is used as the stage boundary in this study and occurrences of *Protogrammoceras paltum*, together with *Lioceratoides propinquum*, are considered as Upper Pliensbachian (see also the description of *P. paltum* and *L. propinquum*, Chapter 6). This approach to delimiting the Pliensbachian/Toarcian boundary is in keeping with a suggestion made by Howarth (written communication to H. W. Tipper, 1984), and has also been adopted by Hall and Howarth (1983) for Arctic Canada, by Smith *et al.*, *in prep.* for western North America, and by Braga *et al.* (1982) for southern Spain.



## 5. PALEOBIOGEOGRAPHY

### 5.1 AMMONITE PROVINCIALITY IN THE OLD WORLD

The division of Jurassic ammonite distributions into a northern Boreal and a southern Tethyan realm has been recognized since the pioneering work of Neumayr (1883). The boundaries of the Boreal and Tethyan realms fluctuated with time but, in general, the Boreal realm can be defined as having occupied the northern part of the northern hemisphere, extending as far south as the Alpine belts of Europe, and to an area between Japan and eastern Siberia in Eurasia. The Tethyan realm comprised all the areas to the south of the Boreal realm.

Analysis of the distribution of Early Jurassic ammonites at the family level by Donovan (1967) and subsequent workers (Hallam, 1969; Howarth, 1973b) has shown that geographic separation (or provinciality) of contemporaneous faunas had begun close to the middle of the Lias. During the Hettangian and at least part of the Sinemurian the Boreal realm was not occupied by a distinct Boreal fauna but rather by an impoverished Tethyan fauna (Hallam, 1969). After the establishment of the first Boreal ammonites towards the end of Sinemurian, the degree of provincialism increased until, during the Late Pliensbachian, there was an almost total segregation of the ammonites into the Tethyan and Boreal realms. At this time the number of ammonite genera of unrestricted distribution was at a minimum for the Early Jurassic. In earliest Toarcian time, the Boreal fauna became largely extinct, the Tethyan faunas were greatly diminished, and the entire area was populated by pandemic ammonite genera.

Donovan (1967) showed that during the Late Pliensbachian the Boreal realm was dominated by the ammonite families Amaltheidae and Liparoceratidae, while to the south the families Hildoceratidae and Dactylioceratidae occupied the Tethys sea. Only rarely are Late Pliensbachian Boreal ammonites found in the Tethyan region, and *vice versa*; however, both Boreal and Tethyan genera are abundant in a narrow zone of overlap

between the two realms that runs approximately east-west through Europe just north of the Mediterranean (fig. 5.1). Neumayr (1883) first recognized this overlap zone and Geczy (1984) argues that this zone should be considered as a separate realm called Neumayria.

Neumayr also recognized that the boundary between the faunal realms was oriented parallel to latitude and concluded that faunal differentiation between the realms was due to climatic factors. Donovan (1967) and Howarth (1973) concluded that water temperature was the main controlling factor in ammonite distribution; whereas the Boreal forms could tolerate wide temperature fluctuations and generally lower temperatures, the Tethyan forms could not. As Hallam (1969, 1972) pointed out, however, the Jurassic was a time of climatic equability such that temperature variations between the Boreal and Tethyan realms were less pronounced than would be observed today over the equivalent span of latitude. Evidence of the condition of the Jurassic climate is twofold; firstly, Jurassic land plant distribution exhibits a near world-wide uniformity (Hallam, 1969) and second, because none of the continents occupied the polar regions during the Jurassic, polar ice caps were unable to develop to any great extent (Sellwood, 1978). Thus, temperature differences between the Tethyan and Boreal realms of the Early Jurassic would be comparable to temperature differences between the tropical and warm temperate areas of modern oceans (Reid, 1973), rather than between modern day tropical and boreal regions.

As an alternative to the temperature control on distribution, Hallam (1969) postulated that the Boreal realm originated in response to lower salinity levels caused by the addition of river water to a partly land-locked, epicontinental Boreal sea. Hallam (1972, p. 403) later abandoned this hypothesis, stating that ". . . it is hard to conceive of salinity in the northern epicontinental sea being kept more or less constant, for a period sufficiently long to allow a boreal fauna to develop, at a level only slightly below that of normal ocean water, thereby allowing stenohaline groups such as ammonites, brachiopods, and echinoderms to survive.". In rejecting the simple temperature and salinity hypotheses, Hallam (1972) and also Reid (1973) adopted the view that the principal

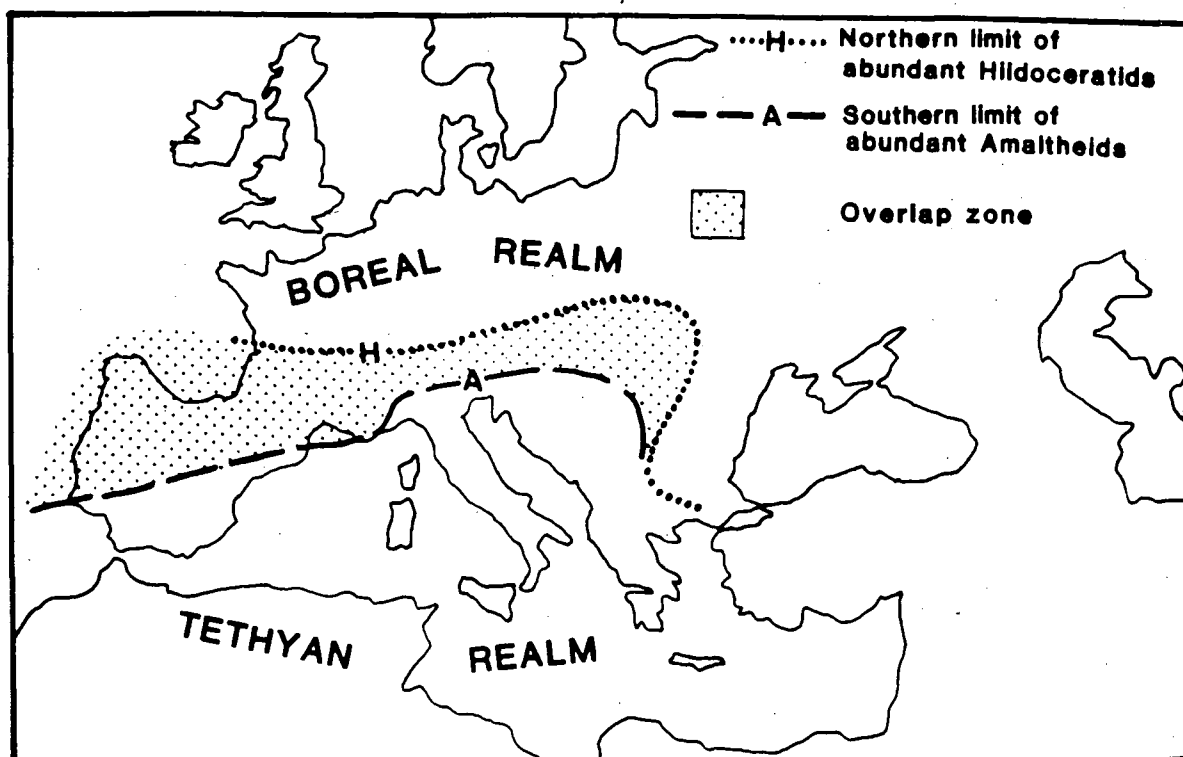


FIGURE 5.1 Tethyan and Boreal distribution of the Late Pliensbachian ammonite families Amaltheidae and Hildoceratidae (modified from Donovan, 1967).

controlling factor in Boreal/Tethyan faunal differentiation was that of environmental stability, as proposed by Saunders (1969) for the distribution control of modern benthic marine invertebrates. According to the environmental stability, or stability-time hypothesis, species diversity decreases as environmental stability or predictability decreases. The stability-time hypothesis has been applied to the Early Jurassic situation as follows. The Boreal Sea is thought to have been a shallow, epeiric sea subject to relatively wide fluctuations in several parameters including salinity, temperature, and turbidity, apart from the potentially drastic effects of even minor changes in sea level. Moreover, because the Boreal sea occupied higher paleo-latitudes than the Tethys, the effects of seasonality would have been more marked. Only a low diversity, eurytopic fauna was able to develop over time in this high-stress environment. The Tethys, by contrast, was a deeper, more stable marine setting in which evolved a high diversity of stenotopic organisms over time. Howarth (1973) reports that during the Late Pliensbachian there were only five ammonite genera restricted to the Boreal realm as compared to about 14 genera in the Tethyan realm. No pandemic genera were living at that time (Howarth, 1973b).

## 5.2 PROVINCIALITY IN WESTERN NORTH AMERICA: THE SPATSI FAUNA

The Early Jurassic ammonite faunas of western North America show the same differentiation into Boreal, mixed, and Tethyan faunas as seen in Europe. Frebold (1964) noted that some of the genera he described from northwestern British Columbia and southern Yukon (namely the Late Pliensbachian genera *Arietoceras* and *Leptaleoceras*) were more common in the Mediterranean region than in the Boreal region. Imlay (1968) described a Pliensbachian/Toarcian fauna from eastern Oregon and western California as being of distinctly Tethyan aspect, and Howarth (1973) outlined in further detail the distribution of Late Pliensbachian Boreal (abundant Amaltheidae), Tethyan (abundant Hildoceratidae and Dactylioceratidae), and mixed faunas of both western North America and South America.

Taylor *et al.* (1985) have divided the Jurassic of western North America into the Boreal, Tethyan, and Eastern Pacific faunal realms. The Eastern Pacific realm is characterized by a fauna of Tethyan or mixed aspect containing certain elements endemic to the eastern Pacific region. The bivalve genera *Weyla* and *Plicatostylus*, all the species of the ammonite genus *Fanninoceras*, and the ammonite *Dubariceras freboldi* are all characteristic of the Eastern Pacific realm. The Spatsizi fauna contains all the above mentioned forms with the exception of *Plicatostylus* which is restricted in western North America to the conterminous United States.

The relatively simple picture of a north to south faunal differentiation in western North America has been recognized as having been greatly complicated by the movement of the various microplates that make up the western portion of the North American Cordillera (see also chapter 1, section 1.4). Each of the terranes is bound, at least in part, by major dextral strike-slip faults along which movement of the terranes occurred. Tipper (1981) showed that the Boreal/Tethyan boundary on each of the three major allochthonous terranes containing Lower and lower Middle Jurassic rocks (Wrangellia, Stikinia, and Quesnellia) has been displaced northward with respect to the position of the Boreal/Tethyan boundary on the craton. Moreover, the boundary appears to have been displaced farthest northward on the westernmost terrane (Wrangellia), somewhat less farther north on Stikinia (on which the Spatsizi fauna is located), and still less on Quesnellia (fig. 5.2a). Estimates of the northward displacement of the terranes are 2500 km, 1800 km, and 500 km, for Wrangellia, Stikinia, and Quesnellia, respectively (Taylor *et al.*, 1984). Only the Jurassic rocks of the Fernie Basin and Sonomia were deposited in the same position they now occupy with respect to the craton. As a result of the northward displacement of the terranes, the Boreal/Tethyan boundary in the western Canadian Cordillera appears to be oriented northwest-southeast (see line A-A' in fig. 5.2a). This apparent trend simply results from post-Pliensbachian northward displacement of Tethyan faunas into Boreal latitudes. If each of the terranes is examined separately the expected

north to south transition is observed in each, and if the terranes are restored to their original latitudes, their respective Boreal/Tethyan boundaries would line-up roughly parallel to latitude as they should (line B-B', fig. 5.2b).

The Spatsizi fauna is considered to be of mixed Boreal/Tethyan affinity and also contains elements of the Eastern Pacific realm. Faunas collected from the entire northern half of the Stikine Terrane, as well as from smaller areas on northern Wrangellia and Quesnellia are of the same affinity as the Spatsizi fauna (fig. 5.2a). Table 5.1, below, gives the affinity of all the Pliensbachian ammonite genera of the Spatsizi and biogeographically related faunas of northwestern North America. The paleobiogeographic affinities of the Spatsizi fauna provides further support to the already established theories concerning the origin, nature, and subsequent tectonic displacement of Pliensbachian faunas in western North America as outlined above.

| <u>GENUS</u>                         | <u>TETHYAN</u> | <u>BOREAL</u> | <u>EAST<br/>PACIFIC</u> | <u>UNRESTRICTED</u> |
|--------------------------------------|----------------|---------------|-------------------------|---------------------|
| <i>Acanthopleuroceras</i>            |                |               |                         | *                   |
| ( <i>Amaltheus</i> )                 |                | *             |                         |                     |
| ( <i>Apoderoceras</i> )              |                |               |                         | *                   |
| <i>Arietoceras</i>                   | *              |               |                         |                     |
| <i>Aveyronoceras</i>                 | *              |               |                         |                     |
| <i>Dayiceras</i>                     | *              |               |                         |                     |
| <i>Dubariceras freboldi</i>          |                |               | *                       |                     |
| <i>Fanninoceras</i>                  |                |               | *                       |                     |
| ( <i>Fontanelliceras</i> )           | *              |               |                         |                     |
| <i>Leptaleoceras</i>                 | *              |               |                         |                     |
| <i>Lioceratoides</i>                 | *              |               |                         |                     |
| ( <i>Liparoceras (Becheiceras)</i> ) |                | *             |                         |                     |
| <i>Luningiceras</i>                  | *              |               |                         |                     |
| <i>Metaderoceras</i>                 | *              |               |                         |                     |
| <i>Protogrammoceras</i>              |                |               |                         | *                   |
| <i>Reynesocoeloceras</i>             | *              |               |                         |                     |
| <i>Tropidoceras</i>                  |                |               |                         | *                   |
| <i>Uptonia</i>                       |                |               |                         | *                   |

Table 5.1: List of genera comprising the mixed-Eastern Pacific fauna of the Spatsizi and biogeographically related areas. Genera in parentheses are elements of the overall northwestern North American mixed fauna but were not found in the thesis area. In addition to the information provided in this study, faunal information was taken from Frebold (1964, 1970), Frebold and Tipper (1970), Tipper and Richards (1976), Tipper (1978), and Imlay (1981).

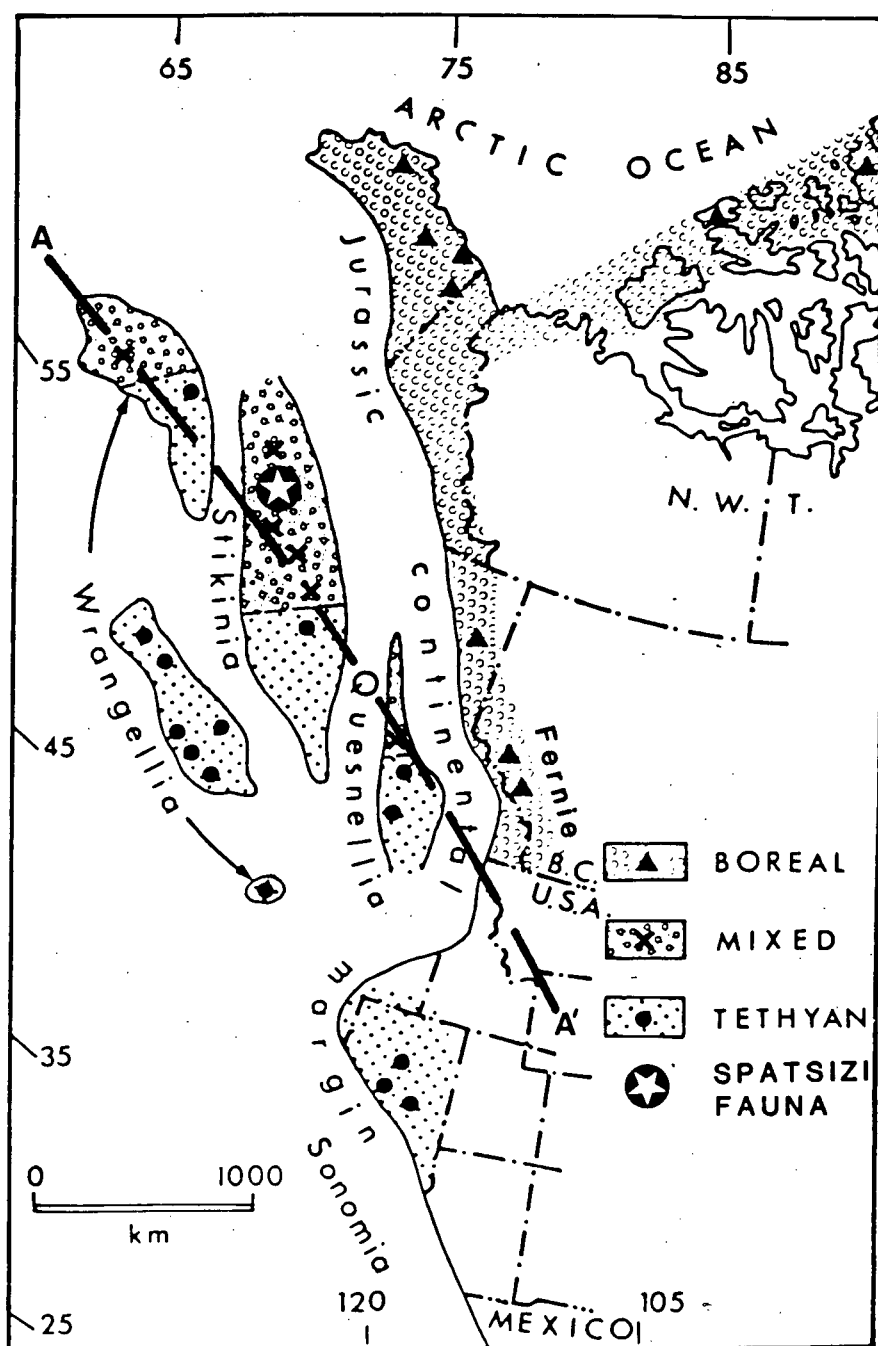


FIGURE 5.2a Diagrammatic illustration of the relative present day positions of the three major allochthonous terranes containing Lower Jurassic rocks with respect to the stable craton. Line A-A' shows the approximate trend of the Tethyan/Boreal boundary as it now appears (modified from Smith and Tipper, *in press*).

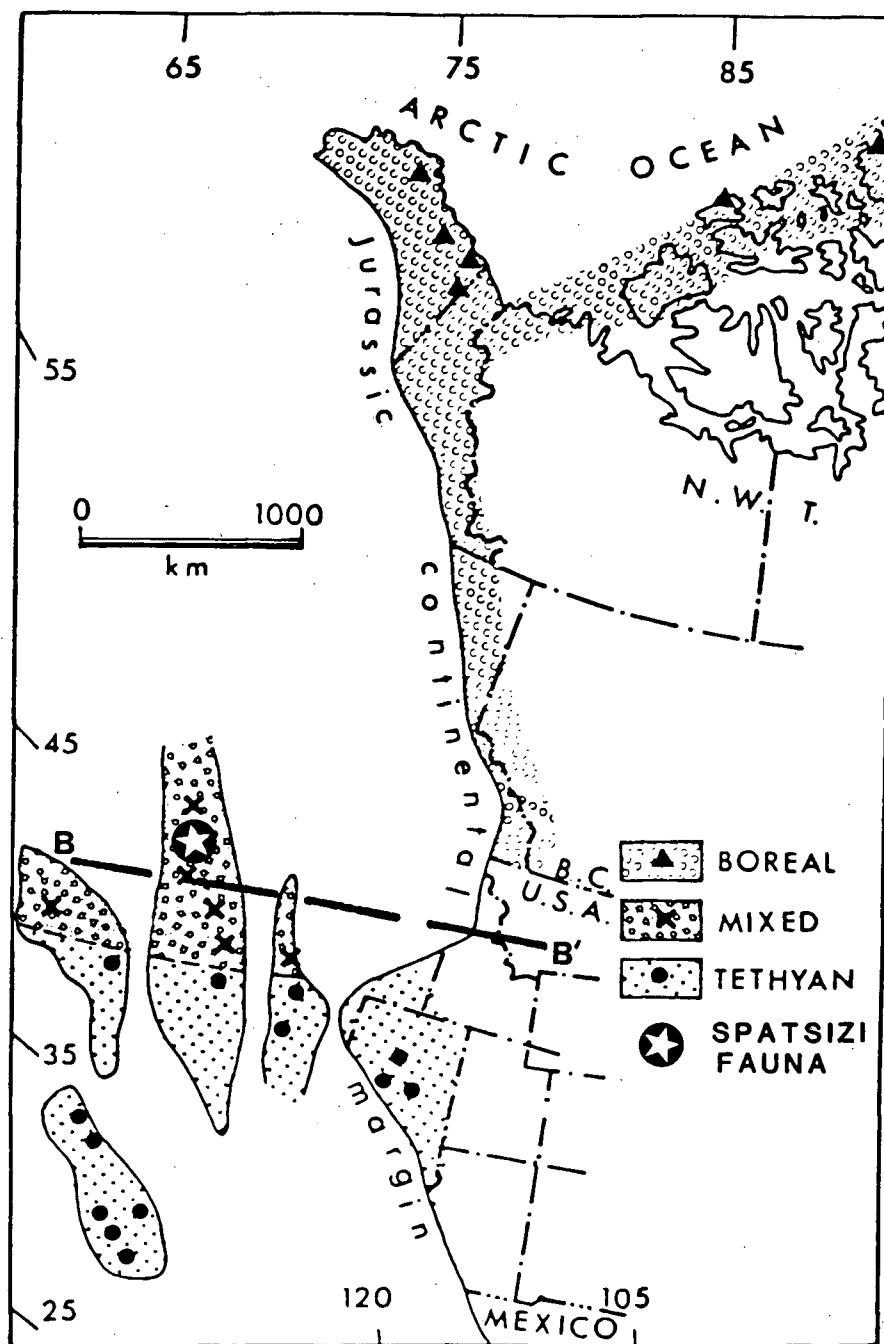


FIGURE 5.2b Diagrammatic illustration of the approximate positions of the three major allochthonous terranes containing Lower Jurassic rocks with respect to the stable craton prior to post-Plensbachian northward transport. Line B-B' shows the approximate trend of the Tethyan/Boreal boundary prior to northward movement (modified from Smith and Tipper, *in press*).



### 5.3 OLD TO NEW WORLD MIGRATION ROUTES

Up to this point in the discussion, Boreal and Tethyan faunas of western North and South America (eastern Pacific region) have been equated to Boreal and Tethyan faunas of Eurasia and Africa, but the question as to how the 'Old World' faunas came to populate the 'New World' (and in some instances, *vice versa*) has not been considered. The question is an important one because its answer(s) bears directly on the as yet poorly understood period of initial breakup of the Pangaea supercontinent during the Early Jurassic, and on the tectonic evolution of the western Cordillera.

The question is primarily one of migration routes – by which route(s) did Early Jurassic organisms make their way from the Tethys and northwest European (Boreal) seas into the eastern Pacific region? To answer this question the life mode (particularly the mode of migration) of the ammonites, the Early Jurassic configuration of the continents, and the physical and geological nature of the migration routes need be considered.

Ammonites were originally thought to have been free nektonic organisms and to have had a world-wide distribution. Although some forms did achieve near world-wide distribution, it became apparent with the discovery of ammonite provinciality that ammonite distribution was constrained by their mode of life, and in some cases their occurrence was restricted to particular facies (Hallam, 1969, 1971; Ziegler 1980). While the distribution of ammonite populations as a whole was controlled by factors explained by the stability-time hypothesis, the mode of life of the individuals controlled where they lived in terms of water depth, food, substrate, *etc.* (Ziegler, 1980). According to Kennedy and Cobban (1976) most ammonites were plankton feeders, generally living close to the substrate in fairly shallow water, either swimming slowly near the bottom (their powers of locomotion were limited), or as benthos. Some groups, particularly the Phylloceratids, were adapted to a more planktonic or nektonic life-habit in areas close to the open ocean such as the deep shelf or shelf edge (Callomon, 1985; Kennedy and Cobban, 1976).

Ammonite fossils from pelagic deposits are rare, and where they do occur, the fauna is usually made up of juveniles. This may be attributed to the fact that ammonites had a pelagic larval stage and that juveniles may have lived farther offshore than the adults, as is the case for many modern cephalopods (Kennedy and Cobban, 1976). Eventually, the juvenile ammonites began their journey to the inner shelf, between 150 and 450 km away, where they spent their adult life (distances approximated from data given by Kennedy and Cobban, 1976). Those individuals that died as juveniles would have sunk to the pelagic sediments below.

The length of the ammonites' larval stage is, of course, unknown, but it does not seem unreasonable to look at the length of the planktonic larval stage in modern marine invertebrates (particularly other molluscs) in order to gain some insight into the problem. Thorson (1961) summarized the relationship between the length of the pelagic larval life of 195 benthic marine species (9% and 19% of which represents the gastropods and bivalves, respectively) to the speed of larval transport by ocean currents. Only 5.5% of all the larval species studied by Thorson were found to remain in the plankton for more than 3 months and can thus be considered true long-distance larvae, which, according to Thorson (1961, p. 461) ". . . have to be considered as the chief objects of transoceanic transport.". Of the species examined, none of the bivalves or gastropods has long-distance larvae. All this is not to say that none of the ammonites had long-distance larvae, but it would seem unlikely that more than 5-10% of all the ammonite species could have had long-distance larvae. This hypothesis is worth consideration when addressing the problem of Old World to New World migration of Early Jurassic ammonites (apart from Early Jurassic bivalves and gastropods). If, as Thorson (1961, p. 469) puts it ". . . under average conditions even most long-distance larvae have a much-too-short pelagic life to survive the critical distances across the eastern Pacific (*i.e.*, from Galapagos to Christmas Island). . .", how could short- or even long-distance ammonite larvae have survived the even greater distances between the Old and New Worlds *via* the ocean of Panthalassa?

(fig. 5.3). It is clear that ammonite migration by means of larval transport in ocean currents must take place either between continents separated by a relatively narrow deep ocean passage, or along the margins of continents, probably not more than about 450 km from the strandline.

In view of the restrictions outlined above, namely that ammonite migration probably did not take place across significant spans of open ocean but rather along or close to continental shelves, or through narrow seaways between continents, the possible Early Jurassic Old to New World migration routes may now be considered. During the Early Jurassic the continents were still coalesced into the supercontinent Pangaea, although rifting of that great landmass had begun in the Late Triassic (Pindell, 1985). Given that the ammonites were able to migrate along continental margins, two obvious routes between the Tethys sea and the eastern Pacific region present themselves, one along the northern and one along the southern margin of Pangaea (routes A and B, fig. 5.3). These two routes are easily explained since they involve the simple migration along the well documented continental shelves of Pangaea. However, they suffer the drawback of presenting the transient Early Jurassic organisms with a wide span of latitude to cross. Especially during periods of high provinciality (for example, the Late Pliensbachian), organisms whose distribution was controlled by factors related to latitude would be prevented from migrating along these routes.

It is fairly well accepted that there existed during the Early Jurassic an epicontinental seaway between Greenland and Scandinavia, connecting the northwest European Boreal sea with the arctic regions of North America and Eurasia (fig. 5.3, route C; Howarth, 1973b; Hallam, 1977). Boreal ammonites could have moved freely from the Old to New World by way of this seaway, but the Tethyan ammonites would not have been able to migrate along this route due to its high latitude position.

Two other routes of a more conjectural nature remain; one through a seaway between east Africa and Antarctica, around Cape Horn and up the west coast of South

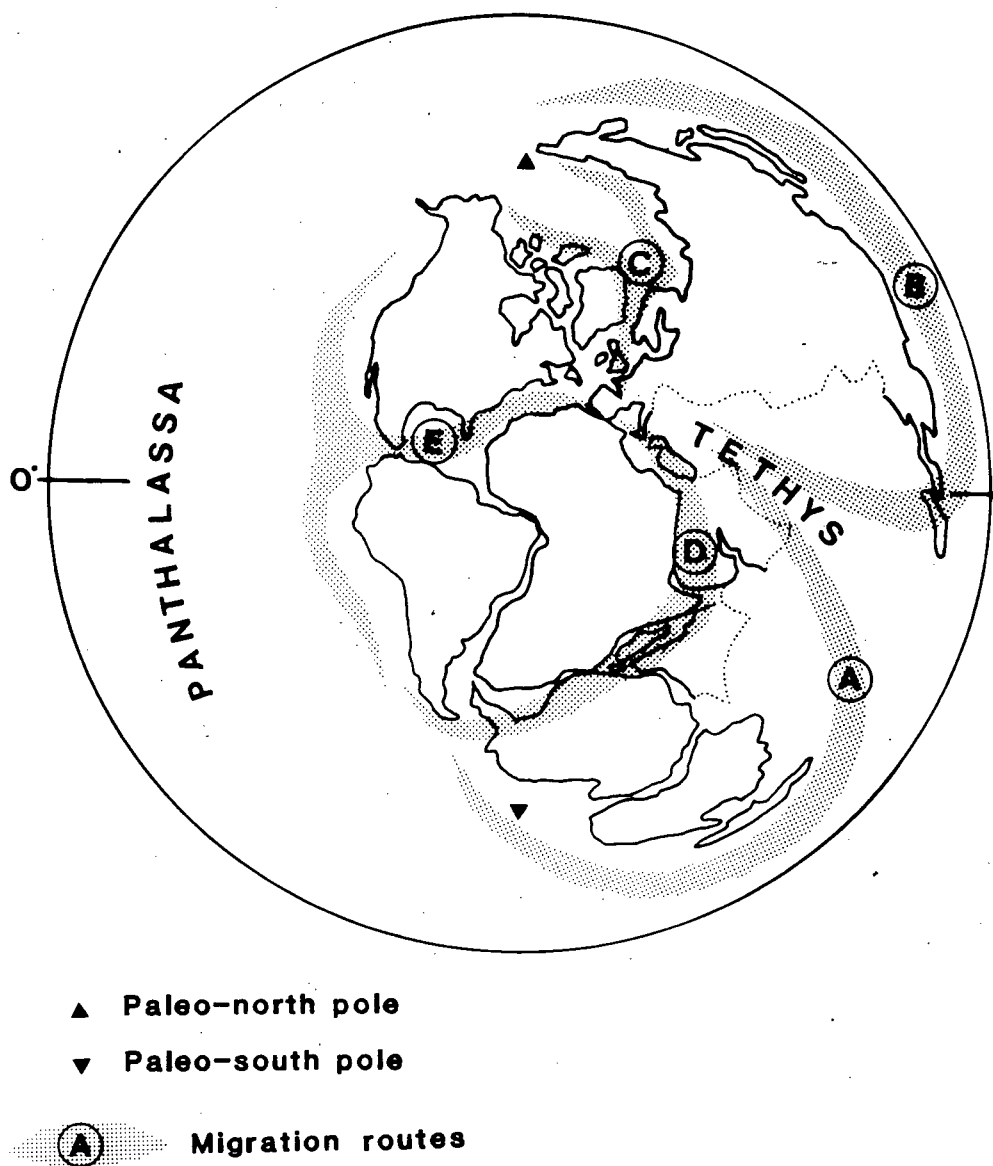


FIGURE 5.3 Early Jurassic continental reconstruction of Pangaea showing the possible Pliensbachian migration routes (modified from Briden *et al.* (1974), and Hallam, 1977).

America; the other through the early central Atlantic and proto-Caribbean area, or Hispanic Corridor of Smith (1983; routes D and E, fig. 5.3). Because both these routes require migration through some portion of Pangaea, rather than around the margins of the supercontinent, the existence of these seaways calls for close investigation of the evidence. As Hallam (1977) and Smith (1983) have pointed out, migration does not necessarily require a seaway floored by true oceanic crust, but may occur along shallow, and often ephemeral, epicontinental seas. Evidence of such epicontinental seaways is not, unfortunately, always well preserved, and thus their existence is not, unfortunately, always well documented. The weight of the evidence now available appears to favour the hypothesis that Early Jurassic (particularly Pliensbachian/Toarcian) faunas of Tethyan distribution in the eastern Pacific region migrated from Tethys to the eastern Pacific region *via* the Hispanic Corridor. Westermann (1977) summarizes the lower Middle Jurassic ammonite data that indicates that the central Atlantic seaway was established at least by the Early Bajocian. Hallam (1977) considered the east African seaway (route D, fig. 5.3) to have been the more likely migration route, but also pointed out that an epicontinental central Atlantic seaway may have existed, at least intermittently, as early as Sinemurian times, but that establishment of a permanent seaway did not occur until the end of the Middle Jurassic.

Paleontologic evidence supporting the existence of the central Atlantic seaway during the Early Jurassic includes the distribution of the bivalve *Weyla* (Damborenea and Mancenido, 1979), the dicoelitid belemnites (Jeletzky, 1980), the calcareous sponge *Stylothalamia* (von Hillebrandt, 1981b), and the Pliensbachian ammonite genus *Dubariceras* (formerly described as *Dayiceras dayiceroides* by Smith, 1983). Thus, there is fairly good paleobiogeographical evidence that the Hispanic Corridor existed as early as the Sinemurian. However, two points of caution must be set forth before the Hispanic Corridor can be accepted. Firstly, as Scott (1984) points out, there is an absence of evidence of the Corridor in the area between eastern Mexico and Morocco; *i.e.*, faunal

evidence of the Corridor can only be found near its postulated end points. Secondly, Taylor *et al.* (1984, p. 124) explain that the Tethyan affinity of western North American faunas ". . . does not necessarily imply a direct connection between the western Tethys and eastern Pacific *via* . . . the Hispanic Corridor of Smith (1983). It merely expresses the observation that during the Early and Middle Jurassic the distribution of numerous genera extended circum-globally . . ., at about the same comparatively low paleo-latitude as those of the Tethys itself. Inference of a Hispanic Corridor can, therefore, be made only if the taxa in question are absent in the eastern Tethys and/or western Pacific."

Geologic and tectonic evidence of an Early Jurassic central Atlantic seaway is tenuous. Sinemurian ammonites found in the Huayacocotla Basin in eastern Mexico provide evidence of a marine influence in the Gulf of Mexico region during that time, but whether this fauna originated from the eastern Pacific or the Tethys is problematic (Schmidt-Effing, 1980; Scott, 1985). According to Pindell (1985), southeasterly transport of crustal blocks along several shear zones in western Mexico maintained a land bridge between North and South America between the Late Triassic and late Middle Jurassic. This suggests that the Sinemurian ammonites in the Huayacocotla Basin must have been derived from the Tethys, but it also implies that a marine connection between Tethys and the east Pacific could not have been established until post-Callovian times. However, Pindell's Central American land bridge may only have been intermittently effective. Pindell (1985) also presents paleogeographic maps of the Gulf of Mexico-central Atlantic region for the Late Triassic and early Middle Jurassic. According to this synthesis, extensive attenuation of continental crust and minor seafloor spreading in the Gulf-central Atlantic region was underway by Bajocian times, and the oldest sedimentary rocks drilled in the area are of Callovian age and rest on oceanic crust (Scott, 1984). Thus, the existence of a central Atlantic seaway prior to the Bajocian is not, based on geologic data, firmly established, but at the same time cannot be ruled out.

The migration routes by which the Spatsizi and biogeographically related faunas made their way to western North America can now be speculated upon. With the exception of those faunal elements of eastern Pacific affinity which were endemic to western North America, forms of different affinities probably arrived in western North America *via* different pathways. Boreal faunal elements are believed to have migrated from the northwest European province to the Arctic region *via* the straits between Greenland and Scandinavia (route C, fig. 5.3). From Arctic North America the Boreal faunas moved southward into the Liassic epeiric seas of western North America as far south as their latitudinal tolerance would permit them; to a paleolatitude now approximated by the 49th parallel.

Most Tethyan ammonites (and other organisms) probably arrived in western North America *via* the central Atlantic seaway in the Pliensbachian (route E, fig. 5.3). During periods of low provinciality such as the Late Sinemurian and Early Toarcian, the more unrestricted faunas may have migrated to western North America by way of more latitude-transcending routes (for example, routes A, B, and D, fig. 5.3). The central Atlantic migration of of the Early Pliensbachian ammonite *Dubariceras freboldi*, the most abundant ammonite of that age found in the Spatsizi fauna, has been documented by Smith (1983). It follows that the other Pliensbachian genera of Tethyan affinity in the Spatsizi fauna (including *Dayiceras* sp., *Metaderoceras muticum*, *M. evolutum*, *Reynesocoeloceras* cf. *R. incertum*, *Aveyroniceras*, *Leptaleoceras*, and *Arietoceras*) arrived in western North America by the same route. The migration pattern of the bivalve *Weyla*, also abundant in Spatsizi, supports the hypothesized central-Atlantic seaway (Damborenea and Mancenido, 1979).

Upon arrival in the New World, the Tethyan forms spread northward (and southward) to their latitude tolerance limit where they mixed with the southernmost members of the North American Boreal faunas. It was in this mixing zone that the Spatsizi fauna lived. Post-Pliensbachian transport of the terranes on which these faunas

were preserved has resulted in their present day distribution in Boreal paleolatitudes.



## 6. SYSTEMATIC PALEONTOLOGY

### 6.1 INTRODUCTION

The classification of Pliensbachian ammonites in this study largely follows that of Donovan *et al.* (1981). However, the following exceptions to this classification scheme have been made.

- 1) The subfamilies Polymorphitinae (including the genera *Uptonia* and *Dayiceras*) and Acanthopleuroceratinae (with the genera *Acanthopleuroceras*, *Tropidoceras*, and *Luningiceras*) of the family Polymorphitidae are retained herein following the classification in the Treatise on Invertebrate Paleontology (Part L, Arkell *et al.*, 1957).
- 2) The genus *Dubariceras* is assigned to the family Eoderoceratidae in accordance with the work of Dommergues *et al.* (1984).
- 3) The genus *Reynesocoeloceras* is assigned to the family Coeloceratidae rather than to Dactylioceratidae, following the work of Géczy (1976), Wiedenmayer (1977, 1980), and von Hillebrandt (1981a).

It should be noted here that the preservation of the Spatsizi material is generally poor. External moulds are the most abundant type of body fossil found, whereas internal moulds and external casts are less common. Original shell material and indications of the suture lines are rarely preserved in the material studied.

### 6.2 MEASUREMENTS AND ABBREVIATIONS

All measurements made in this study are in millimetres. The abbreviations denoting the measurements used in the systematic descriptions are defined as follows:

*c* = *circa*

D = shell diameter

UD = umbilical diameter at diameter=D

U =  $UD/D \times 100$

WH = whorl height at diameter=D

WW = whorl width at diameter=D

PRHW = primary ribs per half whorl, counted on the larger, or adoral half whorl at diameter=D

### 6.3 SYSTEMATIC DESCRIPTIONS

Order **AMMONOIDEA** ZITTEL, 1884

Suborder **AMMONITINA** HYATT, 1889

Superfamily **EODEROCERATACEAE** SPATH, 1929

Family **POLYMORPHITIDAE** HAUG, 1887

Subfamily **POLYMORPHITINAE** HAUG, 1887

Genus *Uptonia* BUCKMAN, 1897

TYPE SPECIES: *Ammonites jamesoni* SOWERBY, 1827 (p. 105, pl. 555, fig. 1) by original designation.

REMARKS: Shell evolute, whorl section ellipsoidal to ogival. Umbilical wall low, shallow; umbilical edge rounded. Ventral shoulder rounded, venter inflated.

Ornament varies with growth. Earliest whorls are similar to *Polymorphites* in that they possess a keel and ventro-lateral tubercles. In the original description, Buckman (1898) stressed the weak development and brevity of this spinous stage. The early spinous stage gives way to a non-tuberculate stage marked by strong, prorsiradiate, straight to slightly sinuous ribs that cross the venter to form ventral chevrons.

SYNONYMS: *?Jamesonites* BUCKMAN, 1923; *Microceras* HYATT, 1867, non HALL, 1845.

**AGE AND DISTRIBUTION:** *Uptonia* is most abundant in the northwest European province but is also found in the Mediterranean region, Mexico, British Columbia and southern Alaska. *Uptonia* is restricted to the *Jamesoni* Zone in northwest Europe, but persists into the *Ibex* Zone in the Mediterranean region (von Hillebrandt, 1981a).

*Uptonia* sp.

Plate 1, fig. 1a-d; 2a-d.

cf. 1981 *Uptonia* sp. B IMLAY, p. 37, pl. 9, fig. 5-7.

**MATERIAL:** Ten specimens preserved as internal and external moulds in siltstone and fine sandstone.

**MEASUREMENTS:**

| SPECIMEN   | D   | UD   | U  | WH  | WW   | PRHW |
|------------|-----|------|----|-----|------|------|
| C-90926    | 25  | 9.5  | 38 | 7   | -    | 20   |
| C-90843(U) | c29 | 11.5 | 40 | 8.5 | c3.5 | 22   |

**DESCRIPTION:** Shell midvolute, whorl section ellipsoidal. Umbilical wall low, shallow; umbilical edge rounded. Flanks are convex; ventral shoulder rounds onto inflated venter.

Ornamentation consists of strong, simple rectiradiate and slightly sinuous ribs that arise at the umbilical edge. The ribs bend sharply forward just below the ventral shoulder and continue onto the venter to form ventral chevrons. At diameters less than about 8 mm, the ribs appear to be marked by small ventro-lateral tubercles.

**DISCUSSION:** The Spatsizi specimens of *Uptonia* sp. are similar to specimens from Alaska assigned to *Uptonia* sp. B by Imlay (1981). If the Spatsizi and Alaskan material is conspecific to any previously defined species of *Uptonia*, their small size has prevented their identification as such.

**OCCURRENCE:** In Spatsizi, *Uptonia* sp. first appears near the base of the range of *Dubariceras freboldi*. At this level it is associated with *Dayiceras* sp. and *Tropidoceras* sp.. A discussion of the relative ranges of the genera *Uptonia*, *Tropidoceras*, and *Acanthopleuroceras* in Spatsizi and northwest Europe is given in Chapter 4 (Biochronology).

As mentioned above, the Spatsizi specimens of *Uptonia* sp. are similar to a specimen from Alaska assigned to *Uptonia* sp. B by Imlay (1981). Imlay also reported specimens of *Dubariceras freboldi* from Alaska, however, *Uptonia* sp. B and *D. freboldi* were not found at the same locality in Alaska so that the relation between their ranges is uncertain. In the Queen Charlotte Islands, a single specimen similar to *Uptonia* sp. was found in association with *Dubariceras freboldi* (H. W. Tipper, pers. comm., 1985).

Localities: 64, 139.

**AGE:** Early Pliensbachian (*D. freboldi* Zone).

#### Genus *Dayiceras* SPATH, 1920

**TYPE SPECIES:** *Dayiceras polymorphoides* SPATH, 1920 (p. 541, pl. 15, fig. 1-4), by original designation.

**REMARKS:** Shell midvolute, whorl section ellipsoidal to ogival. Ornament consists of fine, dense, sinuous ribs that are prorsiradiate on the umbilical wall, sinuous on the flanks, and terminate on the ventral shoulder in radially elongate tubercles. The venter bears a median row of tubercles which commonly coalesce to form a crenulate keel.

**AGE AND DISTRIBUTION:** *Dayiceras* is found in the *Ibex* Zone of southern England but has not been reported from any other part of the northwest European Province (Smith, 1981). It has been reported from the *Ibex* Zone of Portugal (Mouterde, 1951;

Mouterde and Ruget, 1970), North Africa (Rakus, 1972), and northern Italy (Wiedenmayer, 1977, 1980). This distribution suggests that *Dayiceras* was most common in the Tethyan region but that it was also present in that portion of the Boreal realm now occupied by Dorset in southern England. This view is in difference to that held by Dommergues *et al.* (1984) that *Dayiceras* was primarily boreal in distribution.

The presence of rare *Dayiceras* in southern England may be due to limited migration of this Tethyan form *via* a marine connection between the Tethyan and northwest European areas during the Early Pliensbachian. The existence of a connection that allowed Tethyan 'stragglers' to wander into the Boreal realm, and *vice versa*, has been suggested by Donovan (1967) and Howarth (1973b).

#### *Dayiceras* sp.

Plate 1, fig. 3a-d; plate 2, fig. 1a-d, 2a, b.

**MATERIAL:** Four specimens poorly preserved as internal and external moulds in siltstone.

**MEASUREMENTS:** Not available due to poor preservation.

**DESCRIPTION:** Shell evolute to midvolute; whorl section is ogival. Umbilical wall is low, abrupt; umbilical edge rounded. Flanks are convex; ventral shoulder abruptly rounded. The venter is convex, narrow.

Ornament consists of dense, fine sinuous ribs that arise on the umbilical wall where they trend rursiradiately, then become flexuous on the flanks and bend gently forward near the ventral shoulder where they are marked by radially elongate tubercles. The ribs continue weakly past the tubercles onto the venter, but fade rapidly. A low, weakly beaded keel is present on the venter.

**DISCUSSION:** The Spatsizi specimens of *Dayiceras* sp. are similar to *Dubariceras freboldi*

in their form of ribbing and volution, but they differ from *Dub. freboldi* by their low median keel, narrower whorl section, and slightly coarser ribbing. the close morphological and stratigraphic association between *Dub. freboldi* and *Dayiceras* sp. (as well as the association between the two forms just mentioned with *Uptonia* sp. and *Metaderoceras silviesi*) raises questions as to the phylogenetic relationship between these genera. In creating the genus *Dubariceras*, Dommergues *et al.* (1984) stated that although *Dubariceras* was derived from *Metaderoceras*, it is morphologically convergent to the Polymorphitids. Morphologic convergence could effectively explain the similarity between members of the family Eoderoceratidae (*Metaderoceras* and *Dubariceras*) and the family Polymorphitidae (*Uptonia* and *Dayiceras*) found in the Spatsizi collections. Sutural studies of the specimens would provide the most conclusive evidence of the familial association between these genera in Spatsizi, but their poor preservation has made this impossible.

**OCCURRENCE:** The specimens of *Dayiceras* sp. described here represent the first known occurrence of *Dayiceras* in western North America. *Dayiceras* sp. occurs within the range of *Dubariceras freboldi*. It is found with *Uptonia* sp., *Metaderoceras silviesi* and *M. muticum*, but it may range slightly higher than *M. silviesi*.

Localities: 62, 64, 87.

**AGE:** Lower Pliensbachian (*D. freboldi* Zone).

Subfamily ACANTHOPLEUROCERATINAE ARKELL, 1950

Genus *Acanthopleuroceras* HYATT, 1900

**TYPE SPECIES:** *Ammonites valdani* D'ORBIGNY, 1844, by subsequent designation (Getty, 1970).

**REMARKS:** Shell evolute to slightly midvolute; whorl section quadrate (pentagonal) to moderately compressed. Venter is angular and bears a blunt keel. Ornament consists of straight, simple, rectiradiate to slightly rursiradiate ribs. The ribs may be bi- or unituberculate and project weakly onto the venter from ventro-lateral tubercles. *Acanthopleuroceras* differs from *Tropidoceras* by having a generally less compressed whorl section, straighter, tuberculate ribs, a less prominent keel, and a lack of secondary ribbing on the ventral surface.

The phylogenetic relationship between *Acanthopleuroceras* and *Tropidoceras* is a subject for debate. Dommerge and Mouterde (1978, 1981) consider the two genera to represent evolution within a single lineage, whereas Wiedenmayer (1977) considers them to belong to separate lineages. Géczy (1976) draws attention to the fact that there exist numerous forms intermediate between *Acanthopleuroceras* and *Tropidoceras*. This point is exemplified by the generically ambiguous nature of certain species, including *stahli* and *actaeon*, which have been assigned to both genera by different workers.

**SYNONYMS:** *Cycloceras* HYATT, 1867, non McCoy, 1884.

**AGE AND DISTRIBUTION:** *Acanthopleuroceras* is a cosmopolitan form found in both the Boreal and Tethyan realms. It is characteristic of the *Ibex* Zone and reaches its acme in the middle part of this zone (Géczy, 1976; Hoffmann, 1982; Dean et al., 1961).

*Acanthopleuroceras* cf. *A. stahli* (OPPEL, 1853)

Plate 2, fig. 3-5

\*1853 *Ammonites radians nummismalis* OPPEL, p. 51, pl. 3, fig. 2.

1976 *Acanthopleuroceras stahli* (OPPEL)-GECZY, p. 95, pl. 18, fig. 4-6.

1977 *Tropidoceras stahli* (OPPEL)–WIEDENMAYER, p. 65, pl. 14, fig. 3–11.

?1981 *Acanthopleuroceras* sp. SMITH, p. 256, pl. 10, fig. 9, 10.

Other synonyms, see Wiedenmayer, 1977.

**MATERIAL:** Fourteen external and internal moulds all preserved in coarse, poorly sorted volcanoclastic sandstone and pebbly sandstone.

**MEASUREMENTS:**

| SPECIMEN   | D  | UD   | U  | WH | WW | PRHW |
|------------|----|------|----|----|----|------|
| C-90930(A) | 43 | 19   | 44 | 13 | –  | 17   |
| C-90930(B) | 42 | 19.5 | 46 | 13 | 7  | 17   |

**DESCRIPTION:** Shell evolute, whorl section subquadrate. Umbilicus shallow; umbilical wall low, steep; umbilical edge rounded. Flanks convex, ventral shoulder rounded. Venter fairly broad, fastigate, bearing a blunt keel.

Ornament consists of dense, straight, slightly rursiradiate ribs. Ribbing is coarse and bears a single row of small ventro-lateral tubercles from which the ribs project slightly adorally.

**DISCUSSION:** The Spatsizi specimens of *A. cf. A. stahli* are similar to those figured by Géczy (1976) and Wiedenmayer (1977) in their whorl section and form of ribbing. However, the inner whorls of the Spatsizi specimens are more densely ribbed than the illustrated European specimens.

The Spatsizi material may be confused with the inner whorls of *Luningiceras pinnaforme* except that *A. cf. A. stahli* is less evolute (expansion rate about 1.8–2.0) than the holotype of *L. pinnaforme* (expansion rate about 1.5) figured by Smith (1981).



**OCCURRENCE:** *A. stahli* is found in both the Northwest European and the Tethyan faunal realms. It has been reported from England, Germany, France, Italy, and Hungary. The Spatsizi specimens of *A. cf. stahli* are the first reported from western North America, although specimens collected by Smith (1981) from Oregon and Nevada and assigned to *Acanthopleuroceras* spp. are likely conspecific to the Spatsizi material. They occur below the range of *Dubariceras freboldi* in Spatsizi and represent the lowest measured stratigraphic level encountered during the course of this study. They were recovered from rocks directly overlying the highest flow of the Toodoggone volcanics in the thesis map area. Although no other ammonite genera or species are represented at this locality, sediment pods of an equivalent or slightly lower stratigraphic level, found within the volcanic pile, have yielded collections containing *A. cf. A. stahli* with *Metaderoceras evolutum* (see section on *Metaderoceras evolutum* for location). In Oregon and Nevada, *M. evolutum* is found in the *Pinnaforme* Zone of Smith (1981), roughly equivalent to the *Jamesoni* and lowermost *Ibex* Zones of the N.W. European Province. In Europe, *A. stahli* is found in the *Ibex* Zone.

Localities: 70, 137, 138, 141.

**AGE:** Early Pliensbachian (*L. pinnaforme* Zone).

#### Genus *Tropidoceras* HYATT, 1867

**TYPE SPECIES:** *Ammonites masseanum* D'ORBIGNY, 1844, by subsequent designation (Haug, 1885, p. 606).

**REMARKS:** Shell evolute, whorl section compressed, lanceolate to ellipsoidal. Venter bears a distinct, commonly high keel. Ornament consists of straight to sigmoidal, non-tuberculate primary ribs that project onto the venter where they are commonly differentiated into

numerous, adorally projecting secondaries.

The relationship between *Tropidoceras* and *Acanthopleuroceras* is discussed under the generic description of *Acanthopleuroceras*. The Upper Pliensbachian Hildoceratids *Arietoceras*, *Leptaleoceras* and *Protogrammoceras* are believed to have evolved from *Tropidoceras*.

**AGE AND DISTRIBUTION:** Like *Acanthopleuroceras*, *Tropidoceras* is a cosmopolitan genus but is particularly abundant in the Tethyan province (Donovan, 1967; Smith, 1981). The genus first appeared in the Late Sinemurian and reached its acme in the lower part of the *Ibex* Zone.

*Tropidoceras* sp.

Plate 3, fig. 2, 3.

**MATERIAL:** Three specimens, poorly preserved as external and internal moulds in siltstone.

**MEASUREMENTS:**

| SPECIMEN | D   | UD  | U  | WH | WW | PRHW |
|----------|-----|-----|----|----|----|------|
| C-103304 | c48 | c27 | 56 | -  | -  | c20  |

**DESCRIPTION:** Whorl section is ellipsoidal, venter is narrow and bears a high keel. Umbilical wall low, fairly steep; umbilical edge rounded. The ribs arise on or above the umbilical edge, trend slightly rursiradiately, then bend forward as they approach the ventral shoulder where they fade rapidly. The ribs are non-tuberculate and there are no secondaries on the ventral surface.

**DISCUSSION:** The fragmentary nature of these specimens precludes confident specific

assignment but they do show similarities to specimens of *Tropidoceras actaeon* figured by Frebold (1970), Mouterde and Dommergues (1978), Dommergues and Mouterde (1978), Imlay (1981), and Smith (1981).

**OCCURRENCE:** *The Spatsizi specimens of Tropidoceras* sp. were found just at the base of the range of *Dubariceras freboldi*. In the Queen Charlotte Islands, Frebold (1970) found *T. actaeon*, to which the Spatsizi specimens are similar, associated with *Metaderoceras evolutum* and *Dubariceras freboldi*, although Smith (1981) found *T. actaeon* to occur below the range of *D. freboldi* in Oregon.

Localities: 2, 8.

**AGE:** Early Pliensbachian (*L. pinnaforme* to lower *D. freboldi* Zone).

#### Genus *Luningiceras* SMITH, 1981

**TYPE SPECIES:** *Acanthopleuroceras (Luningiceras) pinnaforme* SMITH, 1981, (p. 251, pl. 10, fig. 11) by original designation.

**REMARKS:** This genus was created by Smith (op. cit.) as a subgenus of *Acanthopleuroceras*. It includes forms that possess features characteristic of both *Acanthopleuroceras* and *Tropidoceras*, but Smith considered it more reminiscent of *Acanthopleuroceras*. *Luningiceras* is here raised to generic rank, following a suggestion by Dr. Smith, in order to avoid creating a cumbersome network of genera, subgenera, and so on. The affinities of *Luningiceras* to both *Acanthopleuroceras* and *Tropidoceras* are reflected in its assignment to the subfamily Acanthopleuroceratinae.

Forms belonging to *Luningiceras* are evolute, with subquadrate whorl sections. The venter is fairly broad, convex, and bears a blunt keel. The ribs are moderately dense, straight, slightly rursiradiate, and bituberculate on the outer whorls. The ventral surface is

marked by very dense, strongly projecting secondaries.

In addition to the type species, other forms assigned to this genus include *Acanthopleuroceras rursicosta* BUCKMAN and certain specimens of *Acanthopleuroceras valdani*, specifically *Ammonites valdani* sensu QUENSTEDT (1884, pl. 35, fig. 4; non fig. 2-5).

AGE AND DISTRIBUTION: In Oregon and Nevada, *Luningiceras* occurs in strata below the range of *Dubariceras frebaldi*. In Europe it is found in rocks of the *Ibex* Zone from England and Germany.

*Luningiceras pinnaforme* SMITH, 1981

Plate 3, fig. 1a, b.

\*1981 *Acanthopleuroceras (Luningiceras) pinnaforme* SMITH, p. 261, pl. 13; pl. 14.

MATERIAL: A single, large whorl fragment preserved as an internal mould in a tectonically sheared silty mudstone.

MEASUREMENTS: Not available due to poor preservation.

DESCRIPTION: The specimen has been tectonically compressed, but appears to have had a subquadrate whorl section. The venter is convex, bearing a blunt keel, although the keel of the Spatsizi specimen of *L. pinnaforme* was almost completely lost during preparation due to the brittle nature of the rock it is preserved in. Ornament consists of simple, slightly rursiradiate, bituberculate ribs of moderate density and relief. Dense, strongly prorsiradiate secondary ribs appear on the venter, beyond the ventro-lateral tubercles. These secondary ribs extend to the keel and impart a herring-bone or feather-like appearance to the ventral surface.

**DISCUSSION:** Although no trace of the inner whorls of the single Spatsizi representative of *L. pinnaforme* was found, the large whorl fragment is identical to the outer whorls of the holotype (Smith, 1981). *L. pinnaforme* can be distinguished from *Tropidoceras masseanum* by virtue of the less compressed whorl section and less distinct keel seen in *L. Pinnaforme*. In addition, *L. pinnaforme* is bituberculate whereas *T. masseanum* is unituberculate.

**OCCURRENCE:** Smith (1981) has erected *L. pinnaforme* as the index fossil for the *L. pinnaforme* Zone of the western United States. This is the lowest zone recognized by Smith for the Pliensbachian, found below the range of the superjacent zonal index fossil, *Dubariceras freboldi*. With the exception of an unconfirmed occurrence of *L. pinnaforme* from the Queen Charlotte Islands, also reported by Smith (1981), the Spatsizi specimen of *L. pinnaforme* is the first representative of this genus from a known locality in British Columbia.

Localities: 130.

**AGE:** Early Pliensbachian (*L. pinnaforme* Zone).

#### Family EODEROCERATIDAE SPATH, 1929

##### Genus *Metaderoceras* SPATH, 1925

**TYPE SPECIES:** *Ammonites muticus* D'ORBIGNY, 1844, p. 274, pl. 8, by original designation.

**DISCUSSION:** The taxonomic position of the genus *Metaderoceras* has been, and remains, somewhat uncertain. Its assignment to the family Eoderoceratidae is unquestioned, but the relationship of the species attributed to *Metaderoceras* to other genera within this family,

most notably *Crucilobiceras* and *Eoderoceras*, is problematic. Spath (1925) created the genus *Metaderoceras* and designated *Ammonites muticus* D'ORBIGNY as the type species. This new genus was subsequently synonymized with *Crucilobiceras* in the Treatise (Arkell *et al.*, 1957). Mouterde (1970), however, moved to retain the genus *Metaderoceras* based on differences between its type, *Ammonites muticus*, and the type species of *Crucilobiceras*, *C. crucilobatum* BUCKMAN. Whereas *Crucilobiceras* is characteristically bituberculate and has a narrow whorl section, *Metaderoceras* is unituberculate and has a generally wider whorl section. Furthermore, a range discrepancy exists between the two genera; *Crucilobiceras* is restricted to the Upper Sinemurian *Raricostatum* Zone whereas *Metaderoceras* first appears in the *Jamesoni* Zone and is most abundant in the *Ibex* Zone. Donovan and Forsey (1973) followed the Treatise in considering *Metaderoceras* a junior synonym of *Crucilobiceras* and stated that the illustration of the type, *Ammonites muticus*, by d'Orbigny is probably an idealized and unreliable composite of about nine whorl fragments.

Subsequent workers have adopted different generic assignments. Dubar and Mouterde (1978), Da Rocha (1977), and Géczy (1976) have retained the genus *Metaderoceras*, although Mouterde (1977) points out that there exists a morphological gradation between the genera *Eoderoceras* and *Crucilobiceras* that is bridged by *Metaderoceras beirensis*. Wiedenmayer (1977, 1980) considered *Crucilobiceras* to be the valid genus, and Smith (1981) relegated *Metaderoceras* to subgeneric rank within the genus *Crucilobiceras*.

The use of the genus *Metaderoceras* here follows the work of Donovan *et al.* (1981) who placed *Metaderoceras* on equal generic ground with *Crucilobiceras* and *Eoderoceras*.

**AGE AND DISTRIBUTION:** *Metaderoceras* is characteristically Tethyan in distribution; it is found in Morocco, the Iberian Peninsula, Hungary, and western North America. The

genus ranges from the *Jamesoni* Zone to its acme in the *Ibex* Zone.

*Metaderoceras muticum* (D'ORBIGNY, 1844)

Plate 3, fig. 4a, b, 5; plate 4, fig. 1-3.

- \*1844 *Ammonites muticus* D'ORBIGNY, p. 274, pl. 80, fig. 1-3.  
 non 1909 *Deroceras muticum* (D'ORB.)-ROSENBERG, p. 265, pl. 13, fig. 7.  
 non 1958 *Cruciloboceras* cf. *muticum* (D'ORB.)-DONOVAN, p. 36, pl. 3, fig. 2.  
 1965 *C.* cf. *muticum* (D'ORB.)-BREMER, p. 155.  
 ?1970 *Acanthopleuroceras southerlandbrowni* FREBOLD, p. 440, pl. 1, fig. 1.  
 1976 *M. muticum* (D'ORB.)-GECZY, p. 56, pl. 11, fig. 3,4.  
 1981 *C.* cf. *M. muticum* (D'ORB.)-IMLAY, p. 35, pl. 7, fig. 6-10, 12-15.  
 1981 *C.* cf. *M. muticum* (D'ORB.)-SMITH, p. 236, fig. 1-2; pl. 9, fig. 1.  
 ?1981 *Uptonia* cf. *ignota* (SIMPSON)-HILLEBRANDT, p. 510, pl. 5, fig. 4.

**MATERIAL:** Forty three specimens, preserved mainly as external moulds with some internal moulds, in siltstone.

**MEASUREMENTS:**

| SPECIMEN    | D    | UD  | U  | WH  | WW  | PRHW |
|-------------|------|-----|----|-----|-----|------|
| C-90823     | 39   | 19  | 49 | 11  | 9.5 | 16   |
| C-103305(A) | 60   | 31  | 52 | -   | -   | 18   |
| C-103305(B) | c80  | c43 | 51 | -   | -   | c18  |
| - - -       | c43  | c22 | 51 | -   | -   | 14   |
| C-90527     | 60   | 31  | 52 | -   | -   | 16   |
| - - -       | 31   | 15  | 48 | 8.5 | -   | 16   |
| C-90839     | c184 | 107 | 58 | c43 | -   | 31   |
| - - -       | c107 | 63  | 59 | c26 | -   | 21   |

|          |      |    |    |       |    |    |
|----------|------|----|----|-------|----|----|
| - - -    | c63  | 30 | 48 | c17   | -  | 14 |
| C-90924  | -    | -  | -  | -     | 46 | 28 |
| C-103104 | c107 | 60 | 56 | c24   | -  | 21 |
| - - -    | c60  | 30 | 50 | c16.5 | -  | 17 |

**DESCRIPTION:** Shell evolute; whorl section rectangular to subquadrate. Umbilicus wide and quite shallow; umbilical wall low, convex; umbilical edge rounded. The flanks are convex; ventral shoulder is sharply rounded. Venter is broad, convex, and smooth except for faint swellings that arch adorally from the tubercles on the ventral shoulder in some specimens.

Ornament appears on the innermost whorls observed in specimens of this collection. At diameters less than about 20 mm, ribbing consists of fairly dense, simple, straight, rectiradiate to slightly prorsiradiate ribs that arise at or just above the umbilical edge and terminate at the ventral shoulder in small tubercles. At diameters greater than 20 mm, the ribs arise faintly on the umbilical wall where they may be slightly rursiradiate. They gradually increase in strength and become rectiradiate to prorsiradiate at about 1/4 of the whorl height. They then continue straight to the ventral shoulder where they terminate in large tubercles that represent the bases of long, sharp spines. Rib density is fairly low (between 13 and 18 PRHW up to diameters of about 100 mm) but increases gradually at large (>100 mm) diameters.

**DISCUSSION:** The increase in rib density at large diameters in the Spatsizi specimens of *M. muticum* has also been observed by Dubar and Mouterde (1978) in specimens from the Mediterranean region. Dubar and Mouterde (1978) state that rib density on the last whorl increases to 27 PRHW from 18 PRHW on the penultimate whorl. Unfortunately, no measurements are given to indicate the diameter at which this change occurs, nor are any specimens figured.



Based on observations of specimens collected from Oregon and Nevada, Smith (1981) reports a change in whorl section of *M. muticum* at diameters greater than about 100 mm. At  $D < 100$  mm, the whorl section is subquadrate—higher than wide whereas at  $D > 100$  mm the whorl section is slightly depressed. Smith (*op. cit.*) states that this change in shape may be indicative of maturity. The poor preservation of the Spatsizi material precludes comment on the whorl section, however, the coincidence between the whorl section change reported by Smith (*op. cit.*) and the rib density increase in the Spatsizi material at diameters greater than 100 mm should be noted.

**OCCURRENCE:** *M. muticum* is a Carixian form that is found in the Mediterranean region (Morocco, Hungary) and in the western United States, Southern Alaska, and the Queen Charlotte Islands. In Spatsizi it occurs within the range of *Dubariceras fereboldi* and *Tropidoceras*.

Localities: 1, 3, 4, 8, 9, 10, 13, 63, 64, 79, 95, 99–101, 112, 139, 141.

**AGE:** Early Pliensbachian (*D. fereboldi* Zone).

*Metaderoceras* aff. *M. muticum*

Plate 5, fig. 1–3.

?1981 *Cruciloboceras* cf. *C. densinodulum* BUCKMAN-IMLAY, p. 34, pl. 7, fig. 4,5.

**MATERIAL:** Six specimens, poorly to moderately well preserved as external and internal moulds in siltstone and fine sandstone.

**MEASUREMENTS:**

| SPECIMEN | D   | UD  | U  | WH  | WW | PRHW |
|----------|-----|-----|----|-----|----|------|
| C-103156 | c90 | c55 | 61 | c21 | -  | c13  |

**DESCRIPTION:** Shell evolute, whorl section rectangular to sub-quadrate. Umbilical wall low, steep; umbilical edge rounded. Flanks are convex; ventral shoulder abruptly rounded; venter is broad and low.

Ribbing on the inner whorls consists of fairly dense prorsiradiate ribs that arise on the umbilical wall where they trend slightly rursiradiately. Each rib is terminated at the ventro-lateral shoulder by a long, sharp tubercle. On the outer whorls the ribs become distant, fairly broad, and faint on the lower flank.

**DISCUSSION:** The inner whorls ( $D < 50$  mm) of *M. aff. M. muticum* are similar to *M. muticum* in rib density and form, but at larger diameters the ribbing of *M. aff. M. muticum* becomes much coarser than in *M. muticum*. A single specimen from Alaska, assigned to *Crucilobicerias* cf. *C. densinodulum* by Imlay (1981), is similar to the Spatsizi specimens of *M. aff. M. muticum* except that the ribs on the outer whorls of *C. cf. C. densinodulum* tend to weaken near the middle of the flanks and its whorl section appears more compressed. The ornament on the inner whorls of *C. cf. C. densinodulum* is similar to that of *C. cf. C. muticum* also figured by Imlay (*op. cit.*).

In Spatsizi and Alaska, *M. muticum* (or *C. cf. C. muticum*) and *M. aff. M. muticum* (or *C. cf. C. densinodulum*) share the same stratigraphic position. A possible exception to this exists in Spatsizi where one specimen (pl. 5, fig. 2) was collected low in the sequence, apparently below the other occurrences of *M. muticum*. The similarity in ornament on the inner whorls together with the coincident stratigraphic ranges of both the Spatsizi and Alaskan collections suggest a close affinity between *M. muticum* and *M. aff. M. muticum* (or *C. cf. C. densinodulum*). Indeed, they may well be variants (or even dimorphs?) of the same species. A direct comparison between *M. aff. M. muticum* from Spatsizi and the illustrations of *C. densinodulum* from Europe is not made here due to the apparently wider whorl section and younger age of the Spatsizi specimens (*C. densinodulum* occurs in the lower part of the Upper Sinemurian *Raricostatum* Zone in

Europe). It is interesting to note, however, that Bremer (1965) considered *C. densinodulum* to be a subspecies of *M. muticum*.

**OCCURRENCE:** As noted above, *M. aff. M. muticum* occurs with and possibly below *M. muticum* in Spatsizi. In its lowest position, *M. aff. M. muticum* is associated with *Acanthopleuroceras* cf. *A. stahli* and *M. evolutum*. This range roughly corresponds to the *Pinnaforme* and lower *Dayiceroides (Freboldi)* Zones of Smith (1981), or to the *Jamesoni* and *Ibex* Zones of northwest Europe.

Localities: 5, 15, 73, 104, 142.

**AGE:** Early Pliensbachian (*L. pinnaforme* to Lower *D. freboldi* Zone).

*Metaderoceras evolutum* (FUCINI, 1921)

Plate 6, fig. 3.

- 1899     *Deroceras gemmellaroi* LEVI-FUCINI, p. 16, pl. 20, fig. 1, 2.
- 1909     *Deroceras muticum* D'ORBIGNY-ROSENBERG, p. 265, pl. 13, fig. 7.
- \*1921     *Deroceras evolutum* FUCINI, p. 50, pl. 1, fig. 14a, b.
- 1963     *Crucilobicerias aff. evolutum* (FUCINI)-DU DRESNAY, p. 147, pl. 2, fig. 2, 3.
- 1970     *Crucilobicerias pacificum* FREBOLD, p. 435, pl. 1, fig. 4-8.
- ?1976     *Metaderoceras* sp. aff. *M. evolutum* (FUCINI)-GECZY, p. 61, pl. 12, fig. 5.
- 1977     *Crucilobicerias evolutum* (FUCINI) *bruntum* WIEDENMAYER, p. 59, pl. 13, fig. 1, 2.
- 1977     *Crucilobicerias evolutum evolutum* (FUCINI)-WIEDENMAYER, p. 59, pl. 13, fig. 3.

- 1978 *Metaderoceras evolutum* DUBAR and MOUTERDE, p. 44, pl. 2, fig. 1.
- 1978 *Metaderoceras evolutum* (FUCINI) *bruntum* (WIEDENMAYER)-COLERA *et al.*, p. 311, pl. 1, fig. 3a, b, c, 4.
- non 1978 *Metaderoceras* sp. 3 (gr. *M. evolutum* FUCINI)-COLERA *et al.*, p. 314, pl. 1, fig. 2; pl. 2, fig. 2.
- 1980 *Cruciloboceras evolutum evolutum* (FUCINI)-WIEDENMAYER, p. 48, pl. 1, fig. 3, 4.
- 1981 *Cruciloboceras (Metaderoceras) evolutum* (FUCINI)-SMITH, p. 231, pl. 8, fig. 2, 3, 5; Text-fig. 6-10.
- cf. 1981 *Cruciloboceras* cf. *C. pacificum* FREBOLD-IMLAY, p. 35, pl. 8, fig. 10-12, 15-17.
- cf. 1983 *Metaderoceras evolutum* (FUCINI)-RIVAS, p. 395, pl. 1, fig. 1-8.

**MATERIAL:** Two specimens preserved as internal moulds in limestone.

#### MEASUREMENTS

| SPECIMEN   | D   | UD  | U  | WH | WW | PRHW |
|------------|-----|-----|----|----|----|------|
| C-81970(A) | 31  | 16  | 52 | c9 | c6 | c13  |
| C-81970(B) | c40 | c21 | 52 | -  | -  | -    |

**DESCRIPTION:** Shell evolute; whorl section rectangular to sub-quadrate. Umbilical wall low, shallow; umbilical edge rounded. Flanks are slightly convex; ventral shoulder abruptly rounded. The venter is fairly broad, convex.

Ornament consists of distant, straight, slightly prorsiradiate ribs of low relief. The ribs arise above the umbilical edge and terminate in prominent ventro-lateral tubercles. Faint secondary ribs or inter-rib lirae are visible on these specimens. The venter is featureless.

**DISCUSSION:** *Metaderoceras evolutum* has been the subject of much study and revision

over the last half century. A recent study by Rivas (1983) has shown *M. evolutum* to be a variable species that includes many specimens previously assigned to other species and subspecies. Although Rivas (1983) includes *M. mouterdi* (FREBOLD) in *M. evolutum*, *M. mouterdi* is retained in this thesis based on differences observed in the outer whorls of specimens of *M* cf. *M. mouterdi* from Spatsizi (see the following discussion of *M*. cf. *M. mouterdi*). The possibility remains, however, that the two forms are variants of the same species.

**OCCURRENCE:** *M. evolutum* is common in Pliensbachian (*Jamesoni*-*Margaritatus* Zones) sequences in the Mediterranean region. The Spatsizi specimens of *M. evolutum* were found low in the sequence, below the range of *Dubariceras freboldi*. They occur in association with *Acanthopleuroceras* cf. *A. stahli*. This occurrence corresponds to the *Pinnaforme* Zone of Smith (1981) and is roughly equivalent to the *Jamesoni* Zone of northwest Europe. In the Queen Charlotte Islands (Frebold, 1970) and Alaska (Imlay, 1981) *M. evolutum* is found slightly higher in the section; it occurs with *Dubariceras freboldi* and *Tropidoceras* sp..

Localities: 138.

**AGE:** Early Pliensbachian (*L. pinnaforme* to ?Lower *D. freboldi* Zone).

*Metaderoceras* cf. *M. mouterdi* (FREBOLD, 1970)

Plate 5, fig. 4, 5; plate 6, fig. 1.

cf. \*1970 *Cruciloboceras mouterdi* FREBOLD, p. 437, pl. 1, fig. 2a, b.

**MATERIAL:** Seven specimens, preserved in siltstone as external and internal moulds.

**MEASUREMENTS:**

|          |   |    |   |    |    |      |
|----------|---|----|---|----|----|------|
| SPECIMEN | D | UD | U | WH | WW | PRHW |
|----------|---|----|---|----|----|------|

|            |      |     |    |       |    |    |
|------------|------|-----|----|-------|----|----|
| C-90843(A) | 78   | 43  | 55 | -     | -  | 20 |
| - - -      | c43  | 25  | 58 | c11.5 | -  | 10 |
| - - -      | c25  | 12  | 48 | -     | -  | 11 |
| C-103309   | 44   | 21  | 48 | 12    | -  | 11 |
| - - -      | c22  | 10  | 45 | 7     | -  | 14 |
| C-103307   | c110 | c51 | 46 | 28    | 17 | 23 |
| - - -      | c49  | c24 | 50 | -     | -  | 13 |
| - - -      | c24  | c10 | 42 | -     | -  | 16 |

**DESCRIPTION:** Shell evolute; umbilicus wide and moderately deep. Umbilical wall low, convex; umbilical slope gentle. Whorl section appears to be sub-quadrate with widest dimension at the ventral shoulder. The flanks are convex and the ventral shoulder is angular. The venter is broad, lowly convex and smooth except for very faint swellings that arch adorally from tubercles on the ventral shoulder.

Ornament varies with growth. Ribbing appears at a diameter of less than 5 mm and consists, on the inner whorls, of dense, straight, slender ribs that arise on the umbilical edge, trend rectiradially, and terminate in distinct tubercles. At umbilical diameters greater than about 10 mm, rib density undergoes a decrease from 13-14 PRHW to 10-11 PRHW. This decrease in rib density is most apparent in the holotype figured by Frebold (1970, see the following discussion). The ribs of this reduced-density stage are different from the earlier ribs in that they are indistinct on the lower 1/3 of the flanks then become stronger and quite broad towards the ventral shoulder. The ribs terminate at the ventral shoulder in large tubercles that represent the bases of spines.

The two largest specimens of *M. cf. M. mouterdi* in the Spatsizi collections show a rather dramatic increase in rib density beginning at an umbilical diameter of about 25 mm. At UD=45 mm, both specimens have exceeded a rib density of 20 PRHW, and reach a maximum density of about 24 PRHW. The ribs of this high density stage are different from those of the preceeding stage; they arise on the umbilical wall where they

trend rursiradiately, then curve forward and trend slightly prorsiradiarely on the flank where they are very gently sinuous. They are terminated at the ventral shoulder by sharp tubercles. The whorl section of this densely ribbed stage appears to be relatively more compressed than earlier whorls.

**DISCUSSION:** The Spatsizi specimens of *M.* cf. *M. mouterdi* are similar to the holotype (Frebold, 1970) in their volution and form of ribbing at umbilical diameters less than about 27 mm, although the decrease in rib density, beginning at UD=10 mm, is of greater magnitude in the holotype. Whereas rib density in the holotype drops from a high of 19 PRHW to a low of 12 PRHW, the corresponding decrease in the Spatsizi material is from 14 to 10 PRHW. In spite of this numeric difference, the Spatsizi specimens are probably conspecific to Frebold's (1970) *M. mouterdi*, based on the similar rib form and the fact that all the secimens exhibit a marked rib density decrease.

The high rib density stage observed on the outer whorls of the Spatsizi specimens (a stage that possibly represents the body chamber) is not seen in the holotype of *M. mouterdi*. This high density stage first develops at a diameter exceeding the maximum diameter of the holotype, which, according to Frebold (1970), is septate to the end (UD=26 mm). In other words, the greatest diameter of the holotype roughly corresponds to the onset of the dense ribbed stage of the Spatsizi specimens. The absence of sutures on the internal moulds of these densely ribbed outer whorls lends support to their interpretation as the body chamber, although it is difficult to determine whether the lack of sutures is due simply to poor preservation.

*M. mouterdi* is unique among the species of *Metaderoceras* in its tendency toward decreasing rib density from the inner to middle whorls. It differs from *M. muticm* in having a more variable rib density with growth (fig 6.1), and according to Frebold (1970) a less complicated suture line. It differs from both *M. beirens* and *M. venarens* in having more numerous ribs. *M. mouterdi* is distinguished from *M. evolutum* by the

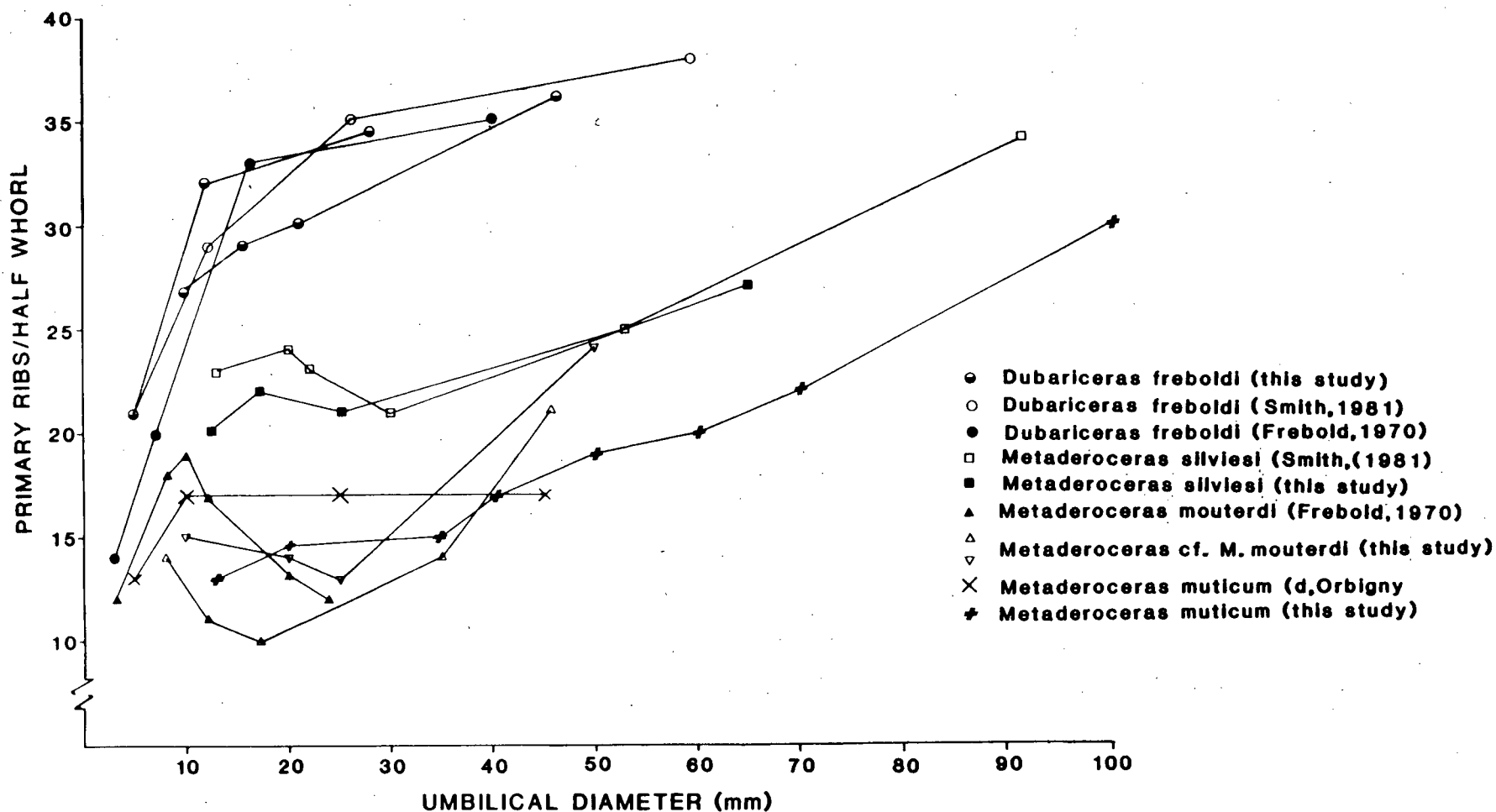


FIGURE 6.1 Graph comparing rib density between members of the family Eoderoceratidae. The fields of *Dubariceras freboldi* and *Metaderoceras silviesi* are distinct. Points for *Metaderoceras muticum* and *M. mouterdi* are somewhat clustered. However, rib density of *M. mouterdi* is more variable than that of *M. muticum*, and shows a distinct decrease (at  $10\text{mm} < \text{UD} < 30\text{mm}$ ) followed by a marked increase (at  $\text{UD} > 30\text{mm}$ ).



absence of ribs joining at the ventro-lateral tubercles, although Rivas (1983) has synonymized *M. mouterdi* with *M. evolutum*. Unfortunately, so few specimens of *M. mouterdi* have been collected that a more precise comparison between the two genera is difficult.

**OCCURRENCE:** Only two specimens of *M. mouterdi* have been reported from the type locality on the Queen Charlotte Islands. These are found in association with *Tropidoceras*, *Dubariceras freboldi*, and *M. evolutum*. Similarly, in Spatsizi, *M. cf. M. mouterdi* is found with *Tropidoceras* and *Dubariceras freboldi*, although *M. evolutum* appears to occur below *M. cf. M. mouterdi* here.

Localities: 5, 7, 64.

**AGE:** Early Pliensbachian (*D. freboldi* Zone).

*Metaderoceras silviesi* (HERTLEIN, 1925)

Plate 4, fig. 4, 5; plate 7, fig. 1.

- \*1925 *Uptonia silviesi* HERTLEIN, p. 39, pl. 3, fig. 1, 2, 5.
- 1981 *Cruciloboceras (Metaderoceras) silviesi* (HERTLEIN)-SMITH, p. 239, pl. 11, fig. 1.
- 1981 *Cruciloboceras cf. C. submuticum* (OPPEL)-IMLAY, p. 33, pl. 5, fig. 1-3.
- ?1981 *Uptonia cf. U. obsoleta* (SIMPSON)-VON HILLEBRANDT, p. 509, pl. 5, fig. 1, 2, 5.

**MATERIAL:** Twenty one specimens preserved as external moulds with rare internal moulds in siltstone.

**MEASUREMENTS:**

|          |   |    |   |    |    |      |
|----------|---|----|---|----|----|------|
| SPECIMEN | D | UD | U | WH | WW | PRHW |
|----------|---|----|---|----|----|------|

|              |      |     |    |     |   |     |
|--------------|------|-----|----|-----|---|-----|
| C-88231      | c150 | c75 | 50 | c43 | - | -   |
| - - -        | c106 | c53 | 50 | c22 | - | 21  |
| C-103324(M1) | 37   | 18  | 49 | c10 | - | c14 |

**DESCRIPTION:** Shell evolute; whorl section appears to be rectangular but cannot be directly observed in the Spatsizi collections due to incomplete preservation. The umbilical wall is low, steep; umbilical edge rounded. Flanks are slightly convex; ventral shoulder is abruptly rounded. The venter is low, slightly convex, and fairly broad.

Ornament consists of dense, simple, straight to slightly sinuous ribs. The ribs arise on the umbilical wall where they appear to trend slightly rursiradiately, then subsequently become prorsiradiate and continue more or less straight to the ventral shoulder. At the ventral shoulder each rib bears a prominent tubercle. The ribs then project forward and continue onto the venter from the tubercles but decrease in strength. On larger whorls the ribs form ventral chevrons, although the apices of the chevrons tend to be faint.

**DISCUSSION:** *Metaderoceras silviesi* appears to be morphologically intermediate between the genera *Metaderoceras* and *Dubariceras* (Mouterde, written communication, 1985). Its dense, relatively finely ribbed inner whorls are reminiscent of *dubariceras*, whereas the more coarsely ribbed, distinctly tuberculate and less dense ribs of the middle and outer whorls are characteristic of *Metaderoceras* (fig. 6.1). The ribs on the outer whorls of *M. silviesi* tend to become slightly sinuous, but again, their coarseness, low density, and tuberculation set them apart from the ribbing of *D. freboldi*.

On the ventral region of the larger specimens of *M. silviesi*, the ribs project beyond the ventro-lateral tubercles and form chevrons.<sup>46</sup> According to Mouterde (written communication, 1985), ventral chevrons are an adult characteristic of *Metaderoceras*, but they also occur faintly on the outermost whorls of some specimens of *Dubariceras dubari* from Italy. As pointed out in the preceeding description of *Dubariceras freboldi*, weak ventral chevrons are also found on the outer whorls of some of the Canadian specimens

(Frebold, 1970; this study). If *Dubariceras* evolved from *Metaderoceras* as Dommergues *et al.* (1984) conclude, then it follows that the ventral chevrons observed in *Dubariceras* are an ancestral feature derived from *Metaderoceras*. The presence of ventral chevrons serves to illustrate the close phylogenetic relationship between *Metaderoceras* and *Dubariceras* in general, and between *M. silviesi* and *D. freboldi* in particular.

**OCCURRENCE:** *Metaderoceras silviesi* appears to be restricted to the eastern Pacific region (see synonymy). In Spatsizi, it is found within the range of *Dubariceras freboldi*, although Smith (1981) found it to occur in the zone below *Dubariceras freboldi*, in association with *Luningiceras pinnaforme*.

Localities: 4, 5, 8–11, 19, 64, 93, 98, 100, 104, 141.

**AGE:** Early Pliensbalian *D. freboldi* Zone.

*Metaderoceras* sp.

Plate 6, fig. 2.

**MATERIAL:** A single specimen preserved as an external mould in fine grained volcanoclastic sandstone.

**MEASUREMENTS:**

| SPECIMEN | D   | UD | U  | WH   | WW | PRHW |
|----------|-----|----|----|------|----|------|
| C-103303 | 53  | 28 | 53 | 14   | —  | 20   |
| — — —    | c28 | 17 | 61 | c8.5 | —  | 20   |

**DESCRIPTION:** Shell is evolute; whorl section is unknown due to preservation. Umbilical wall low, shallow to moderately steep; umbilical edge rounded; flanks are convex. The ventral shoulder appears to be abruptly rounded; the venter is not observed in this

specimen.

Ornament consists of straight, moderately prorsiradiate ribs. Rib density is high, particularly on the inner whorls, and remains fairly constant through the ontogeny of this specimen. The ribs arise on the lower flank and attain their maximum relief at about 1/3 the flank height. The ribs are fairly broad and continue to the ventral shoulder where they bear a ventro-lateral spine. The ornament of the ventral region is unknown.

DISCUSSION: This specimen differs from *Metaderoceras muticum* by its higher rib density, but is similar to *M. muticum* in most other respects. The expansion rate of *Metaderoceras* sp. is less than that of *M. silviesi*, and the ribs are broader and less sinuous than those of *M. silviesi*. The constant rib density of *Metaderoceras* sp. is in marked contrast to the highly variable rib density seen in the ontogeny of *M. cf. M. mouterdi*.

OCCURRENCE: Although the specimen was found *ex situ*, it apparently came from very low in the Pliensbachian section and is possibly from the same stratigraphic level as *Tropidoceras* sp.

Localities: 1.

AGE: Early Pliensbachian (?Lower *D. freboldi* Zone).

Genus *Dubariceras* DOMMERGUES, MOUTERDE and RIVAS, 1984

TYPE SPECIES: *Dubariceras dubari* DOMMERGUES *et. al.* (1984, p. 382, pl. 1), by subsequent designation.

REMARKS: Shells evolute; platyconic, whorl section rectangular. Umbilical wall low to moderate, convex, steep; umbilical edge rounded. Flanks are flat to slightly convex. Ventral

shoulder abruptly rounded; venter is low, slightly convex.

Ornament consists of dense ribs that arise on the umbilical wall where they trend rursiradiately, then subsequently describe a sinuous pattern up the flanks to elongate ventro-lateral tubercles beyond which they fade rapidly on the venter.

The genus *Dubariceras* was created by Dommergues *et. al.* (*op. cit.*) in order to accomodate certain Carixian ammonites of Tethyan aspect which, until now, have been erroneously assigned to the genera *Uptonia*, *Platypheuroceras*, and *Dayiceras* (family POLYMORPHITIDAE). According to Dommergues *et. al.* (*op. cit.*), the confusion surrounding the generic assignment of the members of *Dubariceras* stems from the fact that, although they are phylogenetically related to *Metaderoceras* (family EODEROCERATIDAE), they show a remarkable morphologic convergence to the Polymorphitids. Based on evidence provided by the Spatsizi collections, the creation of the genus *Dubariceras* seems justified.

AGE AND DISTRIBUTION: *Dubariceras* is a Tethyan form found in the Middle and Upper Carixian of the Tethyan region (Hungary, Italy, Morocco, and the Iberian Peninsula). In the New World, *Dubariceras* occurs in the Andes mountains and in the western United States, British Columbia, and southern Alaska. It is significant that the two known species of *Dubariceras*; *D. freboldi* and *D. dubari*, occupy disjoint geographical areas. *D. dubari* is restricted to the Mediterranean region, while *D. freboldi* is restricted to the western Americas. The paleobiogeographic implications of this distribution are discussed in the chapter on paleobiogeography.

*Dubariceras freboldi* DOMMERGUES, MOUTERDE, and RIVAS, 1985

Plate 7, fig 1-4; plate 8, fig. 3, 4.

\*1970 *Uptonia dayiceroides* MOUTERDE-FREBOLD, p. 438, pl. 1, fig. 9a, b, c

- 1981 *Uptonia* cf. *U. dayiceroides* (MOUTERDE)-IMLAY, p. 36, pl. 9, fig. 1-4, 8, 12-16.
- 1981 *Dayiceras dayiceroides* (MOUTERDE)-SMITH, p. 265, pl. 12, fig. 4-8, text-fig. 6-14.
- 1981 *Uptonia* cf. *U. angusta* (OPPEL)-von HILLEBRANDT, p. 509, pl. 5, fig. 3a, b.
- 1983 *Dayiceras dayiceroides* (MOUTERDE)-SMITH, p. 86, fig. 2a, b, c (1981 material partly refigured).
- 1984 *Dubariceras freboldi* DOMMERGUES *et. al.* fig. 3-A3.

**MATERIAL:** Approximately one hundred eighty specimens preserved as external and internal moulds in siltstone and minor limestone.

**MEASUREMENTS:**

| SPECIMEN    | D    | UD  | U  | WH  | WW  | PRHW |
|-------------|------|-----|----|-----|-----|------|
| C-90832(D1) | 74   | 30  | 43 | 26  | 9   | 34   |
| C-90836     | 16   | 6   | 37 | c6  | -   | 29   |
| C-90830     | 63   | 25  | 40 | 20  | -   | 34   |
| C-90843(D1) | -    | -   | -  | c43 | c16 | -    |
| C-103324(A) | c105 | 47  | 45 | 31  | 12  | -    |
| ----        | 47   | 22  | 47 | 16  | -   | 27   |
| C-103314    | c44  | c22 | 50 | c13 | -   | -    |
| ----        | 30   | 14  | 47 | c13 | -   | -    |
| C-103318    | -    | -   | -  | 15  | 11  | -    |
| C-103105    | c125 | 53  | 42 | c43 | -   | 29   |
| C-103306    | 61   | 25  | 41 | -   | -   | 29   |

**DESCRIPTION:** Shell evolute; whorl section rectangular, becoming more compressed with growth. Umbilical wall is low, steep; umbilical edge is abruptly rounded. The flanks are

slightly convex on the smaller whorls but tend to become flatter on larger whorls. The ventral shoulder is abruptly rounded; the venter is low, flat to slightly convex.

Ornament consists of simple, dense, sinuous ribs that appear at diameters of about 2–3 mm (only a single exception to this was found in a small specimen of about 25mm diameter which shows sporadic fasciculation or bundling of ribs into pairs just above the umbilical edge). The ribs arise on the umbilical wall where they trend rursiradiately. Just above the umbilical edge the ribs curve gently forward to trend prorsiradiately to about 1/3 of the flank height. The ribs then curve gently again to trend rectiradiately to slightly prorsiradiately up the flanks. As the ribs approach the ventral shoulder they become increasingly prorsiradiate. At the ventral shoulder each rib bears a radially elongate tubercle beyond which the ribs fade rapidly. Except for these faint, adorally projecting extensions of the ribs, the venter is featureless. On some of the larger whorls, the ribs project forward onto the venter and form indistinct chevrons. Frebold (1970) also noted this feature in the Queen Charlotte material.

DISCUSSION: In the original description of *Dubariceras freboldi* (then assigned to *Uptonia dayiceroideis*), Frebold (1970) drew attention to the striking similarity between the specimens from the Queen Charlotte Islands, which he assigned to *Uptonia* cf. *U. dayiceroideis*, and those from Portugal, described as *Uptonia? dayiceroideis* by Mouterde (1951). Frebold pointed out, however, that ". . . The only difference seems to be the presence of a weakly crenulated faint keel in Mouterde's species". Frebold concluded that the crenulated keel of the Portuguese material may be restricted to the inner whorls and that this difference between the Queen Charlotte and Portuguese material was of little (taxonomic) consequence. Unfortunately, there were no specimens of a size comparable to the Portuguese material present in the Queen Charlotte collections to corroborate Frebold's conclusion. Where visible, the venters of small specimens in the Spatsizi collections do not show any sign of a keel.

Smith (1983) also considered the Queen Charlotte material, as well as material from Oregon, Nevada, and Alaska, to be conspecific with the Portuguese *Uptonia? dayiceroides*. Smith concluded, however, that the species *dayiceroides* belonged not to *Uptonia*, but to the genus *Dayiceras*.

Recently, Dommergues *et al.* (1984) included all the western North American forms attributed to *Uptonia* or *Dayiceras dayiceroides* into *Dubariceras freboldi*. However, they consider that sufficient morphological differences exist between the Portuguese and North American material to retain Mouterde's (1951) *Uptonia dayiceroides* in *Dayiceras dayiceroides*. According to Dommergues *et al.* (1984), *Dubariceras freboldi* differs from *Dayiceras dayiceroides* as follows:

- 1) There is never a trace, in *Dubariceras freboldi*, of the "occasionally slightly crenulated, more or less distinct keel" observed in the specimens of *Dayiceras dayiceroides* from Portugal (phrase in quotes translated from Dommergues *et al.*, 1984).
- 2) The venter of *Dubariceras freboldi* is flatter than that of *Dayiceras dayiceroides*, and the whorl section remains rectangular with growth (i.e., it does not become ogival as in *Dayiceras dayiceroides*).

It may also be significant that in the Portuguese sections *Dayiceras dayiceroides* appears to pass (morphologically) upward into other, less ambiguous species of *Dayiceras* that are found in the overlying beds (Mouterde, 1951). In western North America, no such transition has been observed, although a few specimens of *Dayiceras* sp. are found with *Dubariceras freboldi* in Spatsizi (see the following discussion of *Dayiceras*).

**OCCURRENCE:** *Dubariceras freboldi* is restricted to the East Pacific faunal realm. It is common in Pliensbachian sections of the western Cordillera of North America but is absent in time equivalent sections on the North American craton. In South America, *D. freboldi* is found in Lower Pliensbachian rocks in Chile (von Hillebrandt, 1981a). Although



*D. freboldi* is unknown in the Mediterranean region, the related species *D. dubari* represents the genus around the Mediterranean.

In Spatsizi, *D. freboldi* is abundant in Lower Pliensbachian rocks that are roughly equivalent to the *Ibex* and *Davoei* Zones of northwest Europe. In its lowest position, it is associated with *Uptonia* sp., *Dayiceras* sp., *Metaderoceras muticum*, and *M. silviesi*, and *Tropidoceras* sp.. Higher in the sequence it occurs with *Aveyronicerias* sp. A and B, and *Reynesocoeloceras* cf. *R. incertum*.

Because of its abundance in sections in Oregon and Nevada, Smith (1981) erected *D. freboldi* (which at that time was assigned to *Dayiceras dayiceroides*) as a zonal index fossil for western North America. Its abundance and usefulness in Spatsizi and the Queen Charlotte Islands illustrates its potential as an index fossil for the Lower Pliensbachian of western North America. The use of *D. freboldi* as a zonal index fossil in Spatsizi is discussed in Chapter 4, section 4.4.

Localities: 4, 5, 7–11, 13, 15, 16, 19, 21, 22, 64, 72–75, 79, 96, 99, 101, 102.

AGE: Early Pliensbachian (*D. freboldi* Zone).

Family COELOCERATIDAE HAUG, 1910

Genus *Reynesocoeloceras* GECZY, 1976

TYPE SPECIES: *Coeloceras crassum* YOUNG and BIRD var. *indunensis* MENEGHINI, 1891 (p. 72, pl. 16) by original designation.

REMARKS: The taxonomic position of the genus *Reynesocoeloceras* and the associated genus *Aveyronicerias*, is problematic and there does not appear to be a consensus amongst the various workers who have published on these forms. For a review of the different systematic treatments, the reader is referred to Géczy (1976), Pinna and Levi-Setti (1971), Fischer (1971), Schmidt-Effing (1972), Wiedenmayer (1977, 1980), von Hillebrandt (1981b),

and Donovan et al. (1981). The taxonomic system adopted in this study is essentially a compromise based on the previously published work; it is designed as a practical and relatively streamlined framework within which the Spatsizi material may be comfortably placed.

*Reynesocoeloceras*, although originally defined as a subgenus of *Coeloceras* by Géczy (1976), is given full generic status here, following the work of Wiedenmayer (1977, 1980), Donovan et al. (1981), and von Hillebrandt (1981b). Géczy (1976) considered the morphologic similarities between *Reynesocoeloceras* and *Coeloceras* as evidence of a generic-subgeneric relationship between the two forms, but stratigraphic evidence is contrary to this. Whereas *Coeloceras* is restricted to the *Jamesoni* Zone (Donovan et al., 1981), *Reynesocoeloceras* first appears in the *Ibex* Zone and continues into the *Davoei* Zone. Their ranges do not overlap, suggesting that the two genera are distinct, and that *Reynesocoeloceras* is likely a derivative of *Coeloceras*.

Assignment of the genus *Reynesocoeloceras* to the family Coeloceratidae here follows the work of Géczy (1976), Wiedenmayer (1977, 1980), and von Hillebrandt (1981b). Although Donovan et al. (1981) place *Reynesocoeloceras* into the family Dactylioceratidae, they do state that *Reynesocoeloceras* was derived from Coeloceratidae. This illustrates what is probably a close phylogenetic relationship between the two families (Dactylioceratidae and Coeloceratidae), a possibility already considered in the Treatise (Arkell et. al., 1957, p. L252) and by Fischer (1971).

A contrasting view for the origin of *Reynesocoeloceras* has recently been proposed by Dommergues and Mouterde (1982). They state that the earliest form of *Reynesocoeloceras*, which they have named *Reynesocoeloceras praeincertum*, evolved from the genus *Metaderoceras*. They conclude that *Reynesocoeloceras* did not evolve from *Coeloceras*, but that the similarity between the inner whorls of *Reynesocoeloceras* and those of *Coeloceras* is a result of morphological convergence between the two genera, and indicates a distant common ancestry.

The name, *Reynesocoeloceras*, is derived from the combination of the generic names *Reynesoceras* and *Coeloceras*. *Reynesocoeloceras* is characterized by a change in morphology from *Coeloceras*-like inner whorls (cadiconic, tuberculate with bi- or polyfurcating ribs) to *Reynesoceras*-like outer whorls (serpenticonic with simple, non-tuberculate ribs). It is this change in morphology that distinguishes *Reynesocoeloceras* from both *Coeloceras* and *Reynesoceras*. *Prodactylioceras* differs from *Reynesocoeloceras* by its finer, denser ribbing, sporadic tubercles on the outer whorls, and its more regular growth. *Aveyroniceras*, the Tethyan equivalent of *Prodactylioceras*, is similar to *Reynesocoeloceras* in that it undergoes a change in ornamentation with growth from tuberculate, bifurcating ribs on the innermost whorls to non-tuberculate, simple ribs on the outer whorls. However, the early *Coeloceras*-like stage is more persistent in *Reynesocoeloceras* than in *Aveyroniceras*. In addition, rib density is much greater in *Aveyroniceras*, and some forms possess sporadic tubercles on their body chamber and final whorl of the phragmocone.

**SYNONYMS:** *Indunoceras* WIEDENMAYER, 1977; *Cetonoceras* WIEDENMAYER, 1977.

**AGE AND DISTRIBUTION:** *Reynesocoeloceras* is restricted to the Tethyan Province. In western North America, Smith (1981) reports the occurrence of *Reynesocoeloceras* in east-central Oregon, and also states that certain specimens from Chile, assigned by von Hillebrandt (1973) to *Coeloceras* cf. *C. obesum*, probably belong to the genus *Reynesocoeloceras*. Von Hillebrandt (1981a) himself has described specimens of *Reynesocoeloceras* cf. *R. colubriforme* and *R. cf. R. mortilleti* from western South America.

*Reynesocoeloceras* ranges from the *Ibex* Zone to its acme in the *Davoei* Zone (Géczy, 1976).

*Reynesocoeloceras* cf. *R. incertum* (FUCINI, 1905)

## Plate 8, fig. 1a, b.

- cf. \*1905 *Coeloceras incertum* FUCINI, 1905, p. 137, pl. 10, fig. 9-12.
- cf. 1971 *Coeloceras (Coeloceras) incertum incertum* FUCINI-FISCHER, p. 110, Text-fig. 5j.
- cf. 1976 *Coeloceras (Reynesocoeloceras) incertum* FUCINI-GECZY, p. 131, pl. 23, fig. 4.
- cf. 1976 *Coeloceras (Reynesocoeloceras)* cf. *C. (R.) incertum* FUCINI-GECZY, pl. 23, fig. 5.
- cf. 1981 *Coeloceras (Reynesocoeloceras)* cf. *C. (R.) incertum* (FUCINI)-SMITH, p. 278, pl. 15, fig. 6, 8; Text-fig. 6-15.

**MATERIAL:** Three specimens, moderately well preserved as external and internal moulds in calcareous siltstone.

**MEASUREMENTS:**

| SPECIMEN | D  | UD | U   | WH   | WW    | PRHW |
|----------|----|----|-----|------|-------|------|
| C-90526  | 19 | 60 | c70 | c7.0 | c12.0 | 15   |

**DESCRIPTION:** Shell is evolute, umbilicus is wide and crater-like, deeper on the inner whorls than on the outer whorls. Whorl section is depressed, wide rectangular to coronate. The flanks are convex and slightly divergent; the ventral shoulder is angular. The venter is broad and slightly convex. Ornamentation on the inner whorls consists of short, swollen ribs that become stronger towards the venter and terminate just below the succeeding umbilical seam in large, rounded tubercles. At diameters greater than about 18 mm the ribs become narrower and prorsiradiate, and the tubercles are reduced somewhat in relation to those on the inner whorls. The tubercles give rise to strong, narrow secondary ribs that curve slightly adorally as they cross the venter, and rejoin at the opposing tubercle. At the largest diameter preserved (D = 31.5 mm) there are about two

secondaries per primary rib.

**DISCUSSION:** According to Géczy (1976), the depressed whorl section seen in all stages of growth, and the relatively invariable ornamentation sets *R. incertum* apart from other species of *Reynesocoeloceras*. Whereas the whorl section of most *Reynesocoeloceras* becomes less depressed and the venter more convex with growth, the section remains depressed in *R. incertum*.

**OCCURRENCE:** *R. incertum* has been reported from Hungary (Géczy, 1976) and northern Italy (Fucini, 1905; Fischer, 1971) where it was first described. In Hungary it is found in the Lower *Davoei* Zone. The Spatsizi specimens are found within the upper part of the range of *Dubariceras freboldi*. Smith (1981) also reports the association of *R. incertum* with *Dubariceras freboldi*.

Localities: 140.

**AGE:** Early Pliensbachian (*D. freboldi* Zone).

Family DACTYLIOCERATIDAE HYATT, 1867

GENUS *Aveyroniceras* PINNA and LEVI-SETTI, 1971

**TYPE SPECIES:** *Ammonites acanthoides* REYNES, 1868 (p. 91, pl. 3, fig. 3) by original designation.

**REMARKS:** The ontogeny of *Aveyroniceras* is characterized by a change from tuberculate, bifurcating ribs on the inner whorls to simple, dense, non-tuberculate ribs on the outer whorls. It is this change in morphology that differentiates *Aveyroniceras* from *Prodactylioceras* which lacks the tuberculate, bifurcating ribs on the inner whorls, but rather, bears sporadic tubercles on all its whorls. Géczy (1976), however, points out that

on some species of *Aveyroniceras* the outer whorls possess sporadic tubercles, thereby rendering generic distinction between *Aveyroniceras* and *Prodactylioceras* potentially difficult in some cases.

*Aveyroniceras* differs from *Reynesocoeloceras* in having finer, denser ribs and sporadic tubercles on the outer whorls of some species.

SYNONYMS: *Bettoniceras* WIEDENMAYER, 1977.

AGE AND DISTRIBUTION: *Aveyroniceras* is restricted to the Tethyan Province and is considered to be the Tethyan equivalent to the boreal *Prodactylioceras* (Pinna and Levi-Setti, 1971; Géczy, 1976). It ranges from the *Ibex* Zone to the *Spinatum* Zone. It has been reported from the Lower/Upper Pliensbachian boundary in Oregon (Smith, 1981) and from the Upper Pliensbachian of western South America (von Hillebrandt, 1981a).

*Aveyroniceras* sp. A

Plate 8, fig. 5a, b, 6.

MATERIAL: Four individuals, poorly to moderately preserved as fragments of internal and external moulds in siltstone. Innermost whorls not preserved.

MEASUREMENTS:

| SPECIMEN | D   | UD  | U  | WH | WW | PRHW |
|----------|-----|-----|----|----|----|------|
| C-90834  | c80 | c45 | 56 | 16 | 24 | c40  |
| C-90837  | c80 | c45 | 56 | -  | -  | c43  |

DESCRIPTION: Evolute, outer whorls serpenticonic with wide-ellipsoid whorl section.

Section shape of inner whorls unknown due to poor preservation, but comparison with what appears to be a conspecific specimen from the Queen Charlotte Islands suggests that the inner whorls (to a diameter of about 30 mm) are wide-ellipsoid to coronate. The umbilicus is wide and fairly deep as far as can be seen. The umbilical wall is high and fairly steep on the outer whorls; umbilical edge rounds gradually onto the inflated flanks. Flanks do not form a ventral shoulder; venter is broad, inflated.

Ornamentation varies with growth. The innermost whorls, to a diameter of about 20 mm, are not preserved. Ribbing on the smallest preserved whorl ( $D = 25-30$  mm) consists of fairly stout, moderately dense ribs, most of which bear distinct ventro-lateral tubercles. These *Coeloceras*-like inner whorls are succeeded by *Reynesoceras*-like middle whorls ( $D = 40-50$  mm) which are marked by finer, denser ribs that bear only sporadic tubercles. Rib spacing on these whorls is somewhat irregular and the ribs show a tendency to occur in pairs. On the outermost preserved whorls ( $D > 50$  mm), ribbing is more consistent. The ribs are simple, non-tuberculate, prorsiradiate, and sharp. They arise at the umbilical seam and continue across the flanks and venter without a change in strength.

**DISCUSSION:** Although the specimens described are somewhat intermediate in nature, they are placed in the genus *Aveyroniceras* rather than *Reynesocoeloceras* due to their relatively dense ribbing and early disappearance of the *Coeloceras*-like inner whorls. These same characters, however, set *Aveyroniceras* sp. A apart from other species of *Aveyroniceras*. The *Coeloceras*-like inner whorls of *Aveyroniceras* sp. A disappear at a larger diameter ( $D = 25-30$  mm) than in most species of *Aveyroniceras* ( $D = 10-20$  mm), and the ribbing is less dense than in the majority of species of *Aveyroniceras*.

*Aveyroniceras* sp. A is similar to *A. colubriforme* and *A. inaequiornatum*, both of which are known in western North America. The variable nature of the ornament and the pairing of the ribs on the middle whorls of *Avey.* sp. A is reminiscent of *A.*

*inaequiornatum*, but the ribbing of the outermost preserved whorls of the Spatszi specimens is different from *A. inaequiornatum* in that it becomes coarser and more regular in the Spatszi species. On the other hand, the ribbing and whorl section of the outer whorls of *Avey. sp. A* is similar to that of *A. colubriforme*.

*Aveyroniceras sp. A* is also very similar in rib form and density, as well as in whorl section, to specimens from South America assigned by von Hillebrandt (1981) to "*Reynesocoeloceras (Bettoniceras)*" cf. *mortilleti*. These South American forms (which are not here considered to be conspecific to *A. mortilleti* due to the coarser, less dense ribbing and sporadic tubercles of the South American forms) differ from the Spatszi specimens in possessing sporadic tubercles on their middle and outer whorls.

**OCCURENCE:** *Aveyroniceras sp. A* occurs at the top of, and possibly above the range of *Dubariceras freboldi*. Smith (1981) reports both *A. colubriforme* and *A. inaequiornatum* to occur within the range of *Dubariceras freboldi*. This range is roughly equivalent to the *Ibex* and *Davoei* Zones of northwest Europe.

Localities: 77, 80.

**AGE:** Early Pliensbachian (*D. freboldi* Zone).

*Aveyroniceras sp. B*

Plate 8, fig. 2.

**MATERIAL:** A single specimen preserved as an external mould in siltstone.

**MEASUREMENTS:** Not available due to the fragmentary nature of this specimen.

**DESCRIPTION:** Shell evolute, whorl section appears to be ellipsoidal but cannot be directly observed. Ribbing on the outermost preserved whorl is non-tuberculate, fine, and



very dense. The ribs trend slightly prorsiradiately on the lower flanks and radially on the upper flanks, and appear to continue unchanged across the venter. Ribs on the inner whorl are fine and tuberculate.

**DISCUSSION:** This specimen is similar to *Aveyroniceras inaequiornatum* but poor preservation precludes confident assignment in this species.

**OCCURRENCE:** *Aveyroniceras* sp. B is found near the top of the range of *Dubariceras freboldi*. Specimens from Oregon, similar to *Aveyroniceras* sp. B and assigned to *A. inaequiornatum* by Smith (1981), also occur within the range of *D. freboldi*.

Localities: 78.

**AGE:** Early Pliensbachian (*D. freboldi* Zone).

Ammonite gen. et sp. indet

Plate 6, fig. 6.

**MATERIAL:** A single, small specimen preserved as an internal mould in siltstone.

**MEASUREMENTS:**

| SPECIMEN | D  | UD  | U  | WH | WW | PRHW |
|----------|----|-----|----|----|----|------|
| C-103306 | 19 | 8.2 | 43 | 7  | -  | 14   |

**DESCRIPTION:** Shell fairly evolute, whorl section appears elliptical but the specimen has undergone some lateral compression. Umbilical wall is low, shallow, umbilical edge rounded; flanks convex. Ventral shoulder gently rounded; venter inflated.

Ornament consists of simple, straight, rectiradiate ribs that arise on the umbilical edge. The ribs then terminate at about 3/4 of the flank height in sharp tubercles. Some

of the ribs continue faintly past the tubercles, but these disappear rapidly leaving the venter featureless.

**DISCUSSION:** The small size, incomplete preservation, and unusual features of this specimen preclude its assignment to any genus previously reported from North America or elsewhere. The specimen is similar to a single specimen collected from Morocco and assigned to *Coeloderoceras* sp.? by Du Dresnay (1963). Like the Spatsizi specimen, Du Dresnay's Moroccan specimen is unituberculate on the innermost whorls (although diameters less than 10 mm are not preserved). On the outer whorls of Du Dresnay's specimen two or three slender secondaries arise from the outer row of tubercles and cross the venter.

According to Donovan *et. al.* (1981), *Coeloderoceras* is a synonym of *Epideroceras*. Both genera were created by Spath (1923) to accommodate certain forms of the family Eoderoceratidae that are much more abundant in the Mediterranean region than in the northwest European Province. *Epideroceras* (and *Coeloderoceras*) is characterized by a rounded to compressed whorl section and by straight, bituberculate ribs, although ribbing on the inner whorls of some forms may be unituberculate.

The Spatsizi specimen is also similar to another specimen from Morocco assigned to *Platypleuroceras*(?) sp. by Dubar and Mouterde (1978). Dubar and Mouterde's Moroccan specimen differs from Du Dresnay's Moroccan specimen in that the former lacks secondary ribs on the ventral surface and does not have true bituberculate ribs on the outer whorls, although Dubar and Mouterde do state that the ribs posses, in addition to ventro-lateral tubercles, "more or less distinct swellings on the lower 1/3 of the flank". Both of the Moroccan specimens (as well as the Spatsizi specimen) violate the generic definition of *Platypleuroceras* in that their primary ribs do not pass strongly across the venter.

The unsatisfactory state of knowledge of the relationship between the genera *Coeloderoceras* and *Platypleuroceras* in Morocco is exemplified in the succession of forms

described by Dubar and Mouterde (1978) for the *Jamesoni* Zone west of Mougueur. Marking the bottom of the *Jamesoni* Zone here are specimens assigned to *Coeloderoceras? lina*. Unfortunately, these specimens were neither described or illustrated, but it is apparent that the assignment of these specimens to *Coeloderoceras* is tenuous. *Platypleuroceras*(?) was found 13 m above *Coeloderoceras? lina*. One metre above *Platypleuroceras*(?), a new species, *Platypleuroceras mougueurense*, was collected. Duabar and Mouterde (1978) note, however, that this new species of *Platypleuroceras* possesses features ". . . analogous to those frequently seen in *Coeloderoceras*". A fairly unambiguous specimen of *Platypleuroceras*, assigned to *P. cf. P. rotundum* was recovered 1.3 m above the new species. It is apparent from this sequence that there exists a morphological "grey zone" between *Coeloderoceras* and *Platypleuroceras*. The position of the Spatsizi specimen, as well as Dubar and Mouterde's *Platypleuroceras*(?), within this grey zone, coupled with a lack of well preserved material, renders generic assignment problematic.

**OCCURRENCE:** The specimen of *Coeloderoceras* sp.? figured by Du Dresnay (*op. cit.*) was found in the basal part of the Pliensbachian (Carixian) section near the city of Anoual, Morocco. Dubar and Mouterde's (1978) Moroccan specimen was found just above the base of the *Jamesoni* Zone in a nearby area. The Spatsizi specimen was found *ex situ* from rocks at the base of or just below the range of *Dubariceras freboldi*.

Specimens similar to the Spatsizi specimen collected from the Queen Charlotte Islands are apparently found very low in the Pliensbachian section there, well below the range of *Dubariceras freboldi*. Associated genera in the Queen Charlotte collection include *Tropidoceras* and *Coeloceras* (H. W. Tipper, pers. comm., 1985).

Localities: 4.

**AGE:** Early Pliensbachian (*L. pinnaforme*–?*D. freboldi* Zones).

Superfamily **PSILOCERATACEAE** HYATT, 1867

## Family OXYNOTICERATIDAE HYATT, 1875

Genus *Fanninoceras* McLEARN, 1930

TYPE SPECIES *Fanninoceras fannini* McLEARN, 1930 (p. 4, pl. 1, fig. 3), by original designation.

REMARKS: Involute oxycones with overhanging umbilical wall; early whorls rounded, depressed, becoming compressed with angular venter on later whorls. Ribs on early whorls are short, stout, straight, and distant. On some forms the ribs become finer, denser, and project forward onto the venter with growth. On other forms the ribs disappear with growth, leaving the shell smooth.

The genus *Fanninoceras* has been synonymized by some workers with the European, Lower Pliensbachian genus *Radstockiceras* BUCKMAN, 1918 (Donovan and Forsey, 1973; Donovan *et al.*, 1981). Others, however, have argued for the retention of the genus *Fanninoceras* (Frebold, 1967; von Hillebrandt, 1981a; Smith and Tipper, 1984) based on its younger age (Late Pliensbachian), its unique ontogenetic variations in whorl shape, and its restricted eastern Pacific distribution.

AGE AND DISTRIBUTION: *Fanninoceras* is characteristic of the eastern Pacific faunal province. It is found in southern Alaska, western British Columbia, Oregon, Nevada, Argentina, and Chile. *Fanninoceras* is typically found in Upper Pliensbachian strata, but a few specimens have been recovered from the uppermost Lower Pliensbachian rocks of Oregon (Smith, 1981).

*Fanninoceras latum* McLEARN, 1930

Plate 9, fig. 1.

- \*1930 *Fanninoceras kunae* var. *latum* McLEARN, p. 5, pl. 2, fig. 4.
- 1932 *Fanninoceras kunae* var. *latum* McLEARN-McLEARN, p. 78, pl. 9, fig. 5, 6.
- 1981 *Fanninoceras kunae* var. *latum* McLEARN-von HILLEBRANDT, p. 513, pl. 6, fig. 6; pl. 10, fig. 4.

**MATERIAL:** One specimen preserved as an external mould in siltstone.

**MEASUREMENTS:**

| SPECIMEN   | D  | UD  | U  | WH    | WW | PRHW |
|------------|----|-----|----|-------|----|------|
| GAT83-100A | 28 | 6.5 | 23 | c11.5 | -  | C.18 |

**DESCRIPTION:** Shell is fairly involute but the umbilicus is wider than in most other species of the genus. The whorl section is not preserved, and the umbilical wall and edge have been flattened.

Ornamentation on the inner whorls consists of fairly coarse, strong and distant ribs that arise near the umbilical shoulder, trend rectiradiately, bend slightly prorsiradiately at about 2/3 of the flank height, then fade rapidly. With growth the ribs become finer, denser, gently falcoid, and do not fade on the upper flank.

**DISCUSSION:** McLearn (1930, 1932) originally defined *Fanninoceras latum* as one of three subspecies of *F. kunae* (i.e., *F. kunae kunae*, *F. kunae crassum* and *F. kunae latum*). Based on detailed studies by Smith and Tipper (1984) these three varieties have been raised to species status. This usage, part of a newly developed classification scheme for the genus *Fanninoceras*, is adopted in this study.

The Spatsizi specimen of *F. latum* compares well with the holotype from the Queen Charlotte Islands. *Fanninoceras latum* has a wider umbilicus and slightly coarser ribbing than *F. kunae*. *Fanninoceras crassum* is more coarsely ribbed and has a smaller umbilicus than *F. latum*.

**OCCURRENCE:** *Fanninoceras latum* is found in Upper Pliensbachian strata on the Queen Charlotte Islands (McLearn, 1932; Frebold, 1967), Alaska (Imlay, 1981), and Chile (von Hillebrandt, 1981a). In Spatsizi it occurs in association with *Lioceratoides propinquum*. This association has also been noted in the Queen Charlotte Islands by Frebold (1967).

Localities: 60.

**AGE:** Late Pliensbachian (*L. propinquum* Zone).

*Fanninoceras* sp.

Plate 9, fig. 2.

**MATERIAL:** A single specimen poorly preserved as an internal mould in limestone.

**MEASUREMENTS:**

| SPECIMEN | D   | UD | U | WH | WW | PRHW |
|----------|-----|----|---|----|----|------|
| C-90515  | c27 | -  | - | -  | -  | c13  |

**DESCRIPTION:** The shell is involute; whorl section is compressed. Flanks are convex; the venter is not exposed.

Ornament consists of strong, distant ribs on the inner whorls which become finer, denser and falcoid on the outermost preserved whorl.

**DISCUSSION:** Specific assignment of this specimen is impossible due to poor preservation, but judging by its coarse ribbing belong to *Fanninoceras crassum*. It differs from the specimen described above as *F. latum* in that its rib density is lower and its umbilicus, although obscured by matrix, appears narrower.

**OCCURRENCE:** *Fanninoceras* sp. is found in Upper Pliensbachian strata containing *Arietoceras* and *Leptaleoceras*.

Localities: 136.

AGE: Late Pliensbachian (*F. fannini* Zone).

Superfamily HARPOCERATACEAE NEUMAYER, 1875

Family HILDOCERATIDAE HYATT, 1867

Subfamily ARIETICERATINAE HOWARTH, 1955

Genus *Leptaleoceras* BUCKMAN, 1918

TYPE SPECIES: *Leptaleoceras leptum* BUCKMAN, 1918 (p. 284, pl. 26, fig. 1a, b) by original designation.

REMARKS: Shells evolute; whorl section compressed, elliptical. Flanks are convex, ventral shoulder is rounded. Venter narrow, carinate; keel is flanked by narrow flat zones that become sulcate on the body chamber of some species.

Ornamentation consists of dense, slightly sinuous ribs that arise at or just above the umbilical edge, trend more or less rectiradiately on the flanks, then fade out at the ventral shoulder where they project slightly. Innermost whorls, up to diameters not exceeding 10 mm, are smooth.

*Leptaleoceras* is distinguished from *Arietoceras* by its greater rib density and the non-sulcate venter observed on all but the body chamber of some species of *Leptaleoceras* (e.g., *L. accuratum* and *L. insigne*, according to Alarcon (1983)).

SYNONYMS: *Sequentia* FUCINI, 1931; *Ugdulenia* CANTALUPPI, 1970; *Trinacrioceras* FUCINI, 1931.

AGE AND DISTRIBUTION: *Leptaleoceras* is primarily a Tethyan form but is occasionally found in the boreal realm (England, France, Germany). In Europe it is found in the

Middle Domerian, in association with *Arieticerias algovianum*. In western North America *Leptaleoceras* is found associated with *Arieticerias* and rare *Fanninoceras*, indicating a Domerian age.

*Leptaleoceras* cf. *L. pseudoradians* (REYNES, 1868)

Plate 9, fig. 3–6.

- cf. \*1868 *Ammonites pseudoradians* REYNES, p. 91, pl. 1, fig. 4a–c.
- cf. 1934 *Arieticerias pseudoradians* (REYNES)–MONESTIER, p. 63, pl. 8, fig. 61, 68, non 62; non pl. 11, fig. 5.
- cf. 1957 *Leptaleoceras pseudoradians* (REYNES)–HOWARTH, p. 198, pl. 1, fig. 1, 2.
- 1964 *Leptaleoceras pseudoradians* (REYNES)–FREBOLD, p. 15, pl. 4, non pl. 5, fig. 4, 5.
- cf. 1970 *Leptaleoceras pseudoradians* (REYNES)–FREBOLD, p. 443, pl. 2, fig. 2 (1964 material partly refigured)
- cf. 1970 *Protogrammoceras pseudoradians* (REYNES)–MOUTERDE and RUGET, p. 42, pl. 1, fig. 6.
- cf. 1980 *Leptaleoceras pseudoradians* (REYNES)–WIEDENMAYER, p. 121, pl. 23, fig. 5, 6.
- cf. 1981 *Leptaleoceras* cf. *L. pseudoradians* (REYNES)–IMLAY, p. 40, pl. 11, fig. 12, 13.
- ?1981 *Arieticerias* cf. *A. domarensis* (MENEGHINI)–IMLAY, p. 39, pl. 10, fig. 15; non fig. 1, 2, 6–14, 22.

**MATERIAL:** Three fragmentary specimens preserved as external moulds in micritic calcareous concretion matrix.

**MEASUREMENTS:**



| SPECIMEN    | D     | UD  | U  | WH  | WW | PRHW |
|-------------|-------|-----|----|-----|----|------|
| C-103332(P) | c25   | c10 | 40 | c9  | -  | c25  |
| C-103332(Q) | 38.5  | 17  | 44 | c13 | -  | 26   |
| C-103224    | 31.5  | 14  | 44 | 11  | -  | 27   |
| C-90515(A)  | 39    | 19  | 49 | c13 | -  | 25   |
| C-90515(B)  | c45.5 | c19 | 42 | c15 | c5 | 27   |

**DESCRIPTION:** Fairly evolute forms with a compressed whorl section and a unicarinate venter. Ornament consists of dense, fine sigmoidal ribs. Innermost whorls smooth up to a diameter of about 6 mm.

**DISCUSSION:** The Spatsizi specimens of *L. cf. pseudoradians*, as well as conspecific material from other localities in western North America figured by Frebold (1964) and Imlay (1981; see synonymy), are less densely ribbed than the holotype of *L. pseudoradians*, and are thus not directly comparable to *L. pseudoradians* (fig. 6.2). The North American material is, nevertheless, more densely ribbed than most species of *Leptaleoceras*, and the ribs are of the same form as those of the holotype.

Rib density on the inner whorls of *L. accuratum* FUCINI, particularly the subspecies *L. accuratum preaccuratum* as figured by Alarcon (1983, pl. 11, fig. 27-29) is comparable to the Spatsizi material. However, there is a tendency toward reduced rib density with increasing diameter in *L. accuratum preaccuratum* that is not seen in the North American material (fig. 6.2). The morphologic similarity between *L. pseudoradians* and *L. accuratum* is reflected in the work of Monestier (1934) who figured three specimens as *L. pseudoradians* (Monestier, 1934, pl. 8, fig. 61, 62, 68). Subsequently, Howarth (1957) recognized that one of Monestier's specimens (pl. 8, fig. 62) did not represent *L. pseudoradians*, although Howarth offered no alternative assignment. Alarcon (1983), in turn, assigned the specimen to *L. accuratum*.

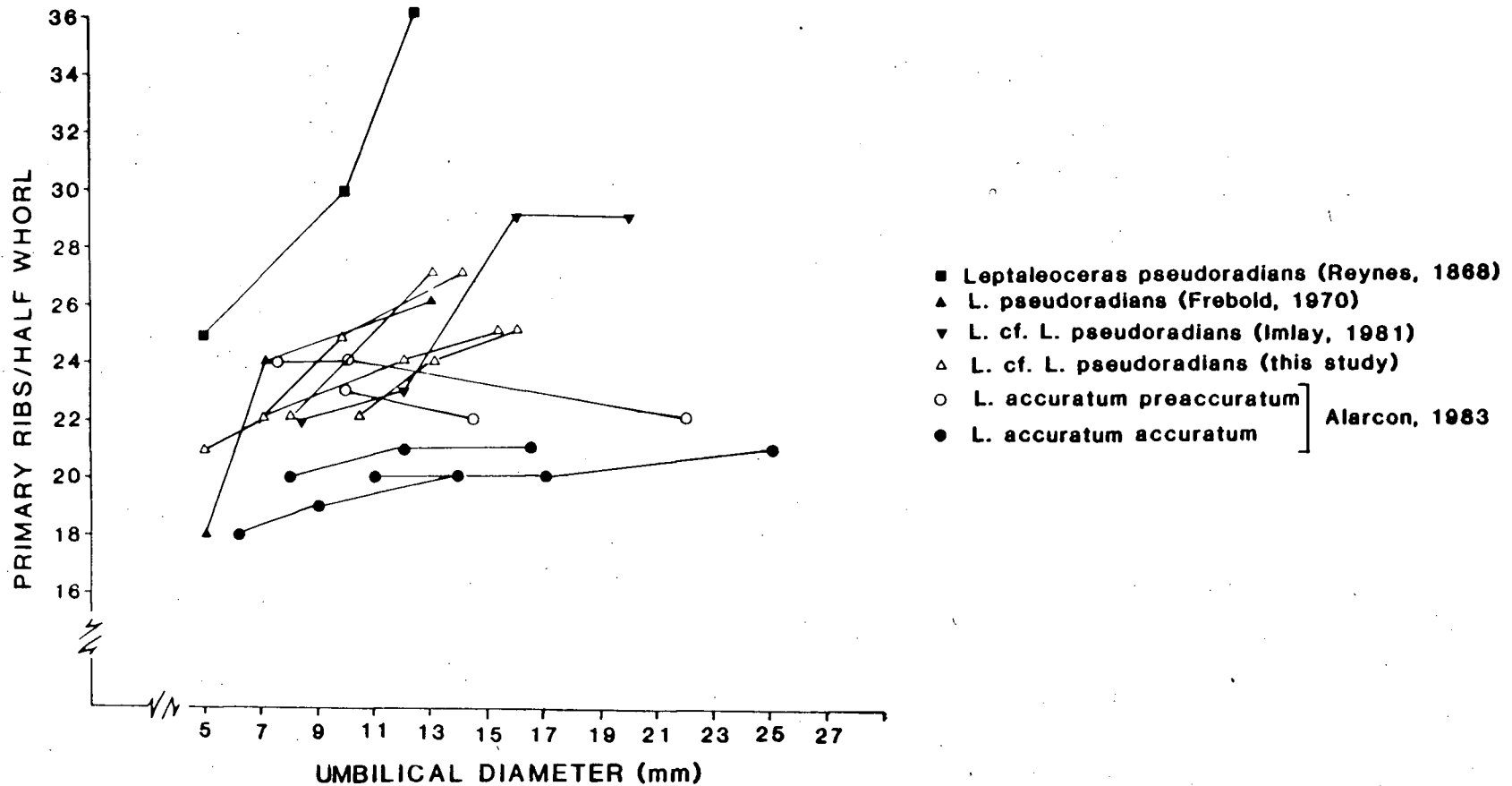


FIGURE 6.2 Graph comparing rib density between *Leptaleoceras pseudoradians* and *Leptaleoceras accuratum*. Points for specimens of *L. cf. L. pseudoradians* from the thesis map area occupy a field between the type specimen of *L. pseudoradians* (Reynes, 1868) and *L. accuratum accuratum* illustrated by Alarcon (1983). Points for specimens of *L. accuratum preaccuratum* (Alarcon, 1983) overlap the field of *L. cf. L. pseudoradians*, but show a trend towards decreasing rib density with diameter.

**OCCURRENCE:** *L. pseudoradians* is reported from the Dorset coast of England, southern France, Italy, Switzerland and Portugal. This distribution is similar to that described for the Lower Pliensbachian genus *Dayiceras* and supports the hypothesis that there may have been a Pliensbachian marine connection between the Boreal and Tethyan realm that allowed limited migration between provinces. In western North America *L. pseudoradians* has been found in northern British Columbia, southern Yukon, and southern Alaska. The Spatsizi specimens of *L. cf. L. pseudoradians* are found in the same concretion bed with *L. accuratum*, *A. algovianum*, *A. cf. A. ruthenense* and rare *Fanninoceras*.

Localities: 24, 26–28, 81, 107, 131, 132, 136.

**AGE:** Late Pliensbachian (*F. fannini* Zone).

#### Genus *Arieticer*as OPPEL, 1862

**TYPE SPECIES:** *Ammonites algovianus* OPPEL, 1862, by original designation.

**REMARKS:** Shell evolute, whorl section elliptical to quadrate. Venter unicarinate, flanked either by shallow sulci or flat zones. Ornamentation consists of strong, simple, straight to moderately sinuous ribs of moderately dense to distant spacing. Ribbing may lose relief and become striate on the outer whorls of large, adult specimens.

*Arieticer*as differs from *Leptaleoceras* by its coarser, less dense ribbing and commonly sulcate venter. *Oregonites* WIEDENMAYER is distinct from *Arieticer*as in its more irregular, often paired ribbing and generally more depressed whorl section.

**SYNONYMS:** *Seguenzicer*as LEVI, 1896; *Meneghinia* FUCINI, 1931; *Emaciaticer*as FUCINI, 1931.

**AGE AND DISTRIBUTION:** *Arieticer*as is a Tethyan form, commonly found in southern

Europe and north Africa. It has been reported from South America (Hillebrandt, 1981b), northwestern British Columbia, southern Yukon (Frebold, 1964, 1970), southern Alaska (Imlay, 1981) and from the western U.S. (Smith, 1981; Imlay, 1968).

*Arieticerias* is characteristic of the Domerian, and is most abundant in the *Algovianum* Zone of the Tethyan region (roughly equivalent to the *Margaritatus* Zone of the N.W. European Province; see Wiedenmayer (1980) and Alarcon (1983)).

*Arieticerias algovianum* (REYNES, 1868)

Plate 9, fig. 7-11.

- \*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.
- 1885 *Amm. radians crassitesta* QUENSTEDT, p. 341, pl. 42, fig. 43, 45.
- 1899 *Arieticerias algovianum* (OPPEL)-FUCINI, p. 175, pl. 24, fig. 1.
- 1908 *Hildoceras algovianum* (OPPEL)-FUCINI, p. 54, pl. 2, fig. 5, 6.
- 1909 *Segueniceras algovianum* (OPPEL)-ROSENBERG, p. 288, pl. 14, fig. 18-20.
- 1931 *Arieticerias almoetianum* FUCINI, p. 105, pl. 8, fig. 1; non fig. 2-4.
- 1934 *Arieticerias algovianum* (OPPEL)-MONESTIER, p. 55, pl. 7, fig. 1-3, non fig. 4.
- 1934 *Arieticerias paronai* GEMMELLARO-MONESTIER, p. 66, pl. 7, fig. 15, 16, 19; pl. 9, fig. 17.
- 1964 *Arieticerias algovianum* (OPPEL)-FREBOLD, p. 13, pl. 3, fig. 4, 5; pl. 4, fig. 2.
- 1964 *Arieticerias* cf. *A. algovianum* (OPPEL)-FREBOLD, p. 13, pl. 3, fig. 3; pl. 5, fig. 3, non fig. 2.
- 1968 *Arieticerias* cf. *A. algovianun* (OPPEL)-IMLAY, p. C34, pl. 4, fig. 1-8.

- 1968 *Arieticerias* cf. *A. domarense* (MENEHINI)-IMLAY, p. C33, pl. 4, fig. 9-12.
- 1977 *Arieticerias algovianum* (OPPEL)-WIEDENMAYER, p. 86, pl. 16, fig. 15, 16.
- 1980 *Arieticerias algovianum* (OPPEL)-WIEDENMAYER, p. 109, pl. 17, fig. 19, 20.
- 1981 *Arieticerias* cf. *A. algovianun* (OPPEL)-IMLAY, p. 40, pl. 10, fig. 16-20.
- 1981 *Arieticerias* cf. *A. domarense* (MENEHINI)-IMLAY p. 39, pl. 10, fig. 1, 2, 9, 10, non fig. 6-8, 11-15, 22.
- 1981 *Arieticerias* cf. *A. algovianum* (OPPEL)-SMITH, p. 292, pl. 17, fig. 1, 2.
- 1983 *Arieticerias algovianum* (OPPEL)-ALARCON, p. 226, pl. 10, fig. 1-6.
- Other synonyms, see Alarcon, 1983, and Smith, 1981.

**MATERIAL:** Thirty specimens preserved as fragmental external and internal moulds in calcareous concretion matrix and siltstone.

**MEASUREMENTS:**

| SPECIMEN    | D   | UD. | U  | WH  | WW   | PRHW |
|-------------|-----|-----|----|-----|------|------|
| C-103223(A) | c65 | 30  | 46 | -   | -    | 22   |
| C-103223(B) | 37  | 15  | 41 | -   | -    | 17   |
| C-103328    | 43  | 19  | 44 | c14 | -    | 17   |
| C-103111    | 55  | 24  | 43 | c20 | -    | 19   |
| C-90915(A)  | -   | -   | -  | 19  | 10.5 | -    |
| C-90515(B)  | 38  | 17  | 45 | 12  | 6.5  | 18   |
| C-90915(C)  | c70 | 33  | 47 | c18 | c19  | 22   |

**DESCRIPTION:** Shell evolute, whorl section ogival to rectangular. Umbilical wall low, shallow; umbilical edge rounded. Flanks are slightly convex, parallel; ventral shoulder

abruptly rounded. Venter bears a high keel bordered by flat zones or shallow sulci which, on internal moulds, appear deeper and wider than on external moulds.

Ornamentation consists of strong, slightly to moderately sinuous ribs whose spacing is equal to or just greater than their width. The ribs have an overall, slightly rursiradiate trend. In general, rib density decreases, whereas sinuosity increases with growth. The ribs arise on the umbilical edge where they trend prorsiradiately. At about 1/3 of the flank height, the ribs curve gently backward and trend rursiradiately to the ventral shoulder where they project adorally for a distance about equal to one inter-rib space, then fade along the sulci.

**DISCUSSION:** The Spatsizi material matches well with specimens of *A. algovianum* and *A. cf. A. algovianum* from northwest British Columbia as figured by Frebold (1964, 1970). The Spatsizi specimens are also similar to Imlay's (1968, 1981) figured specimens of *A. cf. A. algovianum* from Alaska and the western United States, except that Imlay's material tends to have a wider whorl section and coarser ribbing. In addition, some of the specimens assigned by Imlay (*op. cit.*) to *A. cf. A. domarensis* appear conspecific to the Spatsizi specimens of *A. algovianum*. Imlay himself states that because his *A. cf. A. domarensis* ". . . occurs with (*A. cf. A. algovianum*) at many localities and has the same stratigraphic range, it may be a variant" (1969, p. C34).

Wiedenmayer (1980) placed Imlay's (1968) *A. cf. A. algovianum* and *A. cf. A. domarensis* into the new genus *Oregonites* WIEDENMAYER (1980), which is characterized by forms with a depressed whorl section and coarser ribs of irregular relief which are often paired at the base of the flanks. Except for the compressed whorl section of some of the specimens of *A. cf. A. algovianum*, Imlay's (1968) material does not seem to differ markedly from the "conventional" definition of *A. algovianum* and is here considered a morphological variant of that species. The question as to whether or not the genus *Oregonites* is valid, or if the specimens assigned to it (Wiedenmayer, 1980) are,

instead, variants of the European genera *Arieticer*as, *Fontanelliceras*, *Fucinicer*as, or *Canavaria*, has been raised by Alarcon (1983). The status of the genus *Oregonites* is, therefore, unsatisfactory, and requires further investigation.

**OCCURRENCE:** *A. algovianum* is common in the Domerian of Tethys. It is reported from Morocco, Spain, southern France, Italy, Switzerland, and as far north as southern Germany. In North America it occurs in Mexico, the western United States, British Columbia, and southern Yukon and is found associated with *Leptaleoceras* and *Fanninoceras*.

Localities: 24, 26–28, 66, 131, 132.

**AGE:** Late Pliensbachian (*F. fannini* Zone).

*Arieticer*as cf. *A. ruthenense* (REYNES, 1868)

Plate 10; fig. 1, 2.

- cf. \*1868     *Ammonites ruthenense* REYNES, p. 94, pl. 2, fig. 4a–c.
- non 1909     *Seguenzicer*as *ruthenense* (REYNES) emend. Mgh.–ROSENBERG, p. 291, pl. 15, fig. 2a–c.
- cf. 1934     *Arieticer*as *ruthenense* (REYNES) var. *typique*–MONESTIER, p. 59, pl. 8, fig. 2, 4, 5, non fig. 1, 12, 19.
- cf. 1934     *Arieticer*as *ruthenense* (REYNES) var. *meneghiniana*–MONESTIER, p. 59, pl. 8, fig. 39, 40, non fig. 38; non pl. 11, fig. 2.
- non 1964     *Arieticer*as aff. *A. ruthenense* (REYNES)–FREBOLD, p. 14, pl. 4, fig. 3, 4 (= *Leptaleoceras* sp.)
- cf. 1968     *Fucinicer*as cf. *F. acutidorsatum* KOVACS–IMLAY, p. C41, pl. 7, fig. 22, 24.
- cf. 1977     *Arieticer*as *ruthenense* (REYNES)–WIEDENMAYER, p. 85, pl. 16, fig. 17;

pl. 17, fig. 3.

cf. 1980 *Arieticerat ruthenense* (REYNES)-WIEDENMAYER, p. 115, pl. 20, fig. 21-24; pl. 21, fig. 1, 2.

Other synonyms, see Wiedenmayer, 1977.

**MATERIAL:** Nine specimens, poorly to moderately well preserved as external and internal moulds in calcareous concretion matrix.

**MEASUREMENTS:**

| SPECIMEN | D   | UD    | U  | WH | WW   | PRHW |
|----------|-----|-------|----|----|------|------|
| C-103110 | 47  | 17    | 36 | 15 | c6   | 21   |
| C-103120 | 50  | 21    | 42 | 19 | c7.5 | 23   |
| C-103328 | c37 | c14.5 | 39 | 13 | 8    | c21  |

**DESCRIPTION:** Shell evolute, whorl section ellipsoid. Umbilical wall low, shallow; umbilical edge rounds onto convex flanks. Ventral shoulder rounded, venter convex, distinctly carinate; keel bordered by slightly depressed sulci.

Ornament consists of simple, straight to slightly sinuous ribs that arise on the umbilical edge, trend rectiradiately to slightly rursiradiately on the flanks, and project slightly at the ventral shoulder. Rib strength may vary with growth on a single specimen or between specimens; both fine to moderately coarse ribs are observed on the Spatsizi material.

**DISCUSSION:** According to Alarcon (1983), the status of the species *ruthenense*, and its relationship to other species in the genera *Arieticerat* and *Leptaleoceras* is in question. This problem is reflected in the complexity and length of the synonymy for *A. ruthenense* in Wiedenmayer (1977). Alarcon (*op. cit.*) points out the morphologic similarity between *Leptaleoceras accuratum* and *A. ruthenense* and concludes that perhaps the two forms are best considered as end members of a continuous morphologic series. In this



study *A. ruthenense* is retained, as specimens from the Spatsizi collection assigned to *A.* cf. *A. ruthenense* possess generally coarser, straighter, and less densely spaced ribs, and a less compressed whorl section, than specimens assigned to *L. accuratum*. *A. algovianum* has coarser, more sinuous ribs than *A.* cf. *A. ruthenense*.

**OCCURRENCE:** *A. ruthenense* has been found only in the Tethyan region of Europe and north Africa. Its distribution in western North America is poorly documented. A previous report of *A. ruthenense* in northwestern British Columbia (Frebold, 1964) has subsequently been questioned by Wiedenmayer (*op. cit.*; see synonymy), although Wiedenmayer also considered certain specimens from the western U.S., reported by Imlay (1968) as *Fucinieras* cf. *F. acutidorsatum*, to be conspecific with *A. ruthenense*. In Spatsizi, *A.* cf. *A. ruthenense* is found associated with *L.* cf. *L. pseudoradians*, *A. algovianum*, and rare *Fanninoceras*.

Localities: 26, 27, 106–108.

**AGE:** Late Pliensbachian (*F. fannini* Zone).

#### Subfamily HARPOCERATINAE NEUMAYR, 1875

##### Genus *Lioceratoides* SPATH, 1919

**TYPE SPECIES:** *Lioceras? grecoi* FUCINI, 1900 (p. 65, pl. 11, fig. 4) by original designation.

**REMARKS:** Shell midvolute to involute, whorl section ellipsoid to ogival. Venter is narrow and bears a keel (indistinct on some species) and is flanked by two narrow flat zones inclined towards, and separated from the flanks by an obtuse ventral shoulder. Flanks are convex, umbilical edge is rounded, and the umbilical slope ranges from gentle

to moderately steep.

Ornamentation is variable. In general, it consists of falciform ribs that arise on, or just above the umbilical seam. The ribs attain their maximum relief at  $1/3$  or  $1/2$  of the whorl height where they curve adapically. In most species the ribs weaken above the inflection point and often furcate or are separated by intercalary ribs. The ribs then swing forward at about  $2/3$  of the whorl height and fade out along the ventral shoulder. Ornamentation appears on the inner whorls at a diameter of about 5 mm. Ribbing on the inner whorls tends to be less sinuous than the strongly projecting, falciform ribs on the outer whorls.

For the most part, ornamentation of *Lioceratoides* is faint, particularly when preserved on internal moulds (Alarcon, 1983). Moreover, many of the specimens of *Lioceratoides* show a progressive fading of ornament with growth (for example, *L. angionum* FUCINI, *L. silvestrii* FUCINI, *L. naxosianum* FUCINI, *L. naumachensis* FUCINI, *L. lorioli* BETTONI, and *L. expatus* GEMMELLARO).

*Neolioceratoides* has been synonymized with *Lioceratoides* by Donovan et al. (1981), but is considered a separate genus by Wiedenmayer (1980) and Alarcon (1983). According to the proponents of *Neolioceratoides*, it differs from *Lioceratoides* in having a carinate-bisulcate venter, a more angular ventral shoulder, a less compressed whorl section, and simple (non-furcating) ribs that arise higher on the flanks than those of *Lioceratoides*.

*Fieldingiceras* (formerly *Fieldingia* CANTALUPPI) includes some forms that may be confused with *Lioceratoides*; for example, the specimens figured by Fucini (1930, pl. 6, fig. 12, 13) as *Praelioceras pseudofieldingi*. *Fieldingiceras* is more evolute than *Lioceratoides*, and has fewer, straighter ribs.

**SYNONYMS:** *Nagaticeras* MATSUMOTO, 1947.

**AGE AND DISTRIBUTION:** *Lioceratoides* is characteristic of the Tethyan Realm. It is found in the Iberian Peninsula, Morocco, the Alps of northern Italy, and Japan. It is also found in the Western Cordillera of North America. In the Mediterranean region it ranges from the Domerian to the basal Toarcian.

*Lioceratoides propinquum* (WHITEAVES, 1884)

Plate 10, fig. 3-9.

- \*1884 *Schloenbachia propinqua* WHITEAVES, p. 274, pl. 33, fig. 2, 2a.
- 1930 *Harpoceras propinquum* (WH.)-McMLEARN, p. 4.
- 1932 *H. propinquum* (WH.)-McLEARN, p. 66, pl. 6, fig. 1-4; pl. 7, fig. 3.
- 1944 *H. propinquum* (WH.)-SHIMMER 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* POLBOTKO and REPIN, p. 45, pl. 1, fig. 4,5,8.
- ?1968 *O. facetum* P. and R.-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.
- ?1968 *Protogrammoceras?* cf. *P. pseudofieldingi* (FUCINI)-IMLAY, p. C40, pl. 7, fig. 5-7.
- ?1971 *Tiloniceras propinquum* (WH.)-DAGIS, pl. 4, fig. 4,5.
- ?1974 *T. propinquum* (WH.)-DAGIS, p. 21, pl. 1, fig. 1-4; pl. 2, fig. 1.
- cf. 1980 *Lioceratoides expatus* (GEMMELLARO)-WIEDENMAYER, p. 90, pl. 13, fig. 9,10.
- 1981 *Tiloniceras propinquum* (WH.)-SMITH, p. 316, pl. 19, fig. 1-6.

**MATERIAL:** Ninety nine specimens, poorly preserved as external and internal moulds in

calcareous to non-calcareous siltstone.

**MEASUREMENTS:**

| SPECIMEN    | D   | UD  | U  | WH | WW | PRHW |
|-------------|-----|-----|----|----|----|------|
| C-103224(A) | 60  | 19  | 32 | 25 | -  | -    |
| C-103224(B) | 39  | 12  | 32 | 13 | -  | -    |
| GAT83-100A  | 32  | 8   | 23 | 14 | -  | -    |
| C-103203(A) | 33  | 9   | 28 | 15 | -  | -    |
| C-103204(C) | -   | -   | -  | 22 | c8 | -    |
| C-103204(D) | 33  | 10  | 30 | 13 | -  | -    |
| C-103204(E) | 49  | 14  | 29 | 20 | -  | -    |
| C-103332    | c46 | c11 | 24 | 19 | -  | -    |

**DESCRIPTION:** Shell is involute to midvolute; whorl section compressed, ellipsoid. Umbilical slope is low and gentle, umbilical edge rounds evenly onto slightly convex flanks. The venter is narrow and bears a keel flanked by two flat bands sloping towards the flanks; ventral shoulder is rounded.

Ornament varies through ontogeny. The innermost whorls (less than 10 mm diameter) are not observed in this collection. From about 10 to 25 mm diameter the shell is marked by an early stage of moderately distant, somewhat broad but faint primary ribs on the lower 1/3 of the flank. Just below mid-flank, these slightly prorsiradiate primaries give rise to two or three slender secondary ribs which bend backwards from the top of the primaries, then arc adorally as they approach the venter, imparting a falcoid appearance to the ribbing. Some of the secondary ribs appear to be inserted between those arising from the primary ribs. The relief of the ribbing is greatest at the point of furcation, at about 1/3 of the flank height. The ribs fade near the

ventral shoulder. With growth the ribbing becomes fainter and the slender secondaries no longer join below mid-flank, but rather, they become faciculate and fade out just above the umbilical edge. At diameters greater than about 35 mm, ribbing has almost completely faded, leaving the flanks either smooth or marked with faint, densely spaced, falcoid lirae.

**DISCUSSION:** Mounting unpublished evidence, including stratigraphic data from the Spatsizi area, indicates that *Lioceratoides propinquum*, previously placed in the genus *Tiltoniceras* and believed to be of Toarcian age, first appears in, and may be restricted to the Domerian. Ammonites from boulders in the Maude Formation (Queen Charlotte Islands) have recently been examined by M. K. Howarth (written communication to H. W. Tipper, 1980) and were found to contain specimens of *Lioceratoides propinquum* associated with specimens of the Late Pliensbachian genus *Fanninoceras* and "Harpoceras"-like forms possibly belonging to the genus *Protogrammoceras*. Subsequently, a single specimen of *Amaltheus* has been found associated with *L. propinquum* in the Maude Formation (H. W. Tipper, *pers. comm.*, 1985).

In Spatsizi, *Lioceratoides propinquum* and *Protogrammoceras paltum* have been found in the same rock (pl. 10, fig. 8). *Fanninoceras* and *L. propinquum* have also been found in association with one another, and at the Plateau section, *Lioceratoides propinquum* is found in strata below the first appearance of *Dactylioceras*. These occurrences of *L. propinquum* all indicate a Late Pliensbachian age. The relationship between *L. propinquum* and the Toarcian/Pliensbachian boundary is discussed further in the biochronology section.

**OCCURRENCE:** *L. propinquum* is abundant at its type locality in the Maude Formation on the Queen Charlotte Islands, and is also found in Oregon, Nevada (Smith, 1981), and possibly California (Imlay, 1968; see synonymy). To date, *L. propinquum* has not been found in the Mediterranean area, although similar forms have been figured (for example,

*Lioceratoides expatus* (GEMM.) in Wiedenmayer, 1980, pl. 13, fig. 9,10). There is some doubt as to whether the specimens of *Tiltoniceras propinquum* from Siberia (Dagis, 1971a, b; 1974) are conspecific with the North American material (M. K. Howarth to P. L. Smith, *pers. comm.*, 1984), thus the extension of the geographic range of *Lioceratoides propinquum* to the Soviet arctic is problematic.

Localities: 55, 56, 60, 132, 135.

AGE: Late Pliensbachian (*L. propinquum* Zone).

*Lioceratoides* sp. A

Plate 11, fig. 1.

MATERIAL: A single specimen, poorly preserved as an external mould in siltstone.

MEASUREMENTS:

| SPECIMEN    | D    | UD | U  | WH | WW | PRHW |
|-------------|------|----|----|----|----|------|
| C-103204(A) | 51.5 | 15 | 29 | 21 | -  | 19   |

DESCRIPTION: Shell is midvolte, expansion moderate; whorl section poorly preserved but appears to be elliptical. The venter bears a distinct keel that appears to be flanked by two shallow sulci. The umbilicus is shallow and the umbilical slope gentle.

Ornamentation consists of rather broad, rounded, falcoid ribs of moderate density. The ribs arise at about 2/5 the height of the flank, gently bend adapically, then swing foreward and project adorally a short distance before fading completely just below the ventral shoulder.

DISCUSSION: Certain features of this specimen suggest that it may have affinities to the genus *Neolioceratoides* as defined by Wiedenmayer (1980) and Alarcon (1983). The venter, although not well preserved, appears to be carinate-bisulcate, and the ribs are simple

(i.e., do not furcate as is usual in *Lioceratoides*). However, incomplete preservation of the specimen, together with the fact that it is the only one of its kind found in the area, would make its assignment to *Neolioceratoides*, a somewhat controversial genus heretofore unknown in North America, tenuous at best.

**OCCURRENCE:** This specimen of *Lioceratoides* sp. A is found associated with *L. propinquum* and *L.* sp. B.

Localities: 56.

**AGE:** Late Pliensbachian (*L. propinquum* Zone).

*Lioceratoides* sp. B

Plate 11, fig. 2.

**MATERIAL:** A single specimen, poorly preserved in siltstone as an external mould with part of an internal mould.

**MEASUREMENTS:**

| SPECIMEN    | D   | UD  | U  | WH  | WW | PRHW |
|-------------|-----|-----|----|-----|----|------|
| C-103204(B) | c43 | c13 | 30 | c18 | -  | c11  |

**DESCRIPTION:** Although the specimen is distorted, the whorl section appears to have been ellipsoidal. Shell is midvolute, umbilical slope is gentle and the umbilical edge is rounded. The venter is distinctly carinate and possibly bisulcate.

Ornament consists of irregularly spaced, falcoid ribs of variable relief (possibly due to preservation) that arise above the umbilical shoulder, gain their full relief at midflank, gently flex adorally, then fade below the ventral shoulder.

**DISCUSSION:** *Lioceratoides* sp. B, like *Lioceratoides* sp. A, appears to have a

carinate-bisulcate venter and the simple ribs characteristic of *Neolioceratoides*, but here again, a lack of evidence would make assignment to *Neolioceratoides* problematic.

OCCURRENCE: The specimen of *Lioceratoides* sp. B is found associated with *Lioceratoides propinquum* and *Lioceratoides* sp. A.

Localities: 56.

AGE: Late Pliensbachian (*L. propinquum* Zone).

#### Genus *Protogrammoceras* SPATH, 1913

TYPE SPECIES: *Grammoceras bassanii* FUCINI, 1900 (p. 46, pl. 10, fig. 6) by subsequent designation (Spath, 1919).

REMARKS: *Protogrammoceras* is comprised of midvolute to involute, compressed forms characterized by dense to very dense, flat-topped, falcoid ribs that project strongly onto the venter. The umbilical wall is low and may be steep to shallow. The venter bears a high keel.

*Protogrammoceras* is often confused with similar forms belonging to the genus *Fuciniceras*; the two genera can be distinguished by the fact that the ribs are more strongly projecting in *Protogrammoceras* than in *Fuciniceras*.

SYNONYMS: *Paltarpites* BUCKMAN, 1922; *Argutarpites* BUCKMAN, 1923; *Platyharpites* BUCKMAN, 1927; *Bassaniceras* FUCINI, 1923; *Eoprotogrammoceras* CANTALUPPI, 1970; *Neoprotogrammoceras* CANTALUPPI, 1970.

AGE AND DISTRIBUTION: *Protogrammoceras* was most abundant in the Tethyan region but was also common in many other parts of the world (Howarth, 1973b; Smith, 1981).



*Protogrammoceras* has been reported from various points in the circum-Pacific; from Japan (Hirano, 1971), Siberia (Sey and Kalacheva, 1980), and western North America (Imlay, 1968, 1981; Frebold, 1970; Smith, 1981).

The presence of *Protogrammoceras* in the Northwest European Province has been well documented in reports from England (Buckman, 1922, 1923, 1927; Howarth, 1973a), Eastern France and Luxembourg (Maubeuge, 1948; Maubeuge and Rioult, 1964), and Germany (Fischer, 1975). By creating the genera *Paltarpites*, *Argutarpites*, and *Platyharpites*, the early work of Buckman (1922, 1923) on these northwest European representatives of *Protogrammoceras* effectively masked their paleobiogeographic implications. The recognition of *Paltarpites* as a synonym of *Protogrammoceras* by Howarth (1973a) allowed for more detailed paleobiogeographic histories to be worked out. Smith (1981) describes how brief excursions of *Protogrammoceras* from Tethys to the Liassic seas of England resulted in the sparse appearance there of that genus during the Domerian and basal Toarcian. Fischer (1975) gives an account of how *Protogrammoceras*, in the company of *Arieticerias* and *Fucinicerias*, migrated from northern Tethys to the South-German Liassic sea during the Carixian *Ibex* Zone, and subsequently to the Northwest-German Jurassic basin during the Domerian *Margaritatus* Zone.

*Protogrammoceras paltum* BUCKMAN, 1922

Plate 11, fig. 3-5.

- \*1922     *Paltarpites paltus* BUCKMAN, pl. 362a, b.
- 1934     *Polyplectus kurrianus* OPPEL-MONESTIER, p. 90, pl. 5, fig. 23.
- 1964     *Harpoceras* cf. *H. exaratum* (YOUNG and BIRD)-FREBOLD, p. 16, pl. 6,  
fig. 1-5.
- 1970     *Paltarpites paltus* BUCKMAN-FREBOLD, p. 443, pl. 14, fig. 5-7.

- 1971 *Paltarpites paltus* BUCKMAN-HIRANO, p. 115, pl. 19, fig. 7, 8.
- ?1977 *Paltarpites paltus* (BUCKMAN)-WIEDENMAYER, p. 94, pl. 17, fig. 10.
- 1981 *Protogrammoceras* cf. *P. paltum* (BUCKMAN)-IMLAY, p. 41, pl. 12, fig. 11, 12.
- 1983 *Protogrammoceras paltum* (BUCKMAN)-HALL and HOWARTH, p. 1470, fig. 3a-d.

**MATERIAL:** Approximately twenty five specimens poorly to moderately well preserved as external moulds in siltstone and calcareous siltstone.

**MEASUREMENTS:**

| SPECIMEN     | D   | UD  | U  | WH  | WW | PRHW |
|--------------|-----|-----|----|-----|----|------|
| C-103204(P)  | c95 | c27 | 28 | c41 | -  | c50  |
| C-103204(PP) | c68 | c18 | 26 | c30 | -  | c46  |

**DESCRIPTION:** Shell compressed, fairly involute; whorl section not preserved but appears to be ellipsoid or ogival. Umbilical wall is convex, low, moderately steep; umbilical edge rounded. Flanks are convex, ventral shoulder rounded; venter is inflated and bears a high keel.

Ornament consists of dense, falcid, flat-topped ribs that are strongly projected on the venter. The width of the ribs varies slightly with growth; in general, the ribs become narrower at larger diameters.

**DISCUSSION:** *Protogrammoceras paltum* (originally assigned to *Paltarpites paltus* by Buckman, 1922) has a variable morphology as evidenced by differences seen in the holotype (pl. 362a) and paratype (pl. 362b) figured by Buckman (1922). The holotype is less involute and has a more variable (and generally greater) rib density than the paratype. The Spatsizi specimens of *P. paltum* have a comparable rib density to that of Buckman's holotype, but are more involute, as is Buckman's paratype. The variable

morphology of *P. paltum* has also been observed in collections from Arctic Canada (Hall and Howarth, 1983) and from British Columbia and the Yukon by Frebold (1970), who further states that the morphological gap between *P. paltum* and the stratigraphically equivalent *P. argutum* is bridged by transitional forms. The Spatsizi specimens may represent such transitional forms in that their rib density, while generally greater than that of most of the specimens of *P. paltum* listed in the synonymy, is less than that of *P. argutum*.

**OCCURRENCE:** *P. paltum* is a widespread species, primarily of Tethyan aspect; it is common in Europe and has also been reported from Japan (Hirano, 1971), Alaska (Imlay, 1981), the Canadian Arctic Archipelago (Hall and Howarth, 1983), and the western Cordillera of Canada (Frebold, 1970) and the United States (Smith, 1981). In Spatsizi, *P. paltum* is found associated with *Lioceratoides propinquum* and rare *Fanninoceras*, and occurs below the first appearance of *Dactylioceras*, suggesting a Late Pliensbachian age. In the Taku River area of northern British Columbia, *P. paltum* is found associated with *Amaltheus* (Frebold, 1970), also indicating a Late Pliensbachian age. Hall and Howarth (1983) have assigned the arctic specimens of *P. paltum* to the Upper Pliensbachian (*Margaritatus* Zone).

Hall and Howarth (1983) point out that *P. paltum* has a diachronous distribution. Specimens from the Northwest European Province, notably England (Howarth, 1973) and Luxembourg (Maubeuge and Rioult, 1964), are lowest Toarcian in age (Howarth, 1973). Based on biostratigraphic studies of the succession on the Yorkshire coast, Howarth (1973a) proposed the *P. paltum* subzone as the lowest division of the *Tenuicostaum* Zone. In the Alpine and Mediterranean region of Europe, however, *P. paltum* is of Late Pliensbachian age, and as discussed above, *P. paltum* is of Late Pliensbachian age in North America.

Localities: 55, 56, 60, 83, 131, 135.

AGE: Late Pliensbachian (*L. propinquum* Zone).

## 7. SUMMARY AND CONCLUSIONS

The emphasis of this study was to document the Pliensbachian ammonite fauna from the thesis map area and nearby localities, and to describe the general geology, including the lithostratigraphy, depositional history, and subsequent structural deformation of the Spatsizi Group. This study helps fill the need for an updated revision on the status of the Pliensbachian of north-central British Columbia. Previous work (that is, before about 1970) on Pliensbachian ammonites from north-central British Columbia was published prior to the widespread acceptance of modern theories concerning the tectonic evolution of the western Cordillera and to recent publications on the taxonomy of Pliensbachian faunas of both the New- and Old Worlds (for example, Wiedenmayer, 1977, 1980; Géczy, 1976; Alarcon, 1983; Smith, 1981; Imlay, 1981). Moreover, since 1970, revisions of the classification scheme for Liassic ammonites (Donovan and Forsey, 1973; Donovan *et al.*, 1981), and refinements in theories concerning Liassic paleobiogeography (Ziegler, 1981; Taylor *et al.*, 1984) and biochronology (Smith, 1981) necessitated a second look at the Pliensbachian faunas of north-central British Columbia.

Of the twenty five ammonite species examined, many of them are recorded for the first time from northern Stikina. These include *Dayiceras* sp., *Uptonia* sp., *Luningericeras pinnaforme*, *Metaderoceras silviesi*, *Metaderoceras* sp., *Reynesocoeloceras* cf. *R. incertum*, *Lioceratoides* sp. A and sp. B, *Fanninoceras latum*, and the single indeterminate specimen described on page 116 (ammonite gen. *et* sp. indet.). The specimens of *Dayiceras* sp. represent the first known specimens of that genus in North America. Specimens of *Aveyroniceras* from Spatsizi may be conspecific to material from northern Stikina previously described by Frebold (1964, 1970) as *Prodactylioceras*.

Most of the ammonites described herein are of Tethyan affinity, although some (including *Acanthopleuroceras*, *Tropidoceras*, *Uptonia*, and *Protogrammoceras*) are of unrestricted occurrence, and others (*Fanninoceras latum*, *Dubariceras freboldi*, and *Metaderoceras silviesi*) are endemic to the East Pacific faunal realm. No Boreal ammonites

were found in the thesis area. However, Boreal ammonites (*Amaltheus* and *Liparoceras* (*Becheiceras*)) found in biogeographically related faunas from areas surrounding the Spatsizi fauna on northern Stikinia indicate that the entire area occupied a position within the mixed Boreal/Tethyan zone of the eastern Pacific region during Pliensbachian times.

Stratigraphic analysis of the Spatsizi fauna shows that there are discrepancies between the ranges of certain genera in Spatsizi and the ranges of the same genera as listed in the northwest European Zonal standard, by which the Liassic faunas of western North America have been traditionally been analyzed. This, together with the presence in Spatsizi of Tethyan and East Pacific forms, and the absence of many Boreal index genera (for example, *Tragophylloceras ibex* and *Pleuroceras spinatum*), underlines the need for a revised zonal standard exclusive to western North America, such as that now being developed by Smith *et al.* (*in prep.*).

It should be noted here that although only the Pliensbachian fauna of the Spatsizi area was examined in detail in this study, a rich Toarcian fauna was also collected. Further work on the Toarcian fauna of the Spatsizi Group and more precise delineation of the Pliensbachian/Toarcian boundary would be a significant contribution to Lower Jurassic paleontology and biostratigraphy of British Columbia.

The rock sequence examined in this study is informally defined as the Spatsizi Group, and is divided into the Joan, Eaglenest, Gladys, Groves, and Walker Formations (in ascending stratigraphic order). These units will be formalized in forthcoming publications. The Spatsizi Group provides an important insight into the Lower Mesozoic geologic history of northern Stikina, and the use of ammonite biostratigraphy in understanding the geology of the Spatsizi Group has proven indispensable. Geologic events recorded in the rocks of the Spatsizi Group, such as the Early Pliensbachian, Early Toarcian, and Aalenian transgressions, and the Late Toarcian regression, correlate with similar events on a regional and global scale. Further detailed mapping, section measuring, fossil collecting, and sedimentologic studies over the entire exposure of the Spatsizi Group,

in order to determine more clearly the nature of the stratigraphic relationships and geologic history outlined in this thesis, would add considerably to the knowledge of the complex Mesozoic history of north-central British Columbia.

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## APPENDIX 1

This appendix contains print-outs of the data entered into the ammonite database discussed in Chapter 1 (Introduction). Each block of data represents the entry made for a single specimen. Data on all the specimens illustrated in this thesis (pl. 1-11) have been reproduced here, each genus appearing in the order in which it appears in the text. The title of each parameter, and the groupings into which they are placed are shown in Appendix-Figure 1, and a detailed description of each of the parameters is given by Smith (*in press*).

|                                    |                |                |                |                |               |             |               |  |  |
|------------------------------------|----------------|----------------|----------------|----------------|---------------|-------------|---------------|--|--|
| Taxonomy                           | 1 SUBORDER     |                |                | 2 SUPERFAMILY  |               |             | 3 FAMILY      |  |  |
|                                    | 4 SUBFAMILY    |                |                | 5 GENUS        |               |             | 6 SUBGENUS    |  |  |
|                                    | 7 QUALIFIER    |                |                | 8 SPECIES      |               |             | 9 SUBSPECIES  |  |  |
|                                    | 10 TAXAUTHYEAR |                |                | 11 REFAUTHYEAR |               |             | 12 SYNONYMY   |  |  |
| Quantitative Morphology            | 13 DMAX        | 14 DPHRAG      | 15 D           | 16 UD          | 17 U          | 18 EXP      | 19 WH         |  |  |
|                                    | 20 WHD         | 21 WW          | 22 WWD         | 23 WWWH        | 24 PRHW       | 25 SRHW     | 26 THW        |  |  |
|                                    | 27 BSPACE      | 28 CHW         | 29 SF          | 30 APPROX      |               |             |               |  |  |
| Qualitative Morphology             | 31 VOLUTION    | 32 WHORL SHAPE | 33 EXPANSION   |                | 34 UWALL      | 35 UWALLHT  |               |  |  |
|                                    | 36 UWALLANG    | 37 USHOULD     | 38 FLANKS      |                | 39 VENTER     | 40 VENTPROF |               |  |  |
|                                    | 41 KEEL        | 42 SULCI       | 43 PRIBD       |                | 44 PTREND     | 45 PFORM    |               |  |  |
|                                    | 46 PPROF       | 47 FURC        | 48 FURCPOS     |                | 49 SRIBD      | 50 STREND   |               |  |  |
|                                    | 51 SFORM       | 52 SPROF       | 53 TUBERC      |                | 54 UNITUBPOS  | 55 CONSTRD  |               |  |  |
|                                    | 56 CTREND      | 57 CFORM       | 58 APERTURE    |                | 59 SUTURE     | 60 ONTOGENY |               |  |  |
| Stratigraphy                       | 61 STAGE       | 62 SUBSTAGE    | 63 EURZONE     |                | 64 EURSUBZONE |             | 65 ZONE       |  |  |
|                                    | 66 SUBZONE     | 67 HORIZON     | 68 FORMATION   |                | 69 MEMBER     |             | 70 LITHOLOGY  |  |  |
|                                    | 71 DATUM       | 72 RELDATUM    | 73 SITU        |                | 74 ASSOCSPEC  |             |               |  |  |
| Locality and Catalogue Information | 75 COUNTRY     | 76 PROVINCE    | 77 LONG        |                | 78 LAT        | 79 Q        | 80 SECTNAME   |  |  |
|                                    | 81 SECTNO      | 82 LOCNO       | 83 OTHERNO     |                | 84 SUBLOCNO   |             | 85 SUPERLOCNO |  |  |
|                                    | 86 REPOSITORY  | 87 TYPE        | 88 COLLECTORYR |                | 89 GENERALOC  |             | 90 SPECNO     |  |  |
| Miscellaneous                      | 91 REMARKS1    |                |                |                |               |             |               |  |  |
|                                    | 92 REMARKS2    |                |                |                |               |             |               |  |  |
|                                    | 93 REMARKS3    |                |                |                |               |             |               |  |  |
|                                    | 94 REMARKS4    |                |                |                |               |             |               |  |  |

FIGURE AP.1 Parameters and parameter groupings of computer data used in this study.



|                                                                   |                             |                                               |                       |                                  |  |
|-------------------------------------------------------------------|-----------------------------|-----------------------------------------------|-----------------------|----------------------------------|--|
| AMMONITINA<br>POLYMORPHITINAE<br>SP.<br>THOMSON 1985              |                             | EODEROCERATACEAE<br>DAYICERAS<br>THOMSON 1985 |                       | POLYMORPHITIDAE<br>DAYICERAS SP. |  |
|                                                                   |                             |                                               |                       |                                  |  |
| 10<br>3                                                           | 6                           | 3<br>2<br>1                                   | 2<br>4<br>6           | 2<br>1R2CP5CP6<br>2              |  |
| PLIENSBAKHIAN<br>TOODOGGONE                                       | LOWER                       | JAMESONI<br>JOAN<br>1                         | 0                     | FREBOLDI<br>SILTSTONE            |  |
| CANADA<br>1<br>G.S.C.                                             | B.C.<br>PLS:83A<br>HOLOTYPE | 128.5320<br>62<br>SMITH 1983                  | 57.2915 2<br>SPATSIZI | JOAN LAKE<br>PLS:83A             |  |
|                                                                   |                             |                                               |                       |                                  |  |
| AMMONITINA<br>POLYMORPHITINAE<br>SP.<br>THOMSON 1985              |                             | EODEROCERATACEAE<br>DAYICERAS<br>THOMSON 1985 |                       | POLYMORPHITIDAE<br>DAYICERAS SP. |  |
|                                                                   |                             |                                               |                       |                                  |  |
| 10<br>3                                                           | 6                           | 3<br>2<br>1                                   | 2<br>4<br>6           | 2<br>1R2CP5CP6<br>2              |  |
| PLIENSBAKHIAN<br>TOODOGGONE                                       | LOWER                       | JAMESONI<br>JOAN<br>2                         | 0                     | FREBOLDI<br>SILTSTONE            |  |
| CANADA<br>2<br>G.S.C.                                             | B.C.<br>PLS:83B<br>HOLOTYPE | 128.5320<br>87<br>SMITH 1983                  | 57.2915 2<br>SPATSIZI | JOAN LAKE<br>PLS:83B             |  |
| Measurements not available due to fragmentary nature of specimen. |                             |                                               |                       |                                  |  |

|                                                              |                                 |            |                                                              |                       |      |                                    |  |  |
|--------------------------------------------------------------|---------------------------------|------------|--------------------------------------------------------------|-----------------------|------|------------------------------------|--|--|
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>CF.<br>(OPPEL 1853) |                                 |            | EODEROCERATACAEA<br>ACANTHOPLEURO CERAS<br>STAHLI<br>THOMSON |                       |      | POLYMORPHIDAE<br><br>A. CF. STAHLI |  |  |
| 50<br>31                                                     | 7                               | 42<br>16.7 | 19.5<br>54<br>WW                                             | 46<br>17              | 1.78 | 13<br>17                           |  |  |
| 2<br>3<br>12<br>4                                            | 6<br>1                          |            | 2<br>3<br>2<br>1                                             | 3<br>2<br>2<br>6      |      | 1<br>4<br>2R6KP7<br>2              |  |  |
| PLIENSBACHIAN                                                | LOWER                           |            | JAMESONI<br>JOAN                                             |                       |      | PINNAFORME<br>SANDSTONE            |  |  |
| TOODOGGONE                                                   | 4                               |            | 1                                                            | 12                    |      |                                    |  |  |
| CANADA<br>2<br>G.S.C.                                        | B.C.<br>81TD-S3-1A<br>HYPOTYPE  |            | 128.5320<br>137<br>TIPPER 1981                               | 57.2915 2<br>SPATSIZI |      | JOAN LAKE<br>C-90929<br>C-90930B   |  |  |
|                                                              |                                 |            |                                                              |                       |      |                                    |  |  |
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>CF.<br>(OPPEL 1853) |                                 |            | EODEROCERATACAEA<br>ACANTHOPLEURO CERAS<br>STAHLI<br>THOMSON |                       |      | POLYMORPHIDAE<br><br>A. CF. STAHLI |  |  |
| 43<br>30                                                     |                                 | 43         | 19                                                           | 44<br>17              | 1.93 | 13<br>17                           |  |  |
| 2<br>3<br>12<br>4                                            | 6<br>1                          |            | 2<br>3<br>2<br>1                                             | 3<br>2<br>2<br>6      |      | 1<br>4<br>2R6KP7<br>2              |  |  |
| PLIENSBACHIAN                                                | LOWER                           |            | JAMESONI<br>JOAN                                             |                       |      | PINNAFORME<br>SANDSTONE            |  |  |
| TOODOGGONE                                                   | 4                               |            | 1                                                            | 12                    |      |                                    |  |  |
| CANADA<br>2<br>G.S.C.                                        | B.C.<br>81TD-S3-1A<br>HYPOTYPE  |            | 128.5320<br>137<br>TIPPER 1981                               | 57.2915 2<br>SPATSIZI |      | JOAN LAKE<br>C-90929<br>C-90930A   |  |  |
|                                                              |                                 |            |                                                              |                       |      |                                    |  |  |
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>CF.<br>(OPPEL 1853) |                                 |            | EODEROCERATACAEA<br>ACANTHOPLEURO CERAS<br>STAHLI<br>THOMSON |                       |      | POLYMORPHIDAE<br><br>A. CF. STAHLI |  |  |
| 50<br>32                                                     | 11                              | 50<br>22   | 22<br>69                                                     | 44<br>18              | 1.62 | 16<br>18                           |  |  |
| 2<br>3<br>12<br>4                                            | 6<br>1                          |            | 2<br>3<br>2<br>1                                             | 3<br>2<br>2<br>6      |      | 1<br>4<br>2R6KP7<br>2              |  |  |
| PLIENSBACHIAN                                                | LOWER                           |            | JAMESONI<br>JOAN(?)                                          |                       |      | PINNAFORME<br>LIMESTONE            |  |  |
| TOODOGGONE                                                   |                                 |            | 1                                                            | 10                    |      |                                    |  |  |
| CANADA<br>G.S.C.                                             | B.C.<br>79TD-214-FA<br>HYPOTYPE |            | 128.5500<br>138<br>TIPPER 1979                               | 57.4200 2<br>SPATSIZI |      | C-819705                           |  |  |
| Located 3 miles southwest of black Fox Lake.                 |                                 |            |                                                              |                       |      |                                    |  |  |

|                                                                   |                        |                                                          |           |                                   |  |
|-------------------------------------------------------------------|------------------------|----------------------------------------------------------|-----------|-----------------------------------|--|
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>SMITH 1981               |                        | EODEROCERATACEA<br>LUNINGICERAS<br>PINNAFORME<br>THOMSON |           | POLYMORPHIDAE<br>L. PINNAFORME    |  |
| 2                                                                 | 6                      | 2                                                        | 3         | 1                                 |  |
| 3                                                                 | 1                      | 3                                                        | 2         | 4                                 |  |
| 12                                                                |                        | 2                                                        | 2         | 2R6CP7                            |  |
| 3                                                                 | 6                      | 6                                                        | 2         | 5                                 |  |
| 6P7                                                               | 3                      | 2                                                        |           | 2                                 |  |
| PLIENSBAICHIAN                                                    | LOWER                  | JAMESONI                                                 |           | PINNAFORME                        |  |
| TOODOGGONE                                                        |                        | JOAN                                                     |           | SHALE                             |  |
| CANADA                                                            | B.C.                   | 129.0000                                                 | 57.3000 2 |                                   |  |
| G.S.C.                                                            | GAT83-123B<br>HYPOTYPE | 130<br>THOMSON 1983                                      | SPATSI    | C-103222                          |  |
| Measurements unavailable due to fragmentary nature of specimen.   |                        |                                                          |           |                                   |  |
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>SP.<br>THOMSON 1985      |                        | EODEROCERATACEA<br>TROPIDOCERAS<br>THOMSON 1985          |           | POLYMORPHIDAE<br>TROPIDOCERAS SP. |  |
| 48                                                                | 48                     | 27                                                       | 1.65      |                                   |  |
|                                                                   |                        | 20                                                       |           |                                   |  |
|                                                                   |                        | DMAX, D, UD, PRHW                                        |           |                                   |  |
| 2                                                                 | 5                      | 2                                                        | 3         | 1                                 |  |
| 4                                                                 | 1                      | 3                                                        | 4         | 4                                 |  |
| 6                                                                 | 2                      | 2                                                        | 2         | 2S3CR5CP7                         |  |
| 4                                                                 |                        |                                                          |           | 2                                 |  |
| PLIENSBAICHIAN                                                    | LOWER                  | IBEX                                                     |           | FREBOLDI                          |  |
| TOODOGGONE                                                        | 12                     | JOAN                                                     | 0         | SILTSTONE                         |  |
| CANADA                                                            | B.C.                   | 129.5320                                                 | 57.2915 2 | JOAN LAKE                         |  |
| 1                                                                 | GAT83-4B               | 2                                                        |           | GAT83-4C                          |  |
| G.S.C.                                                            | HYPOTYPE               | THOMSON 1983                                             | SPATSI    | C-103304                          |  |
|                                                                   |                        |                                                          |           |                                   |  |
| AMMONITINA<br>ACANTHOPLEURO CERATINAE<br>SP.<br>THOMSON 1985      |                        | EODEROCERATACEA<br>TROPIDOCERAS<br>THOMSON 1985          |           | POLYMORPHIDAE<br>TROPIDOCERAS SP. |  |
|                                                                   |                        |                                                          |           |                                   |  |
| 2                                                                 | 1                      | 2                                                        | 3         | 1                                 |  |
| 4                                                                 |                        | 3                                                        | 4         |                                   |  |
| 6                                                                 |                        | 2                                                        | 2         | 2S3CR5CP7                         |  |
| 4                                                                 |                        |                                                          |           | 2                                 |  |
| PLIENSBAICHIAN                                                    | LOWER                  | IBEX                                                     |           | FREBOLDI                          |  |
| TOODOGGONE                                                        |                        | JOAN                                                     | 0         | SILTSTONE                         |  |
| CANADA                                                            | B.C.                   | 129.5320                                                 | 57.2915 2 | JOAN LAKE                         |  |
| 1                                                                 | GAT83-1AA              | 144                                                      |           | GAT83-4C                          |  |
| G.S.C.                                                            | HYPOTYPE               | THOMSON 1983                                             | SPATSI    | C-103311                          |  |
| Measurements not available due to fragmentary nature of specimen. |                        |                                                          |           |                                   |  |

| AMMONITINA<br>(D'ORBIGNY 1844)                                                                      |                                  | EODEROCERATACEAE<br>METADEROCERAS<br>MUTICUM<br>THOMSON 1985 |                                     | EODEROCERATIDAE<br>M. MUTICUM |                       |
|-----------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------------------------------------|-------------------------------------|-------------------------------|-----------------------|
|                                                                                                     | 28                               |                                                              | 61<br>WH. WW.                       |                               | 46                    |
| 2<br>4<br>3                                                                                         | 9<br>1                           |                                                              | 1<br>3<br>1<br>1                    | 3<br>1<br>4<br>6              | 1<br>3<br>2P5<br>2    |
| PLIENSBAICHIAN                                                                                      | LOWER                            | IBEX<br>JOAN                                                 |                                     |                               | FREBOLDI<br>SILTSTONE |
| TOODOGGONE                                                                                          | 46                               |                                                              | 2                                   |                               |                       |
| CANADA<br>2<br>G.S.C.                                                                               | B.C.<br>81TD-S3-5A<br>HYPOTYPE   | 128.5320<br>143<br>TIPPER 1981                               | 57.2915 2<br>81TD-S5-4C<br>SPATSIZI |                               | JOAN LAKE<br>C-90924  |
| Specimen tectonically compressed therefore measurements are distorted.<br>Near Joan Lake Section 4. |                                  |                                                              |                                     |                               |                       |
| AMMONITINA<br>(D'ORBIGNY 1844)                                                                      |                                  | EODEROCERATACEAE<br>METADEROCERAS<br>MUTICUM<br>THOMSON 1985 |                                     | EODEROCERATIDAE<br>M. MUTICUM |                       |
| 39<br>28                                                                                            | 9.5                              | 39<br>24                                                     | 19<br>86                            | 49<br>16                      | 1.4<br>11<br>16       |
| 4<br>3                                                                                              | 7<br>1                           |                                                              | 1<br>3<br>1<br>1                    | 3<br>1<br>4<br>6              | 1<br>3<br>2P5<br>2    |
| PLIENSBAICHIAN                                                                                      | LOWER                            | IBEX<br>JOAN                                                 |                                     |                               | FREBOLDI<br>SILTSTONE |
| TOODOGGONE                                                                                          |                                  | 1                                                            | 0                                   |                               |                       |
| CANADA<br>G.S.C.                                                                                    | B.C.<br>GAT(F)83-29A<br>HYPOTYPE | 128.5610<br>112<br>THOMSON 1983                              | 57.2855 2<br>SPATSIZI               |                               | C-90823               |
|                                                                                                     |                                  |                                                              |                                     |                               |                       |
| AMMONITINA<br>(D'ORBIGNY 1844)                                                                      |                                  | EODEROCERATACEAE<br>METADEROCERAS<br>MUTICUM<br>THOMSON 1985 |                                     | EODEROCERATIDAE<br>M. MUTICUM |                       |
| 60                                                                                                  |                                  | 60                                                           | 31<br>52<br>16<br>DMAX. UD. EXP.    | 1.71<br>16                    | 16                    |
| 2<br>4<br>3                                                                                         | 1                                |                                                              | 1<br>3<br>1<br>1                    | 3<br>4<br>6                   | 1<br>3P5<br>2         |
| PLIENSBAICHIAN                                                                                      | LOWER                            | IBEX<br>JOAN                                                 |                                     |                               | FREBOLDI<br>SILTSTONE |
| TOODOGGONE                                                                                          |                                  | 1                                                            | 4                                   |                               |                       |
| CANADA<br>G.S.C.                                                                                    | B.C.<br>81TD-S6-14<br>HYPOTYPE   | 128.5610<br>141<br>TIPPER 1981                               | 57.2855 2<br>81TD-S6-12<br>SPATSIZI |                               | C-90527               |
| Near Joan Lake Section 4.                                                                           |                                  |                                                              |                                     |                               |                       |



|                  |             |                                                              |             |                                   |           |
|------------------|-------------|--------------------------------------------------------------|-------------|-----------------------------------|-----------|
| AMMONITINA       |             | EODEROCERATACEAE<br>METADEROCERAS<br>MUTICUM<br>THOMSON 1985 |             | EODEROCERATIDAE<br><br>M. MUTICUM |           |
| (D'ORBIGNY 1844) |             |                                                              |             |                                   |           |
| 60               |             | 60                                                           | 31          | 52                                | 1.96      |
|                  |             |                                                              | 18          |                                   | 18        |
|                  |             | EXP                                                          |             |                                   |           |
| 2                |             | 1                                                            | 3           | 3                                 | 1         |
| 4                | 1           | 3                                                            | 1           | 4                                 | 2P5       |
| 3                |             | 1                                                            | 6           |                                   | 2         |
| PLIENSCHACHIAN   | LOWER       | IBEX                                                         |             |                                   | FREBOLDI  |
| TOODOGGONE       | 12          | JOAN                                                         | 7           |                                   | SILTSTONE |
| CANADA           | B.C.        | 128.5320                                                     | 57.2915 2   | JOAN LAKE                         |           |
| 1                | GAT(F)83-4C | 3                                                            | GAT(F)83-4B | GAT83-6D                          |           |
| G.S.C.           | HYPOTYPE    | THOMSON 1983                                                 | SPATSIZI    | C-103305A                         |           |
|                  |             |                                                              |             |                                   |           |
| AMMONITINA       |             | EODEROCERATACEAE<br>METADEROCERAS<br>MUTICUM<br>THOMSON 1985 |             | EODEROCERATIDAE<br><br>M. MUTICUM |           |
| (D'ORBIGNY 1844) |             |                                                              |             |                                   |           |
| 80               |             | 80                                                           | 43          | 54                                | 2.25      |
|                  |             |                                                              | 18          |                                   | 18        |
|                  |             | DMAX. UD. EXP.                                               |             |                                   |           |
| 2                | 7           | 1                                                            | 3           | 1                                 |           |
| 4                | 1           | 1                                                            | 1           | 3                                 |           |
| 3                |             | 1                                                            | 4           | 2P5                               |           |
|                  |             | 1                                                            | 6           | 2                                 |           |
| PLIENSCHACHIAN   | LOWER       | IBEX                                                         |             |                                   | FREBOLDI  |
| TOODOGGONE       | 12          | JOAN                                                         | 7           |                                   | SILTSTONE |
| CANADA           | B.C.        | 128.5320                                                     | 57.2915 2   | JOAN LAKE                         |           |
| 1                | GAT(F)83-4C | 3                                                            | GAT(F)83-4B | GAT83-6D                          |           |
| G.S.C.           | HYPOTYPE    | THOMSON 1983                                                 | SPATSIZI    | C-103305B                         |           |
|                  |             |                                                              |             |                                   |           |

|                  |             |                  |             |                 |      |
|------------------|-------------|------------------|-------------|-----------------|------|
| AMMONITINA       |             | EODEROCERATACEAE |             | EODEROCERATIDAE |      |
| (D'ORBIGNY 1844) |             | MUTICUM          |             | M. MUTICUM      |      |
| 80               |             | 80               | 43          | 54              | 2.25 |
|                  |             |                  |             | 18              | 18   |
| DMAX. UD. EXP.   |             |                  |             |                 |      |
| 2                | 7           | 1                | 3           | 1               |      |
| 4                | 1           | 1                | 1           | 3               |      |
|                  |             | 1                | 4           | 2P5             |      |
| 3                |             | 1                | 6           |                 |      |
|                  |             |                  |             | 2               |      |
| PLIENSACHIAN     | LOWER       | IBEX             |             | FREBOLDI        |      |
| TOODOGGONE       | 12          | JOAN             |             | SILTSTONE       |      |
| CANADA           | B.C.        | 128.5320         | 57.2915 2   | JOAN LAKE       |      |
| 1                | GAT(F)83-4C | 3                | GAT(F)83-4B | GAT83-6D        |      |
| G.S.C.           | HYPOTYPE    | THOMSON 1983     | SPATSIZI    | C-103305B       |      |





|                                                                                          |    |     |                                                               |    |      |                 |  |  |
|------------------------------------------------------------------------------------------|----|-----|---------------------------------------------------------------|----|------|-----------------|--|--|
| AMMONITINA                                                                               |    |     | EODEROCERATACEAE<br>METADEROCERAS<br>MOUTERDI<br>THOMSON 1985 |    |      | EODEROCERATIDAE |  |  |
| CF.<br>(FREBOLD 1970)                                                                    |    |     |                                                               |    |      | M. CF. MOUTERDI |  |  |
| 44                                                                                       |    | 44  | 21                                                            | 48 | 1.73 | 12              |  |  |
| 27                                                                                       |    |     |                                                               | 11 |      | 11              |  |  |
| 2                                                                                        |    |     | 2                                                             |    | 3    | 1               |  |  |
| 3                                                                                        | 1  |     | 3                                                             |    | 1    | 3               |  |  |
|                                                                                          |    |     | 1                                                             |    | 4    | 3P6             |  |  |
| 4                                                                                        |    |     | 1                                                             |    | 6    | 1               |  |  |
| PLIENSBACHIAN                                                                            |    |     | LOWER                                                         |    |      | FREBOLDI        |  |  |
| TOODOGGONE                                                                               |    |     | IBEX<br>JOAN                                                  |    |      | SILTSTONE       |  |  |
| CANADA                                                                                   |    |     | 128.5320                                                      |    |      | 57.2915 2       |  |  |
| 1                                                                                        |    |     | 7                                                             |    |      | GAT83-5C        |  |  |
| G.S.C.                                                                                   |    |     | THOMSON 1983                                                  |    |      | SPATSIZI        |  |  |
| HYPOTYPE                                                                                 |    |     |                                                               |    |      | C-103309        |  |  |
| Rib density decreases from inner to middle whorls.                                       |    |     |                                                               |    |      |                 |  |  |
|                                                                                          |    |     |                                                               |    |      |                 |  |  |
| AMMONITINA                                                                               |    |     | EODEROCERATACEAE<br>METADEROCERAS<br>MOUTERDI<br>THOMSON 1985 |    |      | EODEROCERATIDAE |  |  |
| CF.<br>(FREBOLD 1970)                                                                    |    |     |                                                               |    |      | M. CF. MOUTERDI |  |  |
| 78                                                                                       |    | 78  | 43                                                            | 55 | 2.07 | 20              |  |  |
|                                                                                          |    |     |                                                               | 20 |      |                 |  |  |
| 4                                                                                        | 9  |     | 2                                                             |    | 3    | 1               |  |  |
|                                                                                          | 1  |     | 3                                                             |    | 1    | 1               |  |  |
| 3                                                                                        |    |     | 1                                                             |    | 4    | 3P6             |  |  |
|                                                                                          |    |     | 1                                                             |    | 6    | 1               |  |  |
| PLIENSBACHIAN                                                                            |    |     | LOWER                                                         |    |      | FREBOLDI        |  |  |
| TOODOGGONE                                                                               |    |     | IBEX<br>JOAN                                                  |    |      | SILTSTONE       |  |  |
| CANADA                                                                                   |    |     | 128.5320                                                      |    |      | 57.2915 2       |  |  |
| 1                                                                                        |    |     | 64                                                            |    |      | JOAN LAKE       |  |  |
| G.S.C.                                                                                   |    |     | THOMSON 1983                                                  |    |      | SPATSIZI        |  |  |
| HYPOTYPE                                                                                 |    |     |                                                               |    |      | C-90843a        |  |  |
| Rib density decreases from inner to middle whorls, then increases again on outer whorls. |    |     |                                                               |    |      |                 |  |  |
|                                                                                          |    |     |                                                               |    |      |                 |  |  |
| AMMONITINA                                                                               |    |     | EODEROCERATACEAE<br>METADEROCERAS<br>MOUTERDI<br>THOMSON 1985 |    |      | EODEROCERATIDAE |  |  |
| CF.<br>(FREBOLD 1970)                                                                    |    |     |                                                               |    |      | M. CF. MOUTERDI |  |  |
| 110                                                                                      |    | 110 | 51                                                            | 46 |      | 28              |  |  |
| 25                                                                                       | 17 | 15  | 61                                                            | 23 |      | 23              |  |  |
|                                                                                          |    |     | OMAX. D. UD.                                                  |    |      |                 |  |  |
| 2                                                                                        | 7  |     | 2                                                             |    | 3    | 1               |  |  |
| 4                                                                                        | 1  |     | 3                                                             |    | 1    | 1               |  |  |
|                                                                                          |    |     | 1                                                             |    | 1    | 3P6             |  |  |
| 3                                                                                        |    |     | 1                                                             |    | 6    | 1               |  |  |
| PLIENSBACHIAN                                                                            |    |     | LOWER                                                         |    |      | FREBOLDI        |  |  |
| TOODOGGONE                                                                               |    |     | IBEX<br>JOAN                                                  |    |      | SILTSTONE       |  |  |
| CANADA                                                                                   |    |     | 128.5320                                                      |    |      | 57.2915 2       |  |  |
| 1                                                                                        |    |     | 5                                                             |    |      | JOAN LAKE       |  |  |
| G.S.C.                                                                                   |    |     | THOMSON 1983                                                  |    |      | SPATSIZI        |  |  |
| HYPOTYPE                                                                                 |    |     |                                                               |    |      | C-103307        |  |  |
| Rib density decreases from inner to middle whorls, then increases again on outer whorls. |    |     |                                                               |    |      |                 |  |  |

|                                                                                                                                                |        |                     |                                                               |                          |  |                                          |                         |           |
|------------------------------------------------------------------------------------------------------------------------------------------------|--------|---------------------|---------------------------------------------------------------|--------------------------|--|------------------------------------------|-------------------------|-----------|
| AMMONITINA                                                                                                                                     |        |                     | EODEROCERATACEAE<br>METADEROCERAS<br>EVOLUTUM<br>THOMSON 1985 |                          |  | EODEROCERATIDAE<br><br>M. EVOLUTUM       |                         |           |
| 31<br>29                                                                                                                                       | 6      | 31<br>19            | 16<br>67                                                      | 52<br>13                 |  |                                          | 9<br>13                 |           |
| D MAX. D. U. WH. WW. PRHW. THW.                                                                                                                |        |                     |                                                               |                          |  |                                          |                         |           |
| 2<br>4<br>3                                                                                                                                    | 7<br>1 |                     | 1<br>1<br>1                                                   | 3<br>1<br>4<br>6         |  |                                          | 1<br>3<br>2R6<br>2      |           |
| PLIENSACHIAN                                                                                                                                   |        | LOWER               |                                                               | JAMESONI/IBEX<br>JOAN(?) |  |                                          | PINNAFORME<br>LIMESTONE |           |
| TOODOGGONE                                                                                                                                     |        |                     | 1                                                             | 1                        |  |                                          |                         |           |
| CANADA                                                                                                                                         |        | B.C.<br>79TD-214-FA |                                                               | 128.5500<br>138          |  | 57.4200 2                                |                         |           |
| G.S.C.                                                                                                                                         |        | HYPOTYPE            |                                                               | TIPPER 1979              |  | SPATSIZI                                 |                         | C-81970a  |
| Faint inter-rib striae present and join with the primary ribs at the ventro-lateral tubercles.<br>Located 3 miles southwest of Black Fox Lake. |        |                     |                                                               |                          |  |                                          |                         |           |
| AMMONITINA                                                                                                                                     |        |                     | EODEROCERATACEAE<br>METADEROCERAS<br><br>THOMSON 1985         |                          |  | EODEROCERATIDAE<br><br>METADEROCERAS SP. |                         |           |
| SP<br>THOMSON 1985                                                                                                                             |        |                     |                                                               |                          |  |                                          |                         |           |
| 53<br>26                                                                                                                                       |        | 53                  | 28                                                            | 53<br>20                 |  | 1.70                                     | 14<br>20                |           |
| 2<br>3<br>3                                                                                                                                    | 1      |                     | 2<br>3<br>2<br>1                                              | 3<br>4<br>6              |  |                                          | 1<br>3P6<br>2           |           |
| PLIENSACHIAN                                                                                                                                   |        | LOWER               |                                                               | IBEX<br>JOAN             |  |                                          | PINNAFORME<br>SANDSTONE |           |
| TOODOGGONE                                                                                                                                     |        | 11                  |                                                               | 2                        |  | 0                                        |                         |           |
| CANADA                                                                                                                                         |        | B.C.<br>GAT83-4A    |                                                               | 128.5320                 |  | 57.2915 2                                |                         | JOAN LAKE |
| 1                                                                                                                                              |        |                     |                                                               | 1                        |  |                                          |                         |           |
| G.S.C.                                                                                                                                         |        | HYPOTYPE            |                                                               | THOMSON 1983             |  | SPATSIZI                                 |                         | C-103303  |

|                       |                               |                                         |                                    |                       |                 |
|-----------------------|-------------------------------|-----------------------------------------|------------------------------------|-----------------------|-----------------|
| AMMONITINA            |                               | EODEROCERATACEAE                        |                                    | EODEROCERATIDAE       |                 |
| (FREBOLD 1970)        |                               | DUBARICERAS<br>FREBOLDI<br>THOMSON 1985 |                                    | DUBARICERAS FREBOLDI  |                 |
| 16<br>31              |                               | 16                                      | 6<br>WH                            | 37<br>29              | 2.04<br>6<br>29 |
| 2<br>3<br>4           | 1                             | 3<br>3<br>1<br>1                        | 3<br>4<br>6                        | 1<br>1R2CP5CP6<br>2   |                 |
| PLIENSBACHIAN         | LOWER                         | JOAN                                    |                                    | FREBOLDI<br>SILTSTONE |                 |
| TOODOGGONE            | 47                            | 1                                       | 1                                  |                       |                 |
| CANADA<br>2<br>G.S.C. | B.C.<br>GAT83-36A<br>HYPOTYPE | 128.5320<br>79<br>THOMSON 1983          | 57.2915 2<br>GAT83-35A<br>SPATSIZI | JOAN LAKE<br>C-90836  |                 |

|                       |                               |                                                             |                       |                                             |    |
|-----------------------|-------------------------------|-------------------------------------------------------------|-----------------------|---------------------------------------------|----|
| AMMONITINA            |                               | EODEROCERATACEAE<br>DUBARICERAS<br>FREBOLDI<br>THOMSON 1985 |                       | EODEROCERATIDAE<br><br>DUBARICERAS FREBOLDI |    |
| (FREBOLD 1970)        |                               |                                                             |                       |                                             |    |
|                       | 11                            |                                                             | 72                    |                                             | 15 |
| 2<br>3<br>4           | 1                             | 3<br>3<br>1<br>1                                            | 3<br>4<br>6           | 1<br>1R2CP5CP6<br>2                         |    |
| PLIENSBAACHIAN        | LOWER                         | JOAN                                                        |                       | FREBOLDI<br>SILTSTONE                       |    |
| TOODOGGONE            | 10                            | 2                                                           |                       |                                             |    |
| CANADA<br>3<br>G.S.C. | B.C.<br>GAT83-66D<br>HYPOTYPE | 128.5610<br>96<br>THOMSON 1983                              | 57.2815 2<br>SPATSIZI | JOAN LAKE<br>C-103118                       |    |

|                |                   |                                                             |                 |                                             |                        |
|----------------|-------------------|-------------------------------------------------------------|-----------------|---------------------------------------------|------------------------|
| AMMONITINA     |                   | EODEROCERATACEAE<br>DUBARICERAS<br>FREBOLDI<br>THOMSON 1985 |                 | EODEROCERATIDAE<br><br>DUBARICERAS FREBOLDI |                        |
| (FREBOLD 1970) |                   |                                                             |                 |                                             |                        |
|                | 16                |                                                             | 37<br>WH. WW    |                                             | 43                     |
| 4              |                   | 3<br>1<br><br>1                                             | 3<br>4<br><br>6 |                                             | 1R2CP5CP6<br><br><br>2 |
| PLIENSBACHIAN  | LOWER             | JOAN                                                        |                 |                                             | FREBOLDI<br>SILTSTONE  |
| TOODOGGONE     | 8                 | 2                                                           | 15              |                                             |                        |
| CANADA<br>1    | B.C.<br>GAT83-51A | 128.5320<br>64                                              | 57.2915 2       | JOAN LAKE                                   |                        |
| G.S.C.         | HYPOTYPE          | THOMSON 1983                                                | SPATSIZI        | C-90843D                                    |                        |







| AMMONITINA                                                                                                                                                         |           | EODEROCERATACEAE<br>AVEYRONICERAS<br>B<br>THOMSON 1985 |           | DACTYLIOCERATIDAE<br>AVEYRONICERAS SP. B |   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------------------|-----------|------------------------------------------|---|
| SP.<br>THOMSON 1985                                                                                                                                                |           |                                                        |           |                                          |   |
| 2                                                                                                                                                                  |           | 1                                                      | 3         | 2                                        |   |
| 3                                                                                                                                                                  | 1         | 4                                                      | 4         | 1P4CR7                                   |   |
| 7                                                                                                                                                                  |           | 2                                                      |           |                                          | 1 |
| PLIENSBACHIAN                                                                                                                                                      | LOWER     | IBEX<br>JOAN                                           |           | PINNAFORME<br>SILTSTONE                  |   |
| TOODOGGONE                                                                                                                                                         | 45        | 1                                                      | 0         |                                          |   |
| CANADA                                                                                                                                                             | B.C.      | 128.5320                                               | 57.2915 2 | JOAN LAKE                                |   |
| 2                                                                                                                                                                  | GAT83-35A | 78                                                     | GAT83-34D | GAT83-36A                                |   |
| G.S.C.                                                                                                                                                             | HOLOTYPE  | THOMSON 1983                                           | SPATSIZI  | C-90835                                  |   |
| Ribs of inner whorls tuberculate, very dense; on outer whorls<br>non-tuberculate, less dense.<br>Measurements not available due to fragmentary nature of specimen. |           |                                                        |           |                                          |   |

| AMMONITINA    |          | EODEROCERATIDAE<br>INDET.<br>INDET.<br>THOMSON 1985 |           | INDET.<br>AMM. GEN. ET. SP. INDET. |      |
|---------------|----------|-----------------------------------------------------|-----------|------------------------------------|------|
| 19            |          | 19                                                  | 8.2       | 43                                 | 2.47 |
| 37            |          |                                                     | 14        | 14                                 | 7    |
| 2             | 2        | 2                                                   | 3         | 3                                  | 1    |
| 4             | 1        | 3                                                   | 1         | 1                                  | 4    |
| 5             |          | 1                                                   | 5         |                                    | 2R5  |
| PLIENSBACHIAN | LOWER    | JOAN                                                |           | FREBOLOI<br>SILTSTONE              |      |
| TOODOGGONE    | 8        | 2                                                   | 0         |                                    |      |
| CANADA        | B.C.     | 128.5320                                            | 57.2915 2 | JOAN LAKE                          |      |
| 1             | GAT83-5A | 4                                                   |           |                                    |      |
| G.S.C.        | HOLOTYPE | THOMSON 1983                                        | SPATSIZI  | C-103306                           |      |
|               |          |                                                     |           |                                    |      |



|                                               |                               |                                 |                                                              |                          |                       |                                 |                 |  |
|-----------------------------------------------|-------------------------------|---------------------------------|--------------------------------------------------------------|--------------------------|-----------------------|---------------------------------|-----------------|--|
| AMMONITINA<br>ARIETICERATIDAE<br>(OPPEL 1853) |                               |                                 | HILDOCERATACEAE<br>ARIETICERAS<br>ALGOVIANUM<br>THOMSON 1985 |                          |                       | HILDOCERATINAE<br>A. ALGOVIANUM |                 |  |
| 70<br>26                                      | 9                             | 70<br>13                        | 33<br>50                                                     | 47<br>22                 | 1.58                  | 18                              | DMAX. D. WH. WW |  |
| 3<br>14<br>4                                  | 6<br>2                        | 2<br>3<br>2                     | 3<br>4<br>2                                                  | 1<br>1P3CR5KP7<br>2      |                       |                                 |                 |  |
| PLIENSBACHIAN UPPER                           |                               |                                 | JOAN                                                         |                          |                       | FANNINI SHALE                   |                 |  |
| TOODOGGONE                                    |                               |                                 | 2                                                            |                          |                       | 10                              |                 |  |
| CANADA<br>4<br>G.S.C.                         | B.C.<br>81TD-S6-1<br>HYPOTYPE | 128.5610<br>136<br>TIPPER 1981  | 57.2855<br>81TD-S6-2<br>SPATSI                               | 2                        | JOAN LAKE<br>C-90515C |                                 |                 |  |
|                                               |                               |                                 |                                                              |                          |                       |                                 |                 |  |
| AMMONITINA<br>ARIETICERATIDAE<br>(OPPEL 1853) |                               |                                 | HILDOCERATACEAE<br>ARIETICERAS<br>ALGOVIANUM<br>THOMSON 1985 |                          |                       | HILDOCERATINAE<br>A. ALGOVIANUM |                 |  |
|                                               | 10.5                          |                                 | 55                                                           |                          |                       | 19                              |                 |  |
| 2<br>3<br>14<br>4                             | 6<br>1<br>2                   | 2<br>3<br>2                     | 3<br>4<br>2                                                  | 1<br>3<br>1P3CR5KP7<br>2 |                       |                                 |                 |  |
| PLIENSBACHIAN UPPER                           |                               |                                 | JOAN                                                         |                          |                       | FANNINI SHALE                   |                 |  |
| TOODOGGONE                                    |                               |                                 | 1                                                            |                          |                       | 10                              |                 |  |
| CANADA<br>4<br>G.S.C.                         | B.C.<br>81TD-S6-1<br>HYPOTYPE | 128.5610<br>136<br>TIPPER 1981  | 57.2855<br>81TD-S6-2<br>SPATSI                               | 2                        | JOAN LAKE<br>C-90515A |                                 |                 |  |
|                                               |                               |                                 |                                                              |                          |                       |                                 |                 |  |
| AMMONITINA<br>ARIETICERATIDAE<br>(OPPEL 1853) |                               |                                 | HILDOCERATACEAE<br>ARIETICERAS<br>ALGOVIANUM<br>THOMSON 1985 |                          |                       | HILDOCERATINAE<br>A. ALGOVIANUM |                 |  |
| 55<br>36                                      |                               | 55                              | 23.5<br>WH                                                   | 43<br>19                 | 2.62                  | 20                              |                 |  |
| 3<br>14<br>4                                  | 6<br>1<br>2                   | 2<br>3<br>2                     | 3<br>4<br>2                                                  | 1<br>3<br>1P3CR5KP7<br>2 |                       |                                 |                 |  |
| PLIENSBACHIAN UPPER                           |                               |                                 | EAGLENEST                                                    |                          |                       | FANNINI SHALE                   |                 |  |
| TOODOGGONE                                    |                               |                                 | 1                                                            |                          |                       | 5                               |                 |  |
| CANADA<br>4<br>G.S.C.                         | B.C.<br>GAT83-65A<br>HYPOTYPE | 128.5610<br>107<br>THOMSON 1983 | 57.2855<br>SPATSI                                            | 2                        | JOAN LAKE<br>C-103111 |                                 |                 |  |
|                                               |                               |                                 |                                                              |                          |                       |                                 |                 |  |







|                                                                        |                                |                                                               |                                     |                                     |                     |      |
|------------------------------------------------------------------------|--------------------------------|---------------------------------------------------------------|-------------------------------------|-------------------------------------|---------------------|------|
| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886)                       |                                | HILDOCERATACEAE<br>LIOCRATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                     | HILDOCERATIDAE<br>L. PROPINQUUM     |                     |      |
| 32.5<br>45                                                             |                                | 32.5                                                          | 9<br>SRHW                           | 28<br>15                            | 2.78<br>33          | 14.5 |
| 4<br>4<br>12<br>3<br>4R5CP6                                            | 2<br>1<br>2<br>3               | 3<br>3<br>1<br>4                                              | 3<br>2<br>4<br>2                    | 1<br>4<br>4                         | 3P4CR5CP6<br>4<br>1 |      |
| PLIENSBACHIAN                                                          | UPPER                          | EAGLENEST                                                     |                                     | PROPINQUUM                          |                     |      |
| TOODOGGONE                                                             | 98                             | 1                                                             | 17                                  | SHALE                               |                     |      |
| CANADA<br>1<br>G.S.C.                                                  | B.C.<br>GAT83-99A<br>HYPOTYPE  | 128.5320<br>55<br>THOMSON 1983                                | 57.2915 2<br>SPATSIZI               | JOAN LAKE<br>GAT83-99D<br>C-103203A |                     |      |
| Secondary ribs become primary at UD=7.5 mm. Ribbing fades at UD>10 mm. |                                |                                                               |                                     |                                     |                     |      |
| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886)                       |                                | HILDOCERATACEAE<br>LIOCRATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                     | HILDOCERATIDAE<br>L. PROPINQUUM     |                     |      |
| 38.5<br>35                                                             |                                | 38.5                                                          | 12.5                                | 32.5                                | 1.60                | 13.5 |
| 3<br>4<br>12                                                           | 2<br>1                         | 2<br>3                                                        | 3<br>2                              | 1<br>4                              | 2                   |      |
| PLIENSBACHIAN                                                          | UPPER                          | JOAN(?)                                                       |                                     | PROPINQUUM                          |                     |      |
| TOODOGGONE                                                             |                                | 2                                                             | 10                                  | CALC. SHALE                         |                     |      |
| CANADA<br>Y<br>G.S.C.                                                  | B.C.<br>GAT83-125B<br>HYPOTYPE | 128.5150<br>132<br>THOMSON 1983                               | 57.3500 2<br>GAT83-125A<br>SPATSIZI | SECTION<br>GAT83-126A<br>C-103224B  |                     |      |

|                                                      |                               |                                                                |                                     |                                     |                           |    |
|------------------------------------------------------|-------------------------------|----------------------------------------------------------------|-------------------------------------|-------------------------------------|---------------------------|----|
| AMMONITINA<br>HARPOCERATINAE<br><br>(WHITEAVES 1886) |                               | HILDOCERATACEAE<br>LIOCERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                     | HILDOCERATIDAE<br><br>L. PROPINQUUM |                           |    |
| 59<br>42                                             |                               | 59                                                             | 19                                  | 32                                  | 2.7                       | 25 |
| 4<br>4<br>12                                         | 2<br>1                        | 3<br>3                                                         | 3<br>2                              | 1<br>4                              | 2                         |    |
| PLIENSBACHIAN                                        |                               | UPPER                                                          | EAGLENEST                           | 10                                  | PROPINQUUM<br>CALC. SILTS |    |
| TOODOGGONE                                           |                               |                                                                | 2                                   |                                     |                           |    |
| CANADA<br>X<br>G.S.C.                                | B C<br>GAT83-125B<br>HYPOTYPE | 128.5150<br>132<br>THOMSON 1983                                | 57.3500 2<br>GAT83-125A<br>SPATSIZI | SECTION<br>GAT83-126A<br>C-103224A  |                           |    |

| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886) |                               | HILDOCERATACEAE<br>LIO CERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                        | HILDOCERATIDAE<br>L. PROPINQUUM     |    |
|--------------------------------------------------|-------------------------------|-----------------------------------------------------------------|----------------------------------------|-------------------------------------|----|
|                                                  | 8                             |                                                                 | 36                                     |                                     | 22 |
| 3<br>4<br>12                                     | 2<br>1                        | 2<br>3                                                          | 3<br>2                                 | 1<br>4                              | 2  |
| PLIENSBACHIAN                                    | UPPER                         | JOAN(?)                                                         |                                        | PROPINQUUM                          |    |
| TOODOGGONE                                       | 95                            | 2                                                               | 0                                      | CALC. SHALE                         |    |
| CANADA<br>1<br>G.S.C.                            | B.C.<br>GAT83-99B<br>HYPOTYPE | 128.5320<br>56<br>THOMSON 1983                                  | 57.2915 2<br>GAT83-13A.B.C<br>SPATSIZI | JOAN LAKE<br>GAT83-14A<br>C-103204C |    |
|                                                  |                               |                                                                 |                                        |                                     |    |
| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886) |                               | HILDOCERATACEAE<br>LIO CERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                        | HILDOCERATIDAE<br>L. PROPINQUUM     |    |
| 33<br>39                                         | 33                            | 10<br>D, UD, WH                                                 | 30                                     |                                     | 13 |
| 3<br>4<br>12                                     | 2<br>1                        | 2<br>3                                                          | 3<br>2                                 | 1<br>4                              | 2  |
| PLIENSBACHIAN                                    | UPPER                         | JOAN(?)                                                         |                                        | PROPINQUUM                          |    |
| TOODOGGONE                                       | 95                            | 2                                                               | 0                                      | CALC. SHALE                         |    |
| CANADA<br>1<br>G.S.C.                            | B.C.<br>GAT83-99B<br>HYPOTYPE | 128.5320<br>56<br>THOMSON 1983                                  | 57.2915 2<br>GAT83-13A.B.C<br>SPATSIZI | JOAN LAKE<br>GAT83-14A<br>C-103204D |    |
|                                                  |                               |                                                                 |                                        |                                     |    |
| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886) |                               | HILDOCERATACEAE<br>LIO CERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                                        | HILDOCERATIDAE<br>L. PROPINQUUM     |    |
| 49<br>41                                         | 49                            | 14<br>UD                                                        | 29                                     |                                     | 20 |
| 3<br>4<br>12                                     | 2<br>1                        | 2<br>3                                                          | 3<br>2                                 | 1<br>4                              | 2  |
| PLIENSBACHIAN                                    | UPPER                         | JOAN(?)                                                         |                                        | PROPINQUUM                          |    |
| TOODOGGONE                                       | 95                            | 2                                                               | 0                                      | CALC. SHALE                         |    |
| CANADA<br>1<br>G.S.C.                            | B.C.<br>GAT83-99B<br>HYPOTYPE | 128.5320<br>56<br>THOMSON 1983                                  | 57.2915 2<br>GAT83-13A.B.C<br>SPATSIZI | JOAN LAKE<br>GAT83-14A<br>C-103204E |    |
|                                                  |                               |                                                                 |                                        |                                     |    |



|                                                     |                               |       |                                                                |          |                                       |                                       |  |  |
|-----------------------------------------------------|-------------------------------|-------|----------------------------------------------------------------|----------|---------------------------------------|---------------------------------------|--|--|
| AMMONITINA<br>HARPOCERATINAE<br>(WHITEAVES 1886)    |                               |       | HILDOCERATACEAE<br>LIOCERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |          |                                       | HILDOCERATIDAE<br>L. PROPINQUUM       |  |  |
| 46<br>41                                            |                               | 46    | 11                                                             | 24       | 2.54                                  | 19                                    |  |  |
| 4<br>4<br>12                                        | 2<br>1                        |       | 3<br>3                                                         |          | 3<br>2                                | 1<br>4                                |  |  |
| PLIENSBAKHIAN                                       |                               | UPPER | EAGLENEST                                                      |          |                                       | PROPINQUUM<br>SHALES                  |  |  |
| TOODOGGONE                                          |                               |       | 1                                                              |          | 0                                     |                                       |  |  |
| CANADA<br>1<br>G.S.C.                               | B.C.<br>GAT83-13B<br>HYPOTYPE |       | 128.5320<br>27<br>THOMSON 1983                                 |          | 57.2915 2<br>SPATSIZI                 | JOAN LAKE<br>C-103332                 |  |  |
|                                                     |                               |       |                                                                |          |                                       |                                       |  |  |
| AMMONITINA<br>HARPOCERATINAE<br>SP.<br>THOMSON 1985 |                               |       | HILDOCERATACEAE<br>LIOCERATOIDES<br>A<br>THOMSON 1985          |          |                                       | HILDOCERATIDAE<br>LIOCERATOIDES SP. A |  |  |
| 51.5<br>41                                          |                               | 51.5  | 15                                                             | 29<br>19 | 2.04                                  | 21                                    |  |  |
| 3<br>4<br>12<br>3                                   | 2<br>1<br>2                   |       | 2<br>3<br>1                                                    |          | 3<br>4<br>3                           | 1<br>4<br>3P4CR5CP6                   |  |  |
| PLIENSBAKHIAN                                       |                               | UPPER | EAGLENEST                                                      |          |                                       | PROPINQUUM<br>SHALES                  |  |  |
| TOODOGGONE                                          |                               | 95    | 2                                                              |          | 0                                     |                                       |  |  |
| CANADA<br>1<br>G.S.C.                               | B.C.<br>GAT83-99B<br>HOLOTYPE |       | 128.5320<br>56<br>THOMSON 1983                                 |          | 57.2915 2<br>GAT83-13A, B<br>SPATSIZI | JOAN LAKE<br>GAT83-14A<br>C-103204A   |  |  |
|                                                     |                               |       |                                                                |          |                                       |                                       |  |  |
| AMMONITINA<br>HARPOCERATINAE<br>SP.<br>THOMSON 1985 |                               |       | HILDOCERATACEAE<br>LIOCERATOIDES<br>B<br>THOMSON 1985          |          |                                       | HILDOCERATIDAE<br>LIOCERATOIDES SP. B |  |  |
| 45<br>42                                            |                               | 43    | 13                                                             | 30<br>11 |                                       | 18                                    |  |  |
| 3<br>4<br>3                                         | 2<br>1<br>2                   |       | 2<br>3<br>1                                                    |          | 3<br>4<br>4                           | 1<br>4<br>3P4CR5CP5                   |  |  |
| PLIENSBAKHIAN                                       |                               | UPPER | EAGLENEST                                                      |          |                                       | PROPINQUUM<br>SHALES                  |  |  |
| TOODOGGONE                                          |                               | 95    | 2                                                              |          | 0                                     |                                       |  |  |
| CANADA<br>1<br>G.S.C.                               | B.C.<br>GAT83-99B<br>HOLOTYPE |       | 128.5320<br>56<br>THOMSON 1983                                 |          | 57.2915 2<br>GAT83-13A, B<br>SPATSIZI | JOAN LAKE<br>GAT83-14A<br>C-103204B   |  |  |

|                                                      |                                |                                                                 |                       |                                     |         |
|------------------------------------------------------|--------------------------------|-----------------------------------------------------------------|-----------------------|-------------------------------------|---------|
| AMMONITINA<br>HARPOCERATINAE<br><br>(WHITEAVES 1886) |                                | HILDOCERATACEAE<br>LIOECERATOIDES<br>PROPINQUUM<br>THOMSON 1985 |                       | HILDOCERATIDAE<br><br>L. PROPINQUUM |         |
| 32<br>43                                             |                                | 32                                                              | 7.5                   | 23                                  | 2.37 14 |
| 4<br>4<br>12                                         | 2<br>1                         | 3<br>3                                                          | 3<br>2                | 1<br>4                              | 2       |
| PLIENSCHACHIAN UPPER                                 |                                | EAGLENEST<br>2                                                  | 15                    | PROPINQUUM<br>SHALE                 |         |
| TOODOGGONE                                           |                                |                                                                 |                       |                                     |         |
| CANADA<br>1<br>G.S.C.                                | B.C.<br>GAT83-100A<br>HYPOTYPE | 128.5320<br>60<br>THOMSON 1983                                  | 57.2915 2<br>SPATSIZI | JOAN LAKE<br>GAT83-100A             |         |

|                                                |                               |                                                               |                                    |                                 |            |
|------------------------------------------------|-------------------------------|---------------------------------------------------------------|------------------------------------|---------------------------------|------------|
| AMMONITINA<br>HARPOCERATINAE<br>(BUCKMAN 1922) |                               | HILDOCERATACEAE<br>PROTOGRAMMOCERAS<br>PALTUM<br>THOMSON 1985 |                                    | HILDOCERATIDAE<br><br>P. PALTUM |            |
| 95<br>43                                       |                               | 95                                                            | 27                                 | 28<br>50                        | 1.89<br>41 |
| DMAX, D. UD. WH. PRHW                          |                               |                                                               |                                    |                                 |            |
| 3<br>4<br>6<br>2                               | 1                             | 3<br>3<br>2                                                   | 3<br>2<br>4                        | 1<br>4<br>1R2CP4KP7             | 1          |
| PLIENSACHIAN                                   | UPPER                         | EAGLENEST<br>EX                                               | O                                  | PROPINQUUM<br>SHALE             |            |
| TOODOGGONE                                     | 92                            |                                                               |                                    |                                 |            |
| CANADA<br>1<br>G.S.C.                          | B.C.<br>GAT83-99B<br>HYPOTYPE | 128.5320<br>56<br>THOMSON 1983                                | 57.2915 2<br>GAT83-13A<br>SPAPSIZI | JOAN LAKE<br>C-103204P          |            |
| Rib density varies with growth.                |                               |                                                               |                                    |                                 |            |

|                                                    |                               |       |                                                               |             |                                    |                                 |                          |  |
|----------------------------------------------------|-------------------------------|-------|---------------------------------------------------------------|-------------|------------------------------------|---------------------------------|--------------------------|--|
| AMMONITINA<br>HARPOCERATINAE<br><br>(BUCKMAN 1922) |                               |       | HILDOCERATACEAE<br>PROTOGRAMMOCERAS<br>PALTUM<br>THOMSON 1985 |             |                                    | HILDOCERATIDAE<br><br>P. PALTUM |                          |  |
| 68<br>44                                           |                               | 68    | 18                                                            | 26<br>J6    |                                    | 1.81                            | 30                       |  |
| D MAX. D. UD. WH. PRHW                             |                               |       |                                                               |             |                                    |                                 |                          |  |
| 3<br>4<br>6<br>2                                   | 1                             |       | 3<br>3<br>2                                                   | 3<br>2<br>4 |                                    |                                 | 1<br>4<br>1R2CP4KP7      |  |
| PLIENSBACHIAN                                      |                               | UPPER | EAGLENEST<br>EX                                               |             | O                                  |                                 | 1<br>PROPINQUUM<br>SHALE |  |
| TOODOGGONE                                         |                               | 92    |                                                               |             |                                    |                                 |                          |  |
| CANADA<br>1<br>G.S.C.                              | B.C.<br>GAT83-99B<br>HYPOTYPE |       | 128.5320<br>56<br>THOMSON 1983                                |             | 57 2915 2<br>GAT83-13A<br>SPARSIZI |                                 | JOAN LAKE<br>C-1032040   |  |
| Rib density varies with growth.                    |                               |       |                                                               |             |                                    |                                 |                          |  |

| AMMONITINA<br>HARPOCERATINAE<br>(BUCKMAN 1922) |                                | HILDOCERATACEAE<br>PROTOGRAMMOCERAS<br>PALTUM<br>THOMSON 1985 |                                    | HILDOCERATIDAE<br>P. PALTUM |  |
|------------------------------------------------|--------------------------------|---------------------------------------------------------------|------------------------------------|-----------------------------|--|
|                                                |                                |                                                               |                                    |                             |  |
| 3<br>4<br>6<br>2                               | 1                              | 3<br>3<br>2                                                   | 3<br>2<br>4                        | 1<br>4<br>1R2CP4KP7<br>1    |  |
| PLYENSBACHIAN<br>TOODOGGONE                    | UPPER                          | EAGLENEST<br>EX                                               | O                                  | PROPINQUUM<br>SHALE         |  |
| CANADA<br>1<br>G.S.C.                          | B.C.<br>GAT83-100A<br>HYPOTYPE | 128.5320<br>60<br>THOMSON 1983                                | 57.2915 2<br>GAT83-13A<br>SPAPSIZI | JOAN LAKE<br>GAT-100A(P     |  |
| Rib density varies with growth.                |                                |                                                               |                                    |                             |  |

APPENDIX 2

## LOCALITY DATA

SECTION 1 LOCALITIES:

See fig. MAP for position of Section 1; see fig. SEC1 for position of localities in Section 1.

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 1                 | GAT(F)83-4A       | C-103303        |                | *              |                 |
| 2                 | GAT(F)83-4B       | C-103304        | *              |                |                 |
| 3                 | GAT(F)83-4C       | C-103305        | *              |                |                 |
| 4                 | GAT(F)83-5A       | C-103306        | *              |                |                 |
| 5                 | GAT(F)83-5B       | C-103307        |                | *              |                 |
| 6                 | GAT(F)83-5C       | C-103308        | *              |                |                 |
| 7                 | GAT(F)83-5D       | C-103309        | *              |                |                 |
| 8                 | GAT(F)83-5E       | C-103310        | *              |                |                 |
| 9                 | GAT(F)83-6A       | C-103314        | *              |                |                 |
| 10                | GAT(F)83-6B       | C-103315        | *              |                |                 |
| 11                | GAT(F)83-6C       | C-103316        | *              |                |                 |
| 12                | GAT(F)83-6D       | C-103317        | *              |                |                 |
| 13                | GAT(F)83-6E       | C-103318        |                | *              |                 |
| 14                | GAT(F)83-6F       | C-103319        |                | *              |                 |
| 15                | GAT(F)83-7A       | C-103320        | *              |                |                 |
| 16                | GAT(F)83-7B       | C-103321        | *              |                |                 |
| 17                | GAT(F)83-7C       | C-103322        | *              |                |                 |
| 18                | GAT(F)83-8A       | C-103323        |                | *              |                 |
| 19                | GAT(F)83-8B       | C-103324        | *              |                |                 |
| 20                | GAT(F)83-8C       | C-103325        | *              |                |                 |
| 21                | GAT(F)83-9A       | C-103326        | *              |                |                 |
| 22                | GAT(F)83-9B       | C-103327        | *              |                |                 |
| 23                | GAT(F)83-11A      | C-103329        | *              |                |                 |
| 24                | GAT(F)83-11B      | C-103331        | *              |                |                 |
| 25                | GAT(F)83-12A      | C-103330        |                | *              |                 |
| 26                | GAT(F)83-13A      | C-103328        | *              |                |                 |
| 27                | GAT(F)83-13B      | C-103332        | *              |                |                 |
| 28                | GAT(F)83-13C      | C-103325        | *              |                |                 |
| 29                | GAT(F)83-14A      | C-103335        | *              |                |                 |
| 30                | GAT(F)83-15B      | C-103339        | *              |                |                 |
| 31                | GAT(F)83-16C      | C-103333        | *              |                |                 |
| 32                | GAT(F)83-18C      | C-103348        | *              |                |                 |
| 33                | GAT(F)83-19B      | C-103350        | *              |                |                 |
| 34                | GAT(F)83-20A      | C-90805         |                | *              |                 |
| 35                | GAT(F)83-21A      | C-90806         |                | *              |                 |
| 36                | GAT(F)83-21B      | C-90826         |                | *              |                 |
| 37                | GAT(F)83-22B      | C-90808         | *              |                |                 |
| 38                | GAT(F)83-22C      | C-90809         |                | *              |                 |
| 39                | GAT(F)83-22D      | C-90810         |                | *              |                 |
| 40                | GAT(F)83-23A      | C-90811         |                | *              |                 |
| 41                | GAT(F)83-23B      | C-90812         |                | *              |                 |

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 42                | GAT(F)83-23C      | C-90813         | *              |                |                 |
| 43                | GAT(F)83-23D      | C-90814         | *              |                |                 |
| 44                | GAT(F)83-23E      | C-90815         | *              |                |                 |
| 45                | GAT(F)83-23F      | C-90822         |                | *              |                 |
| 46                | GAT(F)83-24A      | C-90816         |                | *              |                 |
| 47                | GAT(F)83-24B      | C-90817         | *              |                |                 |
| 48                | GAT(F)83-25A      | C-90818         | *              |                |                 |
| 49                | GAT(F)83-26A      | C-90819         |                | *              |                 |
| 50                | GAT(F)83-27A      | C-90820         |                | *              |                 |
| 51                | GAT(F)83-27B      | C-90821         |                | *              |                 |
| 52                | GAT(F)83-110A     | C-103213        |                | *              | Belemnite       |
| 53                | GAT(F)83-110B     | C-103215        |                | *              |                 |
| 54                | GAT(F)83-111B     | C-103214        |                | *              |                 |
| 55                | GAT(F)83-99A      | C-103203        | *              |                |                 |
| 56                | GAT(F)83-99B      | C-103204        | *              |                |                 |
| 57                | GAT(F)83-99C      | C-103205        |                | *              |                 |
| 58                | GAT(F)83-99D      | C-103206        | *              |                |                 |
| 59                | GAT(F)83-99E      | C-103207        |                | *              |                 |
| 60                | GAT(F)83-100A     |                 |                | *              |                 |
| 61                | GAT(F)83-100B     | C-90839         |                | *              |                 |

SECTION 1 VICINITY:

The following localities are positioned close to, but not directly on the line of Section 1. See fig. MAP for exact position of each of the following localities.

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                                                                           |
|-------------------|-------------------|-----------------|----------------|----------------|-------------------------------------------------------------------------------------------|
| 62                | PLS:83-A          |                 | *              |                | Collected by Dr. P.L. Smith, 1983, lower siltstones of Unit 1, approx. 150m east of lake. |
| 63                | GAT(F)83-43A      | C-90839         |                | *              | Collected from lower siltstones of Unit 1, 100m west of Section 1.                        |
| 64                | GAT(F)83-51A      | C-90843         | *              |                | Collected from lower siltstones of Unit 1, 250m east of Section 1.                        |
| 65                | GAT(F)83-51B      | C-90844         |                | *              | Collected just below Unit 5 near eastern nose of anticline.                               |
| 66                | GAT(F)83-51C      | C-90845         |                | *              | Collected from Unit 5 float, just above loc. 65.                                          |

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>       |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------------|
| 67                | GAT(F)83-51D      | C-90846         |                | *              | Collected from Unit 3 |
| 68                | GAT(F)83-51E      | C-103112        |                | *              | Collected from Unit 3 |
| 69                | GAT(F)83-51F      |                 |                | *              | Nautiloid from Unit 5 |

## SECTION 2 LOCALITIES:

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                                                                |
|-------------------|-------------------|-----------------|----------------|----------------|--------------------------------------------------------------------------------|
| 70                | GAT(F)83-32A      | C-90827         |                | *              |                                                                                |
| 71                | GAT(F)83-33A      | C-90828         | *              |                |                                                                                |
| 72                | GAT(F)83-33B      | C-90829         | *              |                |                                                                                |
| 73                | GAT(F)83-33C      | C-90830         | *              |                |                                                                                |
| 74                | GAT(F)83-34A      | C-90831         |                | *              |                                                                                |
| 75                | GAT(F)83-34B      | C-90832         | *              |                |                                                                                |
| 76                | GAT(F)83-34C      | C-90833         | *              |                |                                                                                |
| 77                | GAT(F)83-34D      | C-90834         | *              |                |                                                                                |
| 78                | GAT(F)83-35A      | C-90835         | *              |                |                                                                                |
| 79                | GAT(F)83-36A      | C-90836         | *              |                |                                                                                |
| 80                | GAT(F)83-36B      | C-90837         |                | *              |                                                                                |
| 81                | GAT(F)83-37A      | C-90841         | *              |                |                                                                                |
| 82                | GAT(F)83-37B      | C-90842         |                | *              |                                                                                |
| 83                | GAT(F)83-38A      | C-90838         | *              |                |                                                                                |
| 84                | GAT(F)83-42A      | C-90840         |                | *              |                                                                                |
| 85                | GAT(F)83-47A      | C-90847         |                | *              | Collected from contact between Units 3 & 5, in cirque 200m north of Section 2. |
| 86                | GAT(F)83-49A      | C-90848         | *              |                | Collected from limestone bed in Ashman Fm., on ridge 200m west of loc.85.      |
| 87                | PLS:83-B          |                 | *              |                | Collected by Dr. Paul Smith from the lower siltstones of Unit 1.               |

SECTION 3 LOCALITIES:

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 88                | GAT(F)83-55A      | C-103101        | *              |                |                 |
| 89                | GAT(F)83-56A      | C-103102        | *              |                |                 |
| 90                | GAT(F)83-58A      | C-103102        |                | *              |                 |

SECTION 3 VICINITY:

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                                              |
|-------------------|-------------------|-----------------|----------------|----------------|--------------------------------------------------------------|
| 91                | GAT(F)83-53A      | C-90849         |                | *              | Collected from Unit 5 about 300 west of section 3.           |
| 92                | GAT(F)83-54A      | C-90850         | *              |                | Collected from Unit 1 in creek gully 300m east of Section 3. |
| 93                | GAT(F)83-54C      | C-103113        |                | *              | As for loc. 92                                               |
| 94                | GAT(F)83-66B      | C-103116        |                | *              | As for loc. 92                                               |
| 95                | GAT(F)83-66C      | C-103117        |                | *              | As for loc. 92                                               |
| 96                | GAT(F)83-66D      | C-103118        |                | *              | As for loc. 92                                               |
| 97                | GAT(F)83-66E      | C-103119        |                | *              | As for loc. 92                                               |
| 98                | GAS(F)83-106C     | C-88231         |                | *              | As for loc. 92; collected by Mr. J. Steel, 1983.             |

SECTION 4 LOCALITIES:

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 99                | GAT(F)83-28A      | C-103114        |                | *              |                 |
| 100               | GAT(F)83-62A      | C-103104        | *              |                |                 |
| 101               | GAT(F)83-62B      | C-103105        | *              |                |                 |
| 102               | GAT(F)83-63A      | C-103106        | *              |                |                 |
| 103               | GAT(F)83-63B      | C-103107        | *              |                |                 |
| 104               | GAT(F)83-64A      | C-103108        | *              |                |                 |
| 105               | GAT(F)83-64B      | C-103109        | *              |                |                 |
| 106               | GAT(F)83-64C      | C-103110        |                | *              |                 |
| 107               | GAT(F)83-65A      | C-103111        | *              |                |                 |
| 108               | GAT(F)83-67A      | C-103120        |                | *              |                 |
| 109               | GAT(F)83-68A      | C-103122        |                | *              |                 |
| 110               | GAT(F)83-69A      | C-103123        | *              |                |                 |
| 111               | GAT(F)83-69B      | C-103124        |                | *              |                 |

|     |              |         |   |                         |                    |          |
|-----|--------------|---------|---|-------------------------|--------------------|----------|
| 112 | GAT(F)83-29A | C-90823 | * | From<br>200m<br>section | Unit<br>east<br>4. | 1,<br>of |
| 113 | GAT(F)83-29B | C-90824 | * | From<br>200m<br>section | Unit<br>east<br>4. | 5,<br>of |



OTHER LOCALITIESNORTH END OF JOAN LAKE:

The following localities are from Middle to Upper Toarcian mudstones of Unit 2, near the north end of Joan Lake (fig. MAP).

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 114               | GAT(F)83-70A      | C-103125        |                | *              |                 |
| 115               | GAT(F)83-71A      | C-103126        |                | *              |                 |
| 116               | GAT(F)83-71B      | C-103127        |                | *              |                 |
| 117               | GAT(F)83-72A      | C-103128        |                | *              |                 |
| 118               | GAT(F)83-72B      | C-103129        |                | *              |                 |

WEST END OF ANTICLINE:

The following localities were found in the area west of the westernmost exposure of volcanic rocks in the thesis map area. See fig. MAP for exact positions.

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                                                              |
|-------------------|-------------------|-----------------|----------------|----------------|------------------------------------------------------------------------------|
| 119               | GAT(F)83-102A     | C-103218        |                | *              | Collected from Unit 5.                                                       |
| 120               | GAT(F)83-102B     | C-103219        | *              |                | As for loc. 119.                                                             |
| 121               | GAT(F)83-102C     | C-103219        |                | *              | As for loc. 119.                                                             |
| 122               | GAT(F)83-103A     | C-103211        |                | *              | From Unit 4.                                                                 |
| 123               | GAT(F)83-105A     |                 |                | *              | From Ashman Fm.                                                              |
| 124               | GAT(F)83-113A     | C-103216        | *              |                | From Unit 2, apparently resting directly on Toadogone Volcanics.             |
| 125               | GAT(F)83-113B     | C-103217        | *              |                | As for loc.124.                                                              |
| 126               | GAT(F)83-113C     | C-103218        |                | *              | As for loc.124.                                                              |
| 127               | GAT(F)83-114A     | C-103219        | *              |                | As for loc.124.                                                              |
| 128               | GAT(F)83-114B     | C-103220        | *              |                | As for loc.124.                                                              |
| 129               | GAT(F)83-123A     | C-103221        | *              |                | From a Lower Pliensbachian inlier 1.5km northwest of westernmost volcanics.  |
| 130               | GAT(F)83-123B     | C-103222        | *              |                | From a Lower Pliensbachian inlier 1.5 km northwest of westernmost volcanics. |

SECTION X LOCALITIES:

The Plateau Section is located 10 km north of the thesis map area and is underlain by Upper Pliensbachian/Lower Toarcian strata (fig. 1.1). The sequence consists of Unit 1 siltstones (Upper Pliensbachian) overlain by shales and tuffaceous shales of Early Toarcian age (fig. 2.10).

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u> |
|-------------------|-------------------|-----------------|----------------|----------------|-----------------|
| 131               | GAT(F)83-125A     | C-103223        |                | *              |                 |
| 132               | GAT(F)83-125B     | C-103224        |                | *              |                 |
| 133               | GAT(F)83-126A     | C-103225        |                | *              |                 |
| 134               | GAT(F)83-126B     | C-103226        |                | *              |                 |

GEOLOGICAL SURVEY OF CANADA: 1981 LOCALITIES

The following localities were examined by Dr. H. W. Tipper of the Geological Survey of Canada during the field season of 1981.

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                                                                       |
|-------------------|-------------------|-----------------|----------------|----------------|---------------------------------------------------------------------------------------|
| 135               |                   | C-87245         | *              |                | Just west of loc. 139.                                                                |
| 136               |                   | C-90515         | *              |                | Vicinity of Section 4; Upper Pliensbachian.                                           |
| 137               |                   | C-90930         | *              |                | Vicinity of Section 2; Lower Pliensbachian.                                           |
| 138               |                   | C-81970         | *              |                | Southwest of Black Fox Lake; Lower Pliensbachian siltstones interbedded in volcanics. |
| 139               |                   | C-90926         | *              |                | Section 2 vicinity.                                                                   |
| 140               |                   | C-90526         | *              |                | Vicinity of Section 4.                                                                |
| 141               |                   | C-90527         | *              |                | As for loc. 140.                                                                      |
| 142               |                   | C-103056        | *              |                | As for loc. 138.                                                                      |
| 143               |                   | C-90924         | *              |                | As for loc. 139.                                                                      |

MISCELLANEOUS LOCALITIES:

| <u>LOCALITY #</u> | <u>NOTEBOOK #</u> | <u>G.S.C. #</u> | <u>IN SITU</u> | <u>EX SITU</u> | <u>COMMENTS</u>                      |
|-------------------|-------------------|-----------------|----------------|----------------|--------------------------------------|
| 144               | GAT(F)83-1AA      | C-103311        |                | *              | Found in volcanic core of anticline. |

## EXPLANATION OF PLATE 1

[All figures natural size unless otherwise indicated]

Fig. 1, 2. *Uptonia* sp.

- 1a. C-90843u; latex cast of external mould from locality 64. X2
- 1b. Internal mould. X2
- 1c. Latex cast of external mould.
- 1d. Internal mould.

- 2a, b. C-90926; internal mould from locality 139. X2
- 2c, d. Specimen number and locality as for figure 2a, b.

Fig. 3. *Dayiceras* sp.

- 3a, b. PLS:83B; internal mould from locality 87. X2
- 3a, d. Specimen number and locality as for figure 3a, b.

# PLATE 1



1a



1b



1c



1d



2a



2b



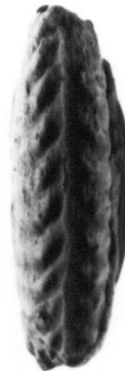
2c



2d



3a



3b



3c



3d

## EXPLANATION OF PLATE 2

[All figures natural size unless otherwise indicated.]

Fig. 1, 2. *Dayiceras* sp.

1a, b. C-90843x; internal mould from locality 64. X2  
1c, d. Specimen number and locality as for figure 1a, b.

2a, b. PLS:83A; latex cast of external mould from locality 62.

Fig. 3-5. *Acanthopleuroceras* cf. *A. stahli* (OPPEL)

3. C-90930b; latex cast of external mould from locality 137.  
4. C-81970s; internal mould from locality 138.  
5. C-90930a; latex cast of external mould, locality as for figure 3.

## PLATE 2



1a



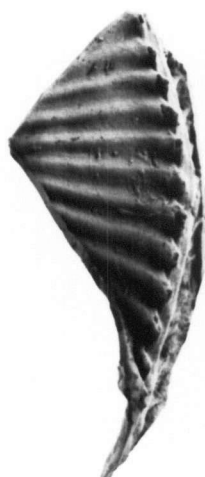
1b



1c



1d



2a



2b



3



4a



4b



5

## EXPLANATION OF PLATE 3

[All figures natural size unless otherwise indicated]

Fig. 1. *Luningiceras pinnaforme* SMITH

C-103222; internal mould from locality 130.

Fig. 2, 3. *Tropidoceras* sp.

2. C-103304; internal mould from locality 2.

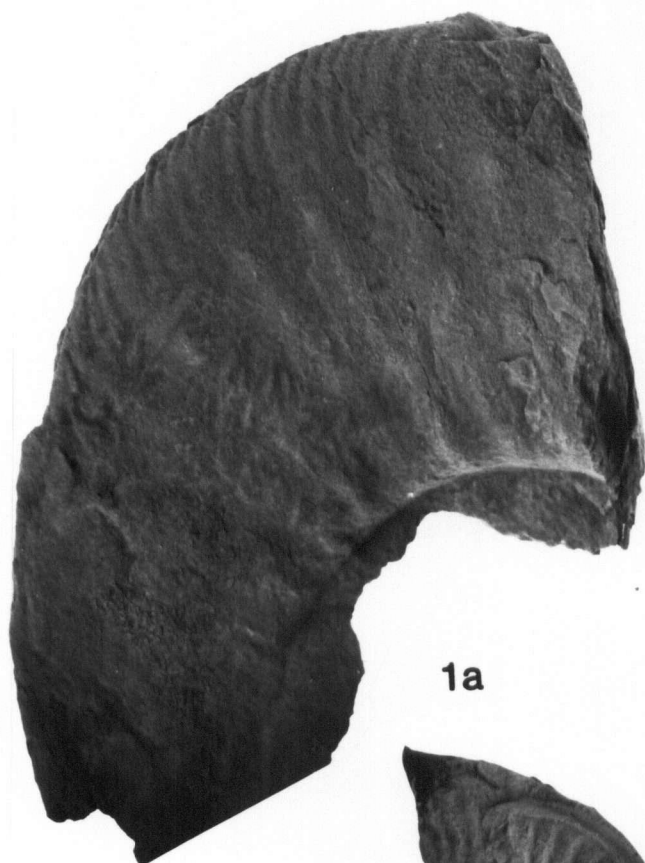
3. C-103311; latex cast of external mould from locality 144.

Fig. 4, 5. *Metaderoceras muticum* (D'ORBIGNY)

4. C-90823; internal mould from locality 112.

5. C-90527; latex cast of external mould from locality 141.

## PLATE 3





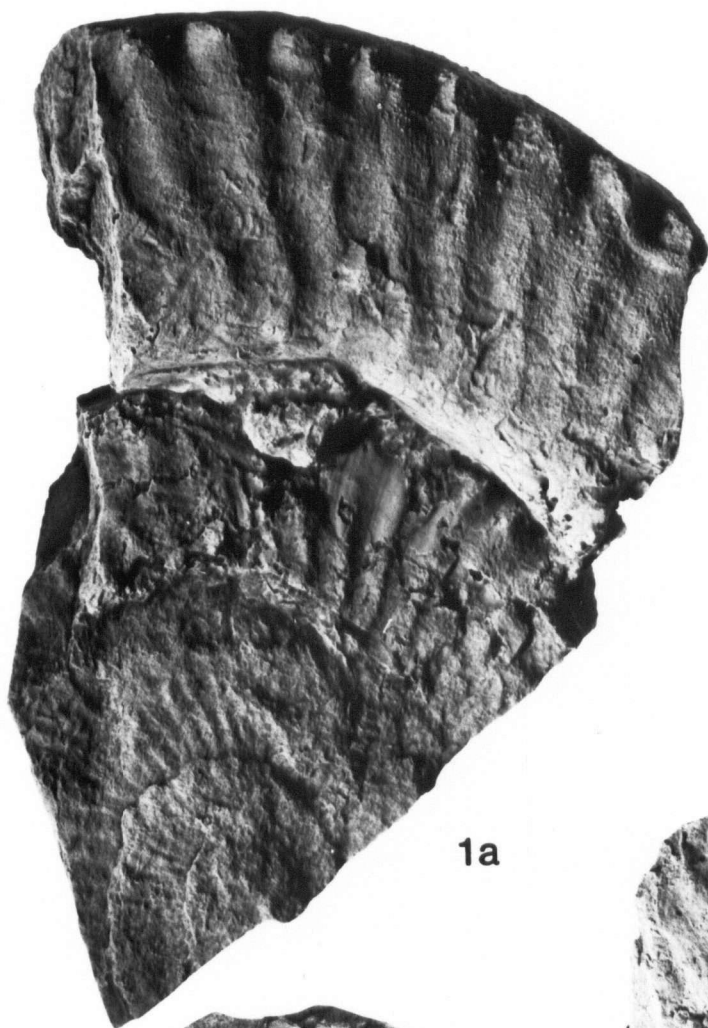
## EXPLANATION OF PLATE 4

[All figures natural size unless otherwise indicated.]

Fig. 1-3. *Metaderoceras muticum* (D'ORBIGNY)

1. C-90924; internal mould from locality 143.
2. C-103305a; latex cast of external mould from locality 3.
3. C-103305b; internal mould from locality 3.

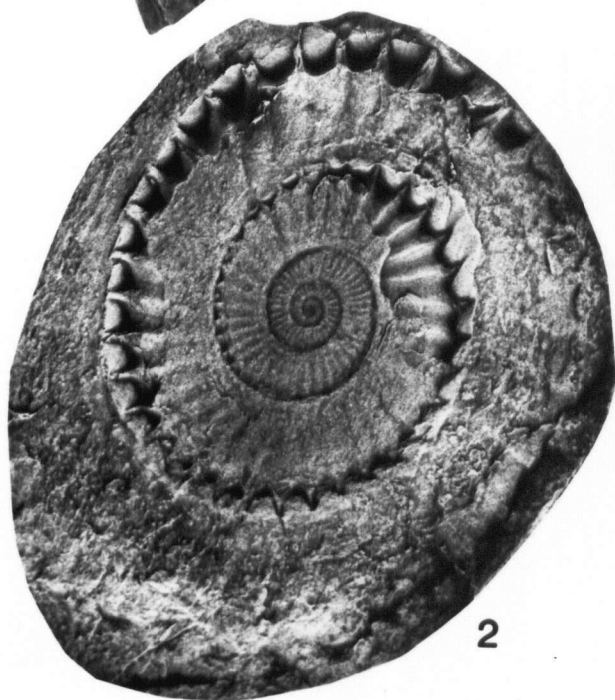
## PLATE 4



1a



1b



2



3

## EXPLANATION OF PLATE 5

[All figures natural size unless otherwise indicated.]

Fig. 1-3. *Metaderoceras* aff. *M. muticum* (D'ORBIGNY)

1. C-103307; internal mould from locality 5.
2. C-103056; internal mould from locality 142.
3. C-103108; latex cast of external mould from locality 104.

Fig. 4, 5. *Metaderoceras* cf. *M. mouterdi* (FREBOLD)

4. C-103309; latex cast of external mould from locality 7.
- 5a. C-90843a; internal mould from locality 64.
- 5b. Specimen number and locality as for figure 5a; latex cast of external mould.

## PLATE 5



1



2



3



4



5a



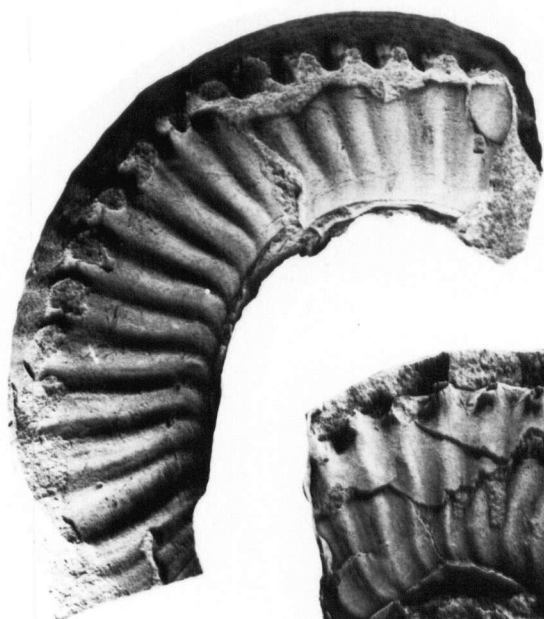
5b

## EXPLANATION OF PLATE 6

[All figures natural size unless otherwise indicated.]

- Fig. 1. *Metaderoceras* cf. *M. mouterdi* (FREBOLD)  
1a, c. C-103307; internal mould from locality 5.  
1b. Specimen number and locality as for 1a, c; latex cast of external mould.
- Fig. 2. *Metaderoceras* sp.  
C-103303; latex cast of external mould from locality 1.
- Fig. 3. *Metaderoceras evolutum* (FUCINI)  
C-81970; internal mould from locality 138.
- Fig. 4, 5 *Metaderoceras silviesi* (HERTLEIN)  
4. C-103324a; latex cast of external mould from locality 19.  
5. C-103324b; internal mould from locality 19.
- Fig. 6. Ammonite gen. et sp. indet.  
C-103306; internal mould from locality 4.

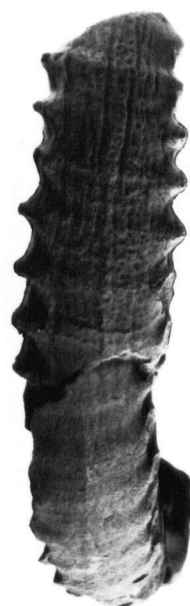
## PLATE 6



1a



1b



1c



2



3



4



5



6

## EXPLANATION OF PLATE 7

[All figures natural size unless otherwise indicated.]

Fig. 1. *Metaderoceras silviesi* (HERTLEIN)

C-88231; latex cast of external mould from locality 98.

Fig. 2-4. *Dubariceras feboldi* DOMMERGUES, MOUTERDE, and RIVAS

2a, b. C-103118; internal mould from locality 96.

3. C-90836; latex cast of external mould from locality 79.

4. C-103114; latex cast of external mould from locality 99.

## PLATE 7



2a



2b



3



4



## EXPLANATION OF PLATE 8

[All figures natural size unless otherwise indicated.]

Fig. 1. *Reynesocoeloceras* cf. *R. incertum* (FUCINI)

C-90526; internal mould from locality 140.

Fig. 2. *Aveyroniceras* sp. B

C-90835; latex cast of external mould from locality 78.

Fig. 3, 4. *Dubariceras freboldi* DOMMERGUES, MOUTERDE, and RIVAS

3a. C-90832d; latex cast of external mould from locality 75.

3b. Specimen number and locality as for figure 3a; internal mould.

4. C-90843; latex cast of external mould from locality 64. Note; ribs projecting strongly onto venter.

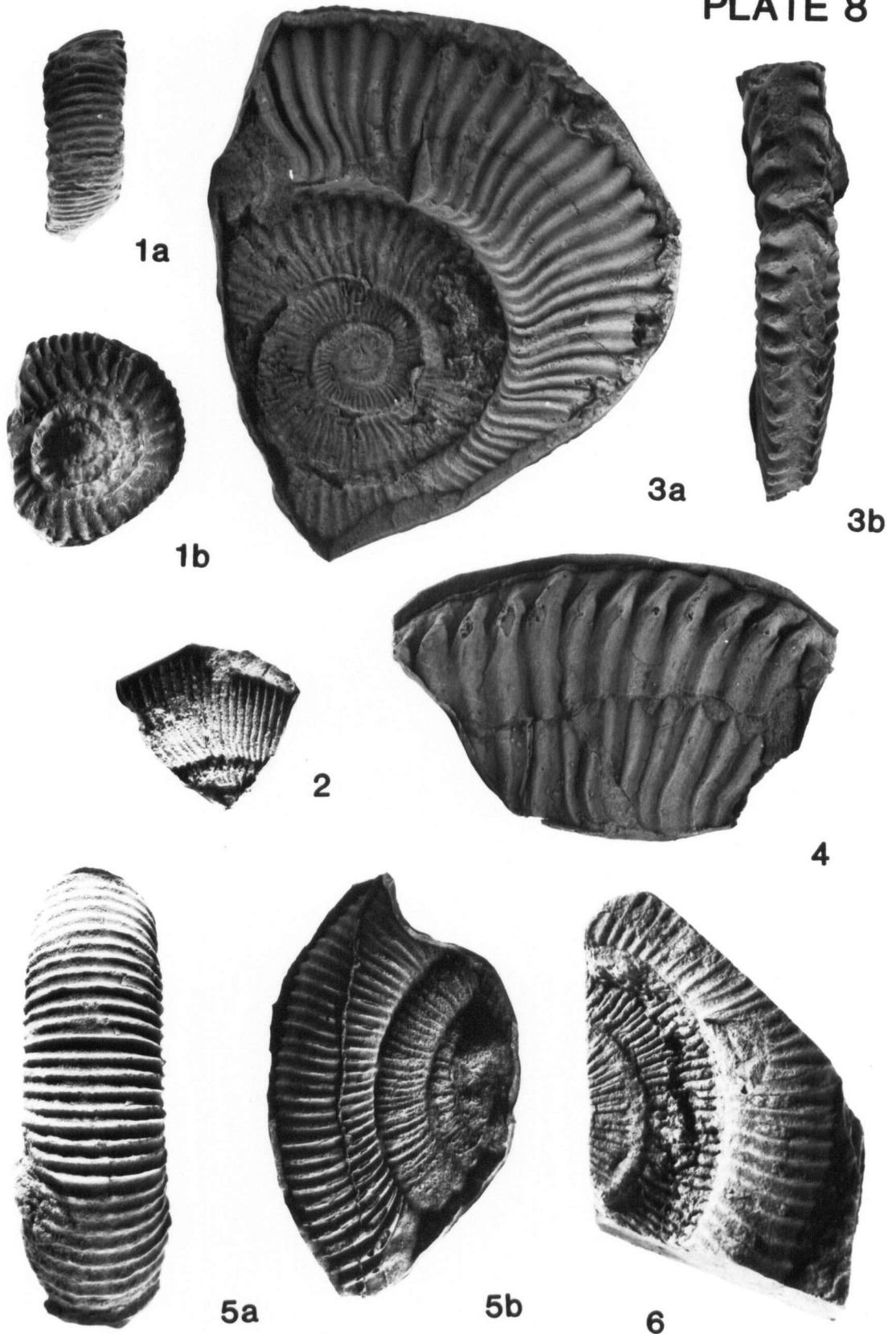
Fig. 5, 6. *Aveyroniceras* sp. A

5a. C-90834a; internal mould from locality 77.

5b. Specimen number and locality as for figure 5a; latex cast of external mould.

6. C-90837; internal/external mould from locality 81.

## PLATE 8



## EXPLANATION OF PLATE 9

[All figures natural size unless otherwise indicated.]

Fig. 1. *Fanninoceras latum* McLEARN

100A(F); latex cast of external mould from locality 60.

Fig. 2. *Fanninoceras* sp.

C-90515; internal mould from locality 136.

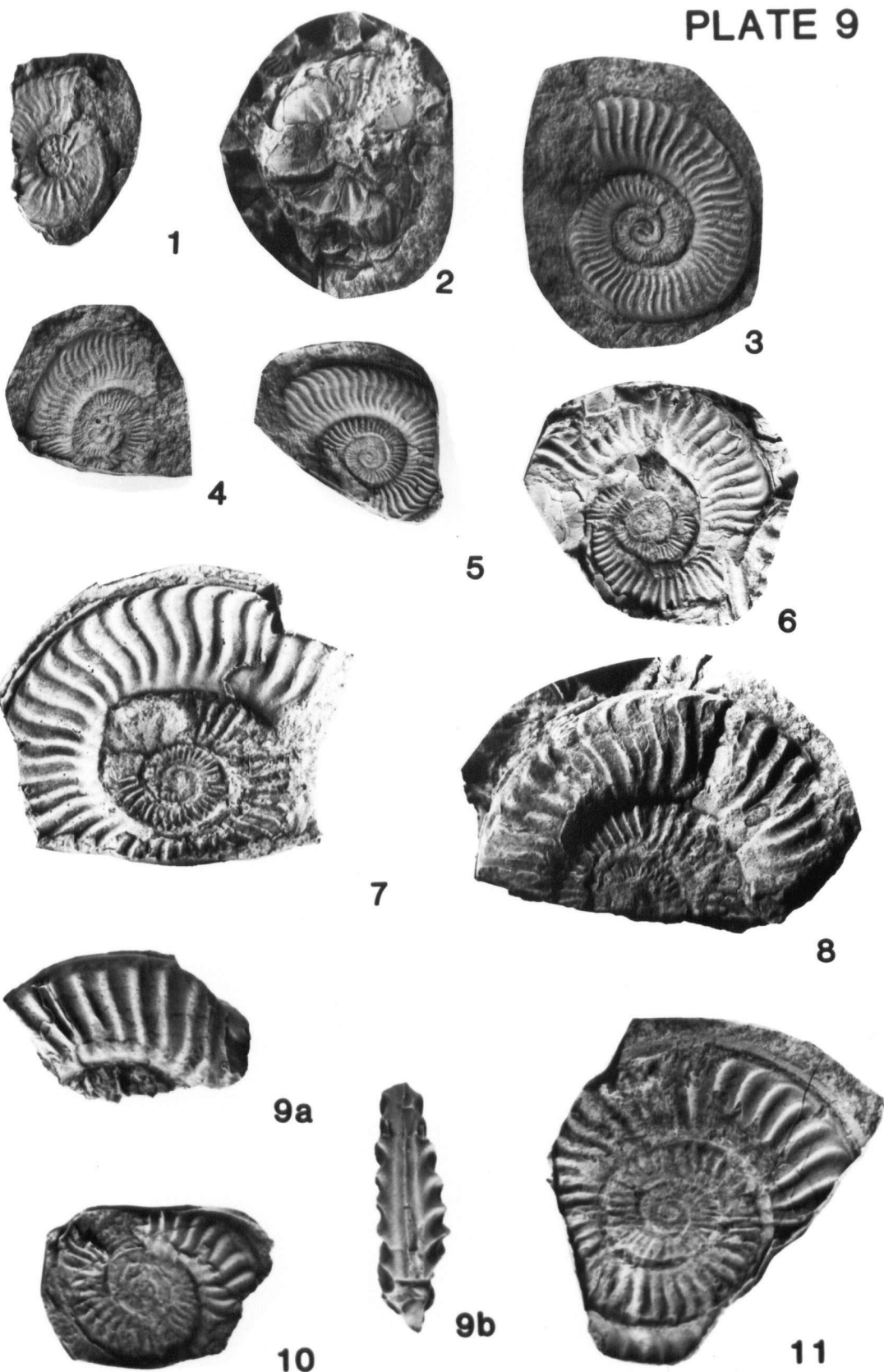
Fig. 3-6. *Leptaleoceras* cf. *L. pseudoradians* (REYNES)

3. C-103332; latex cast of external mould from locality 27.
4. C-103335; latex cast of external mould from locality 29.
5. C-103224; latex cast of external mould from locality 132.
6. C-90515d; latex cast of external mould from locality 136.

Fig. 7-11. *Arietoceras algovianum* (REYNES)

7. C-103223a; latex cast of external mould from locality 131.
8. C-90515c; internal mould from locality 136.
9. C-90515a; internal mould from locality 136.
10. C-103223b; latex cast of external mould from locality 131.
11. C-103111; latex cast of external mould from locality 107.

## PLATE 9



## EXPLANATION OF PLATE 10

[All figures natural size unless otherwise indicated.]

Fig. 1, 2. *Arieticerat* cf. *A. ruthenense* (REYNES)

1. C-103120; latex cast of external mould from locality 108.
2. C-103110; latex cast of external mould from locality 106.

Fig. 3-8. *Lioceratoides propinquum* (McLEARN)

3. C-103203; latex cast of external mould from locality 55.
4. C-103332; latex cast of external mould from locality 27.
5. C-103204e; latex cast of external mould from locality 56.
6. C-103204d; latex cast of external mould from locality 56.
- 7a. C-10322a4; internal mould from locality 132.
- 7b. Specimen number and locality as for figure 7a; latex cast of external mould.
8. C-103224b; latex cast of external mould from locality 56. Note occurrence with *Protogrammoceras paltum*.

## PLATE 10



1



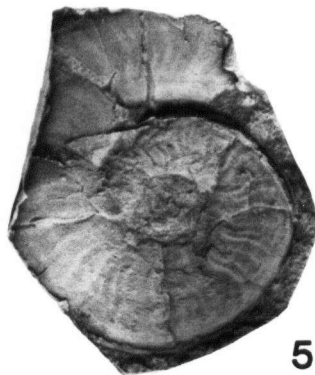
2



3



4



5



6



7a



7b



8

## EXPLANATION OF PLATE 11

[All figures natural size unless otherwise indicated.]

Fig. 1. *Lioceratoides* sp. A

C-103204a; latex cast of external mould from locality 56.

Fig. 2. *Lioceratoides* sp. B

C-103204b; latex cast of external mould from locality 56..

Fig. 3-5. *Protogrammoceras paltum* (BUCKMAN)

3. 100A(P); latex cast of external mould from locality 60.

C-103204p; latex cast of external mould from locality 56.

C-103204q; latex cast of external mould from locality 56.

## PLATE 11



1



2



3



4



5



## PUBLICATIONS (CON'T)

- THOMPSON, R. C., 1984. LOWER JURASSIC AMMONOID BIOSTRATIGRAPHY AND PALEOBIOGEOGRAPHY OF THE NORTHERN BOISER BASIN, BRITISH COLUMBIA (Abst.). CANADIAN PALEONTOLOGY AND BIOSTRATIGRAPHY SEMINAR, SEPT., 1984, OTTAWA. PROGRAMME WITH ABSTRACTS, PALEONTOLOGY DIVISION, GEOLOGICAL ASSOCIATION OF CANADA, p. 9.