TRIASSIC AVICULOPECTINIDS (BIVALVIA)

FROM

BRITISH COLUMBIA

UPPER TRIASSIC

EUMORPHOTIS AND MELEAGRINELLA (BIVALVIA)

FROM

BRITISH COLUMBIA

by

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SCOPE AND CONTENTS: Collections of the Aviculopectinids Eumorphotis and Meleagrinella from the Upper Triassic of British Columbia are described. Four species of Eumorphotis have previously been known only from Indo-China and one from Siberia. Five species of Eumorphotis and one of Meleagrinella are new. Phylogenetic relationships and affinities of the fauna are discussed. The present work is the first detailed study of these Aviculopectinids which are among the important biostratigraphic indices of the Triassic.

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CHAPTER 1

INTRODUCTION

The Triassic System of Northeastern British Columbia is important because of the exceptional completeness and rich and diverse faunas. On account of its bearing on the classification and correlation of the Triassic rocks of different parts of the world, the system holds promise of becoming one of the classic areas for the Triassic system in North America. Since 1877 when the Triassic of British Columbia was discovered by Selwyn, a vast amount of work has been done on the stratigraphy, structure, fauna and sedimentary history of these rocks, but much detailed investigation still remains to be done.

The present study pertains to the biostratigraphy and taxomony of the Middle and Upper Triassic Bivalvia of northeastern British Columbia. The majority of the species here described come from the Pine River Bridge Section (122°41' W long., 55°30' N lat.) in northeastern British Columbia; the Middle Triassic (Anisian) species come from the Tetsa Valley and the vicinity of the Toad River, of the same general area.

The investigation of the Pine River Bridge Section was initiated by Dr. G. E. G. Westermann in 1958-59, and the first results reported in 1962 (Westermann, 1962). His studies, however, were restricted mainly to the distribution and variation of the different species of Monotis. A brief reference was made to the associated fauna including the Aviculopectinidae Eumorphotis and Meleagrinella occurring in the higher beds of the section. The present work entails the taxonomic study of these Aviculopectinids. The present author reinvestigated the Pine River Bridge Section in order to clarify some of the stratigraphic and structural discrepancies and personally communicated to Dr. G. E. G. Westermann by Dr. E. T. Tozer (of the Geological Survey of Canada) and by Dr. N. J. Silberling (of the U.S. Geological Survey) and to enlarge the collections of bivalves especially regarding Aviculopectinidae. The revised structural and stratigraphical details have already been published (Westermann and Verma, 1967).

The middle and Upper Triassic outcrops in the Tetsa Valley and in the vicinity of the Toad River were examined along the Alaska Highway between mile posts 370 and 428 with respect to the stratigraphy and fauna.

Although this field work yielded a rich collection of ammonoids and bivalves from the different faunal zones of the Triassic, it was necessary to restrict this thesis to the Middle and Upper Triassic Aviculopectinidae.

The family Aviculopectinidae was discussed at length by Newell (1937) in his monograph on the late Palaeozoic Pectinacea. Ichikawa's (1958) monograph on Triassic Pteriidae included a detailed description of only Lower and Middle Triassic *Eumorphotis* species making only brief mention of Upper Triassic *Eumorphotis*. This is, therefore, the first detailed study of Upper Triassic *Eumorphotis* and *Meleagrinella*.

The *Eumorphotis* and *Meleagrinella* material of the author was supplemented by specimens collected by Dr. Westermann in 1958-59, by Dr. Peter Martini, formerly of McMaster University who visited the Pine River Bridge Section in 1965 at the request of Dr. Westermann, by the Geological Survey of Canada from the Pardonet formation of northeastern British Columbia, and by Shell Oil Company from the same area.

CHAPTER 2

STRATIGRAPHY

2.1 Previous Literature

Of all geological systems in British Columbia, the Triassic has received the greatest attention with regard to stratigraphy, faunal succession and sedimentation.

The earliest description of the Triassic rocks in the area was given by Dawson (1881) of the Peace River Foothills, although Selwyn (1877) was the first to report their occurrence. Subsequently, McConnell (1891) described the Triassic of the Liard River area. Since then, the officers of the Geological Survey of Canada, the geologists of the Pacific Great Eastern Railway Survey, the British Columbia Department of Mines and the various oil and mining companies have been continuously engaged in preparing geological maps and reports, and describing the stratigraphy, structure and fauna of the Triassic of different areas on in northeastern British Columbia. The most extensive contribution to this work has been that of F. H. McLearn, who, between the period 1917 and 1960 published a large number of papers on several areas in northeastern British Columbia (see references). The investigations up to 1950 were summarized by McLearn and Kindle (1950). Other stratigraphic studies dealing with restricted areas were carried out by Williams (1923, 1944), Williams and Bocock (1930, 1932), Hage (1944, 1945), Kindle (1944, 1946) McLearn (1940, 1940a, 1941, 1941b, 1945a, 1953), Hunt and Ratcliffe (1959) Pelletier (1959), Muller (1961), Conquhoun (1960, 1962). More recently, Pelletier (1960, 1961, 1963, 1964), and Pelletier and Stott (1963) published reports on the Triassic Stratigraphy of northeastern British Columbia. Pelletier (1965) studied the primary current structures in order to determine direction of sedimentary transport, regional sedimentary trends, and probable source areas. He concluded that the early Triassic witnessed a marine transgression from the northeast and that the remaining Triassic is marked by periodic regression follwed towards the end by another major transgression.

Notable contributions among the descriptions of the Triassic faunas of northeastern British Columbia are those of Whiteaves (1889), Warren (1945), McLearn (1939, 1939a, 1940, 1940b, 1940c, 1960), Tozer (1963, 1965, 1965a, 1965b) and Westermann (1963).

Bivalves were dealt with by McLearn (1939b, 1941a) and by Westermann (1962), the latter describing Monotis and the associated fauna from the Pine River Bridge Section. Westermann (1962a), Ager and Westermann (1963), and Logan (1964) studied the Spiriferinid and Rhynchonellid brachiopods. Tozer (19 65b) reviewed the Norian Ammonoid faunas of northeastern British Columbia and discussed their bearing on the classification of the Norian stage. Subsequently, Westermann (1966) described more Monotis species from northeastern British Columbia and compared their sequences in British Columbia with that in Japan. Lastly, Tozer (1965, 1967) has proposed a zonal classification of the Canadian Triassic System, wherein a sequence of thirty-one ammonoid zones is recognized.

2.2 Distribution and Classification of the Triassic System

The Triassic rocks of northeastern British Columbia are exposed in a NNW-SSE elongated area 15 to 60 km wide and about 450 km long north of 55° latitude (Figure 1). These rocks form the folded belt of the Rocky Mountain Foothill zone bounded on the east by the gently folded Cretaceous beds of the Interior Plains, and on the west by the structurally more complicated Rocky Mountain front ranges composed chiefly of Palaeozoic sediments. The Triassic rocks lie disconformably upon Palaeozoic Chert of Permian or Mississipian age. The upper boundary of the Triassic is marked by an unconformity which is followed by Cretaceous sediments in the northern part and by the Jurassic shales in the south. The total thickness of the Triassic has been estimated between 1300 and 2600 meters.

The Triassic has been subdivided (Table 1) into the Grayling, Toad, Liard, "Grey Beds" and Pardonet formations. The Liard formation (Kindle 1946) is roughly equivalent to "Flagstones and Dark Stiltstones" of McLearn and Kindle (1950). The "Grey Beds", a formational term proposed by McLearn and Kindle (1950) and adopted by Pelletier (1964), have been further subdivided into the Lower, Middle and Upper Grey Beds which roughly correspond respectively to the Halfway, Charlie Lake and Baldonnel formations of the subsurface to the east of the Foothills. The overlying unconformity cuts off parts of the sequence in northernmost British Columbia (such as between mile post 370 and 428 of the Alaska Highway), so that the entire succession is not represented. The sequence is more fully represented in the Trutch, Halfway, and Peace River areas.

The following table summarizes the classification of the Triassic System.

TABLE 1

TABLE OF TRIASSIC FORMATIONS-BRITISH COLUMBIA AND ALBERTA

(After Pelletier, 1964)

Time-Stratigraphic Units		Rock-Stratigraphic Units	Thickness	Lithology
Upper Triassic	Norian	Pardonet Formation	660 m	Dark grey platy limestone and Calcareous siltstone.
Upper Triassic	Karnian	Upper Grey Beds (Baldonnel Formation)	0-250 m	Fine-grained, medium grey, bituminous limestones; minor interbedded sandstone
Upper Triassic	Karnian	Middle Grey Beds (Charlie Lake Formation)	48 - 180 m	Inter-bedded fine-grained light grey limestone and dolomite with inter-bedded intraformational breccia, sandstone and shale.
Middle Triassic	Ladinian	Lower Grey Beds (Halfway Formation)	100 - 460 m	Grey, calcareous, medium grained, cross-bedded sandstones with inter-bedded units of massive grey, bioclastic limestones.
Middle Triassic	Ladinian	Liard Formation	200 - 430 m	Massive, grey, calcareous sandstones, minor grey limestones and dark grey siltstones
Middle Triassic / Lower Triassic	Anisian / Scythian	Toad Formation	220 - 400 m	Massive, grey, calcareous siltstones and mudstones, minor sandstones and limestones; platy shales and siltstones.
Lower Triassic	Scythian	Grayling Formation	0 - 115 m	Dark grey shales and minor siltstones and limestones interbedded with sandstone in lower part.

The Grayling Formation (Lower and Upper Scythian) is composed chiefly of dark grey fissile shales and siltstones, and minor limestones and thin sandstones. The shales (3 - 6 m. thick beds) are more susceptible to weathering and occur as recessive intervals in ridgetops and bottoms of anticlinal valleys. Some shale beds contain fossiliferous concretions and sedimentary structures like ripple marks and cross beds. Claraia stachei is the abundant pelecypod with a few ammonites (Xenodiscoides, Proptychites, Paranorites) occurring in this formation indicate an off-shore environment.

The Toad Formation (Upper Scythian, Anisian) consists chiefly of massive grey calcareous platy siltstones with minor sandstones and grey fossiliferous limestone beds are interbedded throughout the Toad Formation. The sandstones are fine-grained and calcareous and show cross-bedding, and ripple marks. The upper part of the Toad Formation is the repository of the Gymnotoceras-Beyrichites fauna which includes Parapopanoceras, Longobardites, Hungarites, Gymnotoceras, Beyrichites, Ussurites, Anagymites and others. The lower part is characterized by Pseudomonotis, Posidonia and Meekoceras. Pelletier (1964) as a result of a study of the sedimentary structures, suggested that the lower part of the Toad Formation represents an off-shore marine environment and the upper represents a marine near-shore environment. According to him, during the latter part of the Toad sedimentation, a marine regression took place which brought quartzose sandstone from the east.

The Liard Formation (Ladinian) is chiefly a sandstone formation consisting of thick, massive, grey, calcareous sandstones with minor limestones and siltstones. These sandstones represent a shallow water marine facies as indicated by the lithology and sedimentary structures. According to Pelletier (1965) the marine regression to the west continued episodically during the Liard times. The Liard is characterized by the *Nathorstites* fauna which includes *Silenticeras*, *Lobites*, *Protrachyceras*, *Sagenites*, *Paratrachyceras*, *Nathorstites*, *Terebratula*, *Spiriferina*, *Daonella*, and *Modiolus*.

"The Grey Beds" is the provisional lithological name given to the rock units lying above the Liard Formation and below the Pardonet Formation and is composed chiefly of thick, medium to light grey fine to coarse sandstones and different types of carbonates. On the basis of correlative evidence Pelletier (1964) subdivided this unit into the Lower, Middle and Upper Grey Beds which roughly correspond with the Halfway, Charlie Lake and Baldonnel Formations respectively of the Peace River and vicinity (Colquohoun 1960, 1962, Armitage, 1962).

The Lower Grey Beds (= Halfway Formation, Middle to

Upper Ladinian) consist of calcareous coarse sandstones, interbedded with massive grey fine limestones. These beds exhibit sedimentary structures, i.e., ripple marks, large scale cross-bedding, sorting, scour features which are characteristic of shallow water environments. The fossils include some elements of the Nathorstites fauna and coquina beds composed of fragments of Spiriferinids, Terebratulids and Gryphaeids. The coarser nature of the Halfway sandstones as compared with those of the Liard led Pelletier (1965) to suggest that the marine regression continued during the Halfway sedimentation.

The Middle Grey Beds (=Charlie Lake Formation, Upper Ladinian-Lower Karnian) is chiefly a carbonate unit consisting of thick beds of fine grained dolomite and limestone interspersed with collapse type of breccia and boxwork system of vugs. This, along with the occurrence of abundant stylolites are indicative of evaporitic origin of this formation. Fossils are generally absent. These evaporites presumably formed east of the Rocky Mountain Foothill zone in the landward side of the off-shore sandbars which underlie these carbonates to the west.

The Upper Grey Beds (=Baldonnel Formation, Karnian) is again mainly a carbonate unit consisting of fine grained grey bituminous limestones interbedded with sandstone units. Its contact with the Lower Grey Beds is rather arbitrary but the upper contact with the Pardonet Formation is more clear. The characteristic fauna of this formation is the Halobia fauna which also includes Spiriferina, Palaeocardia , Lima, Gryphaea, Pecten, Pleuromya, and Entolium.

The Pardonet Formation (Karnian-Norian) is the topmost of the Triassic formations and is composed chiefly of dark, calcareous siltstones and interbedded bituminous limestones and rarely fine-grained calcareous sandstones. The Pardonet beds have a distinctive lithology and serve as a useful mappable unit. The most characteristic faunal zones of this formation are the Middle Norian Himavatites zone (present only in the southern sections) and the Upper Norian Monotis subcircularis zone. The Himavatites zone includes Episculites, Drepnites, Pseudosirenites, Thetitides, Rhacophylites, Juvavites , Parajuvavites and Distichites. The Monotis subcircularis zone includes several species of Monotis.

2.3 Upper Triassic Faunal Zones for Western Canada

The following faunal zonation schemes have been proposed for the Upper Triassic of Western Canada:

TABLE 2

FAUNAL ZONES FOR UPPER TRIASSIC

	Tozer (1965, 1967)	Westermann (1962, 1966)
Upper Norian	(Upp.) *Rhabdoceras suessi* Zone	
	(Lr.) *Rhabdoceras suessi* Zone (=*M. subcircularis* Zone)	*Monotis posteroplana* *M. subcircularis* Zone
		M. callozonensis + *M. jakutica* *M. ochotica densistriata*
Middle Norian	*Himavatites columbianus* Zone	*M. pinensis* Zone
		M. sparsicostata
	Drepanites rutherfordi Zone	
	Juvavites magnus Zone	
Lower Norian	*Malayites dawsoni* Zone	*M. typica*
	Mojsisovicsites kerri Zone	
Upper Karnian	*Klamathites macrolobatus* Zone	
	Tropites welleri Zone	
	Tropites dilleri Zone	
Lower Karnian	*Sirenites nanseni* Zone	
	Trachyceras obesum Zone	

The Lower Norian substage characterized by the M. kerri Zone and the M. dawsoni Zone is well represented in the Pardonet Formation of northeastern British Columbia. Both the Zones have abundant ammonoids and the M. kerri Zone is associated with Halobia alaskana Smith in the Western Cordillera. Westermann (1966) extended the lateral distribution of the Eastern Siberian Monotis typica (Kiparisova) to Lower to early Middle Norian. The J. magnus Zone, the D. rutherfordi Zone and the H. columbianus Zone are also well represented in the Pardonet Formation at the type locality, Brown Hill. Of these, the H. columbianus Zone has yielded the richest collection of Ammonoids in Canada. As far as the bivalves are concerned, M. pinensis Westermann characterizes this Zone. In the Upper Norian R. suessi Zone, Tozer (1967) recognizes two divisions, a Lower R. suessi Zone (=M. subcircularis Zone) and an Upper R. suessi Zone comprising post M. subcircularis beds. Westermann (1962, 1966) on the basis of the occurrence of several Monotis species in the Pine River Bridge Section distinguished within the beds of M. subcircularis Zone three horizons characterized (from the bottom to top) by abundance of M. pinensis Westermann and M. callazonensis Westermann, and of M. subcircularis Gabb, respectively.

2.4 Fossil Localities

The field work was confined to (a) a study of the Grayling, Toad and Liard formations and the Grey beds in the Tetsa-Toad River area (Alaska Highway, Mile POst 370 to 428) and (b) reinvestigation of the Pine River Bridge Section on the Hart Highway, British Columbia (W. long. $122^{\circ}41'$, N. lat. $55^{\circ}30'$)(Fig. 2).

The field work in the Tetsa-Toad River area being not directly related to the fossils described here, is described in Appendix 1. The majority of the material described here comes from the Pine River Bridge Section.

2.5 The Pine River Bridge Section, British Columbia

The Pine River Bridge Section is located about 50 miles west of Chetwynd on the John Hart Highway which runs between Dawson Creek and Prince George. The geology along the highway in the vicinity of the Pine Pass and the location of the Pine River Bridge Section within the Pardonet outcrop area is indicated in Figure 5. At this locality the Hart Highway passes underneath a bridge of the Pacific Great Eastern Railway and about 300 metres further west crosses the Pine River (Plate I).

This section forms the northwestern limb of an anticline within the Pardonet formation. About 400 metres west of the section is the thrust faulted contact of the upper Palaeozoic sediments which form the high, structurally complicated Rocky Mountain Front Ranges. The rocks immediately west of this contact are limestones and dolomites of the Rundle group (Mississipian and ? Permian). Following the topmost bed ("h" or 13) of the section is a conglomerate bed overlain by highly sheared shales which form the base of a sequence of overturned folded shales and limestones which have been tentatively correlated with the Nordegg member of the Jurassic Fernie group. Between these beds and the thrust contact with the Upper Palaeozoic rocks are exposed members of the Pardonet formation and the underlying "Grey Beds".

The first detailed investigation of the Pine River Bridge Section was carried out by Westermann (1962). He distinguished six different species and subspecies of Monotis and briefly described the associated invertebrate fauna. In 1965,Drs. E. T. Tozer of the Geological Survey of Canada and N. J. Silberling of the U. S. Geological Survey visited the section and communicated to Dr. Westermann certain discrepancies in the stratigraphy and succession of the Monotis fauna. The present author, therefore, visited the section in July, 1966, in order to make new fossil collections from the major zones and to study the structure and stratigraphy. This independent collection essentially supplemented and confirmed the originally described succession of

Monotis and also yielded more specimens of *Eumorphotis* and *Meleagrinella* which form the basis of the present work. However, it was found that the discrepancies noted by Tozer and Silberling (recently published by Tozer, 1967) had arisen on account of structural repetition of 27 metres of the section caused by low-angle thrust fault which was omitted in the original sketch (Westermann, 1962, Text - Fig. 3). Westermann's original section was composite, extending in parts along the Hart Highway, the construction trail, and, at the very top only, along the railway (Figures 6, 7). Tozer and Silberling, however, followed the section from the highway directly along the railway. The present author's reinvestigation of the section (Westermann and Verma, 1967) revealed that the lower part of the railway section exposes the structural repetition which is, however, covered by talus along the construction trail. The continuity of the section by Westermann was based upon the correlation of the 2.5 m coquina bed of *Monotis subcircularis* which is present at the southwestern end of the highway section (Plate II, Figs. 1, 2) and near the base of the construction trail section (Plate III, Fig. 1).

The examination of the railway section by the present author revealed the presence of a major fault or narrow fault zone, F2, indicated by sheared rocks and a small fan fold stratigraphically 3 m above the first occurrence of the 2.5 m coquina bed, approximately 10 m west of the railway bridge (Plate III, Fig. 2). This is probably a reverse fault according to the steep inclination of the fault plane which is more or less concordant with 45° southwest dipping beds and has caused the repetition of 27 m of section. Although the lower 5 m above the fault are strongly fractured, the presence of a recumbent fold is strongly suggested. This structure may, therefore, be interpreted as the upper part of a steep overthrust located in the overturned flank of a recumbent fold. Towards the southwest, there follows a normal sequence of $40\text{-}50^{\circ}$ w-dipping beds.

Approximately 35 m southwest of this major fault, about 20 m stratigraphically above it and still within the structurally repeated sequence, is the originally recognized minor supposed reverse fault F1 (Plate IV). Its attitude in the bedding plane except towards the top and its stratigraphical position is close to the base of fossil bed "e" (Locality 9, Fig. 6) or 1 to 2 m below the 2.5 m coquina bed. Since this fault generally follows the markedly curved dip of the beds and a fracture zone is absent, the displacement is assumed to be insignificant. This is in agreement with the apparent normal stratigraphical sequence, which does not show repetition. It is highly unlikely that this fault caused significant stratigraphical loss.

The faults do not alter the true stratigraphical thicknesses as originally compiled from the highway, the construction trail and the uppermost railway sections (solid columns in Fig. 7), because the interval containing the two faults was not included and the correlation of the highway and construction trail sections was based on the 2.5 m coquina bed.

Detailed measurement has altered the originally assumed thickness slightly, the total thickness of the Pardonet Formation exposed being 42.5 m instead of 45.5 m (Figs. 6 and 7).

The revised stratigraphical column from top to bottom is as follows:

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities: Westermann	Fossil Localities: Westermann & Verma, 1967
1.	8 m	Grey to black bituminous limestone massive in 4-8" thick beds, generally unfossiliferous, *Monotis ochotica posteroplana* West. *Anodontophora* sp. occur about 0.5 m from top.	"h"	13
2.	2.5 m	Dolomitic limestone same as above but irregularly bedded.	"g"	12, 12a

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities: Westermann	Fossil Localities: Westermann & Verma, 1967
		Weathered surface expose *Monotis subcircularis*. Fossil bed near the top with *Monotis och. posteroplana*, *Meleagrinella aurisparva*, sp. nov., *Eumorphotis* (*Asoella*) *depressa* sp. nov., *E.* (*E.*) *lemorayensis* sp. nov., *E.* (? *A.*) *acuta*, sp. nov., *E.* (*A.*) cf. *E. australasiatica* (Krumb.), *E.* (*A.*) *convexa* (Mansuy) *E.* (*A.*) *laosensis* (Mansuy), *Gryphaea* sp. *Chlamys* sp.		
		A loose block which probably came from this interval yielded *Monotis och. ochotica* (Keys.) *M. och. posteroplana* West., *Chlamys* sp., *Anodontophora* sp.		

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities Westermann	Fossil Localities Westermann & Verma 1967
3.	0.5 m	Fine-grained, grey limestone bed with fossil bed in the middle containing Monotis subcircularis Gabb, Eumorphotis (Asoella) depressa sp. nov., E. (? A.) acuta sp. nov., E. (A.) westermanni sp. nov., E. (A.) obliqua sp. nov. E. (A.) convexa sp. nov., E. (E.) zitteli (Teller), Meleagrinella aurisparva sp. nov.		11, 11a
4.	0.6 m	Fine grained grey arenaceous limestone, unfossiliferous.		
5.	2.4 m	Alternate beds of limestone and 1-1.5 m thick coquina beds composed of Monotis subcircularis. Limestone beds have M. och. ochotica, (M. och. densistriata (Teller), Gryphaea sp., Gervilia sp., Meleagrinella aurisparva sp. nov., Chlamys sp. Anodontophora sp.		10, 10a

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities Westermann	Fossil Localities Westermann & Verma, 1967
6.	2.0 m	Coquina beds entirely made up of _Monotis_ _subcircularis_ shells		
7.	2.0 m	Medium grey, bituminous limestone bed with _Monotis_ _subcircularis_ scattered at places and about 0.3 m thick coquina bed about 0.6 m from the top.		
8.	2.5 m	Single coquina bed built up of nearly complete but very highly compressed valves of large _Monotis_ _subcircularis_.		
9.	1.5 m	About 0.5 m coquina bed at the base followed by dark grey silty limestone with _Monotis_ _callozonensis_ West., _M._ _jakutica_ (Teller), _M._ _pinensis_ West., _Oxytoma_ sp.	"e"	9, 9a

- - - - - - - F A U L T F1 - - - - - - -

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities Westermann	Fossil Localities Westermann & Verma, 1967
10.	4.3 m	Light grey, fine-grained limestone, unfossiliferous		
11.	0.6 m	Coquina bed made up of *Monotis subcircularis* shells, compressed and tightly packed.		
12.	14.2 m	Fine grained light grey silty limestone, for the most part unfossiliferous. However, at about 7 m from the top, *Monotis pinensis* West. and *Eumorphotis* (*Asoella*) *obliqua* sp. nov. were recovered.		8
13.	1.5 m	Sheared zone showing fan fold, partly covered by talus. Fossils occur in the eastern as well as the western limbs of the fold. *Monotis pinensis*, *Eumorphotis* (*Asoella*) *obliqua*, sp. nov. *Oxytoma* sp.		6,6a,7 4,5

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities Westermann	Westermann & Verma, 1967
		- - - - - - - F A U L T F2 - - - - - - -		
14.	5.5 m	Coquina bed composed of *Monotis subcircularis* shells which are more abundant in the lower half where the weathered sections of the shells are more conspicuous.		
15.	2.0 m	Dark grey bituminous limestone with four (approximately 4" thick) coquina beds separated by about 6-8" barren limestone beds.		
16	3.1 m	Light grey unfossiliferous limestone		
17.	1.2 m	Dark grey limestone with *Monotis subcircularis* and *M. pinensis* scattered here and there.		
18.	4.3 m	Grey limestone, darker than above, fine-grained, a few *M. subcircularis* scattered throughout.		

Unit No.	Thickness	Lithology and Fossil Contents	Fossil Localities Westermann	Westermann & Verma, 1967
		Top weathered surface with cluster of <u>Monotis</u> <u>subcircularis</u> and evidence of sliding movement.		
19.	9.2 m	Light grey massive limestone. <u>Monotis</u> <u>pinensis</u> scattered throughout especially in the top 2 m. The top weathered surface exposes agglomeration of fossils.	"c" "b"	
20.	1.2 m	Grey massive limestone bed with <u>Monotis</u> <u>pinensis</u>, generally restricted to the middle of the bed.	"a"	1,2
21.	1.0 m	Dark grey limestone. Rare <u>Monotis</u> <u>pinensis</u> scattered throughout.		

Base of section at the tight small anticline.

CHAPTER 3

THE GENUS EUMORPHOTIS AND SUBGENERA

GENUS EMORPHOTIS Bittner, 1900 (as subgenus) (Jb. k. k. Geol. Reichsanst., 50 (1900) p. 566)

Type species (subsequent design. Cossman, 1902, p. 75) Pseudomonotis (Eumorphotis) telleri Bittner, 1899 (described in Appendix II)

3.1 Previous Literature

The literature is restricted mainly to the work of German authors, notably Bittner, at the turn of the century and the recent work by Japanese and Russian authors. Ichikawa (1958) has given an exhaustive account of the genus.

Genus Diagnosis - (translated from German) "Shell middle sized to large, acline or slightly opisthocline or prosocline, normally higher than long, winged on both sides, strongly inequivalve and occasionally discordant. Posterior auricle not distinctly separated from the shell body, elongated, clearly embayed below and forming a sharp angle at the posterior end. Anterior auricle not longer than the posterior auricle. External ligament amphidetic. Ligament area very narrow striped lengthwise. Ligament pit relatively moderately weak and narrow. Left valve moderately convex; umbo projecting over the hinge line; anterior auricle separated more or less clearly from the shell, anteriorly convex and forming approximately a right angle at the anterior end. Right valve completely flat or only weakly convex with the exception of moderately convex umbo region; umbo not projecting over the hinge line; byssal auricle well developed, semicircular, connected with the shell by a deeply entrenched very narrow wedge-shaped connecting plate. Byssal notch deeply cut before this connecting plate. Lower rim of byssus without ctenolium. Radial sculpture generally well developed and often with a tendency to scale formation (Schuppenbildüng) but in several species including the type species it is missing or suppressed. Radial sculpture of the ribbed forms of the left valve often differentiated into several orders through insertion, (ribs) on the right valve finer and simpler than on the left. In addition, comparatively fine and closely spaced concentric growth lines present which sometimes develop scales. A large adductor muscle scar immediately behind the middle of the shell. Pedal muscle scar close to the root of the byssal auricle of the right valve."

Bittner (1900, p. 566) included in his new "subgenus" (Eumorphotis) those species of Pseudomonotis which were characterized by "strongly developed wings or auricles".

Furthermore, the left valve of Eumorphotis is more richly ornate than the flattened right valve. However, Bittner restricted the usage of the name to the explanation of plates and made no mention of it in the text. Species of Pseudomonotis are also characterized by the following features: shell highly inequivalved with small byssal auricles, deep byssal notch and reduced posterior wing, left valve rarely winged anteriorly and the right valve with a fairly large byssal notch and has a corresponding furrow in the left valve.

Newell and Kummel (1942, p. 958) while describing Eumorphotis multiformis (Bittner) from the Triassic of Idaho tentatively raised Eumorphotis to generic level. They also suggested that Eumorphotis may be closely related to the upper Palaeozoic genus Limipecten. According to Ichikawa (1958) the external outline of most species of Eumorphotis varies within comparatively small limits but the bisectrix can be acline, prosocline or opisthocline. The posterior auricle is never clearly separated as in typical pectinids. In Bittner's opinion the radial sculpture of the right valve is undeveloped because it lies in the substrate. For taxomic description, the left valve has been found to be more useful and reliable and indeed in many species, the right valves are not known. As in the work of previous authors, more taxomic weight is here placed on the left valves, wherever both the valves were available.

Ichikawa (1958) placed the *Eumorphotis* species into four groups (1 to 4) which correspond to Bittner's (1900) grouping ('a' to 'd') as follows:

	Ichikawa(1958)	Bittner(1900)
Middle and Upper Triassic	4. Group containing *Eumorphotis sptizbergensis* (Boehm)	
Lower Triassic	3. Group of *E. hinnitidae* (Bittner)	'c'
	2. Group of *E. telleri* (Bittner)	'a' and 'd'
	1. Group of *E. multiformis* (Bittner)	'b'

Groups 1 to 3 are irrelevant to the present study. Ichikawa did not designate any species characteristic of group 4, but reported having examined *Eumorphotis* aff. *spitzbergensis* (Boehm) described by Kobayashi and Ichikawa (1949) from the Sakawan (Karnian) of southwest Japan. Boehm's (1903) *Pseudomonotis* (*Eumicrotis*) *spitzbergensis* was later correctly transferred to *Eumorphotis*(Ichikawa, 1958). Ichikawa, however, disagreed with Diener (1923) who placed *Pseudomonotis illyrica* Bittner from the Ladinian of the southern Alps (and ? Karnian of Asia Minor) in *Eumorphotis* because of obtuse dorso-posterior termination.

Ichikawa (1958) also pointed out that the bisectrix of the left valve of the two younger forms (i.e., *E. spitzbergensis* and "*E.*" *illyrica* of the 4th group) is more central than in *E. telleri*.

Tokuyama (1959) distinguished the new subgenus Eumorphotis (Asoella) while describing the late Triassic Pteriacea from the Atsu and Mine series of West Japan. Essentially E. (Asoella) includes Eumorphotis species with reduced auricles, smaller and more broadly convex outline, and more "salient" umbo of the left valve. The diagnosis of this subgenus and the species included in it are described on p. 50.

3.2 Affinities of Eumorphotis

The following genera show close affinities to Eumorphotis: i) Limipecten Girty, 1904 - Newell and Kummel (1942) recognized similarities with the upper Palaeozoic Limipecten Girty and suggested that some of the species usually included in Limipecten could be transferred to Eumorphotis. According to Ichikawa (1958), however, Eumorphotis (1) has larger height/length ratio, (2) does not possess downwardly arched concentric growth lines in the intercostal spaces, (3) (in many species) has ribs of more than one order, whereas Limipecten has ribs only of one order and (4) a shallower ligament pit. Ichikawa, therefore, tentatively suggested that Eumorphotis descended from a close relative of Limipecten. Furthermore, Ciriacks (1963) found that the distinctive intercalated costae on both valves of Limipecten were absent in Eo-Triassic species of Eumorphotis from the Rockies.

ii) *Aviculopecten* McCoy, 1851 - Two divergent views have been expressed with regard to the affinities to *Aviculopecten*. Ichikawa (1958) pointed out that (1) the ribs of higher order on the main portion of the right valve of *Eumorphotis* are intercalated whereas they originate by bifurcation in *Aviculopecten*, (2) the byssal auricle of *Aviculopecten* is larger and higher than in *Eumorphotis*, (3) the posterior auricle of *Aviculopecten* is more clearly separated, and (4) the anterior and posterior margins of *Aviculopecten* are sharply curved whereas in *Eumorphotis* these margins are evenly rounded.

On the other hand, Ciriacks (1963) wrote "*Eumorphotis* is highly similar to *Aviculopecten*. In fact, it is often very difficult to distinguish isolated left valves of the two genera." However, he also pointed out that "*Eumorphotis* differs from *Aviculopecten* in flatness, obsolescent ornamentation, and sharply defined byssal notch of right valves, and in the higher convexity of the left valves." Lower Triassic *Eumorphotis* from the Thaynes formation of Northern Utah as well as Bittner's (1900) original illustrations do not show any bifurcation of the radial ribs, a feature very characteristic of *Aviculopecten*.

iii) *Pseudomonotis* Beyrich, 1862 - *Eumorphotis* is distinguished from *Pseudomonotis* by (1) sharply defined byssal notch of the right valves, (2) well developed byssal auricle, (3) elongated posterior auricle, (4) regular outline, (5) convex right valve and (6) complete absence of a cicatrix.

Although Eumorphotis was recognized as a distinct subgenus as early as 1900, many authors continued to place species of P. (Eumorphotis) in Pseudomonotis s. str. In the present study, the author has transferred some species previously grouped under Pseudomonotis or Eumicrotis Meek to respectively E. (Eumorphotis) or E. (Asoella).

The confusion in the literature regarding the synonymy of Eumorphotis species is mostly due to the fact that new species were based on right or left valves only (mostly the latter). Furthermore, most described or figured material consists of imperfectly preserved specimens. Ichikawa (1958) discussed and attempted to clarify the relationships of E. telleri to homeomorphs mainly from the Lower and Middle Triassic. Brief reference was made above (p. 29) to the Upper Triassic Eumorphotis group represented by E. (A.) spitzbergensis. The present study is the first detailed account of Upper Triassic Eumorphotis.

Structural deformation of the shells tends to alter the morphological characters especially the outline - acline specimens may appear either opisthocline or prosocline. Consequently, many of the allegedly new species which were based on the inclination of the bisectrix only can be considered as junior synonyms. Ichikawa (1958) named Eumorphotis *mucronata* Leonardi and *E. nipponica* Ichikawa as examples.

Phylogenetically, *Eumorphotis* is considered to have descended from a near relative of *Limipecten* (see Fig. p. 18) . However, in the absence of our knowledge about the shell structure of *Eumorphotis*, closer phylogenetic relationship with *Oxytoma* Meek is not entirely ruled out.

3.3 Described Species of Middle and Upper Triassic Eumorphotis

In the *Fossilium Catalogus* Diener (1923) listed only 7 species of *Eumorphotis* from the Middle and Upper Triassic; Kuttassy (1931) listed 12 species but none from the Middle or Upper Triassic. A search of the literature revealed that many more species of *Eumorphotis* have since been recorded from this interval. The the author's knowledge the following is a complete list, in chronological order; several species have previously been placed in *Pseudomonotis* or *Eumicrotis*.

i) "*Pseudomonotis*" *illyrica* Bittner, 1902; Ladinian of Southern Alps.

ii) "*Eumicrotis*" *spitzbergensis* Boehm, 1903; Karnian of Bear Island, "Sakawan" (=Karnian) of Southwest Japan (Kobayashi and Ichikawa, 1949).

iii) *Eumorphotis artus* Boehm, 1903; Karnian of Bear Island.

iv) *E. Variabilis* Boehm, 1903; Karnian of Bear Island.

v) *E. vagans* Boehm, 1903; Karnian of Bear Island.

vi) E. tschernyschewi Wittenburg, 1910; Karnian of Spitzbergen.

vii) E. tolmatschewi Wittenburg, 1910; Ladinian (?) of Spitzbergen.

viii) "Pseudomonotis" convexa Mansuy, 1912; Middle Triassic (?) of Laos.

ix) "P." plicatuloides Mansuy, 1912; Upper Triassic (?) of Yunnan.

x) "P." laosensis Mansuy, 1912; Middle Triassic of Laos.

xi) "P." subconvexa Krumbeck, 1924; ? Middle Triassic of Timor.

xii) "P." australasiatica Krumbeck, 1924; ? Middle Triassic of Timor.

xiii) E. nationalis Smith, 1927; Karnian of Alaska.

xiv) E. tasaryensis Voronetz, 1936; Anisian and Karnian of Siberia.

xv) "P." zitteli Teller, 1886; Norian of Siberia.

xvi) E. deljanensis Kiparisova, 1937; Karnian of Siberia.

xvii) E. (Asoella) confertoradiata Tokuyama, 1959; Karnian/Norian of Japan.

xviii) E. (Asoella) laevigata Tokuyama, 1959; Lower Norian of Japan.

xix) E. (Asoella) nakatsukensis Tokuyama, 1959; Upper Karnian of Japan.

Tokuyama (1959) placed the species "Pseudomonotis" *illyrica*, "*Eumicrotis*" *spitzbergensis*, "*P*." *convexa*, *Eumorphotis* (*Asoella*) *confertoradiata*, *E*. (*A*.) *laevigata*, and *E*. (*A*.) *nakatsukensis* in his new subgenus *E*. (*Asoella*).

A synopsis of the above listed species is given in Appendix III.

CHAPTER 4

SYSTEMATIC DESCRIPTION OF EUMORPHOTIS SPECIES

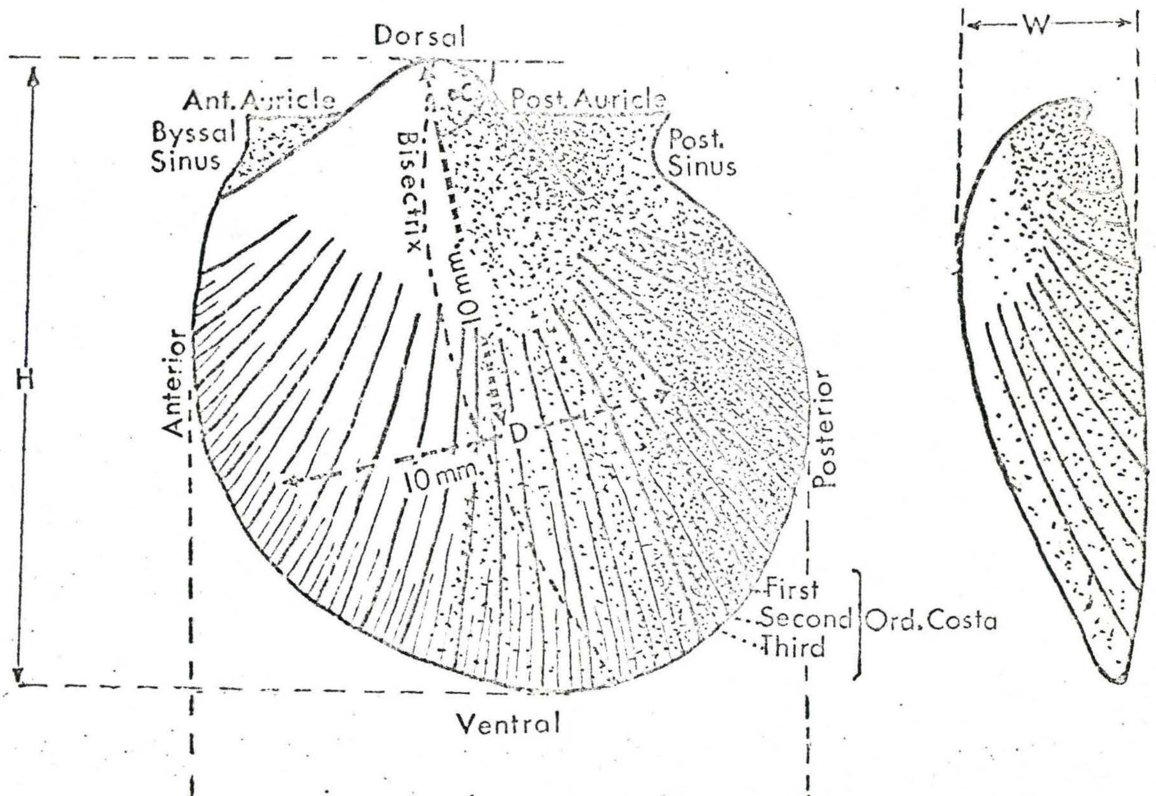
4.1 Terminology of aviculopectinid Shells

4.1.1 Abbreviations (Text - Fig. 1)

L - length; maximum dimension parallel to the hinge line.

H - height; maximum dimension perpendicular to the hinge line.

W - width (thickness); maximal lateral diameter of single valve perpendicular to plane of commissure.



Text - Fig. 1 Terminology of the left valve of the aviculopectinid shell.

D - number of costae (ribs) per 10 mm width (central part of the shell) at 10 mm from the umbo.

α - obliquity; posterior angle between line of maximum curvature (bisectrix) and hinge line; if less than 90^{o} the shell is prosocline, if $\pm 90^{o}$, the shell is acline, if larger than 90^{o} the shell is opisthocline.

4.1.2 Terms

Auricles - The anterior and posterior extensions of the shell along the dorsal margin. These are sometimes also called "ears" or "wings".

Byssal notch - A deep notch under the anterior auricle of the right valve through which the foot of the animal can be extruded without opening the valves.

Byssal sinus - An indentation in the front edge of the anterior auricle in the left valve.

Ribs or Costae - Radial ridges on the surface of the valve. In order of their appearance by intercalation from the umbo, these are termed first, second or third order etc.

Intercostal spaces - External furrows separating adjoining ribs.

Shell body - The body of the shell minus the auricles.

Family AVICULOPECTINIDAE Meek & Hayden, 1864

Subfamily Aviculopectininae Meek & Hayden, 1864

Genus EUMORPHOTIS Bittner, 1901

Subgenus Eumorphotis (Eumorphotis)

4.2 Eumorphotis (Eumorphotis) lemorayensis VERMA, sp. nov.
Pl. V, Figs. 1-8, Text - Fig. 2

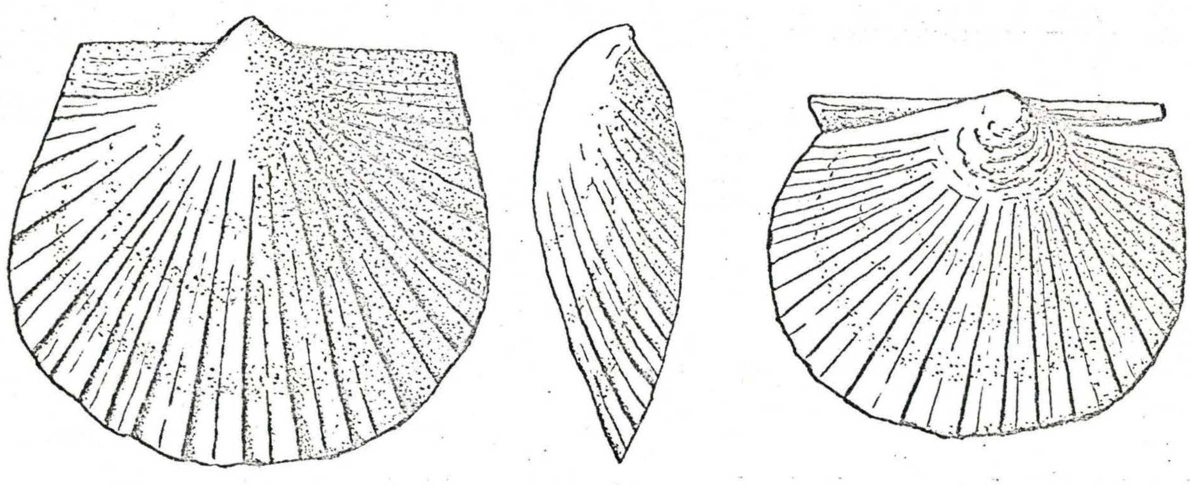
1962 Meleagrinella n.sp.? aff. M. antiqua Tozer. WESTERMANN, Jour. Palaeont., Vol. 36, No. 4, p. 786, pl. 118, Figs. 10, 11 only.

Holotype: McM # Tr. 384 WH; Pl. V, Fig. 1 (Left Valve)
Paratype: McM # Tr. 384 WP; Pl. V, Fig. 2 (Right Valve)
Locus Typicus: Pine River Bridge Section, British Columbia.
Stratum Typicum: Bed "g", M. subcircularis Zone, Up. Norian.
Derivatio nominis: Geographical, after Mount Lemoray, near Pine River Bridge Section, British Columbia.

Diagnosis - A coarsely-ribbed species of Eumorphotis s. str., outline sub-semicircular, left valve moderately convex, weakly opisthocline or acline, with relatively large auricles; costation differentiated; growth markings absent.

Material - 12+ left valves and 2 ? right valves from bed "g" of the Pine River Bridge Section (Westermann coll., McM # Tr. 384 W). 2+ left valves from the Upper Pardonet Formation, Northern Peace River foothills (coll. Shell Oil Co., McM # Tr. 383 S). 10+ left valves from "a boulder in Sikanni Chief River, North bank of East Trail Crossing (? Pardonet Formation)" (F. H. McLearn, G.S.C. coll., Cat. No. 1076 5 McM # 383 G). All from British Columbia.

Description - Shell of medium size, outline sub-semicircular, longer than broad; commissure evenly curved. Left valve moderately convex with gentle slope from the umbo to the ventral margin. The umbo is comparatively small, weakly incurved, sharply pointed, very slightly projecting beyond the hinge line. The hinge line is straight, about 2/3rds



a b c

Text - Fig. 2 - Eumorphotis (Eumorphotis) lemorayensis VERMA, sp. nov, composite sketches; a: exterior of left valve, b: lateral view of left valve, c: exterior of right valve of the species (X4)

of the total length of the shell. The posterior auricle is prominent but obtusely truncated and is continuous with the shell; in some specimens covered with weak ribs like the rest of the shell. The posterior margin is almost straight. The anterior auricle is shorter than the posterior auricle with more steeply inclined surface than on posterior auricle with convex margin. The auricles in general are devoid of any prominent ornamentation. The left valve is ornamented with coarse, sharp, straight radial ribs. Usually intercalated during growth are ribs of the second and rarely of the third order. Growth lines are absent on all specimens.

The probable <u>right valve</u> of the species is very weakly convex, slightly prosocline. The anterior and posterior margins are sub-parallel, the ventral margin highly convex. The byssal auricle is distinct, spearated from the shell body by a deep byssal notch, reaching almost to the umbo where it continues in a groove. The posterior auricle is not clearly demarcated from the shell, triangular, apparently terminating in a spine-like process. Surface is ornamented with faint, equally spaced ribs which become more prominent at the margins. The apex is thickened at the height of the hinge line. The hinge line is straight or bent because of the slightly inclined byssal auricle. The growth lines are missing but three, very faint, equally spaced rugae are present on the outer half of the paratype right valve.

<u>Discussion</u> - The specimens described by Westermann (1962)

as Meleagrinella s.sp. ? aff. M. antiqua Tozer include both Meleagrinella-like forms and Eumorphotis-like forms. The former are described below under Meleagrinella aurisparva sp. nov. while the latter belong to the present species. Meleagrinella antiqua Tozer differs from the present species by the smaller size, less conspicuous umbo, less prominent posterior auricle and more circular outline. M. aurisparva differs from the present species in the rudimentary auricles, and a stouter, incurved umbo. The surface sculpture and the shape of the posterior auricle of the left valve closely resemble "Avicula aff. venetianae Hauer" of Bittner (1899) from the Lower Scythian of Himalayas. Unfortunately, the present author did not have access to the detailed description and is therefore unable to comment on the affinities of this species. Eumorphotis (Asoella) illyrica Bittner, from the Ladinian of the Southern Alps, is much more densely ribbed and higher than long, and the byssal auricle has concentric sculpture. E. (E.) tasaryensis Voronetz, from the Anisian and Karnian of Siberia, most closely resembles this species with respect to outline and shape of the posterior auricle of the left valve, but differs by much smaller size and the supposedly present prominent growth lines.

Table 3

Measurements of Eumorphotis (Eumorphotis) lemorayensis sp. nov.

Specimen	L	H	W	D	α
Holotype left valve (McM # Tr. 384 WH)	16	13	3	20	91^{o}
Paratype right valve (McM # Tr. 384 WP)	14	11	c.1	15	110^{o}
Left valve (McM # Tr. 384 W)	18	15	5	21	112^{o}
" "	16	14	4	20	95^{o}
" "	11	10	3	c.15	98^{o}
G.S.C. # 10765 (McM # Tr. 383 G)	18	14	5	18	93^{o}
" "	12	10	3	24	89^{o}
Right valve (McM # Tr. 384 W)	14	11	c.1	18	75^{o}

The scatter diagram for Length (L) vs. height (H) for this species (Figure 8) shows a moderately strong correlation, with a growth ratio of 0.89. The scatter diagram for height (H) vs. width (W) (Figure 9a) shows a weak correlation as well as a greater dispersion towards small size specimens. It may be attributed to the small sample size or possibly measurement error. The frequency histogram for the obliquity (α) has positive skewness with the mode between 90^{o} and 95^{o} (Figure 9b).

Age and occurrence - Upper Norian, British Columbia.

4.3 Eumorphotis (Eumorphotis) laosensis (Mansuy) 1912

Plate X, Figs. 6, 7. Pl. XI, Figs. 1-2

1912 "Pseudomonotis" laosensis n. sp. MANSUY, Serv. Geol. Indochine, Vol. L, fasc. IV, part I, p. 46, pl. IX, Figs. 8a-d.

Diagnosis - A species of Eumorphotis s. str., left valve entirely covered with thin, thread-like, closely-spaced radial ribs, intercostal spaces similar in width, crossed by concentric rugae; posterior auricle well developed.

Material - Five left valves from the Ladinian/Karnian of Tuchodi Lakes area (Shell Oil Company coll., Cat. No. 7857 McM # 383 SA). One left valve from the Toad Formation (Anisian of Klingzut Mountain (Shell Oil Company coll., Cat. No. 7547, McM # Tr. 383 MA)). All from British Columbia; weathered.

Description - The shell is medium to large, inequivalve, with circular outline, acline or slightly prosocline. In one specimen the ventral margin is less curved than the anterior margin; the dorsal margin is almost straight. The left valve is evenly and moderately convex. The umbo is sharp and weakly inflated, projecting slightly beyond the hinge line. The hinge line is probably straight. The posterior auricle lacks good preservation except for a single specimen; it appears to be not clearly separated from the shell body, flattened, triangular and with an acute truncation. The shell slopes gradually to the posterior auricle. The posterior sinus is not preserved in the specimens under study. The anterior auricle is smaller than the posterior auricle, triangular, somewhat less acutely truncated, and moderately well demarcated from the shell by a change in slope. The ornamentation consists of very dense, thread-like, thin, subequal, blunt ribs and furrows continuing from very near the umbo to the ventral margin. There is no differentiation of ribs into orders. The weakness of the growth rugae is probably due to poor preservation.

One right valve from the Pine River Bridge Section (McM # 383 MA) may belong to this species. The valve is flat, the outline circular, the hinge line straight, the byssal auricle well developed with linear furrows, the deep byssal notch reaching almost up to the umbo; the posterior auricle is triangular, devoid of ornamentation, distinctly separated from the shell. The test is preserved along the anterior, ventral and posterior margins. The superficial sculpture consists of equally spaced dense radial ribs of equal strength, interspersed by equally broad intercostal spaces. Some concentric growth lines are preserved on the internal mold.

Discussion - This species was originally described by Mansuy as "Pseudomonotis" laosensis from the "Middle Trias(?)" of Northern Laos. However, since his figures show regular outline, elongation of the posterior auricle of the left valve and a different surface sculpture, it appears that this species is more akin to Eumorphotis than to Pseudomonotis. The material under description supports this opinion. The ornament distinguishes this species from all other species of Eumorphotis. It differs from E. (Asoella) illyrica (Bittner) also by its circular outline, lack of costae differentation, and linear furrows of the byssal auricle. Eumorphotis (E.) subconvexa (Krumbeck) from the "Middle Trias (?)" of Timor has a thicker and more convex left valve, and possess undulating ribs. E. (E.) tasaryensis Voronetz from the Anisian and Karnian of Siberia is much smaller, obliquely oval, and has fewer and more broadly spaced ribs. E. (A.) zitteli (Teller), E. (A.) convexa (Mansuy), and E. (E.) deljanensis Kiparisova have coarser, sharper and more widely spaced ribs.

Table 4

Measurements of Eumorphotis (Eumorphotis) laosensis (Mansuy)

Specimen	L	H	W	D	α
Left valve (Shell Oil coll. # 7857, McM # 383 SA)	17	16	3	37	88°
Left valve (McM # Tr. 383 MA)	20	18	3	c.32	67°
Left valve (Shell Oil coll. # 7547, McM # 383 SA)	18	17	4	32	94°
Right valve (McM # 383 MA)	c.18	18	-	40 (around edge)	90°

Age and occurrence - Anisian to Norian, Northeastern British Columbia.

4.4 Eumorphotis (Eumorphotis) zitteli (Teller)

Plate XII, Figs. 1-6

1886 Pseudomonotis zitteli TELLER in MOJSISOVICS, Mem. Acad. Imp. Sci. Nat. St. Petersbourg, Ser. 7, Tome 33, p. 137, pl. XIX, Fig. 10.

1927 Pseudomonotis zitteli TELLER in YEHARA, Japan. Jour. Geol. Geogr. Vol. 5, p. 30, pl. 4.

1937 Eumorphotis zitteli TELLER in KIPARISOVA, Trans. Arct. Inst. Vol. 91, p. 195, pl. VI, Figs. 1-3.

cf. 1942 Pecten cadwalladerensis McLEARN, Canad. Fld.-Nat., Vol. LVI, No. 7, pl. L, Figs. 2-4, 10.

Diagnosis - A large species of Eumorphotis s. str. with variable but generally broadly circular outline; left valve weakly inflated; thick and flattened umbo, projecting weakly beyond the hinge line; shell (probably including the auricles) covered with wide blunt ribs usually differentiated into 2 or 3 orders; posterior auricle more prominent and wider than anterior auricle.

Material - 12+ left valves from bed 11, M. subcircularis zone, Pine River Bridge Section (McM # Tr 427 E). Some of the specimens are damaged, the valves are preserved both as external and internal molds.

Description - The shell is generally comparatively large, although a few medium-sized specimens are present. The left valve is prosocline and has a variable outline but is generally broadly circular with curved margins and straight hinge line. The postero-ventral margin is stronger curved than the antero-ventral margin. The hinge line is straight and measures about two-thirds of the total length of the shell. The thick flat umbo projects weakly beyond the hinge line. The posterior auricle is wide and prominent, almost flat, sloping gently towards the shell with triangular outline, and almost rectangularly truncated. Some of the specimens have a weak posterior sinus. The anterior auricle is much smaller and steeper than the posterior auricle. The superficial ornamentation of the left valve consists of blunt radial ribs differentiated into 2 or 3 orders, but the internal molds have only faint, more widely spaced ribs of only one order. Although the internal molds of the umbo and auricles is smooth, it is probable that they had some superficial ornamentation. The right valve is not preserved.

Discussion - "Pseudomonotis" zitteli Teller 1886 was based on a right valve only from the Upper Trias of Werchojansk. Later, Kiparisova (1937) described the corresponding left valves from the Norian of Siberia and transferred this species to Eumorphotis. The material under study is similar to the Siberian species. The left valves also show a great similarity to 'Pecten' cadwalladerensis McLearn from the Upper Triassic of Tyaughton Creek, Bridge River District, British Columbia, with regard to its size, outline and costation. The plastotype of the left valve of McLearn's species (1942, pl. I, Fig. 4) has, contrary to that stated by McLearn, a larger and more prominent anterior auricle. His "inferred" right valve probably does not correspond to the left valve since it is about twice as large and does not show the hinge line and the auricles clearly. The similarity of the left valves of left valves of '<u>P</u>.' <u>cadwalladerensis</u> with <u>E</u>. (<u>E</u>.) <u>zitteli</u> from British Columbia suggests that the former belongs in <u>Eumorphotis</u>. <u>E</u>. (<u>E</u>.) <u>tschernaschewi</u> (Wittenberg) from the Karnian of Spitzbergen resembles <u>E</u>. (<u>E</u>.) <u>zitteli</u> in ornament but is a much larger shell. Meleagrinella aurisparva, Verma, sp. nov., from the Norian of British Columbia has similar ornament as <u>E</u>. (<u>E</u>.) <u>zitteli</u> but differs by oval outline and smaller auricles.

<u>Table 5</u>

<u>Measurements of Eumorphotis (Eumorphotis) zittelli (Teller)</u>

Specimen	L	W	H	D	α
Left valve (McM # 427 E)	14	c.14	4	22	70°
" "	c.16	16	4	14	88°
" "	18	17	4	15	85°
" "	18	17	5	18	78°
" "	c.16	19	4	15	80°
" "	18	c.19	3	24	90°

Note: Except for the last specimen, the density of ribs was measured on the internal mold.

<u>Age and occurrence</u> - Karnian and Upper Norian, <u>M</u>. <u>subcircularis</u> Zone, British Columbia.

4.5 Sub-genus *Eumorphotis* (*Asoella*) Tokuyama, 1959

Tokuyama (1959) distinguished the new sub-genus *Eumorphotis* (Asoella) while describing the late Triassic Pteriacea from the Atsu and Mine series of West Japan. Essentially, *E*. (*Asoella*) includes *Eumorphotis* species with reduced auricles, smaller and more broadly convex outline and more prominent umbo of the left valve.

Diagnosis - (Tokuyama, 1959, p. 2) "Shell small, plano-convex, roundly quadrate, nearly as long as broad. Left valve almost symmetrical or a little inclined anteriorly; anterior auricle almost diminished; posterior one small, subtriangular, separated by a shallow marginal furrow and passing gradually into shell body. Umbo orthogyrous, stout, rounded and produced above long and straight hinge line.

Right valve slightly convex and subrounded except anterior byssal auricle which is elongate-trigonal or crescentic and sharply demarcated by a byssal sulcus; byssal notch shallow; posterior auricle very small. Ligament opisthodetic; ligament area narrow concave striated and depressed triangular; central pit triangular, somewhat prosocline erected just below the beak. Internally a byssal gape and associated shallow sulcus in the left valve corresponding to the notch in the right valve. Posterior muscle scar large and subrounded; anterior and pallial ones unknown. Ornamentation composed of fine radial ribs or concentric striae which are similar on both valves."

Tokuyama (1959, p. 2) listed the following species:

E. (A.) confertoradiata Tokuyama, Lower Norian of Japan.

E. (A.) laevigata Tokuyama, Lower Noriam of Japan.

E. (A.) nakatsukensis Tokuyama, Karnian of Japan.

Pseudomonotis illyrica Bittner, Ladinian-Karnian of Asia Minor.

P. cf. illyrica Mansuy, Karnian of Yunnan.

P. convexa Mansuy, Middle (?) Trias of Laos.

Eumicrotis spitzbergensis Boehm, Karnian of Bear Island.

Tokuyama concluded that E. (Asoella) is a "declined subgenus" of Eumorphotis representing its terminal form in the late Triassic. The present author is in agreement with this classification.

4.6 Eumorphotis (Asoella) depressa VERMA, sp. nov.

Plate V, Figs. 9-13, Plate VI, Figs. 1-7, Text - Fig. 3.

Holotype: McM # 427 AH, Plate VI, Figs. 4, 4a (left valve).

Locus typicus: Pine River Bridge Section, British Columbia.

Stratum typicum: Bed 11, M. subcircularis Zone, Norian.

Deravatio nominis: Latin, meaning low-lying, depressed.

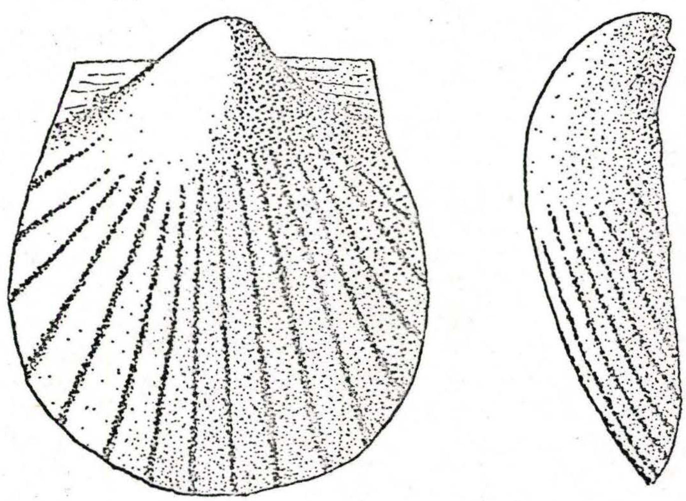
Diagnosis - A species of E. (Asoella) with left valve as high as long, weakly convex, covered with moderately strong, widely spaced blunt ribs; umbo sharp, projecting slightly beyond the hinge line.

Material - 35+ left valves from bed 11, (McM # Tr. 427 A), 2 left valves from bed "g" (Westermann coll., McM # 383 WD), all external molds. Most valves are incomplete.

M. subcircularis Zone, Pine River Bridge Section, British Columbia.

Description - Shell small to medium size (L: 8-17 mm, H: 9-17 mm, W: 3-4 mm). Left valve usually only moderately convex, acline and with circular outline, moderately slightly prosocline with oval outline. Umbo stout, central, and sharply pointed, slightly projecting beyond the straight hinge line. Anterior and posterior auricles are present but not clearly demarcated; without change in curvature of shell margin. The few well preserved specimens show that the posterior auricle is slightly longer than the anterior one. The dorsal margins are smooth and obtusely truncated, without marked sinus. The superficial ornamentation consists of straight, blunt, radial ribs over most of the shell except for the immediate vicinity of the umbo and the auricles where they become obsolete. Fully grown specimens have 16-18 regularly spaced ribs of a single order only. In some specimens a few extremely faint growth lines can be discerned superficially. However, these are masked by the prominent radial ribs. Right valves are missing in the present collection.

Discussion - E. (A.) depressa differs from E. (A.) westermanni sp. nov. by the circular outline, subequality of height and length, the sharper umbo, stronger costation and weaker convexity. E. (A.) spitzbergensis (Boehm) is much smaller and oval in outline. E. (A.) depressa differs from E. (A.) illyrica (Bittner) from the Karnian of Asia Minor and E. (E.) nationalis (Smith) from the Karnian of Alaska. and is distinguished by the absence of secondary ribs



a b

Text - Fig. 3 Eumorphotis (Asoella) depressa VERMA, sp. nov. Sketch of the holotype (McM # 427 AH), a, exterior view of left valve, b, lateral view of the same (X4)

and the straight hinge line, although resembling the latter in outline. E. (E.) zitteli (Teller), from the Norian of Siberia, has more widely spaced and sharper costae, and better developed and more prominent auricles. E. (E.) deljanensis Kiparisova, from the Karnian of Siberia is similarly distinguished. Meleagrinella antiqua Tozer, from the Karnian/Norian of Ellesmere Island closely resembles this species but differs in much smaller size, the very conspicuous anterior auricle, the wider inter-costal spaces and the presence of costae on the whole shell including the umbo.

Table 6

Measurements of Eumorphotis (Asoella) depressa sp. nov.

Specimen	L	H	W	D	α
Holotype left valve (McM # Tr. 427 AH)	14	14	4	15	90°
Left valve McM # 427 A	c.13	13	3	18	80°
" "	13	c.13	4	c.15	90°
" "	c.14	14	3	c.14	90°
" "	13	c.13	3	14	90°
" "	15	15	4	16	90°
" "	17	c.17	4	17	90°
" "	12	11	3	15	85°
" "	11	11	3	16	87°
" "	c.11	11	3	17	88°
" "	c.14	c.14	4	14	70°
" "	c.13	c.13	3	-	85°

Scatter diagram for 12 specimens of left valves of this species (Figure 10a) shows a strong correlation and a positive allometry (m = 1.0434). The frequency histogram for obliquity (α) has a mode of $90^{\circ} - 94^{\circ}$.

Age and occurrence - Upper Norian, British Columbia.

4.7 Eumorphotis (Asoella ?) acuta VERMA, sp. nov.

Plate VII, Figs. 1-8, Text - Fig. 4.

Holotype: McM # Tr. 383 WBH, Pl. VII, Fig. 6 (left valve)

Paratype: McM # Tr. 383 MBP, Pl. VII, Figs. 8, 8a (left valve)

Locus typicus: Pine River Bridge Section, British Columbia

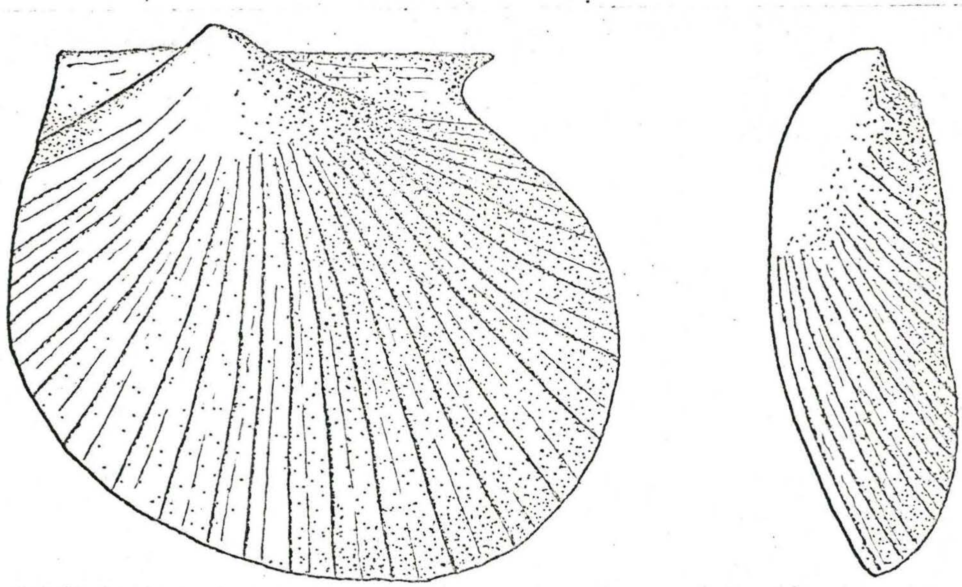
Stratum typicum: Bed 11 and bed "g", M. subcircularis Zone.

Deravatio nominis: Latin, meaning pointed, referring to the posterior auricle.

Diagnosis - A medium to large species of Eumorphotis(Asoella) with moderately to highly inflated left valve; hinge line straight, posterior auricle elongated and acutely truncated with distinct sinus; costation of left valve variable, consisting of first and second order closely spaced ribs or rather widely spaced blunt ribs.

Material - One large-sized and 3 medium-sized left valves from bed 11 (McM # Tr. 427 B), three left valves from ? bed "g" (Martini coll., McM # Tr. 383 MB), two left valves from bed "g" (Westermann coll. McM # Tr. 383 WB). All from the M. subcircularis Zone, Pine River Bridge Section, British Columbia.

Description - The left valve is acline or weakly prosocline, probably inequivalve, and varies greatly in size (Figure 11a, 11b) (L: 11-21 mm, H: 11-22 mm, W: 3-9 mm). The shell outline is sub-circular to sub-ovate with sub-parallel anterior and posterior margins. The hinge line is straight, slightly shorter than the length of the valve. The umbo is prominent, thick and pointed at the apex, slightly pro-



Text - Fig. 4 (a) external and (b) lateral views of left valve of Eumorphotis (Asoella ?) acuta VERMA sp. nov. Sketch of holotype, (specimen No. McM # Tr. 383 WBH) (X4)

jecting beyond the hinge line. The posterior auricle is broad at the base, and truncated acutely to form a sharp process with distinct posterior sinus. The anterior auricle is moderately well developed, the slope intergrading with the shell; the outline is triangular with almost rectantular truncation. The slope of the auricles towards the shell becomes more gentle with growth. The valve is moderately to highly convex. It follows a logarithmic spiral as shown in Figure 12 wherein the radius vectors measured along the profile of a specimen belonging to this species (McM # 383 MBP), when plotted against the angle of radius vector gives a smooth curve approximating a straight line. This is substantiated by the fact that the ratios of successive radius vectors vary within very small limits.

The superficial sculpture consists of radial ribs which are faint in the umbonal portion but gradually gain prominence towards the margins. The auricles are smooth. There appears to be some variation in the strength and spacing of the ribs - some specimens have sharp, closely spaced ribs with intercalated secondaries; others show weak, rather widely spaced, blunt ribs. There is no trace of growth lines. The specimens from bed 11 are deformed and, therefore, incompletely preserved. However, the specimens from bed "g" are well preserved. Unfortunately, right valves of this species are absent in the present collection.

Discussion - Shell outline and shape of the posterior auricle are reminiscent of '*Aviculopecten*' *tenuistriatus*

Boehm from the Karnian of Bear Island. However, an examination of the plastotype (left valve) revealed that the latter is only weakly convex and that Boehm's illustration (Pl. 3, Fig. 20) is twice enlarged, not natural size, as stated. The only other species resembling E. (A.) acuta is 'Avicula' mucronata Gabb, from the Norian of California, which is distinguished by the posterior auricle extending into a much more developed spine-like process (the anterior auricle is unknown), by stronger prosoclinity, finer costation and more conspicuous growth lines. 'A.' mucronata is probably equivalve.

Table 7

Measurements of Eumorphotis (Asoella ?) acuta sp. nov.

Specimen	L	H	W	D	α
Holotype, left valve (McM # Tr. 383 WBH)	20	19	5	21	80°
Left valve (McM # 427 B)	11	11	3	-	85°
" "	13	c.13	3	-	88°
" "	c.13	14	4	6	88°
" "	20	22	17	19	90°
Left valve (McM # Tr. 383 WBH)	17	17	5	19	85°

Table 7 (cont'd)

Specimen	L	H	W	D	α
Left valve (McM # Tr. 383 MB)	14	14	6	17	80^{o}
Left valve (McM # Tr. 383 MBP)	21	22	9	16	85^{o}

The scatter diagram for height (H) vs. length (L) (Figure 11a) shows a positive allometry and a high correlation. However, the scatter diagram for the inflation ratio i.e. height (H) vs. width (W) (Figure 11b) shows a large scatter. The frequency histogram for obliquity (α) (Figure 11c) gives a mode between 85^{o} - 90^{o} i.e. the majority of the sample is slightly prosocline.

Age and occurrence - M. subcircularis Zone, Upper Norian, northeast British Columbia.

4.8 Eumorphotis (Asoella) westermanni VERMA, sp. nov.
Plate VIII, Figs. 1-18, Text - Fig. 5.

Holotype: McM # Tr. 383 CH, Pl. VIII, Figs. 1, 1a (left valve)

Paratype: McM # Tr. 383 CP, Pl. VIII, Figs. 2, 2a (dissociated right valve)

Locus typicus: Pine River Bridge Section, on Hart Highway, British Columbia.

Stratum typicum: Bed 11, M. subcircularis Zone, Upper Norian.

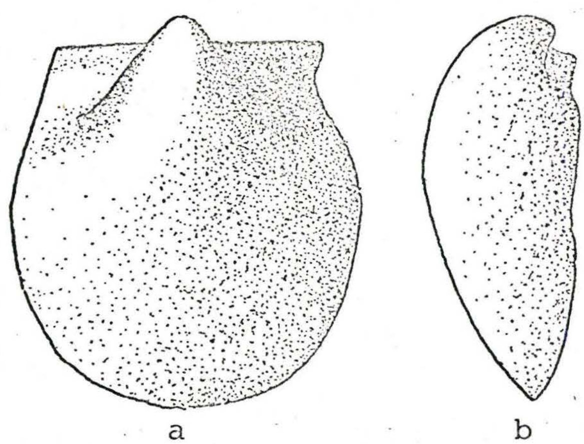
Derivatio nominis: After Professor G. E. G. Westermann of McMaster University, Hamilton, Canada.

Diagnosis - An equilateral species of Eumorphotis (Asoella); shell small to medium size, with prominent central umbo; auricles small, dorsal marginal edge of the posterior auricle semi-cylindrical (tubular); ornamentation absent on both valves or consisting of superficial, very faint radial ribs; growth lines absent.

Material - More than 60 valves, mostly internal molds, and several, probably corresponding, right valves, from bed 11, Pine River Bridge Section, M. subcircularis Zone, (McM # Tr. #383 C). Many specimens are deformed resulting in apparent prosoclinity of the shell. Ten left valves and seven right valves from the Pardonet formation "base of section 300 feet thick, north of Pine River, near mouth of Mountain Creek, British Columbia",(L. D. Burling, Geol. Surv. Canada coll., Cat. No. 14115, McM # Tr. 383 GC). One left valve from the Upper Toad Formation, Toad River, Alaska Highway, Mile 375.3 (Shell Oil Company coll. Cat. No. 1159, McM # Tr. 383 SC).

Description - The shells are of small to medium size (L: 4-8 mm, H: 3-12 mm, W: 2-6 mm). The smaller, probably immature, valves are longer than high, whereas the mature valves are higher than long. The left valves are strongly inflated. The dissociated, probably corresponding right valves of the species are almost flat.

Most of the left valves are acline and the slight prosoclinity, observed in some, can be attributed to deformation. The left valves display logarithmic spiral growth as illustrated in Figure 13, wherein radius vectors, when plotted against the angle of radius vectors give a plot approximating a straight line and the ratio of radius vectors vary between 0.697 to 0.830. The maximum thickness of the shell is at about one-third the height from the umbo. The ventral margin is semi-circular, the posterior and



Text - Fig. 5 Eumorphotis (Asoella) westermanni VERMA, sp. nov. sketch based upon the holotype (McM # Tr. 383 CH). (a) external view of left valve, (b) lateral view of the same.

anterior margins are equally convex. The hinge line is always concealed but was probably straight. In the larger specimens about one-third of the length of hinge line is taken up respectively by the auricles or covered by the umbo. The umbo is thick, stout, straight and projects about 1/6th of the shell height beyond the hinge line. The convexity of the shell grades into the slightly concave posterior auricle which is posteriorly acutely truncated, separated by a weak sinus. The upper edge of the posterior auricle is hollow, tubular. The anterior auricle is usually slightly shorter than and less defined than the posterior auricle with continuous anterior shell margin, little change of convexity, sloping up to the margin and slightly obtuse anterior truncation. The left valves are almost smooth, except for extremely faint ribs which can be noticed only under oblique light. The auricles are completely smooth.

The right valves are much more rare than the left valves, particularly in the sample from the Pine River Bridge Section. This is probably due to the fact that these are more fragile and liable to be destroyed more easily than the left ones. They are semi-circular in outline and sub-planular, or, more rarely, very weakly convex. The sub-rectangular byssal auricle is distinctly separated from the main part of the valve by the byssal notch which reaches almost to the apex. The posterior auricle is elongated into a pointed process, in continuation with the dorsal margin of the valve. The apex is small and does not appear to project beyond the hinge line. Ornamentation is usually lacking but some valves show extremely weak radial ribs. Growth lines are absent.

Discussion - This species has all the characteristics of E. (Asoella). However, muscle scars and ligament area cannot be observed in the present sample. E. (A.) spitzbergensis (1903) from the Karnian of Bear Island differs from E. (A.) westermanni by (1) flat anterior and posterior auricles of the left valve, (2) clearly developed ribbing, (3) non-tubular dorsal edge of the posterior auricle, and (4) smaller size. E. (A.) spitzbergensis is only 1/3rd the size of E. (A.) westermanni, although Boehm's type specimen may be immature. If so, the presence of ribs in the juvenile stage contrasts with the total absence of ribbing in E. (A.) westermanni.

E. (A.) illyrica (Bittner) from the Karnian of Asia Minor and E. (A.) convexa (Mansuy) from the Middle Trias (?) of Northern Laos, and E. (E.) subconvexa (Krumbeck) from the Upper Scythian of Timor are similar in outline, but distinguished by the presence of radial ribs.

Table 8

Measurements of Eumorphotis (Asoella) westermanni sp. nov.

Specimen	L	W	H	α
Holotype				
left valve (McM # Tr. 383 CH)	13	c.15	5	90°
Paratype				
dissociated right valve (McM # Tr. 383 CP)	11	10	c.1	95°
Left valve (McM # Tr. 383 C)	4	c.4	2	85°
" "	5	c.5	2	90°
" "	6	5	3	85°
" "	6	5	3	90°
" "	8	9	4	85°
" "	8	9	5	87°
" "	9	9	4	85°
" "	9	9	4	90°
" "	11	11	6	95°
Left valve (McM # Tr. 427 C)	12	14	7	90°
" "	13	13	7	90°
Dissociated right valve (McM # Tr. 427 C)	11	10	1	92°
Left valve (McM # Tr. 383 SC)	8	8	3	100°

Table 8 (cont'd)

Specimen	L	W	H	α
Left valve (McM # Tr. 383 GC)	13	13	5	93°
" "	16	17	7	88°
Dissociated right valve (McM # Tr. 383 GC)	13	13	2	92°

Age and occurrence - M. subcircularis Zone, Upper Norian, British Columbia.

4.9 Eumorphotis (Asoella) obliqua VERMA, sp. nov.

Plate IX, Figs. 1-14, Text - Fig. 7.

Holotype: McM # 427 DH, Pl. IX, Fig. 9.

Locus typicus: Pine River Bridge Section, on Hart Highway, British Columbia.

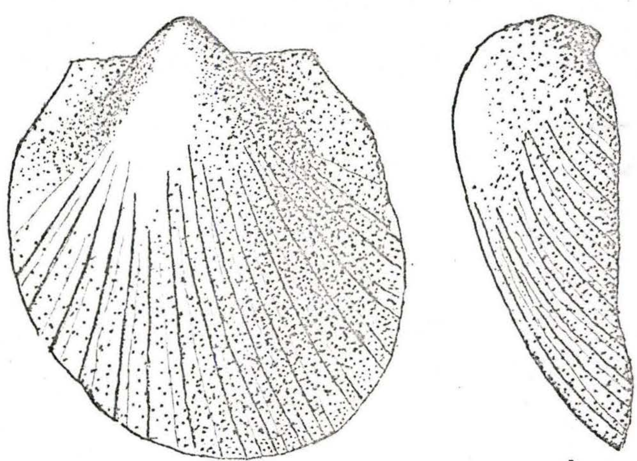
Stratum typicus: Bed 11, M. subcircularis Zone, Norian.

Derivatio nominis: On account of generally greater obliquity than E. (A.) westermanni sp. nov.

Diagnosis - A species of Eumorphotis (Asoella) with prosocline left valve, sharp pointed umbo, marked superficial costation especially marginally, and rather long, obtusely truncated posterior auricle.

Material - 18+ left valves and a few, probably corresponding dissociated right valves from bed 11 (McM # 427 D), one left valve ? from bed "g" (Martini coll., McM # Tr. 383 MD). One left valve from loc. 6A (McM # 421), 5+ left valves from loc. 7 (McM # Tr. 422), and 6 left valves from loc. 8 (McM # Tr. 423); M. pinensis Zone. All from Pine River Bridge Section, British Columbia.

Description - The specimens under study resemble E. (A.) westermanni described above in size and convexity, but are



Text-Fig. 6 Eumorphotis (Asoella) obliqua sp. nov., composite sketch. a, Exterior view of left valve, b, lateral view of same (X4).

more prosocline with more pointed umbo and more marked costation, especially towards the margins; secondary ribs may be intercalated. The posterior auricle is much wider and longer than in E. (A.) westermanni, terminates in an obtuse angle, and is separated from the shell by a well developed posterior sinus.

Table 9

Measurements of Eumorphotis (Asoella) obliqua sp. nov.

Specimen	L	W	H	α
Left valve (McM # 8 Tr. 427 D)	8	8	3	70°
" "	c.9	9	3	72°
" "	11	11	4	69°
" "	c.11	c.11	4	73°
" "	c.10	10	4	65°
" "	10	11	4	70°
" "	12	12	5	70°
" "	13	14	5	72°
Holotype left valve (McM # 427 DH)	12	14	6	74°
Left valve (McM # 427 D)	11	12	5	80°
" "	10	11	5	70°
Left valve (McM # 383 MD)	14	15	7	72°
Left valve (McM # Tr. 421)	7	8	3	70°
Right valve (McM # Tr. 427 D)	8	6	-	80°

Dimensions of E. (A.) westermanni and E. (A.) obliqua - The scatter diagrams of length (L) vs. height (H) of E. (A.) westermanni and its variety obliqua (Figure 14a) give almost parallel regression lines, both with a positive allometry. The scatter diagrams for height (H) vs. width (W) (Figure 14b) indicate a greater dispersion and slightly different slopes and intercepts of regression lines. Both the samples intergrade overall dimensiions. The most important reason of segregating E. (A.) obliqua as a separate species is its lesser obliquity as indicated in Figure 15.

Age and occurrence - Norian, Northeast British Columbia.

4.10 Eumorphotis (Asoella) convexa (Mansuy), 1912
Plate X, Figs. 1-3, Text-Fig. 7.

1912 "Pseudomonotis" convexa n. sp. MANSUY, Serv. Geol. Indochine, Vol. L, fasc. IV, part I, p. 46, pl. IX, Figs. 5a, b, c, d.

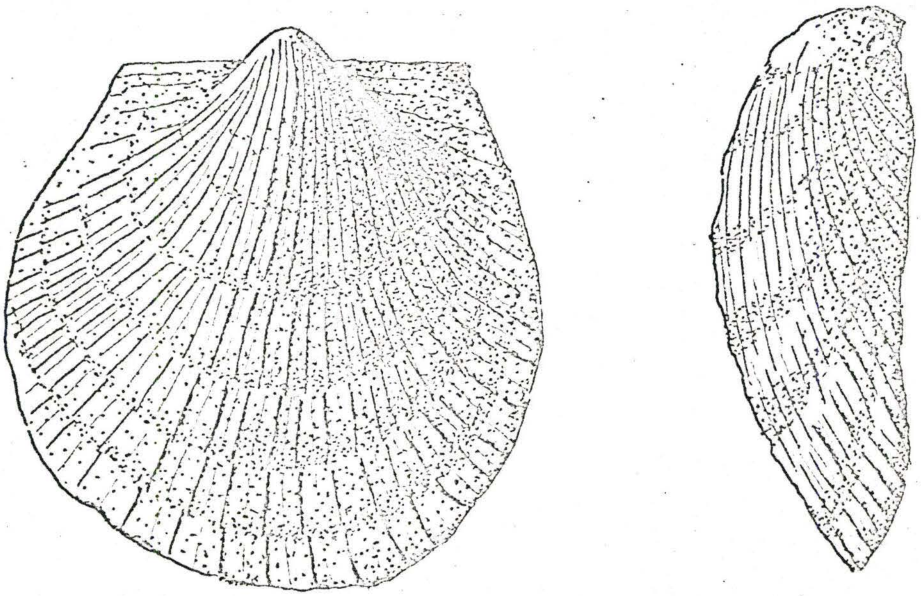
?1961 Monotis, sp. cf. M. montini McLEARN, in ALLENCASTER DE CSERNA, Palaeont. Mexic. No. 11, Part LLL, p. 27, Figs. 1, 2, 3.

Diagnosis - A species of Eumorphotis (Asoella) with sub-elliptical outline; left valve strongly convex with umbo not projecting beyond the hinge line, superficial strong radial ribs, differentiated in two orders, partly broken and off-set, crossed by rather strong growth lines.

Material - Two left valves from loc. G4, Anisian of Tetsa Valley, (McM # Tr. 421 A); 4 left valves and 1 right valve (Martini coll., ? bed "g" McM # Tr. 383 M), 2+ left valves and 1 ? right valve from bed "g" (Westermann coll., McM # Tr. 383 WA) of the Norian Pine River Bridge Section.

Description - The shell is medium to large, inequivalve, asymmetrical, mostly prosocline, sometimes acline; the outline of left valve is sub-elliptical with posterior margin more strongly curved than the anterior margin and weakly incurved ventral margin. The left valve is strongly convex with conically inflated and pointed umbo which is neither strongly curved nor projecting beyond the hinge line. The hinge line is straight, a little more than half the length of the valve. The posterior auricle is distinct, but not separated from the valve, triangular, slightly elongated, steeply sloping towards the shell body and has weak superficial ribs. The anterior auricle is triangular, smaller and steeper than the posterior auricle. The ornamentation on the surface of the valve consists of blunt ribs over the whole shell including the umbo. The ribs are clearly differentiated in first and second orders. At places the ribs show deviations from a straight line and are frequently broken and off-set. The valve is covered by superficial, irregularly spaced, rather strong growth lines.

The right valve, found in association with the left valve, and therefore most probably belonging to this species has a semi-circular outline with straight hinge line, is slightly convex and has weak radial ribs. The umbo is very weak terminating at the hinge line. The byssal auricle is wing-like and the deep byssal notch reaches up to the umbo. The posterior auricle is covered by matrix which cannot be removed without damaging the adjacent left valve. Because of strong weathering, the right valve does not show



a b

Text - Fig. 7 Eumorphotis (Asoella) convexa (Mansuy), composite sketch. (a) exterior view of left valve (b) lateral view of the same.

details. Growth lines are absent on the right valve.

Discussion - "Pseudomonotis" convexa (Mansuy) from the "Middle Trias (?)" of Northern Laos is here transferred to Eumorphotis because of the elongation of the posterior auricle, the regular outline, the flat right valve (described but not figured by Mansuy), and the absence of cicatrix. This classification is supported by the present material which has yielded the structure of the byssal elements of the right valve. Ribbing and convexity of E. (A.) convexa are similar to 'Monotis sp. cf. M. montini McLearn' as described by Allencaster De Cserna (1961) from the Karnian of Santa Clara, Mexico. "M." montini McLearn (1937, pl. I, Fig. 6) from the Karnian of British Columbia is not a Monotis because of the long straight hinge line and the distinct anterior auricle. However, without re-investigation of holotype or topotypes the transfer of 'Monotis' montini to Eumorphotis is suggested only tentatively. E. (E.) subconvexa (Krumbeck) from the "Middle Trias (?)" of Timor closely resembles E. (A.) convexa but has a more circular shell outline, is smaller, more convex, and possesses blunt, wavy radial ribs and 'stripes'. E. nationalis Smith from the Karnian of Alaska and E. zitteli (Teller) from the Norian of Siberia have more pronounced and more widely spaced first order ribs and lack growth lines.

Table 10

Measurements of Eumorphotis (Asoella) convexa (Mansuy)

Specimen	L	H	W	D	α
Left valve (McM # Tr. 421 A)	c.20	19	5	29	75°
Left valve (McM # Tr. 383 M)	13	14	5	31	73°
Left valve (McM # Tr. 383 M)	19	c.18	5	c.28	78°
Right valve (McM # Tr. 383 M)	c.12	12	1	6	91°

Age and occurrence - Anisian to Norian, British Columbia.

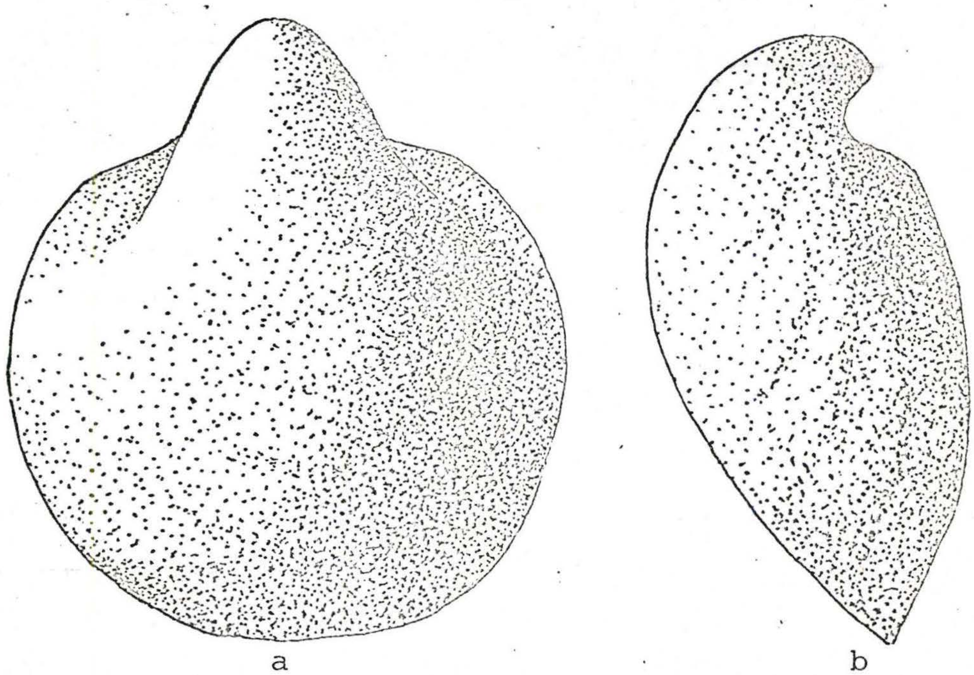
4.11 Eumorphotis (Asoella) cf. E. (A.) australasiatica (Krumbeck) 1924. Plate XI, Figs. 3-7, Text-Fig. 8

cf. 1924 Pseudomonotis australasiatica sp. nov. KRUMBECK Palaeont. Timor II, Vol. XXII, p. 241, pl. CLXXVI (8).

Material - Two left valves from the Nathorstites zone of the Liard Formation, Alaska Highway, Mile Post 386 (Shell Oil Company coll. Cat. No. 1161, McM # Tr. 383 E). Three left valves from bed "g", M. subcircularis Zone of the

Pine River Bridge Section (Westermann coll., McM # Tr. 383 E). Two left valves and two impressions of left valves from the Pardonet Formation, Pine River near Mountain Creek (Geol. Surv. Canada coll., Cat. No. 14115, McM # Tr. 383 GE). All from British Columbia.

Description - The shell is medium to large, broader than long, inequivalve, with obliquely oval to subcircular outline. The posterior margin is straight to weakly convex; anterior margin and ventral margins semi-circular. The



a b

Text - Fig. 8 Eumorphotis (Asoella) cf. E. (A.) australasiatica (Krumbeck); sketch of specimen No. McM # Tr. 383 SE). (a) exterior view of left valve, (b) lateral view of the same. (X4)

left valve is weakly opisthocline, acline or weakly prosocline, highly convex throughout. The umbo is prominent, very strongly incurved, projecting far beyond the hinge line.

The hinge line is straight and short, about one-third of the length of the shell. The posterior auricle is distinct, small, passing gradually into the shell body, obtusely truncated with weakly convex posterior margin. The anterior auricle is slightly shorter, sloping more steeply towards the shell than the posterior auricle and the convex margin is continuous with the anterior margin of the shell.

Ornamentation is usually obsolete. However, equally spaced, weak growth lines are discernible on the entire surface of the shell; extremely faint radial ribs are visible on some specimens, where they become more prominent than the growth lines.

Discussion - There appears to be perfect resemblance in outline, convexity, shape of the umbo and surface features with "Pseudomonotis" australasiatica Krumbeck from the 'Middle Trias (?)' of Timor. Although Krumbeck's figures do not show well developed auricles, a short posterior auricle is reportedly present (1912, Pl. 176, Fig. 9) while the apparent absence of an anterior auricle was said to be possibly owing to poor state of preservation. The suggested affinities between the Timor and the British Columbia faunas (Krumbeck, 1924, p. 241) can now be confirmed. The probable development of posterior and anterior auricles, prominent umbo, and circular outline warrant the classification of E. (A.) australasiatica under E. (Asoella).

This species differs from E. (Asoella) laevigata Tokuyama from the Norian of Japan by the larger and more convex shell, and the more projecting umbo.

Table 11

Measurements of Eumorphotis (Asoella) cf. E. (A) australasiatica (Krumbeck)

Specimen	L	H	W	P*	α
Left valve (McM # Tr. 383 SE)	18	20	19	5	110^{o}
" "	17	18	7	3	78^{o}
Left valve (McM # Tr. 383 GE)	12	13	5	3	70^{o}
" "	11	13	4	2	65^{o}
Left valve (McM # Tr. 383 GE)	12	15	4	c.3	70^{o}

*Note: P indicates the projection of the umbo beyond the hinge line.

4.12 Eumorphotis n. sp. aff. ? E. (E.) subconvexa (Krumbeck)

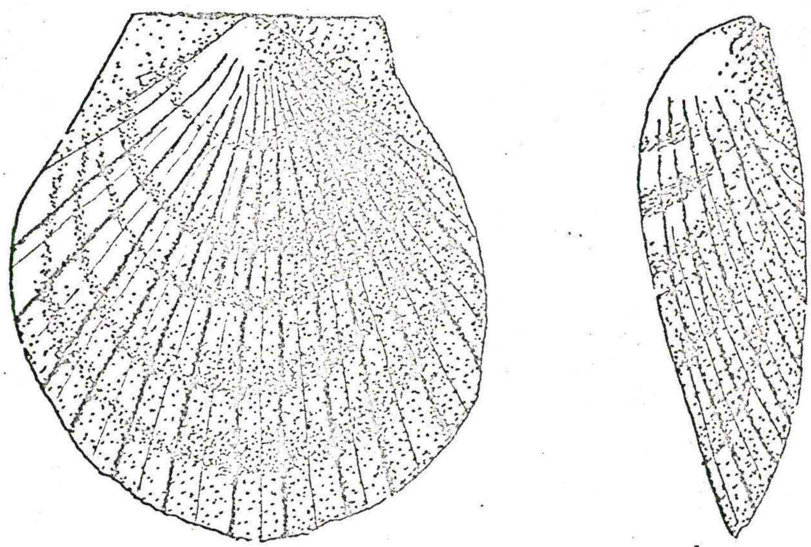
Plate X, Figs. 4, 5 Text- Fig. 9

?1924 Pseudomonotis subconvexa n. sp. KRUMBECK, Palaeont. Timor LL, Vol. XXII, p. 243, pl. CLXXVI (8), Figs. 12a, b.

Material - Two incomplete left valves respectively from the Liard formation, Spike Mountain, Toad Valley, and Alaska

Highway area (Shell Oil Company coll., Cat. No. 4886 and 6888, McM # Tr. 383 SG). (In one specimen the posterior and ventral margins are damaged and in the other, only parts of posterior, ventral and anterior margins are preserved.)

Description - The shell is of medium size and acline. The outline appears to be sub-circular or vertically elongated, sub-ovate. The anterior and posterior margins are weakly convex and sub-parallel; the ventral margin is highly curved. The left valve is weakly convex, attaining maximum convexity



a b

Text - Fig. 9 Eumorphotis n. sp. ? E. (E.) subconvexa (Krumbeck); composite sketch. (a) exterior view of left valve, (b) lateral view of the same.

at about one quarter height. The umbo is thick but rather weakly incurved, pointed and not projecting beyond the hinge line. The hinge line is straight and less than half the length of the shell. The posterior auricle is distinct, flat but continuous with the shell, obtusely truncated and apparently smooth. The anterior auricle, smaller than the posterior auricle, obtusely truncated and devoid of ornamentation. The superficial ornamentation of the left valve consists of equally spaced, undulating, blunt radial costae over the entire shell, excluding the auricles. The ribs are differentiated into two orders, the second order ribs intercalating at one-half size. The almost regular growth lines are present forming a weak node-like protuberance at the intersection with the costae. The right valve corresponding to this species is unknown.

Discussion - Our form resembles *E.* (*E.*) *subconvexa* Krumbeck in ornamentation and outline which according to insufficient original description and illustration may belong to either *Pseudomonotis* or *Eumorphotis*. A single left valve was reported to have a rudimentary posterior auricle, but this is not evident from the figure; the right valve is unknown. The British Columbia form, however, is a typical *Eumorphotis* with distinct anterior and posterior auricles, widely spaced undulating ribs and growth lines forming a reticulate pattern with nodes. It differs from *E.* (*E.*) *subconvexa* in the weaker convexity, the presence of distinct anterior and posterior auricles and of well developed growth lines. It differs from *E.* (*E.*) *nationalis* Smith from the Karnian of

Alaska by the oval outline, weaker costation and the presence of growth lines. Our specimens also resemble Eumorphotis convexa (Mansuy) but have less conves left valves, weaker ornamentation and longer auricles. The differences between Eumorphotis (A.) convexa (Mansuy) and 'Pseudomonotis subconvexa Krumbeck are probably not very significant.

Table 12

Measurements of Eumorphotis n. sp. aff. ? E. (E.) subconvexa (Krumbeck)

Specimen	L	H	W	D	α
Left valve (McM # Tr. 383 SG)	16	19	4	16	88°
" "	c.16	c.18	4	17	91°

Age and occurrence - Upper Ladinian to Norian of Northeastern British Columbia.

The following "key" has been constructed as an aid in identifying and distinguishing between the different species of Eumorphotis, described in the preceding pages. The important diagnostic characters of each species are underlined.

KEY TO THE IDENTIFICATION OF EUMORPHOTIS SPECIES

(Based on Left Valve)

Size	Obliquity	Outline & Convexity	Umbo	Auricles	Ornament	Species Name
small to medium	Acline to Prosocline	Oval, weakly convex	sharp	ant. larger, flatter, post. sinuous	Prominent Ist and IInd ord. ribs	E. (E.) artus Boehm
		Circ., gently convex	sharp	small, hardly differentiated	wide, blunt ribs	E. (E.) nationalis Smith
		Sub-quadr. feebly convex	weak	ant. v. small, post. without sinus	sinuous radial ribs espec. at extremities	E. (E.?) plicatuloides (Mansuy)
		Oval, weakly convex	weak	not exposed	fine, crowded, radial ribs and concentric stripes	E. (E.) variabilis Boehm
		Symmetrical Str. convex	pro-minent	small, roundly triangular	fine, distinct blunt ribs, differentiated	E. (A.) confertoradiata Tokuyama
		Equilat. mod-erately convex	central sharp	not clearly demarcated	strong, wide, blunt ribs	E. (A.) depressa sp. nov.
		Semicirc. moderately convex	broad, projects weakly	ant. distinct-ly separate	prominent, over 100 blunt ribs differentiated	E. (A.) illyrica Bittner
		Semicirc. convex	central	small	smooth	E. (A.) laevigata Tokuyama
		depressed	weakly pro-jecting	-	smooth	E. (A.) nakatsukensis Tokuyama
		Sub-oval gently convex	weak	-	primary ribs break and shift laterally	E. (E.) vagans Boehm

Size	Obliquity	Outline & Convexity	Umbo	Auricles	Ornament	Species Name
small to medium	acline to prosocline	Sub-circ. mdrtly. cvx.	wide, projects	distinct, flat	evenly spaced, thread-like ribs	E. (A.) spitzbergensis (Boehm)
		oblique, oval inflated	sharp pointed	post. long, obtusely truncated	weak ribs	E. (A.) obliqua sp. nov.
		circ. str. inflated	prominent central	post. with weak sinus, upper edge tubular	smooth	E. (A.) westermanni sp. nov
medium to large		circ. cvx.	sharp	post. well developed	thin, thread-like close ribs concentric rugae	E. (E.) laosensis (Mansuy)
		Subovate, mdrtly cvx.	prominent thick	post. broad at base elongated acutely, truncated, distinct sinus.	variable, closely spaced ribs	E. (A.?) acuta sp. nov.
		Sub-circ. highly cvx.	prominent very str. incurved	not distinct	variable, usually obsolete	E. (A.) australasiatica (Krumbeck)
		sub-ellipt. str. cvx.	stout, sharp, not projecting	not well developed	str. ribs, broken and offset	E. (A.) convexa (Mansuy)
		sub-circ. weakly cvx.	pointed, not projecting	distinct	undulating blunt costae differentiated intersecting growth lines with protuberances	E. (A.) subconvexa (Krumbeck)

Size	Obliquity	Outline & Convexity	Umbo	Auricles	Ornament	Species Name
medium	opisthocline to acline	slightly oblique, strongly cvx.	partly pre-served	post. large triangular, with weak post. sinus covered with growth lines	32 radiating costae	E. (E.) deljanensis Kiparisova
		sub-semi circ. mdrtly cvx.	small sharply incurved	large	coarse, sharp straight ribs	E. (E.) lemorayensis sp. nov.
		oblique, mdrtly cvx.	strong, pro-jecting	post. large, wing-like	uniform ribs of varying no., concentric growth lines	E. (E.) tasaryensis Voronetz
large	prosocline	variable, weakly inflated	flat-tened, projects weakly	post. promi-nent, ant. weak	wide, blunt ribs	E. (E.) zittelli Teller
very large	acline	circ. very thick	-	post. wing-like, ant. large, sep-arated by ridge	strong c. 20 radial ribs with 2nd and 3rd ord. ribs and concentric growth lines	E. (E.) tschernyschewi Wittenburg

CHAPTER 5

THE GENUS *MELEAGRINELLA*

Sub-Family	OXYTOMINAE Meek, 1864
Genus	*Meleagrinella*, Whitfield, 1885 (syn. *Echinotis* Marwick, 1935)
Type Species	*Avicula curta* Hall (subsequent designation Cox, 1941) (described in Appendix IV)

5.1 Previous Literature

Although the genus was established in a study of the Cretaceous *Avicula abrupta* Conard from the Lower Green Marls of New Jersey (Whitfield, 1885) the Jurassic "*Avicula*" *curta* Hall and "*Pseudomonotis* (*Eumicrotis*)" *orbiculata* Whitfield, were said to be its "typical species".
Diagnosis - (Whitfield, 1885, p. 71) "Shell aviculoid having the general form of *Meleagrina* Lamarck but differing principally in the form of the byssal fold of the right valve, which is either a deep channel on the external surface of the shell or a simple deep straight notch separating the wing into a linear process, of greater or less length, from the body of the shell. Shells biconvex; hinge straight;

ligamental area narrow, but distinct, strongest on the left valve, which is also the most convex, and more or less gaping opposite the notch of the right valve. A single muscular scar of large size occurs subcentrally behind the middle of the valves; other muscular scars unknown. Surface lamellose or lamellose-radiate, with fine radiate fibrous glistening texture like that of *Placumomya*."

According to Whitfield (*op. cit.*) *Meleagrinella* is most closely allied to *Meleagrina* Lamarck. *Meleagrinella abrupta* Whitf. is not a good representative of the genus. The right valve has a deep anterior byssal notch just below the hinge which continues in a deep groove to apex. The left valve has an internal fold on the anterior side of the umbo corresponding to the byssal notch of the right valve. The same feature is present in *M. curta* Hall but absent in *Meleagrina*. Whitfield (1885) discredited Meek's (1864) reference of *M. abrupta* to *Oxytoma*, because of gross differences with the type species *O. mucronata*.

A junior synonym of *Meleagrinella* is *Echinotis* Marwick, 1935, originally described from the Jurassic of New Zealand, with the type species *Avicula echinata* Smith (1817) from the Jurassic of Europe. The generic identity was established by Cox (1941) after he himself has previously used the name *Echinotis* (Cox *et.al.* 1940). The species group of *M. echinata* had previously been placed in

Pseudomonotis.

Marwick (1935) diagnosed Echinotis as follows: "Shell rather small, inequivalve, outline sub-quadrate, left valve well inflated, right valve flat. Both valves have prominent posterior wings, acutely angled at their junction with the long straight dorsal and strongly concave posterior margin. Anterior wing weak, right byssal auricle well developed, oblique, considerably overlapped by the anterior wing. Sculpture discrepant, right valve with strong radiate ridges, left valve smooth. Hinge area edentulous, with a well excavated triangular ligament pit. Left hinge having a thickening below the umbo with a gentle sinus anteriorly and bounded by ligament posteriorly."

The close affinity between Meleagrinella echinata and M. curta is apparent from the correspondence in the characters of the hinge line as figured for M. curta by Whitfield (1885) and for M. echinata by Pompeckj (1901) and Borissiak (1909) and described by Cox (1940).

Pseudomonotis is distinguished from Meleagrinella mainly by (1) the very irregular shape and uneven convexity and (2) the byssal auricle of the right valve which is separated from the body of the valve by a very deep sinus which usually enlarges adapically. In Meleagrinella the anterior auricle is delimited only by a deep groove and a comparatively shallow marginal notch. Furthermore, Pseudomonotis remains attached with the umbo of the right valve throughout life, a point stressed by Cox (1940, 1941) and Newell (1937).

Cox (1940), in describing "Echinotis" echinata from the Upper Bathonian (Patchham and Chari beds) of Western India discussed the generic characters of "Echinotis" in great detail which is summarized as follows: Shell usually rather small, very inequivalve; left valve strongly convex with a well-curved umbo; right valve flat or feebly convex, smaller than the left. Outline orbicular to sub-quadrate; posterior auricle short or rudimentary. Right valve with a very narrow anterior auricle separated by a deep narrow furrow which leads to an arcuate but usually shallow notch in the margin of the valve. Anterior auricle occasionally present, but more frequently absent in the left valve; anterior margin of this valve has a wide sinus. Cardinal plate narrow in both valves; sub-vertical in the left and inclined outwards in the right, sometimes nearly horizontal. A well-excavated pit stretches posteriorly from below the umbo in each valve. Left valve usually ornamented with narrow closely-spaced radial riblets crossed by well-defined growth-lamellae, but smooth in some species. Right valve smooth or with faint radial ribs.

The type species of "Echinotis" Avicula echinata was originally described from the middle Jurassic of Europe and subsequently found world wide. Pompeckj (1901) published good figures of the British specimens, and Borissiak (1909) illustrated and described specimens from Russia, considered to be the best illustrations of the type species.

M. echinata described by Marwick (1953, pl. 10, Figs. 5-6) from the Bajocian Bathonian of New Zealand, is based on poorly-preserved specimens so that the specific determination remains doubtful.

Only one Upper Triassic species of Meleagrinella has previously been named, i.e., M. antiqua Tozer (1961) from the Lower Heiberg Formation of Ellesmere Island (Queen Elizabeth Islands). Its diagnosis is given in Appendix V.

5.2 Systematic Description of Meleagrinella species

Meleagrinella aurisparva VERMA, sp. nov.

Plate XII, Figs. 7,8, Plate XIII, Figs. 1-8, Text-Fig.10

1962 Meleagrinella n. sp. ? aff. M. antiqua Tozer, WESTERMANN, Jour. Palaeont., vol. 36, no. 4, p. 786, pl. 118, Figs. 8, 9 only.

Holotype: McM # Tr. 383 WFH, Pl. XII, Fig. 7 (left valve)

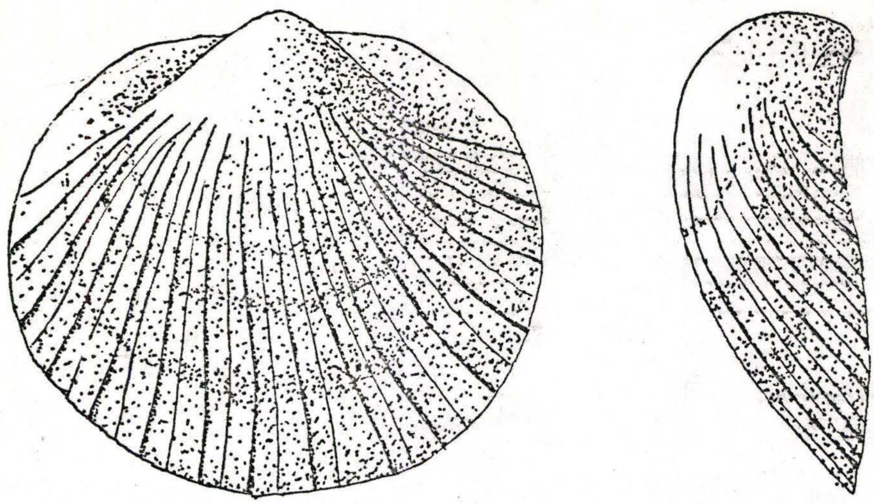
Paratype: McM # Tr. 383 WFP, Pl. XII, Fig. 8, 8a (left valve)

Locus typicus: Pine River Bridge Section, British Columbia.
Stratum typicum: Bed 11, M. subcircularis Zone, Up. Norian.
Derivatio nominis: Latin, meaning short ear.

Diagnosis - A species of Meleagrinella with rudimentary auricles; left valve sub-circular to broadly oval, highly convex with stout, incurved umbo, slightly or not projected beyond the hinge line; whole left valve covered with even sharp ribs.

Material - About 50 left valves and two right valves probably corresponding to the same species, mostly incomplete, from bed 11 (McM # Tr. 427 F). Four specimens, including the holotype, from bed "g" (Westermann coll., McM # Tr. 383 WF). All from the M. subcircularis Zone of the Pine River Bridge Section. Some valves have been broken near the fragile ventral margin because of dense accumulation together with M. subcircularis and subsequent compaction of the rock.

Description - The shell is medium sized, depressed subcircular, sometimes elongate, usually wider than long, inequivalve, usually prosocline, more rarely acline or opisthocline. The left valve is highly arched, growth following a logarithmic spiral. The ventral margin is only weakly curved. The hinge line is straight and short, less than half the maximum length of the shell. The umbo is stout and incurved with very slight or no projection



a b

Text-Fig. 10 Meleagrinella aurisparva VERMA sp. nov.; composite sketch. a) exterior of left valve, b) lateral view of the same.

beyond the hinge line. The posterior and anterior auricles are short and rudimentary. The anterior auricle is very poorly defined and almost indistinguishable from the main part of the shell. The posterior auricle is more distinct than anterior and slightly longer. Both auricles are continuous with the shell margin obtusely truncated and devoid of ornamentation. The ornamentation consists of 30-50 sharp radial ribs, which are regularly differentiated into two, or rarely three orders and usually commence on the umbo. The faint growth lines are often masked by the pronounced ribs.

A few fragments of the right valves were found in close association with the left ones and probably belong to this species. One nearly complete specimen (Pl. XIII, Fig. 8) is slightly convex in the apical region, but otherwise almost flat; the outline is circular; the apex does not project beyond the straight hinge line. The auricles are not completely preserved. The incomplete byssal auricle is more prominent than the posterior auricle, separated from the main part of the shell by a small deep furrow which probably leads to the byssal notch. The surface of the shell has very faint, widely spaced, blunt radial ribs which arise at about one-fourth of full size. A few very faint growth lines in the apical region are visible. In general, the ornament on the right valve is much weaker than on the left valve.

Discussion - Two of the figured left valves of Westermann's (see syn.) '*Meleagrinella* n. sp. ? aff. *M. antiqua* Tozer' belong to *M. aurisparva*. The new species is now established on the additional material from bed 11 of the same locality. *M. antiqua* Tozer from the Karnian/Norian of the Bjorne Peninsula, Queen Elizabeth Islands, is much smaller and less convex, has a more prominent posterior auricle on the left valve, and denser ribbing while its right valve is more strongly ornate. *Eumorphotis* (*Asoella*) *illyrica* Bittner from the Ladinian of Southern Alps has longer auricles, much denser ribbing of 5 or 6 orders (more than 100 ribs along the edge). The closest resemblance in outline and convexity is found in Eumorphotis (E.) subconvexa (Krumbeck) from the 'Middle Trias (?)' of Timor, which differs in the ribs, i.e., undulating in the umbonal region, clearly off-set peripherally, and carrying fine radial 'stripes'.

TABLE 14

Measurements on Meleagrinella aurisparva sp. nov.

Specimen	L	H	W	D	α
Holotype, left valve (McM # Tr. 383 WFH)	18	19	5	17	82°
Paratype, left valve (McM # Tr. 383 WFP)	20	16	6	28	75°
Left valve (McM # Tr. 383 F)	17	17	5	25	91°
" "	18	c.18	5	20	90°
Left valve (McM # Tr. 427 F)	c.18	c.18	5	23	78°
" "	13	13	4	24	90°
" "	18	c.19	c.5	21	110°
" "	19	c.18	6	21	72°
" "	14	16	5	16	90°
Right valve (McM # 427 F)	c.14	c.12	1	-	90°

The scatter diagram for length (L) vs. height (H) (Figure 16a) as well as that for height (H) vs width (W) (Figure 16b) gives regression lines which are significantly different from corresponding regression lines in the case of Eumorphotis species (Figure 17). The frequency histogram for the obliquity gives a mode between 90 and 95°.

Age and occurrence - Upper Norian, *M. subcircularis* Zone, Northeastern British Columbia.

CHAPTER 6

PHYLOGENETIC RELATIONSHIPS

6.1 Classification

The family Aviculopectinidae, which had its peak of development in the late Palaeozoic, is encompassed in the broad group of pteriids which are important Triassic index fossils. Eumorphotis and Meleagrinella, along with Oxytoma, Claraia and Aucella, constitute the most important Triassic genera of the family Aviculopectinidae. Several subfamilies have been proposed among which are the Aviculopectininae which includes Eumorphotis, and the Oxytominae which includes Meleagrinella.

Ichikawa (1958), on the basis of the shell structure, grouped the Oxytominae along with the Aucellinae into the stirps Oxytomini and the subfamilies Pseudomonotinae and Aviculopectininae into the stirps Aviculopectini.

Newell (1938) listed four generally usable characters for the classification of Pectinoids: (1) Musculature, (2) hinge, (3) ornamentation and (4) shell microstructure. Of these Tokuyama (1959) considered the development of ligament and the development of byssal auricle of the right valve as important classificatory characters of Aviculopectinids.

For classification at the specific level, the useful criteria are size, shape and convexity of the shell, nature of ornamentation, nature and comparative sizes of the anterior and posterior auricles, and the shape of the umbo, especially in the case of a collection, like the present one, where hinge line and the musculature are not available for study. The problem of classification is further complicated by the fact that, in general, the right valves, being thin and fragile are less likely to be preserved than the left ones. Consequently, the right valves of many species are either rare or unknown.

6.2 Phylogeny

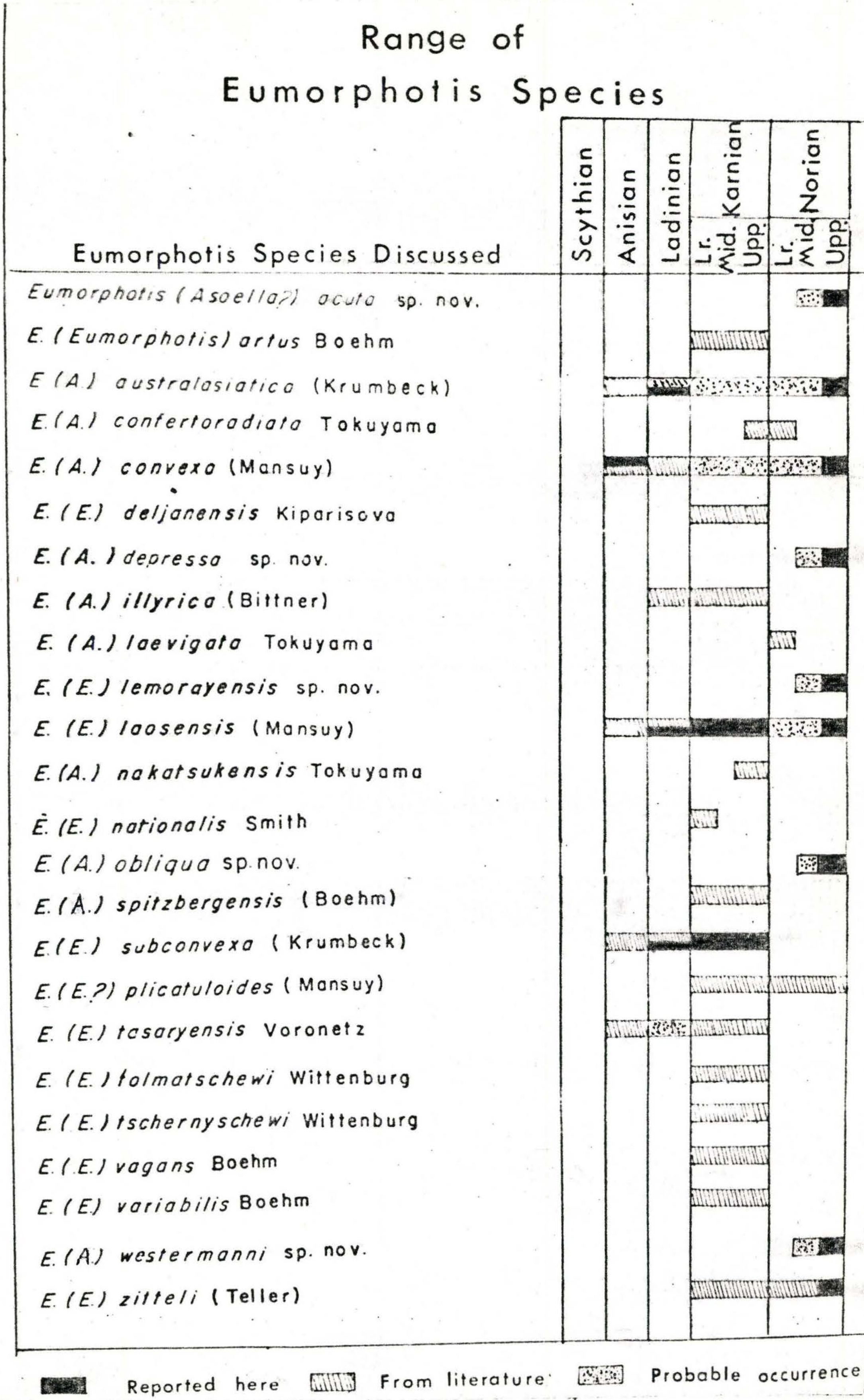
The exact evolutionary pattern of the Aviculopectinidae is not clearly understood. However, it is generally believed that the different genera of the Triassic Pteriids have a polyphyletic origin. Furthermore, the Aviculopectinini are believed to be ancestral to Oxytomini (Ichikawa, 1958).

The exact origin of the genus Eumorphotis is not known. Newell and Kummel (1942) suggested that it was probably derived from a near relative of Limipectin. Furthermore, Kobayashi and Ichikawa (1959) stated that Eumorphotis is closely related to Oxytoma. This is substantiated by the fact that the ligament areas in the two genera are similar except that in Eumorphotis the ligament pit is triangular and the inner margin of the ligament area is straight whereas in Oxytoma, the pit is not perfectly triangular and the inner margin of the ligament area is concave. The greatest development of Eumorphotis was in the early Triassic times. Nonetheless, the present work seems to suggest that it continued to be an important element of the Triassic Aviculopectinidae up to the end of the Triassic. Oxytoma-like forms departed from Eumorphotis in the Middle Triassic (Figure 18).

The origin of Meleagrinella is somewhat more problematical. The present evidence of the association of Meleagrinella with Eumorphotis in the Upper Norian of British Columbia seems to support Ichikawa's views that Meleagrinella arose as a side branch of Eumorphotis during the Upper Triassic, when the latter was in a degenerating stage. However, both in Japan and in the Queen Elizabeth Islands Oxytoma is found in association with Meleagrinella (Tozer, 1961). Oxytoma is also reported in the Upper Triassic of British Columbia (Westermann, 1962). Therefore, pending a detailed investigation of the Upper Triassic Oxytoma in British Columbia, the possibility that Meleagrinella arose from Oxytoma cannot be ruled out. The modified phylogeny is shown in Figure 18. Table 15 gives the ranges of all known Upper Triassic and of some

Middle Triassic species of Eumorphotis discussed here. On the basis of the occurrence of some of the species in British Columbia, probable ages of some of the species are indicated. The geographic distribution of the species (Figure 19) suggests that the North American species migrated from southeast Asia. This opinion was also expressed by Westermann (1962). The probable direction of migration as suggested by the time relationships of the species is indicated in Figure 19. Further support for this hypothesis comes from the fact that the North American species bear very close affinities with the Siberian, Indo-Chinese and southeast Asian species. The Upper Triassic species of Eumorphotis occurring in Bear Island and Spitzbergen do not have close affinities with the North American species.

TABLE 15


Range of
Eumorphotis Species
Eumorphotis Species Discussed
Scythian
Anisian
Ladinian
Karnian
Lr.
Mid.
Upp.
Norian
Lr.
Mid.
Upp.
Eumorphotis (Asoella?) acuta sp. nov.
E. (Eumorphotis) artus Boehm
E. (A.) australasiatica (Krumbeck)
E. (A.) confertoradiata Tokuyama
E. (A.) convexa (Mansuy)
E. (E.) deljanensis Kiparisova
E. (A.) depressa sp. nov.
E. (A.) illyrica (Bittner)
E. (A.) laevigata Tokuyama
E. (E.) lemorayensis sp. nov.
E. (E.) laosensis (Mansuy)
E. (A.) nakatsukensis Tokuyama
E. (E.) nationalis Smith
E. (A.) obliqua sp. nov.
E. (A.) spitzbergensis (Boehm)
E. (E.) subconvexa (Krumbeck)
E. (E.?) plicatuloides (Mansuy)
E. (E.) tasaryensis Voronetz
E. (E.) tolmatschewi Wittenburg
E. (E.) tschernyschewi Wittenburg
E. (E.) vagans Boehm
E. (E.) variabilis Boehm
E. (A.) westermanni sp. nov.
E. (E.) zitteli (Teller)
Reported here
From literature
Probable occurrence

SUMMARY AND CONCLUSIONS

1. The reinvestigation of the Pine River Bridge Section in British Columbia has revealed important structural and stratigraphic details. This has helped in removing the biostratigraphic discrepancies observed in the succession of *Monotis*.

2. The present study has revised the description of Upper Triassic *Eumorphotis* and *Meleagrinella*.

3. It has been found that *Eumorphotis* continued to be an important faunal element in the Upper Triassic times.

4. Five new species of *Eumorphotis*, i.e., *Eumorphotis* (*Eumorphotis*) *lemorayensis*, *E.* (*Asoella*) *depressa*, *E.* (*A.* ?) *acuta*, *E.* (*A.*) *westermanni* and *E.* (*A.*) *obliqua* are described. One species of *Meleagrinella*, i.e., *M. aurisparva* is proposed.

5. The Indo-Chinese species "*Pseudomonotis*" *laosensis* (Mansuy), "*Pseudomonotis*" *convexa* (Mansuy) "*Pseudomonotis*" *australasiatica* (Krumbeck) and "*Pseudomonotis*" *subconvexa* (Krumbeck) are reported for the first time from North America. These species have been transferred to *Eumorphotis* as a result of a study of better preserved material.

6. The Siberian Norian *Eumorphotis* (*Eumorphotis*) *zitteli* (Teller) is also reported for the first time from North America.

7. It is suggested that *Pseudomonotis plicatuloides* Boehm, and *Pseudomonotis tolmatschewi* Wittenburg be transferred to *Eumorphotis* (*Eumorphotis*) and that *Pseudomonotis illyrica* Bittner and *Eumicrotis spitzbergensis* Boehm be transferred to *Eumorphotis* (*Asoella*).

8. The *Eumorphotis* fauna under study bears strong affinities with the Upper Triassic *Eumorphotis* faunas of Siberia and Indo-China. Although no species common to both Japan and North America have been found, yet the occurrence of several species of *E.* (*Asoella*) in both the faunal provinces, suggests close affinities.

9. The present work tends to support the hypothesis that, like some other important bivalve genera, *Eumorphotis* probably originated in southeast Asia and later migrated to North America.

10. The phylogeny of *Eumorphotis* has been modified to show *Eumorphotis* as an important element of the Middle and Upper Triassic and the probable origin of *Meleagrinella* from *Oxytoma*.

APPENDIX I

FIELD WORK IN THE TOAD-TETSA RIVER AREA
ALASKA HIGHWAY

The following is a brief description of the outcrops examined in the Toad-Tetsa River area (Figure 3).

i) Localities G4, C4 (Mile post 376.4) Alaska Highway - A freshly blasted outcrop of flat-lying very hard compact silty limestone beds of the Toad Formation each about 1-1.5 m. thick, is exposed on the north side of the highway. The basal bed, almost at the level of the highway, yielded a prolific *Gymnotoceras*-*Beyrichites* fauna including *Parapopanoceras*, *Gymnites*, *Longobardites* and *Gymnotoceras*. The localities G4 and C4 are approximately near to localities VI and V respectively of McLearn (1948).

ii) Locality A4 (Mile post 382.8) Alaska Highway - The hill on the north side of the Highway consists of Toad formation at the base and the Liard formation towards the top. A few pelecypods were collected at the base of the hill from beds probably bearing the *Gymnotoceras*-*Beyrichites* fauna (Pelletier, 1963).

iii) Locality G3a, G3b (Mile post 386.7) Alaska Highway - This rather inconspicuous outcrop of about 5 m. Liard with 2 fossiliferous horizons yielded a rich *Nathorstites* fauna including Nathorstites, Protrachyceras, Sirenites, Nitanoceras, Daonella and others.

iv) Locality A2, G2 (Mile post 387) Alaska Highway - An exposure of dark Liard siltstones yielded a few specimens of Daonella.

v) Locality G1 (Mile post 388.9) Alaska Highway - The crest of the anticline exposed here yielded some spiriferinids which may indicate the presence of Liard along this part of the highway besides Toad or Grayling as shown in G.S.C. map 29-1963.

vi) Locality A1, F1-F4 (Mile post 389.4) Alaska Highway - About 14 m. of Grayling and Toad siltstones and mudstones are exposed here. The rock is friable and has yielded a few badly preserved Posidonia and at least one ammonite. This locality marks the westernmost limit of the Triassic outcrops exposed along this part of the Highway. It is followed by Permian Chert to the west.

In the Toad River area (Figure 4) three stratigraphic sections, all of them near the Alaska Highway were studied.

vii) Locality D, Racing River Section - Section on the southwest face of the high hill northwest of mile post 417, about 2 miles northeast of the Racing River Bridge. The section of the Toad Formation forms the western limb of the Raving River syncline. Following the concealed interval, the basal 7 m. of platy siltstone yielded Daonella, succeeded by 70 m. of limestone beds and about 22 m. of concealed beds. Above this is a ledge forming sandstone followed by about 30 m. of dark grey, fine grained siltstones highly fractured and cleaved, containing black rounded concretions. At the top is about 30 m. of thick limestone beds. A few fragmentary pelecypods were collected from rolled boulders.

viii) Locality E, Hill section north of Toad River - About 5 miles northeast of the Toad River Lodge (Mile post 424), the exposed section of about 130 m. Toad Formation is almost entirely composed of platy siltstones interbedded with sandstones and shales. The siltstones yielded slabs covered with impressions of Daonella. The top of the section is made up of thick massive limestones forming an almost vertical cliff. These limestones probably represent the post-Liard Grey Beds, and did not yield any fossils. The section is similar to D, except that it is more fossiliferous.

ix) High Hill south of Mile post 427, Alaska Highway Loc.B- Above the lower, vegetation covered portion, about 500 m. of Toad siltstones are exposed from which Halobia was collected. It is followed by about 70 m. of limestones and siltstons, which also yielded faint impressions of Halobia. These upper beds probably represent the Grey Beds. The Liard formation is presumably absent in this section.

APPENDIX II

EUMORPHOTIS TELLERI (BITTNER) 1889
THE TYPE SPECIES OF EUMORPHOTIS

(For synonymy see Ichikawa, 1958, p. 154)

Ichikawa (1958) designated as lectotype the specimens figured by Bittner (1899, Pl. XV, Figs. 11-15) from Oberseeland, North Yugoslavia.

Diagnosis - (Translated from Ichikawa, 1959, p. 154): "A species of Eumorphotis from the group E. telleri with completely obsolescent radial sculpture and the following characteristic features: Shell large (height 40-50 mm, sometimes to 70 mm), weakly prosocline, asymmetrical. Height-length relationship in left valve of mature specimens 1.24-1.33 (increasing with age). The length of the hinge line in mature specimens slightly shorter than the shell length. Umbo forward at approximately 2/5ths of the length of the hinge line. Left valve convex with moderately small umbo projecting over the hinge line. Maximum curvature of the shell is in the front half of the shell. Consequently the anterior side slopes steeply to the front. Anterior auricle triangular, borader than high and more or less clearly separated from the shell, strongly embayed on the lower side. Front convex and rectilinearly truncated at the top. Right valve almost flat, byssal auricle convex in front, clearly separated from the shell, bordered by a binding plate. Anterior rim of the shell evenly rounded, under the byssal auricle, however almost rectilinear or weakly concave and proceeding in the direction of the umbonal point. Outer shell surface in both shells inclusive of auricles practically smooth, only the right valve has sometimes weak radial stripes. Concentric growth lines weak. Besides, occasionally growth rugae present."

APPENDIX III

SYNOPSIS OF AND REMARKS ABOUT THE HITHERTO DESCRIBED SPECIES OF *EUMORPHOTIS*

(SEE LIST P. 33)

(i) *Eumorphotis* (*Asoella*) *illyrica* (Bittner), 1902

1902 *Pseudomonotis illyrica* BITTNER, Jb. K. K. Reichsanst., Vol. 51, pt. 2, p. 227, pl. VII, Fig. 13, 14 (1901)

1959 *Eumorphotis* (*Asoella*) *illyrica* BITTNER in TOKUYAMA, Japan. Jour. Geol. Geogr., Vol. XXX, p. 2 .

Diagnosis - Left valve moderately convex, right valve almost flat; posterior auricle in both valves considerably broader than the anterior, not quite separated from the main convexity of the valves; anterior auricle of the left valve somewhat more clearly separated by a sinus; well developed byssal auricle on the right valve with concentric ornament; ribbing of the left valve extroardinarily dense (>100) in five or six orders; ribs blunt throughout with little intercostal space; growth lines not clearly pronounced; umbo broad and hardly projecting; right valve with wider, weaker, less dense and blurred ribbing.

Occurrence - Upper Ladinian of Southern Alps, and Karnian of Asia Minor.

Remarks - This is one of the very few species of *E.* (*Asoella*) from which both valves are well known. Ichikawa (1958, p. 152) did not classify this species under Eumorphotis, although Bittner (1902) described it as a close relative of "Pseudomonotis" venetiana (Hauer) and Diener (1923) classified it under Eumorphotis. Tokuyama (1959) placed this species in his new genus E. (Asoella). The present author believes that this species, because of its moderately strong development of wings, richer ornamentation of the left valve as compared to the right valve, and sharply defined byssal notch differing significantly from Pseudomonotis, should be placed in Eumorphotis.

ii) Eumorphotis (Eumorphotis) artus Boehm, 1903

1903 Eumorphotis artus BOEHM, K. Svenska Vetensk. Akad. Handl., Vol. 37, No. 3, p. 27, pl. II, Figs. 9, 16, 18.

Diagnosis - Left valve convex, oval, asymmetrical, length approximately 2 mm; anterior and bottom edge continually round; umbo sharp, strongly curved in the middle of the hinge line but only weakly projecting; auricles equally long but otherwise distinct; anterior auricle larger, flatter forming an obtuse angle with hinge line; posterior auricle conically arched, sinuous and forming an acute angle with the hinge line; posterior margin gaping; posterior auricle with radial lines; anteriorly only with growth lines. Sculpture with about eight first-order ribs and 5 second-order ribs in each intercostal space of about equal strength. Entire upper surface covered with dense concentric growth lines.

Occurrence - Karnian of Bear Island.

Remarks - As in many other species of Eumorphotis, the right valve is unknown. The assignment of this shell to Eumorphotis is doubtful especially because the general shape resembles a pectinid, rather than aviculopectinid. However, the characteristic features of this species are the 7 or 8 especially high first-order ribs with 4-5 intercostal ribs and the reduced auricles.

iii) Eumorphotis (Asoella) spitzbergensis (Boehm) 1903

1903 Pseudomonotis (Eumicrotis) spitzbergensis BOEHM, K. Svenska Vetensk. Akad. Handl. v. 37, no. 3. p. 27, p. 2, Figs. 10-13 .

1959 Eumorphotis (Asoella) spitzbergensis (BOEHM) in TOKUYAMA Japan. Jour. Geol. Geogr. v. 30, p. 2 .

Diagnosis - Left valve small, highly arched, very thin shelled, oval, higher than long, umbo projecting strongly, fairly wide, somewhat anteriorly; auricles small, distinct, and flat; surface with thread-like ribs and single intercostal calatories; prominent growth rings.

Occurrence - Karnian of spitzbergen and Japan.

Remarks - Boehm (1903), when originally describing this species referred it to Eumicrotis Meek. But this has now been found to be erroneous. According to Ichikawa (p. 152), it is by no means either a Pseudomonotis or a Eumicrotis. Its reference to Eumorphotis (Asoella) seems to be correct.

As compared to other species of Eumorphotis, this is a small species. The possibility that the specimen figured by Boehm is an immature one can be ruled out because, even at that early stage, (if it is an immature form) the possession of ribs on the upper surface of the left valve is highly improbable. Besides the small size, the other characteristic features of this species seem to be the possession of thread-like ribs and equally developed auricles.

iv) Eumorphotis (Eumorphotis) variabilis Boehm, 1903

1903 Eumorphotis variabilis BOEHM, K. Svenska Vetensk. Akad. Handl., Vol. 37, No. 3, p. 28, pl. II, Figs. 19, 23.

Diagnosis - Oval outline; left valve slightly convex; fine dense radial ribs; first, second and third order costae in similar numbers; umbo with modified costae; ribs change in texture from fine to coarse; anterior auricle higher than long and gently sloping up towards the shell; unequal slope on both sides of the shell; anterior margin rounded, posterior oblique and blunt; surface covered with crowded concentric striae.

Occurrence - Karnian of Bear Island.

Remarks - This is another of Boehm's species based on very fragmentary, poorly preserved material, but represented with good figures and a lengthy, unduly detailed description. On the basis of casts, it is impossible to judge the affinities of the specimens, especially since the right valve is unknown.

v) Eumorphotis (Eumorphotis) vagans Boehm, 1903

1903 Eumorphotis vagans BOEHM, K. Svenska Vetensk. Akad. Handl., Vol. 37, No. 3, p. 29, pl. LL, Figs. 17, 24.

Diagnosis - Similar to E. (E.) variabilis in shape and convexity; ornamentation characterized by a break with lateral shift of the primary ribs which are broader and stronger than in E. (E.) variabilis; four second-order intercalatory ribs.

Occurrence - Karnian of Bear Island.

Remarks - As in the case of E. (E.) variabilis the material is small, poorly preserved and no right valve is mentioned or figured. Again, the affinities of the species are dubious.

vi) Eumorphotis (Eumorphotis) tschernyschewi Wittenburg, 1910

1910 Eumorphotis tschernyschewi Wittenburg, Trav. Mus. geol. Pierre-le-Grand. Acad. Sci. St. Petersbourg, Vol. IV, p. 34, pl. I, Fig. 1.

Diagnosis - Shell very large (length: 48 mm, height: 52 mm, width: 7.5 mm); hinge line straight; left valve with large byssal auricle separated from the umbonal edge by a strongly developed ridge; surface covered with strong, approximately 20 first-order ribs and intercalated second and third-order ribs; internal molds show ribs of equal strength; concentric growth lines present.

Occurrence - Karnian of Bear Island.

Remarks - This is the largest species of *Eumorphotis* so far recorded, which, without obvious reason, Wittenburg compared with the Lower Triassic *E. telleri*. *E. tschernyschewi* may indeed range into the Lower Trias. No right valve was figured. The characteristic features are the distinct byssal auricle, the large size and the strong ornament.

vii) *Eumorphotis* (*Eumorphotis*) *tolmatschewi* (Wittenburg),1910

1910 "*Pseudomonotis*" *tolmatschewi* WITTENBURG, Trav. Mus. geol. Pierre-le-Grand. Acad. Sci. St. Petersbourg, Vol. IV, p. 35, pl. I, Figs. 2, 3.

Diagnosis - Right valve moderately convex; anterior auricle much broader than the posterior; well developed byssal auricle with deep byssal notch; constation strong, evenly interrupted by rugae on lower part of shell; surface covered with fine growth lines; hinge line straight with tooth-like protuberances.

Occurrence - Karnian of Spitzbergen.

Remarks - Unlike other species of Eumorphotis, it is based upon a right valve only. Wittenburg considered this species as a near relative of E. (A.) illyrica. The right valve shows closer affinity to Eumorphotis than to Pseudomonotis. Diener (1923), however, classified the species under Pseudomonotis. It is possible that the holotype is merely an immature or small E. (E.) tschernyschewi.

viii) Eumorphotis (Eumorphotis ?) plicatuloides (Mansuy) 1912

1912 Pseudomonotis plicatuloides MANSUY, Mem. Serv. Geol. de l'Indochine, Vol. I, fasc. II, part II, p. 129, pl. XXIV, Figs. 5, a, b.

Diagnosis - Feebly convex and somewhat oblique; anterior auricle very small; posterior auricle without sinus and continuous with the shell; radial ribs sinuous especially at the marginal extremities; primary ribs narrowly rounded and raised; secondary ribs 1/3rd of shell height; growth lines obsolete.

Occurrence - Upper Trias of Yunnan.

Remarks - This is another example of a species based on imperfect and poorly preserved material i.e., a single left valve. The precise affinities of this species are therefore unknown. However, the left valve is closer to Eumorphotis than to Pseudomonotis, so that the species is tentatively placed in Eumorphotis. Kobayashi and Ichikawa (1949) compared their Karnian E. (E.) spitzbergensis to E. (E.) plicatuoloides.

ix) Eumorphotis (Eumorphotis) nationalis Smith, 1927

1927 Eumorphotis nationalis SMITH, U.S.G.S. Prof. Paper 141, p. 121, pl. CI, Fig. 12.

Diagnosis - Shell small, compact, pectinoid, with anterior auricle distinctly developed; posterior auricle hardly differentiated; surface gently convex; with fine radial ribs.

Occurrence - Very rare in the Lower Karnian of Alaska.

Remarks - E. (E.) nationalis is somewhat related to E. (E.) artus Boehm from the Upper Triassic Dawsonites zone of Bear Island, in the Arctic. No mention is made of the right valve; the left valve is described very briefly but has been excellently figured, warranting the placing of this species in Eumorphotis. This is the only species described from the general vicinity of the present author's area. Smith's figure shows growth lines, which are not mentioned in the text.

x) Eumorphotis (Eumorphotis) tasaryensis Voronetz, 1937

1936 Pseudomonotis tasaryensis VORONETZ, Mesozoic Fauna of Karualakh Range, Trans. Arctic. Instt., p. 19, pl. IV, Fig. 49.

1937 Pseudomonotis (Eumicrotis ?) tasaryensis VORONETZ in KIPARISOVA, Trans. Arctic Inst., Vol. 91, p. 19, pl. VI, Figs. 6, 8, 11.

Diagnosis - Shell of medium size, tending to become relatively higher at maturity; valves convex with strong, straight projecting umbones; anterior auricle small and triangular posterior auricle more wing-like; surface ornamented with uniform radial ribs of varying number; concentric growth lines present, more prominent on the auricles; in some cases a perfect distribution of radial and concentric lines gives a reticulate surface; right valve much less convex than the left valve, less oblique, almost triangular; a deep depression in front of the umbo ending at the posterior margin separates the anterior auricle; ornate as left valve; the mold has pallial line and a large adductor scar in the lower posterior area.

Occurrence - Anisian and Karnian of the Karualakh Mountains, Siberia.

Remarks - This form is similar to E. (A.) spitzbergensis (Boehm) from the Karnian of Bear Island but differs by more oblique outline and larger posterior auricle. Unfortunately, this well described species was poorly figured. However, the assignment of this species to *Eumorphotis* appears justified. The elongate posterior auricle of the left valve, the general shape and the byssal elements are distinctive generic characteristics.

xi) *Eumorphotis* (*Eumorphotis*) *deljanensis* Kiparisova, 1937

1937 *Pseudomonotis* (*Eumorphotis*) *deljanensis*, KIPARISOVA
Trans. Arctic Inst., Vol. 91, p. 240, pl. VI, Fig. 4.

Diagnosis - Represented by left valve, slightly oblique, strongly convex posterior margin; anterior auricle large, triangular with a weak posterior sinus. (It is not understood why the author makes mention of a "byssal notch" in his description. It appears to be a mistake due to translation.) posterior auricle partly preserved; ornamentation consisting of about 32 radiating costae decreasing in height towards the margin; auricles covered by growth lines.
Occurrence - Karnian of Karualakh Mountains, Siberia.
Remarks - The species is based upon a single left valve. Although no right valve of this species is known, the general outline, the strongly developed auricles justify the classification of this species as *E.* (*Eumorphotis*).

xii) Eumorphotis (Asoella) confertoradiata Tokuyama, 1959

1959 Eumorphotis (Asoella) confertoradiata TOKUYAMA, Japan. Jour. Geol. Geog., Vol. XXX, p. 4, pl. I, Figs. 1-6, 12, text-Fig. 1.

Diagnosis - Shell small, roundly quadrate, plano-convex; left valve strongly convex, almost symmetrical; anterior auricle diminished; posterior auricle small, roundly triangular, separated from shell by a weak furrow; right valve slightly convex; anterior auricle more distinct than posterior, fairly large and obtusely truncated; byssal notch shallow; surface covered with many fine distinct and dense ribs and widely spaced concentric growth lines which become prominent along the margins; primary radial ribs blunt, secondaries fine; right valve similarly ornamented.

Occurrence - Upper Karnian/Lower Norian of Japan.

Remarks - Tokuyama designated E. (A.) confertoradiata as the type species of his new sub-genus Asoella (see p. 50) He referred it to "Eumicrotis" cf. spitzbergensis, Boehm, in Katayama (1938). E. (A.) confertoradiata differs from E. (A.) spitzbergensis in its more degenerated auricles, more convex outline and fine and more complicated ribs. The mode of ribbing is reminiscent of E. (A.) illyrica Bittner. In its morphological characters E. (A.) confertoradiata comes closest to E. (A.) convexa (Mansuy). The figures of this well described species do not show the outline of the shells very clearly. However, one can get a fairly good idea of the morphologically distinct characters of this species.

xiii) Eumorphotis (Asoella) laevigata Tokuyama, 1959

1959 Eumorphotis (Asoella) laevigata TOKUYAMA, Japan. Jour. Geol. Geog., Vol. XXX, p. 5, pl. I, Figs. 7-10, text-Fig. 2.

Diagnosis - Smaller than E. (A.) confertoradiata; left valve convex; umbo not prominent; both auricles small, gradually merging with the shell posterior auricle of right valve obsure; anterior one large, distinct and separated from shell by a strong byssal furrow; byssal notch shallow; surface smooth, except for peripheral concentric growth lines.

Occurrence - Lower Norian of Japan.

Remarks - Tokuyama's remarks that "no triassic species of Eumorphotis is comparable with this because it has no radial rib" are questionable. The type species of Eumorphotis i.e. E. telleri itself is devoid of any radial ornamentation. It is difficult to perceive from the figures, any distinct difference between this species and E. (A.) confertoradiata except that E. (A.) laevigata is compressed along the direction of height. The present author did not have access to the plastotypes. In view of this, at present it is reasonable to consider the two species as distinct from each other.

xiv) Eumorphotis (Asoella) nakatsukensis Tokuyama, 1959

1959 Eumorphotis (Asoella) nakatsukensis TOKUYAMA, Japan. Jour. Geol. Geog., Vol. XXX, p. 6, pl. I, Figs. 11, 13, 14.

Diagnosis - Distinguished from E. (A.) confertoradiata and E. (A.) laevigata by its depressed outline and somewhat prosogyrous umbo; right valve flat and has a distinct byssal sulcus and a shallow byssal notch.

Occurrence -Upper Karnian of Japan.

Remarks - Here again it is difficult to comment precisely about the distinctiveness of this species from the preceding two on the basis of the figures alone. Detailed description of the species is also lacking.

APPENDIX IV

MELEAGRINELLA CURTA (HALL) 1852

THE TYPE SPECIES OF MELEAGRINELLA

(For synonymy see Whitfield 1880 and Fox 1941)

Diagnosis - "Shell of moderate size, suborbicular in outline, very slightly oblique, and nearly equivalve, generally a little higher than wide; beaks subcentral or nearest to the anterior end; hinge short, usually less than half the length of the shell below, longest on the posterior side; left valve the most rotund and beak small, but often approaching tumid, the apex incurved and extending a little above the hinge-line; anterior wing small, abruptly rounded toward the beak, its surface strongly curved toward the opposite valve near the cardinal margin, so as to leave a small byssal opening, or gaping at the anterior margin; posterior wing somewhat flattened towards the extremity; surface of the valve marked by raised radiating lines, which are very variable in number and character on different individuals, and also by concentric lines which often form slight asperities or nodes in crossing the radii, especially on the sides and near the basal border of well-preserved specimens; right valve slightly less convex than the left, with a smaller and less conspicuous beak, which does not extend beyond the cardinal line; anterior side characterized by a short and very narrow wing, separated from the body of the shell by a sharp, deep, and very narrow groove, the actual sinus scarcely extending within the limits of the wing, while the anterior margin of the valve below extends considerably beyond the extremity of the wing in a nearly parallel direction; posterior wing proportionally larger and compressed, the extremity angular and sometimes almost pointed, the posterior border of the valve running nearly at right angles to the hinge line, or slightly sinuate below; surface of the valve marked by strong concentric lines of growth, and on the body of the shell by obscure radii, which are often obsolete. Each valve is further characterized by a narrow, longitudinally striated ligamental area, extending nearly or quite to the extremities of the hinge line; and in the right valve the area is narrowed anteriorly, for the accommodation of the internal, slightly oblique fold of the shell, forming the depressed groove between the ear and the body of the shell. On the left valve there is a slight depression or break in the ligamental area beneath the beak, and an apparent depression on the right valve. Muscular impression as seen on a right valve rather large, and subcentrally situated.

APPENDIX V

HITHERTO DESCRIBED SPECIES OF UPPER TRIASSIC *MELEAGRINELLA*

Only one Upper Triassic species of *Meleagrinella* has previously been named, i.e., *M. antiqua* Tozer (1961) from the Lower Heiberg Formation of Ellesmere Island (Queen Elizabeth Islands).

Meleagrinella antiqua Tozer, 1961

1961 *Meleagrinella antiqua* TOZER, Geol. Surv. Canada, Mem. 316, p. 104, Pl. XXIX, Figs. 5-9b.

Diagnosis - Shell small, of about equal height and length; both valves with narrow blunt ribs commencing at umbo and multiplying by intercalation, and faint concentric growth lines (about 10 ribs in 5 mm of ventral margin); left valve with distinct posterior auricle, apparently without posterior auricle; right valve almost flat with anterior auricle (3 mm).
Occurrence - Upper Karnian or Lower Norian of Queen Elizabeth Islands (Heiberg Formation).
Remarks - *M. antiqua* is th e oldest known species of *Meleagrinella*, based on the associated *Oxytoma kiparisovae*. In Japan and Queen Elizabeth Islands, beds with *Oxytoma* underlie beds with *Monotis ochotica*.

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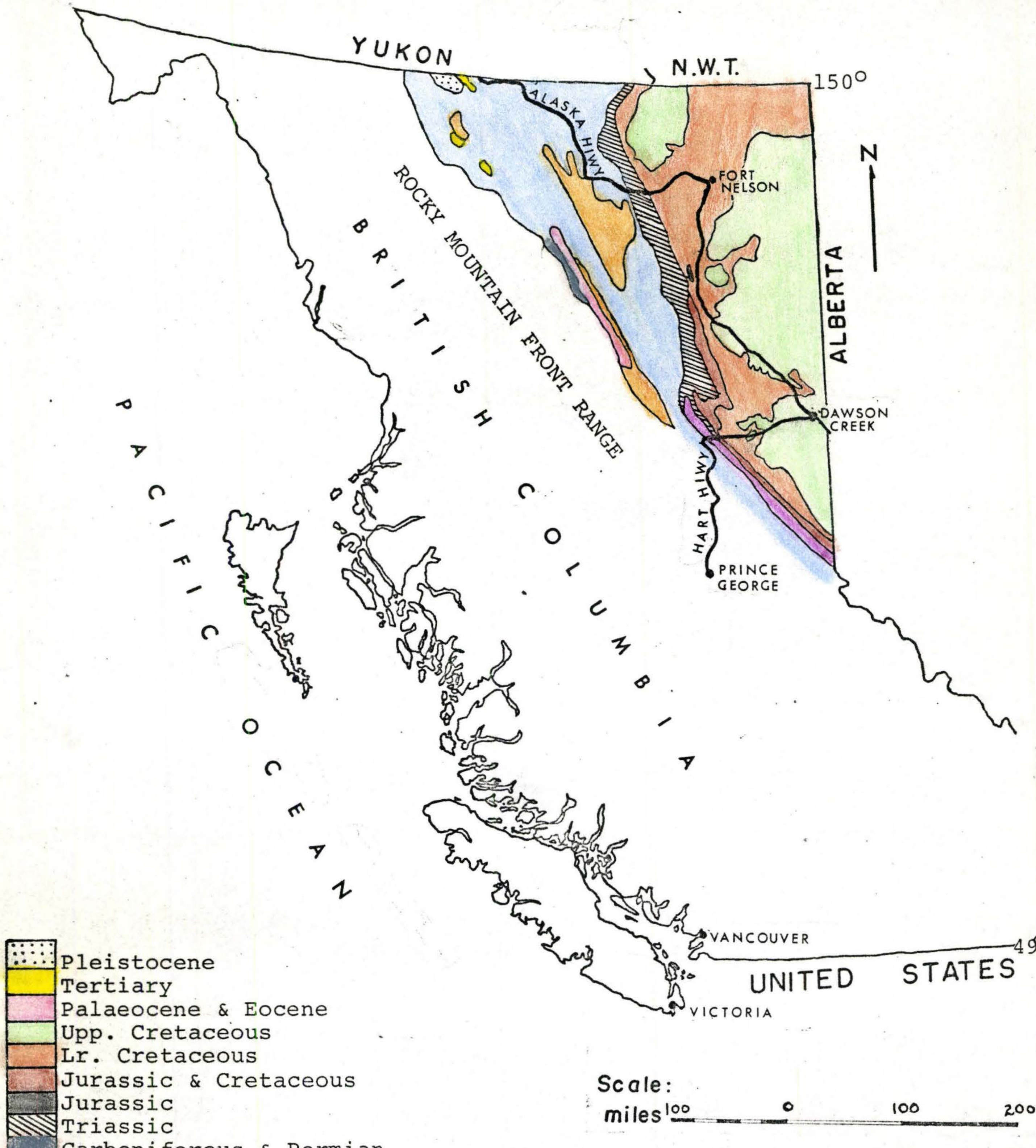


Fig. 1 Map of British Columbia showing generalized geology of the Northeastern part and the extent of the Triassic outcrop in the Rocky Mountain Foothills. (adapted from G.S.C. map 1045A)

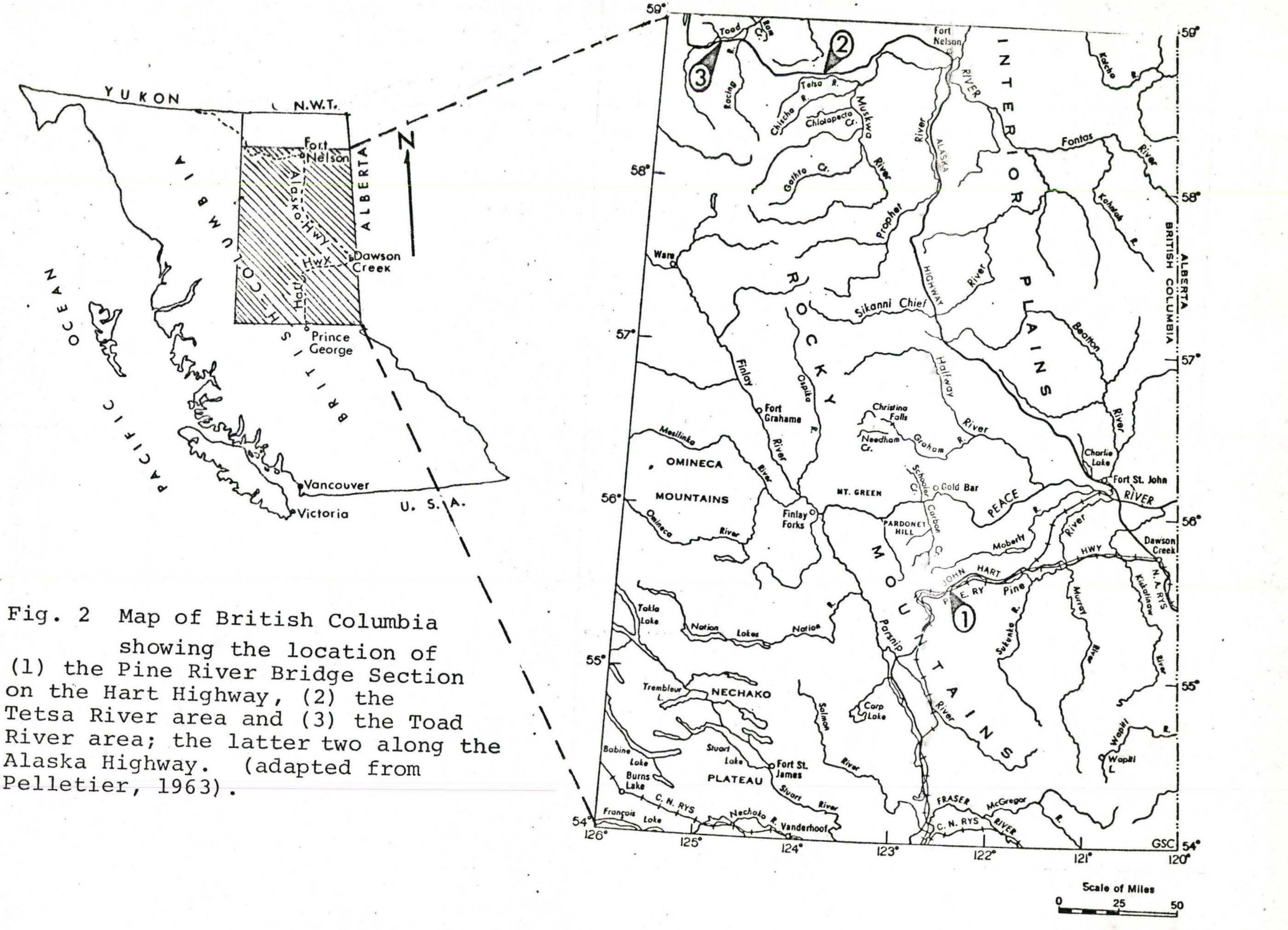
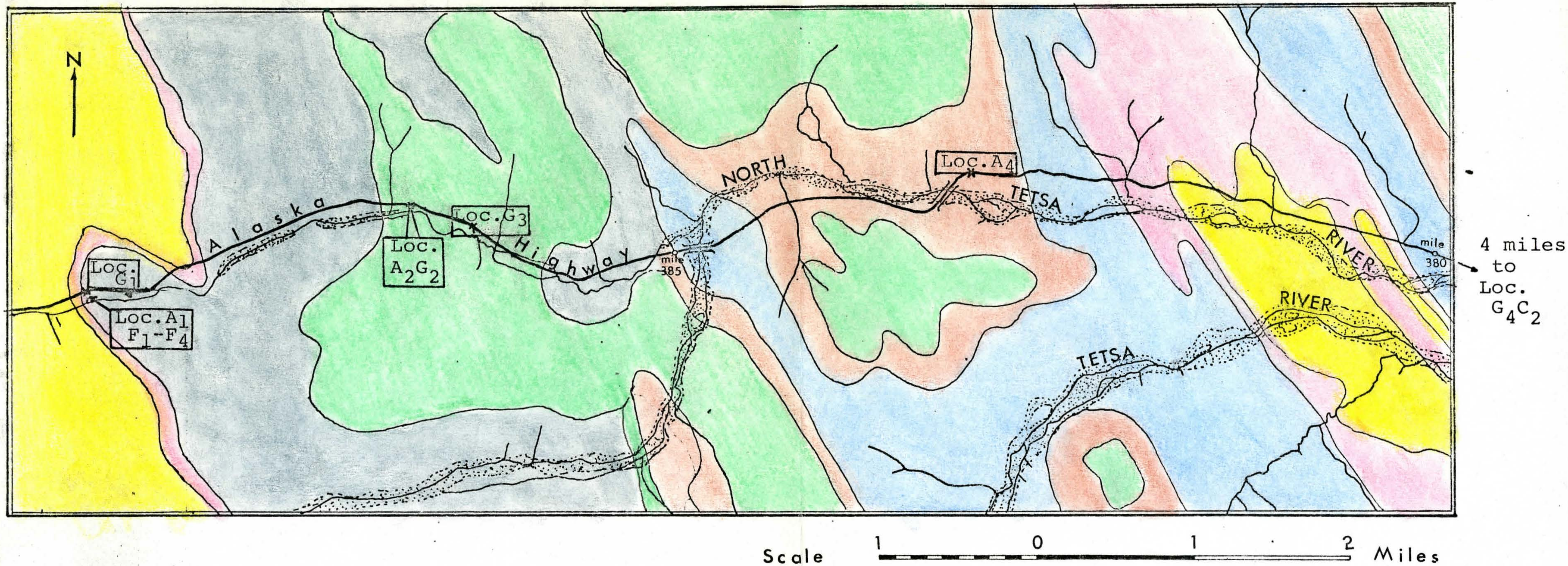
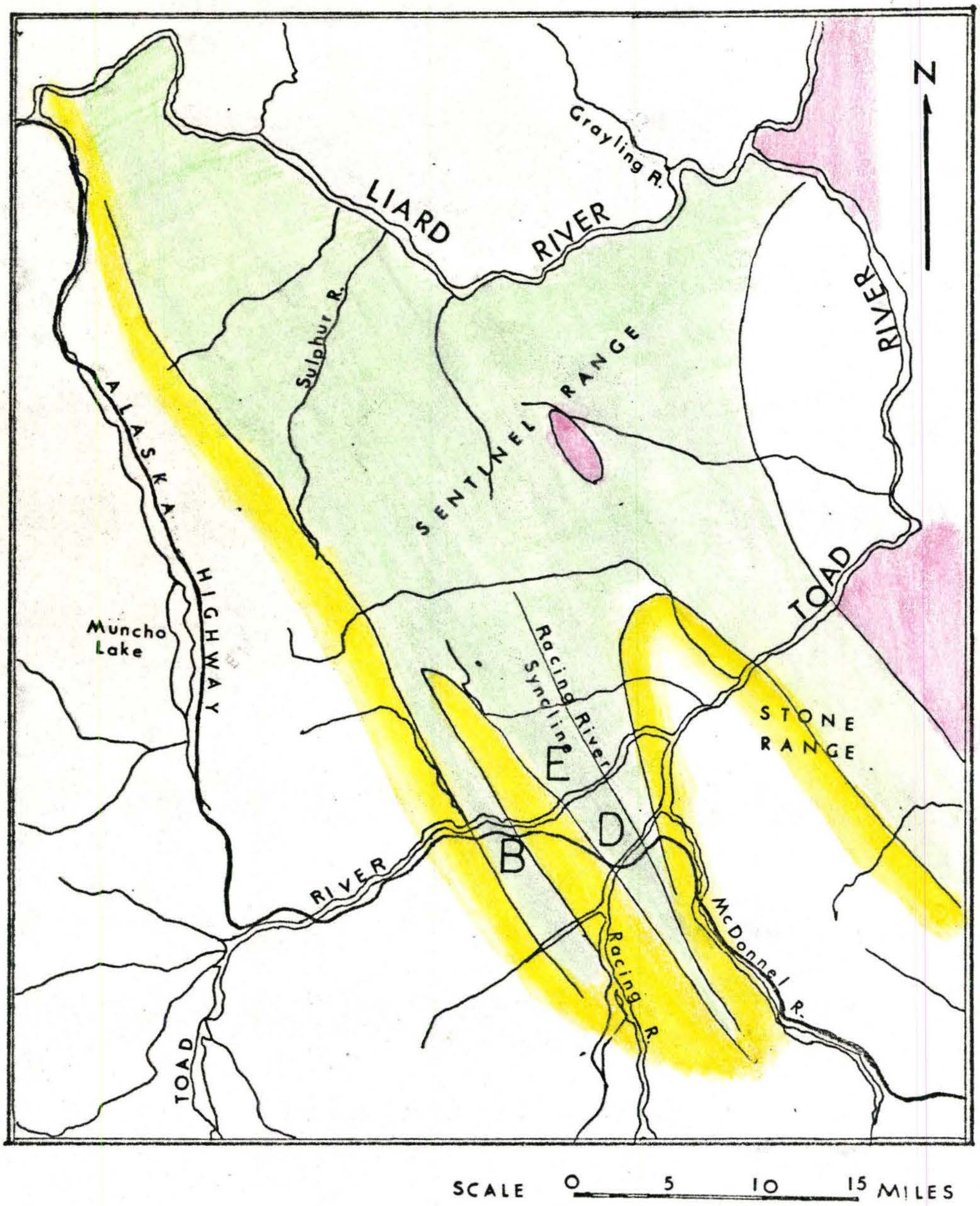


Fig. 2 Map of British Columbia showing the location of (1) the Pine River Bridge Section on the Hart Highway, (2) the Tetsa River area and (3) the Toad River area; the latter two along the Alaska Highway. (adapted from Pelletier, 1963).



- Liard Formation, Middle Triassic
- Toad Formation, Lr. & Mid. Triassic
- Grayling & Toad Formations, undifferentiated
- Grayling Formation, Lr. Triassic
- Chert, Permian
- Kindle Formation, Mississippian

Fig. 3 Geological map along the Tetsa Valley and in the vicinity of the Alaska Highway between mile post 380 and 390 showing the Triassic outcrops, fossil localities and sections, (adapted from G.S.C. maps 29-1959 and 29-1963).



Cretaceous Triassic Palaeozoic

Fig. 4 Geological map of the Toad River area, Northeastern British Columbia, in the vicinity of the Alaska Highway, showing the fossil localities and the sections studied. (adapted from Pelletier, 1961)

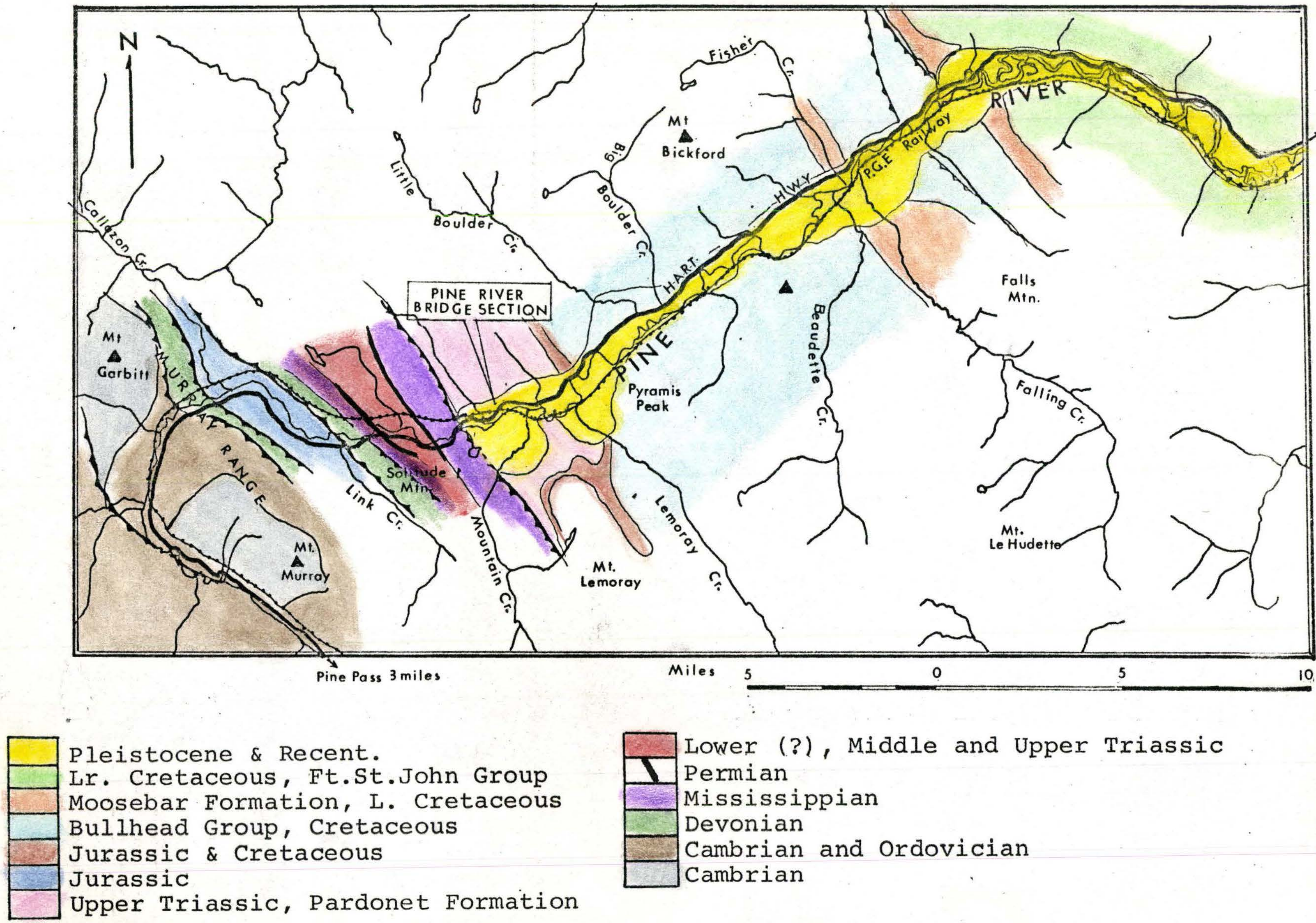


Fig. 5 Geology along the Hart Highway in the vicinity of the Pine Pass, British Columbia, and the location of the Pine River Bridge Section, (adapted from G.S.C. map 11-1961).

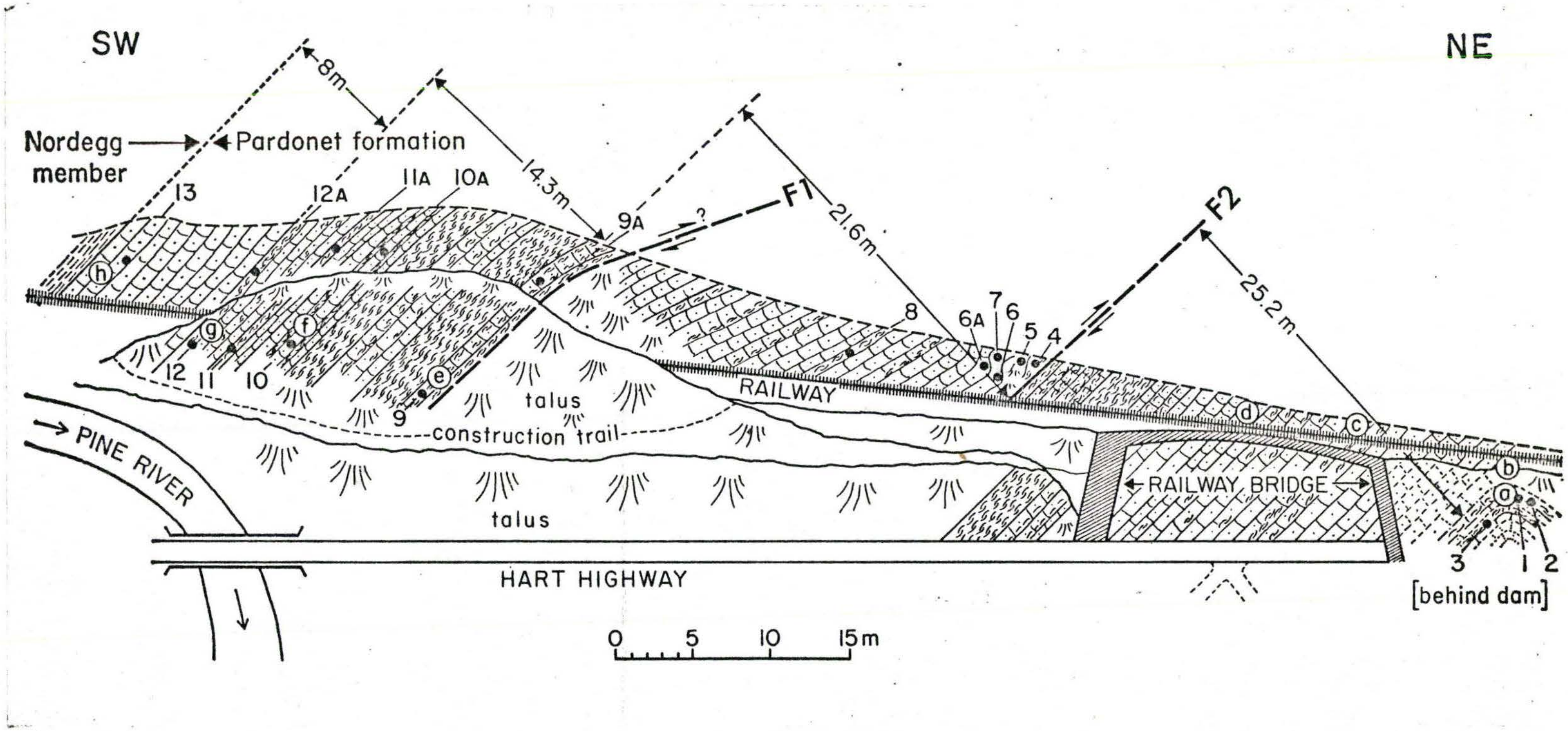


Fig. 6 Revised schematic sketch of the Pine River Bridge Section. Letters "a" to "h" mark original collecting points, (Westermann, 1962); numbers 1 to 13 are the present author's collecting points. (Reproduced from Westermann and Verma, 1967).

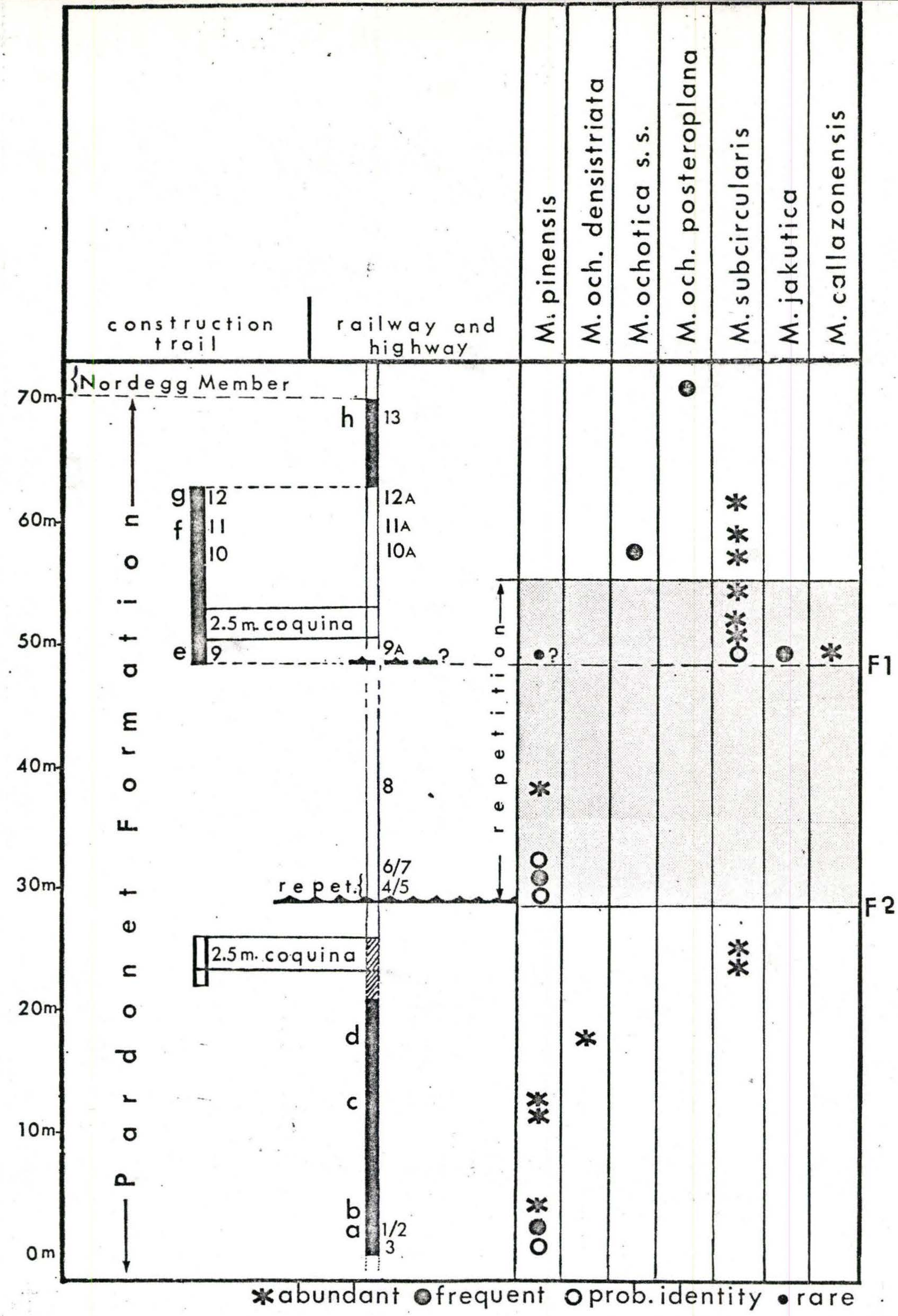


Fig. 7 Pine River Bridge Section, along the Hart Highway, the Railway and the "construction trail" cuts. The distribution of Monotis species from the previous collections and the new collecting points 1 to 13 are indicated. The central part of the highway-railway section is structurally repeated. (Reproduced from Westermann and Verma, 1967)

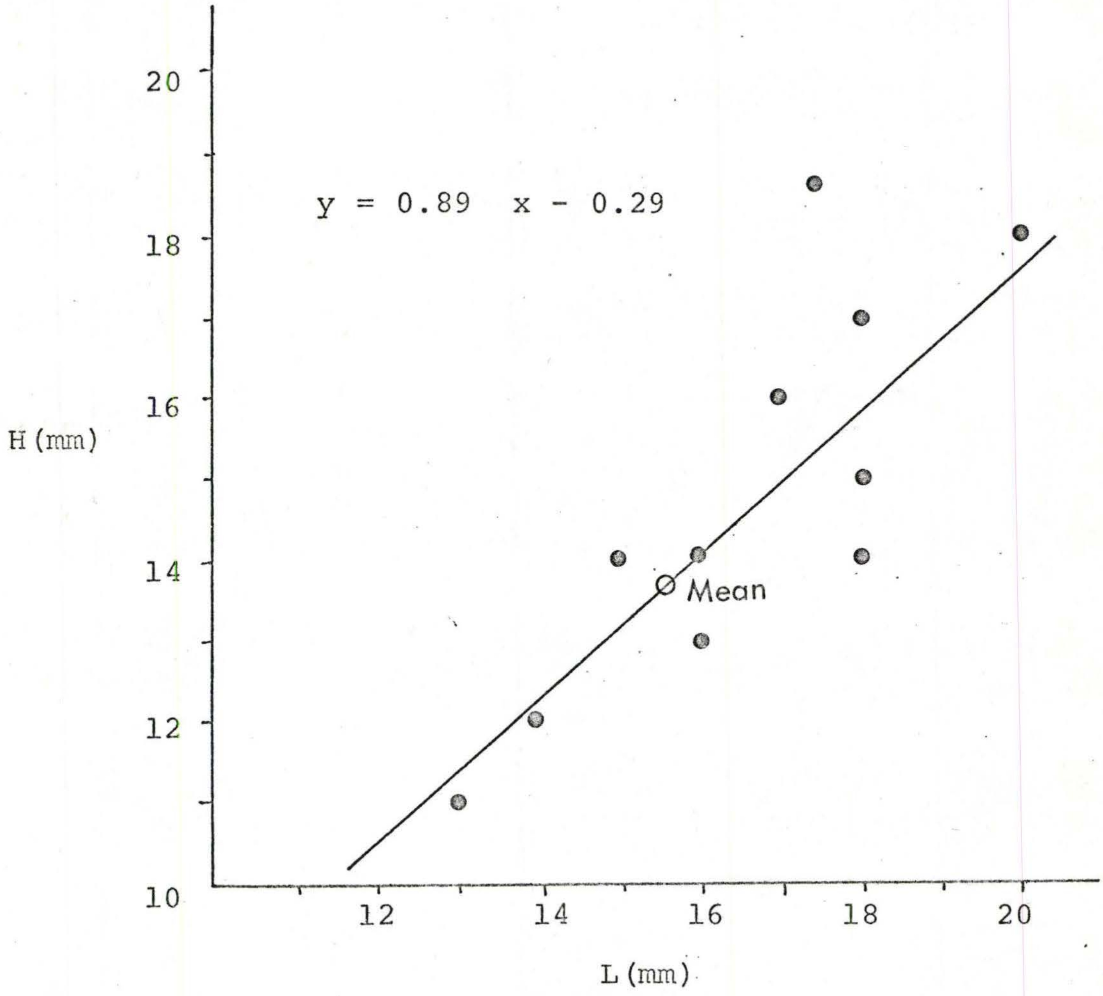


Fig. 8 Scatter diagram with regression line for Length (L) vs. height (H) of left valves of Eumorphotis (Eumorphotis) Lemorayensis VERMA sp. nov.

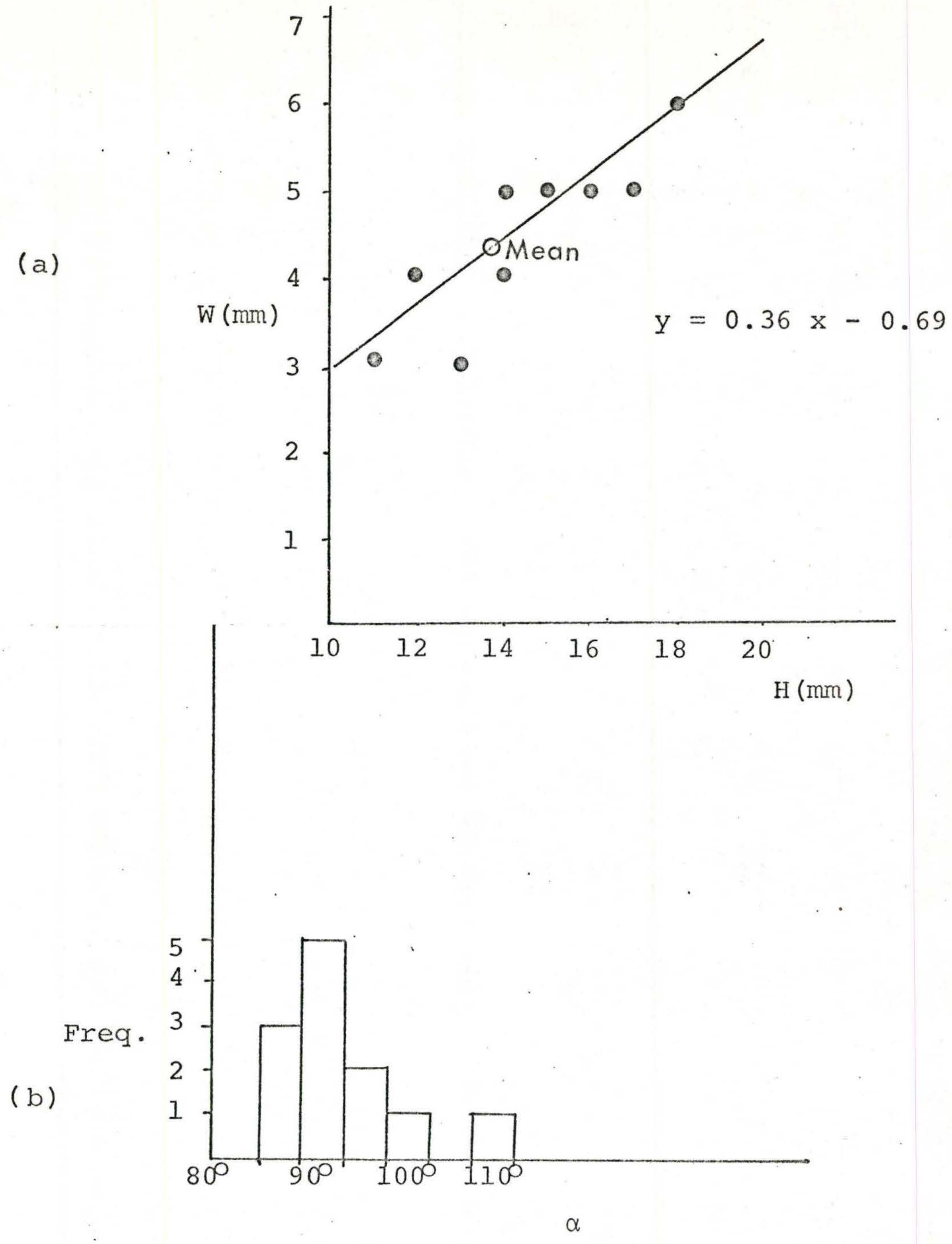
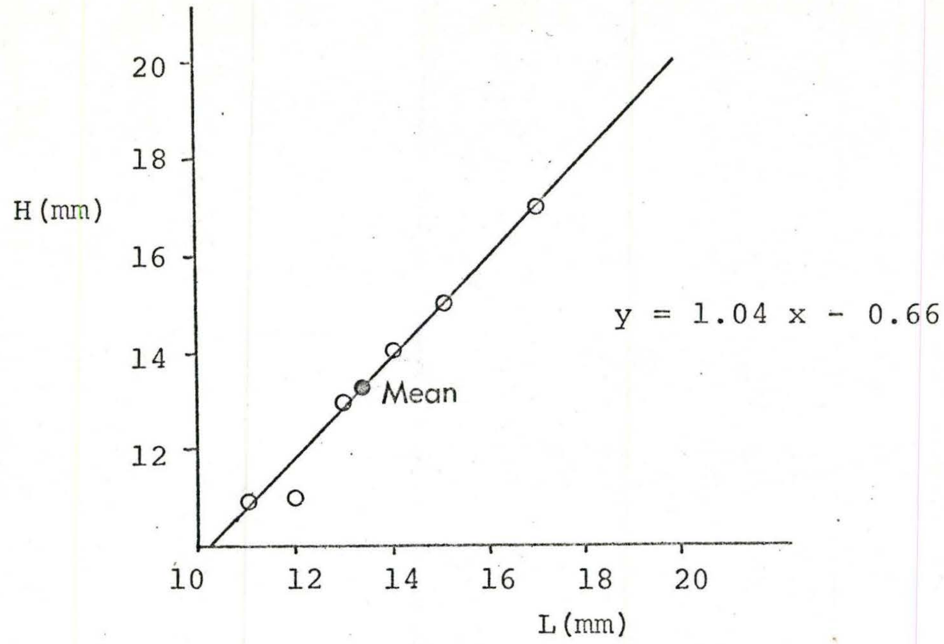


Fig. 9 a) Scatter diagram with regression line for height (H) vs. Width (W) i.e., the inflation ratios of left valves of Eumorphotis (Eumorphotis) Lemorayensis VERMA sp. nov.

b) Histogram for obliquity (α) of left valves of E. (E.) Lemorayensis.

(a)



(b)

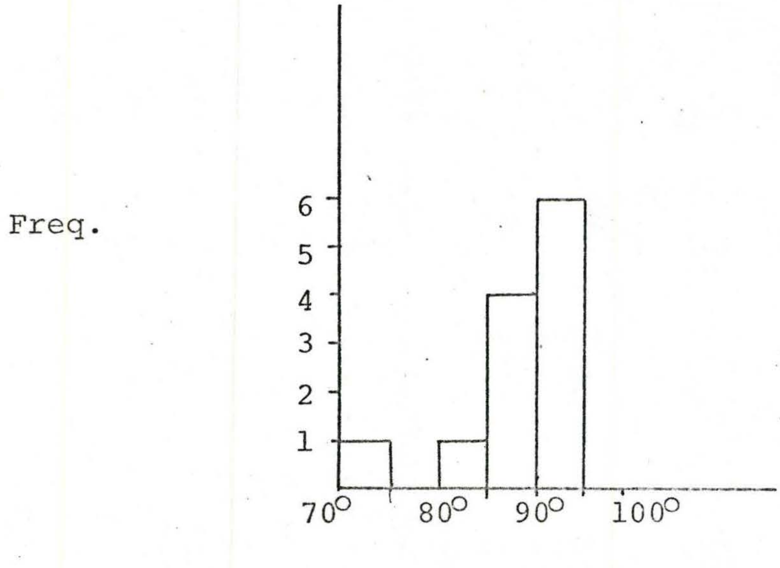


Fig. 10 (a) Scatter diagram with regression line for length (L) vs. height (H) of left valves of Eumorphotis (Asoella) depressa VERMA sp. nov.

(b) Frequency histogram for obliquity (α) of E. (A.) depressa.

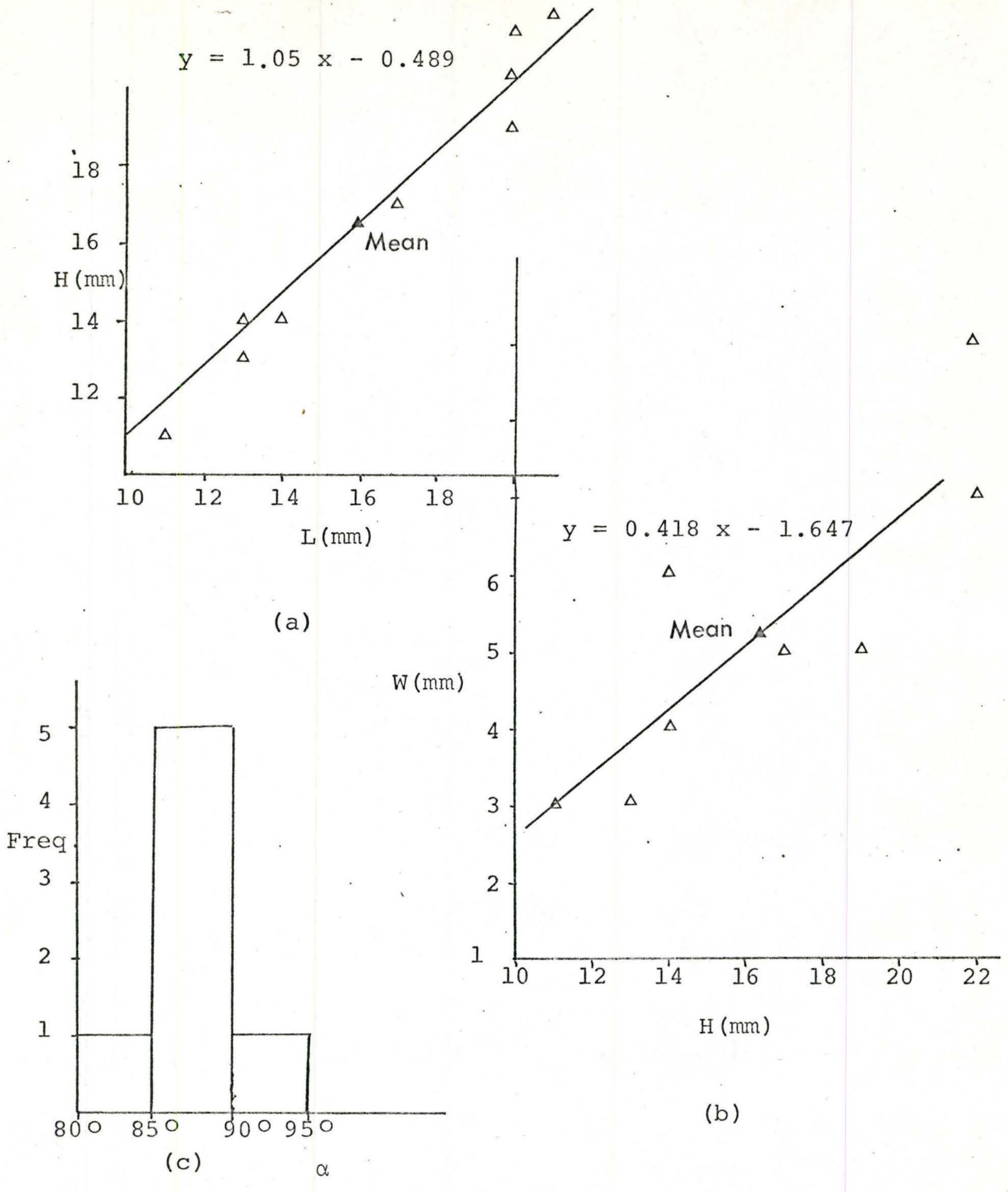
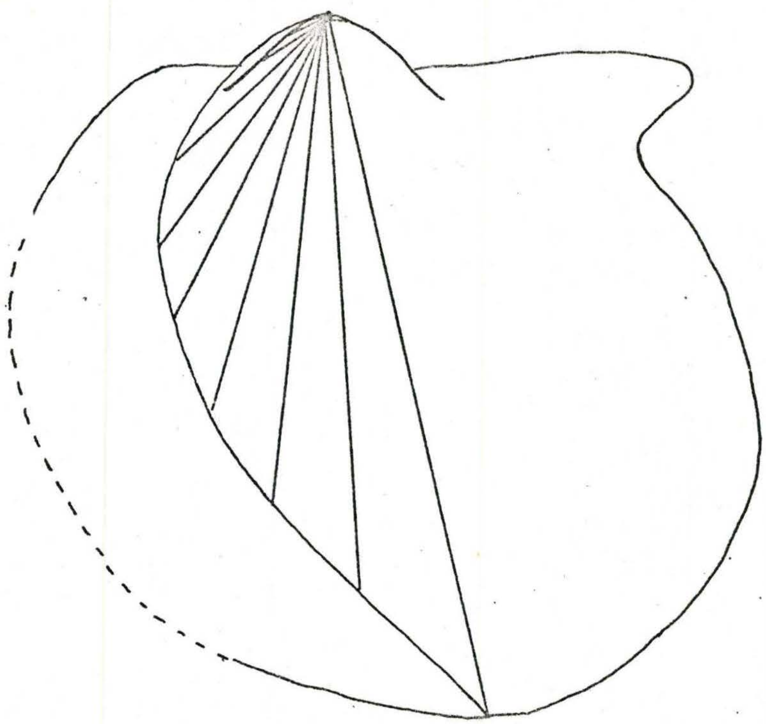


Fig. 11 (a) Scatter diagram with regression line for length (L) vs. height (H) of left valves of <u>Eumorphotis</u> (<u>Asoella</u> ?) <u>acuta</u> sp. nov.

(b) Scatter diagram of height (H) vs. Width (W) of above.

(c) Frequency histogram for obliquity (α) of left valves of <u>E</u>. (<u>A</u>. ?) <u>acuta</u>.



Radius Vector	Ratio of Radius Vector
3	
17	
28.5	0.5964
37.5	0.7600
45.0	0.8333
55.0	0.8181
63.0	0.8730
75.5	0.8344
89.0	0.8483

Fig. 12 (a) Profile of a specimen (McM # Tr. 383 MBP) of left valve of _Eumorphotis_ (_Asoella_ ?) _acuta_ VERMA sp. nov. superimposed on the external outline and the radius vectors drawn along the profile (see Fig. 12 (b))

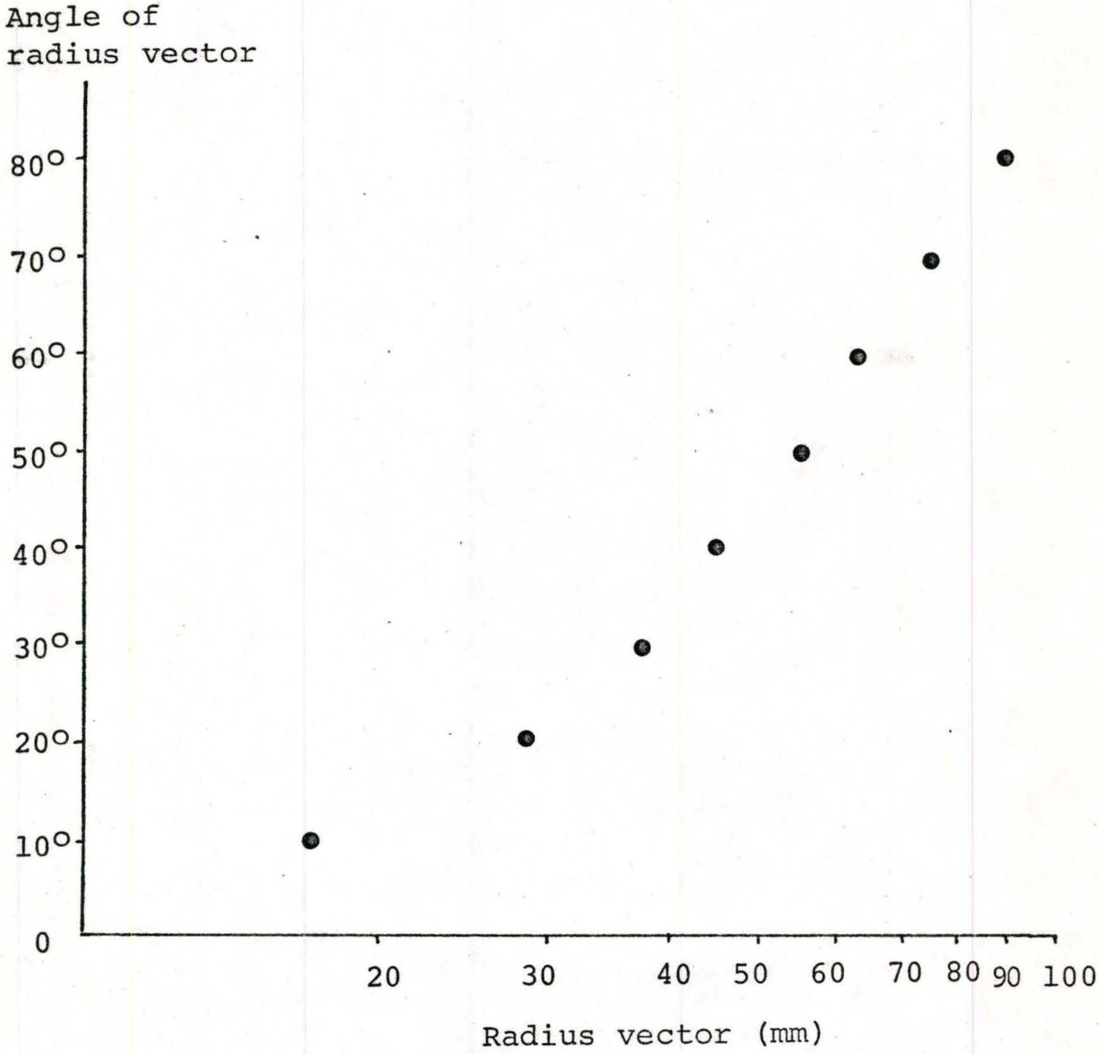
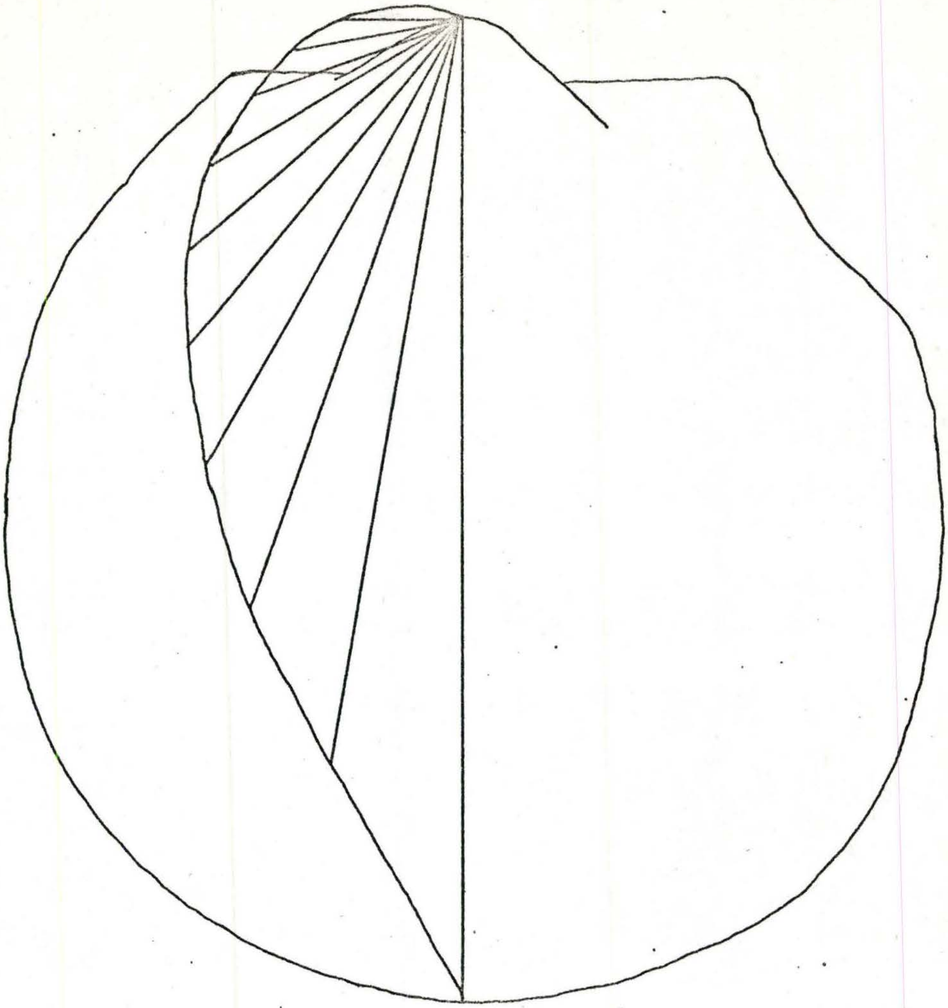


Fig. 12 (b) Scatter diagram of the radius vectors of <u>Eumorphotis</u> (<u>Asoella</u> ?) VERMA sp. nov. plotted against the angle of radius vector (see Fig. 12(a)).



Radius Vector (mm)	Ratio of Radius Vector
15.0	
	0.6976
21.5	
	0.7413
29.0	
	0.7733
37.5	
	0.7895
47.5	
	0.8407
56.5	
	0.8370
67.5	
	0.8132
83.0	
	0.8300
100	

Fig. 13 (a) Profile of a specimen (McM # Tr. 383 CH) of left valve of *Eumorphotis* (*Asoella*) *westermanni* VERMA sp. nov. superimposed on the external outline and the radius vectors drawn along the profile (see Fig. 13 (b)).

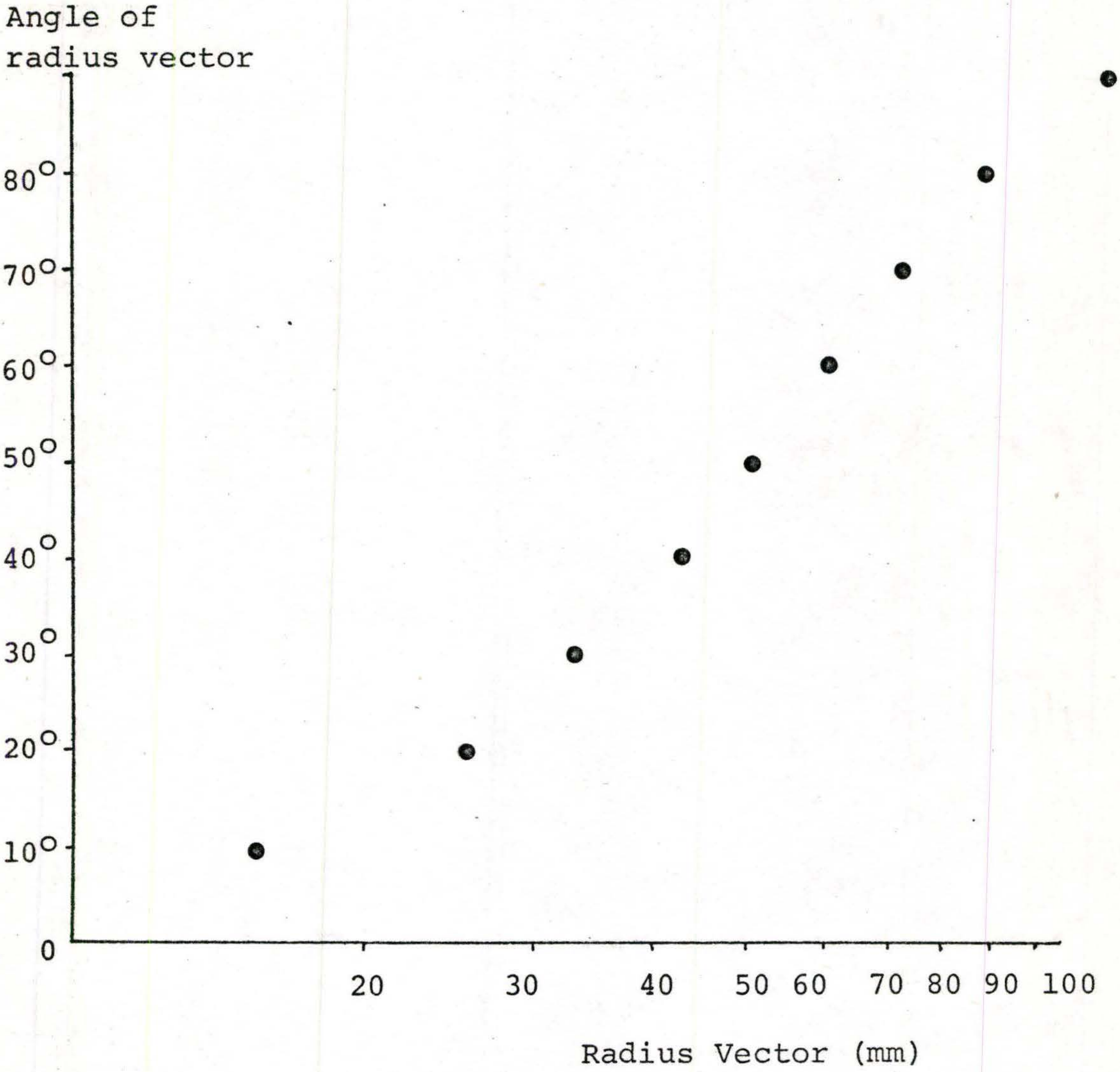
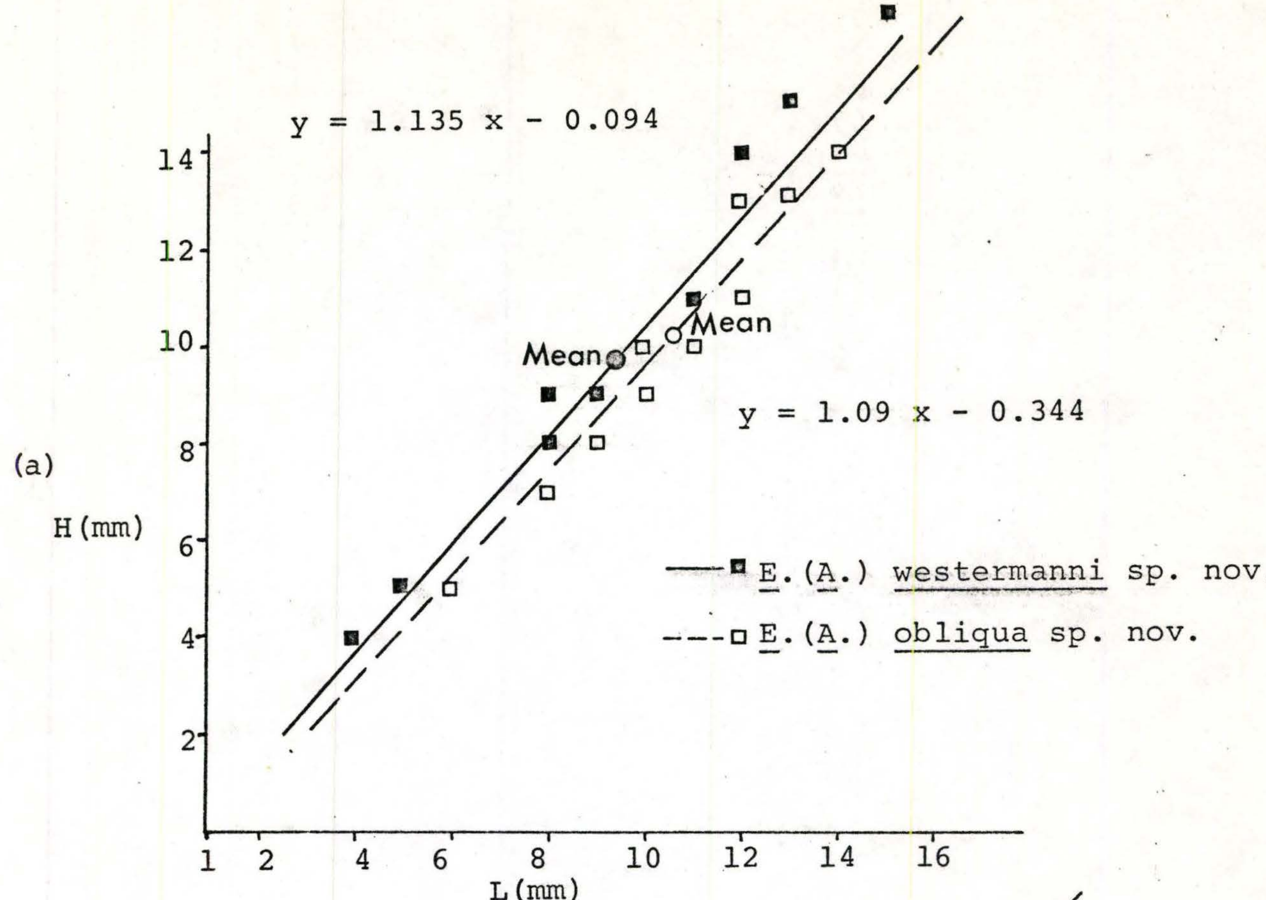


Fig. 13 (b) Scatter diagram of the radius vectors of Eumorphotis (Asoella) westermanni VERMA sp. nov. plotted against the angle of radius vector (see Fig. 13 (a)).



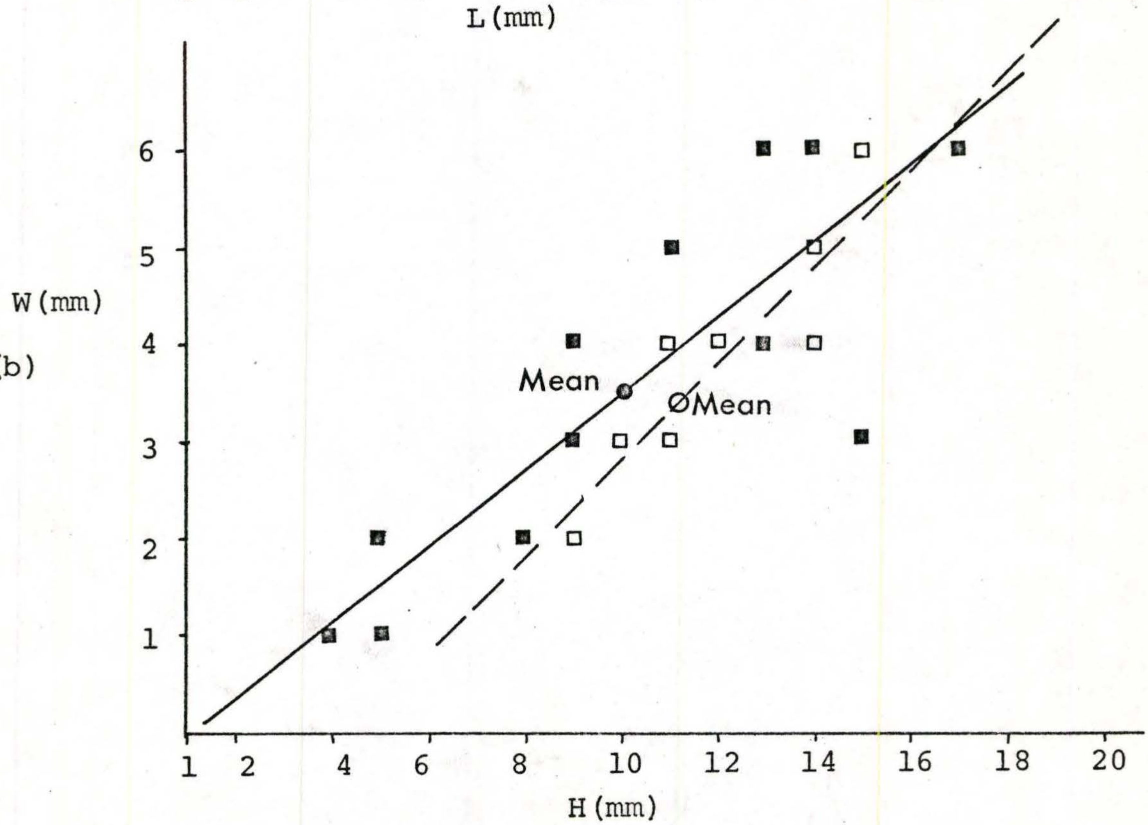


Fig. 14(a) Scatter diagram with regression lines for length (L) vs. height (H) of left valves of *Eumorphotis* (*Asoella*) *westermanni* sp. nov. and *E.* (*A.*) *obliqua* sp. nov.

(b) Scatter diagram with regression lines for height (H) vs. width (W) of the same.

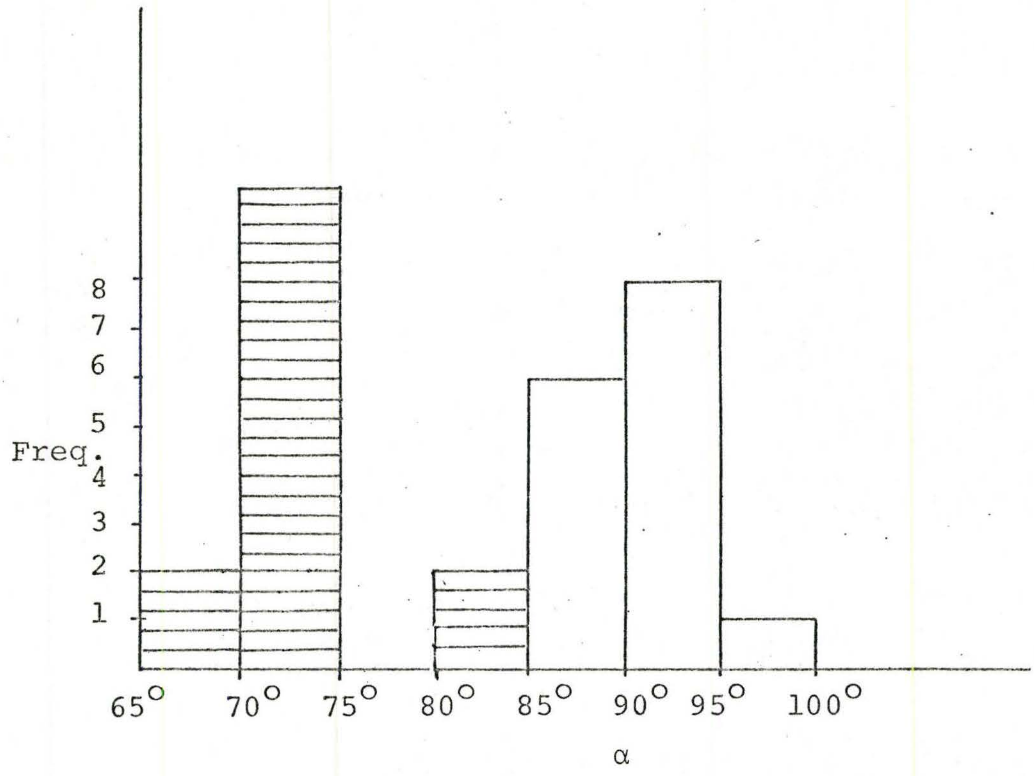


Fig. 15 Frequency histogram for obliquity of *Eumorphotis (Asoella) westermanni* sp. nov. (hollow columns) and *E. (A.) obliqua* (striped columns).

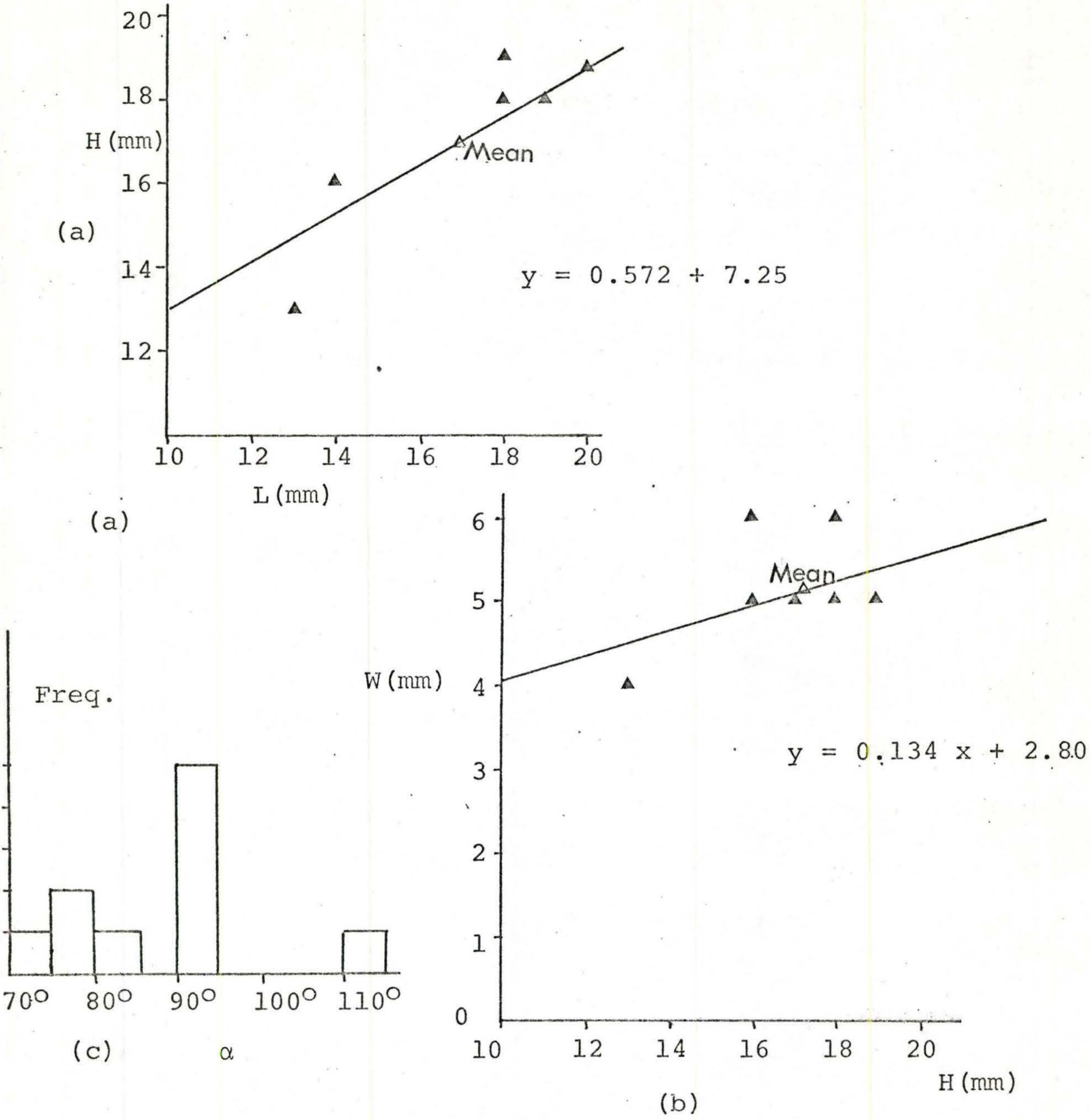


Fig. 16 (a) Scatter diagram with regression line for length (L) vs. height (H) of left valves of <u>Meleagrinella aurisparva</u> VERMA sp. nov.

(b) Scatter diagram for height (H) vs. width (W) of above.

(c) Frequency histogram for obliquity (α) of left valves of above.

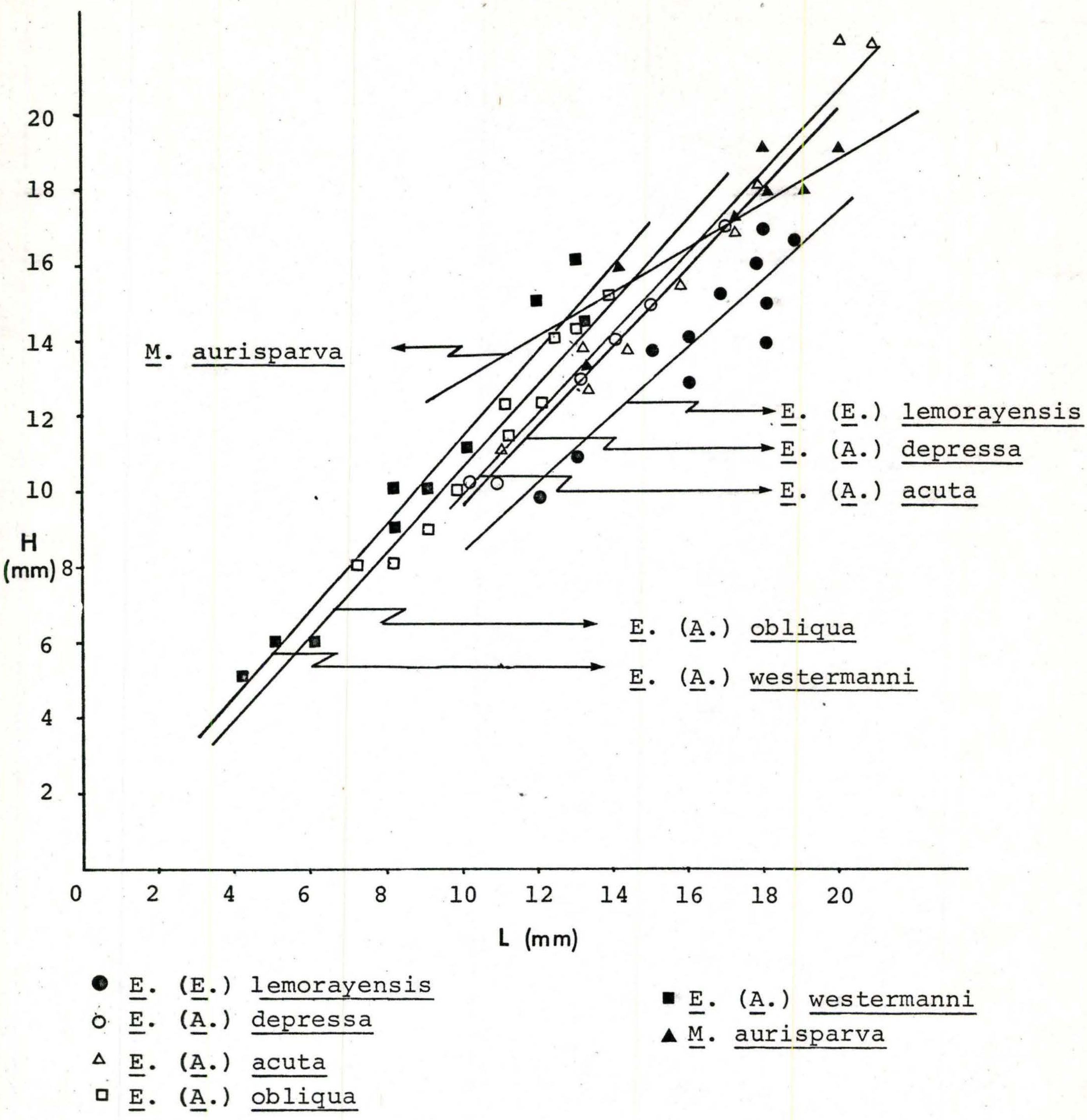


Fig. 17 Combined scatter diagram with regression lines for length (L) vs. height (H) of left valves of Eumorphotis (Eumorphotis) Lemorayensis sp. nov. E. (Asoella) depressa sp. nov., E. (A. ?) acuta sp. nov., E. (A.) obliqua sp. nov., and Meleagrinella aurisparva sp. nov.

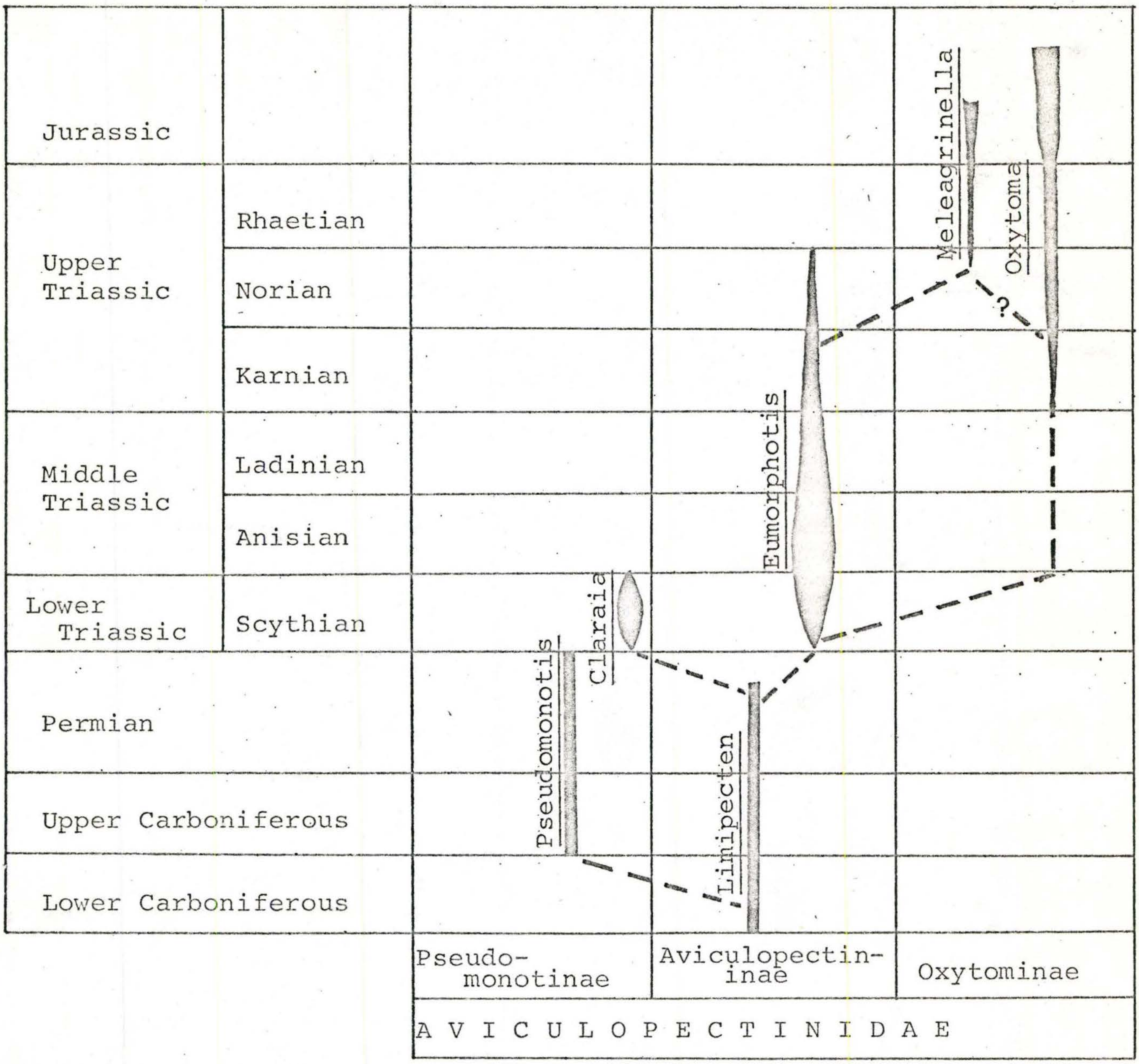


Fig. 18 Modified phylogeny of the Aviculopectinidae

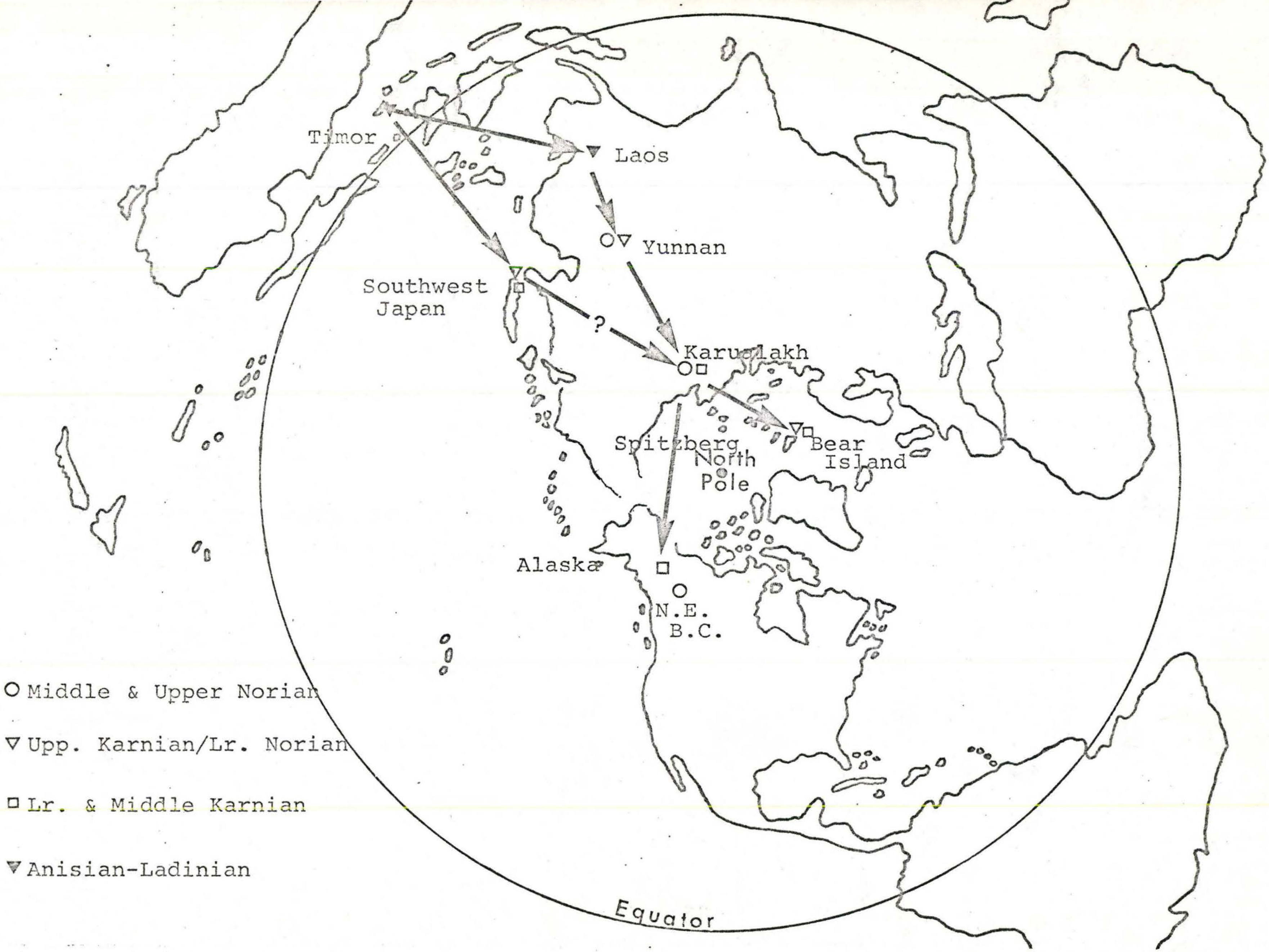


Fig. 19 Geographical occurrence of Middle and Upper Triassic Eumorphotis species and their probable migration.

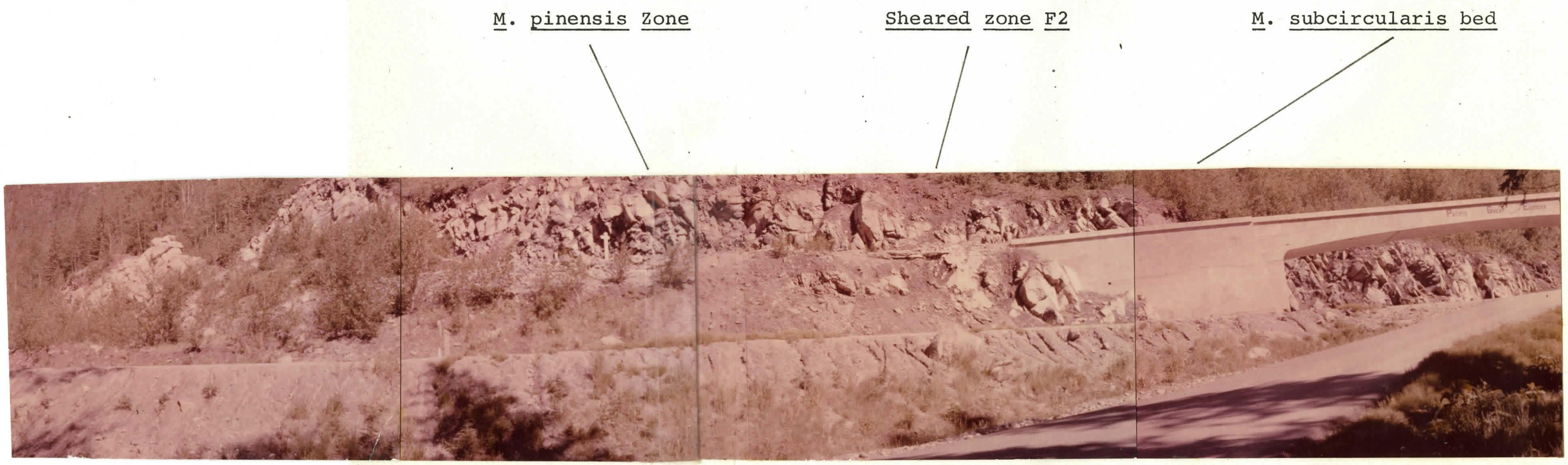


PLATE 1. Panoramic view of the Pine River Bridge Section, Northeastern British Columbia, showing the *Monotis subcircularis* coquina bed, the sheared zone F2, and the *Monotis pinensis* Zone.

EXPLANATION OF PLATE II

Fig. 1 The 2.5 m. coquina bed composed entirely of *Monotis subcircularis* at the southwest end end of the Railway Section.

Fig. 2 Bedding plane surface of the *Monotis subcircularis* coquina bed.

PLATE II

1

2

EXPLANATION OF PLATE III

Fig. 1 The *Monotis subcircularis* bed ("e") exposed at the base of the construction trail section.

Fig. 2 The narrow fault zone F2, 3 m. above the coquina bed approximately 10 m. west of the railway bridge indicated by sheared rocks and a small fan fold.

1

2

PLATE IV

0 1 2
Scale m.

PLATE IV The reverse fault F1, stratigraphically 20 m. above F2 along the Railway Track.

EXPLANATION OF PLATE V

Figs. 1-8. Eumorphotis (Eumorphotis) lamoreyensis VERMA sp. nov. 1, Holotype, left valve showing marked costation and pointed umbo (McM # Tr. 384 WH); 2, Paratype, slightly prosocline, dissociated right valve of the species showing faint radial sculpture and byssal auricle distinctly separated from the shell by a deep byssal notch which reaches almost up to the umbo (McM # Tr. 384 WP); 3, opisthoclinal and 4, almost aclinal left valves (McM # Tr. 383), all from bed "g" of the Pine River Bridge Section, British Columbia; 5, Aclinal left valve from Shell Oil Co. coll. (McM # Tr. 383 S); 6,7, aclinal left valves from G.S.C. coll. # 10765 (McM #383 G); 8, probably corresponding right valve of the species from the Pine River Bridge Section (McM # Tr. 384 W) UPPER NORIAN, M. Subcircularis Zone.

Figs. 9-13 Eumorphotis (Asoella) depressa VERMA sp. nov. 9, almost aclinal left valve showing blunt costation; 10, left valve; 11, left valve with both auricles preserved (McM # Tr. 427 A); 12, left valve distorted by compression (all McM # Tr. 427 A); 13, Prosoclinal left valve. All specimens from bed 11 of the Pine River Bridge Section. UPPER NORIAN. M. Subcircularis Zone.

All figures X2

PLATE V

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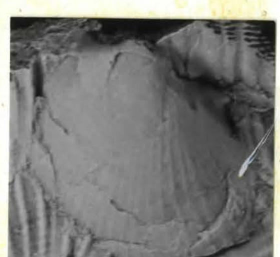

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EXPLANATION OF PLATE VI

Figs. 1-7 Eumorphotis (Asoella) depressa VERMA sp. nov.

1, damaged prosoclinal and 2,3, aclinal left valves (McM # Tr. 427 A); 4, Holotype, left valve showing sharp umbo and widely spaced blunt ribs, anterior auricle slightly damaged; 4a, lateral view of the same (McM # Tr. 427 AH); 5,6,7, left valves; 6a, lateral view of 6 (McM # Tr. 427 A). All from bed 11 of the Pine River Bridge Section, British Columbia. UPPER NORIAN. M. subcircularis Zone.

All figures X2.

PLATE VI

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4a

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6a

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EXPLANATION OF PLATE VII

Figs. 1-8 Eumorphotis (Asoella ?) acuta VERMA sp. nov.

1, left valve with anterior and dorsal margins damaged but with well-preserved posterior auricle (McM # Tr. 427 B)(X4); 2, left valve showing well-preserved posterior auricle (McM # Tr. 427 B)(X3); 3, left valve, same as 2 (McM # 427 B)(X2). Specimens 1-4 from bed 11 of the Pine River Bridge Section, British Columbia. 5, left valve with more prominent costation (McM # Tr. 383 WB); 6, Holotype, left valve with well preserved auricles and costation (McM # 383 WBH)(X2); 7, smaller, inflated left valve with damaged anterior border (McM # 383 MB)(X2); 8, Paratype, very highly inflated left valve with well-preserved posterior auricle (McM # 383 MBP); 8a, lateral view of same. Specimens 5-8 from bed "g" of the Pine River Bridge Section, British Columbia. UPPER NORIAN. M. subcircularis Zone.

PLATE VII

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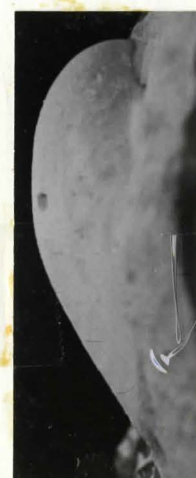

8a

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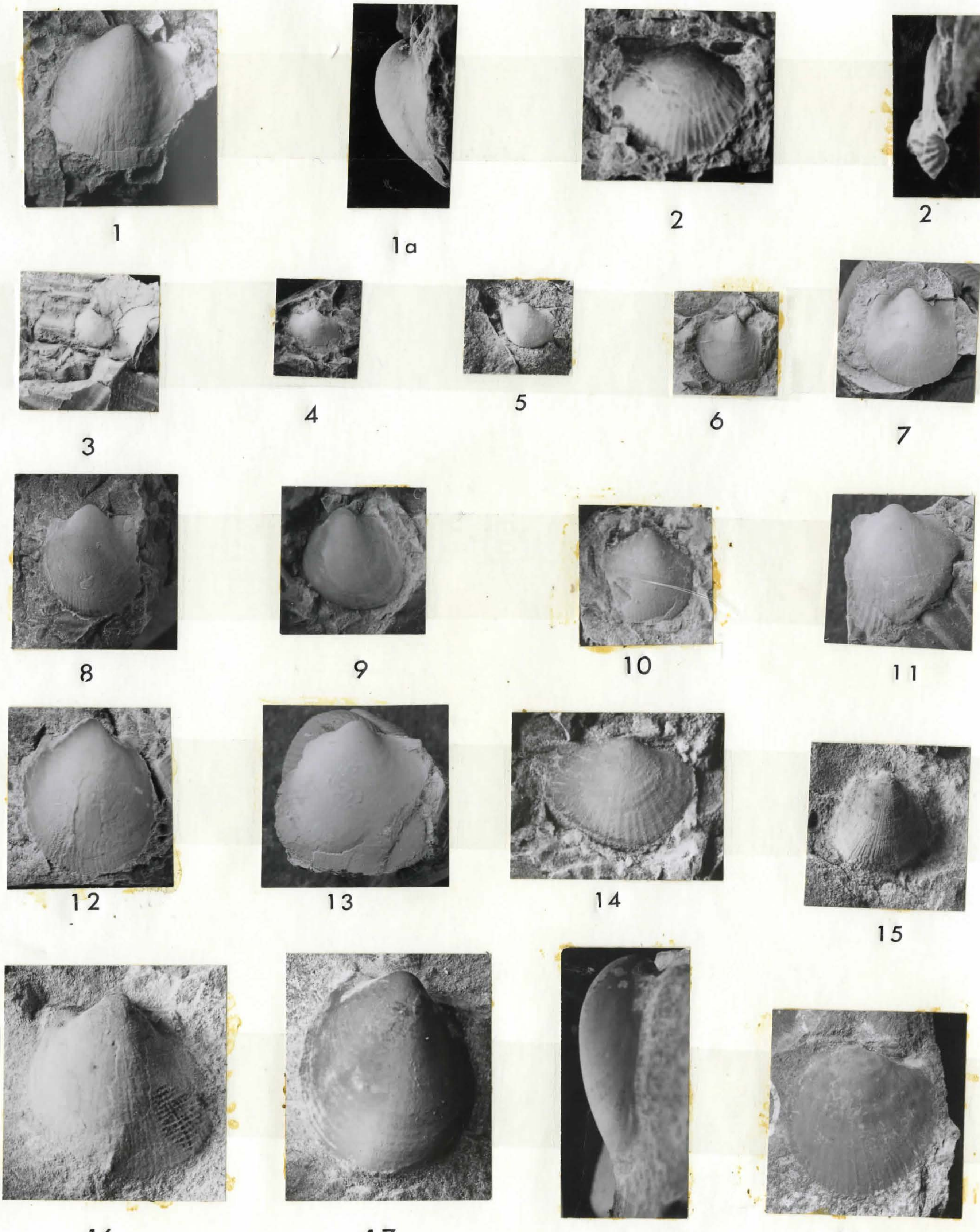
EXPLANATION OF PLATE VIII

Figs. 1-18 *Eumorphotis* (*Asoella*) *westermanni* VERMA sp. nov.

1, *Holotype*, left valve with damaged ventral margin but with characteristic umbo and auricles (McM # Tr. 383 CH); 1a, lateral view of same; 2, *Paratype*, dissociated right valve with well-defined byssal notch and plate like byssal auricle (McM # 383 CP); 2a, lateral view of above; 3-6, immature, probably younger left valves longer than high; 7,8,9, left valves with well preserved outline and auricles; 10, 11, left valves; 12, rather inflated left valve; 13, left valve; 14, dissociated right valve (McM # Tr. 383 C). Above specimens from Pine River Bridge Section, *M. subcircularis* Zone. 15, left valve from Anisian Toad formation, Alaska Highway, Shell Oil Co. # 1159 (McM # 383 SC); 16, 17, left valve; 17a, lateral view of same; 18, slightly inflated right valve G.S.C. coll. # 14115 (McM # Tr. 383 GC).

All Figures X2

PLATE VIII



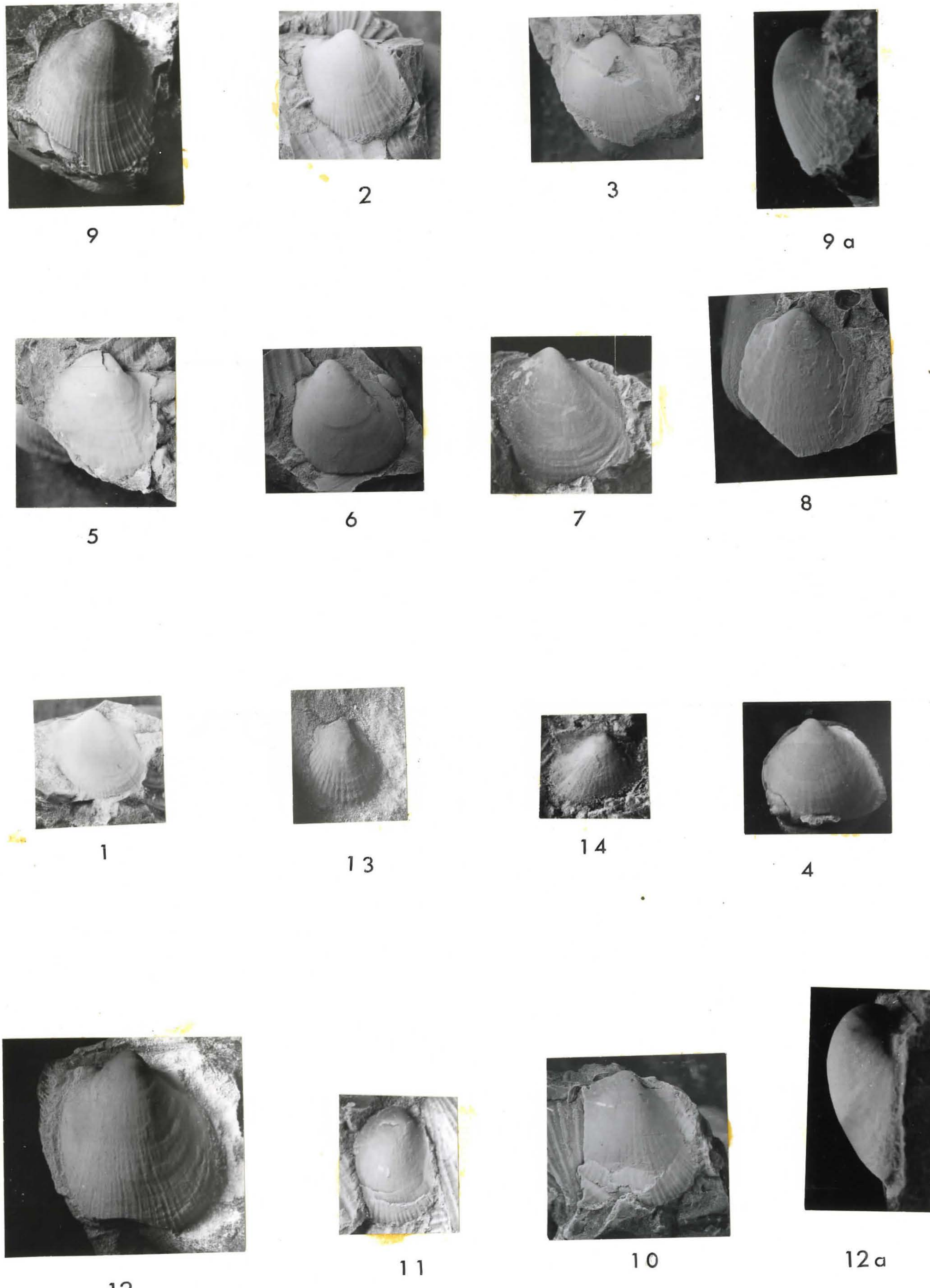
EXPLANATION OF PLATE IX

Figs. 1-14 Eumorphotis (Asoella) obliqua sp. nov.

1, left valve (McM # Tr. 427 DH); 2,3, immature prosocline left valves (McM # Tr. 427 D); 6,7, left valve (McM # 427 D); 8, left valve with damaged margins (McM # Tr. 427 D); 9, Holotype left valve showing fine radial ridges and oblique outline; 9a, lateral view of same (McM # Tr. 427 DH); 10, left valve with damaged anterior margin and auricle (McM # Tr. 427 D); 11, left valve with partially preserved shell material (McM # Tr. 427 D); 12, large prosocline left valve (McM # Tr. 383 MD); 13, small prosocline left valve (McM # Tr. 427 D). All specimens from Pine River Bridge Section, all except 12 from M. subcircularis Zone, 12 from M. pinensis Zone.

All Figures X2

PLATE IX



EXPLANATION OF PLATE X

Figs. 1-3 Eumorphotis (Asoella) convexa (Mansuy)

1, prosocline left valve with damaged posterior margin from Gymnotoceras-Beyrichites zone, Toad formation (Anisian) of Alaska Highway, locality G4, (McM # Tr. 421 A); 2, smaller than above prosocline left valve with damaged umbo (McM # Tr. 383 M); 2a, magnified view of part of exterior surface of 2 showing off-setting of ribs; 3, prosocline left valve (McM # Tr. 383 M).

Figs. 4-5 Eumorphotis n. sp. aff ? E. subconvexa (Krumbeck)

4, exterior view of weakly convex, almost acline left valve with damaged anterior and posterior margins, (Shell Oil Co. coll. # 4888, (McM # 383 SG)); 5, exterior view of acline left valve with damaged posterior and ventral margins, Shell Oil Co. coll. # 4886, (McM # Tr. 383 SG)). Both specimens from Liard Formation (Ladinian) of Alaska Highway.

Figs. 6-7 Eumorphotis (Eumorphotis) laosensis (Mansuy)

6, acline left valve damaged in the middle portion (Shell Oil Co. coll. # 7857 (McM # 383 SA)) from Ladinian-Karnian of Tuchodi Lakes, British Columbia; 7, prosocline left valve with partially preserved shell material (McM # Tr. 383 MA) Pine River Bridge Section, British Columbia.

FIG. 2a, X4

All Other Figures X2

PLATE X

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2a

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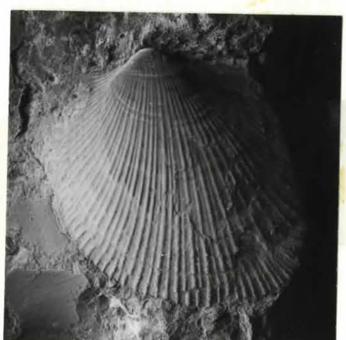

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EXPLANATION OF PLATE XI

Figs. 1-2 Eumorphotis (Eumorphotis) laosensis (Mansuy)

1, acline left valve with well developed auricles and growth rugae (Shell Oil Co. coll. # 7547 (McM # Tr. 383 SA)) from Toad Formation (Anisian) of Klingzut Mountain, British Columbia; 1a, lateral view of same; 2, probably corresponding right valve showing partially preserved shell material with closely-spaced ribs (McM # Tr. 383 MA)

Figs. 3-7 Eumorphotis (Asoella) cf. E. australasiatica (Krumbeck)

3, left valve with highly incurved and projecting umbo, anterior auricle damaged (Shell Oil Co. # 1161, (McM # 383 SE)), Liard formation, Alaska Highway; 3a, lateral view of above; 4, left valve with both auricles preserved, same locality as above; 4a, lateral view of above; 5, prosocline left valve with comparatively less projecting umbo, (G.S.C. # 14115 (McM # 383 GE)), from Pardonet Formation, Pine River, British Columbia; 6, comparatively thicker left valve from same locality as above; 7, left valve (McM # Tr. 383 E) , Pine River Bridge Section, M. subcircularis Zone.

All Figures X2

PLATE XI


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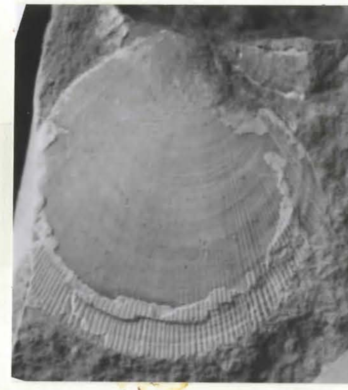
1a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3a


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4a


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EXPLANATION OF PLATE XII

Figs. 1-6 Eumorphotis (Eumorphotis) zittelli (Teller)

1, internal mold of slightly prosocline left valve with damaged posterior margin and partially covered anterior auricle; 2, prosocline left valve showing shell material and internal mold; 3, large deformed left valve with partially preserved shell material; 4, internal mold of prosocline left valve; 5, internal mold of higher than long left valve with posterior margin partly damaged; 6, very imperfectly preserved prosocline left valve. All specimens (McM # Tr. 427 E), from bed 11, Pine River Bridge Section, M. subcircularis Zone, British Columbia.

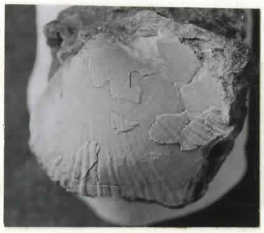
Figs. 7-8 Meleagrinella aurisparva VERMA, sp. nov.

7, Holotype, left valve, cast of imprint in rock, (McM # Tr. 383 WFH); 8, Paratype, prosocline left valve (McM # Tr. 383 WFP); 8a, lateral view of above. Above two specimens from bed "g", Pine River Bridge Section, British Columbia,

All Figures X2

PLATE XII

2



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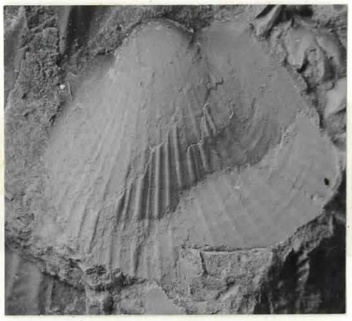

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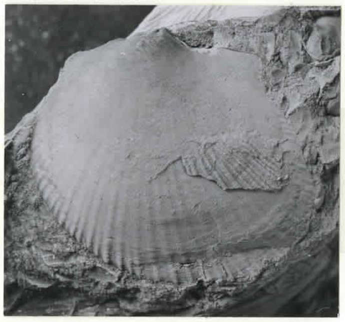

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8a

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EXPLANATION OF PLATE XIII

Figs. 1-8   *Meleagrinella aurisparva* VERMA, sp. nov.

1,2, acline left valves (McM # Tr. 383 WF); 1a, lateral view of above; 3, prosocline left valve (McM # 427 F); 4, smaller, almost acline left valve from the same rock fragment as above; 5, opisthoclinal left valve with coarser ribs (McM # Tr. 427 F); 6, partially preserved left valve (McM # Tr. 427 F); 8, dissociated right valve found in the same rock fragment as above. All specimens from UPPER NORIAN *M. subcircularis* Zone, Pine River Bridge Section, British Columbia.

All Figures X2

PLATE XIII

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1a

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