UPPER CAMBRIAN (DRESBACHIAN) FAUNAS OF THE PILGRIM FORMATION IN SOUTHWESTERN MONTANA

A Thesis

Presented to

the Faculty of the Department of Geology

New Mexico Institute of Mining and Technology

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Rena Mae Bonem

September 1971

ABSTRACT

Dresbachian faunas from the Pilgrim Formation at North Grove Creek and Wolf Creek south of Red Lodge, lower Beaver Creek near Helena, and Castle Rock on Mill Creek south of Livingston in Montana and Beartooth Butte in Wyoming are described.

The Aphelaspis Zone fauna was found only in collections from North Grove Creek and Wolf Creek. Four genera of trilobites, Aphelaspis, Blountia, Cheilocephalus, and Glaphyraspis; four brachiopod genera; and Hyolithes are recognized in the Aphelaspis Zone. The large number of individuals of Aphelaspis which are present in the zone made statistical studies possible. These resulted in recognition of two species. This high number of individuals with low numbers of genera and species indicates a time of stress which might be the result of cooler waters or change in salinity.

The Crepicephalus Zone is characterized by a much larger number of genera and species with fewer individuals than the Aphelaspis Zone. The assemblage contains sponge spicules, Hyolithids, two brachiopod genera and species, and 17 genera and at least 23 species of trilobites. Tricrepicephalus and Coosina are represented by moderately large numbers of individuals. Statistical studies like that for Aphelaspis are included for both genera.

The Cedaria Zone is also represented by a large number of genera and species of trilobites. Fourteen genera and at least 18 species are recognized, as well as numerous inarticulate brachiopods and a few echinoderm plates. However, no hyolithids or articulate brachiopods were found.

Most of the collections were obtained from crystalline or oolitic limestone and limestone pebble conglomerates deposited in lagoons and tidal flats which were periodically exposed.

TABLE OF CONTENTS

ILLUSTRATIONS

INTRODUCTION

The Pilgrim Formation in south and central Montana contains Dresbachian faunas from the Aphelaspis, Crepicephalus, and Cedaria Zones. The present investigation includes systematic descriptions of material from five locations (Figure 1), where complete faunal studies have not been attempted previously, as well as discussions of sedimentation and stratigraphy and possible paleoecological interpretations.

Material available included collections made by Dr. Christina Lochman-Balk in 1937 to 1939 at North Grove Creek near Red Lodge, Mill Creek south of Livingston, and Beaver Creek near Helena in Montana and Beartooth Butte in Wyoming. This material was supplemented by large collections obtained during July 1970 at Wolf Creek north of North Grove Creek, Mill Creek, and Beaver Creek. The collections are closely spaced and their position is shown in the measured sections.

The first systematic study of Upper Cambrian faunas in central Montana was that of Lochman and Duncan (1944) based on small collections from several measured sections. Although this is an extensive work, many genera and species which are present in the Pilgrim Formation in Montana were not found because of the small size of collections. The Lodgepole Creek fauna (Lochman, 1950) and a study of the Aphelaspis Zone from Logan (Lochman and Hu, 1962) are the

only other papers which present studies of Dresbachian faunas in Montana. However, discussion and descriptions of closely related faunas of the Gallatin Formation in Wyoming are found in Miller (1936), Deland and Shaw (1956), and Lochman and Hu (1960, 1961, 1962a). Other important studies of Dresbachian faunas include Walcott (1916a, 1916b), Resser (1938a, 1942), Lochman (1938b, 1940), Palmer (1955, 1962, 1965), and Rasetti (1965).

ACKNOWLEDGEMENTS

I am greatly indebted to my advisor, Dr. Christina Lochman-Balk, and to committee members, Dr. Frank Kottlowski and Dr. Gilbert Sanchez, for their counsel, guidance, and suggestions without which this study could not have been completed. I am grateful for the photographic assistance of Mr. James McGlasson. I am also grateful to the Society of Sigma Xi for field support, to the New Mexico Bureau of Mines and Mineral Resources for a research assistantship, and to New Mexico Institute of Mining and Technology and the National Science Foundation for a National Science Foundation Traineeship which have enabled me to continue my graduate studies. I would also like to acknowledge the assistance of Mr. and Mrs. Arthur Nelson Jr. and my mother, Mrs. David S. Bonem.

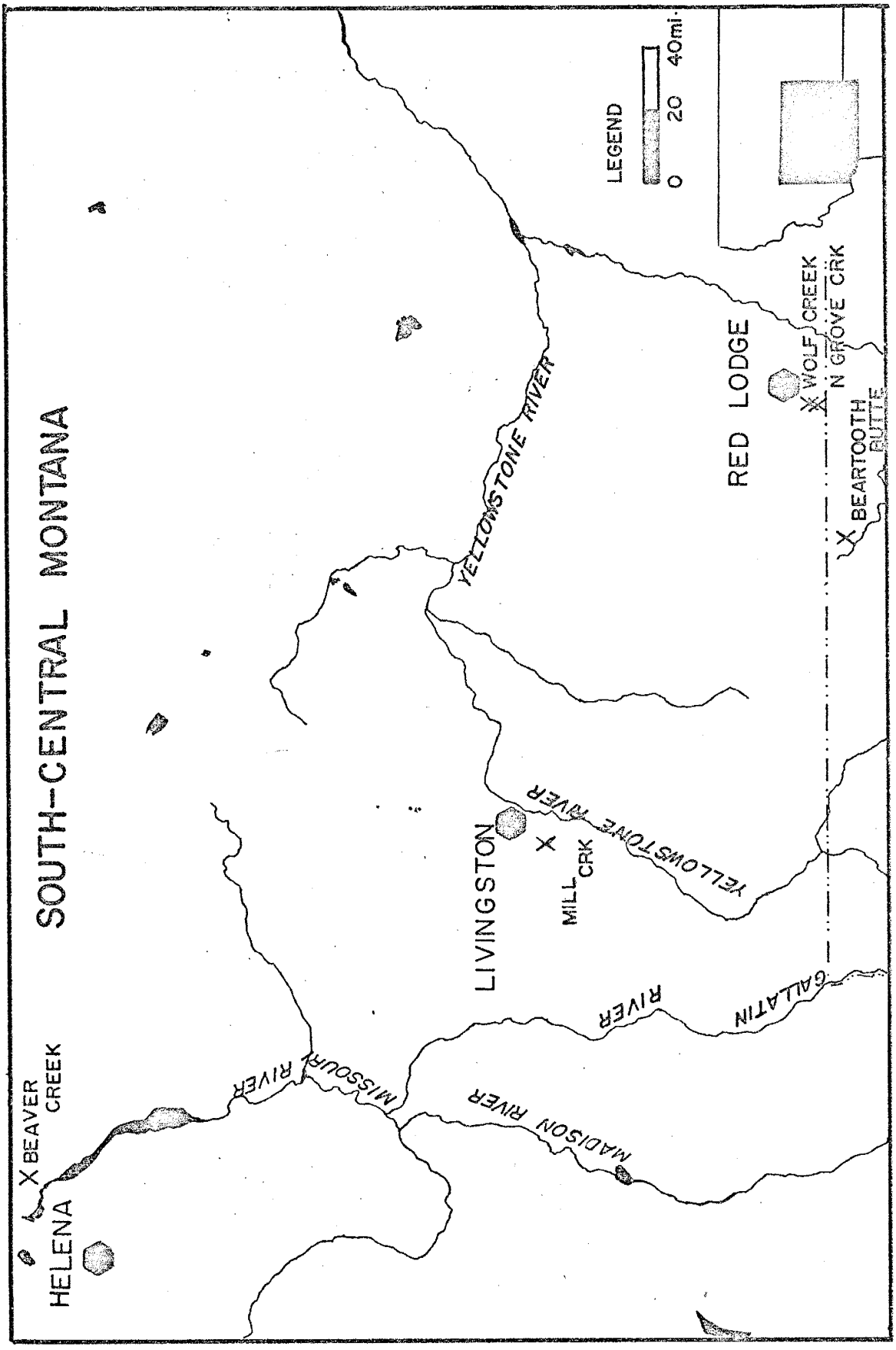


FIGURE 1: Index Map of Fossil Localities

LITHOSTRATIGRAPHY

The Pilgrim Formation was defined by Weed (1900) in the Little Belt Mountains. Deiss (1936) emended Weed's definition, designated the type locality at Dry Wolf Creek in the Little Belt Mountains, and recognized the formation as far south as Yellowstone Park. Later, the term Maurice Formation was applied by Dorf and Lochman (1940) to the oolitic limestone facies of the Pilgrim Formation in south-central Montana. Hanson (1952) stated that the name Maurice Formation was superfluous and that it should be dropped.

The Pilgrim Formation is dominantly a carbonate unit of Dresbachian age underlain by the Park Shale. It is overlain by the Red Lion or Snowy Range Formation except where they have been removed by erosion prior to Late Devonian time. At Beaver Creek the Pilgrim formation is directly overlain by the Maywood Member of the Upper Devonian Jefferson Formation. Hanson (1952) recognized four major rock types in the formation. These are pebble conglomerate, crystalline limestone, oolitic limestone which may be mottled, and dolomite which replaces the other rock types. Dolomitization is reported as minor in the type area, but increases in sections to the south and west. Limestone pebble conglomerates are present throughout the type section, but seem to be restricted to the lower part of the formation in the southern and western sections. The coarse- to finely

PLATE 1

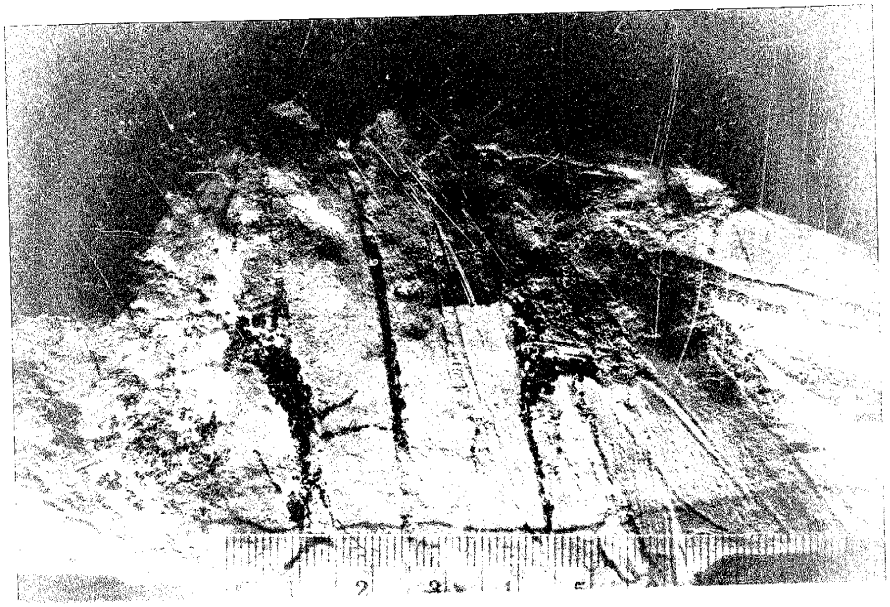


Figure 1: Limestone pebble conglomerate from Wolf Creek.

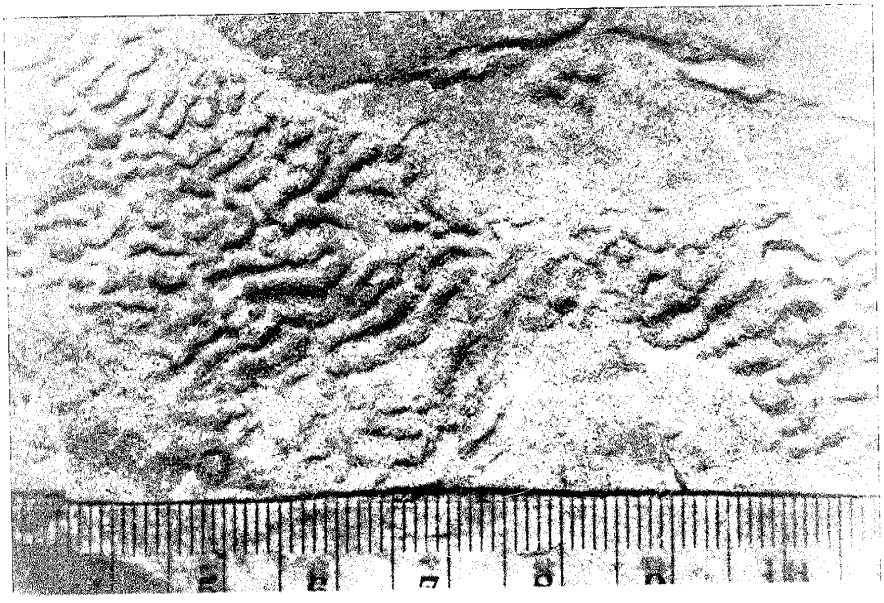


Figure 2: Browsing traces on limestone from Wolf Creek.

crystalline limestone is interbedded with the conglomerates, is very fossiliferous, and varies in color from gray to tan. Mottled oolitic limestone is more common in the southern sections. The mottling has been attributed to partial dolomitization (Brown, 1959).

Three distinct lithologies occur in the Pilgrim Formation at Wolf Creek. At the top of the formation is a 1.5-foot arenaceous crystalline limestone and arenaceous calcarenite. This unit includes abundant medium-grained, subrounded, frosted quartz grains, plagioclase and microcline, and very fine-grained, angular fragments of sphene. The unit is characteristic of the Aphelaspis Zone in Montana and is as much as 100 feet thick (Hanson, 1952). Below the arenaceous unit is 15.5 feet of dark-gray, fine-crystalline limestone pebble conglomerates in a dark-gray, medium- to coarsely crystalline oolitic limestone matrix. The lowest unit exposed at Wolf Creek is predominately buff-gray, medium- to coarsely crystalline, oolitic limestone with only minor pebble conglomerates. Dolomitization is minor, occurring only near the top of the 19.8-foot unit (Figure 3).

Two major lithologic units occur in the Mill Creek section. The upper unit is primarily tan and gray mottled, cliff-forming, dolomitic, oolitic limestone with a medium-crystalline limestone matrix and minor hematite and glauconite. Only seven feet of the 180 foot section belong to the lower lithologic unit. This unit is medium to light gray-brown, fine- to medium-crystalline limestone which has abundant tan shale partings (Figure 4).

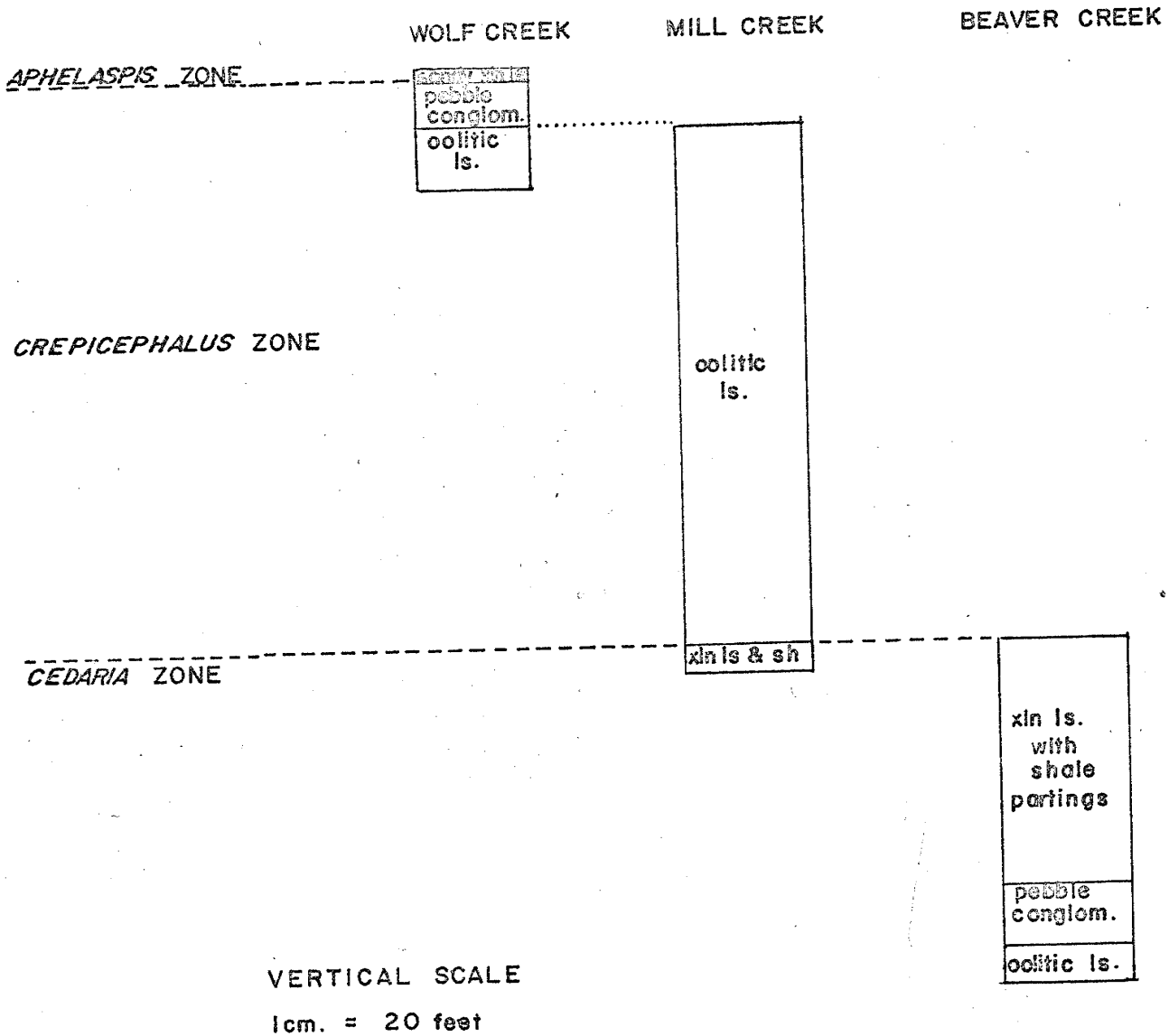


FIGURE 2: Vertical Distribution of Gross Lithologic Units

The upper unit at Beaver Creek consists primarily of dark-gray, fine- to coarsely crystalline limestone which is fractured and has gold shale partings. The unit is 80.2 feet thick. A thinner second unit, 26.6 feet thick, consists of crystalline limestone with shale partings interbedded with light-tan, fine-crystalline, elongate, rounded limestone pebble conglomerate with a medium- to light-gray, medium-crystalline limestone matrix. Ooliths and rounded chert pebbles are found in the lower light-gray, coarsely crystalline, oolitic limestone. This unit has small shale partings and is 19.1 feet thick (Figure 5).

Although minor fluctuations in lithology occur within short vertical and lateral distances, gross lithologic units in the three sections appear to occur in the same positions within faunal zones (Figure 2). At Wolf Creek the Aphelaspis Zone fauna is in an arenaceous crystalline limestone and calcarenite, and the Crepicephalus Zone occurs in an upper pebble conglomerate and a lower mottled oolite. At Mill Creek, the Crepicephalus Zone is found in the thick mottled oolite, and the Cedaria Zone occurs in a thin crystalline limestone with shale partings. A crystalline limestone with shale partings dominates the upper part of the Cedaria Zone at Beaver Creek and is underlain by a pebble conglomerate and a lower oolitic limestone with shale partings.

PLATE 2

Figure 1: Distant view of Wolf Creek section.

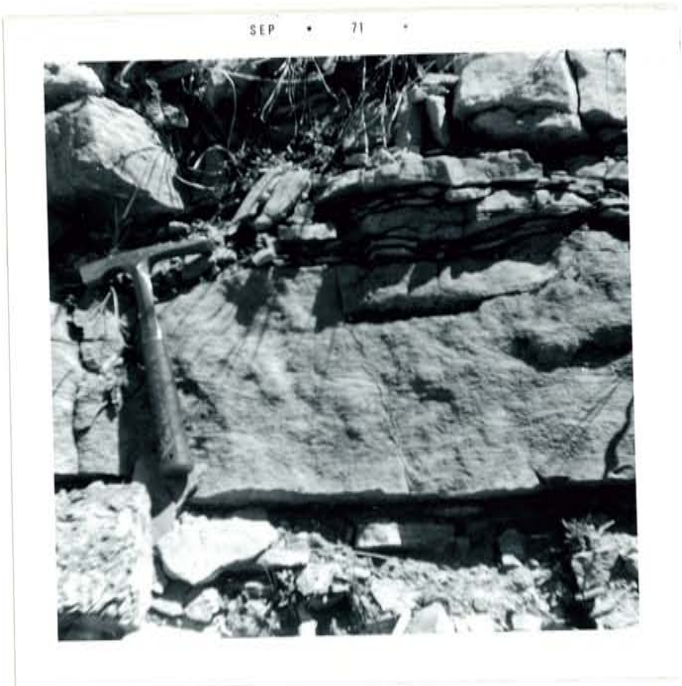
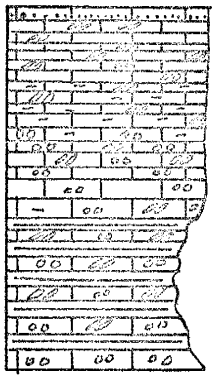


Figure 2: Limestone pebble conglomerate in middle of Wolf Creek section.

WOLF CREEK SECTION

SEC. 22 &23, T. 8 S., R. 20 E.



TAN TO WHITE, COARSE CRYSTALLINE

LIGHT TO DARK GRAY, FINE TO MEDIUM CRYSTALLINE

COARSE CRYSTALLINE

FINE CRYSTALLINE, MASSIVE

BUFF TO GRAY, MEDIUM CRYSTALLINE

COARSE TO MEDIUM CRYSTALLINE

LIGHT BROWN TO GRAY

VERTICAL SCALE
1" = 20'

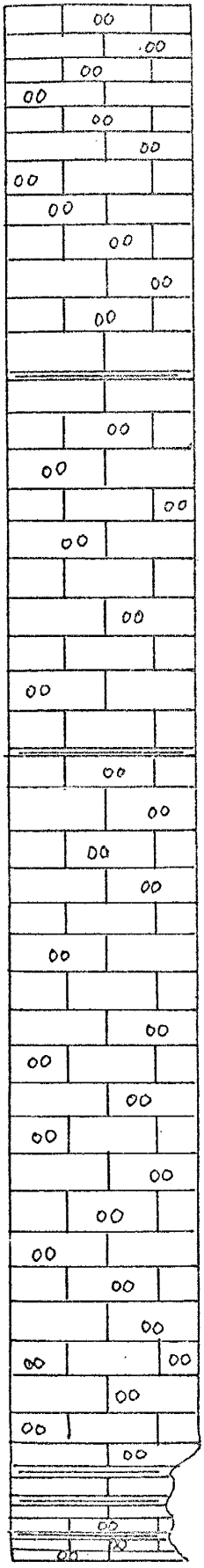
Figure 3

PLATE 3

Figure 1: Cliff at Mill Creek.

Figure 2: Mill Creek section view of Castle Rock.

MILL CREEK SECTION SEC. 13, T. 6 N., R. 10E.



RED-ORANGE WEATHERED ZONE

GRAY TO BUFF, OOLITIC
MOTTLED WITH SOME RED STAIN
AND SLIGHT DOLOMITIZATION

SOME AREAS HIGHLY BRECCIATED

VERTICAL SCALE
1" = 20'

WHITE-PINK AND GRAY, FINE TO MEDIUM
CRYSTALLINE LENSES
LIGHT BROWN-GRAY, FINE TO COARSE
CRYSTALLINE NODULAR LIMESTONE

Figure 4

PLATE 4

Figure: View of Beaver Creek section.

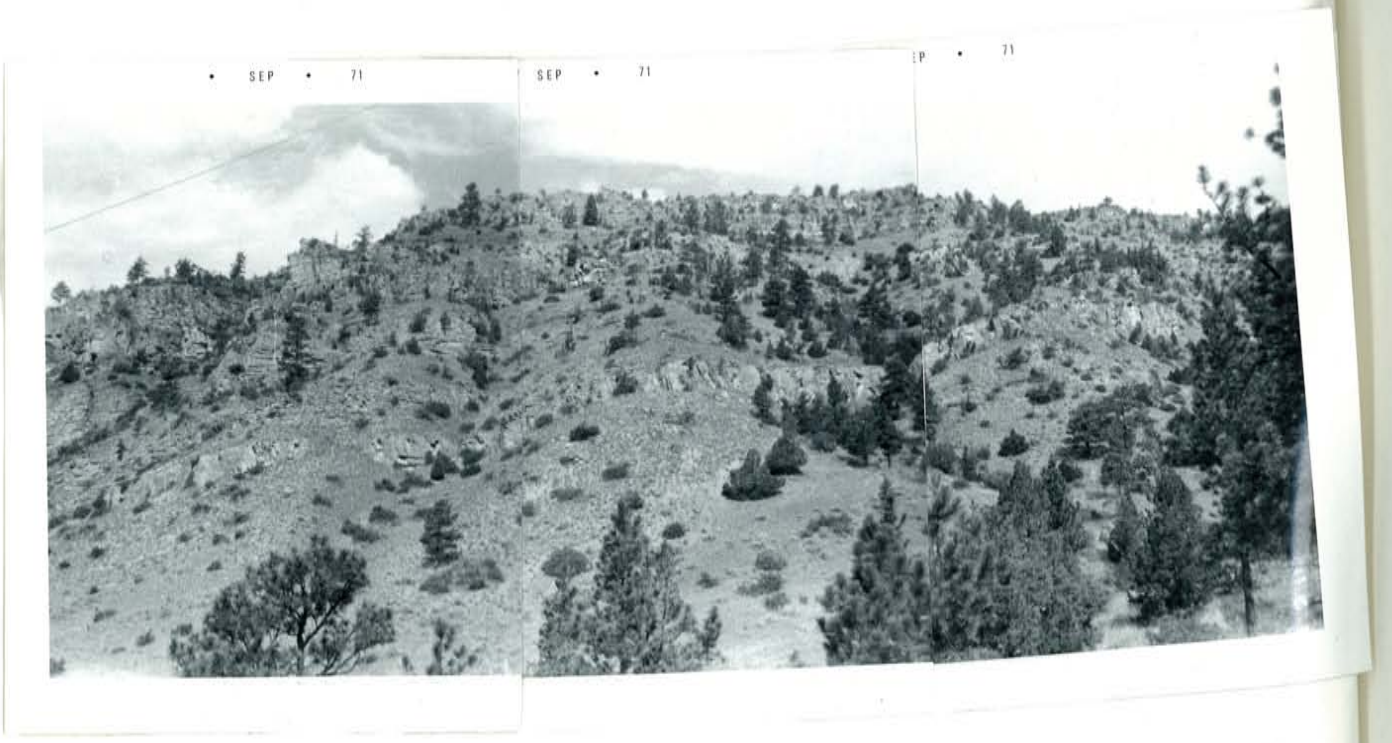
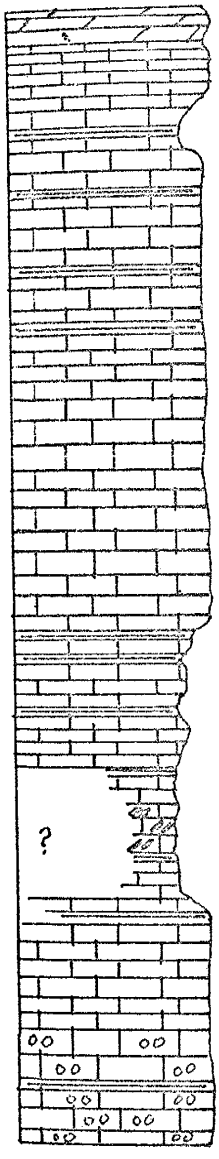


Figure 2: View of area of Beaver Creek section.

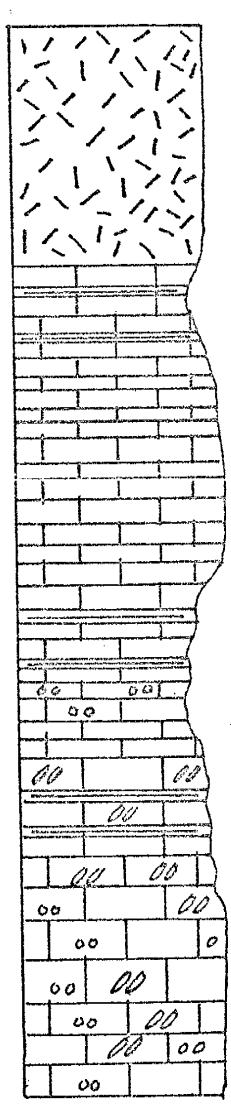
BEAVER CREEK SECTIONS

SEC. 15, T. 12 N., R. 2 W.

SECTION B 1970



SECTION A 1937-9*



VERTICAL SCALE
1" = 20'

* section measured by Lochman-Balk, 1937-9

Figure 5

BIOSTRATIGRAPHY

The Upper Cambrian begins with the appearance of the Cedaria Zone trilobite assemblage and ends with the disappearance of the Saukid genera. The faunal zones are assigned to three stages, Dresbachian, Franconian, and Trempealeauan, named from lithostratigraphic units in the standard Upper Cambrian section in the upper Mississippi Valley where the base of each stage is defined by a marine transgression and the top is a regression (Howell, 1944).

The Dresbachian Stage derives its name from the Dresbach Sandstone defined by Winchell in 1873 in the upper Mississippi Valley. Three faunal zones were originally assigned to the stage from the standard section, the Cedaria, Crepicephalus, and Aphelaspis Zones. The Dunderbergia Zone was later added above the Aphelaspis Zone from Nevada sections. The faunal zones are assemblage zones based on the presence of a number of trilobite genera which are associated at different localities, but whose presence is controlled by ecologic conditions; therefore, the upper and lower boundaries of the assemblage zones need not represent isochronous surfaces.

The base of the Dresbachian stage begins with a transgression and the appearance of the Cedaria Zone fauna. This is followed by the large and varied Crepicephalus Zone fauna which is replaced abruptly by a small number of genera and species with a large number of individuals

in the Aphelaspis Zone. The only genera to continue into the Aphelaspis Zone from the Crepicephalus Zone are Blountia and Glaphyraspis, although Coosella and Tricrepicephalus persisted briefly. No change in sedimentation has been observed at any cratonic site and the faunal break has been attributed to cooler waters invading shelf areas (Lochman-Balk, 1970). Faunal assemblages show regression from the north and central United States shortly after the beginning of the Aphelaspis Zone. The Dunderbergia Zone assemblage was not found in any of the localities studied in south-central Montana.

Faunal Zones

The three lower faunal zones of the Dresbachian Stage are found at Wolf Creek. The Aphelaspis Zone assemblage is present in the top 1.6 feet of the Pilgrim Formation. Most of the described fauna from the Aphelaspis Zone is found in gray to white crystalline limestone at the top of the formation, although a few fragmentary Aphelaspis and Cheilocephalus are found in white fine-grained calcarenite which is gradational with the lithology at the top of the Crepicephalus Zone. This was evident by the presence of a Tricrepicephalus pygidium in the calcarenite. Limestone pebble conglomerates with an oolitic crystalline limestone matrix occur near the top of the Crepicephalus zone. The fossils occur in layers and lenses of crystalline limestone between the pebbles, but are usually fragmentary. The oolitic crystalline limestone

which occurs at the base of the exposed Pilgrim Formation at Wolf Creek is more fossiliferous, especially near the top where abundant pygidia and cranidia of Tricrepicephalus and Coosina occur in layers. The Cedaria Zone assemblage is reported to be present in the Park Shale below the Pilgrim Formation at Wolf Creek, but was not considered in this investigation.

The 1937 to 1939 collections of Lochman-Balk from North Grove Creek are not placed stratigraphically. Crepicephalus Zone fossils were collected in limestone which appeared to be the same lithology as that of the basal Aphelaspis Zone so that the two zones appear to be lithologically gradational also at the North Grove Creek section. Most of the fossils are found in a dark- to light-gray calcarenite between large pebbles of biomicrite. Several lenses of trilobite coquina were present, but the material is badly weathered and falls apart, making identification of fossils difficult.

The Aphelaspis Zone was not found at Mill Creek, although it may be present. Fossils are relatively scarce and poorly preserved in the oolitic beds which form most of the section. One good Coosina cranidium was found on the talus slope. The basal seven feet of the formation consists of fine- to medium crystalline limestone in which fossils are abundant, but are generally fragmentary. Tricrepicephalus, Genevievella, and Kingstonia indicate the presence of the Cedaria Zone.

Crepicephalus Zone fossils were obtained from the small Beartooth Butte collection of Lochman-Balk. However, the horizons were not located stratigraphically.

A fairly large collection of Cedaria Zone fossils was obtained during summer 1970 at Beaver Creek. As noted in Lochman and Duncan (1944), the upper Pilgrim beds have been removed by erosion and only the middle and lower parts of the zone are present. The upper dark gray crystalline limestone contains abundant well preserved specimens of Modocia, Arapahoia, and Paracedaria, as well as specimens of many less well represented genera. Inarticulate brachiopods and agnostids are also common. The lower beds of pebble conglomerate and oolitic limestone have a smaller fauna consisting primarily of broken fragments. However, Paracedaria and Arapahoia were also found there. Similar faunal relations were observed in the 1937 to 1939 material of Lochman-Balk from Beaver Creek.

Faunal Localities

The fossil horizons are indicated by a combination of letters and numbers with prefixes corresponding to each locality. The horizons are arranged in descending stratigraphic order for each section and megascopic lithology as well as some microscopic and insoluble residue data are recorded for each horizon.

Number	Lithology	Footage
WOLF CREEK (WC) sec. 22 and 23, T. 8 S., R. 20 E. (Figure 6)		
WC-2(top)	gray to white, coarse to medium crystalline limestone, weathering gray to ochre, minor amounts of pyrite, galena, common hematite, limonite, and sphene	0.9 ft.
WC-2(base)	white to gray, fine to medium-grained calcareous sandstone with abundant medium-grained, sub-rounded to sub-angular, frosted quartz grains, plagioclase and microcline, and sphene in layers, grains are etched by calcite, floating grain contacts, minor limonite which appears to be altered glauconite	0.8
WC-5	dark gray, fine-grained limestone pebble conglomerate with medium gray, coarse crystalline matrix and some gold shale partings	6.6
WC-4	dark gray, fine-grained limestone pebble conglomerate (pebbles oriented parallel to bedding) with white to buff, coarsely crystalline limestone matrix which contains oolites which may have a hematitic center and rim, common sphene, glauconite pellets altering to limonite, pyrite, hematite, organic residues, and minor quartz grains	3.5
WC-3	medium crystalline, buff to white oolitic limestone with gold shale partings	0.7
WC-6	dark gray, fine crystalline, large, rounded limestone pebbles (oriented parallel to bedding plane) in light gray, coarse to medium crystalline limestone matrix	1.7

WC-7	massive, light gray, fine crystalline oolitic limestone	2.3
WC-8	dark gray, fine-grained, large, flat, rounded limestone pebble conglomerate with medium crystalline light gray limestone matrix, minor shale patches and glauconite	0.7
WC-10	buff to light gray, fine to coarse crystalline limestone with minor glauconite altering to limonite, and fine-grained angular to sub-angular quartz grains, microcline, sphene, and organic residues	
WC-11	light brown to gray and buff, finely crystalline oolitic limestone with surface silicification in slightly dolomitic oolitic patches	2.3
WC-9	buff to gray, medium to coarse crystalline oolitic limestone with some rounded coarsely crystalline calcite grains which may have dust rims, minor organic pellets altering to glauconite on edges and fine-grained, sub-rounded, frosted quartz grains	
WC-14	light gray, coarse to medium crystalline limestone interbedded with tan shale and oolitic limestone pebble conglomerate	11.2
WC-13	white to buff, coarse crystalline, oolitic limestone pebble conglomerates with minor shale partings, organic residues, and glauconite pellets with hematitic nuclei	2.0
WC-12	white to gray, medium crystalline, oolitic limestone pebble conglomerate, glauconite, hematite, and organic residues	2.5
WC-1	light brown to gray oolitic limestone with white to gray medium crystalline matrix which may have patches lacking oolites	0.5

GROVE CREEK (GC) sec. 26, T. 8 S., R. 20 E.

GC GC-1 GC-2	dark to light gray, green, yellow, and brown mottled, medium crystalline, sucrosic limestone with large pebbles of dark gray biomicrite from 1937-39 collections of Lochman-Balk

MILL CREEK (MC) sec. 13, T. 6 N., R. 10 E. (Figure 7)

MC-5	tan to gray mottled, medium crystalline limestone with oolites in gray patches and dolomite ghosts of oolites in tan patches, oolites striated parallel to margin, dolomite rhombs large, hematite, and minor limonite altered glauconite	40.0
MC-6	medium crystalline, light tan to gray limestone with silty patches	89.6
MC-3	same as MC-6 with oolites having hematite nuclei and organic residue layers, oolites buff, dolomite in medium crystalline, light gray matrix	43.0
MC-2	medium to light brown-gray, fine to medium crystalline limestone with silty partings	0.5
MC-2B	light gray, fine to medium crystalline limestone with minor silty partings	3.0
MC-1	light brown-gray, fine to coarse crystalline limestone, oolitic with some oolites forming around calcite-organic nuclei, minor glauconite, some organics and iron rich layers, small silty patches	3.5
MC-4	like MC-5, from talus	

BEAVER CREEK (BC and LOC) sec. 15, T. 12 N., R. 2 W.

1970 COLLECTION (Figure 8)

BC TOP A	buff, dolomitic siltstone (Maywood Member)	1.8
BC HP	dark brown-gray, medium crystalline dolomite with gold and red surfaces and calcite filled fractures, patches of coarsely crystalline dolomite, limestone, minor fine-grained quartz	1.7
BC TOP B	dark gray, weathering buff, coarse crystalline limestone	1.9
BC-4	dark gray, fine crystalline limestone, minor gold shale partings, coarse white crystalline limestone fracture fillings	2.6

BC-X0	gray medium crystalline limestone, minor gold shale partings, white coarse crystalline limestone fracture fillings	1.7
BC-X16	brown-gray, fine to medium crystalline limestone, gold shale partings, white, coarse crystalline limestone fracture and cavity fillings	1.7
BC TOP C	dark gray, coarse crystalline limestone weathering buff, yellow shale patches	7.3
BC TOP D	brown-gray, fine crystalline limestone, patches of medium crystalline, glauconite scattered and on partings, shale patches	8.9
BC-X5	dark gray, fine crystalline limestone with fracture filling	31.3
BC-X9	dark gray, medium to coarse crystalline limestone, buff when weathered, shaly yellow patches	4.0
BC-X8	same as above	6.9
BC-X7	gray, medium to coarse crystalline limestone with common shale laminae and fracture filling	1.7
BC-X6	dark to light gray, medium crystalline limestone, shale laminae, and fracture filling	5.2
BC-X14	dark brown-gray, fine crystalline limestone with gold shaly patches	4.0
BC-X3	elongate, fine-grained, light tan pebbles, slightly rounded and parallel to bedding in medium to light gray, medium crystalline limestone with perpendicular fractures	2.0
BC-X17	as above	3.0
BC-X2	dark gray, fine crystalline limestone without shale partings	2.0
BC-X12	dark gray, fine crystalline limestone with fractures and shale partings	3.0
BC-X1	medium to dark gray, fine to coarse crystalline limestone with shale partings	
BC-X11	light gray, medium crystalline limestone with gold shale partings	16.6

BC-X15	light gray, coarse crystalline limestone with "ooliths", small shaly patches, and fractures	16.0
BC-X10	dark to medium gray, medium to coarse crystalline limestone, minor glauconite, gold shale partings	0.6
BC-Base	ooliths, rounded chert pebbles with irregular orientation in dark gray to black oolitic limestone with shaly patches, and crystalline matrix, minor dolomite in oolites	2.5

1937-39 COLLECTION of Lochman-Balk (Figure 9)

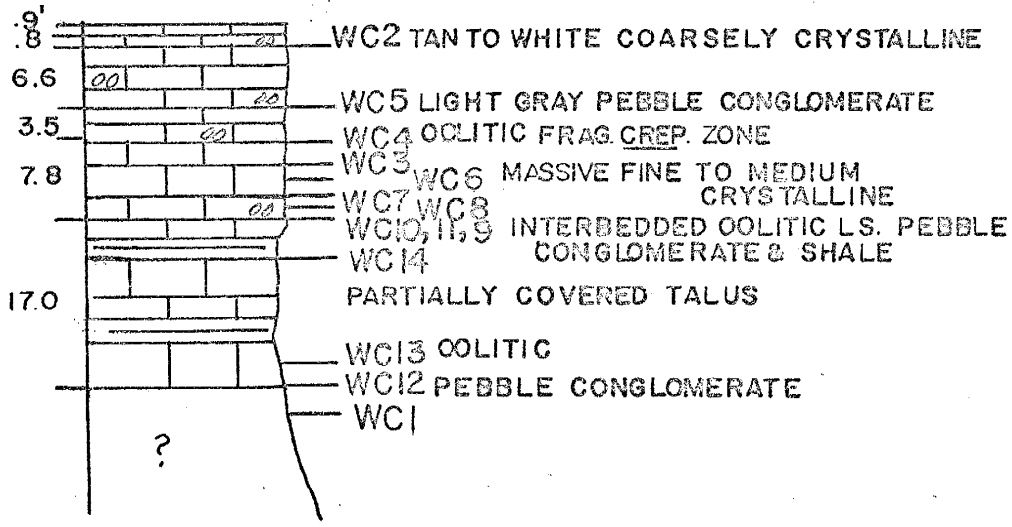
LOC-4a	gray crystalline limestone	53.7
LOC 3	thin bedded oolitic limestone interbedded with pebble conglomerate with light gray crystalline matrix and yellow shale partings	25.3
LOC 2b	mottled edgewise pebble conglomerate	18.9

BEARTOOTH BUTTE (BB) sec. 25, T. 58 N., R. 106 W.

BB BB-1	1937-9 collections of Lochman-Balk; dark gray, medium crystalline limestone, glauconite and hematite minor

WOLF CREEK

SEC. 22 & 23, T 8 S., R 20 E.



VERTICAL SCALE

1" = 20'

FIGURE 6

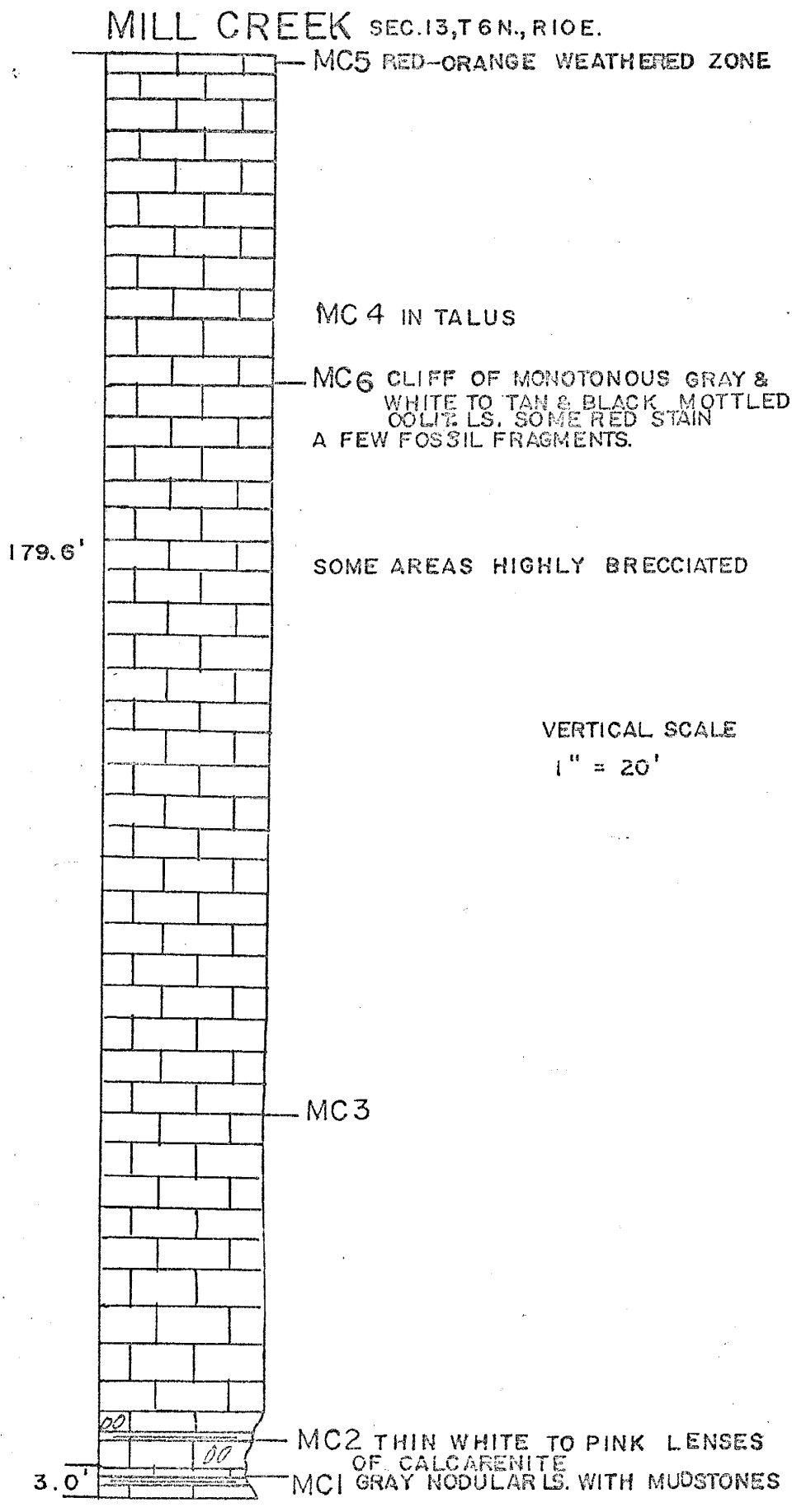

MILL CREEK SEC. 13, T 6 N., R 10 E.
MC5 RED-ORANGE WEATHERED ZONE
MC 4 IN TALUS
MC6 CLIFF OF MONOTONOUS GRAY & WHITE TO TAN & BLACK MOTTLED OOLIT. LS. SOME RED STAIN
A FEW FOSSIL FRAGMENTS.
179.6'
SOME AREAS HIGHLY BRECCIATED
VERTICAL SCALE
1" = 20'
MC3
MC2 THIN WHITE TO PINK LENSES OF CALCARENITE
3.0'
MC1 GRAY NODULAR LS. WITH MUDSTONES

FIGURE 7

BEAVER CREEK SECTION B 1970

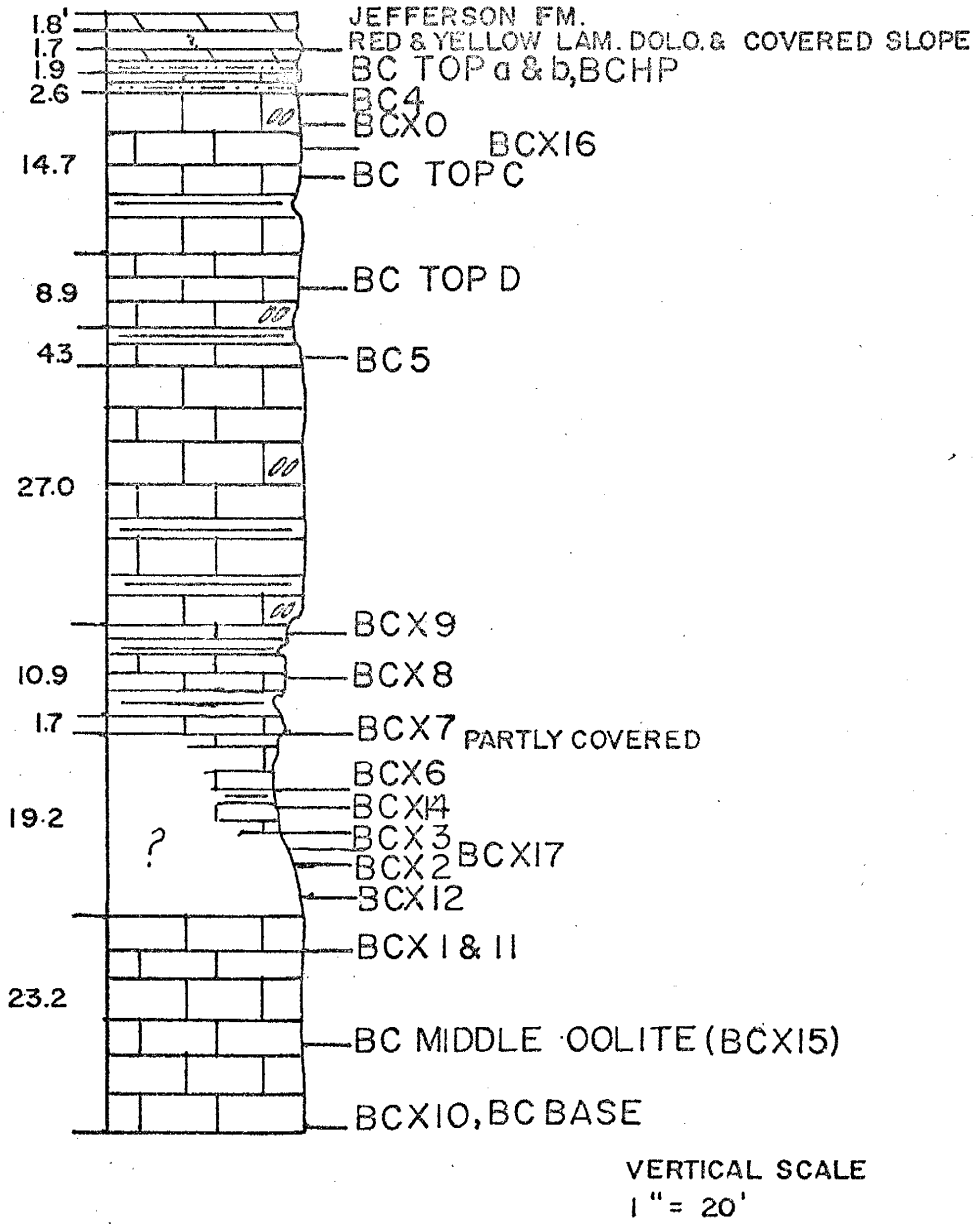


FIGURE 8

BEAVER CREEK SECTION A 1937-9

SEC. 15, T 12 N., R 2 W.

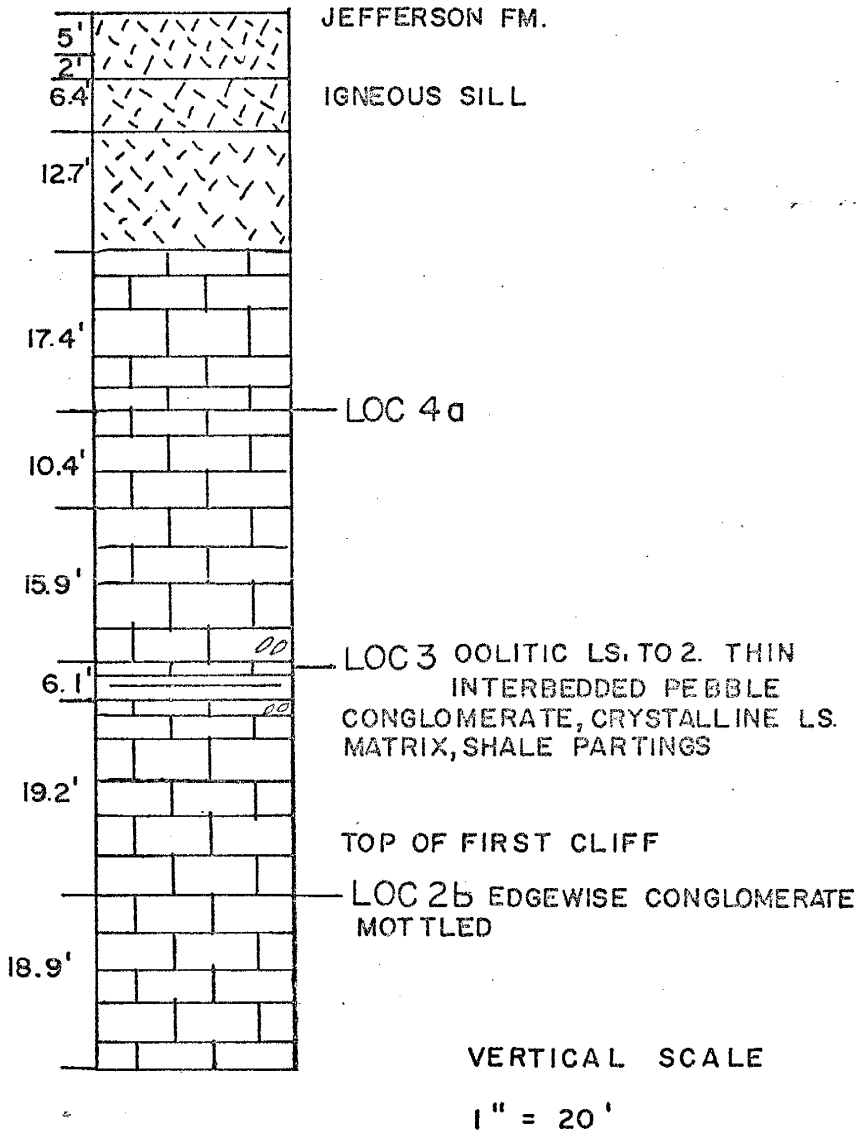


FIGURE 9

DISCUSSION OF FAUNAS

Preservation

Most of the fauna is preserved as internal or external molds and casts. A few chitino-phosphatic inarticulate brachiopods have the original shell material preserved, but the remainder of the fauna is preserved by calcite, except for a small number which have been replaced subsequently by silica. Trilobite material consists of cranidia, pygidia, and librigenae of disarticulated molts.

Fossils from the Aphelaspis Zone are found in a coquina with trilobite material fairly well preserved and showing little sign of wear or breakage. The articulate brachiopods from the zone are poorly preserved and show wear as well as breakage.

In the Crepicephalus Zone fragments are common throughout the section, but well preserved trilobite material and brachiopods are found only in layers and lenses. Posterior areas and occipital spines of cranidia and postero-lateral spines of pygidia of Tricrepicephalus are often broken which suggests moderate to high energy transport.

Fossils of the Cedaria assemblage are scattered vertically and laterally throughout beds of the Cedaria Zone. The material is generally much better preserved and less broken than Crepicephalus Zone material. Fragments of cranidia, librigenae, and pygidia are not concentrated in coquina lenses and layers which are common in the Crepicephalus Zone.

Composition of the Faunas

Aphelaspis Zone

A large Aphelaspis Zone fauna has been found at Wolf Creek and North Grove Creek. The fauna is characterized by a large number of individuals and a small number of genera and species of trilobites and articulate and inarticulate brachiopods.

Two species of Aphelaspis were recognized in the horizons studied, Aphelaspis walcotti Resser and Aphelaspis subdita Palmer. Over 400 cranidia of Aphelaspis were present in the collection and 126 were well enough preserved to allow close study of individual variation.

Previous workers have based separation and designation of species of Aphelaspis upon various characteristics. These include 1) position or horizontality of palpebral lobes, 2) the ratio of border length (sag.) to preglabellar field length, 3) size and shape of the glabella, 4) divergence of the anterior extension of the facial suture, 5) depth of axial glabellar furrow and border furrow, 6) width of palpebral area compared to glabellar width, and 7) slope or convexity of the preglabellar field. The great abundance of Aphelaspis specimens allowed a statistical study to test the validity of species defined on the basis of different combinations of characteristics which have been used. Seventeen ratios were plotted from 24 measured characteristics. Separation considered adequate to define Aphelaspis walcotti Resser and Aphelaspis

subdita Palmer is best demonstrated by length (sag.) ratios of frontal area length vs. total cranidial length, border length vs. frontal area length, border length vs. total cranidial length, and border length vs. glabellar length. The study was based on 126 measured cranidia, 119 of which were determined to be A. walcotti, and 7 to be A. subdita. The graphs obtained in this study may be found in Appendix A.

Frontal area length compared to total cranidial length shows a very regular, step-like growth pattern. Seven molts are observed at 1.25, 2.5, 3.5, 5.5, 7.0, 8.0, and 12.0 mm. of frontal area length. Clusters of points also occur at 4.5 and 9.5 mm. where molts probably occurred without growth of frontal area length. A. walcotti and A. subdita separate with values of frontal area to total length for A. subdita falling slightly below those values for A. walcotti.

Separation of the two species is less pronounced in the comparison of cranidial length to glabellar length. The step-like growth pattern is not as evident as in the previous graph due to individual and preservational variation. Values of glabellar length to cranidial length are higher for A. subdita than for A. walcotti.

The graph of glabellar length (sag.) compared to median glabellar width (trans.) does not show good separation of the species, as is true for all graphs involving width or transverse measurements. Cranidia of A. subdita fall well within the area occupied by A. walcotti. Again, variation is superimposed on the step-like growth pattern.

One of the most obvious and best separations of species is obtained on the graph of border length vs. frontal area length. The step-like growth pattern indicates at least eight molt stages present which occur at 0.75, 1.0, 1.5, 2.0, 2.5, 3.5, 4.0, 4.5 mm. of frontal area length. This is indicated by clustering of points corresponding to instars. The length of the border is one of the most diagnostic characteristics in separating the two species. Variation is slight and the ratio of border length to frontal area length is invariably less for A. subdita than for A. walcotti. If a median line were drawn, as the one in black for A. walcotti, the slope would be 1/6 compared to 1/10 for the red line of A. subdita.

When the length of the border is compared to the length of the cranidium a two way step-like character of the graph appears. This may be preservational or individual variation. The slowing of the growth of the border with age in larger cranidia is also noted. Separation is again very good and increasing separation of species with age is noted.

Good separation is obtained with a comparison of border length vs. glabellar length. Individual variation is also pronounced.

Border length compared to preglabellar field length, border width vs. cranidial length, palpebral area width vs. glabellar width, palpebral area length vs. width, and palpebral lobe length vs. width show little or no separation and much individual variation.

Slight separation is shown by graphs of palpebral area width vs. cranidial length and palpebral area length vs. cranidial length.

Graphs of occipital ring length vs. posterior limb length and posterior limb width vs. occipital ring width contain insufficient data to be considered significant.

Since the position of the palpebral lobes has been used by previous workers to determine species of Aphelaspis and two positions were noted in the specimens studied, I plotted these positions on a graph of frontal area length compared to cranidial length. The two positions are 1) the more common position with the palpebral lobes situated opposite the transverse median line of the glabella and 2) the less common position with the center of the palpebral lobe occurring anterior to the transverse median line of the glabella by about 0.25 of the glabellar length. In A. walcotti no obvious relationships are observed except that the anterior palpebral lobes seem to occur when a large sample is available, as at molt stages. Two specimens of A. subdita appear to have the anterior palpebral lobes and both are small. Whether this is significant is difficult to determine with such a small sample.

Another feature which has been used to separate species is the divergence of the anterior extension of the facial suture. By using specimens of Aphelaspis, I have developed a terminology for the angle of divergence in trilobites. Hyperoblique is used to refer to specimens which have the

measured angle in excess of 40°. Meso-oblique is applied to the more common forms which have an angle between 25°and 40°. The anterior facial suture approaches a straight line in para-oblique forms which have an angle of less than 25°. Hypo-oblique refers to forms such as Glaphyraspis which have convergent anterior facial sutures.

Bar graphs showing the total length of A. walcotti were prepared. The total length ranges from 1.25 to 12.0 mm. When specimens are grouped in one mm. size ranges, a bimodal graph which is skewed to the larger sizes results. Peaks occur at 7.0 to 7.9 mm. and at 4.0 to 4.9 mm. Using molt stages obtained from a graph of border length to cranidial length, another bar graph was prepared of the number of specimens which are found in each of the eight molts. A bimodal graph is obtained with the greatest number of specimens, 30, occurring at 5.1 to 7.0 mm., and a second peak at 3.6 to 4.5 mm. with 22 specimens. Other stages were represented by 5 to 14 specimens. The bimodal nature of the graph is believed to result from processes of transportation superimposed on the natural abundance of specimens of a particular size. Other influencing factors may have been duel transport or bias in preparation.

The statistical study of the pygidia was less conclusive than that of the cranidia. Only one species is obvious in the five graphs prepared. A step-like nature is apparent in all of the graphs, though some individual or preservational variation occurs in graphs with ratios involving pygidial

width. This results in a double or triple step-like growth pattern. The less complicated appearance of the graphs of the pygidia is probably the result of the smaller sample as only 32 pygidia were complete enough to allow measurement.

Bar graphs were also prepared for the pygidia of A. walcotti. The maximum pygidia width ranges from 3.0 to 10.0 mm. There is fairly uniform representation at half mm. stages except for breaks at 5.5 and 6.5 to 7.0 mm. The maximum number, five specimens, occurs at 8.0 mm. The graph of specimens grouped by molt stages is also bimodal.

The fauna also contains 28 cranidia of Glaphyraspis, as well as lesser numbers of librigenae and pygidia. These specimens have been assigned to G. parva because of narrow border, subquadrate cranidium, and broad palpebral area. Much variation in depth of lateral glabellar furrows occurs. The furrows are usually faint, even on the inner surface of the test,and though most previously described specimens have had deep furrows, variation in depth of lateral glabellar furrows has been reported previously and is attributed to preservation.

A moderate number of cranidia and pygidia of Blountia mimula are found in the fauna. Cranidia are most abundant at the Grove Creek locality, but pygidia are abundant at Wolf Creek. This distribution may reflect selective transport since the smooth, semi-circular pygidia could be transported farther with less water resistance.

Cheilocephalus is moderately well represented by two species, C. brevilobus (Walcott) and C. omegus (Lochman and

Hu). The species are differentiated on the concavity of the frontal area. It is interesting to note that the two species were also found together by Lochman and Hu (1962b) which may suggest the possibility of sexual dimorphism.

Both articulate and inarticulate brachiopods are represented in the fauna. Inarticulate species include Angulotreta triangularis Palmer found fairly commonly at North Grove Creek and Dysoristus lochmanae Bell represented by a single well preserved specimen from Wolf Creek. Articulate brachiopods are found only at Wolf Creek and are represented by a few fragmentary undetermined species of Billingsella and Eoorthis.

Crepicephalus Zone

The Crepicephalus Zone fauna is characterized by a much larger number of genera and species than that of the Aphelaspis Zone. Although a few of the species, such as Tricrepicephalus tripunctatus and T. beltensis and Coosina ariston are represented by large numbers of individuals, none of the species are as abundant as was Aphelaspis walcotti in the Aphelaspis Zone. A few inarticulate brachiopods are found, but no articulate brachiopods have been recognized. Hyolithes and Chancelloria as well as echinoderm plates are also found in the zone.

The Agnostida are represented by two genera, Acmarhachis and Pseudagnostus. Acmarhachis arcuatus (Kobayashi) and Pseudagnostus mesleri (Resser) are moderately represented

in the Grove Creek section. Both species seem to have unusually shallow furrows when compared to previously described specimens from British Columbia, Tennessee, Nevada, and Missouri.

The Crepicephalidae are well represented in the fauna. Several species of Crepicephalus are recognized, but are represented by only a few specimens. Crepicephalus snowyensis Lochman is represented by one well preserved pygidium and two fragments and one broken librigena, all from Grove Creek. A single pygidium from J. Tuzo Wilson's collection at Mill Creek is tentatively assigned to C. australis Palmer, and a new species Crepicephalus angulatus, fairly well represented at Grove Creek and Beartooth Butte, is described. The species resembles C. buttsi montanensis in the broad pygidial border, but differs in the curvature of the margin which is similar to that of C. explicata. Five pygidia of Uncaspis discrepans Duncan occur from Wolf Creek and Grove Creek, but no associated cranidia or librigenae were found. One of the best represented genera is Tricrepicephalus of which two species were identified. The number of individuals present was sufficient to permit statistical study of the species. Although separation of the species was not as clear as that for Aphelaspis, some differences were noted.

Fifty-six cranidia were assigned to T. tripunctatus on the basis of the triangular border and occipital spine and 39 were assigned to T. beltensis which has an evenly rounded

border and smooth occipital ring. Only 23 of the cranidia of T. tripunctatus and nine of the cranidia of T. beltensis were complete enough for measurement. Graphs similar to those for Aphelaspis are found in Appendix B.

Linear trends which show only preservational or individual difference were found in graphs of glabellar length vs. cranidial length, glabellar length vs. width, frontal area length vs. cranidial length, border width vs. cranidial length, palpebral area length vs. cranidial length, and glabellar width vs. palpebral area width. Slight separation of species with much preservational or individual variation was noted on other graphs. The study was made more difficult by the apparent lack of smaller sized specimens of T. beltensis. The smallest specimens available for T. beltensis seem to lie close to the measurements for T. tripunctatus specimens of the same size. Border length vs. frontal area length, border length vs. cranidial length, border length vs. glabellar length, and cranidial width vs. border width show specimens of T. beltensis having slightly smaller values than T. tripunctatus in the larger size range. Larger values of T. beltensis occur on the graph of border length vs. preglabellar length. These data seem to indicate that as the individual grows larger, T. beltensis begins to differentiate from T. tripunctatus with a longer preglabellar field and a shorter border. Whereas in the smaller size range (14.0 mm. long or less) proportions of the border and preglabellar field are similar.

tripunctatus with a longer preglabellar field and a shorter border. Whereas in the smaller size range (14.0 mm long or less) proportions of the border and preglabellar field are similar.

Fourteen pygidia of T. beltensis and 17 of T. tripunctatus were plotted on graphs involving ratios of pygidial width vs. length, axial length vs. pygidial length, pygidial width vs. axial width, and pygidial length vs. axial length. These graphs show a linear relationship throughout the size ranges with no good separation of species. The only separation based on association seems to be that T. beltensis has a pygidial border which drops vertically to the margin instead of flattening as in T. tripunctatus.

The concentration of cranidia of T. beltensis only in the large size range when compared to the size range of T. tripunctatus may reflect selective transportation of T. beltensis into the Grove Creek horizon where they are found. T. tripunctatus specimens are found primarily at Wolf Creek, though a few were found at Grove Creek.

Meteoraspis loisi Lochman is poorly represented at Grove Creek by only one cranidium and a pygidium. The occurrence of the cranidium is significant in that this is the first cranidium to be associated with the characteristic pygidium.

The Solenopleuracea are represented by two families, the Lonchocephalidae and the Kingstoniidae. A well represented species of Weeksina which is tentatively assigned to

W. winona (Hall) occurs in the Beartooth Butte and Grove Creek horizons. The specimens studied seem to have a slightly broader palpebral area than that figured by Hall. The pygidium resembles that of Hall's specimen in all details and differs from the type species of Weeksina in the more transverse shape and furrows which extend onto the pygidial border. Kingstonia inflata Resser is poorly represented by two pygidia which exhibit the characteristic proportions of K. inflata. Ankoura apicalis Duncan is also represented by two pygidia which are found at Grove Creek.

The Asaphiscacea are poorly represented in the fauna by two genera, Blountia and Maryvillia. Two pygidia are assigned to Blountia montanensis Duncan and two to B. arcuosa Resser from the Wolf Creek and the Mill Creek horizons. A single cranidium and librigena are assigned to Maryvillia arion Walcott, though the frontal area of the cranidium differs in the concave, upsloping border and wider palpebral area from previously described specimens.

Llanoaspis is represented at Grove Creek by two species. Three poorly preserved specimens with characteristic bulbous glabellas are assigned to L. peculiaris (Resser), but differ from that species in having a more arcuate marginal furrow. Two cranidia and two pygidia are placed in L. undulata Lochman. The frontal area is broken on both cranidia but the broadly rounded glabella and narrowly tapered axis of the pygidium are characteristic of the species.

The Coosellidae are a second well represented family

with three genera present in the fauna, Coosella, Coosia, and Coosina. Seven pygidia resemble Coosella helena Lochman, but have two to three axial rings instead of four rings which have been described on C. helena. Coosella longa, n. sp., resembles C. perplexa Palmer, but has a greater number of axial rings and different proportions of the pygidium. It is represented by six pygidia. Coosia alethes (Walcott) is moderately well represented by four cranidia, a hypostome, a fragmentary librigena, and five pygidia at Grove Creek. The most abundant member of the family is Coosina ariston (Walcott). A statistical study with graphs similar to those for Aphelaspis is included in Appendix C.

Forty-three measured Coosina cranidia revealed the presence of only one species, though differences in preservation including weathering and the differences between external casts and internal molds made some specimens appear to be slightly broader with a shorter border. The graphs show the step-like growth pattern which was also common in the Aphelaspis study. Six to seven molts are revealed at 6.5, 9.0, 10.0, 11.0, 14.0, 18.0, and 19.0 mm. of cranidial length. Much individual variation is observed in double or triple step-like patterns. Graphs which show this nature are glabellar length vs. cranidial length, glabellar width vs. length (width measurements are more step-like than the width measurements for Aphelaspis), frontal area length vs. cranidial length, border length vs. glabellar length, and border length vs. frontal area length.

Much diversification is shown in the graph of palpebral area width vs. length. Cranidia range from 4.0 to 20.0 mm. Librigena are scarce in the collections as only three were identified.

Pygidia range from 2.0 to 22.0 mm. in width. Thirty-five pygidia were studied and also indicate the presence of only one species though preliminary observation seemed to suggest the presence of three or more species. A more transverse shape and lesser convexity of the pygidium seems to have resulted from preservation since all graphs reveal close relationship of specimens with those characteristics of the other pygidia. There is no separation on the step-like graphs of axial length vs. pygidial length, and axial length vs. pygidial width. Pygidial length vs. width shows much individual or preservational variation which was inconsistent with the preliminary separations.

A new species, Minicephalus transversus, occurs at Grove Creek. It is represented by 2 librigenae and 3 pygidia. The pygidium differs from the only other described species in the genus, M. primus Lochman and Hu, by the more transverse outline with a slight median indentation of the posterior border. The pygidium is similar to that of Coosina ariston, but is much more transverse, and the pygidium of C. ariston does not have the median indentation of the border.

Chancelloria drusilla Walcott is found only in lenses at Grove Creek and Wolf Creek, and 18 specimens from the

two horizons were studied. The number of rays, three to seven, and the horizontal or oblique shape is also like that described by Lochman (1940) for C. aurora in the Cedaria Zone. The only apparent distinction between the two species is that C. aurora is smaller than C. drusilla and it is possible that the former may be synonymous with C. drusilla.

Brachiopods are very poorly represented. Only 5 broken valves were found at Grove Creek and were identified as Obolus sp. undet. and Lingulepis cf. L. acuminata.

Numerous hyolithids assigned to Hyolithes gallatinensis Resser were found at Grove Creek, Mill Creek, and Wolf Creek. They occur throughout the section, though they are well preserved only at certain horizons. They vary in length from 6.0 to 30.0 mm.

A few broken plates of Eocrinoidea have been tentatively assigned to two genera, Foerstecystis and Palaeocystites, and are found at Beartooth Butte and Grove Creek.

Cedaria Zone

The Cedaria Zone, like the Crepicephalus Zone, is represented by a large number of genera and species of trilobites. Numerous inarticulate brachiopods and a few echinoderm plates are also present, but no hyolithids or articulate brachiopods were found.

The Agnostida are abundant in the zone at Beaver Creek. Baltagnostus beltensis Lochman is represented

by six pygidia with axial furrows which are only slightly curved. Seven cephala are assigned to Kormagnostus simplex and have a narrow, parallel sided glabella. Nine well preserved pygidia have the posteriorly expanded axial lobe which is characteristic of the species.

Only one species of the Crepicephalacea was found in the Cedaria Zone, contrasted to the large number of genera and species present in the Crepicephalus Zone. Meteoraspis boulderensis Deland is represented by four cranidia and three pygidia. The cranidium is characterized by a moderately convex glabella and downsloping frontal area, and border which is longer than the preglabellar field. The associated pygidia have two short, stout, posteriorly directed spines which curve slightly inward.

Two genera of Kingstoniidae are present. Kingstonia spicata, which has been identified from Wyoming and Missouri, is represented by two pygidia which have the characteristic posterior spine. Three poorly preserved cranidia and one librigena are assigned to Bynumia lata which has a narrow, triangular, posterior area and a broadly triangular frontal area.

One of the best represented families is the Raymondinidae. Four genera, Paracedaria, Cedaria, Cedarina, and Genevievella, are present in the fauna. Paracedaria montanensis is well represented by 16 cranidia, 13 pygidia, and 5 librigenae which are generally broken. The species has fine, imbricating ridges on the frontal area of the cranidium and the ocular platform

of the librigena, a border which is 0.5 times preglabellar field length, and a wide divergence of the facial suture of the cranidium, and a narrow pygidial axis. A single broken cranidium of Paracedaria tarda is found higher in the Beaver Creek section. The species was also found to be near the top of the Cedaria Zone in the Sheep Mountain section of Lochman and Hu (1962a). Because of its stratigraphic position, the species was interpreted by Lochman and Hu to be a descendant of P. viriosa. Species of Paracedaria have been identified thus far only from Montana and Wyoming so that this form may have been restricted to western areas. P. tarda is distinguished by an extremely narrow preglabellar field and broad border. Cedaria milleri is represented by 15 cranidia, 1 librigena, and 3 pygidia. Assignment to this species is based on the relatively narrow frontal area as compared to other species of Cedaria, with a slightly upsloping to flat border, and a distinctive upsloping palpebral area of the cranidium. The pygidium is semicircular in outline and has a flat border. Cedaria buttsi is less well represented by 5 cranidia and 3 pygidia. The cranidium of the species has a very hyperoblique facial suture with a narrow palpebral area and a broad, flat pygidial border. Six cranidia, a librigena, and 2 pygidia are assigned to Cedarina prima because of the long frontal area of the cranidium and the long axis of the pygidium. Specimens from Beaver Creek show variation in the number of axial rings on the pygidium. They may have 4 axial rings as described for the type from Montana, or may have as many as 6 rings and a

terminal section. Cedarina victoria is represented by 7 cranidia and 2 pygidia and is distinguished by the long glabella and the subequal preglabellar field and border of the narrow cranidium and short pygidial spines. Three poorly preserved cranidia and one broken pygidium are assigned to Cedaria cordillerae because of the short occipital spine on the cranidium. Genevievella spinosa occurs at the base of the Mill Creek section and is represented by three cranidia which have the characteristic occipital spine and short preglabellar area. The facial suture appears to be slightly more divergent than in previously described specimens from Wyoming, Montana, and Texas, but this may be due to preservation.

Syspacheilus camurus is the only species of the Cooseliidae found in the fauna. Forty-one cranidia and three pygidia occur in the upper part of the Beaver Creek section. The cranidia are differentiated on the basis of the narrow palpebral area and the border which is slightly longer than the preglabellar field.

A single abundant species, Modocia centralis, belongs to the Marjumiidae. It is characterized by a rectangular cranidium which has a conical glabella with a rounded anterior, and a straight to slightly curved border. Thirty-six cranidia, three librigenae, and three pygidia were found in the fauna. The species ranges throughout the section at Beaver Creek and is common in South Dakota, Montana, Wyoming, and Texas.

Torridella migranata is the only species assigned

to Torridella and it has been previously recognized only from the Wind River Mountains of Wyoming. Two cranidia and one librigena have the horizontal, convex border and conical, slightly raised glabella characteristic of the species.

The Plethopeltidae are represented by two species of Arapahoia. Nine cranidia, twelve librigena, and eleven pygidia of Arapahoia snowyensis occur at Beaver Creek. Though the majority of the specimens are broken, a few are well preserved. These are assigned to the species because of the subovate pygidium and the short frontal area with subequal preglabellar field and border of the cranidium. Arapahoia convexa is represented by five pygidia which are distinguished on the basis of the more triangular pleural lobes, slightly flared anteriorly.

Small well preserved inarticulate brachiopod valves are also abundant in the Cedaria Zone at Beaver Creek.

Paleoecology

Most of the collections were obtained from crystalline or oolitic limestone and limestone pebble conglomerates. The assemblages are transported since all trilobite material consists of disarticulated molts which often show selective transportation of cranidia, pygidia, or librigenae. The posterior areas of the cranidia and pygidial spines are commonly broken as are articulate brachiopods. Librigenae are often relatively rare, perhaps due to ease of transport. This current transported material settled on a sea floor which generally received very little terrigenous sediment and might be exposed subaerially at times.

Although apparent transport of fossil material hampers any specific interpretation of niches inhabited by the faunas, some generallizations may be made from the organisms present. The low number of genera and species and large number of individuals present in the Aphelaspis Zone indicate a time of stress, such as cooler waters or change in salinity, as compared to the larger numbers of genera and species and smaller number of individuals present during the Crepicephalus and Cedaria Zones. Transport of organic material was probably fairly local since breakage of tests is not great. Trilobites except for planktonic agnostids, were normal inhabitants of the sea floor within the general area and browsed on the lime mud substrates.

Oolitic limestones and rounded limestone flat pebble conglomerates with oolitic matrix are interpreted as indicating intertidal and subtidal environments.

Two possible origins have been proposed for limestone, flat pebble conglomerates (Folk, 1962; Pettijohn, 1957). Both involve erosion following partial compaction of lime mud. Erosion may be submarine, caused by storm waves or underwater slides following mild tectonic upwarp, or it may result from low tides permitting wave attack on exposed, mud-cracked tidal flats. Pettijohn (1957) notes that the former have a matrix of lime mud while the latter often have an oolitic matrix. The occurrence of limestone pebble conglomerates with an oolitic or medium-crystalline matrix on tidal flats has been demonstrated by Friedman (1964) in the Bahamas. Recognition of tidal environments in Lower Paleozoic limestones of the northern Appalachians is discussed by Friedman (1969). He divides the intertidal environment into tidal flat and tidal channel facies. The tidal flats are characterized by flat pebble conglomerate, sporadic "birdseye" structures, abundant fossil fragments, erosional breaks with shale stringers, and mottling. The tidal flats have tidal channels which contain fossil fragments and may be locally oolitic.

Close similarity of the lithology of the Pilgrim Formation, including possible "birdseye" structures in the upper part of the Beaver Creek section, to the lithologies described by Friedman (1969) indicate a similar depositional environment for the Pilgrim Formation.

At the base of the Wolf Creek section is an oolitic limestone which was probably deposited in a channel on a tidal flat. The organic remains are scattered and fragmentary,

suggesting moderate to high energy transport. The channel shifted and the tidal flat was exposed briefly and submerged again, resulting in deposition of limestone pebble conglomerates. Trilobites, sponge spicules, and hyolithids are frequently found in the oolitic or crystalline limestone matrix. Breakage is not as common as in the lower beds, suggesting that the fauna may have been transported only locally. A slight influx of quartz sand and sphene may indicate the approach of a prograding shoreline at the beginning of Aphelaspis Zone time. Numerous well preserved Aphelaspis walcotti Resser cranidia and pygidia are found in the coarse- to medium-crystalline limestone. These specimens have been transported, but only locally so that a bimodal size distribution (see Appendix A) of cranidia and pygidia may also reflect the natural abundance of the species. The lack of protaspid forms indicates at least partial transportation. Articulate brachiopods are broken and were probably transported to the lime mud substrate from a habitat which had a firmer substrate to which the brachiopods could attach.

The base of the Mill Creek section has a crystalline limestone with shale partings which accumulated as argillaceous and lime muds on a tidal flat. The area had a limited population since only a few well preserved cranidia of Genevievella are found with a coquina of trilobite debris. Oolitic limestone deposited in a broad channel on the tidal flat dominates the remainder of the section. Only one fairly well preserved cranidium and one pygidium as well

as a few fragments of trilobites and brachiopods are found in this material. The high energy of currents in the channel probably severely limited habitation and resulted in breakage of transported material.

The base of the Beaver Creek section is an oolitic limestone deposited in a channel on a tidal flat. Only fragmentary trilobite material is found in the oolitic limestone and was probably transported by moderately high energy currents. The channel shifted, the area was exposed briefly, and submergence resulted in deposition of limestone pebble conglomerates. As at Wolf Creek, the crystalline or oolitic matrix commonly contains well preserved cranidia and pygidia of trilobites which were probably local inhabitants living on a lime mud substrate. Inarticulate brachiopods are common and though fairly well preserved, were probably transported from a firmer substrate to which they were attached. The lack of breakage may be attributed to the small size of brachiopods which could be readily transported. The large number of agnostid trilobites in the Beaver Creek section suggests that this area was less restricted than Mill Creek or Wolf Creek so that open sea forms could be washed in and deposited. Tidal flat deposition returned at the top of the section with crystalline limestone and shale partings. The fauna is abundant and fairly well preserved probably representing organic debris which was moved only locally before deposition.

SYSTEMATIC PALEONTOLOGY

APHELASPIS ZONE

Phylum ARTHROPODA

Class TRILOBITA

Superfamily DIKELOCEPHALACEA Miller, 1889

Family PTEROCEPHALIIDAE Kobayashi, 1935

Genus APHELASPIS Resser, 1935

Type species Aphelaspis walcotti Resser

Aphelaspis walcotti Resser

Plate 5, figures 1-11

Not Conocephalites depressus Shumard, 1861, p. 219.

Aphelaspis depressa (Shumard) Bridge, in Bridge and Girty, 1937, p. 255, pl. 69, figs. 23-26.

Aphelaspis walcotti Resser, 1938a, p. 59, pl. 13, fig. 14.

Aphelaspis walcotti Resser, Palmer, 1953, p. 157.

Aphelaspis walcotti Resser, Palmer, 1955 (1954), (includes synonymy to that date), p. 746-47, pl. 84, figs. 2,4-6.

Aphelaspis walcotti Resser, Shaw, 1956, p. 51, pl. 9, figs. 1-6.

Labiostria sp. undet. Lochman and Hu, 1962b, p. 439, pl. 68, figd. 1-6.

Aphelaspis walcotti Resser, Palmer, 1962, p. 33, pl. 4, fig. 24.

Aphelaspis walcotti Resser, Rasetti, 1965, p. 76-77, pl. 18, figs. 16-20.

DESCRIPTION

Cranidium with moderate or less than average relief for genus; glabella conical with low convexity, tapering anteriorly with a subrounded front, well defined by axial furrow, two pairs of faint to moderately defined lateral

glabellar furrows in most specimens; occipital furrow broad, shallow; occipital ring smooth, widest at sagittal median line of glabella; frontal lobe 0.6 to 0.8 times length of glabella including occipital ring; nearly flat to convex (sag.), steepening anteriorly; border furrow broad, fairly well defined; border flat to slightly convex, sloping upward with a length of 0.75 times that of the preglabellar field (sag.); anterior margin gently to moderately rounded; facial suture ranges from hyperoblique to paraoblique with most specimens being meso-oblique; palpebral area 0.8 times as wide (trans.) as glabella; palpebral lobe flat to slightly upsloping, situated opposite or anterior to transverse median line of glabella, well defined; posterior area long, slightly narrower than occipital ring with intramarginal furrow. Librigenae with broad, flat to slightly concave border, faintly to moderately defined by furrow; eyes large; ocular platform moderately convex; genal spine short with broad base, tapering rapidly to a sharp point. Thorax unknown.

Pygidium short and broad, subovate, 2.0 to 2.5 times as wide as long; axis convex, sloping steeply to margin, with 2 to 3 distinct axial rings and a terminal section; pleural lobes flat with 2 to 3 pairs of faint pleural and interpleural furrows; border furrow faint; border flat, narrowing markedly at posterior, reaching a maximum width at anterior margin.

Outer surface of test smooth to finely granular; inner surface finely punctate.

LOCATION AND HORIZON: GC, GC-1, and WC-2.

REMARKS

This species is the most common form in the material examined from Wolf Creek and North Grove Creek, including about 400 specimens. Cranidia are best represented, though numerous pygidia and librigenae are also present.

Aphelaspis subdita Palmer

Plate 5, figures 31-32

Aphelaspis subditus Palmer, 1962, p. 35, pl. 4, figs. 20, 22-25.

Aphelaspis subditus Palmer, 1965, p. 60, pl. 8, figs. 22-26.

Not Aphelaspis subditus Palmer, Hu, 1969, p. 459, pl. 2, figs. 1-40.

DESCRIPTION

Glabella conical, moderately convex; two pairs of lateral glabellar furrows faint to obsolete on outer surface of test, well impressed on inner surface; occipital furrow very shallow; occipital ring smooth or with small median tubercle; frontal area broad, width (trans.) approximately equal to total cranidial length (sag.), length 0.8 times glabellar length; preglabellar field slightly convex; border furrow broad, evenly rounded; border narrow, about 0.3 times preglabellar field length (sag.), sloping upward at 25 degrees to horizontal; facial suture meso-oblique to hyper-oblique; palpebral area 0.73 to 0.8 times as wide as glabella (trans.); palpebral lobes flat to slightly upsloping, situated anterior or opposite transverse median line of glabella; posterior limbs long (trans.) about equal in length (sag.) to occipital ring, with deep intramarginal furrow. Librigena, thorax, and pygidium unknown.

Outer surface of test smooth; inner surface finely punctate.

LOCALITY AND HORIZON: GC-1 and WC-2.

REMARKS

This species is represented by seven cranidia ranging in length from 2.0 to 10.0 mm. Palmer describes the librigena and pygidium as similar to A. walcotti Resser, but with pygidium three times as wide as long. It is possible that librigenæ and pygidia belonging to this species may have been assigned to A. walcotti.

Order PTYCHOPARIIDA

Family LONCHOCEPHALIDAE Hupe, 1953

Genus GLAPHYRASPIS Resser, 1937

Type species Liostracus parvus Walcott

Glaphyraspis parva (Walcott)

Plate 5, figures 12-15

Liostracus parvus Walcott, 1899, p. 463, pl. 65, fig. 6.

Glaphyraspis parva (Walcott) Resser, 1937, p. 12.

Raaschella occidentalis Lochman, in Lochman and Duncan, 1944, p. 43, pl. 4, figs. 1-5.

Glaphyraspis parva (Walcott) Rasetti, 1961, p. 112, pl. 22, figs. 14-17.

Glaphyraspis parva (Walcott) Lochman and Hu, 1962a, p. 438, pl. 68, figs. 7-52.

Glaphyraspis parva (Walcott) Rasetti, 1965, p. 40-41, pl. 10, figs. 9-17.

DESCRIPTION

Cranidium small; glabella convex with square front, two pairs of poorly to well defined lateral glabellar furrows, anterior pair less well defined, straight, posterior pair deeper, arcuate; occipital furrow shallow, narrow; sub-triangular occipital ring broad, smooth; frontal area length less than 0.3 times that of the glabella including occipital ring; preglabellar field slightly convex; border furrow deeply incised; border narrow, about 0.5 times preglabellar field length (sag.); facial suture cutting anterior margin well out from median line of cranidium and running in a slight arc almost directly backward to palpebral lobes, curving around palpebral lobes, and passing outward and backward to cut posterior margin within genal angle;

palpebral area convex, 0.33 width of glabella; palpebral lobes narrow, slightly downsloping toward posterior margin, situated opposite transverse median line of glabella; posterior area short, medium width, with deep intramarginal furrow. Librigena short and broad with small eye; ocular platform slightly convex; border broad and flat; genal spine short, tapering rapidly. Thorax unknown.

Pygidium narrow, subovate, about twice as wide as long (sag.); axis convex, sloping to border with 4 to 6 axial rings and a terminal section; pleural lobes wider than axial with at least four well defined interpleural furrows; distinct border furrow; border narrow and flat.

Inner surface of test granular; outer surface smooth to granular.

LOCATION AND HORIZON: GC-1 and WC-2.

REMARKS

This species is fairly well represented in collections from Wolf Creek and Grove Creek by 28 cranidia, 8 librigenae, and 6 pygidia. Cranidial length ranges from 1.0 to 3.0 mm. and average pygidial width is 1.5 mm. Much variation was observed in depth of lateral glabellar furrows. In contrast to previously described specimens, lateral glabellar furrows are usually very faint even on inner surface of test.

Pygidia are of the female form described by Lochman and Hu (1962a).

Superfamily ASAPHISCACEA Raymond, 1924

Family ASAPHISCIDAE Raymond, 1924

Genus BLOUNTIA Walcott, 1916

Type species Blountia mimula Walcott

Blountia mimula Walcott

Plate 5, figures 19-24

Blountia mimula Walcott, 1916a, p. 399, pl. 61, figs. 4a-c.

Blountia mimula Walcott, Resser, 1938a, p. 63, pl. 12, figs. 18, 19.

Blountia mimula Walcott, Rasetti, 1965, p. 59, pl. 10, figs. 3-7.

DESCRIPTION

Cranidium small; glabella conical, convex both transversely and longitudinally, poorly defined by faint axial furrow; lateral glabellar furrows obsolete; occipital furrow faint; occipital ring smooth; frontal area 0.5 glabellar length (sag.); preglabellar field slightly convex; border furrow slightly curving, broad, faint; border flat to concave, 0.5 length (sag.) of preglabellar field; facial suture para-oblique, curving back and around palpebral lobes, then curving outward rapidly, cutting posterior margin just within genal angle; palpebral area 0.3 times glabellar width (trans.), 0.66 times glabellar length; palpebral lobe faintly defined, situated opposite anterior third of glabella; posterior area short, wide. Associated librigena broad; border broad, flat; eyes large; narrow anterior projection; genal spine broad based, narrow, of medium length. Thorax unknown.

Pygidium semi-circular, about 1.2 times as wide as long; axis slightly convex, tapering to margin, with 5 to 7 very faintly defined axial rings and a terminal section; pleural lobes slightly raised, interpleural furrows very faintly defined on outer surface; border furrow moderately deep; border distinct, wide.

Outer surface of test granular; inner surface finely punctate.

LOCATION AND HORIZON: GC-1 and WC-2.

REMARKS

This species is poorly represented in the collection by 5 cranidia, 1 librigena, and 9 pygidia. Most of the pygidia, seven, come from the Wolf Creek collection while four of the cranidia come from Grove Creek. This is probably the result of selective transport. The largest cranidium is 9.5 mm. long; the largest pygidium is 8.0 mm. wide. The most obvious character of the specimens examined is the poor definition of all furrows and the small palpebral lobes.

Superfamily NORWOODIACEA Walcott, 1916

Family CHEILOCEPHALIDAE Shaw, 1956

Genus CHEILOCEPHALUS Berkey, 1898

Type species Cheilocephalus saint croixensis Berkey

Cheilocephalus brevilobus (Walcott)

Plate 5, figures 25-30

Lisania breviloba Walcott, 1916b, pl. 66, figs. 3, a-c.

Pseudolisania breviloba (Walcott) Kobayashi, 1935, p. 162.

Pseudolisania breviloba (Walcott) Resser, 1938a, p. 96, pl. 16, fig. 17.

Cheilocephalus breviloba (Walcott) Palmer, 1955 (1954), (includes synonymy to that date), p. 759, pl. 88, figs. 1-4.

Cheilocephalus brevilobus (Walcott) Lochman and Hu, 1962a, p. 436, pl. 69, figs. 1-24.

Cheilocephalus brevilobus (Walcott) Palmer, 1965, p. 30-31, pl. 1, figs. 9-11.

Cheilocephalus brevilobus (Walcott) Rasetti, 1965, p. 103-4, pl. 17, figs. 1-5.

DESCRIPTION

Cranidium large; glabella convex, subovate, well defined by deep axial furrow, tapered anteriorly, front of glabella subrectangular to slightly rounded; three pairs of broad, moderately defined lateral glabellar furrows; occipital ring and furrow not preserved; frontal area .5 times length (sag.) of glabella including approximate width of occipital ring; frontal area highly concave; facial suture hyperoblique; palpebral area almost horizontal, 0.57 times width (trans.) of glabella; palpebral lobes faintly defined, slanting slightly upward; posterior area narrow and strap-like. Librigena and thorax unknown.

Pygidium semicircular, width 1.6 times length; axis conical, tapered, with 4 to 6 well defined axial rings and a terminal section; pleural lobes slightly raised with faint, broad interpleural furrows extending onto border; no border furrow; border defined by change in slope, very broad, slightly concave.

Outer surface of test smooth; inner surface finely punctate.

LOCATION AND HORIZON: GC-1 and WC-2.

REMARKS

This species is represented by two cranidia and four pygidia as well as numerous broken fragments. Well preserved pygidia are small, only about 6.0 mm wide, but broken specimens indicate that pygidia reached a length of 13.0 mm. The maximum cranidial length is 11.0 mm. This species is distinguished from C. omegus by the much greater concavity of the frontal area. In C. brevilobus the frontal area turns up at an angle of about 90 degrees from the horizontal.

Cheilocephalus omegus (Lochman and Hu)

Plate 5, figures 16-18

Maryvillia omega Lochman and Hu, 1962, p. 435-6, pl. 70, figs. 1-21.

Cheilocephalus omega (Lochman and Hu) Palmer, 1965, p.30.

DESCRIPTION

Cranidium large and broad; glabella broadly conical with three pairs of faint, broad, lateral glabellar furrows; occipital furrow broad, shallow on outer surface; occipital ring with small median tubercle; frontal area narrow, slightly concave, length 0.78 times length (sag.) of glabella; border furrow obsolete; anterior margin evenly rounded; facial suture cuts anterior margin opposite dorsal furrow; palpebral area broad, slightly less than 0.5 times width (trans.) of glabella; palpebral lobes horizontal to slightly downsloping, situated anterior to transverse median line of glabella; posterior area broad, long, with shallow intramarginal furrow. Librigena and thorax unknown.

Pygidium semicircular, 0.66 times as long as wide; axial lobe conical, convex, with 4 axial rings and terminal section; pleural lobes convex, wide, with faint interpleural furrows; border wide, slightly concave.

Outer surface of test coarsely granular.

LOCATION AND HORIZON: GC-1 and WC-2.

REMARKS

This species is represented by four pygidia and four cranidia as well as numerous fragments. The largest cranidium is 19.0 mm long; the largest pygidium is 20.0 mm.

wide. This species was also found with C. brevilobus by Lochman and Hu (1962) and is distinguished from that species by a flatter frontal area (angle from horizontal less than 45 degrees) and a more convex glabella. The association of these two species may indicate the possibility of sexual dimorphism.

Phylum BRACHIOPODA

Class INARTICULATA

Superfamily ACROTRETACEA Schuchert, 1893

Family ACROTRETIDAE Schuchert, 1893

Genus ANGULOTRETA Palmer, 1955

Type species Angulotreta triangularis Palmer

Angulotreta triangularis Palmer

Plate 5, figures 55-56

Angulotreta triangularis Palmer, 1955 (1954), p. 769-70, pl. 91, figs. 1-6.

DESCRIPTION

Pedicle valve with high cataconical or protoconical profile; foramen just posterior to apex; deltoid pseudointerarea long, narrow; apical process small, triangular; apical pits at or near apex of shell.

Brachial valve subcircular, propareas distinct, smooth.

Outer surface of both valves marked by fine, closely spaced concentric growth lines with slight indication of faint radiating laminae near anterior margin.

LOCATION AND HORIZON: GC-1.

REMARKS

Seven pedicle valves and three brachial valves occur in the collection from Grove Creek. These are very well preserved and have an average length of 1.5 mm.

Superfamily SIPHONOTRETACEA Kutorga, 1848

Family SIPHONOTRETIDAE Kutorga, 1848

Genus DYSORISTUS, Bell, 1944

Type species Dysoristus lochmanae Bell

Dysoristus lochmanae Bell

Plate 5, figure 37

Linnarssonella transversa Lochman (not Walcott), 1940, pp. 21-22, pl. 1, figs. 3-7.

Dysoristus lochmanae Bell, in Lochman and Duncan, 1944, p. 147, pl. 18, figs. 32-37.

Dysoristus lochmanae Bell, Palmer, 1955 (1954), p. 766-67, pl. 89, figs. 10, 12, 13.

DESCRIPTION

Outline transversely subelliptical, greatest width anterior to transverse median line, moderately to strongly convex.

Pedicle valve delthyrium unknown, interior unknown; exterior of valve covered with fine concentric growth lines near anterior, covered with filae near posterior margin.

LOCATION AND HORIZON: WC-2.

REMARKS

One well preserved, nearly complete pedicle valve has been assigned to this species; width is 3.5 mm., length is 2.5 mm.

CLASS ARTICULATA

Superfamily BILLINGSELLACEA Schuchert, 1893

Family BILLINGSELLIDAE Schuchert, 1893

Genus BILLINGSELLA Hall and Clark, 1892

Type species Orthis pepina Hall

Billingsella sp. undet.

Plate 5, figure 38, 39

REMARKS

Pedicle valve nearly flat, semicircular to subquadrate; interarea moderately long; muscle scars faint, occurring in anterior half of valve. Exterior surface coarsely costate.

Five valves occur in material from Wolf Creek (WC-2). These are so poorly preserved as to make specific identification impossible. Average transverse width is 11.0 mm., average length 6.0 mm.

Superfamily ORTHACEA Woodward, 1852

Family EOORTHIDAE Walcott, 1908

Genus EOORTHIS Walcott, 1908

Type species Orthis remnicha Winchell

Eoorthis sp. undet.

Plate 5, figures 33-36

REMARKS

Pedicle valve subcircular, moderate to high convexity; muscle scars deeply impressed on anterior third of valve; hinge line nearly straight.

Brachial valve subcircular; muscle scars on anterior fourth of valve, deeply impressed; long median septum.

Surface poorly preserved, costate to smooth.

Seven pedicle and three brachial valves are found at Wolf Creek (collection WC-2). As in Billingsella sp., also found in the Aphelaspis zone from Wolf Creek, the valves are broken and so poorly preserved as to make specific determination impossible.

CREPICEPHALUS ZONE

Phylum ARTHROPODA

Class TRILOBITA

Order AGNOSTIDA Kobayashi, 1935

Family AGNOSTIDAE M'Coy, 1849

Genus ACMARHACHIS Resser, 1938

Type species Acmarhachis typicalis Resser

Acmarhachis arcutus (Kobayashi)

Plate 5, figures 43-45

Homagnostus acutus Kobayashi, 1938, p. 172, pl. 16, figs. 18-22.

Pseudagnostus? acutus (Kobayashi) Palmer, 1960, p. 62, pl. 4, figs. 10-12.

Acmarhachis arcutus (Kobayashi) Palmer, 1962, p. 20, pl. 2, figs. 14, 15.

DESCRIPTION

Cephalon subcircular, strongly convex (trans.), moderately convex (sag.); glabella bilobed, narrow, tapering forward; anterior lobe smaller than posterior, circular; posterior lobe with low median node; axial furrows meet in a triangular depression in front of glabella, but do not continue forward as a preglabellar median furrow; cheeks subtriangular, convex; border well defined, flat, broad at anterior, evenly rounded.

Pygidium subcircular, convex; wide, convex axial lobe extending to marginal border, well defined, sides nearly parallel, median node; pleural lobes slightly greater than

0.5 axial width; border convex with small postero-lateral spines.

Outer surface of test smooth to slightly granular.

LOCATION AND HORIZON: GC, GC-1.

REMARKS

This species is represented by 2 cephala and 4 pygidia, about 1.5 mm. long. The specimens resemble A. arcutus in narrow preglabellar field on cephalon and in broad pygidial axis which lacks a posterior node.

Family PSEUDAGNOSTIDAE Whitehouse, 1936

Genus PSEUDAGNOSTUS Jaekel, 1909

Type species Agnostus cyclopyge Tullberg

Pseudagnostus mesleri (Resser)

Plate 5, figures 46-48

Oedorhachis mesleri Resser, 1938a, p. 50, pl. 11, figs. 13,14.
Pseudagnostus mesleri (Resser) Lochman, 1940, p. 26-7, pl. 2, figs. 38-43

DESCRIPTION

Cephalon subcircular, strongly convex; glabella long, narrow, posterior lobe more convex, rectangular, ovate anterior lobe; dorsal furrow narrow, well defined, forking; transverse furrow broad, well defined, extending forward into narrow, deep marginal furrow; cheeks about same width as glabella, convex with shallow intramarginal furrow on border, border convex, narrowing anteriorly.

Pygidium subcircular, strongly biconvex, axis defined by slightly convergent furrows, becoming obsolete to posterior, low median node and poorly defined terminal node near border; border well defined by shallow furrow, flat, broadening to posterior often showing short posterior spines.

Surface (outer) smooth to minutely punctate.

LOCATION AND HORIZON: GC and GC-1.

REMARKS

This species is represented by 2 cephala and 7 pygidia about 1.5 mm. long. They resemble P. mesleri in shape of

glabella and proportions of pygidium. The faint furrows on the pygidium may be preservational.

Superfamily CREPICEPHALACEA Kobayashi, 1935

Family CREPICEPHALIDAE Kobayashi, 1935

Genus CREPICEPHALUS Owen, 1852

Type species Dikelocephalus? iowensis Owen

Crepicephalus cf. Crepicephalus snowyensis Lochman

Plate 6, figures 10, 11

Crepicephalus snowyensis Lochman in Lochman and Duncan, 1944, p.60-1, pl. 7, figs. 19-22.

DESCRIPTION

Cranidium unknown. Librigena subrectangular; ocular platform convex, medium width; border broad; genal spine broken.

Pygidium transversely subrectangular; axis convex, conical, tapered to rounded posterior; three axial rings and a terminal section; pleural lobes convex, divided into three broad segments; postero-lateral spines short, flat, slender, extending straight backward.

Outer surface of test unknown; inner surface minutely punctate.

LOCATION AND HORIZON: GC-1.

REMARKS

Two very poorly preserved fragmentary pygidia and one librigena seem to resemble C. snowyensis most closely in the rectangular shape of the pygidium, shape and direction of the postero-lateral spines.

Crepicephalus snowyensis Lochman

Plate 6, figure 12

Crepicephalus snowyensis Lochman in Lochman and Duncan, 1944, p. 60-61, pl. 7, figs. 19-22.

DESCRIPTION

Pygidium small, rectangular; axis sub-conical, slightly tapered, broadly rounded posterior, axis slightly narrower than pleural lobes, three well defined axial rings and a terminal section; pleural lobes with deeply impressed interpleural and pleural furrows; border narrow, extending into two postero-lateral spines at about 45 degrees from flat margin.

Outer surface of test minutely granular; inner surface finely punctate.

LOCATION AND HORIZON: GC-1.

REMARKS

One fairly well pygidium, 11.5 mm. wide, resembles this species in the curvature of the posterior margin and position of postero-lateral spines.

Crepicephalus cf. *Crepicephalus australis* Palmer

Plate 7, figure 15

Crepicephalus australis Palmer 1955 (1954), p. 732, pl. 77, figs. 5-8.

DESCRIPTION

Pygidium transversely rectangular; axis less than pleural width, conical, tapered, axial rings unknown; pleural lobes convex with four broad segments; border furrow well defined, evenly rounded; posterior border broad, extending into long, broad, slightly incurved postero-lateral spines.

HORIZON AND LOCALITY: Mill Creek, J. T. Wilson collection; upper part of mottled, oolitic limestone cliff.

REMARKS

One pygidium 21.5 mm. wide with broken axis is assigned to this species on the basis on pleural lobe and spine configuration. Unfortunately, the type is badly weathered so that definite assignment is not possible. The pygidium also resembles *C. edwardi* Raasch except for the broader, more narrow spine.

Crepicephalus angulatus, new species

Plate 7, figures 10-13

DESCRIPTION

Cranidium small, subquadrate; glabella conical, convex with bluntly rounded anterior, well defined by deep, narrow axial furrow, lateral furrows obsolete; occipital furrow broad, deep; occipital ring smooth, triangular, slightly lower than glabella; frontal area 0.33 glabellar length; preglabellar field convex; border furrow deep, narrow, almost straight; border convex, slightly smaller than preglabellar field; facial suture para-oblique; palpebral area convex, less than 0.5 times glabellar width; palpebral lobes crescentiform, situated slightly below transverse median line of glabella; posterior area moderately long, narrow with narrow, deep, intramarginal furrow. Librigena narrow; moderately wide border with thin anterior projection; ocular platform slightly convex with large eyes at inner angle.

Pygidium subovate to subquadrate, slightly greater than twice as wide as long; axis cylindrical, convex, broad, with slight narrow, posterior ridge extending onto border, three well defined axial rings and a terminal section; pleural lobes triangular, about 1.5 times as wide as axial lobe with three pairs of well defined interpleural furrows and faint, broad pleural furrows; border broad, slightly convex with margin slightly curved between long, thin, gently curving spines at a 35 degree angle to posterior margin.

Outer surface of test smooth; inner surface punctate Parallel ridges on frontal border of cranidium and border of librigena may occur on inner surface. Outer surface of librigena tuberculate.

LOCATION AND HORIZON: GC, GC-1, and BB.

REMARKS

This species is fairly common with 5 cranidia, 2 librigena, and 4 pygidia. The largest complete cranidium is 4.0 mm. long; largest pygidium is 22.0 mm. wide. The species resembles C. buttsi montanensis in the broad pygidial border, but differs in curvature of the margin which is similar to that of C. explicata. However, the latter has a much narrower pygidial posterior border.

Genus UNCASPIS Kobayashi, 1935

Type species Crepicephalus unca Walcott

Uncaspis discrepans Duncan

Plate 7, figures 7-9

Uncaspis discrepans Duncan in Lochman and Duncan, 1944, p. 71, pl. 6, fig. 17.

DESCRIPTION

Pygidium subquadrate, about 1.5 times as wide as long, axis cylindrical, convex, sides nearly parallel with rounded posterior, two to three axial rings and terminal section well defined by deep axial furrows; pleural lobe approximately same width as axial, marked by three faint, narrow pleural furrows and three broad interpleural furrows; border narrow and nearly vertical at sides, broadening posteriorly into two posteriorly directed spines which are short and extend from a point posterior to the edge of pleural fields.

Inner surface marked by irregular fine granules arranged randomly.

LOCATION AND HORIZON: GC-1 and WC-10.

REMARKS

This species is represented by 5 pygidia which resemble U. discrepans in proportions and position of spines. Width of largest pygidium 16.5 mm.

Family TRICREPICEPHALIDAE Palmer, 1955

Genus TRICREPICEPHALUS Kobayashi, 1935

Type species Arionellus (Bathyurus) texanus Shumard

Tricrepicephalus tripunctatus (Whitfield)

Plate 6, figures 14-23

Arionellus tripunctatus Whitfield, 1876, p.141, pl. 1, figs. 3-5.

Not Crepicephalus texanus (Shumard) Walcott, 1899, p.460,

Crepicephalus tripunctatus (Whitfield), Walcott, 1916a, p. 215-6, pl. 33, figs. 1, a-b.

DESCRIPTION

Cranidium large, rectangular; glabella narrowly conical, convex, anterior narrowly rounded, well defined by narrow, deep axial furrow, three pairs of faint lateral glabellar furrows present on inner surface; occipital furrow broad, deep, nearly straight; occipital ring broad, triangular with long, slender occipital spine extending straight posteriorly; frontal area long (sag.), more than 0.5 times length of glabella without occipital ring; preglabellar field slightly shorter than border, downsloping, convex; border furrow broad, deep with three long slit-like pits, the central pit being more oval than the other two; border long (sag.), triangular, convexo-concave; facial suture para-oblique; palpebral area convex, 0.33 to 0.5 times as wide as glabella; palpebral lobe medium sized, crescentiform, situated posterior to transverse median line of glabella; posterior area long (trans.), narrow, strap-like with broad, deep intramarginal furrow. Librigena long, narrow; border broad with

long, thin anterior projection; ocular platform very convex; genal spine long, narrow with broad base, irregularly curved to a greater or lesser degree. Thorax unknown.

Pygidium subquadrate, length slightly less than width; axis conical, convex, three axial rings and a terminal section; pleural lobe about equal to axial lobe width with well defined pleural and interpleural furrows; border fairly narrow, dropping vertically at sides and posterior, extending into two postero-lateral spines at wide angle to horizontal and slightly upsloping, broken.

Outer surface coarsely granular, large granules concentrated on glabella, palpebral area, with a few occurring in rows across border and preglabellar field on cranidium; on ocular platform of librigena; and on pleural lobes of pygidium; inner surface of test punctate.

LOCATION AND HORIZON: BB, GC-1, WC-8, WC-10, and WC-11.

REMARKS

This species is very abundant in the upper part of the oolitic limestone at Wolf Creek. It is represented by 56 cranidia, some of which are quite well preserved, 17 pygidia, and 3 librigenae. The cranidia range in length from 7.0 to 27.9 mm. and the pygidia range from 2.5 to 17.5 mm. wide. The species is rarely associated in the same horizon with T. beltensis which is more common at Grove Creek. It appears to be closely related to T. nasutus which occurs with the former species in sections to the north and may be a geographical variant. The species is separated from T.

nasutus by the occipital spine present in the former. The greater triangularity of the border also serves to separate the cranidia of T. tripunctatus from T. beltensis; however, the pygidia are quite similar. There may be a slight difference in the direction of the spine. T. beltensis has a spine which curves inward while T. tripunctatus appears to extend straight outward, though most of the spines are broken. The only other difference which can be used to distinguish the pygidia is the vertical dropping of the border to the margin in T. tripunctatus.

Tricrepicephalus beltensis Resser

Plate 6, figures 1-9

Crepicephalus texanus (Shumard) Walcott, 1916a (part), p. 209, pl. 29, fig. 7.

Tricrepicephalus beltensis Resser, 1937, p. 27.

Tricrepicephalus beltensis Resser, Lochman and Duncan, 1944, p. 61-62, pl. 5, figs. 10-27.

DESCRIPTION

Cranidium large, rectangular; glabella narrow, conical, slightly convex, well defined by deep, narrow axial furrow, anterior narrowly rounded, lateral glabellar furrows obsolete; occipital furrow medium width, shallow; occipital ring convex, medium width, without spine; frontal area about 0.33 times length of glabella including occipital ring; preglabellar field downsloping, convex, slightly narrower than border (sag.); border furrow shallow, broad, evenly curved with three slit-like pits evenly spaced; border broad, convex; facial suture para-oblique; palpebral area convex, broad, about 0.5 glabellar width (trans.); palpebral lobe medium size, crescentiform, situated posterior to transverse median line of glabella; posterior area medium length, narrow with broad, deep intramarginal furrow. Librigena broad, rectangular; ocular platform slightly convex with large eye at inner angle; border broad, convex with thin anterior projection; genal spine long, broad, nearly straight.

Pygidium rectangular, length slightly less than width; axis conical, convex, three axial rings and a terminal section; pleural lobe same width as axial lobe with

well defined pleural and interpleural furrows; border narrow, flattening slightly at sides before dropping vertically, extending into two postero-lateral spines at wide angle to horizontal, upsloping and curving in toward sagittal median line of pygidium.

Outer surface coarsely granular with large granules on glabella, palpebral area, border, and preglabellar field; inner surface of test punctate.

LOCATION AND HORIZON: GC, GC-1, GC-2, WC-2.

REMARKS

This species is very abundant in the Grove Creek collections. It is represented by about 25 well preserved cranidia, 3 librigenae, and 14 pygidia. The cranidia range in length from 14.0 to 22.4 mm. and the pygidia range from 2.0 to 18.0 mm. in width. This species occurs only rarely with T. tripunctatus. It differs from that species in the rounded border of the cranidium and the slightly flattened border of the pygidium. The relative absence of smaller forms when compared to T. tripunctatus may indicate a transported assemblage.

Tricrepicephalus cf. *Tricrepicephalus beltensis* Resser

Plate 6, figure 13

DESCRIPTION

Cranidium large, rectangular; glabella narrowly conical, convex, anterior rounded, well defined by narrow, deep axial furrow, three pairs of broad, shallow lateral glabellar furrows; occipital ring broad, smooth; occipital furrow deep, broad; frontal area slightly less than 0.5 glabellar length including occipital ring; preglabellar field convex; border furrow broad, shallow, evenly rounded with three large circular pits, equally spaced; border evenly rounded, slightly convex, just longer (sag.) than preglabellar field; facial suture para-oblique; palpebral area medium width, about 0.33 times glabellar width, convex; palpebral lobes upsloping, crescentiform, situated opposite transverse median line of glabella; posterior area narrow.

Outer surface of test unknown; inner surface finely punctate.

LOCATION AND HORIZON: GC-1.

REMARKS

One cranidium, 15.0 mm. long, which has a border like *T. beltensis*, but appears to be narrower transversely and has round pits in border furrow. However, these differences may be the result of preservation.

Genus METEORASPIS Kobayashi, 1935

Type species Ptychoparia? metra Walcott

Meteoraspis loisi Lochman

Plate 6, figures 40-42

Meteoraspis loisi Lochman in Lochman and Duncan, 1944, p. 64-5, pl. 5, figs. 24-6.

Meteoraspis loisi Lochman, Palmer, 1955 (1954), p. 753, pl. 82, fig. 1.

DESCRIPTION

Cranidium medium sized; glabella large, highly biconvex, subconical, well defined by deep, narrow axial furrow, glabellar surface irregular, but lacking lateral glabellar furrows; occipital furrow broad, deep; occipital ring broad, smooth; frontal area short, concave, about equal to length (sag.) of occipital ring; preglabellar field short, about equal to border length, downsloping; border furrow broad, deep; border short, upsloping; facial suture meso-oblique; palpebral area very narrow, convex; palpebral lobe biconvex, crescentiform, situated opposite transverse median line of glabella. Librigena unknown.

Pygidium square with two heavy posterior spines directed straight backward; axis subconical, slightly convex, evenly tapered, posterior evenly rounded, two axial rings and a terminal section well defined by broad, deep axial furrows; pleural lobes narrower than axial lobe, convex, downsloping abruptly to margin, smooth; posterior border narrow, slightly raised and narrowed near axis.

Outer surface of test unknown; inner surface minutely punctate.

LOCATION AND HORIZON: GC.

REMARKS

The pygidium assigned to this species is 12.0 mm. wide and resembles M. loisi in position and direction of the spines, as well as general shape and proportions. The associated cranidium is 12.0 mm. long, and though pits are not preserved, seems to have the characteristics of the genus.

Superfamily SOLENOPLEURACEA Angelin, 1854

Family LONCHOCEPHALIDAE Hupe, 1953

Genus WEEKSINA Resser, 1935

Type species Asaphiscus? unispinus Walcott

Weeksina cf. Weeksina winona (Hall)

Plate 7, figures 16-21

Conocephalites winona Hall, 1863, p. 161, pl. 7, figs. 26-28.

DESCRIPTION

Cranidium small, subquadrate; glabella conical, convex, anterior evenly rounded, well defined by narrow, deep axial furrow, three pairs of broad, shallow, downsloping, lateral glabellar furrows poorly defined on inner surface; occipital furrow narrow, shallow across glabella, deep at sides; occipital furrow fairly wide, smooth, widening slightly to sagittal median line of glabella; facial suture hyper-oblique, cutting anterior margin on a line with dorsal furrow, curving outward and straight backward around palpebral lobes, then running straight outward, cutting the marginal furrow of librigena and curving straight down and backward to cut posterior margin within genal angle; palpebral area biconvex, 0.33 glabellar width (trans.); faint, narrow ocular ridge cuts above palpebral area at low angle; palpebral lobe medium sized, crescentiform, upsloping, opposite transverse median line of glabella; posterior area long, narrow, strap-like with narrow, deep intramarginal furrow. Librigena rectangular; border broad with short,

pointed anterior projection; ocular platform slightly convex with large eye at inner angle; genal spine long, flat, broad. Thorax unknown.

Pygidium short, transverse, about twice as wide as long; axis conical, biconvex, four axial rings and a terminal section well defined; axial lobe 0.8 pygidial length, slightly narrower than pleural lobe; well defined, deep interpleural furrows extend onto border and divide pleural area into four segments with faint pleural furrows, pleural lobe slightly convex; border flat, defined by change in slope, narrowing markedly at posterior.

Outer surface of test smooth to minutely granular; inner surface punctate.

LOCATION AND HORIZON: GC, GC-1, BB, and BB-1.

REMARKS

This species is present only at Beartooth Butte and at Grove Creek and is represented by 9 cranidia, 5 librigenae, and 4 pygidia. The largest cranidium is 8.0 mm. long, the largest pygidium is 8.0 mm. wide. The specimen figured by Hall appears to differ from the species examined only in slightly narrower (trans.) palpebral area.

Superfamily ASAPHISCACEA Raymond, 1924

Family ASAPHISCIDAE Raymond, 1924

Genus BLOUNTIA Walcott, 1916

Type species Blountia mimula Walcott

Blountia montanensis Duncan

Plate 5, figure 40

Blountia montanensis Duncan in Lochman and Duncan, 1944, p. 53, pl. 8, figs. 29-34.

Blountia montanensis Duncan, Rasetti, 1965, p. 57, pl. 9, figs. 13-20.

DESCRIPTION

Cranidium and librigena unknown.

Pygidium semicircular, small, nearly flat; axial lobe sharply tapered to border furrow, axial rings indistinct on outer surface, width of axial lobe equal to that of the pleural lobe, slightly convex; pleural lobes slightly convex, unmarked by furrows on outer surface; border furrow shallow, broad on outer surface; very slightly convex border, medium width.

Outer surface of test smooth to minutely granular.

LOCATION AND HORIZON: WC-5 and MC-3.

REMARKS

Two pygidia, one of which is well preserved and is 7.0 mm wide, have same proportions and border width as B. montanensis. The pygidia also resemble B. janei except for border width.

Blountia cf. Blountia arcuosa Resser

Plate 5, figure 42

Blountia arcuosa Resser, 1938a, p. 64, pl. 12, fig. 25.
Blountia arcuosa Resser, Rasetti, 1965, p. 55-56, pl. 9, figs. 1-8.

DESCRIPTION

Pygidium small, transversely subovate, nearly flat; axial lobe slightly convex, tapering posteriorly to rounded terminal just beyond border furrow, seven axial rings and a terminal section are poorly defined on the inner surface, axial lobe same width as pleural lobe; pleural lobe slightly convex, crossed by faint pleural and interpleural furrows, extending onto border; border flat, broad at anterior, vertical at posterior. Cranidium and librigena unknown.

Inner surface of test minutely punctate.

LOCATION AND HORIZON: WC-14.

REMARKS

Two pygidia, the best preserved of which is 6.0 mm. wide, resemble B. arcuosa in direction of furrows and in transverse shape. However, B. arcuosa appears to be slightly less transverse.

Genus MARYVILLIA Walcott, 1916

Type species Maryvillia arion Walcott

Maryvillia arion Walcott

Plate 5, figure 41, Plate 7, figure 39

Maryvillia arion Walcott, 1916b, p. 400-1, pl. 64, figs. 4, a-c.

Blountina triangularis Lochman, in Lochman and Duncan, 1944, p. 57, pl. 8, figs. 12-18.

Maryvillia arion Walcott, Rasetti, 1956, p. 1267.

DESCRIPTION

Cranidium small; glabella nearly flat, broad, conical, with bluntly rounded anterior, well defined by narrow, shallow dorsal furrow on inner surface, lateral glabellar furrows obsolete; occipital furrow broad, shallow; occipital ring flat, medium width; frontal area medium length (sag.), concave; preglabellar field narrow, less than border length, convex; border furrow broad; border broad, up-sloping; facial suture hypo-oblique; palpebral area slightly biconvex, broad, 0.5 glabellar width(trans.); palpebral lobe small, situated approximately opposite transverse median line of glabella, posterior area narrow, medium length with broad, shallow intramarginal furrow. Librigena small, narrow; slightly convex ocular platform with medium sized eye at inner angle; border broad with long, narrow anterior projection, genal angle rounded without genal spine.

Outer surface of test unknown; inner surface finely punctate.

HORIZON AND LOCALITY: WC-11 and GC-1.

REMARKS

One cranidium, 6.25 mm. long, and one librigena seem to resemble this species. The cranidium differs from M. arion in medium width of frontal area, concave and upsloping border as well as wider palpebral area. However, these differences may be preservational.

Superfamily RAYMONDINACEA Clark, 1924

Family RAYMONDINIDAE Clark, 1924

Genus LLANOASPIS Lochman, 1938

Type species Llanoaspis modesta Lochman

Llanoaspis cf. Llanoaspis peculiaris (Resser)

Plate 7, figures 5,6

DESCRIPTION

Cranidium small, strongly arched longitudinally; glabella very biconvex, bulbous, well defined at sides by deep,narrow axial furrow, two pairs of weak, arcuate, lateral glabellar furrows may be present, anterior poorly defined by shallow, nearly straight but slightly arched, dorsal furrow; occipital furrow broad, deep at sides, but shallow across sagittal median line; occipital ring narrow to broad, slightly convex; frontal area broken, about 0.33 to 0.5 glabellar length, slightly convex to flat, slightly downsloping anterior to glabella; facial suture hypo-oblique; palpebral area 0.33 glabellar width, nearly flat; palpebral lobe crescentiform, situated just anterior to transverse median line of glabella. Librigena and pygidium unknown.

Inner surface of test minutely punctate; outer surface unknown.

LOCATION AND HORIZON: GC-1.

REMARKS

Three cranidia with broken frontal areas and large, bulbous glabellas which characterize L. peculiaris

differ from that species in the more arcuate nature of the marginal furrow above the glabella. Size of the largest cranidium is 7.5 mm. long with incomplete frontal area.

Llanoaspis cf. Llanoaspis undulata Lochman

Plate 7, figures 37, 38

Llanoaspis undulata Lochman, 1938a, p. 81, pl. 17, figs. 24-26.

Llanoaspis undulata Lochman, Palmer, 1955 (1954), p. 738, pl. 82, figs. 6-7.

DESCRIPTION

Cranidium small, subquadrate; glabella conical, biconvex, dropping abruptly to frontal area, well defined by deep axial furrow, two pairs of broad, shallow, downcurving lateral glabellar furrows; occipital furrow broad, deep; occipital ring wide, triangular, without evidence of spine; frontal area broad, transverse furrow faint, just above glabella, anterior margin nearly straight; facial suture para-oblique; palpebral area wide, about 0.5 glabellar width, ocular ridge faint to obsolete; palpebral lobes situated opposite transverse median line of glabella; posterior area broad (sag.) with a narrow, deep intramarginal furrow. Librigena and thorax unknown.

Pygidium small, transverse to semicircular, 1.75 times as wide as long; axis conical, slightly tapered with bluntly rounded posterior, seven axial rings and a terminal section are well defined by narrow, shallow axial furrows, axial lobe narrow, less than width of pleural lobe; pleural lobes crossed by faint interpleural furrows; border furrow broad, shallow; border medium width, flat.

Outer surface of test unknown; inner surface minutely punctate.

LOCATION AND HORIZON: GC-1.

REMARKS

The species is represented by two cranidia, 5.0 mm. long, and two pygidia with a maximum width of 6.0 mm. The pygidia are fairly well preserved and seem to resemble L. undulata in the width of the axial lobe on the pygidium and the proportions of the glabella on the cranidium.

Superfamily MARJUMIACEA Kobayashi, 1935

Family COOSELLIDAE Palmer, 1954

Genus COOSELLA Lochman, 1936

Type species Coosella prolifica Lochman

Coosella aff. Coosella helena Lochman

Plate 7, figures 1-4

Coosella helena Lochman, 1938b, p. 468, pl. 57, figs.9-15.

DESCRIPTION

Cranidium and librigena unknown.

Pygidium semicircular, slightly wider than long; axis medium width, short, convex, slightly tapered, with 2 to 3 well defined axial rings and a rounded terminal section; pleural lobes much broader than axial with three pairs of broad, shallow, interpleural furrows and faint, short pleural furrows; border wide, flat, broadly expanded posteriorly with prominent median notch.

Outer surface of test finely granular; inner surface minutely punctate. Peeled posterior pygidial border may be covered with fine transverse ridges.

LOCATION AND HORIZON: GC, GC-1, and BB.

REMARKS

Represented by seven fairly well preserved pygidia, the largest of which is 21.0 mm. wide. These pygidia are distinguished by their broad, flaring border with posterior median inbend which resembles C. helena. They differ from that species in possessing 2 to 3 axial rings and a terminal

Coosella longa, new species

Plate 6, figures 37-39

DESCRIPTION

No cranidium or librigena known.

Pygidium semicircular, 0.75 times as long as wide; axis moderately wide, conical, convex, tapered 0.67 pygidial length, 4 to 5 axial rings and a bluntly rounded terminal section well defined on interior surface by deep, narrow axial furrows; pleural lobes approximately same width as axis, crossed by 4 to 5 pairs of pleural and interpleural furrows on inner surface; border furrow obsolete; border broad, flat, flaring with median notch, defined by change in slope.

Outer surface of test smooth; inner surface finely punctate.

LOCATION AND HORIZON: GC, GC-1, WC-6, and WC-14.

REMARKS

Represented by six pygidia; length of the largest fairly well preserved specimen is 21.0 mm.

This species most closely resembles *C. perplexa* Palmer, but differs from that species in proportions of the axis as well as greater number of axial segments. The latter differentiates the species from other described species, though the expanded border resembles that of *C. helena*.

Genus COOSIA Walcott, 1911

Type species Coosia superba Walcott

Coosia alethes (Walcott)

Plate 5, figures 50-54

Blountia alethes Walcott (part) 1916b, p. 397, pl. 64, figs. 1, 1a (only)

Coosia alethes (Walcott) Resser, 1938a, p. 71.

Coosia alethes (Walcott) Rasetti, 1965, p. 52-3, pl. 6, figs. 15-18; pl. 7, figs. 6-13.

DESCRIPTION

Cranidium large; glabella conical, convex, well defined by deep, broad axial furrow, anterior evenly rounded, lateral glabellar furrows obsolete; occipital furrow broad, deep; occipital ring slightly convex, broad; frontal area wide, about 0.5 glabellar length; preglabellar field slightly convex, downsloping, 1.5 times border length (sag.); border furrow broad, shallow; border convex, upsloping; facial suture tending to be para-oblique; palpebral area 0.5 glabellar width; palpebral lobes medium sized, crescentiform, situated slightly anterior to transverse median line of glabella; posterior area long (trans.), strap-like with broad, deep intramarginal furrow. Librigena narrow, rectangular; margin broad; ocular platform slightly convex.

Pygidium transversely subovate, 2.5 times as wide as long; axis short, broad, convex, conical, with slight tapering from 0.5 to 0.67 pygidial length; three well defined axial rings and a bluntly rounded terminal section; pleural lobes slightly wider than axis, faintly divided into three

broad segments; border broad, flat to slightly upsloping.

Hypostome with oval, convex anterior lobe, posterior ring with shallow pits at each side; broadly expanded postero-lateral border.

Outer surface of test smooth; inner surface finely punctate.

LOCATION AND HORIZON: GC, GC-1, and GC-2.

REMARKS

This species is represented by 4 cranidia, 1 hypostome, 1 fragmentary librigena, and 5 pygidia. The largest well preserved cranidium is 22.0 mm. long; the largest pygidium, 20.0 mm. wide. The specimens from the Grove Creek collection correspond closely to the figures and description given by Walcott.

Genus COOSINA Rasetti, 1956

Type species Maryvillia ariston Walcott

Coosina ariston Walcott

Plate 6, figures 26-35

Maryvillia ariston Walcott, 1916b (part), p. 401, pl. 64, figs. 5,5' (not 5a).

Coosina ariston (Walcott) Rasetti, 1956 (includes complete synonymy to that date), p. 1267.

Coosina ariston (Walcott) Lochman and Hu, 1960, p. 816, pl. 97, figs.15-20.

Coosina ariston (Walcott) Rasetti, 1961, p. 111, pl. 21, figs. 12, 13.

Coosina ariston (Walcott) Rasetti, 1965, p. 51-2, pl. 7, fig. 27.

DESCRIPTION

Cranidium large; glabella conical, convex with bluntly rounded front, poorly defined by shallow, broad axial furrow, more clearly defined at sides, lateral furrows obsolete on outer surface, occasionally represented on internal mold by three pairs of shallow, broad,"dents"; occipital furrow broad, shallow; occipital ring smooth, medium width, approximately equal to median glabellar width (trans.); frontal area 0.25 to 0.33 times glabellar length(sag.); preglabellar field slightly convex to concave, downsloping; border furrow broad, shallow, poorly defined, evenly rounded; border slightly convex, equal to or slightly larger than preglabellar field length (sag.); facial suture para-oblique, curving forward and around palpebral lobes, then backward and outward to cut posterior margin well within genal angle; palpebral area about 0.5 times glabellar width (generally slightly

less); ocular ridge prominent; palpebral lobe long, narrow, crescentiform, situated opposite or anterior to transverse median line of glabella; posterior area broad, moderate length, bluntly rounded end with deep, broad intramarginal furrow. Librigena narrow, convex; ocular platform slightly convex with low eye at inner angle; border slightly convex, broad with short anterior projection and broad, short genal spine.

Pygidium semicircular, about 1.33 times as wide as long; axis convex, cylindrical, slightly tapered, with four poorly defined axial rings and a terminal section, a long narrow projection extending from the posterior of the terminal onto border; pleural lobes convex, slightly wider than axis, dropping abruptly to margin with four pairs of well defined interpleural furrows and faint pleural furrows; border furrow obsolete, border defined by change in slope, varying from 0.25 to 0.13 total pygidial length (sag.).

Outer surface of test smooth; inner surface finely to coarsely punctate.

Associated hypostome large with oval central lobe, depressions at each side of posterior lobe; posterior lobe very poorly defined, narrow, slightly convex, merging into wide, concave posterior border.

LOCATION AND HORIZON: BB, GC-1, WC-11, MC-5, and MC-2.

REMARKS

Forty-three measured Coosina cranidia revealed the presence of only C. ariston, though differences in the

preservation including weathering of external and internal molds and casts made some specimens appear to be slightly broader with a shorter border. Cranidia range from 4.0 to 20.0 mm. long. Librigenae are rather scarce in the collections as only three were identified. This may be a result of selective transportation since most of the specimens came from a coquina block of heads and tails. Pygidia range from 2.0 to 22.0 mm. in width. Thirty-five pygidia were studied and also indicate the presence of only C. ariston though preliminary study seemed to suggest the presence of three or more species. A more transverse shape and less convexity seems to have resulted from preservation since all graphs show close relationship of the pygidia.

Superfamily BATHYURACEA Walcott, 1886

Family LECANOPYGIDAE Lochman, 1950

Genus MINICEPHALUS Lochman and Hu, 1960

Type species Minicephalus primus Lochman and Hu

Minicephalus transversus, new species

Plate 6, figures 24,25

DESCRIPTION

Cranidium, thorax, and librigena unknown.

Pygidium subovate, about twice as wide as long; axis conical, convex, posterior rounded with long, narrow posterior projection extending onto border, three axial rings and a short terminal section; pleural lobes wider than axial, slightly convex with three pairs of well defined interpleural furrows and poorly defined pleural furrows; border defined by change in slope, wide, narrowing posteriorly.

Outer surface of test finely granular; inner surface minutely punctate.

LOCATION AND HORIZON: GC, GC-1.

REMARKS

This species is represented by three pygidia, the largest of which is 24.0 mm. wide. The species is distinguished from M. primus by the greater width (trans.) of the pygidium, especially of the pleural lobes, and the slight median indentation in the border.

Family KINGSTONIIDAE Kobayashi, 1933

Genus KINGSTONIA Walcott, 1924

Type species Kingstonia apion Walcott

Kingstonia inflata Resser

Plate 5, figure 49

Kingstonia inflata Resser, 1938a,p. 84, pl.12, figs.5,6.
Kingstonia rotundata Resser, 1938a,p. 83, pl.12,figs.9,10.
Kingstonia inflata Resser, Rasetti, 1965, p. 60, pl. 8, figs. 21-28.

DESCRIPTION

Pygidium semicircular; axial and pleural lobes same width, convex, dropping abruptly to margin, well defined anteriorly, but poorly defined to margin.

LOCATION AND HORIZON: GC-1.

REMARKS

Two pygidia, 2 mm. long, lack very much detail, but resemble K. inflata in shape and proportions.

Genus ANKOURA Resser, 1938

Type species Ankoura triangularis Resser

Ankoura apicalis Duncan

Plate 7, figures 40, 14

Ankoura apicalis Duncan in Lochman and Duncan, 1944, p.109, pl. 14, figs. 29-31.

Ankoura apicalis Duncan, Tasch, 1951, p. 286, pl.44, figs. 1,2.

DESCRIPTION

No cranidium or librigena known.

Pygidium triangular, strongly convex; axial lobe broad, approximately equal to width of pleural lobe, slightly convex, tapering to vertical border, five axial rings and a terminal section defined by broad, shallow axial furrows; pleural lobes narrow, slightly convex, sharply tapered to posterior margin, crossed by four pairs of distinct pleural furrows; border convex, vertical to posterior where it becomes broader than at sides where it is narrow, flat.

Outer surface smooth; inner surface of test thickly punctate.

LOCATION AND HORIZON: GC-1.

REMARKS

Represented by two pygidia, the best preserved of which is 8.0 mm. long. The proportions of the pleural and axial lobes resemble A. apicalis as well as shape of border.

Phylum PORIFERA

Order HETERACTINIDA Hinde, 1888

Family CHANCELLORIIDAE de Laubenfels, nov.

Genus CHANCELLORIA Walcott, 1920

Type species Chancelloria eros Walcott

Chancelloria cf. Chancelloria drusilla Walcott

Plate 7, figures 22-26

Chancelloria drusilla Walcott, 1920, p. 331-2, pl. 87, figs. 2, a-e.

DESCRIPTION

Specimens consist of scattered skeletal spicules with a central ray and usually 6 to 7 horizontal rays. A few specimens have 3, 4, or 5 oblique rays with a central vertical ray. The spicules were originally siliceous and a minute axial canal through each ray may be distinguished in many specimens. The base of the spicule consists of a bundle of bases of horizontal rays and one vertical one in the center. The side rays may be either horizontal, directed at 90 degrees from vertical ray, or at 45 degrees. Most of the rays are broken near center of the spicule, but a few show the full length of rays to have been about 3.0 mm. with ends enlarged slightly. Single rays often occur suggesting that sutures were not particularly tight. Central ray is usually hexagonal to heptagonal to fit the central juncture of rays.

LOCATION AND HORIZON: GC-1 and WC-8.

REMARKS

These spicules are very common in lenses within the Crepicephalus Zone. Eighteen specimens were included in the study. They most closely resemble C. drusilla which is described from the Conasauga Shale of Georgia; however, no hollowed surface was observed on the upper or outer surface. Slight resemblance in shape and size of rays to C. eros was also noted. When compared to C. aurora Lochman, the specimens are larger as the largest of the former were 2.0 mm. in diameter, but have the same general shape. Larger specimens are 4.0 to 5.0 mm in diameter.

Phylum BRACHIOPODA

Class INARTICULATA Huxley, 1869

Superfamily LINGULACEA Menke, 1828

Family OBOLIDAE King, 1846

Genus OBOLUS Eichwald, 1829

Type species Obolus apollinis Eichwald

Obolus species undetermined

Plate 7, figure 36

REMARKS

One fragmentary valve, small, ovate with radial striations and closely spaced punctations on inner shell layer; shows an irregular scar near center where shell was injured and has partially healed.

LOCATION AND HORIZON: GC-1.

Genus Lingulepis Hall, 1863

Type species Lingula pinnaformis Owen, 1852

Lingulepis cf. Lingulepis acuminata (Conrad)

Plate 7, figures 27,28

Lingula acuminata Conrad, 1839, p. 64.

Lingulella (Lingulepis) acuminata (Conrad), Walcott, 1912 (includes synonymy to that date), p. 545, pl. 40, fig. 1; pl. 42, figs. 1-c.

Lingulepis acuminata (Conrad), Tasch, 1951, p. 304, pl. 45, fig. 18.

DESCRIPTION

Dorsal valve ovate with fine concentric growth lines and radiating striae.

Ventral valve subovate, narrowing anteriorly with concentric growth ridges, slightly convex, posterior evenly rounded.

LOCATION AND HORIZON: GC and GC-1.

REMARKS

The specimens assigned to this species are 3 broken ventral valves and one fragmentary dorsal valve. No internal structure is apparent so identification is made only on exterior surface structure, shape, and horizon.

Phylum MOLLUSCA

Class CALYPTOMATIDA Fisher, 1966

Family HYOLITHIDAE Nicholson, 1872

Genus HYOLITHES Eichwald, 1840

Type species Hyolithes acutus Eichwald

Hyolithes gallatinensis Resser

Plate 7, figures 29-32

Hyolithes primordialis Walcott (part), 1899, p. 454, pl. 63, fig. 2.

Hyolithes gallatinensis Resser, 1938b, p. 21.

DESCRIPTION

Test with slightly convex to nearly flat posterior side; anterior side evenly rounded with hollow parallel to side in some well preserved specimens which is probably an internal structure as it is not seen on outer surface.

Inner surface of test smooth; outer surface with fine concentric growth lines crossed by fine longitudinal striations.

LOCATION AND HORIZON: GC, GC-1, GC-2, BB, MC-2, WC-10.

REMARKS

Thirty-six specimens show the characteristic cross-section of this species. Size ranges from 6.0 to 30.0 mm. long and maximum width is 15.0 mm. which may have been 48.0 mm. long when complete. Large individuals (greater than 8.0 mm. long) often have the pointed end broken and rounded.

Phylum ECHINODERMATA

Class EOCRINOIDEA Jaekel, 1918

Family SPRINGEROCYSTIDAE Bassler, 1950

Genus ?FOERSTECYSTIS Bassler, 1950

Type species Foerstecystis obliqua Bassler

Foerstecystis? species undetermined

Plate 7, figure 33

REMARKS

This genus is represented by two six or seven sided plates, irregular in shape and slightly curved with small granules arranged in rows nearly parallel to sides. The largest plate is 5.0 mm. in diameter.

LOCATION AND HORIZON: GC-1.

Family PALAEOCYSTITIDAE Ubaghs, (1896)

Genus Palaeocystites Billings, 1858

Type species Actinocrinus tenuiradiatus Hall

Palaeocystites ? species undetermined

Plate 7, figures 34, 35

REMARKS

Four fragmentary plates, apparently irregularly hexagonal in outline when perfect, marked by short parallel ridges with a definite pattern which is similar in appearance to pore rhombs of Rhombifera, but from the material available they appear to be only superficial. Ridges are perpendicular to the sides and vary in length with shorter ridges at sides, and longer ones in the center.

LOCATION AND HORIZON: BB, BB-1.

CEDARIA ZONE

Phylum ARTHROPODA

Class TRILOBITA

Order AGNOSTIDA Kobayashi, 1935

Family SPINAGNOSTIDAE Howell, 1935

Genus BALTAGNOSTUS Lochman, 1944

Type species Proagnostus? centralis Resser

Baltagnostus beltensis Lochman

Plate 7, figures 41,42

Baltagnostus beltensis Lochman in Lochman and Duncan, 1944, p. 138-39, pl. 12, figs. 3-5.

Cephalon unknown.

Pygidium subrectangular, biconvex; axis approaches posterior border, axial furrows and dorsal furrow shallow, narrow; posterior lobe rounded posteriorly, slightly enlarged; dorsal furrow very close to marginal furrow; border convex, medium width with two postero-lateral spines extending posteriorly below posterior lobe. Inner surface of test smooth.

LOCATION AND HORIZON: BC X5, X8, X9, and X14.

REMARKS

Represented by 6 pygidia, the largest of which is 2.75 mm. long by 2.5 mm. wide. These pygidia show curvature of axial furrows which is characteristic for the species.

Genus KORMAGNOSTUS Resser, 1938

Type species Kormagnostus simplex Resser

Kormagnostus simplex Resser

Plate 7, figures 43-46

Kormagnostus simplex Resser, 1938a, p. 49, pl. 9, figs. 11-13.

Kormagnostus simplex Resser, Palmer, 1955 (1954) (includes synonymy to that date), p. 718, pl.76, figs. 8-12.

Kormagnostus simplex Resser, Lochman and Hu, 1960, p. 822, pl. 99, figs. 5-31.

Kormagnostus simplex Resser, Rasetti, 1965, p. 38, pl. 1, figs. 8,9.

DESCRIPTION

Cephalon small, biconvex, subcircular; posterior lobe of glabella elevated, convex, well defined by broad, triangular axial furrow and deep transverse furrow; anterior lobe obsolete or poorly defined; border flat, expanded slightly anteriorly, defined by broad, shallow, marginal furrow.

Pygidium small, biconvex, subcircular; anterior lobe broad, well defined by deep,narrow axial furrow; expanded slightly posteriorly to nearly parallel sided axis, nearly reaching marginal furrow; anterior segments faint to obsolete with median node on second segment; border broad with short pair of postero-lateral spines opposite posterior end of axial lobe; marginal furrow broad, shallow. Inner surface of test minutely punctate.

LOCATION AND HORIZON: BC X1, X3, X8, and TOP D.

REMARKS

This species is represented by 7 cephala and 9 pygidia. The largest cephalon is 3.5 mm. long and 3.75 mm. wide; the largest pygidium is 3.25 mm. wide by 3.0 mm. long. The species is characterized by the shape and proportions of the axial and glabellar lobes and the direction of the axial furrow.

Superfamily CREPICEPHALACEA Kobayashi, 1935

Family TRICREPICEPHALIDAE Palmer, 1954

Genus METEORASPIS Resser, 1935

Type species Ptychoparia? metra Walcott

Meteoraspis boulderensis Deland

Plate 7, figures 57-60

Meteoraspis boulderensis Deland in Deland and Shaw, 1956, p. 557-58, pl. 63, fig. 18; pl. 64, figs. 4-6.

Meteoraspis boulderensis Deland, Lochman and Hu, 1961, p. 141, pl. 28, figs. 20-29.

DESCRIPTION

Cranidium small, stout; glabella short, broad, conical, convex, three pairs of faint glabellar furrows, axial and dorsal furrows narrow, deep; occipital ring smooth or with small median node, medium width, broadening to center; occipital furrow shallow across center, deep, broad at sides; frontal area less than 0.33 glabellar length; preglabellar field convex, downsloping; border furrow narrow, deep with two faint pits; border longer than preglabellar field; facial suture hyperoblique; palpebral area long, narrow, about 0.33 glabellar width; palpebral lobe medium sized, crescentiform, opposite center of glabella or just posterior to transverse median line of glabella; posterior area short, narrow with broad, deep intramarginal furrow. Librigena and thorax unknown.

Pygidium subrectangular, slightly wider than long; axis broad, slightly tapered with two axial rings and a

terminal section defined by broad axial furrows; pleural field slightly narrower than axial lobe, slightly convex with two pairs of broad, deep interpleural furrows; border flat, narrow at sides and posteriorly extending into two broad, flat, stout, short posteriorly directed spines which curve slightly inward.

Outer surface of test finely granular; inner surface minutely punctate.

LOCATION AND HORIZON: LOC 3 and BC X8.

REMARKS

This species is represented by 4 cranidia and 3 pygidia. The largest well preserved cranidium is 10.5 mm. long; the largest pygidium is 14.0 mm. wide and 10.0 mm. long excluding postero-lateral spines. The cranidium is characterized by the moderately convex glabella and downsloping frontal area, as well as general proportions of glabella and frontal area. The pygidium is not described previously.

Superfamily SOLENOPLEURACEA Angelin, 1854

Family KINGSTONIIDAE Kobayashi, 1933

Genus KINGSTONIA Walcott, 1924

Type species Kingstonia apion Walcott

Kingstonia spicata Lochman

Plate 7, figure 56

Kingstonia spicata Lochman, 1940, p. 35-4, pl. 4, figs.1-9.

Kingstonia spicata Lochman, Deland and Shaw, 1956, p. 556, pl. 63, fig. 17.

Kingstonia spicata Lochman, Lochman and Hu, 1962a,p. 15-6, pl. 4, figs. 1-11, 13-28.

DESCRIPTION

Cranidium and librigena unknown.

Pygidium triangular, ending in a short, broad spine; axial lobe medium width, very slightly convex almost to base of spine, tapered; eight axial rings faintly defined on outer surface; pleural lobes slightly narrower than axial lobe at anterior, slightly convex, smooth; border very narrow, almost vertical.

Outer surface of test minutely granular; inner surface unknown.

LOCATION AND HORIZON: BC X8, BC TOP C, and MC-1.

REMARKS

Two pygidia with characteristic spine on one specimen, 2.0 mm. long without spine, spine 1.0 mm., and one with broken spine are assigned to this species.

Genus BYNUMIA Walcott, 1924

Type species Bynumia eumus Walcott

Bynumia lata Lochman

Plate 7, figure 47

Bynumia lata Lochman in Lochman and Duncan, 1944, p. 112, pl. 16, figs. 14-20.

Bynumia lata Lochman, Lochman and Hu, 1962a, p. 14-15, pl. 3, figs. 19-39.

DESCRIPTION

Cranidium small, triangular; glabella low, slightly convex, very poorly defined and lacking glabellar furrows on inner and outer surfaces as well as occipital furrow; posterior area long, narrow, triangular. Librigena small, convex, smooth, subovate with thin, short genal spine.

Outer surface of test smooth; inner surface finely punctate.

LOCATION AND HORIZON: BC X1.

REMARKS

Two poorly preserved cranidia, the largest of which is 7.0 mm. long and 1 librigena are assigned to this species because of characteristic shape of frontal area and posterior area of cranidium.

Superfamily RAYMONDINACEA Clark, 1924

Family RAYMONDINIDAE Clark, 1924

Genus PARACEDARIA Duncan, 1944

Type species Pilgrimia montanensis Duncan

Paracedaria montanensis (Duncan)

Plate 7, figures 68-70

Pilgrimia montanensis Duncan in Lochman and Duncan 1944, p. 108-9, pl. 13, figs. 1-6.

DESCRIPTION

Cranidium subquadrate; glabella narrowly conical, convex, two pairs of faint to obsolete lateral glabellar furrows, dorsal and axial furrows deep, well defined; occipital furrow shallow, narrow; occipital ring narrow, slightly convex, smooth; frontal area 0.33 glabellar length; preglabellar field slightly convex; border furrow deep, narrow, with slight median inbend; border upsloping, about 0.5 preglabellar length; facial suture hyperoblique; palpebral area about 0.5 glabellar width; palpebral lobes medium sized, crescentiform, situated opposite transverse median line of glabella; posterior area long (trans.), medium width with broad, deep intramarginal furrow turning up before reaching margin. Librigena narrow, subrectangular; ocular platform with large eye at inner angle; border narrow, flat with long, slender genal spine.

Pygidium transversely subovate, about twice as wide as long; axial lobe medium width, convex, slightly tapered

with four axial rings and terminal section; pleural lobes slightly wider than axial with four broad segments which bend backward to extend onto narrow marginal border

Outer surface of test slightly granular, especially on ocular platform of librigena and frontal area of cranidium which are marked by fine, imbricating ridges; inner surface of test minutely punctate.

LOCATION AND HORIZON: BC X1, X5, X7, X8, X9, X14, TOP D, and LOC 2a.

REMARKS

Sixteen cranidia, 13 pygidia, and 5 librigena represent this species. Many of the specimens are broken, but a few are fairly well preserved. The largest nearly complete cranidium is 7.0 mm. long. The fine imbricating ridges on the frontal area and ocular platform, the border which is 0.5 preglabellar field length, and the divergence of the facial suture of the cranidium and the border width and narrow pygidial axis are characteristic of P. montanensis.

Paracedaria tarda Lochman and Hu

Plate 7, figure 53

Paracedaria tarda Lochman and Hu, 1962a, p. 25, pl. 1, figs. 1-10.

DESCRIPTION

Cranidium rectangular; glabella conical, convex, broadly rounded anterior, well defined by broad, deep axial and dorsal furrows; occipital ring and furrow unknown; frontal area slightly shorter (sag.) than glabella excluding occipital ring; preglabellar field very short; border furrow broad with slight median inbend; border broad, slightly convex; facial suture para-oblique; palpebral area broad, about 0.5 times glabellar width; palpebral lobes and posterior area unknown. Thorax, librigena, and pygidium unknown.

Inner surface of test minutely punctate; outer surface unknown.

LOCATION AND HORIZON: BC X14.

REMARKS

This species is represented by one broken cranidium which is 11.0 mm. long excluding the occipital ring. It is assigned to this species because of the extremely narrow preglabellar field and very broad anterior border which are characteristic of the species.

Genus CEDARIA Walcott, 1924

Type species Cedaria prolifica Walcott

Cedaria milleri Resser

Plate 7, figures 83-86

Cedaria milleri Resser, 1937, p. 5.

Cedaria milleri Resser, Lochman and Hu, 1962a(includes complete synonymy), p. 19-20, pl. 2, figs. 1-34.

DESCRIPTION

Cranidium elongate; glabella convex, conical with narrowly rounded front, three pairs of very faint, arcuate, lateral glabellar furrows; dorsal and axial furrows narrow, deeply incised; occipital ring smooth, medium width; occipital furrow narrow, deep, with slight median upbend; frontal area 0.33 glabellar length; preglabellar field slightly convex; border furrow deep, narrow; border evenly rounded, narrow, about 0.5 preglabellar field length; anterior margin evenly rounded; facial suture para-oblique; palpebral area wide, 0.5 glabellar width (trans.); palpebral lobe crescentiform, medium sized, situated opposite transverse median line of glabella; posterior area medium length, broad with deep, broad intramarginal furrow which curves upward just before reaching margin. Librigena broken, rectangular with convex ocular platform; border broad, flat.

Pygidium semicircular; axis narrow, convex, rapidly tapered, six axial rings and a terminal section faintly defined; pleural lobes wider than axial, lacking definition; border broad, flat.

Outer surface of test finely granular with radiating ridges crossing the preglabellar field of cranidium and ocular platform of librigena; inner surface minutely punctate.

LOCATION AND HORIZON: BC X1, BC X3, BC X4, BC X7, BC X8, BC X9, BC X10, BC TOP D, BC X16, and LOC 3.

REMARKS

This species is represented by 15 cranidia, 1 librigena, and 3 pygidia. The largest well preserved cranidium is 4.0 mm. long; pygidium is 8.0 mm. long. C. milleri is recognized by relatively narrow frontal area (when compared to other Cedaria) with slightly upsloping to flat border, and distinctive upsloping palpebral area. The pygidium is semicircular in outline of larger specimens and has a flat border.

Cedaria buttsi Resser

Plate 7, figures 71-75

Cedaria buttsi Resser, 1938a, p. 68, pl. 11, fig. 8.
Cedaria prolifica Walcott, Palmer, 1962, p. 26, pl. 3, figs. 9,10,14,16-20.

DESCRIPTION

Cranidium subrectangular; glabella cylindrical, transversely convex, sharply tapered, lateral glabellar furrows obsolete on interior of test, axial and dorsal furrows deep; shallow, well defined occipital furrow; occipital ring smooth, medium width, broadening slightly to center; frontal area 0.75 glabellar length; preglabellar field slightly convex; border furrow narrow, well defined; border narrow, about 0.5 preglabellar field length; facial suture very hyper-oblique; palpebral area long, narrow, less than 0.5 glabellar width; palpebral lobes small, crescentiform, situated on transverse median line of glabella; posterior area long, narrow with shallow, narrow intramarginal furrow. Thorax and librigena unknown.

Pygidium semi-circular; axis convex, tapered with four well defined axial rings, axis as wide as pleural field; pleural field slightly convex with four pairs of pleural and interpleural furrows, well defined; curving back to broad, flat border.

Outer surface of test minutely granular; inner surface punctate with radiating ridges on preglabellar field.

LOCATION AND HORIZON: BC X8, X9, TOP D, and LOC 3.

REMARKS

This species is represented by 5 cranidia, the best preserved of which is 10.0 mm. long. Three semi-circular pygidia with broad, flat borders are assigned to this species also. The most striking characteristic of the species is the very divergent facial suture which distinguishes the species from others. The narrow palpebral area is also characteristic.

Genus CEDARINA Lochman, 1940

Type species Cedarina vale Lochman

Cedarina prima Lochman

Plate 7, figures 76-80

Cedarina prima Lochman, in Lochman and Duncan, 1944, p.92-3, pl. 16, figs. 1-8.

DESCRIPTION

Cranidium subquadrate; glabella highly convex, narrowly conical, three pairs of very faint, slanting lateral glabellar furrows, dorsal and axial furrows narrow, well defined; occipital ring smooth, slightly convex, medium width; occipital furrow shallow, narrow; frontal area 0.5 glabellar length including occipital ring; preglabellar field slightly convex and marked by radiating ridges; border furrow shallow, broad; border slightly convex, 0.67 length of preglabellar field; facial suture hyperoblique; palpebral area long, narrow, 0.33 width of glabella; palpebral lobes medium sized, crescentiform, situated opposite transverse median line of glabella; posterior area medium length and width with broad, shallow intramarginal furrow curving upward near margin. Librigena subrectangular; ocular platform convex with fairly broad, flat border extending into a long, heavy genal spine. No thorax known.

Pygidium transversely subovate, over twice as wide as long; axis narrow, convex, cylindrical with 4 to 6 segments and a bluntly rounded terminal section; pleural lobes wider than axial, divided by shallow pleural and interpleural furrows which cross onto the flat, wide border; border nar-

rows abruptly posteriorly.

Outer surface of test unknown; inner surface minutely punctate with radiating ridges on preglabellar field of cranidium.

LOCATION AND HORIZON: BC X1, BC X3, BC X11, and BC TOP C.

REMARKS

This species is represented by 6 cranidia, 1 librigena, and 2 pygidia. The largest well preserved cranidium is 7.5 mm. long, the largest pygidium is 9.0 mm. wide. The species is distinguished from other species by the longer frontal area of the cranidium and the longer pygidial axis. The specimens from Beaver Creek vary from the type of the species is having 4 to 6 axial rings, instead of only 4, on the pygidium.

Cedarina victoria Lochman
Plate 7, figures 87, 88

Cedarina victoria Lochman in Lochman and Duncan, 1944, p. 93, pl. 17, figs. 19-29.

Cedarina victoria Lochman, Lochman and Hu, 1962a, p. 23, pl. 3, figs. 9-14.

DESCRIPTION

Cranidium subquadrate; glabella slightly convex, long, conical, three pairs of very faint to obsolete lateral glabellar furrows, dorsal and axial furrows shallow, narrow; occipital ring medium width, broadening toward center; occipital furrow broad, shallow; frontal area 0.33 glabellar length including occipital ring; preglabellar field slightly convex, equal to border width; border furrow narrow, deep with slight median inbend; border slightly convex, evenly rounded; facial suture meso-oblique; palpebral area long, narrow, about 0.33 glabellar width with faint ocular ridge passing almost straight across and intersecting behind dorsal margin of glabella; palpebral lobes medium sized, crescentiform, situated opposite transverse median line of glabella; posterior area of medium width and length with broad, deep intramarginal furrow which curves forward just before reaching margin. Librigena unknown.

Pygidium transverse, about twice as wide as long; convex with conical axis tapering to bluntly rounded posterior, four axial rings and a terminal section; pleural lobes slightly wider than axial, nearly flat, divided into three broad segments which are faintly defined and curve onto

border; border medium width narrowing at posterior, small blunt, posteriorly directed spine situated opposite end of anterior pleural segment.

Outer surface of test unknown; inner surface minutely punctate.

LOCATION AND HORIZON: BC X1, X10, X11, and TOP D.

REMARKS

This species is represented by 7 cranidia and 2 pygidia. The largest cranidium is 9.0 mm. long and the largest pygidium is 8.0 mm. wide when complete. C. victoria is distinguished by the narrow cranidium and long glabella and the subequal preglabellar field and border of the cranidium and the spines on the pygidium.

Cedarina cordillerae (Howell & Duncan)

Plate 7, figures 81,82

Piedmontia cordillerae Howell and Duncan, 1939, p. 9, pl. 1, fig. 4.

Cedarina cordillerae (Howell & Duncan) in Lochman and Duncan, 1944 (includes synonymy to that date), p. 89, pl. 17, figs. 1-10.

Cedarina cordillerae (Howell & Duncan) Palmer, 1955 (1954), p. 727, pl. 80, figs, 8,10,

Cedarina cordillerae (Howell & Duncan) Lochman and Hu, 1962a, p. 22-3, pl. 2, figs. 50-57.

DESCRIPTION

Cranidium small, rectangular; glabella subquadrate, convex, lateral glabellar furrows obsolete, well defined by deep, narrow axial and dorsal furrows; occipital ring broad, triangular with small spine; occipital furrow broad, shallow; frontal area narrow, less than 0.33 glabellar length; preglabellar field convex; border furrow narrow, deep with prominent median inbend; border convex, about equal to length of preglabellar field; facial suture para-oblique; palpebral area convex, broad, about 0.5 glabellar width; palpebral lobes long, crescentiform, situated opposite transverse median line of glabella; posterior area unknown. Librigena unknown.

Pygidium transversely subovate, about twice as wide as long; axis broad, conical, convex, at least three well defined axial rings and a terminal section; pleural lobes about same width as axial, crossed by deep, broad pleural and interpleural furrows which curve down to flat, smooth, broad, border.

Outer surface of test smooth; inner surface minutely punctate.

LOCATION AND HORIZON: BC X10, X11, and X14.

REMARKS

This species is represented by three poorly preserved cranidia and one broken pygidium. The length of the largest cranidium is 5.0 mm. and the width of the pygidium when complete would be 8.0 mm. The cranidium of the species resembles C. prima and differs from that species in the presence of the occipital spine. The associated pygidium is broken, but appears to be broader than that of other species.

Genus GENEVIEVELLA Lochman, 1936

Type species Genevievella neunia Lochman

Genevievella spinosa Lochman

Plate 7, figures 54,55

Genevievella spinosa Lochman in Lochman and Duncan, 1944, p. 104, pl. 13, figs. 35-41.

Genevievella spinosa Lochman, Palmer, 1955 (1954), p.736, pl. 83, figs. 3,5,6.

DESCRIPTION

Cranidium small, subquadrate; glabella conical, very biconvex, dropping rapidly at anterior, well defined by deep, narrow, axial furrow, a posterior pair of faint, lateral glabellar furrows; occipital furrow deep, narrow; occipital ring broad, triangular with small, thin occipital spine; frontal area broad with raised, straight border; anterior margin slightly convex; palpebral area narrow, about 0.33 glabellar width, convex, ocular ridge narrow, low, crossing palpebral area at about 30 degree angle to glabella, and intersecting just below anterior margin of glabella; palpebral lobe medium sized, crescentiform, situated well below transverse median line of glabella; posterior area narrow, long, strap-like with deep, broad intramarginal furrow. Thorax, librigena, and pygidium unknown.

Outer surface of test unknown; inner surface of test minutely granular.

LOCATION AND HORIZON: MC-2

REMARKS

Represented by three cranidia, the largest of which is 7.0 mm. long. The cranidia resemble the species in the presence of the characteristic spine and short preglabellar area, as well as proportions of glabella and border. The specimens appear to have a slightly more divergent facial suture than the type, but this may be due to preservation.

Family COOSELLIDAE Palmer, 1954

Genus SYSPACHEILUS Resser, 1938

Type species Syspacheilus typicalis Resser

Syspacheilus camurus Lochman

Plate 7, Figures 48-51

Syspacheilus camurus Lochman, 1940, p. 42, pl. 3, figs.21-5.
Syspacheilus camurus Lochman, Palmer, 1955 (1954), p. 734, pl.78, figs. 8,10.
Syspacheilus occidens Lochman in Lochman and Hu, 1961,p.134.

DESCRIPTION

Cranidium subquadrate; glabella broad, conical, convex, slightly tapered to rounded front, three pairs of very faint, short, arcuate, lateral glabellar furrows; axial and dorsal furrows deep, well defined; occipital ring broad, smooth, slightly convex; occipital furrow deep, broad; frontal area about 0.33 glabellar length; preglabellar field convex; border furrow deep, broad; border convex, wider than preglabellar field (sag.); facial suture para-oblique; palpebral area 0.33 glabellar width, convex, upsloping; palpebral lobe medium sized, crescentiform, situated on transverse median line of glabella; posterior area short (trans.) with deep, well defined intramarginal furrow. Librigena unknown.

Pygidium transversely semi-circular, about twice as wide as long; axis medium sized, convex, very slightly tapered with three axial rings and a terminal section well defined; pleural lobes same width as axis, convex with broad, well defined interpleural furrows and faint pleural furrows; border

broad, slightly concave with posterior notch.

Outer surface of test finely granular; inner surface minutely punctate.

LOCATION AND HORIZON: BC X5, X8, X9, TOP B, TOP C, TOP D, and LOC 2a.

REMARKS

Well represented from the upper part of the section at Beaver Creek by 41 cranidia and three pygidia. One of the best preserved cranidia is 16.0 mm. long and the pygidium is 31.5 mm wide. The cranidia are differentiated on the basis of the narrow palpebral area and border which is slightly wider than preglabellar field.

Superfamily MARJUMIACEA Kobayashi, 1935

Family MARJUMIIDAE Kobayashi, 1935

Genus MODOCIA Walcott, 1924

Type species Arionellus (Crepicephalus) oweni Meek & Hayden

Modocia centralis (Whitfield)

Plate 7, figures 61-66

Crepicephalus (Loganellus) centralis Whitfield, 1877, p. 341, pl. 2, figs. 21-24.

Modocia oweni (Meek and Hayden) Walcott, 1924, p. 59.

Modocia oweni (Meek and Hayden) Walcott, 1925, p. 106, pl. 16, figs. 1,2.

Modocia centralis (Whitfield) Resser, 1935, p. 41.

Modocia centralis (Whitfield) Lochman and Duncan 1944, p. 127, pl. 11, figs. 40-43.

Modocia centralis (Whitfield) Palmer, 1955 (1954), p. 763, pl. 87, fig. 8.

Modocia centralis (Whitfield) Deland and Shaw, 1956, p. 55, pl. 64, fig. 10.

Modocia centralis (Whitfield) Shaw, 1956, p. 141-44, pl. 1, figs. 1-4.

Modocia centralis (Whitfield) Lochman and Hu, 1961, p. 136-137, pl. 29, figs. 1-39.

DESCRIPTION

Cranidium large, rectangular; glabella conical, convex, tapering to rounded front; dorsal and axial furrows well defined, three pairs of faint lateral glabellar furrows; occipital ring smooth, convex, medium width, widening to center; occipital furrow broad, deep; frontal area slightly greater than 0.35 glabellar length; preglabellar field convex, downsloping; border furrow deep, broad, nearly straight; border convex, slightly longer than preglabellar

field; facial suture meso-oblique; palpebral area broad, greater than 0.5 glabellar width (trans.); palpebral lobe small, crescentiform, situated opposite transverse median line of glabella; posterior area short, broad with deep, broad intramarginal furrow.

Librigena rectangular, narrowing anteriorly; ocular platform slightly convex; border broad, convex with short anterior projection.

Pygidium transversely subovate, twice as wide as long; axis broad, convex, short, slightly tapered, three axial rings and a terminal section; pleural lobes narrower than axial with three pairs of faint interpleural and pleural furrows which fall onto margin; border broad anteriorly, narrowing posteriorly.

Outer surface of test coarsely granular, especially on librigenae and palpebral lobes, glabella, and frontal area of cranidium; inner surface finely punctate.

LOCATION AND HORIZON: BC X1, X2, X3, X4, X5, X6, X8, X9, X10, X12, TOP B, TOP C, TOP D, LOC 3, and MC-1.

REMARKS

Species very common throughout section at Beaver Creek; represented by 36 cranidia, 3 librigenae, and 3 pygidia which are generally fragmentary. Best preserved cranidium is 15.0 mm. long, pygidium is 10.0 mm. wide. There is a slight degree of variation in divergence of facial suture and curvature of border furrow, but proportions, shape, and outer surface of cranidia and pygidia correspond closely to this species.

Family PAGODIIDAE Kobayashi, 1935

Genus TORRIDELLA Lochman and Hu, 1962

Type species Torridella migranta Lochman and Hu

Torridella migranta Lochman and Hu

Plate 7, figure 67

Torridella migranta Lochman and Hu, 1962a, p. 17, pl. 6, figs. 7-18.

DESCRIPTION

Cranidium quadrate; glabella subquadrate, convex, tapered only slightly to rounded front, dorsal and axial furrows narrow, distinct, two pairs of faint, short lateral glabellar furrows; occipital ring medium width, broadening slightly to center, smooth; occipital furrow deep, narrow; frontal area about 0.25 glabellar length; preglabellar field very short, about 0.5 or less of border length; border convex; facial suture just less than para-oblique; palpebral area wide, 0.5 glabellar width; palpebral lobes medium sized, crescentiform, situated just below transverse median line of glabella; faint, slightly diagonal eye ridge, intersecting just below front of glabella; posterior area medium length and width with broad intramarginal furrow. Associated librigena with slightly convex, narrow ocular platform; border broad, flat, extending into a short spine anteriorly and a long, broad genal spine.

Pygidium unknown.

Inner surface of test finely granular; outer surface unknown.

LOCATION AND HORIZON: BC X1 and BC X2.

REMARKS

This species is represented by 2 cranidia and 1 librigena. The best preserved cranidium is 2.5 mm. long and shows horizontal, convex border characteristic of the species as well as conical, slightly raised glabella.

Superfamily PROETACEA Salter, 1864
Family PLETHOPELTIDAE Raymond, 1925

Genus ARAPAHOIA Miller, 1936
Type species Arapahoia typa Miller

Arapahoia snowiensis Howell and Duncan

Plate 7, figure 52

Arapahoia snowiensis Howell and Duncan , 1939, p. 6, pl. 1, fig. 10.

Arapahoia snowiensis Howell and Duncan, Resser, 1942, p. 46, pl. 7, figs. 12-14.

Arapahoia snowiensis Howell and Duncan, Lochman and Duncan, 1944, p. 120, pl. 15 figs. 1-9.

Arapahoia snowiensis Howell and Duncan, Lochman, 1950, p.341, pl. 50, figs. 5-11.

Arapahoia snowiensis Howell and Duncan, Lochman and Hu, 1962a, p. 17, pl. 7, figs. 1-41; pl. 6, figs. 19-42.

DESCRIPTION

Cranidium rectangular, fairly convex; glabella large, smooth, slightly tapered anteriorly, very slightly elevated above rest of cranidium, three pairs of short, faint lateral glabellar depressions; occipital ring broad, triangular extending into a small spine; occipital furrow broad, shallow; frontal area narrow, about 0.25 glabellar length excluding occipital spine, convex; border furrow faint to obsolete on exterior, dividing frontal area in about two equal parts; facial suture nearly paraoblique; palpebral area narrow, less than 0.33 glabellar width, long, slightly convex; palpebral lobes medium sized, crescentiform, situated opposite center of glabella; posterior area short, wide with moderately deep , broad intramarginal furrow. Librigena elongate, fairly wide with medium sized eye at inner angle; broad

slightly convex ocular platform; border furrow faint to obsolete on outer surface; border fairly broad with short, slender genal spine.

Pygidium short, transverse, about twice as wide as long; axis slightly narrower than pleural lobes with two broad axial rings and a bluntly rounded terminal section well defined by broad, shallow axial furrows; pleural lobes convex with shallow, narrow, well defined pleural furrows; border moderate width, flat, narrowing posteriorly, defined by shallow border furrow.

Outer surface of test smooth to finely punctate; inner surface minutely punctate.

LOCATION AND HORIZON: BC TOP C, BC TOP D, BC-X1, BC-X4, BC-X8, and MC-1.

REMARKS

Well represented by 9 cranidia, 12 librigenae, and 11 pygidia. Length of largest well preserved cranidium is 13.5 mm.; width of pygidium, 9.0 mm. Though the majority of specimens show poor preservation and are broken, a few are quite well preserved. These are assigned to the species on the basis of characteristic glabellar, cranidial, and frontal area proportions and pygidial shape.

Arapahoia convexa Duncan

Arapahoia convexa Duncan in Lochman and Duncan, 1944, p. 117-8, pl. 10, figs. 30-35.

DESCRIPTION

Cranidium and librigena unknown.

Pygidium subtriangular, slightly less than twice as wide as long; axis same width as pleural lobe, slightly tapered with 3 to 4 well defined axial rings and a bluntly rounded terminal section; pleural lobes convex, crossed by 3 to 4 pairs of faint to obsolete interpleural furrows on inner surface, obsolete on outer surface; border furrow very faint to obsolete with border dropping nearly vertically to margin.

Outer surface of test smooth; inner surface minutely punctate.

LOCATION AND HORIZON: BC-X1, BC-X6, BC TOP C, LOC 3.

REMARKS

This species is represented by 5 fairly well preserved pygidia, ranging from 7.0 to 17.0 mm. wide, and distinguished by the triangular shape of the pygidia with slightly flared anterior of pleural lobes.

REFERENCES

Bridge, Josiah and Girty, George H., 1937, A Redescription of Roemer's Paleozoic Types from Texas: U. S. Geol. Survey Prof. Paper 186-M, p. 239-271

Brown, C.W., 1959, Diagenesis of late Cambrian oolitic limestone, Maurice Formation, Montana and Wyoming: Jour. Sed. Petrology, v. 29, p. 260-266

Conrad, T.A., 1839, Second Annual Report of T.A. Conrad: Third Ann. Rept. New York State Survey, Assembly Document no. 275, p. 57-66

Deiss, C.E.., 1936, Revision of type Cambrian formations and sections of Montana and Yellowstone Park: Geol. Soc. America Bull., V. 47, p. 1257-1342

Deland, C.R. and Shaw, A.B., 1956, Upper Cambrian Trilobites from western Wyoming: Jour. Paleont., v. 30, p. 23-34

Dorf, Erling and Lochman, Christina, 1940, Upper Cambrian formations in southern Montana: Geol. Soc. America Bull., v. 51, p. 541-556

Hall, James, 1863, Contributions to Paleontology: 16th Ann. Report, New York State Cab. Natural History, 226 p.

Hanson, A.M.., 1952, Cambrian stratigraphy in southwestern Montana: Montana Bur. of Mines and Geology, Mem., 33, p. 1-44

Howell, B.F., 1945, Revision of the Upper Cambrian faunas of New Jersey: Geol. Soc. America Memoir 12, 46 pp.

_____, 1957, Upper Cambrian fossils from Bucks County, Pennsylvania: Bull. Pennsylvania Geol. Survey, 4th ser., no. G28, 39 pp.

Howell, B.F. and Duncan, D., 1939, Middle-Upper Cambrian transition faunas of North America: Wagner Free Inst. of Science, v. 14, no. 1, 11 pp.

Howell, B.F. and others, 1944, Correlation of the Cambrian formations of North America: Geol. Soc. America Bull., v. 55, p. 993-1003

Hu, Chung-Hung, 1969, Ontogeny and sexual dimorphism of three Upper Cambrian trilobites: Nanyang University Journal, v. III, p. 438-462

Kindle, C.R., 1948, Crepicephalid trilobites from Murphy Creek, Quebec and Cowhead, Newfoundland: Amer. Jour. Science, v. 246, p. 441-451

Kobayashi, T., 1935, The Cambro-Ordovician formations and faunas of South Chosen, Paleontology Pt. 3: Tokyo Univ. Fac. Science Jour., sec. 2, v. 4, p. 49-344

_____, 1938, Upper Cambrian fossils from British Columbia with a discussion on the isolated occurrence of the so-called "Olenus" beds of Mt. Jubilee: Japanese Jour. Geol. and Geog., v. 15, nos. 3-4, p. 151-192

Lochman, Christina, 1936, New trilobite genera from the Bonneterre Dolomite (Upper Cambrian) of Missouri: Jour. Paleont., v. 10, p. 35-43

_____, 1938a, Upper Cambrian faunas of the Cap Mountain formation of Texas: Jour. Paleont., v. 12, p. 72-85

_____, 1938b, Middle and Upper Cambrian faunas from western Newfoundland: Jour. Paleont., v. 12, p. 461-477

_____, 1940, Fauna of the basal Bonneterre Dolomite (Upper Cambrian) of southeastern Missouri: Jour. Paleont., v. 14, p. 1-53

_____, 1950, Upper Cambrian faunas of the Little Rocky Mountains, Montana: Jour. Paleont., v. 24, p. 322-349

_____, 1968, Crepicephalus faunule from the Bonneterre Dolomite (Upper Cambrian) of Missouri: Jour. Paleont., v. 42, p. 1153-62

Lochman-Balk, Christina, 1970, Upper Cambrian faunal patterns on the Craton: Geol. Soc. America Bull., v. 81, p. 3197-3224

Lochman, Christina and Duncan, D. C., 1944, Early Upper Cambrian faunas of central Montana: Geol. Soc. America Spec. Paper 54, 181 pp.

_____ and Hu, Chung-Hung, 1960, Upper Cambrian faunas from the northwest Wind River Mountains, Wyoming, Pt. I: Jour. Paleont., V. 34, p. 793-834

_____, 1961, Upper Cambrian faunas from the northwest Wind River Mountains, Pt. II: Jour. Paleont., v. 35, p. 125-146

_____, 1962a, Upper Cambrian faunas from the northwest Wind River Mountains, Pt. III: Jour. Paleont., v. 36, p. 1-28

_____, 1962b, An Aphelaspis faunule from Logan, Montana: Jour. Paleont., v. 36, p. 431-441

Miller, B.M., 1936, Cambrian trilobites from northwestern Wyoming: Jour. Paleont., v. 10, p. 23-34

Nelson, C.A., 1951, Cambrian trilobites from the St. Croix valley: Jour. Paleont., v. 25, p. 765-784

Palmer, A.R., 1953, Aphelaspis Resser and its genotype: Jour. Paleont., v. 27, p. 157

_____, 1955 (1954), The fauna of the Riley Formation in central Texas: Jour. Paleont., v. 28, p. 709-786

_____, 1962, Glyptagnostus and associated trilobites in the United States: U.S. Geol. Survey Prof. Paper 274-F, 49 pp.

_____, 1965, Trilobites of the Late Cambrian Pterocephaliid Biomere in the Great Basin, United States: U.S. Geol. Survey Prof. Paper 493, 103 pp.

Raasch, G.O. and Lochman, Christina, 1943, Revision of three early Upper Cambrian trilobite genera: Jour. Paleont., v. 17, p. 221-235

_____, 1945, Crepicephalus edwardsi Raasch, new name for Crepicephalus oweni Raasch: Jour. Paleont. v. 19, p. 77

Rasetti, F., 1946, Early Upper Cambrian trilobites from western Gaspé: Jour. Paleont., v. 20, p. 442-462

_____, 1956, Revision of the trilobite genus Maryvillia Walcott: Jour. Paleont., v. 30, p. 1266-1269

_____, 1961, Dresbachian and Franconian trilobites of the Conococheague and Frederick Limestones of the central Appalachians: Jour. Paleont., v. 35, p. 104-124

_____, 1965, Upper Cambrian trilobite faunas of northeastern Tennessee: Smithson. Misc. Colls., v. 148, no. 3, 127 pp.

Resser, C.E., 1935, Nomenclature of some Cambrian trilobites: Smithson. Misc. Colls., v. 93, no. 3, p. 1-46

_____, 1937, Third contribution to nomenclature of Cambrian trilobites: Smithson. Misc. Colls., v. 95, no. 2, p. 1-29

_____, 1938a, Cambrian System (restricted) of the southern Appalachians: Geol. Soc. America Spec. Paper 15, 140 pp.

_____, 1938b, Fourth contribution to nomenclature of Cambrian fossils: Smithson. Misc. Colls., v. 97, no. 10, p. 1-43

_____, 1942, New Upper Cambrian trilobites, Smithson. Misc. Colls., v. 103, no. 8, p. 1-131

Shaw, A.B., 1952, Paleontology of northwestern Vermont II; fauna of the Upper Cambrian Rockledge Conglomerate near St. Albans: Jour. Paleont., v. 26, p. 458-483

_____, 1956, A Cambrian Aphelaspis fauna from Steele Butte, near Boulder, Wyoming: Jour. Paleont., v. 30, p. 48-52

Shumard, B.F., 1861, The primordial zone of Texas, with descriptions of new fossils: Amer. Jour. Science, 2nd ser., v. 32, p. 213-221

Tasch, P., 1951, Fauna and paleoecology of the Upper Cambrian Warrior Formation of central Pennsylvania: Jour. Paleont., v. 25, p. 275-306

Walcott, C.D., 1890, Description of new forms of Upper Cambrian fossils: Proc. U.S. Nat. Museum., v. 13, p. 266-279

_____, 1899, Geology of the Yellowstone National Park: U.S. Geol. Survey, Mono. 32, pt. 2, p. 440-478

_____, 1912, Cambrian Brachiopoda: U. S. Geol. Survey, Mono. 51, vs. 1,2, 872 pp.

_____, 1916a, Cambrian geology and paleontology III, # 3, Cambrian trilobites: Smithson. Misc. Colls., v. 64, p. 157-259

_____, 1916b, Cambrian geology and paleontology III, # 5, Cambrian trilobites: Smithson. Misc. Colls., v. 64, p. 307-456

_____, 1920, Cambrian geology and paleontology IV, # 6, Middle Cambrian Spongiae: Smithson. Misc. Colls., v. 67, # 6, p. 263-364

_____, 1924, Cambrian geology and paleontology V, # 2, Cambrian and Ozarkian trilobites: Smithson. Misc. Colls., v. 75, 53-66

_____, 1925, Cambrian geology and paleontology V, # 3, Cambrian and Ozarkian trilobites: Smithson Misc. Colls., v. 75, p. 61-146

Weed, W.H., 1900, Geology of the Little Belt Mountains, Montana: U. S. Geol. Survey, 20th Ann. Rept. Pt. 3, p. 285-286

Whitfield, R.P., 1876, Rept of reconnaissance from Carroll, Montana Territory on the upper Missouri, to the Yellowstone National Park (Ludlow), p. 141

_____, 1877, Preliminary Report of paleontology of Black Hills: U.S. Geol. Survey, p. 10

Wilson, J.L., 1954, Late Cambrian and early Ordovician trilobites from the Marathon Uplift, Texas: Jour. Paleont., v. 28, p. 249-285

_____, 1956, Revisions in nomenclature and new species of Cambro-Ordovician trilobites from the Marathon Uplift, Texas: Jour. Paleont., v. 30, p. 1341-1349

Winchell, N.H., 1873, The geological and natural history survey of Minnesota: Minnesota Geol. and Nat. Hist. Survey, 1st Ann. Rept. for 1872, 17 pp.

ADDITIONAL REFERENCES

Folk, Robert L., 1962, Spectral Subdivision of Limestone Types, Classification of Limestone Rocks: AAPG Mem. no. 1, pp. 62-84.

Friedman, G. M., 1964, Early Diagenesis and Lithification in Carbonate Sediments: Jour. Sed. Pet., v.34, pp. 777-813.

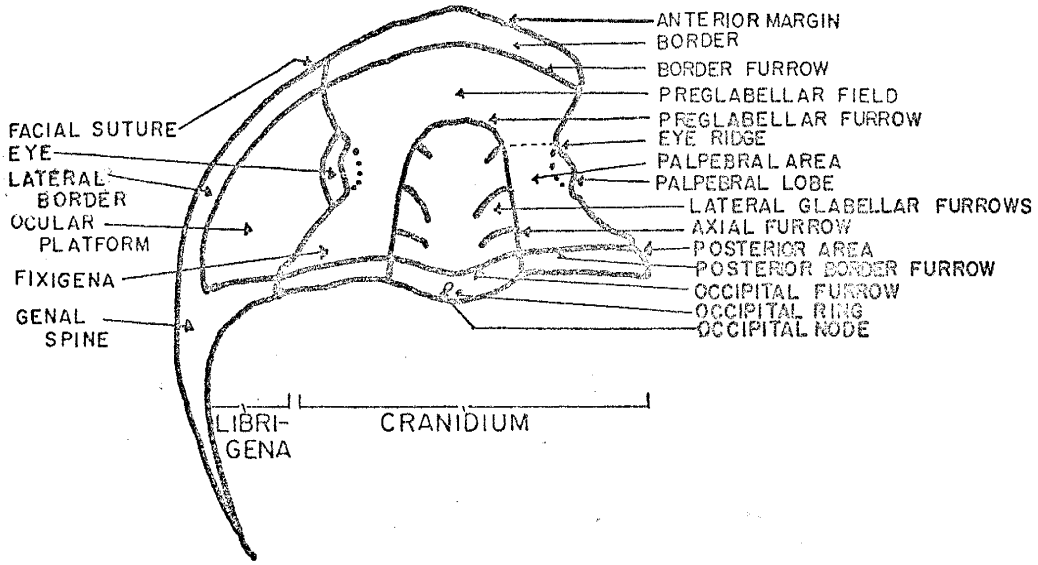
_____, 1969, Recognizing Carbonate Environments in Carbonate Rocks with Particular Reference to those of the Lower Paleozoic in the Northern Appalachians (abst.): Geol. Soc. Amer. N.E. Sec., pp.20-21.

Pettijohn, F.J., 1957, Sedimentary Rocks: Harper and Row, New York, 718 pp.

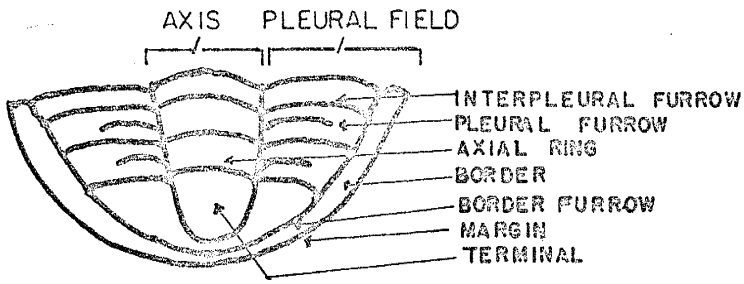
APPENDIX A

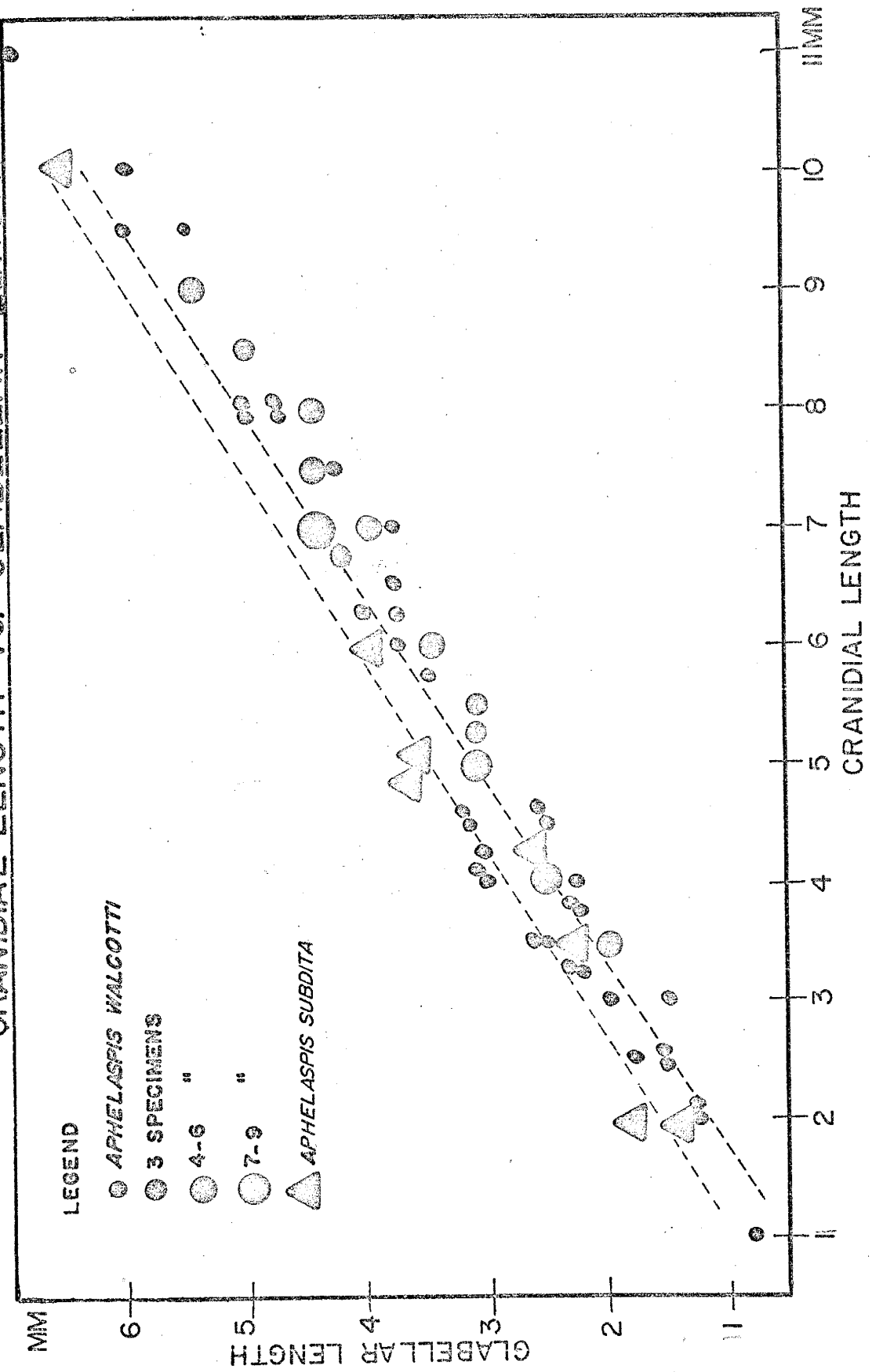
APHELASPIS

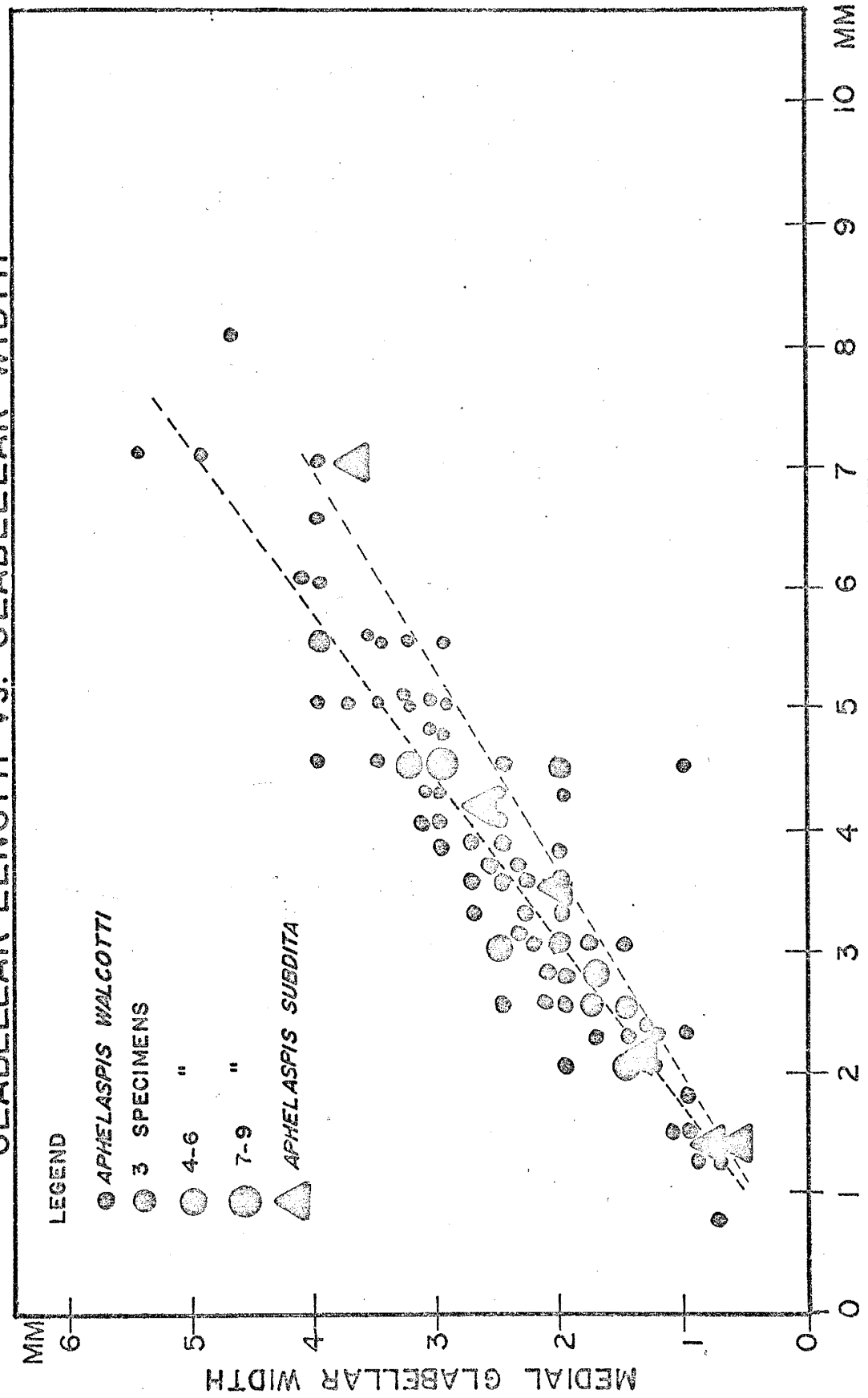
CEPHALON

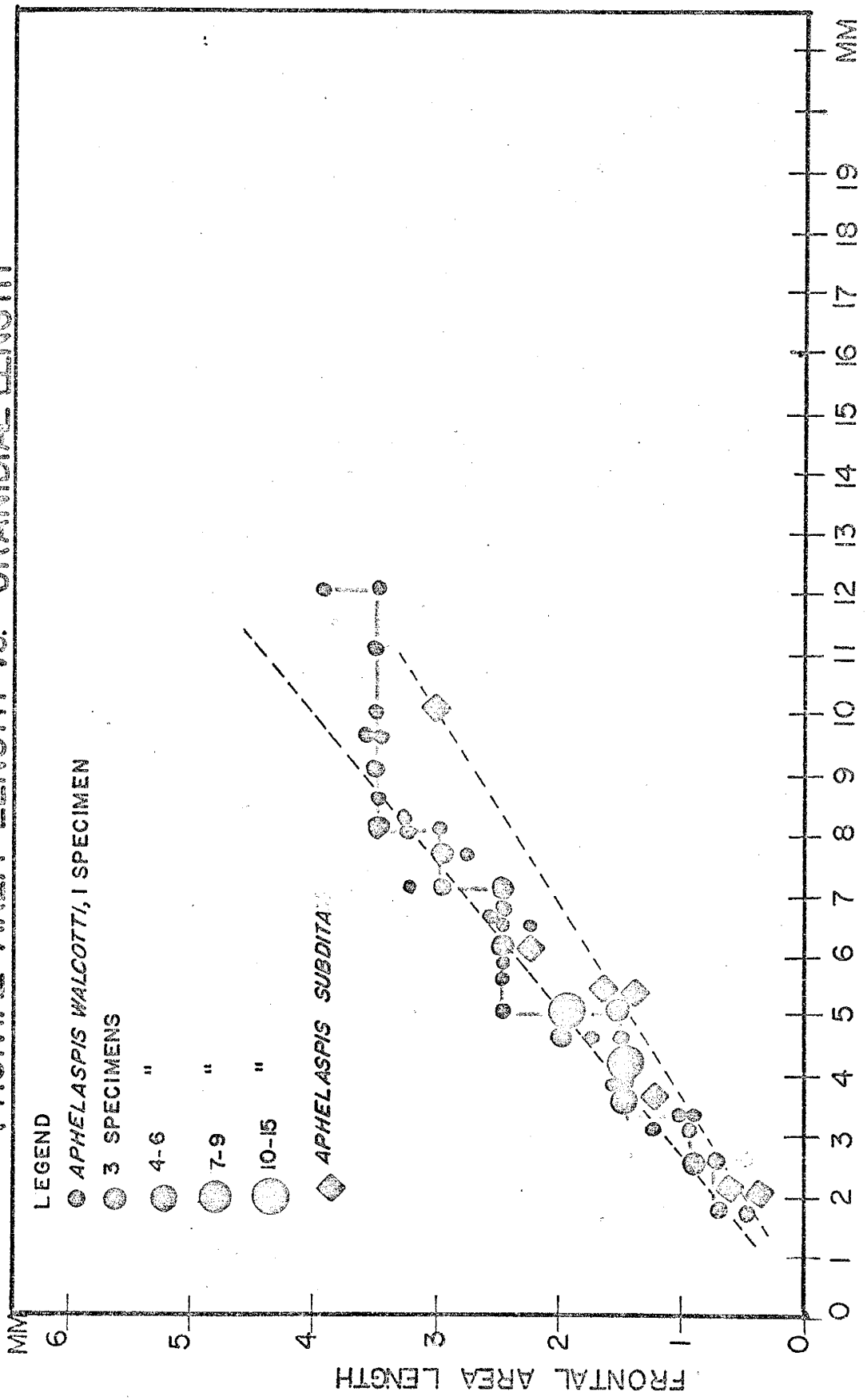


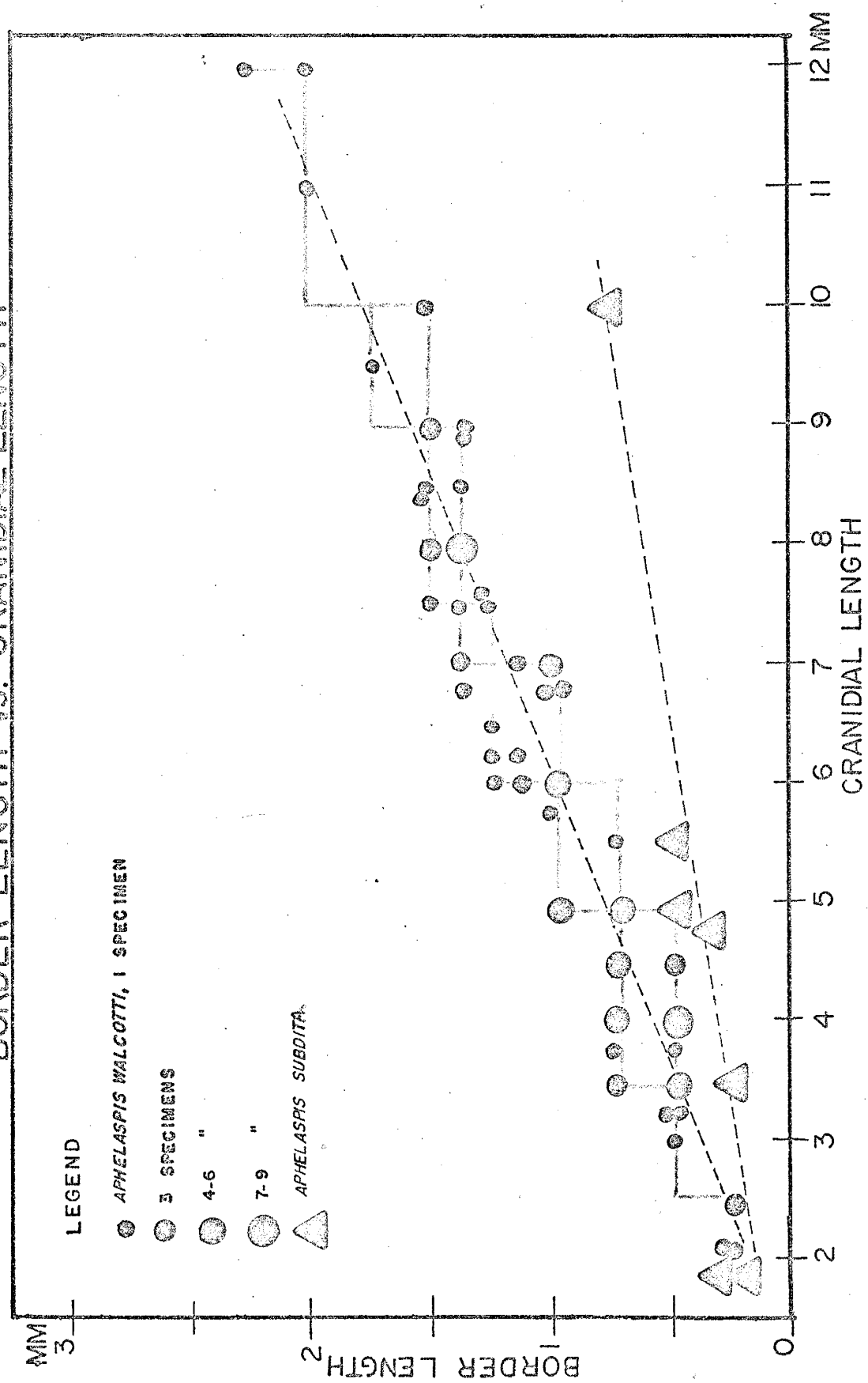
PYGIDIUM

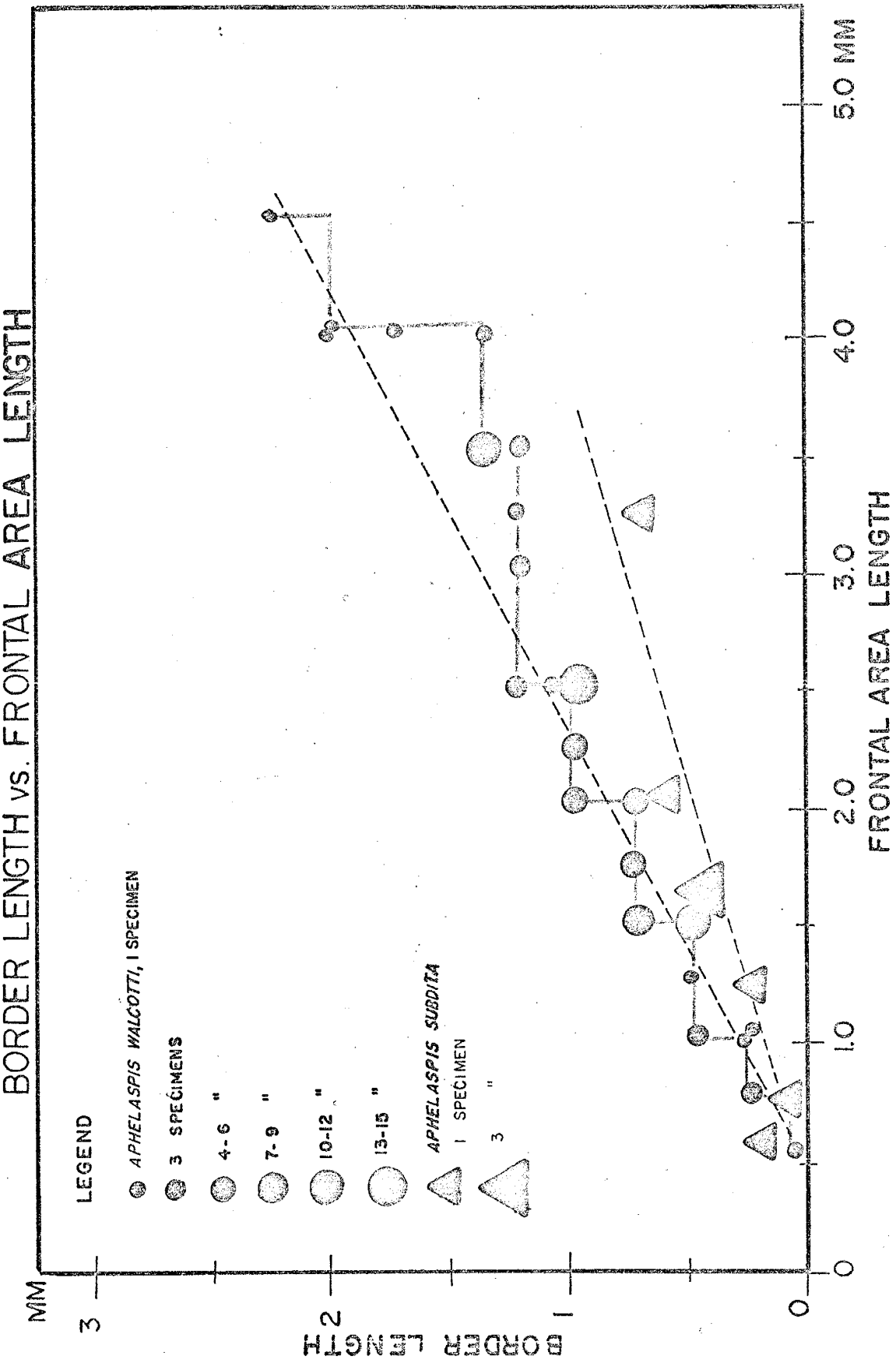


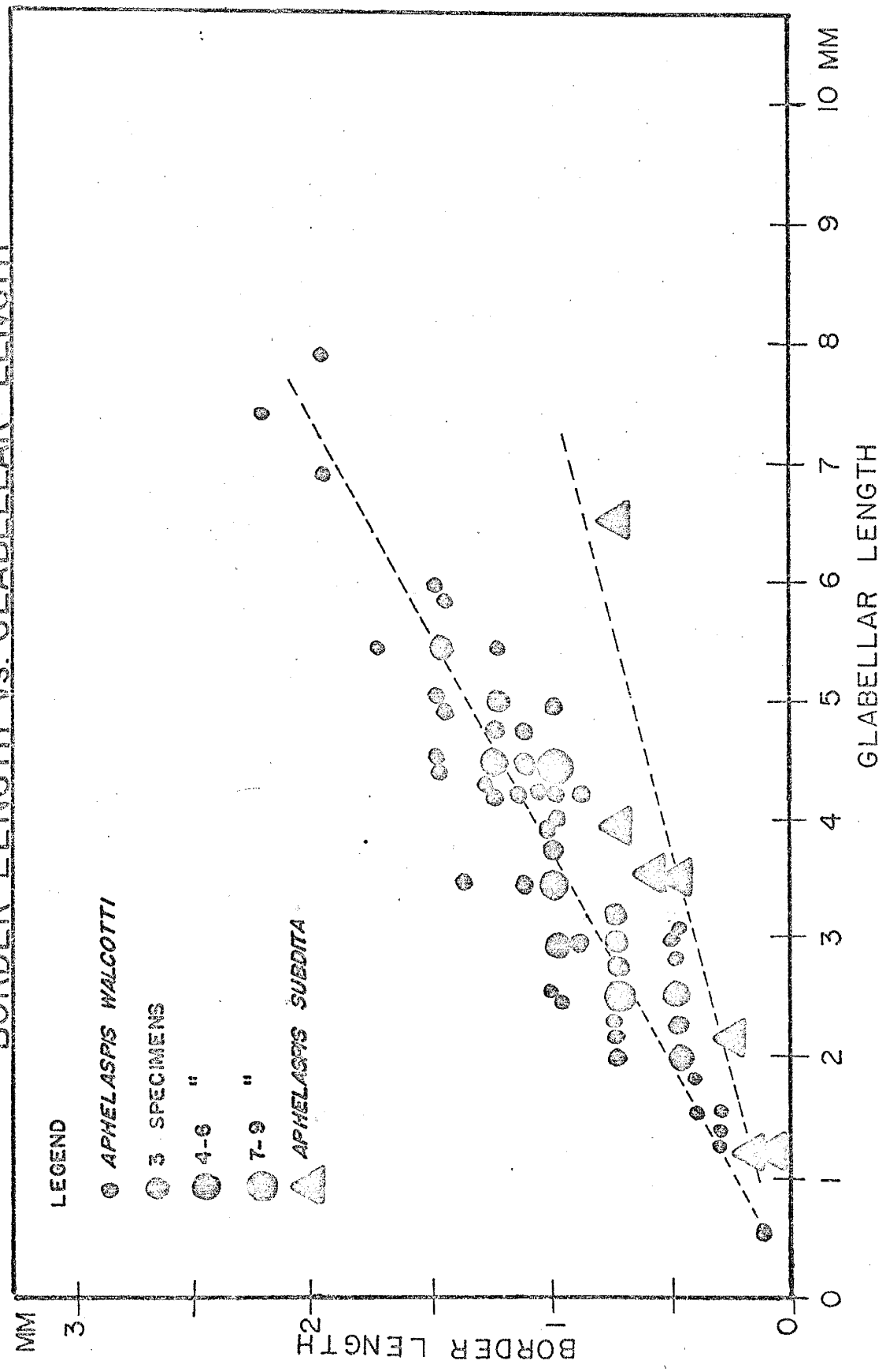

CRANIDIAL LENGTH vs. GLABELLAR LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
MM
GLABELLAR LENGTH
CRANIDIAL LENGTH
MM
1
2
3
4
5
6
7
8
9
10
11

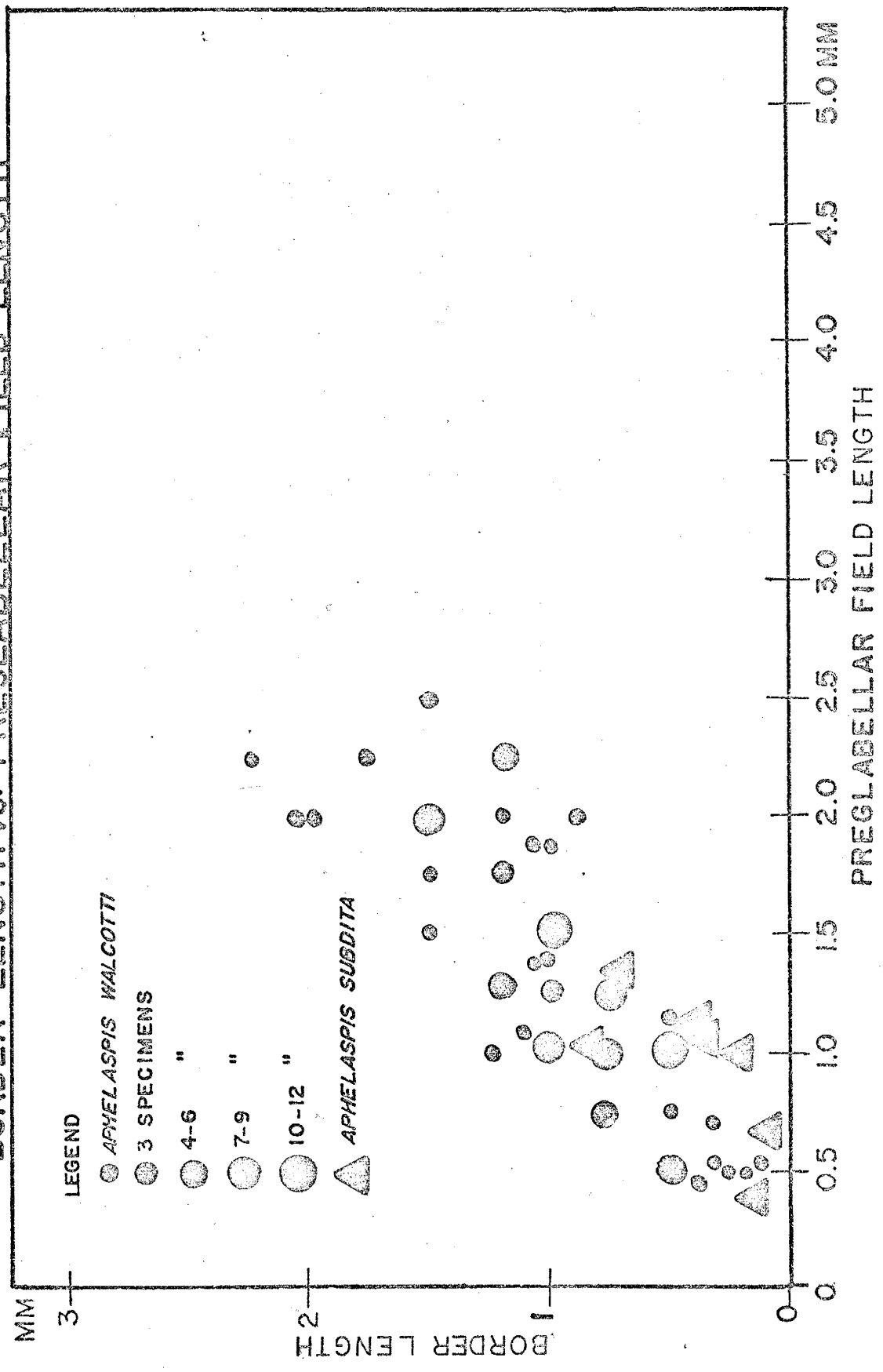

GLABELLAR LENGTH vs. GLABELLAR WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
MEDIAL GLABELLAR WIDTH
MM
0
1
2
3
4
5
6
GLABELLAR LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM

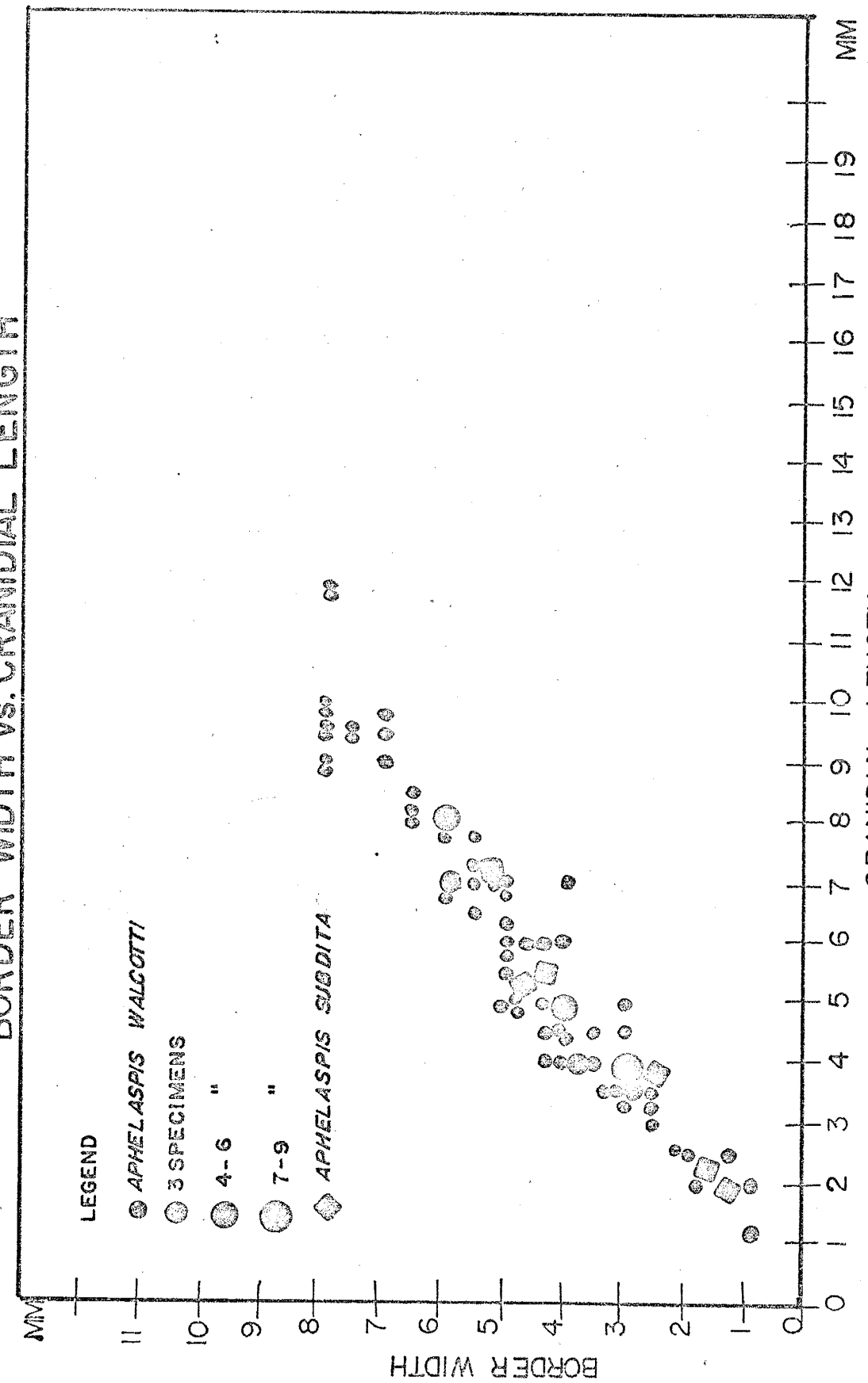

FRONTAL AREA LENGTH VS. CRANIDIAL LENGTH
LEGEND
APHELASPIS WALCOTTI, 1 SPECIMEN
3 SPECIMENS
4-6 "
7-9 "
10-15 "
APHELASPIS SUBDITA
FRONTAL AREA LENGTH
MM
0
1
2
3
4
5
6
CRANIDIAL LENGTH
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
MM

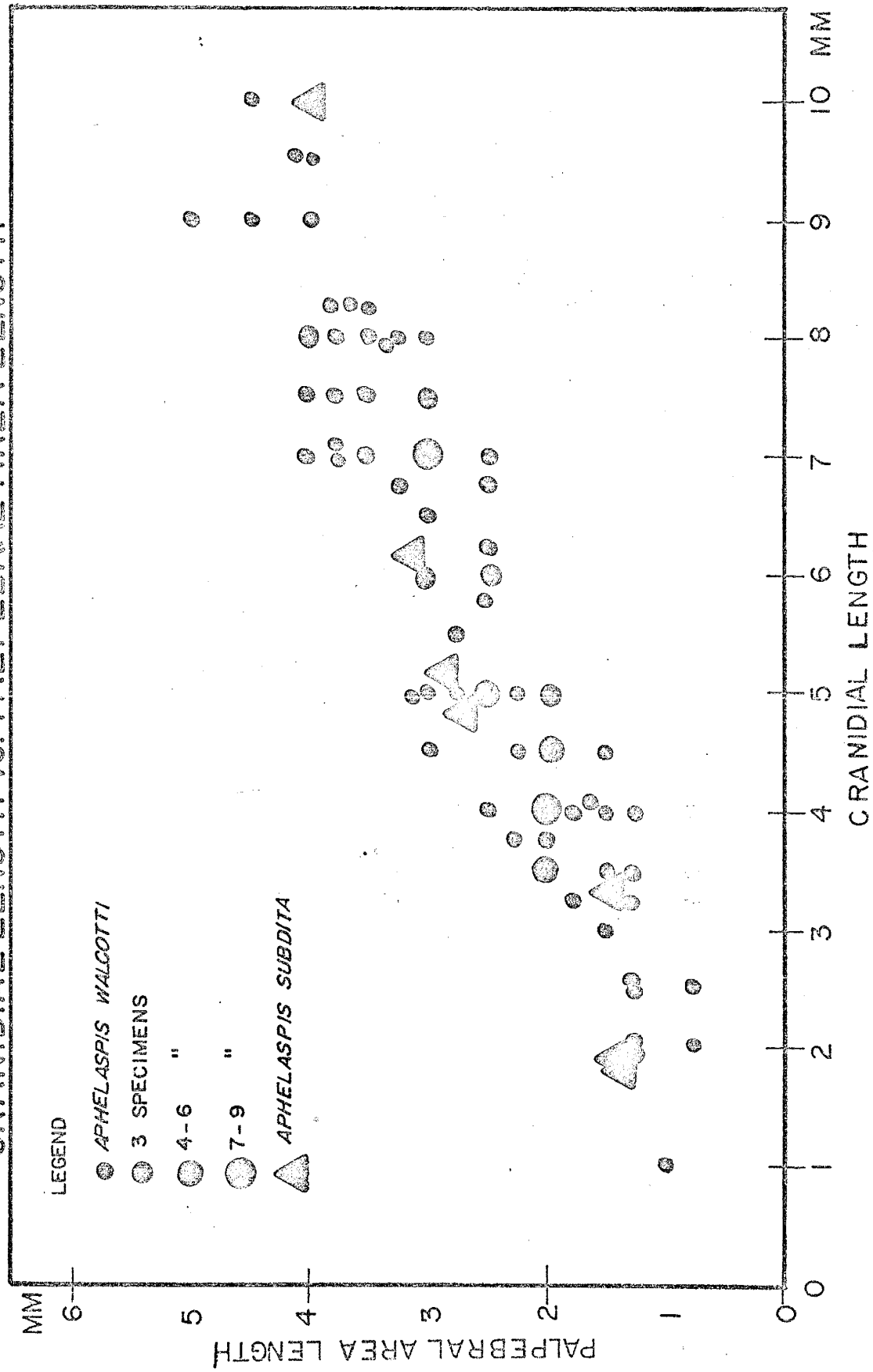

BORDER LENGTH vs. CRANIDIAL LENGTH
LEGEND
APHELASPIS WALCOTTI, 1 SPECIMEN
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
MM
3
2
1
0
BORDER LENGTH
2
3
4
5
6
7
8
9
10
11
12 MM
CRANIDIAL LENGTH

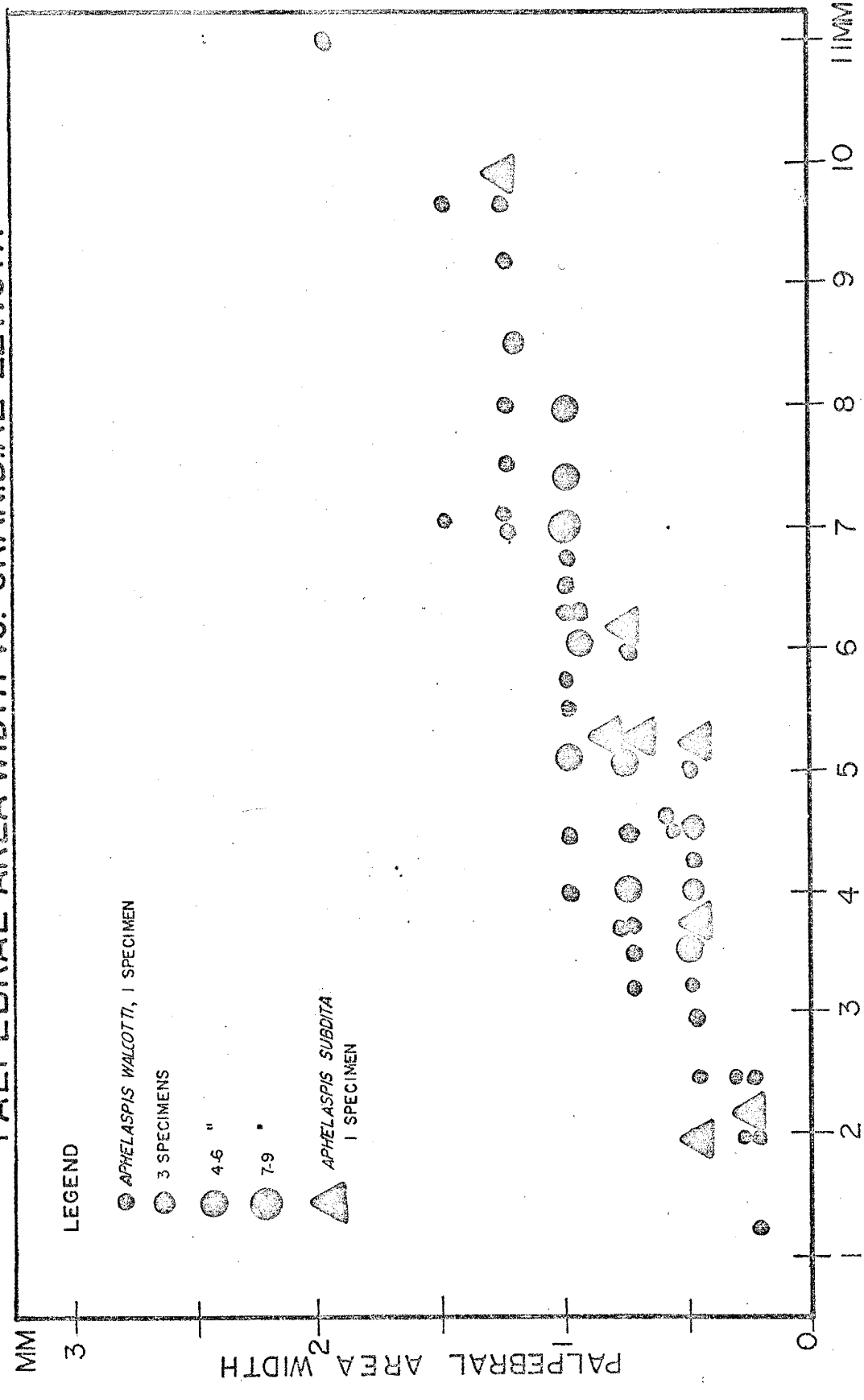

BORDER LENGTH vs. FRONTAL AREA LENGTH
LEGEND
APHELASPIS WALCOTTI, I SPECIMEN
3 SPECIMENS
4-6 "
7-9 "
10-12 "
13-15 "
APHELASPIS SUBDITA
I SPECIMEN
3 "
MM
3
2
1
0
BORDER LENGTH
0
1.0
2.0
3.0
4.0
5.0 MM
FRONTAL AREA LENGTH

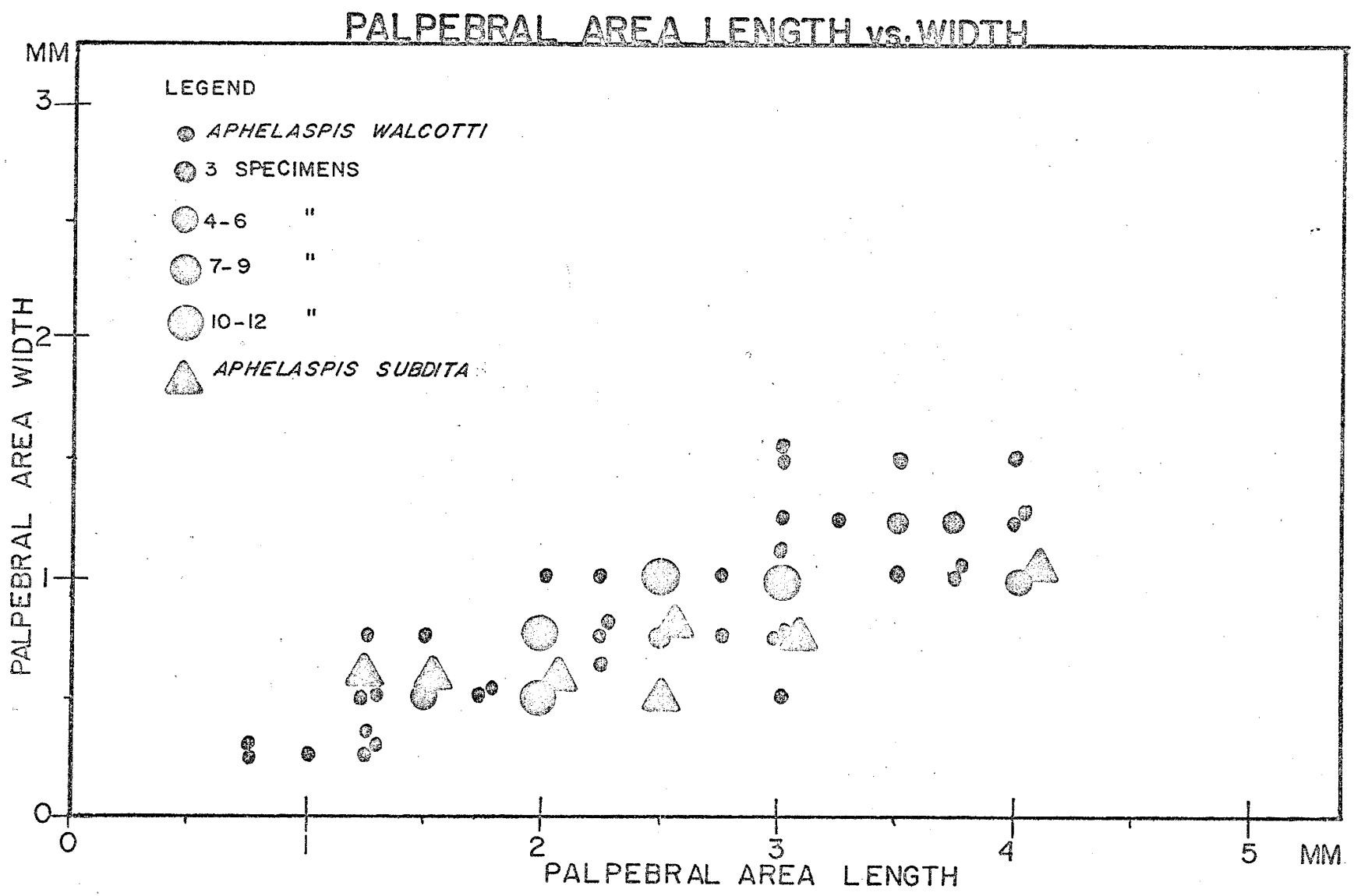

BORDER LENGTH vs. GLABELLAR LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
MM
3
2
1
0
BORDER LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM
GLABELLAR LENGTH

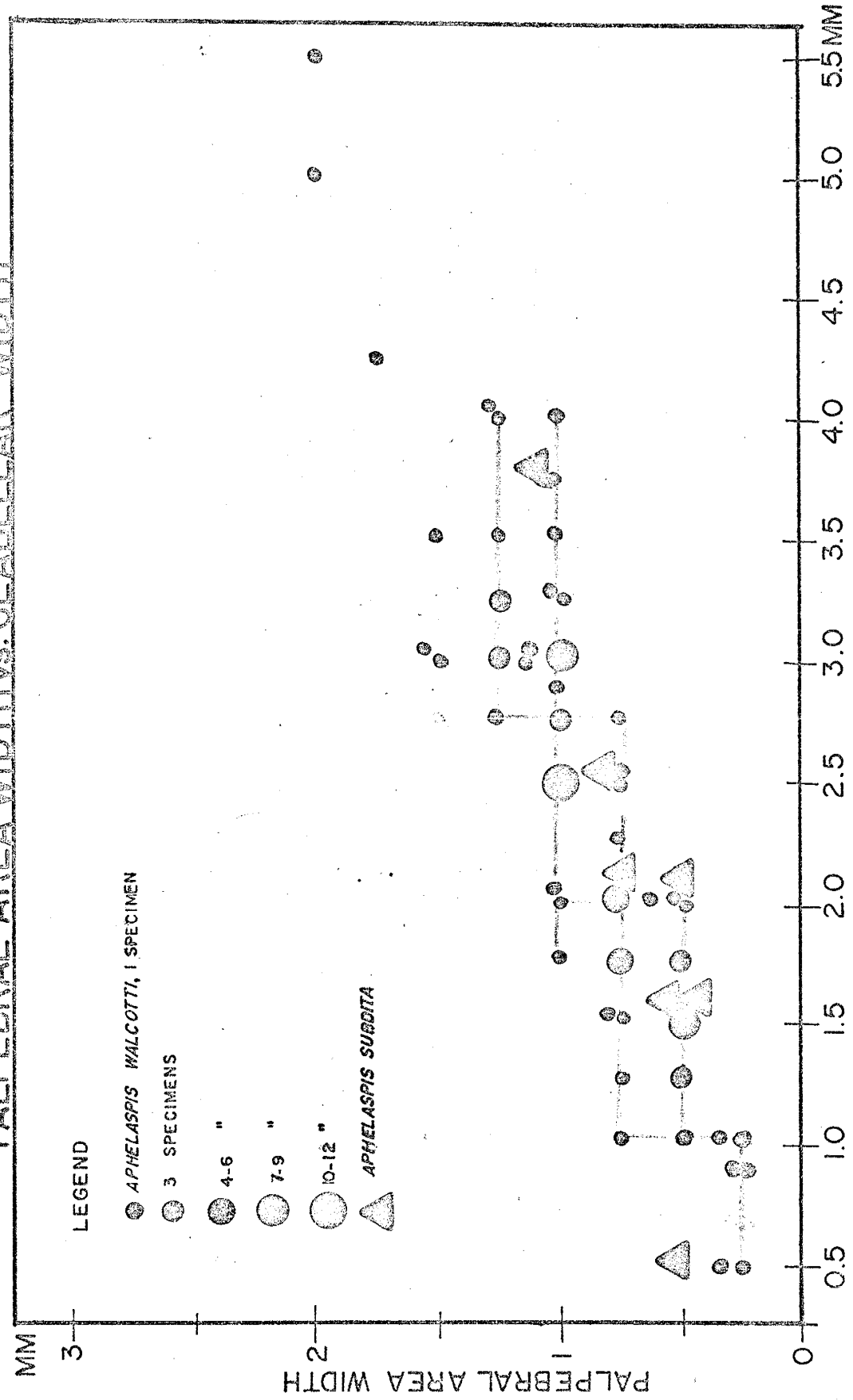

BORDER LENGTH vs. PREGLABELLAR FIELD LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
10-12 "
APHELASPIS SUSDITA
MM
3
2
1
0
BORDER LENGTH
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0 MM
PREGLABELLAR FIELD LENGTH

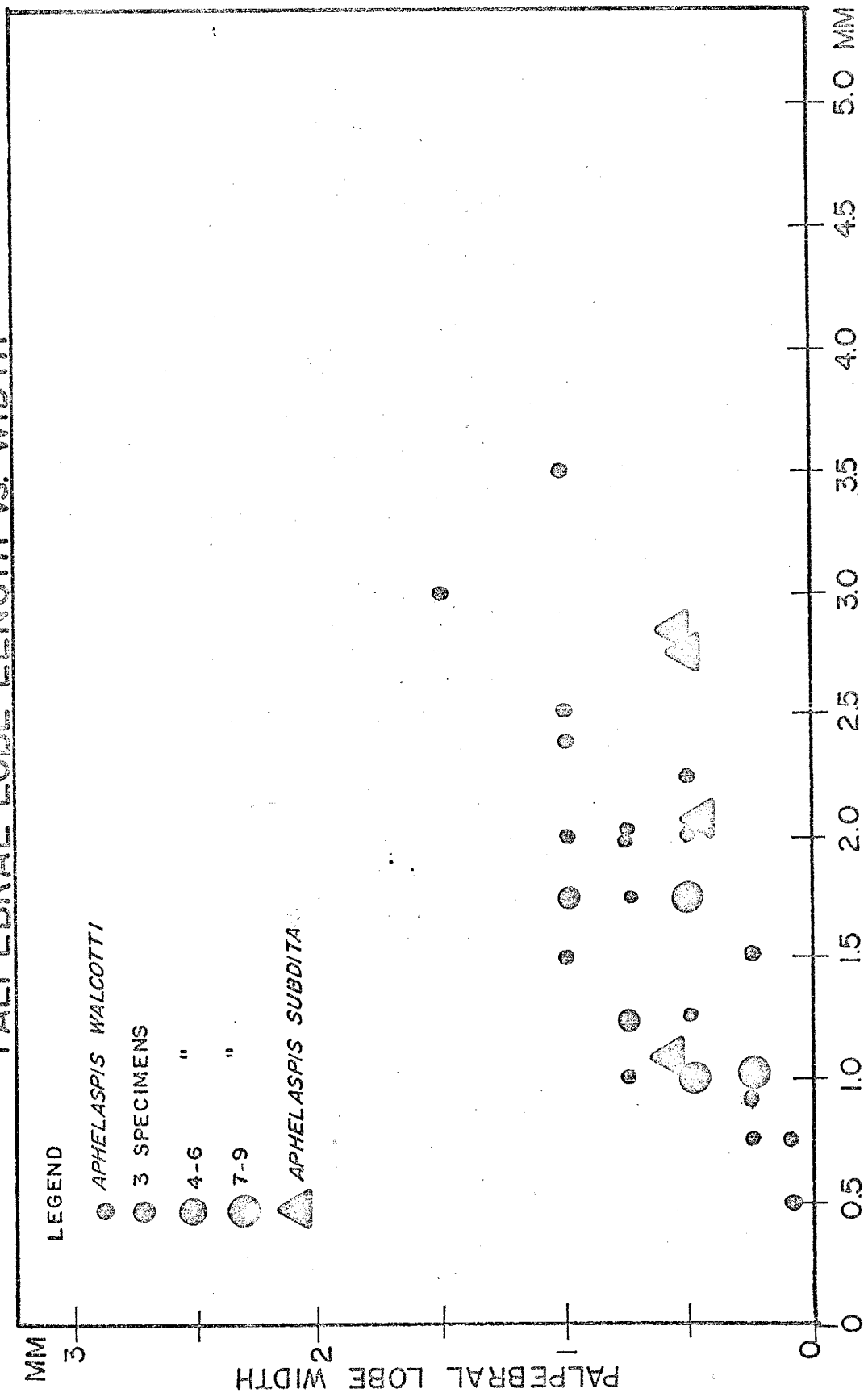

BORDER WIDTH vs. CRANIDIAL LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
BORDER WIDTH
CRANIDIAL LENGTH
MM
MM
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
0 1 2 3 4 5 6 7 8 9 10 11

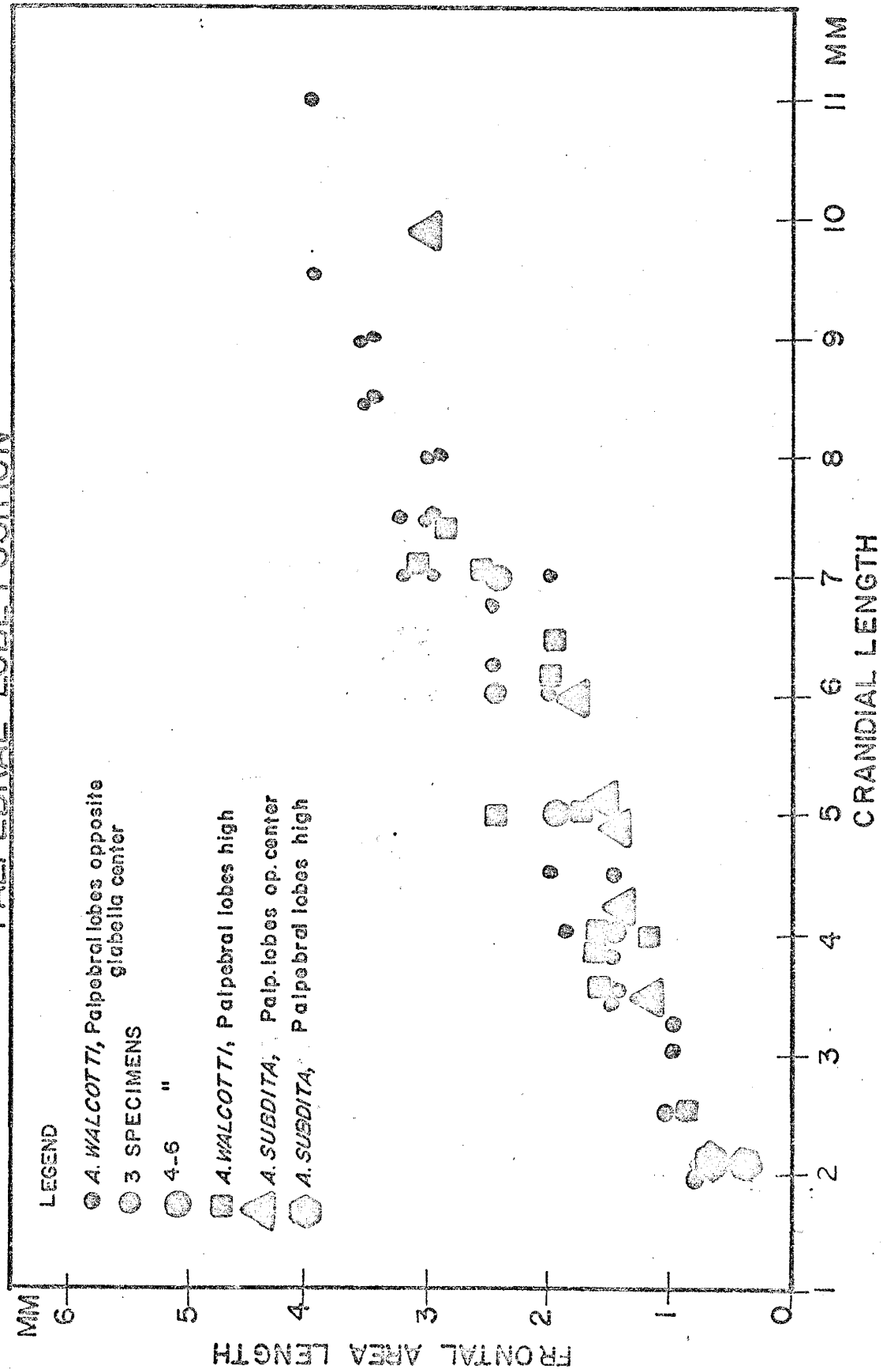

CRANIDIAL LENGTH vs. PALPEBRAL AREA LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
PALPEBRAL AREA LENGTH
MM
0
1
2
3
4
5
6
CRANIDIAL LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM

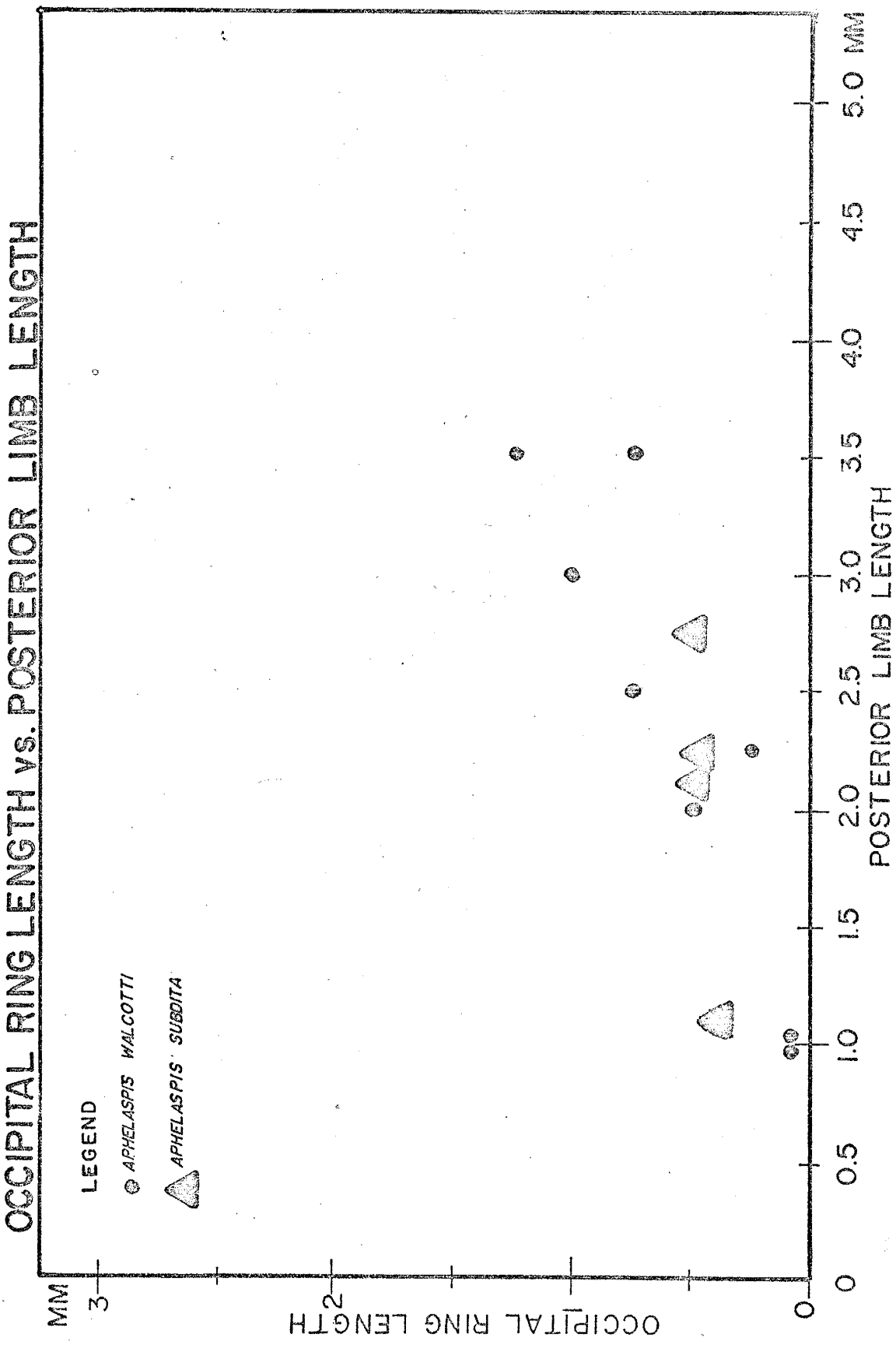

PALPEBRAL AREA WIDTH vs. CRANIDIAL LENGTH
LEGEND
APHELASPIS WALCOTTI, 1 SPECIMEN
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
1 SPECIMEN
MM
3
2
1
0
PALPEBRAL AREA WIDTH
1
2
3
4
5
6
7
8
9
10
11MM
CRANIDIAL LENGTH

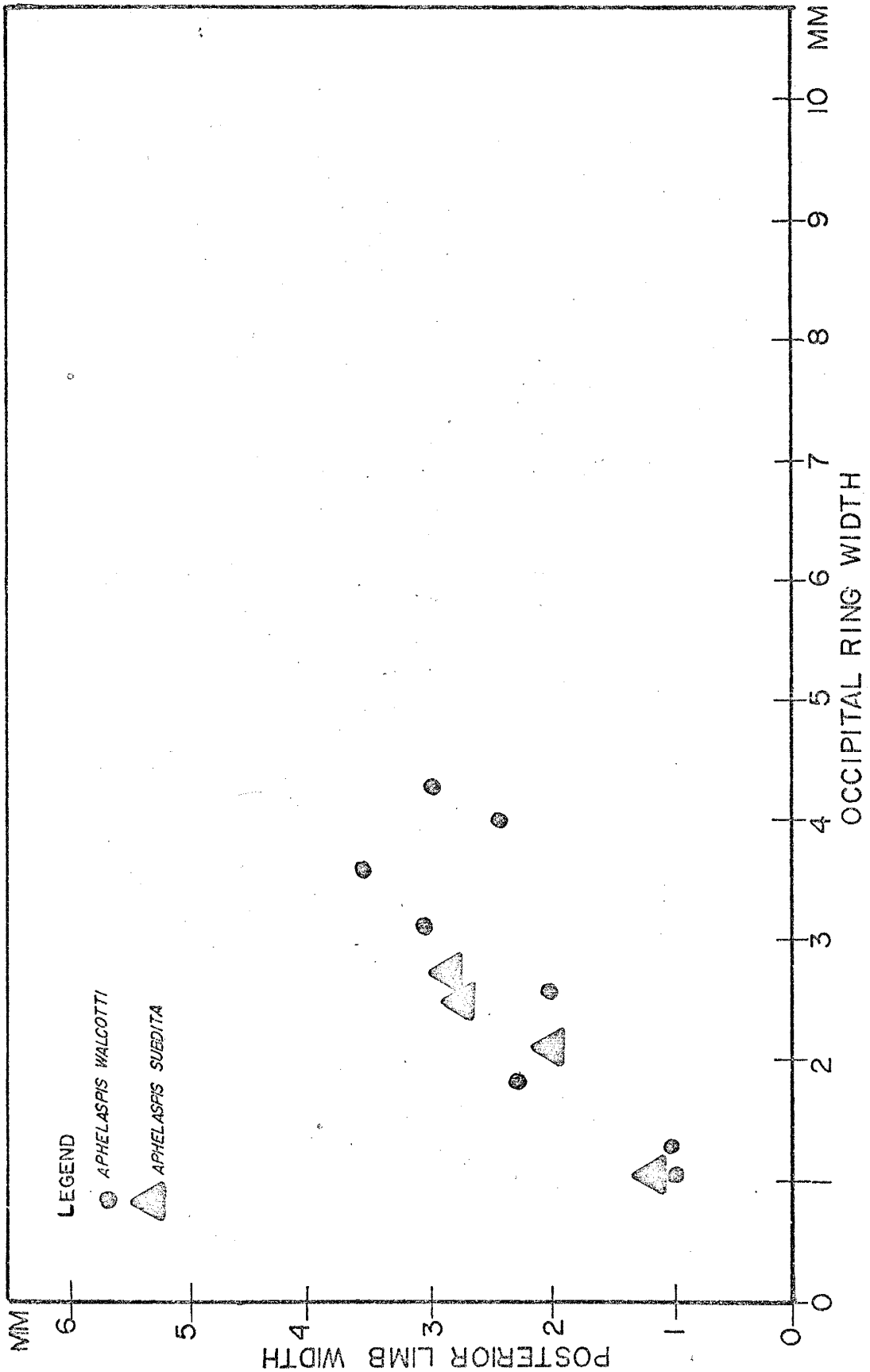

PALPEBRAL AREA LENGTH vs. WIDTH
MM
3
2
1
0
PALPEBRAL AREA WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
10-12 "
APHELASPIS SUBDITA
0
2
3
4
5
MM
PALPEBRAL AREA LENGTH

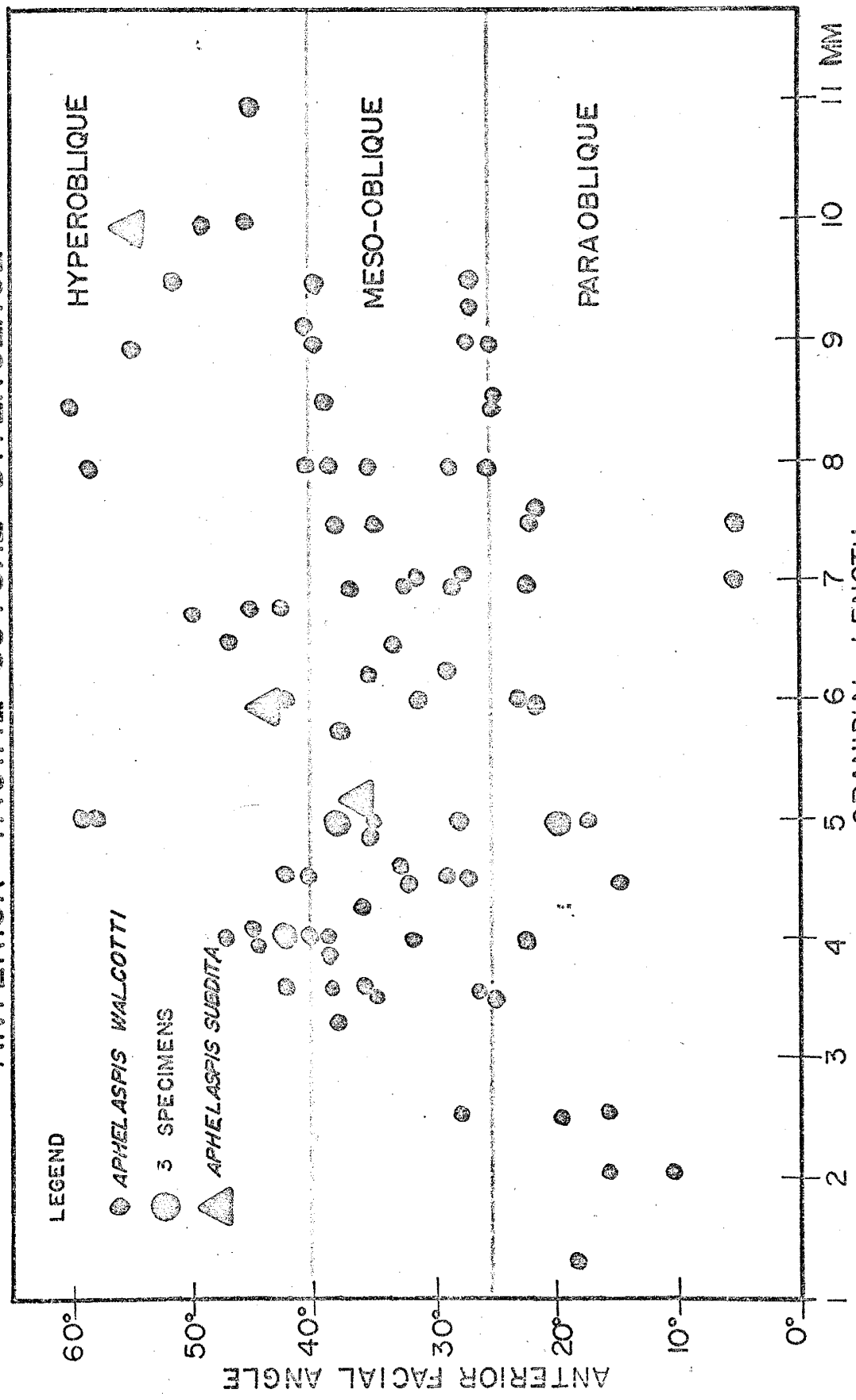

PALPEBRAL AREA WIDTH vs. GLABELLAR WIDTH
LEGEND
APHELASPIS WALCOTTI, 1 SPECIMEN
3 SPECIMENS
4-6 "
7-9 "
10-12 "
APHELASPIS SUBDITA
MM
3
2
1
0
PALPEBRAL AREA WIDTH
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5MM
MEDIAL GLABELLAR WIDTH

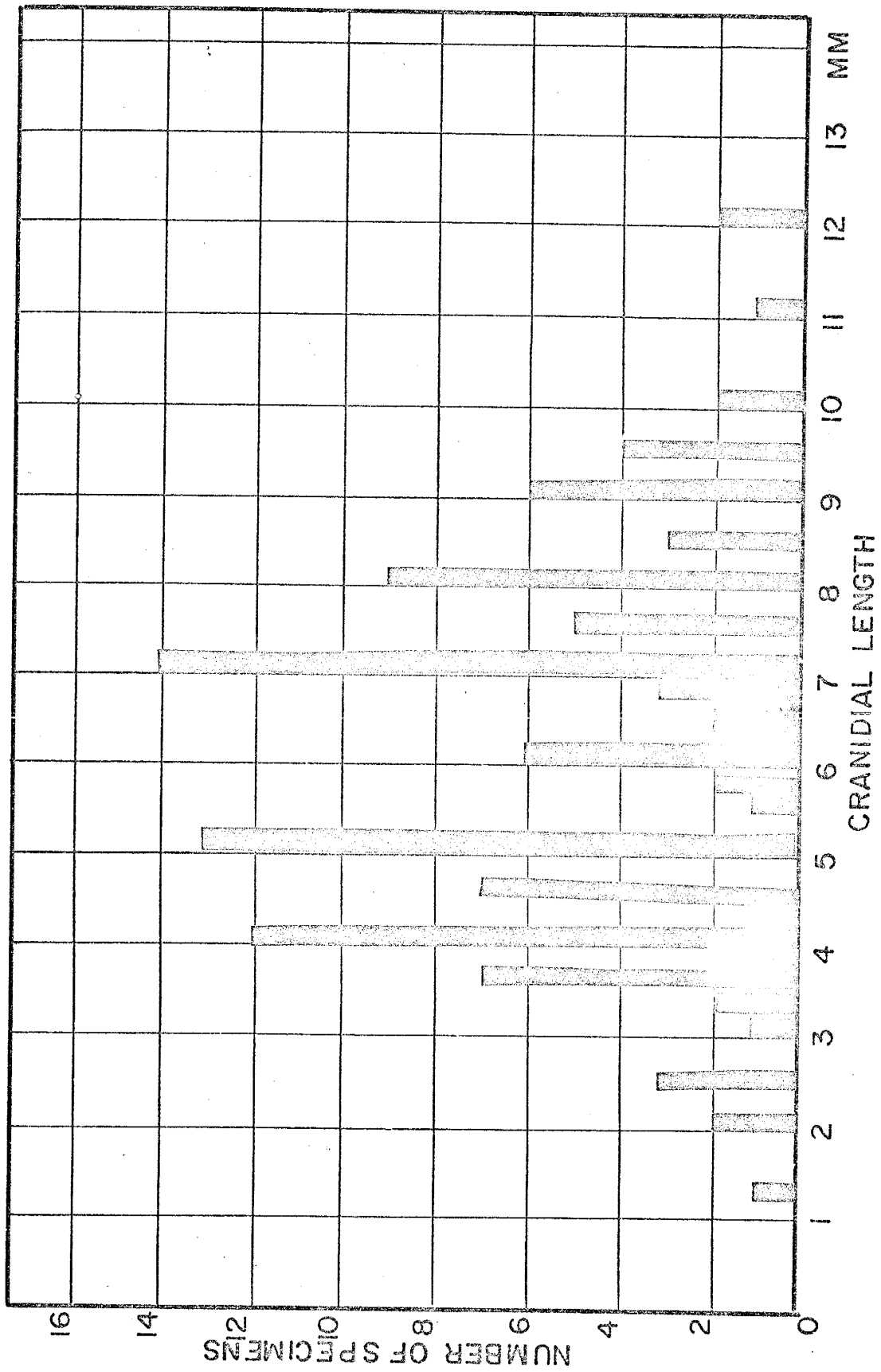

PALPEBRAL LOBE LENGTH vs. WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
APHELASPIS SUBDITA
MM
3
2
1
0
PALPEBRAL LOBE WIDTH
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0 MM
PALPEBRAL LOBE LENGTH

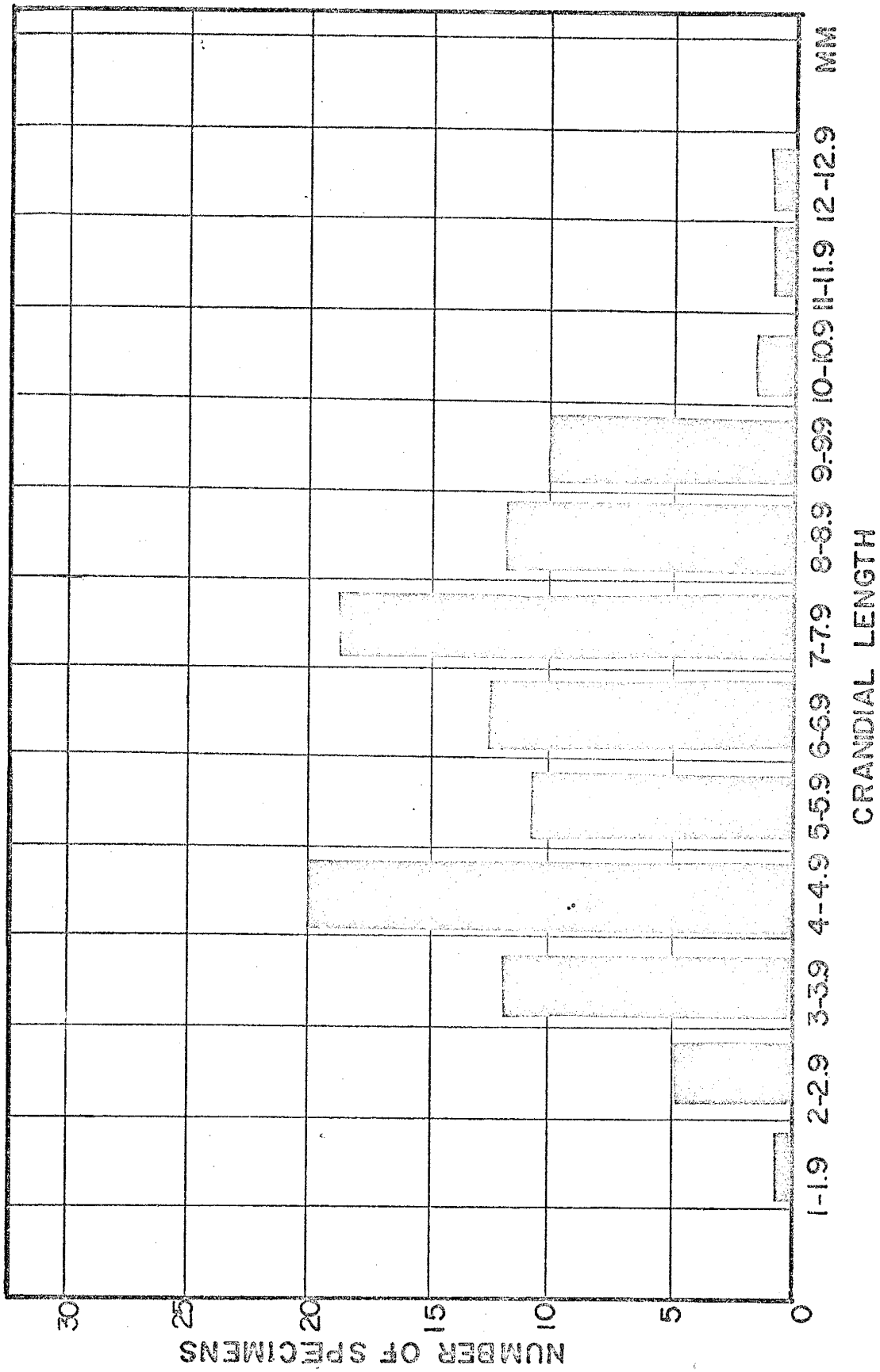

PALPEBRAL LOBE POSITION
LEGEND
A. WALCOTTI, Palpebral lobes opposite glabella center
3 SPECIMENS
4-6 "
A. WALCOTTI, Palpebral lobes high
A. SUBDITA, Palp. lobes op. center
A. SUBDITA, Palpebral lobes high
FRONTAL AREA LENGTH
MM
0
1
2
3
4
5
6
CRANIAL LENGTH
1
2
3
4
5
6
7
8
9
10
11 MM

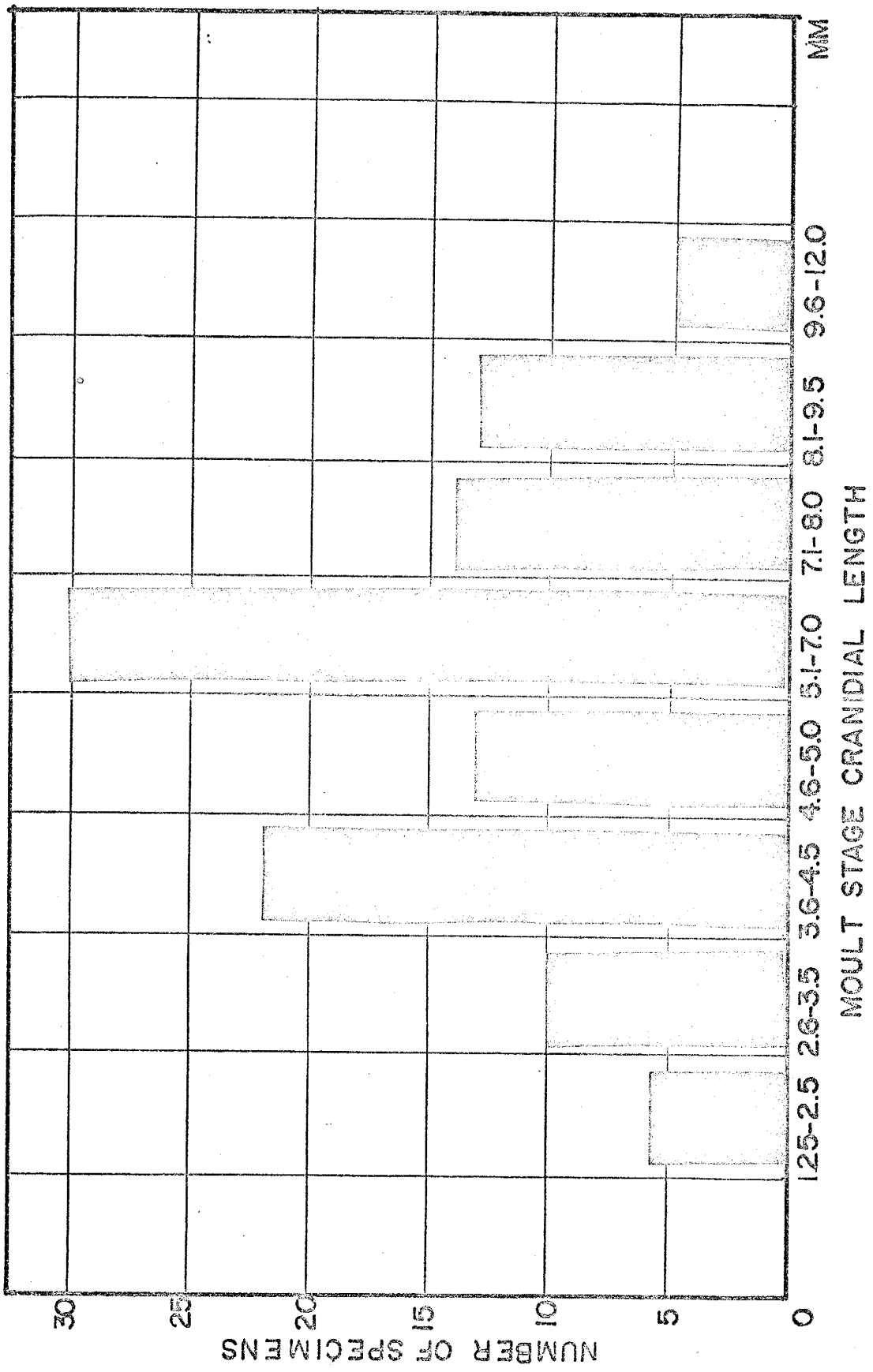

OCCIPITAL RING LENGTH vs. POSTERIOR LIMB LENGTH
LEGEND
APHELASPIS WALCOTTI
APHELASPIS SUBDITA
MM
3
2
0
OCCIPITAL RING LENGTH
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0 MM
POSTERIOR LIMB LENGTH

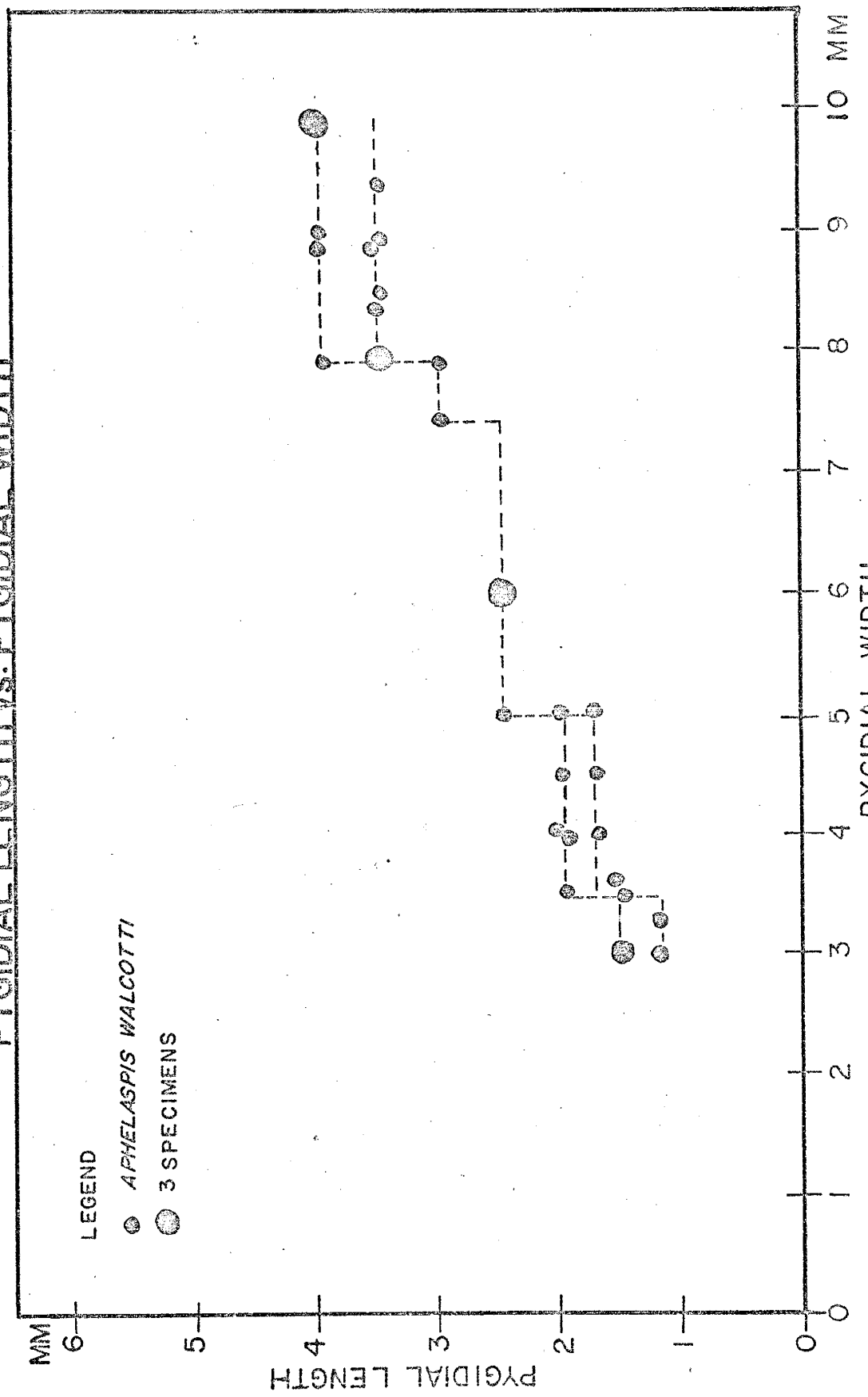

POSTERIOR LIMB WIDTH vs. OCCIPITAL RING WIDTH
LEGEND
APHELASPIS WALCOTTI
APHELASPIS SUBDITA
POSTERIOR LIMB WIDTH
MM
0
1
2
3
4
5
6
OCCIPITAL RING WIDTH
0
1
2
3
4
5
6
7
8
9
10
MM

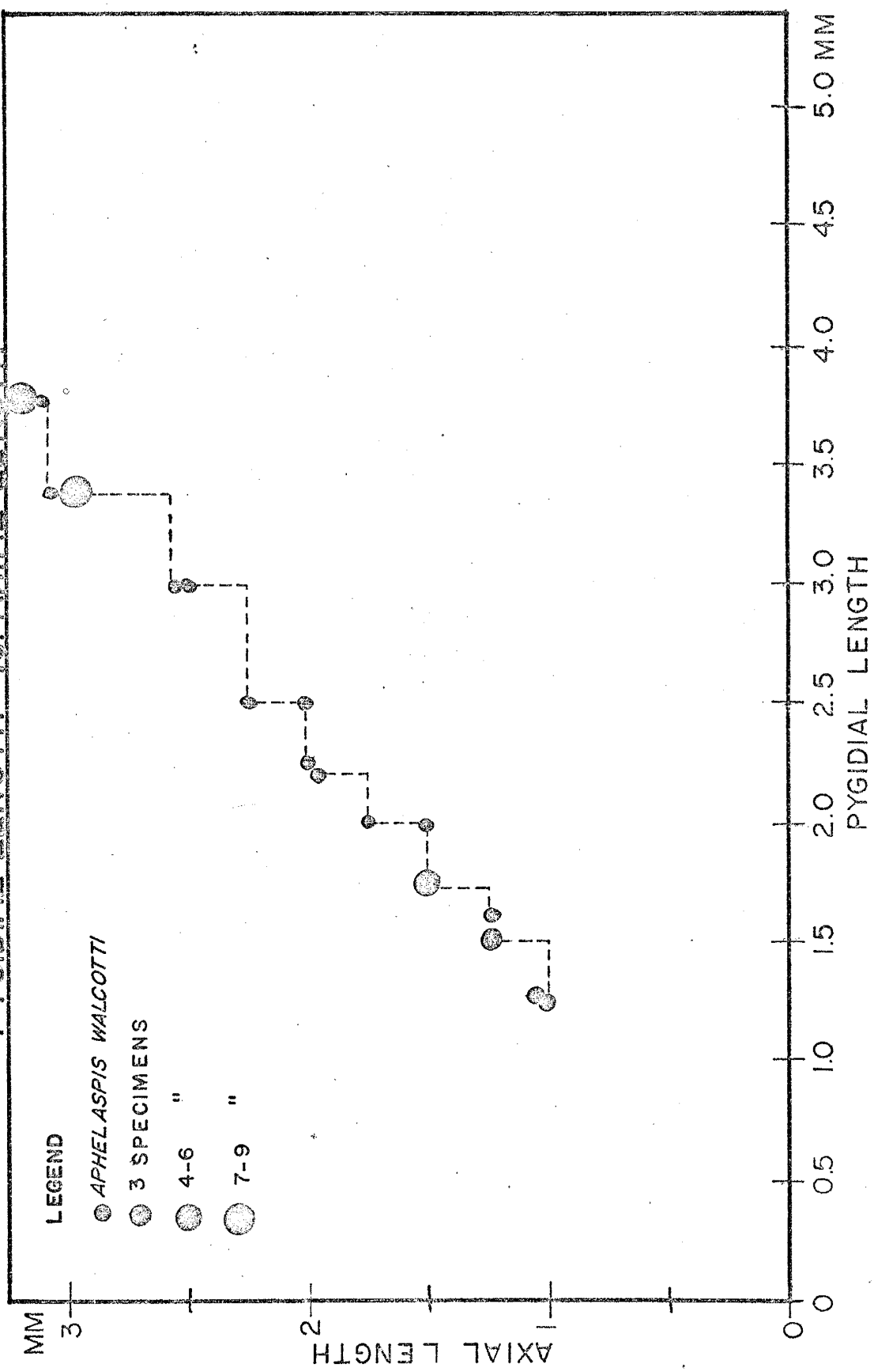

ANTERIOR FACIAL SUTURE DIVERGENCE
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
APHELASPIS SUBDITA
HYPEROBLIQUE
MESO-OBLIQUE
PARAOBLIQUE
ANTERIOR FACIAL ANGLE
60°
50°
40°
30°
20°
10°
0°
1
2
3
4
5
6
7
8
9
10
11 MM
CRANIDIAL LENGTH

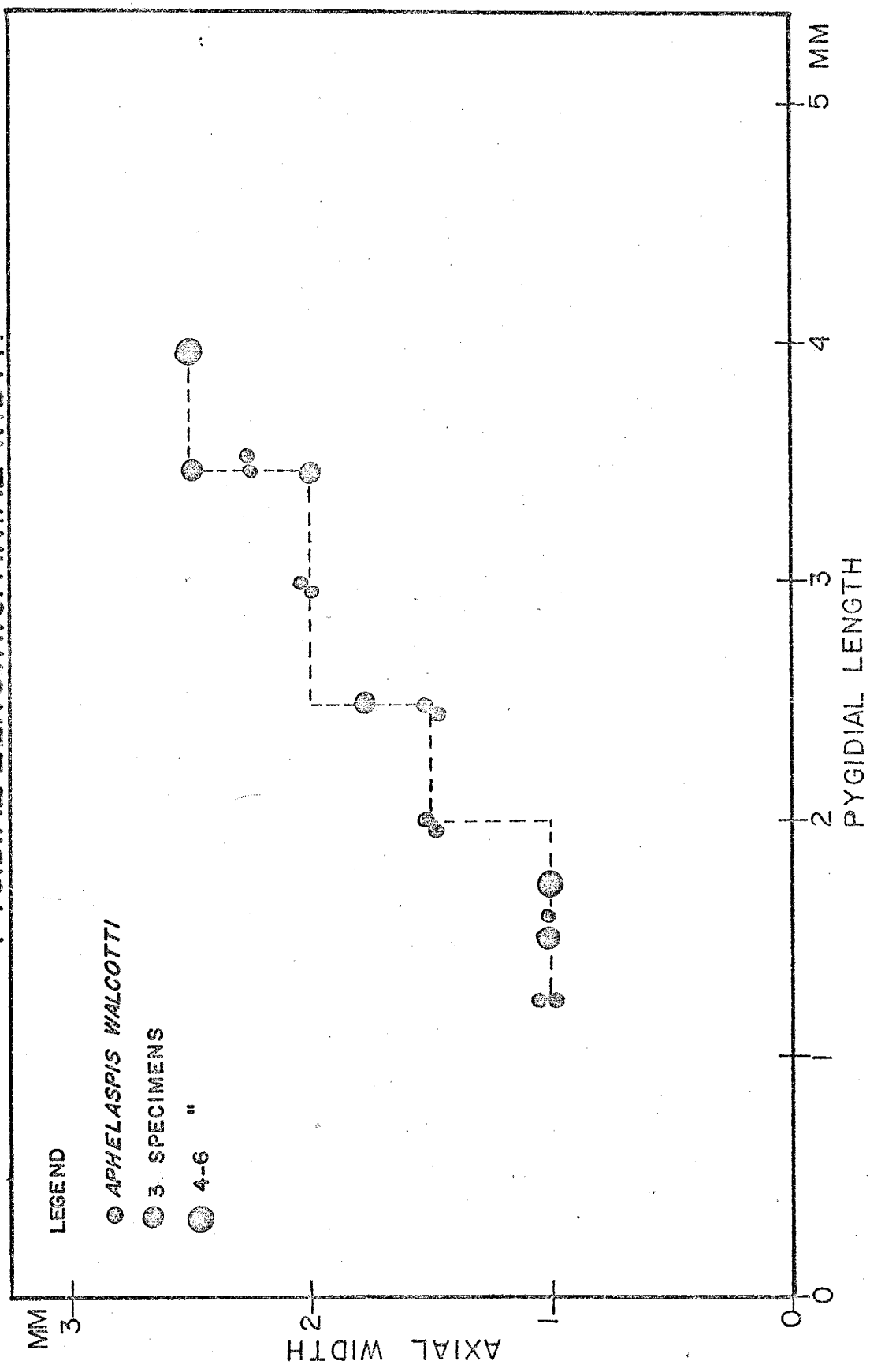

NUMBER OF SPECIMENS
0
2
4
6
8
10
12
14
16
CRANIDIAL LENGTH
1
2
3
4
5
6
7
8
9
10
11
12
13
MM

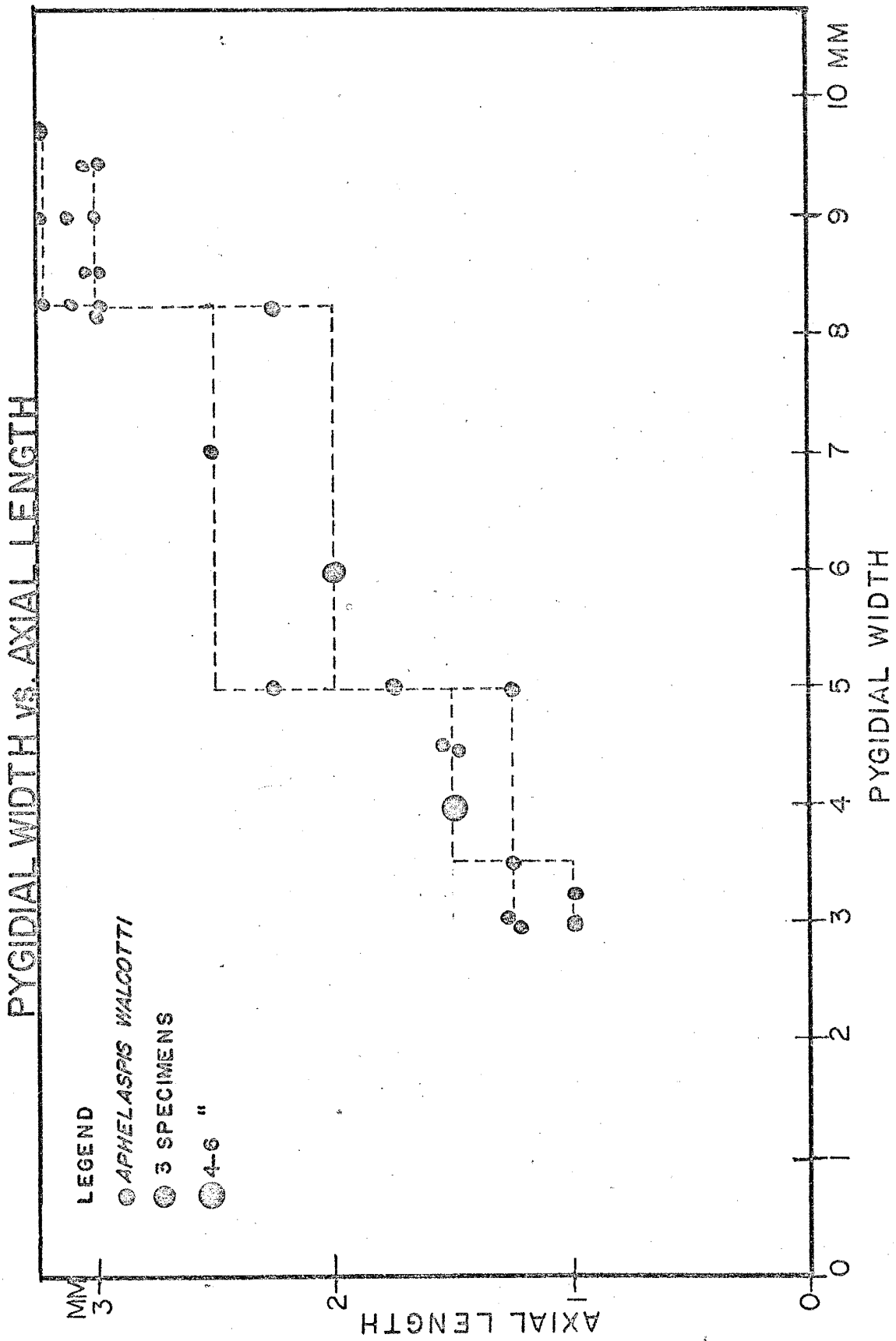

NUMBER OF SPECIMENS
0
5
10
15
20
25
30
1-1.9
2-2.9
3-3.9
4-4.9
5-5.9
6-6.9
7-7.9
8-8.9
9-9.9
10-10.9
11-11.9
12-12.9
MM
CRANDIAL LENGTH

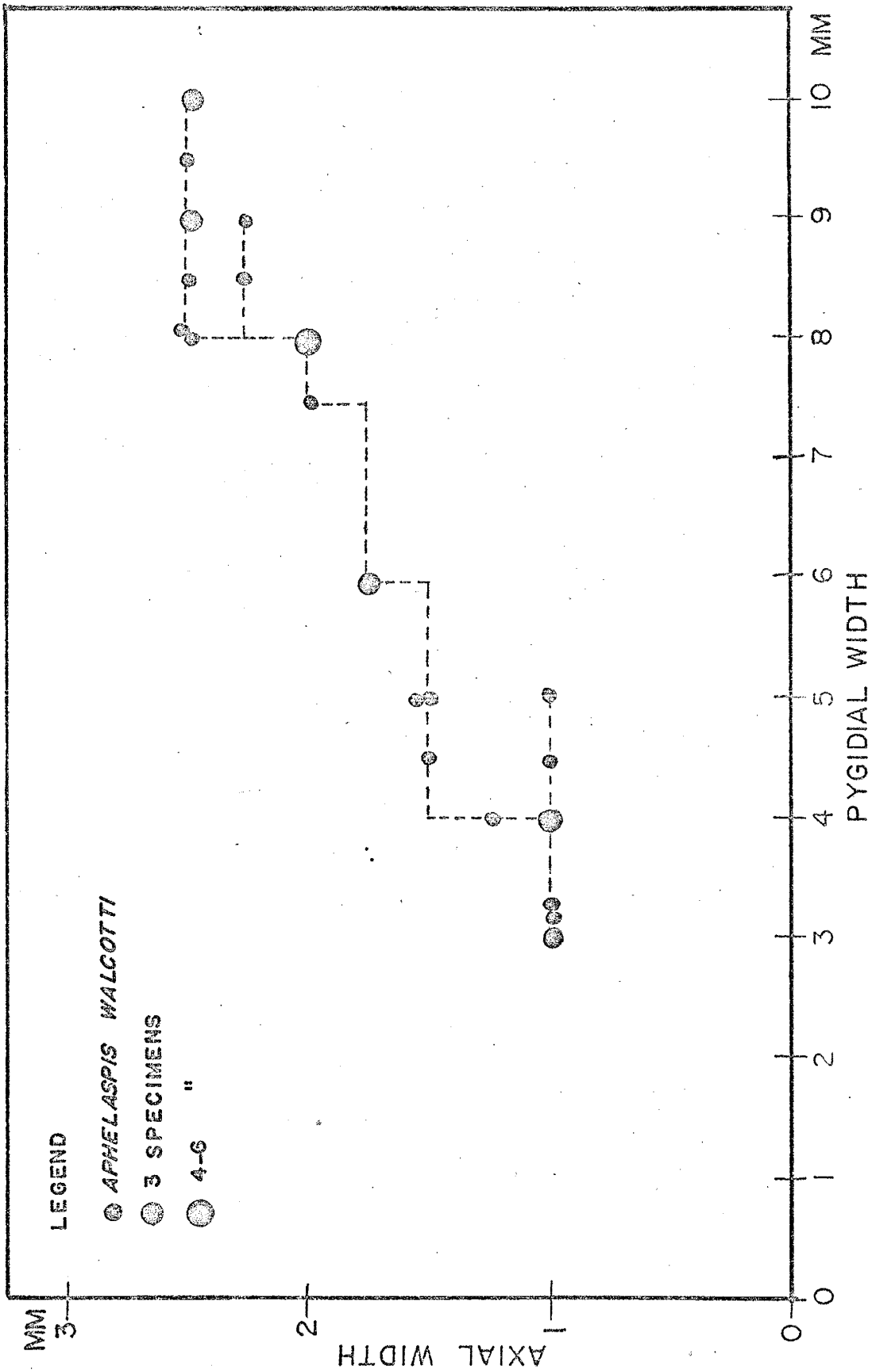

NUMBER OF SPECIMENS
0
5
10
15
20
25
30
MOULT STAGE CRANDIAL LENGTH
1.25-2.5
2.6-3.5
3.6-4.5
4.6-5.0
5.1-7.0
7.1-8.0
8.1-9.5
9.6-12.0
MM

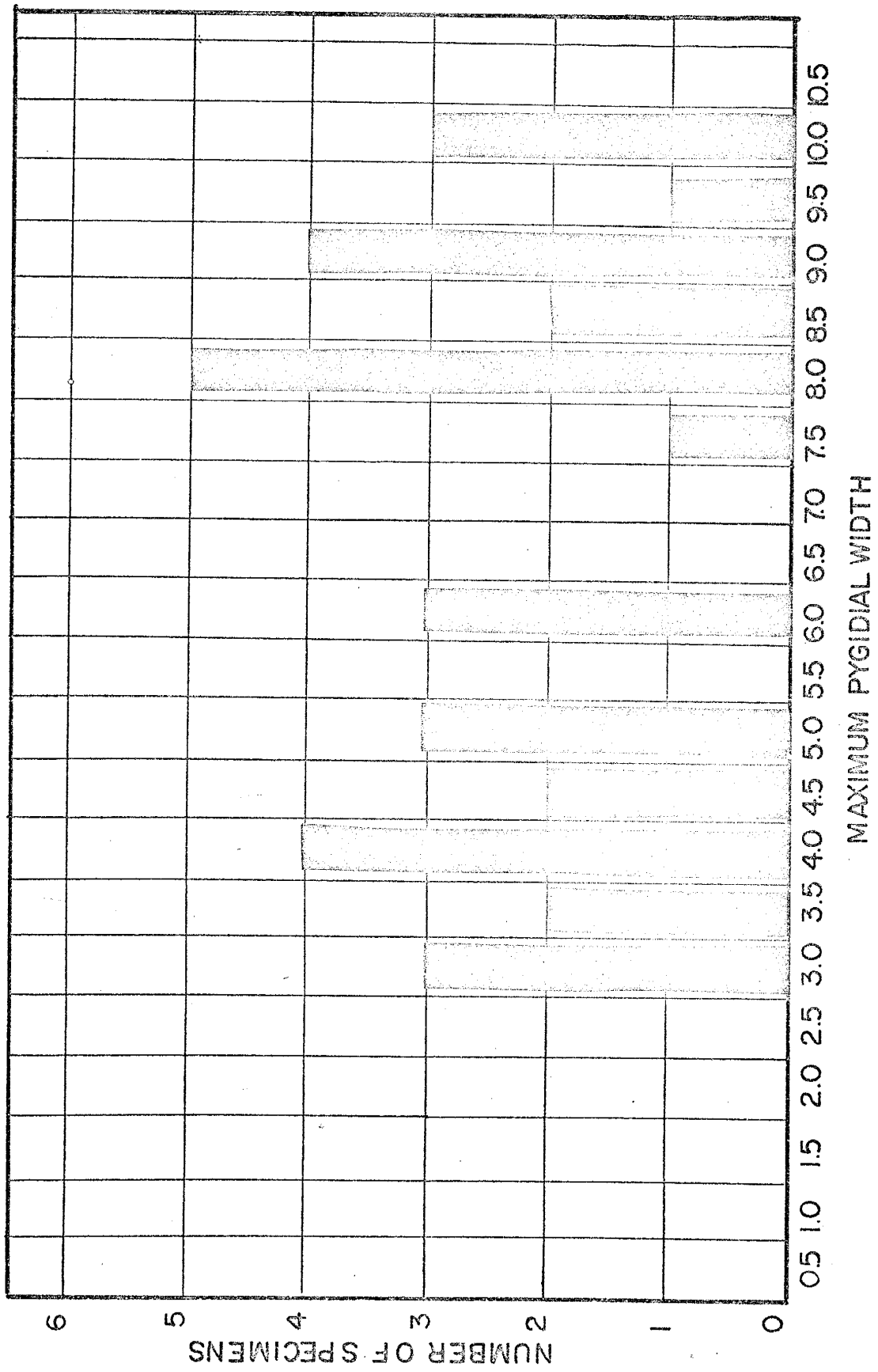

PYGIDIAL LENGTH vs. PYGIDIAL WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
PYGIDIAL LENGTH
MM
0
1
2
3
4
5
6
PYGIDIAL WIDTH
0
1
2
3
4
5
6
7
8
9
10 MM

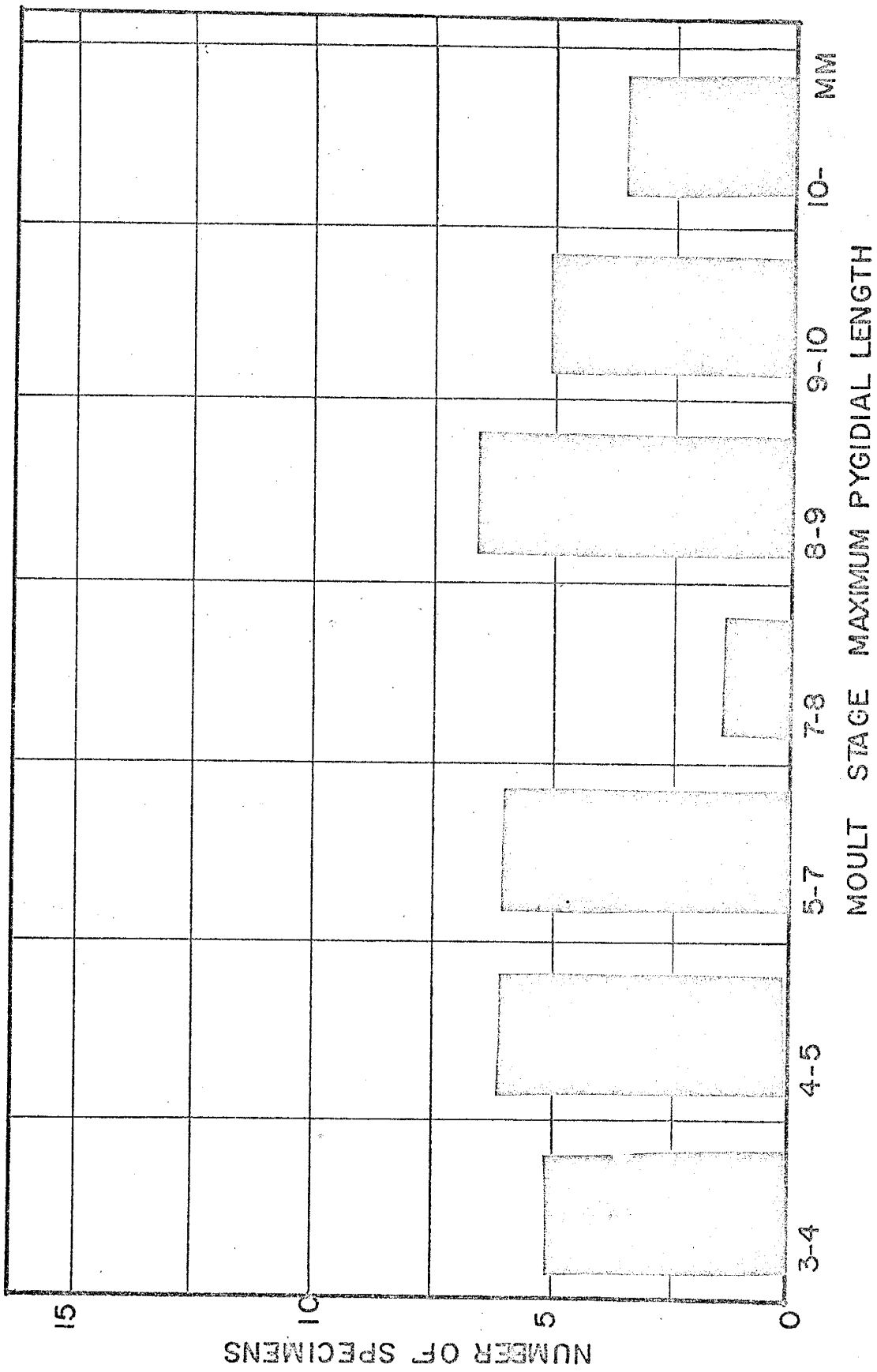

PYGIDIAL LENGTH vs. AXIAL LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
7-9 "
MM
3
2
1
0
AXIAL LENGTH
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0 MM
PYGIDIAL LENGTH


PYGIDIAL LENGTH vs. AXIAL WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
MM
3
2
1
0
AXIAL WIDTH
0
1
2
3
4
5 MM
PYGIDIAL LENGTH

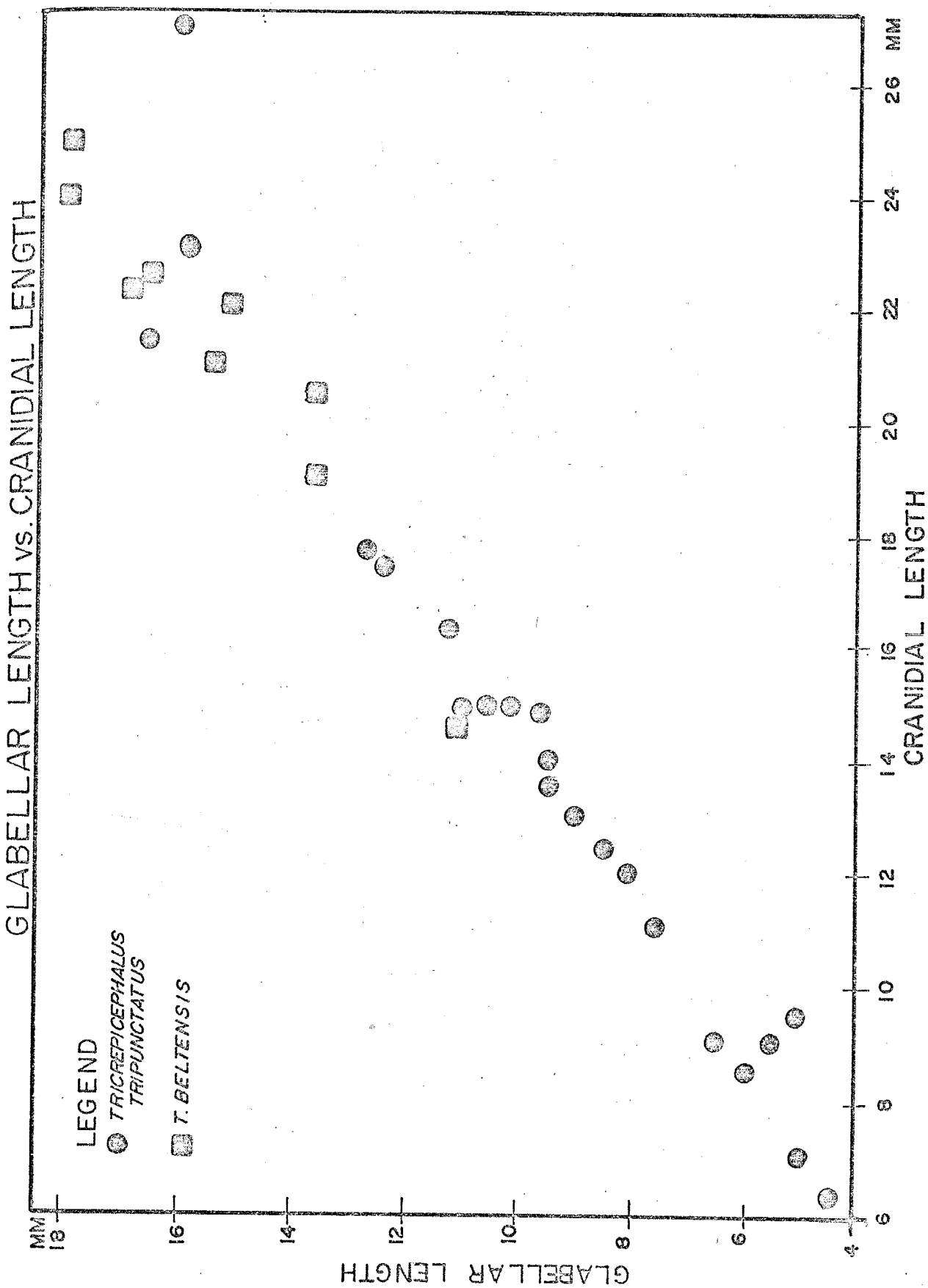

PYGIDIAL WIDTH VS. AXIAL LENGTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
MM
3
2
1
0
AXIAL LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM
PYGIDIAL WIDTH

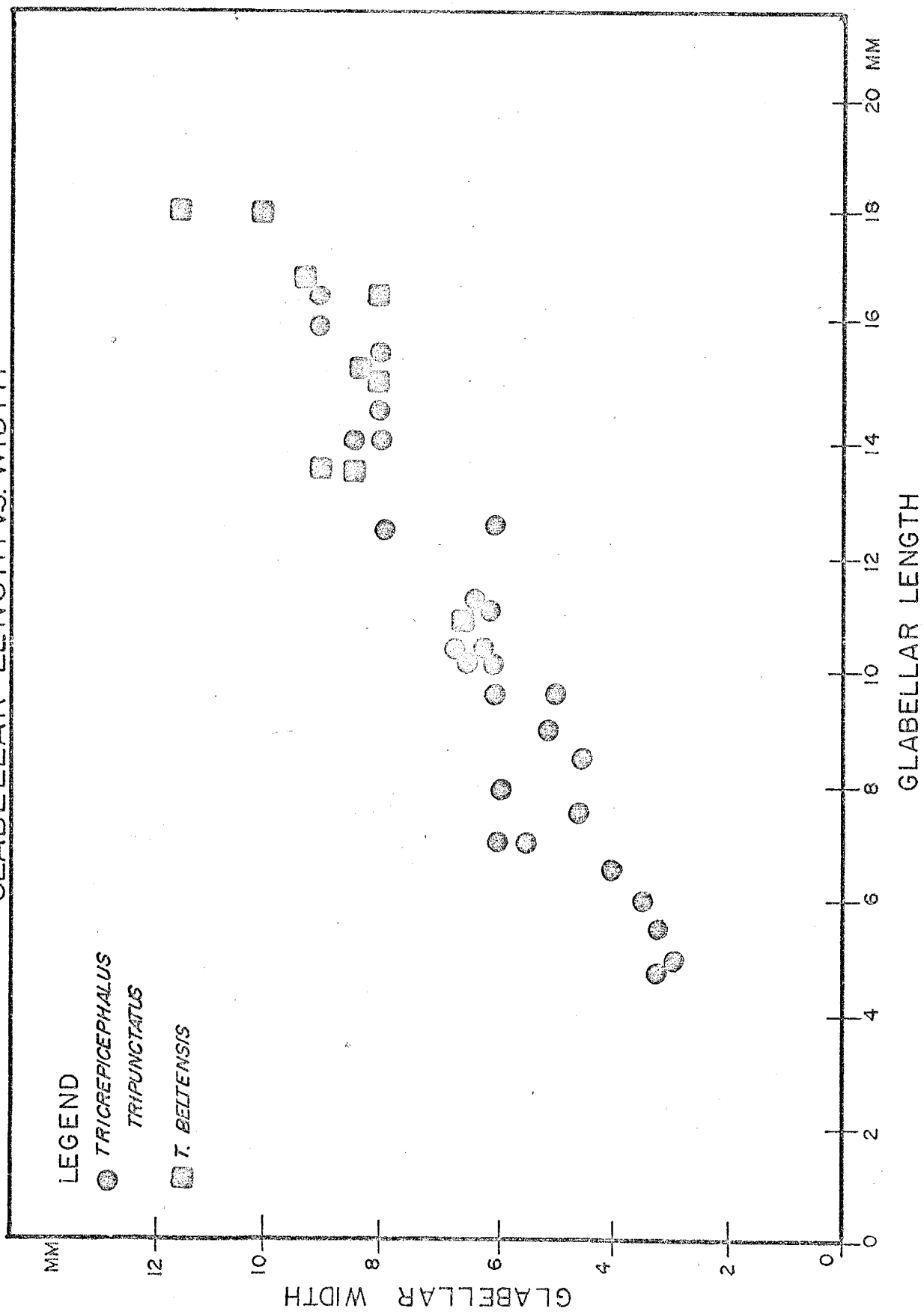

PYGIDIAL WIDTH vs. AXIAL WIDTH
LEGEND
APHELASPIS WALCOTTI
3 SPECIMENS
4-6 "
MM
3
2
1
0
AXIAL WIDTH
0
1
2
3
4
5
6
7
8
9
10 MM
PYGIDIAL WIDTH

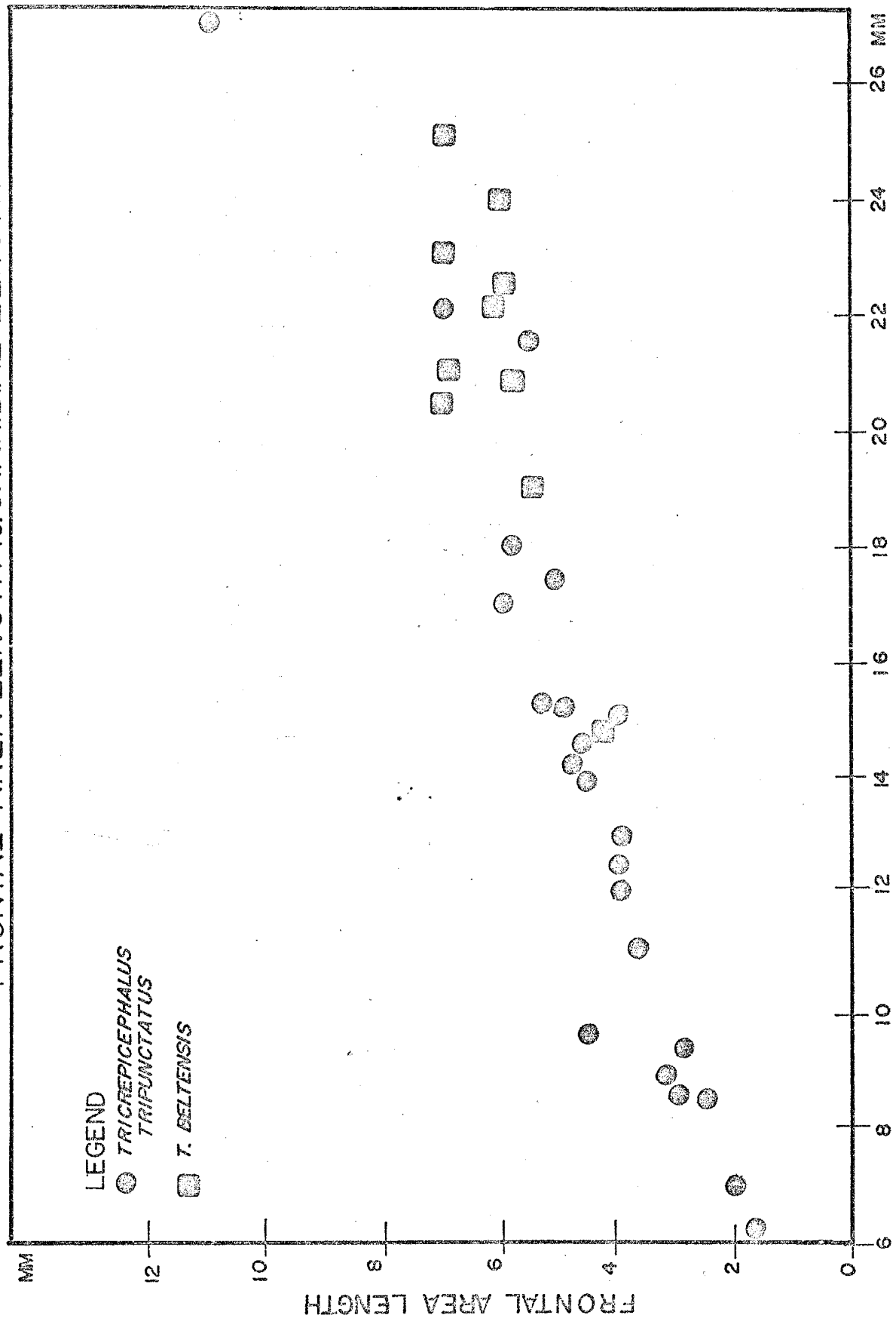

NUMBER OF SPECIMENS
0
1
2
3
4
5
6
MAXIMUM PYGIDIAL WIDTH
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5

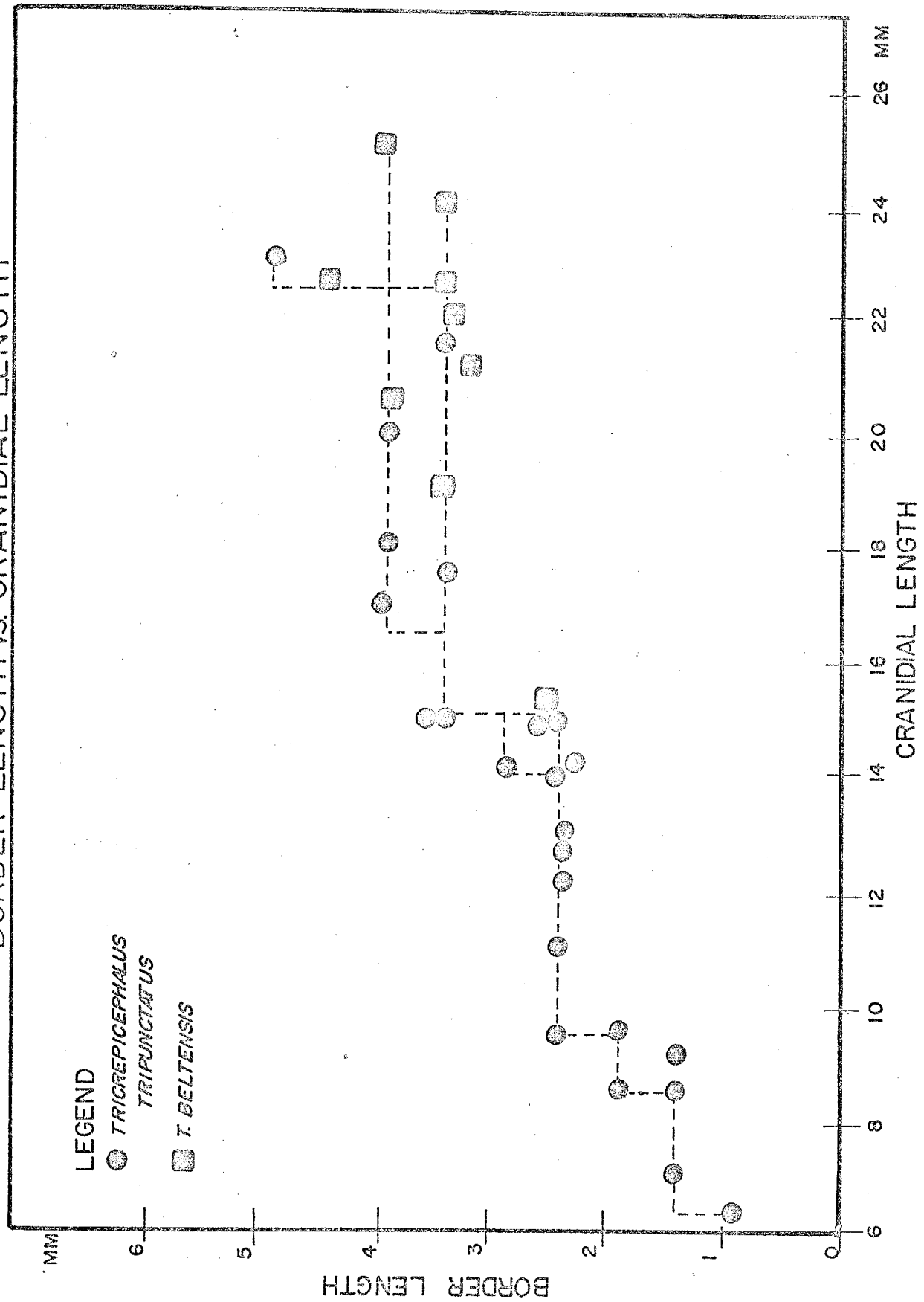

NUMBER OF SPECIMENS
15
10
5
0
MOULT STAGE MAXIMUM PYGIDIAL LENGTH
3-4
4-5
5-7
7-8
8-9
9-10
10- MM

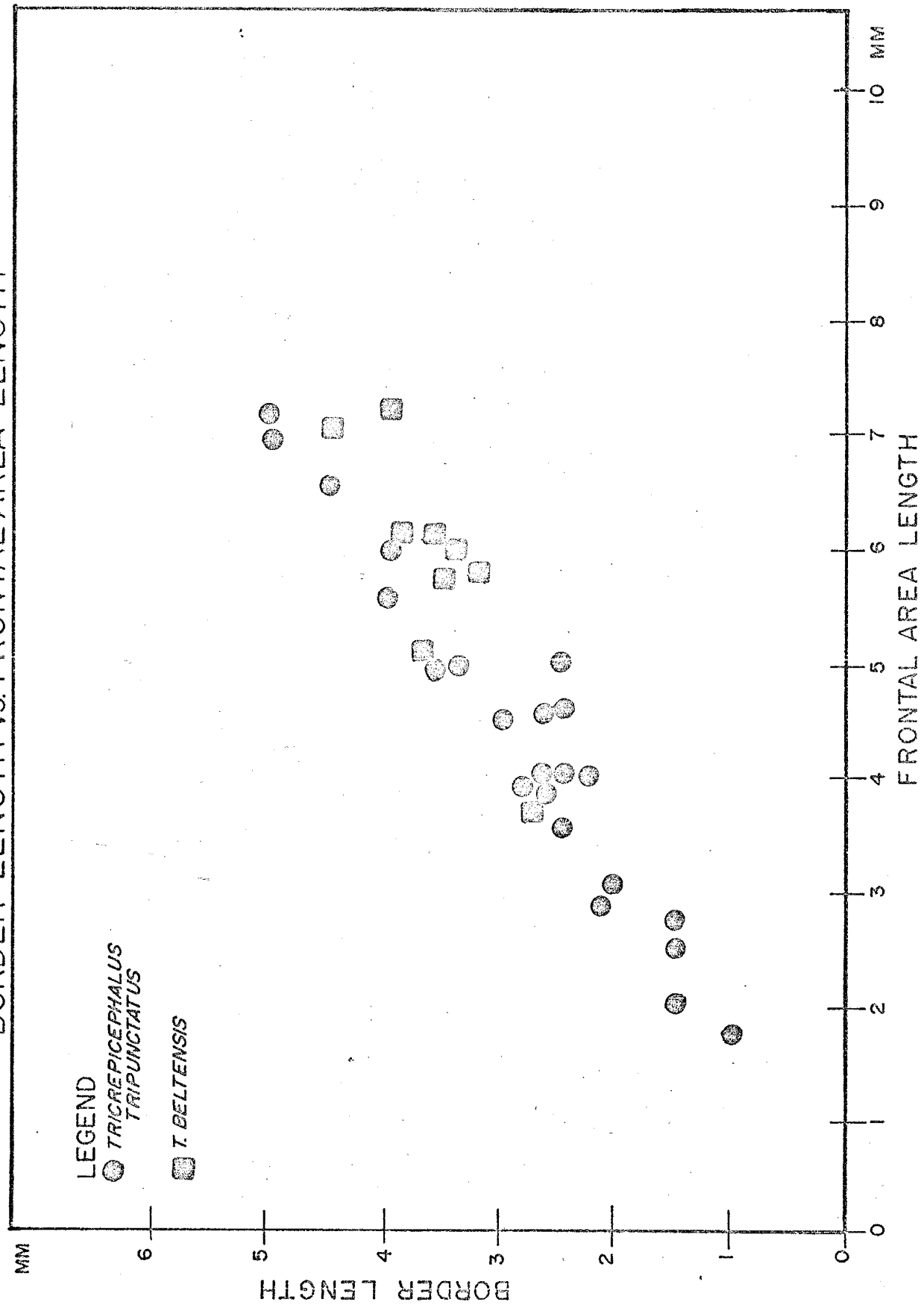
APPENDIX B

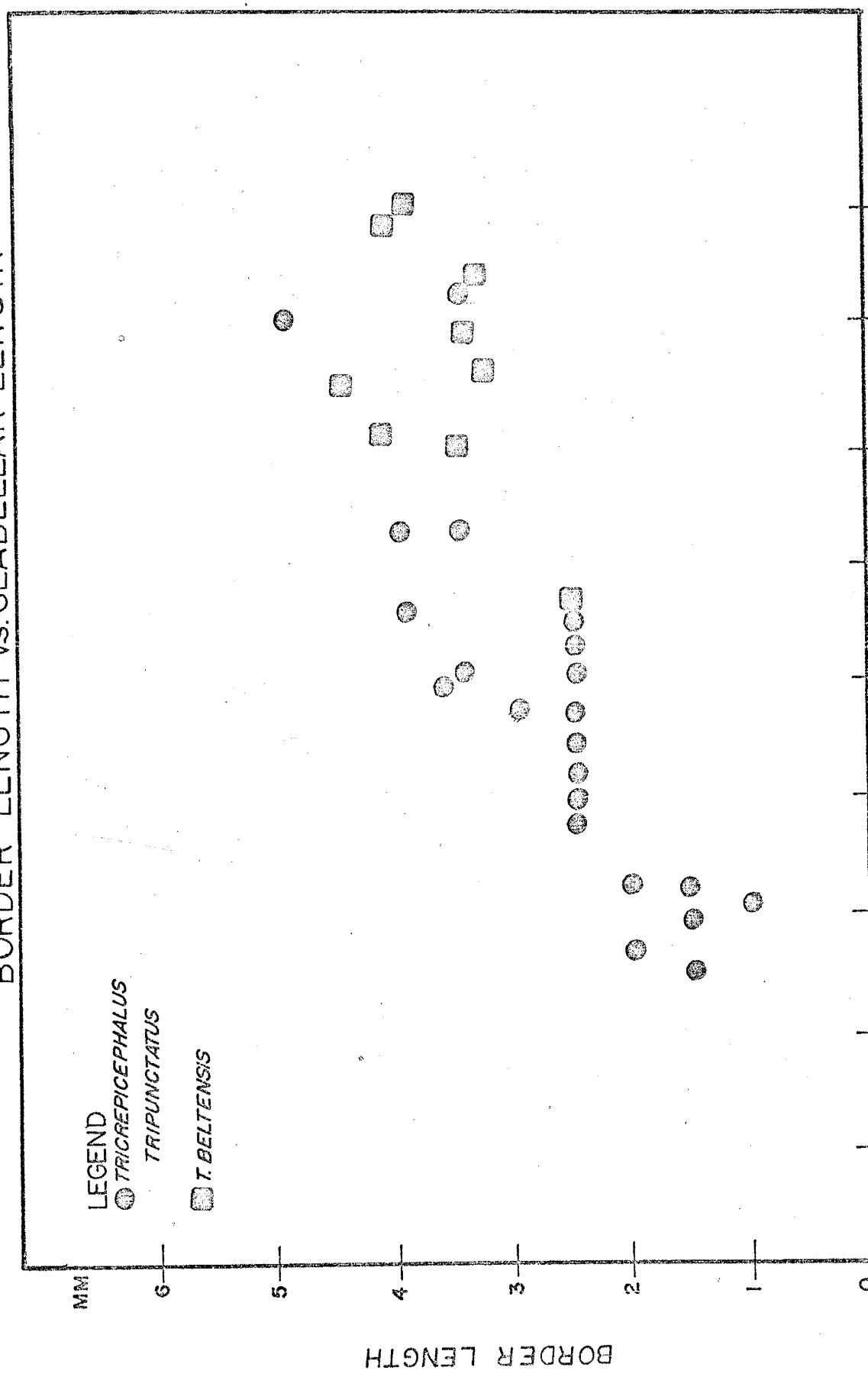

GLABELLAR LENGTH vs. CRANIDIAL LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
GLABELLAR LENGTH
MM
18
16
14
12
10
8
6
4
CRANIDIAL LENGTH
6
8
10
12
14
16
18
20
22
24
26
MM

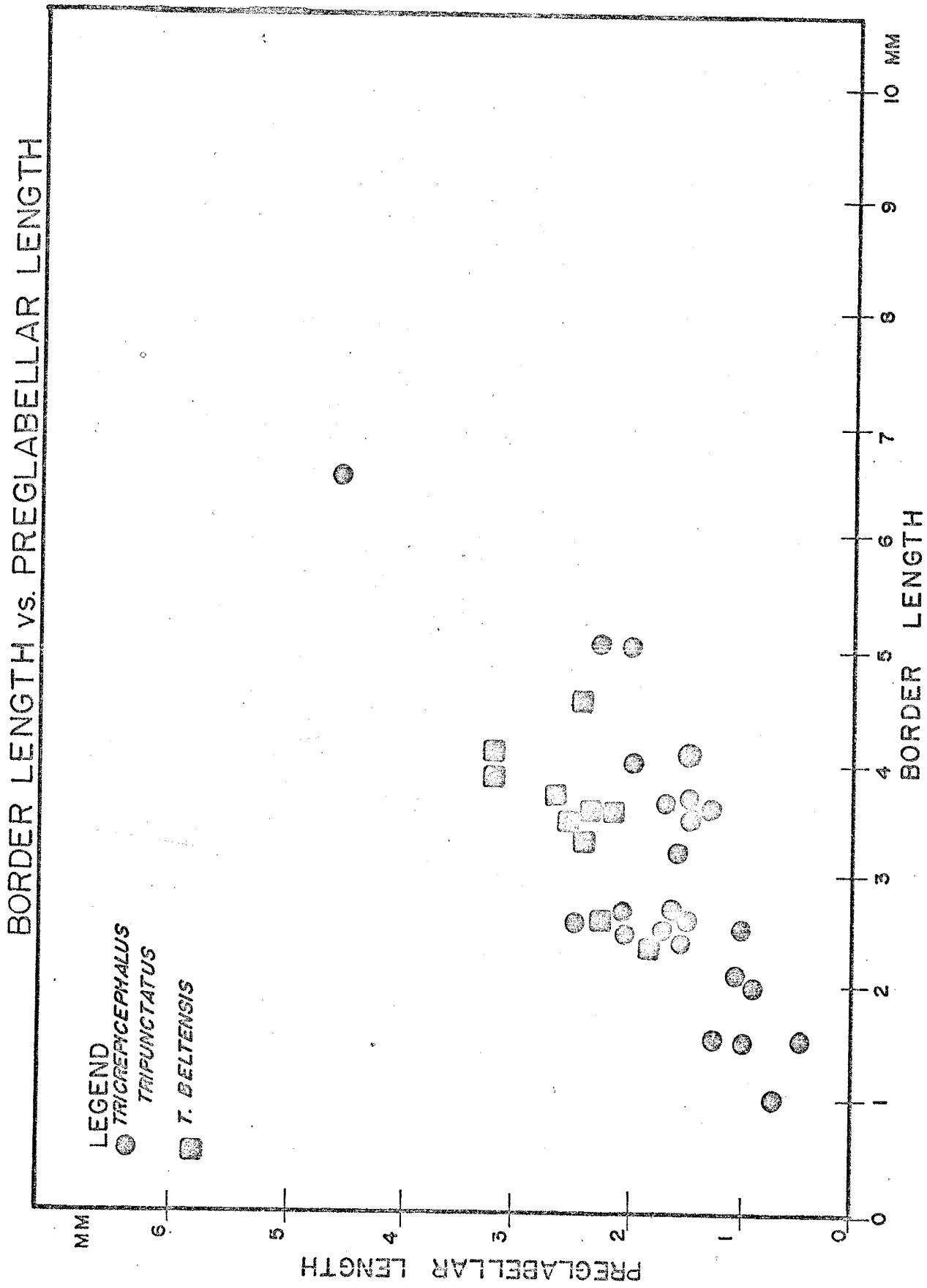

GLABELLAR LENGTH vs. WIDTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
GLABELLAR WIDTH
MM
0
2
4
6
8
10
12
GLABELLAR LENGTH
0
2
4
6
8
10
12
14
16
18
20 MM

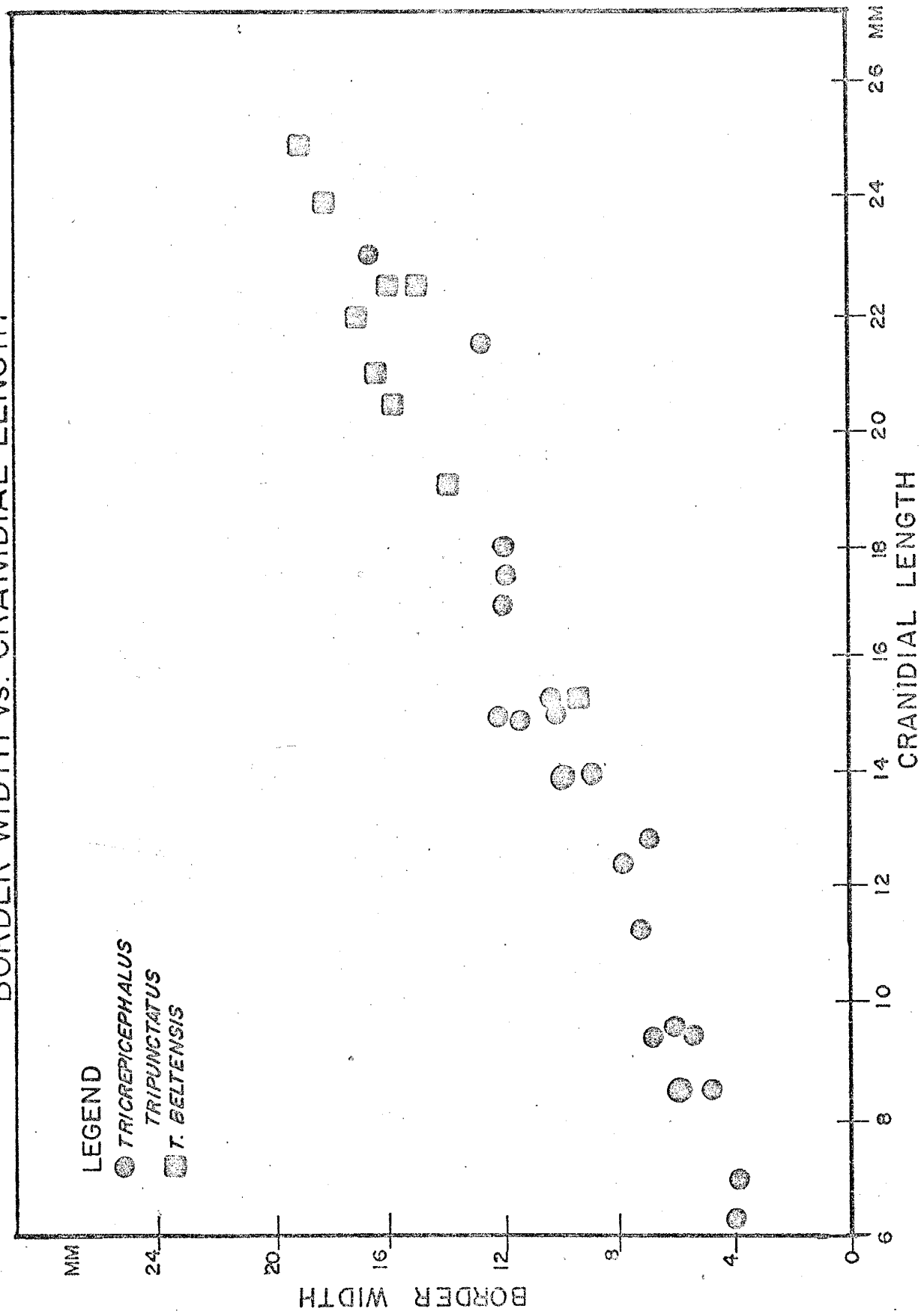

FRONTAL AREA LENGTH vs. CRANIDIAL LENGTH
LEGEND
T. RICREPICEPHALUS
T. TRIPUNCTATUS
T. BELTENSIS
FRONTAL AREA LENGTH
MM
0
2
4
6
8
10
12
CRANIDIAL LENGTH
6
8
10
12
14
16
18
20
22
24
26 MM

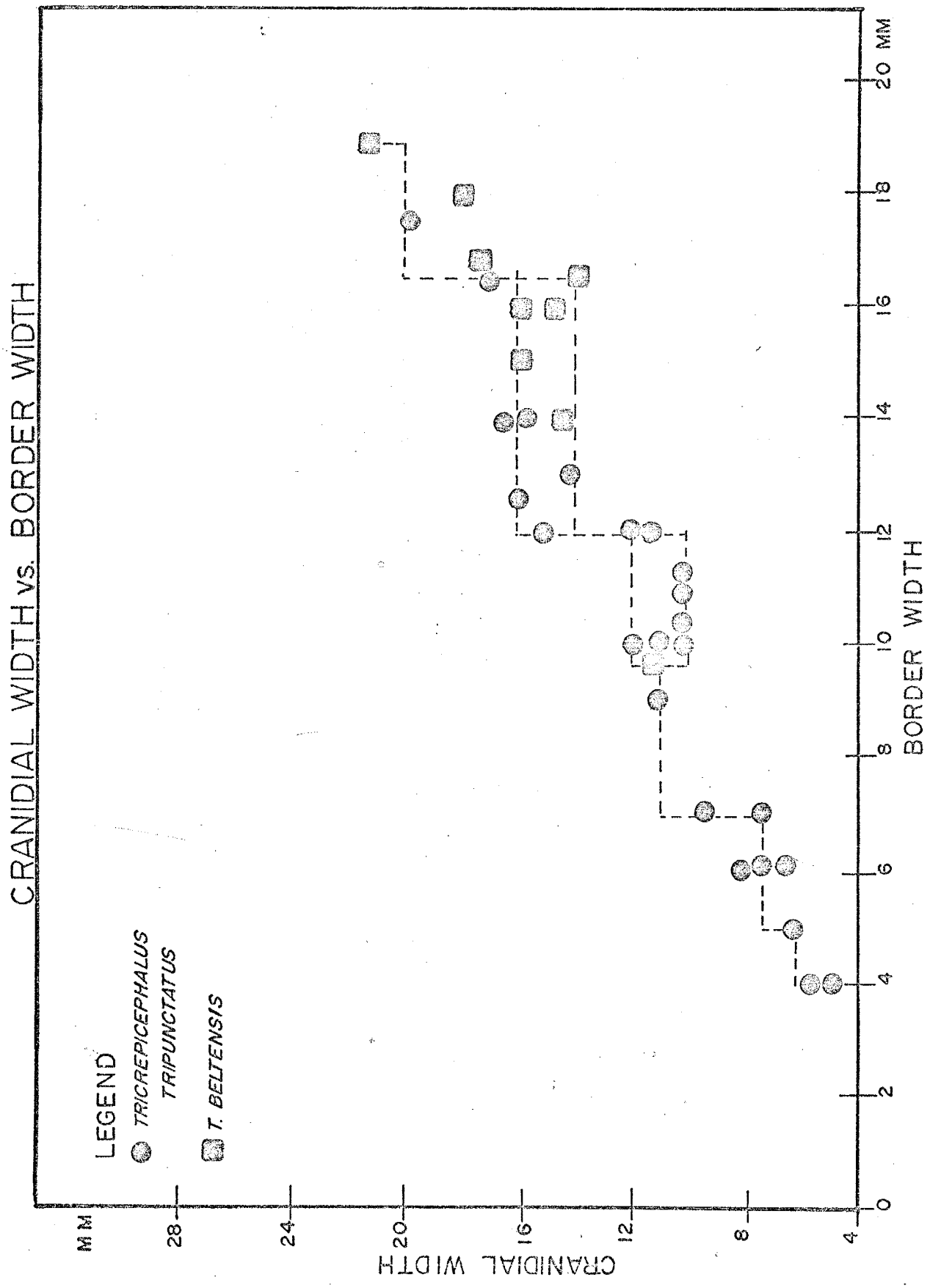

BORDER LENGTH vs. CRANIDIAL LENGTH
LEGEND
T. TRICREPICEPHALUS
T. TRIPUNCTATUS
T. BELTENSIS
BORDER LENGTH
MM
0
1
2
3
4
5
6
CRANIDIAL LENGTH
6
8
10
12
14
16
18
20
22
24
26 MM

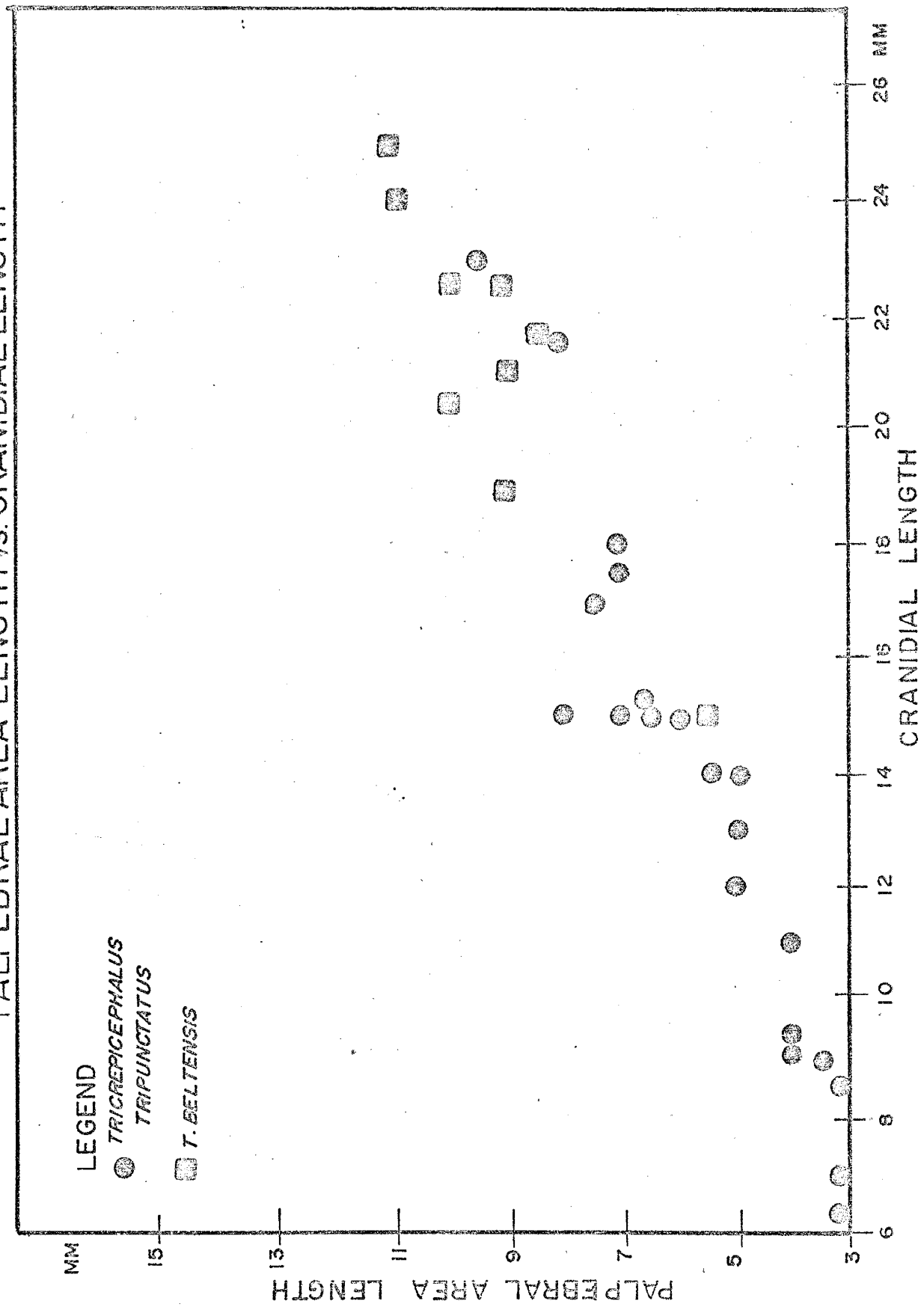

BORDER LENGTH vs. FRONTAL AREA LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
BORDER LENGTH
FRONTAL AREA LENGTH
MM
0
1
2
3
4
5
6
7
8
9
10

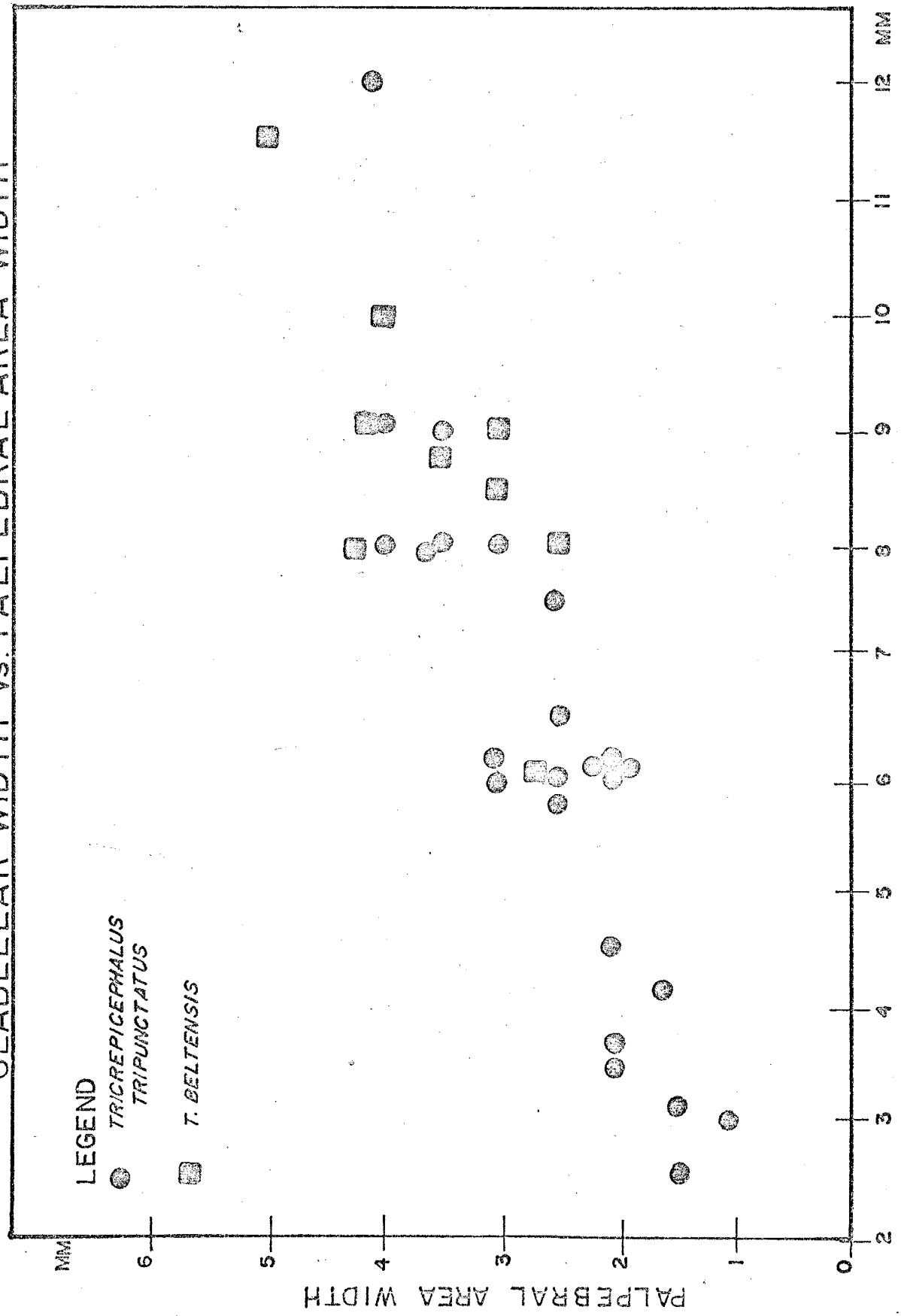

BORDER LENGTH vs. GLABELLAR LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNGTATUS
T. BELTENSIS
BORDER LENGTH
MM
0
1
2
3
4
5
6
GLABELLAR LENGTH
0
2
4
6
8
10
12
14
16
18
MM

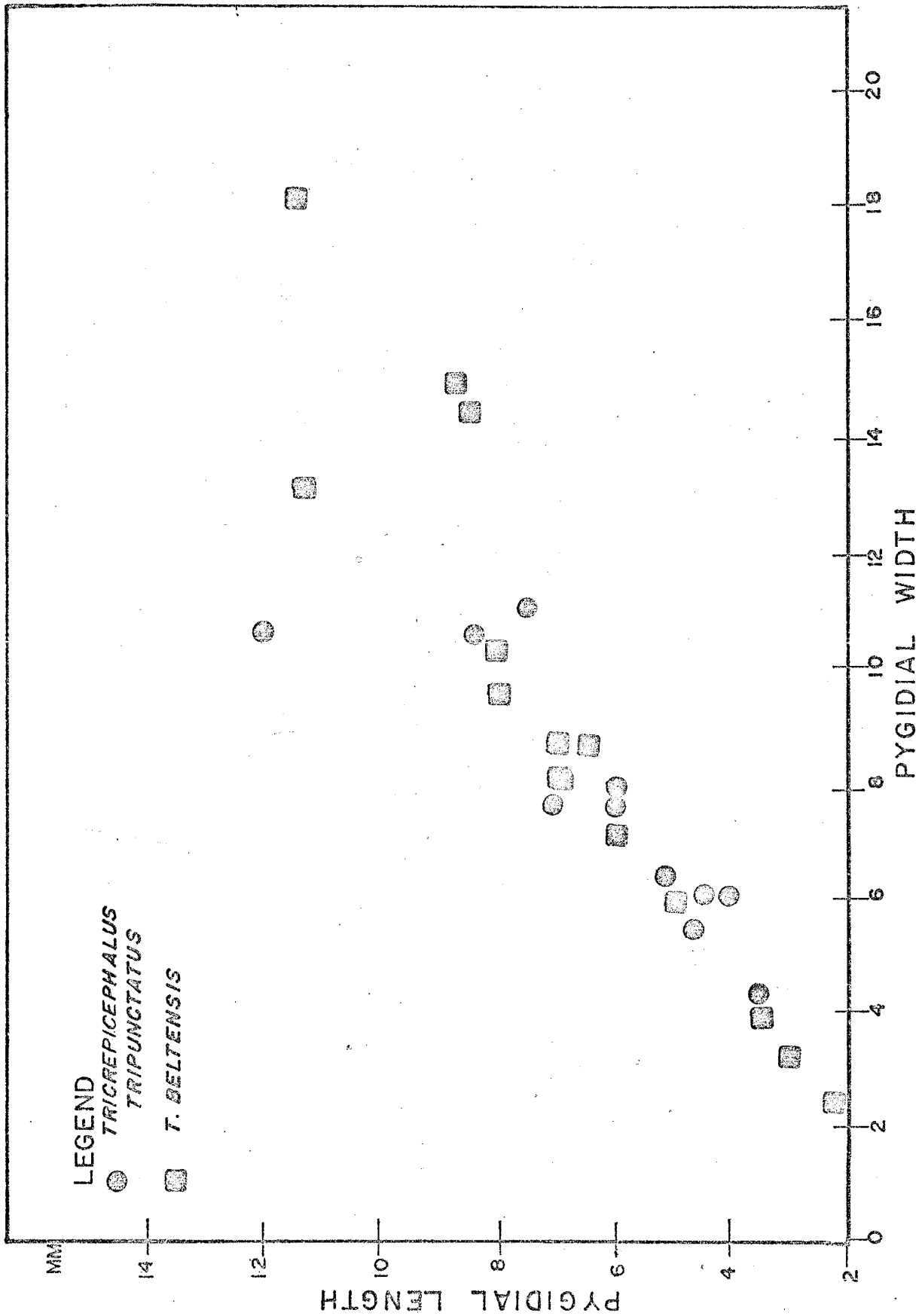

BORDER LENGTH vs. PREGLABELLAR LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
PREGLABELLAR LENGTH
MM
0
1
2
3
4
5
6
BORDER LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM

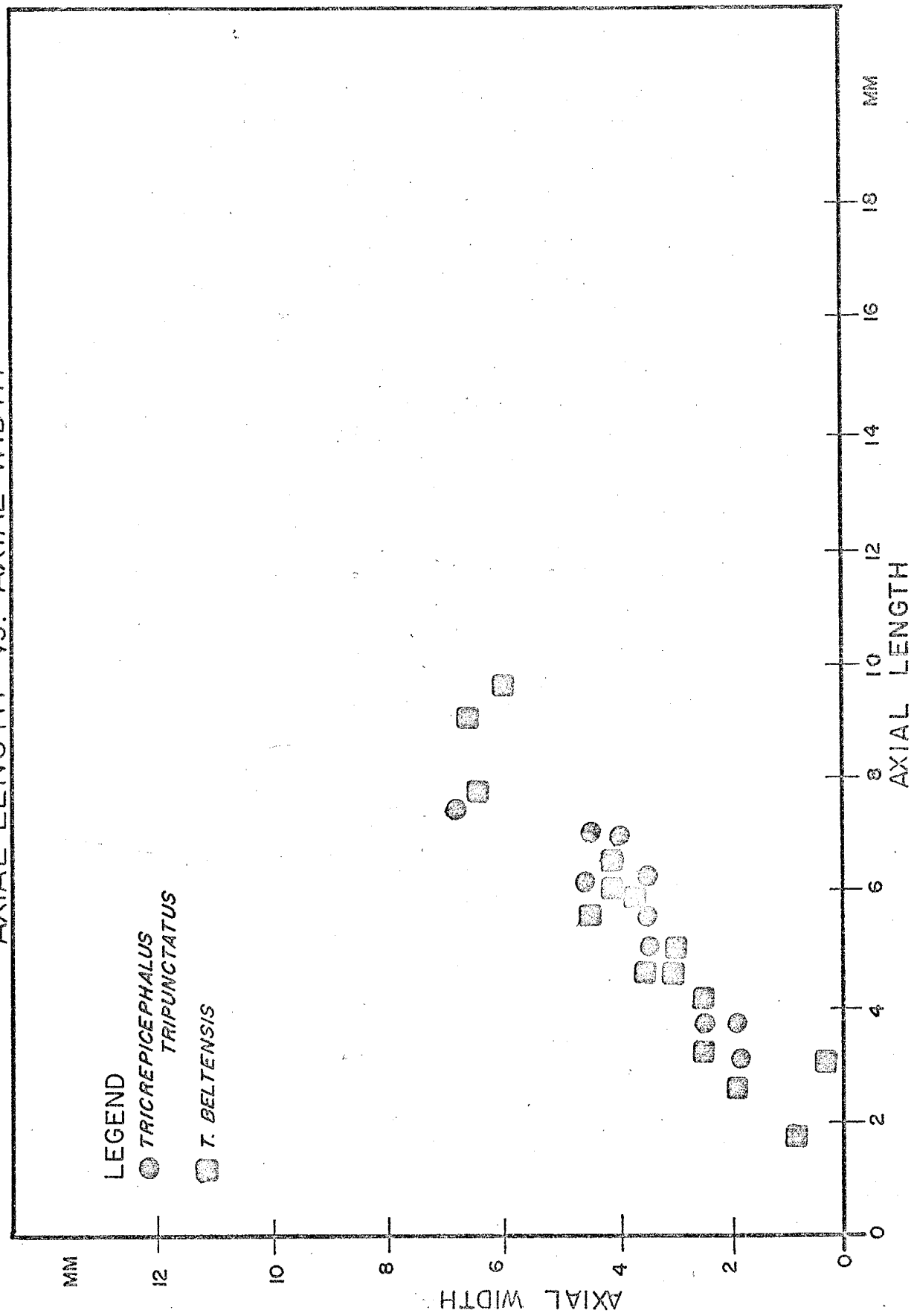

BORDER WIDTH vs. CRANIDIAL LENGTH
LEGEND
TRICREPICEPHALUS
TRIPUNCTATUS
T. BELTENSIS
BORDER WIDTH
MM
0
4
8
12
16
20
24
CRANIDIAL LENGTH
6
8
10
12
14
16
18
20
22
24
26
MM

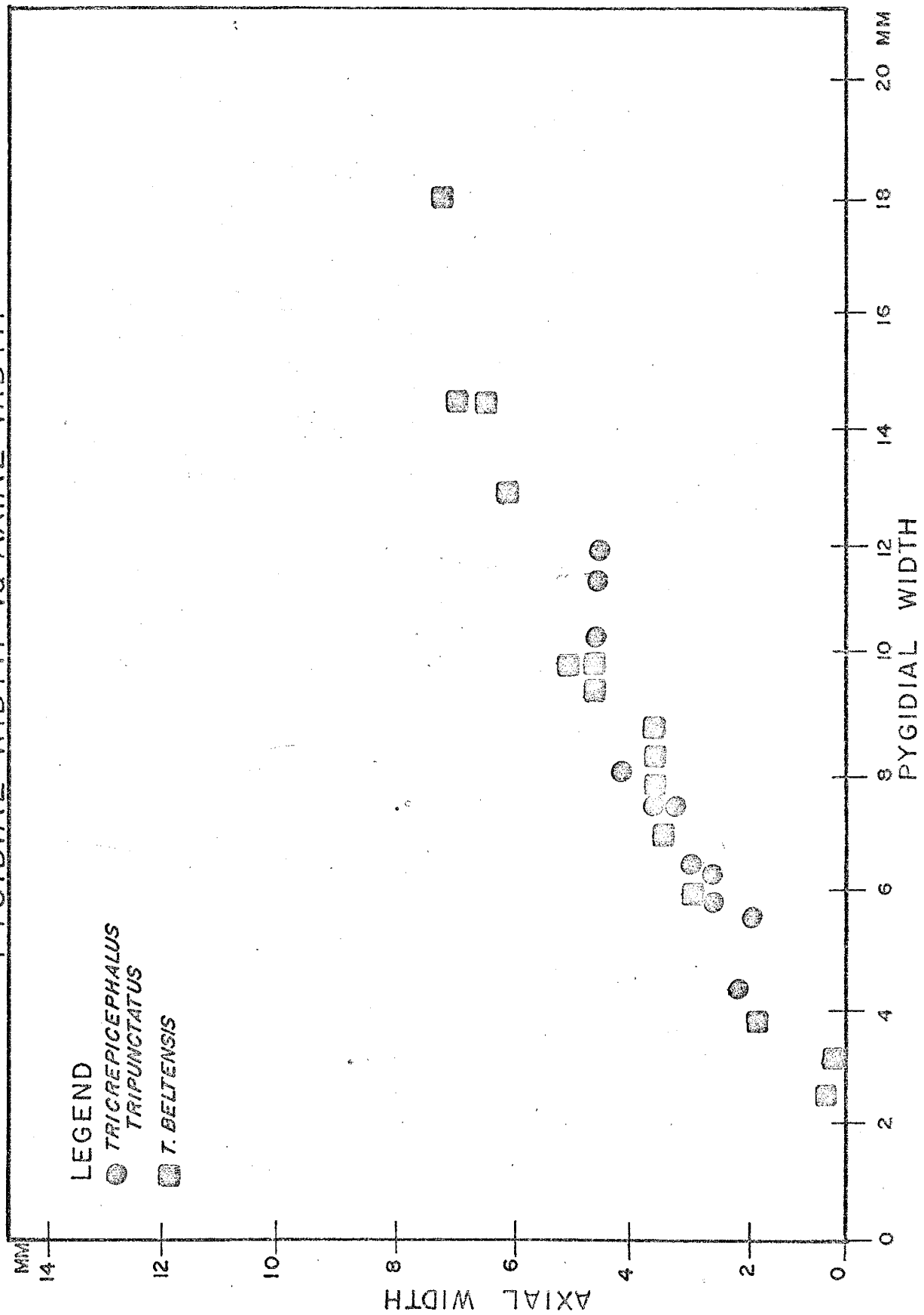

CRANIDIAL WIDTH vs. BORDER WIDTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
CRANIDIAL WIDTH
MM
28
24
20
16
12
8
4
BORDER WIDTH
0
2
4
6
8
10
12
14
16
18
20 MM

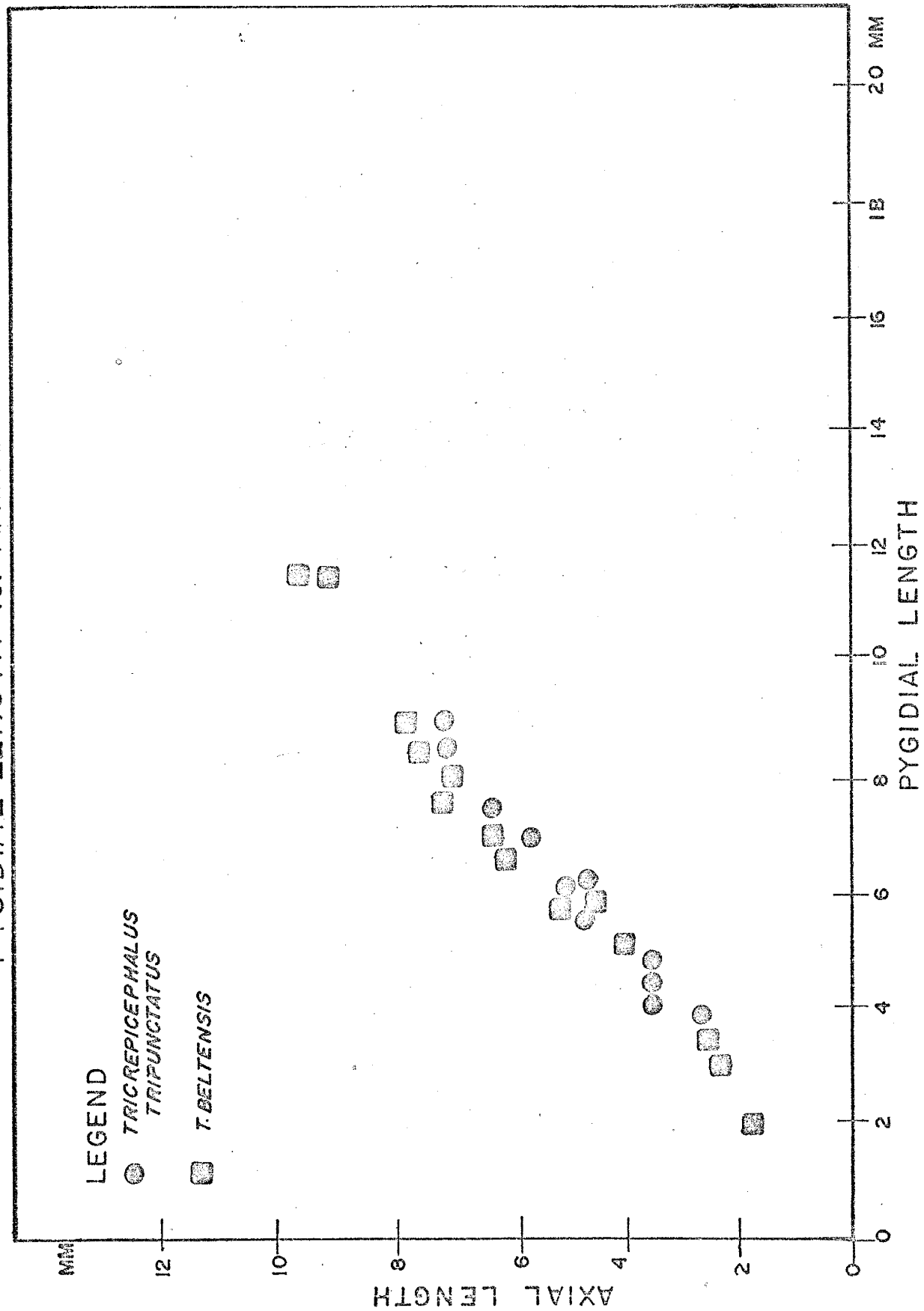

PALPEBRAL AREA LENGTH vs. CRANIDIAL LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
PALPEBRAL AREA LENGTH
MM
15
13
11
9
7
5
3
CRANIDIAL LENGTH
6
8
10
12
14
16
18
20
22
24
26 MM


GLABELLAR WIDTH vs. PALPEBRAL AREA WIDTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
PALPEBRAL AREA WIDTH
MM
0
1
2
3
4
5
6
GLABELLAR WIDTH
2
3
4
5
6
7
8
9
10
11
12
MM

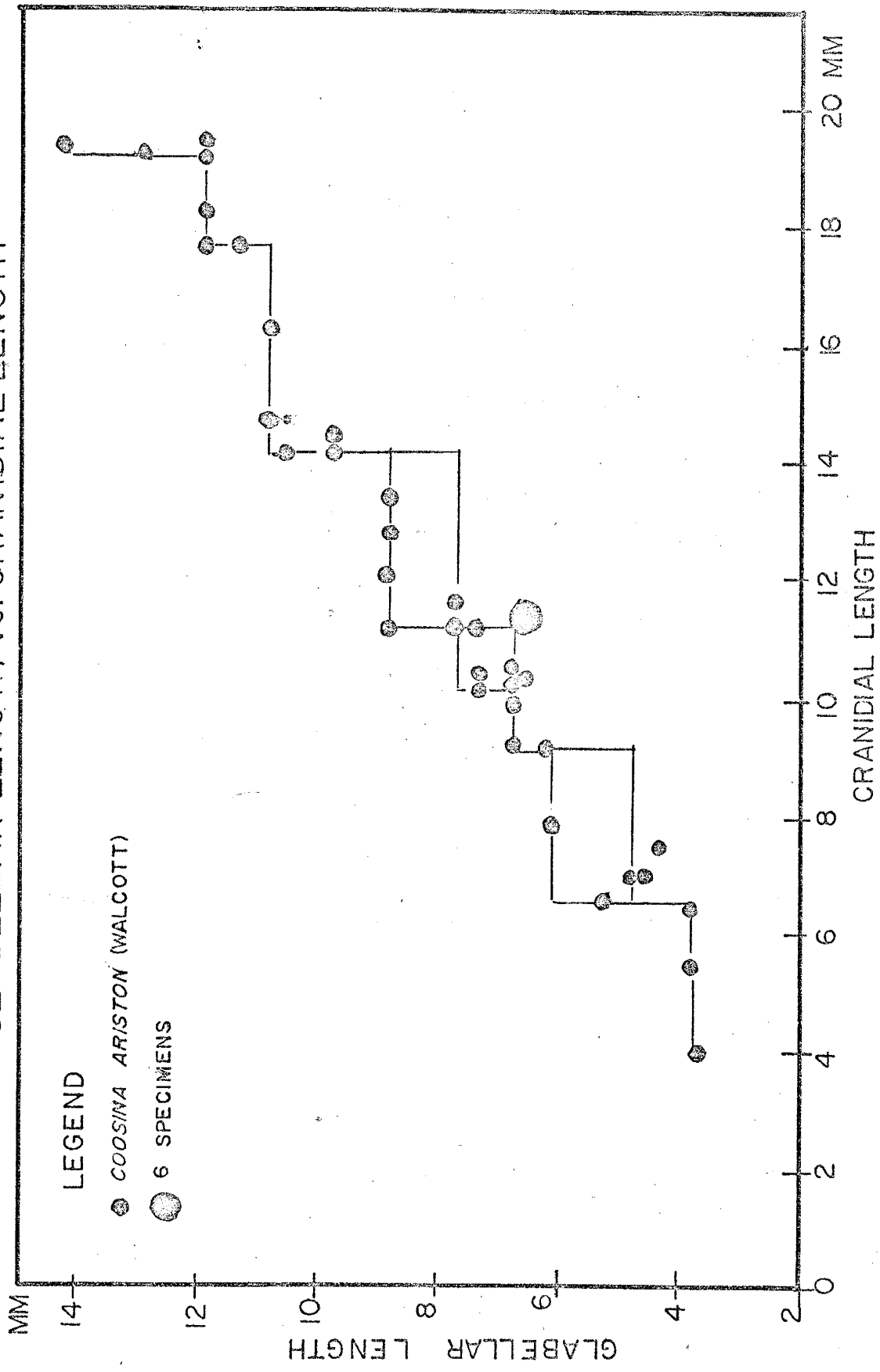

PYGIDIAL WIDTH vs. LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
MM
PYGIDIAL LENGTH
PYGIDIAL WIDTH
0
2
4
6
8
10
12
14
16
18
20

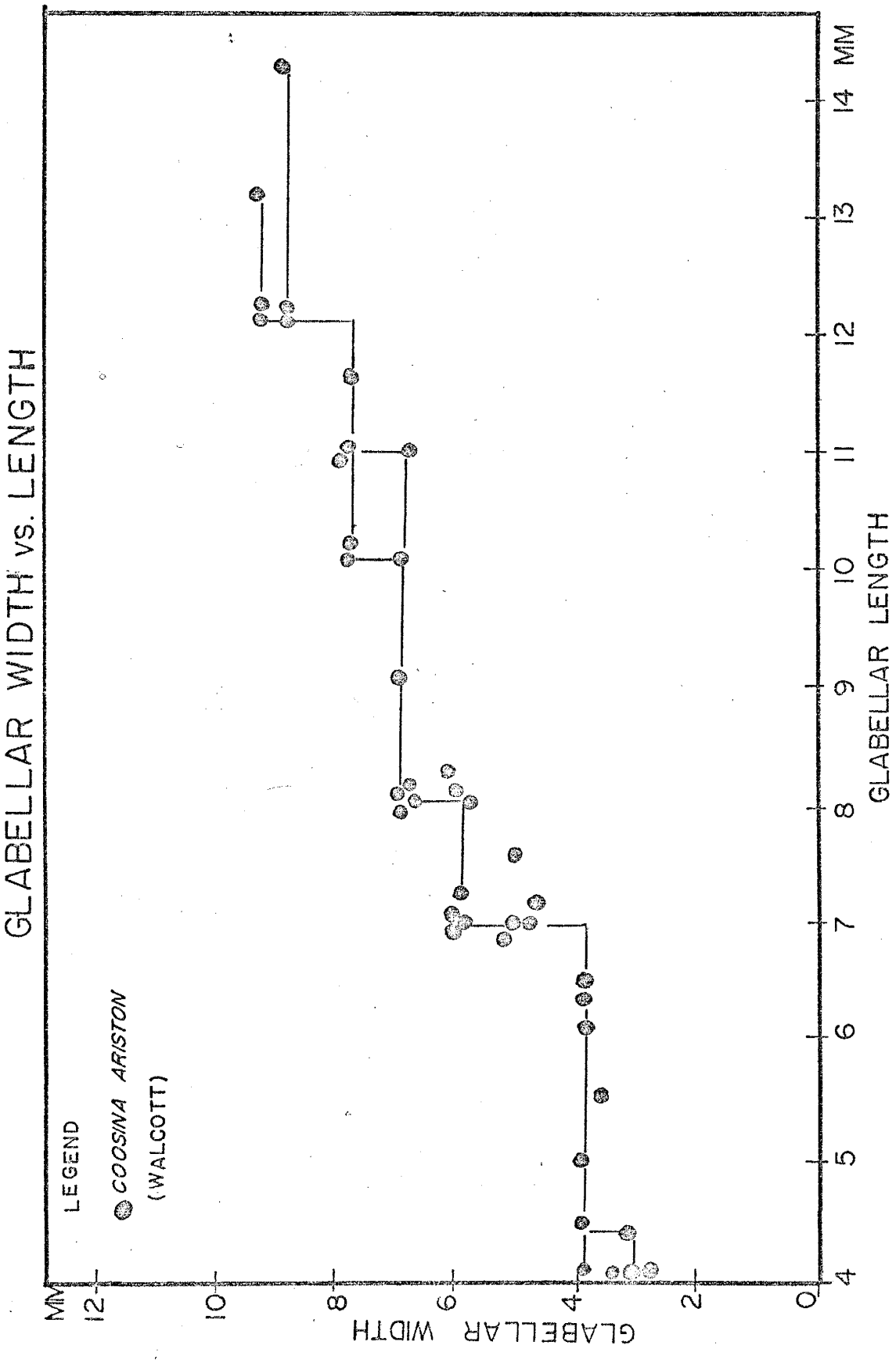

AXIAL LENGTH vs. AXIAL WIDTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
AXIAL WIDTH
MM
0
2
4
6
8
10
12
AXIAL LENGTH
MM
0
2
4
6
8
10
12
14
16
18

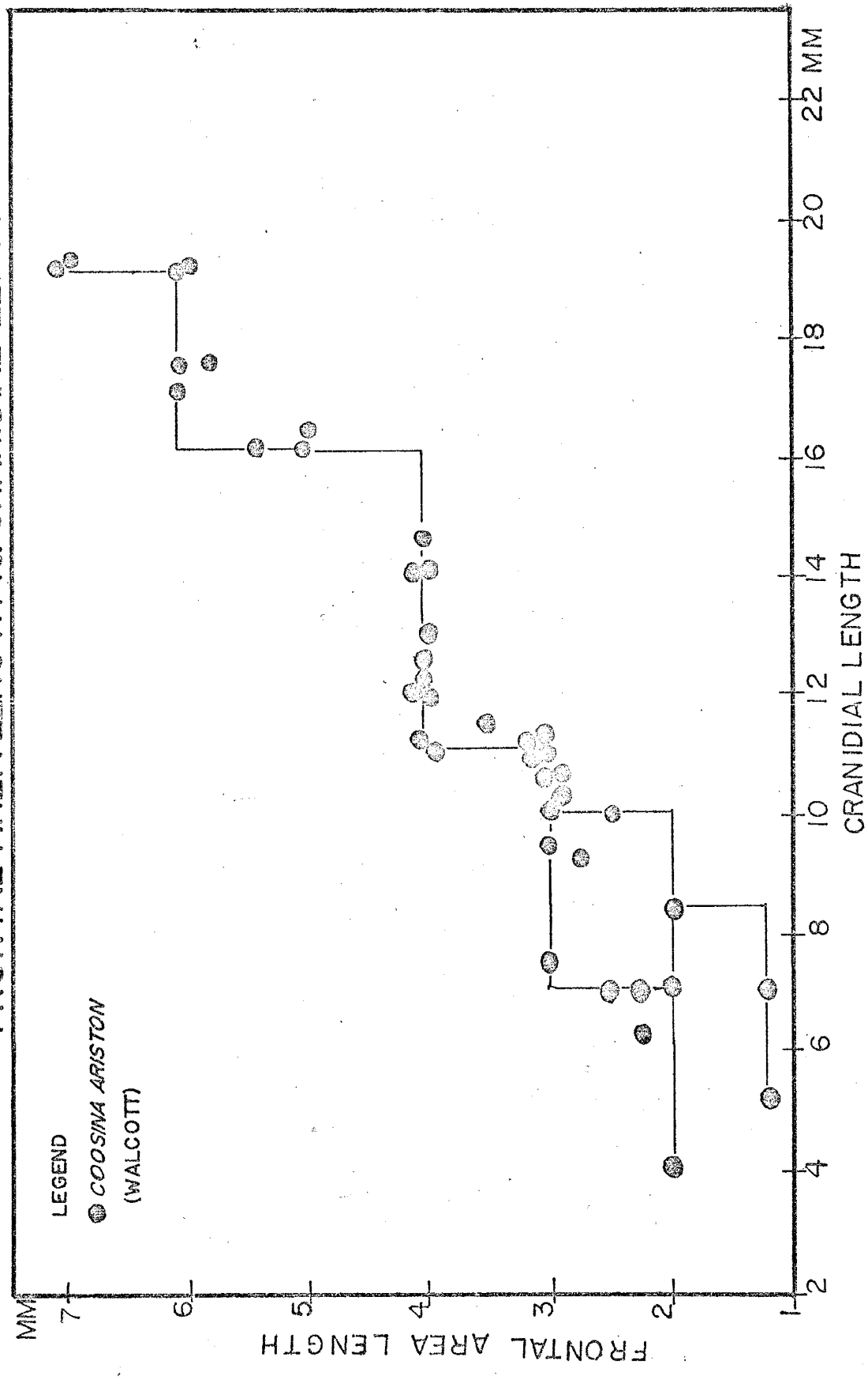

PYGIDIAL WIDTH vs AXIAL WIDTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
AXIAL WIDTH
MM
0
2
4
6
8
10
12
14
PYGIDIAL WIDTH
0
2
4
6
8
10
12
14
16
18
20 MM

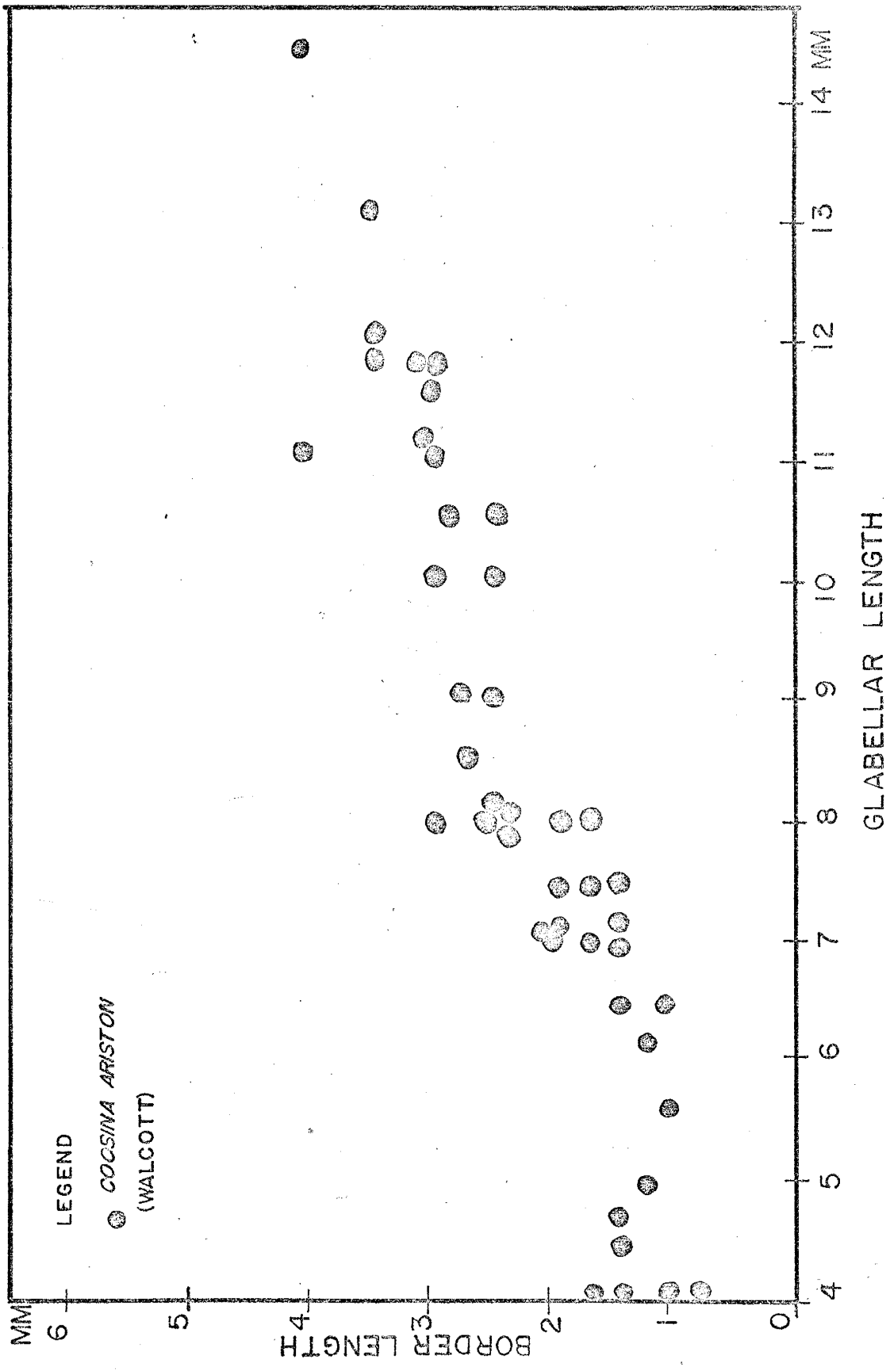

PYGIDIAL LENGTH vs. AXIAL LENGTH
LEGEND
TRICREPICEPHALUS TRIPUNCTATUS
T. BELTENSIS
AXIAL LENGTH
MM
12
10
8
6
4
2
0
PYGIDIAL LENGTH
0
2
4
6
8
10
12
14
16
18
20 MM

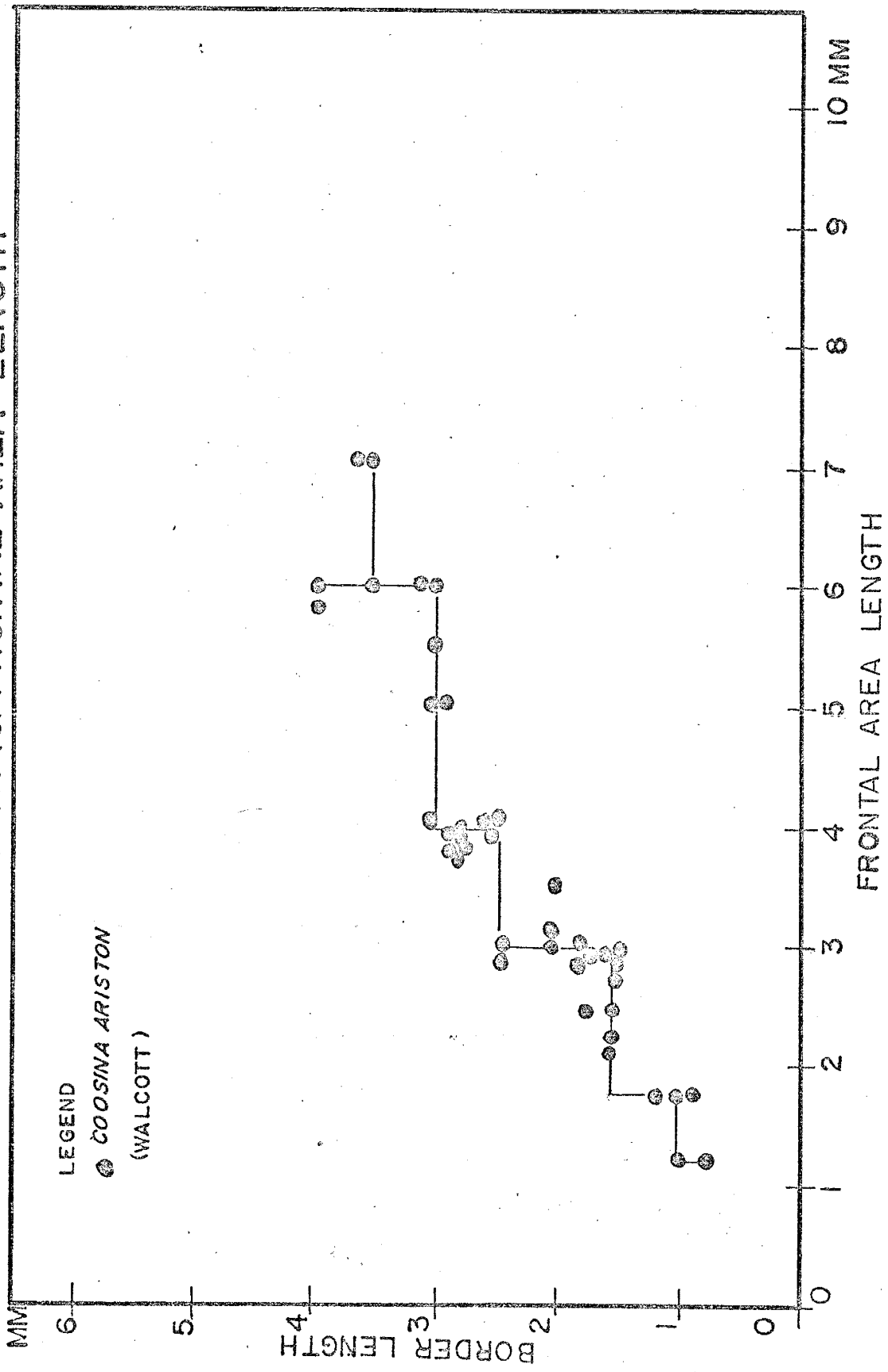
APPENDIX C

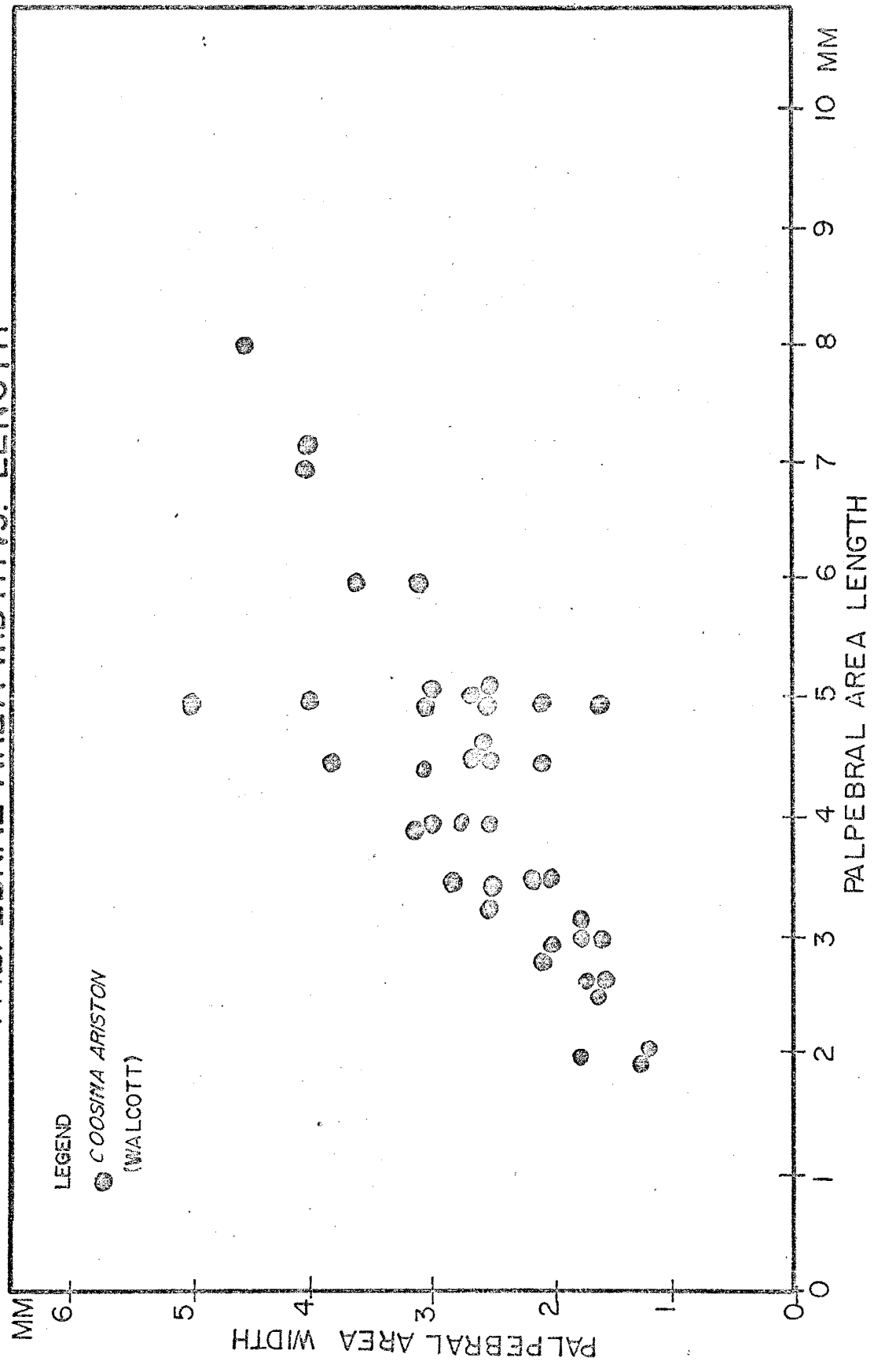

GLABELLAR LENGTH vs. CRANIDIAL LENGTH
LEGEND
COOSINA ARISTON (WALCOTT)
6 SPECIMENS
MM
14
12
10
8
6
4
2
GLABELLAR LENGTH
0
2
4
6
8
10
12
14
16
18
20 MM
CRANIDIAL LENGTH

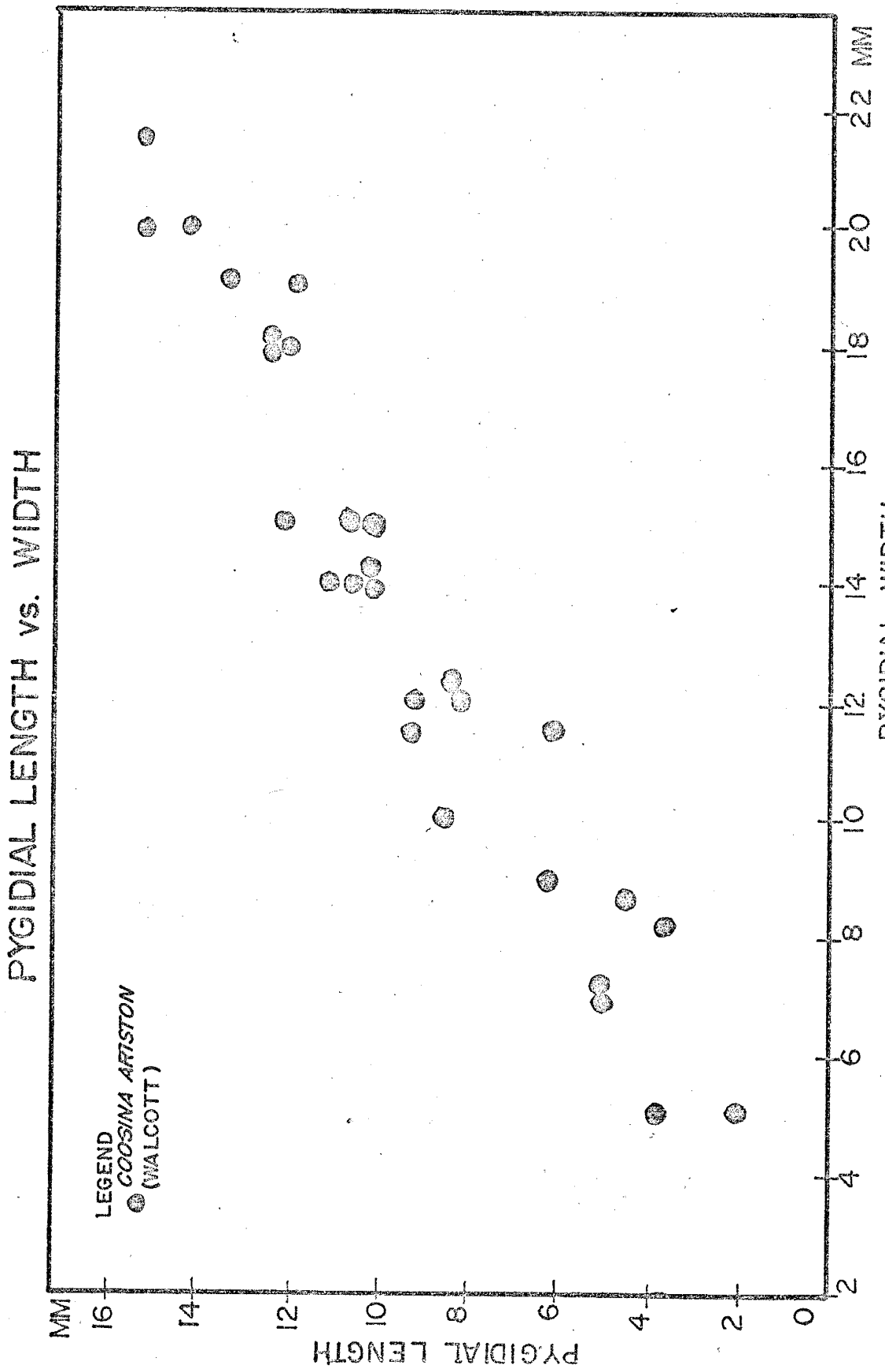

GLABELLAR WIDTH vs. LENGTH
LEGEND
COOSINA ARISTON
(WALCOTT)
MM
12
10
8
6
4
2
0
GLABELLAR WIDTH
4
5
6
7
8
9
10
11
12
13
14 MM
GLABELLAR LENGTH

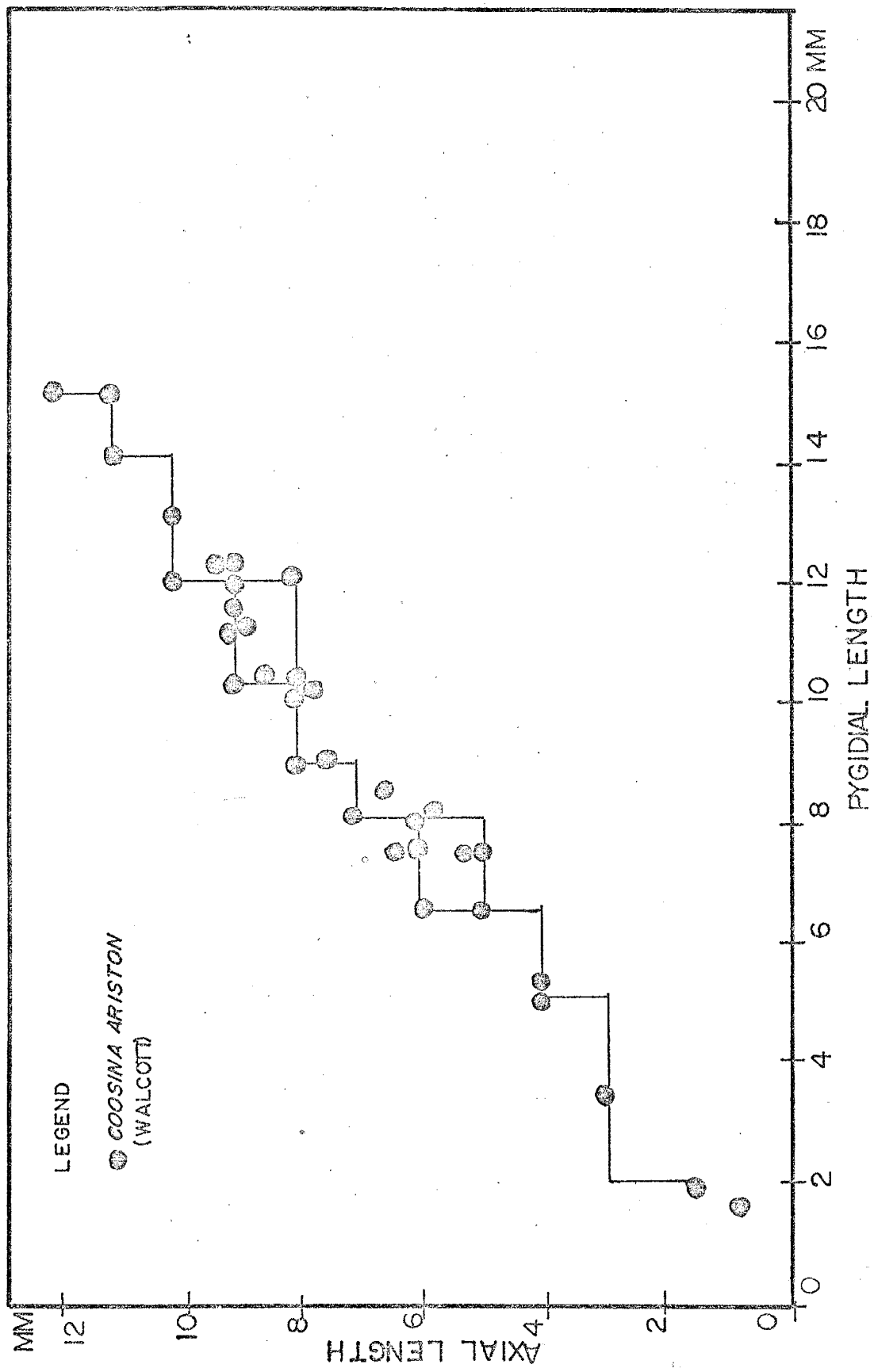

FRONTAL AREA LENGTH vs. CRANIDIAL LENGTH
LEGEND
COOSINA ARISTON
(WALCOTT)
FRONTAL AREA LENGTH
MM
7
6
5
4
3
2
1
CRANIDIAL LENGTH
2
4
6
8
10
12
14
16
18
20
22 MM

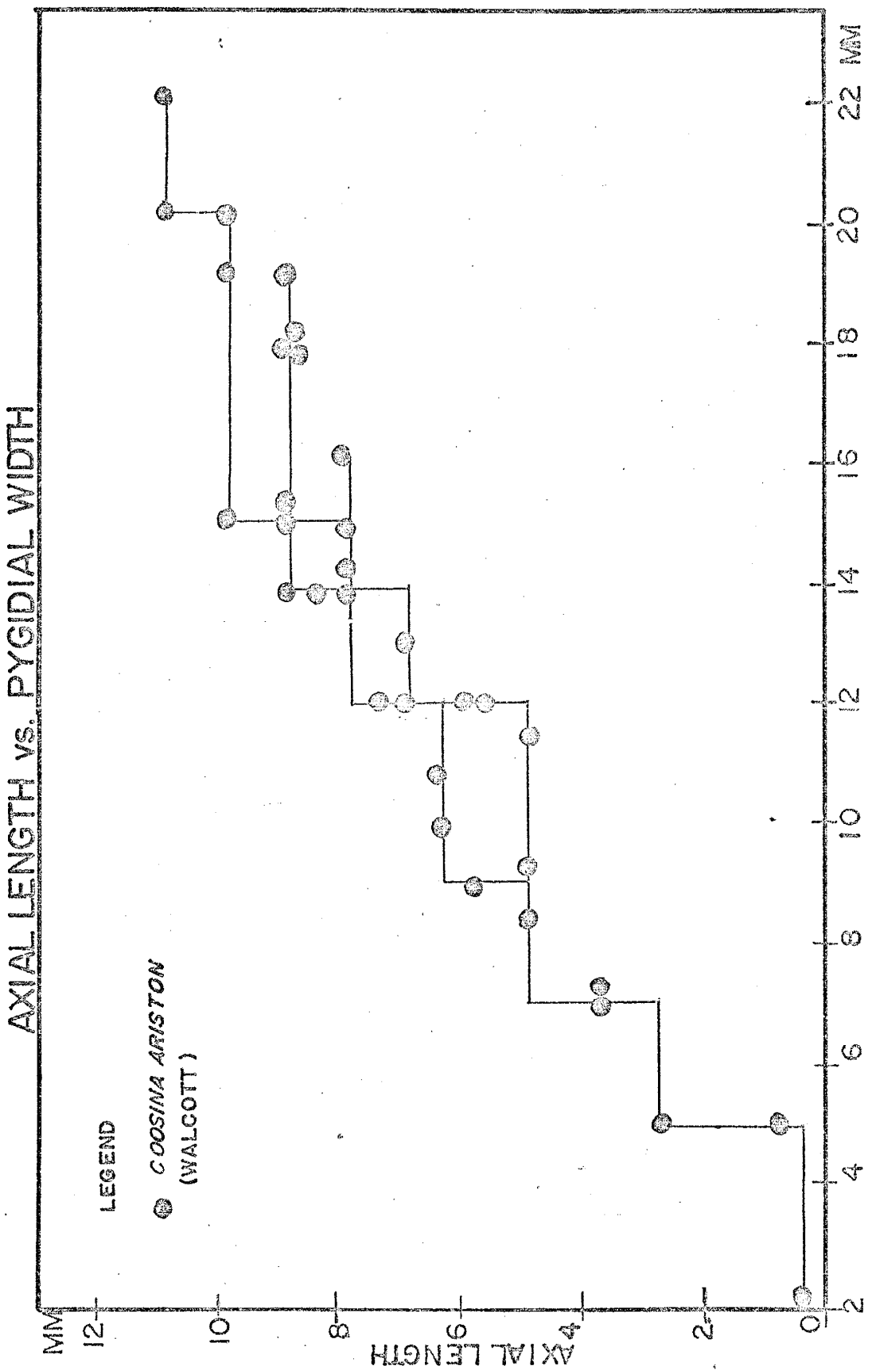

BORDER LENGTH vs. GLABELLAR LENGTH
LEGEND
COCSINA ARISTON
(WALCOTT)
BORDER LENGTH
MM
0
1
2
3
4
5
6
GLABELLAR LENGTH
4
5
6
7
8
9
10
11
12
13
14 MM


BORDER LENGTH vs. FRONTAL AREA LENGTH
LEGEND
COOSINA ARISTON
(WALCOTT)
MM
BORDER LENGTH
FRONTAL AREA LENGTH
10 MM
0
1
2
3
4
5
6
7
8
9


PALPEBRAL AREA WIDTH vs. LENGTH
LEGEND
COOSINA ARISTON
(WALCOTT)
PALPEBRAL AREA WIDTH
MM
0
1
2
3
4
5
6
PALPEBRAL AREA LENGTH
0
1
2
3
4
5
6
7
8
9
10 MM


PYGIDIAL LENGTH vs. WIDTH
LEGEND
COOSINA ARTISTON
(WALCOTT)
MM
16
14
12
10
8
6
4
2
0
PYGIDIAL LENGTH
2
4
6
8
10
12
14
16
18
20
22 MM
PYGIDIAL WIDTH


AXIAL LENGTH vs. PYGIDIAL LENGTH
LEGEND
COOSINA ARISTON
(WALCOTT)
MM
12
10
8
6
4
2
0
AXIAL LENGTH
0
2
4
6
8
10
12
14
16
18
20 MM
PYGIDIAL LENGTH


AXIAL LENGTH vs. PYGIDIAL WIDTH
LEGEND
COOSINA ARISTON
(WALCOTT)
MM
12
10
8
6
4
2
0
AXIAL LENGTH
2
4
6
8
10
12
14
16
18
20
22 MM
PYGIDIAL WIDTH

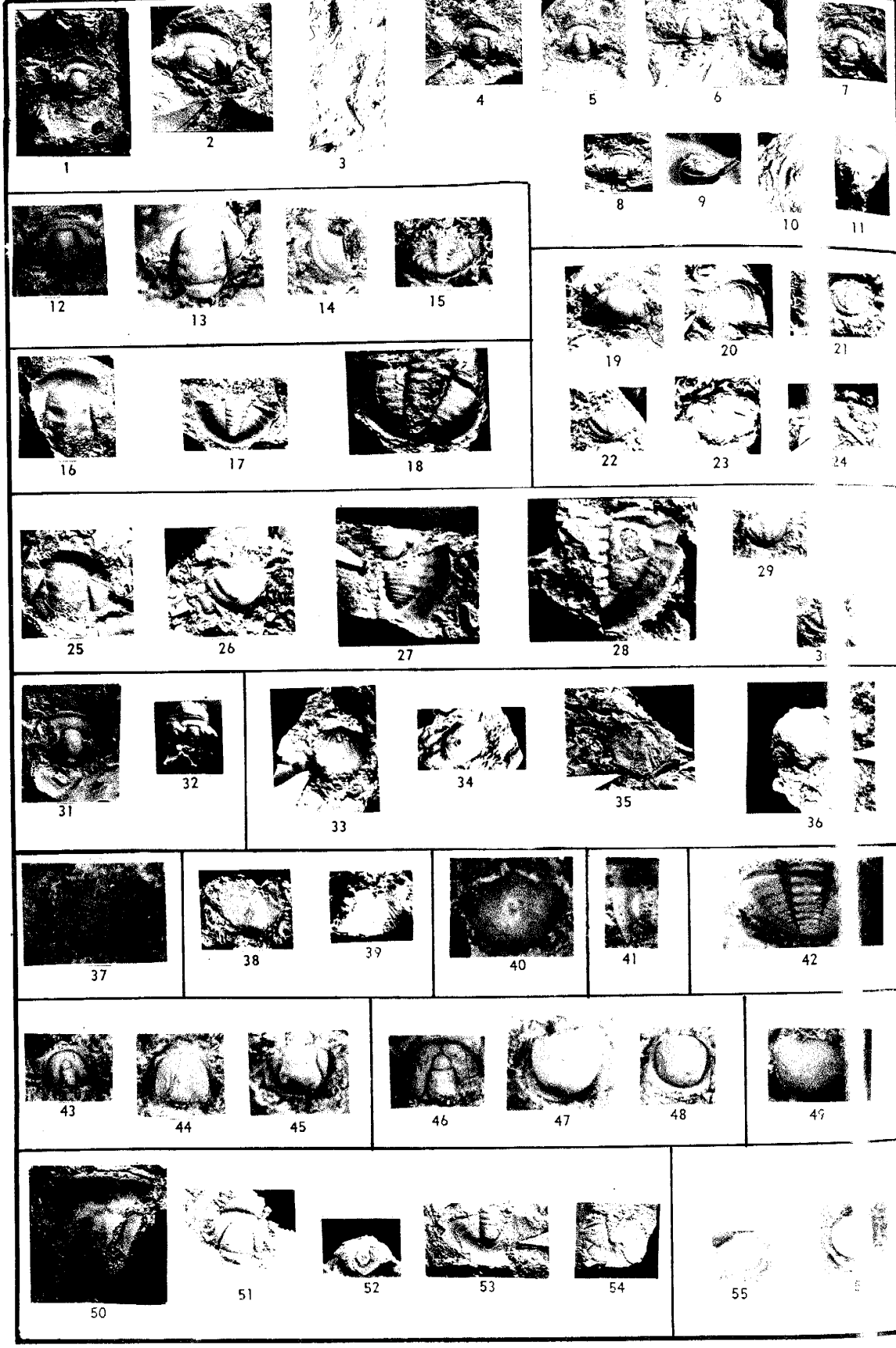

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55

PLATE 5 - *Aphelaspis* and *Crepicephalus* Faunas

Figure

1-11 *Aphelaspis walcotti* Resser. (1,2,4,5,6,7, and 8) large to medium sized cranidia, X1. (3 and 10) well preserved librigenae, X1. (9) large, well preserved pygidium, X1. (11) associated hypostome, X1. All from WC-2, GC, and GC-1.

12-15 *Glaphyraspis parva* (Walcott). (12 and 13) cranidia, X8. (14) librigena, X8. (15) pygidium, X8. From WC-2 and GC-1.

16-18 *Cheilocephalus omegus* (Lochman and Hu). (16) best preserved cranidium, X1. (17 and 18) pygidia, X1. From GC-1 and WC-2.

19-24 *Blountia mimula* Walcott. (19 and 20) cranidia, X1 from GC-1. (24) librigena, X1 and (22 and 23 and 21) pygidia, X1, from WC-2.

25-30 *Cheilocephalus brevilobus* (Walcott). (25) best preserved cranidium. (26-30) pygidia, all X1 from WC-2 and GC-1.

31-32 *Aphelaspis subdita* Palmer. (31 and 32) well preserved cranidia, X1, from GC-1.

33-36 *Eoorthis* sp. undet. (33,34, and 36) pedicle valves X1. (35) brachial valve, X1. All from WC-2.

37 *Dysoristus lochmanae* Bell, pedicle valve, X1, from WC-2.

38-39 *Billingsella* sp. undet. pedicle valves, X1, from WC-2.

40 *Blountia montanensis* Duncan. pygidium, X1 from WC-5.

41 *Maryvillia arion* Walcott. librigena, X6, from GC-1.

42 *Blountia* cf. *B. arcuosa* Resser. pygidium, X1, from WC-14.

43-45 *Acmarhachis arcutus* (Kobayashi). (43 and 44) well preserved cephala, X8, from GC-1. (45) pygidium, X8, GC-1.

46-48 *Pseudagnostus mesleri* (Resser) (46) cephalon, X8. (47 and 48) pygidia, X8, from GC and GC-1.

Figure 49 — *Kingstonia inflata* Resser, pygidium, X8, from GC-1.

50-54 — *Coosia alethes* (Walcott). (50 and 51) best preserved cranidia, X1. (52) hypostome, X1. (53 and 54) pygidia, X1. All from GC, GC-1, and GC-2.

55-56 — *Angulotreta triangularis* Palmer. from GC-1, X7.


1


2


3

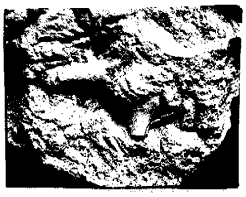

4


5


6


7


8


9


10


11


13


14


15


16


17


18


19


20


21


22


23


24


25

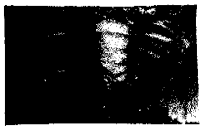

26


27


28


29


30


31


32


33


34


35


36


37


38


39


40


41

42

PLATE 6 - *Crepicephalus* Fauna

Figure

1-9 *Tricrepicephalus beltensis* Duncan. (1-5) cranidia, X1. (6,7) librigenae, X1. (8,9) pygidia, X1. All from GC, GC-1, and GC-2 and WC-2.

10-11 *Crepicephalus* cf. *C. snowyensis* Lochman. (10) librigena, X1, and (11) pygidium, X1, from GC-1.

12 *Crepicephalus snowyensis* Lochman, pygidium, X1, from GC-1.

13 *Tricrepicephalus* cf. *T. beltensis* Duncan, cranidium X1, from GC-1.

14-23 *Tricrepicephalus tripunctatus* (Whitfield). (14-19 and 21) cranidia, X1. (20) librigena, X1. (22,23) pygidia, X1. All from BB, GC-1, WC-8, WC-10, and WC-11.

24-25 *Minicrepicephalus transversus*, pygidia, X1, from GC and GC-1.

26-35 *Coosina ariston* Walcott. (26-27, 29-30) cranidia, X1. (28) librigena, X1. (31-35) pygidia, X1. All from BB, GC-1, WC-11, MC-5, and MC-2.

36 *Coosia alethes* (Walcott), librigena, X1, GC.

37-39 *Coosella longa*, pygidia, X1, from GC, GC-1, WC-6, and WC-14.

40-42 *Meteoraspis loisi* Lochman. (40 and 41) cranidia, X1, (42) pygidium, X1. All from GC.

PLATE

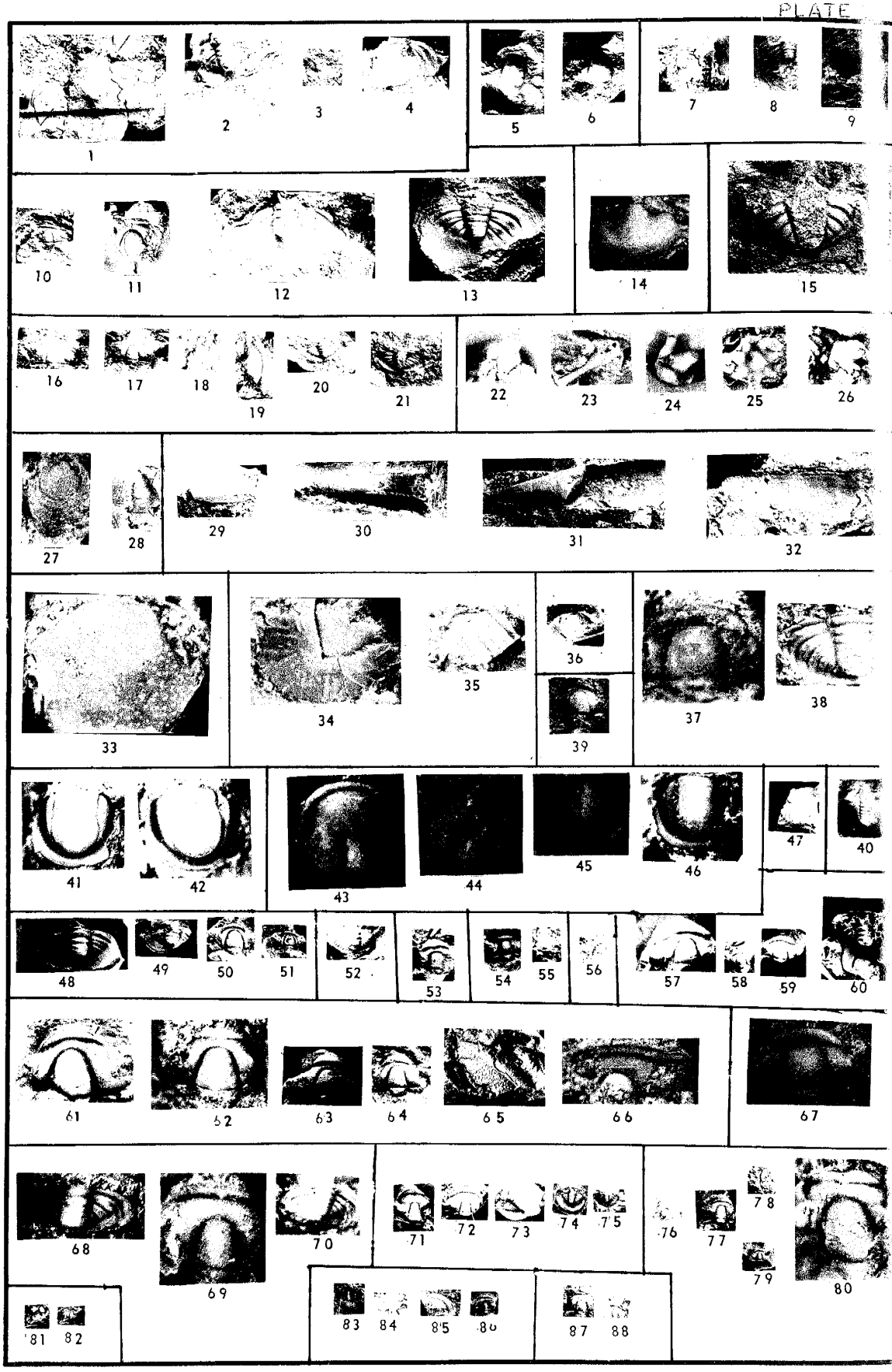

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
41
42
43
44
45
46
47
40
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88

PLATE 7 - *Cedaria* and *Crepicephalus* Fauna

Figure

1-4 *Coosella* aff. *C. helena* Lochman, pygidia X1, from GC, GC-1, and BB.

5-6 *Llanoaspis* cf. *L. peculiaris* (Resser), cranidia, X1, from GC-1.

7-9 *Uncaspis discrepans* Duncan, pygidia X1, from GC-1, and WC-10.

10-13 *Crepicephalus angulatus*, (10,11) cranidia, X1, (12,13) pygidia, X1. From GC, GC-1, BB.

14,40 *Ankoura apicalis* Duncan, pygidia (14) X8 and (40) X1, from GC-1.

15 *Crepicephalus* cf. *C. australis* Palmer, pygidium, X1, from Mill Creek.

16-21 *Weeksina* cf. *W. winona* (Hall), (16,17) cranidia X1, (18,19) librigena X1 and X6, (20,21) pygidia X1. All from GC and GC-1.

22-26 *Chancelloria* cf. *C. drusilla* Walcott, spicules, X8 from GC-1 and WC-8.

27,28 *Lingulepis* cf. *L. acuminata* (Conrad). (27) dorsal valve, X8. (28) ventral valve, X1. From GC and GC-1.

29-32 *Hyolithes gallatinensis* Resser, X1, from GC, GC-1, GC-2, and WC-10.

33 *Foerstecystis*? sp. undet. plate, X8, from GC-1.

34-35 *Paleocystites*? sp. undet. plates, X8, from BB, BB-1.

36 *Obolus* sp. undet. valve, X8, from GC-1.

37-38 *Llanoaspis* cf. *L. undulata* Lochman. (37) pygidium, X8. (38) cranidium X1. From GC-1.

39 *Maryvillia arion* Walcott, cranidium X1, from WC-11.

41-42 *Baltagnostus beltensis* Lochman, pygidia, X8, from Beaver Creek.

43-46 *Kormagnostus simplex* Resser, cranidia (43,44) and pygidia (45,46) from Beaver Creek, X8.

Figure

47 Bynumia lata Lochman, cranidium X1, from BC-1.

48-51 Syspacheilus camurus Lochman, cranidia (48,49) and pygidia (50,51) X1 from Beaver Creek.

52 Arapahoia snowiensis Howell and Duncan, pygidium X1, from Beaver Creek.

53 Paracedaria tarda Lochman and Hu, cranidium X1, from BC X14.

54-55 Genevievella spinosa Lochman, cranidia, X1, from MC-2.

56 Kingstonia spicata Lochman, pygidium X1, from BC X8.

57-60 Meteoraspis boulderensis Deland, cranidia (57-59) and pygidium (60), from LOC 3 and BC X8.

61-66 Modocia centralis (Whitfield), cranidia (61-64) and librigenae (65-66), X1, from Beaver Creek.

67 Torridella migranta Lochman and Hu cranidium X8, from BC X1.

68-70 Paracedaria montanensis (Duncan), cranidium (69) and pygidia (68,70) X8 from Beaver Creek.

71-75 Cedaria buttsi Resser, cranidia (71,72) and pygidia (73-75) X1, from Beaver Creek.

76-80 Cedarina prima Lochman, cranidia (77,79,80), librigena (78), and pygidium (76) all X1 except fig. 80, X8, from Beaver Creek.

81-82 Cedarina cordillerae (Howell and Duncan), cranidia X1, from Beaver Creek.

83-86 Cedaria milleri Resser, cranidium (86), librigena (85), and pygidia (83-84) X1, from Beaver Creek.

87-88 Cedarina victoria Lochman, cranidia X1, from Beaver Creek.

Abbreviations

T.L. total length of cranidium or pygidium

G.L. length of glabella

G.W. width of glabella

FUR. lateral glabellar furrows

O.R.L. occipital ring length

O.R.W. occipital ring width

F.A.L. frontal area length

P.G.S. slope of preglabellar field

- ds downsloping
- up upsloping
- fl flat
- cvx convex

P.G.L. length of preglabellar field

B.S. slope of border

B.L. length of border

B.W. border width

P.A.W. palpebral area width

P.A.L. palpebral area length

P.L.W. palpebral lobe width

P.L.L. palpebral lobe length

P.L.S. slope of palpebral lobe

P.L.P. position of palpebral lobe

PT.L. length of posterior area

PT.W. width of posterior area

T.W. total width of pygidium

A.L. length of axis of pygidium

A.W. width of pygidial axis

A.R. number of axial rings

P.F. pleural and interpleural furrows
IP.F.
FUR.

B.W. maximum border width (lateral)

This thesis is accepted on behalf of the faculty of the Institute by the following committee:

Christina L Balk

Robert Hamilton

Fred E. Lawrence

Date November 24, 1971

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
7.0	3.75	3.0	2 pr.	1.0	3.5	3.25	ds	1.5	flat	6.0	1.5	1.0	3.0	0.75	1.75	up	oc	----	wide	yes
7.0	4.0	3.0	2 pr.	1.0	3.25	3.0	ds	1.75	up	5.0	1.25	1.5	3.5	----	----	----	----	----	----	yes
7.0	4.5	2.75	2 pr.	0.75	3.25	2.5	ds	1.75	flat	5.0	1.1	1.5	3.0	----	----	----	----	----	----	yes
7.0	4.0	3.0	2 pr.	0.75	3.5	3.0	ds	1.4	flat	----	----	1.25	3.75	1.0	2.5	up	up¼	----	----	yes
7.0	4.5	2.5	2 pr.	----	3.0	2.5	ds	1.5	up	6.0	1.0	1.0	3.0	0.75	2.0	fl	oc	----	----	yes
7.0	4.5	2.5	2 pr.	0.75	3.0	2.5	ds	1.25	flat	5.5	1.25	1.0	3.0	----	----	----	----	----	----	yes
7.0	4.5	3.0	2 pr.	1.25	3.5	2.5	ds	1.5	flat	4.0	1.1	1.0	2.5	0.75	1.5	fl	oc	----	----	yes
7.0	5.0	3.0	----	1.0	3.5	2.0	ds	1.0	up	6.0	1.0	1.5	3.0	----	----	----	----	----	----	yes
7.5	4.5	3.25	----	0.75	4.0	3.0	ds	1.5	flat	6.0	1.5	1.0	4.0	0.8	----	fl	oc	----	----	yes
7.5	4.5	3.25	2 pr.	0.75	----	3.0	flat	1.5	up	6.0	1.0	1.0	3.5	0.75	1.75	fl	oc	----	----	yes
7.5	4.5	3.0	----	0.75	3.5	3.0	ds	2.25	flat	----	----	1.25	3.75	1.0	2.5	fl	up¼	----	----	yes
7.5	4.5	2.9	2 pr.	0.75	3.0	3.0	ds	2.0	flat	----	1.1	1.0	3.0	0.8	2.25	----	----	----	----	yes
7.5	4.25	3.0	2 pr.	0.75	3.1	3.25	flat	1.15	up	5.5	1.1	1.1	3.0	0.8	1.25	fl	oc	----	----	yes
8.0	4.5	3.25	2 pr.	1.0	4.0	3.5	ds	2.0	flat	6.0	1.5	----	----	----	----	----	----	----	----	yes
8.0	4.75	3.0	2 pr.	1.0	4.0	3.25	ds	2.0	flat	6.5	1.25	1.0	4.0	----	----	----	----	----	----	yes
8.0	4.5	4.0	2 pr.	1.25	4.25	3.5	ds	2.25	flat	6.5	1.25	1.0+	4.0	0.75	2.0	fl	----	3.0+	wide	yes
8.0	4.75	3.0	2 pr.	0.75	3.5	3.0	ds	1.9	up	6.0	1.25	1.1	3.25	0.8	2.0+	fl	oc	----	----	yes
8.0	4.5	3.25	2 pr.	0.75	4.0	3.5	ds	2.25	up	6.0	1.25	----	3.25	----	----	----	----	----	----	yes
8.0	4.5	3.5	2 pr.	0.75	3.0	3.0	ds	1.75	flat	5.0+	1.25	1.0	3.0	----	----	----	----	----	----	yes
8.0	5.0	3.75	----	1.0	4.0	3.0	ds	1.75	flat	----	1.25	1.0	3.75	----	----	----	----	----	----	yes
8.0	5.0	3.0	----	0.8	3.5	3.0	ds	1.75	up	6.0	1.25	1.25	3.5	1.0	2.25	fl	oc	----	----	yes
8.0	4.5	----	----	----	----	3.5	ds	2.0	flat	----	1.5	----	4.0	----	----	----	----	2.5+	1.0	yes
8.5	5.0	3.25	2 pr.	1.0	4.0	3.5	ds	2.0	up	8.0	1.5	1.25	3.5	1.0	2.0	fl	oc	----	----	yes
8.5	5.0	3.25	2 pr.	1.0	4.0	3.5	ds	2.25	flat	8.0	1.25	1.25	3.5	----	----	----	----	----	----	yes
8.5	5.0	3.5	2 pr.	1.0	4.0	3.5	ds	2.0	up	6.25	1.5	1.25	3.75	1.0	2.25	fl	oc	----	----	yes
9.0	5.5	3.0	2 pr.	1.0	4.0	3.5	ds	2.0	flat	7.0	1.5	1.25	5.0	0.75	2.0	up	oc	----	----	imp.
9.0	5.5	4.0	2 pr.	1.0	4.5	3.5	----	----	----	8.0	----	----	----	----	----	----	----	----	----	yes
9.0	5.5	4.0	2 pr.	1.25	4.5	3.5	ds	2.0	up	7.5	1.5	----	----	----	----	----	----	----	----	yes
9.0	5.5	4.0	2 pr.	0.75	4.5	3.5	ds	2.0	flat	7.5	1.5	1.25	4.0	1.0	2.0+	fl	oc	----	----	yes
9.0	5.5	3.5	2 pr.	1.0	4.0	3.5	ds	2.25	flat	8.0	1.25	----	4.5	----	----	----	----	----	----	yes
9.5	5.5	3.5	----	1.0	4.5	4.0	ds	2.25	flat	7.0	1.75	1.5	4.0	1.0	2.0+	fl	oc	----	----	yes
9.5	6.0	4.0	----	1.0	4.5	3.5	ds	2.0	flat	8.0	1.5	1.25	4.0	----	----	----	----	----	----	yes
10.0	6.0	4.0	2 pr.	1.0	4.75	4.0	ds	2.5	up	8.0	1.5	----	4.5	----	----	----	----	----	----	yes
11.0	7.0	5.5	2 pr.	----	----	4.0	ds	2.0	up	8.5	2.0	2.0	----	1.0	3.0	up	oc	----	----	yes
12.0	7.0	5.0	----	1.0	5.5	4.5	ds	2.25	up	8.0+	2.25	2.0	5.0	----	----	----	----	----	----	yes

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
4.5	2.5	2.0	2 pr.	0.5	2.25	2.0	ds	1.0	up	3.75	1.0	0.65	2.25	0.5	1.25	up	oc	----	----	yes
4.5	2.75	1.75	2 pr.	0.3	2.0+	2.0	ds	1.25	up	3.5	0.75	----	2.0	----	----	----	----	----	----	yes
4.5	3.0	1.5	2 pr.	0.5	2.0	1.5	ds	1.0	flat	3.75	0.5	0.5	1.5	0.75	1.0	up	oc	----	----	yes
4.0	2.5	1.5	2 pr.	0.5	2.0	1.5	ds	1.0	ds	3.0	0.5	0.5	2.0	0.5	1.0	up	oc	----	----	no
5.0	3.0	2.0	2 pr.	0.75	1.75	2.0	ds	1.25	flat	3.0	0.75	0.5	2.0	0.25	1.0	up	oc	----	----	yes
5.0	3.0	----	----	----	----	2.0	----	----	----	----	----	----	----	----	----	----	----	----	----	----
5.0	3.0	2.5	2 pr.	----	2.75	2.0	ds	1.25	flat	4.5	0.75	0.75	3.0	----	----	----	----	----	----	yes
5.0	3.0	2.25	2 pr.	----	2.5	2.0	flat	1.0	up	5.0	1.0	1.0	3.0	----	----	----	----	----	----	yes
5.0	3.25	2.75	2 pr.	0.5	3.25	1.75	ds	1.0	flat	4.0	0.75	0.75	2.75	----	----	----	----	----	----	yes
5.0	3.0	2.5	2 pr.	0.5	2.75	2.0	ds	1.25	flat	4.0	0.75	1.0	2.25	0.5	1.75	up	oc	----	----	yes
5.0	3.0	2.0	2 pr.	0.5	2.5	2.0	ds	1.0	flat	4.0	1.0	0.75	2.0	0.25	0.9	up	oc	----	----	no
5.0	3.25	2.25	2 pr.	0.5	2.75	1.75	ds	1.0	flat	4.0	0.75	0.75	2.5	----	----	----	----	----	----	yes
5.0	3.25	2.0	2 pr.	0.5	2.5	1.75	ds	1.0	flat	4.0	0.75	0.75	2.5	0.25	1.5	up	up½	2.0	0.75	yes
5.0	2.5	2.0	----	----	2.7	2.6	ds	1.5	up	4.5	1.0	1.0	----	0.5	1.0+	fl	up½	----	----	yes
5.0	3.5	2.25	----	0.75	2.75	2.0	ds	1.0	up	4.0	1.0	1.0	2.5	----	----	----	----	----	----	yes
5.0	3.0	2.5	2 pr.	0.5	2.75	2.0	ds	1.25	up	4.0	0.75	1.0	2.5	0.75	1.25	----	----	----	----	yes
5.0	3.0	2.0	2 pr.	0.75	2.5	2.0	ds	1.0	up	4.25	1.0	0.75	2.0	----	----	----	----	----	----	yes
5.5	3.0	2.5	2 pr.	0.5	2.5	2.5	ds	1.75	flat	5.0	0.75	1.0	2.75	----	----	----	----	----	----	yes
5.75	3.5	2.5	2 pr.	0.74	3.0	2.25	ds	1.25	flat	5.0	1.0	1.0	2.5	1.0	1.5	----	----	----	----	yes
6.0	3.5	2.5	2 pr.	0.75	2.5	2.5	ds	1.5	up	5.0	1.0	0.75	3.0	0.5	1.25	fl	oc	----	----	yes
6.0	3.5	2.5	2 pr.	0.5	2.75	2.5	ds	1.5	flat	----	1.0	1.0	3.0	0.5	1.75	fl	up½	----	----	yes
6.0	3.5	2.25	2 pr.	0.75	3.0	2.5	ds	1.5	flat	4.5	1.0	1.0	2.5	----	----	----	----	----	----	yes
6.0	3.5	2.25	2 pr.	0.75	2.75	2.5	ds	1.25	flat	----	1.25	1.0	2.5	----	----	----	----	----	----	yes
6.0	3.5	2.75	2 pr.	0.75	3.0	2.5	flat	1.25	up	4.75	1.25	1.0	2.5+	1.0	1.75	fl	oc	----	----	yes
6.0	3.75	2.0	----	0.75	2.7	2.25	ds	1.25	flat	4.0	1.0	1.0	2.5	0.75	1.25	fl	oc	----	----	yes
6.25	3.75	2.75	2 pr.	----	3.0	2.5	ds	1.4	flat	4.0	1.0	1.0	2.5	0.75	----	fl	oc	----	----	yes
6.25	4.0	2.5	----	0.75	3.0	2.25	ds	1.25	flat	5.0	1.0	1.0	2.5	0.5	2.0	up	----	----	----	yes
6.5	3.75	2.5	2 pr.	1.0	3.0	2.25	ds	1.25	up	5.5	1.0	1.0	3.0	1.0	2.0	fl	up½	3.0+	1.25	yes
6.75	4.25	2.5	2 pr.	0.75	3.25	2.5	ds	1.5	flat	6.0	1.0	----	----	----	----	----	----	----	----	yes
6.75	4.25	2.75	2 pr.	0.75	3.0	2.5	ds	1.5	flat	5.0	1.0	2.0	1.0	1.0	1.75	fl	oc	----	----	yes
6.75	4.25	3.0	2 pr.	0.75	3.0	2.5	flat	1.25	up	----	1.25	----	3.25	----	----	----	----	----	----	yes
7.0	4.5	3.0	2 pr.	0.75	4.0	2.5	ds	1.5	flat	6.0	1.0	1.0	3.0	0.75	1.25	fl	oc	----	----	yes
7.0	4.5	3.0	2 pr.	0.75	3.5	2.5	ds	1.5	flat	5.5+	1.0	1.6	4.0	0.75	1.75	fl	oc	3.5	1.0	no
7.0	4.5	3.0	2 pr.	----	3.5	2.5	flat	1.5	up	6.0	1.0	1.0	3.74	----	----	----	----	----	wide	yes
7.0	4.5	3.0	----	0.75	4.0	2.5	ds	1.5	flat	6.0	1.0	1.0	3.0	0.5	1.75	----	oc	2.5	1.0	no
7.0	4.5	3.0	----	0.75	3.5	2.5	ds	1.5	flat	6.0	1.0	1.0	3.0	1.0	1.75	fl	up½	----	----	no

Measurements of Aphelaspis walcotti Resser

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
1.25	0.60	0.75	2 pr.	0.8	1.0	0.65	flat	0.55	flat	1.25	0.1	0.25	1.0	----	----	----	----	----	----	yes
2.0	1.25	0.75	----	0.1	1.0	0.75	ds	0.5	flat	1.25	0.2	0.3	0.75	0.1	0.6	fl	oc	1.0	o.2	yes
2.0	1.25	0.90	----	0.1	1.25	0.75	flat	0.5	flat	1.75	0.25	0.25	1.25	----	----	----	----	1.0	0.5	no
2.5	1.75	1.0	----	0.1	1.0	0.75	ds	0.42	up	1.5	0.33	0.25	0.75	----	----	----	----	----	----	no
2.5	1.5	1.0	2 pr.	0.25	1.25	1.0	fl-ds	0.75	flat	2.0	0.25	0.5	1.25	0.25	0.75	fl	oc	----	----	no
2.5	1.5	1.0	2 pr.	0.25	1.25	1.0	ds	0.7	flat	2.0	0.3	0.3	1.25	0.25	1.0	up	up¼	----	----	yes
3.0	2.0	1.5	2 pr.	0.25	2.1	1.0	ds	0.5	flat	2.5	0.5	0.5	1.5	0.1	0.75	fl	oc	----	----	yes
3.25	2.25	1.25	2 pr.	0.25	1.5	1.0	ds	0.5	flat	3.0	0.5	0.5	1.75	----	----	----	----	----	----	no
3.25	2.25	1.0	----	0.25	1.5	1.0	ds	0.5	up	2.5	0.5	0.75	1.25	0.25	1.0	fl	oc	----	----	no
3.5	2.0	1.5	2 pr.	0.25	1.75	1.5	ds	0.75	flat	1.75	0.75	0.5	1.25	0.25	1.0	up	oc	2.3+	0.5+	yes
3.5	2.0	1.5	2 pr.	0.25	2.0	1.5	ds	0.75	flat	1.75	0.75	0.5	2.0	----	----	----	----	----	----	no
3.5	2.5	2.0	2 pr.	0.25	2.0	1.0	fl-ds	0.25	flat	2.5	0.75	0.75	2.0	----	----	----	----	----	----	yes
3.5	2.0	2.0	2 pr.	0.5	2.25	1.5	ds	1.0	flat	2.25	0.5	0.5	2.0	----	----	----	----	----	----	yes
3.5	2.0	1.5	2 pr.	0.5	1.75	1.5	ds	1.17	flat	2.0	0.5	0.5	2.0	----	----	----	----	----	----	yes
3.5	2.0	1.5	2 pr.	0.5	1.75	1.5	ds	1.0	flat	2.5	0.5	0.55	2.0	0.45	1.0	fl	oc	----	----	yes
3.75	2.25	1.25	2 pr.	0.25	1.5	1.5	ds	0.75	flat	3.0	0.75	0.75	2.25	----	----	----	----	----	----	no
3.75	2.25	1.5	2 pr.	0.5	2.0	1.5	ds	1.0	up	3.0	0.5	0.75	2.0	0.25	1.0	fl	up¼	----	----	yes
3.5	2.0	1.25	----	0.25	1.5	1.5	ds	1.0	up	3.0	0.5	0.5	1.5	0.5	1.0	up	up¼	----	----	no
4.0	2.5	1.25	2 pr.	0.25	1.5	1.5	ds	1.0	up	3.0	0.5	0.5	1.25	0.25	1.0	fl	oc	----	----	yes
4.0	2.5	1.75	2 pr.	0.5	2.0	1.5	ds	1.0	flat	3.25	0.5	0.75	2.5	----	----	----	----	----	----	yes
4.0	2.25	1.75	2 pr.	0.5	2.0	1.75	ds	1.0	flat	3.5	0.75	0.75	2.0	0.25	1.0	up	oc	----	----	no
4.0	2.75	1.75	2 pr.	0.5	2.0	1.25	ds	0.5	flat	3.75	0.5	0.75	2.0	0.25	1.0	up	up¼	----	----	no
4.0	2.5	1.75	2 pr.	0.5	2.0	1.5	ds	1.0	flat	3.5	0.5+	0.75	2.0	0.25	1.0	fl	oc	----	----	yes
4.0	2.5	1.75	2 pr.	0.5	2.0	1.5	ds	0.75	flat	3.5	0.75	1.0	2.0	0.25	----	fl	oc	----	----	no
4.0	2.5	2.0	2 pr.	0.4	2.5	1.5	ds	0.75	flat	4.0	0.75	0.75	2.0+	0.75	1.0	up	up¼	----	----	yes
4.0	2.5	----	----	----	----	1.5	----	----	----	----	----	----	----	----	----	----	----	----	----	----
4.0	2.5	1.5	2 pr.	0.5	1.75	1.5	ds	0.75	flat	3.0	0.75	0.75	1.5	0.5	----	up	up¼	----	----	yes
4.0	2.5	1.75	2 pr.	0.5	2.0	1.5	ds	0.75	flat	3.0	0.75	0.5	1.75	----	----	----	----	----	----	yes
4.0	2.5	1.75	2 pr.	0.5	1.75	1.5	ds	1.0	flat	3.5	0.5	0.5	2.0	0.5	1.0	fl	oc	----	----	yes
4.25	2.75	1.75	2 pr.	0.25	2.0	1.5	ds	1.0	flat	2.5	0.5	0.5	2.0	0.25	1.0	up	up¼	----	----	yes
4.5	2.75	1.75	2 pr.	0.25	2.25	1.75	ds	1.0	up	3.0	0.75	0.5	3.0	----	----	----	----	----	----	no
4.5	2.5	1.8	----	0.5	2.0	2.0	ds	1.25	flat	3.0	0.75	0.75	2.0	----	----	----	----	----	----	yes
4.5	2.75	1.9	2 pr.	0.5	2.5	1.75	ds	1.0	up	3.0	0.75	0.5+	2.0	----	----	----	----	----	----	yes
4.5	3.0	1.75	----	0.5	2.25	1.5	ds-fl	1.0	up-flat	4.0	0.5	1.0	2.0	----	----	----	----	----	----	no

Measurements of Coosina ariston(Walcott)

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	R.L.W.	P.L.L.	P.L.S.	P.L.P.	PT L.	PT.W.	Peeled
11.0	8.0	7.0	----	1.5+	5.0	3.0	ds	0.5	up	2.5	9.0	2.5	4.5	1.0	3.0	up	up¼	3.0	5.5	yes
11.0	8.0	7.0	----	1.5	5.0	3.0	ds	0.5	up	2.5	8.5	2.5	4.5	0.5	2.0	up	oc	3.0	4.5	yes
6.5	4.0	4.0	----	1.0	4.0	2.5	ds	0.5	up	1.75	5.0	1.5	2.5	----	----	----	----	----	----	yes
17.5	11.5	8.0	----	1.5	8.0	6.0	ds	3.0	up	3.0	16.0	4.0	7.0	----	----	----	----	----	----	yes
19.0	12.0	9.5	----	2.0	10.0	7.0	ds	3.5	up	3.5	1.4	4.5	8.0	----	----	----	up¼	3.5	4.5	yes
13.0	9.0	5.5	----	----	----	4.0	ds	1.5	up	2.5	10.0	2.0	5.0	----	----	----	----	----	----	yes
14,75	10.25	8.0	----	1.0	8.0	4.0	ds	1.0	up	3.0	12.0	3.0	5.0	1.0	3.0	up	oc	3.75	6.0	yes
10.0	7.0	6.0	----	1.0	4.5	2.5	ds	1.0	up	1.5	7.0	2.5	4.5	0.5	1.5	up	up¼	1.5	4.0	yes
4.0	2.5	3.25	----	0.5	3.75	1.5	ds	0.5	up	1.0	5.5	1.5	3.0	----	----	----	----	----	----	yes
11.0	8.0	7.0	----	0.75	5.5	3.0	ds	1.25	up	1.75	8.0	2.0	3.5	0.75	1.5	up	oc	2.0	4.0	yes
7.0	4.75	3.0	----	0.75	3.25	2.25	ds	0.75	up	1.5	5.5	1.5	2.5	----	----	up	oc	1.25	2/5	yes
6.5	4.5	4.0	----	0.75	3.5	2.0	ds	0.5	up	1.5	5.0	1.5	3.0	----	----	----	oc	1.5	3.5+	yes
9.5	7.0	5.0	----	1.25	5.0	3.0	ds	0.75	up	1.75	7.5	2.5	4.0	0.5	----	up	oc	2.5	4.5	yes
7.0	5.0	4.0	----	0.75	3.75	2.0	ds	0.75	up	1.25	6.0	1.5	3.0	0.5	1.0	up	up¼	2.0	3.0	yes
12.5	9.0	7.0	----	1.25	7.5	4.0	ds	1.75	up	2.75	11.0	3.0	5.0	0.75	2.0	up	up¼	3.0	5.0+	yes
10.5	7.0	6.0	----	0.75	6.0	3.0	ds	1.5	up	1.5	9.0	2.0	3.0	0.5	1.0	up	up¼	2.0	4.0	yes
11.0	7.5	6.0	----	1.0	6.0	3.0	ds	1.5	up	1.5	9.5	2.0	3.5	----	----	----	----	----	----	yes
11.5	7.0	6.0	----	1.0	5.0	4.0	ds	2.75	up	1.25	10.0	3.0	4.5	0.75	1.5	ds	up¼	3.0	4.5	no
11.5	7.0	5.0	----	1.5	6.0	4.0	ds	1.5	up	2.5	11.0	3.0	4.0	0.75	1.5	up	oc	4.5	6.0	yes
9.25	6.5	4.0	----	0.75	3.5	2.75	ds	1.25	up	1.5	8.0	1.5	3.0	----	----	----	----	1.5	3.0	yes
11.0	8.0	7.0	----	----	----	4.0	ds	1.25	up	2.75	12.0	2.5	5.0	----	----	up	up¼	2.5	5.0	yes
11.0	8.0	6.0	----	1.0	----	3.0	ds	0.5	up	2.5	9.0	2.75	4.0	0.75	1.5	ds	oc	2.0	4.0	yes
11.0	8.0	6.0	----	----	----	3.0	ds	0.5	up	2.5	10.0	2.5	5.0	----	----	----	----	2.0	4.0	yes
19.0	13.0	9.5	----	1.0	9.0	6.0	ds	2.5	up	3.5	17.0	4.0	7.0	1.0	1.5	----	up¼	3.5	8.5	yes
18.0	12.0	9.5	----	1.25	9.0	5.5	ds	3.0	up	3.0	16.0	4.0	7.0	----	2.5	----	up¼	4.0	9.5	yes
19.0	12.0	9.0	2 pr.	1.5	9.0	7.0	ds	3.5	up	3.5	14.0	3.0	6.0	1.0	3.0	up	up¼	5.0	8.0+	yes
16.0	11.0	8.0	----	1.0	8.0	5.0	ds	2.0	up	3.0	13.0	2.5	5.0	----	----	----	----	4.0	6.0	yes
14.0	10.0	7.0	----	1.5	7.0	4.0	ds	1.5	up	2.5	11.0	2.0	4.5	----	----	----	----	3.5	1.0	yes
18.0	12.0	9.0	----	1.75	9.0	6.0	ds	3.0	up	3.0	15.0	4.0	5.0	1.5	3.0	up	oc	4.0	9.0	yes
19.0	14.5	9.0	----	2.5	10.0	6.0	ds-up	2.0	up	4.0	18.0	5.0	5.0	----	----	----	----	----	----	yes
16.5	11.0	7.0	----	2.0	8.0	5.5	ds	1.5	up	4.0	15.0	3.0	4.0	1.0	3.0	up	oc	5.0	8.0	no
8.5	6.5	4.0	----	0.75	4.0	1.75	ds	0.75	up	1.0	7.0	2.0	3.0	0.75	1.5	up	oc	2.5	3.5	yes
6.5	4.0	2.75	----	0.75	2.5	1.75	ds	0.75	up	1.0	5.5	1.25	2.0	----	----	----	----	2.0	3.5	yes
6.75	5.5	3.5	----	1.25	3.5	1.25	ds	0.25	up	1.0	6.0	1.25	2.0	0.25	1.0	up	oc	2.0	3.0	no
10.0	7.0	5.0	----	----	----	3.0	ds	1.0	up	2.0	9.0	----	----	----	----	----	----	----	----	imp.

Measurements of Coosina ariston (Walcott) Pygidia

T.W.	T.L.	A.L.	A.W.	A.R.	P.F.	IP.F.	B.W.	Peeled?
15.0	10.25	9.0	6.0	4+t	----	4 pr.	1.25	yes
12.0	8.0	7.0	4.5	----	----	----	1.0	yes
18.0	12.0	9.0	5.0	4+t	4 pr.	4 pr.	2.0	yes
20.0	15.0	11.0	6.0	4+t	4 pr.	4 pr.	4.0	yes
14.0	11.0	9.0	5.0	4+t	4 pr.	4 pr.	2.0	yes
13.0	9.0	7.0	3.5	----	----	----	2.0	yes
19.0	13.0	10.0	6.0	4+t	4 pr.	4 pr.	3.0	yes
5.0	2.0	1.5	1.0	3+t	3 pr.	3 pr.	0.5	yes
11.0	7.5	6.0	3.0	4+t	4 pr.	4 pr.	1.5	yes
15.0	12.0	10.0	5.75	4+t	4 pr.	4 pr.	2.0	yes
14.0	10.5	5.5	8.5	4+t	4 pr.	4 pr.	2.0	yes
19.0	11.5	9.0	5.5	4+t	4 pr.	4 pr.	2.5	yes
15.0	10.0	8.0	5.0	4+t	4 pr.	4 pr.	2.0	yes
12.0	5.0	7.5	4.0	4+t	4 pr.	4 pr.	1.5	yes
20.0	----	----	7.0	4+t	4 pr.	4 pr.	----	yes
12.0	8.0	6.0	4.0	4+t	4 pr.	4 pr.	2.0	yes
11.5	6.5	5.0	3.5	4+t	4 pr.	4 pr.	1.5	yes
10.0	8.5	6.5	3.0	4+t	4 pr.	4 pr.	2.0	yes
14.0	10.0	8.0	4.5	4+t	4 pr.	4 pr.	2.0	yes
17.5	12.0	9.0	6.0	4+t	4 pr.	4 pr.	3.0	yes
7.0	5.0	4.0	2.0	----	----	----	1.0	no
5.0	3.5	3.0	1.5	----	----	----	0.5	no
7.0	5.0	4.0	2.0	----	----	----	1.0	no
2.0	1.75	1.25	0.5	----	----	----	0.5	yes
14.0	10.0	8.0	4.0	4+t	4 pr.	4 pr.	2.0	yes
16.5	12.0	8.0	5.5	4+t	4 pr.	4 pr.	4.0	yes
27.0	14.5	10.0	6.0	4+t	4 pr.	4 pr.	4.0	yes
16.0	7.5	6.5	4.5	4+t	4 pr.	4 pr.	1.0	yes
15.0	11.0	9.0	5.0	4+t	4 pr.	4 pr.	4.0	yes
12.0	8.0	6.0	4.0	4+t	4 pr.	4 pr.	3.0	yes
18.0	12.0	9.0	4.5	4+t	4 pr.	4 pr.	3.0	yes
9.0	6.5	6.0	4.0	4+t	4 pr.	4 pr.	5.0	yes
8.5	7.0	5.0	3.25	4+t	----	----	2.0	yes
9.25	7.0	5.0	3.75	----	----	----	2.0	yes

Measurements of										
T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	
14.0	9.5.	6.0	----	2.0+	6.0	4.5	cvx	2.0	cvx	
13.0	9.0	5.0	----	1.5	5.0	4.0	cvx	1.5	cvx	
8.5	6.0	3.5	2 pr.	1.5	3.5	2.5	cvx	1.0	cvx	
----	----	7.5	----	----	----	7.0	cvx	2.0	cvx	
27.0+	16.0+	12.0	----	----	12.0	11.0	cvx	4.5	cvx	
9.5+	5.0+	3.5	----	----	----	4.5	cvx	2.0	cvx	
23.0	16.0	9.0	----	3.5	11.5	7.0	cvx	2.0	cvx	
15.0+	10.0	6.0	2 pr.	2.5	7.0	5.0+	cvx	2.5	cvx	
6.25	4.5	2.5	----	1.0	3.0	1.75	cvx	0.75	cvx	
12.0	8.0	6.0	2 pr.	2.0	6.5	4.0	cvx	1.5	cvx	
12.5	8.5	4.5	2 pr.	1.5	5.5	4.0	cvx	1.5	cvx	
15.0	10.0	6.0	2 pr.	1.5	7.0	5.0	cvx	1.5	cvx	
15.0	10.0	6.0	----	1.5	7.0	5.0	cvx	1.5	cvx	
18.0	12.5	8.0	3 pr.	1.5	----	5.5	cvx	1.5	cvx	
8.5	5.5	3.25	3 pr.	1.0	3.5	3.0	cvx	1.0	cvx	
15.0	11.0	6.0	2 pr.	2.0	6.0	4.0	cvx	1.5	cvx	
11.0	7.5	4.5	3 pr.	1.5	4.5	3.5	cvx	1.0	cvx	
9.5	6.5	4.5	3 pr.	1.5	5.0	3.0	cvx	1.0	cvx	
16.0+	14.5	8.0	3 pr.	2.0	9.5	----	cvx	1.5	cvx	
16.5+	15.0	8.0	3 pr.	3.0	11.5	----	cvx	1.5	cvx	
9.25	6.5	4.0	2 pr.	1.5	4.5	2.75	cvx	1.25	cvx	
17.5+	14.0	8.0	3 pr.	2.5	9.5	3.5+	cvx	3.0	cvx	
21.5	16.5	9.0	3 pr.	2.0	9.0	5.0	cvx	1.5	cvx	

Tricrepicephalus tripunctatus (Whitfield)

B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
2.0	10.0+	3.0	5.5	1.0	2.75	fl	low	----	----	no
2.15	7.0	----	5.0	----	----	----	----	----	----	no
1.5	6.0	2.0	3.0	----	----	----	low	5.0	2.0	yes
5.0	13.5	----	----	----	----	----	----	----	----	yes
6.5	18.0	4.0	1.0	----	----	----	----	8.0	----	yes
2.5	7.0	2.0	----	----	----	----	----	----	----	yes
5.0	16.5	4.0	9.5	----	3.0	up	low	----	----	yes
2.5+	10.0	2.5	6.5	1.25	3.0	up	low	9.0+	2.5	yes
1.0	4.0	1.5	2.75	0.5	1.75	up	low	----	----	yes
2.5	10.0	2.0	5.0	----	----	----	----	----	2.0	yes
2.5	8.0+	----	----	----	----	----	----	----	----	yes
3.5	11.75	2.0	6.5	1.0	2.5	up	low	----	----	yes
3.5	12.0	2.0	7.0	1.0	3.0	up	low	----	----	yes
4.0	12.0	3.5	7.0	1.75	3.5	up	low	----	----	yes
2.0	5.0	1.5	3.25	0.75	1.5	up	low	3.0+1.25		yes
2.5	10.0	2.0	8.0	----	----	up	low	----	----	yes
2.5	7.0	2.0	4.0	1.0	2.0	up	low	----	----	yes
2.0	5.5	----	4.0	----	----	----	----	4.5	1.5	yes
----	14.0	3.5	7.0	2.0	----	up	low	8.0	2.5	yes
----	14.0	4.0	9.0	2.25	4.0	up	low	9.0	3.5	yes
1.5	6.0	1.5	4.0	----	----	----	----	----	----	yes
----	13.0	3.0	8.0	----	----	----	----	8.0	3.0	yes
3.5	12.5	3.5	8.0	----	----	----	----	11.5	2.5	yes

Measurements of Tricrepicephalus beltensis Resser

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
----	7.0	5.5	----	1.5	6.0	----	----	----	----	----	----	----	----	----	----	----	----	5.0	----	yes
19.0	13.5	8.5	----	2.0	----	5.5	cvx	2.0	cvx	3.5	14.0	3.0	9.0	1.5	3.0+	up	low	----	----	yes
20.5	13.5	9.0	----	2.0	----	7.0	cvx	3.0	cvx	4.0	16.0	3.5	10.0	----	----	----	----	4.0	11.5	yes
25.0	18.0	11.5	----	3.0	12.0	7.0	cvx	3.0	cvx	4.0	19.0	5.0	11.0	2.0	4.5+	up	low	----	----	yes
22.5	16.5	9.0	2 pr.	2.5	11.0	6.0	cvx	2.5	cvx	3.5	16.0	3.0	10.0	1.5	3.5	up	low	----	----	no
22.0	15.0	8.0	2 pr.	2.5	9.0	7.0	cvx	2.5	cvx	4.5	16.5	2.5	8.0	1.5	2.5	up	low	2.5	9.0	yes
24.0	18.0	10.0	3 pr.	2.5	11.0	6.0	cvx	2.5	cvx	3.5	18.0	4.0	10.0	1.5	3.5	up	low	3.0	12.0	yes
21.0	15.25	9.0	2 pr.	2.5	10.5	5.75	cvx	2.5	cvx	3.25	16.5	4.0	9.0	1.5	3.5	up	low	----	----	yes
15.0	11.0	6.0	2 pr.	2.0	6.5	4.0	cvx	1.5	cvx	2.5	9.5	2.5	5.0	----	----	----	----	----	----	yes
22.5	16.5	8.0	----	3.0	9.5	6.0	cvx	2.5	cvx	3.5	15.0	4.0	9.0	----	----	----	----	----	----	yes

Measurements of Tricrepicephalus beltensis Resser Pygidia

T.W.	T.L.	A.L.	A.W.	A.R.	FUR.	SPINES	B.W.	Peeled?
14.5	8.5	7.5	6.5	3+t	----	16.0	1.0	yes
14.5	8.5	7.5	6.5	3+t	3 prs.	16.0	1.0	imp.
8.5	7.0	6.25	3.5	3+t	3 prs.	4.0+	0.75	yes
18.0	11.5	9.0	7.0	3+t	3 prs.	21.0	2.5	imp.
10.0	-----	5.5	4.5	3+t	3 prs.	13.0	-----	imp.
8.5	6.5	4.5	3.5	-----	3 prs.	4.5+	2.0	yes
4.0	3.5	2.5	2.0	3+t	3 prs.	4.5	1.0	yes
10.0	8.0	6.5	4.0	3+t	3 prs.	11.5	1.5	yes
9.5	8.0	6.5	4.0	3+t	3 prs.	7.0+	1.5	yes
6.0	5.0	4.0	2.5	3+t	3 prs.	8.0+	1.0	yes
7.5	6.0	4.5	3.5	3+t	-----	6.5	1.5	yes
8.0	7.0	6.0	3.5	3+t	3 prs.	6.5+	1.0	imp.
2.5	2.0	1.75	1.0	3+t	----	1.75+	0.25	no
13.0	11.5	9.5	6.0	3+t	3 prs.	7.0+	2.0	imp.
3.25	3.0	2.5	1.25	3+t	----	----	0.5	no

Measurements of T. tripunctatus (Whitfield)

T.W.	T.L.	A.L.	A.W.	A.R.	FUR.	SPINRS	B.W.	Peeled?
10.5	8.5	7.0	4.0	----	yes	----	1.5	yes
12.0	8.5	7.0	4.5	3+t	yes	----	1.5	yes
7.5	6.0	5.0	3.5	3+t	3 prs.	5.5+	1.0	imp.
7.5	6.0	5.0	3.5	3+t	3 prs.	3.0+	1.0	imp.
6.0	4.5	3.5	2.5	2+t	----	----	1.0	yes
6.0	4.0	3.5	2.5	2+t	----	4.0+	0.5	yes
11.5	7.5	6.0	4.5	3+t	3 prs.	----	1.5	yes
8.0	7.0	5.5	3.5	3+t	3 prs.	6.5+	1.5	yes
4.0	3.5	2.5	2.0	3+t	----	3.0	1.0	yes
5.5	4.5	3.5	2.0	3+t	----	2.0+	1.0	yes
6.0	5.5	4.5	2.5	3+t	----	----	1.0	yes

Measurements of Aphelaspis walcotti Resser Pygidia

T.W.	T.L.	A.L.	A.W.	A.R.	P.F.	IP.F.	B.W.	Border
3.0	1.5	1.25	1.0	2+t	2 pr.	2 pr.	0.25	flat
3.0	1.5	1.25	1.0	2+t	2 pr.	2 pr.	0.25	
3.0	1.25	1.0	1.0	2+t	2 pr.	2 pr.	0.25	
3.5	1.5	1.25	1.0	2+t	2 pr.	2.pr.	0.25	
4.0	1.75	1.5	1.0	2+t	2 pr.	2 pr.	0.25	
4.0	1.75	1.5	1.0	2+t	2 pr.	2 pr.	0.60	
4.0	1.5+	1.0+	1.25+	2+t	2 pr.	2 pr.	0.25	
5.0	1.75	1.25	1.0	3+t	3 pr.	3 pr.	----	
4.5	1.75	1.5	1.0	3+t	3 pr.	3 pr.	0.25+	
4.5	2.0	1.5	1.5	2+t	2 pr.	2 pr.	0.25	
4.0	1.75	1.5	1.0	3+t	3 pr.	3 pr.	0.25+	
3.25	1.25	1.0	1.0	2+t	2 pr.	2 pr.	0.25	
5.0	2.5	2.25	1.5	2+t	2 pr.	2 pr.	0.5	
5.0	2.0	1.75	1.5	3+t	3 pr.	3 pr.	0.5	
6.0	2.5	2.0	1.75	2+t	2 pr.	2 pr.	0.5	
6.0	2.5	2.0	1.75	2+t	2 pr.	2 pr.	0.5	
6.0	2.5	2.0	1.75	3+t	3 pr.	3 pr.	0.5	
7.5	3.0	2.5	2.0	3+t	3 pr.	3 pr.	0.45	
8.0	3.5	3.0	2.0	3+t	3 pr.	3 pr.	0.5	
8.0	3.5	3.0	2.0	3+t	3 pr.	3 pr.	0.5	
8.0	3.5	3.25	2.0	3+t	3 pr.	3 pr.	0.5	
9.0	4.0	3.5	2.5	3+t	3 pr.	3 pr.	0.5	
8.0	4.0	3.5	2.5	3+t	3 pr.	3 pr.	0.75	
8.0	3.0	2.5	2.0	3+t	3 pr.	3 pr.	----	
8.5	3.5	3.0	2.25	3+t	3 pr.	3 pr.	0.75	
9.0	4.0	3.25	2.5	3+t	3 pr.	3 pr.	0.5	
9.0	3.5	3.0	2.25	3+t	3 pr.	3 pr.	0.5	
9.0	3.5	3.0	2 5	3+t	3 pr.	3 pr.	0.75	
9.5	3.5	3.0	2.5	3+t	3 pr.	3 pr.	0.75	
8.5	3.5	3.0	2.5	3+t	3 pr.	3 pr.	0.75	
10.0	4.0	3.5	2.5	3+t	3 pr.	3 pr.	0.75	
10.0	4.0	3.5	2.5	3+t	3 pr.	3 pr.	0.80	
10.0	4.0	3.5	2.5	3+t	3 pr.	3 pr.	0.75	

T.L.	G.L.	G.W.	FUR.	O.R.L.	O.R.W.	F.A.L.	P.G.S.	P.G.L.	B.S.	B.L.	B.W.	P.A.W.	P.A.L.	P.L.W.	P.L.L.	P.L.S.	P.L.P.	PT.L.	PT.W.	Peeled?
12.0	8.0	4.75	2 pr.	----	5.0	4.0	ds	2.0	flat	8.0	2.0	1.75	----	----	----	----	----	----	----	yes

Measurements of Aphelaspis subdita Palmer

2.0	1.25	0.9	----	0.1	1.5	0.75	ds	0.65	flat	1.5	0.1	0.25	1.25	0.1	0.75	up	oc	----	----	no
2.0	1.4	0.75	----	0.25	1.0	0.6	ds	0.4	up	1.75	0.2	0.5	1.25	0.25	0.5	fl	oc	----	----	yes
3.5	2.25	1.5	2 pr.	2.5	1.25	0.35	ds	1.0	up	3.0	0.25	0.5	1.5	----	----	----	oc	1.1	0.5	no
5.0	3.5	2.0	2 pr.	2.5	1.5	0.5	ds	1.0	up	4.5	0.5	0.5	2.5	----	----	----	----	2.75	0.5	yes
5.0	3.5	2.0	2 pr.	2.5	1.5	0.5	ds	1.0	up	4.5	0.5	0.75	2.5	0.5	1.5	up	oc	2.75	0.5	no
6.0	4.0	2.5	2 pr.	2.75	2.0	0.5	ds	1.25	up	4.75	0.75	0.75	3.0	0.75	1.5	up	oc	2.0	0.5	yes
10.0	6.75	3.75	2 pr.	4.5	3.25	1.0	ds	2.75	flat	10.0	0.75	1.0	4.0	----	----	----	oc	----	----	yes

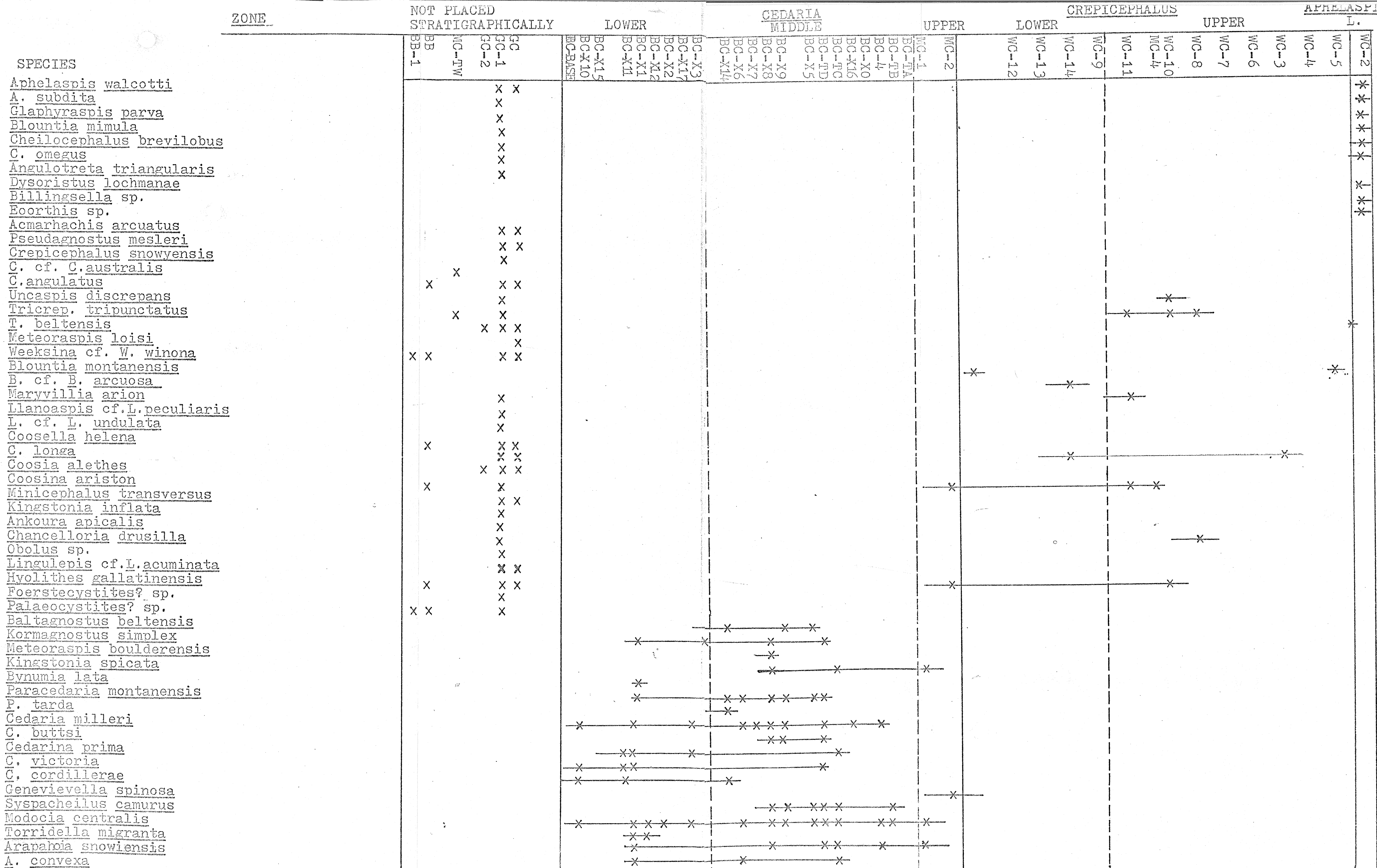


PLATE 9: Ranges of Described Faunas