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SILURIAN TRILOBITES OF JAPAN

IN COMPARISON WITH ASIAN, PACIFIC AND OTHER FAUNAS

By

Teiichi KOBAYASHI and Takashi HAMADA

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SILURIAN TRILOBITES OF JAPAN IN COMPARISON WITH ASIAN, PACIFIC AND OTHER FAUNAS

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Abstract

KOBAYASHI, T. and HAMADA, T. (1974) : Silurian Trilobites of Japan in comparison with Asian, Pacific and other Faunas. *Palaeont. Soc. Japan, Sp. Pap., No. 18*, 155 pp., 12 pls.

The Silurian trilobites here monographed were collected in six areas in Japan with three trilobite horizons at Mt. Yokokura, Shikoku Island. They belong to more than 30 species in 21 genera and subgenera and 7 families, viz. the Illaenidae, Scutelluidae, Lichidae, Phacopidae, Cheiruridae, Encrinuridae and Proetidae. The richest is the early Ludlovian Gomi fauna of the mountain comprising some 30 species including 8 indeterminable forms. Seven or eight trilobite horizons are distinguishable in Japan in a range from upper Wenlockian to upper Ludlovian. They are tentatively correlated to coralline horizons. In comparison with the mode of occurrence of trilobites in limestones of the Silurian of Gotland, Sweden and the Niagaran of the Great Lakes, North America, the reef breccia-type limestone of the *Cerauroides orientalis* horizon reveals a very rough water environment on the oceanic side of a barrier reef.

Trilobites known from the Silurian rocks in eastern and southeastern Asia are summarized and six trilobite horizons are distinguished there in a period from late Ashgillian to early Devonian. The *Prodontochile* fauna of the Langkawi Islands, Northwest Malay is a rich one yielding more than 17 species in 10 genera. Its age is late Llandoverian or/and early Wenlockian. Various records of Silurian trilobites gathered in South Asia show the wide extension of the Tethys sea from Central Himalayas to Asia Minor through Pamir and Afghanistan. The faunal comparison of Silurian trilobites of Siberia and Turkestan is made with the eastern and southeastern Asiatic ones. Broadly speaking, trilobites have thrived in North and South Asia in the early and middle Silurian period, but in Central and eastern Asia in the middle and late Silurian period. The Siberian trilobites are related to the Arctic as well as European ones, while Central and South Asiatic ones are allied to the European ones.

The comparative study is further extended to Australia and Tasmania, the Arctic region, North and South Americas. The upper Llandoverian *Thomastus* fauna of Victoria is nearly coeval with the *Prodontochile* fauna of Malay, but it is quite different from each other.

The late Silurian trilobites of Japan reveal some similarities to those of New South Wales, but the faunal affinity of the Japanese fauna is stronger with the European ones through Central Asia. The Gazelle trilobites of California are nearly contemporaneous with the Gomi fauna, but they are related more intimately to the Bohemian ones than either Japanese or central North American ones. As the result of a critical review, it was found out that five or probably six trilobite horizons can be distinguished in the Arctic Palaeozoic from Ashgillian to Gedinnian.

As to the provincialism of the Silurian trilobites, the Andine province is best defined and the next is the Arctic province. Eur-Asia and Australia to which North Africa and eastern North America are combined constitute a large province and its division into subprovinces is a future problem. As to the Ordovician-Silurian boundary problem, the reader is referred to the authors' recent paper reviewed in the postscript of this paper.

In the palaeontological part are described more than 34 species, of which 27 are newly established, in 18 genera and 5 subgenera of Japanese trilobites in addition to *Proetus (Gerastos) vietnamensis* nov., *Cerauroides lunshanensis* (GRABAU) and Lower Ordovician *Koraipsis shansiensis* SHENG. Not only their photographs are illustrated on 12 plates, but also their restoration is made as much as possible and shown in text-figures.

The family Scutelluidae and the subfamily Encrinurinae are discussed in some detail. The former is classified into two sections and seven subfamilies, namely, the Eobronteinae SINCLAIR and Octobronteinae MAXIMOVA in section 1 and the Planiscutelluinae nov., Meroperixinae nov., Scutelluinae RICHTERS, Thysanopeltinae HAWLE and CORDA and Paralejurinae PILLET in section 2. Supplementary notes are added to HAMADA's classification of the Encrinurinae in 1959, and 11 genera and subgenera are here referred to the subfamily. Its distribution in Asia, Australia and the Arctic region is summarized. As the result, it is ascertained that *Frammia* is a key to the Arctic-Subarctic province. Encrinurid pygidia in Japan and eastern Asia are classified into two morphic groups and four subgroups in each.

Some notes are given on the Illaenidae, Goldillaeninae, Homolichinae, *Ancyropyge, Ekwanoscutellum, Ptilillaenus, Spaerexochus,* Pre-Carboniferous proetoids in Asia, growth of scutelloid cephala and so forth. Assuming that the previous identification and comparison in literatures are correct, it is surprising to find out that 36 to 43 genera and subgenera in 13 subfamilies of the Pre-Carboniferous Proetidae and 9 to 10 genera in 4 subfamilies of the Lichidae in modern taxonomy are probably represented in the Asiatic fauna. Likewise, 13 to 16 genera and 9 genera of the Scutelluidae may be present in the faunas of North and Central Asia and eastern and southern Asia respectively.

New subfamilies and genera proposed in this monograph are as follows:

- Meroperixinae, subfam. nov. in Scutelluidae
- Planiscutelluinae, subfam. nov. in Scutelluidae
  - *Apolichas*, gen. nov. in Homolichinae
  - *Illaenoscutellum*, gen. nov. in Meroperixinae
  - *Tosacephalus*, gen. nov. in Meroperixinae
    - *Bumastella*, subgen. nov. in *Bumastus*

Finally, this volume consists of 137 pages of text and 12 plates in total. Five fossil lists, eight tables and eight text-figures inserted in text, and a bibliography in 15 pages, an index in 18 pages and place names in alphabet and Chinese characters in a page appended at the end would facilitate the readers in use.

Preface

Among small but numerous Silurian areas in Japan three important ones are Sakari area in the Kitakami mountains, Mt. Yokokura (Yokokura-yama) in Shikoku and Mt. Gion (Gion-yama) area in Kyushu as a summary of her Silurian System was given in "*Geology of Japan*", 1963. During ten years since then the cliff-making limestone of Mt. Yokokura which has been almost inaccessible was found very productive of trilobites at certain quarries recently opened. Merit to ardent hunting of Mr. M. HIRATA and many others a large number of trilobites were collected there besides brachiopods and other fossils. Fortunately enough this profused collection was submitted to the authors for study.

Inspite of keen interest in search of trilobites, Silurian ones belonged to a very rare group of invertebrates in Japan. Therefore the authors have taken up this subject of study with great pleasure. As the trilobites are rather poorly preserved, they spent considerable times for cleaning, observation and comparison. As the result more than 30 species were distinguished among the trilobites of the so-called Gomi horizon in this monograph. They constitute the major part of the Japanese trilobites, but minor collections of other localities are also added to them. The authors were quite surprised to see that the Silurian trilobites of Japan total now 40 species or more including several specifically indeterminable ones.

Japanese Silurian trilobites are Wenlockian-Ludlovian in age, but the authors have already described older Silurian ones from Malay. It is certainly a remarkable fact that more than six trilobite horizons are now distinguishable in the Silurian System in Eastern and Southeastern Asia. For the purpose of correlation and palaeogeography the authors looked over other faunas as much as possible, paying special attention to the Asiatic fauna and the Western and Northern Pacific ones, because these faunas are not the less important than the standard faunas in classical areas of the Atlantic side from the perspective point of view. The results of such a trend of research are also included in this monograph with the hope that such a compilation would be a step toward the well balanced synthesis of the Silurian world picture.

Silurian trilobites of Japan known at present belong to 21 genera, 4 new genera and subgenera inclusive, and 7 families among which palaeontological notes are given on the Illaenidae, Scutelluidae, Lichidae, Encrinuridae and Proetidae.

Finally, the authors record their sincere thanks to Mr. Motomé HIRATA and his cooperators in fossil collecting, Mr. Jun'ichi HAMADA, Mr. Tadahiko IMAMURA, Mr. Isamu SHINOHARA, Mr. Shigeki HADA of Kôchi University, Dr. Ken'ichi ISHII of Ôsaka City University, Dr. Mitsuo NODA, Prof. Em. of Kyushu University, Fukuoka and others for the privilage of studying their trilobite collections, and to Prof. Tatsuro MATSUMOTO, Prof. Ryuzo TORIYAMA and Assoc. Prof. Kametoshi KANMERA of the Kyushu University, Prof. Toshio KIMURA, Prof. Tetsuro HANAI, Prof. Tadashi SATO, and Assoc. Prof. Itaru HAYAMI of the University of Tokyo, Dr. Nobukazu KAMBE of the Geological Survey of Japan, Tokyo, Dr. Munemitsu SUGITA of Department of

Earth Science, Okayama University and several other persons for their assistances which the authors received in the course of laboratory works and publication. The senior author is particularly grateful to Prof. N. E. TSCHERNYSHEVA of the VSEGEI, Leningrad, Dr. Ed. D. GILL of the National Museum of Victoria, Melbourne, Dr. J. H. SHERGOLD of the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A. C. T. and some other persons for tendering him some important publications. The authors appreciate not the less for the subsidy granted from the Ministry of Education to the Palaeontological Society of Japan for publishing this number of Special Papers.

Contents

Subfamily Scutelluinae
Genus *Kosovopeltis*

Genus *Dentaloscutellum*

Genus *Microscutellum*

Subfamily Paralejurinae

Family Phacopidae
Genus *Phacops*

Family Cheiruridae
Subfamily Cheirurinae

Subfamily Pilekinae

Family Encrinuridae

Text-figures

I. The Trilobite-bearing Silurian Rocks in Japan

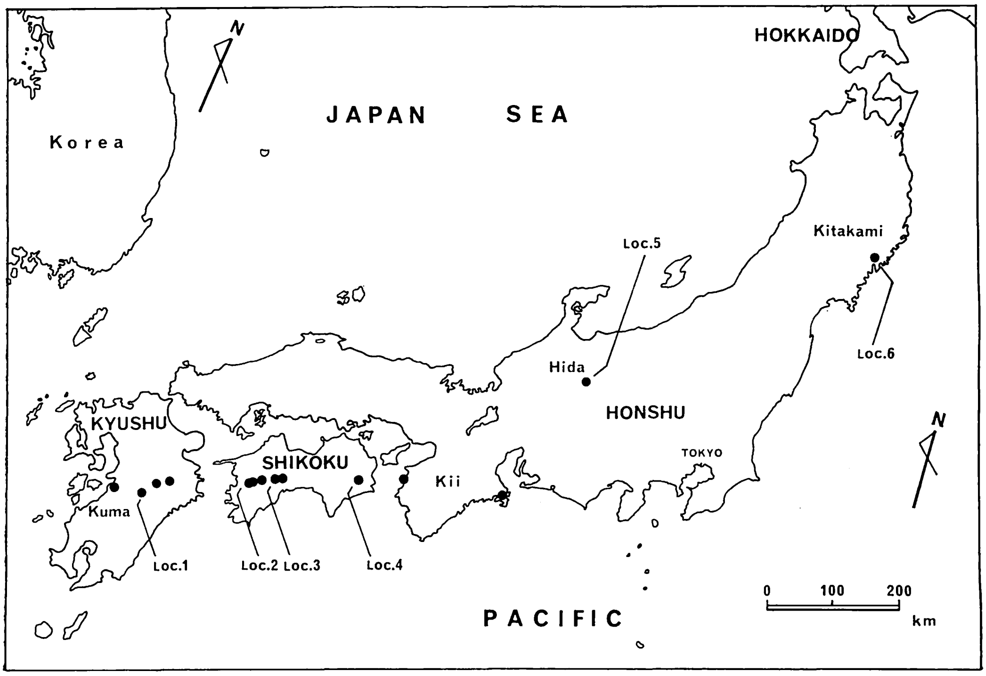
The Silurian System is the oldest fossiliferous one in Japan, although Pre-Cambrian age is estimated among metamorphic rocks. ONUKI (1937) was the first to discover *Halysites* and some other Silurian fossils in the Higuchi-zawa limestone of the Kawauchi (=Kawauti) Series in the Sakari area in Kesén-gun, Iwaté Prefecture, Northeast Japan. Subsequently, *Halysites* was found also in Southwest Japan in the Imosé limestone in the Sakawa basin, Kôchi Prefecture (KOBAYASHI and IWAYA, 1941). Now Silurian rocks are known to be distributed in Japan extensively from the Kitakami mountains to Kyushu as indicated by small areas yielding various Silurian fossils.

Among these fossils stromatoporoids, corals, brachiopods and calcareous algae were fairly well studied by SUGIYAMA, NODA, HAMADA, JOHNSON and KONISHI. Bryozoans, pelecypods, gastropods, cephalopods, ostracods and trilobites were, however, not much investigated, as they are rare and mostly ill-preserved. In fact, only four species of trilobites have so far been described from Japan.

In 1941, SUGIYAMA described *Encrinurus* (*Coronocephalus*) *kitakamiensis* from a black limestone in the upper part of the second horizon of the Kawauchi Series on the southern foot of Takainari-yama, Hikoroichi-chō, Sakari-machi, Kesén-gun, Iwaté Prefecture. Later *Coronocephalus kabayashii* and *Octobronteus* (?) sp. were added from the G_2 beds at Kuraoka, Gokasé-machi, Nishi-usuki-gun, Miyazaki Prefecture and *Scutellum* (New Subgenus) *japonicum* from the Silurian limestone of Yokokura-yama (=Mt. Yokokura), Ochi-machi, Kôchi Prefecture (HAMADA, 1959; KOBAYASHI and HAMADA, 1965).

Beside them Silurian trilobites are known to occur at three other localities. Namely, ISHII (1952) reported *Encrinurus* from tuffaceous clayslate at Okanaru, Higashi-uwa-gun, Ehimé Prefecture. KAMEI and IGO (1955) have once reported *Cheirurus sternbergi* from sandy shales at Fukuji, Kami-takara mura, Yoshiki-gun, Gifu Prefecture as an Upper Silurian trilobite, but it was *Cheirurus* (*Crotalocephalus*) *japonicus* KOBAYASHI and IGO, 1956 of the Coblenzian-Eifelian age. Recently, however, the existence of Silurian rocks in this area was warranted by a new find of *Encrinurus* at Hitoégané as described in this monograph. In addition, *Goldillaenus* was obtained by Mr. SHINOHARA in the Silurian rocks from Miyaga-tani, Tatsukawa, Tokushima Prefecture. Thus we know now that Silurian trilobites occur in Japan in six areas, namely, Gion-yama, Okanaru, Yokokura-yama, Tatsukawa, Hitoégané and Sakari. These areas, however, yield only one or a few species of trilobites except for Mt. Yokokura.

Recently, a rich Silurian fauna was found in the Yokokura limestone of Mt. Yokokura at Gomi and Ichiyama quarries and a large number of trilobites were collected by M. HIRATA, J. HAMADA and many others. In this area the limestone formation is underlain by tuffaceous sandstone and green siliceous tuff, and is



Text-fig. 1. Silurian areas (solid circles) and the trilobite localities (numbered) in Japan.

Loc. 1. Gion-yama, Kuraoka, Nishi-usuki-gun, Miyazaki Prefecture, Kyushu. Wenlockian G_2 stage.

Loc. 2. Okanaru, Higashi-uwa-gun, Ehimè Prefecture, Shikoku. Basal part of the G_4 stage; probably Upper Silurian.

Loc. 3. Yokokura-yama, Ochi-machi, Kôchi Prefecture, Shikoku. Ys: Yokokura-yama (mainly at Gomi), Ys 5: west of the summit, Wenlockian G_2 stage, Ys 6: Sugihara shrine, Wenlockian-lower Ludlovian shelly beds, Ys 8, Ys 9: north of Gomi, basal part of the G_3 stage, probably lowest Ludlovian, Ys 11, Ys 13: Ichiyama quarry, lower Ludlovian limestone of G_3 stage, Ys 14, Ys 15: Gomi quarry, lower Ludlovian limestone of G_3 stage.

Loc. 4. Miyaga-tani, Tatsukawa-machi, Tokushima Prefecture, Shikoku. Probably lower Ludlovian limestone of G_3 stage.

Loc. 5. Hitoègané, Kamitakara-mura, Yoshiki-gun, Gifu Prefecture, Central Honshu. Auloporoid limestone of probably uppermost Silurian.

Loc. 6. Kusayami-zawa, Sakari-machi, Ôfunato City, Iwatè Prefecture, Northeast Honshu. Calcareous slate bed of the Kawauchi Series, probably of upper G_3 stage, probably middle Ludlovian.

overlain by a thick formation which is composed of rhyolitic tuff and tuffaceous (?) sandstone and yields Upper Devonian plants besides *Orbiculoidea*. These Silurian and Devonian formations are intruded by gneissose granitic rocks and cut by faults on the north side, while they thrust themselves upon Mesozoic formations on the south side (HAMADA, 1961; HIRATA, 1966).

It is a remarkable fact that Silurian trilobites occur in three horizons in this area. Namely, a few trilobites were collected in the Yokokura limestone formation at Sugihara shrine from a little lower horizon than the very productive Gomi-Ichiyama horizon. A pygidium of *Encrinurus* was found by NODA (1964) near the summit in tuffaceous and arenaceous limestone adjacently below the Yokokura limestone.

II. Silurian Trilobites of Japan and the Age of the Trilobite Horizons

The Silurian trilobite fauna of Japan which was found in six areas with three trilobite horizons at Mt. Yokokura consists of more than 31 species in 17 genera and 7 families, viz. the Illaenidae, Scutelluidae, Lichidae, Phacopidae, Cheiruridae, Encrinuridae and Proetidae as shown in Fossil list 1.

As mentioned already, the Gomi fauna is the richest comprising some 30 species including eight indeterminable forms, other localities yielding only one or a few species. There is no common species among these trilobite horizons and localities except for *Bumastus* (*Bumastella*) *aspera* and *Japonoscutellum japonicum* which occur in two horizons of Gomi and Sugihara shrine at Mt. Yokokura.

Let us start from the Gomi fauna. Its trilobites belong to seven families including fourteen subfamilies. The Lichidae, Phacopidae, Cheirurinae, Proetidellinae and Decoroproetinae are represented by one or a few species of a genus. The Illaenidae consist of several species in two subgenera of *Bumastus*, viz. *Bumastus* s. str. and *Bumastella*. The Scutelluidae consist of the Planiscutelluinae, Meroperixinae, Scutelluinae and Thysanopeltinae each including one or two species. The Sphaerexochinae are represented by two species and one forma of *Sphaerexochus*. The Proetinae include three species in three subgenera of *Proetus*. *Encrinurus* is represented by two species founded on the cranidia in addition to four forms of pygidia. Among various trilobites *Sphaerexochus hiratai* is most abundant and well represented by the cranidium and pygidium. The next abundant is *Japonoscutellum japonicum*, whose pygidia are common but its cranidium and free cheek are very rare. In this sense the Gomi horizon may be called the *Sphaerexochus hiratai* horizon.

None of the trilobites in the fauna is exactly identifiable with any known species. Several forms are not so well represented to determine their generic position or to give new names. Some forms belong to new genera. *Scutellum* (New subgenus) *japonicum* KOBAYASHI and HAMADA, 1965 is one of them for which PŘIBYL and VANĚK (1971) proposed *Japonoscutellum*. Three other new genera and one new subgenus instituted by the authors on this occasion are as follows:

Tosacephalus, a new genus of Scutelluidae
Illaenoscutellum, a new genus of Scutelluidae
Apolichas, a new genus of Lichidae
Bumastus (*Bumastella*), a new subgenus of Illaenidae

Known genera and subgenera of the Gomi trilobites and their geological ranges are as follows:

1. Silurian and older	
Bumastus	Middle Ordovician-Silurian
Bumastus (*Bumastus*)	Upper Ordovician-Silurian (Ludlow)
Sphaerexochus	Middle Ordovician-Silurian
Encrinurus	Middle Ordovician-Silurian
2. Lower Silurian and/or younger	
Microscutellum	Lower Devonian
Proetus (*Gerastos*)	Silurian-Middle Devonian
Proetus (*Bohemiproetus*)	Silurian-Middle Devonian
Decoroproetus	Silurian-Middle Devonian
3. Silurian	
Kosovopeltis	Upper Silurian (Kopanina-Lochkov)
Phacops (*Acernaspis* or *Ananaspis*)	Lower Silurian-Upper Silurian
Proetus (*Proetus*)	Silurian
Cerauroides	Upper Silurian (Budnany)

The Silurian age of the fauna is quite warranted by these three generic assemblages. According to PILLET (1969), *Proetus* (*Proetus*) is restricted to the Silurian (calcaire de Gothland). *Proetus* (*Proetus*) *concinnus* (DALMAN) and *P.* (*P.*) *consperus* (ANGELIN) occur in Gotland in Wenlockian and early Ludlovian (REGNÉLL and HEDE, 1960). *Acernaspis* is a Llandoverian phacopid whereas *Ananaspis* ranges from late Llandoverian to late Ludlovian (CAMPBELL, 1967). *Phacops metacernaspis* is intermediate in character between these two subgenera. *Kosovopeltis* is a Ludlovian scutelloid in the Kopanina-Lochkov stages in Bohemia (ŠNAJDR, 1960). *Kosovopeltis angusticostata* is, however, allied also to *Planiscutellum* (Wenlockian-early Ludlovian). These Silurian genera suggest the range from Wenlockian to Ludlovian, or probably late Wenlockian-early Ludlovian for the age of the Gomi fauna.

The inclusion of *Microscutellum* in the fauna on the contrary contradicts against this chronological determination, because it is a Lower Devonian genus of Bohemia. *Microscutellum primigenium*, however, has a cephalon not so specialized as *M. hawlei* (BARRANDE) from the Koneprusy formation. Therefore this Gomi species must be homotaxial to the Bohemian species and the former is older than lower Praguian.

Most important for chronology is *Cerauroides orientalis*. Its cephalon reveals that it is intermediate between *C. hawlei* and *C. propinquus* (MÜNSTER). The former occurs in Bohemia in the upper part of the Kopanina formation (HORNÝ and BASTL, 1970). It is ascertained with the latter in the Carnic Alps in the Alticola-Kalk which is correlated to the top part of the Kopanina formation (FLÜGEL, 1967). Therefore the age of the Gomi fauna must be Ludlovian rather than late Wenlockian and most probably early Ludlovian. This age determination is in support of the junior author's conclusion (1959, 1961) deduced from *Schedohalysites kitakamiensis* (SUGIYAMA) occurring at many localities including Gomi and accompanied by *Kirkidium* cf. *knighti* at Gion-yama, Kyushu.

The *Encrinurus tosensis* horizon at Sugihara shrine which is slightly lower than

Fossil list 1. Silurian trilobites of Japan.

	Localities Trilobites	Gion-yama	Okanaru	Yokokura-yama			Tatsukawa	Sakari Area	Hitoégané
				Summit	Sugihara	Gomi			
1	*Bumastus* (*Bumastus*) *glomerosus*					°°×			
2	*Bumastus* aff. *barriensis*					×			
3	*Bumastus* (*Bumastus*) *subquadratus*					×			
4	*Bumastus* (*Bumastella*) *spiculus*					×			
5	*Bumastus* (*Bumastella*) *bipunctatus*					°×			
6	*Bumastus* (*Bumastella*) *aspera*				×	×			
7	Bumastid, gen. et sp. indt.					×			
8	*Goldillaenus shinoharai*						×		
9	*Octobronteus* (?) sp.	×							
10	*Japonoscutellum japonicum*				×	°×			
11	Juvenile scutelloid cephalon					×			
12	*Tosacephalus fungiformis*					×			
13	*Illaenoscutellum platiceps*					×			
14	*Kosovopeltis angusticostata*					°×			
15	*Microscutellum primigenium*					°×			
16	*Microscutellum* sp.					×			
17	Scutelloid free cheeks, rostrum					×			
18	*Apolichas truncatus*					×			
19	*Phacops metacernaspis*					×			
20	*Cerauroides orientalis*					×			
21	*Cerauroides elongatus*					×			
22	*Sphaerexochus hiratai*					°°×			
23	*Sphaerexochus hiratai* forma *robustus*					×			
24	*Sphaerexochus planirachis*					×			
25	*Coronocephalus kobayashii*	°×							
26	*Encrinurus yokokurensis*					×	×*		
27	*Encrinurus mamelon*					×			
28	*Encrinurus kitakamiensis*							×	
29	*Encrinurus nodai*			×					
30	*Encrinurus tosensis*				×				
31	*Encrinurus ishii*		×						
32	*Encrinurus fimbriatus*								°×
33	Encrinurid pygidia (A-1 type)					×			
34	Encrinurid pygidia (A-2 type)					×			
35	*Staurocephalus* (?) sp.					×			
36	*Proetus* (*Proetus*) *subovalis*					×			
37	*Proetus* (*Gerastos*) *subcarinatus*					×			
38	*Proetus* (*Gerastos*) *sugiharensis*				×				
39	*Proetus* (*Bohemiproetus*) *magnicerviculus*					×			
40	*Prantlia biloba*		×						
41	*Decoroproetus granulatus*					×			
	Total	2	2	1	4	31	2	1	1

* A fragmental pygidium was reported by Shiki and Okazaki (oral comm., 1973).
°: common, °°: gregareously occur in some places.

the preceding within the same Yokokura limestone formation is considered to be early Ludlovian, because *Bumastus (Bumastella) aspera* and *Japonoscutellum japonicum* are two common species between the two horizons and because they are accompanied by *Schedohalysites kitakamiensis.*

In the *Encrinurus nodai* horizon at the summit whence a pygidium of *Encrinurus* was collected by NODA, *Schedohalysites kitakamiensis* does not occur notwithstanding the fact that it contains *Halysites, Favosites* and *Heliolites.* Therefore, this horizon is considered already late Wenlockian. Thus, the trilobite occurrences support the junior author's correlation of the summit horizon to the upper part of the G_2 stage of the Gion-yama group.

Table 1. Correlation of Silurian trilobite horizons in Japan.

Geological Age	Gion-yama	Okanaru	Yokokura-yama	Tatsukawa	Hitoégané	Sakari Area	Gion-yama Group
Late Ludlovian		*Prantlia biloba*			*Encrinurus fimbriatus*		G_4 stage
Middle Ludlovian						*Encrinurus kitakamiensis*	G_3 stage
Early Ludlovian			*Cerauroides orientalis* *Encrinurus tosensis*	*Goldillaenus shinoharai*			
Late Wenlockian	*Coronocephalus kobayashii*		*Encrinurus nodai*				G_2 stage

At Gion-yama the G_2 stage yields *Octobronteus* (?) sp. and *Coronocephalus kobayashii.* This horizon would be slightly lower than the summit horizon of Yokokura-yama. It is presumed to be early upper Wenlockian, if not late middle Wenlockian.

It is a question whether the trilobite horizon of Okanaru which bears *Encrinurus ishii* and *Prantlia biloba* belongs to the G_2 stage, because *Prantlia* is so far known to be an Upper Silurian genus and because *Prantlia longula* (HAWLE and CORDA) and *P. minuta* PŘIBYL and VANĚK occur respectively in the Kopanina formation and the basal part of the Lochkov formation in Bohemia. Therefore the authors are of opinion that this horizon is upper or middle Ludlovian and represents the basal part of the G_4 stage.

The fossiliferous limestone of Miyaga-tani, from which *Goldillaenus shinoharai* was obtained would be early Ludlovian, as it contains *Schedohalysites kitakamiensis.*

According to SUGIYAMA (1940), the Silurian formation which is overlain by the Devonian and which is intruded in the lower part by granite in Sakari area, can be divided into two series with five fossiliferous horizons in descending order as follows:

2. Takainari Series: 115 m thick, composed of chiefly variegate siliceous slates.
1. Kawauchi Series: shale and sandstone in main, but limestones intercalated at places.
   e. *Solenopora* limestone
   d. *Encrinurus* bed
   c. *Halysites* limestone
   b. *Clathrodictyon* limestone
   a. *Favosites* limestone

Because the *Encrinurus kitakamiensis* horizon lies immediately above the *Halysites* limestone containing *Schedohalysites kitakamiensis*, its age may be middle Ludlovian rather than lower Ludlovian.

Finally, *Encrinurus fimbriatus* was contained in small floats at Hitoégané, Hida plateau. Because the supposed mother formation at the locality is apparently isolated from the Devonian formation by faults, it is difficult to say the age of this trilobite horizon, but it is probably Ludlovian or the upper part of the Ludlovian.

Reserving some ambiguities on the ages of the *Encrinurus ishii* and *E. fimbriatus* horizons, the Silurian trilobite horizons in Japan can be correlated as shown in Table 1. Their relation to the horizons of tabulate corals may be as shown in Table 2.

Table 2. Relation between horizons of trilobites and tabulate corals in Japan.

Fossil Horizons		Gion-yama Group
Trilobites	Tabulate corals*	
Prantlia biloba		G_4 stage
(*Encrinurus fimbriatus*)	Auloporoid	
Encrinurus kitakamiensis		G_3 stage
(*Goldillaenus shinoharai*) *Cerauroides orientalis*	*Schedohalysites kitakamiensis*	
Encrinurus tosensis		
Encrinurus nodai	*Falsicatenipora shikokuensis*	G_2 stage
Coronocephalus kobayashii		

* The junior author's study on the Middle Palaeozoic zonation by means of tabulate corals is now in progress. A further information will be given in some near future of the horizons of tabulate corals cited above. In this paper a tentative correlation between the horizons of trilobites and tabulate corals is given.

III. Mode of Occurrence and Palaeoecology of the Silurian Trilobites of Japan

As shown in Text-fig. 1 and in the Fossil list 1, Silurian trilobites are known from six localities in the Japanese Islands. The most important locality among them is Yokokura-yama in Shikoku (Loc. 3) where more than 31 species in 17 genera are found in the rock sequence from Wenlockian G_2 stage to lower Ludlovian G_3 stage. Especially the G_3 limestone, here called the Yokokura limestone, is prolific of these trilobites, at several small quarries of Gomi and Ichiyama.

From the lithological point of view, Silurian trilobite occurrences in Japan are classified into two main types, i. e. one is reef limestone type and the other less calcareous bioclastic type. The former is well represented by the G_3 limestone, and is entirely composed of reef-breccia of various sizes. Massive stromatoporoid and favositoid colonies are the main constituents in these breccia which are often cemented by " *stromatactis*-like " hermatypic organism (HAMADA, 1961). The colonial coelenterata including several species of halysitid corals (HAMADA, 1958) are always fragmentary in the breccia. Large, thick-shelled *Kirkidium* cf. *knighti* and other pentamerid brachiopods are also found broken and disarticulated. This type of limestone is grey in general, but sometimes it shows pinkish or greenish colour probably due to contamination of tuffaceous material. However, the chemical analysis of such a grey limestone and an associated fine-grained pink limestone from Gion-yama, Kyushu (Loc. 1) (HAMADA, 1962, p. 243, table 1, no. 2) proves high purity of calcium carbonate of the limestone with very low contents of SiO_2 (1.08), Fe_2O_3 (0.06), MgO (0.12) and alkalies (Na_2O+K_2O : 0.25) in weight percent. This vindicates these limestones were deposited at a certain place where almost completely free from terrigenous detritus. Being combined this lithology with the fossil contents above mentioned, it may be concluded that the breccia represents submarine talus deposits along the outer slope of the wave resistant reef front.

None of the trilobite specimens obtained from the G_3 limestone is, actually, completely preserved. Their carapaces are usually dismembered and often fragmentarily broken into small pieces. The thoracic segments are rarely found. Globular cephala and pygidia of *Sphaerexochus* and bumastids sometimes gregareously occur in small banks. It is quite noteworthy that almost all of these trilobites in the reef-breccia are provided with smooth or only a little ornamented surface of thick tests. No spiniferous trilobite like odontopleurids is found therein. Only an exception is *Bumastus* (*Bumastella*) *spiculus* with short but stout genal spines. *Apolichas* has a nearly entire pygidial margin in marked contrast with other lichid genera, and the cephalic granulation of *Encrinurus yokokurensis* and *E. mamelon* is less prominent than the normal encrinurid ornamentation.

The second type of the trilobite-bearing rocks is characterized by much less calcareous contents. In other words, these rocks are rich in argillaceous or arenaceous materials. They are represented by calcareous shale, calcareous sandstone, sandy limestone and so on. Most of the other occurrences of Silurian trilobites than the above stated G_3 limestone are known in this second type of lithofacies.

The *Coronocephalus kobayashii* horizon of the G_2 stage in Kyushu is composed of calcareous sandstones and shales with small limy and tabulate coralline nodules (HAMADA, 1959, 1961). Greenish coloured G_2 limestone at Yokokura-yama, where *Encrinurus nodai* was contained, is characteristic in its high contents of detrital materials especially of angular quartz fragments (HAMADA, 1962). *Halysites sussmilchi* in this sandy limestone forms, however, a fairly large and tall colonies attaining more than 20 cm high.

The lowest part of the G_3 stage of Yokokura-yama, here called *Encrinurus tosensis* horizon, is lithologically different from the main G_3 limestone in having tuffaceous and bedded calcareous sandstones and shales. This part yields various small colonies of different halysitids, favositids, and heliolitid corals. Cup-shaped solitary corallites of zaphrentids and tryplasmatids are also abundant in this horizon.

Prantlia biloba and *Encrinurus ishii* occur in the thin, calcareous and tuffaceous sandstone-shale beds which overlie the coralline G_3 limestone at Okanaru in Shikoku (Loc. 2).

In the Kitakami mountains, *Encrinurus kitakamiensis* horizon occupies the uppermost part of the Kawauchi Series, which is correlatable to the G_3 limestone in Southwest Japan. It is mainly composed of calcareous black slates and thinly bedded black limestones. Some brachiopods are sparsely found in the beds.

Encrinurus fimbriatus is characteristically found at Hitoégané, near Fukuji in a bedded sandy limestone that is filled with small auloporoid colonies.

Table 3. Diversity in genera and species of Silurian trilobites in Japan.

Locality	OUTER ZONE				INNER ZONE	
	Kuma—Kii Mountains (Southwest Japan)				Hida Plateau (Central Japan)	Kitakami Mts. (NW. Japan)
Stage	Gion-yama	Okanaru	Yokokura-yama	Tatsukawa	Hitoégané	Sakari
lowest G_4		$2-_{2}$			$1-_{1}$	
upper G_3						$1-_{1}$
up.-mid. G_3			$17-_{31+}$	$2-_{2}$		
lower G_3			$4-_{4}$			
G_2	$2-_{2}$		$1-_{1}$			

Abbreviation: $X-_{y}$, X: number of genera, $_{y}$: number of species
(including uncertain species).

As stated above, encrinurid trilobites are widely distributed in various places and horizons of the Silurian rocks in Japan both of the reef-breccia and less calcareous rocks. Best (1961) collected a large number of *Encrinurus ornatus* Hall and Whitfield from a stratigraphic interval of at most one and a half feet in the Eramosa member of the Middle Silurian Lockport formation in Ontario. The thin, dark brown, bituminous and calcareous shale and calcareous bioclastic dolomite yielded nearly a thousand pygidia and more than a hundred cranidia of this species. In this locality, it is noted that the only trilobites found in these beds were *Encrinurus, Calymene, Dalmanites* and *Acanthopyge,* in order of abundance respectively 100 : 10 : 2 : 1.

In the Isle of Gotland, *Encrinurus punctatus* Wahlenberg and *Calymene tuberculata* (Brünnich) are the two popular trilobites in the rock sequences from the Högklint beds through the Hemse beds both in the reef-limestone and crinoid-limestone facies. These occurrences are summarized here in form of a table on the basis of the data taken from Manten's observation (1971).

Table 4. Two common trilobites in the limestones of Gotland.

Horizon	Locality	*Encrinurus punctatus*		*Calymene tuberculata*	
		reef ls.	crin. ls.	reef ls.	crin. ls.
Hemse Beds	Gannberg	×			
	Linkeklint		×		
Slite Beds	Stenkumla	×	×		×
	Bogeklint	×	×	×	
	Kvarnbacken		×		
	Spillingsklint		×	×	
	Tjeldersholm	×	×		
Högklint Beds	Högklint		×	×	
	Snäckgärdsbaden		×		
	Sigsarvebodar				×
	Hallshunkklint	×	×	×	×
Total of occurrence		5	9	4	3

(Data from Manten, 1971, tables 17–19).

The above mentioned two examples of encrinurid occurrences may stand for rather quiet water condition characteristic in peri- or intra-reef sites on the stable shelf.

According to Lowenstam (1950, 1952, 1957), in the Niagaran reef complex of the Great Lakes area, encrinurids were the most popular constituent of the trilobite assemblages in various sedimentary facies. Especially, they were abundant in the initial growing stage of reefs or the quiet-water stage in association with *Sphaerexochus* species. *Bumastus* and *Calymene* were, on the other hand, the dominant genera of the late rough-water stage. At the same time, the generic diversity of the reefdwelling trilobites became great as the water turbulence increased upwardly or towards the semirough-water and rough-water stages.

Table 5. Trilobite assemblages in various reef facies.

Niagaran Reefs (Lowenstam, 1957)			Yokokura Reef
Quiet-water	Semirough-water	Rough-water	Frontal reef flank
Sphaerexochus	*Sphaerexochus*	*Bumastus**	*Sphaerexochus** 3
Encrinurus	*Encrinurus*	*Calymene*	*Bumastus** 3
(*Bumastus*)	*Bumastus*	*Sphaerexochus*	*Bumastella* 3
	(*Calymene*)	*Encrinurus*	*Encrinurus* ....2+
	(*Cheirurus*)	*Cheirurus*	*Gerastos* 2
	(*Odontopleura*)	(*Illaenoides*)	*Cerauroides* 2
	(*Eophacops*)	(*Metopolichas*)	(*Japonoscutellum*) 1
		(*Acidaspis*)	(*Kosovopeltis*) 1
		(*Bronteus*)	(*Microscutellum*) 1
			(*Illaenoscutellum*)......1
			(*Apolichas*) 1
			(*Phacops*) 1
			(*Bohemiproetus*)........1
			(*Decoroproetus*) 1
			(*Staurocephalus*) 1
			(*Proetus*) 1
			(*Tosacephalus*) 1

( ) : subordinate genus
....n : number of species in the genus (Yokokura reef)
* : gregariously occur in some places

Such a tendency may be recognized in the trilobite assemblages in the Japanese Silurian rocks also. As summarized in Table 5, the trilobites in the *Cerauroides orientalis* horizon of reef-breccia type limestone show far greater generic and specific diversities than those of the rough-water stage in the Niagaran reefs. This suggests an extremely rough sedimentary condition of the G_3 limestone, in some places at least, capable of existing on the bottom of the outer reef slope along the wave resistant reef edges in the Outer Zone of Southwest Japan in early Ludlovian time. As concluded by the junior author (Hamada, 1961) mainly based on the coral ecology, the G_3 limestone sites stood as a kind of barrier reefs in the ancient Pacific probably on the series of islands or bottom swells at that time.

IV. Silurian Trilobites in Eastern Asia

a. The Mongolian geosyncline

In 1914 KAZANSKI reported an occurrence of the *Calymene blumenbachi*-bearing Silurian marly shale on the Omutnaya stream on the north side of the upper Amur valley (RAUPACH, 1938). Recently *Tuvaella* and other brachiopods and corals were found in Transbaikalia and the Zeya basin (MODZALEVSKAYA, 1965, 1969). The Omutnaya Series in the upper Amur tributary and the Zeya basin yields various fossils including *Scotiella* (?) sp. and *Eudolatites orientalis* MAXIMOVA (1969) in the middle-upper part of the series. It is a remarkable fact that the Silurian is transgressive on the Pre-Cambrian crystalline schists between the Zeya and Silindji rivers (MAKARENKO, 1938).

No Silurian fossil had been known from Northeast China, i.e. Manchuria until *Pseudomphyma infundibula* YABE and EGUCHI and some other fossils were described from a coralline limestone at Ertaokou, west of Kirin (=Chilin) (YABE and EGUCHI, 1943, 1944, 1946). Lately KUO Hong-tsun (1962) described the following trilobites from three coralline limestone horizons near Ertaokou and concluded their age at late Wenlock or early Ludlow.

Encrinurus sinicus KUO
Otarion diffractum conveximarginatum KUO
Otarion sphaericum KUO
Calymene cf. *blumenbachi* BRONGNIART

Because *Otarion diffractum* ZENKER occurs in the Liteň formation and *Otarion diffractum diffractum* in the Kopanina formation in Bohemia, KUO's conclusion may be justifiable.

The Wenlockian sea flooded into Inner Mongolia as indicated by Middle Silurian corals in a limestone near Beiyin Obo, Suiyuan, Inner Mongolia (WU Wang-shih, 1950), but no trilobite is as yet known therefrom.

In western Mongolia and Tuva, the Silurian System is wide-spread and fossiliferous. N. TSCHERNYSHEVA (1937) described the following four trilobites.

Lichas (*Corydocephalus*) *sivovae* TSCHERNYSHEVA
Lichas (*Corydocephalus*) cf. *hirsutus* FLETCHER
Homalonotus (*Trimerus*) *mongolensis* TSCHERNYSHEVA
Dalmaniturus weberi TSCHERNYSHEVA

Dalmaniturus is an indigenous genus in the Silurian sea of Central Asia. Assuming that *Dalmaniturus* is referable to the Calmoninae which floruished greatly in the southern continents in the Devonian period (STRUVE, in Treatise, 1959), this indigenous genus must have been a link from Ordovician *Phacopidina* of Europe to the Devonian genera. Is *Scotiella* (?) sp. of the upper Amur Valley another link ?

Corydocephalus HAWLE and CORDA, 1847 is known now a synonym of *Trochurus* BEYRICH, 1845. The coexistence of *Trimerus* (Mid. Silurian-Devonian) with *Trochurus* (Up. Ordovician-Mid. Silurian) shows that the trilobite beds of the northwestern slope of the Terekte ridge, western Mongolia are probably Wenlockian. The fossil beds of the Chirgite ridge, western Mongolia may also be about Wenlockian in view of the fact that *Trochurus* cf. *hirsutus* which is accompanied by *Dalmaniturus weberi* shows proximity of the trilobite horizon to the Dudley limestone, England.

In the Mongolian geosyncline, the Silurian transgression reached the inundation phase at the Wenlockian age.

Incidentally, OBRUTSCHEW (1926) cited in his *Geologie von Sibirien* the wide distribution of three species of trilobites as below.

Calymene blumenbachi	Wilui,	Olenek,	Amur
Bumastus barriensis	,,	,,	,,
Cheirurus maackii	,,	,,	,,

b. The Hwangho basin

The so-called Chungchao massif by HUANG extends from North China to North Korea and South Manchuria. The depression on this heterogeneous block or Heterogen in which the Sinian and Cambro-Ordovician sediments were accumulated is the Hwangho basin. Sea, however, retreated in the late Upper Ordovician time and the whole block was emergent in the Silurian period. North Korea was an exception. There the Halysitidae and other corals are contained in limestone boulders in the older Mesozoic Kyeomipo (=Kenjiho) limestone conglomerate near Kyeomipo, Hwanghae-do (SHIMIZU, OZAKI and OBATA, 1934; KOBAYASHI, 1935; HAMADA, 1960, 1961). Therefore it is certain that the Silurian sea has ingressed there from the side of the Japan Sea. No Silurian trilobite is, however, as yet discovered among the derived fossils in the conglomerate.

c. The Kilianshan and Tsinlingshan: East Tienshan and West Kuenlun

The Chungchao block wedges out toward the west and the Kilianshan and the Tsinlingshan-Weiyangshan are aligned *en échelon* on the southwest side of the block. The oldest fossil record so far known is Middle Cambrian in the former and Lower Cambrian in the latter. These zones were two geosynclines in the Older Palaeozoic periods.

Of the Silurian trilobites, KAYSER was the first to describe *Encrinurus* sp. from "Mergeliger Kalkstein zwischen Kiau-tschang-pa und Shönn-hsüen-yi" in RICHTHOFEN's collection. This locality lies on the border between Shensi and Szechuan in the southern part of the Tsinlingshan. The age of the fauna was considered Middle Silurian by KAYSER and LINDSTRÖM (1883). Among KAYSER's three pygidia of *Encrinurus* sp. one in fig. 22, pl. 2 in RICHTHOFEN's China, vol. 4 was later identified with *Coronocephalus rex* GRABAU by LU et al. (1965).

In the Kilianshan or Nanshan range, *Encrinurus* spp. 1 and 2 and *Scutellum*

(*Thysanopeltis* ?) sp. were collected respectively from the Middle Silurian and the uppermost Silurian near Yümên, Kansu (LU et al. 1965).

In farther west, East Tienshan and Kuenlun run respectively on the north and south side of the elliptical Tarim basin. Insofar as the authors are aware, no trilobite was reported from the Silurian of either the West Kuenlun or the East Tienshan (CHANG, Jeh-tung, 1959; CHAO, 1963; MU, 1961) except for *Encrinurus* contained in NORIN's collection from the Arpishemobuluk (=Arpishmebulaq) Series in the Chinese Tienshan (REGNÉLL, 1961).

d. The Yangtze basin

In Central and South China, the graptolite shales are wide-spread especially in the Lower Silurian, but the shelly facies is less developed in the Yangtze basin. In the upper Yangtze valley the *Dalmanitina* beds extensive from South Shensi to Kueichow through Szechuan and Hupeh, yield *Dalmanitina nanchengensis* LU, *D. mucronata* (BRONGNIART), *Hammatocnemis tetrasulcatus* KIELAN and *H. tetrasulcatus ovatus* SHENG. As noted elsewhere (KOBAYASHI, 1969), it is a moot question in China to locate the *nanchagensis* horizon either at the base of the Silurian System (CHANG, 1964 and MU, 1964) or at the top of the Ordovician System (SHENG, 1965). Quite recently, it is emphasized by SHENG (1973) that the *Dalmanitina* beds designate the top of the Ordovician System in Central China.

Trilobites are, however, not uncommon in China in the higher beds, although only a small number of species are so far described. In 1924 GRABAU proposed two new names for the following trilobites. One is *Cheirurus lunshanensis* GRABAU from the Kaochiapien shales at Lunshan, Nanking hills, Kiangsu. It was in association with *Calymene* sp., *Proetus* sp. and *Phacops* cf. *shanensis* REED. As he noted that the trilobite beds appear in fault contact with the Lower Ordovician Lunshan limestone, their reference to the Kaochiapien shale formation containing Lower Silurian graptolites is a question. LU and others (1965) contend that *Cheirurus* (?) *lunshanensis* is probably a Lojopingian trilobite. Morphologically it is typical of *Cerauroides*, as pointed out already (KOBAYASHI, 1960). Therefore the authors are of opinion that the *lunshanensis* horizon would be a correlative to the Gomi horizon in Shikoku, Japan. Then, how the lower Ludlovian trilobite shale wedged in the Lower Silurian Kaochiapien shales is a tectonic question.

The other trilobite was *Encrinurus* (*Coronocephalus*) *rex* GRABAU from the Fuchih shale in Yangsing district, Hupeh which was found together with *Proetus latilimbatus*, *Spirifer hsiehi* and some other brachiopods.

Next year, GRABAU reported several trilobites from three horizons in the Shamaoshan section near Lojoping, west Hupeh as follows:

Horizon	Lower	Middle	Upper
1. *Coronocephalus rex* GRABAU	×	×	
2. *Proetus latilimbatus* GRABAU	×		×
3. *Harpes* cf. *venulosa* CONRAD var. *sinensis* GRABAU		×	
4. *Acidaspis octaspinosus* GRABAU		×	
5. *Acidaspis* sp.		×	
6. *Bronteus* cf. *partschi* BARRANDE	×		
7. *Illaenus asaphoides* GRABAU		×	

Among these trilobites, 2, 3 and 7 were restudied and denominated by LU (1962) as follows:

2. *Latiproetus latilimbatus* (GRABAU)....................Middle and Upper Silurian
3. *Aristoharpes sinensis* (GRABAU) em. LU.............Middle Silurian
7. *Ptilillaenus lojopingensis* LU.........................Middle Silurian

Coronocephalus rex was, on the other hand, thoroughly revised by WANG (1938). As summarized by the junior author (1959), *Coronocephalus* and allied forms referred to *Encrinurus* and *Cromus* are widely distributed in the Lojopingian and Hanchiatienian Series in Central and South China. Many of them are simply listed, but those illustrated or described are discussed in the palaeontological part.

It is certainly a remarkable fact that in the Hunghsien section, Szechuan *Encrinurus* (*Coronocephalus*) *rex* occurs in the lower horizon, *Cromus* sp. and *Proetus* sp. in the middle and *Encrinurus* sp. in the upper horizon in the thickness of 280 meters. In the Shamaoshan section of 589 meters' thickness *Coronocephalus rex* is found in four horizons accompanied by different trilobites and other fossils (HSIEH and CHAO, 1925). As pointed out on page 94, there appears to be several species of encrinurids among them. Therefore the zonation by means of encrinurids must be an important subject for the Middle and Upper Silurian biostratigraphy of the Yangtze basin.

e. The Burmese-Malayan geosyncline

As noted elsewhere (KOBAYASHI, 1973), this geosyncline was tranquile during the three older Palaeozoic periods. Broadly speaking, the Silurian system there consists of the Panghsapyge graptolite facies, Kuala Lumpur limestone facies and the Washih-Zebingyi facies in ascending order. The Panghsapyge facies is represented by the lower Jenhochiao Series in West Yunnan, Panghsapyge beds in the Shan States, the Llandoverian graptolite shales in West Thailand and the so-called Lower Detrital Band of the Langkawi Islands, Malay.

The *Camarocrinus* bearing Nyaungbaw limestone in the Northern Shan States is located at the Ordovician-Silurian transition. It is generally placed at the top of the Upper Ordovician System by Burmese and Indian geologists. Chinese geologists on the contrary consider it to be at the base of the Silurian System. In West Yunnan

Table 6. Silurian trilobite horizons in eastern and southeastern Asia.

Area / Age		Malay	East Burma	Yunnan	Central China	N. E. China	Japan
Lower Devonian	U		Pon *Phacops*				
	L						
Ludlow	U		*Odontochile swinhoei* ?				*Prantlia* *Encrinurus kitakamiensis*
	M						
	L		*Encrinurus konghsaensis*		*Cerauroides lunshanensis*	Ertaokou	Gomi horizon *E. tosensis*
Wenlock	U		Main Namhsim		*Coronocephalus rex*		*C. kobayashii*
	M						
	L	*Prodontochile*					
Llandovery	U						
	M						
	L	*Dalmanitina*	Panghsapyge	*Leonaspis*	*Dalmanitina nanchengensis*		
Ashgill	U						
	L						

Monograptus concinnus was found in the *Camarocrinus* zone in the Shihtien basin. In Paoshan area the Lower Silurian *Leonaspis* shale yielding *L. yunnanensis* CHEN, *L.* cf. *shanensis* (REED) and *Primaspis suni* CHEN is intercalated between the lower and upper *Camarocrinus* limestones. The *Leonaspis* shale must be penecontemporaneous to the trilobite band at the basal part of the Panghsapyge beds in Northern Shan States. It yields *Acidaspis shanensis* REED and *Phacops* (*Dalmanites*) *hastingsi* REED which belong respectively to *Leonaspis* and *Dalmanitina*.

In the Langkawi Islands, West Malaysia there are two trilobite horizons. One containing *Dalmanitina malayensis* KOBAYASHI and HAMADA, 1964, *Stenopareia* (?) sp. and some other fossils is located at the basal part of the Lower Detrital Band, and is early Llandoverian in age. The other is the *Prodontochile igoi* limestone in the basal part of the upper Setul limestone superjacent to the band. Trilobites obtained from this limestone *in situ* and limestone floats containing *Prodontochile igoi* constitute a copious trilobite assemblage comprising more than 17 species in ten genera, as listed below. The late Llandoverian or/and early Wenlockian age of the fauna is in support of associated conodonts (IGO and KOIKE, 1967, 1968).

Octobronteus (?) spp.
Scutelluid indt.
Cheirurus sp.
Sphaerexochus orientalis KOBAYASHI and HAMADA

Prodontochile igoi KOBAYASHI and HAMADA
Zeliszkellioid (?) spp.
Langgonia biplicata KOBAYASHI and HAMADA
Langgonia araiorachis KOBAYASHI and HAMADA
Langgonia (?) *pliomeroides* KOBAYASHI and HAMADA
Malayaproetus bulbus KOBAYASHI and HAMADA
Malayaproetus sp. nov.
Proetoid gen. et sp. indt. a
Proetoid gen. et sp. indt. b
Proetoid (?) indt.
Calymene scrivenori KOBAYASHI and HAMADA
Aristoharpes sp.
Lonchodomas (*Metalonchodomas*) *masjidiformis* KOBAYASHI and HAMADA

In the Northern Shan States the Silurian formation is divided into three series as follows:

3. Zebingyi Series
2. Namhsim Series { Konghsa marls, Namhsim sandstone }
1. Panghsapyge Series

The Namhsim Series contains the following trilobites.

Illaenus namhsimensis REED (i. e. *Illaenus* aff. *aemulus* SALTER by REED, 1906)
Dalmanites longicaudatus var. *orientalis* REED
Cheirurus cf. *bimucronatus* (MURCHISON)
Cheirurus (?) *inexpectans* REED
Encrinurus konghsaensis REED
Proetus spp. a and b
Calymene blumenbachi BRONGNIART var.

According to REED the resemblance of *C.* (?) *inexpectans* with Llandeilian *Lehua vinculum* (BARRANDE) is astonishing, hence the name *Cheirurus* (?) *inexpectans.* On the other hand *Dalmanites longicaudatus*, *Illaenus namhsimensis* (or *I.* aff. *aemulus*) and *Proetus* sp. a are allied to certain Wenlockian trilobites. *Encrinurus konghsaensis* is also close to Lower and Middle Silurian *Encrinurus punctatus.* In view of the fact that the fauna is quite distinct from the *Prodontochile* fauna, the age of the former may be middle Wenlockian or younger.

In Southern Shan State, Burma REED (1923) reported the occurrence of the following three trilobites from half a furlong, west of bridge 378, Heho-Namnoi railway section.

Proetus sp.
Cyphaspis cf. *convexa* CORDA
Phacops (*Dalmanites*) sp.

None of them was illustrated, but he noted that the last is allied to *Ph.* (*Dalmanites*) *longicaudatus* var. *orientalis* REED from the Namhsim sandstone of Panghsapyge.

No Silurian trilobite is as yet uncovered from Thailand, but *Encrinurus punctatus* EMMRICH var. *laosensis* PATTE and *Lichas* cf. *scabra* BEYRICH from Laos indicate the Indochinese branch of the Burmese-Malayan geosyncline probably in the Wenlockian epoch.

In West Yunnan the Silurian System consists of the lower and upper Jenhochiao Series and the Washih formation in ascending order. The *Leonaspis-Primaspis* faunule occurs in the basal part of the lower Jenhochiao Series beneath the *Monograptus cyphus* zone. Trilobites are scarce in the higher beds, although *Phacops* is reported from the *Tentaculites elegans* zone containing *Monograptus vomerinus* in the upper part of the Wahshih formation in the Paoshan area.

In Burma four trilobites are described from the Zebingyi beds. In the Northern Shan States, *Dalmanites* (*Odontochile* ?) *swinhoei* REED is accompanied by *Monograptus dubius* SUESS at loc. 1, Zebingyi. *Phacops shanensis* REED at loc. 2, Zebingyi as well as the preceding trilobite were found together with *Tentaculites elegans* BARRANDE. *Phacops ponensis* REED and *Phacops* (*Odontochile* ?) *sternbergi* were collected at Pon, Southern Shan State with *Tentaculites* sp. *Reedops sternbergi* (BARRANDE) occurs in Bohemia in the Lower Devonian Zlichov limestone. It is probable that the Pon phacopids are Devonian in age.

V. Silurian Trilobites of South Asia

REED (1912) described Silurian trilobites from Kashmir (1) and Central Himalaya (2) as follows:

Calymene cf. *blumenbachi* (BRONGNIART)	1	
Calymene (?) sp.		2
Acidaspis kashmirica REED	1	
Illaenus aff. *maccalumi* SALTER	1	
Encrinurus cf. *punctatus* (WAHLENBERG)	1	2

Only the last species is common between the two areas. *Leonaspis deflexus* (LAKE), to which *Acidaspis kashmirica* is allied, is Wenlockian.

Incidentally, Silurian graptolites and other shelly fossils were recently found in the Mount Jolma-Lungma regions, South Tibet, but no trilobite is reported therefrom (MU et al., 1973).

In Pamir, *Dalmanitina mucronata arsachensis* BALASHOVA from Ashgillian is followed by three other species of *Dalmanitina*. In addition, two Wenlockian trilobites are described by BALASHOVA (1966) as follows:

	West Pamir	East Pamir
Dalmanitina kosyndensis BALASHOVA	Llandovery	
Dalmanitina pamirica BALASHOVA	Llandovery	Llandovery
Dalmanitina subduplicata sorabata BALASHOVA		Llandovery
Encrinurus tuyuxuensis BALASHOVA		Wenlock
*Pamiritellus** *pamiricus* (BALASHOVA)	Wenlock	

* =*Pamirites* BALASHOVA

Some records of Silurian trilobites which the authors could find in further west are as follows:

(1) *Encrinurus* (*Encrinurus*) *konghsaensis* REED is reported to occur at Sar-e-Pori, about 100 km southwest of Kaboul, Afghanistan by PILLET and DE LAPPARENT (1969).

(2) In East Iran, marls of the Silurian Nuir formation in the Shirgecht area are rich in trilobites, brachiopods and other fossils and WINSNES tentatively determined *Calymene* cf. *platys*, *Dalmanites* sp. and *Cyphaspis* (?) sp. (RUTTEN et al., 1968).

(3) FRECH (1916) found *Calymene* and *Acaste* in micaceous clayslate between Airan and Bagtsch in Amons, southernmost Turkey, but the latter may be a *Dalmanitina* (R. RICHTER in DUBERTRET, 1953).

(4) In East Taurus BASAL and ERENTÖZ (1966, in FLÜGEL, 1971) discovered Silurian graywacke with *Homalonotus*.

Recently, a copious Silurian-Devonian faunas were described by HAAS (1968) from Bithynia, extreme northwest Asia Minor. Five Silurian trilobites he described are as follows:

Llandovery: Tavson-Tepe formation (lower part) and Umur-Dere Folge
Encrinurus (Encrinurus) brevispinosus HAAS
Flexicalymene (Flexicalymene) sp.
Ludlow: Upper Pelitli formation
Kosovopeltis crebristriata complicata HAAS
Proetus (Proetus) barrangus HAAS
Calymene arotia HAAS

Table 7. Correlation of Silurian trilobite horizons in South Asia.

Area / Age	Turkey		Afghanistan	Pamir	Kashmir	Central Himalaya
	Bithynia	Amons				
Ludlow	Upper Pelitli					
Wenlock			*Encrinurus konghsaensis*	*Encrinurus-Pamiritellus*	*Leonaspis kashmirica*	*Encrinurus* cf. *punctatus*
Llandovery	Tavson-Tepe	*Dalmanitina*		*Dalmanitina*		

VI. Silurian Trilobites in Siberia

In Siberia SCHMIDT (1886) described *Phacops* (*Monorakos*) *lopatini* n. sp. and *P.* (*M.*) *sibiricus* n. sp. from the "Untersilur" of the middle Tunguska. Subsequently TOLL (1899) added *Monorakos schmidti* nov. and a few other trilobites from Kotelny island, New Siberia. WEBER (1951) listed them in the Llandoverian fauna, but the family Monorakeidae KRAMARENKO, 1952 is now generally accepted to be an Upper Ordovician family typical of Siberia (Treatise, 1959; Osnovy, 1960) and Greenland (TROEDSSON, 1929), ignoring Middle Ordovician *Isalaux* of the United States of America.

On the north side of the Siberian platform, the Silurian System overlying the Ordovician disconformably reveals a marine sequence except for the Ludlovian gypsiferous facies near the southern margin of its distribution. All of the trilobites known to the authors are Llandoverian except for a few Wenlockian encrinurids and calymenids (MAXIMOVA, 1962). Lower Silurian trilobites were amplified by BALASHOVA (1960) from the Taimyr peninsula as listed below.

Incidentally, *Acanthaloma* is now synonymized with *Leonaspis*. MAXIMOVA referred *Phacops quadrilineatus* to *Eophacops*. CAMPBELL (1967) commented that *Eophacops pulcher* as well as most of MAXIMOVA's *quadrilineatus* can be placed in his new genus *Acernaspis*. MAXIMOVA replaced her *Calymene blumenbachi*, 1955, by *Calymene* sp. β in 1962.

It is a remarkable fact that Llandoverian trilobites in the three areas of Siberia are quite different from one another except for *Eophacops quadrilineatus* occurring common in the three faunas. *Acernaspis* is widely distributed in the Lower Silurian of Eur-America and New South Wales, Australia, but it is unknown from Asia except Siberia. The *Prodontochile* fauna of Malay has no genus common with the Llandoverian-Wenlockian faunas of Siberia.

In describing *Proetus* (*Pseudoproetus*) *regalis* from the upper Llandoverian Cape Schuchert formation, POULSEN (1934) noted the probable inclusion of *Proetus micropygus* HAWLE and CORDA in *Pseudoproetus*. Later, however, PŘIBYL (1946) founded *Scharyia* on this Bohemia species. *Pseudoproetus* is an Arcto-Boreal genus and the two MAXIMOVA's species of the genus reveal the faunal connection from Central Siberia to North Greenland. Furthermore it is noted that *Harpes latior* POULSEN and *Goldius borealis* POULSEN are closely allied to *Aristoharpes taimyricus* BALASHOVA and *Eobronteus norilskensis* MAXIMOVA respectively. They show that the Cape Schuchert fauna of North Greenland is intimately related to the Llandoverian fauna of Siberia.

Finally, two comments are added to the Siberian trilobites. TOLL's pygidium of *Bronteus andersoni* from Kotelny island well agrees with *Planiscutellum* and *Protoscutellum* in the distinct axial rings and seven ribs on each side of the simple median ribs. The axis is, however, not trilobed as in the former genus and the pygidium and the median rib are not so wide as in the latter. Nevertheless it is intimately related to these Silurian genera.

Fossil list 2. Silurian trilobites of Siberia.

Area / Horizon / Trilobite Species	A		B	C
	Siberian Platform		Taimyr Peninsula	New Siberian Islands
	Lland.	Wenl.	Llandoverian	Llandoverian
Stenopareia bowmanni (SALTER)	X			
Stenopareia thomsoni (SALTER)	X			
Stenopareia angulata MAXIMOVA	X			
Bumastus nordicus BALASHOVA			X	
Bumastus taimyricus BALASHOVA			X	
Eobronteus norilskensis MAXIMOVA	X			
Eobronteus sp.	X			
Scutellum taimyricum BALASHOVA			X	
Bronteus andersoni ETH. and NICH.				
Acanthaloma emarginata (SCHM.)	X			Ko
Phacops khatangensis WEBER	Ka			
Phacops ? macropyge MAXIMOVA	X			
Eophacops quadrilineatus (ANG.)	X		X	Ko
Eophacops pulcher MAXIMOVA	X			
Cheirurus maackii SCHMIDT	O			
Encrinurus punctatus WAHL.	X	W		
Encrinurus globosus MAXIMOVA	X?	W?		
Encrinurus creber MAXIMOVA		W		
Proetus ramisulcatus NIERZKOWSKI			X	
Proetus tolli WEBER	Ka			
Pseudoproetus bellus MAXIMOVA	X			
Pseudoproetus tertius MAXIMOVA	X			
Unguliproetus enodis (MAXIMOVA)	X			
Unguliproetus aff. *enodis* (MAXIMOVA)	X			
Calymene taimyrica BALASHOVA			X	
Calymene sp. α (*C. blumenbachi*)	X			
Calymene sp. β		W?		
Aristoharpes taimyricus BALASHOVA			X	

X: Llandovery, W: Wenlock, Ka: Khatanga, O: Olenek, Ko: Kotelny
A after WEBER, 1951 and MAXIMOVA, 1962, B after BALASHOVA, 1960,
C after WEBER, 1951.

The pygidium of *Cheirurus maackii* has long spines in two pairs, instead of three pairs as common in the Cheiruridae. They are equally prolonged and divergent. *Proromma* LANE has two pairs of spines which are, however, subparallel and the anterior ones are much longer than the posterior ones. *Didrepanon* LANE has two pairs of long spines but in addition it has the third pair of rudimentary spines behind them. In the divergence of two paired spines in similar length it agrees with Lower Ordovician *Seisonia*, but in *Seisonia* the pleural ribs are each divided by an intercalating furrows. *Cheirurus maackii* represents most probably an unnamed genus which is nearer to these Silurian genera than *Seisonia*.

VII. Silurian Trilobites of Turkestan and West Siberia

In the vast terrain from the Kuznetsk basin, Southwest Siberia to Turkestan Silurian sediments are wide-spread and yield various trilobites. Among them Ludlovian ones are most profused whereas Llandoverian ones are quite rare.

Cheirurus welleri is a well known Niagaran species. RAYMOND (1916, p. 35) said that " it is probably the most cosmopolitan species of *Cheirurus*." TSCHERNYSHEVA (1951) reported the occurrence of *Cheirurus* aff. *welleri* from the Kuznetsk basin, but WEBER (1951) called this Kuznetsk form *Cheirurus* sp.

Trilobites from Ak-Kul, Akerme inlet, Pribalkhash include four Bohemian species as follows:

Kosovopeltis partschi (BARRANDE)	high Liteň-Kopanina
Pseudocheirurus beyrichi (BARRANDE)	Kopanina
Staurocephalus murchisoni BARRANDE	high Liteň
Sphaerexochus mirus BEYRICH	high Liteň

As the occurrence in Bohemia is cited behind each species, they point the age of the Ak-Kul trilobite horizon at upper Wenlock—lower Ludlow. The range of *Decoroproetus decorus* in Bohemia is Liteň to Kopanina. Therefore *D.* aff. *decorus* may be an additional trilobite suggesting a similar age and faunal affinity of the Turkestan trilobites. Because *Ananaspis fecunda* and *Cromus beaumonti* are two Kopanina species, their varieties respectively from Central Kazakhstan and Samarkand would be about the same age.

Encrinurus punctatus is a typical Wenlockian trilobite in Gotland, although the the *punctatus* species-group ranges from late Llandoverian to Ludlovian in North Europe (TRIPP, 1962). *Proetus conspersus* is on the other hand a characteristic member of the early Ludlovian fauna of Gotland.

The Ak-Kul and allied trilobite faunas of Turkestan must be penecontemporaneous with the Gomi fauna containing *Kosovopeltis*, *Sphaerexochus*, *Decoroproetus* and the *punctatus* type of *Encrinurus*, which reveals at the same time the faunal connection between Japan and Central and North Europe through Kazakhstan.

BALASHOVA (1968) instituted two new species, *Encrinurus tchingisicus* and *E. donenjalensis* respectively for *Encrinurus punctatus* by WEBER, 1932 and 1951 and *E. punctatus*? by WEBER, 1932 from Kazakhstan. According to her the former is Llandoverian in age and the latter is a member of the Donejalsky fauna (lower Ludlovian and older). She added further *Scutellum* (*Planiscutellum*) *tolenicum* BALASHOVA as another Llandoverian member and *Proetus ainasuensis* BALASHOVA and *Reedops serratus spiniferus* BALASHOVA as two upper Ludlovian members of the Kazakhstan fauna. *Phacops schischkathensis* BALASHOVA is an upper Ludlovian species in Tadjikstan.

How much one can rely on *Encrinurus* cf. *konghsaensis* from Ferghana and

Fossil list 3. Silurian trilobites of Central Asia.

Occurrences / Trilobite Species	Kuznetsk, S_2 TCHERNYSHEVA, 1951	Turkestan, etc., WEBER, 1932, 1951; BALASHOVA, 1968		Central Kazakhstan, MAXIMOVA, 1960
		Loc.	Age	
Bumastus barriensis var. *ferganensis* WEBER		F	u	
Bumastus (?) sp. indt.		N		
Scutellum pustulatiformis (TSCHERNYSHEVA)	X			
Scutellum partschi (BARRANDE)		P	u	
Scutellum crebristriatus var. *magna* WEBER		P	lu	
Scutellum michnevitchi MAXIMOVA				X
Scutellum aff. *lichaoides* (WEBER)		T	s-d	X
Scutellum (*Planiscutellum*) *tolenicum* BALASHOVA				Ll
Decoroscutellum indefensum MAXIMOVA				X→
Scutellum spp.	X	P	u	
Acanthopyge markovskyi (WEBER)		T		
Acanthopyge altirhachis (TSCHERNYSHEVA)	X			
Acanthopyge sp.		P	u	
Acanthaloma longispina (BALASHOVA)				X
Tetralichas contractus WEBER		P	w	
Dicranopeltis (?) *balkhaschicus* WEBER		P	w	
"*Lichas*" spp.	X	P		
Phacops fecundus orientalis MAXIMOVA				X
Phacops ainasuensis BALASHOVA				X
Phacops kazachstanicus BALASHOVA				X
Phacops schischkathensis BALASHOVA		Tj	u	
Phacops aff. *shanensis* REED	X			
Phacops spp.		T		X
Reedops serratus spiniferus BALASHOVA				u
Dalmanites septicostatus MAXIMOVA				X
Dalmanites kazachstanicus BALASHOVA				X
Dalmanites saryakensis MAXIMOVA				X
Odontochile kiikbaica MAXIMOVA				X→
Odontochile pristina MAXIMOVA				X
Odontochile graciosa MAXIMOVA				X
Odontochile caudatum BRÜNNICH			w	
Odontochile batymarginata MAXIMOVA				X→
Cheirurus strabo WEBER		F	u	
Cheirurus beyrichi BARRANDE		P	lu	
Cheirurus quenstedti orientalis MAXIMOVA				X

Cheirurus aff. *welleri* RAYMOND	X			
Cheirurus (?) *uratubensis* WEBER		T		
Cheirurus spp.		N		X
Crotalocephalus myops (ROEMER)	X→	T	u	
Crotalocephalus myops var. *scissa* WEBER		F	u	
Crotalocephalus expansus BALASHOVA				X
Crotalocephalus gemmatus (WEBER)		T	u	X
Crotalocephalus cf. *sternbergi* BOECK				X
Staurocephalus murchisoni BARRANDE		P	u	
Sphaerexochus mirus BEYRICH		FP	wu	
Youngia alaica WEBER		T		
Encrinurus punctatus WAHLENBERG		F	wl	
Encrinurus tchingisicus BALASHOVA				Ll
Encrinurus donenjalensis BALASHOVA				w
Encrinurus beaumonti var. *novaki* FRECH (?)		S	u	
Encrinurus konghsaensis (?) REED		F	l	
Encrinurus sp.		N		
Proetus bohemicus CORDA		T		
Proetus conspernus ANGELIN		T		
Proetus markovskyi WEBER		F	l	
Proetus romanovskyi WEBER		N	u	
Proetus circumscriptus WEBER		P		
Proetus ainasuensis BALASHOVA				u
Proetus aff. *decorus* BARRANDE		T		
Proetus sp.		P		
Otarion sp.		T		
Calymene blumenbachi BRONGNIART		F	wl	
Calymene blumenbachi var. *asiatica* WEBER		F	wlu	
Calymene blumenbachi var. *producta* WEBER		T		
Calymene weberi MAXIMOVA				X→
Calymene aff. *weberi* MAXIMOVA				X
Calymene sp.				X
Trimerus sp.				X
Harpes pansa MAXIMOVA				X

Abbreviations

F: Ferghana, N: Nura Tau (Mid. Asia), P: Pribalkhash (Kazakhstan), S: Samarkand, T: Turkestan, Tj: Tadjikestan, u: Upper Ludlow, l: Lower Ludlow, w: Wenlock, Ll: Llandovery, X: S_2, X→: S_2 to D_1^1

Bronteus GOLDFUSS, 1839, *Cyphaspis* BURMEISTER, 1846 and *Euarges* GÜRICH, 1901 are respectively replaced in the list by *Scutellum* PUSCH, 1833, *Otarion* ZENKER, 1833 and *Acanthopyge* HAWLE and CORDA, 1847 owing to synonymy.

Phacops aff. *shanensis* from the Kuznetsk basin for correlation is a question, primarily because their identification to the Burmese species is indefinite and secondarily because the exact age of these Burmese species is not yet determined.

Table 8. Correlation of Silurian trilobite horizons in Asia.

Age \ Area		North Asia	Turkestan and West Siberia	East and Southeast Asia
Lower Devonian				Pon *Phacops*
Ludlow	Přidoli		Kochbaital horizon	*Prantlia biloba*
				Encrinurus kitakamiensis
	Kopanina		Ak-Kul horizon	Gomi horizon
				Encrinurus tosensis
Liteň	Wenlock	*Encrinurus punctatus*		*Coronocephalus kobayashii*
			Encrinurus punctatus	*Coronocephalus rex*
				Prodontochile horizon
	Llandovery	*Acernaspis quadrilineatus*		
				Dalmanitina nanchengensis
Ashgill				

It is a remarkable fact that *Crotalocephalus* occurs in Turkestan together with Silurian trilobites. In WEBER's monograph (1932) the following trilobites are reported from three localities as below.

Species \ Locality Number	20	22	53
Bumastus barriensis ferganensis	×		×
Encrinurus ex gr. *punctatus*	×	×	×
Cheirurus myops	×		×
Cheirurus myops interruptus	×		×
Sphaerexochus mirus			×
Youngia alaica		×	
Proetus aff. *decorus*	×		
Cyphaspis sp.	×		

20. Ujehnyehree Sklon Khahr Keklik-uar (Ferghana). Upper Silurian. J. RHEINWALD collection.

22. Apparently same to No. 20. Upper Silurian. J. RHEINWALD collection.
53. Gora Keklikuchar, Ujehnyehre Sklon u Otmetki 475, lc, Oshsjkiy (Ferghana). Upper Silurian. D. NALIVKIN and D. MUSHUKETOV collection.

Incidentally, *Cheirurus myops* belongs to *Crotalocephalus. Cheirurus myops interruptus* was later called *Crotalocephalus myops scissa* by WEBER (1951).

In the Kuznetsk basin, *Cheirurus* (*Crotalocephalus*) *myops* occurs in the Upper Silurian at the Mamontova area with four other trilobites, but it is found alone in the Lower Devonian rocks in the Kara-Chumyerschkoi area (TSCHERNYSHEVA, 1951).

According to MAXIMOVA (1960, 1968), the Kochbaital horizon of Central Kazakhstan yields *Crotalocephalus expansus, C. gemmatus* and *C.* cf. *sternbergi* with *Phacops fecunda orientalis, Cheirurus quenstedti orientalis* and many other trilobites. According to her, the Ainasu beds of the horizon is upper Ludlovian but the higher part of the Kochbaital horizon is possibly early Devonian. Four species of the Kochbaital fauna ranges from Upper Silurian to Lower Devonian (S_2-D_1^1) as follows:

Decoroscutellum indefensum MAXIMOVA
Calymene weberi MAXIMOVA
Odontochile kiikbaica MAXIMOVA
Odontochile batymarginata MAXIMOVA

It is certainly a remarkable fact that the Upper Silurian fauna transmitted into the Lower Devonian one gradually in the megageosyncline between the Angara urkraton and the Koreo-Chinese heterogen, while in North Asia it is quite conspicuous that the sea retreated toward the end of the Silurian period by the upheaval of the Angara land or the Siberian platform.

Finally, NIKITIN (1972) reports the occurrence of *Dalmanitina mucronata* in the *Glyptograptus persculptus* zone in Kazakhstan, but the Ordovician-Silurian boundary is drawn there between the *G. persculptus* zone below and the *Akidograptus acuminatus* zone above.

VIII. Silurian Trilobites of Australia and Tasmania

The history of research in Silurian trilobites of Australasia has prolonged almost a century counted from the description of *Forbesia euryceps* and *Homalonotus harrisoni* in McCOY's *Prodrome* in 1876. The number of Silurian trilobites attaining more than seventy-fives species is the largest among the Silurian faunas around the Pacific basin.

Recently CAMPBELL (1973) described *Dalmanitina* (*Dalmanitina*) *darrawaitensis*, nov. from Victoria in a horizon above a Bolindian graptolite horizon yielding *Pleurograptus* sp. and *Diplograptus* cf. *calcaratus*. Its age is presumed to be latest Ashgillian, but its earliest Llandoverian age is also possible as the locality has been mapped as Silurian.

The *Illaenus* Band at Heathcote, Victoria which is dated by graptolites at early upper Llandovery yields three species of *Thomastus* which is an indigenous genus of blind illaenids on muddy bottom. It is accompanied by *Ananaspis*, *Eudolatites* and *Dalmanites* besides other groups of fossil animals. Its age is near the *Prodontochile* fauna of Malay, but it may be a little older. In the litho-facies it is nearer to the *Dalmanitina malayensis* horizon which yields also various kinds of fossils. In New South Wales, two species of *Acernaspis* (?) and one of *Encrinurus* are Lower Silurian trilobites.

GREGORY (1903) proposed Melbournian for the lower unit in his bipartation of the Silurian System in Victoria. Among CHAPMAN's four trilobites from the Melbournian (1911), *Thomastus* (?) *jutsoni* suggests the proximity of some members of the Melbournian fauna to the Llandoverian *Illaenus* Band. Between two species of *Raphiophorus*, *R. yarraensis* has a large forwardly protruded glabella like *Lonchodomas masjidiformis* of the *Prodontochile* fauna. This and *Encrinurus spryi* were collected from South Yarra. CHAPMAN compared his *Homalonotus vomer* with *H. delphinocephalus* from the Middle Silurian of Eur-America. It is the type-species of *Trimerus* (*Trimerus*). In Asia *Trimerus mongolensis* is a solitary Middle Silurian species of the genus. According to GILL (1949), *Trimerus vomer* as well as *T. harrisoni* (McCOY) are either Upper Silurian or Lower Devonian in age.

Silurian trilobites were largely amplified by ETHERIDGE and MITCHELL (1892, 1894, 1896, 1897, 1915, 1917) with rich materials from the Yass-Bowning area, New South Wales. There are three trilobite beds which they considered primarily Wenlockian (?). Later, however, MITCHELL (1919, p. 446) noted " Upper and Middle Trilobite Beds, Bowning and Yass Series, Upper Silurian and perhaps in the upper zone of its occurrence, Lower Devonian." As the result of recent studies on graptolites and conodonts respectively by JAEGER (1967) and LINK (1970) it is known at present that the Upper Trilobite Bed is early Gedinnian or Lochkovian in age. Likewise, the Yeringian which was originally proposed by GREGORY (1901) for the upper unit of his bipartation of the Silurian rocks in Victoria and which was accepted also as

Fossil list 4. Silurian trilobites of Australia and Tasmania.

Trilobites / Area	New South Wales		Victoria	Tasmania
Illaenus johnstoni ETHERIDGE			S	S
Thomastus thomastus ÖPIK			I	
Thomastus collusor ÖPIK			I	
Thomastus vicarius ÖPIK			I	
Thomastus (?) *jutsoni* (CHAPMAN)			I	
Scutellum jenkinsi (ETHERIDGE and MITCHELL)		l		
Scutellum longispinifex MITCHELL		l		
Scutellum molongensis (E. and M.)	(Su)			
Scutellum mesembrinus (E. and M.)	(Su)			
Scutellum angusticaudatus (E. and M.)	(Su)			
Scutellum singularis MITCHELL		l		
Scutellum platynotus M.		l		
Odontopleura parvissima E. and M.		l		
Odontopleura hartleii M.	(Su)			
Leonaspis rattei (E. and M.)		m→		
Leonaspis bispinosa PHILIP			B	
Primaspis (*Taemaspis*) *bowningensis* (E. and M.)		l		
Ceratocephala vogdesi E. and M.		l		
Ceratocephala jackii E. and M.		m		
Ceratocephala impedita E. and M.		m		
Ceratocephala phalaeocephala M.		l		
Bounyongia bowningensis E. and M.		l		
Dicranurus kinglakensis GILL			S	
Dicragomus bartonensis FLETCHER	Sl			
Trochurus sinuata (RATTE)	(Su)			
Phacops latigenalis E. and M.		m		
Ananaspis typhlagogus (ÖPIK)			I	
? *Acernaspis macdonaldi* (FLETCHER)	Sl			
? *Acernaspis oblatus* SHERWIN	Sl			
Denckmanites rutherfordi SHERWIN	SD			
Dalmanites wandongensis GILL			M	
Dalmanites athamas ÖPIK			I	
Eudolatites aborigenum ÖPIK			I	
Dalmanitina darrawaitensis CAMPBELL			O or Sl	
Odontochile loomesi (M.)		m→		
Odontochile meridianus (E. and M.)		m→	S	
Cheirurus sp.			B	
Crotalocephalus silverdalensis E. and M.	Su		B	
Crotalocephalus sculptus E. and M.		l		
Crotalocephalus (?) sp.	SD			

Sphaerexochus mirus Beyrich		l		
Staurocephalus murchisoni Barrande		l		
Staurocephalus (?) *clarki* de Koninck				
Encrinurus bowningensis Foerste		l		
Encrinurus mitchelli Foerste		l		
Encrinurus silverdalensis E. and M.		l		
Encrinurus etheridgei M.	(Su)			
Encrinurus duntroonensis E. and M.	(Su)			
Encrinurus frontalis M.		m		
Encrinurus platynotus (M.)		l		
Encrinurus robustus (M.)		l		
Encrinurus perannulatus (M.)		t		
Encrinurus angustus (M.)		t		
Encrinurus spryi Chapman			M	
Encrinurus borenorensis Fletcher	Sl			
Encrinurus simpliciculus Talent			Su	
Encrinurus incertus (M.)		u		
Encrinurus rothwellae E. and M.		u		
Proetus rattei M.		l		
Proetus bowningensis M.		m→		
Proetus australis M.		l		
Proetus euryceps (McCoy)			M	
Otarion (*Otarion*) *bowningensis* (M.)		m→		
Otarion (*Otarion*) *horani* (E. and M.)		l		
Otarion yassensis (E. and M.)		l		
Otarion rotunda (E. and M.)		l		
Otarion filmeri (M.)		l		
Otarion spryi (Gregory)			S	
Calymene duni E. and M.	(Su)			
Flexicalymene sp.			S	
Gravicalymene australis (E. and M.)		lm→		
Gravicalymene angustior (Chapman)			B	
Gravicalymene cootamundrensis Gill	Su			
Gravicalymene hetera Gill			S	
Gravicalymene kilmorensis Gill			S	
Trimerus harrisoni (McCoy)			M	
Trimerus vomer (Chapman)			S	
Harpes trinucleoides E. and M.		l		
Raphiophorus parvulus var. *jikaensis* (Chap.)			M	
Raphiophorus yarraensis (Chapman)			M	

the upper unit in the tripartation by THOMAS and KEBLE in 1933 is now located in Lower Devonian by GILL (1940). Therefore the trilobites from these formations are transferred from the Silurian to the Devonian fauna. Even though these early Devonian trilobites are eliminated, about a half of Silurian trilobites of Australasia belong to the species which ETHERIDGE and MITCHELL have dealt with in their papers.

The Lower and Middle Trilobite Beds are now known to be respectively middle to late Ludlovian and late Ludlovian in age. In Victoria there are also Upper Silurian trilobites. PHILIP (1962) is of opinion that the Boola beds are Upper Silurian and the inclusion of *Crotalocephalus silverdalensis* and *Pleurodictyum* in the Boola fauna are homotaxial elements in comparison with congeneric forms of Europe. Thus there are many Ludlovian trilobites. On the contrary, Wenlockian ones appear sparse. It is a question whether *Bumastus* (?) *jutsoni* of the Melbournian and *Bumastus* of the *Illaenus* Band is really a conspicuous example of widely isolated occurrences in Ludlovian (?) and Llandoverian in Victoria.

Seven families to which the Japanese Silurian trilobites belong are all represented among thirteen families of the Australian ones. If the generic level is taken, comparable forms are not so many, but there are some among illaenids, scutelloids, *Phacops*, *Sphaerexochus* and *Encrinurus*.

Illaenus johnstoni has a cephalon similar to *Bumastus* (*Bumastella*) *bipunctatus*, although they are different in the relative breadth of the glabella to the cheeks and other aspects.

The pygidium of *Scutellum jenkinsi* is allied to that of *Japonoscutellum japonicum*, but the former belongs probably to *Kosovopeltis*.

Scutellum mesembrius has the pygidium resembling *Kosovopeltis angusticostata* in the slender ribs, broad interspaces and other characteristics, but the former is granulate, instead of crenulate in the latter.

Phacops metacernaspis is intermediate in character between *Acernaspis* and *Ananaspis*, but it disagrees with any Australian species of *Ananaspis* and (?) *Acernaspis*.

Sphaerexochus mirus from the Lower Trilobite Bed, N. S. W. somewhat resembles *S. hiratai*, but the description of the former is inadequate to make an exact comparison.

Proetus browningensis has a subovate glabella like *P. subovalis*, although they can be easily distinguished by the convexity of the cranidium, differentiation of

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Explanation of Fossil list 4

Abbreviation O: Ordovician, S: Silurian, Sl: Lower Silurian, Su: Upper Silurian, (Su): Upper Silurian ?, M: Melbournian (Ludlovian or lower Ludlovian plus uppermost Wenlockian ?), I: Lower Silurian *Illaenus* Band, B: Upper Silurian Boola Beds, SD: Upper Silurian or Lower Devonian, t: Ludlovian-Gedinnian trilobite beds in Yass-Bowning area, New South Wales, l: Lower Trilobite Bed (middle to upper Ludlovian), m: Middle Trilobite Bed (upper Ludlovian), m→: m to Upper Trilobite Bed (lower Gedinnian or Lochkovian), u: Upper Trilobite Bed.

occipital lobes and other features.

Finally, *Encrinurus tosensis* and *E. ishii* bear similarities to *E. borenorensis* in outline and segmentation. *E. mamelon* is allied to *E. silverdalensis* and also *E. borenorensis* in coarse tuberculation. *E. yokokurensis* somewhat resembles *E. incertus* (MITCHELL). The pygidia of *E. kitakamiensis* and *E. fimbriatus* are comparable to the pygidium of *E. mitchelli* (?).

In New Zealand, the oldest fossiliferous formation is Middle Cambrian, and Cambro-Ordovician as well as Devonian trilobites are known, but none had been a definitely Silurian fossil (COOPER, 1968) until COOPER and WRIGHT (1970) reported the occurrence of an undoubted Silurian brachiopod *Conchidium* from the Hailes Knob quartzite, though no trilobite has so far been described. In New Guinea, the oldest is an Ordovician cephalopod followed by some Silurian fossils (KOBAYASHI and BURTON, 1971), but no trilobite is included among them.

IX. Silurian Trilobites of the Arctic Province

As mentioned already, *Pseudoproetus* reveals the faunal connection between Siberia and North Greenland in the Llandoverian epoch. On the other side of the Arctic pole a more intimate relation of the Cape Schuchert fauna (POULSEN, 1934) is shown in the early Gala-Tarannon fauna of the Yukon territory which bears *Monograptus terriculus* (RAASCH et al., 1961). Four trilobite species found there are all Cape Schuchert members as follows:

Scutellum borealis (POULSEN)
Leonaspis semiglabra POULSEN
Encrinurus cf. *princeps* POULSEN
Aulacopleura socialis POULSEN

With this fresh material it was found that *Scutellum borealis* has a forked median rib on the pygidium. It is noteworthy that *Aulacopleura socialis* is a solitary representative of the genus in North America.

Scutellum magnificum TEICHERT, 1937, from the Offley Island formation, North Greenland and from Kûk, Southampton Island is, as noted by the author, the nearest relative of *Bronteus ekwanensis* from the Ekwan River formation of the Hudson Bay region. It is the type species of *Ekwanoscutellum.* As indicated by the occurrences of *Goldius laphami* WHITEAVES in the Hopkinton dolomite, Iowa and the Joliet dolomite, Illinois (MILLER and UNKELSBAY, 1944), the genus was distributed further to the south in the middle Niagaran or early Wenlockian to latest Llandoverian age or the age of the Joliet dolomite, although the Hopkinton dolomite ranges from upper Llandoverian to Wenlockian in age (BERRY and BOUCOT, 1970). In Eastern Canada imperfect pygidia from the Lavieille formation of Gaspé were identified with *Goldius ekwanensis* (WHITEAVES) by NORTHROP (1939).

Encrinurus (*Frammia*) HOLTEDAHL, 1914, is widely spread in the lower and middle Ludlovian formations of the Canadian Arctic islands (BOLTON, 1965), but its distribution did not extend so far south as *Ekwanoscutellum.* On the other side, however, it migrated toward the Urals as shown by *Encrinurus* (*Frammia*) *rossicus* MAXIMOVA, 1970, from Waigatchi Island.

In the Canadian Arctic archipelago *Hemiarges bigener* BOLTON, 1965 designates a still higher horizon at the top of the Silurian or the basal Devonian.

Now the following five or six horizons are distinguishable in the Arctic rocks from upper Ordovician to basal Devonian with trilobites as keys:

Ashgillian: *Monorakos* horizon in North Greenland and Siberia.
Llandoverian: *Pseudoproetus-Aulacopleura* horizon in North Greenland, Yukon and Siberia.
Lower Wenlockian: *Ekwanoscutellum* horizon from North Greenland to the upper Mississippi valley.

Lower and middle Ludlovian: *Encrinurus* (*Frammia*) horizon in the Canadian Arctic archipelago and Waigatchi Island.

Upper Ludlovian or/and Gedinnian: *Hemiarges bigener* horizon in the Canadian Arctic archipelago.

The trilobites from Kronprins Christians Land, Northeast Greenland which LANE (1972) considered approximately Wenlockian in age is quite different from other Arctic Silurian faunas. This fauna probably fills up the gap between the lower Wenlockian *Ekwanoscutellum* horizon and the lower and middle Ludlovian *Encrinurus* (*Frammia*) horizon. Because the Profilfjeldet shales are dated at an upper Wenlock age by graptolites, the trilobites derived from the underlying limestones would be approximately middle Wenlockian.

The Arctic Silurian trilobites in the Eurasiatic and North American sides have common genera. *Aulacopleura* of Greenland and Yukon as well as *Eophacops quadrilineatus* in Siberia reveal the alliances between Arctic and European faunas of the Llandoverian age. As discussed later, *Ekwanoscutellum* may be ancestral to *Paralejurus* which was restricted to European and Mediterranean areas in the Devonian period. The relationship of the Eastern Asiatic trilobites to the Arctic ones is slight except for *Goldillaenus* and the Meroperixinae which are a rare genus and a rare subfamily but having common representatives between the two areas.

X. Silurian Trilobites of North and South America

CHURKIN (1961) described the following Silurian trilobites from the Gazelle formation, Klamath mountains, California, emphasizing their intimate relationship to the Bohemian fauna.

Scutellum sp. indt.	
Leonaspis (Acanthomina) minuta (BARRANDE)	Kopanina
Dicranopeltis cf. *decipiens* (W. and M.)	(Niagaran)
Trochurus sp. indt. (aff. *T. palmatus,* i. e. *T. speciosus*)	(high Liteň)
Cheirurus cf. *insignis* BEYRICH	(high Liteň)
Cromus beaumonti (BARRANDE)	Kopanina
Proetus sp. indt.	

Insofar as can be judged from the occurrences of four species in Bohemia as cited behind the specific names, two of them are Kopanina members and another two are allied to late Liteň species. *Dicranopeltis* cf. *decipiens* on the other hand shows resemblances to the Niagaran trilobite.

The authors are of opinion that *Proetus* sp. indt. is so closely allied to *Latiproetus latilimbatus* (GRABAU) that they would be congeneric where the latter species is Middle and (?) Upper Silurian in age. It resembles also Upper Silurian *Prantlia,* but the eyes are as large as those of *Latiproetus.*

In weighing these facts the age of the Gazelle trilobites is judged to be in the range from upper Wenlock to lower Ludlow. In other words, they are about the same age with the fauna of the Yokokura limestone in addition to the *Coronocephalus kobayashii* horizon. The Gazelle fauna is, however, more intimately related to the Bohemian fauna than any North American or eastern Asiatic fauna.

The Henryhouse shales, Oklahoma which DECKER (1935) correlated to the lower Ludlow of Great Britain by graptolites yield trilobites in ten genera and seven families. CAMPBELL (1967) suggested upper Wenlock-lower Ludlow out of the coexistence of *Kosovopeltis* and *Dudleyaspis.* In other words, the Henryhouse and Gazelle trilobites are nearly coeval, but *Leonaspis* is a sole genus common between them. Compared to the trilobites of the Yokokura limestone *Proetus* and *Kosovopeltis* are two genera common between the two faunas of Japan and Oklahoma.

WELLER (1907) described some forty species of trilobites from the Niagaran limestone in the Chicago area which were distributed into 21 genera of 10 families, or 12 families, if his Phacopidae be splitted into the Phacopidae and Dalmanitidae and his Proetidae into the Proetidae and Otarionidae. Subsequently, RAYMOND (1916) added 13 species and revised the Illaenidae. Still later WALTER (1924) described 13 species of Silurian trilobites from Iowa, 5 of which were new species of *Illaenus, Metopolichas* and *Actinurus.* As the result the Niagaran trilobites total more than 60 species. The family Illaenidae comprises some twenty species including more than nine species of *Bumastus* are the richest family and genus. In the great profusion of *Bumastus* the Yokokura fauna agrees with the Niagaran fauna. However, the Harpidae, Otarionidae, Odontopleuridae, Calymenidae and Dalmanitidae are unrepresented in the Yokokura fauna.

In the correlation chart of the Silurian Formations of North America (Swartz et al., 1942) the Niagaran Series is correlated to the Wenlockian and upper Llandoverian Series combined. The St. Clair limestone in Arkansas and Oklahoma was placed at the lower Niagaran or upper Llandoverian (Swartz et al., 1942), and is now correlated to the Wenlock plus the top part of the Llandovery (Berry and Boucot, 1970). Van Ingen (1910) distinguished 21 species in 17 genera and 11 families in the trilobites of the St. Clair fauna, but the description was published only of 16 species of them.

The St. Clair fauna agrees with the Niagaran fauna of the Great Lakes district in the major family composition, but the Harpidae and Phacopidae are represented and the Raphiophoridae unrepresented in the Niagaran fauna. The Illaenidae are

Fossil list 5. Silurian trilobites of South America.

Area Trilobites	Bolivia	Argentina	Paraguay
Cheirurina, gen. et sp. indt.	×		
Leonaspis aracana (Steinmann)	×		
Leonaspis chacaltayana (Kozlowski)	×		
Phacops argentinus Thomas		×	
"*Eophacops*" sp.	×		×
Dalmanites andii Kozlowski	×		
Dalmanites (?) sp.	×		×
Dalmanitoides drevermanni (Thomas)		×	
Phacopina braziliensis chojnacotensis (Swartz)	×		
Phacopina (*Scotiella*) *itacurubensis* Harrington			×
P. (*Scotiella*) *obsoleta perroana* Wolfart			×
Proetus (?) spp.		×	×
Otarion dereimsi (Kozlowski)	×		
Calymene boettneri Harrington			×
Calymene spp.	×	×	×
Diacalymene aff. *crassa* Shirley			×
Brongniartella (?) *bistrami* (Hoek)	?		
"*Homalonotus*" sp.	×	×	
Trimerus lineares (Salter)	×		
Trimerus kayseri (Thomas)		×	
Trimerus (?) sp. indt.		×	×
Digonus noticus (Clarke)	×		

Dalmanites drevermanni (Thomas) and *Burmeisteria* (*Digonus*) *noticus* (Clarke) ? are listed in the Lower Devonian fauna of Argentina by Castellaro (1966).

not so profused in the St. Clair fauna as in the Niagaran one. Compared to the Yokokura fauna the Raphiophoridae, Calymenidae, Otarionidae and Dalmanitidae are present but the Phacopidae absent in the St. Clair fauna. In the geological age it is nearer to the *Prodontochile* fauna of Malay which consists of the Cheiruridae, Dalmanitidae, Scutelluidae, Calymenidae, Proetidae, Harpidae and Raphiophoridae. Is it accidental that *Ampyx niagarensis* VAN INGEN, *Ampyx jarraensis* CHAPMAN and *Lonchodomas (Metalonchodomas) masjidiformis* KOBAYASHI and HAMADA, three relic species around the Pacific basin near the Llandovery-Wenlock boundary in age have all conspicuously developed glabellae ?

In summary, the *Prodontochile* fauna and the St. Clair fauna are penecontemporaneous. Likewise, the Yokokura limestone plus the *Coronocephalus kobayashii* horizon is nearly coeval with the Gazelle formation and the Henryhouse shale. However, common genera between the faunas on the two sides of the Pacific are rare. *Latiproetus* belongs to the rare exceptions. The Arctic trilobites are very distinct from these faunas. The development of *Bumastus* in the Yokokura limestone and the Niagaran limestone of the Chicago area depends chiefly upon the ecological similarities of the reef facies.

Here the authors do not go so far on the Atlantic side of North America.

Finally, a glimpse is made on Silurian trilobites of South America. In GERTH's *Geologie Südamerikas*, 1932 are cited three Silurian trilobites, namely, *Homalonotus kayseri* THOMAS, *Phacops argentinus* THOMAS and *Dalmanites* sp. Additional trilobites were described from Paraguay by HARRINGTON (1950) and WOLFART (1961). Furthermore some trilobites primarily thought Devonian were found to be Silurian ones. Because the age determination of Middle Paleozoic trilobites of this continent has been confused, here Silurian ones are picked up from " Correlation of the South American Silurian Rocks " by BERRY and BOUCOT (1972). As shown in the Fossil list 5 the trilobites known from Bolivia, Argentina and Paraguay belong to eight families and about fifteen genera and subgenera as follows:

Odontopleuridae:	(" *Acidaspis* ", *Leonaspis*)
Phacopidae:	*Phacops*, " *Eophacops* "
Calmonidae:	*Phacopina* (*Scotiella*)
Dalmanitidae:	*Dalmanites*, *Dalmanitoides*
Proetidae:	*Proetus*
Otarionidae:	*Otarion*
Calymenidae:	*Calymene*, *Diacalymene*, *Brongniartella* (?)
Homalonotidae:	*Homalonotus*, *Homalonotus* (*Digonus*), *Trimerus*

As it is geographically nearly antipodal to Japan or Eastern Asia, the faunal composition as high as the family level is almost reciprocal between the two areas. More precisely, the South American fauna lacks the Illaenidae, Scutelluidae, Lichidae, and Encrinuridae, but contains the Odontopleuridae, Calmonidae, Otarionidae, Calymenidae and Homalonotidae which are unknown from the Silurian of Japan. The Homalonotidae in particular is totally absent in eastern Asia and very rare in the Silurian faunas of Asia as a whole, whereas the family is the best represented one by no less than three genera and one subgenus.

Compared to the Silurian faunas of Australia and North America it is very simple and monotonous. The Illaenidae and Encrinuridae which are two families died out through the Silurian period have already been absent in the Andine sea. These trilobites have constituted a better defined province than the Arctic one.

No Silurian fossil has so far been discovered from Antarctica (ADIE, 1972).

XI. Summary and Conclusion

The Silurian fauna of Japan is greatly amplified with numerous trilobites from six areas, namely Gion-yama, Okanaru, Yokokura-yama, Miyaga-tani, Hitoégané and Sakari areas (see Text-fig. 1).

With these trilobites six trilobite horizons are now distinguished in Japan in the sequence from Wenlockian to Ludlovian, namely the *Coronocephalus kobayashii* horizon, *Encrinurus nodai* horizon, *E. tosensis* horizon, Gomi horizon, *Encrinurus kitakamiensis* horizon and the *Prantlia biloba* horizon (see Table 1).

The Gomi trilobites which reveal the richest Silurian trilobite fauna on the northwestern side of the Pacific basin are characterized by abundance of non-spiny trilobites with strong convexity which are contained in the reef limestone rich in hermatypic organisms.

Supplemented with the trilobites from China, Burma and Malay, eight trilobite horizons can now be distinguished in eastern and southeastern Asia from upper Ashgillian to Lower Devonian, as shown in Table 6.

Broadly speaking, trilobites have thrived in North and South Asia in the early and middle Silurian period, but in Central and eastern Asia in the middle and late Silurian period.

The Siberian trilobites are related to the Arctic as well as European ones, while the Central and South Asiatic ones are allied to the European ones. A further study is needed to say about the relationship between the southeastern Asiatic and Australian ones, but it is evident that the *Thomastus* fauna of Victoria is very distinct from the *Prodontochile* fauna of Malay. The Silurian trilobites of Japan, on the other hand, reveal some resemblance to those of New South Wales. The connection of the Japanese fauna was, however, stronger with the European ones through Central Asia. The Gazelle trilobites of California are nearly coeval with the Gomi fauna, but they are related more intimately to the Bohemian ones than the Japanese or central North American ones.

As the result of a critical review it was found that five or probably six trilobite horizons are distinguishable in the Arctic Palaeozoic from Ashgillian to Gedinnian.

As to the lower boundary problems of the Silurian System in shelly facies, Central China, Northern Shan States, Langkawi Islands of Malay and Pamir are particularly important in Asia because of the occurrences of *Dalmanitina* in one or more horizons. Intensive studies of selected areas with special attention not only to trilobites but also to graptolites, brachiopods, corals, conodonts and other fossils will be a method of attack on the decision of the base of the Silurian System in Asia. As to the top of the system, Kazakhstan and Southeast Australia are two important areas in the Asia-Pacific region, although a further note is deferred to another occasion.

As to the provincialization of the Silurian trilobites, the Andine province is best defined, and the next is the Arctic province. Eur-Asia and Australia to which North Africa and eastern North America are added constitute a large province. Silurian trilobites belong to fifteen families which are widely distributed in these continents except for the Aulacopleuridae restricted to the Arctic and Europe and the Calmonidae absent in Australia. How to divide this major province into subprovinces is a future problem which would be only possible in the generic level.

The existing knowledge is greatly different between Eur-America and the vast remainder of the province. Trilobite taxonomy is going far in detail in the Barrandian and North European ones, but generic names are still used in a much wider sense for the trilobites of most other areas. Such unbalances make one most difficult to make a comparative study between the faunas of these areas.

Now, take the Scutelluidae for example. There would be 11 to 15 genera in North and Central Asia and 9 genera in eastern and southern Asia in the Middle Palaeozoic periods. There are, however, more common genera between the Bohemian and either one of the two Asiatic areas than between the two Asiatic areas. The localization of the fauna is represented by three or four endemic genera in the two areas of the Asiatic continent. They, combined with the generic composition of the Scutelluidae, reveal two faunal subprovinces of the Middle Palaeozoic periods.

It is a conspicuous fact that scutelloids having spiniferous pygidia have developed in the Devonian period greatly from Europe to Central Asia with the Urals as the center of distribution. In the present knowledge, *Thysanopeltella minima* in Japan is connected with the Barrandian allies through Kazakhstan rather than South Asia where no spiniferous scutelloid is known. The status shows at the same time how much remains to be studied in future.

XII. Palaeontological Description

In the palaeontological part are described more than 34 species in 18 genera and 5 subgenera of Japanese Silurian trilobites in addition to *Proetus* (*Gerastos*) *vietnamensis*, nov., *Cerauroides lunshanensis* (GRABAU) and Lower Ordovician *Koraipsis shansiensis* SHENG (see Fossil list 1).

The family Scutelluidae and the subfamily Encrinurinae are discussed in some detail. The former is classified into seven subfamilies in two sections. Supplementary notes are added to the junior author's classification of the latter (HAMADA, 1959, 1960) as to additional taxa and taxonomy of encrinurid pygidia. An extensive survey of *Encrinurus* species is carried out with the result it was ascertained that *Frammia* is a key to the Arctic-Subarctic province. Some notes are given on the Goldillaeninae, Homolichinae, *Ancyclopyge, Ekwanoscutellum, Ptilillaenus* and so forth.

New subfamilies and genera proposed in this monograph are as follows:

Meroperixinae subfam. nov. in Scutelluidae
Planiscutelluinae subfam. nov. in Scutelluidae
  Apolichas, gen. nov. in Homolichinae
  Illaenoscutellum, gen. nov. in Meroperixinae
  Tosacephalus, gen. nov. in Meroperoxinae
    Bumastella, subgen. nov. in *Bumastus*

The abbreviations of repositories for the specimens described and illustrated are as follows:

IGPS =Institute of Geology and Paleontology of Tôhoku University at Sendai
KPFM=Kôchi Prefectural Fossil Museum, Kôchi
OCU =Ôsaka City University at Ôsaka
PAt =University Museum, University of Tôkyo

Family Illaenidae HAWLE and CORDA, 1847

a. Classification of the family

While SALTER (1867) classified *Illaenus* into 8 subgenera, HOLM (1883) distinguished three groups in *Illaenus* s. str. with reference to the number of thoracic segments and accepted *Bumastus* as a subgenus of *Illaenus*. In discussing 17 genera or subgenera of the Illaenidae RAYMOND (1916) divided the family into the Illaeninae with 5 genera and the Bumastinae (nov.) with 3 genera with regard to the breadth of the axial lobe and presence or absence of the concave border on the pygidium or/and the cephalon. This bipartation was later upheld by HUPÉ (1955) and BALASHOVA (1966 in Osnovy).

In his exhaustive revision of the Bohemian illaenoids, ŠNAJDR (1957) classified them into 13 genera in three major groups. The central comprehensive group comprises *Illaenus*, *Platillaenus* and *Ectillaenus*, while the two others including *Bumastus* or *Dysplanus* are two side-branches. Among five Ordovician new genera he erected in 1955 and 1957, JAANUSSON (1957) accepted *Cekovia*, *Zbirovia* and *Zdicella* as valid ones, but he synonymized *Zetillanus* with *Dysplanus* and *Svobodapeltis* with *Illaenus* retaining a question on the latter synonymy.

JAANUSSON (in MOORE's Treatise, 1959) discriminated the Ectillaeninae (nov.) laying stress on the degeneration of eyes, the rostral plate and other aspects and provisionally added the Theamataspidinae which HUPÉ (1955) proposed as an independent family. Incidentally, *Theamataspis* ÖPIK, 1937, was primarily considered a member of the Styginidae.

JAANUSSON classified 17 genera into 4 subfamilies leaving *Hyboaspis* RAYMOND, 1925 whose subfamily reference was uncertain. Subsequently LU (1962) founded *Ptilillaenus* (nov.) on *Ptilillaenus lojopingensis* LU from the Middle Silurian of South China whose taxonomic position was a question. Next year WHITTINGTON proposed *Harpillaenus* for *Illaenus arcuatus* BILLINGS whose subfamily reference was also uncertain.

Recently BRUTON (1970) separated the Panderinae (nov.) by peculiarities of small convex cephala with backwardly narrowing glabella and a median tubercle internally, but no lateral cranial scar on *Panderia*. Its triangular rostral flange like in *Stenopareia* suggests its alliance to the Illaeninae. Furthermore he erected a new genus *Ottenbyaspis* to include *Illaenus oriens* MOBERG and SEGERBERG, 1906, and two other species, but its subfamily reference was undetermined.

Bumastids are well represented in the Yokokura fauna by no less than six species three of which belong to a new subgenus named *Bumastella*.

The Goldillaeninae, which BALASHOVA (1959) proposed as a new subfamily of the Scutelluidae, are in our opinion acceptable as a subfamily of the Illaenidae. Now the family Illaenidae consist of the Illaeninae, Bumastinae, Ectillaeninae, Goldillaeninae, Panderinae and probably the Theamataspidinae and a few unclassifiable genera as listed below.

b. Synoptic list of the family Illaenidae

	(Type-species)
Illaenidae HAWLE and CORDA, 1847	
Illaeninae HAWLE and CORDA, 1847	
Illaenus DALMAN, 1827	*Entomostracites crassicaudatus* WAHLENBERG, 1818
Thaleops CONRAD, 1843	*Thaleops ovata* CONRAD, 1843
Octillaenus SALTER, 1867	*Illaenus hisingeri* BARRANDE, 1846
Stenopareia HOLM, 1886	*Illaenus linnarssoni* HOLM, 1882
Nanillaenus JAANUSSON, 1954	*Illaenus conradi* BILLINGS, 1859
Cekovia ŠNAJDR, 1856	*Illaenus transfurga* BARRANDE, 1852
Panderinae BRUTON, 1970	
Panderia VOLBORTH, 1863	*Panderia triquetra* VOLBORTH, 1854

Ectillaeninae JAANUSSON, 1959	
Ectillaenus SALTER, 1867	*Illaenus perovalis* MURCHISON, 1839
Zbirovia ŠNAJDR, 1956	*Illaenus aratus* BARRANDE, 1855
Zdicella ŠNAJDR, 1957	*Illaenus zeidleri* BARRANDE, 1872
Bumastinae RAYMOND, 1916	
Bumastus MURCHISON, 1939	*Bumastus barriensis* MURCHISON, 1839
(*Bumastus*) MURCHISON, 1839	ditto.
(*Bumastoides*) WHITTINGTON, 1954	*Illaenus milleri* BILLINGS, 1859
(*Bumastella*) KOBAYASHI and HAMADA, nov.	*Bumastus* (*Bumastella*) *spiculus* KOBAYASHI and HAMADA, nov.
Dysplanus BURMEISTER, 1843	*Asaphus* (*Illaenus*) *centrotus* DALMAN, 1826
Thomastus ÖPIK, 1953	*Thomastus thomastus* ÖPIK, 1953
Platillaenus JAANUSSON, 1954	*Illaenus ladogensis* HOLM, 1886
Goldillaeninae BALASHOVA, 1959	
Goldillaenus SCHINDEWOLF, 1924	*Trinucleus* (?) *nilsoni* MÜNSTER, 1840
Illaenoides WELLER, 1907	*Illaenoides trilobus* WELLER, 1907
Ptilillaenus LU, 1962	*Ptilillaenus lojopingensis* LU, 1962
Theamataspidinae HUPÉ, 1953	
Theamataspis ÖPIK, 1937	*Theamataspis illaenoides* ÖPIK, 1937
Subfamily uncertain	
Hyboaspis RAYMOND, 1925	*Hyboaspis shuleri* RAYMOND, 1925
Harpillaenus WHITTINGTON, 1963	*Illaenus arcuatus* BILLINGS, 1865
Ottenbyaspis BRUTON, 1970	*Illaenus oriens* MOBERG and SEGERBERG, 1906

c. Silurian genera of the Illaenidae

The family comprises twenty-one genera with three subgenera in *Bumastus*. Taking the number of genera it is quite evident that the Illaenidae have flourished greatly in the Ordovician period but quite declined in the Silurian period. Of the family 14 genera are Ordovician and 3 genera Silurian in age and two or three genera range from Ordovician to Silurian. Genera which occur in the Silurian rocks are as follows:

Illaeninae
Stenopareia:—Middle Ordovician-Wenlockian
Bumastinae
Bumastus:—Middle Ordovician-Silurian
Thomastus:—Lower Silurian
Goldillaeninae
Goldillaenus:—Silurian
Illaenoides:—Upper Ordovician (?)-Middle Silurian (Niagaran)
Ptilillaenus:—Middle and Upper Silurian

d. Asiatic species the of the Illaenidae

Bumastus sp. from the *Dictyonema-Asaphellus* zone of the Yehli limestone, east Hopei, North China (CHANG, 1949) would be an oldest illaenid, if it is correctly referred to. It is, however, represented by a poor pygidium. The next oldest in eastern Asia is *Illaenus yuhangensis* SHENG (1934) from the *Asaphopsis-Birmanites* zone of Chekiang, Central China of which only the thorax and pygidium are known.

Illaenus hinomotoensis KOBAYASHI and *I. semioviformis* KOBAYASHI (1934) from the *Clarkella* zone of South Korea are late Canadian. *Illaenus orientalis* (ENDO), which ENDO (1935) referred to the Wuting fauna of South Manchuria, Northeast China, is about the same age.

The Illaenidae have flourished in eastern and southern Asia in the Middle Ordovician times or from Llanvirnian to early Caradocian. The Shihtzupu fauna of Central China comprises 7 species of *Illaenus* and 3 of *Bumastus* (SUN, 1931; KOBAYASHI, 1951). The illaenoids known from the Tsinling-shan to the Shan plateau, Burma through Yunnan attain 22 species and 1 variety including 4 species of *Bumastus* and *Stenopareia* (?), *Ectillaenus* (?) and *Thaleops* (?) one in each. Nine species of illaenids including one of *Panderia* and one of *Stenopareia* are reported from Central Himalaya, Karacorum and Pamir (KOBAYASHI, 1969).

In the Ordovician period, various illaenids have thrived also in North and Central Asia. In 1928, WEBER described 7 species of *Illaenus* and 3 of *Bumastus* besides 3 indeterminable ones from Upper Ordovician of the Kirghiz steppe and Kuznetsk basin. Then TSCHERNYSHEVA (1937) reported an occurrence of *Illaenus* sp. in the Ordovician of West Mongolia. In WEBER's monograph of Ordovician trilobites of U. S. S. R., 1948, are described some 45 forms of the Illaenidae from Kazakhstan and Kirghiz including those in his previous papers. More than 25 species of them were, however, specifically indeterminable. Some 10 forms belonged to *Bumastus* and one might be a *Thaleops*. Most others are placed in *Illaenus*.

According to TSCHUGAEVA (1958), 2 species of *Illaenus* and other 2 of *Bumastus* occur in the Middle and Upper Ordovician of the Chu-Illi area, Kazakhstan. According to BALASHOVA (1960), MAXIMOVA (1962) and TSCHUGAEVA (1964), 3 species of *Illaenus*, 1 of *Stenopareia*, 1 of *Thaleops* and 2 of *Bumastus* are distributed in the Ordovician of Siberia.

In looking over these occurrences there are several tens of illaenid species in Asia which are distributed in *Illaenus*, *Bumastus*, *Stenopareia*, *Thaleops*, *Panderia* and (?) *Ectillaenus*. About a half of them are known from North and Central Asia and the remainder from eastern and southern Asia. While the family appeared in the Lower Ordovician and most flourished in the Middle Ordovician in the latter region, many illaenoids thrived in the Middle and Upper Ordovician and particularly in late Ordovician times in the former region. In the Silurian period the family declined in Asia, although it was better represented in Siberia than other parts of the continent. Eight Silurian species which the authors could dug out from literatures are as follows:

Bumastus taimyricus BALASHOVA, 1960	Taimyr peninsula; Llandovery
Bumastus nordicus BALASHOVA, 1960	ditto
Stenopareia bowmanni (SALTER) in MAXIMOVA, 1962	Siberian platform; Llandovery
Stenopareia thomsoni (SALTER) in MAXIMOVA, 1962	ditto
Stenorareia angulata MAXIMOVA, 1962	ditto
Bumastus barriensis MURCHISON var. *ferganensis* WEBER, 1932	Turkestan: upper Ludlow
Illaenus namhsimensis REED, 1915	Shan States, Burma; Wenlock
Ptilillaenus lojopingensis LU, 1962	Central China; Wenlock

Illaenus namhsimensis from the lower Namhsim beds which was first determined as *Illaenus* aff. *aemulus* SALTER by REED (1906) would be a *Bumastus*.

The Silurian Illaenidae are represented in Southwest Japan by six species of the Bumastinae and one of the Goldillaeninae besides a bumastid gen. et sp. indt. Little is known of their hypostoma, rostral plate or doublure, but it is remarkable that the number of species is so great that it is equal to the total of Silurian illaenoids so far described from Asia.

Subfamily Bumastinae RAYMOND, 1916

Genus *Bumastus* MURCHISON, 1839

Bumastus glomerosus KOBAYASHI and HAMADA, sp. nov.

Pl. 1, Figs. 3-8; Text-fig. 2A

Description:—Cephalon strongly convex, 2/3 in height-length proportion, widest at about 1/3 the length from the posterior margin where eyes are opposed; length and width there in ratio of about 3/4 to 4/5; anterior and lateral margins well rounded; posterior margin broadly arcuate and incised a little at about a quarter of the cephalic breadth from the lateral extremity; occipital margin half as wide as cephalon. Eyes of moderate size prominent above general spheric surface, found a little outside of the occipital incision. Facial sutures running from eyes nearly straight forward and turning more inward near frontal margin and almost diagonal behind eyes. Dorsal furrows very shallow; no marginal border discernible. Test smooth.

Observation:—Four cephala at hand are all similar in size. None of them is perfect, but they as a whole reveal specific characteristics. This is the largest illaenid species in the Yokokura fauna.

An imperfect pygidium (KPFM 12704; Pl. 1, Fig. 8) contained in similar limestone resembles these cephala in size and L/W ratio. It is strongly and simply convex without flattened marginal border. The anterior margin is unpreserved in this specimen. Its doublure appears narrow.

Another pygidium (KPFM 16102; Pl. 1, Fig. 7) also from Gomi is strongly convex, especially steep along well rounded lateral and posterior margins. The axial lobe is almost half as wide as pygidium, insofar as can be judged from angular depressions on the two sides of the axial part. The doublure appears much broader in this than in the preceding pygidium. It is probable that either one of them belongs to this species.

Comparison:—This cephalon somewhat resembles those of *Bumastus barriensis* MURCHISON in SALTER, 1867 and in HOLM, 1883, or *Bumastus* (?) *glomerinus* (DALMAN) in ANGELIN, 1854 and *Bumastus lindströmi* ANGELIN, 1854 both HOLM identified with *B. barriensis* and also *Bumastus ioxus* (HALL) in WELLER, 1907 which was primarily called *B. barriensis* by HALL. Because *B. barriensis* is the type species of *Bumastus*, this is a diagnostic form of the genus. However, it does not fit in either one of them in the outline of the cranidium, size and relative position of the eye, relative breadth of the fixed cheek to glabella and the convexity of the cephalon. The axial furrows are well pronounced in *Bumastus barriensis* var. *ferganensis* WEBER (1932, 1951), but they are quite obsolete in this species.

Occurrence and repository:—Loc. 3 (Ys 14). Cephalon: KPFM 874-1 (holotype) coll. by S. NISHIMORI and M. HIRATA, 1966, 2. 13, PAt 7343 (paratype), KPFM 873, 874-2; pygidium: KPFM 12704 coll. by M. HIRATA, 1965, 10. 24, 16102 coll. by T. MATSUMOTO, 1965, 1, 17.

Bumastus aff. *barriensis* MURCHISON, 1839

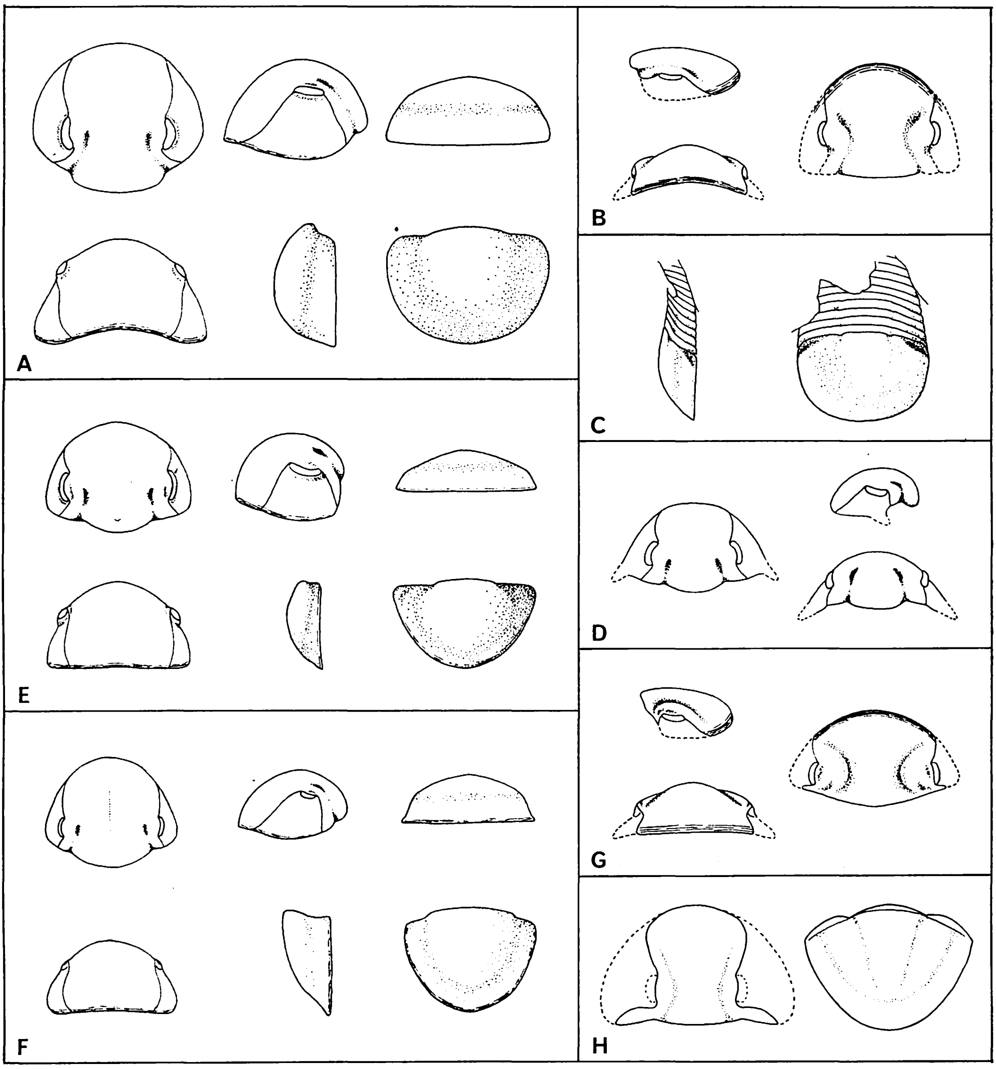
Pl. 3, Fig. 2; Text-fig. 2C

Pygidium broader than long and moderately and regularly convex, L/W and H/L being about 7.5 and 6.4 respectively; anterior margin gently and regularly arcuate; antero-lateral facets obscure; lateral margins slowly convergent backward and merging gradually into well rounded posterior margin; neither axial furrow nor marginal border discernible.

Ten (?) thoracic segments attached to pygidium very short, as wide as pygidium; axial and pleural furrows so completely obsolete that no sign of boundaries is present either between axial ring and pleuron or between anterior and posterior pleural bands. Test somewhat rough.

This pygidium belongs to the *barriensis* group but the pygidium of *B. barriensis* is semi-circular and evidently shorter than this pygidium. Compared to this form, *Bumastus barriensis* from Kazakhstan (WEBER, 1951) has the pygidium with more regularly rounded posterior and lateral margins. In outline it is nearer to *B. barriensis* var. *ferganensis* (WEBER, 1932, 1951).

Occurrence and repository:—Loc. 3 (Ys); KPFM 1323.



Text-fig. 2. Restoration of illaenids.

A. *Bumastus glomerosus* KOBAYASHI and HAMADA, sp. nov. ×3/4.
B. *Bumastus subquadratus* KOBAYASHI and HAMADA, sp. nov. ×2.
C. *Bumastus* aff. *barriensis* MURCHISON, 1839 ×3/2.
D. *Bumastus* (*Bumastella*) *spiculus* KOBAYASHI and HAMADA, subgen. et sp. nov. ×2.
E. *Bumastus* (*Bumastella*) *bipunctatus* KOBAYASHI and HAMADA, sp. nov. ×3/2.
F. *Bumastus* (*Bumastella*) *aspera* KOBAYASHI and HAMADA, sp. nov. ×1.
G. *Goldillaenus shinoharai* KOBAYASHI and HAMADA, sp. nov. ×3.
H. *Ptilillaenus lojopingensis* LU, 1962 ×1.

Bumastus subquadratus KOBAYASHI and HAMADA, sp. nov.

Pl. 2, Figs. 1, 2; Text-fig. 2B

Description:—Cranidium subquadrate, as long as wide, gently convex; anterior margin broadly arcuate; palpebral lobes located posterior to mid-length where glabellar outline is distinctly contracted; glabella there about half as wide as cranidium and expanding therefrom more strongly forward than backward; dorsal furrows pronounced in middle and posterior, but dying out in anterior; palpebral lobe as long as a quarter of cranidial length; fixed cheek depressed in front of the lobe and narrowing forward.

Observation:—In the holotype cranidium (PAt 7344), the glabella is more convex than cheeks and distinctly elevated above them. The dorsal furrows are all well pronounced. In another cranidium (KPFM 1323), the furrows are no less strong near the palpebral lobes, but in still another cranidium (KPFM 16101) from loc. 3 (Ys 14) they are not so distinct and the glabella is less prominent than in the holotype.

Comparison:—This species is allied to *Bumastus bouchardi* (BARRANDE) on one side and *Ptilillaenus lojopingensis* LU on the other. It agrees with *B. bouchardi* in the general outline of the cranidium, but the glabella is much broader, eyes are larger and located more posteriorly, and anterior facial sutures more widely divergent from eyes in that species. Furthermore, the dorsal furrows are suddenly effaced anterior to the eyes in that species, but they are traceable forward for some distance from their constrictions as in *P. lojopingensis.* Compared with this species the outlines of the cranidium and glabella are more slender in *P. lojopingensis.* However, if they are broadened, the two species become much closer to each other as they have other common characteristics. The lessened contraction of the cranidial outline and the greater expansion of the glabella in the anterior of the cranidium are additional distinctions of this species from that species.

Occurrence and repository:—Loc. 3 (Ys 15′); PAt 7344 (holotype), KPFM 1323, coll. by O. AZUMA, 1967, 10. 1. These two cranidia of this species were collected at the same point with the specimen of *Bumastus* cf. *barriensis* (KPFM 1323).

Subgenus *Bumastella* KOBAYASHI and HAMADA, subgen. nov.

This subgenus differs from *Bumastus* s. str. in the narrower axial lobe which is clearly separated in thorax from pleurae by pronounced axial furrows. Eyes are very large in comparison with those of *Stenopareia.* Short genal spines are present in the type-species.

Type-species:—*Bumastus* (*Bumastella*) *spiculus* KOBAYASHI and HAMADA, subgen. et sp. nov.

Distribution:—Middle and Upper Silurian; eastern Asia.

Bumastus (Bumastella) spiculus KOBAYASHI and HAMADA, sp. nov.

Pl. 2, Fig. 3; Text-fig. 2D

This species is very much like *Bumastus (Bumastella) bipunctatus*, but the cephalon is much broader, L/W in a ratio of 2/3 and bears a pair of genal protuberances. The occipital margin is conspicuously protruded behind the cheek margins. The dorsal furrows terminate at strong pits which are slightly posterior to eyes. There the glabella is as wide as a cheek. No median tubercle is present or discernible. The fixed cheek is narrower than the free cheek. Eyes are medium sized, somewhat prominent and located a little behind the mid-length of the cheek. Facial sutures anterior to eyes are nearly parallel but abruptly incurved near the frontal margin; those posterior to eyes short and diagonal. The free cheek is subtriangular and protruded at the genal angle into a short but stout protuberance.

The spine which is broken off in the specimen shows a circular cross section.

Comparison:—This species is quite distinct from *Octillaenus, Thaleops, Dysplanus* and *Harpillaenus* which are all Ordovician illaenids bearing genal spines. It is indeed a rare spiniferous form among Silurian illaenids.

Occurrence and repository:—Loc. 3 (Ys), PAt 7345.

Bumastus (Bumastella) bipunctatus KOBAYASHI and HAMADA, sp. nov.

Pl. 2, Figs. 4-9, (?) Pl. 3, Fig. 1; Text-fig. 2E

Description:—Cephalon globular; dorsal furrows extending forward from posterior margin for a short distance with a weak inward convexity and terminating at elongate depressions; there relatively large, prominent eyes opposed; glabella through eyes narrower than cheeks; median tubercle present a little posterior to eyes; fixed cheek through the same line half as wide as free cheek; genal angle well rounded; facial sutures slightly divergent forward from eyes and widely divergent behind them.

In thorax axial ring defined clearly by strong axial furrows only a little broader than a half of the segment.

Pygidium one and a half as long as broad; anterior margin nearly straight, transversal except for terminal facet where lateral margin abruptly turns inward and becomes oblique to anterior margin; marginal border depressed and defined inside by marginal furrow which runs into a furrow behind the facet; main part of pygidium simply and gently convex.

Test smooth or somewhat rough.

Observation:—The holotype specimen (KPFM 15155) consists of a cephalon and four thoracic segments. The paratype (KPFM 1063) is composed of pygidium and two thoracic segments.

Comparison:—The cephalon of *Illaenus johnstoni* ETHERIDGE from New South

Wales looks similar to this, but the glabella is broader than twice a cheek and has no median tubercle.

Occurrence and repository:—Loc. 3 (Ys 8); KPFM 15155 (holotype) coll. by M. HIRATA. Loc. 3 (Ys 14); PAt 7346, 7347 coll. by T. IMAMURA. Loc. 3 (Ys); PAt 7348, 7349 coll. by T. KUMAZAWA, KPFM 1063 (paratype), 760.

Bumastus (*Bumastella*) *aspera* KOBAYASHI and HAMADA, sp. nov.

Pl. 3, Figs. 3-6; Text-fig. 2F

This species differs from *B.* (*Bumastella*) *bipunctatus* in the more or less weaker convexity of the glabella, complete effacement of dorsal furrows leaving the paired elongate depressions, absence of a median tubercle and somewhat rough texture by minute punctae. Palpebral lobes are comparatively small. A fine median carina emerges by cross light.

The pygidium tentatively referred to this species is, compared to *B.* (*B.*) *bipunctatus*, more convex and provided with a concave border. The pygidia of the two species are different in outline. The anterior margin is broadly arcuate and very distinctly facetted on the two sides in this species. The median part between these facets is broader than half the pygidium.

Occurrence and repository:—Loc. 3 (Ys 8); KPFM 809 (holotype) coll. by M. HIRATA, 1962, 10. 28. Loc. 3 (Ys 13); KPFM 1048 (paratype). Loc. 3 (Ys 14); KPFM 16100 coll. by M. HIRATA, 1965, 1. 3, 16106 coll. by T. MAEDA, 1965, 4. 2. Loc. 3 (Ys); PAt 7350, 7351 coll. by T. KUMAZAWA.

Bumastid, gen. et sp. indt.

Pl. 1, Fig. 2; Pl. 3, Figs. 7, 8

Flattish and fairly broad pygidium with straight anterior margin and regularly rounded lateral and posterior margins; axial lobe effaced; marginal border and furrow absent.

Though very poorly preserved, this pygidium belongs to the Illaenidae, or probably either *Bumastus* or *Stenopareia* but no cephalon in the collection belongs to *Stenopareia*.

Occurrence and repository:—Loc. 3 (Ys) found in brachiopod limestone; PAt 7342 (pygidium). Loc. 3 (Ys); PAt 7350, 7351 (free cheeks) coll. by T. KUMAZAWA.

Subfamily Goldillaeninae BALASHOVA, 1960

Diagnosis:—Illaenoids having long axial furrows, strongly concave inward; occipital furrow and ring completely obsolete, but posterior border furrows may be present; eyes small to medium in size, varying in position; outline of cranidium also different among genera. Pygidium with concave border; axial furrows very faint or completely obsolete.

Remarks:—This subfamily comprises *Goldillaenus, Illaenoides* and probably *Ptilillaenus.* It differs from obsolete Scutelluidae in the absence of the occipital furrow which is always present in the Scutelluidae.

Goldillaenoides BALASHOVA, 1960 having a distinct occipital furrow is excluded from this subfamily. Insofar as its cranidium is concerned LANE's opinion (1972) that it is a scutelloid may be justifiable.

Distribution:—Silurian; Europe, Asia and North America.

Genus *Goldillaenus* SCHINDEWOLF, 1924

Cranidium trapezoidal; eyes small, located posterior to mid-length; posterior border furrow present.

SCHINDEWOLF instituted this genus on *Trinucleus* (?) *nilsoni* MÜNSTER, 1840 and added *Trinucleus* (?) *otarion* MÜNSTER, 1840.

Goldillaenus peculiaris TEICHERT, 1937, occurs in the Trentonian of Washington Land and an allied form in Melville peninsula, but TEICHERT contends that these Arctic Ordovician forms are homoeomorphic with the German species from the Upper Silurian Elbersreuth limestone.

Distribution:—Silurian, Eurasia; Trentonian, Arctic North America.

Goldillaenus shinoharai KOBAYASHI and HAMADA, sp. nov.

Pl. 3, Fig. 9; Text-fig. 2G

Description:—A relatively broad and regularly convex cranidium, though imperfect, fairly well reveals the glabellar outline by long dorsal furrows. It is very broad in anterior, but contracted to almost one-half the breadth of cranidium in posterior to the mid-length of cranidium and then expanded backward again half as wide as the cranidium; palpebral lobes small, opposed near the contraction; fixed cheek half as wide as glabella at the contraction, but narrowing on two sides, especially on the anterior side; posterior border of cheek short and narrow; test smooth. Free cheek and other parts of carapace unknown, but the free cheek must be very narrow.

Comparison:—Among illaenid genera this species best agrees with *Goldillaenus* in the contraction of the glabellar outline and the posterior position of small palpebral lobe.

This species fits in *Goldillaenus nilsoni* (MÜNSTER) in the posterior position of eyes, but the former can be easily distinguished from the latter in the greater expansion of the anterior part of the glabella. In comparison with this species *G. otarion* (MÜNSTER) has a narrower glabella, broader free cheek and more anteriorly set eyes. In that species the glabella is somewhat narrower than the fixed cheek at its contraction where eyes are opposed.

Occurrence and repository:—Loc. 4; PAt 7352 coll. by I. SHINOHARA.

Genus *Illaenoides* WELLER, 1907

Illaenoides triloba WELLER, 1907 from the Niagaran of Illinois is the type-species whose cephalon is unusually well trilobed among illaenoids. Eyes are small and situated far anteriorly; cranidium subtrapezoidal, but well rounded anteriorly.

Distribution:—Upper Ordovician (?), Lower and Middle Silurian; North America.

Genus *Ptilillaenus* LU, 1962

1962. *Ptilillaenus* LU, *Acta Pal. Sinica, vol. 10, no. 2,* p. 167.
1965. *Ptilillaenus,* LU et al. *Chinese Trilobites, vol. 2,* p. 566.

Diagnosis:—Cranidium nearly as long as wide and gently convex; glabella more convex than cheeks, half as wide as cranidium in posterior through palpebral lobes, but expanding on two sides; dorsal furrows becoming obsolete near frontal margin. Pygidium semi-elliptical to subtriangular, provided with a flat narrow border; axial lobe improminent, about two-thirds as long as pygidium; axial furrows weak.

Type-species:—*Ptilillaenus lojopingensis* LU, 1962 (i. e. *Illaenus asaphoides* GRABAU, 1925, non HAWLE and CORDA, 1847). Vide Text-fig. 2H.

Remarks:—The axial lobe of the pygidium is longer than post-axial field in this genus as in *Panderia* VOLBORTH, 1863 and *Thaleops* CONRAD, 1843. In the cephalon it is quite different from them but more allied to *Goldillaenus* and *Illaenoides* and even *Octillaenus* and *Illaenus* s. str. in the contraction of the glabellar outline through eyes. In this genus, however, the cranidium is also more or less contracted, the aspect resembling certain asaphids, as the type-species of this genus was primarily named *Illaenus asaphoides* by GRABAU. This genus can be distinguished from *Illaenoides* and *Goldillaenus* not only by the cranidial outline, but also by the size and position of the palpebral lobes and relative breadth of the glabella to the cranidium through eyes.

Distribution:—Middle and Upper Silurian; eastern Asia.

Family Scutelluidae R. and E. RICHTER, 1955

Synonym:—

Bronteoides HAWLE and CORDA, 1847; Thysanopeltides HAWLE and CORDA, 1947; Bronteidae HAWLE and CORDA, ANGELIN, 1854; Goldiidae RAYMOND, 1913; Scutellidae R. and E. RICHTER, 1925; Eobronteidae SINCLAIR, 1949; Thysanopeltidae HAWLE and CORDA, in MOORE, 1959.

a. Historical review

The classification of this family was repeatedly discussed by REED (1904), PRANTL and PŘIBYL (1946), R. and E. RICHTER (1955), ŠNAJDR (1960), ERBEN (1967), MAXIMOVA (1968), PŘIBYL and VANĚK (1971) and others. As a result of an extensive critical review of the scutelloid species in Eur-Asia, Australia and North America REED distinguished two major groups. One of them is *Bronteus* (*Eobronteus*) subg. nov.

The other was *Bronteus* (i.e., *Scutellum*) which he divided into 9 subgroups. Now most of these subgroups are considered to bear generic values. For example, the subgroups a and i (*campanifer* and *speciosus*) correspond respectively to *Paralejurus* and *Thysanopeltis*, s. l., although REED did not accept them as two distinct genera. Not only these two already proposed, but *Octobronteus, Stoermeraspis* (i. e., *Stoermeria*), *Kolihapeltis, Planiscutellum, Scabriscutellum, Thysanopeltella, Weberopeltis* and many other genera were later distinguished from *Scutellum*.

While PRANTL and PŘIBYL (1946) took the *Scutellum costatum* group for the main trunk of the Barrandian scutelloids and the *Scutellum planum* group as an early offshoot, RICHTERS (1956) traced five subgenera of *Scutellum* back to *Scutellum* (*Planiscutellum*). ŠNAJDR (1958, 1960) investigated the Barrandian scutelloids in a great detail and as the result he added 11 genera and one subgenus. According to him *Eobronteus* indicates the incipient lineage from which *Planiscutellum* was derived. And most of the Silurian-Devonian scutelloid genera were derived from *Planiscutellum*, while *Scutellum* indicates an isolate lineage in the periods from which only *Metascutellum* and possibly *Paralejurus* were branched off.

Among these numerous genera *Thysanopeltis* had long been a solitary genus having a spiniferous pygidium until *Thysanopeltella* and *Weberopeltis* were distinguished by KOBAYASHI, 1957 and MAXIMOVA, 1959, respectively. Subsequently ERBEN (1967), in discussing various types of marginal spines and dentitions of pygidia, reached a conclusion that *Weberopeltis* and *Ancyropyge* reveal an independent branch from *Thysanopeltis* and *Thysanopeltella* which were derived from *Scabriscutellum*. Incidentally, VANĚK (1970) pointed out that *Scabriscutellum* must be a subgenus of *Thysanopeltis*, instead of the latter to be a subgenus of the former.

Lately MAXIMOVA (1968) classified the family into three subfamilies, viz. (I) the Octobronteinae nov. represented by *Octobronteus*, (II) the Eobronteinae including *Eobronteus* and *Protobronteus* and (III) the Scutelluinae which consist of three generic groups with two subgroups. The III-b subgroup comprising *Scutellum* and *Weberopeltis* is located between the *Planiscutellum* group (III-a) and the *Decoroscutellum* subgroup (III-c), and the III-d group is the largest one including *Scabriscutellum, Thysanopeltis, Kolihapeltis, Paralejurus* and so forth. According to her these four were issued probably from *Bronteöpsis* which she included provisionally in III-a group.

PILLET (1972) proposed the Paralejurinae for *Paralejurus* and accepted the Thysanopeltinae as a separate subfamily from the Scutelluinae which were in turn classified into four groups, namely the *Scutellum, Kosovopeltis, Scabriscutellum* and *Breviscutellum* groups. He suggested with question mark that *Kosovopeltis* may be the derivative from *Bronteopsis*.

Of *Bronteopsis* REED (1904) pointed out its isolation from the Bronteidae to which it has been customary referred. RAYMOND (1920) transferred the genus to the Styginidae VOGDES, 1893 (i. e., Styginidae WARBURG, 1925) from the Goldiidae in which RAYMOND (1913) had previously included it. While WARBURG (1925) and WHITTINGTON (1950) also removed *Bronteopsis* from the Scutelluidae, SKJESETH (1925) combined *Bronteopsis* with *Stygina, Protostygina, Raymondaspis* and *Leptopilus* in the Styginidae.

Bronteopsis (Middle Ordovician) is still retained in the family by BALASHOVA and MAXIMOVA in Osnovy (1960), but as pointed out by RAYMOND (1920), REED (1928), SKJESETH (1955), RICHTERS (1956) and others it is allied to *Stygina* and is placed in the Styginidae by HUPÉ (1955) and RICHTERS in Treatise (1959). *Bronteopsis* differs from the Scutelluidae in the possession of glabellar furrows in four pairs instead of three and the cylindrical well segmented axial lobe of the pygidium extending into a post-axial ridge. Its hypostoma lacks maculae. The preglabellar depression which is commonly present in the primitive scutelloids is absent. Therefore it would be relevant to locate *Bronteopsis* in the Styginidae, although it bears some characters ancestral to the scutelloids.

PŘIBYL and VANĚK (1971), on the contrary, included the Stygininae and Dulanaspinae, nov. with the above three subfamilies in MAXIMOVA's classification of the Scutelluidae. *Dulanaspis* (late Middle and early Upper Ordovician) was erected by TSCHUGAEVA (1956) as a genus of the Bronteidae, and it is still included in the Scutelluidae in Osnovy (1960). However, TSCHUGAEVA has already pointed out that it was intermediate in character between *Illaenus* and *Eobronteus*. In the small triangular axial lobe of the pygidium it resembles *Platillaenus*, but *Dulanaspis* has marginal borders well developed both on the cephalon and pygidium like *Goldillaenoides*. *Goldillaenus* would be, however, more distinct from *Dulanaspis*. Like *Bronteopsis* eyes are located far back, but it has ten segments in thorax. In the presence of a boss or a distinct ala on each side of the occipital furrow, *Dulanaspis* is quite distinct from the Illaenidae as well as the Styginidae. Because it is a Caradocian genus in Kazakhstan and Pamir, it could be an endemic off-shoot of the Illaenacea near the Goldillaeninae BALASHOVA. Whether this subfamily belongs to the Scutelluidae or not is, however, a question. MAXIMOVA (1968) excluded *Dulanaspis* out of the Scutelluidae in her recent classification.

LANE (1972) accepted the Goldillaeninae BALASHOVA, 1960 and the Theamataspididae HUPÉ, 1955 in the Scutelluidae where the former was primarily proposed so, but the latter was instituted first as a family of the Scutelloidea.

RICHTER (1932) placed Scutelluidae and Illaenidae in the superfamily Bathyuriscidea. WHITTINGTON added the Styginidae to the superfamily and SKJESETH pointed out the possibility of the derivation of the family from the zacanthoid stock through *Hemirhodon* and suggested that the two other families were branched off on the two sides of the Styginidae. PŘIBYL and VANĚK (1971) and LANE (1972) emphasized the derivation of the Illaenacea from the Order Corynexochida emphasizing *Clavaspidella* POULSEN, 1927, of the Dolichometopidae as a linking form.

b. Classification of the Scutelluidae

Here the family Thysanopeltidae or the Scutelluidae are as widely accepted as, for example, in MOORE's Treatise, 1959. The Styginidae VOGDES, 1890, the Dulanaspidae PŘIBYL and VANĚK, 1971 and probably the Phillipsinellidae WHITTINGTON (?)

may be closer to this family than any other family of the Asaphina or Illaenina, but they are sufficiently distinctive to be separate families from the Scutelluidae in the superfamily Scutelluidea.

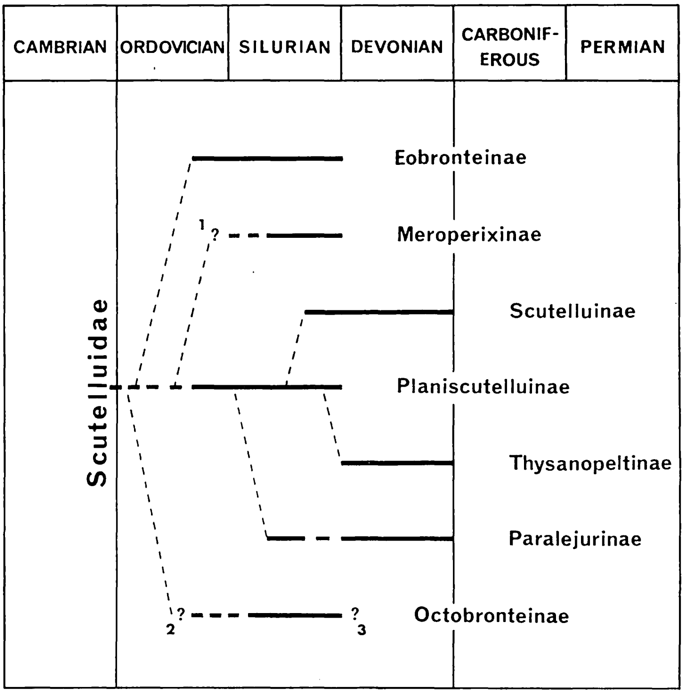
MAXIMOVA (1968) classified this family into three subfamilies with three generic groups in the Scutelluidae. In the new classification here proposed generic grouping of her Scutelluinae is rearranged on the basis of principal evolutional trends, and obtained five subfamilies, viz. Planiscutelluinae, nov., Meroperixinae nov., Scutelluinae em., Thysanopeltinae and Paralejurinae PILLET, 1972. The first subfamily indicates the stock of the family and the second and last ones are two small but distinct off-shoots from the first toward the trend of effacement of furrows and reduction of convexity-difference between axial and pleural lobes (*e trend*).

The classification of typical scutelloids is so difficult that the proposed phylogenetic schemes by PRANTL and PŘIBYL (1947), RICHTERS (1956), ŠNAJDR (1960), ERBEN (1967), MAXIMOVA (1968) and PŘIBYL and VANĚK (1971) disagree with one another in many essential points. However, most of them agree with one another in that *Planiscutellum*, instead of *Scutellum* (*Scutellum*) of PRANTL and PŘIBYL (1946), is incipient as pointed out by RICHTERS (1956). Caradocian *Eokosovopeltis* would be ancestral to *Planiscutellum* as suggested by PŘIBYL and VANĚK (1971). They are indeed two primitive genera having three pairs of lateral furrows. The latter is older than the former, but the former is morphologically more primitive than the latter in the well defined glabella more expanded in anterior, smaller eyes and segmented axis of pygidium.

The *Scutellum* and *Scabriscutellum* groups, the former of which includes the *Scutellum* and *Decoroscutellum* subgroups, are two large branches from the stock. The *Decoroscutellum*-*Scutellum* lineage reveals the partial deepening of lateral furrows into pits on the cranidium (*p trend*), while the *Scabriscutellum*-*Thysanopeltis* trend was the trilobation of the glabella by longitudinal paraxial furrows connecting laterals (*t trend*). The Scutelluinae and the Thysanopeltinae are adopted for the former and latter groups respectively. A new subfamily Planiscutelluinae is proposed for the *Eokosovopeltis*-*Planiscutellum* group.

Finally, *Paralejurus* in the Lower and Middle Devonian of Europe and North America is so isolated from these subfamilies that it requires a separate subfamily by itself. As discussed later, the authors are of opinion that *Ekwanoscutellum* in the Niagaran of the Arcto-American region would be a possible progenitor of this subfamily. Besides the Paralejurinae, there are Middle and Upper Silurian four genera of scutelloids, of which the effacement of lateral glabellar furrows is more advanced, the glabella is mushroom-shaped and the difference of convexity between the axial and pleural parts more reduced. Because they indicate as a whole an older off-shoot from the stock which is by no means ancestral to the Paralejurinae, a new subfamily Meroperixinae is proposed for them.

A classification of the Scutelluidae into seven subfamilies in two section is here given. The existing knowledge on scutelloid genera and subgenera is still insufficient for the subfamily grouping and so many questions remain to trace their radiance from genus to genus. Therefore, only the relation among the seven subfamilies are tentatively shown in Text-fig. 3.



Text-fig. 3. Phylogeny of the Scutelluidae.

?: Three scutelloids of doubtful subfamily reference; 1: *Goldillaenoides taimyricus* BALASHOVA, 1960; 2: *Bronteus kolovae* WEBER, 1948; 3: *Bronteus barrandei* HALL, 1859.

Section 1. Pygidium with six or eight ribs on each side of broad simple median rib; axial lobe not trilobed.

1. Eobronteinae SINCLAIR. Ordovician (Caradocian)-Silurian.

   Scutelluidae with six pairs of lateral ribs on pygidium. *Eobronteus, Protobronteus,* (?) *Craigheadia,* (?) *Delgadoa.* It was said that *Goldius newfoundensis* SHROCK and TWENHOFEL, 1939, has only five pairs of lateral ribs besides a broad median one, but its pygidium is so poorly preserved to confirm this statement as an exception.

2. Octobronteinae MAXIMOVA, 1968. Upper Silurian.

   Scutelluidae with eight pairs of lateral ribs on pygidium. *Octobronteus, Stoermeraspis.*

Section 2. Pygidium with seven ribs on each side of a median rib simple or bifurcate; axial lobe of pygidium small subtriangular and mostly trilobed.

1. Planiscutelluinae nov. Upper Ordovician to Upper Silurian.

   Glabella provided with three pairs of simple nearly equidistant lateral furrows; pygidium non-spiniferous; median rib of pygidium simple. *Eokosovopeltis, Planiscutellum, Japonoscutellum, Protoscutellum.*

2. Meroperixinae nov. Middle and Upper Silurian.
   Glabella strongly expanded in anterior; lateral furrows completely effaced or only discernible by rudimentary pits near dorsal furrows; median rib of pygidium simple or bifurcate. *Opoa, Meroperix, Tosacephalus, Illaenoscutellum.*
3. Scutelluinae RICHTERS. Upper Silurian-Upper Devonian.
   Lateral furrows of glabella strongly pitted, differentiating in form and complicated in disposition; axial and palpebral spines present in some genera; median rib of pygidium mostly bifurcate; spines in certain genera very long and not interrupted by marginal borders. *Kosovopeltis, Decoroscutellum (Decoroscutellum, Flexiscutellum, Radioscutellum), Bojoscutellum (Bojoscutellum, Meridioscutellum), Cornuscutellum, Dentaloscutellum, Scutellum, Weberopeltis, Ancyropyge.*
4. Thysanopeltinae HAWLE and CORDA. Upper Silurian to Upper Devonian.
   Lateral furrows connected by paraxial furrows by which glabella is trilobed; median rib of pygidium generally bifurcate; long or very short spines present in some genera. *Spiniscutellum, Platyscutellum (Platyscutellum, Poroscutellum), Boreoscutellum, Tenuipeltis, Scabriscutellum (Scabriscutellum, Cavetia), Thysanopeltis (Thysanopeltis, Septimopeltis), Altaepeltis, Arctopeltis, Metascutellum, Microscutellum (Microscutellum, Breviscutellum),* (?) *Kolihapeltis.*
5. Paralejurinae, PILLET. Middle Silurian to Middle Devonian.
   Glabella expanded forward, its lateral furrows obsolete; occipital furrow and ring broad; axis of pygidium smooth; intercostal furrow linear. *Paralejurus, Ekwanoscutellum.*

c. Synoptic list of genera and subgenera of the Scutelluidae

Scutellum PUSCH, 1833 (*Brontes* GOLDFUSS, 1839; *Goldius* DE KONINCK, 1841; *Bronteus* GOLDFUSS, 1843; *Dicranactis* HAWLE and CORDA, 1847)—Type species: *Scutellum costatum* PUSCH, 1833

Paralejurus HAWLE and CORDA, 1847—*Bronteus campanifer* BEYRICH, 1845

Thysanopeltis HAWLE and CORDA, 1847—*Thysanopeltis speciosa* HAWLE and CORDA, 1847

? *Bronteopsis* NICHOLSON and ETHERIDGE, 1879 (*Homoglossa* RAYMOND, 1912)—*Ogygia ? concentrica* LINNARSSON, 1869 (*Bronteopsis scotica* NICHOLSON and ETHERIDGE, 1879)

Ancyropyge CLARKE, 1892—*Acidaspis romingeri* HALL and CLARKE, 1888

Eobronteus REED, 1928—*Entomostracites laticauda* WAHLENBERG, 1818

Octobronteus WEBER, 1945—*Octobronteus khodalevitchi* WEBER, 1945

? *Delgadoa* THADEU, 1947—*Choffatia loredensis* DELGADO, 1908

Kolihapeltis PRANTL and PŘIBYL, 1947—*Bronteus parabolinus* BARRANDE, 1822

Støpmeraspis PRANTL and PŘIBYL, 1947 (*Støpmeria* PRANTL and PŘIBYL, 1947)—*Bronteus franconicus* GÜMBEL, 1879

? *Craigheadia* HUPÉ, 1953—*Eobronteus grayi* REED, 1904
Planiscutellum R. and E. RICHTER, 1956—*Bronteus planus* HAWLE and CORDA, 1847
Scabriscutellum R. and E. RICHTER, 1956—*Bronteus scaber* GOLDFUSS, 1843
? *Dulanaspis* TSCHUGAEVA, 1956—*Dulanaspis laevis* TSCHUGAEVA, 1956
Thysanopeltella KOBAYASHI, 1957—*Bronteus acanthopeltis* BARRANDE, 1952
Bojoscutellum ŠNAJDR, 1958—*Bronteus palifer* BEYRICH, 1845
Decoroscutellum ŠNAJDR, 1958—*Bronteus haidingeri* BARRANDE, 1846
Kosovopeltis ŠNAJDR, 1958—*Kosovopeltis svobodai* ŠNAJDR, 1958
Platyscutellum ŠNAJDR, 1958—*Bronteus formosus* BARRANDE, 1846
Poroscutellum ŠNAJDR, 1958—*Bronteus porosus* BARRANDE, 1846
Weberopeltis MAXIMOVA, 1959—*Bronteus aculeatus* WEBER, 1945
Goldillaenoides BALASHOVA, 1959—*Goldillaenoides taimyricus* BALASHOVA, 1959
Breviscutellum ŠNAJDR, 1960—*Bronteus transversus* HAWLE and CORDA, 1847
Cornuscutellum ŠNAJDR, 1960—*Bronteus rhinoceros* BARRANDE, 1872
Decoroscutellum (*Flexiscutellum*) ŠNAJDR, 1960—*Decoroscutellum* (*Flexiscutellum*) *hanusi* ŠNAJDR, 1960
Metascutellum ŠNAJDR, 1960—*Bronteus pustulatus* BARRANDE, 1846
Microscutellum ŠNAJDR, 1960—*Bronteus hawlei* BARRANDE, 1852
Protobronteus ŠNAJDR, 1960—*Eobronteus reedi* SINCLAIR, 1949
Protoscutellum ŠNAJDR, 1960—*Bronteus similans* BARRANDE, 1845
Spiniscutellum ŠNAJDR, 1960—*Bronteus umbellifer* BEYRICH, 1845
Tenuipeltis LÜTKE, 1965—*Tenuipeltis tenuicosta* LÜTKE, 1965
Altaepeltis MAXIMOVA, 1968—*Thysanopeltella bublitchenkoi* MAXIMOVA, 1960
Arctipeltis MAXIMOVA, 1968—*Bronteus arcticus* WEBER, 1945
Breviscutellum (*Meridioscutellum*) FEIST, 1970—*Bronteus meridionalis* BARROIS, 1886
Boreoscutellum PŘIBYL and VANĚK, 1971—*Scabriscutellum boreum* MAXIMOVA, 1960
Dentaloscutellum CHATTERTON, 1971—*Dentaloscutellum hudsoni* CHATTERTON, 1971
Ekwanoscutellum PŘIBYL and VANĚK, 1971—*Bronteus ekwanensis* WHITEAVES, 1906
Eokosovopeltis PŘIBYL and VANĚK, 1971—*Bronteus romanovskii* WEBER, 1948
Japonoscutellum PŘIBYL and VANĚK, 1971—*Scutellum* (Subgenus nov.) *japonicum* KOBAYASHI and HAMADA, 1965
Thysanopeltella (*Septimopeltis*) PŘIBYL and VANĚK, 1971—*Bronteus clementinus* BARRANDE, 1872
Scabriscutellum (*Cavetia*) PILLET, 1972—*Bronteus* (*Dicranactis*) *furcifer* HAWLE and CORDA, 1847
Opoa LANE, 1972—*Opoa adamsi* LANE, 1972
Meroperix LANE, 1972—*Meroperix ataphrus* LANE, 1972
Radioscutellum ŠNAJDR, 1972—*Bronteus intermixtus* HAWLE and CORDA, 1847
Illaenoscutellum KOBAYASHI and HAMADA, nov.—*Illaenoscutellum platiceps* KOBAYASHI and HAMADA, gen. et sp. nov.
Tosacephalus KOBAYASHI and HAMADA, nov.—*Tosacephalus fungiformis* KOBAYASHI and HAMADA, gen. et sp. nov.

d. The Scutelluidae in Asia

This family is very poorly represented in eastern and southern Asia, but well known in Central and North Asia. In fact only one was known from China. *Bronteus richteri* SUN, 1931 (pygidium) is combined with *Lichas browni* SUN, 1931 (cranidium) in *Amphilichas browni* (SUN). *Bronteus* sp. (cranidium) by SUN, 1931 was identified with *Thaihungshania shui* SUN (KOBAYASHI, 1951). These are Middle Ordovician trilobites found at Tsungyi, Kueichow, Central China. *Scutellum* (*Thysanopeltella* ?) sp. is reported to occur in the Upper Silurian or uppermost Middle Silurian of the Kilian-shan, Kansu (CHANG and FAN, 1960 in LU et al., 1965). It is represented by two deformed pygidia having 6 pairs (?) of short spines besides a median rib broader than lateral ribs. The axial lobe is short, subtrapezoidal and distinctly trilobed. It is quite probable that this form represents a new spiniferous genus of the Eobrontinae, if the spines are really in 6 pairs.

In Japan were known four species of scutelloids as follows:

1. *Scutellum* (Subgenus nov.) *japonicum* KOBAYASHI and HAMADA, 1965, from the upper Wenlockian limestone of Yokokura-yama, Shikoku (Loc. 3 in Text-fig. 1)
2. *Octobronteus* (?) sp. from the upper Wenlockian shale of Gion-yama, Kyushu (Loc. 1)
3. *Thysanopeltella paucispinosa* (OKUBO), 1955, from the early Middle Devonian or Eifelian of Hikoroichi, Sakari area, Kitakami mountains (near Loc. 6)
4. *Scutellum* (?) sp. from the Middle Devonion shale of Fukuji area, Hida plateau (Loc. 5)

Japonoscutellum was proposed for the first species by PŘIBYL and VANĚK, 1971, and *Bojoscutellum* (?) n. sp. will be described from the Devonian limestone of the Fukuji area in the succeeding paper.

Octobronteus spp. contained in the early Silurian *Prodontochile* fauna of the Langkawi islands, West Malaysia are represented by poorly preserved specimens (KOBAYASHI and HAMADA, 1971). Because the distribution of the Octobronteinae has been restricted to the area from North America to the Urals through Central Europe, the above occurrences are of special interest in that the distribution is extended to Malay and possibly into Japan.

In the Northern Shan States *Scutellum* (*Scutellum*) *caudatum* TINT and WAI, 1970 is described from the lower part of the Lower Plateau limestone in Maymyo district. It is represented by a cast and mold of a nearly complete pygidium of relatively broad cordiform with the median rib apparently forked and considered Siegenian in age by the authors of the species.

Little was known of the family in South Asia, but the following five species have recently been described from Afghanistan by PILLET and de LAPPARENT (1969) and from Bithynia, Northwest Turkey by HAAS (1968).

Scutellum aff. *flabelliferum* (GOLDFUSS) from Middle Devonian, Afghanistan
Scutellum costatum PUSCH from Frasnian, Afghanistan
Scutellum sp. from Frasnian, Afghanistan
Kosovopeltis crebristriata complicata HAAS, 1968, from early Upper Ludlovian, Turkey
Spiniscutellum larviferum HAAS, 1968, from Praguian, probably lower Emsian, Turkey

According to TSCHUGAEVA (1958), *Dulanaspis laevis* TSCHUGAEVA, *D. laevis anderkensis*, *D. costatus* TSCHUGAEVA and *Bronteus romanovskii* WEBER occur in some horizons of the Caradocian in the Chu-Ilii mountains. In East Pamir *Dulanaspis* cf. *laevis* was found in the Llandeilian (BALASHOVA, 1966).

In Turkestan WEBER (1932) described the followings:

Bronteus lichaoides WEBER (Ludlow-Lower Devon.) ....*Scutellum* ?
Bronteus elegans PEETZ (Lower Devon.) ....*Scutellum* ?
Bronteus n. sp. (ditto)
Bronteus sp. indt. (ditto)
Bronteus nalivkini WEBER (Middle Devon.) ....*Breviscutellum* ?
Bronteus tarak WEBER (ditto) ....*Weberopeltis*
Bronteus radiatus WEBER (ditto).......................*Weberopeltis sidereus* (WEBER), 1945
Bronteus yakovlevi WEBER (ditto ?) ....*Weberopeltis* or *Thysanopeltella*
Bronteus aff. *planus* CORDA (from Ferghana) ....*Planiscutellum* ?

Subsequently, WEBER (1948) described the following four species from the Upper Ordovician of Kazakhstan.

Bronteus (*Eobronteus*) *bifurcatus* WEBER, 1948
Bronteus kolovae WEBER
Bronteus aff. *partschi* BARRANDE
Bronteus romanovskii WEBER..........................*Eokosovopeltis*

Recently PŘIBYL and VANĚK (1971) proposed *Eokosovopeltis* for the last species.

WEBER (1951) added the following species from the Ludlovian of Pribalkhash in Kazakhstan.

Bronteus partschi BARRANDE ....*Kosovopeltis*
Bronteus crebristriatus LINDSTR. var. *magna* WEBER

The family was further amplified by MAXIMOVA (1968) with the following four species from Central Kazakhstan:

Scutellum michnevitchi MAXIMOVA S_2
Scutellum aff. *lichaoides* WEBER S_2
Decoroscutellum indefensum MAXIMOVA S_2, D_1^1
Bojoscutellum (?) aff. *paliferum* (BEYRICH) D_1^2

Futhermore, she (1960) described the following species from the Devonian of the Rudi Altai.

Scutellum alutaceum GOLDFUSS D_3^1
Scutellum longicaudatum MAXIMOVA D_3^1
Scutellum cf. *orientalis* MAXIMOVA D_3^1
Scutellum elegans PEETZ D_2^1
Scabriscutellum sibiricum (TSCHERNYSHEVA) D_2^1
Scabriscutellum aff. *scabrum* GOLDFUSS D_2^1
Weberopeltis bublitchenkoi MAXIMOVA D_2 ....*Altaepeltis*
Weberopeltis kurjensis MAXIMOVA D_2^1

The Upper Silurian and Devonian formations of the Kuznetsk basin are very rich in the Scutelluidae as listed below (TSCHERNYSHEVA, 1951):

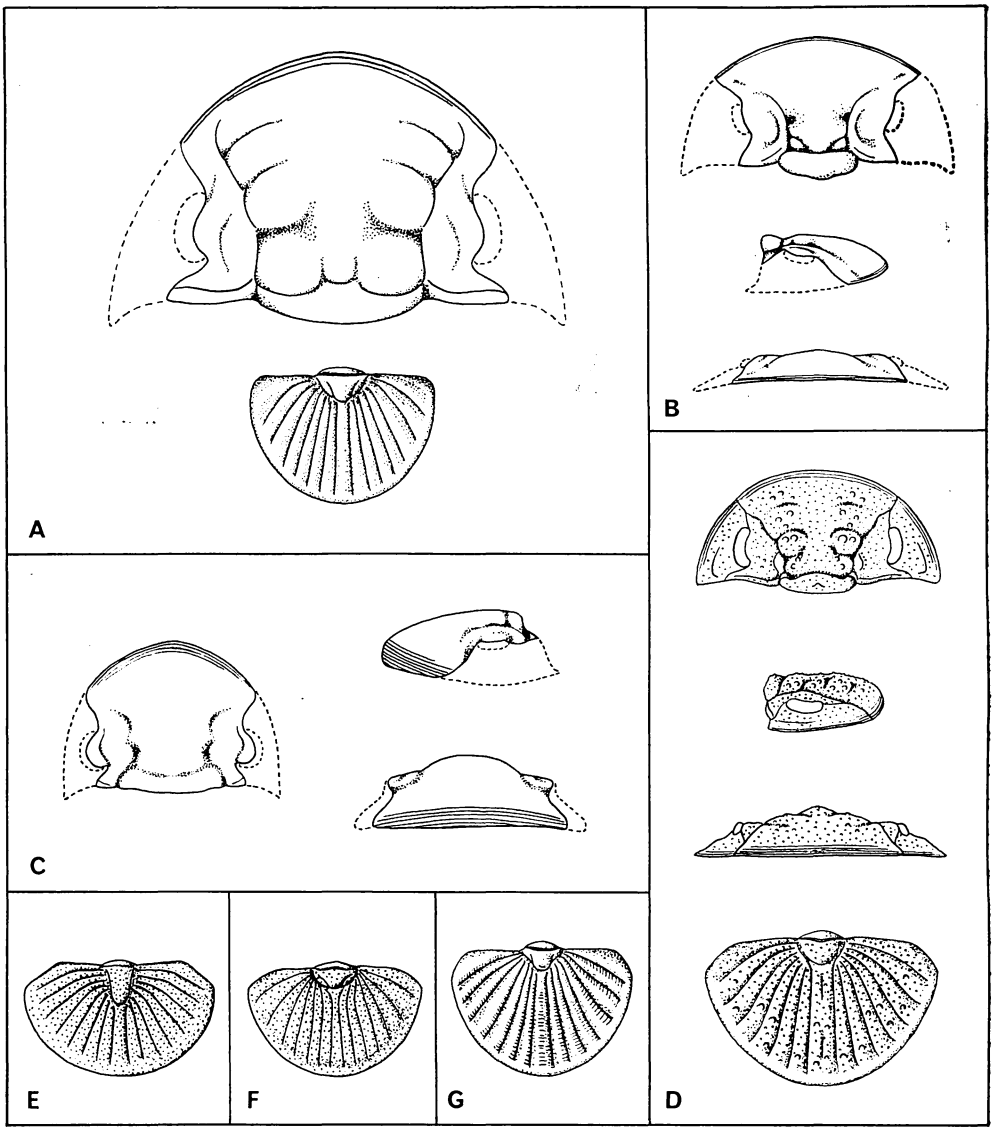
Bronteus costatus PUSCH (D_3)	*Scutellum*
Bronteus elegans PEETZ D_1^2, D_2^1	*Scutellum*
Bronteus tullius HALL D_2^1	*Scutellum*
Bronteus sibiricus TSCHERNYSHEVA D_1^2, D_2^1	*Scutellum*
Bronteus arcticus WEBER D_2^1	*Arctipeltis*
Bronteus eugeni TSCHERNYSHEVA D_2^1	*Weberopeltis* or *Thysanopeltella*
Bronteus tenuistriatus TSCHERNYSHEVA D_2^{1-2}	*Bojoscutellum* ?
Bronteus mirabilis TSCHERNYSHEVA D_3	*Scutellum* ?
Bronteus signatus GOLDFUSS D_1^1 to D_2^2	*Scabriscutellum* ?
Bronteus pustulatiformis TSCHERNYSHEVA S_2	*Metascutellum* ?
Bronteus aff. *pustulatus* BARRANDE D_2^1	*Metascutellum* ?
Bronteus aff. *bischofi* ROEMER D_2^1	
Bronteus sp. No. 1 S_2	
Bronteus sp. No. 2 S_2	

Eobronteus norilskensis MAXIMOVA, 1962 and *Eobronteus* sp. are reported from the Llandovery of the Siberian platform. SINCLAIR (1949, p. 45) pointed out the easterly migration of *Eobronteus* saying that "The distribution is peculiar in that the genus is not known in America after the Trenton and first appears in Europe in Upper Ordovician Craighead limestone which was considered Caradocian or Ashgillian."

Finally, *Goldillaenoides taimyricus* BALASHOVA and *Scutellum taimyricum* BALASHOVA (1960) were respectively described from the Upper Ordovician and Llandoverian of the Taimyr peninsula. The latter is allied to *Bronteus estonicus* SCHMIDT. Later *Scabriscutellum boreum* MAXIMOVA was added from the Lower Devonian and *Scutellum* aff. *elegans* (PEETZ) from the Middle Devonian of Taimyr. Recently *S. boreum* was made the type-species of *Boreoscutellum* by PŘIBYL and VANĚK (1971). *Scutellum* (*Planiscutellum*) *tolenicum* BALASHOVA, 1968 is a rare Llandoverian trilobite in Kazakhstan or Central Asia.

Is it not surprizing that the oldest record of Asiatic scutelloid would be *Bronteus andersoni* ETHERIDGE and NICHOLSON which was reported by TOLL (1889) in far north from Island Kotelny, New Siberia in the Arctic sea.

In summary the Scutelluidae in Asia comprise *Eobronteus, Planiscutellum, Scutellum, Decoroscutellum, Bojoscutellum, Scabriscutellum, Goldillaenoides, Weberopeltis, Altaepeltis, Arctopeltis, Kosovopeltis, Eokosovopeltis* and *Boreoscutellum* and probably *Breviscutellum, Metascutellum* and *Thysanopeltella* in North and Central Asia and *Octobronteus, Japonoscutellum, Kosovopeltis, Cornuscutellum, Spiniscutellum, Thysanopeltella* (*Septimopeltis*), *Microscutellum, Illaenoscutellum* and *Tosacephalus* in eastern and southern Asia. Such a conspicuous difference in the generic assemblage combined with endemic genera might show that two faunal provinces of Asia are in Northwest and Southeast. *Boreoscutellum, Goldillaenoides* and probably *Altaepeltis* and *Arctopeltis* are indigenous to the former and so *Japonoscutellum, Illaenoscutellum* and *Tosacephalus* to the latter area, or to Japan and the northwestern Pacific area.



Text-fig. 4. Restoration of scutelloids.

A. *Japonoscutellum japonicum* (Kobayashi and Hamada, 1965) ×2, ×1.
B. *Tosacephalus fungiformis* Kobayashi and Hamada, gen. et sp. nov. ×2.
C. *Illaenoscutellum platiceps* Kobayashi and Hamada, gen. et sp. nov. ×2/3.
D. *Microscutellum primigenium* Kobayashi and Hamada, sp. nov. ×4/3.
E. *Octobronteus* (?) sp. by Kobayashi and Hamada, 1965. ×2.
F. *Microscutellum* sp. ×2.
G. *Kosovopeltis angusticostata* Kobayashi and Hamada, sp. nov. ×3/2.

Subfamily Octobrontinae MAXIMOVA, 1968

Genus *Octobronteus* WEBER, 1954

Octobronteus spp.

1971. *Octobronteus* spp. KOBAYASHI and HAMADA, *Geol. Pal. SE. Asia, vol. 9,* p. 116, pl. 23, figs. 18–19.

Occurrence:—Upper Llandovery—lower Wenlock *Prodontochile* horizon; Pulao Langgon, Langkawi Islands, Malay.

Octobronteus (?) sp.

Pl. 4, Fig. 1; Text-fig. 4E

1961. *Octobronteus* sp. HAMADA, *Jour. Fac. Sci. Univ. Tokyo, sec. 2, vol. 13,* pt. 1, p. 29.
1965. *Octobronteus* (?) sp. KOBAYASHI and HAMADA, *Trans. Proc. Pal. Soc. Japan, N.S. No. 58,* p. 79, pl. 7, figs. 5a–b, text-fig. 4.

Occurrence:—Upper Wenlockian G_2 stage of the Gion-yama group; Gion-yama, Kuraoka, Miyazaki Prefecture, Kyushu (Loc. 1).

Subfamily Planiscutelluidae KOBAYASHI and HAMADA, subfam. nov.

Genus *Japonoscutellum* PŘIBYL and VANĚK, 1971

1971. *Japonoscutellum* PŘIBYL and VANĚK, *Acta Univ. Carolinae, Geol.,* No. 4, p. 385.

Type-species:—Scutellum (Subgenus nov.) *japonicum* KOBAYASHI and HAMADA, 1965.

Diagnosis:—Cephalon moderately convex; cranidium large; glabella very large, more or less contracted at posterior lateral furrows, greatly expanding forward and trilobed in posterior; three pairs of lateral furrows nearly straight, subrectangular to dorsal furrows and nearly equidistant from one another; posterior furrow expanded inward; occipital lobe narrowing by backward expansion of basal lobes on the two sides of narrow median part; eyes large; eye-ridge present; paraglabellar semicircular area about half as wide as fixed cheek; preglabellar depression absent; facial sutures divergent from eyes diagonally. Median rib unforked in pygidium.

Remarks:—This genus was probably derived from *Planiscutellum* by development of the glabella in size and trilobation and enlargement of eyes. Reciprocally to the cranidium the free cheek diminishes its size. The three lateral furrows are all simple and nearly equidistant as in *Planiscutellum.* The para-axial longitudinal furrows are by no means so strong as in *Spiniscutellum* and allied genera. It is quite unusual that these paired furrows join the occipital furrow which is in turn bent back by the invasion of the basal lobes. As this is a unique aspect in the Scutelluidae, *Japonoscutellum* must be an off-shoot from the *Planiscutellum* trunk in a trend parallel to the glabellar trilobation of the Thysanopeltinae.

Distribution:—Middle and Upper Silurian; eastern Asia.

Japonoscutellum japonicum (KOBAYASHI and HAMADA, 1965)

Pl. 4, Figs. 2-11; Pl. 5, Figs. 15-18; Text-fig. 4A

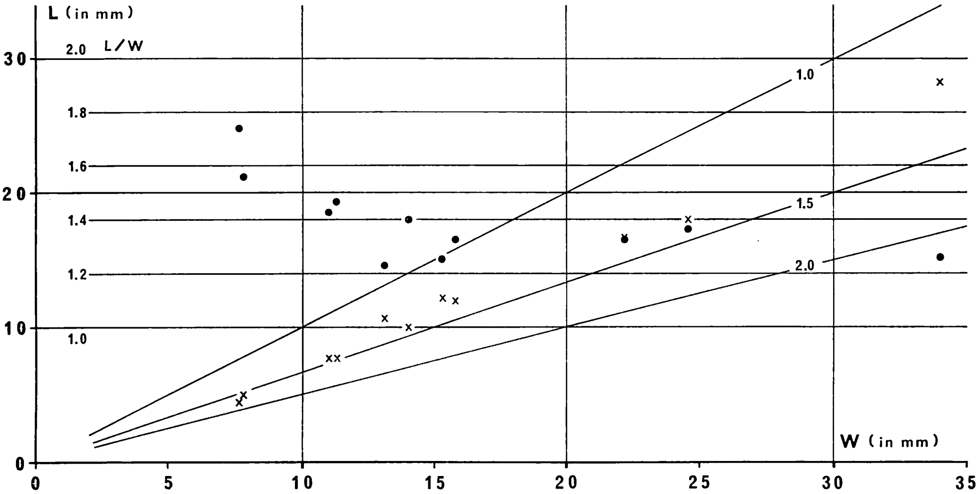
1965. *Scutellum* (Subgenus nov.) *japonicum* KOBAYASHI and HAMADA, *Trans. Proc. Pal. Soc. Japan, N.S., No. 58,* p. 77, pl. 7, figs. 1-3, text-fig. 2.

Description:—Cranidium moderately convex; glabella almost as long as broad, widest at about one-fourth the length from the anterior margin and the breadth is almost half reduced in posterior; glabellar outline somewhat constricted at posterior lateral furrows and thereform strongly expanded forward and slightly broadened backward; glabellar convexity moderate except near the anterior margin where the frontal lobe slants forward; glabella trilobed by a pair of weak longitudinal furrows; anterior furrow shallow, extending a little forward and as far as one-third the breadth of the glabella; middle furrow shorter and somewhat shallower than the preceding; posterior furrow strong and expanding inward in form of a triangle and interrupted by median lobe; posterior lateral lobe oval, convex and protruded back into neck ring; occipital furrow profound and transversal in the median part but curved on lateral sides; occipital ring engraved at the protrusions, but its breadth is greater than the posterior lobe of the glabella. Whole surface of the glabella striated by lines subparallel to the anterior margin of the glabella. Dorsal furrows deep in posterior but shallow in anterior. Fixed cheek narrow; eyes relatively large and opposed at the posterior glabellar furrows. Eye-ridge and palpebral lobe form a weak elevation as seen by cross light; semi-circular lobe present on the anterior lateral side of the glabellar base.

Pygidium semiparabolic in outline, slightly inflated and depressed near margin; axial lobe small, triangular, trilobed, but not very distinctly; articulating half-ring clearly defined back by a deep transverse furrow; median rib simple, evidently thicker than others; lateral furrows seven on each side, similar in strength, separated from one another by furrows posterior four or five of which are a little narrower than ribs whereas anterior two or three furrows become much broader toward the margin; all of these ribs become obsolete very near the axial lobe; doublure very wide. Ribs finely crenulate; finer lines seen to cross the axial lobe.

Observation:—It is a tendency for the pygidium to reduce the relative breadth to the length through growth in the Scutelluidae, as exemplified in some species by ŠNAJDR (1960), FEIST (1970) and CHATTERTON (1971). Nine holaspid pygidia at hand are similar to one another in most biocharacters, but their outline is different according to their size, although some of them are imperfect and immeasurable.

The smallest pygidium (KPFM 16099) is 4.7×8.8 mm, but the next one (KPFM 16095) is 8.7×12 mm. The third pygidium (KPFM 16093) is 12×14 mm and the largest (KPFM 16091) are 20×24 mm. Thus the smaller ones are broader. The ratio of length by breadth increases from 0.53 to 0.83 through these pygidia.



Text-fig. 5. Growth of the pygidium of *Japonoscutellum japonicum*.

W : width, L : length, × : L/W, ● : L/W against W.

Seven thoracic segments are attached to the smallest pygidium. The axial ring and pleuron of the fourth segment are respectively 7.5 mm and 9.5 mm in breadth but those of the first segment counted from the rear side are 8.5 mm and 7.6 mm. The pleuron is bent and pointed at the end (KPFM 16099).

Comparison:—Bronteus jenkinsi ETHERIDGE and MITCHELL, 1887, from the Lower Trilobite Beds of the Bowning Series (? Wenlock), New South Wales, Australia has the pygidium similar to this species in the simple median rib, crenulate texture and the general outline (see figs. pl. XVIII, ETHERIDGE and MITCHELL, 1887). The occipital furrow of their species is conspicuously bent back on the lateral sides. As the result the neck ring becomes there very narrow, like in this species. As it was primarily identified with *Bronteus partschi* BARRANDE by DE KONINCK, 1876, the Australian species may be a *Kosovopeltis*.

Occurrence and repository:—Loc. 3 (Ys6); PAt 7353 (holotype) coll. by J. HAMADA. Loc. 3 (Ys14); KPFM 158, 16093-1, 16093-2, 16095, 16099 coll. by M. HIRATA, 1965, 8, 29, 15459 coll. by T. OKUBO, 16104 coll. by S. NISHIMORI, 1965, 7, 31, 16091 coll. by M. HIRATA, 1965, 3, 14, and PAt 7356 coll. by T. OKUBO. Loc. 3 (Ys); KPFM 75, 158 coll. by M. HIRATA, 1965, 3, 14, 16086 coll. by R. TAKAHASHI, 1965, 1, 3, 13192, PAt 7354 coll. by T. KUMAZAWA.

Juvenile scutelloid cephalon

Pl. 5, Fig. 1

A nearly complete immature cephalon, 3.2 mm long and 5.7 mm broad. It is nearly semicircular but a little longer than half the breadth and well convex. Glabella more or less roof-shaped by axial carination, subcylindrical in posterior where it is separated from cheeks by very profound dorsal furrows, but the furrows become shallower in anterior of the glabella which is flared as wide as twice the posterior breadth. Three pairs of lateral furrows all horizontal; posterior ones long, deep and connected with dorsal furrows; anterior ones short and pitted; occipital furrow deep and persistent; occipital ring slightly shorter than a third the posterior breadth of the cephalon. Palpebral lobes opposed in the posterior of the glabella and strongly vaulted; eyes lunate, thick and well developed. Posterior of cheek border very narrow behind the palpebral lobe, but twice thickened laterally and joins a narrow lateral border at sharp genal point or short spine. Test smooth.

Although the frontal area is absent, the cephalon is planiscutelloid in the outline of the glabella and its regular lobation. Eyes are unusually large and posterior border furrows are very distinct.

Because the test is partly exfoliated at the occipital ring, it is indeterminable whether or not it bears a median posterior spine, as many of juvenalia of the Scutelluidae have. Judging from the posterior extension of the glabellar carina, however, a median tubercle is possibly present.

Ontogeny of the Scutelluidae is now fairly well known of *Dentaloscutellum hudsoni*, *Scutellum calvum* (CHATTERTON, 1971), *Breviscutellum* (*Meridioscutellum*) (FEIST, 1970) and some other species. The strong anterior expansion of the glabella and large posterior eyes are two very distinctive characteristics of this juvenile form. The cephalon at hand would be in an early holaspid stage. Among the cephala of the Yokokura trilobites it looks nearest to *Japonoscutellum japonicum*. *Tosacephalus fungiformis* may be the next to it. It is nearer to these adult forms than any juvenalium so far known.

Occurrence and repository:—Loc. 3 (Ys); PAt 7355 coll. by T. KUMAZAWA.

Subfamily Meroperixinae KOBAYASHI and HAMADA, subfam. nov.

This subfamily indicates an early off-shoot of scutelloids which branched off from the Planiscutelluinae by the effacement of lateral glabellar furrows and the lateral expansion of the glabella in its anterior part by which the preglabellar depression was reduced and the fixed cheeks became narrow anterior to eyes.

The subfamily includes the following four or five genera:

Meroperix LANE, 1972. Middle and Upper Silurian; Greenland and Esthonia
Opoa LANE, 1972. Middle Silurian; Greenland
Tosacephalus KOBAYASHI and HAMADA, nov. Early Upper Silurian; Japan
Illaenoscutellum KOBAYASHI and HAMADA, nov. Early Upper Silurian; Japan
? *Goldillaenoides* BALASHOVA, 1960. Upper Ordovician; Siberia

Illaenoscutellum and *Tosacephalus* appear to be very similar to *Bumastus*, *Stenopareia* or *Goldillaenus*, but they can readily be distinguished from the Illaenidae by the possession of the straight transversal occipital furrow.

Distribution:—Upper Ordovician (?), Middle and Upper Silurian; Arctic and

Eurasia.

Genus *Tosacephalus* KOBAYASHI and HAMADA, gen. nov.

Diagnosis:—Scutelloid cephalon having mushroom-shaped glabella on which only shallow and short posterior lateral furrows are marked; a pair of triangular lobes intercalated between glabella and lenticular neck ring; palpebral lobes as high as glabella opposed near posterior lateral furrows.

Type-species:—Tosacephalus fungiformis KOBAYASHI and HAMADA, gen. et sp. nov.

Remarks:—This genus resembles *Opoa* and *Meroperix* in the glabellar outline, but the cranidium is more flattened, posterior lateral furrows are rudimentary and dorsal furrows less pronounced. The aspect of the occipital region is quite different between this genus and these two allies in the possession of a pair of triangular lobes. The surface of the cranidium and pygidium is ornamented with tubercles and honeycomb sculpture in *Opoa*. Fine striae are densely crossing these shields in *Meroperix*. In this genus the cranidium is smooth. All of the scutelloid pygidia from the Yokokura limestone have simple median ribs whereas the rib is bifurcate in *Opoa* and *Meroperix*.

Distribution:—Upper Silurian; eastern Asia.

Tosacephalus fungiformis KOBAYASHI and HAMADA, sp. nov.

Pl. 5, Fig. 2; Text-fig. 4B

Description:—Cranidium broader than long and slightly inflated, anterior part of glabella being nearly in same level with palpebral lobes. Glabella contracted at posterior lobes, expanding anteriorly more than twice the breadth at the contraction; only posterior lateral furrows indicated by shallow and short depressions. Neck ring lenticular, broader than glabellar base, provided with a pair of subtriangular lobes on two sides. Dorsal furrows fairly well pronounced, but becoming weakened along the anterior expansion of glabella. Fixed cheek wide and high at palpebral lobe, a little posterior to mid-length of cranidium; semi-circular ala fairly well marked; posterior border furrow obscure.

Occurrence and repository:—Loc. 3 (Ysl4); KPFM 481 coll. by M. HIRATA, 1965, 11, 23.

Genus *Illaenoscutellum* KOBAYASHI and HAMADA, gen. nov.

The Meroperixinae having cephalon of low convexity and triangular occipital lobes. All what is known of this genus is included in the monotypic species, *Illaenoscutellum platiceps*, nov.

Distribution:—Upper Silurian; eastern Asia.

Illaenoscutellum platiceps KOBAYASHI and HAMADA, sp. nov.

Pl. 1, Fig. 1; Text-fig. 4C

Description:—Cranidium a little broader than long and gently convex toward axis, flat in sagittal section; eyes fairly large, located posterior to mid-length of cranidium; dorsal furrow pronounced between eyes where glabella is contracted half as wide as cranidium; anterior outline of glabella, however, becoming obscure forward; dorsal furrow strongly pitted at the contraction of glabella; occipital furrow and ring simple, transversal; fixed cheeks horizontal at eyes, but distinctly slanting laterally in front of eyes; breadth of the cheeks not so different between two sides of eyes as in *Tosacephalus*; doublure seen partly in dorsal view as it is nearly vertical and convex forward; test smooth.

Occurrence and repository:—Loc. 3 (Ys); KPFM 16090 coll. by S. TAKAHASHI, 1965, 1, 3.

Subfamily Scutelluinae R. and E. RICHTER

Genus *Kosovopeltis* ŠNAJDR, 1958

Kosovopeltis angusticostata KOBAYASHI and HAMADA, sp. nov.

Pl. 5, Figs. 3-6; Text-fig. 4G

Description:—Pygidium roundly subpentagonal, widest at one-third from anterior, its length corresponding to three-fourths the breadth; axial lobe triangular, its length and breadth occupying a little less than one-fourth the pygidium, distinctly elevated above pleural field and trilobed; articulating half-ring limited behind by profound lunate furrow; pleural field slightly inflated, composed of convex inner part and flat or more or less concave outer part; median rib simple and broader than a lateral rib; lateral ribs narrowing distally so much that a pleural furrow becomes twice broader than a rib near margin; doublure extending more than distal two-thirds; ribs crenualted by striae which cross axial lobe also.

Observation:—Four pygidia are contained in the collection. In the holotype pygidium (KPFM 15334) the axial lobe increases its prominence in posterior. The post-axial rib is twice as broad as a lateral one. In cross section the lateral ribs look somewhat asymmetrical. Transverse striae are visible not only on the ribs but also on the furrows.

In the three other pygidia the difference between the median and lateral ribs is, however, not so conspicuous. The cross section of the lateral rib looks almost symmetrical. The striae are obsolete in the pleural furrows. The axial furrows are not so pronounced as in the holotype pygidium. The outline of a pygidium (KPFM 837) appears more rounded than others.

Comparison:—In the outline of the pygidium this form is allied to *Decoroscutellum*, but the median rib is not bifurcate. It agrees better with *Planiscutellum* and

Kosovopeltis in the mode of ribbing. Of the type pygidium the broad median rib reminds one of *Planiscutellum*, but the laterals are asymmetrical as in *Kosovopeltis*. These aspects are, however, insignificant in the other pygidia. The distal narrowing of the ribs, as seen in *Planiscutellum planum* (HAWLE and CORDA) (ŠNAJDR, 1960, pl. II, fig. 1), is the characteristic commonly seen in these pygidia. In *P. planum*, however, the ribs are also broadened in other pygidia (ŠNAJDR, 1960, pl. I, figs. 8 & 9). In the unforked median rib and slender lateral ribs this species agrees with *Tenuipeltis* (upper Emsian—Adorfian), but they disagree in outline. The pygidium is semi-elliptial and broadest in anterior in that genus.

In the combination of these biocharacters, this species does not fit in any of these genera exactly. Therefore it is probable that it will be found to be a new genus, if the other part is discovered.

Occurrence and repository:—Loc. 3 (Ys8); KPFM 15334 (holotype) coll. by K. HIRATA, 1973, 3, 18, Loc. 3 (Ys15); KPFM 15189 coll. by T. OKUBO, 1965, 5, 5, Loc. 3 (Ys); KPFM 837, 15195 coll. by T. OKUBO, 1965.

Genus *Dentaloscutellum* CHATTERTON, 1971

Dentaloscutellum (?) *goniopeltis* (DE KONINCK)

Bronteus goniopeltis DE KONINCK, 1876, from Rock Flat Creek, New South Wales is, as compared to *B. thysanopeltis* and *B. clementinus* by the author, represented by a spiniferous scutelloid pygidium. Although a restudy of the species is needed to be done with topotypes to solve its generic position, it agrees best with *Dentaloscutellum hudsoni* in its broad outline, granulate test, broad median rib, short marginal spines and furrows separating fifteen ribs which are persistent from axial lobe to margin. These spines are shorter, compared to those of *D. hudsoni*. The median rib is not bifurcate and accordingly its spine singular in *B. goniopeltis*. Nevertheless, such differences must be specific in view of the conspicuous coincidence between the two species among various spiniferous scutelloid pygidia and their habitat in the same isolated area from all other spiniferous scutelloids.

Genus *Ancyropyge* CLARKE, 1891

This genus has long been located in the Odontopleuridae by CLARKE (1891), PRANTL and PŘIBYL (1949), STUMM (1953) and WHITTINGTON (1959), but now in the Scutelluidae by ERBEN (1967), ORMISTON (1967) and PŘIBYL and VANĚK (1971). ERBEN and ORMISTON are of opinion that this genus is closely allied to *Weberopeltis*, although it has no simple median rib. PŘIBYL and VANĚK, on the contrary, considered it to be an off-spring of the Eobronteinae notwithstanding the facts that the subfamily generally has a non-spiny pygidium and that there is no Lower Devonian link.

As mentioned later, there are various kinds of marginal projection on the pygidia of the Scutelluidae, although most spines of segmental origin are prolongation of lateral ribs. In *Scutellum trutati* BARROIS long and short spines extend beyond the marginal border respectively from the ribs and furrows. In *Thysanopeltella acanthopeltis* (BARRANDE) lateral spines are in direct extention of lateral ribs, but the median spine issues behind the median furrow between two branches of the median rib which terminate at the posterior border. In *Ancyropyge* the median rib is completely degenerated, while the fourth of seven lateral spines takes abnormal trend in comparison with the normal radiance of six others. In this genus the pleural field of the pygidium is wholly or almost wholly divided into spines. Furthermore the occipital ring and furrow are unusually indistinct.

In the possession of the occipital, palpebral and genal spines on the cephalon *Ancyropyge* resembles *Cornuscutellum*, *Scabriscutellum* (*Cavetia*) *furciferum* (HAWLE and CORDA) and also *Weberopeltis*. According to ORMISTON, this genus comprises *Bronteus manitoensis* WHITEAVES, 1892, and *Ancyropyge arcticus* ORMISTON, 1967 besides the type-species. They are all Middle Devonian trilobites indigenous to North America. Therefore *Ancyropyge* would be a highly specialized endemic genus of the Scutelluinae branched off from near *Weberopeltis* which also occurs in the Arctic Canada.

Subfamily Thysanopeltinae HAWLE and CORDA, 1847

Since the senior author had segregated *Thysanopeltella* out of *Thysanopeltis* in 1956, scutelloids with spiniferous pygidia were split into more and more genera. MAXIMOVA (1959, 1968) instituted *Weberopeltis* and later proposed *Arctopeltis* and *Altaepeltis*. *Arctopeltis* has *Breviscutellum* type cranidium and *Thysanopeltella arctica* type pygidium whereas *Altaepeltis* possesses *Microscutellum* type cephalon and *Thysanopeltis bublichenkoi* type pygidium. Then CHATTERTON (1971) added *Dentaloscutellum* to them. Recently, PŘIBYL and VANĚK (1971) distinguished *Septimopeltis* as a subgenus of *Thysanopeltella*.

PŘIBYL and VANĚK noted the synonymy of *Dentaloscutellum* with *Altaepeltis*. Compared to the latter, the lateral furrows are narrower and persistent in the former. The median furrow is quite distinct in the latter genus. It is a matter of discussion how intimately these two genera are related.

As a result of a study on the relation between the spinosity and segmentation of scutelloid pygidium ERBEN (1967) classified marginal modifications of the pygidium into four kinds, namely (a) pseudoindentation, (b) genuine indentation, (c) marginal spines of non-segmental origin and (d) marginal spines of primarily segmental origin. The spines of the above genera bear high taxonomic value not only of the segmental origin but also of their morphic significance in size, length and prominence.

Little is known of the cephala of *Thysanopeltella acanthopeltis* as well as *T.* (*Septimopeltis*) *clementina*, but they are tentatively referred to the Thysanopeltinae, because the glabella is clearly trilobed not only in *Thysanopeltis speciosum* but also in *Thysanopeltella tcherkessovae* MAXIMOVA, the fact vindicating this reference to be correct.

The pygidium of *Thysanopeltella* by MAXIMOVA (1968) looks very much like that of *Arctipeltis arcticum* (WEBER). Assuming that this pygidium is combined with her *Thysanopeltella*'s cephalon having distinctly trilobed glabella resembling *Breviscutellum, Arctipeltis* must be a member of the Thysanopeltinae. Insofar as the pygidium is concerned, there is no objection against the reference of *Altaepeltis* to the Scutelluinae. If its cephalon is of *Microscutellum* type, the reference to the Thysanopeltinae becomes suitable.

The cephala of *Weberopeltis aculeatus* and *Dentaloscutellum hudsoni* which bear the characteristics of the Scutelluidae are quite different from those of *Thysanopeltella* and *Arctipeltis*. Therefore the resemblance of the pygidium between *Weberopeltis* and *Arctipeltis* or between *Dentaloscutellum* and *Thysanopeltella* must be homoeomorphic.

So far as the authors are aware there are more than 20 species and varieties of scutelloids having segmental spines on the pygidium. They are *acanthopeltis* BARRANDE, 1856, *aculeatus* WEBER, 1945, *aculeatus lata* WEBER, 1945, *aculeatus scalpratus* WEBER, 1945, *alferovi* WEBER, 1945, *arctica* WEBER, 1945, *bublitchenkoi* MAXIMOVA, 1960, *clementina* BARRANDE, 1872, *cristata* WEBER, 1945, *eugeni* TSCHERNYSHEVA, 1887, *halli* WOODWARD, 1910, *hudsoni* CHATTERTON, 1971, *kerbelecensis* MORZADEC, 1967, *kurjensis* MAXIMOVA, 1960, *magnispina* MAILLIEX, 1928, *manitoensis* WHITEAVES, 1892, *paucispinosa* OKUBO, 1951, *romingeri* HALL and CLARK, 1888, *sidereus* WEBER, 1945, *tarak* WEBER, 1932, *tcherkessovae* MAXIMOVA, 1968, *totensis* WEBER, 1945, *trutati* BARROIS, 1886, *yakovlevi* WEBER, 1932, and so forth where *halli* can be synonymous with *acanthopeltis* according to RICHTERS (1956).

Among them *arcticus* ORMISTON, *romingeri* HALL and CLARKE and *manitoensis* WHITEAVES belong to *Ancyropyge*.

As to the remainder the generic reference of separate pygidia by which many of these forms are represented, ERBEN (1967) and MAXIMOVA (1968) agree with each other for some species (ex. *tarak, paucispinosa*), but they disagree in many others (*arctica, eugeni, kurjensis, yakovievi*, etc.). Which biocharacters are most essential for their generic distinction between similar pygidia requires more and more studies with their cephala.

These spiny scutelloids were widely distributed in the Devonian period in Eurasia, North America and Australia and especially well flourished in the region from the Urals to Central Asia. *Thysanopeltella paucispinosa* (OKUBO) is a solitary species in Japan, which is a *Septimopeltis* of *Thysanopeltella*, having a pentagonal pygidium.

Genus *Microscutellum* ŠNAJDR, 1960

Microscutellum primigenium KOBAYASHI and HAMADA, sp. nov.

Pl. 5, Figs. 7-10; Text-fig. 4D

Description:—Cephalon semicircular. Glabella mushroom-shaped, so strongly expanding that its breadth in anterior is twice as wide as in posterior, slightly inflated and elevated above cheeks, divided into lobes by three pairs of lateral furrows which are subparallel and disposed equidistantly. Posterior furrows relatively broad, cutting into glabella from dorsal furrows, bent forward and then bent again laterally and outward to form middle furrows which terminate before reaching dorsal furrows. Anterior lateral furrows extending inward from dorsal furrows long, relatively thin. Frontal lobe from which a median unfurrowed zone extends backward, somewhat longer than three lateral ones. Longitudinal furrows shallow, connecting middle lateral with posterior lateral furrows. Occipital furrow more pronounced than the precedings, arcuate as much as lateral furrows; occipital ring narrowing near lateral ends as its posterior margin becomes oblique there. Dorsal furrows strong. Cheeks depressed. Palpebral lobes opposed at posterior lateral furrows; fixed cheeks there as wide as frontal lobe of glabella; ala seen rather distinctly on the side of posterior lobe.

Pygidium subpentagonal, moderately convex, length corresponding roughly to three-fourths of width; anterior margin straight and transversal; antero-lateral margin forming obtuse angle with anterior which is larger than the angle with lateral margin. Axial lobe semispheric, trilobed and separated from articulating half-ring by straight narrow and deep furrow. Pleural field moderately convex, but distally slanting with shallow concavity at marginal one-third; median rib very stout and unforked, but a linear median furrow may be seen on the rib by cross light; lateral ribs narrower, seven on each side; interpleural furrow linear. Doublure extending to distal half of pygidium.

Test densely granulate; granules scattered on whole surface; some large ones on pygidium distributed irregularly.

Observation:—The paratype pygidium (KPFM 573′) provided with a stout median rib shows the subpentagonal outline of the pygidium and the broad doublure. The axial lobe and its articulating half-ring are clearly seen in the second pygidium also with a stout median rib (KPFM 15464). In both of them the median rib is elevated above lateral ones and twice as wide as a lateral rib. In the third pygidium (KPFM 723), however, the median rib is neither so braod nor so prominent. In this pygidium the pleural field changes its convexity so suddenly that it looks geniculated. On this pygidium are found large granules near geniculation, axial lobe and lateral margin.

By cross light a very shallow median furrow emerges on the median rib in the first and third pygidia, but not the second one. The furrow runs through the rib, but is neither quite persistent nor emphasized distally.

Comparison:—The cranidium of *Microscutellum* known of *M. hawlei* (BARRANDE) looks very similar to this cranidium, but in that species the cranidium is more inflated and the glabella more convex and less expanded forward; longitudinal furrows are more pronounced, the middle lateral lobes remarkably degenerated whereas anterior ones are developed. It has a relatively large axial protuberance near the base of the anterior lobe, but in this species the median zone is simple and not so well outlined. These differences show as a whole that *M. hawlei* is more specialized than this species. It is probable that *M. hawlei* was derived from such a form as this species. In the equidistant lobation of the glabella this species agrees better with *Spiniscutellum* and *Platyscutellum*, but the cranidium is narrower, the glabella less expanded forward, their pygidium longer and ovate in outline and its median rib distinctly forked. The latter genus has a large preglabellar area. The test is seldom ornamented with such coarse granules in these genera. Therefore, this species is not referable to either one of them, although the primitive lobation of the glabella resembling *Spiniscutellum* reveals that this is an earlier form of the Tenuipeltinae older than *Microscutellum hawlei.*

The pygidium of this species, particularly the third one resembles *Microscutellum*, *M. hawlei* for example, in the general outline, mode of ribbing and granulation. The antero-lateral outline is, however, not truncated and the median rib more broadened suddenly near the end in that species.

Opoa adamsi LANE has another resembling pygidium, but the outline is longer and the median rib more distinctly bifurcate. *Opoa* is a Wenlockian genus, and in Bohemia *Microscutellum* a Gedinnian-Emsian one. This species is considered an older member of *Microscutellum*, but it is not a linking form with *Opoa*, because it is quite distinct from *Opoa* in cephalon.

Occurrence and repository:—Loc. 3 (Ys); PAt 7383 (holotype) coll. by T. KIMURA, KPFM 573′. Loc. 3 (Ys14); KPFM 15464 coll. by K. NAKAHASHI. Loc. 3 (Ys15′); KPFM 722, 723 (counter part).

Microscutellum, sp. nov.

Pl. 5, Fig. 11; Text-fig. 4F

This is another granulate pygidium of similar outline. It differs from the preceding in the flat pleural lobes from which the axial lobe is distinctly elvated and in the slender median rib as wide as a lateral rib. The interpleural furrows are linear, narrow and relatively deep in the preceeding species.

Occurrence and repository:—Loc. 3 (Ys14); KPFM 15386 coll. by T. OKUBO.

Scutelloid free cheek

Pl. 5, Fig. 14

An imperfect right free cheek, subtriangular, moderately elevated toward a large eye located posteriorly, but its ocular part is unpreserved; eye-platform flat, depressed and limited by a prominent ridge; free cheek with wavy striae divided into a narrow inner band and broad outer band by a furrow.

Among the Yokokura trilobites it is most probable that it belongs to *Kosovopeltis angusticostatus*, but no cranidium is known of the species.

Occurrence and repository:—Loc. 3 (Ysl1); KPFM 145 coll. by M. HIRATA, 1965, 9, 11.

Free cheek of scutelloid (?)

Pl. 5, Fig. 13

Very poorly preserved free cheek possibly of a scutelloid, strongly convex, divided into three roles by two furrows; outer role very broad.

The inner role looks neither an eye nor an eye-platform. It is nearer *Japonoscutellum* than any other trilobite in the collection merely on account of the strong convexity of the cephalon.

Occurrence and repository:—Loc. 3 (Ys); KPFM 761.

Scutelloid rostrum

Pl. 5, Fig. 12

Rostrum lunate, moderately vaulted, prolonged and narrowing laterally; anterior margin much more arcuate than posterior one which is nearly straight; parallel striae distributed densely and almost equidistantly.

Lateral extremities are imperfect, but it resembles the rostrum of *Kosovopeltis* or its ally. In the Yokokura fauna it belongs probably to either *Kosovopeltis angusticostata* or *Japonoscutellum japonicum*. If its association with the former at Gomi quarry is emphasized, its reference to the former becomes more probable.

Occurrence and repository:—Loc. 3 (Ys); KPFM 1162.

Subfamily Paralejurinae PILLET, 1971

Genus *Ekwanoscutellum* PŘIBYL and VANĚK, 1971

This genus comprizing *Bronteus ekwanensis* WHITEAVES, *Goldius laphimi* WHITEAVES and *Scutellum magnificum* TEICHERT has the pygidium with a simple or bifurcate median rib and smooth, granulate or transversely striate test (MILLER and UNKLESBAY, 1944). In the semiparabolic outline of the pygidium, effaced axial lobe, flat topped ribs and linear intercostal furrows it agrees best with *Paralejurus*, although the pygidium is flat and the axial lobe relatively long. On this account it agrees with *Planiscutellum*, but the axial lobe is segmented and trilobed in that genus.

Scutellum rochesterensis HOWELL and SANFORD, 1946, has the pygidium nearer to *Planiscutellum* in the trilobed axis. Its cranidium is closely allied to that of

Planiscutellum, but the anterior and middle furrows of glabella are effaced.

Judging from these morphological similarities, it is probable that *Planiscutellum* (?) *rochesterensis* and three species of *Ekwanoscutellum*, all from the Niagaran, are linking forms to *Paralejurus* from the Planiscutelluinae stock.

Outside the Arcto-Euro-American area, *Bronteus angusticaudatus* ETHERIDGE and MITCHELL, 1917, from the Upper Silurian (?), New South Wales may be the most resembling one. This species agrees much better with *Ekwanoscutellum* than non-lanceolate *Kolihapeltis, K. lintuatum* (NOVAK) for example. Morphologically and chronologically it fills up the gap between the Niagaran and Devonian genera, but as it is geographically isolated from them, a further confirmation is needed to accept it as a link.

It is a question whether *Kolihapeltis* was derived from the Paralejurinae stock or whether it is an aberrant parallel off-shoot from the Tenuipeltinae stock.

Distribution:—Arcto-American in Niagaran; (?) Australia in Ludlovian.

Family Lichidae HAWLE and CORDA, 1847

In Korea *Metopolichas* (?) *martellii* KOBAYASHI, 1934 from the *Protopliomerops* Zone has been thought possibly an aberrant lichid. Later, however, it was found to be a kainellid most closely related to *Lingukainella robusta* KOBAYASHI, 1955, from British Columbia, Canada. Thus, *M.* (?) *martellii* was the second species of *Lingukainella*, instead of a lichid. Incidentally, CLARKE (1924) founded *Bienvillia* on the cranidium of *Dikelocephalus* (?) *corax* BILLINGS, 1865, from Point Levis, Quebec, East Canada. As noted by HENNINGSMOEN (1956), *Dikelocephalus* (?) *corax* is a composite species whose pygidium is totally distinct from *Bienvillia* or any other olenid. It represents most probably the third species of *Lingukainella*.

In Central China, two lichid species, *Lichas* (*Metopolichas*) *sinensis* SUN and *Lichas browni* SUN (1931), were described from the Middle Ordovician Shihtzupu shales. The latter species is probably an *Amphilichas* and *Bronteus richteri* SUN would be its pygidium (KOBAYASHI, 1951).

In one way, these Central Chinese lichids may be related to *Metopolichas* cf. *celorhin* (ANGELIN) var. *coniceps* HERZ von LEUCHTENBERG and *Metopolichas* aff. *verrucosus* (EICHWALD) which were described by REED (1917) respectively from Shihtien and Pupiao, Yunnan. The latter form is accompanied by *Lichas* (*Acrolichas* ?) and *Lichas* spp. in the Naungkangyi beds in East Burma (REED, 1915, 1936) and by *Amphilichas tibetanus* (SALTER) in the Himalayas (REED, 1912). These South Asiatic species are all Ordovician, but some may be a little younger and some others slightly older than the Shihtzupu fauna.

In another way, these Central Chinese lichids reveal connection to Central Asiatic faunas where the family was well flourished. The following species were described from the area from the Kuznetsk basin to Kazakhstan (WEBER, 1928, 1932, 1948).

Metopolichas anderkensis WEBER, 1948, Upper Ordovician
Amphilichas batchaticus WEBER, 1928, ditto
Amphilichas snitkovi WEBER, 1923, ditto
Amphilichas karakanensis WEBER, 1948, Lower Ordovician
Amphilichas karakanensis var. *disjunctus* TSCHUGAEVA, 1958, Caradocian
Acrolichas cucullus (MEEK & WORTHEN) by WEBER, 1948, Upper Ordovician
Acrolichas punctatus WEBER, 1948, ditto
Lyralichas bronnikovi (WEBER), 1932, Middle Ordovician
Trochurus törnquisti (GÜRICH) by WEBER, 1948, Upper Ordovician

The family is known to occur in the Ordovician further in North Asia as follows:

Lichas (*Dicranopeltis* ?) *kuckersiana* SCHMIDT by MAXIMOVA, (1955, 1960) from Middle Ordovician of the Siberian platform and early Middle Ordovician of Taimyr
Tetralichas taimyricus BALASHOVA (1960), Upper Ordovician, Taimyr

No Silurian lichid is known from China, Burma and the Himalayas, but *Dicranopeltis* cf. *scabra* (BEYRICH) occurs in association with *Encrinurus punctatus* var. *laoensis* PATTE (1929) in the Silurian beds in Laos. The second Silurian species in eastern Asia is *Apolichas truncatus* here described from Japan.

In 1937, *Trochurus sisoviae* (TSCHERNYSHEVA) and *T.* cf. *hirsutus* (FLETCHER) were reported from the Silurian of Western Mongolia and then *Acanthopyge altirhachis* (TSCHERNYSHEVA), 1951, from the Ludlow of the Kuznetsk basin. In the same year the followings were described from Central Asia by WEBER.

Tetralichas contractus WEBER, 1951, Pribalkhash, Kazakhstan, Wenlock
Dicranopeltis (?) *balkhaschicus* WEBER, 1951, ditto
Acanthopyge markovskyi (WEBER, 1951), Turkestan range

In the Soviet Far East, *Acanthopyge* aff. *haueri* (BARRANDE) was recently found in the Devonian of the Upper Amur (MAXIMOVA in MODZALEVSKAYA, 1969).

Furthermore, *Acanthopyge parvulus* (NOVAK) var. *convexa* TSCHERNYSHEVA and *A. sibirica* (TSCHERNYSHEVA), 1951, are known from the Lower and Middle Devonian of the Kuznetsk basin. *Acanthopyge haueri* (BARRANDE) and *A.* (?) *plana* (WEBER), 1932, occur respectively in the Lower and Middle Devonian of Turkestan. Recently, additional lichids were described from the Lower Devonian of Central Kazakhstan by MAXIMOVA as follows:

Lobopyge (*Lobopyge*) *limbata* MAXIMOVA, 1968
L. (*L.*) *longiaxis* MAXIMOVA, 1968
L. (*L.*) *brevis* MAXIMOVA, 1968
L. (*L.*) sp.

Thus the Lichidae have thrived in Central and North Asia during the Ordovician, Silurian and Devonian periods, but no Devonian lichid is so far known from Japan, China and South Asia except for the following two species from Bithynia, Turkey.

Lobopyge erinacea HAAS, 1968, lower Emsian.
Lobopyge (?) *pulex* HAAS, 1968, upper Emsian.

In summary, the four subfamilies of the Lichidae are represented in Asia by the following genera:

Lichinae: *Metopolichas, Dicranopletis* (?)
Homolichinae: *Apolichas*
Tetralichinae: *Amphilichas, Acrolichas, Lyralichas, Tetralichas*
Ceratarginae: *Trochurus, Acanthopyge, Lobopyge*
Among them *Lyralichas* and *Apolichas* are indigenous to Asia.

Subfamily Homolichinae PHLEGER, 1936

Lichas depressus ANGELIN, 1854, was founded on a pygidium from Oeland in boulders presumably derived from the *Chasmops* beds (WESTERGÅRD, 1910), but its posterior outline was imperfect. Later SCHMIDT (1885) proposed Gruppe *Homolichas* to include *L. depressus* and four other species and referred a cephalon having tricomposite lateral glabellar lobe to *L. depressus*.

Incidentally, *Lichas* (*Homolichas*) aff. *depressus* described from South Ural by WEBER (1930) is represented by a cranidium and pygidium which the latter has an entire well rounded lateral and posterior margins, long axial lobe flared in posterior and three pairs of pleurae, each divided into two bands. The former has large tricomposite lobes and well defined occipital lobes.

REED (1902) accepted *Homolichas* as a subgenus of *Lichas* and *L. depressus* as its type-species. FOERSTE (1920) and PHLEGER (1936) promoted it to a valid genus, and the latter erected a new subfamily Homolichinae. WARBURG (1939), on the contrary, united *Homolichas* with *Conolichas* DAMES, 1877. TRIPP (1957, 1958, 1959) maintained this opinion and took *H. depressus* for a *nomen dubium*, but he retained the Homolichinae to include *Conolichas*, *Hoplolichas* DAMES, 1877 and *Platylichas* GÜRICH, 1901. BALASHOVA (1960), on the other hand, accepted *Homolichas* as well as the Homolichinae.

Genus *Apolichas* KOBAYASHI and HAMADA, gen. nov.

Diagnosis:—Cephalon semi-circular, strongly convex; glabella divided into mushroom-shaped median lobe and tricomposite lateral lobes by persistent longitudinal furrows; cheeks very narrow and depressed; hypostoma subtrapezoidal but posterior margin pointed back on each side of median sinuation. Pygidium semi-parabolic or semi-circular, provided with short conical tripartate axial lobe, two double banded pleurae truncated at ends and relatively narrow posterior area without furrows; posterior margin well rounded. Test granulate.

Type-species:—*Apolichas truncatus* KOBAYASHI and HAMADA, gen. et sp. nov.

Distribution:—Middle and Upper Silurian; eastern Asia.

Apolichas truncatus KOBAYASHI and HAMADA, sp. nov.

Pl. 8, Figs. 9-12; Text-figs. 6A

Description:—Cephalon semi-circular, strongly vaulted, largely occupied by glabella. Its median lobe of mushroom-form, expanded laterally in anterior one-third and very slowly tapering back in posterior two-thirds, separated from tricomposite lateral lobes by profound longitudinal furrows which are extending far back; occipital lobe rudimentary. Cheek very narrow, much lower than glabella, having genal spine; marginal rim narrow and gently arched in frontal view. Surface granulose.

Hypostoma subtrapezoidal but posterior margin sinuated. Central body moderately convex, a little protruded forward in median part; lateral margin more or less concave inward and particularly constricted at a point one-third the length from posterior; paired maculae just behind posterior margin of the body low and flat; marginal furrow and border equally broad, the latter triangularly protruded back on each side of posterior sinuation; surface smooth.

Pygidium semi-parabolic, gently inflated; anterior margin straight and transversal except for projection of articulating half-ring; axial lobe short, conical, about one-third as wide as pygidium, abruptly narrowing backward, moderately convex, composed of two rings and a triangular piece; no post-axial projection; two pleural ribs truncated by lateral margin, each divided into two bands by a diagonal interpleural furrow and pointed at its end, forming a small incision behind the points; posterior area narrower than two pleurae; post-axial ridge and pleural or axial furrow there absent; posterior margin entire; test granulate.

Observation:—A cephalon, hypostoma and two pygidia before hand were all collected from Gomi quarry. In the holotype cephalon, cheeks are so poorly preserved that eyes and facial sutures are very obscure; occipital ring is also ill-preserved, but its presence is recognizable by tracing the longitudinal furrow into the occipital furrow. Of the hypostoma the anterior margin is unknown, but the median body in the specimen must be complete as can be judged from its depressed anterior edge.

The concept of the pygidium can be obtained from the two pygidia combined. The smaller one consists of slightly inflated two pleural ribs and a convex axial lobe whose articulating half-ring, two axial rings and part of the terminal piece are preserved. The axial segmentation is obscure in the larger specimen, but one can see two pleural ribs and a relatively narrow posterior area having an entire posterior margin. The two pleural ribs are broad and each bisected by an interpleural furrow which is bent forward near the proximal end and backward near the distal end. It is clearly seen that the second rib is pointed at the end and the lateral margin is a little incised behind the point. The posterior area is unfurrowed and not wide enough to have a flared post-axial projection between a pair of the third pleural ribs.

Comparison:—In the tricomposite lateral lobes and the persistent longitudinal furrows joining the occipital furrow this cephalon agree best with *Platylichas*, but in the mushroom-shaped median lobe non-expanded at the base it disagrees with that genus. The associated hypostoma is quite isolated from other lichid ones in outlines of the hypostoma and its median body. The posteriorly pointed wings are particularly very distinctive among lichid hypostomata. It somewhat resembles a scutelloid hypostoma in general outline, but in the latter the posterior margin is entirely rounded or produced back into a median spine, instead of forked as in most lichid hypostomata.

The pygidium resembles *Lichas depressus* ANGELIN, 1854, *Lichas phaleni* SCHMIDT, 1885, and *Lichas eichwaldi* NIERSZKWOWSKI, 1857, all in the *Homolichas* group by SCHMIDT and also *Metopolichas kuckeriana* (SCHMIDT), 1885, *Lichas affinis* ANGELIN and *Lichas laciniatus* ANGELIN, 1854 in the undeveloped free points of the pleurae and the entire posterior margin of the pygidium. It is especially allied to *Homolichas depressus* in the outline of the pygidium and other aspects, but even in *H. depressus* the third double pleuron and the posterior flaring of the axial lobe are well marked as in many other lichids. In this pygidium the two anterior segments are so much engarged in comparison with those of *H. depressus* and allied species that the posterior area does not allow the posterior flaring of the axial lobe. The effacement of the pleural and interpleural furrows on this area is also very distinctive of the genus. Thus this pygidium as well as the cephalon is quite aberrant among the lichids.

Occurrence and repository:—Loc. 3 (Ys); KPFM 628 (holotype cranidium). Loc. 3 (Ys14); KPFM 16087 (paratype pygidium) coll. by M. HIRATA, 1966, 6, 8, 16097 (paratype pygidium) coll. by N. IKÉ, 1965, 1, 15, 15215 (hypostoma) coll. by T. OKUBO, 1966, 10, 17.

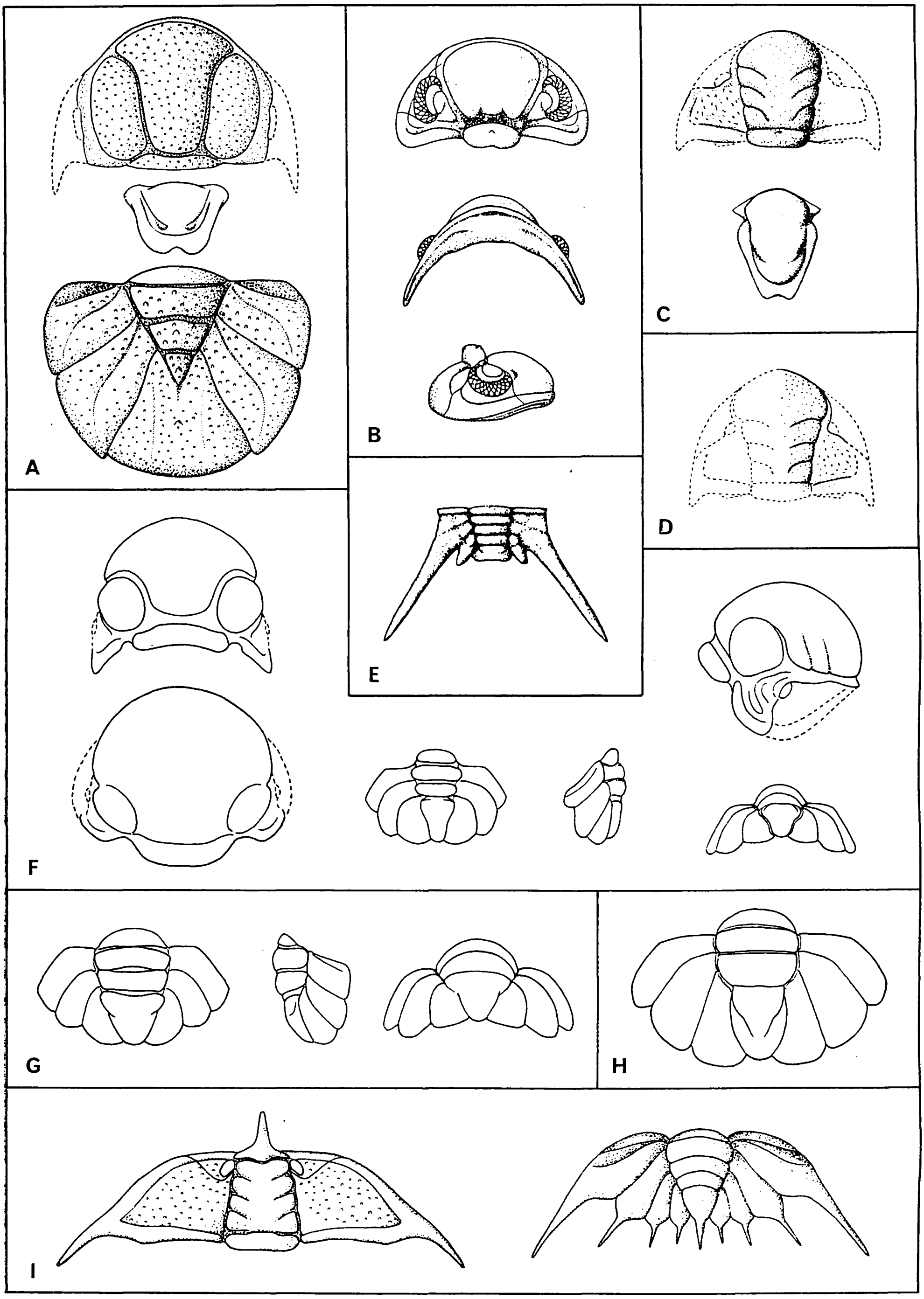
Family Phacopidae HAWLE and CORDA, 1847

Genus *Phacops* EMMRICH, 1837

Phacops (Subgen. nov. ?) *metacernaspis* KOBAYASHI and HAMADA, sp. nov.

Pl. 3, Fig. 10; Text-fig. 6B

Description:—Cephalon semi-circular in outline and most inflated in anterior part of glabella, thence becoming subvertical in front, length/width in ratio of about 3/4. Glabella exclusive of neck ring subpentagonal, 3/4 in L/W ratio, suddenly expanded laterally to a small extent in front of eyes and rounded in anterior. Dorsal furrows very strong; posterior and middle lateral furrows discontinuous at median part; anterior lateral furrows obscure. Occipital ring stout, its anterior margin seemingly incised on two sides. Preglabellar furrow distinct. Eyes fairly large, at about centers of cheeks and very prominent; lateral and posterior marginal furrows pronounced; marginal borders very thick and somewhat roof-shaped. Vincular furrow indented and continuous in anterior; coarse granules scattered on dorsal surface as well as doublure.



Text-fig. 6. Restoration of *Apolichas*, *Phacops*, *Cerauroides*, *Sphaerexochus* and *Koraipsis*.

Observation:—The holotype cephalon (KPFM 16088-1) with which the above description was prepared overlies another or paratype cephalon (KPFM 16088-2) which shows the eye better. In the upper cephalon the depression between the glabella and occipital ring looks unusually large probably because the intercalary ring was exfoliated. Its scar in the median part and the wide divergence of lateral sides suggest that a triangular median projection and a small boss on each side were lost by exfoliation. In the right eye of the underlying cephalon, ocular lenses are seen to be disposed in checker pattern. Six lenses are countable in a diagonal row in the middle part.

Comparison:—In the outline of the glabella and the aspect of lateral furrows this species is distinct from *Phacops* (s. str.), *Eophacops* and *Reedops*, but allied to *Acernaspis* and *Ananaspis*. Like *Acernaspis* the vincular furrow is continuous, but it agrees better with *Ananaspis* in the sagittal profile of the cephalon, broad glabella and the anterior incisions of the neck ring. Thus this species is intermediate in character between *Acernaspis* and *Ananaspis*.

This species can easily be distinguished from *Lochkovia* CHLUPÁČ, 1972 (Silurian-Lower Devonian) by the clear tripartation of the preoccipital lobe and more anterioly located smaller eyes of that genus.

This species disagrees with (?) *Acernaspis macdonaldi* FLETCHER and (?) *A. oblatus* SCHERWIN (1970) from New South Wales in the very large neck ring, size of eyes, strength of marginal furrows and coarse granulation.

Occurrence and repository:—Loc. 3 (Ys); found in brachiopod limestone, KPFM 16088-1 (holotype), 16088-2 (paratype).

Family Cheiruridae HAWLE and CORDA, 1847

Subfamily Cheirurinae HAWLE and CORDA, 1847

Genus *Cerauroides* PRANTL and PŘIBYL, 1946

Cerauroides hawlei (BARRANDE), the type-species of this genus, occurs in Bohemia in the upper part of the Kopanina formation (HORNÝ and BASTL, 1970). In the

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Explanation of Text-fig. 6.

A. *Apolichas truncatus* KOBAYASHI and HAMADA, gen. et sp. nov. ×1.
B. *Phacops* (Subgen. nov.?) *metacernaspis* KOBAYASHI and HAMADA, sp. nov. ×2.
C. *Cerauroides orientalis* KOBAYASHI and HAMADA, 1973; reproduced from KOBAYASHI and HAMADA (1973, p. 543, text-figs. 4, 5). ×1, ×2.
D. *Cerauroides elongatus* KOBAYASHI and HAMADA, sp. nov. ×2.
E. *Cerauroides lunshanensis* (GRABAU, 1924); reproduced from GRABAU (1924, p. 430, fig. 295). ×2.
F. *Sphaerexochus hiratai* KOBAYASHI and HAMADA, sp. nov. ×1.
G. *Sphaerexochus hiratai* forma *robustus* KOBAYASHI and HAMADA, forma nov. ×1.
H. *Sphaerexochus planirachis* KOBAYASHI and HAMADA, sp. nov. ×5/4.
I. *Koraipsis shansiensis* CHANG, 1966.

Carnic Alps it is found in association with *Cerauroides propinquus* (MÜNSTER) in the Alticola-Kalk which is correlated to the top of the Kopanina formation (FLÜGEL, 1967). In East Asia this genus is represented by *Cerauroides lunshanensis* (GRABAU) in the lower Yangtze valley and *Cerauroides orientalis* and *Cerauroides elongatus*, nov. here described.

Cerauroides orientalis KOBAYASHI and HAMADA, 1973

Pl. 6, Figs. 1-4; Text-fig. 6C

1973. *Cerauroides orientalis* KOBAYASHI and HAMADA, *Proc. Japan Acad., vol. 49, no. 6,* p. 543, text-figs. 1-5.

Description:—Glabella moderately convex, slowly expanding anteriorly; frontal lobe rounded and abruptly slanting forward; dorsal furrows nearly straight; three pairs of lateral furrows subparallel to one another, somewhat arcuate, all oblique to axis and disconnected at median one-third of glabella; anterior and middle lateral lobes a little narrower than subtriangular posterior one; posterior furrow almost in contact with occipital furrow; neck ring slightly elevated above posterior lobes, mesially thickened and provided with a median tubercle; eyes apparently small, opposed at anterior lobes; fixed cheek gently sloping down laterally and pitted, but its borders not pitted; glabella smooth.

Observation:—Three cranidia and a hypostoma are at hand. In the holotype cranidium the glabella is 17 mm long and 13 mm broad at the frontal lobe. It is somewhat more convex than the paratype cranidium, but they agree with each other in most other aspects. These cranidia as well as the third one have smooth glabella. Genal spines are unpreserved in these specimens.

In an associated hypostoma with the paratype cranidium the central body is long, ovate and convex, but a pair of short and oblique furrows are incised in posterior. It is surrounded by a prominent border laterally and posteriorly, but the border suddenly terminates at about one-third the length of the central body from its front. The anterior lateral border is depressed and possibly a little auriculate laterally. This hypostoma is very similar to that of *Cheirurus hawlei* BARRANDE, 1852, pl. 12, figs. 9-10.

Comparison:— PRANTL and PŘIBYL (1947) proposed *Cerauroides* for *Cheirurus hawlei* BARRANDE as its type-species and added *Cerauroides propinquus* (MÜNSTER), 1840 as its second species. The cranidia of this species appear diagnostic of the genus as revealed by the outline of the glabella, course of lateral and occipital furrows and large fixed cheeks. Compared to the type-species, however, the glabella is relatively broad, anterior and middle lateral lobes somewhat narrower and lateral and dorsal furrows are less pronounced. Although the fixed cheeks are ill-preserved, they look as wide as the frontal lobe of the glabella as it is so in the type-species. The posterior border is, however, not so slender and pits on the cheeks are distinctly larger in this species than *Cerauroides hawlei.* Eyes are obscure, but they are probably a little larger than those of the type-species and located more posteriorly near the anterior lateral lobes.

If compared with the type-species, *Cerauroides propinquus* from the Silurian Orthocerenkalk of Elbersreuth, Germany (HELLER, 1925, S. 203, Taf. 1, Fig. 5, GAERTNER, 1930, S. 198) has the glabella more slender and more abruptly expanding toward the frontal lobe which is relatively large and spheric, having a semi-circular anterior margin. The present species is intermediate between these two European ones. It agrees better with *C. hawlei* in the L/W proportion and the gradual backward tapering of the glabella, but the frontal lobe is relatively large, convex and well rounded in front as in *C. propinquus.*

Occurrence and repository:—Loc. 3 (Ys14); KPFM 16098 (holotype) coll. by M. HIRATA, 1965, 1, 2, PAt 7357 (paratype) coll. by T. HAMADA, KPFM 15461 coll. by T. OKUBO, 1965, 10, 10, PAt 7358 (hypostoma) coll. by T. HAMADA.

Cerauroides elongatus KOBAYASHI and HAMADA, sp. nov.

Pl. 6, Fig. 5; Text-fig. 6D

This species is distinguishable from the preceding by the outline of the glabella which is relatively long and distinctly concave inward on the lateral side, its subtriangular frontal lobe which is conspicuously expanded near the base and minute tuberculation of the glabellar test. Pits on the cheek are on the contrary not so large in this as in the preceding species. The cephalon is longer and the cheeks are narrower in comparison with the glabella in this species than the preceding.

The specimen before hand shows that the fixed cheek anterior to the eye is a narrow zone extending forward near the anterior lobe and then turning toward the axis along the frontal margin of the glabella.

Occurrence and repository:—Loc. 3 (Ys14); KPFM 16103 coll. by M. HIRATA, 1965, 2, 27.

Cerauroides lunshanensis (GRABAU, 1924)

Text-fig. 6E

1924. *Cheirurus lunshanensis* GRABAU, *Stratigraphy of China, vol. 1,* p. 430, fig. 295.
1957. *Cheirurus lunshanensis* by LU, *Index Fossils of China, Invertebrates, vol. 3,* p. 291, pl. 153, fig. 8.
1960. *Cerauroides lunshanensis* by KOBAYASHI, *Japan. Jour. Geol. Geogr., vol. 31, no. 1,* p. 47.
1965. *Cheirurus* (?) *lunshanensis* by LU et al., *Trilobites of China, vol. 2,* p. 601, pl. 127, fig. 14.

Pygidium broad, with straight anterior margin and two pairs of pleural spines; axial lobe a little broader than pleural lobe along anterior margin, composed of four rings in addition to a terminal semi-elliptical lobe; ring furrows transversal; axial furrows gradually converging back to terminal lobe; first pleural rib and furrow straight and the former narrow; succeeding three pleural ribs twice thicker than the first rib, and convex near axis, but flattened on the other side; second and third ribs combined and produced into a large long postero-lateral spine, fourth rib extending into a short spine; post-axial band embracing terminal lobe with straight posterior margin.

As pointed out already (KOBAYASHI, 1960), it is astonishing to see that this pygidium fits in *Cerauroides* so well in the general outline, proportional size of the axis to pleural lobes and the possession of two pairs of spines, long anterior and short posterior. In *Cerauroides hawlei* the axis is composed of four segments, instead of five in this species. The pleural ribs are more prominent and run into the spines keeping the prominence, while in this species the ribs are prominent near the axis, but depressed on the other side and merge into the spines.

Occurrence:—Kaochiapien shales at Lunshan, Nanking hills, Kiangsu, China, in association with *Calymene* sp., *Proetus* sp. and *Phacops* cf. *shanensis* REED (GRABAU, 1924). This trilobite horizon lies in the upper part of the Kaochiapien shales (LU, 1957) probably of the Lojoping Group (LU et al., 1965).

Subfamily Sphaerexochinae ÖPIK, 1937

This subfamily was proposed by ÖPIK for *Sphaerexochus* to indicate an isolated branch of the Cheiruridae. WARBURG (1925) instituted *Pompeckia* on *Sphaerexochus wegelini* ANGELIN. These two genera were included in this subfamily by HENNINGSMOEN (1959). Subsequently WHITTINGTON (1963, 1965) added to the subfamily *Kawina* BARTON, 1915, and *Cydonocephalus* WHITTINGTON, 1963, and then *Heliomera* RAYMOND, 1905, and *Xystocrania* WHITTINGTON, 1965. This opinion was upheld by LANE (1971). In the configuration of the glabella, however, *Heliomera* is so different from *Sphaerexochus* that it has been combined by EVITT (1951) with *Heliomeroides* EVITT, 1951 as a separate subfamily, Heliomerinae.

Recently LANE (1972) erected *Hyrokybe* on *H. pharanx*, nov. from the Silurian of Greenland in which anterior glabellar furrows are absent and posterior ones deep but they do not reach the occipital furrows. He suggested that *Youngia uralica* (TSCHERNYSHEVA, 1893 in WEBER, 1951, pars) from the lower Ludlow of the Urals belonged possibly to this genus.

Finally, *Kotymella* TSCHUGAEVA, 1973 and *Parasphaerexochus* TSCHUGAEVA, 1973 were founded respectively on Middle Ordovician *Kawina plana* TSCHUGAEVA, 1964 and Lower Ordovician *Parasphaerexochus galealus* TSCHUGAEVA, 1973, both from eastern Siberia.

Genus *Sphaerexochus* BEYRICH, 1845

Remarks:—*Nierzkowskia* SCHMIDT, 1881, *Pseudosphaerexochus* SCHMIDT, 1881, *Hemisphaerocoryphe* REED, 1896 and *Pompeckia* WARBURG, 1925 were founded respectively on *Sphaerexochus cephaloceras* NIERZKOWSKI, *S. hemicranidium* KUTORGA, *S. pseudohemicranidium* NIERZKOWSKI and *S. wegelini* ANGELIN. Several other species of *Sphaerexochus* were transferred into *Actinopeltis*, *Cyrtometopus* and others including the above genera.

The remainder of *Sphaerexochus* constitutes such a solid genus that it can be easily discriminated from resembling genera. The intrageneric variation is, on the contrary, so gradual that various Ordovician and Silurian forms from Eurasia, North America and Australia were collectively called *Sphaerexochus mirus*, notwithstanding the fact that this type-species has never been found from Ordovician rocks in the Barrandian area (HAVLÍČEK and VANĚK, 1966).

There are *Sphaerexochus calvus* MCCOY, 1846, *S.* (?) *boops* SALTER, 1851, *S. scabridus* ANGELIN, 1854, *S. romingeri* HALL, 1862, *S. parvus* BILLINGS, 1865, *S. bohemicus* BARRANDE, 1872 and many other species of *Sphaerexochus* s. str. among which *Sphaerexochus angustifromis* ANGELIN, 1854, *S. latirugatus* REED, 1896 and several others were invalidated by synonymy by some authors. There are, however, still some 25 species considered to be valid (LANE, 1971). A monographic work is required to straight out the ambiguity of the *Sphaerexochus* taxonomy.

The outline and convexity of the cephalon as well as the glabella, the shape of basal lobes and their proportional size to the glabella are variable among species and also in growth stages. It may be a tendency for anterior and middle lateral furrows of the glabella to be more commonly distinct in Ordovician species than in Silurian ones. Genal spines as seen in Chazyan *Sphaerexochus pulcher* WHITTINGTON and EVITT, 1954 and *S. haspidotus* WHITTINGTON and EVITT, 1954 are absent in *S. mirus*, *S. romingeri* and many other species. Small genal spines are present in Upper Ordovician *Sphaerexochus eurys* TRIPP, 1962 and *S. filius* TRIPP, 1967, only in young stages.

For specific distinction of *Sphaerexochus* the pygidium is no less important than the cephalon. The axial lobe is primarily composed of three rings and a terminal piece, but secondarily the third ring becomes anchylosed with the piece. In *S. filius* the articulating half-ring appears between the first and second rings, but this is an uncommon instance. Broadly speaking, pleurae are projected into spines in older species, but they become lobate and even truncated at the ends. The evolution along this trend is, however, not simple in view of the fact that early Silurian *Sphaerexochus orientalis* is spinose whereas lobate pleurae are not rare in Ordovician forms. The pleurae are generally simple, but ribbed in *S. laciniatus* LINDSTRÖM, 1885, from the Wenlockian or Ludlovian of Gotland. It is quite unusual that only the second pleuron is bifurcated into two ribs in *S. bohemicus*. Axial furrows are persistent through the pygidium in many species, but they are interrupted in all of the three species (*calvus*, *hisingeri* and *tuberculatus*) in the *Leptaena* limestone of Sweden (WARBURG, 1925) and also in penecontemporaneous *S. bridgei* COOPER and KINDLE, 1936, from Percé, Quebec at the junction of the third pleuron with the axial lobe.

WARBURG noted that the texture of the carapace is an important criterion to distinguish the three species of the *Leptaena* limestone.

Distribution of the genus in Asia:—This genus was wide spread in North and Central Asia in the late Ordovician period as represented by the following three species.

(1) *Sphaerexochus taimyricus* BALASHOVA, 1959, from eastern Taimyr, Siberia (BALASHOVA, 1968)
(2) *Sphaerexochus* cf. *calvus* M'COY from Khirghiz steppe (WEBER, 1932, 1948)
(3) *Sphaerexochus hisingeri* WARBURG, 1925 from Pribalkhash and Kirghiz steppe (?) (WEBER, 1948) and the Chu-Illi mountains, Kazakhstan (TSCHUGAEVA, 1958)

In Central Asia, *Sphaerexochus mirus* BEYRICH is reported from the Silurian (upper Ludlow) of Ferghana, Turkestan (WEBER, 1932), and of Pribalkhash, Kazakhstan (WEBER, 1951). In Podolia this species occurs not only in the upper Ludlow but in the Wenlock also.

Sphaerexochus idiotis SALTER and BLANFORD, 1865 is represented in the Central Himalayas by two very fragmentary specimens from an isolated locality from other Ordovician rocks (REED, 1912). Except for this dubious form none is known from the Ordovician of southern and eastern Asia. There are, however, three Silurian species. One is *Sphaerexochus orientalis* KOBAYASHI and HAMADA, 1971 from the Langkawi Islands, West Malaysia. The others are *S. hiratai*, nov. and *S. planirachis*, nov.

Sphaerexochus hiratai KOBAYASHI and HAMADA, sp. nov.

Pl. 6, Figs. 6–10; Pl. 7, Figs. 1–8; Pl. 8, Figs. 1–5, 6, 7; Text-fig. 6F

Description:—Cephalon semi-circular and strongly vaulted; glabella nearly semi-globular and overhanging in front; basal lobes subcircular, more or less roundly quadrate in outline and completely isolated from the rest of glabella by a profound posterior furrow which turns from lateral to posterior rather abruptly to join an occipital furrow; anterior and middle lateral furrows linear, fairly long and subparallel to posterior furrow; anterior furrow a little shorter than middle one; lateral margin of glabella a little notched at the end of these two furrows; anterior and middle lobes equal in length and shorter than basal lobe; frontal lobe nearly as long as these two lobes; occipital ring narrow, but somewhat thickened mesially, while it narrows laterally behind basal lobes as these lobes are extended backward in comparison with axial part; median tubercle or spine absent on the ring; circumglabellar and occipital furrows very strong; the former slanting forward in antero-lateral part and running below the glabellar protrusion; the furrow provided there with a narrow frontal rim; cheek small and slanting steeply from small eye which is located near middle lobe and posterior lateral furrow of glabella; fixed cheek behind eye subtriangular; posterior border and border furrow well pronounced and bent anteriorly at lateral end; no genal spine issuing from this point. Free cheek, hypostoma and thorax unknown.

In pygidium axial lobe which is highly elevated above pleural lobes, composed of an articulating half-ring, two axial rings and a terminal piece in which the third ring is involved; ring furrows separating them all well pronounced; articulating half-ring almost as large and as prominent as the second ring and separated from the first ring by a deep furrow in same line with anterior margin of pleural lobes;

terminal piece nearly half as long as axial lobe, tripartate by Y-shaped ridge; its anterior and lateral sides steeply inclined; third axial ring marked on the piece only by a pair of constrictions from which the terminal piece suddenly narrows back slowly; pleural lobe broader than axial lobe, horizontal on inner side, inclined moderately or rather steeply on outer side, composed of three flat-topped ribs and deep pleural furrows; anterior and lateral margins of the first pleuron geniculated, forming an obtuse angle between these margins and the rib becoming broadest at geniculation; second rib gently arcuate and more or less broadened distally; third rib wide and somewhat lunate; all of these ribs rounded or subangulate at the ends but not protruded into long spines; lateral margin incised at the end of pleural furrows; posterior margin gently sinuate behind axial lobe.

Test smooth.

Observation:—Thirteen cranidia and seven pygidia are before hand among which fixed cheeks are very poorly preserved or largely lost in nine cranidia. The general concept of the cranidium can be obtained out of the holotype (KPFM 1167-1) and three other cranidia (KPFM 15221, 16094, 16105). The smallest glabella is 5.0×4.5 mm (PAt 7360) whose basal lobes are relatively small. Anterior and middle lateral furrows are generally seen on the test or exfoliated surface. It can be confirmed that neither a median tubercle nor a spine is present on the perfectly preserved occipital ring (KPFM 16092). In the cranidia (KPFM 15221, 16105) the dorsal furrow is traceable from eye to eye along the anterior portion of the glabella where one can see the narrow frontal rim and the very narrow anterior fixed cheeks.

The paratype pygidium (PAt 7363) is best to see the outline, convexity and segmentation. This as well as four other pygidia (PAt 7364, 7365, KPFM 16096, PAt 7366) belong to the typical form of this species having the pleural lobe broader than the axial lobe. In two pygidia which are distinguished as forma *robustus* (Pl. 8, Figs. 6, 7), on the other hand, the axial lobe is nearly as wide as the pleural lobe (vide Text-fig. 6G). However, the typical and varietal forms are otherwise not different. The pleural ribs are abruptly narrowing near the ends in an imperfect pygidium (KPFM 15227), but the terminus is less pointed, or well rounded in most others. In forma *robustus* (PAt 7367) the third pleural rib is connected with the anterolateral angle of the terminal piece of the axial lobe where the axial furrow is interrupted, but it is unusual.

Comparison:—This species may be said a *Sphaerexochus* having three lobate pleural ribs, two axial ring and a long terminal piece provided with a Y-shaped ridge and a pair of lateral constrictions on the pygidium. Distinctive biocharacters of the cephalon are the very strongly vaulted glabella drooping in front, very strong dorsal, posterior lateral and occipital furrows beside two rudimentary lateral furrows of glabella, subtriangular cheeks with very small eyes and absence of genal and occipital spines and a median tubercle.

WEBER's *S. mirus* from Ferghana (1932, pl. 1, fig. 39) is similar to this species in the pygidium having a terminal piece of the axial lobe which "shows vestige of lateral constrictions", but they are longer and oblique to the axis. Its axial lobe is much broader even compared with that of forma *robustus* of this species. This distinction applies to his pygidium from the upper Ludlow of Pribalkhash, Kazakstan (1951, pl. 6, fig. 10). This pygidium has short furrows by which pleural ribs are distinctly bisected near the axial lobe. The posterior lateral and occipital furrows are comparatively slender in the glabella from the same locality (pl. 6, fig. 6).

Sphaerexochus mirus from New South Wales appears to have pleurae of the pygidium truncated at the ends, although Australian specimens were scarcely described by ETHERIDGE and MITCHELL (1917, p. 494, pl. 26, figs. 1-5). In Malayan *S. orientalis*, on the other hand, the pleurae are produced into spines (KOBAYASHI and HAMADA, 1971).

As it is the so-called *mirus* of Australia and Central Asia, this species closely resembles *Sphaerexochus mirus* BEYRICH illustrated by BARRANDE, 1852 and HORNÝ and BASTL, 1970. Compared to this species the pygidium in figs. 22-23, pl. 42 in BARRANDE, however, possesses the terminal piece of the axis less constricted laterally and accordingly its posterior part is broader. Ring furrows are stronger and pleural furrows narrower in the Bohemian pygidium. In the cephalon in figs. 16 and 17 in BARRANDE as well as in figs. 5 and 6, pl. 15 in HORNÝ and BASTL the occipital ring is distinctly convex forward, but nearly straight or convex backward in the Japanese form. The glabella is less convex and more or less flat on top in the sagittal profile in fig. 17 (BARRANDE's) and fig. 5 (in HORNÝ and BASTL's). The anterior and middle lateral furrows are somewhat longer and the posterior border of the cheek is slender in *mirus*. s. str., if compared with the very stout border in this species. In SHAW's pygidium of *S. mirus* from Beraun, Bohemia (1968) the occipital ring is also convex forward and the terminal piece is less constricted and more stout than in this species.

SALTER's *S. mirus* in England is also distinct from the Bohemian so much that DEAN (1971) denominated it *S. britannicus*. The Japanese species can easily be distinguished from this British one, if compared it with that one in fig. B, text-figure 3 in DEAN.

Occurrence and repository:—Cranidia: Loc. 3 (Ys15′); KPFM 1167-1 (holotype) and 1167-2 coll. by M. HIRATA, 1967, 11, 26. Loc. 3 (Ys14); PAt 7359, 7360, 7361, 7362, KPFM 146 coll. by T. OKUBO, 1965, 3, 23, 16092 coll. by M. HIRATA, 1964, 12, 30, 16094 coll. by M. HIRATA, 1965, 1, 3, 16105 coll. by A. YOKOYAMA, 1964, 12, 30. Loc. 3 (Ys); 7382 coll. by S. HADA, KPFM 74. Loc. 3 (Ys15); KPFM 15221 coll. by T. OKUBO, 1965, 3. Pygidia: Loc. 3 (Ys14); PAt 7363 (paratype), 7364, 7365, 7366, KPFM 16096 coll. by A. YOKOYAMA, 1964, 12, 30.

Forma *robustus*: Loc. 3 (Ys14); KPFM 15227 coll. by T. OKUBO, 1965, 2, PAt 7367.

Sphaerexochus planirachis KOBAYASHI and HAMADA, sp. nov.

Pl. 8, Fig. 8; Text-fig. 6H

An imperfect large flat pygidium differs from all others of the Yokokura forms in the comparatively large second pleural rib, slender pleural furrows, narrower axial lobe and its relatively long terminal piece. These differences cannot be effects of secondary deformation, because such a deformation is inrecognizable in other specimens from Gomi which are in the same kind of mother rock. At the same time the combination of the above distinctions applies to *Sphaerexochus orientalis* and other species of *Sphaerexochus* which the authors are aware. Therefore, a new name is proposed for this species.

Occurrence and repository:—Loc. 3 (Ys14); PAt 7368 coll. by T. IMAMURA.

Subfamily Pilekinae SDZUY, 1955

Genus *Koraipsis* KOBAYASHI, 1934

Type-species:—*Koraipsis spinus* KOBAYASHI, 1934

Remarks:—This genus was proposed for *Protopliomerops*-like cheiruroids having a preglabellar spine because the spine was unique among similar trilobites, although the holotype of *K. spinus* from the *Clarkella* zone of Sesong-ni, South Korea was a very imperfect cranidium. The cranidium of the type species was, however, well clarified with a find of additional material in Korea (KOBAYASHI, 1960).

Subsequently the second species, *Koraipsis shansiensis* CHANG, 1966, was described from the Tremadocian of Pingting, eastern Shansi. This species was represented by a nearly complete cranidium (holotype) and pygidium (paratype). (Vide Text-fig. 6I). This cranidium differs principally from that of *K. spinus* in the forwardly tapering glabella and very broad fixed cheeks, but they are evidently congeneric, because they agree with each other in many other characteristics, particularly in the possession of the pre-glabellar spine. Not only the cephalon but also the pygidium of *K. shansiensis* is very broad. The axial lobe of this pygidium is breviconic and composed of four axial rings and a triangular terminal piece. The pleural lobes are quadrisegmented, each produced into a long spine. The first pleural furrow is quite pronounced, but the succeeding ones are very weak or completely obsolete. Interpleural ones are on the other hand nearly straight, narrow, deep and very distinct.

The cranidium of *Protopliomerops punctatus* KOBAYASHI (1934, 1960) is so similar to those of *Koraipsis* that it was thought possible to belong also to *Koraipsis*, if it bears such a frontal spine. The pygidium found together with the cranidium in the *Protopliomerops* zone at Dongjeom-ni (Doten-ri), South Korea consists of six segments, beside a terminal axial piece and pleural ribs are pointed at their ends, but not so prolonged into such long spines as in *Koraipsis*.

In 1934, the senior author instituted *Koraipsis* as a genus of the Cheiruridae. SDZUY (1955) grouped *Pilekia* BARTON, *Parapilekia* KOBAYASHI and *Anacheirurus* REED in the Pilekidae nov. in the Cheiruracea. Later, the subfamily Pilekinae was placed in the Pliomeridae by HARRINGTON (in Treatise, 1959), but the subfamily was retained in the Cheiruridae by KOBAYASHI (1960) and LANE (1971). *Koraipsis* has the pygidium best agrees with *Pilekia*. Its cephalon fits better with the Cheiruridae than the Pliomeridae.

Distribution:—Lower Ordovician; East Asia (Korea and North China).

Family Encrinuridae ANGELIN, 1854

Subfamily Encrinurinae ANGELIN, 1854

In 1959 the junior author (HAMADA) proposed a quadripartation of the Encrinuridae into the Cybelinae, Dindymeninae, Staurocephalinae and Encrinurinae besides an unnamed new subfamily by EVITT, 1957 and the reference of five genera to the Encrinurinae, viz. *Encrinurus*, *Cromus*, *Coronocephalus*, *Encrinuroides* and *Mitchellia* VOGDES, 1917, i. e. *Mitchellaspis* HENNINGSMOEN, 1959, besides an unnamed new genus by EVITT, 1957. It was quite unexpected that this classification so well agreed with HENNINGSMOEN's in MOORE's Treatise printed in the same year (HAMADA, 1961).

Frammia HOLTEDAHL, 1914 which had been overlooked in the two schemes of the Encrinuridae above cited was later accepted by BOLTON (1965) as a subgenus of *Encrinurus.* Prior to this, the junior author discussed the cephalic evolution of the Encrinurinae on the basis of the effacement of glabellar furrows and other cephalic segmentation and pointed out that the Upper Silurian *Cromus* represented the most advanced type of the subfamily, while the Upper Ordovician *Encrinuroides* or the *Encrinurus multisegmentatus* group was the most primitive one. According to BOLTON, Upper Silurian *Encrinurus* (*Frammia*) *arcticus* (HOUGHTON) and Lower Silurian *Encrinurus princeps* POULSEN (1934) are intermediate in character between *Encrinurus* s. str. and *Cromus.* The latter is, however, an *Encrinurus* s. str. whereas the former is much closer to *Cromus* than *Encrinurus* s. str.

Paying attention to the basic arrangement of tubercles on cranidium and pygidium, TRIPP (1962) revised an *Encrinurus punctatus* species-group, including the lectotype pygidium of *E. punctatus* (WAHLENBERG), from the Silurian rocks of several localities such as British Isles, Estonia, Gotland, Oslo region in Norway and Anticosti Island, Canada. Prior to this, BEST (1961) examined the intraspecific variation in *Encrinurus ornatus* of North America. He showed that the median tuberculation on the pygidium might be well-controlled genetically as it matched to the statistical operation of the Hardy-Weinberg law of genetics.

In 1967, WHITTINGTON and CAMPBELL erected *Fragiscutum* on *F. rhytium* which is a closest ally to the species-group of *Encrinurus variolaris* by REED, 1928. Recently, SHRANCK (1972) regarded the *variolaris* group as it is synonymous with *Frammia.* He also considered *Fragiscutum* itself to be a synonym of *Frammia* with slight hesitation. Both subgenera are actually similar in several characteristics as exemplified by a few anterior pleurae fitted the axial rings in the pygidium which has no median band on the axial rings.

In 1968, BALASHOVA established a new genus *Dnestrovites* in the Encrinuridae on *D. podolicus* which came from the upper Ludlovian of Podolia. Its cephalic feature is, however, known imperfectly.

Encrinuraspis WEBBY, MOORE and MCLEAN, 1970, which was founded on their monotypic new species, *Encrinuraspis optimus* from the middle Caradocian (upper Eastonian) of New South Wales, Australia, is an encrinurid with rounded genal angle, small tubercles on glabella, large eyes and pitted cheeks. Four pairs of lateral furrows on the glabella are all distinct but widely interrupted in the axial part.

In 1971, CHLUPÁČ noted the youngest encrinurids in the Barrandian area where *Cromus krolmusi* occurred in the *Monograptus transgrediens* zone of the uppermost Silurian (upper Pridolian), i. e. the post-Ludlovian age. *C. krolmusi* was regarded to be the latest representative of the *Cromus intercostatus* species-group of encrinurid trilobites.

Erratencrinurus KRUEGER, 1971 is a new genus found in erratic boulders of the ages from middle Caradocian to lower Ashgillian in the Baltic region. It is quite distinctive from all known Encrinuridae by the development of extrarodinary horn-like large spines on the glabella. The oldest of the genus is middle Caradocian *Erratencrinurus kauschi* KRUEGER from which the *Erratencrinurus nebeni* group and the *Erratencrinurus seebachi* group were derived respectively in upper Caradocian and lower Ashgillian. The latter group bears some characteristics common with *Encrinuroides*. Actually, MÄNNIL (1958) and WHITTINGTON (1950) have regarded *seebachi* as a species of *Encrinuroides*.

Summarizing the above stated progress in the encrinurid classification since Treatise was published eleven genera and subgenera can now be cited in the subfamily Encrinurinae as follows:

Encrinurus (*Encrinurus*) EMMRICH, 1844
Encrinurus (*Frammia*) HOLTEDAHL, 1914
Cromus BARRANDE, 1852
Coronocephalus GRABAU, 1924
Encrinuroides REED, 1931
Mitchellaspis HENNINGSMOEN, 1959
? *Fragiscutum* WHITTINGTON and CAMPBELL, 1967
? *Dnestrovites* BALASHOVA, 1968
Encrinuraspis WEBBY, MOORE and MCLEARN, 1970
Erratencrinurus KRUEGER, 1971
Unnamed new genus A by EVITT, 1957

a. Distribution of *Encrinurus* and *Coronocephalus* in Asia

Two species of *Coronocephalus* have been described in Japan, namely (1) *Coronocephalus kitakamiensis* SUGIYAMA, 1941, from the upper part of the Kawauchi Series (probably Ludlovian) of Kitakami mountains, Northeast Japan and (2) *Coronocephalus kobayashii* HAMADA, 1959, from the Wenlockian G_2 stage of the Gion-yama Series, Kyushu, West Japan.

Since KAYSER had described in 1883 *Encrinurus* sp. from "Mergeler Korallenkalk zwischen Kiau-tschang-pa und Shönn-hsüen-yi" on the Shensi-Szechuan border, encrinurids have been reported from various places in China.

As summarized by WANG (1935) and the present junior author (HAMADA, 1959), *Coronocephalus rex* GRABAU is widely distributed in Central and South China more commonly in the Hanchiatienian than in the Lojopingian Series. HAMADA is of opinion that the species thrived most in late Wenlockian, if not earliest Ludlovian and that the Lojopingian and Hanchiatienian forms may be distinguished in future when a close comparison be made.

WIRTH (1937) described *Encrinurus* sp. from Szechuan. PATTE's *Cromus* sp. nov. aff. *beaumonti* also from Szechuan (1935) may be another species of *Encrinurus*, s.l., but by no means of *Cromus*.

In 1960, two unnamed species of *Encrinurus* were reported from the Wenlockian of Kansu by CHANG and PAN (in LU et al., 1965). They are represented by multisegmented pygidia without distinct median band and tuberculation on the axial lobe.

In Northeast China (or Manchuria), *Encrinurus sinicus* KUO, 1962 is described from the upper Wenlockian or lower Ludlovain sandstones and shales of the Ertaokou Group in Kirin.

In Southeast Asia, *Encrinurus konghsaensis* REED, 1906 is known from the Namhsim sandstone in Northern Shan States, and *Encrinurus* sp. from Southern Shan State, Burma, and *Encrinurus punctatus* EMMRICH var. *laosensis* PATTE, 1929 from the Silurian of Laos. The Namhsim fauna is evidently younger than the Llandoverian *Prodontochile* fauna of Malay (KOBAYASHI and HAMADA, 1971) and within the range from Middle to Upper Silurian.

Encrinurus konghsaensis has a subtriangular pygidium with an arcuate anterior margin. Its axial lobe occupies about a quarter of its breadth and consists of more than 18 annulations; median tubercle absent; lateral lobes are 9 to 10 in number. It resembles the paucisegmented pygidium with an euryrachis (ex. *E. tosensis*, KPFM 13396, below mentioned) best, but the surface of the pygidium is said coarsely granulated and ring furrows are apparently complete in the Burmese species.

According to PATTE (1929), *Encrinurus punctatus* var. *laosensis* is an intermediate form between *Encrinurus punctatus* and *E. konghsaensis*. There are some difference among several pygidia of *laosensis*, but all subtriangular; the axial lobe occupies about a quarter of the breadth; lateral field divided into 9 to 10 ribs and furrows. More than 19 annulations on the axial lobe are commonly interrupted by the median band where 5 or 6 tubercles are counted.

In Central Himalaya, REED (1912) described *Encrinurus* aff. *punctatus* BRÜNNICH. This is another paucisegmented pygidium with an euryrachis; 9–10 lateral lobes are counted; axial annulations "more or less interrupted or faintly marked in the middle". No mention is given of median tuberculation. Lately, GUPTA reported *Encrinurus* cf. *punctatus*, *Encrinurus sexcostatus* and *Encrinurus* (*Cromus*) *beaumonti* from Kashmir (1965), and proposed *Encrinurus kashmirica* (1967).

In Afghanistan, an occurrence of *Encrinurus konghsaensis* is reported by PILLET and DE LAPPARENT (1969). In further west, in Northwest Turkey is known *Encrinurus* (*Encrinurus*) *brevispinosus* HAAS, 1968, from upper Llandovery-lower Wenlock of Bithynia. This has still another paucisegmented pygidium with an euryrachis. Lateral lobes of this trilobite are only 7 in number and 5 or 6 median nodes found on 18-20 axial annulations.

In the Asiatic part of the Soviet Union, *Encrinurus tuyuxuensis* BALASHOVA, 1966 is described from the Ludlow in East Pamir. It is represented by the pygidium comparable with *E.* cf. *konghsaensis* by WEBER, 1951 and *E.* (*Coronocephalus*) *rex* GRABAU em. WANG, 1938. As it consists of about 28 axial rings and 11 lateral lobes, it is nearer to *C. kobayashii* in the number, but the axis is more annulated in *kobayashii* and much more so in *rex*. In the perfect annulation, it agrees better with *rex* than *kobayashii.*

According to WEBER, 1932, the following three species are known from the Silurian of Turkestan.

Encrinurus punctatus WAHLENBERG (?)	(cephalon and thorax)
Group of *Encrinurus punctatus* WAHLENBERG	(four pygidia)
Encrinurus konghsaensis REED (?)	(cranidium)

The group of *Encrinurus punctatus*, as noted by WEBER himself, comprises two types of pygidia, one with 11 or more pleurae and the other 10 or less pleurae. The former has no more than 25 axial rings which are tuberculate. The latter has about 20 rings and median tubercles are few or none. Subsequently, in 1951, he combined parts of the first and second forms of the above encrinurids with the third into *Encrinurus* cf. *konghsaensis* and referred part of the second one to *Encrinurus punctatus.* However, the former and latter types were later regarded by BALASHOVA (1968) a new species, i.e. *E. donenjalensis* and *E. tchingisicus.* According to WEBER (1951), *Encrinurus* is so well represented in U.S.S.R. as the following many species besides two *Encrinurus* spp. of the Urals and Tien-Shan.

Wenlockian
Encrinurus punctatus WAHLENBERG from Podolia
Encrinurus beaumonti var. *lozvensis* WEBER from Ural
Encrinurus magnituberculatus REED from Podolia
Lower Ludlovian
Encrinurus punctatus WAHLENBERG from Ferghana
Encrinurus cf. *konghsaensis* REED from Ferghana
Encrinurus beaumonti var. *novaki* FRECH (?) from Samarkand

Recently, BANDALETOV (1969) added several occurrences of encrinurid trilobites in Kazakhstan as follows:

- Alpeis horizon (lower Llandoverian)
  - *Encrinurus* sp.
  - *Encrinurus punctatus* WAHLENBERG
- Lower Zhumak horizon (upper Llandoverian)
  - *Encrinurus mullochensis* REED
  - *Encrinurus onniensis* WHITTARD
  - *Encrinurus inusitatus* KOLOBOVA

Upper Zhumak horizon (uppermost Llandoverian—lower Wenlockian)
Encrinurus mullochensis REED

Prior to this, TSCHUGAEVA (1958) listed the following encrinurid name from the Dulankarin horizon (upper Caradocian-lower Ashgillian) at Chu-Illi mountains in Kazakhstan.

Encrinurus (cf. *punctatus*) sp.

b. Australian encrinurids

Most of the encrinurids in Australia were described from the Silurian formations in New South Wales. As early as in 1860, SALTER reported the encrinurid occurrence in this region, i. e. *Encrinurus australis*, but its precise locality has been unknown. More than 20 species have been reported since SALTER's age as summarized below.

Among them, the oldest occurrence is middle Caradocian *Encrinuraspis optimus* from New South Wales and the youngest *Encrinurus* aff. *silverdalensis* by GILL from the Lower Devonian Eldon Group in West Tasmania. Concerned with the latter occurrence, GILL noted by himself " It is probably significant that *Encrinurus* was in no case found on the same slab as any of the Devonian forms ". Although FLETCHER (1950) also threw an question to this occurrence, no definite conclusion on the biostratigraphical position of this encrinurid has been obtained (GILL, 1962).

Another Tasmanian encrinurid was listed by MONTGOMERY as *Cromus murchisoni* DE KONINCK. But its specific or even generic identification is said to be doubtful (ETHERIDGE and MITCHELL, 1915).

Encrinurus australis SALTER, 1860 New South Wales (loc. unknown)
Encrinurus barrandei DE KONINCK, 1876 Yarralumla, N. S. W.
**Cromus murchisoni* DE KONINCK, 1876 Yarralumla; Quedong, N. S. W.
***Cromus bohemicus* (?) BARRANDE by DE KONINCK, 1876 Yarralumla, N. S. W.
Encrinurus bowningensis FOERSTE, 1888 Lower Trilobite Beds, Hume Ser., N. S. W.
Encrinurus mitchelli FOERSTE, 1888 ditto
Encrinurus sp. aff. *mitchelli* FOERSTE by HILL, PLAYFORD and WOODS, 1969 Up. Sil., Queensland
****Encrinurus* (*Cromus*) *spryi* CHAPMAN, 1912 Melbournian, S. Yarra, Victoria
Encrinurus punctatus BRÜNNICH by CHAPMAN, 1914 Yeringian, N. S. W.
Encrinurus duntroonensis ETHERIDGE and MITCHELL, 1915 Up. Sil.?
Encrinurus etheridgei MITCHELL, 1915 (in ETHERIDGE and MITCHELL, 1915) Up. Sil.?, N. S. W.
Encrinurus rothwellae ETHERIDGE and MITCHELL, 1915 Up. Tril. Beds, Hume Ser., N.S.W.
Encrinurus silverdalensis ETHERIDGE and MITCHELL, 1915 Low Tril. Beds, Hume Ser., N. S. W.
Encrenurus aff. *silverdalensis* ETHERIDGE and MITCHELL by GILL, 1948 L. Dev. Eldon Group, W. Tasmania
Encrinurus angustus (MITCHELL, 1924) Bowning, N. S. W.

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* Not *Cromus* but *Encrinurus* by ETHERIDGE and MITCHELL, 1915.
** Not illustrated.
*** It is not *Cromus* according to ETHERIDGE and MITCHELL, 1915.

Encirnurus frontalis (MITCHELL, 1924) Mid. Til. Beds, Bowning, N.S.W.
Encrinurus incertus (MITCHELL, 1924) Up. Tril. Beds, Yass-Bowning, N.S.W. (immediately above the *Monograptus* horizon)
Encrinurus perannulatus (MITCHELL, 1924) Bowning, N.S.W.
Encrinurus platynotus (MITCHELL, 1924) Bowning, Low. Tril. Beds, N.S.W.
Encrinurus robustus (MITCHELL, 1924) ditto
Encrinurus borenorensis FLETCHER, 1950 L. Sil., Orange, N.S.W.
Encrinurus simpliciculus TALENT, 1965 U. Sil. Dargil formation, Victoria
Encrinuraspis optimus WEBBY, MOORE and MCLEAN, 1970 Up. Eastonian (Mid Caradocian), N.S.W.

Besides the above listed species several *Encrinurus* were reported from various localities by DAVID (1950), but no specific identification was made on these forms.

c. Encrinurids in the Arctic region

Many species of encrinurid trilobites were reported from the Ordovician-Silurian rocks in the Arctic region, i.e., Waigach (Yaygatch), Petschora-land, Siberian platform in the U.S.S.R., Greenland, Arctic islands, Anticosti Island, Gaspé peninsula and Manitoba in mainland Canada. The wide distribution of Ludlovian *Frammia* and its allied forms as shown in the list below characterizes that region, and suggests a strong faunal relationship among these localities to form a closely related paleobiogeographic province of that time. If *Fragiscutum* be an akin to *Frammia* as supposed by SHRANCK (1972), this faunal province may extend southwardly to Maine and Oklahoma in the United States as well. On the other hand, this encrinurid province seems to have little connection with the Asiatic and Australian encrinurid realms in Silurian times.

Northern Waigach (MAXIMOVA in CHERKESOVA, 1970)
Encrinurus (*Frammia*) *rossicus* MAXIMOVA Ludlovian
Waigach and Pai-Khoi (Geol. Struct. U.S.S.R., 1, 1958)
Encrinurus rarus WALCOTT Up. Ord.
Petschora-land (KEYSERLING, 1846; EICHWALD, 1860)
Encrinurus punctatus (WAHLENBERG) Sil.
Siberian platform (MAXIMOVA, 1962)
Encrinurus creber MAXIMOVA Wenlockian, Norilsk region
Encrinurus globosus MAXIMOVA Llandoverian-Wenlockian?, Norilsk region; Podkamennaya Tunguska basin; Reka Akkit, Kantaiki basin. Llandoverian?, Reka Moierokan, Tukalakt
Encrinurus punctatus (WAHLENBERG) Wenlockian, Norilsk region. Llandoverian, Podkamennaya Tungska basin
Greenland (TROEDSSON, 1929; POULSEN, 1934)
Encrinurus rarus (?) WALCOTT Up. Ord., Cape Calhoun
Encrinurus sp. ditto
Encrinurus inflatus POULSEN Cape Schuchert formation
Encrinurus moderatus POULSEN ditto
Encrinurus princeps POULSEN ditto
Encrinurus spp. indt. ditto
Canadian Arctic Archipelago (ETHERIDGE, 1878; HOLTEDAHL, 1914; TEICHERT, 1937; BOLTON, 1965)
Encrinurus (*Frammia*) *dissimilis* HOLTEDAHL Low.-Mid. Ludlovian or younger, S.W.

Ellesmereland	
Encrinurus (*Frammia*) *arcticus* (HAUGHTON, 1858)	Low. Ludlovian, Prince of Wales Island, N. Somerset Island, E. Somerset Island, S.W. Devon Island, S. Cornwallis Island, Griffith Island, Seal Island, N.E. Stefansson Island, Beechey Island
Encrinurus laevis (ANGELIN)	Low. Ludlovian, Cornwallis Island, Griffith Island
Encrinurus sp.	S.W. Ellesmereland
Encrinurus sp.	Sil., N. Southampton Island
Encrinurus (?) sp.	S.W. Ellesmereland
Anticosti Island (BILLINGS, 1866; TWENHOFEL, 1928)	
Encrinurus punctatus WAHLENBERG	Anticostian
Encrinurus elegantulus BILLINGS	ditto
Encrinurus laurentinus TWENHOFEL (=*E. multisegmentatus* by BILLINGS, 1866)	Richmondian
Gaspé, Quebec (COOPER, 1930; NORTHROP, 1939)	
Encrinurus perceensis COOPER	Up. Ord.
Encrinurus spp. indt.	ditto
Encrinurus caplanensis NORTHROP	Sil.
Manitoba (WHITEAVES, 1906; BASSLER, 1915)	
Encrinurus varicostatus WALCOTT	Black River
Encrinurus sp. indt.	Sil.

Among the species above cited, *Encrinurus globosus* described by MAXIMOVA from Siberian platform seems to be referable to *Frammia*.

As far as the Ordovician faunal province of the encrinurid trilobites are concerned, we have not so many species enough to figure it out at this time. However, the Arctic region under consideration may belong to the "Siberian platform-North east U.S.S.R.-North America trilobite complex" proposed by BALASHOVA (1967) for the Ordovician trilobite distribution. Further to the west of Siberia, *Frammia* specis were also found in the erratic boulders of northern Europe (SCHRANK, 1972).

d. Encrinurid pygidia

Various pygidia of *Encrinurus* and allied genera are found at Yokokura-yama and other localities in Japan which are here classified into two groups and four subgroups in each group as follows;

A group: Pygidia without median tubercles on the axial lobe. Axial rings and particularly middle and posterior ones constitute commonly a smooth median band.

A-1 subgroup: Multisegmented pygidium with stenorachis as represented by two pygidia (Pl. 10, Figs. 7, 8; Text-fig. 7l). Pygidium triangular; axial lobe about 1/5 as wide as the pygidium; axial furrow weak; lateral ribs numbering 13-14.

Encrinurus sp. by WIRTH, 1937 belongs probably to this subgroup, although the outline of the pygidium cannot be figured.

Coronocephalus rex by TSIN, 1956 is closely allied to this, but the lateral margins of its pygidium are distinctly arcuate, while those of the Yokokura forms are nearly straight.

Encrinurus (*Coronocephalus*) *kitakamiensis* SUGIYAMA bears characteristics of this subgroup, but specifically distinct from others of this subgroup in the narrower axial lobe and more numberous axial rings.

A-2 subgroup: Paucisegmented pygidia with stenorachis as represented by a specimen (Pl. 10, Fig. 9, Text-fig. 7J). Pygidium subquadrate; axial lobe about 1/5 as wide as pygidium; lateral ribs one or two more than 8 which are strong; axial and lateral furrows well pronounced.

A-3 subgroup: Multisegmented pygidia with euryrachis as represented by pygidia probably of *E. mamelon* (Pl. 10, Figs. 5, 6). Pygidium triangular; axial lobe about 1/4 as wide as pygidium; lateral ribs 12-13; axial and pleural furrows narrow.

Coronocephalus kobayashii HAMADA is intermediate between this and the succeeding subgroups, but closer to this. Its axial lobe is about 1/4 as wide as pygidium, but axial annulations are denser, counting 30-40. Lateral ribs are 11 and axial and lateral furrows are narrow.

Coronocephalus rex GRABAU em. WANG has also the axial lobe of 1/4 pygidial breadth (vide Pl. 11, Fig. 13). Axial rings are more numerous, attaining 35 to 45. Lateral ribs are 14-15.

A-4 subgroup: Paucisegmented pygidia with euryrachis as represented by three pygidia of *Encrinurus tosensis* (Pl. 10, Figs. 10, 11; Pl. 11, Fig. 2). Pygidium subtriangular, but posterior angle and probably antero-lateral angles are somewhat rounded; axial lobe 1/4 as wide as pygidium; lateral ribs countable 8-9, flat-top, roof-shaped in cross section; axial and lateral furrows are well pronounced.

Cromus aff. *beaumonti* by PATTE, 1935 may be allied to this subgroup, but the outline of the pygidium is much broader in PATTE's.

KAYSER's two pygidia of *Encrinurus* (1883), which are reproduced in Pl. 9, Figs. 21 and 22, have a broad axial lobe and 10-11 lateral ribs. These two are very different in outline, particularly in the curvature of the anterior margin which is incomparably stronger in the pygidium in Fig. 22 than that in Fig. 21.

Encrinurus sp. (1) from Kansu (in LU, et al., 1965) has a very broad axial lobe as wide as 1/3 of the pygidium and lateral ribs are 9. *Encrinurus* sp. (2) from Kansu (ibid.) has the axial lobe as wide as 1/4 the pygidium and 11-13 lateral ribs.

Encrinuroides sexcostatus has the pygidium allied to this subgroup, but lateral ribs number only six pairs hence the specific name.

B group: Pygidia having median tubercles on the axial lobe.

B-1 subgroup: Paucisegmented pygidium with euryrachis as represented by *Encrinurus nodai*, i. e., a pygidium collected by NODA from the G_2 stage of the Yokokura section (Pl. 11, Fig. 9). Pygidium subtriangular; a little longer than broad; axial lobe as wide as 1/4 or more the pygidium; lateral ribs countable 6-7; ring furrows mostly transversal.

B-2 subgroup: Paucisegmented pygidium with posteriorly curved pleurae of *Cybele*-type. Represented by several pygidia, possibly of *E. yokokurensis*, exemplified in Pl. 11, Figs. 5-8. The axial lobe occupies about 1/4 or less of the pygidial breadth; weak median band recognizable, especially at the posterior portion of the axial lobe; lateral ribs countable 8-9; pleural furrows deep and wide.

B-3 subgroup: Multisegmented pygidia with euryrachis as represented by the Okanaru specimens, i. e. *Encrinurus ishii* (Pl. 11, Figs. 3, 4). Pygidium triangular in outline; the median lobe about 1/4 as wide as the pygidium; lateral ribs 9-10 and widely separated by rather shallow pleural furrows; median band is well developed on the axial lobe where small tubercles are aligned along the axis.

They are allied to *Encrinurus sinicus* KUO from near Kirin in the axial tuberculation and pleural segmentation (9-10). But the axial lobe is much slender in this Manchurian form than that of the Japanese form.

B-4 subgroup: Multisegmented pygidia with stenorachis as represented by the Hitoégané form or *Encrinurus fimbriatus* (Pl. 11, Figs, 10-12). Pygidium triangular; axial lobe about 1/4 as wide as the pygidium; lateral ribs countable 10; axial furrows narrow but well marked; lateral furrows deep and narrow; median band is feebly recognizable; posterior part of pleurae tend to be bent toward the pygidial end, but no *Cybele*-type.

It is a noteworthy fact that none of these forms in the B subgroup from Japan is mucronate as the species-group of *Encrinurus punctatus* from Europe and *Encrinurus ornatus* from North America which were well exemplified by TRIPP (1962) and BEST (1961) respectively.

As a result of an extensive critical review of the Encrinuridae REED (1928) distinguished six kinds of pygidia and pointed out that the *Encrinurus punctatus* group, which was postulated to have derived from the *E. multisegmentatus* group, reveals morphologically the final stage. As clearly shown by TRIPP (1962) *Encrinurus punctatus* and allied species all having pygidia well specialized by euryrachis mostly tuberculate regularly, paucisegmented pleural lobes and commonly developed mucro in posterior. Eastern Asiatic species even of the tuberculate B group as mentioned above are quite distinct from these European species. Most of the Asiatic ones and particularly the nontuberculate A group having stenorachis resembles the *E. multisegmentatus* and allied species of Middle and Upper Ordovician species (TRIPP, 1957). The cephalon of *Coronocephalus* is, however, very different from those of the *multisegmentatus* and *punctatus* groups. Therefore the resemblance of the pygidia between *Coronocephalus* and the *multisegmentatus* species-group would be an example of heterochronous parallelism between the two sides of Eurasia.

As discussed already (HAMADA, 1961), the cephalic evolution is quite conspicuous in the Encrinurinae, but at the same time specific distinction by means of the pygidium must be so important as TRIPP has shown with the species group of *multisegmentatus* and *punctatus.*

Therefore it is certain that there are several species of *Encrinurus* in Japan and probably more than 10 species of *Encrinurus* may be distinguishable in eastern Asia, if the pygidial characteristics be taken into account.

Genus *Coronocephalus* (GRABAU, 1924) em. WANG, 1938

Coronocephalus kobayashii HAMADA, 1959

Pl. 9, Figs. 1-18; Text-fig. 7A

1959. *Coronocephalus kobayashii* HAMADA, *Japan. Jour. Geol. Geogr., vol. 30,* p. 80, pl. 6, figs. 1-18, text-fig. 2.

Diagnosis:—Medium-sized encrinurid with complete two posterior and an incomplete third lateral furrows on the glabella. The fourth furrows extend towards frontal area of the glabella joining with each other at the position of the shallow median furrow. Genal spines are slender, gently curved inwardly, and as long as the thoracic length. Eyes highly project on eye mounds as high as the free cheek width in the largest individual. Stenorachis pygidium is triangular in outline, moderately inflated, multisegmented on the axial lobe where are counted 32-40 annulations, of which only several frontal ones are confluent and the rest interrupted by a shallow median band; 10-11 pleurae tend to be bent distally toward posterior to form almost parallel caudal termination by the last one or two pairs of pleural ribs. No tubercle is on the pygidium.

Comparison:—Encrinurus kitakamiensis has somewhat similar pygidial features, though it may be a large form of the A-1 subgroup in the present classification of encrinurid pygidia. Its annulation on the axial lobe is complete through the pygidial length.

One of the *Coronocephalus rex* forms illustrated by WANG (1939, pl. 1, fig. 2) has extraordinarily larger genal spines than the present species, and they extend posteriorly beyond the pygidial end. It is also different from the type species of the genus in the rounded pygidial margin that is somewhat similar to the shape of another *Coronocephalus* species described and illustrated by TSIN (1956, pl. 4, fig. 14). It is highly probable that these two forms may represent a distinct species separated from the typical one of the genus, *C. rex* GRABAU that is provided with triangular pygidial outline and rather short genal spines.

Occurrence and repository:—Loc. 1, G_2 stage, PAt 7280 (holotype cranidium), 7281 (paratype cranidium), 7282-7297 coll. by T. HAMADA.

Genus *Encrinurus* EMMRICH, 1844

Encrinurus yokokurensis KOBAYASHI and HAMADA, sp. nov.

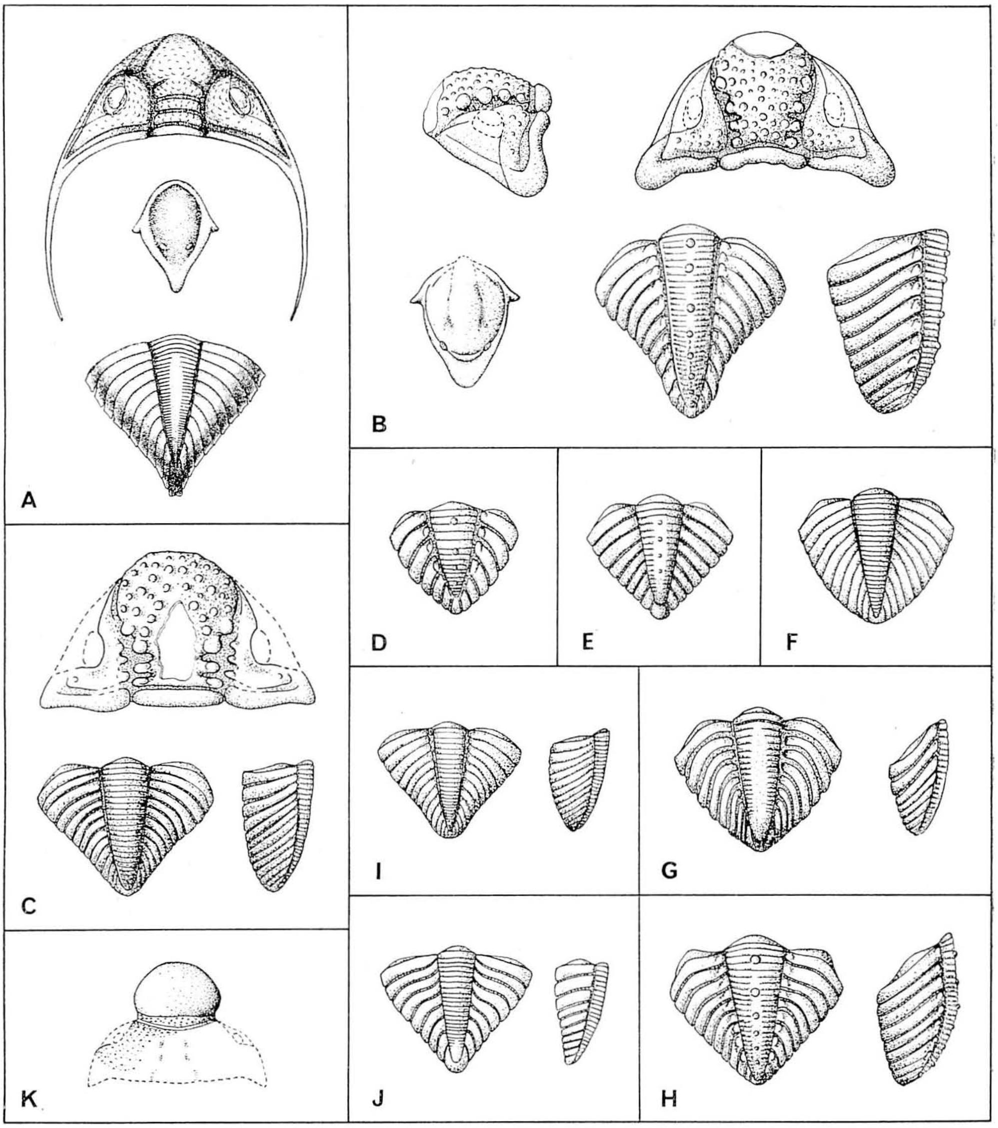
Pl. 10, Figs. 1, 2, 4; Text-fig. 7B

Description:—Cephalon strongly convex, semi-circular in outline, but anterior part more or less protruded; genal angle rounded and a little protruded posteriorly; glabella clavate, most expanded in anterior where it is one-third as wide as cephalon, gently convex in middle and posterior and abruptly slanting in anterior; four pairs of lateral furrows well marked by profound incision of lateral margin, but furrows are obsolete on glabella except for posterior two which are weak but traceable for some distance and die out within botryoidal tuberculation. Three pairs of tubercles along lateral margins very large; others a little smaller and their disposition complicate; basal lateral ridges slender. Occipital furrow relatively narrow; dorsal furrows very broad and deep, but interrupted by an occipital ring which is broader than glabellar base; posterior and lateral marginal furrows well pronounced. Marginal borders and occipital ring all convex and non-tuberculate. Cheeks tuberculate: eyes insofar as can be judged from their scars, fairly large and located in posterior and inner part of the cheeks. Facial sutures obliquely cutting lateral borders in front of genal angles. The preglabellar area is not well preserved.

Observation:—An incomplete cranidium (Pl. 10, Fig. 2) belongs to this new species judging from the expanded anterior portion of the glabella with the well rounded margin of lateral lobes with rather large tuberculation. A hypostoma (Pl. 10, Fig. 4) may also be referred to this species. Its frontal wings are much slender than those of *C. rex* (WANG, 1939, pl. 1, figs. 1, 6), and situated more anteriorly. As the result, the median lobation of the present species does not protrude the anterior margin of the hypostoma, while that of *C. rex* strongly projects with a distinct lateral boundary.

It is a question what type of pygidium matches this species among the A-1, 2, 3 and B-2 subgroups mentioned before, because all specimens obtained are disarticulate. Only one can do is, therefore, to presume that the possible combination of such separate portions judging from various natures of shape and ornamentation of the carapaces. The cephalon of *E. yokokurensis* is more distinctly tuberculate than another species *E. mamelon* which has rather low, indistinct tuberculation as mentioned later. The latter species is furthermore characteristic in its broader basal part of the glabella. These facts may imply the possible or plausible combination of *E. yokokurensis* with the stenorachis type and *E. mamelon* with the euryrachis type of pygidium respectively. One may speculate that the former may be assorted with the pygidium with tuberculation on the axial portion, i.e. the B-2 type as illustrated on Pl. 11, Figs. 5-7 in relation to the cephalic tuberculation of these species.

On the other hand, the euryrachis non-tuberculate pygidium (Pl. 10, Figs. 5, 6) might be combined with *E. mamelon*, though it is quite uncertain. Both of the



Text-fig. 7. Restoration of encrinurids.

A. *Coronocephalus kobayashii* HAMADA, 1959; reproduced from HAMADA (1959, p. 81, text-fig. 2). ×3/2.
B. *Encrinurus yokokurensis* KOBAYASHI and HAMADA, sp. nov. and B-2 type pygidium. ×5/4.
C. *Encrinurus mamelon* KOBAYASHI and HAMADA, sp. nov. and A-3 type pygidium. ×4/3.
D. *Encrinurus nodai* (B-1 type pygidium). ×2.
E. *Encrinurus ishii* KOBAYASHI and HAMADA, sp. nov. (B-3 type pygidium). ×1.
F. *Encrinurus kitakamiensis* SUGIYAMA, 1941 (A-1 type pygidium). ×2/3.
G. *Encrinurus tosensis* KOBAYASHI and HAMADA, sp. nov. (A-4 type pygidium). ×2.
H. *Encrinurus fimbriatus* KOBAYASHI and HAMADA, sp. nov. (B-4 type pygidium). ×5/4.
I. *Encrinurus* A-1 type pygidium. ×1.
J. *Encrinurus* A-2 type pygidium. ×2.
K. *Staurocephalus* ? sp. ×3.

remaining pygidia or the A-1 and A-2 types are undoubtedly stenorachis. They are similar in outline and convexity, and only a slight difference is in the number of pleurae. The A-1 subgroup (Pl. 10, Figs. 7, 8) has 13-14 lateral ribs on one hand, and the A-2 (Pl. 10, Fig. 9) probably 10 or less on the other. At this moment, it is impossible to confirm that these two stenorachis pygidia are conspecific with each other or in a certain range of variation within a species as the specimens available are quite insufficient in quantity and in quality as well.

Comparison:—This new species is quite different from *Coronocephalus rex* and *C. kobayashii* in the more obsolete lateral furrows, low but well developed tuberculation and lack of genal spines. In the development of the tuberculation, it is allied to *Encrinurus sinicus*, but the tuberculation is more complicated in the present species. Like *E. multisegmentatus* this species has basal lateral ridges on the glabella, but in this species two small tubercles lie on each ridge and a pair of median tubercles of them isolate the ridges.

Encrinurus konghsaensis may be the nearest to this species. It resembles this in the clavate outline of the glabella, four pairs of lateral notches, the basal ridge and the absence of genal spines. The genal angle is, however, more produced postero-laterally, if compared to the angle of this species. The basal ridges are confluent on the axial part and the postero-lateral furrows in front of this ridge are also persistent in *E. konghsaensis*. The disposition of tubercles is different from that of this species, and tubercles on the glabella are smaller than those of this species. In the possession of two nodes between the basal lobes this species agrees with *Encrinurus* (*Encrinurus*) *breviceps* HAAS, 1968, but it is quite distinct from the present species in many other aspects.

Encrinurus incertus (MITCHELL) described from the Middle Trilobite Beds of the Bounyongian Series in New South Wales (MITCHELL, 1924, pl. 10, fig. 7) also has some resemblance to the present species in its general outline and the rounded, posteriorly protruded genal angle of the cephalon. This Australian species is, however, different from *E. yokokurensis* in having the granulated occipital ring and posterior borders of the fixed cheeks.

Occurrence and repository:—Loc. 3 (Ys14); KPFM 618 (holotype) coll. by T. MATSUMOTO. Loc. 3 (Ys); KPFM 901, PAt 7369 (hypostome) coll. by T. IMAMURA.

Encrinurus mamelon KOBAYASHI and HAMADA, sp. nov.

Pl. 10, Fig. 3; Text-fig. 7C

Description:—This is represented by an imperfect cranidium. Its glabella consists of a large spheric frontal lobe and posterior part which comprises three lateral lobes and occipital ring; frontal lobe longer than the posterior part and ornamented by coarse but low, mamelon like tubercles apparently aligned in parallel to lateral and anterior margins of the lobe; lateral furrows extending into glabella from dorsal furrows, as deep as the latter at entrances, but soon shallowing adaxially; occipital furrow narrow but seemingly transversal; three lateral lobes becoming nodose at ends, corresponding two paraglabellar incisions and posterior marginal furrow of cheek; cheek margin protruded adaxially toward three lateral furrows taking mammillary shape, anterior one of which is particularly prominent; no fold, however, extending laterally into cheek from the projection; cheek or at least this part of the dorsal surface non-granulate.

Observation:—The anterior portion of the glabella is unknown. Somewhat poor preservation prevents more detailed observation on the nature of lateral furrows and especially of the lateral incision of free cheeks. The presence of such peculiar incisions along the dorsal furrows reminds one of the Southeast Asian genus *Langgonia* KOBAYASHI and HAMADA, 1971. But it has much smaller size of the cephalon with more distinct boss-shaped incision projected in between the lateral ends of glabellar lobes.

Comparison:—This unusual new species, though imperfectly known, is distinct from the preceding species, *Encrinurus yokokurensis* in the glabellar nodes and corresponding portion of fixed cheeks. In addition to that, the present species is characterized by less expanded frontal lobe than that of *E. yokokurensis* to show rather euryaxial lobation of the cephalon.

Encrinurus silverdalensis ETHERIDGE and MITCHELL and *E. borenorensis* FLETCHER, both described from Australia have somewhat similar development of tuberculation at the lateral ends of the glabellar lobes. But they are clearly provided with rather coarse tuberculation on the free cheeks, and some tubercles along the dorsal furrows form a certain incision to some degree.

Occurrence and repository:—Loc. 3 (Ys14); KPFM 16107 coll. by T. MAEDA, 1964, 12, 30.

Encrinurus kitakamiensis SUGIYAMA, 1941

Pl. 9, Figs. 19, 20, Pl. 11, Fig. 12; Text-fig. 7F

1941. *Encrinurus (Coronocephalus) kitakamiensis* SUGIYAMA. *Proc. Imp. Acad. Tokyo, vol. 17, no. 4,* p. 108, figs. 1, 2.

1959. *Coronocephalus kitakamiensis* (SUGIYAMA) by HAMADA. *Japan. Jour. Geol. Geogr., vol. 30,* pl. 6, figs. 19, 20.

Remarks:—This species is known of a few pygidia, and was first described as of *Coronocephalus.* SUGIYAMA noted some resemblance with the Chinese *Coronocephalus rex* in its multisegmentation of rachis for example. Only a significant difference between them was, however, on the much larger size of the Japanese form. But now one may easily understand that these two forms are distinct from each other, if not only the number of annulation but also of the relative breadth of the axial lobe to the pleural lobes be taken into account. *C. rex* has a wider axial lobe, i. e. of the euryrachis type pygidium belonging to the A group of our classification before mentioned. *E. kitakamiensis* evidently has a narrower rachis. Moreover the latter seems to be provided with more slender pleurae than *E. rex.*

In 1959 the present junior author also regarded this species as a *Coronocephalus.*

But there is no keen index to this generic assignment in the pygidial natures.

A pygidium of *Encrinurus mitchelli* (?) illustrated by ETHERIDGE and MITCHELL (1915, pl. 55, fig. 10) from New South Wales apparently belongs to the A-1 subgroup and is similar to *E. kitakamiensis* in general features except smaller size. *E. etheridgei* has an encrinurid cephalon but not of *Coronocephalus*.

Occurrence and repository:—Loc. 6 (*Encrinurus* bed of the Kawauchi Series); IGPS 61513-1 (holotype pygidium), 61513-2 coll. by T. SUGIYAMA.

Encrinurus nodai KOBAYASHI and HAMADA, sp. nov.

Pl. 11, Fig. 9; Text-fig. 7D

Description:—Only an incomplete pygidium at hand. The pygidium triangular in outline with blunt posterior termination; euryrachis, or the axial lobe occupies almost 1/3 the pygidial width at anterior extremity; paucisegmented and only six or seven blunt pleural ribs are counted and 16-17 annulations on the axial lobe; axial rings transversal with several round-topped tubercles along the axis; no distinct median band.

Remarks and Comparison:—This new species is quite distinct from other encrinurid pygidia from Japan in having the fewer number of pleurae and also some strong tubercles on its axial lobe.

As to the general outline and the B-1 type features, it reminds one of the lectotype of *Encrinurus punctatus* illustrated by TRIPP and WHITTARD (1951, pl. 3, figs. 1, 2). However, this popular European species and the widely distributed North American tuberculate species *E. ornatus* HALL and WHITFIELD (ex. BEST, 1961, pl. 124, figs. 12-20) as well are provided with more numerous pleurae (8-9) in general. Their posterior termination tends to be mucronate very often (ex. TRIPP, 1962).

Llandeilian *Encrinurus sexcostatus* SALTER also has the few number of pleurae (6-7), hence the specific name, but has no median tubercles on the axial lobe (SALTER, 1855, p. 1, pl. 4, figs. 9-11) being different from the present species.

Occurrence and repository:—Loc. 3 (Ys5) (*Falsicatenipora shikokuensis* horizon); PAt 7380 coll. by M. NODA.

Encrinurus tosensis KOBAYASHI and HAMADA, sp. nov.

Pl. 10, Figs. 10, 11; Pl. 11, Fig. 2; Text-fig. 7G

Description:—Three pygidia are at hand. The type specimen (Pl. 11, Fig. 2) triangular in outline, much wider than long, and has moderately euryrachis type features with a median band where no tuberculation is developed; more than 20 annulations are recognizable on the axial lobe; pleurae 9 or more in number and flat-top roof-shaped in cross section, gently curved posteriorly; pleural extremity not spinose.

Remarks:—Two other specimens (Pl. 10, Figs. 10, 11) are imperfectly preserved, but agree with the type specimen in its outline and nature of segmentation in axial and pleural lobes. The larger one is, however, so severely deformed along a fracture, which runs just on the axial lobe, that the median band is indiscernible. The smaller one is, on the other hand, the left antero-lateral portion is broken off. This species is easily distinguishable from similar non-tuberculate euryrachis pygidia from the G_3 limestone, or of the A-1 subgroup in its paucisegmentation.

Comparison:—*Encrinurus borenorensis* FLETCHER (1950, p. 227, pl. 56, fig. 6) is quite similar to this new species in its wide outline and segmentation. But, the surface of the axial rings especially in its anterior portion are distinctly tuberculate.

Occurrence and repository:—Loc. 3 (Ys); calcareous sandstone of the *Encrinurus tosensis* horizon, KPFM 13396 (holotype) coll. by T. OKUBO, 1967, 7, 12, Loc. 3 (Ys 6) KPFM 15213 coll. by T. OKUBO, 1967, 10, 9, 590 coll. by T. TAMURA, 1967, 2, 26.

Encrinurus ishii KOBAYASHI and HAMADA, sp. nov.

Pl. 11, Figs. 3, 4; Text-fig. 7E

Description:—Only two incomplete pygidia represent this new species. Triangular outline of the pygidium is suggested by a smaller specimen, probably wider than long or equidimensional; euryrachis type; axial lobe with a median band on which several small but distinct tubercles are superposed; axial annulations more than 20; lateral ribs 9 or 10 or more if complete; interpleural furrows shallow and wide; pleurae probably ornamented by small tuberculations.

Comparison:—This differs from the preceding species in having the tubercles on the median band and small granulations on the pleurae. This feature is much similar to that of the Australian *E. borenorensis* FLETCHER before mentioned. The anterior three annulations instead of five are, however, transversal on the axial lobe of the present species. Owing to the poor preservation, more close comparison between these two forms will be retained at this moment.

Occurrence and repository:—Loc. 2 (*Prantlia biloba* horizon); OCU PA0003 (holotype pygidium), OCU PA0004 (another pygidium) collected by K. ISHII.

Encrinurus fimbriatus KOBAYASHI and HAMADA, sp. nov.

Pl. 11, Figs. 10, 11; Text-fig. 7H

Description:—Represented by some pygidia. A well preserved pygidium (Pl. 11, Fig. 11) is selected as the type specimen which has a triangular outline with somewhat arcuate anterior margin owing to the posteriorly bent pleural ribes well inflated provided with distinct stenorachis; axial lobe about 1/4 as wide as the pygidial width in the dorsal view; 10 pleural ribs long and slender with moderate curvature, and attain twice as long as the breadth of the rachis; dorsal furrows and pleural furrows narrow but distinctly marked; axial lobes without a median band but with several rounded tubercles on the axias; 26-27 annulations transversal through the whole rachis; blunt and small granulations seen on some pleurae especially on the posterior four or five ones to form a boss-shaped inner ends along the dorsal furrows; outer termination of the pleurae not spinose but flattened and widened to some degree in a fimbriate form.

Comparison:—This beautiful pygidium is very similar to that of the preceding species in general feature except the absence of a median band on the axial lobe.

Encrinurus mitchelli FOERSTE from New South Wales (ex. ETHERIDGE and MITCHELL, 1915, pl. 55, figs. 1-3) agrees also to this in its outline, the number of segmentation both on the axial lobe and pleural lobes, but it has only a few anterior annulations transversal on the axial lobe, and is provided with a median band in the posterior rest portion.

Occurrence and repository:—Loc. 5 (auloporoid limestone); PAt 7381 (holotype) coll. by O. ONO, PAt 7382 coll. by O. SOFUÉ.

Subfamily Staurocephalinae PRANTL and PŘIBYL, 1947

Genus *Staurocephalus* BARRANDE, 1846

Staurocephalus ? sp. indt.

Pl. 11, Fig. 1; Text-fig. 6K

Description:—Only an imperfect cranidium was obtained. Glabella with an inflated anterior lobe of hemispherical shape, overhanging in front; anterior lobe slightly wider than long, being somewhat asperate with minute granules on the surface except for the posterior end where a narrow, coarsely granulate belt is present being parallel to a smooth, transversal constriction that separates the anterior lobe from the posterior glabella; lateral glabellar furrows not seen partly because of the poor preservation of this specimen and partly because of its probably effaced glabellar segmentation; fixed cheek also granulate, but posterior rim is much less ornamented; eye scar may be present at the anterolateral portion of the fixed cheek; genal spine unpreserved, or possibly absent, judging from the general feature of the posterior border of the cheek; marginal serration undetected.

Remarks:—This incomplete trilobite is somewhat enigmatic in its taxonomic position. The mode of the anterior lobe, which is rather strongly projected anteriorly and separated from the posterior glabella by a distinct constriction, however, may reject the possibility of its assignment to *Dindymene*. The type species of this genus, i.e., *Staurocephalus murchisoni* BARRANDE, 1846 (BARRANDE, 1852, pl. 43, figs. 28, 32; reillustrated in The Type Specimens of Fossils in the National Museum Prague "Trilobita", 197, pl. 15, fig. 7) from the Liteň formation has a similar less tuberculate zone at the constriction of the glabella. But the Barrandian species has distinct dorsal furrows and much coarse granulation on the anterior lobe.

Incidentally, *Encrinurus* sp. described by REED (1936, pl. 6, fig. 9) from the Southern Shan State has a largely inflated anterior lobe but no glabellar furrows at all, and is by no means of *Encrinurus*. This enigmatic Asian form is more akin to some cheirurids with a large anterior lobe such as *Dindymene*, *Hemisphaerocoryphe* or *Onycopyge* in its general proportion of the glabellar segmentation than to *Staurocephalus.*

Occurrence and repository:—Loc. 3 (Ys); PAt 7371.

Family Proetidae SALTER, 1864

The family Proetidae inclusive of five subfamilies of the Phillipsiidae is the most comprehensive one of the Trilobita which comprises 27 subfamilies (KOBAYASHI and HAMADA, 1973). Putting aside the Permo-Carboniferous proetoids and phillipsioids, how many subfamiles are represented in the Asiatic faunas is an interesting question. Therefore the writers gathered the known Asiatic proetoids as much as possible and tried to refer them to the subfamilies in modern trilobitology, assuming that previous identification and comparison are correct. As the result it was found that they would be possibly distributed to more than a dozen subfamilies as follows:

Proetinae: *Proetus* (*Proetus, Gerastos, Bohemiproetus, Orbitoproetus*), *Coniproetus* ?, *Isbergia* ?
Crassiproetinae: *Crassiproetus*
Lepidoproetinae: *Lepidoproetus* (*Lepidoproetus, Diadematoproetus*), ? *Perakaspis* (*Perakaspis, Krohbole*)
Cornuproetinae: *Cornuproetus* (*Buchioproetus,* ? *Quadratoproetus*)
Eremiproetinae: *Eremiproetus*
Unguliproetinae: *Unguliproetus* (*Unguliproetus*)
Proetidellinae: *Prantlia, Latiproetus, Pseudoproetus*
Prionopeltinae: *Prionopeltis,* ? *Malayaproetus*
Tropidocoryphinae: *Astycoryphe*
Decoroproetinae: *Decoroproetus*
Eodrevermanniinae: ? *Bailielloides*
Cyrtosymbolinae: *Cyrtosymbole* (*Calybole*), *Waribole, Macrobole, Langgonbole, Diacoryphe* ?, *Typhoproetus* (*Typhoproetus*), *Semiproetus*
Dechenellinae: *Dechenella, Lacunoproetus, Khalfinella, Praedechenella, Basidechenella, Monodechenella, Dechenellurus, Benessovella, Schizoproetus, Ganinella, Bitumulia, Linguaphillipsia,* ? *Palaeophillipsia*

Interrogation mark anterior or posterior to a generic name indicates a tentative subfamily reference of the genus or a tentative generic reference of an Asiatic proetoid species respectively.

a. Pre-Carboniferous proetids in East and Southeast Asia

Proetus (?) sp. indt. by WELLER, 1913 from Szechuan and *Proetus* sp. by REED, 1936 from the Shan States are two imperfectly known Ordovician trilobites. The former is a pygidium resembling *Basiliella lorenzi* KOBAYASHI (1951) and the latter a free cheek compared to *Proetus ramisulcatus* NIERZK.

In the Shan States, *Proetus* spp. a and b are reported by REED (1906) to occur in the Silurian Namhsim sandstones. The a and b species are represented only by a quadrate and ovate glabella respectively. In the Langkawi Islands, West Malaysia the following proetoids are known from the Lower Silurian.

Malayaproetus bulbus KOBAYASHI and HAMADA
Malayaproetus sp. nov.
Proetoid gen. et spp. indt. a and b
Proetoid (?) indt.

Malayaproetus is allied to the Proetidellinae as well as the Prionopeltinae in one or another biocharacter. In China is found *Latiproetus latilimbatus* (GRABAU) in the Middle Silurian of Central China. *Latiproetus* LU is here referred to the Proetidellinae.

The early Middle Devonian fauna of Kroh in the Malayan peninsula contains the following proetoids:

Perakaspis trapezoidalis KOBAYASHI and HAMADA
Perakaspis (*Krohbole*) *elongata* KOBAYASHI and HAMADA
Perakaspis (*Krohbole*?) *burtoni* KOBAYASHI and HAMADA
Proetoid, gen. et sp. indt.
Bailielloides inexpectans KOBAYASHI and HAMADA

Perakaspis and its subgenus *Krohbole* belong more probably to the Lepidoproetinae than the Cornuproetinae. *Bailielloides* was provisionally placed in the Eodrevermanniinae, but it is more similar to *Bailiella* of the Conocoryphidae than any genus of the Proetidae.

The Langgon red beds, Famennian-Tournaisian in age, of the Langkawi Islands and the Malayan peninsula yield the following species of the Cyrtosymbolinae.

Langgonbole vulgaris KOBAYASHI and HAMADA
Waribole perlisense KOBAYASHI and HAMADA
Macrobole kedahensis KOBAYASHI and HAMADA
Diacoryphe (?) sp.

Proetus cf. *coddonensis* by REED, 1920 from the Lower Carboniferous at Phattalung, Peninsular Thailand would be a cyrtosymbolid pygidium. *Typhloproetus sinicus* CHANG, 1955 was described from the Upper Devonian limestone of Kwangsi, South China. According to CHLUPAČ (1966), *Cyrtosymbole* (*Calybole*) and *Typhloproetus* (*Typhloproetus*) occur in Kueichow, South China.

Proetus chitralensis REED from the Lower Devonian of Chitral is represented by free cheeks and pygidia which were compared with *Proetus bohemicus*. *Proetus* (*Euproetus*) *mediospinus* REED, 1927 is founded on a pygidium from the Eifelian limestone of Talifu, Yunnan resembling *Proetus chamoeleo* RICHTER on one side and *Proetus eremita* BARRANDE on the other. *Proetus namanensis* MANSUY, 1916, from the schistes à *Spirifer crispus* in the Silurian-Devonian passage beds in Tonkin, Viet-Nam is here placed in *Proetus* (*Gerastos*). REED's free cheek of *Phaetonides* aff. *cyclurus* HALL from the Wetwin shale in the Shan States, Burma may be coeval to the Middle Devonian Hamilton fauna of North America. Incidentally, *Phaetonides* ANGELIN, 1954 is a synonym of *Prionopeltis* HAWLE and CORDA, 1847.

Proetus indonsinensis MANSUY, 1916 from Eifelian, Tonkin, Viet Nam and
Yunnan, China .... *Dechenella*
Proetus blondeli PATTE, 1929 from Middle Devonian, Viet-Nam
.... *Basidechenella*
Proetus aff. *macrophyllus* HALL by PATTE, 1929 from Middle Devonian, Viet-Nam
.... *Monodechenella*
Proetus chengi SUN, 1937, from Frasnian, Honan .... *Dechenella* ?
Proetus sp. (?) MANSUY, 1918 .... *Proetus* (*Gerastos*) *vietnamensis*
KOBAYASHI and HAMADA, nov.

In Japan, *Dechenella* (*Dechenella*) *minima* OKUBO was described from the Middle Devonian Nakazato Series in the Kitakami mountains. *Proetus* aff. *latilimbatus* GRABAU was included in the faunal list of the Gion-yama Series (HAMADA, 1961) and it is denominated here *Prantlia biloba*.

New Silurian proetoids described in this paper from Japan are as follows:

Proetus (*Proetus*) *subovalis* KOBAYASHI and HAMADA, nov.
Proetus (*Gerastos*) *subcarinatus* KOBAYASHI and HAMADA, nov.
Proetus (*Bohemiproetus*) *magnicerviculus* KOBAYASHI and HAMADA, nov.
Prantlia biloba KOBAYASHI and HAMADA, nov.
Decoroproetus (?) *granulatus* KOBAYASHI and HAMADA, nov.

b. Pre-Carboniferous proetoids from North and Central Asia

Proetus (*Phaeton*) *slatkowski* SCHMIDT, 1886, from Torgoshino near Krasnoyarsk was the oldest *Proetus* in Asia which is, however, known now to be a *Kooteniella* of the Dorypygidae and its age is late Lower Cambrian. *Proetus* (*Isbergia* ?) *mailisorensis* WEBER and *Proetus* sp. were described by WEBER (1914) respectively from the Middle Ordovician of North Kazakhstan and Upper Ordovician of Pribalkhash. The Proetidae are well represented in the Silurian fauna. In North Asia the family is represented by the Lower Silurian species as follows:

Proetus ramisulcatus NIERZKOWSKI (pygidium) from Eastern Taimyr (BALASHOVA, 1960)
Pseudoproetus bellus MAXIMOVA, 1962
Pseudoproetus tertius MAXIMOVA, 1962
Unguliproetus enodis MAXIMOVA, 1955
Unguliproetus aff. *enodis* MAXIMOVA, 1955 from the Siberian platform

Proetus tolli WEBER, 1951, occurs in the Llandovery of New Siberia. It resembles *Pseudoproetus* POULSEN, 1934, which is an Arctic Llandoverian genus of the Proetidellinae (?).

In Central Asia, WEBER (1932) described the followings from the Silurian of Turkestan.

Proetus bohemicus CORDA .... *Proetus* (*Bohemiproetus*)
Proetus conspernus ANGELIN .... *Proetus* (*Coniproetus* ?)
Proetus romanovskyi WEBER
Proetus aff. *decorus* BARRANDE .... *Decoroproetus*
Proetus markovskyi WEBER (Ferghana)
Proetus circumscriptus WEBER (Pribalkhash)
Proetus sp. (Pribalkhash)

The Proetidae flourished greatly in the Devonian period. WEBER's monogaph of the Turkestan trilobites includes the following species.

Lower Devonian	
Proetus bohemicus BARRANDE	*Proetus* (*Bohemiproetus*)
Proetus aff. *oehlerti* BAYLE	*Proetus* (*Proetus*)
Proetus chitralensis REED	*Proetus* (*Proetus*)
Proetus cf. *orbitatus* NOVAK	*Proetus* (*Orbitoproetus*)
Proetus cf. *myops* BARRANDE	*Proetus* (*Proetus*)
Proetus aff. *gosseleti* BARROIS	*Proetus* (*Proetus*)?
Proetus lepidus BARRANDE	*Lepidoproetus* (*Lepidoproetus*)
Middle Devonian	
Proetus aff. *gosseleti* BARROIS	*Proetus* (*Proetus*)?
Proetus triangulus WEBER	*Proetus* (*Proetus*)
Proetus champernowni WHIDHORNE	*Astycoryphe*
Proetus (?) sp. III	Comp. *Proetus* (*Proetus*) *koeneni* MAUER
Upper Devonian	
Proetus sp. I	Cyrtosymbolid ?
Proetus (*Cyrtosymbole* ?) sp. II	

Recently, MAXIMOVA (1968) added, besides various dechenellids, the following two from the Lower Devonian of Central Kazakhstan.

Proetus (*Proetus*) sp.	Comp. *Proetus* (*Orbitoproetus*) *orbitatus*
Proetus (*Crassiproetus*) *globosus* MAXIMOVA, 1960	

In 1951 TSCHERNYSHEVA described the following species of *Proetus* besides four species of *Dechenella* from the Devonian of the Kuznetsk basin:

Proetus buchi CORDA (D_1^2)	*Cornuproetus* (*Buchioproetus*)
Proetus subplanatus MAUER var. *granulata* TSCHERNYSHEVA	*Cornuproetus* (*Quadratoproetus*)
Proetus peetzi TSCHERNYSHEVA (D_2^2)	*Proetus* (*Proetus*)
Proetus lazutkini TSCHERNYSHEVA (D_3^1-D_2^2)	*Proetus* (*Proetus*)
Proetus kuznetskiensis TSCHERNYSHEVA (D_2^1)	*Praedechenella*
Proetus ex. gr. *bohemicus* CORDA (D_1^2)	*Proetus* (*Bohemiproetus* ?)
Proetus aff. *laevigatus* MAUER (non GOLDFUSS) (D_2^2)	*Unguliproetus* (*Unguliproetus*)
Proetus sp. (D_2^2)	Comp. *Proetus* (*Proetus*) *peetzi*

Subsequently, KHALFIN (1955) added *Proetus carinatus* KHALFIN from the Lower Devonian of the high Altai. It is now referred to *Khalfinella* by YOLKIN (1968) who has carried out a detailed study on the dechenellids in western Siberia. Prior to this, MAXIMOVA (1960) amplified proetoid species from the Devonian and Lower Carboniferous of the Rudi Altai as follows:

Proetus (*Proetus*) *oehlerti* BAYLE (D_2^1)	
Proetus (*Proetus*) *sibiricus* TSCHERNYSHEVA (D_2^1)	
Proetus (*Proetus*) *bohemicus supraconvexus* MAXIMOVA (D_2^1)	
Proetus (*Proetus*) ex. gr. *bohemicus* HAWLE & CORDA (D_2^1)	*Proetus* (*Bohemiproetus*)
Proetus aff. *retroflexus* BARRANDE (D_2^1)	*Proetus* (*Proetus*) ?
Proetus pseudocarbonicus MAXIMOVA (D_2^1)	Dechenellid
Proetus (*Semiproetus* ?) aff. *sargaensis* WEBER (C_1^1 b)	

Proetus (*Semiproetus* ?) *ussuilensis* var. *altaica* WEBER (C_1^1 b)
Cornuproetus cf. *holzapfeli* (NOVAK) (D_2^1) .... *Lepidoproetus* (*Diadematoproetus*),
Cornuproetus altaicus MAXIMOVA (D_2^1)
Eremiproetus cf. *eremita* (BARRANDE) (D_2^1)
Cyrtosymbole ? sp. (C_1^1 b)

Their ages are shown by D and C symbols with brackets behind specific names. For the dechenellids see our "*Devonian Trilobites of Japan*", now in preparation.

Subfamily Proetinae SALTER, 1864

Genus *Proetus* STEININGER, 1931

Proetus subovalis KOBAYASHI and HAMADA, sp. nov.

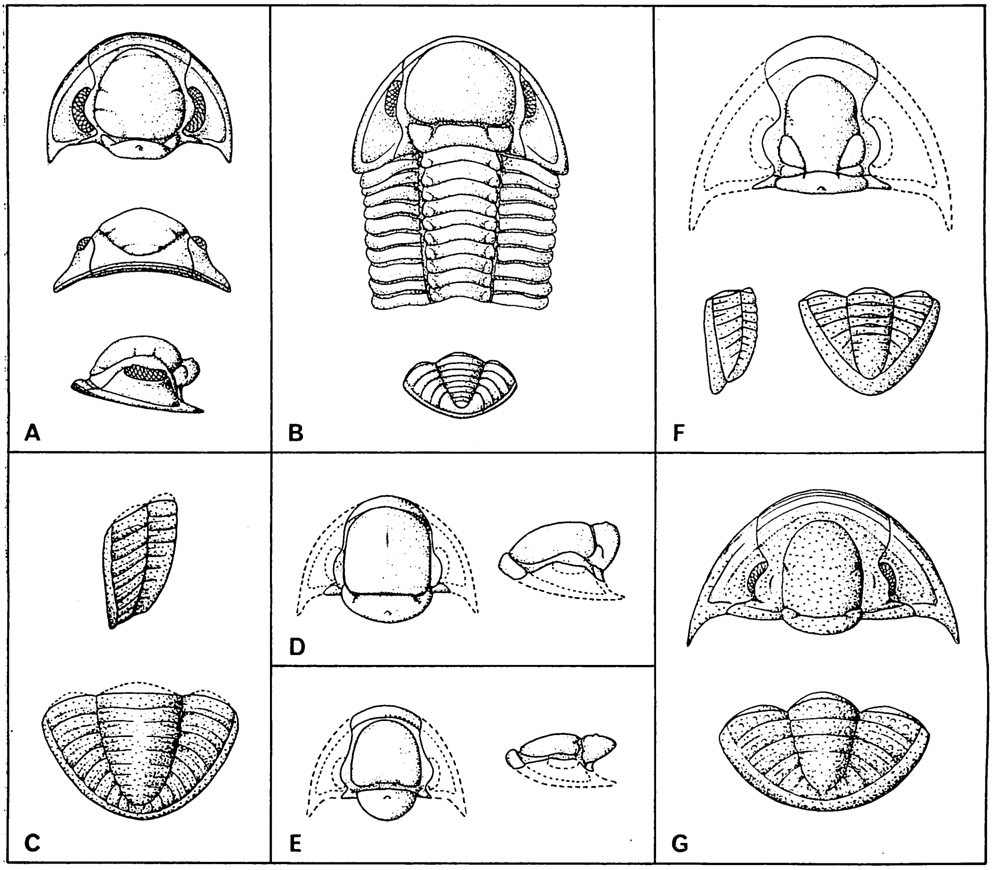
Pl. 12, Fig. 1, (?) Fig. 2; Text-fig. 8A

Description:—Glabella large, suboval, as long as wide, strongly vaulted; three pairs of lateral furrows seen very faintly only by cross light; posterior margin of basal lobes more or less produced back; occipital furrow pronounced; neck ring bearing a median tubercle; occipital lobe subtriangular and well defined; dorsal furrows narrow but a little broadened along frontal lobe; anterior marginal furrow deeper than dorsal ones; frontal border roof-shaped, broader than marginal furrow and its anterior side with parallel striae; anterior branches of facial sutures a little divergent forward, but recurved axially on doublure as seen in anterior view. Fixed cheeks presumably narrow.

Observation and Comparison:—This cranidium bears many important characteristics common with *Proetus concinnus* (DALMAN), but in that species the glabella is not so oval as this. The glabella is larger, broader and more protruded forward and the frontal border is more convex in anterior view in *Proetus* (*Gerastos*) *cuvieri* GOLDFUSS.

Among three pairs of lateral furrows on the glabella, two posterior ones are short, but the anterior ones are confluent with each other forming a shallow backward convexity at the junction and running very near the anterior margin of the glabella. This aspect is so unusual but apparently not accidental. Therefore, it may be the most conspicuous character of this form which would be evaluated more than specific, if it can be confirmed with more material.

An imperfect free cheek which may belong to this species has a large eye at a little posterior to the mid-length of the cheek. The marginal border is roof-shaped. Its striated outer side narrows backward and suddenly bent inward at genal angle. Its inner side reveals shallow concavity and nerve-like lines are seen in the posterior inner part. A triangular area between the eye and this depression is convex and a linear ridge runs forward along the eye from the anterior end of this area. Beyond the anterior branch of the facial suture the doublure extends from the marginal border. It is obliquely truncated by the connective suture. The surface is smooth.



Text-fig. 8. Restoration of proetoids.

A. *Proetus subovalis* KOBAYASHI and HAMADA, sp. nov. x2.
B. *Proetus* (*Gerastos*) *vietnamensis* KOBAYASHI and HAMADA, sp. nov. x1.4.
C. *Proetus* (*Gerastos*) *sugiharensis* KOBAYASHI and HAMADA, sp. nov. x4.
D. *Proetus* (*Gerastos*) *subcarinatus* KOBAYASHI and HAMADA, sp. nov. x3.
E. *Proetus* (*Bohemiproetus*) *magnicerviculus* KOBAYASHI and HAMADA, sp. nov. x3.
F. *Prantlia biloba* KOBAYASHI and HAMADA, sp. nov. x3.
G. *Decoroproetus granulatus* KOBAYASHI and HAMADA, sp. nov. x4.

Among the proetids from Gomi this free cheek fits best with the cranidium of *Proetus subovalis*. If this cheek belongs to an identical species with the cranidium, the triangular area and the concave depression are very distinctive features in *Proetus*.

Proetus bowningensis MITCHELL (ETHERIDGE and MITCHELL, 1892) has a similar glabella, but is less convex. No mention is given of occipital lobes. The preglabellar aspect is also different between the two species.

Occurrence and repository:—Loc. 3 (Ys15); KPFM 15188 (holotype) coll. by T. OKUBO, 1966, 1, 6.

Subgenus *Gerastos* GOLDFUSS, 1843

Proetus STEININGER, 1831, founded on *Calymene concinna* DALMAN, 1827, is different from *Gerastos cuvieri* GOLDFUSS, 1843 and its allies in the long conical glabella and possession of genal spines of moderate length. The differences are evident if compared the type species of these genera clearly illustrated by RICHTERS (1956) and WHITTINGTON and CAMPBELL (1967). The marginal border of the cephalon is generally convex in them but concave in *Proetus tenuimargo* RICHTER, 1909 for which *Longiproetus* was proposed by PILLET (1969) as a subgeneric name of *Proetus*. *Coniproetus* ALBERTI, 1966 differs from *Proetus* (*Proetus*) principally in the presence of a narrow preglabellar field.

In *Gerastos* the cephalon is massive and strongly convex. The genal angles are pointed into short spines in *Gerastos* s. str., but rounded in the groups of *Proetus bohemicus* and *Proetus orbitatus* for which PILLET (1969) proposed subgeneric name, *Bohemiproetus* and *Orbitoproetus* respectively. Eyes are small in the former and large in the latter subgenus.

Thus *Gerastos* which has long been synonymized with *Proetus* in MOORE's Treatise, ORLOV's Osnovy and many others can be distinguished from *Proetus* s. str. at least as a valid subgenus. PILLET who revived it as a genus divided into three subgenera, viz. *Gerastos*, *Bohemiproetus* and *Orbitoproetus* which correspond to the *cuvieri*, *bohemicus* and *orbitatus* groups by PŘIBYL, ERBEN and others approximately. They are accepted here as three subgenera of *Proetus*. *Crassiproetus* STUMM, 1953 has the cephalon closely resembling *Gerastos* s. str., but the pygidium of *Crassiproetus* is much longer and so multisegmented that OSMÓLSKA (1970) erected the Crassiproetinae for such genera.

Proetus (*Proetopeltis*) PŘIBYL, 1965 may be said a *Gerastos* but with a narrow preglabellar field. *Proetus fallex* BARRANDE, 1864, on which PŘIBYL erected *Erbenites* in 1964 also has a narrow but distinct preglabellar field. In addition, little paramedian tubercles on the glabella are conspicuous in *Erbenites*. Their references to *Gerastos* are still a question.

It is noteworthy that *Gerastos* and its allies occur more commonly than *Proetus* s. str. in eastern Asia.

Proetus (*Gerastos*) *subcarinatus* KOBAYASHI and HAMADA, sp. nov.

Pl. 12, Fig. 3; Text-fig. 8D

Description:—Glabella very large, subquadrate, broadly rounded in front, moderately convex, and subangulate along the axis; its length exclusive of neck ring slightly longer than its breadth; lateral furrows indiscernible; occipital ring of moderate size; occipital lobes relatively small and triangular; median tubercle present on the ring; fixed cheek very narrow and depressed; frontal border relatively narrow, clearly separated from glabella; test smooth.

Comparison:—This species is closely allied to *Proetus* (*Gerastos*) *cuvieri*, but the glabella is larger, less convex, quite parallel-sided and subcarinate axially; its lateral furrows are completely effaced and the occipital ring is more thickened mesially.

This species can easily be distinguished from *Proetus subovalis* by the subquadrate outline and lessened convexity of the glabella and the aspects of the occipital ring of this species.

Occurrence and repository:—Loc. 3 (Ys); PAt 7373 (holotype), 7374 (found in brachiopod limestone).

Proetus (*Gerastos*) *sugiharensis* KOBAYASHI and HAMADA, sp. nov.

Pl. 12, Figs. 5, 6; Text-fig. 8C

Description:—Pygidium semicircular, strongly convex, provided with marginal border and furrow. Axial lobe as wide as pleural lobe, highly elevated above pleural lobes, composed of about 10 rings and a terminal piece, anterior five of which are separated from one another by distinct ring furrows, but the succeeding furrows are linear and weak; short post-axial ridge extending from rounded terminal piece to posterior border. Pleural lobe nearly horizontal in very near anterior part of axial furrow, but most part is inclined laterally and posteriorly with moderate convexity, divided into 7 or 8 ribs by pleural furrows; in anterior ribs posterior band of a pleuron and anterior band of the succeding one separated by interpleural furrow which is linear proximally, but becoming wider distally; in posterior ribs two bands completely fused. Marginal furrow on each side persistent except for a few anterior segments in which it is interrupted by posterior bands; furrows of two sides separated in posterior by post-axial ridge; marginal border narrow and slanting outward with a weak convexity. Marginal border is flat and horizontal in lateral and posterior views. Test smooth.

Two pygidia are at hand where the larger one is imperfect.

Comparison:—This form is diagnostic of the pygidium of *Gerastos*, but the axial and pleural lobes have one or two segments more.

Occurrence and repository:—Loc. 3 (Ys6) where no other proetid remain is found; PAt 7375 (holotype), KPFM 809 coll. by M. HIRATA.

Proetus (*Gerastos*) *vietnamensis* KOBAYASHI and HAMADA, sp. nov.

Text-fig. 8B

1916. ?*Proetus namanensis* MANSUY, pars, *Mém. Serv. géol. l'Indochine, tom. 5, fasc. 4*, p. 58, pl. 8, fig. 9b, non 9a, ? 9c-d.

1918. *Proetus* sp. (?), MANSUY, *Bull. Serv. géol. l'Indochine, tom. 5, fasc. 2*, p. 12, pl. 2, figs. 8a-f.

MANSUY's *Proetus* (?) sp. 1918 in figs. 8a-c, which is composed of a cephalon and thorax, is the holotype and an associated pygidium in figs. 8c-f in the shale of Naca the paratype.

This species is well characterized by the vaulted cephalon, large, very broad and convex glabella extending as far as the frontal border, obsolete lateral furrows, pronounced occipital furrow, thick occipital ring provided with large distinct lobes at lateral ends, large eyes close-set to the glabella, lack of preglabellar field and genal spine, facial sutures cutting the middle point of the posterior border of the cheek and 10 thoracic segments with broad axial rings and rounded pleural ends.

The associated pygidium is broad, semicircular in outline and axial and pleural lobes provided with no less than 9 rings and 5 ribs respectively.

Crassiproetus crassimarginatus (HALL) and *Monodechenella macrocephala* (HALL) to which MANSUY compared his *Proetus* (?) sp. can easily be distinguished by their much longer and multisegmented pygidia.

The cephalon and thorax of *Proetus namanensis* MANSUY, 1916 in fig. 9b is the closest ally to this species. Incidentally, the cephalon of *P. namanensis* in fig. 9a, pl. 4, MANSUY, 1918 must be the lectotype of the species, insofar as can be judged from MANSUY's description.

Occurrence:—Naca and Naman, Pho-bin-gia and That-khé sheets, Northeast Tonkin, Viet-Nam. Série schisto-calcaire de Naca is now considered Eifelian and Série schisto-calcaire de Naman Emsian (SAURIN, 1956).

Subgenus *Bohemiproetus* PILLET, 1969

Proetus (*Bohemiproetus*) *magnicerviculus* KOBAYASHI and HAMADA, sp. nov.

Pl. 12, Fig. 7; Text-fig. 8E

Description:—Glabella ovate, gently convex; lateral furrows obsolete; occipital ring extraordinarily large, nearly semi-circular, carrying a median tubercle; preoccipital band narrow, depressed, and well defined by linear furrows on anterior and posterior sides; fixed cheek narrow, depressed; eyes of medium size located a little posterior to the middle of glabella; frontal border fairly thick, strongly convex and separated from glabella by frontal furrow near axis and by anterior triangular parts of fixed cheeks on the two sides; test smooth.

Besides the holotype cranidium there is a smaller glabella which is somewhat less ovate in outline.

Comparison:—This species best agrees with *Proetus* (*Bohemiproetus*), although it has a preoccipital band instead of occipital lobes. The unusually large occipital ring is most distinctive. In the subovate outline of the glabella this species resembles *Proetus subovalis*, but it is quite distinct from that species in the simple large occipital ring and other characteristics.

Occurrence and repository:—Loc. 3 (Ys); PAt 7376 (holotype cranidium).

Subfamily Proetidellinae HUPÉ, 1953

Genus *Prantlia* PŘIBYL, 1946

Prantlia biloba KOBAYASHI and HAMADA, sp. nov.

Pl. 12, Figs. 8, 9; Text-fig. 8F

Description:—Glabella exclusive of neck ring twice as long as preglabellar field, subconical, somewhat carinate from middle to posterior, provided with relatively large triangular basal lobes which are completely isolated by diagonal posterior lateral furrows; occipital ring strongly swelling up mesially and provided with occipital lobes and a median tubercle; palpebral lobe longer than basal lobe, set close to middle-posterior part of glabella; preglabellar field large, depressed, gently convexo-concave from inner to outer side; facial suture semicircular anterioa to eye.

Free cheek, hypostoma and thorax unknown.

Pygidium subtriangularly ovate, well convex, provided with distinct depressed marginal border which is somewhat thickened backward; axial lobe one-third as wide as pygidium at the first ring, but more or less abruptly narrowing in anterior half behind the ring; the remainder of the lobe more or less expanded at mid-length and then narrowing to blunt end; axial lobe highly convex, elevated above pleural lobes; anterior half of the former lobe divided into four rings by ring furrows of which the first is broadened mesially, but others are linear; posterior half of the lobe appears to be composed of 5 or more rings. Pleural lobes separated from the preceding by distinct axial furrow, gently inclined distally; its anterior part consists of 3 well defined ribs in addition to an anterior half-rib which are all well separated from one another by narrow but distinct interpleural furrows; posterior part composed of more than three ribs but furrows among them are too weak to count their number exactly.

Test smooth.

Comparison:—This species agrees best with *Prantlia longula* (HAWLE and CORDA, 1847) which is illustrated by HORNÝ and BASTL (1970) and CHLUPÁČ (1971), but the glabella of this species is more conical and its occipital lobes are more triangular. Only the posterior pair of lateral furrows are well pronounced and others completely obsolete in this species. The outline of the pygidium looks more or less triangular due in part to secondary lateral compression. CHLUPÁČ's pygidium of that species is evidently wider and more rounded and pleural furrows are more distinct in comparison to this species. In this species there is no trace of such a low preglabellar lobate tract as seen in *Prantlia* (*Tetina*) CHLUPÁČ, 1971.

Latiproetus latilimbatus (GRABAU) looks similar to this species, but the basal lobes are not clearly isolated by posterior lateral furrows, but the furrows are bifurcated near the axis. The anterior facial suture is nearly straight and diagonal and the frontal border low but convex in that species. The semi-circular outline of the pygidium and its narrower axial lobe are additional distinctions of that species.

Cyphoproetus depressus (BARRANDE) resembles this species in the cephalon, but the glabella is larger and more or less trapezoidal in that species. Its pygidium is quite different from this pygidium in the aspect of the pleural lobes.

Occurrence and repository:—Loc. 2; OCU PA0006 (holotype cranidium), OCU PA0002 (paratype pygidium) coll. by K. ISHII.

Genus *Latiproetus* LU, 1962

1962. *Latiproetus* LU, *Acta Pal. Sinica, vol. 10, no. 2,* p. 169.
1965. *Latiproetus* LU, et al. *Chinese Trilobites, vol. 2,* p. 574.

Type-species:—*Proetus latilimbatus* GRABAU, 1914; monotypic.

Remarks:—Proetoid having subovate glabella, three pairs of weak lateral furrows of which the posterior ones are bifurcated, triangular occipital lobes, large palpebral lobes in posterior, large preglabellar field, convex marginal border, short genal spines, forwardly divergent facial sutures, 9 segments in thorax which are truncated at lateral ends and semi-circular pygidium with distinct marginal border. The axial ring one-third as wide as a pleuron in the first pleural thoracic segment.

LU compared this genus with *Unguliproetus* and *Lepidoproetus*, but their genal spines are much longer. Occipital lobes are undeveloped or absent in them. They possess 10 segments in thorax. Their pygidia are broader and the posterior margins sinuated, especially distinctly in *Unguliproetus*. The marginal border is absent in the pygidium of *Lepidoproetus*.

This genus is more allied to *Prantlia* than these two genera, but it can be distinguished from *Prantlia* by the posterior lateral furrows not so pronounced on the glabella as they isolate the basal lobes and the eyes are larger in *Latiproetus*.

Distribution:—Middle and (?) Upper Silurian; Central and South China and western North America (see p. 37).

Subfamily Decoroproetinae ERBEN, 1966

Genus *Decoroproetus* PŘIBYL, 1847

Decoroproetus granulatus KOBAYASHI and HAMADA, sp. nov.

Pl. 12, Figs. 10–13; Text-fig. 8G

Description:—Glabella convex, subquadrate, well rounded in front, provided with a pair of short but deep oblique lateral furrows in posterior; palpebral lobes of moderate size opposed at posterior part of glabella; preglabellar field divided by a tropidial crest into a granulate inner part and a smooth outer band which the latter is separated by a furrow from the frontal border; facial sutures widely divergent from eyes with weak lateral convexity. Occipital region unknown. Test of cranidium granulate, especially coarse on glabella.

Associated pygidium semi-elliptical, obliquely truncated antero-laterally, almost twice broader than long, moderately inflated and provided with depressed narrow marginal border. Axial lobe short, conical, abruptly narrowing near posterior end, highly elevated above pleural lobes, composed of three or four rings and relatively large terminal piece; axial ring bearing a tubercle on each side, besides fine granules; axial furrow distinct. Pleural lobe exclusive of border, nearly as wide as axial lobe, nearly horizontal in adaxial part and gently slanting in the other, divided into five or six ribs by pleural furrows which run into border; first rib distinctly facetted laterally; succeeding ribs bisected by linear interpleural furrows into two unequal bands on which granules are aligned.

Observation:—Between two pygidia at hand the small one is better preserved. The large one is slightly deformed and largely exfoliated. Nevertheless it coincides with the small one in most details, even the paired tuberculation of the axial rings. Two thoracic segments attached to this pygidium are identical with those of the pygidium in transverse profile, and the pronounced pleural furrow dividing a pleuron into two bands. The thoracic pleurae are slightly falcate and depressed near the pointed lateral ends. These depressed terminals are on the extention of the marginal border of the pygidium.

Comparison:—The holotype cranidium looks diagnostic of *Decoroproetus* except for the frontal border which is considerably thicker than in *Decoroproetus decorus* (BARRANDE), 1846. Compared to the pygidium of the type-species of *Decoroproetus* this pygidium is shorter and its axial lobe broader and longer. The thoracic segments reveal better agreement with those of *D. decorus.*

Occurrence and repository:—Loc. 3 (Ys 14); PAt 7377 (holotype cranidium), 7378 (free cheek). KPFM 15230 coll. by T. OKUBO, 1965, 3. 23, 15465 coll. by T. OKUBO, 1966, 11. 23.

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Place Names

Arpishmebulaq	阿爾皮斯米布拉克
Beiyin Obo	白雲鄂博
Chekiang	浙江
Chungchao	中朝
Dongjeom-ni (Doten-ri)	銅店里
Ehimé	愛媛
Erhtaokou (Er-tao-gou)	二道溝
Fuchih	冨池
Fukuji	福地
Fukuoka	福岡
Gifu	岐阜
Gion (-yama)	祇園（山）
Gokasé	五ヶ瀬
Gomi	五味
Hida	飛驒
Higashi-uwa	東宇和
Higuchi-zawa	樋口沢
Hikoroichi	日頃市
Hitoégané	一重ヶ根
Honshu	本州
Hopei	河北
Hunghsien	洪県
Hupeh	湖北
Hwanghai-do	黄海道
Hwangho	黄河
Ichiyama	市山
Iwate	岩手
Jenhochiao	仁和橋
Kamitakara	上宝
Kansu	甘粛
Kaochiapien	高家辺
Katsu-ura	勝浦
Kawauchi (Kawauti)	川内
Kiangsu	江蘇
Kiau-tschang-pa	校場覇
Kilian-shan	祁連山
Kirin (Chilin, Jilin)	吉林
Kitakami	北上
Kôchi (Koti)	高知
Kueichow	貴州
Kuenlun	崑崙
Kuma—Kii	球磨一紀伊
Kuraoka	鞍岡
Kwangsi	廣西
Kyeomipo	兼二浦
Kyushu	九州
Lojoping	羅惹坪
Lunshan	崙山
Manchuria (Mandchrei)	満州
Miyaga-tani	宮ヶ谷
Nanking	南京
Nanshan	南山
Nishi-usuki	西臼杵
Ochi	越知
Ôfunato	大船渡
Okanaru	岡成
Paoshan	保山
Pingting	平定
Pupiao	蒲縹
Sakari	盛
Sakawa	佐川
Sesong-ni (Saisho-ri)	細松里
Shamaoshan	紗帽山
Shansi	山西
Shensi	陝西
Shihtien	施甸
Shihtzupu	十字鋪
Shikoku	四国
Shönn-hsüen-yi (Shensuanyi)	神宣駅
Sugihara	杉原
Suiyuan	綏遠
Szechuan	四川
Takainari (-yama)	高稲荷（山）
Tarim	塔里木
Tatsukawa	立川
Tienshan (Tien-Shan)	天山
Tokushima	徳島
Tsinling-shan	秦嶺山
Tsungyi	遵義
Yangsing	陽新
Yangtze (-kiang)	揚子（江）
Yehli	冶里
Yokokura (-yama)	横倉（山）
Yoshiki	吉城
Yümên	玉門
Yunnan	雲南
Washih	挖色
Weiyang-shan	淮陽山
Wuting	五頂

Postscript

1) A new Ordovician encrinurid, *Encrinurus spicatus*, from the Galena formation of Wisconsin was described by TRIPP (1974). The new species has coarse tuberculations on the cephalon which is provided with long and stout genal spines. The pygidium consists of rearward curved pleurae, six on each side, and a euryrachis with a few but large tubercles in the median smooth zone. As a whole, the newly described species is closely similar to *E. praecursor* from the Craighead mudstones of the Girvan district, Scotland as far as the cephalic characters are concerned on one hand, it may not belong to the *Encrinurus multisegmentatus* species-group as the pygidium has the smaller number of segments on the other. Additional pygidium of *Encrinurus* sp., which is akin to the new species but has eight pleurae on one side, was described also from the Galena formation of Iowa.

TRIPP, R. P. (1974): New encrinurid trilobites from the Galena formation (Ordovician) of Wisconsin and Iowa. *Jour. Pal., vol. 48, no. 3,* pp. 485-488, pl. 1.

2) The Ordovician-Silurian boundary is discussed by the present authors with reference to selected sequences in Eurasia. The boundary between the *Glyptograptus persculptus* zone and the *Dalmanitina* (*mucronata* and *nanchengensis*) beds at Lojoping, Hupeh, China must be almost exactly coeval with the classical boundary at the base of the *persculptus* zone at Moffat, Scotland. The boundary between the Alpeis horizon and the Ulkunas beds of the Tolen horizon in Kazakhstan is probably a little higher than these boundaries. Judging from the coexistence of *G. persculptus* with Ashgillian species of *Dalmanitina*, the Ulkunas beds must be the real transitional sediments which would contain a supplementary fossil record that is missing in about 30 meters barren mudstones beneath the *persculptus* zone at Dobb's Linn section.

KOBAYASHI, T. and HAMADA, T. (1974): On the time-relation between the graptolite zones and *Dalmanitina* beds near the Ordovician-Silurian boundary in Eurasia. *Proc. Japan Acad., vol. 50, no. 7,* pp. 487-492.

INDEX

Brackets bounding a page number indicate a provisional identification with cf., aff. or the like.

Plate 1

Explanation of Plate 1

Illaenoscutellum platiceps KOBAYASHI and HAMADA, gen. et sp. nov.................... p. 70

Figs. 1a–c. Upper, anterior and left lateral views of the holotype cranidium. ×1.0. Loc. 3 (Ys). KPFM 16090.

Bumastid, gen. et sp. indt. .... p. 52

Fig. 2. An incomplete pygidium showing somewhat flattened shield and its rounded posterior margin. ×2.0. Loc. 3 (Ys). PAt 7342 (found in brachiopod limestone).

Bumastus glomerosus KOBAYASHI and HAMADA, sp. nov................................ p. 47

Figs. 3a–c. Anterior, upper and left lateral views of the holotype cephalon. ×1.3. Loc. 3 (Ys14). KPFM 874-1.

Figs. 4a–c. Anterior, upper and left lateral views of the second cephalon. ×1.4. Loc. 3 (Ys14). KPF 874-2.

Figs. 5a, b. Upper and anterior views of the third cephalon. ×1.3. Loc. 3 (Ys14). KPFM 873.

Figs. 6a–c. Upper, posterior and right lateral views of the paratype cranidium. ×1.3. Loc. 3 (Ys14). PAt 7343.

Figs. 7a–c. Upper and left lateral and posterior views of an incomplete pygidium. ×1.5. Loc. 3 (Ys14). KPFM 16102.

Figs. 8a, b. Upper and posterior views of another pygidium. ×1.3. Loc. 3 (Ys14). KPFM 12704.


1a


1b


1c


2

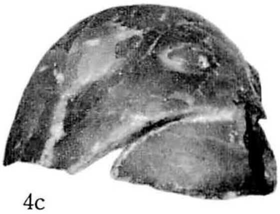

3a


3b


3c


4a


4b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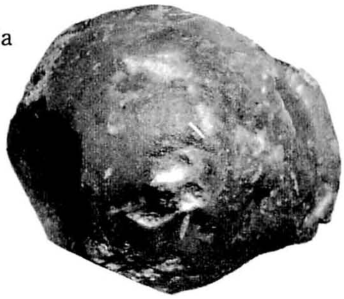
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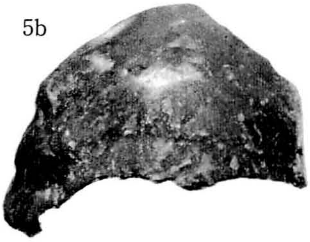

5b


6a


6b


6c


7a


7b


7c


8a


8b

Plate 2

Explanation of Plate 2

Bumastus subquadratus Kobayashi and Hamada, sp. nov. .... p. 50

Figs. 1a–c. Upper, anterior and left lateral views of the holotype cranidium. ×3.7. Loc. 3 (Ys15′). PAt 7344.

Figs. 2a–c. Three views of the second cranidium. ×3.7. Loc. 3 (Ys15′). KPFM 1323.

Bumastus (*Bumastella*) *spiculus* Kobayashi and Hamada, subgen. et sp. nov. .... p. 51

Figs. 3a–c. Upper, left lateral and posterior views of the holotype cephalon. ×4.8. Loc. 3 (Ys). PAt 7345.

Bumastus (*Bumastella*) *bipunctatus* Kobayashi and Hamada, sp. nov. .... p. 51

Figs. 4a–f. Anterior, posterior, two upper, left and right lateral views of the holotype cephalon with five thoracic segments. ×3.0. Loc. 3 (Ys8). KPFM 15155.

Figs. 5a, b. Upper and left lateral views of an incomplete cranidium (anterior portion unexposed). ×3.9. Loc. 3 (Ys). KPFM 1063.

Figs. 6a–d. Upper, anterior, posterior and left lateral views of a small cranidium. Note a detached free cheek with an eye in fig. 6d. ×2.1. Loc. 3 (Ys14). PAt 7346.

Figs. 7a–c. Three views of another small cranidium. ×2.4. Loc. 3 (Ys14). PAt 7347.

Figs. 8a–d. Upper, right lateral and posterior views of the paratype pygidium. Fig. 8d shows an external feature of the latex replica of this species. ×2.0. Loc. 3 (Ys). PAt 7348.

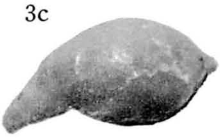
Figs. 9a, b. Upper and right lateral views of an incomplete pygidium. ×1.5. Loc. 3 (Ys). PAt 7349.


1a


2a


3a


3b


3c


1b


2b


5a


5b


1c


2c


8b


8a


4a


4b


8c

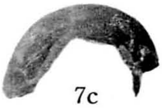

4c


4d


9b


9a


8d


7c


4e


4f


7b


6d


6c


6b


6a


7a

Plate 3

Explanation of Plate 3

Bumastus (*Bumastella*) cf. *bipunctatus* KOBAYASHI and HAMADA .... p. 51
Figs. 1a–c. Upper, right lateral and anterior views of a cranidium. ×2.8. Loc. 3 (Ys). KPFM 760.

Bumastus aff. *barriensis* MURCHISON, 1839 .... p. 48
Figs. 2a, b. Upper and right lateral views of an incomplete pygidium and thoracic segments. ×2.5. Loc. 3 (Ys). KPFM 1323.

Bumastus (*Bumastella*) *aspera* KOBAYASHI and HAMADA, sp. nov. .... p. 52
Figs. 3a, b. Upper and right lateral views of the holotype cranidium. ×4.6. Loc. 3 (Ys8). KPFM 809.
Figs. 4a, b. Upper and left lateral views of another cranidium. ×1.6. Loc. 3 (Ys14). KPFM 16106.
Figs. 5a–c. Upper, posterior and right lateral views of a cranidium. ×1.4. Loc. 3 (Ys8). KPFM 16100.
Figs. 6a–c. Upper and posterior right lateral views of the nearly complete paratype pygidium. ×2.2. Loc. 3 (Ys13). KPFM 1048.

Bumastid, gen. et sp. indt. (free cheeks) .... p. 52
Fig. 7. Right free cheek with eyes and incomplete genal angle. ×2.9. Loc. 3 (Ys). PAt 7350.
Fig. 8. An incomplete left free cheek showing an outer rim of the eye mound. ×1.5. Loc. 3 (Ys). PAt 7351.

Goldillaenus shinoharai KOBAYASHI and HAMADA, sp. nov................................ p. 53
Figs. 9a–c. Upper, anterior and lateral views of the holotype cranidium. ×5.7. Loc. 4 (Miyaga-tani). PAt 7352.

Phacops (Subgen. nov.?) *metacernaspis* KOBAYASHI and HAMADA, sp. nov.............. p. 81
Figs. 10a–e. Upper, anterior, antero-ventral (and right frontal), right lateral and left lateral views of a cephalon with another cephalon. ×3.0. Loc. 3 (Ys). (found in brachiopod limestone) KPFM 16088-1, 2.


1a


2b


2a


3a


1b


5a


5b


3b

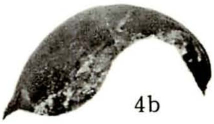

1c


4a


5c


7


9a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8


9c


9b

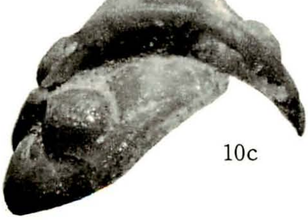

6b


6c


6a


10e


10d


10c


10a


10b

Plate 4

Explanation of Plate 4

Octobronteus (?) sp. .... p. 65

Figs. 1a–c. An outer cast (1a) and its clay mould (1b) and the counter part of 1a (1c). ×3.0. Loc. 1. Reproduced from KOBAYASHI and HAMADA, 1965, pl. 7, figs. 5a, b and 6.

Japonoscutellum japonicum (KOBAYASHI and HAMADA, 1965) .... p. 66

Figs. 2a–c. Upper, anterior and right lateral views of the holotype cranidium. ×2.7. Loc. 3 (Ys6). PAt 7353. Reproduced from KOBAYASHI and HAMADA, 1965, pl. 7, figs. 1–3.

Fig. 3. The smallest pygidium with 7 or more attached thoracic segments. The most part of the dorsal carapace is exfoliated being exposed the wide doublure. ×3.0. Loc. 3 (Ys14). KPFM 16099.

Fig. 4. The second smallest pygidium of the species in the collection. ×3.0. Loc. 3 (Ys14). KPFM 16095 (16093 is on the same slab).

Fig. 5. The third smallest pygidium. ×2.0. Loc. 3 (Ys14). KPFM 16093.

Fig. 6. A slightly deformed incomplete pygidium showing the wide doublure. ×1.3. Loc. 3 (Ys14). KPFM 15459.

Fig. 7. Latex replica of nearly complete but exfoliated pygidium showing the doublure. ×2.0. Loc. 3 (Ys). KPFM 16086.

Fig. 8. A larger pygidium. ×1.4. Loc. 3 (Ys14). KPFM 16104.

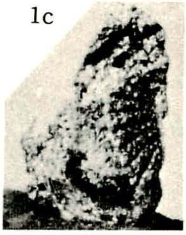
Fig. 9. Partly exfoliated pygidium. ×1.5. Loc. 3 (Ys). PAt 7354.

Fig. 10. Latex replica of a large incomplete pygidium. ×1.7. Loc. 3 (Ys). KPFM 13192.

Figs. 11a, b. Incomplete but the largest pygidium. a ×1.3, b ×1.6. Loc. 3 (Ys14). KPFM 16091.


1b


1a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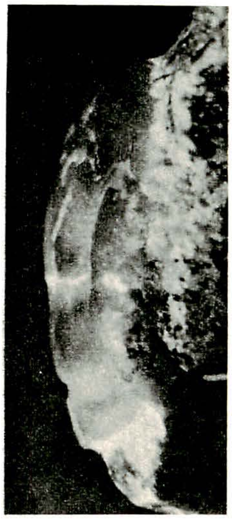
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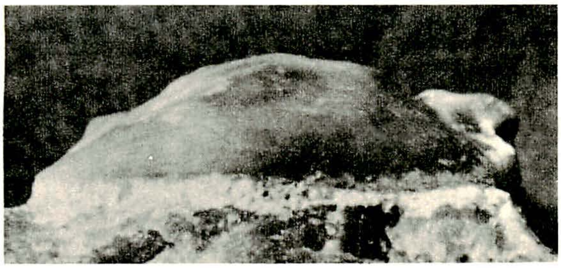
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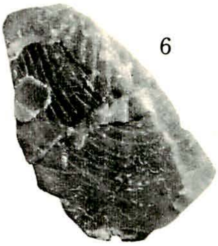
4


5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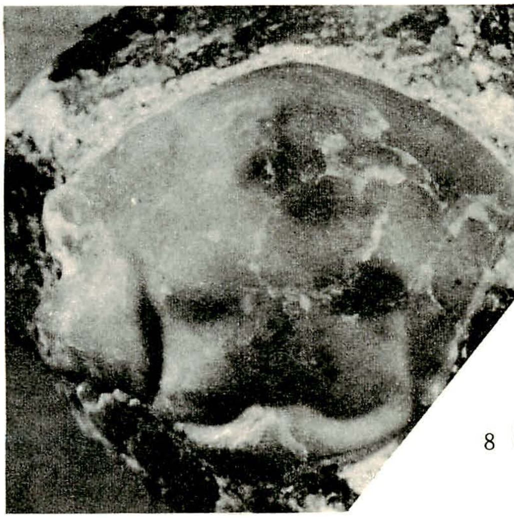

2a


3


7


8


9


10


11b


11a

Plate 5

Explanation of Plate 5

Juvenile scutelloid cephalon .... p. 67
Figs. 1a–c. Upper, anterior and right lateral views of a cephalon. ×5.5. Loc. 3 (Ys). PAt 7355.

Tosacephalus fungiformis KOBAYASHI and HAMADA, gen. et sp. nov. .... p. 69
Figs. 2a–c. Upper, anterior and right lateral views of the holotype cranidium. ×3.0. Loc. 3 (Ys14). KPFM 481.

Kosovopeltis angusticostata KOBAYASHI and HAMADA, sp. nov. .... p. 70
Fig. 3. The holotype pygidium. ×2.1. Loc. 3 (Ys8). KPFM 15334.
Fig. 4. Nearly complete pygidium. ×2.2. Loc. 3 (Ys15). KPFM 15189.
Fig. 5. Another pygidium. ×2.1. Loc. 3 (Ys). KPFM 837.
Fig. 6. The smallest pygidium. ×5.0. Loc. 3 (Ys). KPFM 15195.

Microscutellum primigenium KOBAYASHI and HAMADA, sp. nov. .... p. 74
Figs. 7a–c. Upper, anterior and right lateral views of the holotype cephalon. ×2.0. Loc. 3 (Ys). PAt 7383.
Fig. 8. An incomplete, largely exfoliated pygidium. ×2.5. Loc. 3 (Ys). KPFM 573′.
Figs. 9a, b. External replica (a) and internal mould of another pygidium. ×2.3. Loc. 3 (Ys15′). a: KPFM 723, b: 722 (counter part of a).
Fig. 10. A fragmentary pygidium. ×2.5. Loc. 3 (Ys14). KPFM 15464.

Microscutellum, sp. nov. .... p. 75
Fig. 11. An incomplete pygidium showing a narrower middle pleura than the preceding species. ×2.5. Loc. 3 (Ys14). KPFM 15386.

Scutelloid rostrum .... p. 76
Fig. 12. A large rostral plate. ×1.3. Loc. 3 (Ys). KPFM 1162.

Free cheek of scutelloid (?) .... p. 76
Fig. 13. Well inflated free cheek. ×2.7. Loc. 3 (Ys). KPFM 761.

Scutelloid free cheek .... p. 75
Fig. 14. Latex replica of a right free cheek. ×2.2. Loc. 3 (Ys11). KPFM 145.

Japonoscutellum japonicum (KOBAYASHI and HAMADA, 1965) .... p. 66
Figs. 15–18. Four incomplete pygidia. 15 ×2.3. Loc. 3 (Ys). KPFM 75. 16 ×1.3. Loc. 3 (Ys). KPFM 158. 17 ×2.9. Loc. 3 (Ys14). PAt 7356. 18 (latex replica) ×2.0. Loc. 3 (Ys14). KPFM 16095.


1a


2a


7a


1b


2b


7b


1c


2c


7c


5


4


3


12


13


8


9a


6


14


11


9b


10


15


16


17


18

Plate 6

Explanation of Plate 6

Cerauroides orientalis KOBAYASHI and HAMADA, 1973.................................. p. 84

Figs. 1a, b. Upper and right lateral views of the holotype cranidium (reproduced from KOBAYASHI and HAMADA, 1973, p. 542, figs. 1, 2). ×1.5. Loc. 3 (Ys14). KPFM 16098.

Figs. 2a, b. Upper and left lateral views of the paratype cranidium. ×1.5. Loc. 3 (Ys14). PAt 7357.

Figs. 3a, b. An incomplete glabella. ×2.4. Loc. 3 (Ys14). KPFM 15461.

Fig. 4. Ventral view of a hypostoma (reproduced from KOBAYASHI and HAMADA, 1973, p. 542, fig. 3). ×2.5. Loc. 3 (Ys14). PAt 7358.

Cerauroides elongatus KOBAYASHI and HAMADA, sp. nov. .... p. 85

Fig. 5. The holotype cranidium. ×2.5. Loc. 3 (Ys14). KPFM 16103.

Sphaerexochus hiratai KOBAYASHI and HAMADA, sp. nov. .... p. 88

Figs. 6a–d. Upper, left lateral, right lateral and posterior views of the holotype cranidium showing the general features. ×2.0. Loc. 3 (Ys15′). KPFM 1167-1.

Figs. 7a, b. Upper and anterior views of the largest carnidium. ×2.1. Loc. 3 (Ys). PAt 7382.

Fig. 8. Upper view of an incomplete cranidium. ×2.6. Loc. 3 (Ys15′). KPFM 1167-2.

Fig. 9. An enlarged figure of right lateral side of a cranidium showing the two feebly marked glabellar furrows (right-hand side anterior). ×4.3. Loc. 3 (Ys14). PAt 7359.

Figs. 10a–d. Posterior, upper, right lateral and anterior views of another cranidium. ×1.5. Loc. 3 (Ys14). KPFM 16094.

1a

2a

3a

5

1b

2b

3b

4

7a

6a

8

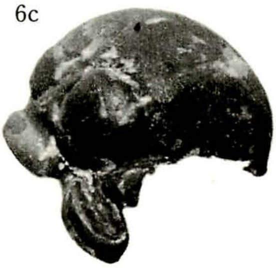
6b

7b

9

10c

6c



10a

6d

10b

10d

Plate 7

Explanation of Plate 7

Sphaerexochus hiratai KOBAYASHI and HAMADA, sp. nov. .... p. 88

Fig. 1. Upper view of the smallest cranidium. ×4.5. Loc. 3 (Ys14). PAt 7360.

Figs. 2a–c. Upper, right lateral and anterior views of another small cranidium. ×3.0. Loc. 3 (Ys). KPFM 74.

Figs. 3a–d. Upper, left lateral, anterior and posterior views of a cranidium. ×1.5. Loc. 3 (Ys14). PAt 7361.

Figs. 4a–e. Upper, posterior, frontal, left and right lateral views of a small cranidium. ×2.4. Loc. 3 (Ys15). KPFM 15221.

Figs. 5a–c. Upper, posterior and eight lateral views of an exfoliated cranidium. ×2.2. Loc. 3 (Ys14). KPFM 146.

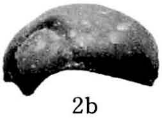
Figs. 6a–d. Upper, posterior, anterior, left and right lateral views of a cranidium. ×1.5. Loc. 3 (Ys14). KPFM 16105.

Figs. 7a–e. Upper, anterior, left lateral views and enlarged portion of the left glabellar furrows (left-hand side anterior). a–d ×1.5, e ×3.5. Loc. 3 (Ys14). KPFM 16092.

Figs. 8a, b. Posterodorsal and upper views of another cranidium. ×1.6. Loc. 3 (Ys14). PAt 7362.


1


2a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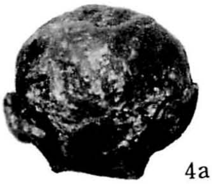
3c


2c


3b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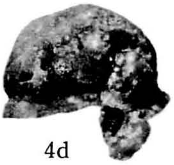
4c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4e


3a

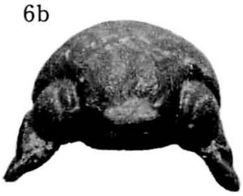

4b


5c


6c


3d

6b




5a


5b

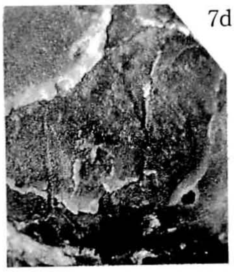

6d


7a

7b


6e


8a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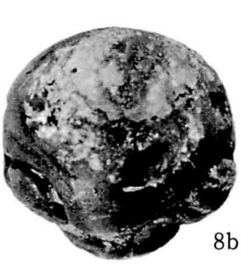

8b

Plate 8

Explanation of Plate 8

Sphaerexochus hiratai KOBAYASHI and HAMADA, sp. nov. .... p. 88

Figs. 1a–c. Upper, posterior and left lateral views of a pygidium. ×1.5. Loc. 3 (Ys14). PAt 7363.

Fig. 2. An incomplete pygidium. ×1.5. Loc. 3 (Ys14). KPFM 16096.

Figs. 3a–c. Upper, left lateral and posterior views of a pygidium. ×1.5. Loc. 3 (Ys14). PAt 7364.

Figs. 4a–c. Three views of another pygidium. ×1.5. Loc. 3 (Ys14). PAt 7365.

Fig. 5. Posterior view of an incomplete pygidium. ×1.6. Loc. 3 (Ys14). PAt 7366.

Sphaerexochus hiratai forma *robustus* KOBAYASHI and HAMADA, forma nov. .... p. 89

Figs. 6a–c. Upper, posterior and right lateral views of a large pygidium. ×1.5. Loc. 3 (Ys14). PAt 7367.

Fig. 7. Another incomplete pygidium showing a rather broad rachis. ×1.5. Loc. 3 (Ys14). KPFM 15227.

Sphaerexochus planirachis KOBAYASHI and HAMADA, sp. nov. .... p. 90

Fig. 8. Latex replica of a large but incomplete pygidium. ×1.7. Loc. 3 (Ys14). PAt 7368.

Apolichas truncatus KOBAYASHI and HAMADA, gen. et sp. nov. .... p. 80

Figs. 9a–c. Upper, anterior and left lateral views of the holotype cranidium. ×2.3. Loc. 3 (Ys). KPFM 628.

Fig. 10. A large paratype pygidium. ×1.0. Loc. 3 (Ys14). KPFM 16087.

Fig. 11. Another small and incomplete paratype pygidium. ×1.5. Loc. 3 (Ys14). KPFM 16097.

Fig. 12. Ventral view of a small hypostoma. ×2.5. Loc. 3 (Ys14). KPFM 15215.

1a

1c

2

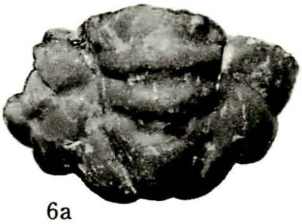
3a

1b

4a

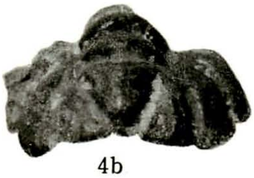
4c

3b



6a

3c



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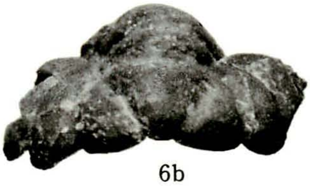

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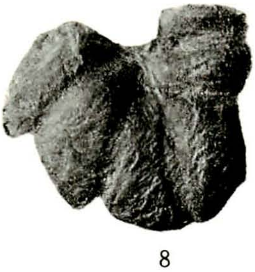

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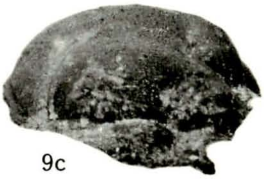
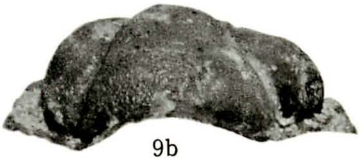


9c

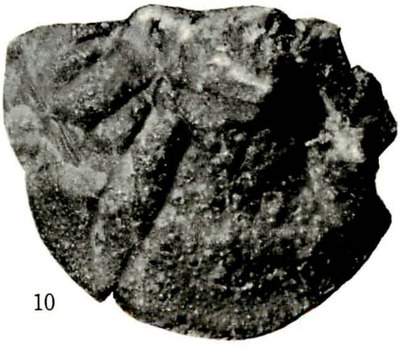
6c

7

11



9b



10

12

9a

Plate 9

Explanation of Plate 9

Coronocephalus kobayashii HAMADA, 1959 .... p. 101

(All figures are reproduced from HAMADA, 1959, pl. VI, figs. 1-18; Loc. 1)

Figs. 1a, b. Dorsal (1a) and oblique (1b) views of the holotype. Right genal spine in 1a is slightly disjuncted from fixed cheek. ×2. Specimen No. PAt 7280. Slightly deformed.

Fig. 1c. A clay model of a separated genal spine. ×2. PAt 7293-2.

Figs. 2a, b. Dorsal (2a) and upper frontal (2b) views of a paratype (PAt 7281). 2b shows a median furrow at anterior part of a frontal lobe and a narrow preglabellar furrow. Slightly deformed. ×2.

Fig. 3. An incomplete but not so deformed cranidium showing glabellar furrows and preglabellar furrow. ×3. Paratype, PAt 7282.

Figs. 4a-c. 4a shows a slab with a right (1) and a left (2) complete free cheeks, a hypostoma (3), a pygidium (4) with *Lingula* sp. (5). Posterior inner margin of 2 is slightly broken off to observe a hypostoma. 4b and 4c show lateral and frontal views of 2 respectively showing large stalked eye and thin lateral margin. ×2. PAt 7283.

Fig. 5. An external cast of a hypostoma (3 in Fig. 4a) showing maculae, lateral projections and posterior tongue-like plate. Note absence of median ridge. ×3. PAt 7283-3.

Fig. 6. An external cast of obliquely deformed hypostoma. ×2. PAt 7284.

Fig. 7. A clay model of right free cheek. ×2. PAt 7285.

Fig. 8. Ditto. Another specimen. ×2. PAt 7286.

Figs. 9a, b. An internal cast (9a) and a clay model of a slightly depressed right free cheek. ×2. PAt 7287.

Fig. 10. An internal cast of a right free cheek. ×2. PAt 7288.

Fig. 11. A clay model of a right free cheek. ×2. PAt 7289.

Fig. 12. A clay model of a left cheek. ×2. PAt 7290.

Figs. 13a, b. Four thoracic segments. Internal cast (13a) and clay model of an external model (13b). ×2. PAt 7291.

Fig. 14a. An internal cast of a thoracic segment. ×2. PAt 7292.

Fig. 14b. A clay model of a left pleural rib showing an anterior pleural band. ×3. PAt 7293-1.

Fig. 15. A clay model of a pygidium. ×2. PAt 7294.

Fig. 16. A clay model of a part of a pygidium showing discontinuity of annulations at the median zone of rachis. ×2. PAt 7295.

Fig. 17. Oblique view of a clay model of posterior part of a pygidium. ×2. PAt 7296.

Figs. 18a, b. An internal cast (18a) and a clay model of an external mould (18b) of posterior part of an incomplete pygidium showing posterior extremity with a few parallel ribs. ×2. PAt 7297.

Encrinurus kitakamiensis SUGIYAMA, 1941 .... p. 105

Fig. 19. The holotype pygidium (SUGIYAMA, 1941, p. 108, fig. 1). ×1.1. Loc. 6. IGPS coll. cat. no. 61513-1.

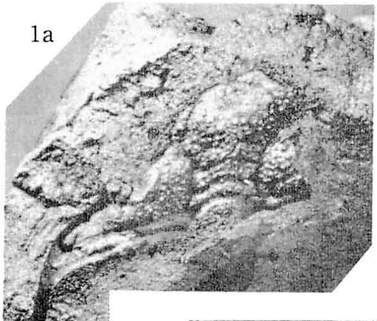
Fig. 20. The third pygidium (illustrated by HAMADA, 1959, pl. VI, fig. 21). ×1.2. Loc. ditto. IGPS coll. cat. no. 61540a. (Figs. 20, 21 photo. by KUMAGAI)

Encrinurus spp. by KAYSER, 1883 .... p. 99

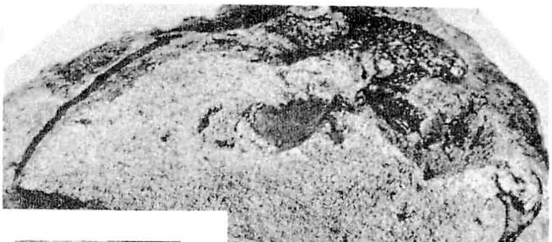
Fig. 21. A clay model of KAYSER's specimen in his fig. 21, pl. 2.

Fig. 22. A gypsum replica of KAYSER's specimen in his fig. 22, pl. 2.

(Reproduced from HAMADA, 1959, pl. VI, figs. 21, 22)

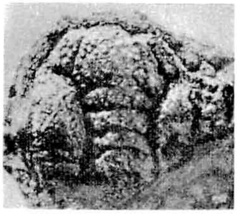

1a


1c


1b


4b


5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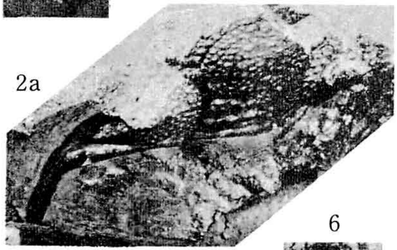
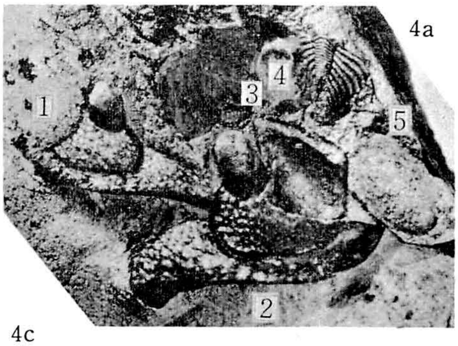

2a


2b


7



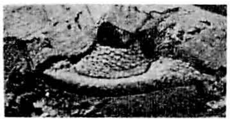
4a


6


9a


4c


8


9b


13b


13a


10


16

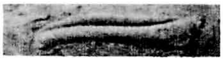

11


17


18b


18a


14a


14b


12


19


20


15


22


21

Plate 10

Explanation of Plate 10

Encrinurus yokokurensis KOBAYASHI and HAMADA, sp. nov. .... p. 102

Figs. 1a–c. Upper, anterior and left lateral views of the holotype cephalon. ×3.7. Loc. 3 (Ys14). KPFM 618.

Fig. 2. An incomplete glabella. ×3.0. Loc. 3 (Ys). KPFM 901.

Fig. 4. Ventral view of a hypostoma. ×4.0. Loc. 3 (Ys). PAt 7369.

Encrinurus mamelon KOBAYASHI and HAMADA, sp. nov. .... p. 104

Figs. 3a–c. Upper, anterior and right lateral views of the holotype cranidium. ×1.9. Loc. 3 (Ys14). KPFM 16107.

Encrinurus pygidium of A-3 Subgroup (probably of *E. mamelon*) .... p. 99

Figs. 5a–c. Upper, left lateral and posterior views of a pygidium. ×1.5. Loc. 3 (Ys14). KPFM 573.

Figs. 6a, b. Upper and right lateral views of another pygidium. ×2.6. Loc. 3 (Ys). PAt 7379.

Encrinurus pygidium of A-1 Subgroup .... p. 98

Figs. 7a, b. Upper and left lateral views of a pygidium. ×2.8. Loc. 3 (Ys14). PAt 7370.

Figs. 8a, b. Upper and right lateral views of another pygidium. ×2.7. Loc. 3 (Ys14). KPFM 575.

Encrinurus pygidium of A-2 Subgroup.. p. 99

Figs. 9a–c. Upper, right lateral and posterior views of a pygidium. ×2.8. Loc. 3 (Ys14). KPFM 459.

Encrinurus tosensis KOBAYASHI and HAMADA, sp. nov. .... p. 106

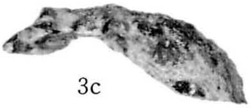
Figs. 10a–c. Upper, right lateral and posterior views of a small pygidium which belongs to the subgroup A-4. ×3.9. Loc. 3 (Ys6). KPFM 15213.

Fig. 11. Another large but depressed pygidium. ×1.8. Loc. 3 (Ys6). KPFM 590.

(Vide Pl. 11, Figs. 2a, b also)


1a


3a

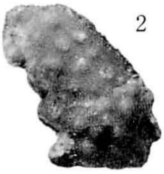

3c


4a


1b


3b


1c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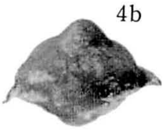
4c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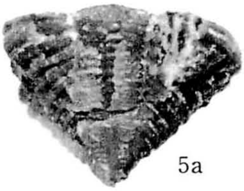
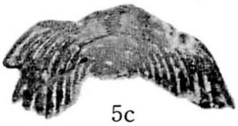

5a


5b


6b


6a


5c


9c


9a

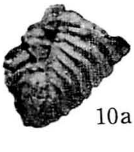

7b

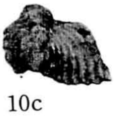

8b


8a


9b


7a


10a


10c


10b

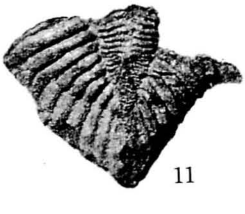

11

Plate 11

Explanation of Plate 11

Staurocephalus ? sp. indt. .... p. 108

Figs. 1a, b. Upper and left lateral views of an incomplete cranidium showing the inflated anterior glabella. ×4.5. Loc. 3 (Ys). PAt 7371.

Encrinurus tosensis KOBAYASHI and HAMADA, sp. nov. .... p. 106

Figs. 2a, b. Upper and left lateral views of the external replica of the holotype pygidium. ×2.5. Loc. 3 (Ys). KPFM 13396.

Encrinurus ishii KOBAYASHI and HAMADA, sp. nov. .... p. 107

Figs. 3, 4. Two internal moulds of the laterally compressed pygidia (Subgroup B-3). Fig. 4 shows the holotype. ×2. Loc. 2. OCU PA0004, OCU PA0003.

Encrinurus pygidium of Subgroup B-2 (probably of *E. yokokurensis*) .... p. 100

Figs. 5a–c. Upper, left lateral and posterior views of an incomplete pygidium. ×2.2. Loc. 3 (Ys14). KPFM 15466.

Figs. 6a–c. Upper, right lateral and posterior views of another incomplete pygidium. ×1.8. Loc. 3 (Ys14). KPFM 15409.

Figs. 7a–c. Upper, left lateral and posterior views of an extremely imperfect pygidium. ×2.6. Loc. 3 (Ys14). 15462.

Fig. 8. Upper views of a fragmentary pygidium. ×2.1. Loc. 3 (Ys14). KPFM 574.

Encrinurus nodai KOBAYASHI and HAMADA, sp. nov. .... p. 106

Figs. 9a, b. Upper and right lateral views of the holotype pygidium (Subgroup B-1). ×3.0. Loc. 3 (Ys5). PAt 7380.

Encrinurus fimbriatus KOBAYASHI and HAMADA, sp. nov. .... p. 107

Fig. 10. A small fragmentary pygidium. ×4. Loc. 5. PAt 7382.

Figs. 11a–c. Upper, posterior and right lateral views of an almost complete holotype pygidium. ×1.7. Loc. 5. PAt 7381.

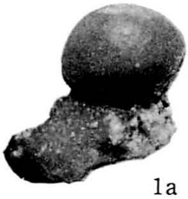
Encrinurus kitakamiensis SUGIYAMA, 1941 .... p. 105

Fig. 12. Severely depressed pygidium of the second specimen illustrated by SUGIYAMA, (1941, p. 108, fig. 2). ×1.0. Loc. 6. IGPS coll. cat. no. 61513-2.

Coronocephalus rex GRABAU .... p. 99

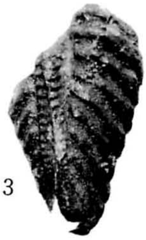
Fig. 13. Upper view of the internal mould of an incomplete pygidium. ×1.5. Loc. Hupeh, China. IGPS coll. cat. no. 64550.

(Figs. 12, 13 photo. by KUMAGAI)


1a


2a


2b


3


1b

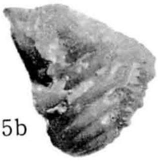

6c


5a

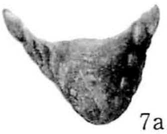

4


6a


6b

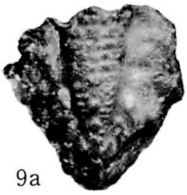

5b


5c


7a


8


9b


9a


7c


7b


10


11b


13


12


11c


11a

Plate 12

Explanation of Plate 12

Proetus subovalis Kobayashi and Hamada, sp. nov. .... p. 113

Figs. 1a-d. Upper, anterior, right and left lateral views of the holotype cranidium. ×2.7. Loc. 3 (Ys15). KPFM 15188.

Proetus cf. *subovalis* Kobayashi and Hamada .... p. 113

Fig. 2. A right free cheek with an eye. ×4.6. Loc. 3 (Ys). PAt 7372.

Proetus (*Gerastos*) *subcarinatus* Kobayashi and Hamada, sp. nov. .... p. 115

Figs. 3a, b. Upper and left lateral views of the holotype cranidium. ×5.0. Loc. 3 (Ys). PAt 7373.

Figs. 4a, b. Two views of another incomplete cranidium. The glabellar area is diagonally dislocated by a small fault. ×7.0. Loc. 3 (Ys) (found in brachiopod limestone). PAt 7374.

Proetus (*Gerastos*) *sugiharensis* Kobayashi and Hamada, sp. nov. .... p. 116

Figs. 5a-c. Upper, posterior and left lateral views of the holotype pygidium. ×5.8. Loc. 3 (Ys6). PAt 7375.

Fig. 6. Upper view of another incomplete pygidium. ×4.5. Loc. 3 (Ys6). KPFM 809.

Proetus (*Bohemiproetus*) *magnicerviculus* Kobayashi and Hamada, sp. nov. .... p. 117

Figs. 7a, b. Upper and left lateral views of the holotype cranidium. ×5.0. Loc. 3 (Ys). PAt 7376.

Prantlia biloba Kobayashi and Hamada, sp. nov. .... p. 118

Fig. 8. Upper view of the holotype cranidium (internal mould). ×5.0. Loc. 2. OCU PA0006.

Figs. 9a, b. Upper and left lateral views of the paratype pygidium. ×4.0. Loc. 2. OCU PA0002.

Decoroproetus granulatus Kobayashi and Hamada, sp. nov. .... p. 119

Figs. 10a-c. Upper, left lateral and anterior views of the holotype cranidium. ×5.2. Loc. 3 (Ys14). PAt 7377.

Fig. 11. A left free cheek with an eye mound. ×4.1. Loc. 3 (Ys14). PAt 7378.

Figs. 12a-c. Upper, posterior and right lateral views of a pygidium with two thoracic segments. ×4.0. Loc. 3 (Ys14). KPFM 15465.

Fig. 13. Upper view of another small pygidium. ×7.7. Loc. 3 (Ys14). KPFM 15230.

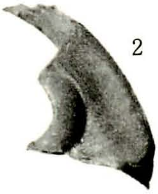

1a


1b


3a


4a


1c


2


3b


4b


1d


6


5b


7b

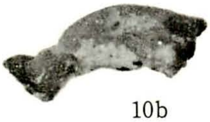

5a


5c


7a


10a


12b


10b


8

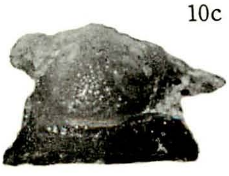

11


12c


12a


9a


9b


10c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