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Devonian Trilobites from the Fukuji Formation in the Hida Massif, Central Japan

By

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Abstract

Among trilobites from the Fukuji formation (Devonian) in the Hida Massif, Central Japan, six genera are distinguished: *Crotalocephalus, Gravicalymene, Proetus, Scutellum, Otarion* and ? *Craspedarges*. Most of them are provided with the Lower Devonian characters, but some with the Silurian features. Four abundant species belonging to the genera *Crotalocephalus, Gravicalymene* and *Proetus* are described and shortly discussed.

Introduction

Since KOZU (1911), many geologists studied stratigraphically and paleontologically the Devonian Fukuji formation. Above all, KAMEI (1955) divided the formation into three members and further into eleven beds. He recognized two coral zones and four subzones in them, mainly based on the faunal assemblage of favositoids. His work is partly revised and shown in Table 1.

Concerning trilobites from the Fukuji formation, KAMEI and IGO (1955) reported first *Cheirurus sternbergi*; KOBAYASHI and IGO (1956) described and illustrated *Cheirurus* (*Crotalocephalus*) *japonicus* and *Ch.* (*Cr.*) sp. Since then, following species have been reported: *Calymene* sp. (HAMADA, 1959), ? *Scutellum* sp. (KOBAYASHI and HAMADA, 1965), *Cheirurus* (*Crotalocephalus*) *japonicus*, *Ch.* (*Cr.*) sp. α, *Ch.* (*Cr.*) sp. β, ? *Gravicalymene* sp., *Scutellum* sp. (KOIZUMI and KAKEGAWA, 1970).

A promenade was constructed in 1971 along the eastern slope of Mt. Sorayama to observe fossiliferous limestone beds. Since then, many trilobite specimens have been collected. Most of them have been offered at my disposal for my graduation thesis at Kyoto University. They are, unfortunately, not satisfactorily preserved to be specifically identified, except for a single species. Four forms belonging to the genera *Crotalocephalus, Gravicalymene* and *Proetus* occur rather

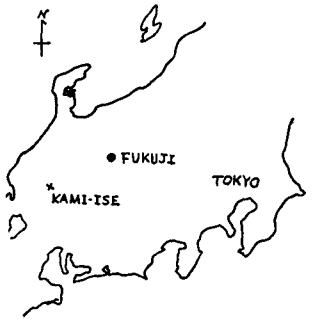

Fig. 1. Index-map of fossil locality.

abundantly, and are worthy to be described, because the former descriptions and illustrations of trilobites from the Fukuji formation are based on few fragmental specimens (Table 2).

In description, the morphological terms are mostly adopted from the list of HARRINGTON et al. (MOORE, editor, 1959).

Table 1. Division of the Fukuji formation (KAMEI, 1955; partly revised)

Fukuji formation	upper member	bed 11	gray sandy shale	*Favosites hidensis* zone	*F. ichinotanensis* sz.	F2d
			fault			
		10	black calcareous shale		*F. flexuosus* sz.	F2c
		9	gray massive limestone			
		8	black calcareous shale		*F. uniformis* sz.	F2b
		7	gray crinoidal limestone			
	middle member	6	green vitric tuff			
		5	gray limestone with tuff			
		4	alternation of tuff and ls.		*F. hidensis* subzone	F2a
		3	black impure limestone			
		2	blue acidic vitric tuff			
	lower member	1	gray limestone black limestone with shale black shale	*Favosites baculoides* zone		F1

Table 2. List of fossils

zone	bed	*Crotalocephalus (Cr.) japonicus*	*Crotalocephalus (Cr.)* sp.	*Granicalymene* sp.	*Proetus* sp.	*Scutellum* sp.	*Otarion* sp.	*?Craspedarges* sp.
F2d	11	+		+		+		
F2c	10	+		+	+	+		
F2b	9							
	8	+	+					
	7	+						
F2a	6							
	5							
	4							
	3							
	2							+
F1	1	+		+	+		+	

Description of species

Family Cheiruridae HAWLE and CORDA, 1847
Subfamily Cheirurinae SALTER, 1864
Genus *Crotalocephalus* SALTER, 1853
Subgenus *Crotalocephalus* SALTER, 1853
Crotalocephalus (*Crotalocephalus*) *japonicus* (KOBAYASHI and IGO)
plate 8, figures 1–9

1956, *Cheirurus* (*Crotalocephalus*) *japonicus* KOBAYASHI and IGO, partim, pp. 150–152, plate X, figures 1–3 (non plate X, figure 4)
1956, *Ch.* (*Cr.*) sp. indet. KOBAYASHI and IGO, pp. 152–153, plate X, figures 5a–b
1970, *Ch.* (*Cr.*) sp. α KOIZUMI and KAKEGAWA, p. 184, plate I, figures 4–7
1970, *Ch.* (*Cr.*) sp. β KOIZUMI and KAKEGAWA, pp. 184–185, plate I, figure 8

Description: Isolated cephalon, thoracic segments, pygidium and hypostoma are known.

Cephalon semicircular; convex dorsally. Glabella about 1/3 width (tr.) of cephalon at occipital ring; expanding forward, maximum width (tr.) at frontal lobe. 1L triangular, interrupted axially by preoccipital furrow and 1S. 3L interrupted axially by median longitudinal furrow, which joins 2S and 3S. 2L and 3L are blunt V-shaped. Frontal lobe large, much convex either longitudinally or transversely. 1S confluences with preoccipital furrow at the axis. 1S, 2S and 3S blunt V-shaped, 2S less angled than 1S and 3S. Occipital ring triangular, bearing a mesian tubercle and laterally paired tubercles. Finer tubercles on glabella entirely, weaker ones on occipital ring. Narrow anterior border along anterior margin of the frontal lobe without preglabellar field. Anterior section of facial suture running outward-forward from eye almost parallel with axial furrow; turning inward-forward at border furrow. Posterior section of facial suture running laterally from eye parallel with posterior margin of the cephalon, turning the direction backward along midline of lateral border, and turning again laterally to lateral margin. Two weak peaks on the border at each turning points. Librigene small; pitted except border. Fixigene large; tubercled and pitted except border. Pits coarser laterally. Border also tubercled but very obscurely. Eye round shaped; high above from cheek, close to glabella opposite 3L. Genal angle spined or angled.

Hypostoma imperfectly known; tubercled entirely.

Axial furrow of thorax tapering posteriorly. Each thoracic segments bearing two laterally-paired tubercles on axial ring. Pleural end of the segment pointed.

Pygidium with three axial rings; paired tubercles on the ring as thoracic segments. Pleural region with pleural- and interpleural furrows; three pairs of long

spines ejecting laterally-posteriorly. No terminal axial spines.

Remarks: *Crotalocephalus* was first erected by SALTER (1853) as a subgenus. But in the present paper, *Crotalocephalus* is treated as a genus, according to LANE (1971).

As discussed by KOBAYASHI and IGO (1956), the present species is characterized mainly by broad outline and low convexity of the dorsal shield, narrow axial rings of the cephalon and thorax, and lacking of terminal axial spine. It is separated from the *Crotalocephalus gibbus* group, and affiliated with the *Cr. myops* and *Cr. sternbergi* group. KOBAYASHI and IGO (1956, pp. 152–153, plate X, figure 5) described and illustrated *Cheirurus* (*Cr.*) sp., and KOIZUMI and KAKEGAWA (1970, pp. 184–185, plate I, figures 4–8) also *Ch.* (*Cr.*) sp. α and *Ch.* (*Cr.*) sp. β. But the differences pointed by them may be arisen from individual variation, and accented by preservation, judging from specimens in my hand.

KOBAYASHI and IGO (1956) and KOIZUMI and KAKEGAWA (1970) show a pygidium (plate X, figure 4) and pygidia (plate I, figures 6, 7), respectively. Their figures suggest that one pair of spines are existed. But such feature is not seen in any species of the genus *Crotalocephalus,* in which three pairs of spines are characteristic.

Some complete cephala at hand show that the fixigene is wider (tr.) than the occipital ring. And in the pygidium, pleural spines are not hook-like shaped but slightly curved. The features are also characteristic in Silurian species of the genus *Cheirurus*. Namely, the present species maintains such old features rather clearly for the genus *Crotalocephalus*.

Occurrence: The present species is rarely found from the F2d and F2b subzones, abundantly from the F1 zone and the F2c subzone through the present study.

Measurement: In cephalon, following lengths are measured (in mm).

a ; length (sag.) of cephalon
b ; length of frontal lobe
c ; width (tr.) of cephalon
d ; width of 1L
e ; width of 2L
f ; width of 3L
g ; width of frontal lobe
h ; width of occipital ring
* ; measured in half side and twiced
**; supposed

no.	pl. 8, fig.	a	b	c	d	e	f	g	h
1	1	35.9	14.3	57.8	20.9	21.2	21.9	22.8	18.1
2	2	32.8	14.6	51.0*	17.4	17.7	19.2	19.1	15.3
3	4	15.2	6.6	23.8	9.6	9.5	9.8	10.5	6.4
4	6	8.9	3.6	12.6*	5.6	5.5	5.9	6.0	3.6
5	7	—	—	40.4*	15.8*	15.2*	16.8*	19.6*	13.4**
6	8	20.0**	8.0**	—	9.2*	10.4*	10.8*	11.2*	—
7	—	21.3	9.6	—	11.8*	12.6	13.6	14.8	9.0*
8	—	33.7**	12.3**	—	21.0	22.4	23.6*	23.0**	15.5
9	—	31.2**	11.2**	59.0*	20.8	20.0*	20.8*	23.4*	18.0*

In pygidium, followings are measured.

i ; length (sag.) of pygidium without spines
j ; width (tr.) of pygidium without spines
k ; width of anterior axial ring
l ; length of posterior spine along it
m; length of middle spine along it
n ; length of anterior spine along it
* and **; same as in cephalon

no.	pl. 8, fig.	i	j	k	l	m	n
1	9	6.9	12.2*	6.0	6.9	4.2	—
2	—	9.4	17.7	9.6	4.8+	7.1+	—

Crotalocephalus (*Crotalocephalus*) sp.
plate 8, figure 10

Description: Only pygidium known. Pygidium triangular; axial ring narrower (tr.) than pleural regions. Three axial rings. Pleural and interpleural furrows distinct. Three pairs of pleural spines; anterior ones more conical and shorter, posterior ones cylindrical, middle pair intermediate. Surface of the pygidium finely tubercled.

Remarks: The present species is represented by a single specimen. It is distinguished from *Cr.* (*Cr.*) *japonicus* in pygidial region; namely the former has cylindrical spines, but the latter has flat spines, and the directions of anterior spines are more backward in the former species.

Occurrence: The specimen occurred from the F2b subzone.

Measurement: Followings are measured in the same way as in *Cr.* (*Cr.*) *japonicus* (above).

no.	pl. 8, fig.	i	j	k	l	m	n
1	10	12.1	17.0*	6.6	7.4	8.8	7.7

Family Calymenidae BURMEISTER, 1843
Subfamily Calymeninae BURMEISTER, 1843
Genus *Gravicalymene* SHIRLEY, 1936
Gravicalymene sp.
plate 8, figures 1–5
1970, ? *Gravicalymene* sp. KOIZUMI and KAKEGAWA, p. 183, plate I, figs. 1, 2

Description: Isolated cranidium, thoracic segments and pygidium are known.

Cranidium convex dorsally; glabella bell-shaped. Axial furrow deep and narrow. Deep preglabellar furrow between frontal lobe and anterior border, and no preglabellar field. Frontal lobe reaching forward than fixigene. 1S deepest, bifurcating with small intermediate lobe. 2S deep, wider (sag.) and shallower axially. 3S distinct and shortest. According to furrows, 1L isolated from the axial part of the glabella, ovate in shape. 2L smaller than 1L, but also almost isolated. 3L distinct but small. None papillated. Glabella entirely covered by fine tubercles. Occipital ring bow-shaped, curved forward at axial part. Occipital furrow wider (sag.) and shallower than the axial furrow and anterior border furrow. Fixigene convex; almost equal hight as glabella, but much lower anteriorly. Margin of the fixigene opposite axial furrow smooth. Librigene unknown. Eye also unknown, but palpebral lobe opposite 2L. Anterior section of facial suture tapering slightly from eye. Posterior section expanding backward from eye. Anterior border considerably convex laterally, tubercled.

Thoracic segment much convex laterally and saggitally; convexity greater in axial ring than in pleural region. Pleural end rounded.

Pygidium semicircular, posterior margin more linear. Axial ring wider (tr.) than pleural regions; six axial rings. Five pleural furrows distinct. Interpleural furrows shallower than pleural furrows; clear in surface, faint or disappear inside of dorsal shield. Pleural and interpleural furrows curved backward, and nearly rectangular with margin at posterior margin. Pygidium entirely tubercled.

Remarks: The present species shows deep, narrow (sag.) preglabellar furrow, highly lifted, thick anterior border and absence of papillation of glabellar lobes. These characters indicate the species to belong to the genus *Gravicalymene* (SHIRLEY, 1936). KOIZUMI and KAKEGAWA (1970, p. 183, plate I, figs. 1, 2) described and illustrated ? *Gravicalymene* sp. indet. from the Fukuji formation, and remarked that it might belong to another genus, because of ratios of glabellar lobes and some other

respects. But the differences are not so remarkable to separate the species from the present genus. That form is identical with the present species, judging from its important features.

The genus *Gravicalymene* ranges from the Upper Ordovician to the Lower Devonian, but the Ordovician forms and Devonian forms have possibility to be derived from different ancestors (WHITTINGTON, 1971). The present form is provided with the Devonian features, but differs clearly from any Devonian species descrived already. Anyway, the occurrence of the present species from Japan proves a widespread geographical distribution of the genus in the Devonian.

Occurrence: The present species is reported from the F2b subzone (KOIZUMI and KAKEGAWA, 1970), and occurs abundantly from the F1 zone and F2c subzone.

From the outcrop along the promenade of Mt. Sorayama, a considerable number of materials occur, but thoracic segments are few. Isolated segments would be deposited to make their posterior or anterior side in contact with still water bottom, owing to the strong convexity. Accordingly, it is difficult to find the segments in shale, on bedding planes.

Measurement: Followings are measured in cranidium.

a; length (sag.) of cranidium
b; length (sag.) of anterior border
c; width (tr.) of cranidium
d; width of 1L
e; width of 2L
f; width of 3L
g; length (sag.) of isolated 1L

no.	pl. 9, fig.	a	b	c	d	e	f	g
1	1	14.2	1.1	25.4+	15.1	11.5	9.9	4.4
2	2	14.9	1.5	20.1+	10.1	7.6	6.6	4.6
3	3	13.7	1.2	25.8	9.8	7.7	7.1	3.2
4	—	15.1	1.0	22.1	11.7	9.2	7.4	5.0
5	—	12.9	1.1	—	11.1	9.9	8.7	2.9

Followings are measured in pygidial region.

h; length (sag.) of pygidium
i; width of pygidium
j; width of axial furrows at anterior margin
k; average length (sag.) of five anterior axial rings

no.	pl. 9, fig.	h	i	j	k
1	4	12.6	21.2*	7.8*	1.5
2	5	13.1	22.9	9.0	1.6
3	—	12.8	25.0**	7.3	1.9

Family Proetidae SALTER, 1864
Subfamily Proetinae SALTER, 1864
Genus *Proetus* STEININGER, 1831
Proetus sp. indet.
(Plate 9, figures 6–9)

Descriptions: Isolated cranidium, librigene and pygidium are known.

Cephalon semicircular. Glabella oval, much convex dorsally; lifted high above from cheeks, glabellar furrows obscure. Preglabellar field very narrow (sag.). Anterior border convex dorsally in axial profile. Occipital ring unknown. Librigene broad; with lateral border and short genal spines. Facial suture opisthoparian; anterior sections expanding forward slightly.

Pygidium short (sag.); with border. Nine axial rings smooth, lifted strongly from pleural regions. Five pleurae in pleural region; pleural and interpleural furrows curved backward and ending rectangular with margin. Inside of dorsal shield, interpleural furrows faint. Postaxial ridge distinct, but no terminal axial spine.

Remarks: The present species has not been reported from the Fukuji formation. Its important features, such as narrow preglabellar field, rather short genal spine, and nine axial rings in the short (sag.) and wide (tr.) pygidium, indicate the present species belonging to the genus *Proetus*. The genus is devided into two subgenera, *Proetus* (s. s.) and *Cyphoptoetus*. But it is not determined which subgenus does the present species belong to, because of lacking enough materials.

Occurrence: The present species occurs commonly from the F1 zone and rarely from the F2c subzone.

Measurement: Followings are measured.
In cephalon;

a; existing length (sag.)
b; existing width (tr.)
c; length of glabella
d; length of anterior border
e; length of preglabellar field
f; width of glabella

no.	pl. 9, fig.	a	b	c	d	e	f
1	6	5.3	4.7	4.0	0.8	0.5	3.6
2	—	3.6	2.6	2.6	0.8	0.2	2.1
3	7	8.4	6.9				

In pygidium;

g; length of pygidium
h; length of axial rings
i; width of pygidium
j; width of axial ring at anterior margin

no.	pl. 9, fig.	g	h	i	j
1	8	2.8	2.4	5.7	1.7
2	9	2.8	2.3	4.2	1.3

Consideration

Seven species in six genera of trilobites occur from the Fukuji formation; *Crotalocephalus* (*Crotalocephalus*) *japonicus*, *Cr.* (*Cr.*) sp., *Gravicalymene* sp., *Proetus* sp., *Otarion* sp., *Scutellum* sp. and ? *Craspedarges* sp. Trilobite fauna of the Upper and Lower member of the Fukuji formation is almost uniform. The only trilobite found in the Middle member is ? *Craspedarges* sp. from the bed 2, and the present species occurs abundantly together with many pelecypods, gastropods and Rhynchonellid brachiopods. The assemblage shows a unique biofacies in the Fukuji formation, inasmuch as the other faunas are mainly composed of corals, bryozoan and Atripoid, Orthid and Strophomenid brachiopods. It is explained by a different lithofacies of the bed consisting mainly of tuffaceous sediments, while the other faunas are found in limestone facies.

The described trilobites show the Lower Devonian characters, but the Silurian features are kept also. The geological ranges of the genera mentioned above are as follows:

Crotalocephalus	Lower Devonian — Middle Devonian
Gravicalymene	Ordovician — Lower Devonian
Proetus	Ordovician — Middle Devonian
Otarion	Middle Ordovician — Upper Devonian
Scutellum	Middle Ordovician — Upper Devonian
Craspedarges	Middle Silurian — Upper Devonian

Therefore, from the trilobite, it is most possible that the Fukuji formation is the Lower Devonian in horizon.

Besides the trilobite fauna, the occurrence of *Rhizophyllum enorme* ETHERDGE (Rugosa) indicates the age of the formation to be the Siegenian or Emsian (RESEARCH GROUP for the PALAEOZOIC of FUKUJI, 1973), and the Lower Devonian fauna of conodonts is extracted from the bed 1 (ibid, unreported yet). The facts are in well concordance with the age from the trilobite fauna.

In Japan, following trilobites are reported from the Middle Devonian Nakazato series of Kitakami District: *Phacops okanoi* SUGIYAMA (MS), *P. nonakai* OKUBO, *Dechenella* (*Dechenella*) *minima* OKUBO and *Scutellum* (*Thysanopeltella*) *paucispinosum* (OKUBO) (listed by HAMADA, 1961). The fauna is clearly different from that of Fukuji. A trilobite fauna, which is found recently from Kami-Ise in the southwest part of Hida Massif, and composed of *Crotalocephalus* (*Cr.*) *japonicus*, ? *Gravicalymene* sp., *Proetus* sp. and *Scutellum* sp., is almost identical with that of the Fukuji formation. Any more comparable fauna of trilobites has not been reported from Japan.

The generic composition of trilobites of the Fukuji formation shows resemblance with that of the Lower — Middle Devonian strata in Germany, Turkey and Australia, and is more similar to that of the former two.

In addition to these trilobites, *Encrinurus* sp. has been collected by KITO from Hitoegane, from a rolled stone, about 2 kilometers northeast of Fukuji (unreported yet). It is no doubt that the Silurian strata also exist in the area, although the provenance has not been confirmed yet. Therefore, it is expected that the Middle Paleozoic of Hida District is rather longly ranged in age.

At last, I wish to record my sincere thanks to Mr. S. YAMAGOSHI of Natural Museum of Hida, who comprehended my study and helped me kindly in field surveys and offered me materials from his abundant collection. I also wish to acknowledge my appreciation of Prof. T. KAMEI's sympathetic aid and valuable suggestions, and of many advices of Prof. T. HAMADA and Mr. H. KOIZUMI. Of the members of the Research Group for the Palaeozoic of Fukuji, Drs. M. KATO, K. MORI and Y. NOGAMI gave me significant discussions and critisisms, Messrs. K. KITO, T. OHNO and T. ONO offered me their important specimens. The specimens are also offered from Messrs. M. TATEMATSU, Y. MIZUNO and K. KITAGAWA.

The specimens, used in the present study, are stored in the Natural Museum of Hida, in Fukuji, except borrowed ones from my friends.

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Explanation of plates and figures

plate 8.

Figs. 1–9 *Crotalocephalus* (*Crotalocephalus*) *japonicus* (KOBAYASHI and IGO)
- 1 Cranidium from bed 1, showing paired tubercles on occipital ring; ×1
- 2, 3 Internal moulds of cephalon from bed 1; ×1
- 4a Dorsal view of cranidium, outer surface; ×1.5
- 4b Lateral view, 4a, b from bed 7; ×2.5
- 5 Cranidium from bed 1, outer mould; ×1
- 6 Cranidium from bed 10, outer surface; ×3
- 7 Cephalon from bed 8, outer surface; ×1.5
- 8 Glabella from bed 11, internal mould; ×1.5
- 9 Pygidium from bed 11, outer mould; ×3

Fig. 10 *Crotalocephalus* (*Crotalocephalus*) sp.
Pygidium from bed 8, internal surface; ×1.5

plate 9.

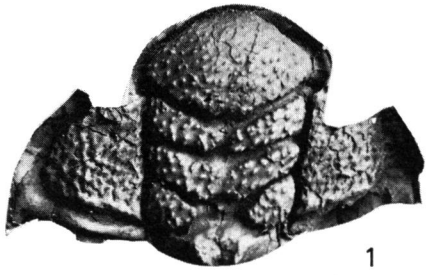
Figs. 1–5 *Gravicalymene* sp.
- 1, 2 Cranidium from bed 1, outer surface; ×1
- 3 Cranidium and pygidium with Brachiopods from bed 1; ×1
- 4, 5 Pygidium from bed 1, outer surface; ×1

Figs. 6–9 *Proetus* sp.
- 6 Cranidium from bed 1, outer surface; ×3
- 7 Librigene from bed 1, internal mould; ×3
- 8, 9 Pygidia from bed 1, internal mould (partly outer surface); ×3

Figs. 10, 11 *Otarion* sp.
- 10 Cephalon from bed 1, internal mould; ×6
- 11 Thorax and pygidium from bed 1, internal mould (partly outer surface); ×6

Figs. 12–14 ? *Craspedarges* sp.
- 12, 13 Cranidia from bed 2, internal mould; ×3
- 14 Pygidium from bed 2, internal mould; ×3

Figs. 15, 16 *Scutellum* sp.
- 15 Cranidium from bed 10, outer surface; ×3
- 16 Pygidium from bed 11, outer mould; ×2



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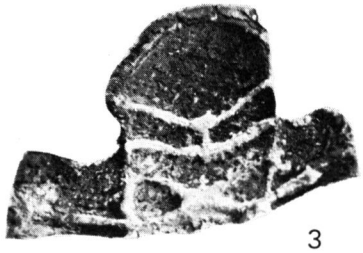

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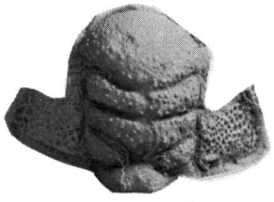
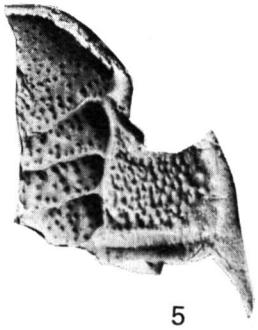


4 a

4 b



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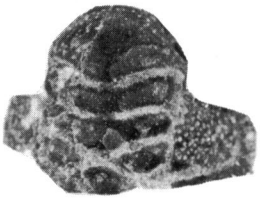

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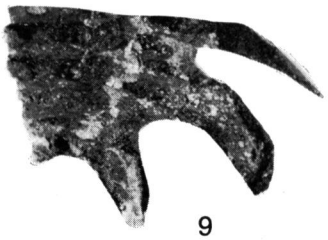

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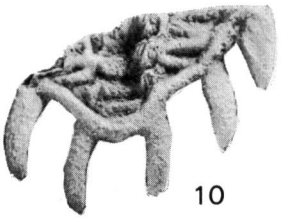

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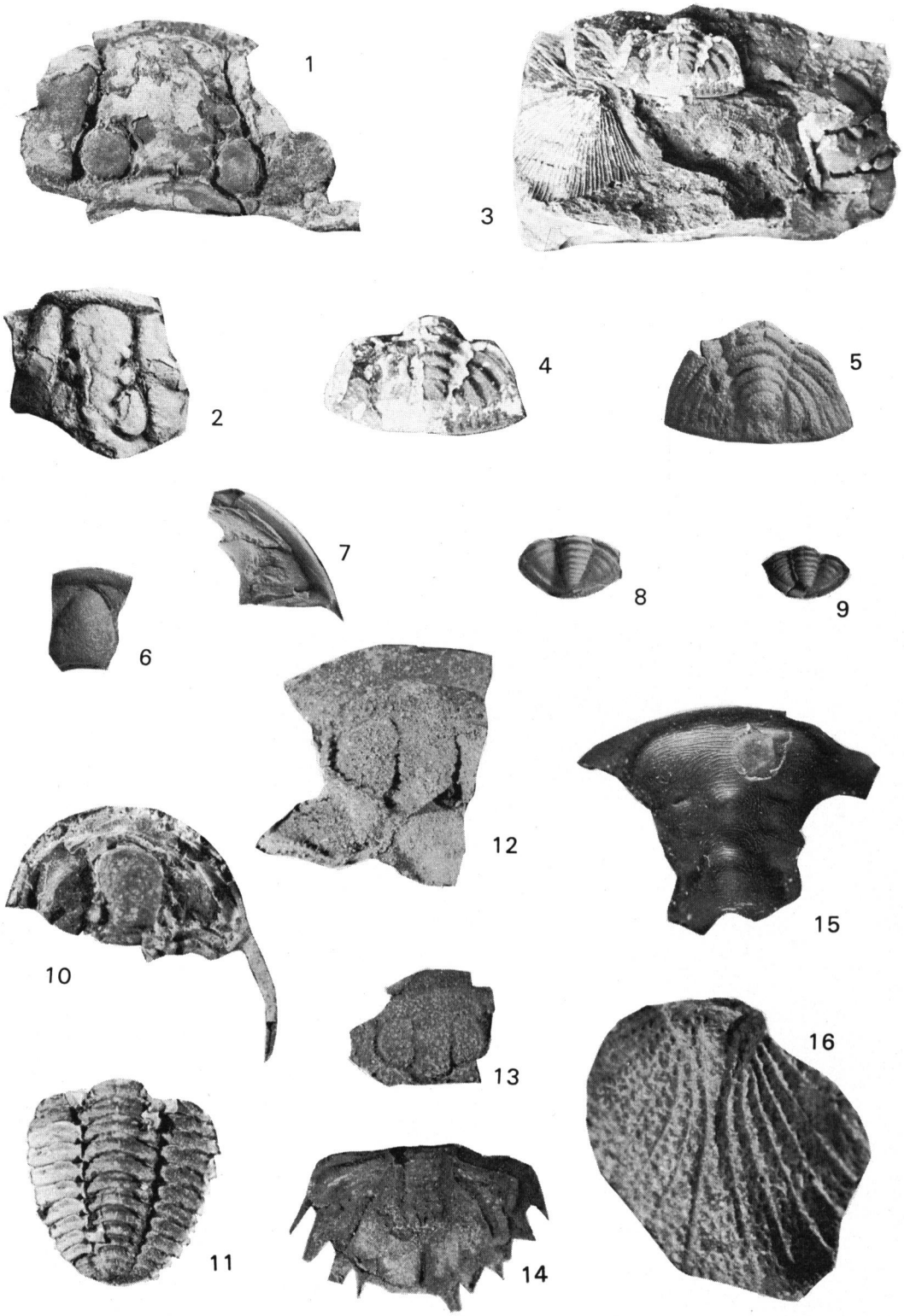

OKAZAKI: Devonian Trilobites from the Fukuji Formation