

A NEW GRAPTOLITE FAUNA FROM THE LOWER ORDOVICIAN SHALE OF TSAIDAM, CHINGHAI PROVINCE

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(With 5 plates and 4 text-figures)

I. Discussion on the stratigraphical position of the graptolite-bearing shale and the distinguishing features of the fauna

Our country, being vast in territory and rich in natural resources, unremittingly affords us interesting scientific materials of both theoretical and practical significance. The finding of the new graptolite fauna from the Ordovician shale of Tsaidam is one of a thousand like instances. This finding brings forward a series of scientific problems which we should resolve, and thus points out more definitely the direction in which we must lay stress on our study.

The graptolites were discovered and collected in 1956 by Comrade Sun Tien-Ching and other members of the Laboratory of Geomechanics, Ministry of Geology, from the Ordovician shale at Shih-Hui-Kou, a pass across the range of hills about 80 kilometers to the Southeast of Ta-Tsai-Tan, a village in the eastern part of Tsaidam Basin. According to the geological section surveyed by the geological party, the Ordovician deposits exposed there commence with a sequence of thick-bedded siliceous limestones which amount to a thickness of about 1000 meters and contain trilobites and straight-shelled cephalopods. Next comes the thin-bedded limestone which is in turn overlain by the black shale. The latter measures about 100 meters in thickness and carries the graptolite fauna.

Having studied the fossil specimens it is revealed that the fauna comprises altogether 18 species and varieties, among which 10 forms are new. They are as listed below.

1. *Loganograptus tsaidamensis*, sp. nov.
2. *Loganograptus* cf. *gracilis* Mu
3. *Tetragraptus harti* Hall, T. S.
4. *Didymograptus linealis*, sp. nov.
5. *Didymograptus nodosus* Harris
6. *Isograptus chinghaiensis*, sp. nov.
7. *Isograptus curvithecatus*, sp. nov.
8. *Isograptus caduceus* (Salter) mut. *nanus* Ruedemann
9. *Trigonograptus praelongus* Keller et Lisogor
10. *Trigonograptus ensiformis* (Hall)
11. *Glyptograptus dentatus* (Brongniart), var. *intermedius*, var. nov.
12. *Pseudoclimacograptus romanovskyi* Keller, var. *sinensis*, var. nov.
13. *Glossograptus* cf. *echinatus* Ruedemann
14. *Paraglossograptus regularis*, sp. nov.
15. *Paraglossograptus latus*, sp. nov.
16. *Paraglossograptus multifibratus*, sp. nov.
17. *Paraglossograptus multifibratus*, var. *longus*, sp. et var. nov.

18. *Cryptograptus tricornis* Carruthers

All the genera listed above are known to be of usual occurrence in Lower Ordovician formations, except one, *Paraglossograptus*, which is recently established by Comrade A. C. Mu. Eight (Nos. 2, 3, 5, 8, 9, 10, 13 and 18 in the above list) out of eighteen species and varieties have been recorded by previous authors as Lower Ordovician forms. It is therefore beyond doubt that the fauna is of Lower Ordovician in age. The association of such forms as numbers 5, 8, 9, 10, 13 and 18 in the above list with *Loganograptus* and *Tetragraptus*, leads us to believe that the graptoliferous shale must be of late Lower Ordovician age. Its stratigraphical position most probably corresponds to the "Zone with *Amplexograptus confertus*" in the Ningkuo Shale of the Lower Yangtze valley, and may be correlated with at least a part, most probably the lower part, if not the whole of the deposits comprised in the Kapalinsky Horizon in Kazakhstan, U.S.S.R. and the Llanvirnian Formation in Britain. In order to work out the whole succession of fossil horizons in the Lower Ordovician deposits in Tsaidam, collection of fossils from bed to bed should be commenced from the limestones below the graptoliferous shale, and special studies should be made of the various kinds of fossils thereby collected. Here we only studied the graptolites and discussed the stratigraphical position of the graptolite shale.

One of the distinguishing features of this graptolite fauna is afforded by the fact that the fauna comprises a considerable number of forms which closely resemble those occurring in Middle Ordovician, indicating that they are the forerunners of the latter. For example, *Pseudoclimacograptus romanovskyi* var. *sinensis* is closely related to the species to which it is referred, the latter species, however, was found from the Middle Ordovician formation in Kazakhstan, U.S.S.R. As we know, the marginal lacinia attached to the rhabdosome of this organism, is generally characteristic of the Middle Ordovician genera such as *Neurograptus* and *Hallograptus* etc.; but in this Lower Ordovician fauna we have several forms of *Paraglossograptus* garnished with well-developed lacinia. This implies that they are the forerunners along this special path of evolution, a path which leads to the formation of an entire lacinia through the elaboration of the thecal spines. There is again in this fauna the species *Glossograptus* cf. *echinatus* Ruedemann which, in the general characters of thecae, closely approaches the Middle Ordovician form *Glossograptus hincksi* (Hopkinson), and is probably the ancestral form of the latter. The appearance of these heraldic forms indicates that the time when they lived was approaching to the end of Lower Ordovician, and the features characteristic of these forms usually point to the beginning of certain new evolutionary trends which were followed by their descendants in Middle Ordovician.

The second distinguishing feature of the fauna is that it comprises a considerable number of very thin and delicate forms. For example, Nos. 2, 3, 4 and 5 in the foregoing list are species with tiny rhabdosome composed of characteristically thin and fragile stipes; and Nos. 8 and 11 are dwarfed forms. All of these forms, except No. 11, belong to the family *Dichograptidae*. Their pathologic look suggests that a portion of the *Dichograptidae* is already in a declining state. On the other hand, however, there are in the same fauna those forms with great vitality as shown by their usually fully developed rhabdosomes. These are the forms belonging to the genera *Pseudoclimacograptus*, *Glossograptus*, *Paraglossograptus* and *Trigonograptus* (Nos. 9, 10, 12—17 in the foregoing list). They are in a most flourishing state instead of being declining. Thus we see that the old, declining forms had lived side by side with the newly arisen, flourishing ones. As we know, all organisms are in unity with the necessary conditions of living, or in other words, they form an entity with their environment. The waning and the flourishing of different forms

contained in the fauna suggest that the environment (including the climate, the salinity of sea-water and so forth) in that period and that region was unfavourable to the development of uniserial and branched forms belonging to the family *Dichograptidae*, but favourable to the biserial and un-branched *Pseudoclimacograptus*, *Glossograptus*, *Paraglossograptus* and *Trigonograptus*. Meanwhile this also implies that the former forms have little ability of adaptation, and the latter forms, which are the forerunners mentioned in the foregoing paragraph, have superior ability of adaptation to the environment. In order to make a concrete and convincing explanation of this phenomenon, we have to deal with a series of problems relating on the one side to the external conditions such as the climate, sedimentation and so forth in the past geological period, and on the other side to the intrinsic conditions such as the functions of various structures of the organisms and their relations to ecological succession. Recently in Lung-Yu district, Chekiang province, the writer noticed that, in the Lower Ordovician shale, the beds abounding in graptolites are intercalated with the layers of the sedimentary iron ore. Therefore, taking into consideration the mineral resources of sedimentary origin, we immediately become aware of the fact that the above-mentioned problems are not only of theoretical but also of practical significance, and their resolution requires further studies to be made in different fields of science related to them.

As shown by the specimens at my disposal, the fauna appears to bear a distinct regional character, and this may be regarded as its third distinguishing feature. By comprising a relatively great number of new species and varieties which appear to be of an endemic nature, the fauna forms a unit of its own. As a whole, it differs not only from the contemporaneous ones found in remotely separated foreign countries, but also from that occurring in the lower Yangtze valley of our country. It has very few species such as *Cryptograptus uricornis* Carruthers and *Trigonograptus ensiformis* (Hall) in common with the assemblage in the equivalent horizon, the uppermost graptolite horizon of the Ningkuo Shale; while a greater number of the forms are different. It appears that in that time the connection between the sea on the northwest and that on the south was not a very open one. This is a question about the Ordovician paleogeography of our country, and needs further study with more material.

As we know, the graptolites had an extensive distribution and underwent rapid specific changes in definite geological periods, therefore the contemporaneous graptolite fauna we found now from different regions, no matter how far they are separated, generally have some common characters, especially some species in common. The common faunal characters render possible the correlation of major chronological divisions of strata in widely separated regions. But meanwhile, we must keep in mind that the faunas of different regions also bear certain particularities of their own. Therefore the detailed subdivisions of strata based upon fossil zones are by no means exactly alike every-where. It is for this reason that the established succession of fossil zones of one region, upon which the detailed subdivision of strata is based, is not always entirely fit for use in other regions, especially in regions far separated. It is then clear that, the standard succession of fossil zones established in foreign countries should not be adopted as an unalterable formula and inflexibly applied, although it is important and useful for the purpose of reference and comparison. We must, therefore, engage ourselves in great, creative labour to establish the succession of fossil zones of our own country with the actual materials from various districts within our territory.

As mentioned above, the distinguishing features of the Lower Ordovician graptolite fauna of Tsaidam have made us to call to mind once more a series of scientific problems, the resolution of which requires thorough studies to be made in different fields of science related to them. Our country is rich in paleontological and geological materials. We, paleontologists and geologists,

must therefore make unremitting exertions to study them under the guidance of the principles of materialist dialectics in order to make our best contributions to the development of paleontology and geology in our country.

II, Description of species

Family Dichograptidae Lapworth

Genus *Loganograptus* Hall

Loganograptus tsaidamensis, sp. nov.

(Pl. I, figs. 1—2)

Material: There are three specimens, one (No. 109) of which represents a complete half of the rhabdosome; the other two (Nos. 136, 139) are detached stipes.

Diagnosis: Rhabdosome large, consisting of 20 thin and slightly flexuous terminal stipes; dichotomy taking place five times. Thecae very slender; overlapping about $1/3$ of their length; numbering 8—9 in 10 mm; inclined at an angle not more than 26° ; with slightly undulating ventral walls and widened apertures.

Description: The specimens show that the complete rhabdosome should be more than 10 cm in diameter. The “funicle” appears to be fairly long, a portion of which preserved in our specimen (No. 109) measuring 2 mm in length. The stipes of the second and third orders are equal in length and in width, being about 2 mm long and 0.2—0.3 mm wide. The terminal stipes are more than 40 mm in length and have a maximum width of 0.5—0.8 mm (measured across the thecal aperture). The stipes of the second and third orders bifurcate at the same angle, an angle of about 115° , while those of the fourth order at an angle a little less than 90° .

Thecae very slender, measuring 2—2.5 mm in length, about 5 times as long as wide; numbering 8—9 in 10 mm; overlapping about $1/3$ of their length. They are inclined at different angles at different portions of the stipe. In the initial portion of the terminal stipe the thecae are inclined at about 14° or even less, whereas in the distal portion this angle of inclination increases to 26° . Owing to their slenderness, the thecae wall usually bears a gently undulating curvature; but, as a whole, the general trend of the ventral wall is concave. The apertures are widened and somewhat mucronate.

Comparison: At first glance one would think that our species is very similar to *L. logani* (Hall), which it approaches in the size and general shape of the rhabdosome. The important distinctions between the two species lie in the characters of the thecae. The thecae of our species are more slender, and have a smaller overlap and smaller angle of inclination. It also differs from *L. logani* (Hall) in having widened, mucronate apertures and concave but slightly undulating ventral walls of thecae.

Loganograptus cf. gracilis Mu.

(Pl. I, figs. 3—6)

1957, *Loganograptus gracilis* Mu, Acta Palaeontologica Sinica, Vol. 5, No. 3, P. 418, Pl. 2, figs. 4—7.

Material: There are three specimens (Nos. 146, 148, 250), each of them represents a fairly complete rhabdosome.

Description: The rhabdosome is very small, about 20—30 mm in diameter. Dichotomy takes place five times. In one specimen, 19 terminal stipes are observed, and in another they are 18 in number. The terminal stipes are about 7—10 mm long and 0.2—0.3 mm wide. They

are as thin as a thread, but bear a characteristically rigid appearance. The "funicle" is about 3.5 mm long. With regard to the difference in length, the stipes of the second order fall into two groups: The stipes of one group are longer, being about 1.5—2 mm in length, while those of another group are about 1—1.4 mm long. In the same way, the stipes of the third order also fall into two groups, and are approximately equal in length to those of the second order.

The stipes of the second order bifurcate at an angle of about 126° . As bifurcation goes further on, the angles of bifurcation become increasingly smaller. Thus, the stipes of the third order bifurcate at $75\text{--}90^\circ$, and those of the fourth order at about 60° . The angle of bifurcation of the fifth-order stipes varies from 44° to 55° .

The thecae in our specimens are scarcely discernible. Most probably they are very slender and overlapping a slight portion of their length.

Comparison: This form closely resembles *L. gracilis* Mu in the size of the rhabdosome, the length of the "funicle" and the mode of bifurcation of the successive orders of stipes. As the details of the thecae are not observed in our specimens, it is still uncertain whether our form exactly belongs to Mu's species.

Genus *Tetragraptus* Salter *Tetragraptus harti* Hall, T. S.

(Pl. I, figs. 7—11)

1914, *Tetragraptus harti*, T. S. Hall, Roy. Soc. Victoria, Vol. XXVII (N.S.) Pt. 1, pp. 113—114, text-figs. 5, 6.

1938, *Tetragraptus harti*, Harris and Thomas, Victorian graptolites, (N.S.) Pt. V, Mining and Geological Journal, pp. 74, figs. 14 a—b.

Material: Five specimens, one (No. 150) of which is probably a young form.

Description: Rhabdosome very thin. Sicula usually indiscernible, only its apical portion is shown in one specimen (No. 123). It appears to be very small, not exceeding 1 mm in length. The two primary stipes form a "funicle" which measures about 2.3—2.5 mm in length. From the primary stipes start four horizontally placed terminal stipes which are characteristically thin and straight. Generally, their length does not exceed 20 mm, while their width is about 0.2—0.3 mm. The width may increase to 0.4—0.5 mm in the distal portions of the stipes. In larger specimens (Nos. 115a, 115b), the terminal stipes may reach a length of 24 mm and a width of about 1 mm. The angle of bifurcation of the terminal stipes varies in different specimens from 98° to 110° .

Thecae obscurely shown in our specimens, appearing to be very slender tubes with slightly widened apertures; overlap small, not more than $1/3$ of the thecae length; inclined at about 25° ; numbering 5 in a space of 5 mm.

Comparison: Our form agrees in all characters with *T. harti* figured by W. J. Harris and D. E. Thomas in 1938, except that the thecae in our specimen are more closely arranged. Measurements taken from the figures made by Harris and Thomas show that the thecae in the Victorian specimens number 8 in 10 mm, while in our specimens the thecae number 10—11 in the same unit of space.

T. harti Hall, T. S. is similar in many respects to *T. quadribranchiatus* (Hall), but is conspicuously smaller in size. The two species appear to be near affinities. In our specimens there are two larger rhabdosomes which approach in size to *T. quadribranchiatus* (Hall), and may serve as the transitional form between the two species.

Genus *Didymograptus* M'coy
***Didymograptus linealis* sp. nov.**

(Pl. II, figs. 1—9)

Material: Altogether six specimens (Nos. 237, 242, 246, 235, 271, 256), all preserved in carbonaceous films.

Diagnosis: Rhabdosome minute and delicate, composed of tow declined, thread-like stipes which do not exceed 20 mm in length. Thecae slender, with small angle of inclination; numbering 12—14 in 10 mm; ventral walls with elongated sigmoid curvature; apertural margins concave, situated in excavations; overlap slight.

Description: The angle of divergence between the stipes is about 130—143°. The length of the stipes ranges from 9—15 mm. The width at the proximal end is about 0.1 mm, increasing gradually to a width of 0.2 mm, which is then maintained to the distal extremity.

Sicula slender but conspicuous, about 1 mm long.

Thecae in general characters closely approach to those of a *Leptograptus*, except that they are smaller in size. They are about 1 mm long, with a width about one sixth of the length and inclined at a low angle which does not exceed 10°. Their ventral margins show an elongated sigmoid curvature. Apertural margins are somewhat concave and situated in semicircular excavations. The overlap is nearly one sixth of the thecal length.

Comparison: *Didymograptus linealis* sp. nov. resembles, in some degree, *D. ellesi* Ruedemann (Ruedemann, 1904, Grapt. New York, pt. 1, p. 682, pl. 14, figs. 22—24) in the size and the general shape of the rhabdosome. But the stipes of the latter have a greater width (0.4 mm). Besides, the characters of the thecae of the two forms are quite different: In Ruedemann's species the ventral walls of thecae are straight, while in the present form the thecae approach to those of a *Leptograptus*, with ventral walls bearing slightly sigmoid curvature and thecal apertures situated in excavations.

***Didymograptus nodosus* Harris**

(Pl. III, figs. 1—3)

1926, *Didymograptus nodosus* Harris, Victorian Graptolites (N.S.), pt. II, p. 56, pl. I, figs. 1—4.

1935, *Didymograptus nodosus* Harris and Thomas, Victorian Graptolites (N.S.), pt. III, p. 295, figs. 2, 27.

Material: Two specimens, one of which (No. 137) is a detached stipe. The following description is based upon the specimen (No. 350) preserved with two stipes.

Description: Rhabdosome small, consisting of two declined stipes which at the beginning diverge at about 120°, but later tend to expand laterally. Stipes having a preserved length about 10 mm; very narrow at their initial end, widening distally. It is probably due to the difference in the direction in which compression has been effected that the widths of the two stipes of the rhabdosome differ from each other. One of the stipes (on the right side of text-fig. 1, incorporated in the Chinese text) widens fairly rapidly so that its mature portion attains a width of 0.8 mm; while the other stipe (on the left side of text-fig. 1) is almost uniform in width, its mature portion being only about 0.4 mm wide. The stipes are furnished with dorsal spines which are perpendicular to the axis of the stipe and number 7—6 in a space of 5 mm.

Thecae of the *Dichograptid* type, about four times as long as wide; numbering 7 in 5 mm in the proximal portion and 5—6 in the same unit in the distal portion; overlapping about 1/3 their length; apertural margins straight, with their outer ends extended into spines. The ventral

margin of the thecae is concave for the greater part of its length; but its initial portion bears a convex curvature so as to allow its initial end to be included in the triangular base of the dorsal spine placed just above it (see text-fig. 1). This feature indicates that the dorsal spines are formed by dorsal folds in which the initial portion of the thecae is involved. The fold is so tight as to give rise to a pointed apex which is then prolonged into a spine.

Comparison: Our form corresponds in all characters to the Victorian specimens described by Harris in 1926 and 1935. As shown by the drawings made by Harris in 1926, the Victorian specimens bear conspicuous dorsal folds, and a few of the dorsal spines proceeded from the apices of the folds are also discernible, although most of them are not preserved in the Victorian specimens owing, probably, to their delicacy and fragility. It is therefore beyond doubt that the Victorian specimens bear the dorsal spines as well.

In respect of origination of the dorsal spines, this species is very similar to *Tylograptus spinatus* Mu (Mu, 1957, Acta Paleontologica Sinica, Vol. 5, No. 3, pp. 398—399, text-fig. 16, Pl. VI, figs. 7—9). But the thecae in *Tylograptus* are characteristically of the Leptograptid type, being very slender, having introverted apertures and furnished with ventral instead of apertural spines; whereas in *D. spinosus*, the thecae, as described above, still linger in the *Dichograptid* stage of evolution.

Didymograptus nodosus closely resembles *Didymograptus spinosus* Ruedemann (Ruedemann, 1904, Grapt. New York, Pt. I, p. 688, text-figs. 84—85, pl. 14, figs. 30—32) in the size and general form of the rhabdosome and in having dorsal spines. The main distinction lies in the fact that the latter species does not bear the conspicuous dorsal spines such as observed in the former.

Sub-genus *Isograptus* Moberg

Isograptus chinghaiensis sp. nov.

(Pl. II, figs. 10—11)

Material: There are two specimens, in both of which the proximal extremity of the rhabdosome is imperfectly preserved.

Diagnosis: Rhabdosome consists of two reclined, subparallel stipes. Stipes about 12 mm long; maintaining a width of 1.5—1.8 mm for the greater part of their length; with more or less widened proximal and abruptly narrowed distal extremities. Thecae having a width a little less than one third of its length; numbering 6—5 in 5 mm; overlapping $3/4$ — $2/3$; ventral margins slightly concave; apertural margins concave, produced into spines.

Description: The recurved stipes become straight distally and run subparallel to each other. Each stipe is about 12 mm long, and widest at origin where it measures 2.5 mm in width. Not far above its origin the stipe rapidly narrows down to a width of 1.5 or 1.8 mm. This width is then maintained for the greater part of the length. A rapid diminution of width again takes place near the distal extremity where the width is only about 1 mm.

The thecae are 2—2.5 mm long, and have a width a little less than one-third of its length. They number 6 and 5 in a space of 5 mm in the proximal and the distal portions of the stipe respectively. The ventral wall is straight or slightly concave. The apertural margin is concave and its lower end protrudes so as to form a sharp spine. The thecae are in contact about $3/4$ — $2/3$ of their length.

Comparison: This species somewhat resembles *I. curvithecatus* sp. nov. in thecal characters. The main distinction lies in the shape of the rhabdosome. As compared with the latter species, the

rhabdosome of this species has a broader base, and its two stipes are placed farther apart. Besides, the rhabdosome of this species appears to be relatively broader and shorter than that of the latter.

***Isograptus curvithecatus* sp. nov.**

(Pl. II, figs. 12—13)

Material: Only one comparatively complete specimen (No. 145).

Dignosis: Stipes subparallel; about 17 mm long; maintaining a width of 1.7 mm in the greater part of their length, with much wider proximal and narrowed distal extremities. Thecae proportionally wide and short, being only a little more than two times as long as wide; ventral walls strongly concave; apertural margins concave, produced into spines; overlapping throughout; numbering 6—5 in 5 mm.

Description: The rhabdosome has a horseshoe-shaped proximal extremity. It consists of two reclined stipes which become subparallel distally. Each of the stipes is about 17 mm long. Its proximal extremity measures 2.5—3 mm in width, but is rapidly narrowed down to a width of about 1.7 mm. This width is then maintained in the greater part of the length. The distal extremity again tapers rapidly to a width of 1 mm.

The sicula with its apical and apertural portions exposed to the observer, measures about 3 mm in length. In our specimen, only the initial portion of the nema is preserved, which appears rigid and straight.

The thecae are in general characters similar to those of a *Phyllograptus*. They are narrow at their bases, but rapidly widen towards apertures which measure about 1 mm in diameter. The earliest thecae in the sicular region grow downward, the succeeding ones bend horizontally outward, and in the distal portion, which constitutes the main part of the length of the stipes. The thecae grow obliquely upward. The thecae in the distal portion of the stipes are inclined at their bases at an angle not more than 30°, but owing to the strong curvature of the thecae, the angle of inclination at the apertural portions increases to more than 80°. The earliest developed thecae are slender, being about 2.5 mm long; while the succeeding ones are short and relatively broad, having a length of 2 mm and a width nearly one-half of the length. The ventral walls are strongly concave. The apertural margins are concave, with their lower ends produced into spines. The thecae are in contact almost throughout their length. They number 6—5 in a space of 5 mm.

Comparison: In the general shape of the rhabdosome our species resembles *I. forcipiformis* Ruedemann (Ruedemann, 1947, p. 352, pl. 57, figs. 37—40), but differs from the latter species in having a smaller sicula, shorter and relatively broader thecae which are more densely arranged and have more strongly curved ventral walls. In Ruedemann's species the thecae number 9—10 in 10 mm, whereas in our species the thecae number 12—10 in the same unit of space.

In some respects our species also resembles *I. manneri* Keller (Keller, 1956, p. 69, pl. 1, fig. 3); but as shown in the figure drawn by Keller, the ventral walls of the thecae in *I. manneri* are rather straight instead of being strongly curved as those in our species.

***Isograptus caduceus* (Salter) mut. *nanus* (Ruedemann)**

(Pl. II, figs. 14—19)

1904, *Didymograptus caduceus* Salter mut. *nanus* Ruedemann, Grapt. New York, Pt. I, Memoir 7, p. 698, text-fig. 90, Pl. 15, figs. 8, 9.

1947, *Isograptus caduceus* (Salter) mut. *nanus* (Ruedemann), Grapt. North America, p. 351, Pl. 57, figs. 17—19.

Material: Two specimens (Nos. 152, 153) preserved in carbonaceous films.

Description: Rhabdosome very small, horseshoe-shaped, consisting of two short and relatively broad, reclined stipes. Sricula about 2.8 mm long; having a thread-like, straight or curved nema. Each stipe about 3—4 mm long and 2.2—2.3 mm wide at origin, narrowing abruptly toward the distal extremity where it measures about 1 mm in width. Thecae narrow at their base, increasing in width toward aperture which is about 0.5 mm wide; apertural margin concave. The thecae are furnished with rigid and straight apertural spines. In one specimen (No. 152), each of the stipes is about 3 mm long and consists of 7—8 thecae, while in another specimen the stipe measures 4 mm in length and consists of 9 thecae.

The rapid diminution in width in the distal extremity of the stipes shows that the polyparies have attained their full development, and should not be regarded as young forms of some species other than the one here referred to.

Family Phyllograptidae Lapworth

Genus *Trigonograptus* Lapworth

Trigonograptus paelongus Keller et Lisogor

(Pl. III, fig. 4)

1908, *Trigonograptus ensiformis* Elles et Wood, Brit. Grapt., pl. XXXIV, figs. 1c.

1934, *Trigonograptus ensiformis* Hsü, Grapt. Lower Yangtse Valley, pl. IV, fig. 1a.

1954, *Trigonograptus paelongus* Keller et Lisogor, Караканский Горизонт Ордовика, С. 75, Таб. IV—12.

Material: There are two specimens, one of which representing the median portion of the rhabdosome is better preserved, and is described in the following paragraph.

Description: Rhabdosome fairly long and parallel-sided; having a width of 3.4 mm and a preserved length of 46 mm. Thecae about 3 mm long, inclined at about 45°; numbering about 9 in 10 mm.

Comparison: Our form agrees in all characters with that described by Keller and Lisogor (Keller et Lisogor 1954) except that the width of rhabdosome of our form is slightly greater.

Trigonograptus ensiformis (Hall)

(Pl. III, fig. 5)

1890, *Trigonograptus ensiformis* Nicholson, Geol. Mag., dec. 3, Vol. VII, p. 340, figs. 1, 2.

1908, *Trigonograptus ensiformis* Elles et Wood, Paleont. Soc. pt. VII, p. 302, pl. XXXV, fig. 1a.

1934, *Trigonograptus ensiformis* Hsü, Grapt. lower Yangtse Valley, p. 53, pl. IV, figs. 1c, 1g, 1h.

1954, *Trigonograptus ensiformis* Keller et Lisogor, Караканский Горизонт Ордовика, С. 74, рис. 28 Таб. V—8.

Material: There are several specimens, only one (No. 102) of them is better preserved, which is described below.

Description: Rhabdosome about 13 mm long; having a maximum width (3 mm) in its median portion, and narrowing toward both extremities so as to give the rhabdosome a fusiform shape. Thecae inclined at about 45°; numbering 13—12 in 10 mm. In the median portion of rhabdosome the thecae measure about 2 mm long, while those placed nearer to the extremities of rhabdosome became smaller in length.

Comparison: The form described above agrees in general characters with those described by former authors, except that in our form the rhabdosome is smaller, and its thecae are somewhat more closely arranged.

Family Diplograptidae Lapworth

Genus *Glyptograptus* Lapworth*Glyptograptus dentatus* (Brongniart), var. *intermedius*, var. nov.

(Pl. IV, figs. 1—10)

Material: Altogether five specimens (Nos. 241, 244, 291, 286, 255), two of which are in the juvenile stages of development.

Description: Rhabdosome very small; about 15 mm long and 1 mm wide at the initial end; widening rapidly to a maximum width of 1.5 mm, which is then maintained distally; initial end rounded and obtuse, furnished with a virgella and two lateral spines; virgula prolonged beyond the distal end; initial portion of septal groove usually bearing an undulating curvature.

Thecae overlapping slightly; numbering 7—6 in a space of 5 mm in the proximal and 5 in the same space in the distal portion of the rhabdosome; apertural regions introverted and introverted; apertural margins apparently concave, curved upward and inward; excavations deep, oblique and pouch-shaped; ventral margins showing gentle, sigmoidal curvature.

Comparison: The variety is distinguished from the type form in having a much smaller size of rhabdosome and in the fact that the curvature of the ventral wall of thecae is very gentle and smooth instead of being sharp and angular as in the type form.

The variety resembles *G. dentatus* var. *pusillus* Hsü (Hsü, 1934, Grapt. Lower Yangtse Valley, p. 80, pl. VI, figs. 4a—k) in the size of rhabdosome, but differs from the latter in the characters of the thecae. The apertural margin of the thecae in the latter form is not so much oblique and curved inward as it is in the present variety, and the excavation is less conspicuous. Besides, the proximal portion of rhabdosome of *G. dentatus* var. *pusillus* is narrower and more pointed.

The present form is closely related to *G. dentatus*—*teretiusculus* transient Bulman (Bulman, 1936, On the graptolites prepared by Holm, pp. 57—61, pl. 3, figs. 1—4, 8—11; pl. 4, figs. 1—3, text-figs. 22—23), to which it is similar in the characters of the thecae. But all the specimens at my disposal show that the rhabdosome of our variety is always much thinner than that described by Bulman. This prevented me to identify our variety with Bulman's form.

Bulman alleged that the form described by him is a transitional one between *G. dentatus* and *G. teretiusculus*. In view of the thecal characters and the undulation of the septal groove usually shown in the proximal portion of the rhabdosome, both the forms described by Bulman and our variety approach, to a certain degree, *Pseudoclimacograptus romanovskyi* Keller (Келлер, 1956, Стратиграфия Ордовика Чу-иллийских Гор, Ордовик Казахстана, 2, стр. 94, Табл. 2, Фиг. 5—6). Therefore the writer thinks that both forms, Bulman's and ours, are rather transitional ones between the two genera *Glyptograptus* and *Pseudoclimacograptus*. It appears that *Glyptograptus dentatus*, with its varieties as the intermediate links, may be connected with *Pseudoclimacograptus romanovskyi*. This probably indicates a special line of evolution in the family Diplograptidae.

The variety is also closely related to *Glyptograptus* (?) *curvithecatus* Mu et Lee (Mu et Lee, 1958, Acta Paleontologica Sinica, Vol. VI, No. 4, p. 404, pl. II, figs. 15—17); but differs from the latter in having a longer and relatively narrower rhabdosome and more closely arranged thecae. Besides, the latter species appears not adorned with the lateral spines as observed at the proximal end of the rhabdosome of our variety.

Genus *Pseudoclimacograptus* Pribyl

Pseudoclimacograptus romanovskyi Keller, var. *sinensis*, var. nov.

(Pl. III, figs. 6—11)

Material: Three imperfectly preserved specimens.

Description: Rhabdosome about 20—30 mm long, nearly 1 mm wide at origin, widening gradually to a maximum width of 2 mm at the distal extremity. A fairly stout virgella and traces of two basal spines are sometimes observed at the proximal extremity. The zigzag-form of the median septal groove is shown in the proximal portion of the rhabdosome, but toward the distal portion its curvature gradually becomes loose and then the septum appears almost straight. Thecae introverted and introverted; markedly alternate; overlapping nearly one third of their length; numbering 16—14 and 12—11 in a space of 10 mm in the proximal and distal portions of the rhabdosome respectively; ventral wall convex; excavation pouch-shaped, deep, occupying one fourth of the width of the rhabdosome.

Comparison: The characters of the thecae and the septal groove of the present form are almost identical with those of Keller's species (Keller, 1956, Ордовик Казахстана, 2, стр. 94, Табл. 2, Фиг. 5—6). It is, however, distinguished from the latter by the fact that the rhabdosome has a greater width, and the maximum width is attained near the distal extremity by gradual increase from the origin, whereas in Keller's species this is attained not far above the origin; the thecae of our form is more closely arranged (in Keller's species they number 11 in 10 mm).

Family Glossograptidae Lapworth

Genus *Glossograptus* Emmons.

Glossograptus cf. *echinatus* Ruedemann

(Pl. IV, figs. 11—16)

1904, *Glossograptus echinatus* Ruedemann, Grapt. of New York, Pt. 1, p. 725—726, text-fig. 102, pl. 16, figs. 30—32.

1947, *Lasiograptus echinatus* (Ruedemann), Grapt. N. America, p. 462—463, pl. 77, figs. 9—13.

Material: Among several young forms there are two large specimens (Nos. 143, 144), one of which is the counterpart of the other. The following description is based upon the large specimens.

Description: Rhabdosome fairly large, about 22 mm long; wider in middle than at ends; middle portion about 4 mm wide (including thecal apertures, exclusive of spines); proximal and distal ends measuring about 1.8 mm and 2 mm in width respectively; prolongation of virgula beyond distal end exceeding one half the length of rhabdosome.

Thecae straight tubes; inclined at about 19° ; overlapping more than $\frac{1}{2}$; numbering 10—11 in 10 mm in the middle portion of rhabdosome; apertural margins straight, oblique to thecal axis, with their outer margins protracted into stout spines; ventral margins concave.

Comparison: This form appears closely related to *G. echinatus* Ruedemann, although it has a greater size of rhabdosome and somewhat greater overlap of thecae. As regards the size of rhabdosome, it approaches to some extent *G. echinatus* var. *major* Ruedemann (Ruedemann, 1947, p. 463, pl. 77, fig. 15). It is probably an intermediate form between the species and the latter variety.

Genus *Paraglossograptus* Mu, MS., 1958.

This genus is recently established by Comrade Mu An-Chi. His paper on this new genus has not yet been published when the writer writes this article. According to Mu's oral information and what observed from the specimens at the writer's disposal, the general characters of this genus may be outlined as follows:

Rhabdosome biserial and bilaterally symmetrical, closely related to *Glossograptus* Emmons, to which it is similar in all respects except that the apertural spines of thecae, which, instead of being free, form together lacinia; test of rhabdosome attenuated, but thickened and strengthened at the ventral edges and apertural angles of the thecae; virgula usually conspicuous; proximal end usually adorned with stout basal spines.

Thecae of the *Glossograptus* type; apertural spines of thecae fall into two types which differ in curvature. One type of these include those spines which extend from the aperture obliquely upward almost throughout their length, only with their distal portion slightly curved downwards. These are the "normal apertural spines", and are similar to those in a *Glossograptus*. Another type includes those which, for the sake of discrimination, may be designated the "twisting apertural spines". These spines extend from the thecae aperture obliquely upward only at the beginning, but soon and abruptly bend downwards so that their terminal ends meet the apertural spine given off from the thecae next below, thus forming together a mesh. A string of meshes are formed in the same manner by these spines.

Besides the apertural spines there are in addition cross-bars or dissepiments which serve as the connecting process between the apertural spines, and are placed both inside and outside the above-mentioned meshes. A complete row of lacinia is thus formed on both sides of the rhabdosome.

Although the general way of the formation of the meshes of lacinia, as described above, is common to all forms of the genus, the way of construction of the lacinia still varies with different species. In some species (*P. regularis*, *P. multifibratus*), it appears that the construction of lacinia follows to a great degree a definite rule; while in others (*P. multifibratus* var. *longus*) the construction of the same appears more or less in confusion.

Comparison: Hall formerly described a Canadian species which he designated *Retiograptus tentaculatus* (Hall, 1865, Grapt. Quebec Group, Canadian Organic Remains, Decade II, P. 31, 47, 116, Pl. XIV, figs. 6—8). It has the structure of lacinia similar to some degree to that of our forms, and the rhabdosome also bears a conspicuous virgula and basal spines. But according to Hall's description and drawings, in the Canadian species the thecae extend almost in a horizontal direction from the virgula instead of extending obliquely upward. The test of the rhabdosome is apparently smooth, being not thickened at the ventral walls and the apertural angles of the thecae as in our forms. Besides, in the Canadian species the outermost spines of the lacinia originate from the middle point of the outer margin of the meshes; whereas in our forms the outstanding spines of the lacinia are nothing else than the extensions of the normal apertural spines of the thecae.

Later on, Ruedemann again described several specimens under the same generic and specific designation (Ruedemann, 1947, Grapt. N. America, pp. 460—1, Pl. 80, figs. 1—10). He revealed that the test of rhabdosome, instead of being smooth, bears the structure of fine reticulation. This shows that these American forms should belong to the genus *Retiolites*. Our genus is closely related to *Glossograptus*, and evidently differs from the American forms.

In 1947, Ruedemann described *Lasiograptus echinatus*, and pointed out that the specimen

collected from Windermere possesses a distinct lacinia (Ruedemann, Grapt. of North America, p. 463, pl. 77, fig. 13). He considered that the lacinia is of the same nature as that of the *Lasiograpti*, and it is for this reason that he removed this species from the genus *Glossograptus*, to which it was previously referred, to *Lasiograptus*. As shown in Ruedemann's drawings, the specimen with lacinia differs both in form of rhabdosome and in thecae characters from the authentic *Lasiograptus echinatus* and should be separated from it. In this specimen there are thin and thread-like connecting processes which form collectively a continuous longitudinal line running across the apertural spines of a row of thecae, thus forming together a string of meshes. These connecting processes are similar to some extent to the dissepiments in the lacinia of *Paraglossograptus multifibratus* described below. But the important distinctions lie in the fact that in the American specimen all the apertural spines of thecae are of the one and same type, the normal type, there being no twisting apertural spines; that the structure of its lacinia is very simple, not so much complicate and perfectly woven as that in *Paraglossograptid*. The American specimen with simple and rudimentary lacinia probably represents an early stage of evolution from *Glossograptus* into *Paraglossograptus*.

***Paraglossograptus regularis*, sp. nov.**

(Pl. V, figs. 1—4)

Material: Two fairly well preserved specimens. (Nos. 289, 130).

Diagnosis: Rhabdosome when complete about 20 mm long and 3 mm wide (exclusive of the lacinia); virgula conspicuous. Thecae straight tubes; numbering 10 in 10 mm. Normal apertural spines alternate with twisting apertural spines in successive thecae, forming together a string of meshes; adjacent apertural spines are again connected by dissepiments, thus forming on both sides of the rhabdosome a complete row of lacinia.

Description: One of the specimens represents the middle and distal portions of the rhabdosome (Pl. V, figs. 1—2) and measures about 13 mm in length; while the other (Pl. V, figs. 3—4) represents the proximal portion and is about 11 mm long. The rhabdosome appears parallel-sided for the greater part of its length. Proximal end about 1.6 mm wide, widening rapidly to a width of 3 mm, which is maintained to the distal end; virgula extended beyond the distal end; proximal end adorned with stout basal spines.

Thecae inclined at about 35—40°; overlapping 2/3 or more of their length; numbering 10 in 10 mm.

There are two types of apertural spines of the thecae. As shown in text-fig. 3 (incorporated in the Chinese text), thecae A gives off a normal apertural spine which extends obliquely outward and upward, only with its distal portion curved gently downwards. From the aperture of the theca next above (theca B) extends outward a twisting apertural spine, of which the distal portion bends abruptly downwards so as to meet the normal apertural spine of theca A, thus forming together a mesh. From theca C again comes out the normal apertural spine, while from theca D proceeds again the twisting apertural spine. It is according to the rule of alternate arrangement of the two types of spines in successive thecae that a string of meshes is formed. There are in addition the dissepiments which serve as the connecting processes between the adjacent apertural spines, and the lacinia is then made denser and strengthened. The dissepiments are placed both inside and outside the above-mentioned meshes. Generally inside each mesh there is a dissepiment which divides the mesh into two parts; and on the top of each of the meshes there is also a dissepiment which connects the mesh with the normal apertural spine of the theca next above.

As mentioned above, the construction of the lacinia follows the rule of alternation of the two types of apertural spines. But it must be pointed out that this rule of construction is not well shown in all parts of the lacinia. Usually in the one and same specimen, only in the lacinia on one side of the rhabdosome (on the right side of text-fig. 3, and the right side of figs. 1—2, Plate V) this rule of construction is well maintained; while in the lacinia on the other side (on the left side of text-fig. 3, and the left side of figs. 1—2, Plate V) the rule is more or less spoiled. Furthermore, even in the row of lacinia with regular construction, the rule of construction is only maintained in the greater portion, usually the middle portion of the lacinia; while the portion alongside the distal end of the rhabdosome usually becomes irregular too.

In the irregular portion of the lacinia, the apertural spines of the same type (either the normal or the twisting ones) may appear twice continuously in adjacent thecae instead of two types appearing alternately.

The dissepiment connecting each pair of adjacent apertural spines is generally small in length; but in the irregular portion of lacinia there is occasionally a very long dissepiment (text-fig. 3, l) which connects two spines placed far apart.

The writer is inclined to believe that, the irregularity of construction shown in certain parts of the lacinia is not original, but formed later on. It is very probable that during the life of the organism, the lacinia projecting far beyond the rhabdosome is subject to break, and the wounded and broken parts may be repaired and reorganized later on, thus giving rise to the irregularity in the construction of the lacinia.

***Paraglossograptus latus*, sp. nov.**

(Pl. V, figs. 5—6)

Material: Only one specimen (No. 109).

Description: Rhabdosome broad and relatively short; initial end about 1.8 mm wide, widening gradually until a maximum width of 4 mm is attained near the distal end; prolongation of virgula beyond the distal end exceeding one half the length of the rhabdosome.

Thecae numbering 13—12 in 10 mm; with everted apertural margins; but owing to the direction in which compression has been effected, the apertural margins of a portion of thecae appears to be apparently even and horizontal (see thecae on the right side of figs. 5—6, Pl. V).

On one side of the rhabdosome (the left side of figs. 5—6, Pl. V) it is observed that the rule of construction of lacinia is fundamentally of the same as that in *P. regularis*; but the development of dissepiments is much less perfect. Only a few of the meshes contain a dissepiment, while in most of them it is absent. The mesh which contains a dissepiment assumes the shape of a flattened oval or rectangle, and is divided into two unequal parts by the dissepiment. The meshes which have no dissepiment inside, are smaller in size and assume a shape approaching to an equal-sided polygon or a circle.

On the other side of the rhabdosome (the right side of figs. 5—6, Pl. V), the lacinia appears to be irregular in construction. It is very probable that, during the life of the organism, parts of the original structure of the lacinia are broken, and the repairment and reorganization made later on give rise to the irregularity of the structure.

Comparison: This species differs from *P. regularis* in the imperfect development of dissepiments in the lacinia, the greater width and smaller length of rhabdosome and the closer arrangement of the thecae.

***Paraglossograptus multifibratus*, sp. nov.**

(Pl. V, figs. 7—8)

Material: Only one specimen (No. 126).**Description:** Rhabdosome elongate-elliptical; about 23 mm long; having a maximum width of 3 mm in the middle portion, narrowing gradually towards both extremities; proximal and distal extremities about 1.6 and 1.8 mm wide respectively; virgula prolonged beyond the distal extremity; proximal extremity furnished with stout basal spines.Thecae similar in characters to those of *P. regularis*; numbering 11—10 in 10 mm.

In the structure of lacinia, it is noticed that there are two ways of grouping of the apertural spines. In the first way of grouping (text-fig. 4, I), two apertural spines, a normal and a twisting one of two adjacent thecae form a group. As shown in text-fig. 4, Theca A gives off a normal apertural spine which extends obliquely outward and upward; and from theca B, the theca next above, comes out a twisting apertural spine, of which the terminal end meets the normal apertural spine of theca A, thus forming together a mesh. Inside the mesh there is a dissepiment which assumes a nearly vertical direction and divides the mesh into two parts. In the second way of grouping (text-fig. 4, II) which occurs immediately above the first just mentioned, three apertural spines, one normal and two twisting ones, take part. As shown in text-fig. 4, from theca C proceeds a normal apertural spine like that of theca A; but each of the two succeeding thecae, D and E, gives off a twisting apertural spine which forms together a mesh respectively with the apertural spine next below. Thus in the second way of grouping three apertural spines are incorporated and two polygonal meshes are formed. Inside of each mesh there is also a nearly vertical dissepiment. Occasionally there is a mesh with a specially large size, and inside of it there are two dissepiments which then divide the mesh into three parts (text-fig. 4, I).

Further above, the apertural spines of thecae F and G are again grouped together in the first way; and those of thecae H, I, and J the second way. It is according to the rule of alternation of the two ways of grouping in a series of apertural spines that a row of meshes is formed.

As mentioned above, there is generally a dissepiment inside each mesh; but outside the meshes there are also dissepiments which connect the adjacent meshes. All the dissepiments assume a nearly vertical direction and are so placed that they almost form collectively in the lacinia a continuous longitudinal line parallel to the virgula of the rhabdosome.

It must be pointed out that, so far as our specimen is concerned, the rule of alternation of the two ways of grouping of apertural spines is well shown only in the lacinia on one side of the rhabdosome (the left side of text-fig. 4); while in the lacinia on the other side of the rhabdosome (the right side of text-fig. 4), This rule is partially spoiled, and the structure of parts of the lacinia then appear somewhat in confusion.

Comparison: This species differs from *P. regularis* chiefly in the construction of the lacinia. Besides, the apertural spines of this species appear more flexible, and its rhabdosome assumes an elongate-elliptical shape instead of being parallel-sided.

***Paraglossograptus multifibratus* var. *longus*, sp. et var. nov.**

(Pl. V, figs. 9—10)

Material: One imperfectly preserved specimen (No. 147).**Description:** Rhabdosome about 24 mm long and 2.4 mm wide; parallel-sided throughout its length; virgula prolonged beyond the distal end; proximal end furnished with stout basal

spines.

Thecae inclined at about 26° ; overlapping more than $2/3$ of their length; numbering 10—9 in 10 mm.

The rule of construction of lacinia is fundamentally of the same as that in *P. multifibratus*. It is observed in the structure of the greater portion of the lacinia (for instance, in the middle and lower portions of the lacinia on the left side of fig. 10, pl. V), although in certain parts of the lacinia the structure departs from it.

The variety differs from the type form by the fact that the dissepiments in the lacinia are less perfectly developed, many meshes having no dissepiment inside; that the rhabdosome is parallel-sided instead of being elongate-elliptical in shape as that of the type form.

***Cryptograptus tricornis* (Carruthers)**

(Pl. V, figs. 11—12)

1859, *Diplograptus tricornis*, Carruthers, Ann. Mag. Nat. Hist. (3), Vol. III, p. 25.

1868, *Diplograptus tricornis*, Carruthers, Geol. Mag., Vol. V, p. 131, pl. V, figs. 11a—b.

1908, *Cryptograptus tricornis*, Elles and Wood, Monogr. Brit. Grapt., p. 296, pl. XXXII, figs. 12a—d.

1908, *Cryptograptus tricornis*, Ruedemann, Grapt. New York, pt. II, p. 443, pl. XXVIII, figs. 1—4.

1934, *Cryptograptus tricornis*, Hsü, Grapt. Lower Yangtze valley, p. 87—88, pl. VI, figs. 13a—m.

Material: Two exceedingly small specimens (Nos. 352—353), one of which is the counterpart of the other.

Description: Young rhabdosome with a preserved length of about 8 mm; about 1 mm in width throughout, but slightly expanded near the initial end; initial end furnished with three short but conspicuous basal spines, one virgella and two lateral spines given off by earliest thecae.

Thecae showing sharp sigmoid curvature; excavation conspicuous; other characters of thecae obscure.