

SOME LOWER CAMBRIAN TRILOBITES FROM WESTERN HUPEI

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With 4 plates and 1 table

In the museum of our institute there are many specimens of minute trilobites that merit description. As shown on the labels the great majority of these were collected from the Shihpai Shale and its overlying formations in western Hupei by Messrs. S. C. Hsu and C. T. Ma. The composition of the fauna is of great significance, because several Lower Cambrian trilobites of typical Atlantic province are associated with their larval forms occurring in the Shihpai Shale and in the Archaeocyathina Limestone in the Gorge district of Yangtze.

A short description of the fossils and a discussion on the stratigraphical relations will be set forth below.

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Systematic Paleontology

Family Pagetiidae Kobayashi

Genus *Hebediscus* Whitehouse 1936

Hibediscus orientalis n. sp.

(Pl. I, figs. 1-20, 33-37)

Diagnosis: Proparian pagetids with eye ridges and conical glabella, transglabellar furrows, three thoracic segments, semi-elliptical pygidium with three axial nodes and pustulose carapace.

Description: The adult specimens: Body elliptical, cranidium slightly larger than pygidium, width about half its length, both extremities perfectly rounded. Dorsal carapace pustulose. Cranidium semi-elliptical, moderately convex, dorsal furrow narrow and deep, with very shallow marginal furrow in front of the glabella. Glabella long, narrow and conical, faintly segmented into three lobes. Occipital furrow shallow and wide, occipital ring sub-triangular with a median tubercle pointed backward and upward. Fixed cheek wider than the glabella. Eye ridge very narrow and distinct, eye lobe indistinct in the internal moulds. Facial suture nearly perpendicular, cutting the anterior lateral border then turning backward and cutting the posterior lateral border at a point before the genal angle. Posterior lateral furrow wide with moderate depth, confluent joining the dorsal furrow and the marginal furrow at both extremities. Free cheek small. Marginal furrow wide and shallow. Border narrow, somewhat a little reflexed upward in the anterior. Thorax consisting of three thoracic segments. Axial lobe a

little narrower than pleural lobe, each axial ring bearing a median tubercle. Pygidium semi-circular to semi-elliptical, relatively smaller than the cranidium. Three axial tubercles ornamenting the axial lobe.

The larval specimens: The smallest cranidium measured 0.47 mm in length with convex cheeks (pl. 1, fig. 20), glabella sharply pointed, three glabellar lobes faintly observed. Occipital spine distinct. Eye ridge very narrow and faint. Cranidia measured ca. 0.65–0.75 mm in length bearing proparian suture, three glabellar lobes and occipital node. Cranidium ca. 1.14 mm long and 1.75 mm wide retaining many characteristics of the adult cranidium.

Many interesting specimens of minute pygidia are in the material. They show a series of changes of growth and are suggested to be the larval forms of this new species. According to the measurements and their characteristic features three stages are thus arranged.

Late meraspid stage: (Pl. I, figs. 8-11, 33-34.) Pygidia ranging from 0.33 mm to 0.56 mm in length and 0.63 mm to 0.74 mm in width having tapering and faintly segmented axial lobe, and four deep, broad, oblique and incurved furrows on each pleural lobe, marginal furrow narrow, border narrow.

Later meraspid stage: (pl. 1, fig. 12, 35) Some larger pygidia measured ca. 0.55–0.81 mm in length and 0.85–1.20 mm in width, with 3 or 4 axial tubercles on the axial lobe and two incurved furrows on the anterior part of the pleural lobe.

Early holaspid stage: (Pl. 1, figs. 13-14, 36) Pygidia reaching 0.83–1.13 mm in length and 1.38–1.68 mm in width with three axial tubercles and anterior lateral furrow.

Remarks: From the foregoing account it is evident that from larval to adult stage there is a tendency of reduction in the number of the incurved pygidial furrows. The pleural furrows of the larval stage will gradually disappear on the pygidium during its further growth.

This new species resembles closely *Eodiscus chintingshanensis* Lu^[26] from the Minghsingssu Formation in northern Kueichow, but the later species is distinguished by five indistinct tubercles on the marginal rim of the cephalon, absence of eye ridges, 7 annulations on the pygidial axis and 2 or 3 groove on the pleural lobe. Our species differs also from *Hebediscus cobboldi* and *Hebediscus attleboroensis* in its conical glabella, in three axial tubercles on the pygidial axis and in its finely pustulose surface of the dorsal carapace.

Occurrence and horizon: Lower Shihpai Shale, I-Chang and Changyang, western Hupei.

Holotype and Paratype: Cat. no. 7033-7048. (coll. S. C. Hsu & C. T. Ma)

Genus *Dipharus* Clark, 1923.

Dipharus spinosus n. sp.

(Pl. I, figs. 21-32)

Diagnosis: Pagetids with eye ridge; cheek bearing strongly elevated conical mound, occipital spine and slender genal spine, probably proparian suture.

Description: The cranidia are very minute, ranging from 0.30 mm to 0.45 mm in length; the glabella is conical and long, sometimes with two or three faint glabellar furrows. Occipital furrow distinct, occipital spine very long. A pair of relative broad

eye lobe is well defined in anterior lateral part of the fixed cheek. Border narrow, gently convex and curved slightly downward in front of the glabella. Fixed cheek strongly elevated, with a small tubercle near its posterior margin. The genal spine is slender, pointing outward and downward. The only specimen of cranidium (Pl. I, 29, 30, 32) seems to have proparian suture on its right cheek, but the proparian suture on the left cheek is covered.

Thorax unknown.

Larval specimens: Many small spheroidal specimens probably belong to the protaspis stage of this species. One specimen Pl. I, fig. 25, measures 0.24 mm in length and 0.23 mm in width; its axial lobe is sharply pointed, convex and clearly defined by dorsal furrows; two strongly elevated mounds can be observed in the anterior lateral part. Another specimen Pl. I, figs. 23, 24 measures 0.35 mm in length and 0.30 mm in width and also convex axial lobe, anterior pair of elevated mound and a pair of eye lobes. A small and short spine is observed on the right posterior margin. The presence of the eye lobe and the spine on this specimen certainly represents an advanced step of growth. Other specimens figured in Pl. I, figs. 21, 22, retain many characteristics as Pl. I, fig. 25, which has been already stated.

Remarks: It is interesting to note that the specimens of *Hebediscus orientalis* are found in association with *Dipharus spinosus* in the Lower Shihpai Shale of western Hupei. On account of their tiny size and meagre material many authors are of the opinion that *Dipharus* is an immature form of *Hebediscus*. Having recently revised these two genera, Shaw suppressed the generic name *Hebediscus* in favor of the name *Dipharus*, because he also believed that *Dipharus insperatus* may be an immature form of *Hebediscus atleborensis*. As a result of careful observation on the present specimens the writer has found, however, that although the young cranidium of *Hebediscus orientalis* resembles the adult cranidium of *Dipharus spinosus* the former differs from the later in many respects, i.e., the front border, fixed cheeks, genal angle, etc. Both *Hebediscus* and *Dipharus* are valid genera, and *Dipharus* can never be the immature form of *Hebediscus*.

Occurrence and horizon: Lower Shihpai Shale, Changyang, western Hupei.

Holotype and paratype: Cat. no. 7049-7055. (coll. S. C. Hsu & C. T. Ma).

Gen. et sp. indet.

(Pl. I, figs. 38, 39)

The specimen figured in Pl. I, figs. 38, 39 which has been formerly considered a pygidium of *Dipharus spinosus* by the writer, is very interesting. It measures 0.43 mm long and 0.60 mm wide, the axial lobe being faintly segmented into five segments, its anterior part expanding forward and its posterior part rounded. Side lobe being less stalked as compared with the fixed cheek of the genus *Dipharus*. Border narrow, clearly defined by the narrow furrow, its posterior border being somewhat horizontal. Two lateral spines attached to the posterior part curve outward.

The writer is in complete agreement with Shaw that *Dipharus* represents an ancestral connection between agnostids and eodiscids, for the pygidium of these two groups resembles closely its cranidium. The writer is inclined to refer this specimen to *Dipharus* probably a pygidium of *Dipharus spinosus*, for its side lobes are also stalked and the two lateral spines considered as two pygidial spines can be compared with the genal spines of the cephalon of *D. spinosus*.

It is however possible that this specimen may be a protaspis of other trilobite genus, but owing to meagreness of material the writer can express no definite opinion regarding the zoological position of this interesting specimen.

Occurrence and Horizon: Lower Shihpai Shale, Changyang, western Hupei, (coll. S. C. Hsu & C. T. Ma, cat. no. 7056).

Family Redlichiidae Poulsen

Genus *Redlichia* Cossman 1902

For half a century after the erection of the genus *Redlichia* at least 25 species have been ascribed to this genus. With the increasing number of species a series of intermediate forms are brought to light. But the more our knowledge of transitional forms extends the greater is the difficulty we encounter in defining our species although many authors unduly favor the erection of new specific names for these intermediate forms.

The previous classification of *Redlichia* is mainly based on the outline of glabella, course of facial suture anterior to the eye, shape of free cheek and position of the genal spine. Among these the course of facial suture anterior to the eye is considered to be the most important characteristic. The course of facial suture posterior to the eye has often been overlooked by different authors. As a result of careful observations on the present specimens the writer has found three distinguishing types of facial suture of *Redlichia* (s. str.) namely, the *chinensis*-form, the *noetlingi*-form and the *nobilis*-form. These forms are illustrated in plate III.

The genus *Redlichia* (s. str.) is restricted only to the Shihpai Shale and the Archaeocyathina Limestone and their equivalent formations. The earlier species of *Redlichia*, i.e., *Redlichia intermedia*, *Redlichia walcotti*, *Redlichia carinata* etc. should be separated from *Redlichia*, for they differ from the typical species, *R. chinensis*, *R. noetlingi*, *R. saitoi*, *R. nobilis* etc. in the facial suture, glabella and form of cranidium.

It seems therefore desirable to revise this genus by means of the types of facial suture and other important features which, as many authors have frequently pointed out, should be obtained from the study of actual specimens and not from old and inaccurate literatures. A thorough revision of *Redlichia* is however not within the scope of the present paper.

Redlichia chinensis Walcott

(Pl. IV, fig. 9; Pl. III, fig. 15)

The specimen figured in plate IV, fig. 9 was collected from Kueichow. It shows the characteristic facial suture of *chinensis*-form.

Cat. no. 7057.

Redlichia saitoi Lu

(Pl. IV, fig. 8)

1934. *Redlichia* cf. *walcotti* Saito, Japan. Jour. Geol. Geogr., vol. 11, nos. 3-4, p. 255, pl. 26, figs. 19-21, text-fig. 5.

1948. *Redlichia* cf. *saitoi* Hsu, Contr. Inst. Geol. Academia Sinica, no. 8, p. 299-300, Pl. I, figs. 12-14.

1949. *Redlichia saitoi* Lu.

1950. *Redlichia saitoi* Lu.

The type specimen of Hsu's Pl. I, fig. 14, 1948. (cat. no. 160) is refigured here (Pl. IV, fig. 8). On this specimen facial suture of *chinensis-form* is clearly shown on both postero-lateral sides of the glabella.

Occurrence and horizon: Archaeocyathina Limestone, I-tu-hsien, western Hupei. (coll. S. C. Hsu, cat. no. 160).

Redlichia nobilis Walcott

(Pl. III, fig. 13; Pl. IV, figs. 1-4)

1913. *Redlichia nobilis* Walcott, Cambrian fauna of China, Res. in China.

Some cranidia and free cheeks are found in the material. They agree closely with the type species described by Walcott. The courses of facial suture at both anterior and posterior end of the eye lobe are comparatively short. Genal spine of the free cheek extends more outward. Each posterior lateral border of the free cheek forms an angle of about 90° with its posterior border.

Occurrence and horizon: Archaeocyathina Limestone, I-tu-hsien, western Hupei. (coll. S. C. Hsu & C. T. Ma, Cat. no. 7058a-d).

Redlichia cylindrica n. sp.

(pl. IV, figs. 5-7)

This new species is represented by only a few crushed cranidia.

Cranidium slightly convex. Glabella cylindrical and contracted very slightly at both anterior end of the eye lobe, with three pairs of curved glabellar furrows. Occipital ring of uniform width and with a small median tubercle. Eye lobe close to the glabella with the posterior end near the occipital ring.

The anterior branch of facial suture of this species quite like that of *Redlichia noetlingi*; the posterior course is unknown.

Occurrence and horizon: Lower Shihpai Shale, Changyang, western Hupei.

Syntype: cat. no. 7059a-b. (coll. S. C. Hsu & C. T. Ma).

Subgenus *Wutingaspis* Kobayashi

1950. *Eoredlichia* Chang, in Lu's Paper, Acta Geologica Sinica, Vol. 32, no. 3, p. 186, 1953.

Diagnosis: Cranidium subquadrate in outline. Glabella conical, convex and marked by three pairs of glabellar furrows. Occipital ring distinctly separated from the glabella by a broad and deep occipital furrow. Eye lobe crescentic, its posterior end far

from the occipital furrow. Posterior lateral limb large. Posterior lateral furrows wide and shallow. Anterior branch of facial suture extending outwards and nearly perpendicular to the border. Posterior branch of facial suture cutting obliquely outwards but slightly backwards.

Remarks : In 1940 Lu described a characteristic species of *Redlichia*, *R. intermedia*, from the Chiungchussu Formation near Kunming District, Yunnan. He gives in his paper not only a detailed study on the ontogenetic history of this species, but also discussions and comparison of the phylogenetic relationship of the Family *Redlichiidae*. His conclusion is very important to the Lower Cambrian trilobites of the Pacific province, especially to the Family *Redlichiidae*, for it has the first time cleared up the ontogenetic history of the genus *Redlichia*.

In 1944 Kobayashi* published a new genus, *Wutingaspis*, based upon the specimens of the Peking University formerly collected by Ting and Wang in eastern Yunnan. Kobayashi's species, *W. conditus*, *W. tingi* are undoubtedly synonyms of *Redlichia intermedia* Lu. *Redlichia*(?) sp. (1944, p. 114, Pl. X, fig. 5), *Yunnanocephalus yaoyingensis* Kobayashi (1944, p. 132, Pl. X, fig. 6) are probably two larvae of *Redlichia intermedia* Lu.

Judging from its pygidium, glabella, free cheek and thorax etc., *Redlichia intermedia* Lu is more closely related to the typical species of *Redlichia* than to *Paleolenus* and *Sinolenus*. With regard to the stratigraphic position of *Redlichia intermedia* Lu and *Paleolenus* a detailed stratigraphic sequence has also been given by Lu (1941). Owing to meagreness of material and inadequate stratigraphic records Kobayashi arrived at a wrong conclusion when he dealt with such a characteristic trilobites.

In 1950 the writer designated *Redlichia intermedia* Lu as the genotype of a new genus, *Eoredlichia*** (Lu, 1953) under the family *Redlichiidae*. Later study and critical discussion with Lu has led the writer to consider *Wutingaspis* as a subgenus of *Redlichia*. Therefore, we have the following arrangement:

Genotype: *Redlichia intermedia* Lu, 1940.

Wutingaspis intermedia Lu, 1940.

Wutingaspis walcotti Mansuy, 1912.

Wutingaspis carinata Mansuy, 1912.

Occurrence and horizon : Lower part of the Chiungchussu Formation (Early Lower Cambrian), eastern Yunnan and western Szechuan.

***Redlichia* (*Wutingaspis*) *intermedia* Lu**

(Pl. III, figs. 1-12)

1940. *Redlichia intermedia* Lu, Bull. Geol. Soc. China vol. 20, no. 3-4.

1944. *Wutingaspis tingi* Kobayashi, Japan. Jour. Geol. Geogr. vol. XX, no. 1-4, Pl. X, fig. 7.

1944. *Wutingaspis conditus* Kobayashi, ibid., Pl. X. fig. 9.

*Japan. Jour. Geol. Geogr. 20, (1-4).

**Acta Geologica Sinica, 32 (3), 186, 1953.

1944. *Yunnanocephalus yaoyingensis* Kobayashi, *ibid.*, Pl. X, fig. 6.

1944. *Redlichia* (?) sp. Kobayashi, *ibid.*, Pl. X, fig. 5.

The specimens figured in plate III were also collected by Ting and Wang from eastern Yunnan (field number Y338). All of their collections are kept in the Paleontological Institute, Academia Sinica.

Occurrence and horizon: Lower part of the Chiungchussu Formation (Early Lower Cambrian), eastern Yunnan. (cat. no. 7060-7070).

Family Ellipsocephalidae Matthew

Genus *Lusatiops* R. & E. Richter 1941

Since the species "*Protolenus*" *coreanicus* (Saito) was first described from North-western Chosen from a bed stratigraphically below the Lower *Redlichia* Shale many authors take it as belonging to the genus *Protolenus*, a characteristic trilobite of the Hanfordian of New Brunswick region. Grabau^[8] pointed out that even a cursory comparison of the cephalon of "*Protolenus*" *coreanicus* Saito with the New Brunswick types of Matthew, *Protolenus paradoxides* and *Protolenus bituberculatus*, or with the species of the subgenus "*Bergeronia*" shows a number of pronounced differences, which need to be carefully considered before the asiatic forms are referred to the New Brunswick genus. With this view the writer is in complete agreement. R. & E. Richter in 1941 made "*Protolenus*" *coreanicus* the type of his new genus *Lusatiops*. If we compare "*Protolenus*" *coreanicus* (Saito) and *Lusatiops sinensis* n.sp. with other Lower Cambrian trilobite genera, it will be shown that they resemble so much *Paleolenus* so they must be closely related to the later genus.

Lusatiops sinensis n. sp.

(Pl. II, figs. 1-16)

The adult specimen: This species is represented by many cranidia and separate free cheeks. Cranidium quadrate in outline, glabella cylindro-conical, convex and marked by three pairs of glabellar furrows. The two posterior pairs of glabellar furrows oblique and detached, the anterior pair of glabellar furrow extending somewhat horizontally. Eye lobe stout, its posterior end being far from the occipital furrows. Posterior lateral limb short, posterior lateral furrow wide and with moderate depth. Occipital furrow narrow, occipital ring with a maximum width in its middle. The anterior branch of facial suture extends divergently outwards and nearly perpendicular to the border the posterior course is short. Preglabellar field narrow, border of uniform width and convex. Free cheeks of moderate size, plano-convex with a long spine pointing backward and outwards.

The larval specimens: A description of the post-embryonic development of the cranidium of this species is given below. It is unfortunate that the early protaspids and complete larval dorsal shield are absent.

Pl. II, figs. 1, 34: Cranidia very small, a protaspids of later stage, 0.50—0.55 mm long; the glabella expending toward the front, distinctly separated from a uniform and

very narrow frontal border; 4 distinct transglabellar furrows cutting horizontally the glabella into 5 rings of unequal size.

Eye ridge and eye lobe undifferentiated, confluent marked by a very closed narrow ridge with its posterior end detached at a distance from the glabella.

Pl. II, figs. 2, 35: A cranidium in early meraspid stage, 0.68 mm long, occipital ring curved backward, border narrow, posterior lateral furrow and limb clear.

Pl. II, figs. 3-4, 36: Meraspid stage, cranidium measured 0.91 mm in length, glabella expanding slightly forward, eye ridge and eye lobe stout, border thickened, anterior transglabellar furrow detached at its middle part and the posterior lateral furrows gradually extending upward and outward.

Pl. II, figs. 5, 6, 37: Late meraspid stage. Cranidium reaching 1.13 mm in length with a cylindrical glabella; two posterior pairs of glabellar furrows oblique and detached, the anterior pair of glabellar furrow running a little horizontally. Eye lobe stout.

Pl. II, fig. 38: Early holaspid stage. Cranidium of 1.50 mm long retaining many characters of an adult cranidium.

Occurrence and horizon: Lower Shihpai Shale, Changyang, western Hupei.

Holotype and paratype: cat. no. 7071-7086. (coll. S. C. Hsu & C. T. Ma).

***Lusatiops* sp. n. sp.**

(Pl. II, figs. 17-25)

This new species differs from *Lusatiops sinensis* chiefly in its stout glabella. This feature is characteristic not only in the adult individuals but also in their larval forms. Many protaspid of this species are characterized by a stout axial lobe that expands forward. In a later stage of growth both eye ridge and occipital ring were differentiated, but glabella still expands forward. In the last stage of growth the glabella gradually becomes cylindrical and cylindro-conical.

Occurrence and horizon: Lower Shihpai Shale, Changyang, western Hupei.

Syntype: cat. no. 7087-7094. (coll. S. C. Hsu & C. T. Ma).

Genus *Protolenus* Matthew

(?) ***Protolenus hupeiensis* n. sp.**

(Pl. II, figs. 26-27)

Only specimens of two cranidia are referred to this new species.

Cranidium semi-circular in outline; glabella cylindro-conical, slightly expanded at its posterior and strongly convex, with three pairs of short glabellar furrows; dorsal furrow distinct, occipital furrow narrow and deep, occipital ring convex and curved backward; fixed cheeks also convex somewhat narrower than the glabella. Both eye ridge and eye lobe indistinct, probably due to poor preservation. Posterior lateral limbs convex and narrow. Border narrow, bounded by a convex narrow marginal furrow.

Remarks: The present specimens occur in the shaly sandstone layers and are tentatively referred to *Protolenus*. Although our species agrees with *Protolenus* in many respects, it differs from the latter in the front border, preglabellar field, occipital ring etc. Owing to inadequate material and poor state of preservation in our specimens it is impossible to erect a new genus.

Occurrence and horizon: Archaeocyathina Limestone, I-tu-hsien, western Hupei.

Syntype: cat. no. 7095, 7096. (coll. S. C. Hsu & C. T. Ma).

Genus *Paleolenus* Mansuy
***Paleolenus douvillei* Mansuy**
(pl. II, fig. 28)

1912, *Paleolenus douvillei* Mansuy, Mem. Serv. Geol. Indochine, vol. 1, fasc. 2, p. 29, pl. 3, figs. 6a-6d, pl. d, figs. 1a-1d.

1941, *Paleolenus douvillei*, Lu, Bull. Geol. Soc. China, vol. 21, no. 1, p. 83, Pl. I, fig. 14.

This species is represented by two small cranidia of which one is 5.50 mm long and 6.80 mm wide, while the other 3.20 mm long and 4 mm wide, showing three pairs of glabellar furrows. Eye and eye ridge are faintly shown. The slightly contracted glabella resembles closely Lu's specimen.

Occurrence and horizon: Upper Shihpai Shale, I-Chang, western Hupei. (cat. no. 7097).

Correlation of the fauna

The genus *Redlichia* (s. str.) has a long stratigraphic range in the Lower Cambrian formations in China. In eastern Yunnan *Redlichia chinensis* and *Redlichia mai* first appear in the Tsanlangpu Formation and disappear in the upper part of the Lungwangmiao Formation which represents the upper part of the Lower Cambrian. The Lungwangmiao Formation is also characterised by the presence of *Micmacca* and *Archaeocyathus*. Species of *Redlichia* remains of the Chiungchussu Formation in the same province should be referred to a separate genus. In northwestern Chosen Saito^[37, 38, 39] has worked out the fauna of the *Redlichia* shales the lower part of which is characterised by *Redlichia chinensis*, *Redlichia nobilis*, *Bonnia orientalis* etc., and the upper part *Neoredlichia nakamurai*, *Redlichia chinensis*, *Redlichia coreanicus* and *Redlichia saitoi* Lu. While studying the stratigraphy of Chiawang District, southern Shantung in 1949, the writer found several specimens of cranidia and free cheeks of *Neoredlichia nakamurai* and *Redlichia chinensis* in the upper horizons, and a few specimens of *Redlichia chinensis* and *Redlichia sp.* in the lower horizons. The two *Redlichia* horizons are separated by a conglomerate bed of 2 m thick. The same relation seems to hold also in the case of the Gorge District of Yangtze where the Lower Cambrian Formations are represented by the Archaeocyathina Limestone above and the Shihpai Shale below. The new species (?) *Protolenus hupeiensis* described in the present paper is in association with *Redlichia chinensis*, *Redlichia nobilis* and *Redlichia saitoi* Lu in the Archaeocyathina Limestone. The species *Paleolenus douvillei* is restricted only to the upper part of the Shihpai Shale in association also with *Redlichia chinensis*. The lower Shihpai Shale is

characterised by the presence of *Lusatiops sinensis*, *Lusatiops* sp. n. sp., *Hebediscus orientalis*, *Dipharus spinosus* and *Redlichia cylindrica*.

The occurrence of *Hebediscus*, *Dipharus* and *Lusatiops* in the lower Shihpai of the Yangtze Gorge District is of great stratigraphic significance. It makes possible the correlation of the Lower Cambrian stratigraphy of China, Chosen and N. America. On account of the presence of such forms the vertical range of the genus *Redlichia* becomes also clear. The conception of many authors that the genus *Redlichia* as a whole is of about the same or even higher stratigraphic range than that of the genus *Protolenus* can not be accepted, as *Redlichia* appeared actually earlier than *Protolenus*, and survived with *Protolenus* to the late Lower Cambrian.

In 1942 Lu^[26] correlated the Chintingshan Formation of Kueichow with the Lungwangmiao Formation of eastern Yunnan and the Shihlungtung Limestone (=Archaeocyathina Limestone) of the Yangtze Gorge. The Minghsinssu Formation is certainly equivalent to the Tsanlangpu Formation on account of the presence of *Paleolenus*. In the Gorge District we have found evidence of the presence of *Paleolenus* in the upper Shihpai Shale which can be correlated with the Minghsinssu and Tsanlangpu Formations. The lower Shihpai Shale may be correlated with the "*Protolenus*" shale in northwestern Chosen, and tentatively with the upper part of the Chiungchussu Formation in eastern Yunnan.

In 1947 Howell^[10] made a correlation of the Cambrian formations between China and N. America in the light of fauna analysis. He grouped the Tsanlangpu and the Chiungchussu Formations in eastern Yunnan into one Formation which is correlated with the entire *Olenellus* zone. On his chart he also correlated the *Salterella* beds of eastern Yunnan with the *Bonnia* and *Obolella* zones of N. America. Some revision of this correlation now seems possible.

It is noteworthy that *Bonnia orientalis* Saito has been found near the basal part of the lower *Redlichia* shale in northwestern Chosen. Remembering that the *Bonnia* zone is below the *Olenellus* zone in North America, we can correlate the lower *Redlichia* shale of northwestern Chosen and China with the entire *Olenellus* zone, or the greater part of it. In the latter case *Redlichia* zone is slightly older than the *Olenellus* zone of North America.

A comparison of the faunas of the Hoppin slate of eastern Massachusetts with the lower Shihpai Shale of China shows that trilobite genera common to both are *Hebediscus* and *Dipharus*. Recently the species of *Hebediscus* were referred to the genus *Dipharus* and the fossil beds were correlated with the *Obolella* zone in North American chart by Shaw^[40]. Although species of both genera from the lower Shihpai Shale described in the present paper are new, it is believed that the lower Shihpai Shale is of the same age as the Hoppin slate.

The Chiungchussu Formation of eastern Yunnan is characterised by the presence of *Wutingaspis intermedia* Lu and *Yunnanoccephalus reedi* Lu, the former species being regarded by Howell as a *Redlichia* and the later species considered to be identical with *Hebediscus attleboresensis* Shaler & Foerste which is a species of the *Callavia* zone of North America. In eastern Yunnan the beds containing *Salterella* and *Hyolithes* recorded by P. Misch have no trilobites, but many indubitable specimens of *Wutingaspis intermedia* Lu from eastern Yunnan have been found in association with numerous specimens of *Hyolithes* which is also a common species of the *Callavia* bed, as stated by Howell. Notwithstanding that *Salterella* and *Hyolithes* are not good horizon markers for stratigraphic purposes, the Chiungchussu Formation in eastern Yunnan should not be regarded as younger than the *Bonnia* zone of the North American chart.

TABLE 1 Correlation table of the Lower Cambrian of China, Chosen, North America and Northwestern Europe.

E. Yunnan	N. Kueichow	W. Hupei	S. Shantung	N. W. Chosen	N. America	N. W. Europe
Lungwang-miao Formation	Chintingshan Formation	Archaeocyathina Limestone (Shihlungtung Ls.)	Upper Redlichia Shale	Upper Redlichia Shale	Syspacephalus zone	Protolenus zone
Tsanlangpu Formation	Minghsinssu Formation	Upper Shihpai Shale	Lower Redlichia Shale	Lower Redlichia Shale	Olenellus zone	Olenellus zone
Chiung-chussu Formation	Niutitang Formation	Lower Shihpai Shale		"Protolenus" Shale	Bonnia zone	Callavia zone
						Holmia zone
					Obolella zone	Obolella zone

Explanation of Plate I.

Figs. 1-20-*Hebediscus orientalis* Chang (n. sp.)

- 1, 2, 3, dorsal carapace (the same specimen figured), $\times 4\frac{1}{2}$, Holotype, cat. no. 7033.
- 4, 5, crushed dorsal carapace (the same specimen figured), $\times 4\frac{1}{2}$, cat. no. 7034.
- 6, 7, dorsal carapace (the same specimen figured), $\times 4\frac{1}{2}$, cat. no. 7035.
- 8, larval pygidium of early stage, $\times 20$, cat. no. 7036.
- 9, 10, 11, larval pygidia showing late meraspid stage, $\times 10$, cat. no. 7037, 7038, 7039.
- 12, immature pygidium showing the later meraspid stage, $\times 10$, cat. no. 7040.
- 13, pygidium showing the early holaspid stage, $\times 13\frac{1}{2}$, cat. no. 7041.
- 14, pygidium showing the early holaspid stage, $\times 17$, cat. no. 7042.
- 15, adult pygidium, $\times 2$, cat. no. 7043.
- 16, 17, adult pygidia, $\times 4\frac{1}{2}$, cat. no. 7044, 7045.
- 18, separate free cheek, external mold, $\times 4\frac{1}{2}$, cat. no. 7046.
- 19, adult cranium, $\times 4\frac{1}{2}$, cat. no. 7047.
- 20, immature cranium, $\times 20$, cat. no. 7048.
- 21-32-*Dipharus spinosus* Chang (n. sp.)
- 21, a protaspis, $\times 28\frac{1}{2}$, cat. no. 7049.
- 22, a protaspis, $\times 28\frac{1}{2}$, cat. no. 7050.
- 23, 24, a protaspis (the same specimen figured) showing an advanced step of growth, $\times 28\frac{1}{2}$, cat. no. 7051.

- 25, a protaspis highly magnified, $\times 60$, cat. no. 7052.
 26, a sketch showing dorsal view of the protaspis.
 27, a sketch showing an advanced step of growth of the protaspis.
 28, cephalon highly magnified, $\times 60$, cat. no. 7053.
 29, 30, cephalon (the same specimen figured), Holotype, $\times 28\frac{1}{2}$, cat. no. 7054.
 31, crushed cephalon, $\times 28\frac{1}{2}$, cat. no. 7055.
 32, a sketch showing the dorsal view of the cephalon.
 33-37-*Hebediscus orientalis* Chang (n. sp.)
 33, 34, sketches showing the pygidia of late meraspid stage.
 35, a sketch showing the pygidium of later meraspid stage.
 36, a sketch showing the pygidium of early holaspid stage.
 37, a sketch of an adult pygidium.
 38-39-Gen. et. sp. indet.
 38, 39, the same specimen figured, $\times 28\frac{1}{2}$, cat. no. 7056.

Explanation of Plate II.

Figs. 1-16-*Lusatiops sinensis* Chang (n. sp.)

- 1, a cranidium probably in the later protaspid stage, $\times 10$, cat. no. 7071.
 2, a cranidium in early meraspid stage, $\times 10$, cat. no. 7072.
 3, 4, cranidia in meraspid stage, $\times 10$, cat. no. 7073, 7074.
 5, a cranidium in late meraspid stage, $\times 19$, cat. no. 7075.
 6, a cranidium in later meraspid or early holaspid stage, $\times 10$, cat. no. 7076.
 7, adult cranidium, $\times 4\frac{1}{2}$, cat. no. 7077.
 8, an adult cranidium associated with *Hebediscus orientalis*, $\times 2$, cat. no. 7078.
 9, an adult cranidium associated with *Hebediscus orientalis*, $\times 2$, cat. no. 7079.
 10, adult cranidium, $\times 4\frac{1}{2}$, cat. no. 7080.
 11, adult cranidium, $\times 4\frac{1}{2}$, cat. no. 7081.
 12, adult cranidium, $\times 4$, Holotype cat. no. 7082.
 13, 14, 15, separate free cheeks probably belonging to this species, $\times 4\frac{1}{2}$, cat. no. 7083, 7084, 7085.
 16, immature pygidium fused with thoracic segments probably belonging to this species, $\times 10$, cat. no. 7086.
 17-25-*Lusatiops* sp. (n. sp.)
 17, protaspis, $\times 20$, cat. no. 7087.
 18, protaspis, $\times 20$, cat. no. 7088.
 19, protaspis, $\times 20$, cat. no. 7089.
 20, immature cranidium, $\times 20$, cat. no. 7090.
 21, immature cranidium, $\times 28\frac{1}{2}$, cat. no. 7091.
 22, immature cranidium, $\times 10$, cat. no. 7092.
 23, 24, immature cranidium (the same specimen figured), $\times 4\frac{1}{2}$, cat. no. 7093.
 25, an adult cranidium, $\times 2$, cat. no. 7094.
 26-27-(?) *Protolenus hupeiensis* Chang (n. sp.)
 26, 27, dorsal view of the cranidia, $\times 2$, cat. no. 7095, 7096.
 28-*Paleolenus douvillei* Mansuy
 28, dorsal view of the cranidium, $\times 4\frac{1}{2}$, cat. no. 7097.
 29-33-*Lusatiops* sp. Chang (n. sp.)
 29, 30, 31, 32, 33, sketches showing the post-embryonic development of the cranidium from larval stages to adult.
 34-39-*Lusatiops sinensis* Chang (n. sp.)
 34, 35, 36, 37, 38, 39, sketches showing the post-embryonic development of the cranidium from larval stages to adult.

Explanation of Plate III.

Figs. 1-12-*Wutingaspis intermedia* (Lu)

- 1, dorsal carapace and an immature cranidium, $\times 2$, cat. no. 7060.
- 2, 3, complete dorsal carapace, internal and external molds, $\times 2$, Cat. no. 7061, 7062.
- 4, crushed dorsal carapace, $\times 2$, cat. no. 7063.
- 5, 6, 7, 8, adult cranidia, $\times 2$, cat. no. 7064, 7065, 7066, 7067.
- 9, 10, immature cranidia, $\times 2$, cat. no. 7068, 7069.
- 11, immature dorsal carapace, $\times 2$, cat. no. 7070.
- 12, figure showing the general view of the cephalon and the course of facial suture.
- 13-*Redlichia nobilis* Walcott
- 13, figure showing the general view of the cephalon and the *nobilis*-form facial suture.
- 14-*Redlichia noeltingi* (Redlich)
- 14, figure showing the general view of the cranidium and the *noeltingi*-form facial suture.
- 15-*Redlichia chinensis* Walcott
- 15, figure showing the general view of the cephalon and the course of the *chinensis*-form facial suture.

Explanation of Plate IV.

Figs. 1-4-*Redlichia nobilis* Walcott

- 1, 2, 3, 4, dorsal view of a complete free cheek and cranidia, showing the course of the *nobilis*-form facial suture, cat. no. 7058a-d.
- 5-7-*Redlichia cylindrica* Chang (n. sp.)
- 5, 6, crushed cranidia showing its cylindrical glabella, $\times 2$, Syntype, Cat. no. 7059a-b.
- 7, sketch showing the characteristics of the cranidium.
- 8-*Redlichia saitoi* Lu
- 8, dorsal view of cephalon and thorax, showing the posterior course of the *chinensis*-form facial suture and slender posterior lateral limbs preserved on both side of the glabella, natural size. (refigured from Hsu's type specimen of Pl. I, fig. 14, cat. no. 160).
- 9-*Redlichia chinensis* Walcott.
- 9, crushed dorsal carapace, a specimen collected from Kueichow, showing the posterior course of the *chinensis*-form facial suture, natural size, cat. no. 7057.