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ORIGINAL ARTICLES.

I.—NOTES ON THE BRITISH SPECIES OF *CERATIOCARIS*.

By Prof. T. RUPERT JONES, F.R.S., and HENRY WOODWARD, LL.D., F.R.S.

(PLATE X.)

DR. PACKARD'S observations on the structure of the Phyllopoda, and his comparative anatomical studies of allied living and extinct genera, supply the palæontologist with sound reasoning for referring the Phyllocarida to the Nebaliad type as a centre for a great group of obscure fossil forms, and as a starting-point for the Decapoda.<sup>1</sup> His views have been referred to in some detail in the GEOL. MAG. for August last, pages 349–352.

Order PHYLLOCARIDA, Packard (1879).

Genus *CERATIOCARIS*, M'Coy (1849).

The generic characters of *Ceratiocaris* have been described by M'Coy, Salter, H. Woodward, and Barrande in their several works and memoirs referred to in the sequel. James Hall, R. P. Whitfield, A. S. Packard, J. M. Clarke, Fr. Schmidt, C. E. Beecher, O. Novák, and others have added much information, general and special, on this and allied genera. The appended synonymy of the genus supplies full references to published notices on *Ceratiocaris* and some of its kindred.

We offer the following diagnosis of *Ceratiocaris*.

Carapace bivalved, probably with membranous attachment, no distinct hinge-joint observable; valves subovate, semiovate, subquadrate, or trapezoidal; contracted in front with the end sharp or rounded above the median line of the valve; more or less truncate behind. Rostrum elliptical in shape, of a single, lanceolate piece, chevron-marked. Antennæ (?) obscure. Dentate mandibles often apparent. Body many-jointed, with fourteen or more segments, of which 4–7 extend beyond the carapace; ornamented with delicate raised lines. Some or all of these segments bore small, lamelliform, branchial appendages.<sup>2</sup> Last segment longest, supporting three caudal spines, namely, (1) a strong tapering telson (style), thick at the top or proximal end, with its trifid articulating surface

<sup>1</sup> See "Monograph of the Phyllopod Crustacea of North America, with remarks on the Order Phyllocarida. By Dr. A. S. Packard, jun. (Extracted from the Twelfth Annual Report of the U. S. Geol. and Geograph. Survey), 1883."

<sup>2</sup> See the Sixth Report on Fossil Crustacea, Brit. Assoc. Report for 1872, p. 323; and GEOL. MAG. Vol. IX. p. 564; also a descriptive note by Mr. R. Etheridge, jun., in the Mem. Geol. Surv. Scotl., Explan. Sheet 23, 1873, p. 93, and Ann. Mag. Nat. Hist. ser. 4, vol. xiv. 1874, p. 9.

(resembling that in the telson of *Limulus*) pointed at the distal extremity, and more or less spinose, as shown by the bases of attachment for small lateral prickles, and (2) two shorter, simpler, lateral appendages (stylets). The surface of the valves has a lineate ornament, and the ventral margin has a thin raised rim.

CERATIOCARIS, M'Coy, 1849.

1839. *Onchus*, Agassiz (in part). In Murchison's Silurian System, p. 607.
1848. *Onchus*, Phillips (in part). Mem. Geol. Surv. vol. ii. part 1, p. 226.
1849. *Pterygotus*, M'Coy. Ann. Mag. N. H. ser. 2, vol. iv. p. 394.
1849. *Ceratiocaris*, M'Coy. Ann. Mag. N. H. ser. 2, vol. iv., p. 412.
1851. *Pterygotus*, M'Coy. Brit. Palæoz. Fossils, fasc. 1, p. 175.
1851. *Leptocheles*, M'Coy. Brit. Palæoz. Fossils, fasc. 1, p. 176.
1851. *Ceratiocaris*, M'Coy. Brit. Palæoz. Fossils, fasc. 1, p. 136.
1851. *Pterygotus* (*Leptocheles*), Bronn. Lethæa Geognost. vol. i. part 1, p. 40.
1852. *Onchus*, James Hall. Geol. Surv. New York, Palæontol. vol. ii. p. 320.
1852. *Ceratiocaris*, Bronn. Leth. Geogn. vol. i. part 2, p. 539.
1853. *Dithyrocaris*, Geinitz. Verst. Grauwack. Sachsen, Heft 2, p. 23.
1853. *Leptocheles*, M'Coy. Quart. Journ. Geol. Soc. vol. ix. p. 13.
1853. *Ceratiocaris* (*Leptocheles*), Barrande. Neues Jahrb. für Min. etc. 1853, Heft 3, p. 342.
1853. *Dithyrocaris*? D. Sharpe. Quart. Journ. Geol. Soc. vol. ix. p. 158.
1854. *Ceratiocaris et Leptocheles*, Murchison. Siluria, 1st edit. p. 236.
1854. *Ceratiocaris*, Morris. Catal. Brit. Foss. 2nd edit. p. 102.
1856. *Ceratiocaris*, Salter. Quart. Journ. Geol. Soc. vol. xii. p. 33.
1859. *Ceratiocaris*, J. Hall. Geol. Surv. New York, Palæontol. vol. iii. p. 420.
1859. *Ceratiocaris*, Salter. In Murchison's Siluria, 2nd edit. (3rd including Sil. Syst.), pp. 262, 538.
1860. *Ceratiocaris*, Salter. Ann. Mag. Nat. Hist. ser. 3, vol. v. p. 158.
1863. *Ceratiocaris*, James Hall. Sixteenth Ann. Rep. of Regents, p. 72, pl. 1.
1865. *Ceratiocaris*, H. Woodward and Salter. Catal. and Chart. Foss. Crustacea.
1865. *Ceratiocaris*, H. Woodward. GEOL. MAG. Vol. II. p. 401.
1865. *Ceratiocaris*, Huxley and Etheridge. Catal. Foss. Mus. Pract. Geol. p. 79.
1866. *Ceratiocaris*, H. Woodward. GEOL. MAG. Vol. III. p. 203.
1866. *Ceratiocaris*, Salter. Mem. Geol. Surv. vol. iii. p. 294.
1867. *Ceratiocaris*, Salter. In Murchison's Siluria, 3rd edit. (4th including Sil. Syst.) pp. 236 and 516.
1868. *Ceratiocaris*, Bigsby. Thesaur. Silur. p. 73.
1871. *Ceratiocaris*, H. Woodward. GEOL. MAG. Vol. VIII. p. 104.
1872. *Ceratiocaris*, H. Woodward. GEOL. MAG. Vol. IX. p. 564; and Report Brit. Assoc. for 1872, p. 323.
1872. *Ceratiocaris*, Barrande. Syst. Sil. Bohême, vol. i. Suppl. p. 437.
1873. *Ceratiocaris*, Salter. Catal. Camb. Sil. Foss. Woodw. Mus. p. 177.
1873. *Ceratiocaris*, R. Etheridge, jun. Mem. Geol. Surv. Scot. Exp. M. 23, p. 93.
1873. *Ceratiocaris*, Marschall. Nomenclator Zoologicus, p. 404.
1874. *Ceratiocaris*, R. Etheridge, jun. Ann. Mag. N. H. ser. 4, vol. xiv. p. 9.
1876. *Ceratiocaris*, F. Roemer. Leth. Geogn. Th. i. Leth. palæoz. Expl. pl. 19.
1877. *Ceratiocaris*, H. Woodward. Catal. Brit. Foss. Crust. p. 70.
1877. *Ceratiocaris*, Miller. Catal. Palæoz. Foss. America, p. 213.
1878. *Ceratiocaris*, Huxley and Etheridge. Catal. Foss. Mus. Pract. Geol. p. 84.
1878. *Ceratiocaris*, Bigsby. Thes. Devonico-Carbonif. pp. 26, 246 and 247.
1878. *Ceratiocaris*, Young. Proceed. R. Phys. Soc. Edinb. vol. iv. p. 168.
1880. *Ceratiocaris*, Whitfield. Amer. Journ. Sci. ser. 3, vol. xix. p. 35.
1882. *Ceratiocaris*, B. N. Peach. Trans. R. Soc. Edinb. vol. xxx. part 1, p. 73.
1883. *Ceratiocaris*, A. S. Packard, jun. Monogr. North Amer. Phyllop. Crust.; Twelfth Ann. Rep. U. S. Geol. and Geograph. Survey, p. 450.
1884. *Ceratiocaris*, C. E. Beecher. Ceratiocaridæ Upper-Devon. Measures; Second Geol. Serv. Penns. P.P.P. p. 2.
1885. *Ceratiocaris*, O. Novák. Sitzungs. k. böhm. Gesellsch. Wissensch.
1883. *Ceratiocaris*, H. W. and T. R. J. Report Brit. Association for 1883, p. 217.
1884. *Ceratiocaris*, T. R. J. and H. W. GEOL. MAG. Dec. III. Vol. I. p. 396.

## 1. CERATIOCARIS MURCHISONI (Agassiz), and its variety LEPTODACTYLUS (M'Coy).

Some imperfect caudal appendages or spines (telson or style, and lateral spines or stylets), from the Uppermost Ludlow strata, near Ludlow, were figured in Murchison's Silurian System, in 1839, as fish-defences. These were recognized by Prof. F. M'Coy in 1853 as being very similar to some analogous fossils, referred by him at first (in 1849) to a slender-clawed kind of *Pterygotus* from the Lower Ludlow, at Leintwardine, near Ludlow, which he separated from that genus as *Leptocheles leptodactylus*. M'Coy suggested that Murchison's fossil should be known as *L. Murchisoni*.<sup>1</sup>

In each case we have only caudal spines to deal with; but M'Coy's specimens (Brit. Pal. Foss. pl. 1 E, figs. 7, 7a, 7b) are much more slender than Murchison's (Sil. Syst. pl. 4, figs. 10 and 64, and Siluria, pl. 1 E, figs. 1, 2), and less strongly ribbed; and therein they seem at first sight to have specific differences.

Several good examples of more or less perfect sets of the three caudal spines corresponding in size, strength, and ribbing, with Murchison's fossils have been met with. These show evidence of lines of prickles (by the presence of little pits, representing their bases, along one or more lines); and on close examination the engravings in the Sil. Syst. and Siluria (the specimens have been lost) show some slight indications of this spinose ornament. This is not visible, however, in M'Coy's figures or specimens (Cambridge Museum, a/923, a/924). Of these latter, more delicate, caudal appendages, very few other examples occur.

In the collocation of these caudal appendages with their respective carapaces we have some doubt and difficulty.

We have not found a carapace directly associated with any complete spines of either the *Murchisoni* or *leptodactylus* type except in the case of a very small specimen (M. P. G. x  $\frac{1}{2}$ ), which appears to have the caudal appendages of *C. Murchisoni* and the carapace of Salter's "*leptodactylus*." With regard to both, however, the late Mr. J. W. Salter satisfied himself that he knew their special carapaces, for he described them at p. 157 of the Ann. Mag. Nat. Hist. for March, 1860: where also he refers both species to the *Ceratiocaris* of M'Coy. Judging from his Latin diagnoses, he allocates to the former—"a cephalothorax (carapace) two inches long, oblong, convex, ornamented with interrupted, nearly-straight, wide-apart lines. The caudal appendages long, sub-cylindrical; the centre spine (telson) strong, bulbous at its base, and with a strong dorsal rib; the side spines long. All ribbed. The whole animal medium-sized. Specimens possessed by the geologists at Ludlow and by the Museum of Practical Geology." The carapace described here does not agree

<sup>1</sup> Prof. M'Coy's observations are as follows:—" . . . As before mentioned, figs. 9, 10, and 11 [Sil. Syst. pl. 4; omit figs. 9 and 11], representing the so-called *Onchus Murchisoni*, Ag., are almost identical in form, size, sculpturing, and all other characters (as far as they are represented in these drawings), with the distinctly didactyle pincers which I have figured (Brit. Pal. Foss. pl. E, fig. 7) from Leintwardine, under the name *Lept. leptodactylus*. . . . If this approximation prove correct, the fossil should in future be called *Leptocheles Murchisoni* (Ag. sp.)."—Q. J. G. S. vol. ix, 1853, p. 13.

with any that we can associate with the caudal spines intended. Nor do we find at Ludlow exactly the kind of carapace required.

To *C. leptodactylus* Mr. Salter apportioned "a cephalothorax long, triangular, acute in front, broad and rounded behind. Free abdominal segments 7-8 in number, subquadrate, deeply impressed at the sides. Caudal appendages long, striate; the central spine (telson) scarcely thicker than the long lateral spines. Surface of the head (carapace) smooth, or marked with only very short sparse lines. Abdominal segments strongly striate. The whole animal elongate and more than a foot long." One particular specimen in the Mus. Pract. Geol. is referred to by Mr. Salter at p. 158. We are at a loss here also in fitting the indicated (*slender*) appendages to the carapace described. We have examined this and other good specimens, labelled *C. leptodactylus* by Mr. Salter or at his direction, in which the carapace agrees with his description. One carapace is of large size, nearly perfect, about 125 mm. (5 inches) long, by 55 mm. at greatest height, M. P. G. x  $\frac{1}{2}$ , Catal. Cambr. Sil. Foss. 1878, p. 142. A specimen nearly perfect, M. P. G. x  $\frac{1}{2}$  (Catal. 1878, p. 142), 60 mm. long by 28 mm., gives no certain indication of the length of its telson and its two stylets, for they are crushed off short. The abdomen exposed is about 50 mm. long. In specimen D of the Ludlow Museum, which has the proximal portion only of the caudal spines preserved, and in specimen B, with the appendages also broken off short, the telson was ribbed and pitted (= prickly), thereby differing from the spines known as *C. leptodactylus* (M. Coy).

There is also a well-preserved *small* specimen (M. P. G. x  $\frac{1}{2}$ , Catal. 1878, p. 142), with its carapace measuring only 25 mm. in length and 11 mm. in height, from the Lower Ludlow of Bow Bridge, Ludlow. This is labelled "*C. leptodactylus*," and belongs to the same species as the foregoing. Its caudal appendages are perfect, with the telson (25 mm.) about one-third of the length of the whole animal; but they differ from M. Coy's *C. leptodactylus*, for they are not only ribbed or ridged, but the telson was prickly; the laterals were probably rather more than half its length. Specimen M. P. G. D  $\frac{1}{2}$ , from Dudley, however, is a thin spiniform fragment, faintly striated like *C. leptodactylus*.

Altogether the telson (style) and stylets of these specimens have a very close resemblance to those known as *C. Murchisoni* (see above, p. 387). One example, from Dudley, described and figured as such in the GEOL. MAG. Vol. III. p. 204, Pl. X. Fig. 8 (stylets and the upper moiety of the style, 90 mm., even more than 5 inches long when perfect), was doubtlessly proportionate to the large carapace, M. P. G. x  $\frac{1}{2}$ , above alluded to, as belonging to an animal more than 12 inches long; the carapace, exposed segments, and the telson being each a third of the whole length.

Other good specimens of these caudal appendages are:—

Ludlow Museum, C. Lower Ludlow; Leintwardine.<sup>1</sup> Lower portion of the style and stylets, 130 mm. (5 $\frac{1}{2}$  inches).

<sup>1</sup> This is mounted with specimen D as one specimen; but the discrepancy between the two parts is readily seen. It is referred to by the Rev. J. D. La Touche in his *Geology of Shropshire*, 1884, p. 77.

Owens College Museum. From near Ludlow. Style and stylets, not perfect, 105 mm.

M. P. G.  $\frac{3}{8}$ , Catal. 1878, p. 118. Leintwardine. Style, 103 mm. This and a piece of a carapace associated are labelled "*C. tyrannus*, Salter."

Mr. Morgan's Collection: Cwm-y-sul, near Welshpool (Wenlock Shale). Fragment of style, with stylets, 95 mm.

Ludlow Museum, P. Lower Ludlow; Trippleton, near Leintwardine. Lower part of style and stylets, 80 mm.

Specimens B, C, D, in the Oxford Museum, from the greenish-grey mudstone near Ludlow, are also good tail-pieces.

Broken pieces:—

Murchison's fig. 10, pl. 4, Sil. Syst. (fig. 1, pl. 19, Siluria), Upper Ludlow beds. One piece measures 92 mm., and more, if the piece lying at its end belonged to it.

Fig. 9, Pl. X. GEOL. MAG. Vol. III. (M. P. G.  $\frac{1}{2}$ , Catal. p. 84), Casterton, Low Fell, Kirkby-Lonsdale; Wenlock Shale. Fragments, 50 mm.

Cambridge Museum, b/7. Upper Ludlow beds; Benson Knot, Kendal. Fragment, 43 mm.

M. P. G. x  $\frac{1}{2}$ , Catal. p. 142. Upper Ludlow; Benson Knot, Kendal. Fragments, 40 mm.

Cambridge Museum (Marr Coll.). Upper Coldwell beds=Wenlock; south of Coldwell quarry, Windermere. Part of style and ends of stylets, 40 mm.

Small fragments, smooth (? *Murchisoni*); straight and ribbed; curved and ribbed (? *Murchisoni*); M. P. G. x  $\frac{1}{30}$ ,  $\frac{1}{31}$ ,  $\frac{1}{32}$ ; from the Downon Sandstone; Kington, Herefordshire.

Strongly ribbed and pitted (=spinose), British Museum; Bury Ditch, Salop; and Oxford Mus. D, Ludlow.

Both in M'Coy's *C. leptodactylus* and *C. Murchisoni* (the latter =Salter's *C. leptodactylus*, in part, and his MS. *C. tyrannus* and *C. gigas*) the last abdominal segment is striated with straight, somewhat inosculating, raised lines; and other segments, where preserved, are similarly marked. A somewhat crushed specimen from Dane-field, Kington, Herefordshire (Lower Ludlow), M. P. G. x  $\frac{1}{2}$ , Catal. p. 141, showing a terminal segment with similar nearly straight, but wriggly, inosculating, thin riblets, and ridged and fluted caudal appendages, as far as preserved, has been labelled *C. gigas* by Salter; but this may well belong to the series here placed as *C. Murchisoni*; *C. leptodactylus* being restricted to M'Coy's specimens and figs. 7, 7a, 7b, and a few other slender and simply striate forms. The carapace belonging to these is not yet known. It is quite possible that these rare and thinner styles and stylets may have belonged to some variety of *C. Murchisoni*. In this case a separate specific name is not required for them, and they should be merged in *C. Murchisoni*, as arranged in H. Woodward's Catal. Brit. Foss. Crust. 1877, p. 71.

There is little or no doubt that the figure given by Mr. Salter in the Catal. Cambr. Silur. Fossils, 1873, pp. 16, 164, and 178, as

illustrative of the genus, is *C. Murchisoni* as here defined. The eye-spot, however, and the hinge-joints are, in our opinion, superfluous and not substantiated.

The synonyms of *CERATIOCARIS MURCHISONI* (Agassiz), 1839:—

- 1839. *Onchus Murchisoni*, Agassiz, in Silur. Syst. p. 607, pl. 4, fig. 10 (not figs. 9 and 11); and *Onchus*, fig. 63?, and Ichthyodorulites, fig. 64.
- 1851. *Leptocheles Murchisoni*, M'Coy. Synops. Brit. Palæoz. Foss. fasc. 1, p. 176.
- 1853. *Leptocheles Murchisoni* (Agass.), M'Coy. Quart. Journ. Geol. Soc. vol. ix. p. 13 (omitting allusion to figs. 9 and 11, Sil. Syst.).
- 1854. *Leptocheles Murchisoni* (M'Coy), Murchison. Siluria, 1st ed. p. 236, pl. 19, figs. 1, 2, and sp. fig. 3.
- 1859. *Leptocheles Murchisoni* (M'Coy), Murchison. Siluria, 2nd ed. (3rd including Sil. Syst.), pp. 263, 538, pl. 19, fig. 1 (2 and 3?).
- 1860. *Ceratiocaris Murchisoni* (M'Coy), Salter. Ann. Mag. Nat. Hist. ser. 3, vol. v. p. 157.
- 1866. *Ceratiocaris Murchisoni*, H. Woodward. GEOL. MAG. Vol. III. p. 205, Pl. IX. Figs. 8 and 9.
- 1867. *Leptocheles Murchisoni* (M'Coy). Salter, in Siluria, 3rd ed. (4th including Sil. Syst.), p. 134, pl. 19, figs. 1 and 2.
- 1867. *Leptocheles (Ceratiocaris) Murchisoni* (M'Coy). Salter, in Siluria, 3rd (4th) ed. p. 237, pl. 19, figs. 1 (2, 3?).
- 1867. *Ceratiocaris Murchisoni* (Agass.). Salter, in Siluria, 3rd (4th) ed. p. 516, pl. 19, figs. 1 and 2.
- 1867. *Ceratiocaris Murchisoni* (M'Coy), H. Woodw. Cat. Brit. Foss. Crust. p. 71.
- 1884. *Ceratiocaris Pardoensis*, La Touche. Geol. Shropshire, p. 77, pl. 17, fig. 563.
- 1884. *Ceratiocaris leptodactylus*, La Touche. Geology of Shropshire, p. 77, pl. 17, fig. 566 (young *C. Murchisoni*).

The synonyms of *CERATIOCARIS LEPTODACTYLUS*, M'Coy, founded on certain slender tail-spines, which may have belonged to a varietal form of *C. Murchisoni* (Agassiz):—

- 1849. *Pterygotus leptodactylus*, M'Coy. Ann. Mag. Nat. Hist. ser. 2, vol. iv. p. 394.
- 1851. *Pterygotus leptodactylus*, M'Coy. Synops. Brit. Palæoz. Foss. fasc. i. p. 170, pl. 1 E, figs. 7, 7a, 7b (not figs. 7c, 7d).
- 1853. *Leptocheles leptodactylus*, M'Coy. Quart. Journ. Geol. Soc. vol. ix. p. 13.
- 1859. *Leptocheles leptodactylus* (M'Coy), Murch. Siluria, 2nd (3rd) ed. pp. 263, 538.
- 1860. *Ceratiocaris leptodactylus* (M'Coy), Salt. Ann. Mag. Nat. Hist. ser. 3, vol. v. p. 157.
- 1867. *Leptocheles (Ceratiocaris) leptodactylus* (M'Coy). Salter, in Siluria, 4th ed. (including Sil. Syst.), p. 237.
- 1867. *Ceratiocaris leptodactylus* (M'Coy). Salter, in Siluria, 4th ed. (including Sil. Syst.), p. 516.
- 1873. *Ceratiocaris leptodactylus*, Salter. Catal. Camb. Sil. Foss. p. 164.

Taking M. Salter's description of the carapace of *leptodactylus* and the appendages of *Murchisoni* as really both belonging to the latter, and the more slender caudal spines (*leptodactylus* of M'Coy) as belonging to a variety of the latter, we have looked for the two-inch oblong carapace which Mr. Salter thought he had found for *Murchisoni* (Ann. Mag. Nat. Hist. l.c.), but we have not met with it at Ludlow, as led to expect by his remarks; nor is it in the Museum of Practical Geology, to which also he refers us. Indeed, we cannot help thinking that some confusion of the specimens is hereby indicated.

The carapace of *C. Murchisoni* (as defined by us) is pyriform, or acutely subovate, deep behind, narrow in front; gently convex on

the back; outlined by a bold elliptical curve on the ventral margin, which rises up to form with the dorsal edge a sharp angle in front, above the median line of the valve; but this and other features were varied by age and sex, and have been modified by pressure in the different specimens. The antero-ventral margin is sometimes indrawn, making the point in front more acute. The hinder margin is truncate with an elegant ogee curve, full below, and ending above in the postero-dorsal angle, often but not always sharply defined. In some cases the ventral margin is much deeper than in others. Some fragments of carapaces from Leintwardine (Ludl. Mus. O., and M. P. G.  $\frac{2}{3}$ ) are ornamented with longitudinal lines or striæ of varying strength.

Seven abdominal segments are usually exposed.

Good specimens of *C. Murchisoni* (Agass.) :—

- M. P. G. x  $\frac{1}{2}$ .—Carapace, 125 × 55 mm., with acute prow. Smooth, longitudinal linear ornament. Long form of carapace. Leintwardine.
- M. P. G. x  $\frac{1}{2}$ .—Carapace, 60 × 28 mm. Smooth and glazy.  
Seven segments, about 50 mm. (the last one about 20 mm.).  
Telson crushed. Long form of carapace. Leintwardine.
- Ludl. Mus. D.—Carapace, 50 × 30 mm. Smooth.  
Seven segments, 55 mm. (the last one 20 mm.). Some with straight striæ.  
Telson imperfect. Short form of carapace. Leintwardine?
- Ludl. Mus. B.—Carapace, about 50 × 30 mm. Short form of carapace.  
Exposed segments (crushed up), 50 mm. With straight, wriggly striæ.  
Telson broken. Leintwardine.
- M. P. G. x  $\frac{1}{2}$ .—Carapace, 40 × 20 mm., with acute prow. Smooth and glazy; at the place of the teeth.  
Five? segments, about 30 mm. Long form of carapace. Leintwardine.
- M. P. G. x  $\frac{1}{2}$ .—Carapace, 25 × 11 mm. Small, smooth, sharp in front, marked by teeth inside.  
Seven? segments, 28 mm. (the last one 14 mm.). Linear ornament.  
Telson, 25 mm. Ridged and pitted (spines). (Stylets about 12 mm. Ridged.) Long form of carapace. The whole animal  $3\frac{1}{2}$  inches in length. Bow Bridge, near Ludlow.
- Ludl. Mus. A.—Carapace, 24 × 13 mm. Small, smooth, subovate, sharp in front.  
Seven segments, 30 mm. (the last one 12 mm.). Longitudinally striate.  
Telson imperfect (12 mm. preserved). Medium form of carapace. Leintwardine?
- Oxford Mus. J, K, Q, are small specimens from the Lower Ludlow, with features closely resembling those of *C. Murchisoni*.

#### Addendum.

1853. *Dithyrocaris Murchisoni* (Agass.), Geinitz. Verstein. Grauwackenformation in Sachsen, u.s.w. Heft 2, p. 24, pl. 19, fig. 13.
1866. *Ceratiocaris Murchisoni*, Jones. Ann. Mag. N. H. ser. 3, vol. xviii. p. 40.

This is the distal end of tapering, costulate telson (or stylet?), and is quite comparable with *C. Murchisoni* (Agassiz), as indicated by Dr. H. B. Geinitz. It was obtained from the Silurian Grauwacké beds of the Gunzenberg, between Möschwitz and Pöhl, near Plauen, together with Graptolites, *Orthoceras*, and *Pterinea*.



## 2. CERATIOCARIS LUDENSIS, H. Woodward.

1871. *Ceratiocaris ludensis*, H. Woodward. GEOL. MAG. Vol. VIII. p. 104, Pl. III. Fig. 3.

1884. *Ceratiocaris ludensis*, Jones and Woodward. GEOL. MAG. Dec. III. Vol. I. p. 396.

This large and indeed gigantic *Ceratiocaris* is represented by seven abdominal segments, with the caudal appendages of telson and two stylets, in the Ludlow Museum, and has been described in the GEOL. MAG. for March, 1871, and illustrated with a reduced figure. The carapace is there estimated as having probably been eight inches in length. The segments giving eight inches, and the telson being about nine inches in length, the animal would be more than two feet in total length. As pointed out in the paper referred to, the telson is certainly the longest known. Thus we find the relative proportions to be for *C. ludensis*, H. W., 144; *C. Murchisoni* (Agass.), 128 (as defined above); *C. Dewei* (J. Hall), 100; *C. bohémica*, Barr. (Brit. Mus.), 84; *C. stygia*, Salter, 32; *C. Næthingi*, F. Schmidt, 26; *C. papilio*, Salter, 16.

The segments are ornamented along the back with imbricated or lattice-like, raised, lines, which pass downwards on the sides into oblique and then curved wrinkles, and sometimes form a reticulation. The ultimate segment is striated longitudinally with interrupted and inosculating lines. The spines are stout, tapering slowly, slightly curved inwards (downwards), delicately ribbed, and bear close-set marks of the bases of small spines between or on some of the ridges.

This fine specimen is imbedded in the greenish-grey, sandy, laminated mudstone of the Lower Ludlow series, at Church Hill, Leintwardine, near Ludlow, with Graptolites. It was found by the late Mr. H. Pardoe, and is preserved in the Ludlow Museum.

## 3. CERATIOCARIS PAPHIO, Salter. (Pl. X. Fig. 1.)

1859. *Ceratiocaris*, Salter. In Murchison's Siluria, 2nd (3rd) edit. p. 262, woodcut fig. 1, p. 538.

1860. *Ceratiocaris papilio*, Salter. Ann. Mag. Nat. ser. 3, vol. v. p. 154, woodcut fig. 1, and p. 155.

1865. *Ceratiocaris papilio*, Salter and H. Woodward. Catal. and Chart Foss. Crust. p. 17 (not fig. 5).

1865. *Ceratiocaris papilio*, H. Woodward. GEOL. MAG. Vol. II. p. 403, Pl. II, Figs. 1 and 2.

1867. *Ceratiocaris papilio*, Salter. In Siluria, 3rd (4th) edit. p. 236, woodcut fig. 1 (not fig. 2), and p. 516.

1873. *Ceratiocaris papilio*, Salter. Catal. Camb. Sil. Foss. p. 178.

1873. " " R. Etheridge, jun. Mem. Geol. Surv. Scotl. Expl. Map 23, pp. 55, 56.

1876. *Ceratiocaris papilio*, Armstrong and others. Catal. W.-Scot. Fossils, p. 24.

1877. " " H. Woodward. Catal. Brit. Foss. Crust. p. 71.

1878. " " Huxley and Etheridge. Catal. Camb. Sil. Foss. p. 142.

Of the two species, so abundant in the Upper-Ludlow Shales of the Logan Water, near Lesmahago, in Lanarkshire, and described (unfortunately without good figures) by J. W. Salter in the Ann. and Mag. Nat. Hist. for March, 1860, we have examined many good specimens. As mentioned by Salter, one (*C. papilio*) has the carapace more oblong than the other (*C. stygia*), which is deepened by



a greater or less angularity on its ventral margin. In the woodcut diagrams at p. 154 of his memoir, fig. 1 is the oblong form, and figs. 2 and 3 have the deep ventral angle (*C. stygia*), and yet they are all there termed *C. papilio*, evidently from oversight. In the Lesmahago district multitudes of the two species seem to have been imbedded in the black mud (now shales); and frequent references to these interesting deposits are made in Siluria, Memoirs of the Geological Survey of Scotland (especially Explanation of Map 23, p. 49, etc.), in other works on Scottish Geology, in geological manuals, etc., and in Dr. J. S. Hunter's papers in the Trans. Geol. Soc. Glasgow, vol. vii. pp. 56, 272, etc.

Carapace sub-oblong; straight on the back, gently curved below; like the prow of a boat in front, and truncate with an ogee curve behind. The anterior extremity is rather sharp and is rarely preserved; it slopes with a gentle curve downwards and backwards from the antero-dorsal angle to the ventral margin. The latter is somewhat convex in outline, with its greatest fullness near the middle and rather forward, but varying with every specimen, all being more or less squeezed out of their true shape. The front moiety usually keeps its shape more truly than the posterior region, of which sometimes the dorsal angle (as in Brit. Mus. 41896, 41897), and sometimes the boldly-curved ventral portion (as in Brit. Mus. 41894, 58669; Cambridge Mus. b/135; and M. P. G. x  $\frac{1}{15}$ ) becomes the more prominent. The surface of the valves is delicately striate, with longitudinal lines, curving parallel with the ventral margin, and coarser on the ventral than on the dorsal region. In some specimens the lines are seen to converge at, or rather, as it were, to start from, the postero-dorsal angles. The telson (style), relatively stout, and very little longer than the laterals or stylets, was faintly ridged, and perhaps prickly or spinose. The whole adult animal was probably from four to six inches long.

Having seen but few specimens in which the caudal appendages are well preserved in their place (as in Brit. Mus. 41894), we get only few good measurements.

Mr. Salter says that only three or four of the abdominal segments were free (external to the carapace), but probably there were even five; for in one specimen (Brit. Mus. 58669) five segments of large size, now loose and reversed, were probably exposed beyond the carapace; and in another (Brit. Mus. 41895) four, with an imperfect fifth, have been shifted out. The segments, excepting the last one, appear in their squeezed condition to be half as long as high, and the last one as long as three of the others.

In Brit. Mus. 41894, the carapace is 60 mm. long by 30 mm. deep (or high), and probably once rather deeper, having suffered from pressure. The penultimate segment is 10 mm. long, and if there were four of that length (40 mm.), with the ultimate segment, the body-rings would be nearly 80 mm. The telson was 25 mm. (stylets 18 mm.). Thus, altogether, the animal was about 152 mm., or 6 inches, in length.

Brit. Mus. 58669 has a longer (narrowed) carapace, five body-rings, and a broken telson; altogether,  $6\frac{1}{4}$  inches long,

In another, but smaller, individual (Brit. Mus. 41895) the carapace,  $40 \times 20?$  mm.; segments, 40 mm., but shortened; and style, about 20 mm. (stylets, 15 mm. each), make about 100 mm., or four inches, of total length.

In ten good specimens from Lesmahago we have seen two of carapace only; and in all the others the body-portion is shifted, and in six of them it is quite reversed—that is, lying at the anterior instead of the posterior end, as described by Mr. Salter (Siluria, 1867, p. 236, etc.).

The specimen Cambridge Mus. *b*/135 has the rostrum lying at an angle across the anterior extremity.

Of *C. papilio*, good specimens from Lesmahago:—

Cambridge Mus., *b*/135. M. P. G.  $\times \frac{1}{15}$ ,  $\times \frac{1}{25}$ .

Brit. Mus. 41894, 41895, 41896, 41897, 45161, 47989, 58669.

We have seen also some fossil carapaces from Benson Knot, Kendal (Upper Ludlow), which agree perfectly in form and proportions with *C. papilio* from Lesmahago, also in ornament, except that the postero-dorsal convergence of the striae is not present. These are Brit. Mus. some of those marked 44342; M. P. G.  $\times \frac{1}{4}$  (Catal. 1878, p. 141); and Cambridge Mus. *b*/35. They range from 65 mm. long and 32 mm. high to  $75 \times 40$  mm. Also a large imperfect specimen and some fragments in brown shale from Linburn near Muirkirk (Brit. Mus., all marked 58878.) The specimen *b*/35 is included in *C. inornata*, McCoy, by Mr. Salter, Catal. C. S. Foss. 1873, p. 177.

Moreover, the specimen N in the Ludlow Museum has the proportions and appearance of *C. papilio*, as far as it is preserved (wanting the antero-dorsal angle), from Church Hill, Leintwardine.<sup>1</sup>

#### 4. CERATIOCARIS STYGIA, Salter. (Pl. X. Fig. 2.)

1859. *Ceratiocaris*, Salter. In Murchison's Siluria, 2nd (3rd) ed. p. 262, woodcut fig. 2.

1860. *Ceratiocaris stygius*, Salter. Ann. Mag. Nat. Hist. ser. 3, vol. v. p. 154, woodcut figs. 2, 3 (fig. 1 is *C. papilio*).

1865. *Ceratiocaris papilio*, Salter and Woodward. Cat. and Chart Foss. Crust. p. 17, fig. 5.

1867. *Ceratiocaris stygius*, Salter. In Siluria, 3rd (4th) ed. p. 236, woodcut fig. 2, and p. 517.

1873. *Ceratiocaris stygius*, Salter. Cat. Camb. Sil. Foss. p. 178.

1873. " " R. Etheridge, jun. Mem. Geol. Surv. Scotl. Expl. Map 23, pp. 55, 56.

1876. *Ceratiocaris papilio*. Roem. Leth. geogn. Th. i. Leth. palæoz. pl. 19, fig. 4.

1876. *Ceratiocaris stygius*, Armstrong and others. Cat. W. Scot. Fossils, p. 24.

1877. " " H. Woodward. Catal. Brit. Foss. Crust. p. 73.

1878. " " Huxley and Etheridge. Cat. Camb. Sil. Fossils, p. 142.

Carapace-valves trapezoidal; back straight, but curving down for a short distance to the mucronate dorsal angle of the anterior edge, which then slopes with a slight convexity at a sharp angle, down-

<sup>1</sup> The very rich localities for these Silurian PhyllopoDS in the neighbourhood of Ludlow are enumerated and described in the Rev. J. D. La Touche's Handbook of the Geology of Shropshire, 1884, pp. 26, 27, especially Ludford Lane, Bow Bridge, Leintwardine, Church Hill, and Trippleton Farm. See also the Rev. W. S. Symonds' Record of the Rocks, 1872, p. 194, etc., for notices of Ludlow and its environs from a geologist's point of view.

wards and backwards, to about the middle of the ventral margin, where the valve is deepest (highest); and the other half of the ventral edge rises slowly with a straight or nearly straight oblique edge to the blunt postero-ventral corner, whence the truncate hind margin rises, with a gentle concave curve, to the sharp postero-dorsal angle. When the valves are spread open, a triangular space is left between the antero-dorsal angles. This condition and the shape are well shown in the specimen M. P. G. x  $\frac{1}{13}$ . The outline is often modified by pressure in other positions; but not to quite so great an extent, as the shape of *C. papilio* is altered by squeeze in some instances. The valves are delicately striate, with longitudinal lines curving parallel with the ventral edge, and crowded at the postero-dorsal angles. The body-segments, of which probably five were outside the carapace (though often the segments seem to have been pushed back within the carapace after death), are marked with delicate, raised, oblique, wrinkly lines on the sides, coming from angular imbricated lines on the back (as in *C. Scharyi*, Barrande, and *C. Dewei*, Hall). The joints are sometimes more than twice as high as long. The last one is as long as three of the others. The telson is short, and is apparently in some cases about half as long again as the stylets (as 50 is to 30); and some specimens show traces of thin costulae, and perhaps of prickles. The whole adult animals were from 4 to 8 inches long.

Specimen M. P. G. x  $\frac{1}{25}$  has the rostrum and teeth squeezed out loose near the front end. A large individual, Cambridge Mus. b/65, measures—

Carapace . . .	83 × 55 mm.
Four segments . . .	40 } 65 mm.
Last segment . . .	25 }
Telson . . .	50 ,,

198 mm. or nearly 8 inches.

A small specimen, M. P. G. x  $\frac{1}{13}$ , measures—

Carapace . . .	40 × 26 mm.
Four segments . . .	20 } 30 mm. ?
Last segment . . .	? 10 }
Telson . . .	30 ,,

About 100 mm. or nearly 4 inches.

*C. stygia* was rather larger than *C. papilio*; its telson was larger; the carapace was markedly distinct by its trapezoidal outline, deep ventral region, and mucronate antero-dorsal angle, which was not nearly so often lost in fossilization as the front angle of *C. papilio*. In its rostrum, teeth, superficial ornament of carapace and of body-joints, it seems to have closely resembled *C. papilio*. In ten good specimens from Lesmahago, two are simple carapaces; three have body-segments in places, and five have them shifted or reversed. In his respect *C. stygia* seems to have been rather less liable to the dissolution of the membranous attachments of the body than its associate *C. papilio*.

A postero-dorsal fragment in Cambridge Museum (Marr Coll.),

from the Denbighshire series (Wenlock), at Dinasbran, Llangollen, showing fine striæ above, and coarse striæ below, and the usual convergence of striæ, belongs probably to *C. stygia*.

Good specimens of *C. stygia* from Lesmahago are Cambridge Mus. b/136, b/65 (the last is referred to as *C. papilio*, evidently by mistake, in Cat. C. Sil. Foss. p. 178); M. P. G.  $\times \frac{1}{3}$  and  $\frac{1}{4}$ ,  $\times \frac{1}{6}$ ,  $\times \frac{1}{8}$ ,  $\times \frac{1}{10}$ ,  $\times \frac{1}{12}$ ; and B. M. 41898, 45154, 45155, 45156.

In the Mem. Geol. Scotl. Expl. Map 23, 1873, at p. 49, Mr. R. Etheridge, jun., enumerates the places near Lesmahago and Muirkirk, in Lanarkshire, where *Ceratiocarides* have been found by the Surveyors, namely—

*Ceratiocaris papilio*, Salter, at Dunside (Logan Water), Eaglinside Burn, Logan Water (2 m. S. of Lesmahago), and Linburn.

*Ceratiocaris stygia*, Salter, at Kip Burn (Logan Water), Eaglinside Burn, and Linburn.

*Ceratiocaris*, caudal appendages, at Long Burn (Logan Water), Dunside (Logan Water), Logan Water (6 m. S.W. of Lesmahago), Lann Burn, and Douglas Water.

Abdominal segments and appendages probably belonging to *C. stygia* are:—

B. M. 58878, Linburn, Muirkirk. A telson, not quite perfect at base, 35 mm. long, associated with some obliquely-striate segments.

B. M. 41899, Lesmahago. Four segments, 27 mm., and M. P. G.  $\times \frac{1}{2}c$ , four segments, 30 mm., and in each case two short ensiform stylets attached (style wanting).

B. M. 41900 and 41901, Lesmahago. Three abdominal segments, obliquely striate, and an ultimate segment with both oblique and straight striæ, probably due to two layers of the test. Telson, 30 mm. long; and two ensiform stylets, each about 13 mm. long.

M. P. G.  $\times \frac{1}{5}$ ,  $\frac{2}{3}a$ ,  $\frac{2}{3}b$ ,  $\frac{2}{3}d$ , Logan Water, Lesmahago. Segments with oblique striæ (one ultimate segment has straight striæ), not well preserved.

\*Oxford Mus. E. Seven segments and two spines, imperfect. Leintwardine.

One of the specimens in the Brit. Mus. marked 59648, from Lesmahago, is a small acute-ovate carapace (25  $\times$  15 mm.), to which is attached a complete, but somewhat crushed body of 13–14 segments, 6–7 (15 mm.) of which are external, and have appended two caudal spines, of which the longest may be the telson (12 mm. long), and the other, nearly as long, one of the stylets.

At first sight this looks like the small *C. Murchisoni*, Ludl. Mus. A., but it differs considerably in details. If it be not a distinct species, it may be the young of *C. stygia*.

On another of the specimens, B.M. 59648, from Lesmahago, are three loose small *bodies*, without carapaces. The largest has 13 or 14 segments, 45 mm., some of which are obliquely striate. The last five measure 25 mm., and the last one 10 mm., equal to three of the others. The telson is 20 mm. long. Another such specimen, smaller and narrower, 35 mm. long, has 14 (?) segments; the last one 7 mm. long; appendages imperfect.

These may be the loosened and shifted abdomens of young individuals of *C. stygia* or *C. papilio*, both common at Lesmahago. They cannot be mistaken for the Carboniferous *Acanthocaris*, Peach, or the Devonian *Campeccaris*, Page.

## EXPLANATION OF PLATE X.

- FIG. 1. *Ceratiocaris papilio*, Salter. Entire specimen from the Upper Ludlow Shales, Logan Water, Lesmahago, Lanarkshire. The abdominal segments are displaced and reversed (as is very frequently the case in specimens from Logan Water) and protrude from the rostral end of the carapace. Part of the carapace of another specimen is seen near the posterior border.
- „ 2a. *Ceratiocaris stygia*, Salter, from the same locality and formation.
- „ 2b. Portion of the carapace, near the postero-dorsal line, showing the delicate raised wavy lines with which the entire surface is covered (enlarged three times).
- „ 2c. The rostrum of same enlarged four times, to show the concentric striae covering the surface.

Figs. 1 and 2a drawn of the natural size from specimens in the British Museum, (Natural History).

(To be continued.)

## II.—CAN UNDERGROUND HEAT BE UTILIZED?

By J. STARKIE GARDNER, F.G.S.

GEOLOGY has long been the handmaid of Engineering. Instances are numerous in which the practical bearing of facts discovered by the devotee of the one have been recognized and utilized by the other. On the other hand, engineering enterprise has often put geologists in possession of facts of the greatest value as bases for fresh inductions. The subject now brought forward may perhaps sooner, or in a remote future, furnish another instance in which knowledge gained by the geologist may become available for a great economic purpose.

The subject of "Underground Heat" is one about which very little is known even by the specialist. There is much divergence of opinion as to the form and conditions under which this heat exists, and still more as to the depth at which it occurs. Whether the interior of the earth is solid or fluid, hot or cold, is still a debated subject; though all leading geologists are at all events agreed that it is hot, and many believe that it is partially fluid, the fluid being situated beneath the solid crust, and resting upon a solid interior. The question we have to consider is whether zones of considerable heat are likely to be within a depth at which it might be practicable to reach them.

The paramount importance of the subject, and its pressing nature, will come to be recognized when the scarcity of coal in this country shall render it impossible for us to pay for the vast supplies of food we are compelled to import from abroad either by it or by articles produced by its aid. Our statesmen and others whom it may concern will then perhaps awake to the necessity of promoting experimental research, and of obtaining new scientific knowledge; but let us hope not too late to arrest a serious diminution of our national wealth.

Coal began to be used as fuel in some localities about the 13th century; but until the beginning of the 17th, prejudice and other causes prevented its coming into anything like general use. We may



