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Charles D. and Mary Vaux Walcott
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(With 3 Plates)

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HARRY B. WHITTINGTON
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(Publication 4146)

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(With Three Plates)

The specimens of silicified trilobites described in the following pages were collected and prepared by Dr. Arthur L. Bowsher, of the United States National Museum (hereafter abbreviated as U.S.N.M.). I am indebted to Dr. Bowsher for suggesting that I study this material and to Dr. G. Arthur Cooper for permitting the loan of it to me. All the specimens are in the National Museum collections and are from the following localities:

U.S.N.M. locality 3070.—Helms formation, El Paso quadrangle, Hueco Mountains, Tex., 2½ miles west of Powwow Tanks, latitude approximately 31°50′17″ N., longitude 106°04′40″ W. This locality is stop 13 (p. 40), West Texas Geological Society Guidebook, Field Trip No. 5, November 1949, and stop 1 on the map accompanying West Texas Geological Society Field Trip of May-June 1946. No. 3070-2 is from a limestone thought to be the same as bed 9, section "C" of 1946 Field Trip Guidebook, and No. 3070-4 is from a limestone thought to be the same as bed 11 of the same section.

U.S.N.M. locality 3069.—Helms formation, El Paso quadrangle, Hueco Mountains, Tex., 1.1 miles west of Powwow Tanks, latitude approximately 31°50′17″ N., longitude 106°03′38″W. No. 3069-2 is from about 10 feet above the base of the Helms in the saddle, from an oolitic limestone lens, and approximately equivalent to the horizon of No. 3070-2. No. 3069-4 is from about 25-30 feet above the base of the Helms in the saddle, from an oolitic limestone with *Archimedes*, and approximately equivalent to the horizon of No. 3070-4.

The numbers of these localities are used in subsequent references to the specimens. The Helms formation in west Texas and adjacent New Mexico has been described briefly by Laudon and Bowsher (1949, pp. 19-20, 31-34), and the term is used here in the restricted sense of these authors. The Helms formation is stated by Laudon and Bowsher to be of Chester (Upper Mississippian) age, and it is of interest that the commonest trilobite in the formation, described here as *Paladin* (*Paladin*) *helmsensis,* new species, is very much like the type species of the genus from the Morrow Series (Lower Pennsylvanian) of Oklahoma.

The silicified specimens show the morphology of the exoskeleton in unusual detail and perfection; hence in the next section significant features of morphology and development are described and discussed, and these comments are not repeated in the ensuing detailed descriptions. The terminology employed follows that of previous papers (Whittington, 1950, p. 533), except that I have used *pleural region* of the pygidium rather than pleural lobes or side lobes of Warburg (1925), and *interpleural grooves* rather than furrows. The additional terms used in describing the articulation of the thorax, and the hypostome, are explained on plates 2 and 3.

In order to avoid ambiguity in the terms "length" and "breadth" in descriptions, I have used (in the abbreviated form indicated in parentheses) sagittal (sag.) to describe a measurement in the median line; exsagittal (exs.), parallel to, but outside of, the median line; and transverse (tr.), at right angles to the median line.

MORPHOLOGY AND DEVELOPMENT OF THE SILICIFIED SPECIES

An unusual feature of the silicified exoskeletons is the relatively great thickness, as compared, for example, to those of silicified Ordovician trilobites. I consider the thickness to be original and not a result of the process of silicification. Plate 2, figures 5 and 6, and plate 3, figures 3, 5, and 6, show the thickness of the exoskeleton at the suture lines and along selected sections. The doublure of both pygidium and cephalon is thicker than the immediately overlying dorsal exoskeleton (pl. 3, figs. 3, 5), nowhere more so than at, and adjacent to, the rostrum. The inner part of the thoracic pleurae is also thick, at a maximum at the posterior edge, the inner surface flat and sloping forward to the much thinner anterior edge. The thickness is such that there is no ridge on the inner surface corresponding to the pleural furrows on the outer surface (pl. 3, figs. 10, 13).

Four pairs of glabellar furrows have been observed in some Carboniferous trilobites (e.g., Stubblefield, 1948, p. 99; R. and E. Richter, 1951, pl. 5). On the inner surface of the exoskeleton (pl. 3, fig. 2) these furrows form inwardly projecting platforms with a well-defined edge (cf. R. and E. Richter, 1951, p. 225). These are areas of muscle attachment, as is also the thickened and projecting outer one-third of the occipital furrow. On the outer surface (pl. 3, fig. 1) only the first (basal) furrow appears as a depression, the second, third, and fourth furrows as smooth areas, in larger specimens appearing as conspicuous dark patches, dark perhaps because the exoskeleton is thicker here. The articulating furrows of the thoracic axis are slightly thickened at the extremity, and presumably are areas of muscle attachment. On the pygidial axis (pl. 3, fig. 5), however, the outer parts of the ring furrows become shallower, and the ovate areas between them, appearing darker in some specimens, are areas of muscle attachment.

The eye surface (pl. 3, figs. 4, 6) is externally almost smooth, the facets faintly convex. On the inner surface each circular facet is strongly convex, and the facets are close-spaced and arranged in vertical and diagonal rows. The course of the cephalic sutures is revealed in detail (pl. 2, figs. 1, 5, 6; text fig. 1), and I am not aware of any previous descriptions of the rostrum of a Carboniferous trilobite. The edge of the exoskeleton at the sutures is thick and flat, and the hypostome fits against both the posterior edge of the rostrum and the adjacent inner edge of the doublure. The wing process (at the tip of the large anterior wing) evidently rested in the conspicuous circular pit in the anterior boss on the inner surface of the cranidium (pl. 3, fig. 17). Thus the hypostome was attached to the rest of the cephalon in the same manner as in calymenids, cheirurids, and other trilobites.

Articulation between the segments of the thorax and the cephalon and pygidium is effected by a series of devices (see pl. 3, figs. 7-13, 15, 16, and compare Whittington and Evitt, 1954, pp. 21-24). The ring process is a large boss situated at the outer, posterior edge of the axial ring, and fits into a ring socket at the anterior, outer edge. Above the ring socket, in line with the axial furrow, is a tiny, round axial process, which fits into the axial socket in the posterior edge of the segment at the base of the ring process. A narrow (exs.) strip along the anterior edge of the inner part of the pleura is defined by a shallow furrow, and the leading edge is thin and bluntly rounded. It fits into a groove in the thick posterior edge of the inner part of the pleura, this groove being beneath the upper, outer margin of the pleura. This "tongue and groove" articulation extends out to the fulcrum, where it dies out, and there are no articulation processes and sockets at the fulcrum. The posterior edge of the cephalon inside the branches of the facial suture, and the anterior margin of the pygidium inside the fulcra, are shaped like the corresponding edges of the thoracic segments. The outer parts of the thoracic pleurae, and the pygidium, are faceted to facilitate overlap in enrollment. In the doublure of each segment is a broad V-shaped notch (pl. 3, fig. 14), the Panderian opening, and the anterior edge of this notch is raised (inwardly projecting), and acts to limit the amount of overlap between segments.

Only what are probably the later meraspid stages of the development are known (pls. 1, 2). The cranidium shows a general reduction in convexity with increasing size. The glabella in the smallest specimens is almost parallel-sided, and with increasing size the lateral expansion of the anterior lobe takes place, the posterior part widens between the eye lobes, and the relative convexity of the posterocentral glabellar region, and of the basal glabellar lobes, is reduced. The eye lobe becomes relatively shorter. The pygidium shows a considerable reduction in convexity with increasing size, and the shallow median notch in the posterior margin of small specimens soon disappears. The meraspid development of *Ditomopyge* was described by Weller (1935), and the smallest cranidium, 1 mm. in length, has the subparallel-sided glabella, long (sag.) anterior border and eye lobe seen in *Paladin*. However, the glabellar lobation is absent, in contrast to the presence of well-marked basal lobes and furrows in *Paladin*. Small pygidia of *Ditomopyge* show a median notch in the posterior border (Newell, 1931, pl. 31, fig. 31; Weller, 1935, p. 508) like that seen in *Paladin*. While the development of the pygidium in the two genera has some features in common, a notable difference is that in *Ditomopyge* the pleural regions increase in convexity (Weller, 1935, figs. 4c, 5c, 7c, 8c), in contrast to the decrease in *Paladin*.

The meraspid specimens of *Paladin* do not resemble any geologically older adult Carboniferous trilobite, and Weller (1935, p. 513) likewise found that the meraspid specimens of *Ditomopyge* resembled no known geologically older adult trilobite. One may take these observations as further evidence of the untruth of the so-called "law" of recapitulation, in the strict sense of Haeckel (cf. de Beer, 1951).

SYSTEMATIC DESCRIPTIONS

Family PROETIDAE (Hawle and Corda, 1847), Salter, 1864

Subfamily PHILLIPSIINAE (Oehlert, 1886), Přibyl, 1946

A characterization of this subfamily has recently been given by Přibyl (1946, pp. 33-34). The present material of *Paladin* shows that up to four pairs of glabellar furrows may be present. Few illustrations have been published of phillipsiinid hypostomes, but those available (e.g., Woodward, 1883-1884; Weber, 1937) suggest that they are similar to each other and like that of *Paladin* (pl. 1, figs. 29, 30, 35; pl. 2, figs. 21, 26, 27, 32, 33). Characteristic are the large anterior wings, lack of distinct anterior border, narrow lateral, but wider (sag.) posterior, border, and short (sag.), crescentic, inflated posterior lobe of the middle body. This type of hypostome is not like known examples of hypostomes (Přibyl, 1947, figs. 12-15, 17-19) of proetid genera in other subfamilies, and may be typical of the Phillipsiinae. The shape of the rostrum may equally well be characteristic of the subfamily, but little information is available.

Genus PALADIN Weller, 1936

Type species.—*Griffithides morrowensis* Mather, 1915, by original designation of Weller, 1936, p. 707.

Discussion.—The most abundant of the two species of silicified trilobites described below has been compared with the holotype of *Paladin morrowensis,* and belongs in this genus. The second species differs from the first notably in the greater convexity of the cephalon and pygidium, the shorter anterior cephalic border, and the outline of the glabella, which is less expanded between the eye lobes but more strongly expanded anteriorly. These relatively minor differences ally it with *Kaskia chesterensis* (Weller, 1936, pp. 708-711, pl. 95, figs. 4a-6), the type of the genus *Kaskia* Weller, 1936. *K. chesterensis* has an even shorter (sag.), steeper anterior border. Weller admitted (1936, p. 708) that *Paladin* and *Kaskia* were closely similar, and that there were species intermediate between typical species of the two genera. The second silicified species here described is one of these intermediates. In view of these facts, it seems to me preferable to regard *Kaskia* as a subgenus of *Paladin,* with *P. morrowensis* representing the typical subgenus *Paladin* (*Paladin*), and this procedure has been followed below.

Reed (1942, pp. 653, 660-667, pl. 10, figs. 4-5b, pl. 11, figs. 1-5a; 1943, pp. 179-184, pl. 2, figs. 6, 7, pl. 3, figs. 1-8) considered that the forms he referred to his genus *Weberides* included most of, if not all, the originals of Woodward's (1883-1884) plate 4, and were similar to the Russian species described by Weber (1933, pp. 33-35, 37-41, pl. 2, figs. 2-11, 17-33, 36-41, text figs. 14-17, 19-21; 1937, pp. 74-75, pl. 8, figs. 31-34, 36, 39-44, 48) under the names *Griffithides lutugini* and varieties and *G. transilis* and varieties. Weller (1936, pp. 707-708), however, had previously placed these Russian species and varieties in his genera *Paladin* and *Kaskia.* Reed recognized this (1943, p. 180) but did not say how *Weberides* differed from *Paladin.* It seems that some of the species referred to above may be congeneric, and if so ought to be placed in *Paladin.* Before it is concluded that

Weberides Reed, 1942, is a synonym of *Paladin,* however, the diplotype of *Weberides* should be reexamined, for Reed (1942, p. 663) admits that he did not see it. The specimen in question (original of M'Coy, 1844, pl. 4, fig. 5) is a pygidium, with a short, blunt spine on the posterior border.

The genus *Ditomopyge* Newell, 1931 (as emended by Weller, 1935) is related to *Paladin* (*Kaskia*), as Weller pointed out (1936, p. 711). The inflation of the central region of the glabella in front of the occipital ring seen in *P.* (*K.*) *rarus,* new species, could give rise to the preoccipital lobe of *Ditomopyge.* The free check of *P.* (*K.*) *rarus,* new species, is much more like that of *Ditomopyge* than that of *P.* (*P.*) *helmsensis,* new species, which lacks the flattened upper surface of the border. Contrary to the opinion of Weller (1936, pp. 713-714), I regard *Ameura* as related to *Paladin.* I have examined the holotype of *Ameura sangamonensis* (Meek and Worthen, 1865) and the glabella is only slightly wider between the eye lobes than across the anterior lobe. The basal glabellar lobes do have independent convexity. The pygidium, of length (sag.) about equal to width, recalls the original of Woodward's (1883-1884) plate 4, fig. 9, and the elongated appearance is distinctive.

The aforementioned four genera, together with *Sevillia* (Weller, 1935, p. 506, explanation of text fig. 9, *nomen nudum;* Weller, 1936) and *Linguaphillipsia* Stubblefield, 1948, probably form a related group ranging from Lower Carboniferous to Lower Permian in age, widespread in North America and Eurasia.

PALADIN (PALADIN) MORROWENSIS (Mather, 1915)

Plate 1, figures 1-6, 9

Holotype.—Walker Museum No. 16174, incomplete cephalon, from Brentwood limestone, Morrow Series, lower Pennsylvanian, Sawney Hollow, head of Indian Creek, Okla., and 3½ miles south of Evansville, Ark.

Description.—The holotype is refigured here, and the following notes are added to supplement Mather's (1915, pp. 244-246, pl. 16, figs. 13, 13a) original description. Basal glabellar furrow deepest at about the midlength, disappearing before reaching axial furrow. Additional furrows not represented by depressions in outer surface. Anterior branch of facial suture running at first outward at about 50° to the sagittal line, then on the border, opposite the maximum width of the anterior glabellar lobe, curving to run inward straight to the margin. The angle between the two sections is about 100°. The doublure of the cephalon is convex and slopes steeply laterally, but is flattened and slopes gently anteriorly. The rostral suture runs close to the outer edge, the connective sutures curve inward, and the hypostomal suture runs in a curve convex forward. The rostrum is thus similar in outline to that of *P.* (*P.*) *helmsensis,* new species.

The associated pygidium is also refigured, and the border is gently convex, not concave as stated by Mather (1915, p. 245).

PALADIN (PALADIN) HELMSENSIS Whittington, new species

Plates 2, 3; text figure 1

Holotype.—U.S.N.M. No. 116513, cranidium, original of plate 2, figures 1, 2, 5, 6; locality 3070-2.

Paratypes.—U.S.N.M. Nos. 116514a-h; free cheek, rostrum, and hypostome from locality 3070-2; two segments from locality 3069-4; two segments from locality 3070-4; pygidium from locality 3069-2.

Description.—Dimensions of holotype in millimeters: Length (sag.) 7.0, height 2.7; length of glabella (sag.) 6.3, width across anterior lobe 3.9, at third furrows 3.1, of occipital ring 3.9. Length of paratype pygidium (sag.) 6.3, width 7.8, height 2.8. Cephalon subsemicircular in outline, gently convex. Glabella gently convex (sag. and tr.), outlined by shallow axial and preglabellar furrows; narrowing slightly immediately in front of the occipital ring, expanding between the eye lobes, then narrowing again forward to the minimum width opposite the third furrows, and then expanding forward again until width across anterior lobe is the same as, or slightly greater than, that of occipital ring. Latter moderately convex, highest point near posterior margin, from which it slopes down to the shallow, sinuous occipital furrow; faint median tubercle. Four pairs of glabellar furrows (pl. 3, figs. 1, 2), the first (basal) appearing as shallow depressions, gently curved, directed inward and backward to isolate triangular, gently convex basal lobes. The basal furrows are deepest at midlength, becoming poorly defined at the outer extremity, faint at the inner ends as they meet the occipital furrow. The maximum width of the basal lobes is one-third the glabellar width in front of the occipital furrow. Between the basal lobes the central glabellar region is slightly inflated and posteriorly slopes steeply. The second and third glabellar furrows are progressively shorter and directed less strongly backward, the fourth short, ovate, directed slightly forward and commencing a short distance inside the axial furrows. Cheeks sloping gently outward and forward, with a broad (tr.) lateral border defined by the slight change in slope at the faint border furrow, the anterior border narrower (sag.). Posterior border defined by a deep border furrow, and with independent convexity. Genal spine broad at base, relatively long. Eye lobe large, length (exs.) more than one-third that of cephalon, situated with the anterior edge about opposite the glabellar midpoint, and close to the axial furrow, the highest point lower than the glabellar midline between the eye lobes. Palpebral lobe without rim, outer part horizontal, inner part sloping down to axial furrow. Eye surface (pl. 3, figs. 4, 6) with numerous small, gently convex facets. Anterior branch of suture runs straight outward and forward from the eye lobe onto the border, then curves and runs straight inward and forward to reach the anterior margin at a point in line (exs.) with the inner margin of the eye lobe. The posterior branch runs outward and backward to the border furrow, then curves, at first more strongly outward, over the posterior border to reach the margin just inside the base of the genal spine. Doublure laterally of less width (tr.) than the border, gently convex and sloping steeply outward. Anteriorly doublure becomes flattened, horizontal, and narrower (sag.). The rostral suture runs along the outer edge of the doublure, the connective suture in a curve convex outward. The anterior and posterior margins of the rostrum are thus forwardly curved, the lateral margins outwardly so. The rostrum (pl. 2, figs. 40-42) is also thickest along a line midway between the anterior and posterior margins, so that while the outer surface is flat, the inner is convex. The doublure of the free cheek adjacent to the rostrum shows a corresponding thickening, which fades out laterally. Certain features displayed by the inner surface of the cephalon have been discussed above. Plate 3, figure 2, shows the doublure of the occipital ring. In the inner edge of the doublure of the free cheek (pl. 3, fig. 6) is a shallow notch, in line with the posterior border. I interpret this notch as the Panderian opening, and as corresponding with the larger notches in the thoracic pleural doublures.

Length of hypostome (pl. 2, figs. 21, 26, 27, 32, 33) (sag.) slightly greater than maximum width across anterior wings. Middle body gently convex longitudinally, more strongly so transversely, not defined anteriorly or separated from the anterior wings by a furrow, but laterally and posteriorly outlined by the change in slope at the borders. The crescentic posterior lobe, the tips at about two-thirds the length of the middle body and opposite the lateral shoulders, has a faint independent convexity, most marked at the tips. The anterior sutural edge of the hypostome is thick, extending between the bases of the wings, and fits against both the inner edge of the rostrum and the doublure of the free cheeks (text fig. 1). The anterior wings are broad (exs.) at the base, slope steeply upward, with a small articulating boss at the outer, anterior corner. The lateral borders narrow, gently convex, shoulder well marked, posterior border broader, margin sinuous, posterolateral corners rounded. The interior view shows that the doublure is narrow along the lateral borders, wider along the posterior border, and the furrow dividing the middle body more evident. In lateral view the notch between shoulder and anterior wing is seen, and posterior wings seem not to be developed.

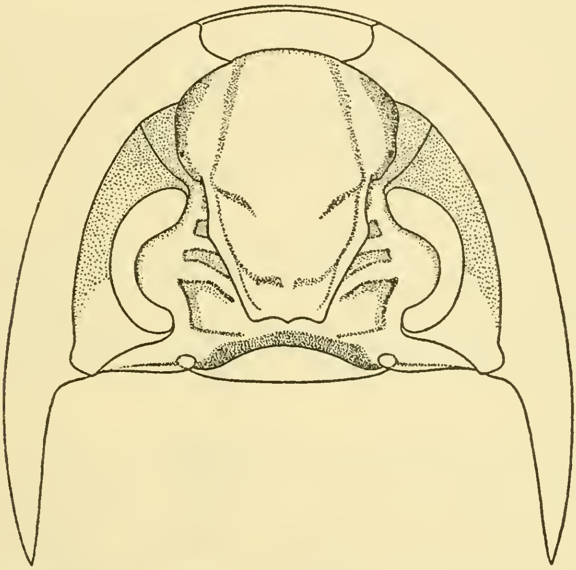

FIG. 1.—*Paladin* (*Paladin*) *helmsensis,* new species. Outline reconstruction of the exoskeleton of the cephalon in ventral view, approximately × 7.

Number of thoracic segments unknown. Axis moderately convex, each ring subdivided into a short (sag.) anterior part that disappears laterally, and a longer (sag. and exs.) posterior part. The articulating furrow narrow and deep, the half-ring short (sag. and exs.). Inner part of pleura horizontal, outer part bent steeply down, faceted, the facet of the anterior segments (pl. 3, figs. 10-13) abruptly cutting off the narrow (tr.) outer pleural part. The narrowness of these latter enables these segments to fit between and under the genal spines of the cephalon. Succeeding segments (pl. 3, figs. 7-9, 15, 16) have the outer pleural parts wider (tr.). Pleural furrow narrow and deep, situated at about half the length (exs.) at the fulcrum, and extending to the inner edge of the facet. The interior view (pl. 3, fig. 10) shows the doublure of the axial ring and the low ridge, the area of muscle attachment, formed by the outer part of the articulating furrow. The devices which facilitate articulation between the segments have been described above. In the doublure of the outer pleural part (pl. 3, fig. 14) is the broad notch of the Panderian opening. The doublure in front of, and outside, this notch is gently convex.

Pygidium moderately convex, axis moderately convex and gently tapering. In largest specimens 17 ring furrows, the inner part straight, deep, the outer shallow, turning slightly back. Inner, anterior part of pleural region horizontal, outer part gently convex, steeply sloping, border distinctly separated by change in convexity, and sloping outward. Ten deep pleural furrows in largest specimens, progressively more strongly backwardly directed, ending at inner edge of border. Interpleural grooves faint, sometimes absent, sometimes first five visible, not extending on to border. Doublure of same width as border, inner part bent steeply up.

External surface of glabella and palpebral lobes with shallow, irregular pits (pl. 3, fig. 1), largest near the median line. Small tubercles occur along the posterior edge of the occipital and axial rings. Raised lines, parallel to each other and the margin, on the outer part of the cephalic and pygidial borders and the outer surface of the doublures. Hypostome with similar lines on the middle body and borders, and tiny, shallow, scattered pits on the middle body.

Discussion.—Comparison of the cephalon of *Paladin* (*Paladin*) *morrowensis* with the type of *P.* (*P.*) *helmsensis* shows that the latter differs from the former principally in characters of the glabella. That of *P.* (*P.*) *helmsensis* is less inflated (as seen in longitudinal profile), has the basal glabellar lobes and posterior part of the central glabellar region less inflated, and has the anterior lobe less expanded transversely, though between the eye lobes the glabella of *P.* (*P.*) *helmsensis* is more markedly expanded than that of *P.* (*P.*) *morrowensis*. The external surface of the glabella and palpebral lobes is tuberculate in *P.* (*P.*) *morrowensis*, pitted in *P.* (*P.*) *helmsensis*. The lateral cephalic border of *P.* (*P.*) *morrowensis* slopes more steeply than that of the Texas species. The pygidia of the two species (pl. 1, figs. 4-6; pl. 2, figs. 9, 10, 14, 15) are similar, that of *P.* (*P.*) *helmsensis* being distinguished by the axis showing more rings and being more inflated posteriorly, and by the border being relatively broader (sag.) posteriorly. The axial rings of *P.* (*P.*) *morrowensis* are apparently without the row of tubercles on the posterior margin. Evidently *P.* (*P.*) *helmsensis* and *P.* (*P.*) *morrowensis* are closely related species, though they differ considerably in age.

DEVELOPMENT OF *Paladin* (*Paladin*) *helmsensis,* NEW SPECIES

Cranidium.—Length of smallest cranidium (pl. 2, figs. 34-36) (sag.) 1.5 mm., glabella narrowest between the anterior end of the eye lobes, but since it lacks the anterior and posterior expansions of larger forms it appears almost parallel-sided. Basal glabellar furrows deep and broad, so that the basal lobes are prominent, and the posterior part of the central glabellar region is quite strongly inflated. The second and third glabellar furrows are ill-defined patches on the exoskeleton. Length of anterior border of the cranidium (sag.) about one-eighth that of the glabella. Length of palpebral lobes (exs.) more than one-third that of cranidium. In cranidia of increasing size that part of the glabella in front of the third furrow becomes relatively wider (compare figs. 1 and 34, pl. 2). The palpebral lobes become relatively smaller, the length (exs.) being reduced to less than one-third that of the cranidium. The basal glabellar furrows become shallower, and the convexity of the basal lobes and posterior part of the central glabellar region is reduced. Small cranidia with close-spaced tubercles on the glabella and palpebral lobes, the tubercles on the frontomedian glabellar lobe close-spaced and arranged in lines subparallel to the anterior margin. With increasing size of the cranidium these tubercles become less prominent, and in the largest cranidia only the reticulate pattern of pits remains.

The smallest hypostome known (pl. 2, figs. 39, 44) is little different from the largest—the shoulders are rather more prominent, and the tips of the crescentic posterior lobe of the middle body are more strongly inflated. The smallest pygidium known (pl. 2, figs. 37, 38, 43) is 1.6 mm. in length (sag.), 2.2 mm. in width. Axis of 15 rings. Pleural region convex, inner, anterior part horizontal, outer part steeply sloping, the border sloping outward but less steeply. Eleven pleural furrows visible, terminating at the inner margin of the border. First three interpleural grooves shallow, situated close to the succeeding pleural furrows, and extending on to the inner part of the border. Border broad (sag.) posterolaterally, narrow (tr.) anterolaterally, with a shallow median notch in the posterior margin. With increasing size the pygidium maintains about the same ratio between length and width, and the original of plate 2, figures 30, 31, is 2.2 mm. in length (sag.), 3.3 mm. in width. The convexity of the pleural regions is markedly reduced, the notch in the posterior margin disappears and the difference in the width of the border laterally and posteriorly is reduced. In a pygidium (sag.) 3.2 mm. long only the first interpleural groove is visible. The tubercles on the median part of the axial rings are visible in this and larger specimens.

PALADIN (KASKIA) RARUS Whittington, new species

Plate 1, figures 7, 8, 10-35

Holotype.—U.S.N.M. No. 116511, cranidium, original of plate 1, figure 7, 8, 10, 11, locality 3070-4.

Paratypes.—U.S.N.M. Nos. 116512a-c, free cheek and pygidium from locality 3070-2, hypostome from locality 3069-4.

Description.—Length of holotype cranidium 5.6 mm., height 3.2 mm.; length (sag.) of glabella 5.1 mm., width across anterior lobe 3.6 mm., between anterior ends of palpebral lobes 2.9 mm., of occipital ring 3.2 mm.

The cephalon of this species is similar to that of *Paladin* (*Paladin*) *helmsensis,* new species, but is distinguished by (1) the greater convexity; (2) the glabella being slightly expanded between the eye lobes, but more strongly expanded across the anterior lobe; (3) the sharper angle in the course of the anterior branch of the facial suture on the border (compare the antero-lateral margins of the cranidia in pl. 1, fig. 7, and pl. 2, fig. 1); (4) the relatively shorter (sag. and exs.) anterior border; (5) the much greater change in slope at the border furrow of the free cheek, resulting from the inner part of the border being flattened. Additional ways in which the cephalon of *P.* (*K.*) *rarus* differs from that of *P.* (*P.*) *helmsensis* are: (6) the basal glabellar furrows are deeper, the basal lobes more inflated; (7) the palpebral lobes are narrower (tr.); (8) the middle body of the hypostome is more convex, with deeper middle furrows, and tiny maculae are present. There is a sharper angle in the anterior margin between where the hypostome fits against the rostrum and the doublure of the free cheek, the shoulders are more prominent, and the posterior border has the three blunt spines; (9) the external surface of the glabella and palpebral lobes is tuberculate rather than pitted.

Rostrum and thorax unknown.

Length of paratype pygidium (sag.) 5.0 mm., width 6.9 mm., height 3.0 mm. This pygidium is distinguished from that of *P.* (*P.*) *helmsensis* by the greater convexity and consequent height. Both the axis and the pleural regions inside the border are more convex in *P.* (*K.*) *rarus,* and the border slopes more steeply outward. The number of axial rings and pleural furrows is the same in the two species, but the ribs between the furrows in *P.* (*K.*) *rarus* are much more convex.

Discussion.—*Paladin* (*Kaskia*) *rarus* is distinguished from the type species *P.* (*K.*) *chesterensis* (Weller, 1936, pp. 708-711, pl. 95, figs. 4a-6), also of Chester age, by the less steep slope of the anterior part of the glabella and the longer (sag.) projecting anterior border (compare pl. 1, fig. 10, with Weller, 1936, pl. 95, fig. 4c). The pleural regions of the pygidium of the Texas species appear to be more convex than those of *P.* (*K.*) *chesterensis.* Four pairs of glabellar furrows are present in *P.* (*K.*) *rarus,* but only three are described as present in *P.* (*K.*) *chesterensis.*

Weller (1936, pp. 708-710) pointed out that forms intermediate between the type species of *Paladin* (*Paladin*) and *Paladin* (*Kaskia*) occur. In the outline and convexity of the glabella, *P.* (*K.*) *rarus* is more like *P.* (*P.*) *morrowensis* than is *P.* (*P.*) *helmsensis,* a further illustration of the close relationship between these species.

DEVELOPMENT OF *Paladin* (*Kaskia*) *rarus,* NEW SPECIES

The smallest cranidium (pl. 1, figs. 23, 24) is 3.2 mm. in length (sag.). Compared with the largest cranidium it is more convex as a whole, as well as considering the frontomedian and basal glabellar lobes separately; the glabella is less expanded anteriorly, and the palpebral lobes are longer. The development thus parallels that of *Paladin* (*Paladin*) *helmsensis,* with an expansion of the glabella anteriorly, a general reduction in convexity, and decrease in size of the palpebral lobes. The smallest pygidium (pl. 1, figs. 26-28) is 1.7 mm. in length (sag.), strongly convex, the outer parts of the pleural regions overhanging the border. There are 13 or 14 axial rings, 10 pleural furrows, no interpleural grooves. There is no median notch in the posterior margin of the border. The chief change with increasing size of the pygidium is the reduction in convexity, so that the outer parts of the pleural regions slope steeply but do not overhang the border.

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EXPLANATION OF PLATES

PLATE 1

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Figs. 1-6, 9.—*Paladin* (*Paladin*) *morrowensis* (Mather) 6

1, 2, 3, Dorsal stereograph, left lateral, and anterior views of holotype, Walker Museum No. 16174, × 3. 4, 5, 6, Dorsal stereograph, posterior, and right lateral view of pygidium, Walker Museum No. 16174, × 3. 9, Ventral view of cephalic doublure of holotype, position of left (right in picture) edge of rostrum dotted, × 7½. Brentwood limestone, Morrow Series, lower Pennsylvanian, Sawney Hollow, head of Indian Creek, Okla., and 3½ miles south of Evansville., Ark.

Figs. 7, 8, 10-35.—*Paladin* (*Kaskia*) *rarus* Whittington, new species 12

7, 8, 10, 11, Dorsal stereograph, interior, right lateral, and anterior views of holotype cranidium, U.S.N.M. No. 116511, locality 3070-4, × 3. 12, 13, 14, Dorsal stereograph, posterior, and left lateral views of paratype pygidium, U.S.N.M. No. 116512a, locality 3070-2, × 3. 15, 18, Anterior view, dorsal stereograph of cranidium and free cheek, locality 3070-2, × 3. 16, 17, Dorsal and posterior views of pygidium, locality 3070-2, × 3. 19, Right lateral view of cranidium, original of figures 15, 18, × 3. 20, 21, 22, Dorsal, posterior, and ventral views of pygidium, locality 3070-2, × 3. 23, 24, Dorsal and right lateral views of cranidium, locality 3069-2, × 3. 25, 31, Left lateral and dorsal views of paratype free cheek, U.S.N.M. No. 116512b, × 3. 32, Interior view of same, × 10, locality 3070-2. 26, 27, 28, Dorsal, posterior, and left lateral views of pygidium, locality 3070-2 × 4. 29, 30, 35, Ventral, interior, and left lateral views of paratype hypostome, U.S.N.M. No. 116512c, locality 3069-4, × 3. 33, 34, Ventral and left lateral views of hypostome, locality 3069-2 × 3. Helms formation, Chester Series, upper Mississippian, Hueco Mountains, west Tex. Locality numbers are explained on page 1.

PLATE 2

Paladin (*Paladin*) *helmsensis* Whittington, new species 7

1, 5, 6, Dorsal stereograph, anterior view, anterolateral stereograph of holotype cranidium (U.S.N.M. No. 116513), and paratype free cheek (U.S.N.M. No. 116514a), locality 3070-2, × 3. 2, Left lateral view of holotype cranidium, U.S.N.M. No. 116513, locality 3070-2, × 3. 3, 4, Dorsal and left lateral views of free cheek, locality 3069-4, × 3. 7, 8, Dorsal and right lateral views of cranidium, locality 3069-4, × 3. 9, 10, 14, 15, Dorsal stereograph, interior, posterior, and right lateral views of paratype pygidium, U.S.N.M. No. 116514b, locality 3069-2, × 3. 11, 12, Dorsal and right lateral views of cranidium, locality 3069-4, × 3. 13, 20, Dorsal and posterior views of pygidium, locality 3069-2, × 3. 16, 17, Dorsal and right lateral views of cranidium, locality 3069-4, × 3. 18, 19, Dorsal and posterior views of pygidium, locality 3069-4, × 3. 21, 26, 27, Right lateral, ventral, and interior views of paratype hypostome, U.S.N.M. No. 116514c, locality 3070-2, × 3. S = shoulder; n = lateral notch.

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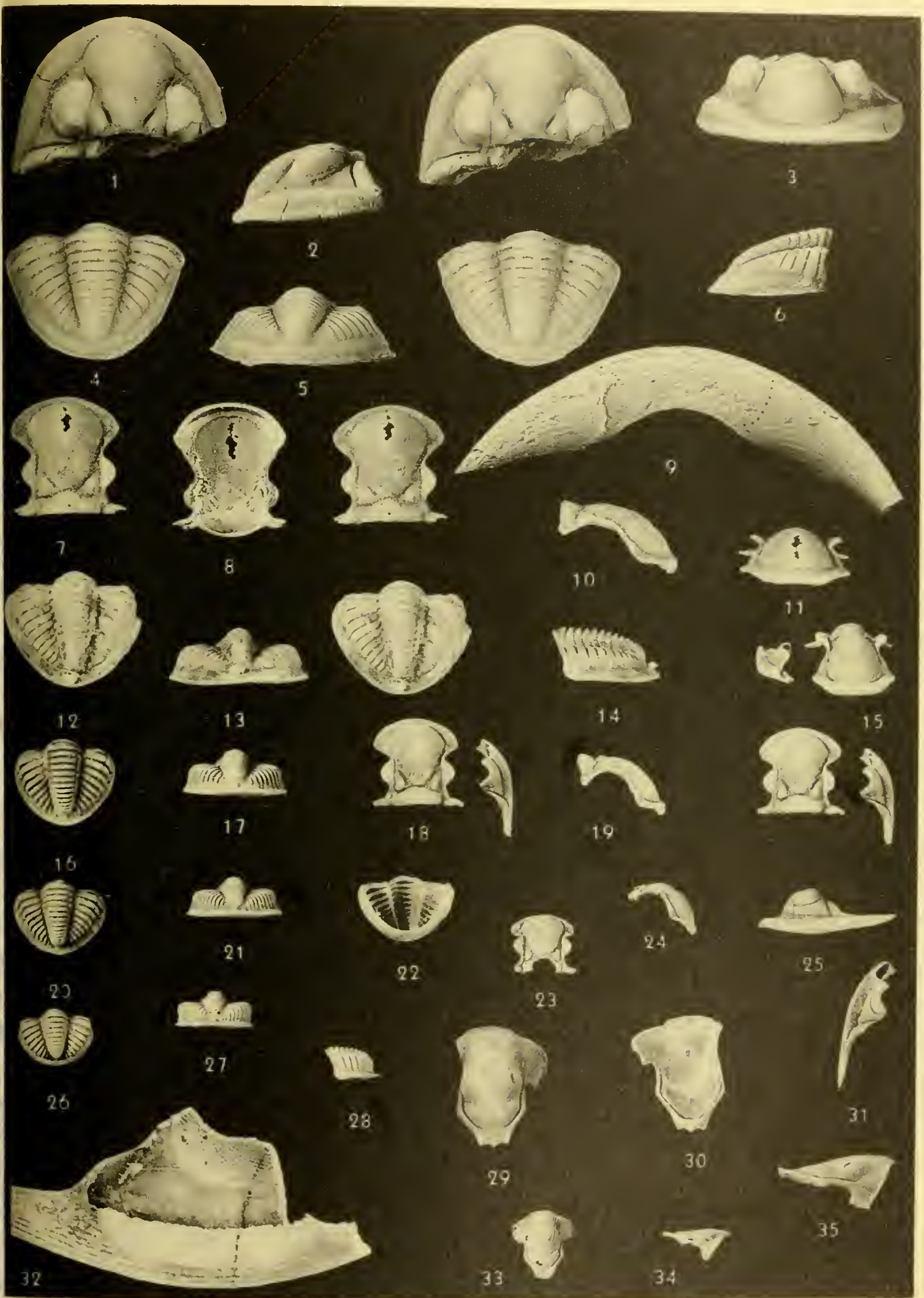
22, 23, Dorsal and right lateral views of cranidium, locality 3069-4, × 3. 24, 25, Dorsal and posterior views of pygidium, locality 3069-4, × 3. 28, 29, Dorsal and right lateral views of cranidium, locality 3069-4, × 7½. 30, 31, Dorsal and posterior views of pygidium, locality 3069-4, × 3. 32, 33, Ventral and right lateral views of hypostome, locality 3069-2, × 3. 34, 35, 36, Dorsal, right lateral, and anterior views of cranidium, locality 3069-2, × 7½. 37, 38, 43, Dorsal, posterior, and right lateral views of pygidium, locality 3069-2, × 7½. 39, 44, Left lateral and ventral views of hypostome, locality 3069-2, × 3. 40, 41, 42, Exterior, posterior, and interior views of paratype rostrum, U.S.N.M. No. 116514d, locality 3070-2, × 6. 45, Dorsal view of free cheek, locality 3069-4, × 3. Helms formation, Chester Series, upper Mississippian, Hueco Mountains, west Tex. Locality numbers are explained on page 1.

PLATE 3

Paladin (*Paladin*) *helmsensis* Whittington, new species.................... 7

1, 2, Exterior and interior views of incomplete cranidium, showing the four pairs of glabellar furrows and the pits in the external surface, locality 3070-4, × 6. 3, Anterior view of broken edge of free cheek, showing thickness of exoskeleton, locality 3070-4, × 6. 4, 6, Exterior and interior views of paratype free cheek, U.S.N.M. No. 116514a, showing eye surface and Panderian notch (p), locality 3070-2, × 7½. 5, Interior view of incomplete pygidium, showing muscle scars as dark patches between ring furrows of axis, and thickness of exoskeleton, locality 3070-2, × 6. 7, 8, 9, Posterior, dorsal, and left lateral views of paratype segment, U.S.N.M. No. 116514e, locality 3070-4, × 3. 10, 11, 12, Ventral, posterior, and anterior views of paratype segment, U.S.N.M. No. 116514g, locality 3069-4, × 6. rp = ring process; ap = axial process; as = axial socket; g = groove in posterior edge of inner part of pleura. 13, Dorsal view of same, × 3. 14, Interior view of paratype incomplete segment, U.S.N.M. No. 116514h, locality 3069-4, × 7½, showing notch in doublure termed Panderian opening. 15, Dorsal view of paratype segment, U.S.N.M., No. 116514f, locality 3070-4, × 6. 16, Left lateral view of same, × 3. 17, Interior view of right half of holotype cranidium, U.S.N.M. No. 116513, showing pit in boss formed by anterior pit in external surface, locality 3070-2, × 7½. Helms formation, Chester Series, upper Mississippian, Hueco Mountains, west Tex. Locality numbers are explained on page 1.

PLATES

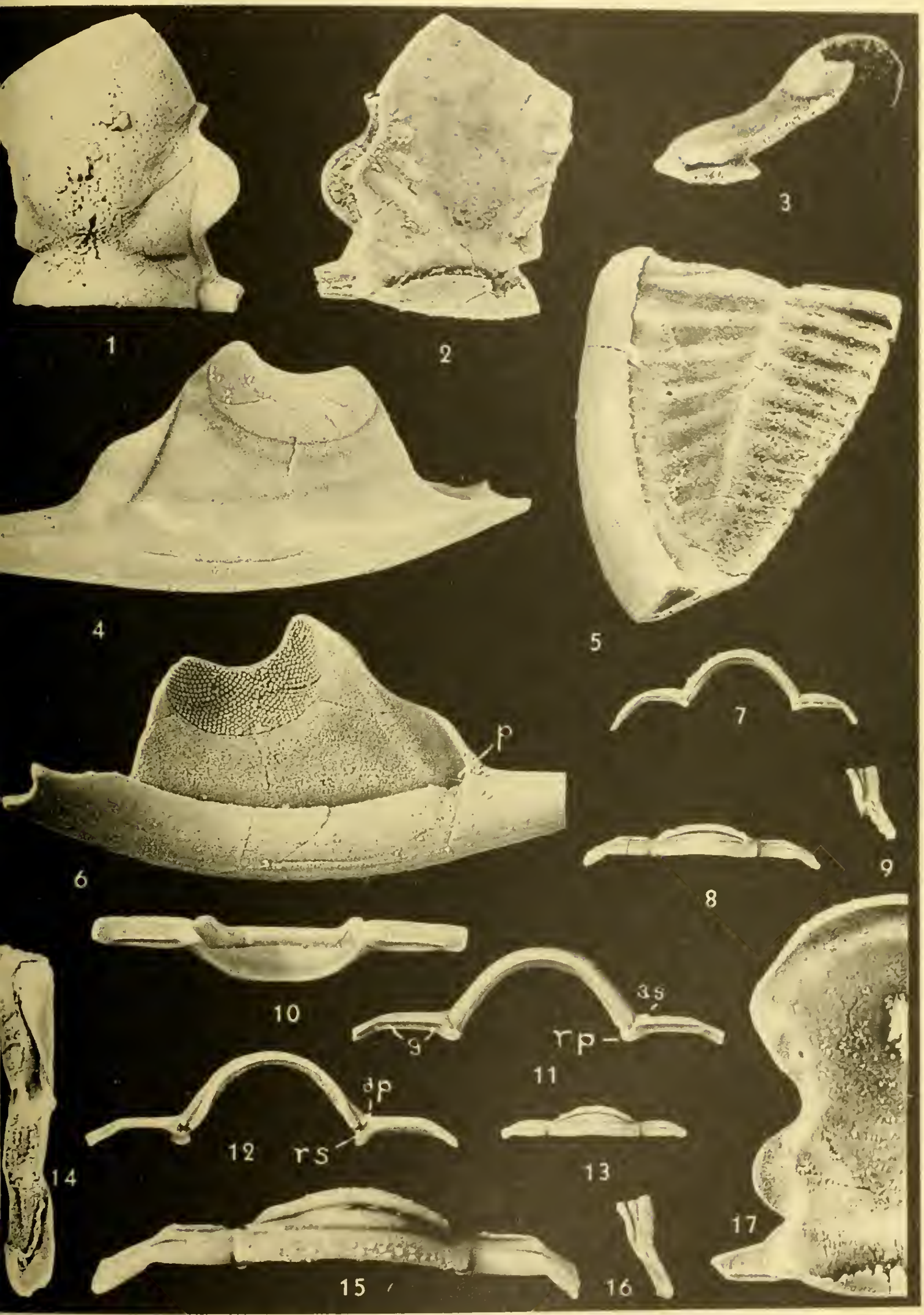


PALADIN (PALADIN) MORROWENSIS AND PALADIN (KASKIA) RARUS

(SEE EXPLANATION OF PLATES AT END OF TEXT.)

PALADIN (PALADIN) HELMSENSIS

(SEE EXPLANATION OF PLATES AT END OF TEXT.)



PALADIN (PALADIN) HELMSENSIS

(SEE EXPLANATION OF PLATES AT END OF TEXT.)