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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Redlichia of the Ordian (Cambrian) of Northern Australia and New South Wales

by

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SUMMARY

Morphology and affiliation. Pleural facets are absent in *Redlichia,* but their function is performed by short acute processes (pleural guides) on the anterolateral corners of each pleura; the absence of fulcra in *Redlichia* and the affiliated olenellids is possibly a primary character, and so is the presence of fulcra in ellipsocephalids, corynexochids, protolenids, and ptychopariids; the resulting division of the early trilobites into fulcrates and non-fulcrates bears on their suprageneric taxonomy.

Occurrence of Redlichia outside Australia. The recent discoveries of *Redlichia* in Spain and in southern Siberia are noted and discussed.

Geographic and stratigraphic distribution. The specific composition of *Redlichia* in the Ordian of Queensland and of the Northern Territory is rather disparate—no common species (*Redlichia chinensis* excepted) are evident yet. A temporal succession of some five *Redlichia*-bearing faunal assemblages is apparent; these are termed 'biostratigraphic operational units' until a scale of zones is established; nevertheless, assemblage 1, of *Redlichia chinensis,* has the character of a zone of the final Ordian. Sites and sections that provided data on the geographic and temporal distribution of assemblages and species are described.

Taxonomy of species. Redlichia idonea Whitehouse, *R. venulosa* (Whitehouse) and *R. chinensis* Walcott are revised, and the following nine new species established: *R. advialis, R. micrograpta, R. versabunda, R. creta, R. vertumnia, R. mayalis, R. lepta, R. petita,* and *R. amadeana.* The hitherto unknown external ornament varies from species to species and provides valuable criteria in the discrimination and subsequent identification of species of *Redlichia.*

Mode of life and burial. The Ordian species of *Redlichia* led a nectonic life in southeastern Asia and Australia: being unadapted to pelagic conditions they were unable to cross oceans and are therefore absent in America. Hypothetically, biological causes (rarity of males, incidence of moulting failure) contributed to the extinction of the *Redlichia* stock. Examples of individuals which died during the process of moulting are described.

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INTRODUCTION

The systematic part of this paper is the continuation of my study (Öpik, 1958) of the anatomy and concept of the genus *Redlichia,* presented on the basis of *Redlichia forresti* from the Negri Group of Western Australia, *Redlichia idonea* from the Yelvertoft Beds of Queensland, and some other, then unnamed, species. At that time (op. cit., p. 36) the taxonomy of the species was reserved for the future. This paper serves a double purpose—first, in presenting such species-taxa as can be established from selected and properly preserved material, and second, in establishing a sequence of informal 'biostratigraphic operational units' in advance of a scale of Ordian zones. Such a scale of zones would be premature in view of the difference between the specific composition of *Redlichia* in Queensland and in the Northern Territory, and because of the incompleteness of data regarding the vertical distribution and specific taxonomy of *Redlichia* in many sites of the Territory, and the numerous undescribed other fossils of the Ordian of Australia.

The fossils are kept in the Museum of the Bureau of Mineral Resources and the specimen numbers (CPC) refer to the Commonwealth Palaeontological (type) Collection.

The name Ordian designates a time and time-rock division of the Cambrian scale antedating the Paradoxidian Middle Cambrian and post-dating the Lower Cambrian, as defined and discussed in detail by Öpik (1967).

MORPHOLOGY AND AFFILIATION

The integumental morphology (Öpik, 1958) of *Redlichia* needs to be amplified as regards the structure of the pleurae. The material in hand and all published illustrations indicate that pleural fulcra were absent in *Redlichia* and the pleurae in their whole length were not connected by the abaxial ball-and-socket device with each other. If the pleurae were horizontal the presence of a flexible connective interpleural tissue would not prevent their articulation; but the pleurae are curved down (Öpik, op. cit., pl. 1, fig. 3) to an almost vertical attitude at their tips.

The anterolateral corners of the pleurae are acute, with a short forward-directed process—the pleural guide; during articulation it guided each pleura under the pleura in front, thus preventing accidental entanglement. Pleural guides are present in many diverse trilobites in which facets are undeveloped or absent.

The pleural fulcra in trilobites are aligned with the palpebral lobes (Öpik, 1967, p. 52; 57); in *Redlichia* these lobes are extremely close to the axial furrows, indicating the site of fulcra and fulcral lines in relation to the axial furrows of the thorax; in *Redlichia,* however, no fulcra could be detected in

this or any other position. Of course, the absence of fulcra is hardly the result of the position of the palpebral lobes: for example, the palpebral lobes are close to the axial furrows in many dolichometopids, including *Saukianda,* but these forms nevertheless have prominent fulcra close to the axial furrows.

The external ornament observable in Australian species of *Redlichia* is quite diverse: in some the test is smooth and shiny (*R. forresti*), or lineate minutely (*R. micrograpta*) to coarsely (*R. chinensis*); in others it is microgranulose (*R. lepta*) to visibly granulose (*R. mayalis*) as well as pustulose (*R. creta*). The ornament is strictly external, but it may be imperfectly and occasionally imprinted on internal casts during the compaction of the matrix. The caecal veins, in contrast to the ornament, are rarely reflected externally even if they are graphic on the inner surface and imprinted on the matrix. No ornamented material (*R. chinensis* excepted) is evident in the published multitude of Chinese species, apparently owing to the inferior preservation in shale.

The affiliation of the Olenellidae with *Redlichia* is evident on morphological grounds (Öpik, 1958); and *Redlichia,* having retained its cephalic sutures, is the nearest to the roots from which the olenellids originated; these lost their sutures quite early—a specialization as compared with the conservative *Redlichia;* in the Olenellidae pleural fulcra are also absent, as can be seen in the published illustrations—a similarity with *Redlichia* previously overlooked (Öpik, 1958). To conclude, it is fair to assume that the absence of fulcra in the Olenellidae and in *Redlichia* is an initial character and probably not a phyletic simplification inherited from some unknown fulcrate forms of the Precambrian. Nevertheless, simplifications of this kind are possible in principle: incidental reduction or even complete loss of fulcra has occurred independently in diverse stocks of trilobites; an example is *Dresbachia,* according to Öpik (1967). But, at the same time, no fulcrate trilobites are known to have developed their fulcral apparatus as a phyletic complication imposed on an original non-fulcrate structure of the tergite.

It appears that the early Cambrian polymerid trilobites are heterophyletic—a conclusion from the fact that, side by side with non-fulcrate olenellids and redlichiids, diverse trilobites (ellipsocephalids, protolenids, ptychopariids, corynexochids) existed, all equipped with a similar fulcral apparatus. The contemporaneity, and the absence of any knowledge regarding the seniority of either of the two structural groups, leaves open for speculation the question of their origin. Within the explored part of trilobite history, the first non-fulcrates disappeared early and, apparently, without progeny; the fulcrates however, comprising the vast majority of trilobites, persisted throughout the whole of Palaeozoic time.

The absence of fulcra in some, and their presence in most, of the trilobites may have some bearing on the general classification of the polymerids. In subsequent aberrant forms the non-fulcrate structure is polyphyletic and incidental—a character of generic and family categories only. A partition is feasible, however,

into two separate divisions (the fulcrates and the non-fulcrates) of the Lower Cambrian and Ordian polymerids, including in the fulcrates all subsequent forms together with their non-fulcrate derivatives. New taxa need not be introduced formally as long as the currently used nomenclature can be adjusted to meet the requirements.

So, the Order Redlichiida Richter, 1933, which includes also the Olenellacea (Olenellina Resser, 1938), covers the early and presumed original (initial) non-fulcrates; there are also five to seven orders of fulcrate trilobites employed in the current literature.

From the Order Redlichiida the following taxa should be excluded; Ellipsocephalacea (including the protolenids), Paradoxidacea, Bathynotina, Dolerolenidae, Metadoxididae, Saukiandidae, Pararedlichiinae and Neoredlichiidae; but a further discussion of these forms and their classification is reserved for another occasion. As examples, however, *Eoredlichia* Chang, 1950 (Chang, 1962), of the Pararedlichiinae, and *Wutingaspis* Kobayashi (Chang, 1966) should be mentioned. These are closely allied forms, possibly even synonyms, known from complete tergites which are fulcrate; their small pygidia are externally reminiscent of *Redlichia,* but also of some protolenids and early corynexochids. I am inclined to attribute such pygidia to a common grade of evolution rather than to a taxonomic affinity.

OCCURRENCE OF *REDLICHIA* OUTSIDE AUSTRALIA

The geographical distribution of the known species of *Redlichia* has already been discussed (Öpik, 1958). Well known occurrences are Korea, Manchuria, China (especially southern China), the Himalayas, Pakistan (Salt Range), and several sites in Iran. Farther west, Sdzuy (1961) discovered a *Redlichia* (n.sp.) in Spain. This European form cannot be compared with any of the Asian and Australian species, but some affinity with the *chinensis* group (*Pteroredlichia* Chang, 1966) can be suspected. Palaeogeographically and stratigraphically significant also is the recent discovery of *Redlichia* in Siberia by L. N. Repina. Repina (1966) described from the Lena stage of southern Siberia four species of *Redlichia*—a not unexpected discovery once more supporting the correlation of the Ordian with the Lena stage; furthermore, *Redlichia* is now obviously much more widely distributed than was earlier believed. Of Repina's species *Redlichia bella* has diminutive interocular cheeks and short palpebral lobes and represents a genus of its own; *R. lata* is similar. These forms will not be considered further. The two remaining species—*R. knjazevi* and *R. zharkovi*—are, however, regular species of the genus and discussed in the differential diagnoses of *R. creta, R. lepta,* and *R. advialis.*

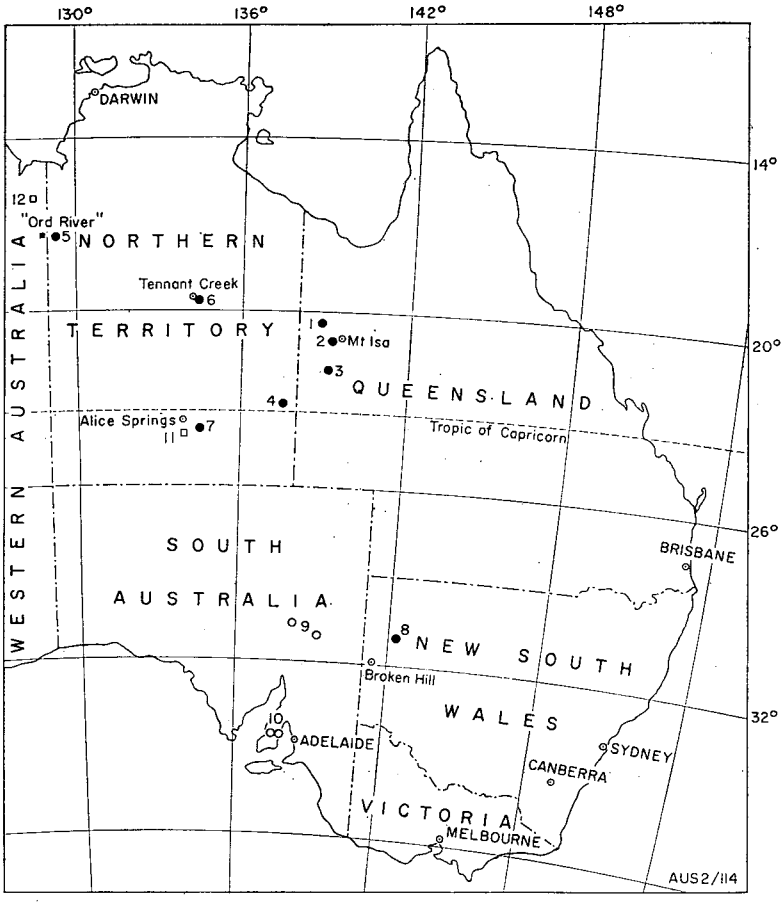

Figure 1: Geographic occurrence of selected localities with the Ordian *Redlichia* and *Onaraspis* fauna. Full circles: localities of *Redlichia* specimens described in this paper; circles: Ordian *Redlichia* localities in South Australia; squares: sites with *Onaraspis*.

1. **Yelvertoft Bed locality M426;**
2. **Cornford Bore Locality M262;**
3. **Localities D41 and D131, Urandangi Area;**
4. **Dinner Creek, Tobermory Area;**
5. **Mount Panton, Northern Territory;**
6. **Gum Ridge at Tennant Creek, Northern Territory;**
7. **Locality AS 59, Phillipson Pound, Alice Springs Area;**
8. **Mount Wright, White Cliffs Area, New South Wales;**
9. **Wirrealpa Limestone, Lake Frome Area, South Australia;**
10. **Wirrealpa Limestone at Curramulka (surface) and in the Minlaton Bore, York Peninsula, South Australia.**
11. **Deep Well, South of Alice Springs;**
12. **Blatchford Escarpment, Western Australia.**

The data for South Australia (9 and 10) are adapted from Daily (1958); the localities 11 and 12 are described by Opik (1967).

GEOGRAPHIC AND STRATIGRAPHIC DISTRIBUTION OF THE DESCRIBED SPECIES OF *REDLICHIA*

The diagrammatic map shows the geographical distribution of the eight sites that supplied the material described in this paper; they can be accurately positioned from the geographical co-ordinates given in their descriptions below. Many more than these eight localities are represented in the collections containing *Redlichia.* The material in these is, however, poorly preserved and is therefore unsuitable for a definite diagnostic taxonomy on its own merit. Nevertheless, in some of the collections from the Northern Territory forms are evident which are different from any of the established species.

The geographical and palaeogeographical distribution of species of *Redlichia* in northern Australia, including New South Wales, (all Ordian in age) is as follows: (1) Queensland and the Northern Territory have no species in common except for *Redlichia chinensis,* which in the Northern Territory is only found in the Tobermory area close to Queensland; (2) the stratigraphic distribution of the known species—late Ordian in Queensland and earlier forms in Northern Territory—may partly explain the difference in the faunal composition; but late Ordian species, still undescribed, exist in the Northern Territory (see below under Gum Ridge Formation) and in this undescribed material (which includes delicately ornamented forms) no Queensland species are evident yet; (3) in New South Wales, at Mount Wright, *R. petita* sp. nov. is a species older than the Queenslanders which may yet be found in Northern Territory; (4) in the Ordian of South Australia undescribed forms are present with delicate ornaments of lines and granules, reminiscent in this aspect of *R. versabunda* sp. nov.; I was able to inspect the material, by courtesy of Dr B. Daily, from sites 9 and 10, Text-figure 1.

The described distribution pattern of the species of *Redlichia* is about the same as in the palaeogeographic map of *Redlichia* time (Öpik, 1956; 1957, p. 251); the designation '*Redlichia* time' means Ordian as employed now.

The temporal (stratigraphic) succession of species and assemblages of species of *Redlichia* of the Ordian of Northern Australia, in descending order, is as follows:

Assemblage 1—The *Redlichia chinensis* assemblage, comprising the fauna of the Yelvertoft Bed (locality M426) of Queensland; the species are *advialis* nov., *chinensis* Walcott, *creta* nov., *idonea* Whitehouse, *micrograpta* nov., *venulosa* Whitehouse, and *versabunda* nov.; concomitant are some ten species of Bradoriida (Öpik, 1968). Of about the same age is the chert with *Redlichia chinensis,* on Dinner Creek, Tobermory area. The assemblage at D41, with *chinensis, versabunda,* and *lepta,* is probably slightly older.

Assemblage 2—The assemblage of locality M262 (Cornford Bore) of Queensland, with *versabunda, vertumnia* nov., and *mayalis* nov. The presence of *versabunda* connects this assemblage with the younger *R. chinensis* fauna; the *Redlichia* sp. a (Öpik, 1958), of Northern Territory, is presumably of the same age as Assemblage 2 (see below, under Gum Ridge Formation).

Assemblage 3—This assemblage of Ordian fossils from the Mount Wright area, New South Wales, contains a single species—*R. petita* nov. It occurs below a limestone of a late Ordian age, but above later Lower Cambrian (see Öpik, 1967b).

Assemblage 4—This assemblage refers to the *Redlichia forresti* fauna of the Negri Group (Northern Territory and Western Australia).

Assemblage 5—Only one species—*amadeana* nov.—belongs to this assemblage; it is the oldest species of *Redlichia* so far known in the Ordian of the Northern Territory and is known from the Negri sequence of Mount Panton, Gum Ridge Formation at Tennant Creek, and Giles Dolomite southeast from Alice Springs.

The five faunal assemblages are biostratigraphic operational units in a superpositional order—a rough scale of a major part of the Ordian. Assemblage 1 (*Redlichia chinensis*) can be taken as a zone of general validity with the proviso that its transition upward into the Templetonian is its latest part or may represent a separate zone with a species of *Redlichia* not yet determinable. Assemblage 2 (*R. mayalis* and *vertumnia*) represents the oldest Ordian zone in Queensland; its regional validity, however, is in need of further field work and palaeontological study.

Assemblage 3, with *Redlichia petita,* cannot be regarded as a zone that provides for an accurate scale position. It is older than *R. chinensis* and younger than *R. forresti* in terms of known temporal ranges of these species.

Assemblage 4 (*R. forresti*) and 5 (*R. amadeana*) are two zones in superpositional order applicable to the Negri sequence; the upper limit of *R. forresti* is, however, unexplored, and the vertical distribution of *R. amadeana* in the Gum Ridge Formation and in Central Australia is unknown and cannot be even surmised.

The oldest faunal assemblages of the Ordian of the Northern Territory refer to *Onaraspis somniurna* and *O. adusta* (Öpik, 1967b). These forms constitute a separate biostratigraphic operational unit whose vertical span is in need of further exploration. Its occurrence (sites 11 and 12) is shown in the map, Text-figure 1.

To sum up, in Queensland the Ordian is represented by its two uppermost zones or BSOUs (biostratigraphic operational units), whose fauna is also more

or less described; in the Northern Territory, as a whole, the Ordian sequence appears complete, but the faunal content of its BSOUs is still a matter for further study. In New South Wales the recently discovered Ordian sequence and fossils remain a problem for further enquiry, as do those in South Australia.

Description of collecting sites (Text-fig. 1)

Locality M426, latitude 20°11°S; longitude 138°53°E; on Barkly Highway, at the D.S. Hall Memorial, about 1.5 miles north from Yelvertoft homestead, Mount Isa area (Öpik, Carter, & Noakes, 1961). The Cambrian sequence at this place is known as the Yelvertoft Bed, and was discovered by Whitehouse (1939). The total thickness, including the lateritic top, is (or was) about 15 feet. It rests on an uneven rolling surface of the Precambrian Pilpah Sandstone. The section comprises (1) a gritty conglomerate with quartz pebbles, 3 feet; (2) above the grit a discontinuous bed of grey silica (a silicified dolomite or limestone) with *Biconulites,* some 4 to 6 inches; and (3) off-white (externally red) siliceous shale and siltstone with chert, about 7 feet; the lateritic top has been converted to road metal.

The fossils, all in the shale or chert, described so far are: the trilobites *Redlichia idonea* Whitehouse, *R. venulosa* (Whitehouse), *R. chinensis* Walcott, and the new *R. advialis, R. creta, R. micrograpta,* and *R. versabunda;* the Bradoriida *Indota otica, Tropidiana cirrata, Bradoria cornulata, Bradoria curvifrons, B.* cf. *curvifrons, Ophiosema spicatum, Comptaluta calcarata,* and *Comptaluta profunda*—described by Öpik (1968); *Biconulites, Hyolithus,* some three forms of phosphatic brachiopods, and the alga *Girvanella* have been noted.

Locality D41, latitude 21°41', longitude 139°16'; southeastern part of the Urandangi area, Queensland (Noakes, Carter, & Öpik, 1959); the site is a part of the Ardmore outlier of the Cambrian strata, a down-faulted enclave in the basement. There is no number D41 on the map, but the place is marked by a 'fossil symbol'. The *Redlichia*-bearing sequence of about 35 to 50 feet of grey dolomitic limestone with chert and thin bituminous laminae rests on erosional residuals of red sandstone (presumably Lower Cambrian) as well as direct on the uneven surface of the basement; the dolomitic limestone, attributed to the Thorntonia Limestone, is covered by a chert bed and white friable and very fossiliferous shale with *Xystridura* of the Templetonian Beetle Creek Formation. The dolomitic limestone is well exposed in a south and west facing escarpment and yielded *Redlichia chinensis, R. versabunda* nov., and *R. lepta* nov. Some 18 miles west-southwest from the Ardmore outlier, at latitude 21°55'S and longitude 139°07½'E, *Redlichia chinensis* (collection No. D131) occurs in grey dolomite resting on Precambrian schist and basalt. In the same Urandangi area, close to its southeastern edge, the transition between the Ordian grey dolomite (Thorntonia Limestone) and the Templetonian sequence is exposed in several sections; the transitional strata consist of interbedded dolomite and chert with the incoming Templetonian *Xystridura* fauna. Conspicuous is the abundance of shells of *Hyolithus* of all sizes packed together in some of the dolomite beds.

Outcrops of the transitional sequence are observable on the fringe of locality D69 (lat. 21°53', long. 139°07').

Ordian strata (shale with chert) with *Redlichia* occur also south from the 22nd parallel in the Glenormiston area (Öpik, 1967).

Locality M262, latitude 20°49'S, longitude 139°06'E, at Cornford Bore, on Yaringa Creek, May Downs station, Mount Isa area, Queensland (Öpik, Carter, & Noakes, 1961). Cambrian sediments resting on the Precambrian constitute a small mesa (a minor outlier). The lower part of the sequence consists of a friable silica rock (probably silicified dolomite or limestone) with *Biconulites* and *Redlichia vertumnia* nov., *R. versabunda* nov., and *R. mayalis* nov.; associated are fragments of an *Onaraspis* (?), and several forms of phosphatic brachiopods. Above this bed follow siliceous shale and chert, about 50 feet thick, with phosphatic brachiopods, *Pagetia* (indeterminable species) and *Xystridura* sp. nov. which is unrelated to the Templetonian forms.

Collection JW13—FBH/J from Dinner Creek, west of Christmas Hole, latitude 22°53', longitude 137°40', Tobermory area, Northern Territory; collection by geologists of Frome-Broken Hill Co. Pty Ltd. The rock is a layer of chert with several cranidia of *Redlichia chinensis,* identical with the Yelvertoft cranidium, Plate 4, figure 1 of this paper. The nearest Queensland site of the same species (D41) lies over 100 miles to the northeast. Some more occurrences of this chert with *Redlichia* have been observed by the present author westward from Dinner Creek. This chert is the oldest known Cambrian bed in the area. The age is late Ordian; at some sites it is seen resting below siltstone, or bituminous limestone with chert layers, containing fossils of Templetonian age.

Mount Panton, latitude 17°18', longitude 129°09', Northern Territory, about 14 miles east from the border of Western Australia. The occurrence of *Redlichia* in the limestone of Mount Panton is well known in the literature and is in this paper determined as *R. amadeana;* it is associated with an undescribed new species of *Xystridura;* Öpik (1967b) in proposing the concept of the Ordian Stage placed the Mount Panton strata below the Linnekar Limestone, and below the beds with *Redlichia forresti,* which have been revised by Öpik (1958).

Gum Ridge Formation, Northern Territory, at Tennant Creek. The co-ordinates of the southern end of the Gum Ridge are latitude 19°36', longitude 134°26'; and the distance (as the crow flies) from Tennant Creek is about 17 miles eastward. The distribution of the Cambrian outcrops east of Tennant Creek is shown on a map by Ivanac (1954, pl. 1). Öpik (Ivanac, op. cit., p. 30-32) in describing the Cambrian Gum Ridge Formation indicated the presence of a succession of four separate fossil horizons, in ascending order: (1) a shale with *Redlichia* and *Xystridura;* (2) shale with *Redlichia;* (3) 'nodular shale' with *Redlichia,* a ptychopariid, *Wimanella,* and *'Helcionella';* the nodules are fossiliferous silicified grey sphaeroidal concretions; and (4) the highest

horizon (Owen Hill bed), in Owen Hills, some 15 miles north from Gum Ridge; it yielded a species of *Redlichia* associated with Templetonian trilobites. Öpik's original paper and field notes concerning the geology and fossils of the Gum Ridge Formation, including the Owen Hill Bed, and most of the collections were destroyed in a fire, and the 'new species' in the list (op. cit., p. 31-32) remain therefore *nomina nuda.* In this bulletin, the cranidium Plate 2, figure 2, attributed to *Redlichia amadeana* nov., is presumed to have been collected in the lowermost bed of the Gum Ridge sequence; and the form mentioned as *Redlichia* sp. a (Öpik, 1958, text-figs 5 and 9) in Assemblage 2 was collected certainly in the 'nodular bed' on top, in the northern part of Gum Ridge. In passing, Gum Ridge is topographically an east-dipping cuesta, almost a low plateau with a west-facing escarpment.

Locality AS59 (AS stands for Alice Springs area); latitude 23°58', longitude 134°24', southeast from Alice Springs, in the hills and ridges of the Phillipson Pound; the formation is Giles Creek Dolomite. Described from this place is *Redlichia amadeana* nov.

Mount Wright—Mootwingee Range Area, New South Wales. *Redlichia petita* occurs in a white shale at about latitude 31°12', longitude 142°22'. The Cambrian sequence of the area has been discussed by Öpik (1967).

MODE OF LIFE AND MODE OF BURIAL OF *REDLICHIA*

Kobayashi (1961) lists 36 species-taxa attributed or attributable to the genus *Redlichia;* two more species of Hsu (1948) should be added to this figure; some of the species (*Redlichia finalis, R. intermedia*) have been transferred, with good reason, to other genera, and some others to genera or subgenera whose separation from *Redlichia* is a matter of subjective assessment.

Kobayashi's (op. cit.) figure is increased by 18 subsequently described forms to a total of 56: two from China by Lu (1961) and by Chang (1966): four from Siberia by Repina (1966); one from Spain, by Sdzuy (1961); eleven from Australia (this bulletin). The total number of known species, however, depends on taxonomic considerations regarding synonyms and generic classification of the material; it is still large (close to 45), but is less than the maximal number of 56.

The mode of life of a genus of trilobites is, needless to say, a generalization: the real objects of ecological studies are species and populations; among the fifty or so known species of *Redlichia* preferences for habitats and response to the physical environment parameters were quite diverse.

In the first part of the discussion that follows the mode of life of *Redlichia,* its palaeogeographic distribution, and aspects of its extinction are presented in

a generalized form; the second part deals with observations in support of the generalized conclusions.

The species of *Redlichia* were independent of the composition and character of the sediments of the sea floor and lived in the warm surface waters of the seas of the shelves, banks, and geosynclinal troughs fringing the lands; they occasionally visited shallows and left their tracks and dragtrails on tidal flats. No global travellers, their species populated the seaways of Australia, southeastern and southern Asia, but never reached either the American Cordilleran and Appalachian, or the Acado-Baltic Caledonian seaways. The oceans were, apparently, impassable, and single individuals which may have survived the drifting across produced no progeny.

The main realm of *Redlichia* is found in southeastern Asia and Australia; the seaways of these regions were in communication in the Ordian, as is evident from the ubiquitous occurrence of *Redlichia chinensis;* some more of such species may exist camouflaged by the diversity of the specific taxonomic nomenclature. Nevertheless, a mosaic of areas with endemic populations of species is also apparent, as seen from the different composition of the species lists in Queensland and Northern Territory. The species of *Redlichia* were no long-distance swimmers—nectonic in a restricted sense, and some may have been pelagic within their near-coastal biotopes. They were not pelagic as were the subsequent agnostids, many species of which have a global distribution (Öpik, 1961 and 1967a).

The extinction of the *Redlichia* stock at the end of Ordian time is a fact, but its cause or causes are obscure. The invertebrate stocks concomitant with *Redlichia* in the Ordian continued to diversify in Templetonian time—a sign of a continuity and stability (within limits of tolerance) of the regime of the seas. Some biological causes may have contributed to the extinction of the *Redlichia* stock: the numerical predominance of females over the extremely rare males (Öpik, 1958), which were eaten up by females after mating; this may explain the remarkable scarcity of larvae and of breeding grounds; an exceptional occurrence of larvae has been described by Kobayashi & Kato (1951), attributed to *Redlichia chinensis,* a species of interregional distribution. Another and even more hypothetical factor contributing to the extinction may have been the frequent incidence of decline in the efficiency of the moulting hormones, which may also explain the frequent occurrence of complete dead bodies as compared with the rarity of coherent exuviae. Extinction in this context refers to the latest Ordian species, which stopped breeding and died without progeny. *Redlichia,* externally a comparatively little specialized, primitive trilobite, appears highly specialized regarding its sex ratio and endocrinal activity.

The same biological factors and some more unknown causes controlled the fate of *Redlichia* during the whole of Ordian time. The number of coeval populations was gradually reduced and the chance of total extinction therefore was concurrently increasing with advancing time. The last populations did

not disappear all at once, but still within a relatively short temporal interval at the passage from the Ordian into the Templetonian age.

Independence from the conditions of the sea floor. Redlichia has been collected in shale, siltstone, mudstone, chert, marly limestone, sandy limestone, aphanitic limestone, phanerocrystalline pure limestone, dolomite, tuffaceous beds, and bituminous shale and limestone. I know of no *Redlichia*-bearing sandstone, but no sandstone formations of Ordian age are known either. It is, of course, possible that *Redlichia* possessed an absolute tolerance of all kinds of sediments, but it is most probable that the trilobite was not a bottom dweller, but lived in waters above the sea floor.

Tracks and trails on tidal flats. Seilacher (1955) described from the Salt Range an abundance of trilobite trails, attributable to *Redlichia noetlingi.* The abundance of trails and nests (*Cruziana*) is no measure of the abundance of individuals: a single arthropod may cover in a short time a large surface with his trails. Among the Cruzianas (*Rusophycus didymys*) illustrated by Seilacher one is possibly the mating nest of two individuals (Öpik, 1959, p. 8 and 9); assuming that the nest belongs to *Redlichia* it provides a supplement to the mating habits as discussed by Öpik (1958).

The realm of Redlichia. The western extent of the realm is diffuse; the number of species of *Redlichia* in the Salt Range, Himalayas, Eastern Tien Shan, Iran, and Spain (about one in each place) is very small as compared with southeastern Asia and Australia; nevertheless, no prohibitive barriers are apparent when compared with the total absence of *Redlichia* in America.

Moulting, dying, and burial. The usual and most common manner of preservation and burial is evident in Plate 1, figure 4. Isolated sclerites occur scattered, or accumulated on bedding planes. These sclerites may belong to disarranged exuviae, as well as to subsequently dismembered dead bodies, all re-shuffled and re-sorted according to size, form, and conxevity. An example of an exuvia has been described earlier (Öpik, 1958, pl. 4); but such well preserved and coherent moults are very rare, probably because of subsequent sorting of the disunited parts.

The complete specimens of *Redlichia* illustrated by Whitehouse (1939) and in this bulletin are exoskeletons of dead bodies. This condition is indicated by the cephala preserving the rostral shield and the hypostoma in their original frontal position. The absence of the rear part of the integument, as for example in Plate 4, figure 2, Plate 5, figure 3, and Plate 1, figure 1, is accidental: it was not collected, or lost among the fragments in the field. The holotype of *Redlichia micrograpta,* Plates 7 and 8, as discussed in its description, represents an individual which died during the process of moulting. In other specimens cephalic sclerites are slightly displaced and were probably liberated at the onset of moulting; but the thorax remained coherent; it is possible that this

part of the armour still adhered to the dying body. The bodies in armour of *Redlichia* are relatively frequent in the Yelvertoft Bed at locality M426. Quiet water and absence of scavengers are indicated. The armour remained for a while on the sea floor, where it was buried by the slowly accumulating mud. The shells of Bradoriida are associated with *Redlichia;* these Crustacea were probably of a pelagic mode of life.

Warm surface waters. The realm of *Redlichia* in the Ordian was named the 'oldest Tethys' by the Richters (1941, p. 35); their concept of the Tethys of *Redlichia* stands within now wider geographical limits stretching from northern Spain to western New South Wales and touching in southern Siberia the present latitude of 50°N. By the present geographic position of the poles it was a sea (or seas) with warm surface waters; with the position of the palaeomagnetic poles at Bikini and at St Helena (see Öpik, 1956, P278) in Cambrian time, and accepting (as a hypothesis) the same position for the climatic poles, warm surface water also should have prevailed in the 'oldest Tethys'. By the way, the distribution of the presumably warm-water archaeocyathids, which is bipolar in terms of the present positions of the climatic poles, supports either the Bikini—St Helena palaeo-positions or an Ordian thermal regime generally warmer than it is now.

TAXONOMY OF SPECIES

REDLICHIA ADVIALIS sp. nov.

(Pl. 1; Pl. 2, figs 5 & 6; Pl. 3, fig. 1)

Material. The illustrated material consists of one cephalon with a part of a thorax; one complete shield; part of a thorax with the pygidium; one isolated pygidium; one free cheek; and three cranidia. Some fifteen cranidia, three complete specimens, and a number of less complete shields have been examined.

Holotype. The cephalon (Plate 1, fig. 1, the mould of its exterior in hard shale), CPC 7149, is selected as the holotype; it is 14 mm long without the thorax, its test is smooth except for weak veins on the free cheeks and traces of lines on the right interocular cheek. The rim is flattened and, therefore, relatively wide.

Previous record. The two cranidia of *Redlichia* sp.d (Öpik, 1958, pl. 6, figs 7 and 8) belong to *R. advialis* sp. nov.

Diagnosis. Redlichia advialis sp. nov. has a narrow frontal limb, a slender thorax of sixteen free segments with the anterior segments along the joints as wide as the length of ten segments, and no axial ornament; and is distinguished by relatively long (about 0.8-0.85 of glabella) and narrow palpebral lobes whose rear tips are placed from the occipital lobe at a distance of 0.23-0.27 of the width of that lobe, and by the presence of axial spines on each of the annulations of the thorax.

Differential diagnosis. R. advialis belongs to the group of species with a relatively narrow frontal limb (1.0-1.1 of cephalic length) and a smooth or weakly ornamented glabella and interocular cheeks; this group includes the type of the genus, *R. noetlingi* (Redlich), *R. forresti* (Etheridge), *R. nobilis* Walcott, and *R. idonea* Whitehouse. In these, and in other species of the same group, the rear tips of the palpebral lobes are almost in touch with the occipital lobe; furthermore, in *R. forresti* and *idonea* most of the annulations are spineless and *forresti* has seventeen and *idonea* fifteen free segments. Also, in cranidia attributed by Saito (1934, pl. 24, fig. 18) to *R. nobilis* Walcott the position of the rear tips of the palpebral lobes is similar to that of *R. advialis* but the palpebral lobes are shorter and wider. *R. nobilis* itself is discussed below. The differential diagnosis of *R. idonea* (q.v.) also refers to *R. advialis.* Reminiscent of *R. advialis* is *R. zharkovi* Repina (1966) in the position of the posterior tips of the palpebral lobes; in *zharkovi,* however, the glabellar front is angular and the posterior glabellar furrows (which are transcurrent in *advialis*) are disconnected. Further comparison is prevented by the fragmentary state of the Siberian specimens.

Description. The complete exoskeleton Plate 3, fig. 1, CPC 9157, is 34.5 mm long; it is completely flattened in siliceous shale. The cephalon is as long as seven anterior segments of the thorax, about one third of the total length and half the length of the thorax and pygidium together. In front, the thorax is as wide as 0.6 of its length with the pygidium attached; the width is taken without the pleural spines and the proportions refer to the flattened test; a test preserving the original convexity should be even narrower. The associated *R. idonea* is less slender, with a frontal width of the thorax about 0.7, also in a flattened state. The free cheeks and the rostral shield have shifted rearward; the glabellar front is collapsed but retained some of its convexity over the hypostoma. All parts are still present, indicating a dead body and not an exuvia. The free cheek is relatively narrow, narrower than in *R. idonea* and much narrower than in *R. chinensis,* but reminiscent of *R. forresti;* the flattened cephalon, therefore, should be slightly elongate semielliptical, and not semicircular as in *R. forresti,* or transverse semielliptical as in *idonea* and *chinensis.* The genal spine is long, reaching the seventh segment, and undeflected; it is moderately advanced forward and the angle at its base of 50-55° is acute. The free cheeks are shifted adaxially, covering the palpebral lobes almost completely, but it is still evident that between the rear tip of the left lobe and the axial furrow the distance is about 0.25 of the occipital lobe. The glabella is conical, with straight flanks, and in the rear is as wide as 0.6 of its length. The posterior glabellar furrows are transcurrent but shallow in the middle, the second and third furrows are relatively short. A small marginal occipital spine is present. The test is smooth, without ornament, but the free cheeks, as seen in better preserved material, are delicately venulose. The cephalic rim bears terraced lines which on the genal spines are arranged in a chevron pattern.

In the thorax the tips of the anterior pleurae are short advanced spines passing rearward into curved, retral, and falcate spines. Each pleura (measured along the frontal edge) is narrower (transversely) than the axial lobe of its segment, even in flattened specimens; an anterior pleura is about 0.7 of the width of its axial lobe—a proportion seen also in *R. chinensis*—and the axial spines of the thorax are of several different sizes: the spine on the eleventh segment is strong and long as in all species of *Redlichia;* weaker, but still prominent, is the spine of the fourth segment, followed by a lesser spine on the fifth; the rest of the segments, beginning with the first, have small, inconspicuous spines. These spines are seldom visible, being worn externally.

The pleurae and the free cheeks were originally downsloping and the unflattened body was narrow indeed.

The pygidium is small, about as long as the anterior segment of the thorax. The pygidium Plate 2, figure 6, CPC 9156, however, is sufficiently preserved. It is assigned to *R. advialis* because it lacks the anchylosed segment—a condition observed in several thoraces with attached pygidium. It is transverse elliptical and 3.1 mm long; there are three annulations interrupted in the middle, a

short bilobed (bi-globose) terminus, and two pairs of small posterolateral spines; the lateral doublure is exposed on the left side, as in *R. forresti,* and the rear of the pygidium has no doublure.

The ornament consists of weak raised reticulate lines on the interocular cheeks visible in exceptionally well preserved specimens, but the axial lobe, including the glabella, is smooth. In the holotype a film of matrix on the test conceals the ornament on the interocular cheeks; in Plate 1, figure 4 this ornament is present in specimens preserving the test (fig. 5) but absent in internal casts (fig. 6).

Comment on other illustrated specimens

The piece of shale, Plate 1, figure 4, CPC 9151, shows some seven cranidia of *R. advialis;* the two uppermost cranidia are illustrated separately on Plate 1, figures 5 and 6.

The fragmentary cranidium, Plate 1, figure 5, is (or was) about 15 mm long; the exterior of the test is exposed showing the reticulate ornament of the interocular cheek.

The cranidium Plate 1, figure 6, is 12.5 mm long; it is an internal cast lacking the ornament.

The free cheek, Plate 1, figure 2, CPC 9150, an internal cast, is 22.0 mm long to the tip of the genal spine. The veins are strong in the anterior part and weak and reticulate in the rear; this cheek is attributed to *R. advialis* because its border is narrower than in *R. idonea* (Pl. 3, fig. 2).

The incomplete thorax with the pygidium, CPC 9155, Plate 2, figure 5, is 21.0 mm long (16.5 mm along the axial lobe): it is a worn internal cast in chert. The eleventh segment is indicated by the remnant of the base of the axial spine. There are five free segments behind that segment, indicating a total of sixteen; this number and the slenderness of the thorax are characters of *R. advialis.* Note the hollow mould of the axial spine extending well beyond the pygidial rear. This thorax, of a relatively small taxonomic value, is important regarding the general morphology of *Redlichia*: the pleural doublure is present on the flanks but absent in the pygidial rear; this structure was already described in *Redlichia* sp. *b* (Öpik, 1958, text-fig. 4 and pl. 1, fig. 6), which was lost. *R. advialis* and *R.* sp. *b.* are not conspecific, differing in the structure of the pygidial axial lobe.

The cranidium, an internal cast, Plate 1, figure 3, CPC 2335, is 14.5 mm long (see Öpik, 1958, pl. 6, fig. 8). It illustrates the long and narrow glabella, narrow palpebral lobes, the distance of the rear palpebral tip from the occipital lobe, and the convexity of the narrow rim, which is completely flattened and dilated in the holotype. There are tiny pits in the marginal frontal furrow—invisible in most of the other specimens.

Occurrence and age. Redlichia advialis sp. nov. comes from the Yelvertoft Bed, locality M426; its age is Ordian and high in the sequence.

REDLICHIA VENULOSA (Whitehouse, 1939)

(Pl. 2, fig. 1; Text-fig. 2)

The holotype of *Redlichia venulosa* is the cranidium described by Whitehouse (1939, pl. 19, fig. 1) as *Mesodema venulosa.* A second cranidium was described by Öpik (1958, p. 31 and 35-36, and pl. 6, figs 1-3), who suggested that *Mesodema* and *Redlichia* are synonymous. The hitherto published specimens are rather incomplete, especially regarding the structure of the palpebral lobes, which is evident in our specimen.

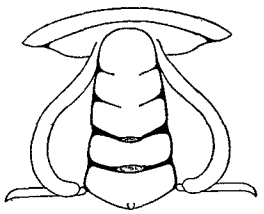

Figure 2: ***Redlichia venulosa*** **(Whitehouse), cranidium reconstructed.**

The cranidium Plate 2, figure 1, CPC 9152, is 11.0 mm long; the matrix is a relatively soft porous siliceous shale. The front of the cranidium is crushed, the left part of the frontal limb is displaced, the rim is flattened, and the left side of the glabellar front is deformed. The right side of the glabellar front, however, is relatively well preserved. The glabella and the occipital lobe show no difference from Öpik's (op. cit.) specimen and the glabella alone is the same as in the holotype.

For the purpose of further comparison the state of preservation of the occipital and palpebral lobes of the holotype should be considered: (1) the occipital lobe in the holotype (Whitehouse, op. cit., pl. 19, fig. 1) appears triangular to crescentic and pointed at its ends because its posterolateral corners are not preserved in the mould; the preserved part, however, with its marginal median node fits our specimen well. (2) The palpebral lobe is incomplete—its rear part including the palpebral tip is missing; the preserved part extends to the level of the occipital furrow and is separated from it by a distance of half the width of the occipital lobe; the palpebral lobe is the same distance from the occipital furrow in our specimen.

To conclude, the structure of the holotype (as preserved) is recognizable in, and identical with, the structure of the cranidium Plate 2, figure 1. The characters of *Redlichia venulosa* (Whitehouse) can be summarized as follows: (1) The glabella is slender and long with a rear as wide as 0.55-0.6 of its length; (2) the occipital lobe is pentagonal; (3) the palpebral lobes are very long, about as long as the glabella; (4) the rear palpebral tips are placed close to the occipital lobe but separated from it by a distance somewhat wider than the axial furrow; (5) the rear tips of the palpebral lobes are extremely retral, extending beyond the posterolateral corners of the occipital lobe and even slightly beyond the posterior cranidial margin and concealing the adaxial part of the posterolateral limbs; and (6) the frontal limb is as wide as the length of the cephalon.

Occurrence and age. Redlichia venulosa (Whitehouse) comes from the Yelvertoft Bed of the Beetle Creek Formation, locality M426. Only three cranidia attributable to *venulosa* have been found; hence, it is a very rare species. Its age is Cambrian—late Ordian.

REDLICHIA IDONEA Whitehouse, 1939

(Pl. 2, figs 3 and 4; Pl. 3, fig. 2)

In *Redlichia idonea* the palpebral lobes are separated from the occipital lobe only by the axial furrows, which are as wide as 0.1 of that lobe; this character is evident in the holotype (Whitehouse, 1939, pl. 19, fig. 4) and in his specimens

figures 6 and 8. The large cranidium (ibid., pl. 20, fig. 1) shows, apparently, remnants of heavy ornamental lines, and cannot be placed therefore in *idonea;* other specimens (ibid., pl. 19, figs 2, 7, and 9) belong apparently to *R. advialis* sp. nov.

It should be noted that the palpebral lobes in *Redlichia* are never in contact with the occipital lobe, as can be seen in flattened cranidia (Öpik, 1958, pl. 4, fig. 2, and pl. 5); in specimens having the palpebral tip broken or covered the apparent distance larger than 0.1 should not be mistaken for the true distance.

Diagnosis (*and Differential Diagnosis in parenthesis*) revised herein. *Redlichia idonea* Whitehouse belongs to the group of *R. noetlingi, R. advialis* sp. nov., *R. nobilis* Walcott, and *R. forresti* (Etheridge), whose species have a narrow frontal limb (1.0-1.1 of glabellar length) and a smooth or weakly ornamented glabella and axial test; within this group *R. idonea* is distinguished by the combination of the following characters: (1) the glabellar and axial tests are smooth (also smooth in *R. forresti* and *R. advialis,* but weakly ornamented in other species); (2) acute and deep genal angle (relatively shallow and blunt in *R. noetlingi,* but close to *R. advialis*); (3) palpebral lobes close to the occipital lobe (as in *R. noetlingi* and *R. nobilis,* but closer than in *R. advialis* and even in *R. forresti*); (4) anterior segments of the thorax as wide as the length of eleven to eleven and one half segments (as in *R. forresti;* but ten in *R. advialis;* unknown in *R. noetlingi* and *R. nobilis*): (5) strong axial spine on the eleventh segment (as in many species of *Redlichia,* but on the twelfth in *R. forresti*); (6) fifteen free segments in the thorax (sixteen in *R. advialis,* probably fourteen in *R. nobilis,* seventeen in *R. forresti,* unknown in *R. noetlingi*); and (7) pygidium with an anchylosed segment (as in *R. forresti,* but not in *R. advialis;* unknown in *R. noetlingi* and doubtful in *R. nobilis*).

Remarks. The delicate ornament on the glabella of *R. noetlingi* and the structure of its free cheek have been described by Schindewolf (1955). For *Redlichia forresti* see Öpik (1958); *Redlichia advialis* sp. nov. and *R. nobilis* Walcott are discussed in this Bulletin. *R. idonea* and *R. advialis* sp. nov. occur together in the Yelvertoft Bed (locality 426), and *advialis* is dominant numerically; fragments of inferior preservation and isolated free cheeks are also numerous, which may belong either to *idonea* or *advialis,* but cannot be allocated conclusively.

Comment on illustrated material.

The incomplete exoskeleton, Plate 3, figure 2, CPC 9158, is a mould of the external surface of the test; the specimen is 27 mm long as preserved; it is creased but not flattened completely. The segments of the thorax are somewhat telescoped together, but their individual length is measurable, with the result that eleven and one half of the segments are as long as the width of any of the four anterior segments without spines. The axial spine of the eleventh segment is strong and long, but of the fourth is rather weak, and a weak node is also apparent on the eighth segment. The right palpebral lobe is in its rear over-ridden by the anterior segment of the thorax, but the rear tip of the left lobe, partly in shadow, is close to the occipital lobe. An external ornament is present only on the border of the free cheeks and on the genal spines and the pleural tips, and consists of lines in chevrons; the rest of the test is smooth; no veins are visible on the exterior of the free cheeks.

The cranidium Plate 2, figure 3, CPC 9153, is 16.0 mm long, flattened and completely decorticated. It is attributable to *R. idonea* on account of the closeness of the palpebral lobes to the occipital lobe and the proportions of the frontal area, slender glabella, and occipital lobe. The interocular cheeks, however, are less wide than in other specimens of *R. idonea.* It even recalls *R. versabunda,* but its rim is too wide for the latter species; some similarity with *R. micrograpta* is also apparent.

The collapsed pygidium, Plate 2, figure 4, CPC 9154, is 6.0 mm long; it illustrates the presence of the semi-anchylosed segment (compare *R. advialis,* Pl. 2, fig. 6).

Occurrence and age. Redlichia idonea Whitehouse was originally described from the Yelvertoft Bed, locality M426; it has also been recorded from other localities of the Camooweal and Mount Isa Sheet areas (e.g. at Beetle Creek), in siliceous shale and chert immediately below the *Xystridura, Pagetia,* and *Peronopsis*-bearing beds, and in dolomitic limestone and limestone of the Thorntonia Limestone of the Camooweal and Lawn Hill Sheet areas, reaching the incoming of *Pagetia* and *Peronopsis.* Its age is Cambrian—late Ordian.

REDLICHIA PETITA sp. nov.

(Pl. 3, figs 3 and 4; Text-fig. 3)

Material. One cranidium and one free cheek are illustrated and described; about twelve cranidia, numerous free cheeks, and one pygidium have been examined. The matrix is a white soft shale, partly indurated red.

Holotype. The cranidium Plate 3, figure 3, CPC 9159, is selected as the holotype.

Diagnosis. Redlichia petita sp. nov. has a smooth (unornamented) test and a frontal limb of about 1.1 of glabellar length; it is distinguished by its very long palpebral lobes (as long as the glabella), large interocular cheeks, and a helicoid free cheek with a deep genal angle at the base of the well advanced genal spine. The rear tips of the palpebral lobes are placed at a short distance from the occipital lobe.

Differential diagnosis. Redlichia petita sp. nov. belongs to the group of species having the frontal limb as wide as 1.0-1.1 of the glabellar length. The majority of known species belongs to this group, but no other species has palpebral lobes as long as *R. petita,* except for *R. venulosa* (Whitehouse), which has a much narrower glabella. It appears close to *Redlichia forresti* (see Öpik, 1958), whose test is also smooth; but the palpebral lobes of *forresti* are shorter, the genal angle less deep, and the posterolateral free margin behind the genal spine relatively short and straight; in *R. petita* this margin is curved and longer. The free posterolateral margin is also curved in *Redlichia noetlingi* (see Schindewolf, 1955, pl. 7, figs 1 and 2), but its genal angle is relatively shallow and wide. Furthermore, the test in *R. noetlingi* is ornamented (see under *R. idonea*) and its palpebral lobes are shorter and interocular cheeks narrower than in *R. petita.* The position

of the rear palpebral tips away from the axial furrows reminds one of *R. advialis* sp. nov.; but in *advialis* the palpebral lobes are relatively narrow and visibly shorter than the glabella, and the rim is also narrow. The differences from the close *Redlichia creta* sp. nov. are discussed under that species.

Description. The holotype cranidium is 20.0 mm long. Owing to the length of the palpebral lobe the start of the anterior suture at the anterior tip of the lobe is placed well forward, with the result that the sutures are about horizontal and diverge almost diametrically; they take the same direction in *Redlichia chinensis,* in which the divergence is affected by the great width of the frontal limb and not by the length of the palpebral lobes; in *R. chinensis* these are shorter than the glabella—about 0.8 of its length. Furthermore, the long palpebral lobe margin is moderately arched forward and the rim is broad. The distance of the rear palpebral tips from the occipital lobe is about 0.15 of its width and less than in *R. advialis* sp. nov. The glabella is relatively broad, with a rear width of 0.8 of its length, and its flanks are straight. The two posterior glabellar furrows are apparently transcurrent or only connected in the middle by a depression; the anterior furrows are disconnected and shallow. The occipital lobe is relatively long—about as long as the posterior glabellar lobe—and bears a low pointed marginal median spine. The rim bears delicate wavy and closely spaced terraced lines; no other ornament is detectable either in the holotype or in the internal casts and external moulds of the rest of the material.

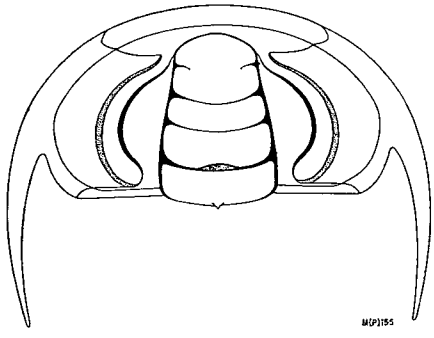

Figure 3: *Redlichia petita* **sp. nov., reconstruction of the cephalon.**

The free cheek, Plate 3, figure 4, CPC 9160, is 21.5 mm long to the tip of the genal spine. It is described as helicoid because its margin with the spine and the marginal furrow and the eye are curved in a similar manner and the posterolateral free margin is also curved. The same margin is straight in *R. forresti, R. idonea,* and *R. advialis.* The cheek is weakly venulose.

The available pygidium (a fragmentary external mould, not illustrated), CPC 9192, is 6.5 mm long, including an anchylosed segment with its free pleurae; the shield itself shows one axial annulation, no axial spine, a bilobed swollen terminus, and a pair of falcate pleural tips.

Occurrence and age. Redlichia petita sp. nov. was collected by the geologist Mr G. A. Brown, from a nameless formation at Mount Wright Tanks in the Mootwingee Ranges, north of Broken Hill, New South Wales; its age is Ordian.

REDLICHIA AMADEANA sp. nov.

(Pl. 2, fig. 2; Pl. 3, figs 5 and 6)

Material. Three cranidia are illustrated and described.

Holotype. The cranidium Plate 3, figure 6, CPC 9162, is selected as the holotype.

Diagnosis. Redlichia amadeana sp. nov. has a strongly developed lineate ornament of about five somewhat discontinuous lines in one millimetre, a relatively narrow frontal area, a broad glabella, forward arched middle part of its occipital lobe, and a pair of small nodes at the rear tips of its interocular cheeks.

Differential diagnosis. Redlichia amadeana has an external ornament reminiscent of *R. chinensis* (Pl. 4, fig. 1) but the ornamental lines in *chinensis* are coarser and continuous; moreover, in *chinensis* the glabella is slender and the frontal area is much wider than in *amadeana.* In other species the test is smooth; or where ornamented, the lines are much finer than in *amadeana* and *chinensis.* No other species is known to have nodes (bacculae) at the rear tips of the interocular cheeks.

Description. The cranidium, Plate 2, figure 2, CPC 2328, an internal cast in chert, is 22.0 mm long; its frontal limb is 23.2 mm wide and only slightly wider than the length of the cranidium. The glabella is straight-sided and somewhat angulate in front, and the small nodes on the rear tips of the interocular cheeks are relatively prominent. The occipital lobe is relatively flat and slightly lobate on flanks, and protrudes in the middle forward in a low arc. The test is lost, but weak traces of the ornament lines are reflected on parts of the glabella.

This specimen comes from the Gum Ridge Formation at Tennant Creek, Northern Territory, presumably from the lowermost bed of the local Ordian sequence.

The holotype cranidium, Plate 3, figure 6, CPC 9162, silicified in dolomite, locality AS 59, is 16.5 mm long as preserved. The test, whose surface is preserved, shows coarse, somewhat irregularly interrupted raised lines in a Bertillon pattern; the node on the rear tip of the right interocular cheek is distinct.

The cranidium, Plate 3, figure 5, CPC 9161, associated with CPC 9162, is 14 mm long as preserved. Its test is worn, and even missing in the middle, and the ornamental lines are not reflected in its internal side.

Numerous but mostly ill preserved cranidia of *R. amadeana* are found also in a limestone sequence of Mount Panton—a part of the Negri Group. Material from this place is not illustrated; two cranidia, however (CPC 9188 and 9189),

are included in the CPC type collection; in the first the characteristic ornament is partly preserved.

Occurrence and age. Redlichia amadeana sp. nov. occurs in the Northern Territory in the Gum Ridge Formation at Tennant Creek, in the Giles Creek Dolomite (lower part) at locality AS 59 (Alice Springs area), and in the Negri Group, Mount Panton sequence. The age is Ordian.

REDLICHIA CHINENSIS Walcott, 1905 (1913)

(Pl. 4, fig. 1; Pl. 5, figs 1 and 2)

Material. The available material consists of five specimens: (1) A cranidium, an external mould in chert, CPC 9163; (2) a fragment consisting of a part of the glabella, free cheek, and three anterior segments of the thorax; also an external mould in chert, CPC 9165; (3) a distorted small cranidium, CPC 9187, not illustrated, an unornamented internal cast in chert, locality M426; (4) a small cranidium, CPC 9166, Plate 5, figure 2; and (5) an unillustrated cranidial fragment, CPC 9191, 17.0 mm long (chert in dolomite, locality D131), showing the lineate ornament on the glabella and occipital lobe.

The holotype of *Redlichia chinensis* as illustrated for the first time by Walcott (1913, pl. 7, fig. 11) is about 22.5 mm long; its proportions, especially the width of the frontal limb of 1.4 of cephalic length, coincide with the Australian cranidium, Plate 4, figure 1. There is no ornament; I have examined the specimen and assumed that its test is either worn, or covered with a thin film of the matrix concealing the external ornament.

All subsequent authors in identification of their material of *Redlichia chinensis* relied on cranidial proportions identical with, or close to, the proportions of the holotype. To my knowledge, ornamented tests of *Redlichia chinensis* have been published only twice—by Saito, and later by Kobayashi. Saito (1934) illustrated: (1) a fragmentary cranidium with a broad striate rim, pitted frontal marginal furrow and the frontal area about 1.4 of cranidial length; the rather worn glabella, however, shows no ornament (Saito, pl. 26, fig. 3); and (2) a fragment of a segment of the thorax (ibid., fig. 6) with a heavy lineate ornament identical with our specimen, Plate 5, figure 1. Furthermore, in one of the cranidia of *R. chinensis* illustrated by Saito (ibid., fig. 1) the caecal veins running along the anterior suture have the same position as seen in our specimen; and in another cranidium (Saito's fig. 2) remnants of the test in the rear of the glabella are apparently lineate. Kobayashi's (1961, pl. 11, fig. 6) specimen is a large cranidium showing the regular lineate ornament seen also in our Plate 4, figure 1; its very wide frontal limb conforms with the concept of *R. chinensis.*

To sum up, evidence as discussed above supports the identification of the Australian material as belonging to *Redlichia chinensis;* final proof is, however, needed regarding the ornament from a revision of the type, and supplementary material of *chinensis* from the 'Slaty black limestone in lower part of the Manto shale, 2 miles south of Chang-hia, China' (Resser & Endo, 1937, p. 279).

In advance of Walcott's (1913) conclusive illustrations and description of the holotype of *R. chinensis,* Mansuy (1912, pl. 2, figs 1a, b) attributed a complete shield to that species. In subsequent reconstructions by Kobayashi (1944, pl. 9, fig. 4) and by Hupé (1953, p. 79, fig. 56) it is referred to as *Redlichia verneaui* (Mansuy), and afterwards (e.g. in Harrington et al., 1959) again as *Redlichia chinensis.* Its cranidial proportions are the same as in the holotype; the test is worn, but coarse forward-arched ornamental lines on the axial lobe of the eighth segment are visible in Mansuy's illustration—as in our Plate 5, figure 1. There are fifteen segments in the thorax and an axial spine on the eleventh segment.

As regards *Redlichia verneaui* Mansuy's own explanations (1912, p. 23, including a footnote) are relevant; it was originally attributed to *Olenellus* (*Mesonacis*) and based on two imperfect cranidia which have not since been revised; the date of publication is taken as 1907, but, according to Mansuy (loc. cit.), the name was used as early as 1905, which is subject to confirmation. It should be noted that Mansuy (1912) in replacing the name *verneaui* by *chinensis* based his description of *R. chinensis* on taxonomically disparate specimens; one of these (Mansuy's pl. 2, figs 1c, d) was illustrated by Walcott (1913, pl. 24, fig. 1) as *R. chinensis*—the holotype of the subsequent *Redlichia mansuyi* Resser & Endo, 1937. Finally, Lu (1961, pl. 1, fig. 1) attributed a cranidium to *Redlichia verneaui* (Mansuy), but without further explanation; it seems different from *R. chinensis.* To conclude, on the present state of knowledge, *R. verneaui* cannot be regarded as a synonym of *R. chinensis.*

Kobayashi (1961, p. 199) has produced a list of subjective synonyms of *Redlichia chinensis* which includes some six differently named species. The original paradigms of some of these species (for example *R. manchuriensis* Resser & Endo) may include specimens attributable to *chinensis,* others (for example *R. yunnanensis* Resser & Endo) will remain inconclusive because of the inferior preservation, or (*R. murakamii* R. & E.) retain their independent status.

Chang (1966) established the subgenus *Redlichia* (*Pteroredlichia*) for the group of *Redlichia chinensis* distinguished by a very large frontal limb; this is a plausible subgenus, but its application depends on what should be regarded as the lower limit of the 'very large frontal limb'. I agree with Chang (op. cit., p. 152) that *R. manchuriensis* can be placed in *Pteroredlichia,* but disagree regarding *R. murakamii* (see Öpik, 1958, p. 34). According to Chang, the 'type species' of *Pteroredlichia* is '*Pteroredlichia chinensis lui* Chang, var. nov.'—an ambiguous statement regarding the taxonomic rank of the type: it either is a

new species, or an infrasubspecific form of *R. chinensis* Walcott; it is illustrated (op. cit., pl. 1, fig. 7) but undescribed. In the illustrated cranidium, about 20 mm long, the frontal limb is 1.6 of cranidial length, the palpebral lobes about 0.85 of glabella, and the test is ornamented by granules, which in parts are confluent and vermiculate. These are diagnostic characters distinguishing the form from all others of the *Pteroredlichia* group; hence, I regard *Redlichia chinensis lui* Chang as a separate monotypical species.

Description of illustrated specimens

The cranidium Plate 4, figure 1, is 27 mm long; it is illustrated from a latex cast of the mould in hard chert; the specimen is flattened. The posterolateral limbs are missing and the outer parts of the palpebral lobes are worn. The frontal area is 1.45 of cranidial, and the palpebral lobes 0.75 of glabellar, length, and the width of the glabella in its rear is 0.7 of its length. These are the proportions of the type specimen of *Redlichia chinensis* Walcott as well. The rim is wide and flat, apparently flattened, the marginal furrow deep and pitted. The anterior sutures are gently sinuate and horizontal. The rim bears terraced lines; the brim is covered by osculating veins, and a pair of prominent veins ('facial lines'), close to the sutures, marks the rear of the brim. The ornament consists of raised lines: on the interocular cheeks the lines curve forward and outward; on the flanks of the occipital and glabellar lobes the lines run longitudinally, but toward the middle they meet in a Bertillon pattern. About three lines in one millimetre occur on the axial lobe. Three pairs of glabellar furrows are apparent; they appear somewhat transcurrent, probably because the glabella itself has collapsed.

The fragment, Plate 5, figure 1, CPC 9165, is 26.5 mm long as preserved. It consists of a part of the cranidium, the free cheek, and three segments of the thorax. The cheek is venulose (reticulate); the ornamental lines (about three in 1 mm) are partly preserved on the interocular cheek, the glabella, and the occipital lobe; the ornament on the axial rings of the thorax is similar to the glabella, but on the pleurae it is somewhat obscured by a longitudinal rugosity. The pleura of the anterior segment is pathological with a marginal scar and abbreviated pleural furrow.

The fragmentary cranidium, Plate 5, figure 2, CPC 9166, chert in dolomite, locality D41 (west), is about 4.5 mm long; it is attributable to *R. chinensis* because of its wide frontal limb (not less than 1.35 of cranidial length) and relatively short palpebral lobes; its test of granular silica shows some forward-arched ornamental lines on the rear glabellar lobe.

Occurrence and age. Redlichia chinensis Walcott has been found in Australia in the Yelvertoft Bed, at locality M426, Mount Isa area, and in dolomite and dolomitic limestone attributed to the Thorntonia Limestone, localities D41 and D131, Urandangi Sheet area. It also occurs in the Tobermory area of Northern Territory. Its age is Cambrian, late Ordian.

REDLICHIA MICROGRAPTA sp. nov.

(Pl. 4, fig. 2; Pl. 5, figs 3 & 4; Pls 6-8)

Material. The species *R. micrograpta* is based on one complete shield, and two cephala with attached anterior part of the thorax. All these specimens represent parts of dead bodies and not exuviae.

Holotype. The complete specimen, Plates 7 and 8 (and Plate 6, figure 3) CPC 9168, is selected as the holotype because of its rather informative mode

of preservation; the lineate ornament, however, is only partly preserved on the frontal lobe of the glabella and is identical with the ornament seen in the supplementary cephala.

Diagnosis. Redlichia micrograpta sp. nov. is a species of the group of forms with a frontal limb as wide as 1.0-1.1 of glabellar length, distinguished by its fine and dense lineate ornament of about 14 (12 to 15) lines in 1 mm, fourteen segments in the thorax with a stout axial spine on the tenth segment, a weak spine on the fourth, and no segment anchylosed with the pygidium.

Differential diagnosis. In the majority of known species of *Redlichia* the frontal limb is about equal to the glabellar length, but none (*R. murakamii* excepted) has the ornament of *R. micrograpta;* in species whose thorax is known the axial spine is on the eleventh or twelfth (*R. forresti*) and the number of segments (*R. murakamii* excepted again) is more than fourteen; according to Kobayashi (1961, p. 200) *R. chinensis* has fourteen, but his reconstruction shows fifteen, which is correct. The full number of segments is attained in maturity and the holotype of *R. micrograpta,* over 5 cm long, is a mature specimen (a holaspis). The holaspis of *R. chinensis* (q.v.) has fifteen segments, but Kobayashi & Kato (1951, pl. 5, fig. 8) also have illustrated a specimen only 11.5 mm long with fourteen segments—a late meraspis with a wide brim. *Redlichia murakamii* Resser & Endo (1937, p. 281) has a lineate cephalic ornament (whose density is unknown) and fourteen segments, but differs from *R. micrograpta* in having the spine on the eleventh segment and falcate pleural tips throughout. The authors (op. cit., p. 280) mention also fourteen segments in a specimen of *R. manchuriensis,* but their illustrated specimens appear immature.

Description. Descriptive data are given in the diagnosis and in comments on illustrated specimens, especially the holotype; amplifications follow below. The cephalon is as long as seven anterior segments of the thorax and slightly wider than long in flattened specimens. The genal spines are relatively long, longer than the cephalon or half the thorax; the genal angle is 45° and may be even slightly less and acute. The rim is relatively flat, interocular cheeks are relatively narrow—about half the glabella—and the rear tips of the palpebral lobes are close to the occipital lobe; the flanks of the glabella are slightly concave and its posterior furrows are almost transcurrent, being connected in the middle by a depression. The occipital lobe bears a small marginal axial node. The posterolateral limbs are narrow and the intergenal spines are deflected and in line with the serrate edge of the thorax. In the six or seven anterior segments the pleural tips are extended into advanced slender spines repeating in miniature the structure of the free cheeks and genal spines; the rear pleurae, beginning with the eighth, have falcate tips. The pleural lobes are narrow, about 0.75 of the axial lobe in front, and about 0.6 and less in the rear of the thorax. The pygidium is small, as long as three posterior segments, or 1.2 of an anterior segment, trapezoidal, and has three axial annulations interrupted in the midline by a median depression.

Comment on illustrated specimens

The holotype is 52.0 mm long. It is the exoskeleton of an animal which died at the onset of moulting. It cannot be regarded as an abandoned exuvia because the rostral shield and the hypostoma and both free cheeks are almost in their correct position. The cranidium is displaced forward and spun to the right; the right palpebral lobe rests on the border of the free cheek; the free cheek itself is turned upside down and its genal spine rests on pleural segments; it is apparent that the exuvia of the free cheek was liberated first, overturned, and then covered by the palpebral lobe of the shifted cranidial exuvia. The cranidial exuvia was already lifted up from the soft part of the cephalon. It is necessary to assume also that the soft part of the genal spine was torn off, being captured in the integument. Notable also are the following features: (1) the cranidial rim is somewhat concave, apparently by flattening; most probably it was almost flat; (2) the glabella has concave flanks; (3) the pits in the marginal frontal furrow are small, numerous, and close together; the left cheek, right side up, shows its external surface without any trace of veins, and the right (upside down) shows the venulose internal surface; (4) the left posterolateral limb detached from the cranidium is partly visible and shows its deflected intergenal spine; (5) the pleural tips (Pl. 6, fig. 3) are divided each by a prominent narrow ridge arising from the propleuron at the end of the pleural furrow (compare *R. advialis,* Pl. 2, fig. 5); a narrow furrow on the ventral side of the doublure corresponds to that ridge.

The specimen Plate 5, figures 3 and 4, and Plate 6, figures 1 and 2, CPC 9167, consists of the cephalon, 25.5 mm long, and a fragment of the thorax (four segments) 14.0 mm long. It is a part of a dead individual (not exuvia) as indicated by the rostral shield and hypostoma almost in situ. In the internal cast (Pl. 5, fig. 3), silica filling the hypostomal cavity has been removed and the hypostoma is exposed from inside; in Plate 6, figure 1 (the external mould), the rear margin of the hypostomal test with a pair of spines is preserved in detail. On the free cheek (Pl. 6, fig. 2), the external lines and the caecal veins crossing each other are imprinted equally well. The hypostomal test is absent, separated from the glabella by inorganic silica, and the ornament (forward-arched lines) belongs to the collapsed glabella; on the hypostoma the arcs of the ornamental lines are retral.

The specimen Plate 4, figure 2, CPC 9164, consists of the cephalon 16.0 mm long and six segments together 14.0 mm long. It is an external mould in which by compaction of the shale the caecal veins became accentuated. The frontal limb is fractured and dilated and appears therefore somewhat wider than in the holotype. The hypostoma is outlined. The flattened rim appears slightly concave. The chevrons of terraced lines on the genal spines and border are delicate and dense and on the rim the peaks of the chevrons point to the midline. The lineate ornament (about 14 lines in 1 mm) is also visible on the axial lobe of the thorax. The free cheeks are slightly displaced but posterolateral limbs are in place; intergenal spines are evident.

Occurrence and age. Redlichia micrograpta sp. nov. is a rare species in the Yelvertoft Bed, locality M426; its age is Cambrian, late Ordian.

REDLICHIA VERSABUNDA sp. nov.

(Pl. 9)

Material. The available material consists of the four illustrated cranidia.

Holotype. The cranidium Plate 9, figures 1 and 2, CPC 9169, locality M262, is selected as the holotype because both its external mould and its internal cast are available.

Diagnosis. Redlichia versabunda has a moderately wide anterior limb of about 1.1 of cranidial length and wider than the cranidium across the palpebral lobes, slightly concave glabellar flanks, laterally well defined posterior glabellar furrows

connected in the middle by a shallow depression only; and a trapezoidal occipital lobe with a small marginal node; the test is ornamented by raised lines, 8-9 in 1 mm, in a Bertillon pattern; the palpebral lobes are papillate.

Differential diagnosis. Redlichia versabunda is somewhat reminiscent of *R. chinensis* as regards the general aspect of the cranidium; but the narrower frontal limb and the finer ornament of *versabunda* prevent any confusion with *chinensis.* The cranidial proportions are also close to *R. nobilis,* which, however, has a flat downsloping rim—as in *R. vertumnia* (q.v.). *R. versabunda* is also close to *R. noetlingi,* whose preservation in shale, however, prevents a conclusive comparison; the same applies to the mostly distorted material of China and Korea. Finally *Redlichia venulosa* (Whitehouse), Öpik (1958), differs in glabellar shape, and has an almost straight frontal margin of the cranidium and, apparently, a smooth glabella. Lineate Bertillon ornament of about a similar density (7-8 lines in 1 mm) is apparent also in *Redlichia mansuyi* Resser & Endo, as seen in the cranidium published by Mansuy (1912, pl. 2, fig. 1f); Mansuy's (op. cit., p. 24) phrase: 'la surface de la glabella est finement chagrinée' refers apparently to this illustration. Apart from the ornament *R. mansuyi* differs from the Australian species by the structure of its frontal limb; see also Öpik (1958, p. 34).

Description. The holotype is 12.8 mm long and of a low convexity; the rim is convex (not flat) as in most of the other species of the genus. The marginal furrow, deep and wide on the flanks, is interrupted in the middle by a swelling reminiscent of a plectrum. Small pits are present in the lateral parts of the furrow. The wings of the frontal limb are moderately convex; the anterior sutures are slightly curved and strongly divergent; a prominent vein (the 'facial line') on each wing runs along its edge. The palpebral lobes are moderately wide and widen slightly rearward, and their rear tips are close to the occipital lobe and almost in line with its rear. The cranidium across the palpebral lobe is about 0.9 of the frontal limb.

The glabella, owing to a slight expansion of its posterior lobe, has concave flanks; its frontal lobe is rounded. The glabella is also slightly arched upward (not flat) and appears carinate in cast. The ornament consists of terraced lines on the rim, raised lines in Bertillon pattern on the glabella, papillate lines on the interocular cheeks, and papillae on the palpebral lobes.

The cranidium Plate 9, figure 3, CPC 9170, locality M426, is about 14.0 mm long. Its front is crushed and no plectral swelling is apparent. The chevrons of the terraced lines on the rim are extremely well preserved with peaks pointing to the midline. The ornament, including the papillosity of the left palpebral lobe, is preserved in parts.

The incomplete cranidium, Plate 9, figure 4, CPC 9171, locality D41 (west), chert in dolomite, is 14.0 mm long; it differs from the holotype in the absence of the plectrum-like swelling, but its proportions are the same; no ornament

is visible, the surface is rough with silica; but it is associated with another fragment (Pl. 9, fig. 5, just in front of the rim) showing a lineate ornament similar to *R. versabunda.*

Occurrence and age. Redlichia versabunda sp. nov. occurs in the Yelvertoft Bed of the Beetle Creek Formation, at localities M262 and M426; and in a dolomite, locality D41 (west), attributed to the Thorntonia Limestone. Its age is Cambrian, late Ordian.

REDLICHIA VERTUMNIA sp. nov.

(Pl. 10)

Material. The species *R. vertumnia* is based on two illustrated cranidia in chert.

Holotype. The cranidium Plate 10, figures 1-6, CPC 9172, is the holotype because its internal cast and external mould are both available. The surface is somewhat rough, with irregularly distributed tiny quartz crystals not to be mistaken for ornamental granulosity.

Diagnosis. Redlichia vertumnia has a relatively narrow frontal limb of 0.9 of cranidial chordal length, a broad and flat downsloping rim, a deep and broad frontal marginal furrow with numerous small and irregularly distributed ventral pits, broad palpebral lobes, straight glabellar flanks, deep and transcurrent posterior glabellar furrows, short second and diminutive anterior glabellar furrows, and an almost triangular occipital lobe with a short marginal occipital spine on a broad triangular base. There is a pair of small pits close to the middle of the anterior edge of the occipital lobe; the cranidium across the palpebral lobes is slightly wider than the frontal limb; the test is ornamented by delicate raised lines, about 8 lines in 1 mm, in Bertillon pattern.

Differential diagnosis. Only in the type of *Redlichia nobilis* Walcott (1913, pl. 7, fig. 12) from Shantung, a flat and downsloping rim seems to be present; in *nobilis,* however, the frontal limb is wider than the cranidium across the palpebral lobes and the interocular cheeks are narrower than in *R. vertumnia* sp. nov. Furthermore, in *nobilis* the posterior glabellar furrows are connected only by a shallow depression and the glabella (in Walcott's type) is narrow conical or parallel sided (Walcott's fig. 12b)—shapes different from *R. vertumnia.* The specimens from Korea attributed to *R. nobilis* by Kobayashi (1961) are too distorted and cannot be compared with *R. vertumnia* or with Walcott's material of *nobilis.* The density of ornamental lines is about the same as in *versabunda* sp. nov. (q.v.), which, however, is otherwise quite different. No ornament is known in the types of *R. nobilis* nor in specimens attributed to it subsequently.

Description. The holotype cranidium is rather convex in profile, having a depth of about 0.5 of its length when the palpebral lobes are taken as horizontal (attitude A); in this attitude (Pl. 10, fig. 1) its length is close to 9.0 mm, and the width of the frontal limb equals the cranidial length. The chordal length of the same cranidium (in attitude B) (Pl. 10, fig. 2) measured from the frontal margin to the occipital tip is close to 9.8 mm, and the frontal limb is about 0.9 of that length. The attitudes A and B are convertible mutually by rotating the specimen on a transverse axis; transverse measurements are not affected by the rotation. Depending on the attitude the cranidium shows two quite different faces: in attitude A the glabella is somewhat plump, the middle glabellar furrows are close to the frontal tips of the palpebral lobes, the rim appears narrow, and the anterior sutures are straight and diverge almost diametrically. In attitude B the glabella looks slender, the middle glabellar furrows are almost in the middle, the rim is really wide, and the sutures are wavy and diverge less than in A. It is evident that a comparison of such undistorted three-dimensional material as is represented by *R. vertumnia* with two-dimensional shale specimens will remain inconclusive because the original attitude of the specimens before compaction cannot be established. Still one hopes that the attitude B (specimen embedded dorsum up and resting on the largest possible surface) should be recognizable sometimes.

The slope of the rim coincides with the curvature of the cranidial profile; the rear of the rim is angulate and behind it on the internal cast there is a dense row of knobs—the fillings of the ventral pits; externally almost no traces of these pits are present. Each lateral wing of the frontal limb is developed as a fold, as seen also in *R. nobilis.* The palpebral lobes in the rear are close to the occipital lobe, and defined by deep and broad palpebral furrows. The glabella has straight flanks and a somewhat angulate front reaching into the marginal furrow. It is relatively flat as seen in frontal view. The occipital lobe is relatively large and triangular. The pair of pits on its frontal edge are a peculiarity of *R. vertumnia* and have no anatomical explanation yet. The ornament consists of terraced lines on the exterior of the rim; external ornamental lines are preserved on the frontal part of the glabella of the holotype.

The cranidium Plate 10, figure 7, CPC 9173, is 5.2 mm long; it is a fragmentary internal cast. Associated with it is a free cheek; its genal angle is quite large and the genal spine is less advanced than usually seen in species of *Redlichia.*

Occurrence and age. Redlichia vertumnia comes from the Yelvertoft Bed of the Beetle Creek Formation, locality M262 (Cornford Bore, west of Mount Isa); its age is Cambrian, late Ordian.

REDLICHIA MAYALIS sp. nov.

(Pl. 11, figs 1 and 2)

Material. The describable and described material consists of two cranidia—external moulds in chert.

Holotype. The cranidium Plate 11, Figure 1, CPC 9174 is selected as the holotype because its ornament is better preserved.

Diagnosis. Redlichia mayalis sp. nov. is distinguished by its densely granulose test, relatively broad and plump glabella, with a bluntly rounded frontal lobe separated by a distinct brim from the convex and prominent rim.

Differential diagnosis. None of the known species of *Redlichia* has the frontal glabellar lobe as wide and bluntly rounded as in *R. mayalis;* furthermore, among the species with a granulose test *Redlichia creta* sp. nov. (q.v.) has a much finer granulation than *mayalis,* and *R. lepta* sp. nov. is distinguished by its longer brim and wider frontal limb. In *Redlichia* cf. *walcotti* of Saito (1934, p. 225) (*Latiredlichia saitoi* Hupé, 1953, the type of its genus) the 'surface of the glabella is very finely granulose'. In this form, however, the glabella is wider than long, whereas in *R. mayalis* it is 0.75 of its length. The density of the granulation of *R. saitoi* is unfortunately unknown.

By the way, consulting Kobayashi (1950, p. 343) it appears that the name *R. saitoi* (Hupé, 1953), is a homonym of *R. saitoi* Lu, 1950; Saito's specimen (op. cit. pl. 26, fig. 19) is apparently the type of Lu's as well as of Hupé's species, as evident from the synonymy in Hsu (1948). *Latiredlichia* is a junior synonym of *Redlichia* (see Öpik, 1958, p. 34).

The date of publication, *Latiredlichia saitoi* Hupé, 1952, is the date of the original paper included in the references; Hupé (1953, p. 144) refers to the same date (1952); the 1953 date of the taxon (*L. saitoi*) employed by Kobayashi is the same as in Harrington et al. (1959); this is correct because Hupé in 1955 (p. 278, bibliography) gives the year 1953 as the actual date of publication of his original paper dated as 1952.

Description. The holotype cranidium is 8.0 mm long; it is fragmentary—without the right wing of the frontal limb, the tip of the left limb, the left rear of the interocular cheek, and part of the occipital lobe; the preserved part, supplemented by the specimen Plate 11, figure 2, is, however, sufficient for a taxonomic description. In the holotype the rim is broad, convex, and prominent, the palpebral lobe is almost as long as the glabella (about 0.95 of its length), broad, and widens somewhat rearward, and its tip is rather close to the occipital lobe. The glabella has slightly concave flanks and with the rear of 0.8 of its length is relatively broad for a species of *Redlichia;* it tapers to about 0.75 of its width in the rear and is, therefore, less 'conical' than in others. The posterior glabellar furrows are oblique and straight and connected in the middle by a shallow depression; the second furrows are disconnected but distinct; the anterior furrows are rather shallow—almost vestigial. The occipital lobe appears relatively short longitudinally, especially when compared with *R. creta* sp. nov. (q.v.), and bears a low median marginal node set off by a depression at its base. The ornament consists of a dense granulation (about 8 rounded granules in

1 mm) arranged in a Bertillon pattern; in parts the granules merge to form short ridges. The rim is covered by somewhat irregular terraced lines without chevrons.

The cranidium Plate 11, figure 2, CPC 9175, is large, 17.2 mm long. Its frontal limb is about 1.0-1.05 of cranidial length; the pits in the marginal furrow are small but numerous. The ornamental granules are almost invisible, being plugged by remnants of the test and therefore inaccessible to the casting latex; a background Bertillon lineation is however visible unobscured by the otherwise dominant granulation.

Occurrence and age. Redlichia mayalis sp. nov. comes from the Yelvertoft Bed of the Beetle Creek Formation, locality M262 (Cornford Bore on May Downs, west of Mount Isa); its age is Cambrian, late Ordian.

REDLICHIA LEPTA sp. nov.

(Pl. 11, figs 3-5; Pl. 12; Text-fig. 4)

Material. The illustrated and described material consists of six cranidia and two free cheeks.

Holotype. The largest cranidium, Plate 11, figures 3 and 4, CPC 9176, is selected as the holotype; the right wing of its frontal limb is missing, but is supplemented by the specimen Plate 12, fig. 2.

Diagnosis. Redlichia lepta sp. nov. is distinguished (1) by its relatively flat transverse elliptical frontal limb about as wide as 1.2 of cephalic length and as long as 0.3 of glabella in maturity; (2) by its broad and relatively flat rim and a distinct brim divided in the middle by a low and broad plectrum; (3) by its narrow cranidium across the palpebral lobes, as wide as 0.7 of the frontal limb, and rather narrow interocular cheeks; (4) by a shallow and wide genal angle of about 70°; (5) by its bluntly rounded glabellar front; and (6) by the ornament consisting of a dense granulation (some 24 granules in one mm) without a Bertillon arrangement.

Differential diagnosis. Redlichia lepta is rather peculiar with its large plectrate frontal limb, blunt glabellar front and almost complete absence of the Bertillon pattern and may suggest a separate subgenus; still the general design, including closeness of the palpebral lobes to the occipital lobe, conforms to the concept

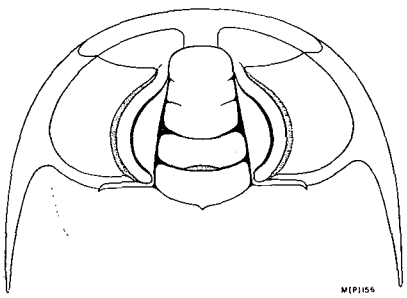

Figure 4: *Redlichia lepta* **sp. nov. reconstruction of the cephalon.**

of the genus *Redlichia* (see Öpik, 1958, p. 32) and a new name is therefore unnecessary. The plectrate frontal limb is somewhat reminiscent of *Eoredlichia* Chang (1962), which otherwise is, however, a separate genus of the Redlichiacea. The ornament of *R. lepta* and *R. creta* sp. nov. is quite similar as regards its density, but the papillae in *creta* are arranged in Bertillon pattern, and its frontal limb is relatively narrow and the cranidium wide across the palpebral lobes. The Siberian *Redlichia knjazevi* Repina, 1966 also has a fine granulose ornament and even a short plectrum; but its frontal limb is visibly narrower than in *R. lepta,* and the rear tips of the palpebral lobes are placed away from the axial furrows. *Redlichia mayalis* sp. nov. has also a bluntly rounded frontal glabellar lobe, but its granulation is much coarser than in *lepta,* the rim is strongly convex and the frontal limb relatively narrow. Finally, reminiscent of *R. lepta* is *R. hupehensis* Hsu, 1948, with its transverse elliptical frontal limb wider than the cranidium across the palpebral lobes; *R. hupehensis,* however, has no plectrum, its rim is convex, the glabellar furrows are discontinuous, the glabellar front is not blunt, and its test is, apparently, smooth.

Description. The cephalon of *Redlichia lepta* is semicircular and relatively low in convexity; the rim and the border of the free cheeks are broad and only slightly convex, the genal spines are advanced only moderately—less than in other species of the genus—and the genal angle of about 70° appears rather wide. In the cranidium the elliptical frontal limb with its brim and plectrum is rather conspicuous; the posterolateral limbs are narrow and relatively short bands. The palpebral lobes are close to the glabella and about 0.9 of its length; their posterior tips are placed on the midline of the occipital lobe. The glabella has somewhat concave flanks owing to its laterally expanded posterior lobe; it tapers forward to about 0.7 of its width in the rear and the rear width is about 0.7 of its length. The posterior glabellar furrows are transcurrent, but shallow, the second and third (foremost) furrows are weak and short. The occipital furrow is deep at its flanks, and shallow and broad in the middle, with a forward-arched anterior edge—a frequent structure in *Redlichia.* The occipital lobe is subpentagonal, angulate in its rear, where a low median node is seen on its edge. The lobe itself is long, as long as the posterior glabellar lobe, and about 0.3 of glabellar length.

Morphogenesis. Five cranidia ranging in length from 3.6 to 8.0 mm are available; as indicated in the comment (below) the relative length of the frontal limb decreases during growth, that is, the glabella grows faster than the frontal limb; the relative width of the frontal limb (1.2 of glabellar length) remains unchanged and the density of the ornament (24 granules in 1 mm) seems to be constant. In relation to the width of the frontal limb the cranidial width across the palpebral lobes is decreasing; at a cranidial length of 4.4 mm it is 0.75, at 6.7 mm 0.7, and at 8.0 mm (holotype) 0.65 of the frontal width. Specimens larger than the holotype are unknown yet; but it can be expected that in such specimens the space between the glabellar front and the rim may become rather narrow.

Comment on illustrated specimens

All specimens come from the dolomite and calcareous dolomite attributed to the Thorntonia Formation, locality D41 (west), Urandangi Sheet area; the free cheeks and the next four cranidia were won from a single somewhat bituminous siliceous limestone interbed about 1 inch thick in dolomite.

The free cheek, Plate 12, figure 1, CPC 9178, is rather small—about 2.5 mm long; the course of the posterior suture is preserved and the size of the posterolateral limb (Text-fig. 4) was measured in it.

The free cheek Plate 11, figure 5, CPC 9177, is 5.8 mm long; it is somewhat venulose; its proportions are the same as in the smaller cheek above.

The holotype cranidium Plate 11, figures 3 and 4, CPC 9176, is 8.0 mm long; the granulose test is preserved; on the whole, no oriented distribution of the granules is apparent, except for the flanks of the posterior lobe in which a somewhat linear arrangement is visible. The length of its frontal area is 0.3 of glabellar length.

The cranidium Plate 12, figure 2, CPC 9179, is 6.7 mm long; the glabella is filled with calcite and deformed, and of the occipital lobe a small part of the rear is preserved. The frontal limb and the ornament are well preserved; the frontal area is as long as 0.4 of glabellar length.

The cranidium Plate 12, figure 3, CPC 9180, is 4.4 mm long; part of the left wing of the front is missing; the ornament of the palpebral lobe and the interocular cheek is intact; its frontal area is 0.42-0.43 of glabellar length.

The cranidium Plate 12, figure 4, CPC 9181, is 3.6 mm long, with the length of frontal area about 0.47 of glabellar length.

The two cranidia Plate 12, figure 5, CPC 9182, are preserved in a chert pod in dolomite; the larger cranidium is 4.0 mm and the smaller 3.1 mm long. Their ornament is not preserved, but the structure of the frontal limb, the plectrum, and the transcurrent posterior glabellar furrow indicate *R. lepta*. In the larger cranidium the frontal area has a length of 4.4. of the glabella.

Occurrence and age. Redlichia lepta sp. nov. has been found so far only in the dolomite of locality D41 (west) attributed to the Thorntonia Formation; its age is Cambrian, late Ordian.

REDLICHIA CRETA sp. nov.

(Pls 13 and 14)

Material. One segment of the thorax, one cranidium, and one partly damaged exoskeleton are described; several less informative fragments have been examined. It is a rare form.

Holotype. The exoskeleton Plate 14, CPC 9186, is selected as the holotype.

Diagnosis. Redlichia creta sp. nov. belongs to the group of species having the frontal limb about as wide as the length of the cranidium; it is distinguished by its minute, dense, and papillate Bertillon ornament and the combination of a large occipital lobe, relatively forward placed posterior tips of the palpebral lobes at a small distance from the axial furrows, a cranidium across the palpebral lobes wider than the frontal limb, and well advanced acute genal angles. The pygidium has two axial annulations and the anterior one bears a short axial spine.

Differential diagnosis. Only *Redlichia lepta* sp. nov. has the ornament as minute and dense as *R. creta;* but in *lepta* the granules are rounded whereas in *creta* they are hollow pustules; in *lepta* the frontal limb is much wider than the cranidium across the palpebral lobes, the palpebral tips are close to the axial furrows and well in the rear, and the genal angle is wide and advanced less than in *creta.* From the granulose *R. saitoi* (see under *Redlichia mayalis*), *R. creta* differs by its slender glabella. In the Siberian *Redlichia knjazevi* Repina, 1966, the test is also granulose and the posterior tips of the palpebral lobes are in the same position as in *R. creta; R. knjazevi,* however, has a more slender glabella, narrower interocular cheeks, and glabellar furrows more oblique than *creta.* Nevertheless, *R. creta* and *R. knjazevi* appear rather close to each other and should be compared further when better preserved material becomes available. Finally, *Redlichia petita* sp. nov. recalls *creta* in the structure and position of the rear part of the palpebral lobes and the shape of the occipital lobe; but its test is smooth, its glabella is wider, the free cheeks are different, the pygidium has no axial spine and one axial annulation less than *creta.* Note that the deformed cranidium of *R. creta,* Plate 13, figure 1, with its longitudinally telescoped front, attained proportions close to *R. petita,* Text-figure 3.

To conclude, the disparity of *R. creta* and *R. petita* refers to the differences in ornament and in the structure of the free cheeks and the pygidium in the first place; this accepted, specific significance can be attributed to such cranidial characters as the width of the rim (narrow in *creta,* wide in *petita*), proportions of the glabella, and length of the palpebral lobes (longer in *petita* than in *creta*); nevertheless, cranidia alone are not easily separable from each other.

Description. The holotype, Plate 14 and Plate 13, figures 4 and 5, an external mould in siliceous hard shale, is 31.0 mm long. The cephalon, as long as about six anterior segments of the thorax, is damaged in front and on its left side. The right free cheek is preserved almost in situ. Its border is relatively narrow, and the genal angle of about 45° is acute and deep. The course of the anterior suture, however, is masked by the edge of another fossil fragment. The width of the glabella in its rear is close to 0.7 of its length—a relatively slender glabella as compared with *R. petita.* The occipital lobe is relatively long, parallel sided, and almost rectangular, and not tapering abaxially—an uncommon shape shared with *R. petita.* The posterior palpebral tips reach the transverse occipital midline and are therefore less retral than in other species of the genus; the distance of the palpebral tips from the occipital lobe is about 0.2 of the width of that lobe with a clear space in between much wider than the axial furrow. The cephalic test is as papillate as the test of the thorax, which is described below.

In the thorax fourteen free segments are evident; one segment (the twelfth) is apparently lost, as indicated by the gap behind the eleventh; hence, the total number of segments was probably fifteen. The pleural tips were quite short in all segments, as can be judged from the tenth and eleventh segments. Axial

spines are present on the fourth and eleventh segments—the most common position of spines in *Redlichia;* an extra spine may have been present also on the tenth segment, whose axial lobe is prominent, tilted rearward, and has a broken edge—the scar of the base of the missing spine. The pygidium is trapezoidal, about 0.2 of cephalic length, and lacks an anchylosed segment. There are three axial annulations, a bulbous bilobed terminus, and an axial spine on the first annulation.

The whole test is minutely and densely papillate with about 20 pustules in 1 mm; the papillae on the axial lobe are arranged in forward-arched lines.

The cranidium Plate 13, figures 1 and 2, CPC 9184, is 8.2 mm long; its glabellar front is crushed and over-ridden by the frontal limb, which is displaced retrally; its wings are swept rearward from the original position of subhorizontal (diametrically divergent) sutures. The rim is relatively narrow—narrower than in *R. petita.* The palpebral lobes are long and broad, with their posterior tips in the same position as in the holotype; the palpebral lobes are short in the rear, not overhanging, and not concealing the adaxial part of the posterolateral limbs: in many other species of *Redlichia* (compare, for example, *R. venulosa,* Text-figure 2) this part remains mostly hidden. The cranidium across the palpebral lobes is the widest—about 1.1 of the width of the frontal limb. The occipital margin bears a tiny median node. The papillate ornament is the same as in the holotype; it is less well preserved, but is visible on the occipital lobe and the left interocular cheek, including the palpebral lobe.

The fragmentary segment of the thorax, Plate 13, figure 3, CPC 9185, is about 6.5 mm long (transversely); its ornament is well preserved; it appears that the papillae are hollow—their casts are preserved on the internal mould; the inside face of the test is, consequently, punctuate. It is a notable structure because the ornament of *Redlichia* consists usually of solid surficial lines (ridges) which are not reflected internally.

Occurrence and age. Redlichia creta sp. nov. comes from the Yelvertoft Bed of the Beetle Creek Formation, locality M426; its age is Cambrian, late Ordian.

GLOSSARY

(Explanation of new species names of *Redlichia*)

advialis: Latin, at the roadside (at the Barkly Highway).

amadeana: geogr., of the Amadeus Basin.

creta: Latin, separated; the species became evident after elimination of other associated species.

lepta: Greek, thin, in reference to the thinness of its test.

mayalis: geogr., from the name May Downs.

micrograpta: Greek, finely engraved.

petita: Latin, asked for (found on author's request).

versabunda: Latin, abounds with lines (ornamental).

vertumnia: Latin, changeful (in appearance; depending on the orientation of a specimen).

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PLATE 1

Redlichia advialis sp. nov. .... Page 15

1.—**Holotype**, rubber cast of CPC 9149, x2.

2.—Isolated free cheek, CPC 9150, x4.

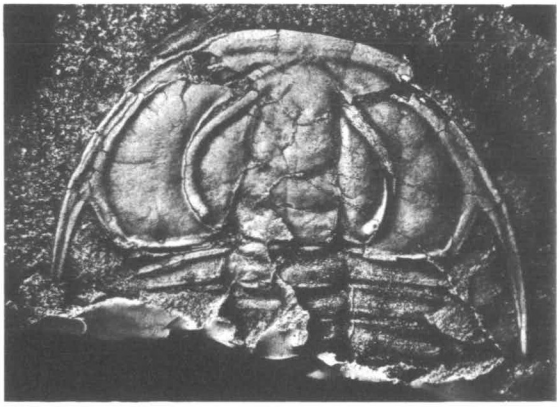
3.—Cranidium, CPC 2351, x2.

4.—Several cranidia in a piece of shale, CPC 9151, x1.2.

5.—Cranidium (from Fig. 4), interocular cheek ornamented, x4.

6.—Cranidium, internal cast (from Fig. 4), unornamented, x4.

Locality M426, Mount Isa area.



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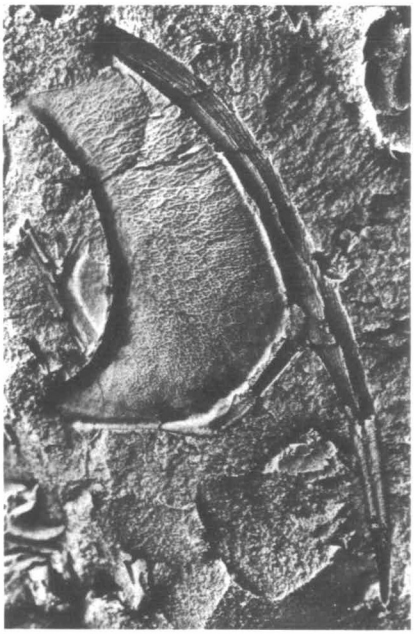

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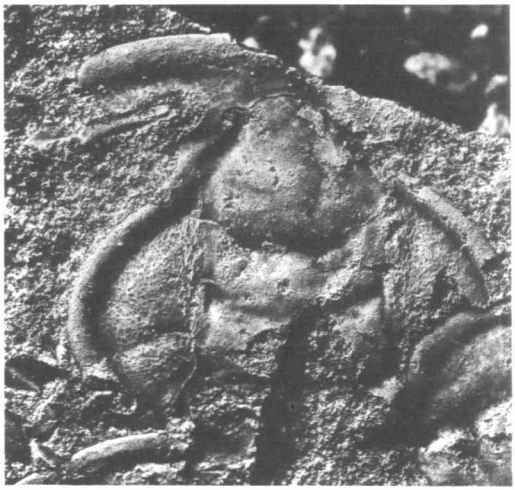

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PLATE 2

Redlichia venulosa (Whitehouse) .... Page 17

1.—Cranidium, internal cast, CPC 9152, x4.

Redlichia amadeana sp. nov. .... Page 22

2.—Cranidium, internal cast, CPC 2328, x2.

Gum Ridge, Northern Territory.

Redlichia idonea Whitehouse .... Page 18

3.—Cranidium, internal cast, CPC 9153, x2.5.

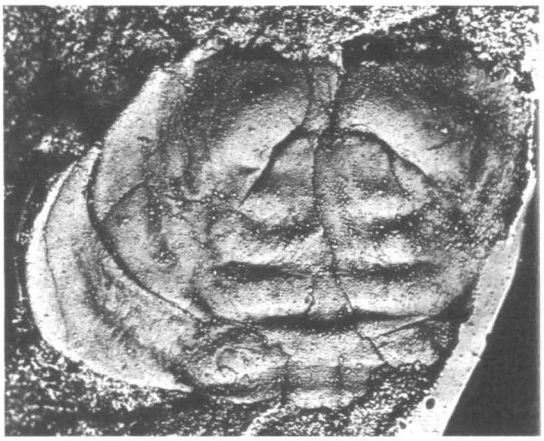
4.—Pygidium, rubber cast of CPC 9154, x8.

Redlichia advialis, sp. nov. .... Page 15

5.—Thorax with pygidium, CPC 9155, x4.

6.—Pygidium, CPC 9156, x10.

Locality M426, Mount Isa Area.



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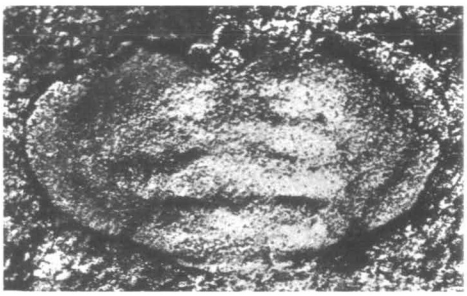

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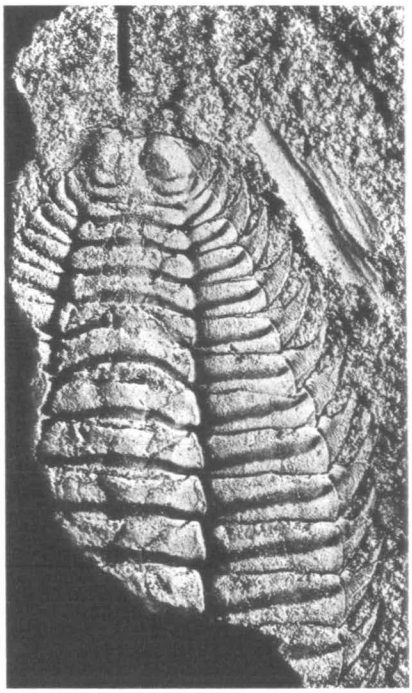

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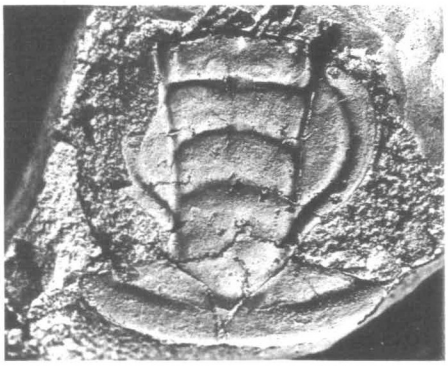

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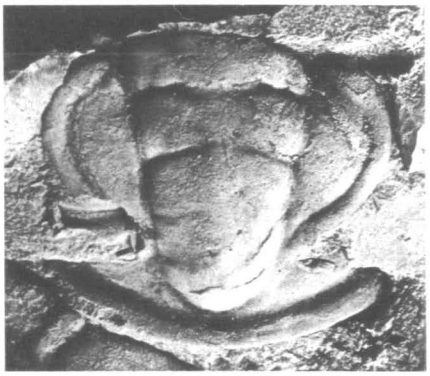

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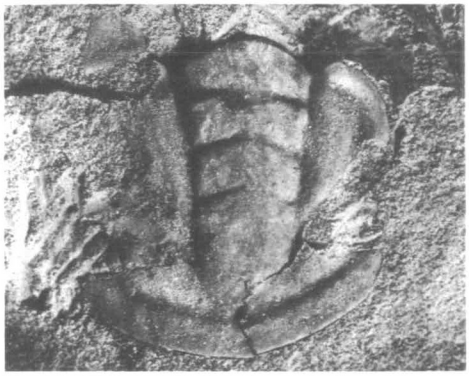

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PLATE 3

Redlichia advialis sp. nov. .... Page 15

1.—Complete shield, rubber cast of CPC 9157, x3.5.

Redlichia idonea Whitehouse .... Page 18

2.—Exoskeleton, rubber cast of CPC 9158, x2.

Locality M426, Mount Isa Area.

Redlichia petita sp. nov. .... Page 20

3.—Cranidium, holotype, CPC 9159, x2.4.

4.—Free cheek, CPC 9160, x2.4.

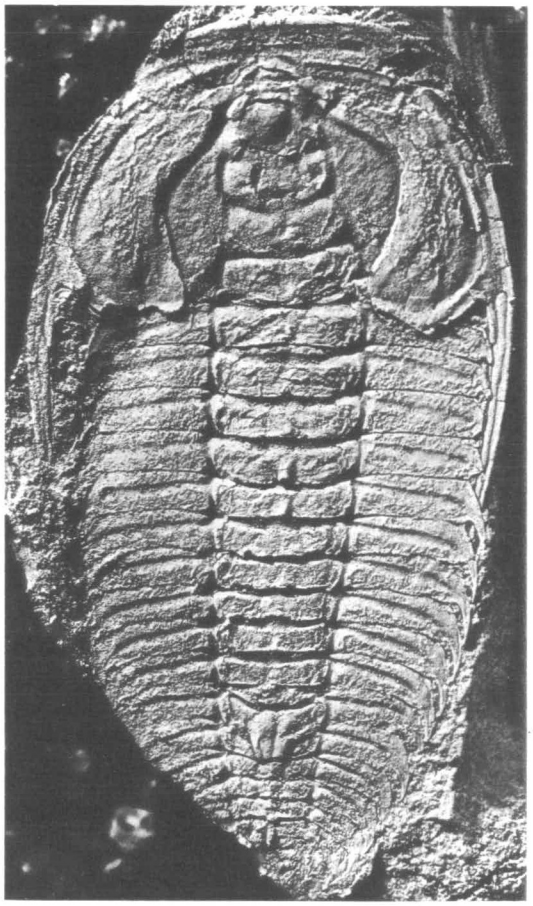
Mount Wright Tanks, Mootwingee Area, New South Wales.

Redlichia amadeana sp. nov. .... Page 22

5.—Cranidium, CPC 9161, x2.5.

6.—Cranidium, holotype, CPC 9162, x3.5.

Alice Springs Area, Locality AS 59, Northern Territory.



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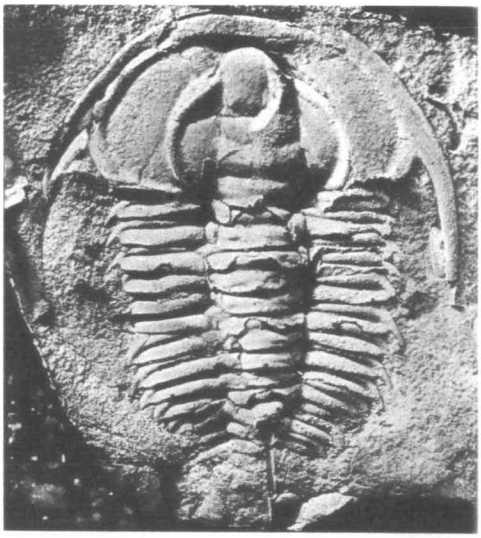

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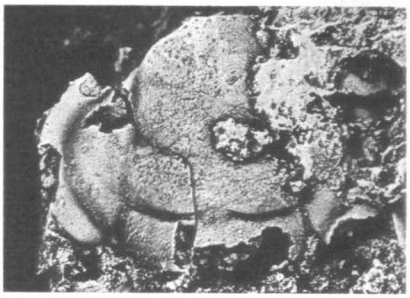

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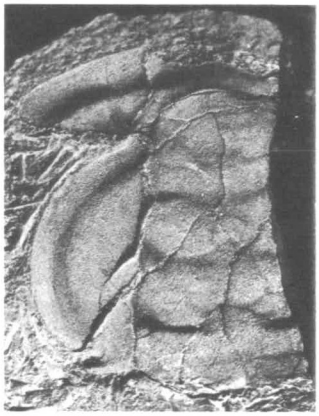

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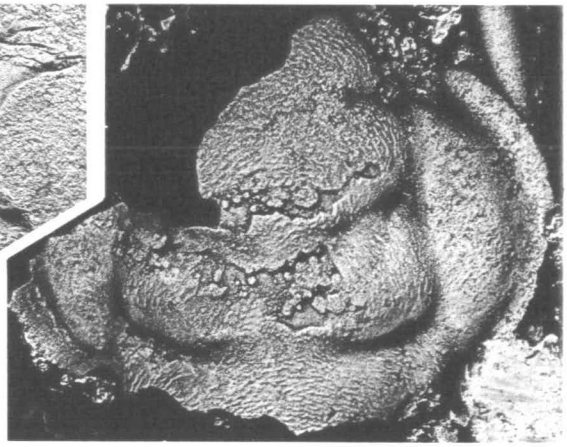

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PLATE 4

Redlichia chinensis Walcott .... Page 23

1.—Cranidium, rubber cast of CPC 9163, x3.7.

Redlichia micrograpta sp. nov. .... Page 25

2.—Cephalon and part of thorax, rubber cast of CPC 9164, x5.

Locality M426, Mount Isa Area.

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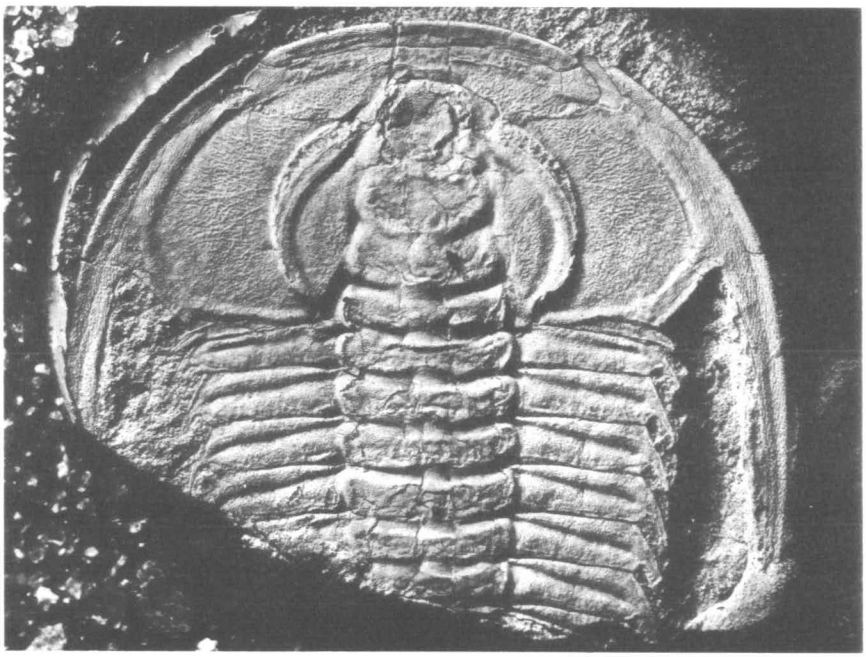

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PLATE 5

Redlichia chinensis Walcott .... Page 23

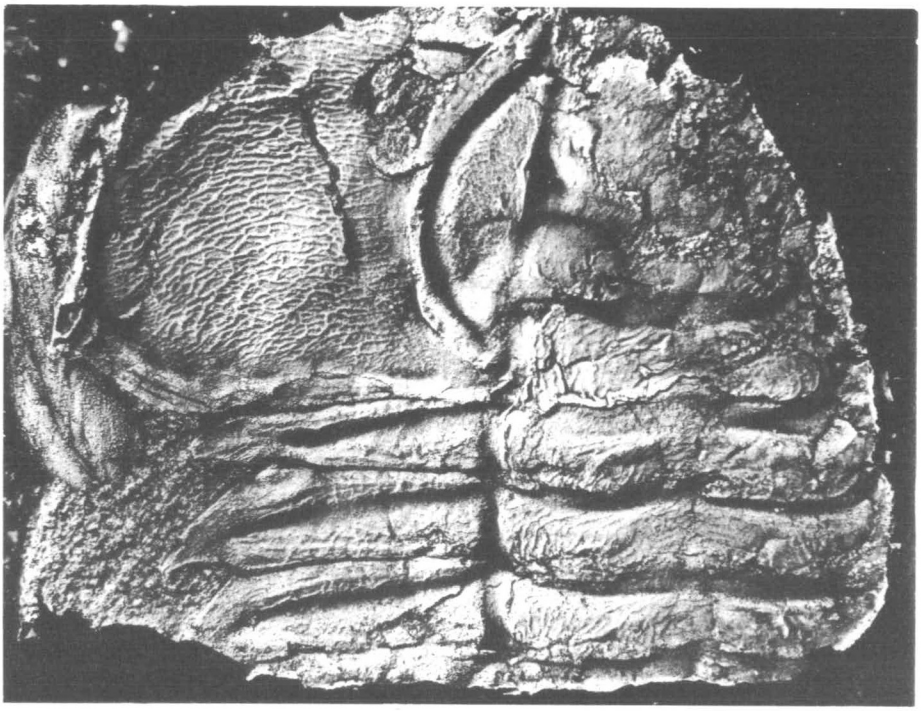
1.—Fragment of cephalon and thorax, rubber cast of CPC 9165, x4.

2.—Cranidium, CPC 9166, x8.

Redlichia micrograpta sp. nov. .... Page 25

3. & 4.—Cephalon, CPC 9167, same specimen, Plate 6, figs 2 and 3, x1.8 and 1.

Locality M426, Mount Isa Area.



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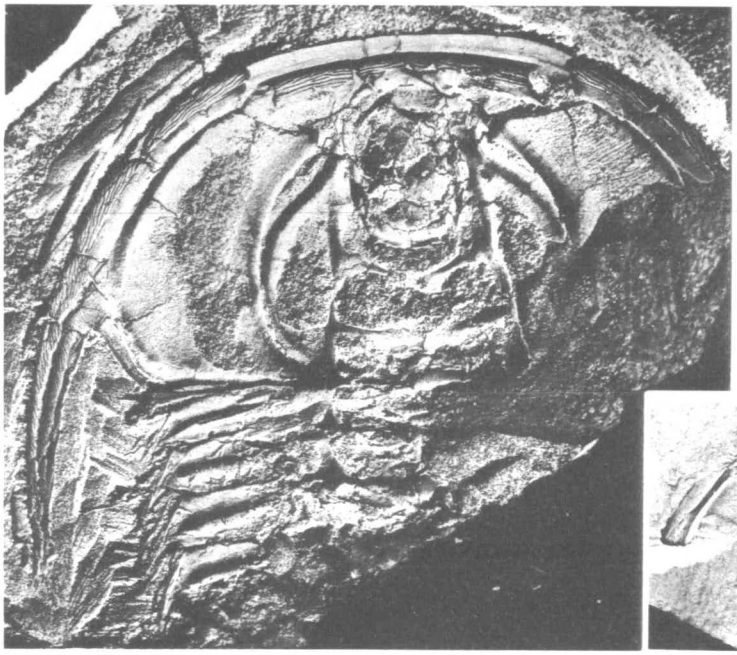

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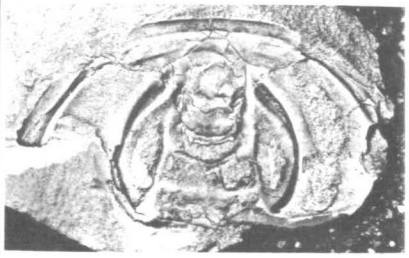

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PLATE 6

Redlichia micrograpta sp. nov. .... Page 25

1.—Cephalon, same specimen Plate 5, figs 3 and 4, x5.4.

2.—Cephalon, detail, same as Figure 1, x5.4.
3.—Pleurae of **holotype**, Plate 8, x7.

Locality M426, Mount Isa Area.

1

2

3

PLATE 7

Redlichia micrograpta sp. nov. .... Page 25

Rubber cast, external surface of the holotype, Plate 8, x2.7.

The left free cheek is venulose.

Locality M426, Mount Isa Area.

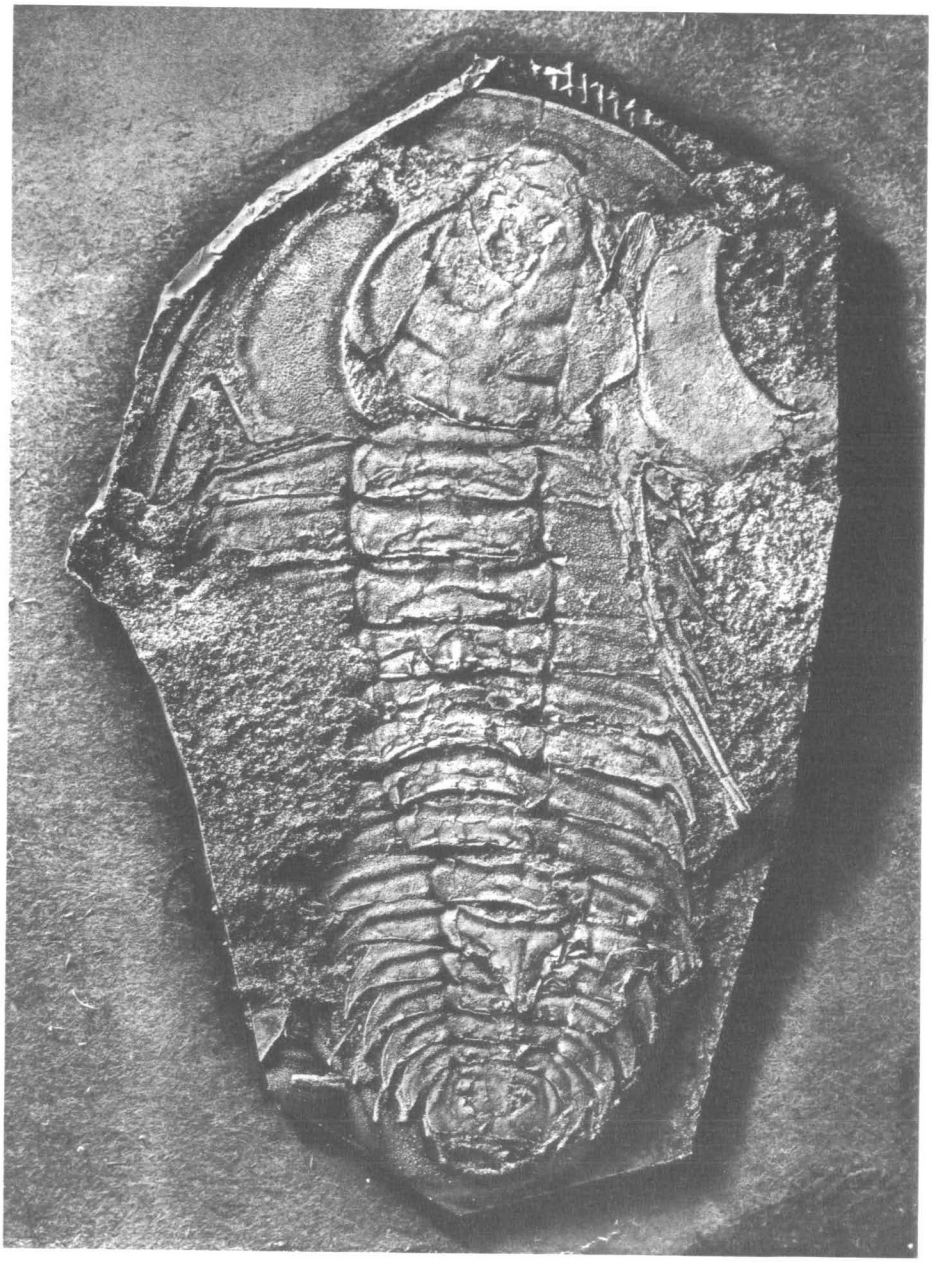


PLATE 8

Redlichia micrograpta sp. nov. .... Page 25

Holotype CPC 9168, x2.8; same specimen in Plate 7; also Plate 6, fig. 3. Internal cast in shale; only the right cheek is venulose.

Locality M426, Mount Isa Area.

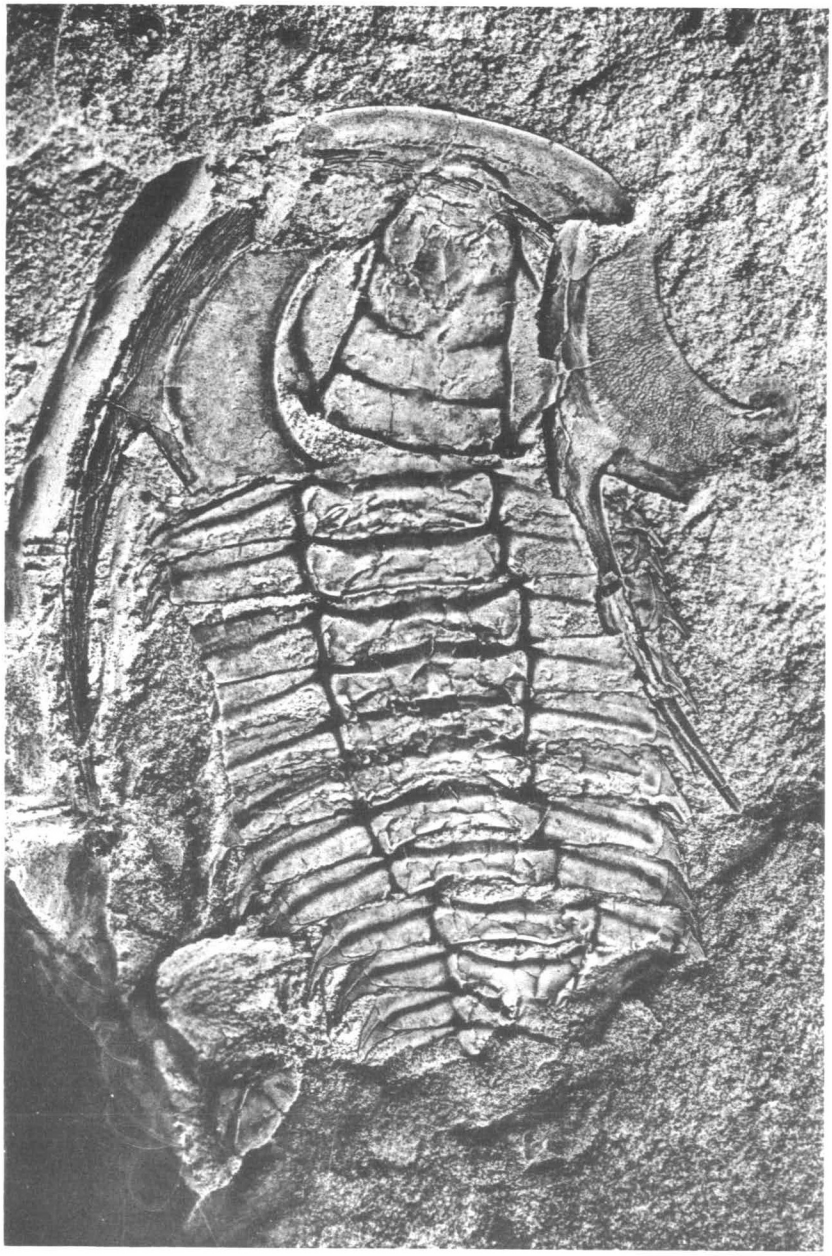


PLATE 9

Redlichia versabunda sp. nov. .... Page 27

1. & 2.—**Holotype**, cranidium, CPC 9169:

Figure 1—rubber cast of external surface, x6:

Figure 2—internal cast in chert, x3.5.

Locality M262 (May Downs, Mount Isa Area)

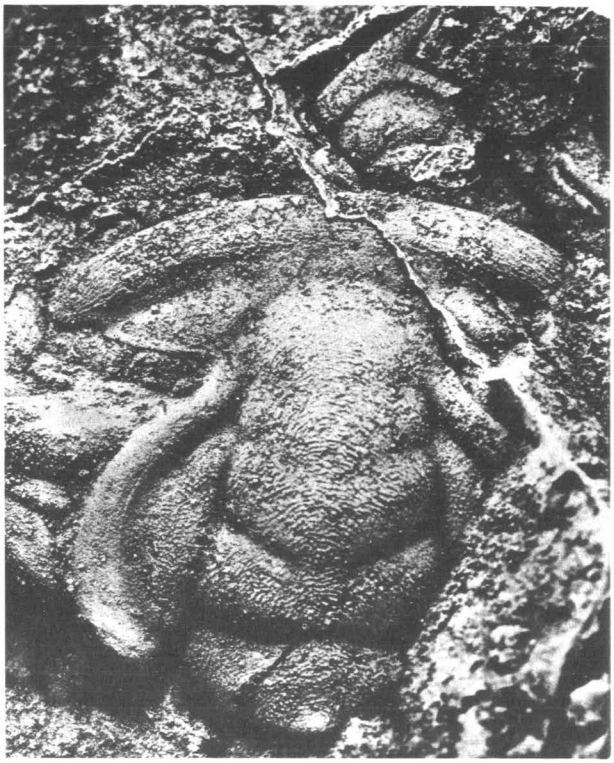
3.—Cranidium, rubber cast of external surface, CPC 9170, x5.

Locality M426, Mount Isa Area.

4.—Cranidium, CPC 9171, x3.6, in chert.

5.—Ornamented fragment, same in front of cranidium, Figure 4; x7.4.

Locality D41 (Urandangi Area).



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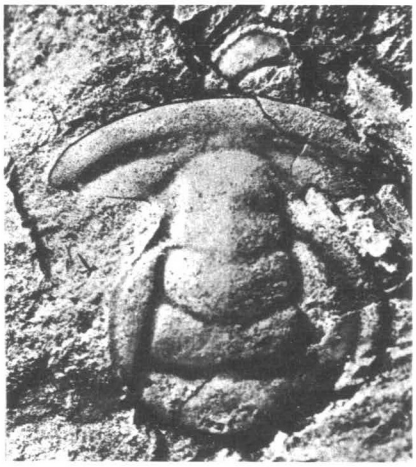

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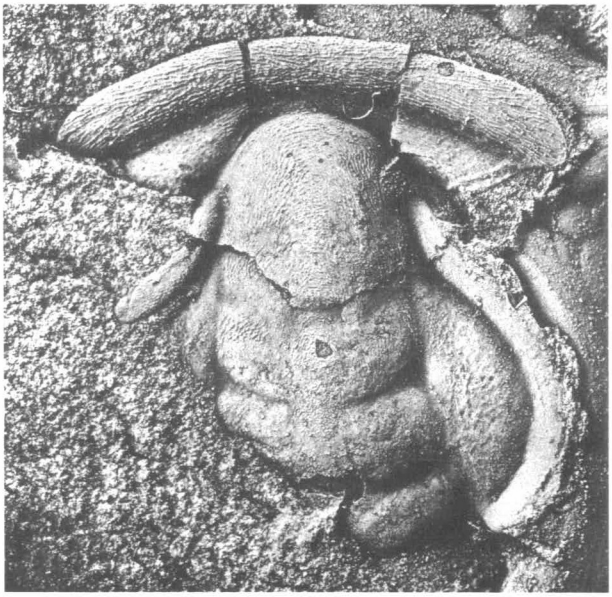

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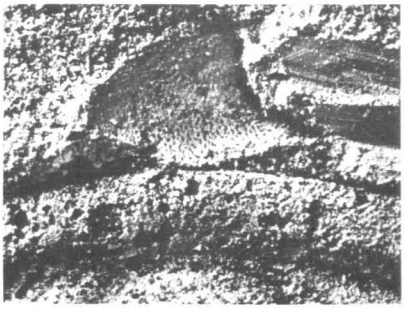

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PLATE 10

Redlichia vertumnia sp. nov. .... Page 29

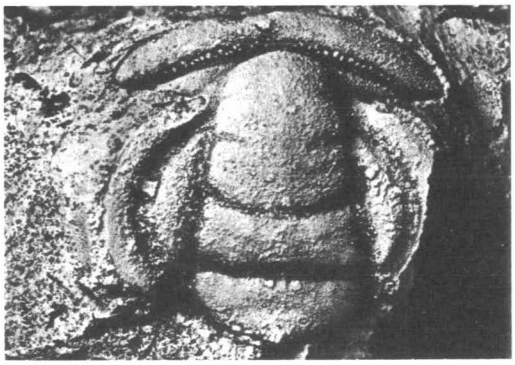
1-6.—**Holotype** cranidium, CPC 9172;

Figures 1-4; internal cast in chert, x5.2;

Figures 5 & 6; rubber cast of external surface, x5.

7.—Cranidium and a free cheek, CPC 9173, x5.

Locality M262 (Mount Isa Area).



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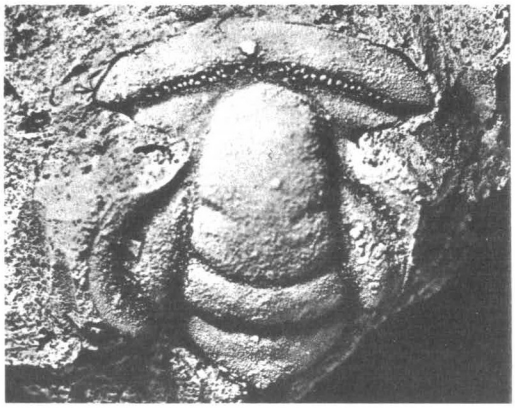

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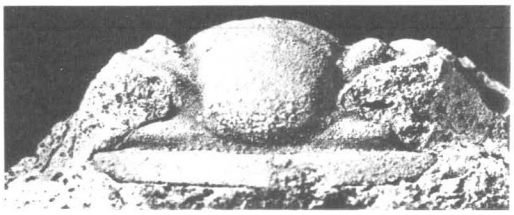

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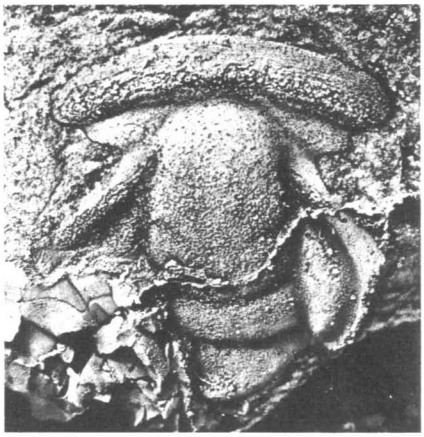

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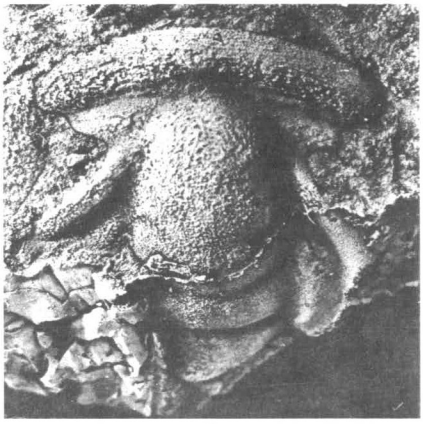

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PLATE 11

Redlichia mayalis sp. nov. .... Page 30

1.—Holotype cranidium, rubber cast of external surface of CPC 9174, x8.

2.—Cranidium, rubber cast of CPC 9175, x2.7.

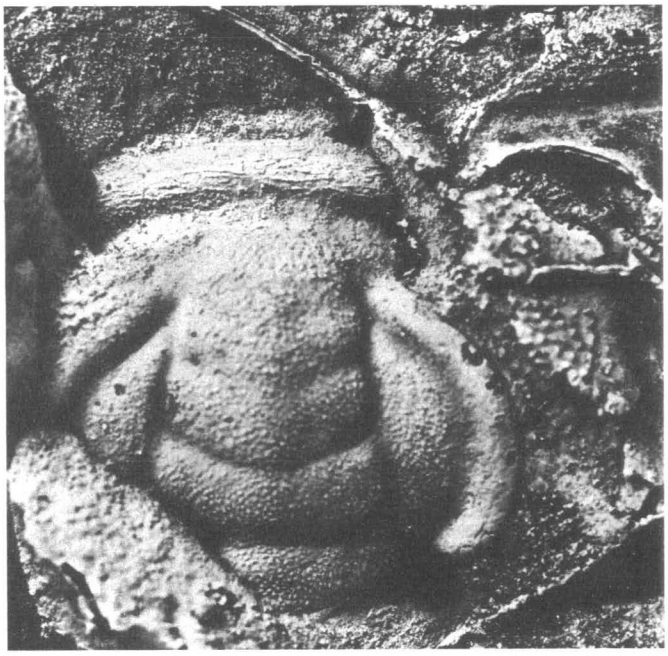
Locality M262 (May Downs, Mount Isa Area)

Redlichia lepta sp. nov. .... Page 32

3. & 4.—Holotype cranidium, CPC 9176, x3 and x10.

5.—Free cheek, CPC 9177, x7.

Locality D41, Urandangi Area.



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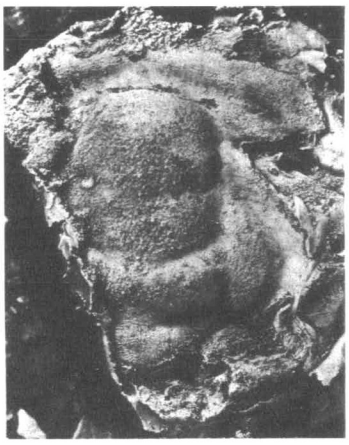

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PLATE 12

Redlichia lepta sp. nov. .... Page 32

1.—Free cheek, CPC 9178, x17.

2.—Cranidium, frontal limb intact, CPC 9179, x11.

3.—Cranidium, CPC 9180, x15.

4.—Small cranidium, CPC 9181, x17.

Figures 1-4: limestone lamina in dolomite.

5.—Two cranidia in chert, CPC 9182, x7.

Locality D41, Urandangi Area.

2

1

5

3

4

PLATE 13

Redlichia creta sp. nov. ... ... Page 34

1.—Cranidium CPC 9184, and rostral shield, x5.

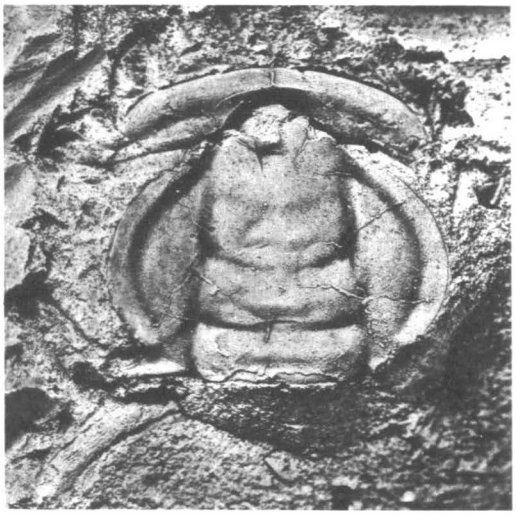
2.—Same specimen as Figure 1, rubber cast, x8.3.

3.—Segment of thorax and rostral shield, rubber cast of CPC 9185, x8.

4.—Pygidium and rear part of thorax of **holotype** (Pl. 14), x10.

5.—Segments to Nos. 5-8 of thorax of **holotype** (Pl. 14), pustulose, x10.

Locality M426, Mount Isa Area.



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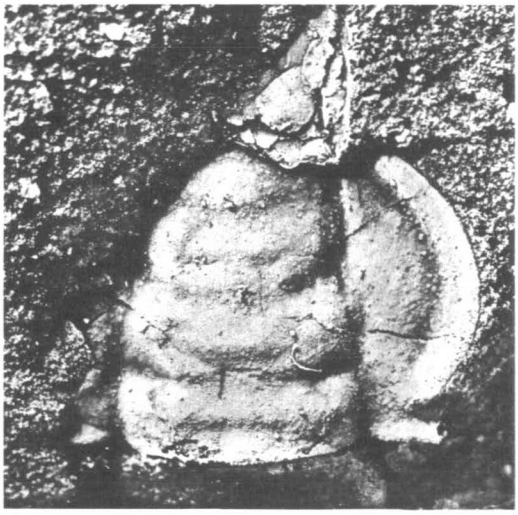

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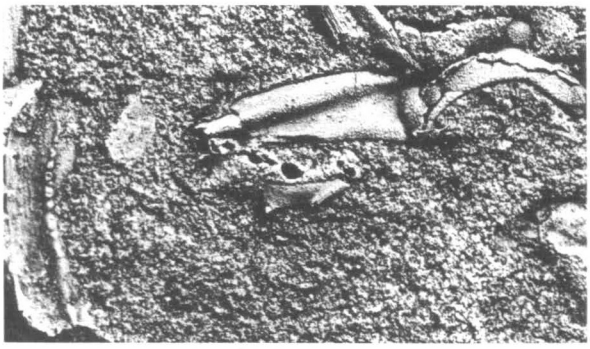

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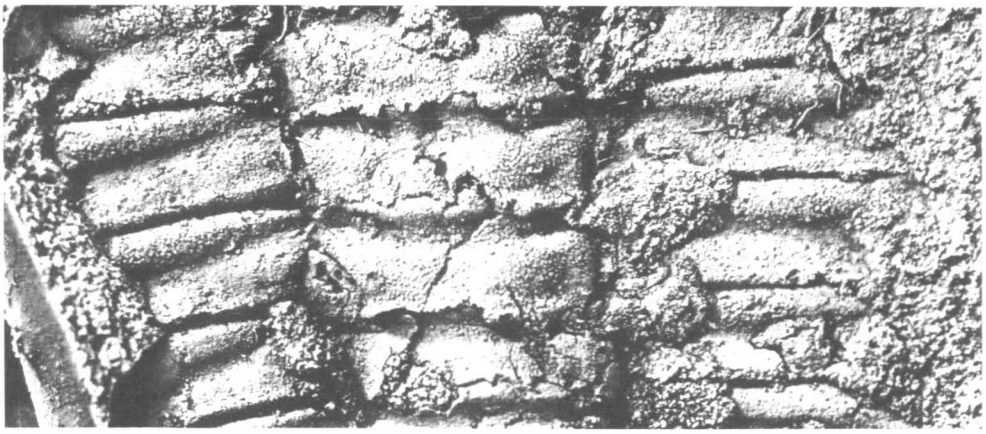

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PLATE 14

Redlichia creta sp. nov. .... Page 34

Holotype exoskeleton, rubber cast of CPC 9186, x5.7.

Locality M426, Mount Isa Area.