REVISION OF CROIXAN DIKELOCEPHALIDS*

GILBERT O. RAASCH
Illinois Geological Survey, Urbana

The trilobites under consideration are classic in that before 1914 all species then known were assigned to the genus *Dikelocephalus,* Owen, 1852, which genus was regarded as the principal index fossil for the Upper Cambrian of the Pacific realm.

Today these same trilobites are consciously ignored by biostratigraphers. This change dates from the early 1930's, when Ulrich and Resser published their monographic revision of the Upper Mississippi Valley Dikelocephalidae (Milwaukee Public Museum Bull., vol. 12, nos. 1 and 2, 1930 and 1933).

Before 1914, less than a dozen species of *Dikelocephalus* were recognized as occurring in Upper Mississippi Valley strata. That year Walcott's paper reduced the scope of the genus by adding several new genera, as well as several new species to his "Dikelocephalinae."

By 1933, Ulrich and Resser had multiplied this conservative figure to the astounding total of 123 species and varieties. They simultaneously succeeded in rendering the Dikelocephalidae useless for purposes either of biostratigraphy or phylogeny, and this important fossil group has subsequently been shunned by paleontologists and stratigraphers.

The primary intent of the present paper is the restoration of the Dikelocephalidae to a useful status. This has involved a reduction of names from Ulrich and Resser's 123 to 41, or by exactly two-thirds, thus eliminating 82 names. Such a revision is of course tentative, but is quite representative of the degree of species designation that the situation merits.

Consideration of Stratigraphic Assignments

A secondary objective is assignment of the species to their proper places in the fauni-stratigraphic succession. This is necessitated because Ulrich's conception of the regional stratigraphic relations was at serious variance with the facts. Since these erroneous stratigraphic considerations seriously affected Ulrich and Resser's taxonomic conclusions, the results were unfortunate.

For example, what is now considered a single sequence, the Franconia formation, Ulrich formerly interpreted as three successive formations. He applied the name Franconia to the greensand facies occurring in the region of the Mississippi. To the equivalent non-glauconitic sandstone facies in central Wisconsin he applied the name Mazomanie. To a shore facies of the same, he applied the term Devils Lake formation. He interpreted the Mazomanie as successive to the Franconia and the Devils Lake as

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successive to both, in fact post-Cambrian. Thus the phylogenetic succession of Franconian dikelocephalids is thrice repeated.

The Trempealeau formation, which succeeds the Franconia, he conceived as a simple lithologic succession of basal dolomite (his St. Lawrence), siltstone (his Lodi), fine sandstone (his Norwalk). All fossils, therefore, that occurred in siltstone he considered to be "Lodi" in age, and all in sandstone to be "Norwalk."

The fact is that Lodi siltstone lithology occurs at eight different time-stratigraphic horizons and Norwalk sandstone lithology at six different horizons. Not only does the same lithology occur at a number of different stratigraphic horizons, but the same stratigraphic horizon is commonly represented by different lithologies in different areas. In these cases there is commonly a double set of names for each species, one for the supposed "Lodi" and one for the supposed "Norwalk."

Some of the authors' stratigraphic misconceptions have interesting results. For example, the rich faunas from leached calcareous fine sandstones at Osceola, Wis., are considered to be the latest of Trempealeau faunas; they are in fact, the earliest.

Another unfortunate result of the stratigraphic confusion was the application of some singularly inappropriate specific names. *Dikelocephalus norwalkensis, Saukiella norwalkensis,* and *Tellerina norwalkensis* do not occur in the Norwalk, nor does *Osceolia lodensis* occur in the Lodi. Fortunately, all drop into the synonymy.

Consideration of Taxonomic Criteria

A third objective of the present paper is to present a concrete instance of the effect, on taxonomic results, of differing species concepts among different paleontologists. Once we leave the realm of living forms, the species concept is no longer subject to the restraint of genetic criteria. Inevitably, individual paleontologists resort to their own methodology in grouping organisms into species, genera, and higher categories. The only test against which the quality of any worker's results may be applied is the pragmatic one of applicability of his biologic classification in the fields of biostratigraphy and of phylogeny. If the classification contributes to order it may be assumed to be valid; if it contributes to confusion it may with equal justice be assumed to be invalid. The responsibility demanded of the paleontologist is accordingly great.

From this viewpoint it follows logically that paleontologic studies must go hand in hand with stratigraphic studies. But erroneous stratigraphy renders confusion twice confounded.

In the case of Ulrich and Resser's work in the Dikelocephalinae, the following practices and concepts have contributed to confused taxonomy:

(1) Basing of species on type individuals rather than on populations.

(2) Seeking for minute differences rather than for likenesses.

(3) Misassociation of the various, separated component parts of the skeleton, commonly combining a cranidium from one locality, a pygidium from a second, and free cheeks from a third.

(4) Failure to consider that variations may be a result of successive growth stages.

(5) Rejection of any concept of individual variation.

(6) The influence of stratigraphic misconceptions.

(7) Rejection of trinomial classification for varieties or subspecies.

(8) Establishment of species on inadequate material.

Basing of species on type individuals rather than on populations.—Under discussion of *Calvinella spiniger*, on page 222, the authors state:

> However, we will admit at once that in studying the many slightly differing cranidia of *Calvinella* that we possess *from the same bed and place* [italics the writer's] on Trempealeau Mountain that provided Hall's original type of the species, we found it no easy task to determine precisely which particular kind is best entitled to the distinction of being recognized as the typical form of *C. spiniger*. Though our final selection is not entirely satisfactory to us we are so nearly correct that the margin of error is practically negligible. . . .
>
> The remainder of the specimens of *Calvinella* that were found with *C. spiniger*, as here restricted, is divided into seven varieties and species.

The series is clearly intergrading and in this writer's opinion, constituted a single interbreeding species population of distinct zonal value.

Seeking for minute differences rather than for likes.—An example of proliferation of species by Ulrich and Resser is provided by the *Prosaukia* occurrence at Table Rock in Adams County, Wis. The fauna here comes from a six-inch layer about a foot below the bare rock summit of the mesa, the area of which is less than an acre. From this layer, Ulrich and Resser describe eight species of *Prosaukia*, all but one of which appear to constitute a single species. The eighth, *P.* ? *anomala*, belongs to another genus, not of the Dikelocephalidae. Most of the "species" the authors credit to the type locality only. Quoting from p. 146:

> All of the . . . species found at the Table Rock locality, except *P.*? *anomala*, seem very closely related. Their cranidia, in particular, though distinguishable by features that may seem of little importance, are much alike. The associated pygidia, on the contrary, indicate six readily discriminated forms, and on this account the species are based mainly on these. Cranidia, and in most cases also free cheeks, are assigned to them according to our best judgment.

Actually none of their pygidia are complete, most are highly fragmentary, and in the writer's opinion show no significant differences.

In connection with one of Ulrich and Resser's species, "*P. alternata*," these authors frankly state:

> Again the material, which consists of a single cranidium, a good free cheek, and three imperfect but supplementing pygidia, leaves much to be desired. But as none of these specimens quite fits any of the previously described species and, despite their imperfections, permits acquiring . . . probably a true conception of the complete animal, we feel warranted . . . in describing these and other combinations of such dismembered remains under new names.

Misassociation of the various component parts of the skeleton.—Many examples might be cited, but the following should suffice:

Dikelocephalus inaequalis is based on three types from the basal Jordan at Trempealeau, Wis., but the fourth type (an hypostoma) comes from the basal Trempealeau (five zonal

units lower in the section) at a distant locality. Its proper association should have been with quite a different species, *D. thwaitesi.* The writers, of course, were of the impression that the enclosing strata at the two localities were of the same age.

Failure to consider that variations may be a result of successive growth stages.—Ulrich and Resser's multiplication of species of *Dikelocephalus* from the Lodi Member is a consequence largely of failure to recognize morphological changes which accompany growth stages. Ulrich and Resser cite (p. 31), but do not figure, evidence to refute this, but such evidence this writer has never observed although he collected most of the specimens used by them. He feels that at least four of their Lodi species are successive growth stages of a single species. Since most specimens are molts, it was quite possible for a single individual to produce four of Ulrich and Resser's species.

Rejection of any concept of individual variation.—This point is best illustrated by an oral communication of the junior author to the writer. When the latter raised the question as to whether some of the differences among specimens of *Dikelocephalus* might not represent individual variation, Resser categorically stated that "trilobites do not vary. If two specimens are different, they represent different species."

The influence of stratigraphic misconceptions. — Instances are innumerable and lead the authors repeatedly into frustrating phylogenetic discussions, in an attempt to rationalize seeming anomalies.

The degree of stratigraphic error might best be summed up by citing the fact that, of the 473 figures used to illustrate the Saukinae, at least 290 are referred to the wrong stratigraphic horizon.

Rejection of trinomial classification.—The authors' proliferation of species is in part a result of the fact that they discriminated, according to their criteria, down to the variety or subspecies level and then usually omitted the middle or species name. This is borne out by such printed statements as the following:

> However, in general we are opposed to trinomial designations. [p. 206.]
>
> It is of little concern to us whether these forms are regarded as "species" or "varieties," or "mutations" or "hybrids." [p. 170.]

Establishment of species on inadequate material.—That many species were set up by the writers on a single fragmentary cranidium, pygidium, or free cheek is readily evident from even a casual inspection of the plates.

Revision of the Family Dikelocephalidae

Inasmuch as the family Dikelocephalidae, as conceived by Miller (1889), Walcott (1914), and Ulrich and Resser (1930), is revealed by unpublished studies of the writer to be polyphyletic, it is proposed that Ulrich and Resser's (1930) Saukinae be raised to a separate family, the Saukidae. Biostratigraphic studies show that the Saukinae arise from the mid-Franconian Ptychaspidae, which are descended in turn from early Franconian conaspid trilobites. The latter appear to arise directly from Old World *Parabolina,* present

in the Upper Mississippi Valley section in the base of the *Conaspis* zone. The Dikelocephalinae (including the Osceolinae), on the other hand, appear to have descended through the late mid-Franconian *Briscoia,* from the earlier Franconian genus *Wilbernia.* The writer also questions the need for the subfamily Osceolinae, comprising the genera *Walcottaspis* and *Osceolia. Walcottaspis* appears to be merely a descendant of *Dikelocephalus,* whereas *Osceolia* is an early Trempealeauan, probably terminal offshoot of *Briscoia.*

Revision of the "Dikelocephalinae"

Ulrich and Resser's, 1930, Dikelocephalinae, comprising 36 species of the genera *Dikelocephalus, Briscoia, Osceolia,* and *Walcottaspis,* are reduced by the writer to a status of 12 species, as indicated in the following presentation, in ascending biostratigraphic order:

Franconia

Hudson member–*Prosaukia curvicostata* faunal unit
Briscoia schucherti U & R

Hudson member–*Briscoia sinclairensis* faunal unit
Briscoia sinclairensis Walcott
Note: referred by Ulrich and Resser (1930—p. 59) to the "Lower Ozarkian, Devils Lake Formation," but actually occurring late in the *Prosaukia* subzone of the Franconia, Hudson member.

Bad Axe member–*Saukiella minor* faunal unit
Dikelocephalus postrectus U & R

Trempealeau

Arcadia member–*Osceolia osceola* faunal unit
Osceolia osceola (Hall)
Synonyms: *O. obsoleta* U & R, *O. arguta* U & R, *O. lodensis reflexa* U & R, *O. praecipta* U & R
Dikelocephalus thwaitesi U & R
Synonyms: *D. weidmani* U & R, *D. halli* U & R, *D. inaequalis* U & R, *pars* (pl. 19, fig. 6)
Note: *D. thwaitesi* of pl. 21, figs. 7-10 is *D. oweni* U & R.

Lodi member–*Saukia subrecta* faunal unit
Dikelocephalus (oweni var.?) *barretti* U & R
Synonyms: *D. brevis* U & R (except pl. 14, fig. 2), *D. edwardsi* U & R, *D. subplanus pars* (pl. 14, figs. 3, 5), "*D.* cf. *gracilis* and *retrorus*" (pl. 14, fig. 9)
D. norwalkensis U & R (except pl. 21, figs. 19, 20)

Lodi member–*Saukia sublonga* faunal unit
Dikelocephalus oweni U & R
Synonyms: *D. gracilis* U & R, *D. ovatus* U & R, *D. wisconsinensis* U & R, *D. subplanus* U & R, *D. retrorsus* U & R, *D. beani* U & R, *D. raaschi* U & R (pl. 10, fig. 1 may be a distinct variety), *D. brevis pars* (pl. 9, fig. 5?), *D. marginatus pars* (pl. 15, figs. 6, 7), *D. thwaitesi pars* (pl. 21, figs. 7 to 10), *D. norwalkensis pars* (pl. 21, figs. 19, 20)

There is some doubt as to the proper reference of the specimen, fig. 6, pl. 9, designated as *D. gracilis* by Ulrich and Resser.

Note: There is admittedly considerable variation evident among the various parts of the dorsal shields of *Dikelocephalus* occurring in the Lodi member. Much of this seems to be a matter of the age or stage of the molt, which doubtless most of the specimens represent. On this basis the *Saukia sublonga* zonal unit material seems to group itself as follows:

1. Small pustulose forms, with palpebral lobes close to parallel with longitudinal axis, and relatively posterior in position. Pygidia with five pairs of equal pleural ribs and long slender postlateral spines.

2. Medium-sized forms, generally not pustulose, with palpebral lobes intermediate between those of groups 1 and 3 in orientation and position. Pygidia averaging four pairs of subequal pleural ribs, with more triangular spines.

3. Large forms with palpebral lobes relatively far forward and oriented to anterior convergence. Pygidia averaging 3½ pairs of pleural ribs, alternatingly wide and narrow; pygidial spines short and basally broad.

The *Dikelocephalus* of the underlying *Saukia subrecta* unit is not greatly different from the *S. sublonga* species except that the more juvenile characters of slender spines and of pustulation seem to persist in individuals of medium size.

Lodi member–*Saukia lodensis* faunal unit
Dikelocephalus minnesotensis Owen
Synonyms: *D. hotchkissi* U & R, *D. intermedius* U & R, *D. granosus* U & R, *D. wiltonensis* U & R, "*D.* cf. *orbiculatus*" U & R (pl. 17, fig. 1), *D. brevis pars* (pl. 14, fig. 2). Probably also *D. orbiculatus* U & R, and *Briscoia?* sp. (pl. 17, fig. 10)
Note: As in the immediately ancestral *D. oweni* group of forms, young individuals are granulose (cf. *D. granosus* U & R, above). The *D. minnesotensis* group differs from the *D. oweni* group particularly in possessing a more expanded frontal limb and a narrower and more elliptical pygidium with subequal ribs even in the largest specimens.

Jordan member–*Calvinella wisconsinensis* faunal unit
Dikelocephalus marginatus U & R (except pl. 15, figs. 6 and 7)
Synonym: *D. declivis* U & R

Jordan member–*Calvinella pustulosa* faunal unit
Dikelocephalus marginatus U & R (as above)
Dikelocephalus inaequalis U & R (except pl. 19, fig. 6)
Note: *D. juvenalis* U & R of this zone is not recognized, being most probably the very young of the above.

Jordan member—*Saukiella pepinensis* faunal unit
Dikelocephalus marginatus U & R

Jordan member–*Walcottaspis vanhornei* faunal unit
Walcottaspis vanhornei (Walcott).
Note: The true position of this species in the Trempealeau faunal succession was pointed out to the writer by W. C. Bell and R. Berg in connection with its occurrence near Reno, Minnesota.

Dikelocephalid fragments occurring higher, in the Madison, may represent *Walcottaspis* rather than *Dikelocephalus*, but generically identifiable material has not yet been obtained.

Revision of the Saukinae

Simple synonymic cross references do not suffice, in the case of the Saukinae revision, to indicate proposed revised nomenclature. This is because many of Ulrich and Resser's (1933) species not only appear to be synonyms, but the illustrated material which they figure as one species from one stratigraphic horizon commonly must be distributed among several species and several stratigraphic horizons. Accordingly, in many cases it has been necessary to make reassignments, both taxonomic and stratigraphic, on the basis of individual plate figures. Stratigraphic references cited below are those of the writer, not of Ulrich and Resser.

Plate 24.
Figs. 1-9. *Prosaukia misa* (Hall) =*P. misa* (Hall)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).
Figs. 10-13. *Prosaukia resupinata* U & R=*P. misa* (Hall)
Same occurrence as above.

Plate 25
Figs. 1-7. *Prosaukia curvicostata* U & R
Figs. 8-12. *Prosaukia alternata* U & R
Figs. 13-16. *Prosaukia transversa* U & R
Figs. 17-18. *Prosaukia demissa* U & R
Fig. 19. *Prosaukia subconica* U & R
} =*P. curvicostata* U & R
Franconia formation, *Prosaukia* subzone, *curvicostata* zonal unit.

Fig. 20. *Saukiella transita* U & R= *S. conica* U & R
Franconia formation, *Saukiella minor* zonal unit, Prairie du Sac, Wis. (Not "Gibraltar Rock, Wis.")

PLATE 26.

Fig. 1. *Prosaukia concava* U & R= *P. misa* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).

Figs. 2-8. *Prosaukia subrecta* U & R
Figs. 9-12. *Prosaukia subaequalis* U & R
} =*P. curvicostata* U & R
Franconia formation. *Prosaukia* subzone, *curvicostata* zonal unit.

Figs. 13-17. *Prosaukia delecostata* U & R=*P. delecostata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit.

PLATE 27.

Figs. 1-2. *Prosaukia longa* U & R= *P. longa* U & R
Franconia formation, *Prosaukia* subzone, *Briscoia sinclairensis* zonal unit.

Figs. 3-9. *Prosaukia halli* U & R= *P. halli* U & R
Franconia formation, *Prosaukia* subzone, *P. misa—longicornis* zonal unit (*P. misa* facies).

Figs. 10-11. *Prosaukia brevisulcata* U & R=*P. longicornis* var. *brevisulcata* (U & R)
Franconia formation, *Prosaukia* subzone, *P. misa—longicornis* zonal unit (*longicornis* facies)

Figs. 12-21. *Prosaukia longicornis* U & R=*P. longicornis* U & R
Occurrence same as preceding.

Figs. 22-25. *Prosaukia ampla* U & R= *P. ampla* U & R
Franconia formation, *Saukiella minor* zonal unit.

PLATE 28

Figs. 1-2,4. *Prosaukia magnicornuta* U & R=*P. longicornis* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies)

Fig. 3. *Prosaukia magnicornuta* U & R =*P. l.* var. *brevisulcata* (U & R)
Occurrence same as preceding.

Fig. 5. *Prosaukia tuberculata* U & R= *P. tuberculata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Figs. 6-7. *Prosaukia longula* U & R= *P. tuberculata* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Fig. 8. *Prosaukia valida* U & R=*P. valida* U & R
Franconia formation, *Prosaukia* zone, zonal unit undetermined.

Fig. 9. *Prosaukia lodensis* U & R= *Saukia* cf. *curvata* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Figs. 10-11. *Prosaukia* sp. undet.= *Saukia subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.

Figs. 12-17. *Prosaukia incerta* U & R= *Saukiella* (?) *incerta* (U & R)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).

Fig. 18. *Prosaukia granosa* U & R= *P. beani* U & R
Franconia formation, Hudson member.

Fig. 19. *Prosaukia berlinensis* U & R: validity undetermined
Exact stratigraphic position undetermined.

Fig. 20. *Prosaukia dubia* U & R=*P. beani* U & R
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*longicornis* facies).

Fig. 21. *Prosaukia beani* U & R=*P. beani* U & R
Occurrence same as preceding.

PLATE 29

Figs. 1-3. *Prosaukia* (?) *anomala* U & R: not a Prosaukia, but belongs to an undescribed, non-saukid genus
Franconia formation, *Prosaukia* subzone, *curvicostata* zonal unit.

Figs. 4-6. *Saukia obtusa* U & R=*S. acuta* U & R
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 7. *Saukia sublonga* U & R=*S. sublonga* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit.

Fig. 8. *Saukia angusta* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Figs. 9-10. *Saukia modesta* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.

Fig. 11. *Saukia rudis hybrida* U & R cf. *S. acuta* U & R
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).
Figs. 12-13. *Saukia whitfieldi* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.
Fig. 14. *Saukia whitfieldi* U & R=*S. acuta* U & R
Occurrence same as preceding.
Figs. 16-17. *Saukia acuta* U & R=*S. acuta* U & R
Occurrence same as preceding.
Fig. 18. *Saukia* cf. *whitfieldi* U & R= *S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.
Fig. 19. *Saukia subrecta* U & R=*S. subrecta* U & R
Occurrence same as preceding.
Fig. 20. *Saukia subrecta* U & R=undetermined trilobite, cf. *Eurekia*
Occurrence same as preceding.

PLATE 30

Figs. 1-2. *Saukia nitida* U & R=*S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.
Fig. 3. *Saukia ornata* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.
Fig. 4. *Saukia ornata* U & R=undetermined trilobite cf. *Eurekia.*
Trempealeau formation, Lodi member.
Fig. 5. *Saukia curvata* U & R=*S. curvata* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.
Fig. 6. *Saukia laevigenata* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.
Fig. 7. *Saukia subgranosa* U & R=*S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.
Figs. 8-10. *Saukia separatoidea* U & R =*S. subrecta* U & R
Trempealeau formation, Lodi member, *S. subrecta* zonal unit.
Figs. 11-12. *Saukia tumida* U & R: not recognized; material inadequate.
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).
Figs. 13-16. *Saukia retusa* U & R=*S. acuta* U & R
Occurrence same as preceding.
Figs. 17-25. *Saukia rudis* U & R=*S. lodensis* (Whitfield)
Occurrence same as preceding.
Fig. 26. *Saukia parva* U & R=*S. acuta* U & R
Trempealeau formation; exact zonal occurrence not known.

PLATE 31.

Figs. 1-5. *Prosaukia acclivis* U & R= *P. halli* var. *acclivis* (U & R)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies).
Figs. 6-8. *Prosaukia* (?) *ambigua* U & R=undescribed genus aff. *Taeniocephalus*
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies, late stage).
Figs. 9-10a. *Saukia prima* U & R= *Prosaukia* (?) *dilata* U & R
Stratigraphic occurrence uncertain.
Fig. 11. *Saukia granilineata* U & R: not recognized
Trempealeau formation, Lodi member, *Saukia subrecta* zonal unit.
Figs. 12-13. *Prosaukia minuscula* U & R=*P. halli* var. *acclivis* (U & R)
Franconia formation, *Prosaukia* subzone, *misa—longicornis* zonal unit (*misa* facies, late stage).
Figs. 14-20. *Saukia separata* U & R= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit (sandstone facies).
Figs. 21-25. *Saukia imperatrix* U & R =*S. imperatrix* U & R
Trempealeau formation, exact stratigraphic occurrence undetermined.
Fig. 26. *Saukia lodensis* (Whitfield): relation undetermined; preservation inadequate
Trempealeau formation, Lodi member, *S. sublonga* zonal unit.
Fig. 27. *Saukia lodensis* (Whitfield)= *S. lodensis* (Whitfield)
Trempealeau formation, Lodi member, *S. lodensis* zonal unit.
Figs. 28-31. *Prosaukia dilata* U & R= *P. dilata* U & R
Stratigraphic occurrence uncertain.

PLATES 32 and 33.

All specimens figured are conspecific with *Saukiella pepinensis* Owen and accordingly the following names may be considered synonyms:
Saukiella typicalis
Saukiella typicalis convexa
Saukiella typicalis subrecta
Saukiella subgracilis

Saukiella subgracilis hybrida
Saukiella subgracilis parallela
Saukiella ampla
The occurrence is not from the Lodi shale, as the authors state, but from the *Saukiella pepinensis* zonal unit of the overlying Jordan member of the Trempealeau formation.

PLATE 34

Saukiella pyrene (Walcott)=*Saukiella pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

PLATE 35.

Figs. 1-8. *Saukiella pyrene* (Walcott) =*S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.
Fig. 9. *Saukiella* cf. *pyrene*=*S. pyrene* (Walcott)
Trempealeau formation, Lodi member, sandstone facies.
Fig. 10. *Saukiella* cf. *pyrene*=*S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.
Fig. 11. *Saukiella* cf. *pyrene*=*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia lodensis* zonal unit (sandstone facies).
Figs. 12-14. *Saukiella pyrene limbata* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).
Figs. 15-21. *Saukiella signata* U & R= *S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.
Fig. 22. *Saukiella frontalis* U & R= *Saukiella frontalis* U & R
Trempealeau formation, Jordan member, Norwalk sandstone, *Saukiella frontalis* zonal unit.
Figs. 23-25. *Saukiella indenta* U & R =*S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).
Figs. 26-30. *Saukiella indenta* U & R =*Saukiella frontalis* U & R
Trempealeau formation, Jordan member, Norwalk sandstone, *Saukiella frontalis* zonal unit.

PLATE 36.

Figs. 1-3. *Saukiella indenta* U & R= *S. indenta* U & R
Trempealeau formation, Lodi member, *Saukia lodensis* zonal unit (sandstone facies).
Fig. 4. *Saukiella indenta intermedia* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, sandstone facies.
Figs. 5-11. *Saukiella norwalkensis* U & R=*Saukiella pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.
Figs. 12-14. *Saukiella norwalkensis* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit (sandstone facies).
Figs. 15-25. *Saukiella norwalkensis* U & R=*S. pyrene* (Walcott)
Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.
Figs. 26-27. *Saukiella norwalkensis* U & R=*S. indenta* U & R
Trempealeau formation, Lodi member, *S. sublonga* zonal unit (sandstone facies).
Figs. 28-30. *Saukiella simplex* U & R= *S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.
Figs. 31-32. *Saukiella* (?) *weidmani* U & R=*Tellerina? leucosia* (Walcott) Trempealeau formation, Arcadia member, *Osceolia osceola* zonal unit.

PLATE 37.

Figs. 1-5. *Saukiella conica* U & R= *S. minor* U & R
Franconia formation, Bad Axe member, *Saukiella minor* zonal unit.
Figs. 6-17. *Saukiella minor* U & R= *S. minor* U & R
Same occurrence as preceding.
Figs. 18-29. *Calvinella spiniger* (Hall) =*C. spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.
Figs. 30-35. *Tellerina granistriata* U & R=*T. granistriata* U & R
Trempealeau formation, Lodi member, exact zonal position undetermined.

PLATE 38.

All specimens figured are conspecific with *Calvinella spiniger* (Hall), and, coming all from the same stratum at the same locality, represent the range of variation of a single species population. Accordingly, the following names, appearing on the explanation of plate 38, may be considered as synonyms:
Calvinella spiniger altimuralis U & R
Calvinella spiniger communis U & R
Calicinella spiniger communis mutation U & R

Calvinella spiniger postlevata U & R
Calvinella clivula U & R
Calvinella spiniger (Hall) ? (of U & R)
Occurrence: Trempealeau formation, Jordan member, *Calvinella spiniger* zonal unit, which the writer believes to lie at the base of the Jordan, below siltstone bearing the *Calvinella wisconsinensis* fauna.

PLATE 39.

Figs. 1-10. *Calvinella pustulosa* U & R =*Calvinella pustulosa* U & R
Trempealeau formation, Jordan member, *C. pustulosa* zonal unit.
Figs. 11-16. *Calvinella sparsinodata* U & R=cf. *Calvinella spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.
Figs. 17-18. *Calvinella pustulosa vernonensis* U & R=*Calvinella pustulosa* U & R
Trempealeau formation, Jordan member, *C. pustulosa* zonal unit.
Figs. 19-24. *Calvinella notata* U & R= *Calvinella walcotti* U & R
Trempealeau formation, Jordan member, zonal unit undetermined.
Figs. 25-30. *Calvinella lata* U & R= *Calvinella walcotti* U & R
Occurrence same as preceding.
Figs. 31-34. *Calvinella walcotti norwalkensis* U & R=*Calvinella spiniger* (Hall)
Trempealeau formation, Jordan member, *C. spiniger* zonal unit.
Figs. 35-36. *Calvinella wisconsinensis junior* U & R=*Calvinella spiniger* (Hall)
Occurrence same as preceding.

PLATE 40.

Figs. 1-14. *Calvinella walcotti* U & R= *C. walcotti* U & R
Trempealeau formation, Jordan member, exact zonal position undetermined.
Figs. 15-22. *Calvinella walcotti planulata* U & R=*C. walcotti* U & R
Occurrence same as above.
Figs. 23-33. *Calvinella wisconsinensis* U & R=*C. wisconsinensis* U & R
Trempealeau formation, Jordan member, *Calvinella wisconsinensis* zonal unit.
Fig. 34. *Calvinella walcotti* ? U & R: cf. *C. walcotti* U & R
Fig. 35. *Calvinella notata* ? U & R: cf. *C. wisconsinensis* U & R
Figs. 36-39. *Calvinella walcotti* ? U & R=*C. walcotti* U & R
Trempealeau formation, Jordan member, exact zonal position undetermined.

PLATE 41

Figs. 1-9. *Tellerina crassimarginata* (Whitfield)=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 42.

Fig. 1. *Tellerina crassimarginata* (Whitfield)=*T. crassimarginata* (W.)
Occurrence same as above.
Figs. 2-3. *Tellerina curta* U & R=*T. crassimarginata* (W.)
Occurrence same as preceding.
Figs. 4-5. *Tellerina gothamensis* U & R =*T. gothamensis* U & R
Trempealeau formation, Lodi member, *Saukia subrecta* zonal unit.
Fig. 6. *Tellerina bigeneris* U & R: cf. *Saukia acuta* U & R
Trempealeau fromation, Lodi member, *Saukia lodensis* zonal unit.
Fig. 7. *Tellerina strigosa* U & R=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 43.

Figs. 1-5. *Tellerina strigosa* U & R= *T. crassimarginata* (W.)
Occurrence same as preceding.
Fig. 6. *Tellerina lata* U & R: cf. *T. crassimarginata* (W.)
Occurrence undetermined.
Fig. 7. *Tellerina recurva* U & R=*T. crassimarginata* (W.)
Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit.

PLATE 44.

All specimens figured are conspecific with *Tellerina* ? *leucosia* (Walcott), and the following names may be regarded as synonyms:
Tellerina leucosia (Walcott)
Tellerina leucosia variety
Tellerina leucosia parallela U & R
The occurrence is not the Norwalk sandstone (a member of the Jordan formation), but the basal Trempealeau, Arcadia member.

PLATE 45.

Figs. 1-10. *Tellerina extrema* U & R= *Tellerina* ? *leucosia* (Walcott)
Occurrence same as preceding plate.
Figs. 11-13. *Tellerina norwalkensis* U & R=*T. crassimarginata* (W.)

Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

Fig. 14. *Tellerina norwalkensis* U & R: not identifiable.

Figs. 15-16. *Tellerina norwalkensis* U & R=*T. crassimarginata* (W.) Trempealeau formation, Lodi member, *Saukia sublonga* zonal unit (sandstone facies).

Stratigraphic Note

Arcadia Member

Since the latest published account of Trempealeau stratigraphy (Raasch, 1939), an additional member of that formation has been discriminated. This member, for which the term *Arcadia* is proposed, lies beneath the basal conglomerate of the St. Lawrence member, and rests with a strong basal conglomerate upon the Franconian, Bad Axe greensands. Areally the member is evidently continuously extensive north of the Black River valley, in Wisconsin and Minnesota, but to the southward is only locally present where small remnants have escaped pre-St. Lawrence erosion. The member bears the *Osceolia osceola* faunal assemblage.

The type locality selected is a road cut and small quarry on State Highway No. 93, 1 mile south of its junction with Highway No. 95, east of Arcadia, Trempealeau County, Wisconsin. Here the persistent greensands of the Franconia, Bad Axe member, are unconformably overlain by a spectacular 3-foot bed of edgewise conglomerate, flat pebbles of buff siltstone in a greensand matrix. This bed grades upward into 17.1 feet of somewhat lenticular strata of varied lithology, dominantly dolomitic siltstone and fine, greenish gray to light brown, somewhat dolomitic sandstone. *Osceolia osceola* Hall and *Dikelocephalus thwaitesi* U & R were collected.

The Arcadia succession is overlain by the basal St. Lawrence conglomerate (with dolomitic matrix and Arcadia sandstone pebbles), succeeded by 11.2 feet of sandy dolomite.

St. Lawrence Member

The fauna of the St. Lawrence member continues to be designated by the term *Platycolpus*, to which the specific term *eatoni* has been added, since the range of the genus greatly exceeds the span of the member. However, as the St. Lawrence member, which seldom exceeds 20 feet in the Wisconsin-Minnesota region, attains a thickness of more than 100 feet in parts of northeastern Illinois, it may represent a complex of faunal units, in addition to the substantive one to which the term *Platycolpus eatoni* is properly applied.

Lodi Member

The Lodi member is characterized faunally by a succession of at least three closely related faunal units. Of these, the middle or *Saukia sublonga* faunal unit yielded most of the classic collections from the "Dikelocephalus beds." The earlier *Saukia subrecta* faunal unit occurs in a lentil of limited thickness, as yet known only from the lower Wisconsin Valley. The *Saukia lodensis* faunal unit occurs in siltstone in the upper part of the Lodi member, largely in Sauk, Columbia, and Dane counties in southern Wisconsin, but also in similar lithology at Stillwater, Minnesota. In the intervening area (in a direct line), the Lodi member passes wholly to sandstone,

Chart No. 1.—Zonal Succession of Dikelocephalid Species

	Zonal Unit	Dikelocephalidae	Associated Genera
SAUKIA ZONE	14. "Madison Fauna" unconformity	undescribed *Tellerina*, *Calvinella*, *Dikelocephalus*(?) base of Madison formation	*Plethometopus*, *Entomaspis*, *Stenopilus*, *Plethopeltis*
	13. "Van Oser Fauna"	undescribed *Saukia*, *Saukiella*, *Tellerina*	*Stenopilus*, *Euptychaspis*
	12. *Saukiella frontalis*	*Saukiella frontalis* U.& R	
	11. *Walcottaspis vanhornei*	*Walcottaspis vanhornei* (Walcott)	*Stenopilus*
	10. *Saukiella pepinensis*	*Saukiella pepinensis* (Owen) *Dikelocephalus marginatus* U & R	*Plethometopus*
	9. *Calvinella pustulosa* unconformity	*Calvinella pustulosa* U & R *Dikelocephalus inaequalis* U & R *Dikelocephalus marginatus* U & R	*Eurekia*, *Corbinia*, *Triarthropis*, *Entomaspis* *Stenopilus*, "*Agnostus disparilis*" Hall
	8. *Calvinella wisconsinensis*	*Calvinella wisconsinensis* U & R *Dikelocephalus marginatus* U & R *Tellerina* sp. nov. *Prosaukia* sp. nov.	*Eurekia*, *Corbinia*
	7. *Calvinella spiniger*[1] unconformity	*Calvinella spiniger* (Hall) base of Jordan member	*Eurekia*, *Corbinia*
	6. *Saukia lodensis*[2]	*Saukia lodensis* (Whitfield) *Saukia acuta* U & R *Tellerina crassimarginata* (Whitfield) *Saukiella ? indenta* U & R *Saukiella ? incerta* U & R *Dikelocephalus minnesotensis*	*Illaenurus*, *Eurekia*, *Corbinia*, *Plethometopus*, *Triarthropsis*, *Entomaspis*, *Euptychaspis*, *Acheilops*, "*Agnostus disparilis*"
	5. *Saukia sublonga*	*Saukia sublonga* U & R *Saukiella indenta* U & R *Tellerina crassimarginata* (Whitfield) *Dikelocephalus oweni* U & R	*Illaenurus*, *Acheilops*, *Euptychaspis*, "*Agnostus disparilis*" Hall, *Plethometopus*, *Corbinia*, *Entomaspis*, *Eurekia*, *Triarthropsis*, *Stenopilus*
	4. *Saukia subrecta* U & R base of Lodi member	*Saukia subrecta* U & R *Saukia curvata* U & R *Tellerina gothamensis* U & R *Dikelocephalus oweni* var. barretti (U & R)	*Illaenurus*
	3. *Platycolpus eatoni* (Whitfield) unconformity	undescribed *Tellerina*, *Dikelocephalus* base of St. Lawrence member	*Illaenurus*, *Eurekia*, *Plethometopus*, *Stenopilus*, *Corbinia*, *Platycopus*

SAUKIA ZONE	2. *Osceolia osceola*	*Osceolia osceola* (Hall) *Dikelocephalus thwaitesi* U & R *Saukiella pyrene* (Walcott) *Tellerina ? leucosia* (Walcott)	*Illaenurus, Eurekia,* *Corbinia, Triarthropsis,* *Euptychaspis*
	unconformity	base of Arcadia member, Trempealeau formation	
	1. *Saukiella minor* U & R	*Saukiella minor* U & R *Prosaukia ampla* U & R *Dikelocephalus postrectus* U&R *Dikelocephalus* sp. nov. *Briscoia* sp. nov. *Calvinella* sp. nov.	*Illaenurus, Monocheilus*
	unconformity?	base of Bad Axe member, Franconia formation	
PROSAUKIA SUBZONE	4. *Briscoia sinclairensis*	*Briscoia sinclairensis* *Prosaukia longa* U & R	*Platycolpus*
	3. *Briscoia* (unnamed)	*Briscoia* sp. nov. *Prosaukia* near *longa* U & R	*Platycolpus,* *Monocheilus*
	2. *Prosaukia curvicostata*	*Prosaukia curvicostata* U & R *Briscoia schucherti* U & R	
	1. *Prosaukia longicornis*	*Prosaukia misa* (Hall)[3] *Prosaukia halli* U & R[3] *Prosaukia halli acclivis* U & R[3] *Prosaukia delecostata* U & R[4] *Prosaukia longicornis* U & R *Prosaukia l. brevisulcata*[4] *Prosaukia tuberculata* U & R[4] *Briscoia* sp. nov.[4]	*Dartonaspis*[4] *Chariocephalus*[3] *Idahoia* *Ellipsocephaloides*[3] *Ptychaspis*[3] *Wilbernia*[3] *Litagnostus*[3]
	Ptychaspis subzone	*Wilbernia*, ancestral to *Dikelocephalus* *Ptychaspis*, ancestral to *Prosaukia*	*Monocheilus, Psalaspis,* *Idahoia, Ellipsocephaloides,* *Litagnostus, Pseudagnostus*
	local unconformity	base of Hudson member, Franconia formation	

[1] Stratigraphic position not conclusively established.
[2] A central and southern Wisconsin facies.
[3] Greensand facies; *P. misa* faunal facies.
[4] Non-greensand facies; *P. longicornis* faunal facies.

in which somewhat different faunal facies of both the *Saukia sublonga* and *Saukia lodensis* faunal units have tentatively been identified.

Jordan Member

In western Wisconsin, conglomeratic and dolomitic strata marking the base of the Jordan member overlie the Lodi siltstone. The limited thickness of basal Jordan strata, including intercalated dolomitic shales, contains a closely packed succession of faunal units, each characterized by a distinct species of *Calvinella*. Thus there appears to have prevailed here, as in the case of the lithologically rather similar St. Lawrence member, a condition where factors favoring deposition were closely balanced by those favoring limited submarine erosion and/or nondeposition. Faunal units thus tend to be closely packed vertically and in lenses in areal distribution.

Along the Mississippi, the basal Jordan *Calvinella* beds are succeeded by siltstone strata similar lithologically to those of the Lodi member. These strata enclose fossils belonging to the *Saukiella pepinensis* faunal unit, and where the beds attain their greatest thickness, in Dakota County, Minnesota, the succeeding *Walcottaspis vanhornei* fauna as well. The siltstone grades eastward into unfossiliferous sandstone. The main body of the Jordan member above and lateral to the siltstones and conglomeratic dolomites just described consists of fine, friable, more or less dolomitic sandstones which Ulrich (1924) embraced in his term *Norwalk*. The higher Norwalk beds are sparingly fossiliferous and best characterized by *Saukiella frontalis* U & R.

The Jordan member was deeply eroded previous to the deposition of the Madison formation in central and southern Wisconsin; but along the Mississippi and in the lower Minnesota Valley the member is essentially its original thickness, with terminal sands ("Van Oser Beds," Stauffer, 1940) interpreted as a regressive phase of Jordan deposition (Raasch, 1939). Stauffer (1940) figures, but does not describe, a fauna from these beds.

Sunset Point Formation

At most places, south of a line through central Trempealeau County, an independent depositional cycle, dominantly sand with varied proportions of dolomite, intervenes between the Jordan member of the Trempealeau and the Ordovician Oneota formation. To this unit, the term Madison has been applied (ref. Raasch, 1935). Because pre-Madison erosion deeply truncated the Jordan member in central and southern Wisconsin, the Madison merits the status of an independent formation. However, the application of the term Madison to these strata has created much confusion, owing especially to the widespread use of the same name for a Mississippian limestone unit in Montana and Wyoming. The writer therefore proposes that, for the Cambrian unit, the term *Sunset Point* be substituted, after the bluff of that name at the Madison sandstone type locality.

The unit is locally fossiliferous, but the fauna has not been specifically described.

The Saukia Zone

Because many trilobite genera range through much of the Trempealeau and in fact back into the Bad Axe member of the Franconia and into the Madison (or Sunset Point) formation, this inclusive succession of faunal units is considered to represent a single faunal zone. The saukid genera, *Saukia*, *Saukiella*, *Tellerina*, and *Calvinella*, i.e. *Saukia* in the sense of Walcott's (1914) use of the term, together characterize this succession, but the later subdivision and restriction of the term *Saukia* by Ulrich and Resser leaves no single genus whose range coincides completely with the full time and rock span. Accordingly the writer proposes to apply the term *Saukia* to the succession involved, using that term in the broader sense of Walcott. Thus the biochron of the Saukinae coincides with the time span of the *Saukia* zone, except for the genus *Prosaukia*, which is ancestral to the other members of the subfamily and characterizes the *Prosaukia* subzone of the preceding *Ptychaspis-Prosaukia* zone.

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