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THE CASPER FORMATION OF WYOMING AND ITS CEPHALOPOD FAUNA

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THE CASPER FORMATION (PENNSYLVANIAN) OF WYOMING AND ITS CEPHALOPOD FAUNA

A. K. MILLER and H. D. THOMAS

ABSTRACT

The general nature of the Casper formation of southeastern Wyoming is discussed in this paper, an attempt is made to explain its relationships to other Late Paleozoic formations of the same and near-by regions, and much of its fauna is illustrated and described in detail. The fossils treated systematically represent one species of fusulinids, nine species of cephalopods (all nautiloids), and one species of trilobites. It is concluded that the formation probably represents the major portion of the Pennsylvanian period.

Long ago Hayden (1872) and Hague (1877) reported the occurrence of Carboniferous fossils in some of the sedimentary rocks of the Laramie Range in southeastern Wyoming. Darton (1908) described the strata which crop out on Casper Mountain (fig. 1) and in the hogbacks along the flanks of the Laramie Mountains, and listed Late Paleozoic fossils from many localities. The only Carboniferous cephalopods he obtained came from Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming, and these were identified by Girty (Darton, 1908) merely as *Tainoceras occidentale*, *Nautilus* sp., *Orthoceras* sp., and "Ammonoid indet."

In 1933, while trying in vain to determine just where Darton obtained his specimens, we located in beds of slightly different lithology what is probably the same abundant cephalopod fauna, and intermittently we have been collecting from it ever since. This fauna merits consideration both because of the rarity of cephalopods in the Late Paleozoic rocks of Wyoming and because of the evidence it affords in regard to the age of the Casper formation in which it occurs. The cephalopods, and a few other significant fossils, are described below and the beds which yielded them are discussed at some length with an attempt to explain their relationships to the other Late Paleozoic strata of southeastern Wyoming and adjacent portions of Colorado. A description of the brachiopods, which are abundant in certain portions of the Casper, is, however, left for the future.

The Geological Survey of Wyoming helped to finance the field work on which this report is based, and we wish to express our sincere appreciation to Dr. S. H. Knight, State Geologist, for this assistance. Acknowledgment is also due to Prof. C. O. Dunbar, who helped us greatly with identification of the brachiopods listed below; Dr. M. L. Thompson and Dr. M. K. Elias, who studied the fusulinids we obtained; Dr. J. Marvin Weller, who advised us in regard to the significance of our

trilobites; Dr. N. D. Newell, who compared certain of our cephalopods with specimens in the collections of the Kansas Geological Survey; and several students at the University of Wyoming who aided in the collecting of specimens. Essentially all of the field and stratigraphic work was done by Thomas and the descriptions and illustrations of the fossils were prepared largely by Miller.

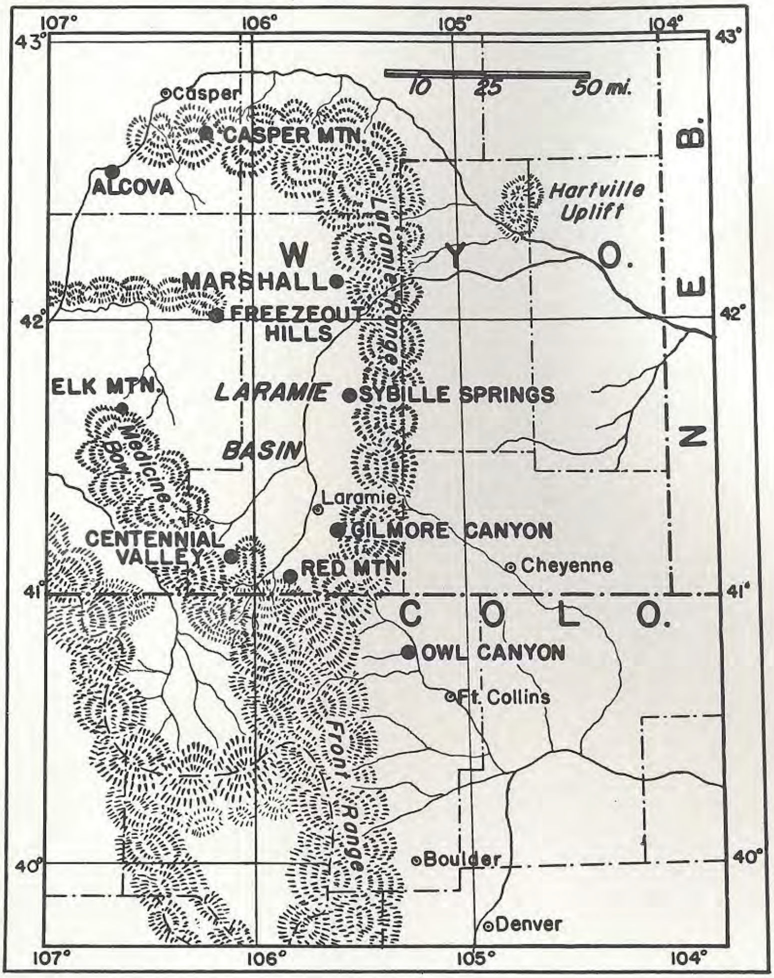

FIG. 1—Index map of southeastern Wyoming and north-central Colorado, showing localities mentioned in the text.

NOMENCLATURE OF CERTAIN LATE PALEOZOIC FORMATIONS IN THE LARAMIE BASIN

The name Casper formation was applied by Darton (1908) to a sequence of Carboniferous rocks which crop out along the Laramie Mountains. In the type region, around Casper Mountain, the lower part of the sequence is of Mississippian age and is now generally eliminated from the Casper. Later, Darton and Siebenthal (1909) published a detailed discussion of the lithology of the Casper beds of the Laramie Basin, and they pointed out that in the southern part of the basin the lower part of the formation consists of arkose grits, which directly overlie pre-Cambrian granite. Lee (1927) recognized that these arkoses are a northward extension of the Fountain formation of Colorado, and he carried the name Fountain into the Laramie Basin. Previously, Butters (1913) had applied the name Ingleside to the alternating sandstones and limestones which in Colorado overlie the Fountain and underlie the Lykins red-beds. Lee (1927) suggested that this name also be carried into the Laramie Basin and applied to the portion of Darton's Casper "formation" which overlies the Fountain, advocating that the name Casper be abandoned. Two years later Knight (1929) discussed in detail the distribution, lithology, and lithogenesis of the Fountain and the Casper formations in the Laramie Basin, and suggested that the name Casper be retained but used in a restricted sense, that is, to refer to the beds which overlie the Fountain arkose.

Because of the striking changes in lithology of the Casper from place to place, and because of the complex nature of the intertonguing of the beds of different lithologies, it seems to us that it is impossible without a great deal of additional detailed stratigraphic knowledge to devise a satisfactory nomenclature for the beds in the Laramie Basin which were called Casper by Darton. For the present, therefore, it will perhaps be best in areas where the Fountain is present, as in the southern part of the Laramie Basin, to use the term Casper in Knight's restricted sense. However, in the northern part of the Basin, where the Fountain beds seem to be replaced by others of different lithology, there is no name to use except Casper in Darton's sense, excluding, of course, the Mississippian strata which in some places occur between the Casper and the pre-Cambrian granite. It does not seem advisable or practical to use the term Ingleside in the Laramie Basin because the Casper at most localities, as at Sybille Springs, although lithologically similar to the typical Ingleside, represents a very much greater time interval than does the type section of that formation in Colorado. The erection of a satisfactory nomenclature for the beds now called Casper will probably have to be postponed until the time when we understand better their stratigraphic relations to the Tensleep and Amsden of central Wyoming, the Hartville of eastern Wyoming, and the Fountain and Ingleside of northern Colorado.

STRATIGRAPHY

The Casper in a broad sense represents a complex phase of intertonguing of three distinct facies: a continental arkose facies (Fountain), a cross-laminated sandstone facies (Tensleep), and a marine limestone facies. At different localities these three facies appear in varying degrees of prominence. This feature, coupled with the cyclical nature of the sedimentation and with lateral gradations in lithology, causes nearby sections of the formation to be strikingly different and makes their correlation very difficult.

In Gilmore Canyon (fig. 1) the Casper consists of about 700 feet of alternating arkose grits, festooned cross-laminated sandstones, and fossiliferous limestones. The sequence rests upon pre-Cambrian granite and is overlain by red Satanka shale of Permian age. Darton and Siebenthal (1909) measured a section of the Casper along this canyon, but their reported thickness of 1,259 feet is almost twice that of our thickness of 700 feet. It is possible that a zone of normal faulting was overlooked by them and part of the formation duplicated in measurement.

We measured detailed sections of the Casper at several points along Gilmore Canyon and traced key-beds from one section to the next. The top and bottom of the formation are exposed about 6 miles apart, and within this distance there are striking changes in the thicknesses of many of the beds, principally because the formation consists of sequences of sets of beds, cyclothems, separated by erosion surfaces which thin or completely cut away beds in the subjacent cyclothems. In general, thinning of the beds in one cyclothem seems to be compensated for by corresponding thickening of the basal unit of the superjacent cyclothem. Because of these lateral variations, the section given below is of necessity quite generalized.

Table I.—Generalized section of Casper formation, compiled from sections measured between mouth of Gilmore Canyon and a point about 1 mile south of Crow Creek Hill bench-mark, Laramie-Sherman quadrangles, Albany County, Wyoming.

	Thickness in feet
Satanka shale (Permian)	
Red shale with one thin but prominent ripple-marked sandstone in lower part....................	250?
Casper formation (Pennsylvanian)	
Alternating thin sandstones and siltstones, red and buff in color.	9
Derbya beds. Thin-bedded fossiliferous pink calcerous sandstone..	9
Cross-laminated fine-grained pink sandstone....................	41
Purple limestone. These beds and the subjacent ones form ledges and extensive dip-slopes along both sides of the canyon.......	5
Meekella beds. Dense mottled pink fossiliferous limestone..........	3
Salmon-pink sandstone; upper portion thin-bedded, lower portion cross-laminated. Separated from subjacent beds by marked erosion surface..................	5–19
——Erosion surface——	
Stenopoceras beds. White to gray calcareous sandstone containing abundant cephalopods in the upper part in the northwest corner of sec. 1, T. 14 N., R. 73 W., where it is thickest. Eastward these beds thin to a minimum of 2 feet because of the erosion surface at the top. No cephalopods present where thin..................	2–42
Cross-laminated red to pink sandstone........................	33–63
——Erosion surface——	
Pink to gray limestone with *Meekella* sp. and *Schizodus* cf. *S. wheeleri* (Swallow). Forms ledges and dip-slopes................	0–11
Cross-laminated pink to red sandstone. These beds and the over-	

	Thickness in feet
lying ones are cut out by the erosion surface which occurs above and are not present along the western end of the canyon.....	0–11
Triticites beds. Pink limestone becoming gray downward and containing abundant *Triticites ventricosus*? near base. In places the overlying sandstone and limestone have been removed and these beds thinned by erosion. Forms ledges and dip-slopes and may be traced along the canyon for about 4 miles..............	13–19
Cross-laminated red sandstone....	10
?———Erosion surface———?	
Purple limestone containing small fragments of fossils; present only along east end of canyon.......	0–3
Red to pink sandstones with a number of intercalated beds of arkose grits..........................	102
Gray limestone at top grading downward into arenaceous limestone which locally contains sporadic angular grains of quartz and feldspar; crinoid columnals and large planispiral gastropods are abundant in the calcareous matrix.......................	9
Red to pink sandstones and arkose grits composing upper portion; lower portion of pink cross-laminated sandstone which becomes buff near base.................	94
Platy purple limestone in 3- to 4-foot beds...................	15
Arkose grits, cross-laminated pink arkosic sandstones, and limestones containing sporadic quartz and feldspar pebbles...........	78
Gray limestone containing scattered quartz and feldspar pebbles, and crinoid columnals and planispiral gastropods..........	26
Pink arkosic sandstones and arkose grits.......................	100
Finely laminated cross-bedded pink arkosic sandstones, fine-grained arkose grits, and interbedded limestones which are thickly studded with quartz and feldspar pebbles. Crinoid columnals present in the calcareous beds...	47
Covered interval, with arkosic soil.	33
Pre-Cambrian granite	
The granite probably extends upward through much of the unexposed interval above.	

The Gilmore Canyon section presents definite evidence of the interdigitation of the Fountain and the Casper, and shows conclusively that, as postulated by Knight (1929) in contradiction to Lee (1927), the two formations represent contemporaneous continental and marine facies. The basal beds, although arkosic, are definitely marine, for they contain abundant crinoid columnals. Higher up are beds of coarse arkosic grit which are almost certainly of continental origin. A similar alternation of continental and marine beds characterizes the lower 325 feet of the section and hence there is no horizon at which a satisfactory dividing line can be drawn between typical Fountain beds and typical Casper beds. The highest arkose grit is about 50 feet below the *Triticites* beds.

In the Centennial Valley (fig. 1) the Fountain comprises about 670 feet of alternating arkose grits and pink sandstones which are lithologically similar to the festooned cross-laminated sandstones of the Casper along Gilmore Canyon. As now understood, the Casper in the Centennial Valley consists of a 60-foot basal cross-laminated gray sandstone, a middle 150-foot red and gray siltstone member, and an upper 40-foot cross-laminated tan sandstone. None of these members is fossiliferous and we are not able to suggest specific correlations with the Gilmore Canyon section.

The upper sandstone member of the Casper in the Centennial Valley is cut by an erosion surface with 5 or 6 feet of relief and is sharply separated from the overlying red Satanka shale of Permian age. It has been shown that this break is probably the same as the one that separates the Tensleep sandstone and the Permian Phosphoria formation in the Wind River Mountains of west-central Wyoming (Thomas, 1934). However, no marked stratigraphic break has been distinguished between the Casper and the Satanka at the mouth of Gilmore Canyon, and there we are drawing the contact rather arbitrarily at the horizon above which red shales, a type of rock lithologically foreign to the Casper, become dominant, and above which no festooned cross-laminated sandstones are found.

Northward along the Laramie Range from Gilmore Canyon the arkosic beds in the lower part of the Casper disappear. They persist to the northwest, however, as far as Elk Mountain. At a point about 30 miles north of Laramie, near Sybille Springs (fig. 1), the formation consists of about 700 feet of alternating cross-laminated sandstones and massive limestones. The basal member is a red sandstone about 40 feet thick which rests directly on the pre-Cambrian granite. A short distance above it is a very fossiliferous limestone the fauna of which is discussed below. Sandstones are conspicuous in the upper part of the formation and one attains a thickness of about 200 feet.

Further north, near Marshall, Giddings (1935) reports a basal Casper conglomerate resting on pre-Cambrian granite and containing derived chert pebbles which carry Mississippian fossils. Above the conglomerate, about 35 feet from the granite, Giddings obtained well-preserved representatives of *Chaetetes milleporaceous* Milne-Edwards and Haime which are now in the paleontological collections of the University of Wyoming. At a near-by locality he found a lithologically similar basal sequence overlain by about 250 feet of sandstones and fossiliferous limestones, followed by about 200 feet of cross-laminated buff sandstone at the top of the formation just below the red Satanka shale. *Juresania nebrascensis* (Owen) and *Linoproductus prattenianus* (Norwood and Pratten) were obtained from the sandstone-limestone sequence, and a short distance away *Composita subtilita* (Hall), *Neospirifer dunbari* King, and *Marginifera haydenensis* Girty were found in beds about 60 feet above the granite. It is probable that this last faunule is the same as that in the lowest fossiliferous limestone near Sybille Springs.

AGE AND CORRELATION OF THE CASPER FORMATION

We are not entirely satisfied with the results of our study of the Casper fauna in so far as determining the age of the formation is concerned. The oldest known Casper fossil of value in age determination seems to be *Chaetetes milleporaceus*, which in the vicinity of Marshall, Wyoming, occurs near the base of the formation. This coral characterizes the Cherokee and Marmaton beds of Kansas, but in Texas it ranges up into the lower

Canyon group. Condra and Reed (1935) have recently reported the occurrence of *Chaetetes* about 65 feet above the base of the Hartville formation in the Hartville Uplift of Wyoming, and the containing beds there are regarded as Marmaton or older. In view of the rare occurrence of this coral in southeastern Wyoming, it might be concluded that the *Chaetetes*-bearing beds near Marshall and those in the Hartville Uplift represent the same horizon, but this conclusion, if seriously challenged, would be difficult to defend.

Near Sybille Springs we obtained a fauna from beds, about 45 feet above the pre-Cambrian granite, which probably represent a slightly higher horizon than the *Chaetetes* beds. It consists of the following forms:

Fauna of lower Casper beds near Sybille Springs, Wyo.

Bryozoans	A[1]
Lindstroemella cf. *L. patula* (Girty)	R
Derbya crassa (Meek and Hayden)?	S
Derbya sp. (large)	S
Chonetes sp.	C
Meekella sp.	R
Juresania nebrascensis (Owen)	C
Dictyoclostus portlockianus (Norwood and Pratten)	A
Dictyoclostus morrowensis (Mather)?	R
Marginifera haydenensis Girty?	A
Linoproductus prattenianus (Norwood and Pratten)	A
Wellerella aff. *W. delicatula* Dunbar and Condra	S
Dielasma bovidens (Morton) var.	C
Reticulariina? sp.	R
Neospirifer dunbari King	A
Composita subtilita (Hall)	A
Composita ovata Mather	R
Aviculopinna nebrascensis Beede	S
Edmondia aspinwallensis Meek?	R
Pleurophorus sp.	R
Myalina sp.	R
Allorisma sp.	R
Orthocerotoid fragments	R
"*Phillipsia*" sp.	R
Cladodus occidentalis Leidy	R

[1] A=abundant; C=common; S=scarce; and R=rare.

The brachiopods were examined for us by Prof. C. O. Dunbar, who has written in regard to their age as follows:

> Unfortunately, the collection is about as noncommittal as to precise horizon as would be possible. The *Lindstroemella*, if correctly identified, would suggest the Lower Pennsylvanian. This is perhaps confirmed by *Reticulariina* and *Marginifera haydenensis*. On the basis of these I should be inclined to correlate with the Des Moines, but on the other hand, it is remarkable that the really distinctive species, such as *Mesolobus*, are lacking.

In addition, Professor Dunbar pointed out to us that *Reticulariina* and a species of *Dielasma* much like the Casper form occur in the Strawn of Texas. The single shark tooth, which was identified by Dr. C. C. Branson as *Cladodus occidentalis*, seems to be of little stratigraphic value, for that species occurs in Wyoming as high as the mid-portion of the Phosphoria formation, which is Middle Permian in age. The trilobite, of which only a pygidium is known, apparently is conspecific with a form that occurs in the *Triticites* beds of the Casper at Gilmore Canyon, near Laramie.

From the portion of the Casper which we are calling the *Triticites* beds we obtained, in addition to *Triticites ventricosus* (Meek)?, *Linoproductus prattenianus* (Norwood and Pratten), *Neospirifer dunbari* King, *Composita* sp., *Allorisma* sp., crinoid columnals, and a trilobite pygidium which we are describing below as "*Phillipsia*" sp. and which is conspecific with the one we found near Sybille Springs. Dr. J. Marvin Weller has written us that these trilobites (one species represented only by pygidia) are related to an undescribed form from the Lower Permian Luta and Fort Riley formations of Kansas, but that they are somewhat more primitive and therefore probably a little older than that form. Also, Dr. M. L. Thompson and Dr. M. K. Elias state that our fusulinids, though similar to both Upper Pennsylvanian and Lower Permian forms, are perhaps more like those known from the Wabaunsee.

The *Stenopoceras* beds of the Casper have yielded, in addition to the many cephalopods described below, numerous representatives of *Derbya* aff. *D. multistriata* (Meek and Hayden), several specimens identified by Professor Dunbar as a new species of *Orthotichia*, and rare representatives of *Pseudomonotis hawni* Meek and Hayden, *Schizodus* sp., *Myalina* sp., *Dentalium sublaeve* Hall?, and *Euphemus carbonarius* (Cox). Most if not all of the cephalopod genera represented in these beds are known to occur in both the Pennsylvanian and the Permian, and whereas the assemblage seems to be more or less typical of the Upper Pennsylvanian, it would not be incompatible with the Lower Permian. The chief difficulty in making a precise age-determination is that we know relatively little about Lower Permian nautiloids, and the only Lower Permian nautiloid fauna known from America came from the Fort Riley limestone of Kansas. Dr. N. D. Newell, who compared our forms for us with undescribed specimens of Fort Riley nautiloids in the collections of the Kansas Geological Survey, writes that whereas the genera *Metacoceras*, *Tainoceras*, *Stenopoceras*, and *Solenochilus* are common to both the Casper and the Fort Riley faunas, none of the species are particularly close, and the Fort Riley has a peculiar fauna, rather different from that of the horizons above and below, so that specific similarities would not be difficult to detect—still, the Casper brachiopod we are identifying tentatively as *Derbya* aff. *D. multistriata* (Meek and Hayden), although a new species, is closely related to both *D. multistriata* and *D. cymbula* Hall and Clarke which occur in the Fort Riley. The collections of the Kansas Geological Survey also contain an undescribed representative of *Stenopoceras* from the Lower Permian Florena shale of Kansas that is very similar to the Casper representative of that genus, but in so far as we have been able to ascertain no other similarity worthy of note exists between the faunas of the Florena and the Casper.

From the *Meekella* beds of the Casper we obtained the following:

Fauna of the Meekella *beds in the Casper formation*

Derbya aff. *D. multistriata* (Meek and Hayden)	C[1]
Meekella striatocostata (Cox)	A
Orthotichia sp.	S
Schizodus wheeleri Swallow?	C
Aviculopecten occidentalis Shumard	R
Edmondia gibbosa Swallow	R
Pleurophorus sp.	C
Deltopecten? sp.	R
Parallelodon sp.	R
Euphemus carbonarius (Cox)	R
Bellerophon sp.	C
Stenopoceras abundum Miller and Thomas	R
Metacoceras? sp.	R

[1] A=abundant; C=common; S=scarce; and R=rare.

The occurrence of *Derbya* aff. *D. multistriata*, *Orthotichia* sp., *Euphemus carbonarius*, *Stenopoceras abundum*, and *Metacoceras* sp. in both the *Meekella* beds and the underlying *Stenopoceras* beds, indicates that there is no great difference in the age of the two, in spite of the fact that a rather striking erosion surface intervenes between them.

The *Derbya* beds of the Casper have also yielded a considerable fauna, but many of the fossils obtained represent new species and others are too fragmentary to permit their specific affinities to be determined. Still, we recognize in our collections representatives of the following genera: *Polypora*, *Derbya* [aff. *D. multistriata*], *Orthotichia*, *Pseudomonotis*, *Astartella*, *Aviculopecten*, *Schizodus*, *Worthenia*, and probably *Bellerophon* and *Metacoceras*. *Derbya* aff. *D. multistriata* is abundant and *Schizodus* sp. and *Bellerophon?* sp. are not uncommon, but the rest of the forms listed are rare. This fauna is clearly related to those of the *Meekella* and the *Stenopoceras* beds, and presumably it is not greatly different in age from them.

It now seems to us, from a study of all of these faunas as well as the apparent stratigraphic relationships of the containing beds to each other, that whereas the upper part of the Casper may be Lower Permian in age, it is more probable that the entire formation is referable to the Pennsylvanian. Furthermore, the paleontological data appear to indicate that both Lower and Upper Pennsylvanian strata are present, and it seems quite probable that the Casper represents the major portion of the Pennsylvanian period. As a result of our studies we have reached the following tentative conclusions in regard to the relationships of the Casper with formation of adjacent regions:

(1) It seems probable that the Fountain sandstone of Colorado thins northward by continental overlap, so that the Fountain of the Laramie Basin, which near Laramie interfingers with marine beds of the Casper, represents only the upper

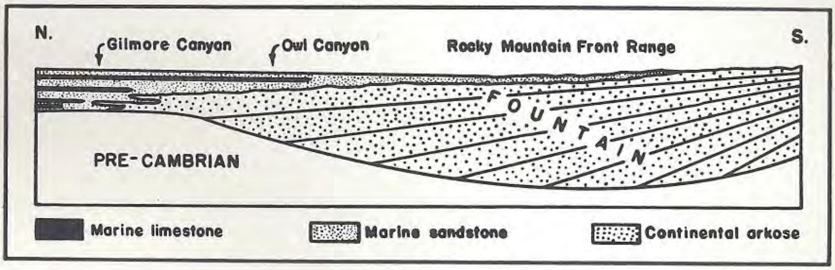

FIG. 2—Diagrammatic restored section showing (1) northward overlap of the Fountain and the interfingering of its upper part with marine beds of the lower Casper, and (2) onlapping nature of the marine beds across the eroded surface of the fan. Presumably this stage was followed by a regression of the sea.

part of the type Fountain in Colorado (fig. 2). The arkosic beds disappear north of Laramie and are replaced by marine beds of different lithology.

(2) The Ingleside formation of northern Colorado represents only the upper part of the Casper of the Laramie Basin. The unconformity which Lee described between the Fountain and the Ingleside in northern Colorado is not present in the Laramie Basin where the Fountain arkose interfingers with the sandstone-limestone facies of the Casper. Presumably the margin of the Fountain fan was built into a transgressive sea, and continued transgressions brought about the onlapping of the sandstone-limestone facies southward across the eroded surface of the fan.

(3) Northward and westward from the Laramie Basin, the change from the sandstone-limestone lithology of the Casper to the cross-laminated sandstone lithology of the Tensleep is brought about by the lensing out of the limestone tongues. Limestones persist in the lower part of the formation, but the upper part is predominantly sandstone, as shown by the Sybille Springs and Marshall sections. At certain localities in central Wyoming, the upper sandstone part has been called Tensleep and the lower limestone-sandstone part has been called Amsden, as at Alcova (fig. 1). It is probable that in places beds of Mississippian age, but younger than Madison, have been included in the "Amsden" with the lower Casper beds.

(4) The Casper limestones are probably the margins of tongues of limestones extending westward from the Hartville formation of eastern Wyoming.

(5) The disconformity which separates the Tensleep and the Phosphoria beds in the Wind River Mountains is probably the same as that which separates the Casper and the Satanka beds in the Centennial Valley (but which we could not locate in Gilmore Canyon). If, as we now believe, the Casper formation is referable to the Pennsylvanian and is of about the same age as the Tensleep, it seems logical to conclude, at least until evidence to the contrary is brought forth, that the Pennsylvanian-Permian boundary should be drawn between the Casper and the Satanka in the Laramie Basin, between the Tensleep and the red-bed "Embar" (Phosphoria equivalent) in central Wyoming, and between the Tensleep and the Phosphoria in the Wind River Mountains.

SYSTEMATIC DESCRIPTIONS

Foraminifera

Genus Triticites Girty

Triticites ventricosus (Meek)?

Plate 96, figures 1–5

Fusulinids are locally abundant at one horizon in the Casper formation, but apparently only one species is represented. The specimens occur firmly imbedded in a limestone matrix so that it is not possible to remove individuals. Dr. M. L. Thompson has kindly prepared oriented thin-sections of many specimens and has compiled the following detailed description of the species represented:

Shell of medium size, short, rather

highly inflated. Poles sharply pointed. Lateral slopes steep and uniform. External furrows distinct and shallow. Specimens of five volutions are about 4.4 mm. in length and 2.4 mm. in width; specimens of six volutions are about 5.8 mm. in length and 2.8 mm. in width; and specimens of seven volutions are about 6.4 mm. in length and 3.3 mm. in width. The form ratios of these same specimens are about 1:1.8, 1:2.0, and 1:1.9, respectively. However, the form ratio of mature specimens varies from 1:1.5 to 1:2.5.

The septa are numerous and rather thin. The septal count is 12 for the first volution, 17 to 20 for the second volution, 19 to 21 for the third volution, 22 to 28 for the fourth volution, and about 26 for the fifth volution. The septa are rather highly and narrowly fluted in the extreme polar regions, but only the lower portions of the septa are fluted in the central fourth of the shell, and there the fluting is very broad. The proloculum is spherical and it is very large. Its inside diameter averages about 300 microns but varies from 280 to 340 microns. The rate of expansion of the shell is essentially uniform, and the average heights of the first six volutions measure about 100, 130, 185, 240, 300, and 380 microns.

The spirotheca is thick. The keriotheca increases in thickness very rapidly from an almost invisible layer in the first volution to 42 microns in the second volution, 87 microns in the third volution, 90 microns in the fourth volution, and 105 microns in the fifth volution. The alveoli become very distinct near the end of the first volution, and they are very coarse throughout the remainder of the shell.

The tunnel is low and wide, and the tunnel angle is 36 to 37 degrees in the sixth volution. The chomata are well developed in all parts of the shell, except the outer portion of the outer volution.

Remarks.—In regard to the affinities of the Casper fusulinids, Doctor Thompson states:

These specimens are very closely similar to the fusulinids from the upper portion of the Pennsylvanian and the lower portion of the Permian of the Mid-Continent region which have been referred by Dunbar and Condra, White, and others to *Triticites ventricosus* (Meek) and its several varieties. So many different types of specimens have been referred to that species and its varieties that it is difficult to point out even a single character that will differentiate the Wyoming specimens from all of the Mid-Continent forms. The specimens under consideration are shorter and smaller and they have a larger proloculum, better developed chomata, and apparently more rapidly thickening spirotheca than the illustrated topotypes and metatypes of *T. ventricosus* from the Hughes Creek shale at Manhattan, Kansas. However, some of the specimens from the Hughes Creek at Eis Hill, Nebraska, which Dunbar and Condra figured as *T. ventricosus*, do not differ from the Wyoming specimens in all of the features listed. The specimens from the Saddle Creek limestone of Texas which White described as *T. ventricosus* "third sample" agree very closely with the Casper forms in so far as size, shape, development of chomata, size of proloculum, and rate of expansion of shell are concerned, but it is clear from the figures given by White for the thickness of the spirotheca in the different volutions that the spirotheca of the Texas specimens is much thinner than that of the Wyoming form.

We sent photographs of our specimens to Dr. M. K. Elias so that they could be compared directly with the numerous thin-sections of Mid-Continent fusulinids in the collections of the Kansas Geological Survey. He has written us (personal communication, dated March 12, 1936) that our fusulinids

seem to belong to *Triticites ventricosus* in a broad sense, but this common form ranges through the Wabaunsee and the Big Blue . . . [but the Wyoming specimens] seem to be more like those from the Wabaunsee.

Occurrence.—Abundant in *Triticites* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Figured specimens.—Univ. Iowa, nos. 1140–1144.

Cephalopoda

Genus Pseudorthoceras Girty

Pseudorthoceras knoxense (McChesney)

Plate 96, figures 6, 7

Recently Miller, Dunbar, and Condra (1933) have described this species in detail and have listed its extensive synonymy. This species is not rare in the Casper formation, but we obtained only fragmentary moderate-sized representatives of it. These are in all respects typical and those that are well preserved show all of the characteristic features: long slender conch, simple septa and sutures, central siphuncle composed of pyriform segments, and lamellar deposits in the camerae next to the walls of the phragmacone (pl. 96, fig. 6).

We have not seen the specimens (or specimen) from the same general horizon and locality as ours which Girty (Darton, 1908) identified as "*Orthoceras* sp.," but it seems likely that they represent this species. They may, however, represent the form described below as *Mooreoceras?* sp., or, of course, they may represent both or be distinct from both.

Occurrence.—This species is widely distributed both geographically and stratigraphically in the Pennsylvanian of North America, and it may occur also in the Upper Carboniferous of Europe. Stratigraphically it ranges from the Cherokee at least to the Wabaunsee and from the Bend to the Cisco; and geographically it is known from Pennsylvania to Colorado, and from Texas to Michigan. Also, Misch and Heritsch have recently referred to this species some specimens from the Upper Carboniferous near Nassfeld, in the Carnic Alps on the Austro-Italian border, and in so far as we are able to tell from their descriptions and illustrations, these specimens do not differ essentially from the American forms. Girty (1915) indirectly referred some Lower Permian forms to this species by placing references to them in its synonymy, and whereas it does not seem improbable that this species ranges into the Permian, all of the numerous Permian cephalopods that we have sectioned belong in different genera. The Casper specimens we are studying all came from the *Stenopoceras* beds, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Figured specimens.—Univ. Iowa, nos. 1147, 1148.

Genus Mooreoceras Miller, Dunbar and Condra

Mooreoceras(?) sp.

Plate 97, figure 1

In a few of the straight cephalopods in our collections from the Casper, the

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Explanation of Plate 96

All specimens illustrated came from the Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

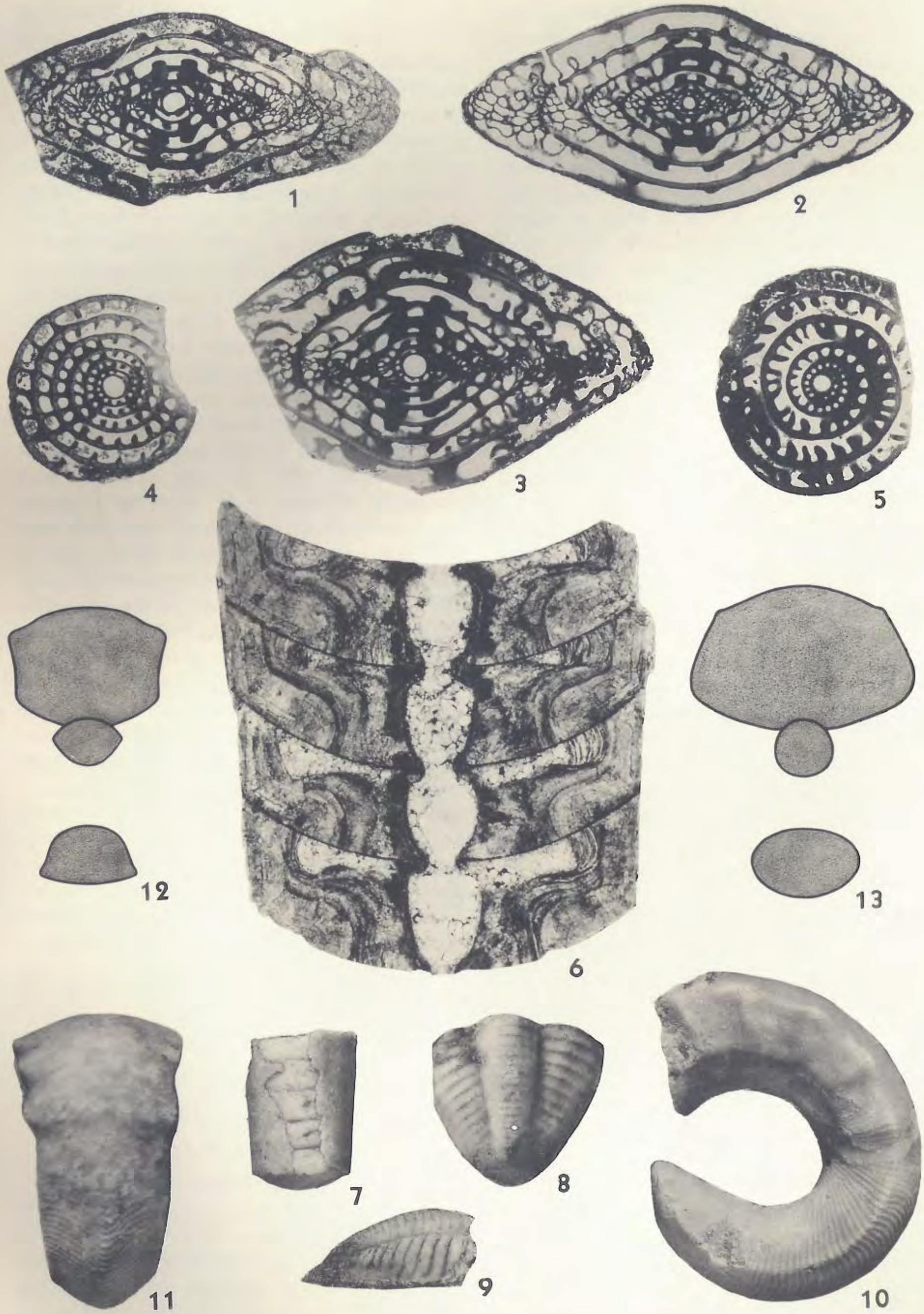
Figs. *1–5*—*Triticites ventricosus* (Meek)? Axial and sagittal sections (unretouched photographs) of typical specimens, ×10. *Triticites* beds. (p. 724)

6, 7—*Pseudorthoceras knoxense* (McChesney). Median longitudinal section (unretouched photograph) of a typical specimen, showing the siphuncle and the lamellar deposits in the camerae next to the walls of the phragmacone, ×8; and lateral view of another typical specimen, ×2. *Stenopoceras* beds. (p. 726)

8, 9—*Ameura* sp. Dorsal and lateral views of an essentially complete pygidium, ×2. *Triticites* beds. (p. 737)

10–12—*Metacoceras* sp. *10, 11,* Lateral and ventral views of an immature specimen (Univ. Iowa, no. 1153), ×4, and diagrammatic cross section, ×2, showing shape and surface markings of conch during early growth stages. *12,* Composite figure based on Univ. Iowa specimens nos. 1153, 1154. *Stenopoceras* beds. (p. 730)

13—*Tainoceras wyomingense* Miller and Thomas, n. sp. Diagrammatic cross section, showing shape of conch during early growth stages, ×2. *Stenopoceras* beds. [See pl. 97, fig. 6 and pl. 98, figs. 3, 4.] (p. 732)



Miller and Thomas, Pennsylvanian Invertebrates siphuncle is located distinctly ventrad of the center of the conch and there are no peripheral deposits in the camerae. Therefore, these forms can be differentiated readily from the more abundant *Pseudorthoceras knoxense* (McChesney), described above. The conch is long, slender, straight, gradually expanded orad, and circular or broadly elliptical, in cross section, being slightly depressed dorso-ventrally; it attains a diameter of at least 30 mm. The test is thin and is marked externally by only straight or slightly sinuous transverse growth-lines, which on some specimens are quite distinct. The septa are simple saucer-shaped disks, moderately convex apicad, and the camerae are of average length (see pl. 97, fig. 1). The sutures are straight or only very slightly sinuous, and they are transverse to the long axis of the conch. Due to the poor preservation of our specimens, we have not been able to ascertain with certainty the structure of the siphuncle, and therefore we can not refer them definitely to any genus. However, in one of the sectioned specimens we encountered structures which probably represent siphuncular segments, and they are fusiform in shape as in the Late Paleozoic genus *Mooreoceras*. Since the other characters of our specimens coincide precisely with those of typical representatives of that genus, we are referring our form to it with question.

Occurrence.—*Stenopoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Figured specimen.—Univ. Iowa, no. 1150.

Genus Coloceras Hyatt

Coloceras sp.

Plate 98, figures 5, 6

We obtained only a single representative of *Coloceras* from the Casper. It is rather small and septate throughout, presumably representing only the adapical, immature portion of the phragmacone. It is only a little more than a volution in length and is subglobular in shape, attaining a maximum diameter (measured across the umbilicus) of about 14 mm. and a maximum width and height of conch of about $11\frac{1}{2}$ mm. and $8\frac{1}{2}$ mm., respectively. The conch is expanded orad rather rapidly and at the adapical end of the outer volution of the specimen, the conch is only about 5 mm. wide and 3 mm. high. Whorls are broadly rounded ventrally, somewhat more narrowly rounded laterally, impressed dorsally, and reniform in cross section.

Umbilicus, which appears to be perforate, is rather small, and its diameter is equal to only about one-fifth that of specimen. Umbilical shoulders rounded and not very distinct, though they appear to increase in prominence adorally. Umbilical walls rounded.

No trace of surface markings is discernible on adoral part of specimen, which is not very well preserved. However, on portions of the test, or a replacement of it, which adhere to the adapical part of the outer volution of the specimen there are rather prominent longitudinal lirae or raised lines; these are about one-fifth mm. apart. Traces of the growth-lines on the preserved portions of the test indicate that the conch is marked ventrally by a moderately deep rounded hyponomic sinus and laterally by similar but more broadly rounded salients.

Camerae moderate in length. Sutures are not very distinct on this specimen but they appear to be essentially straight and to be directly transverse to long axis of conch. Siphuncle subcentral in position but distinctly nearer dorsum than venter.

Remarks.—The genus *Coloceras* is widely distributed both geographically and stratigraphically. It is well represented in the Mississippian, Pennsylvanian, and Permian of both Europe and North America, and it occurs also in Asia. In North America it is known to range from the Upper Mississippian (Chester) to the Lower Permian (Wichita), but it seems to be abundant only in the Pennsylvanian. The longitudinal lirae on the adapical portion of the outer volution of the above-described specimen are not a specific character, for similar lirae have been observed on the adolescent portion of the conch of more than one species of *Coloceras*. Since this specimen apparently is not mature, it can not be identified specifically and it is therefore of little stratigraphic value.

Occurrence.—*Stenopoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Figured specimen.—Univ. Iowa, no. 1152.

Genus Metacoceras Hyatt

Metacoceras knighti Miller and Thomas, n. sp.

Plate 97, figures 2, 3

Conch, which at maturity consists of at least three or four volutions, is subdiscoidal, nautiliconic though only slightly involute, and large, attaining a diameter (measured across the umbilicus) of at least 115 mm. and a maximum height and width of conch of at least 45 mm. and 55 mm., respectively. Extreme adapical portion of conch is rapidly expanded and is circular or nearly so in cross section. However, lateral diameter increases more rapidly than dorso-ventral diameter, and conch becomes depressed very early in its ontogenetic development. During the first volution the dorsal side of the conch is less strongly arched than the ventral side, and the cross section of the conch is subelliptical. Immediately orad of the first volution of the conch umbilical shoulders are gradually developed and at about the same time there appears on the ventro-lateral zones of the conch a low narrow ridge—the lateral walls of the conch are thus defined and the whorls become subrectangular in cross section, which shape is retained throughout ontogenetic development. At full maturity the ventral part of the conch is gently convex, the lateral walls which converge slightly ventrad are nearly straight, and the dorsal part is composed of three divisions—nearly straight umbilical walls separated by a median shallow rounded impressed zone. Both the ventro-lateral and the dorso-lateral zones of the conch are subangular.

Umbilicus large and perforate. Its diameter is equal to about one-half that of specimen. Umbilical perforation is oval in shape and it is about 4 mm. wide and 5 mm. long. Umbilical walls moderately steep.

Apertural margins not retained on any of the numerous specimens available for study, but growth-lines are essentially straight and directly transverse on umbilical walls and lateral sides of conch, and form broad deep rounded sinuses on ventral side (pl. 97, fig. 2). With exception of the growth-lines, the first volution of the conch is smooth or nearly so, though at the adoral end of the first half-volution there is a slight but very distinct constriction. On the adapical portion of the second volution of the conch a low narrow ridge appears on each of the

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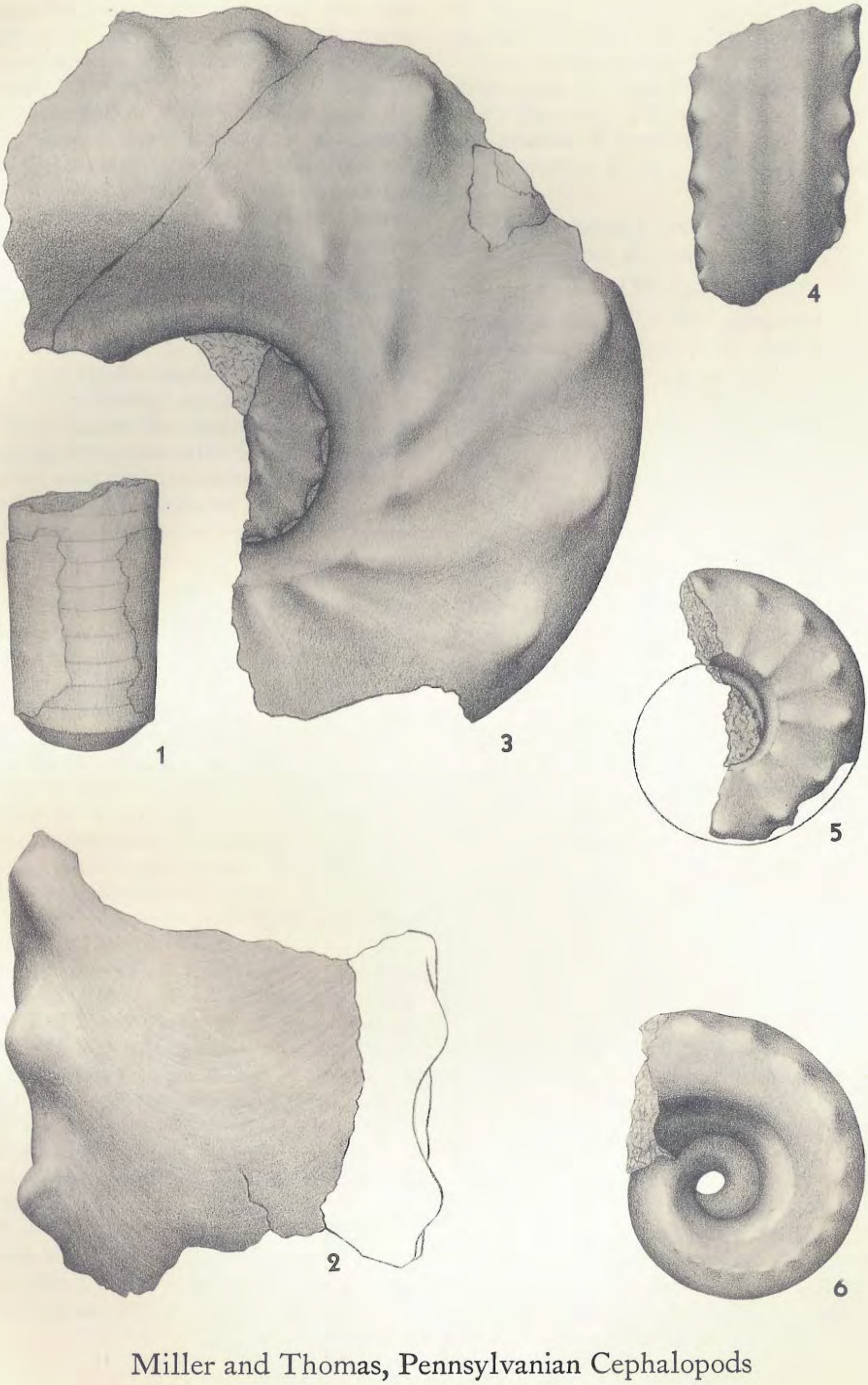
Explanation of Plate 97

All specimens illustrated on this plate came from the *Stenopoceras* beds of the Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming. Drawings by Dan Enich.

Figs. *1*—*Mooreoceras* (?) sp. Ventral view of an average specimen, somewhat restored, ×1. (p. 726)
2, 3—*Metacoceras knighti* Miller and Thomas, n. sp. Ventral and lateral views (somewhat restored) of a typical large specimen (a syntype), ×1. (p. 728)
4, 5—*Metacoceras sulciferum* Miller and Thomas, n. sp. Ventral and lateral views of a typical mature specimen (a syntype), ×1. (p. 729)
6—*Tainoceras wyomingense* Miller and Thomas, n. sp. Lateral view of an immature specimen (a syntype), showing the umbilical perforation, the gradual development of the ventro-lateral nodes, and the appearance of the ventral nodes near the adoral end of the specimen, ×1. [See pl. 96, fig. 13, and pl. 98, figs. 3, 4.] (p. 732)



Miller and Thomas, Pennsylvanian Cephalopods

ventro-lateral zones. During the first quarter of the second volution these ridges become nodose and each is transformed into a row of longitudinally elongate nodes. These nodes soon develop lateral extensions, and gradually they become obliquely elongate (pl. 97, fig. 3). Orad of the first volution of the conch umbilical shoulders are developed, and these also gradually become nodose during ontogenetic development. The nodes on them likewise become obliquely elongate. Throughout ontogenetic development there is a distinct tendency for the umbilical nodes to be paired with the ventro-lateral nodes.

At maturity the sutures are like those of typical representatives of *Metacoceras;* that is, each mature suture forms a broad shallow rounded lobe on the ventral, the lateral, and the dorsal sides of the conch, and these are separated by subacute saddles. The part of the suture forming the dorsal side of the lateral lobe continues to curve orad across the umbilical wall, and the subacute dorso-lateral saddle centers on the umbilical seam rather than on the umbilical shoulder; there is, however, a marked decrease in the amount of adoral curvature of the sutures on the umbilical shoulder. The siphuncle is small, circular in cross section, subcentral in position (but distinctly nearer the venter than the dorsum), and apparently orthochoanitic in structure—at any rate it is composed of cylindrical segments.

Remarks.—This fine, large species is named for Prof. S. H. Knight, in recognition of his work on the Casper formation. Its most distinctive characters are the large size of its conch, the oblique elongation of the ventro-lateral nodes, and the obliquely elongate nodes on the umbilical shoulders. In only a few of the previously described representatives of *Metacoceras* do the umbilical shoulders bear nodes, and in none of them are the nodes obliquely elongate. In the form from the Casper that we are describing below as *M. sulciferum* the ventral side of the conch is marked centrally by a shallow rounded longitudinal groove.

Occurrence.—Abundant in *Stenopoceras* beds of Casper formation in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Syntypes.—Univ. Iowa, nos. 1155, 1156.

METACOCERAS SULCIFERUM Miller and Thomas, n. sp.

Plate 97, figures 4, 5

Associated with the numerous large specimens described as *M. knighti* are a few smaller, moderate-sized specimens which differ from equal-sized portions of typical representatives of *M. knighti* in that the ventral side of their conch is marked medianly by a shallow rounded longitudinal groove. In some specimens this groove is very prominent, whereas in others it is small and shallow and is easily overlooked. Nevertheless, these forms can be readily differentiated from typical *M. knighti.*

Conch forms at least two and one-half volutions, and it is subdiscoidal and nautiliconic though only slightly involute. It attains a maximum diameter, measured across the umbilicus, of at least $37\frac{1}{2}$ mm. and a maximum height and width of conch of at least 13 mm. and 23 mm., respectively. Extreme adapical portion of conch is circular or nearly so in cross section, but throughout most of the first volution the conch is depressed dorso-ventrally and is subelliptical in cross section, its ventral side being more strongly convex than its dorsal. By the time the conch has completed one full volution both umbilical and ventro-lateral shoulders have started to develop, and these rapidly become subangular; the conch then becomes subrectangular in cross section. Even after the conch has attained full maturity, however, its lateral walls, which are nearly straight, converge ventrad, and its ventral and dorsal sides, though concave medianly, are in general convex.

Diameter of umbilicus is equal to

about one-half that of specimen. Umbilicus is perforate and umbilical perforation is oval in shape and is about 5 mm. long and 4 mm. wide. Umbilical walls are steep.

Growth-lines are nearly straight on umbilical walls and lateral parts of conch, but they form very shallow subangular sinuses as they cross the umbilical shoulders and broad deep rounded sinuses as they cross the ventral side of the conch. First volution of conch is essentially smooth, but thereafter a row of longitudinally elongate nodes with low rounded inconspicuous lateral extensions is developed on each of the ventro-lateral shoulders of the conch. After the conch has completed almost two volutions a row of similar but smaller nodes is developed on each of the umbilical shoulders. The nodes on the umbilical shoulders also bear lateral extensions, and they seem to be paired with those on the ventro-lateral zones of the conch. There are about 15 or more of these nodes to the volution.

In so far as we have been able to ascertain, the sutures of this species are like those of all typical representatives of *Metacoceras*, and they do not differ materially from those of *M. knighti*. The siphuncle, like that of *M. knighti*, is orthochoanitic in structure, or at any rate it is composed of cylindrical segments. Where the conch is about 15 mm. high, the center of the siphuncle is about 5 mm. from the venter and about 8 mm. from the dorsum, the impressed zone being about 2 mm. deep.

Remarks.—The most distinctive character of this species, which has suggested its name, is the longitudinal furrow along the venter. It may be that the specimens on which we are basing this species should be regarded as aberrant representatives of *M. knighti*, or as representing a variety of that species, but it now seems to us best to regard them as belonging in a distinct species.

Occurrence.—*Stenopoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Syntypes.—Univ. Iowa, nos. 1157, 1158.

METACOCERAS sp.

Plate 96, figures 10–12

From the *Stenopoceras* beds of the Casper formation we obtained numerous specimens which apparently are referable to *Metacoceras*, but many of them are poorly preserved and incomplete and others are small and presumably immature. There seems to be a great deal of variation among these specimens, and due to their fragmentary nature we have not been able to determine just which of the small, immature specimens are conspecific with certain of the large ones. A few of the small specimens are ex-

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EXPLANATION OF PLATE 98

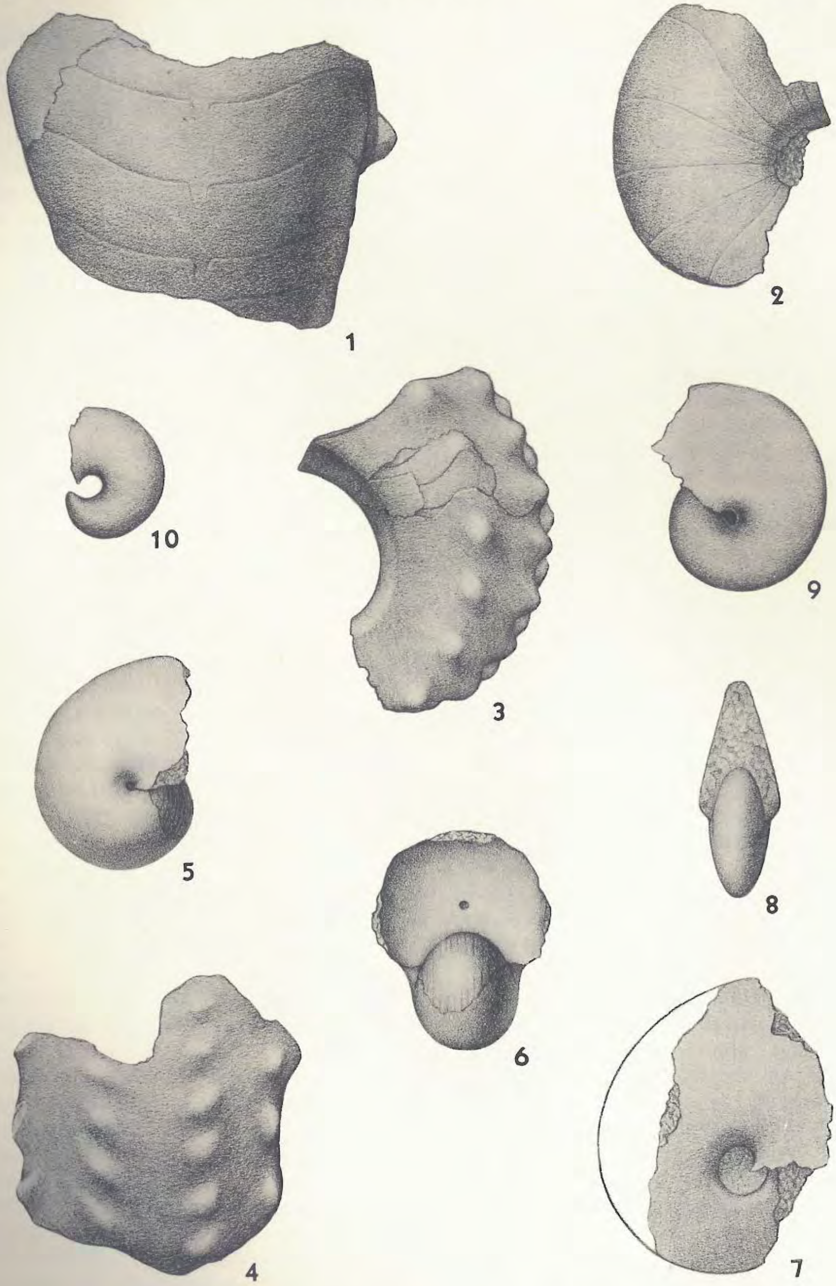
All specimens illustrated on this plate came from the *Stenopoceras* beds of the Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming. Drawings by Dan Enich.

FIGS. *1, 2*—*Solenochilus* cf. *S. brammeri* Miller, Dunbar, and Condra. Ventral and lateral views of a fairly well preserved but rather small specimen representing a late adolescent or early mature portion of the conch, ×1. (p. 736)

3, 4—*Tainoceras wyomingense* Miller and Thomas, n. sp. Lateral and ventral views of two of the syntypes (mature specimens), both ×1. [See pl. 96, fig. 13, and pl. 97, fig. 6.] (p. 732)

5, 6—*Coloceras* sp. Lateral and ventral views (somewhat restored) of the only representative of *Coloceras* known from the Casper formation, ×2. (p. 727)

7–10—*Stenopoceras abundum* Miller and Thomas, n. sp. Lateral view of an immature specimen (a syntype) of about two volutions showing the start of the abrupt closure of the umbilicus; ventral and lateral views of another syntype of about one and one-half volutions showing the shape of the conch and the perforate umbilicus during early ontogenetic development; and lateral view of extreme adapical portion of conch; all ×1. [See pl. 99, figs. 1, 2.] (p. 734)



Miller and Thomas, Pennsylvanian Cephalopods

ceptionally well preserved. Some of these represent the extreme adapical portion of the conch and are therefore worthy of consideration even though we can not be certain of their specific affinities. One of these, which does not complete a full volution, is figured (pl. 96, figs. 10–12). Its extreme adapical part, which is expanded orad very rapidly, is circular or nearly so in cross section, but its lateral diameter increases more rapidly than its dorso-ventral diameter, and it becomes subelliptical in cross section very early in its ontogenetic development, the ventral side being less strongly convex than the dorsal. At the same time that the conch becomes depressed it develops lateral keels which migrate to a ventro-lateral position. After the conch has completed almost one-half of a volution these keels are abruptly transformed into rows of very prominent longitudinally elongate nodes, each of which possesses a low rounded lateral extension. Soon umbilical shoulders are developed and the lateral parts of the conch are defined. At first these converge dorsad rather strongly, but they gradually become more nearly parallel. The adapical non-nodose portion of the conch is marked by very prominent transverse lirae which presumably represent increments of growth. Each of these forms a narrowly rounded ventral sinus which becomes progressively deeper and more nearly V-shaped during ontogenetic development, and on each side of it a broad gently rounded salient, a shallow subangular sinus which centers on the lateral or ventro-lateral keel, and a broad rounded dorsal salient which extends from one of the keels to the other. At the same time that the conch develops lateral nodes, these transverse lirae become much reduced in size and prominence, and they are thus transformed into typical growth-lines. As umbilical shoulders are developed the growth-lines become straight on the lateral walls of the conch, and then dorso-lateral sinuses are rapidly developed. It should perhaps be mentioned in this connection to avoid possibility of ambiguity that the dorsal side of the conch does not become concave until after a full volution is completed, and a dorsal impressed zone is then gradually developed—that is, in contrast to *Stenopoceras*, an impressed zone is not developed until it is needed.

Remarks.—The early growth-stages of *M. knighti* differ markedly from those of the above described form. The conch of *M. knighti* is non-nodose until it has completed about one and one-fourth volutions. Umbilical shoulders are gradually developed immediately orad of the first volution, and at about the same time a low narrow ridge appears on each of the ventro-lateral zones of the conch. During the first quarter of the second volution this ridge becomes nodose, and it gradually evolves into the nodose ventro-lateral zones of the conch. This species, then, during its ontogenetic development does not seem to pass through a *Temnocheilus* stage as does the form described above, but it may be said to pass directly from an *Endolobus* to a *Metacoceras* stage, suggesting that the genus *Metacoceras* as now understood may not be monophyletic.

The early growth stages of the Casper representative of *Tainoceras*, *T. wyomingense* Miller and Thomas, differ markedly from those of the small *Metacoceras* described above (compare figs. 12 and 13 of pl. 96), but in general they are similar to those of *M. knighti*. In *T. wyomingense* after the conch has completed a little over half of a volution low broad inconspicuous lateral nodes appear. Soon after the conch completes the first volution these lateral nodes disappear, umbilical shoulders become distinct, and a row of longitudinally elongate nodes is then developed rather gradually on each of the ventro-lateral shoulders. Near the mid-length of the second volution of the conch, two rows of longitudinally elongate nodes are gradually developed on the ventral side of the conch. In this species, as in the representatives of *Meta-*

coceras discussed above, a dorsal concave zone is not developed until the conch has completed a full volution and an impressed zone is necessary if the conch is to become involute.

Genus TAINOCERAS Hyatt

TAINOCERAS WYOMINGENSE Miller and Thomas, n. sp.

Plate 96, figure 13; Plate 97, figure 6; Plate 98, figures 3, 4

(?) *Tainoceras occidentale* GIRTY, *1908*, Geol. Soc. America, Bull., vol. 19, p. 429.

Conch, which forms at least three volutions, is subdiscoidal, nautiliconic, and rather large at maturity. One of the syntypes attains a maximum diameter, measured across the umbilicus, of about 60 mm. and a maximum height and width of conch of about 25 mm. and 35 mm., respectively; and another crushed fragmentary syntype, which represents only a portion of one volution of the conch, is at least 25 or 30 per cent larger. Mature whorls are depressed dorso-ventrally and are octagonal in cross section (see text-figure 3A). Ventral, ventro-lateral, and dorso-lateral sides of conch are relatively narrow, compared with lateral and dorsal sides. Except near apex, where conch is circular or nearly so in cross section, adapical portion of conch is subelliptical in cross section, being strongly depressed dorso-ventrally, very broadly rounded ventrally and dorsally, and rather narrowly rounded laterally; dorsal side of conch is less strongly convex than ventral (see pl. 96, fig. 13). Conch is expanded orad rapidly, and at adoral end of first volution it is about $12\frac{1}{2}$ mm. wide and 8 mm. high. One-half volution orad of this point it is about 20 mm. wide and $12\frac{1}{2}$ mm. high.

Umbilicus moderately large and perforate. In large mature individuals diameter of umbilicus is equal to nearly one-half diameter of specimen, and in younger individuals it is relatively larger. Umbilical perforation is oval in shape and it is about 5 mm. long and 3 mm. wide. Umbilical walls steep; umbilical shoulders subangular and at full maturity slightly nodular.

On mature portion of conch each growth-line forms a broad moderately deep rounded ventral sinus and on each side of it a broad low gently rounded lateral salient, but growth-lines are essentially straight and directly transverse on umbilical walls. Adapical portion of conch is smooth or nearly so but near adoral end of adapical volution lateral zones of conch become very slightly nodular, and on adapical portion of next volution there is developed rather gradually on each of the ventro-lateral shoulders of the conch a row of longitudinally elongated nodes. Near the mid-length of the second volution of the conch two rows of similar nodes are gradually developed on the ventral side of the conch. Apparently the nodes in all four of these rows continue to enlarge throughout ontogenetic development, and they seem to become progressively less elongated longitudinally. Nevertheless, on large specimens the ventro-lateral nodes are distinctly elongated longitudinally and the ventral nodes are elongated obliquely (pl. 98, fig. 4). During full maturity the ventral nodes become as large and prominent as the ventro-lateral nodes and also the umbilical shoulders become slightly nodular.

Camerae moderate in length (see pl. 98, fig. 3). As shown in text figure 3B, each mature suture forms broad shallow rounded ventral, lateral, and dorsal lobes, and these are separated by subangular saddles. As a result of the ventral nodes, the flanks of the ventral lobe are sinuous. Also, it should be noted that on the umbilical shoulder there is an abrupt change in the curvature of the sutures, and that on the umbilical walls the sutures are essentially straight. Siphuncle small, circular in cross section, and subventral in position.

Remarks.—In 1908 Girty studied a specimen (or specimens) from the same general horizon and locality as the types of the above-described species, and he referred it to *Tainoceras occidentale.* We have not seen that specimen, but it seems likely that it is conspecific with the form under consideration, which differs considerably from *T. occidentale* as now understood.

The genus *Tainoceras* is abundantly represented in the Pennsylvanian and Lower Permian of the United States, and it has been found also in the Upper Carboniferous and Permian of Europe and the Upper Carboniferous of Asia (near Vladivostok). In the United States it is widespread both geographically and stratigraphically and ranges from Pennsylvania to Colorado; stratigraphically it ranges throughout most of the Pennsylvanian and well up into the Lower Permian (upper Wichita). In Europe it has been found in the Upper Carboniferous of Russia (near Moscow), the Sosio beds (Middle Permian) of Sicily, and the *Bellerophon* limestone (Upper Permian) of the Dolomite Alps. The species under consideration is not closely similar to most of the European and Asiatic forms but it is somewhat similar to *T. trautscholdi* (Waagen) of the Upper Carboniferous of Russia (near Moscow), *T. nebrascense* Miller, Dunbar, and Condra of the Lower Permian (Hughes Creek shale and Fort Riley limestone) of Nebraska, the specimen from some unknown horizon and locality which Miller, Dunbar, and Condra illustrated and described in 1933 as *Tainoceras* sp., and the specimens from the Lower Permian (Wichita formation) of Texas which Hyatt illustrated and described in 1893 and erroneously referred to *T. quadrangulum* (McChesney). *T. wyomingense* is readily distinguished from all of these forms by means of the shape of the cross section of its conch and the size, shape, and position of the nodes.

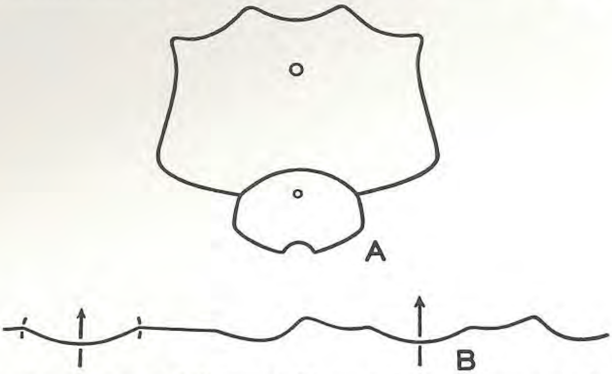


FIG. 3—*Tainoceras wyomingense* Miller and Thomas, n. sp. Diagrammatic cross section of ultimate and penultimate volutions of conch, and diagrammatic representation of a mature suture, both ×1. B is based on specimen represented by figure 3 on plate 98, whereas A is a composite figure and is based on specimens represented by figures 3 and 4 on plate 98. Both of these specimens are syntypes.

In 1893 Hyatt stated that during ontogenetic development representatives of *Tainoceras* pass through first a *Temnocheilus* and then a *Metacoceras* stage before assuming their own generic characters. *T. wyomingense* passes through a *Metacoceras* stage during late adolescence but its early adolescent stage (with subelliptical conch and low lateral nodes) is not at all like *Temnocheilus* but is reminiscent of *Endolobus.*

Occurrence.—Abundant in *Stenoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Syntypes.—Univ. Iowa, nos. 1159–1163.

Genus STENOPOCERAS Hyatt

STENOPOCERAS ABUNDUM Miller and Thomas, n. sp.

Plate 98, figures 7–10; Plate 99, figures 1, 2

Ammonoid indet. GIRTY, 1908, Geol. Soc. America, Bull., vol. 19, p. 429.

Our collections from the Casper contain some 45 specimens that are referable to the genus *Stenopoceras*, but all of these seem to represent only one species. Most of them are rather incomplete and fragmentary, but they supplement one another very well and a great deal of detailed information can be gleaned from them.

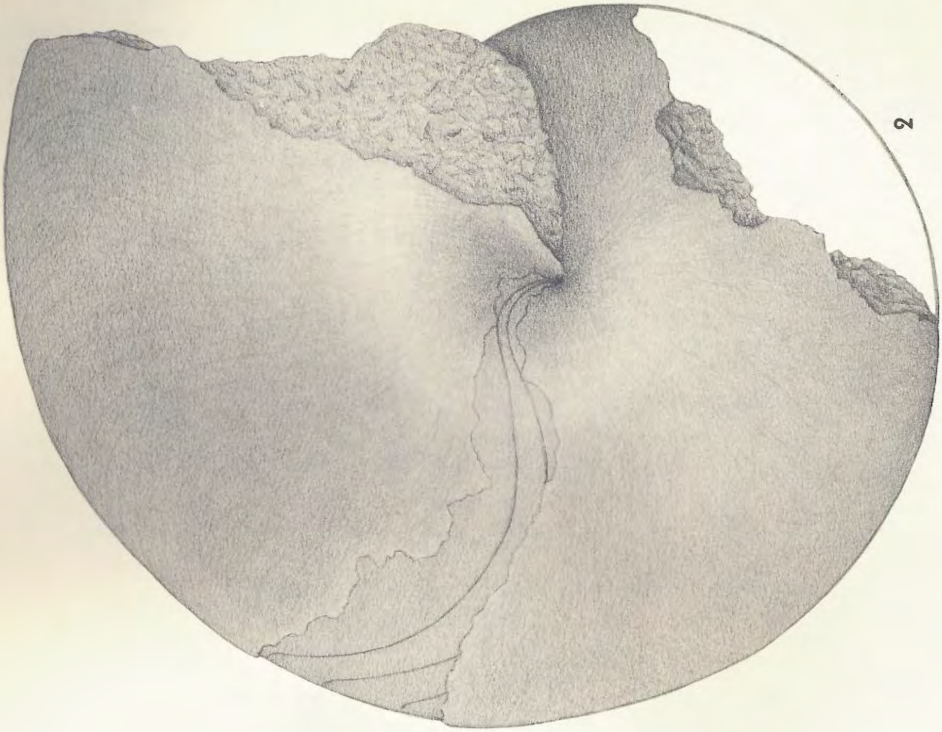
Conch which forms at least three volutions, at maturity is sublenticular in shape, nautiliconic in its mode of growth, and large, attaining a maximum diameter (measured across the umbilicus) of more than 125 mm., and a maximum height and width of conch of at least 70 mm. and 35 mm., respectively. Extreme adapical portion of conch is circular (or essentially so) in cross section, but dorsoventral diameter of conch is increased much more rapidly than lateral diameter and very early in its ontogenetic development conch becomes oval in cross section, being much more narrowly rounded ventrally than dorsally. Following this stage of development, dorsal side of conch becomes flat, and before conch has completed the first half-volution its dorsal side is distinctly concave (see text figure 4A). At first the dorsal concave zone is broad, shallow, and broadly rounded, but it becomes progressively deeper and relatively narrower, and by the time the conch has completed one and one-half volutions it is impressed dorsally to almost two-fifths its height (pl. 98, fig. 8). It should be stated unambiguously that a dorsal concave zone is developed long before the conch completes one volution and becomes involute; that is, it almost seems as though an impressed zone is developed before it is needed. After the conch has completed about one volution, its broad lateral walls become noticeably more and more flattened; and its ventral side, which has become very narrow, is also gradually flattened and ultimately (after conch has reached a height of about 35 mm.) it becomes concave. The lateral walls of the conch converge ventrally and the cross section of the whorls is cordate during adolescence but subsagittate (though slightly concave ventrally) at maturity. Apertural margins are not preserved on any of our specimens, but living chamber is at least one-fourth of a volution in length.

At maturity umbilicus is small and closed, and the umbilical shoulders are broadly rounded and very indistinct. During early growth stages the umbilicus is small but perforate, the umbilical perforation being oval in shape and, after the conch has completed one volution, about 4 mm. long and 3 mm. wide. During the next half-volution the umbilicus appears to become smaller; then it seems to become larger, only to be closed rather abruptly after the conch has completed a little more than two volutions (pl. 98, fig. 7).

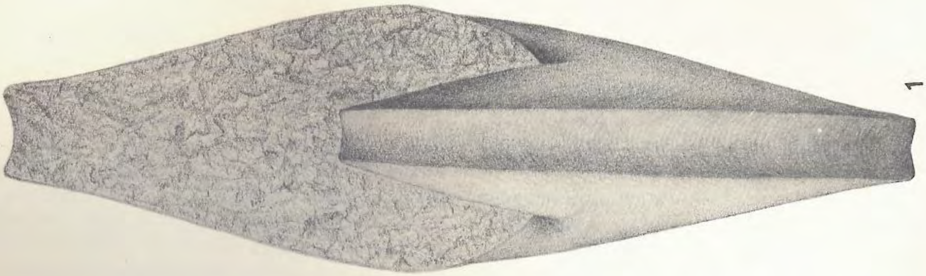
Test thin, and even on large mature specimens it does not seem to have been more than 1 mm. thick. Surface of test smooth and marked only by growth-lines, which are fine and though very distinct are not particularly prominent. At full maturity each growth-line forms a deep rounded ventral sinus, a shallower rounded ventro-lateral salient (which centers on the ventral portion of the flattened lateral side of the conch, a

EXPLANATION OF PLATE 99

FIGS. *1, 2*—*Stenopoceras abundum* Miller and Thomas, n. sp. Ventral and lateral views (somewhat restored) of a large mature specimen (a syntype) from the *Stenopoceras* beds of the Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming, ×1. [See pl. 98, figs. 7–10.] (p. 734)



2



1

Miller and Thomas, Pennsylvanian Cephalopods

broad shallow broadly rounded lateral sinus, and a similar but smaller dorso-lateral salient which centers slightly dorsad of the umbilical shoulders (pl. 99, figs, 1, 2). On the penultimate volution of the conch the growth-lines are in general similar to those on the ultimate volution but the lateral sinus is relatively narrow and the ventro-lateral salient is relatively broad.

Septa rather close together and camerae therefore numerous and rather short (pl. 99, fig. 2). At maturity each suture forms a high rather narrow ventral saddle in the center of which there is a shallow broadly rounded lobe which results from the concavity of the ventral side of the conch, and on each side of it there is a broad deep gently rounded lateral lobe, a much smaller rounded dorso-lateral saddle which centers on the umbilical wall, a similar but slightly smaller lobe which centers on the umbilical seam, and a similar internal lateral saddle which extends to the dorsal lobe. The dorsal lobe is moderate in size and it is depressed-V-shaped but truncated.

Siphuncle small, circular in cross section, and intermediate in position. Where the conch is about 35 mm. high the siphuncle is about 1 mm. in diameter and is located about 1 mm. from the venter. Unfortunately, we were not able to determine the structure of the siphuncle.

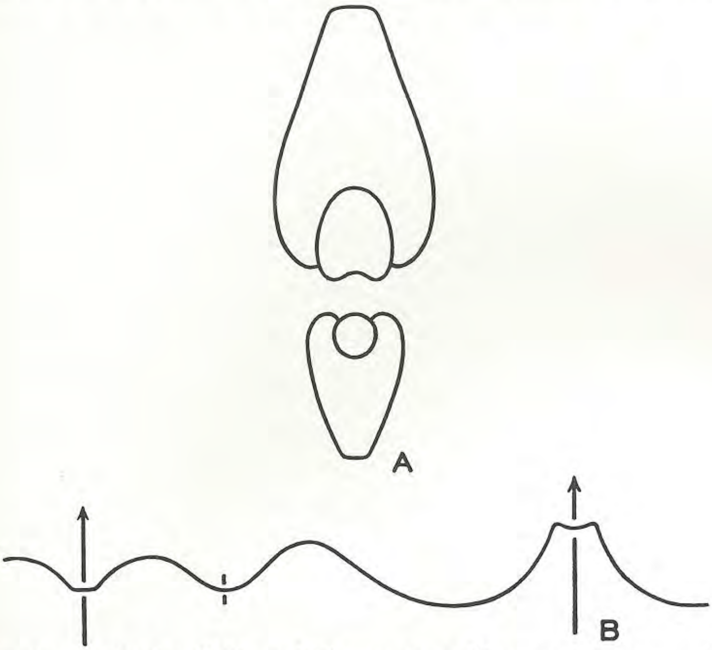


FIG. 4—*Stenopoceras abundum* Miller and Thomas, n. sp. Diagrammatic cross section of early volutions of conch, $\times 1\frac{1}{2}$, and diagrammatic representation of a mature suture, $\times 1$, both based on syntypes.

Remarks.—Only a few representatives of *Stenopoceras* have been mentioned in the literature. These came from the Fort Riley limestone (Lower Permian) of Kansas, some unrecorded horizon and locality in Texas, the Pennsylvanian of Nebraska, the Upper Pennsylvanian (Abo ?) of New Mexico, and the Upper Carboniferous of central European Russia. The umbilici of all of these forms have been described as being not closed, but those of *S. dumbli* (Hyatt) of Kansas and Texas (?) and *S. tularosense* Miller are small; the nature of the umbilicus of *S. tularosense* at full maturity is not known, and as the umbilicus of the holotype of that species, a moderate-sized specimen, "becomes relatively smaller in the later stages of growth," it may be closed during late maturity. At any rate, the species under consideration seems to be rather close to *S. dumbli* and *S. tularosense*, and it may be closer to the latter than the former. The ventral portion of the conch of *S. rouillieri* (de Koninck) is angular at maturity, and that species does not appear to be particularly close to *S. abundum*. The Texas and Nebraska representatives of *Stenopoceras* have never been described or illustrated and therefore comparisons with them are not possible.

Dr. N. D. Newell of the Kansas Geological Survey recently sent us for comparison an undescribed representative of *Stenopoceras* from the Lower Permian Florena shale of Cowley County, Kansas. In general physiognomy this specimen is closely similar to the Casper form, but apparently it is not conspecific with it. The umbilicus of the Florena specimen is quite small, but although the part of the conch (phragmacone) represented apparently attained a diameter of at least 45 mm., the umbilicus is not closed, and there is no good reason to assume that it was ever closed during ontogenetic development.

Dr. G. H. Girty kindly loaned us for study the specimen from the Casper formation in Gilmore Canyon which he identified in 1908 as "Ammonoid indet." It is a small fragment of a *Stenopoceras*, apparently conspecific with the form we are studying, though preserved in a different type of matrix. Traces of its sutures are discernible and the shape of the ventral and ventro-lateral portions of its conch can be determined quite accurately. The block of limestone in which it is imbedded contains small fragmentary specimens which appear to represent the genera *Pseudorthoceras* and *Metacoceras*.

Occurrence.—Abundant in *Stenopoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming; and it occurs at the same locality in the *Meekella* beds of the same formation, about 20 feet above the horizon in the *Stenopoceras* beds at which cephalopods are so abundant.

Syntypes.—Univ. Iowa, nos. 1164–1170.

Genus SOLENOCHILUS Hyatt

SOLENOCHILUS cf. S. BRAMMERI Miller, Dunbar, and Condra

Plate 98, figures 1, 2

We have five specimens from the Casper that are referable to *Solenochilus*. All of these are rather fragmentary and incomplete but they appear to be conspecific. In so far as we have been able to ascertain they do not differ materially from *S. brammeri* Miller, Dunbar, and Condra, but the largest of them, which, however, does not represent the adoral portion of the conch, is considerably smaller than the holotype of that species. Furthermore, the fragmentary nature of our specimens prevents us from referring them definitely to any species. The most nearly complete of the five, which is also the smallest, is here figured.

Conch, which apparently consists of only a very few volutions, is subglobular, nautiliconic, and moderately large. Phragmacone attains a maximum diameter, measured across the umbilicus, of more than 100 mm. Whorls rapidly expanded orad, depressed dorso-ventrally, about half as high as wide, and subrectangular in cross-section though somewhat impressed dorsally. Ventral side of conch is very broadly rounded, ventrolateral zones are rounded, and lateral sides are nearly straight and almost parallel. On adapical portion of figured specimen dorso-lateral zones of conch are rounded but near mid-length of this specimen a subangular dorso-lateral keel is developed on the umbilical shoulder, and in the larger specimens this keel becomes very prominent and the umbilical shoulders are flared; the zones immediately ventrad of the umbilical shoulders are then concave. The umbilicus appears to be relatively small, but its diameter can not be ascertained from our specimens.

Test rather thin, and that of specimens somewhat larger than figured specimen is slightly less than 1 mm. thick. Surface of internal mold smooth, and test appears to be marked by only growth-lines. Traces of growth-lines preserved on our specimens indicate that flared umbilical shoulders project slightly forward at apertural margins as low subangular or very narrowly rounded salients, and that there are broad very shallow broadly rounded sinuses along concave zones just ventrad of umbilical shoulders and similar but broader salients along ventrolateral zones of conch; the course of growth-lines across ventral side of conch can not be ascertained from our specimens.

Camerae are moderate in length, and along venter distance between successive sutures is equal to about one-fourth width of conch. Each suture forms a broad very low broadly rounded ventral lobe and on each side of it there is a similar but somewhat deeper and less broadly rounded ventro-lateral saddle; sutures are nearly straight or only very slightly convex apicad on lateral walls of conch.

Siphuncle small, circular in cross section, ventral and marginal in position, and orthochoanitic in structure. Its diameter is equal to about one-twentieth of the width of conch. Septal necks are about two-fifths as long as camerae, and connecting rings are cylindrical in shape.

Remarks.—The genus *Solenochilus* is known to be widespread in both Europe and North America, and stratigraphically it ranges at least from the Lower Mississippian to the Lower Permian. It does not seem to be abundantly represented at any horizon or any locality, but the majority of the known representatives of it come from the Carboniferous. The similarity of the above-described specimens to the types, particularly the juvenile paratype, of *S. brammeri*, which came from the Upper Pennsylvanian (Kansas City) Argentine limestone of Nebraska, may not be very significant, for none of the known representatives of this genus differ greatly from *S. brammeri*. *S. kentuckiensis* Hyatt of the Lower (?) Pennsylvanian of Edmonson County, Kentucky, also seems to be very similar to it. Many of the described species of *Solenochilus* are based on such fragmentary specimens that adequate comparisons are not possible.

Occurrence.—*Stenopoceras* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming.

Figured specimen.—Univ. Iowa, no. 1171.

TRILOBITA

Genus AMEURA J. M. Weller

Plate 96, figures 8, 9

Trilobites are rare in the Casper, and we obtained only three specimens, all of which appear to be conspecific. They are moderately well preserved but they represent only pygidia. The largest of the three, which is rather fragmentary, is about 20 per cent wider than the figured specimen, whereas the smallest specimen is only about three-fourths as large as the one figured.

Dr. J. Marvin Weller has kindly examined our specimens and has written us that they belong to a new genus which is represented by the form commonly identified as *Phillipsia major* Shumard. He further states that our specimens

> most closely resemble a new species . . . from the Luta and Fort Riley limestones of Kansas, but are a little larger and have fewer pleural segments (10 instead of 12).

In regard to the stratigraphic significance of our specimens, Doctor Weller states that their relatively small number of pleural segments leads him to suspect that they are a little older than the Luta-Fort Riley species, of which the most characteristic part is the glabella, not represented by our specimens. Still, he has no congeneric forms from the uppermost Pennsylvanian, and he, therefore, concludes that he can give us

no more definite statement than that they [our specimens] are probably either lowermost Permian or uppermost Pennsylvanian.

Occurrence.—*Triticites* beds of Casper formation, in Gilmore Canyon, about 8 miles southeast of Laramie, Wyoming; and lower Casper limestone, near Sybille Springs, 30 miles north of Laramie, Wyoming.

Figured specimen.—Univ. Iowa, no. 1173.

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