

Brachiopods from the Serpukhovian Tonka Formation of Carlin Canyon, Elko, Nevada (USA): Systematics and biostratigraphy

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Abstract

Systematic study of a brachiopod assemblage from the Upper Mississippian Tonka Formation in Carlin Canyon, Elko, Nevada, USA, led to the recognition of 13 species, representing 12 genera and seven orders: ?*Antiquatonia* sp., *Flexaria* sp., ?*Marginatia* sp., *Echinoconchus* sp. of the Productida, ?*Orthotetes* sp. of the Orthotetida, *Rhipidomella* sp., *Schizophoria* sp. of the Orthida, *Cleiothyridina* cf. *sublamellosa* Hall, 1858, *Composita sulcata* Weller, 1914 of the Athyridida, *Anthracospirifer shawi shawi* Gordon, 1975, *Anthracospirifer* aff. *A. shawi* of the Spiriferida, *Punctospirifer* sp. of the Spiriferinida, and *Girtyella indianensis* Girty, 1909 of the Terebratulida, with the addition of one undetermined linoproductid and one genus and possibly two undetermined species of the Delthyridina. The assemblage shares affinities with upper Chesterian (middle Serpukhovian) *Carlinia phillipsi* and *C. amsdeniana* associations from western North American units, though the presence of *Composita sulcata* makes it also close to uppermost Chesterian faunas (*Rhipidomella nevadensis* and *Composita popsiensis* zones, upper Serpukhovian). The recorded faunal association, in terms of composition at the genus-level, is characteristic of brachiopod Unit 16 of Carter (1990a). Unit 16 spans the middle Chesterian (*Gnathodus bilineatus* conodont Zone) to upper Chesterian (*Rachistognathus muricatus* conodont Zone), corresponding to the upper Visean–Serpukhovian interval. A monospecific *Vogelnathus postcampbelli* conodont assemblage from the same locality confirms a late Chesterian (Serpukhovian) age of the fauna. © 2024 Elsevier B.V. and Nanjing Institute of Geology and Palaeontology, CAS. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Keywords: Chesterian; Carboniferous; brachiopods; conodonts; Mississippian correlation

1. Introduction

Brachiopods have played a significant role in the classification and correlation of Mississippian rocks of North America as they are abundant and widely distributed across different regions and lithofacies (Angiolini et al., 2022a). Weller (1926) established a biostratigraphic zonation for the Mississippian region in the upper Mississippi Valley and the Midcontinent, primarily based on Lower and Middle Mississippian brachiopods. However, for the Upper Mississippian (Chesterian), the zonation relied on

echinoderms and bivalves. Correlation of Chesterian units across North America has proven to be particularly challenging for the high degree of endemism of Chesterian brachiopod faunas. As a result, various authors have developed their own regional zonation in different parts of western North America (e.g., Sadlick, 1955; Sando et al., 1969; Gordon and Duncan, 1970; Gordon, 1975; Smith and Ketner, 1975).

Dutro et al. (1979) attempted to synthesize these regional faunal schemes into a comprehensive brachiopod zonation for the Mississippian of North America. Their classification revised Weller's (1926) scheme for the Lower-Middle Mississippian, integrating it with three zones for the Chesterian named after brachiopod taxa from

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western North American units: *Striatifera* Assemblage Zone, *Spirifer brazerianus* Assemblage Zone, *Rhipidomella nevadensis* Assemblage Zone (Sadlick, 1955). However, the zonation by Dutro et al. (1979) is not easily applicable throughout North America, particularly in the Chesterian (Henry and Gordon, 1992).

Carter (1990a) proposed a different brachiopod zonation for the Mississippian of North America aimed to facilitate correlation across the continent. His zonation consisted of 17 units based on the stratigraphic range of 185 brachiopod genera. However, Carter's zonation heavily relied on his studies of the Lower-Middle Mississippian in the Midcontinent (e.g., Carter, 1967, 1968), and its accuracy for the Chesterian of western North America was limited due to endemism and the scarcity of data. Moreover, Carter's zonation was not calibrated with foraminiferal (Skipp and Mamet, 1970; Mamet et al., 1971) and conodont zones (e.g., Collinson et al., 1962; Poole and Sandberg, 1977, 1991; Abplanalp et al., 2009), which are widely used for correlation in different regions of North America. Carter (1990a, fig. 1) provided a correlation between his faunal units and lithostratigraphic units in the type Mississippian region.

This paper focuses on the systematic descriptions of a brachiopod assemblage collected from the Upper Mississippian Tonka Formation in Carlin Canyon, Elko, north-eastern Nevada, in October 2022 by LA and CH. Carlin Canyon is located near Carlin, renowned for its gold ores and its historical significance as part of the California Trail used by pioneers in the 19th century. Geologists have known about the Carboniferous–Permian succession in Carlin Canyon since the 19th century, primarily due to the presence of an impressive angular unconformity between Upper Pennsylvanian limestone and Mississippian to mid-Pennsylvanian sedimentary clastic rocks (Fig. 1A; McPhee, 1981; Trexler et al., 2003, 2004a, 2004b; Beauchamp et al., 2022). The Permian succession of Carlin Canyon and nearby area, first investigated by Fails (1960), has recently attracted considerable interest because a base-Kungurian GSSP candidate was identified at Rockland (Henderson et al., 2012) section, and possibly the Standard Auxiliary Boundary Stratotypes for the base-Sakmarian, base-Artinskian, and base-Kungurian at Carlin Canyon, Elko (Angiolini et al., 2022b).

The study of the collected brachiopod assemblage from the Tonka Formation provides the first systematic descriptions of this diverse fauna, which was only listed by previous studies (Dott, 1955; Smith and Ketner, 1975). Additionally, a small assemblage of conodonts collected from the same beds as the brachiopods allows for correlation with other units and zonations in North America. By comparing and correlating the studied assemblage with other coeval faunas in North America (e.g., Weller, 1914; Easton, 1962; Gordon, 1975; Butts, 2007), this paper contributes to the understanding of brachiopod distribution and Late Mississippian correlation in western North America.

2. Geological setting

The Carlin Canyon area is located in Nevada, in the Great Basin region of the Basin and Range Province, which records a complex geological evolution dating back to the Proterozoic. Several orogenic events affected the region from the Mississippian to the Cenozoic, such as the Antler, Sonoma, Nevadan, Sevier, and Laramide orogenies (Dickinson, 2006; Beranek et al., 2016). Superimposed on these is the late Cenozoic extensional tectonics, which produced the physiography of the Basin and Range (e.g., Wernicke, 1981).

The Lower Mississippian–Middle Permian succession belongs to the Antler Overlap sequence, which covers the Antler Belt formed during the Late Devonian–Early Mississippian by the collision of a magmatic arc with western Laurentia (Speed and Sleep, 1982). The succession was deposited in the Strathearn Basin, and it records several deformation events recognized in the Carlin Canyon area by distinct unconformities (Trexler et al., 2003, 2004a, 2004b). According to Beauchamp et al. (2022, and references therein), to which reference is made for a more detailed synthesis of the tectonic evolution of the region, the sequence has been lumped with other units in the Ely–Bird Spring Basin.

The Tonka Formation was defined by Dott (1955) in the Carlin Canyon area. Interbedded chert-quartzite-lithic conglomerate, sandstone, calcareous siltstone, marlstone, and sandy limestone characterize the Tonka Formation that crops out above an angular unconformity (C₂, Fig. 2A) on the turbidity current deposits of the Tournaisian–Visean Melandco Formation. The Tonka Formation was deposited in a marginal-marine deltaic setting (Trexler et al., 2004a, 2004b); conglomerate and sandstone preserve channel geometries and structures indicative of fluvial processes, while siltstone and carbonate lenses are interpreted as overbanks deposits and lagoonal facies. The siltstone and limestone units are fossiliferous with crinoids, brachiopods, corals, fenestellid bryozoans, gastropods, and bivalves (Dott, 1955, table I). The brachiopod assemblage under study was collected from the most fossiliferous part of the Tonka Formation, likely representing a maximum flooding interval (Fig. 1B).

Dott (1955), based on the brachiopod and bryozoan fauna considered the Tonka Formation as deposited around the Mississippian–Pennsylvanian boundary. The age was later confirmed by Smith and Ketner (1975), who, based on brachiopods, considered the Tonka Formation as ranging from the Visean to the Early Pennsylvanian. According to Trexler et al. (2004a) the Tonka Formation is middle-late Chesterian in age (late Visean–Serpukhovian). The Tonka Formation has been also called Diamond Peak Formation (Hague 1882, 1892) by some authors (e.g., Smith and Ketner, 1975), but this name should be restricted to fine clastic units in the eastern Great Basin in central Nevada (Trexler et al., 2003).

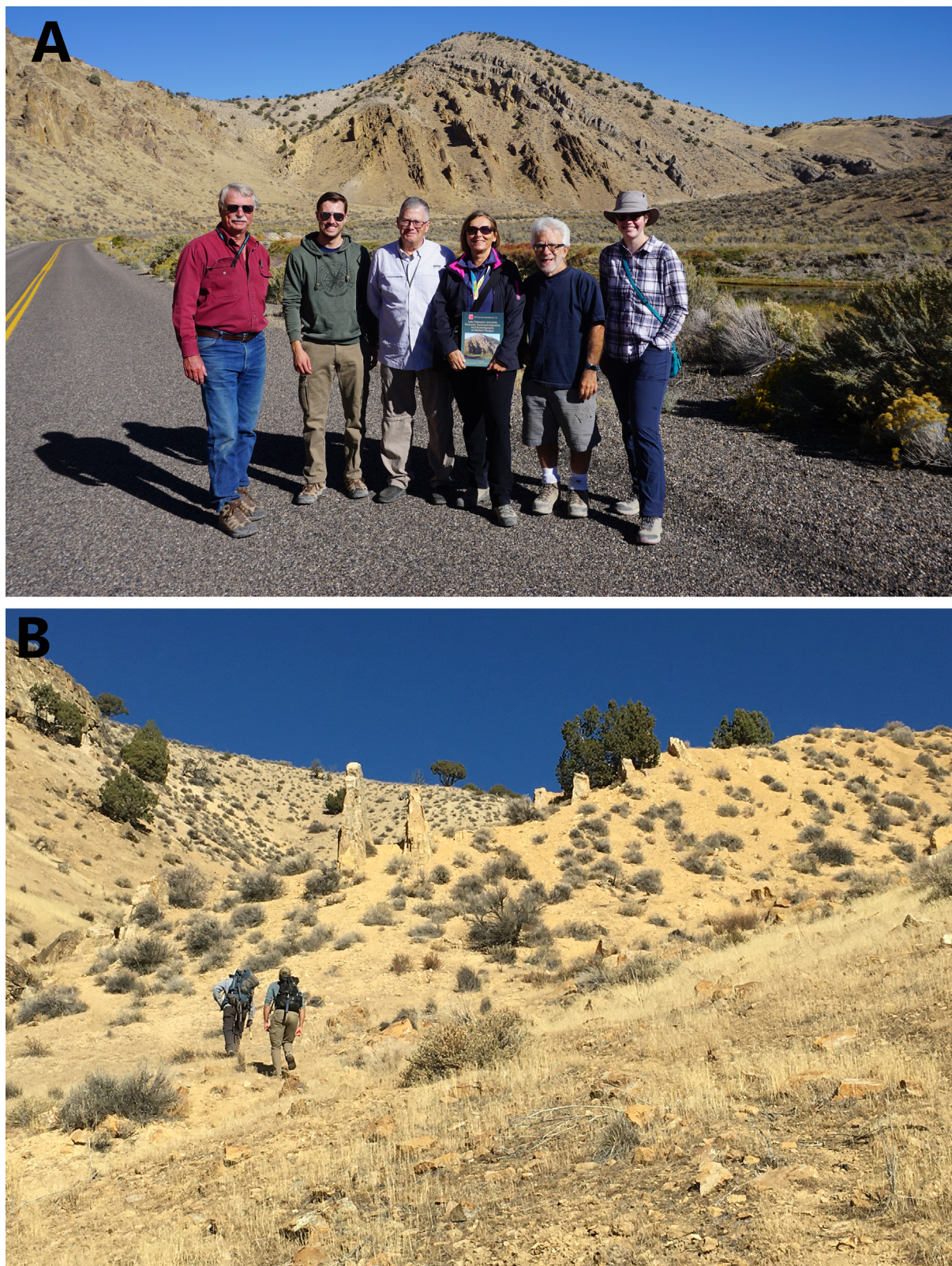


Fig. 1. Field photographs of Carlin Canyon, Elko, Nevada. (A) Panoramic view from Interstate 80 of the spectacular angular unconformity (C₆ of [Trexler et al., 2003, 2004a](#)) of Upper Pennsylvanian limestone (Strathearn Formation) overlying Mississippian to mid-Pennsylvanian sedimentary units (Tonka Formation and Ely Group) on the northwestern slope of Carlin Canyon. (B) The Tonka Formation on the northwestern slope of Carlin Canyon, underneath the C₆ unconformity. The two resistant beds just right of the gulley and strata in-between is the locality of sampling of the brachiopod and conodont assemblages under study.

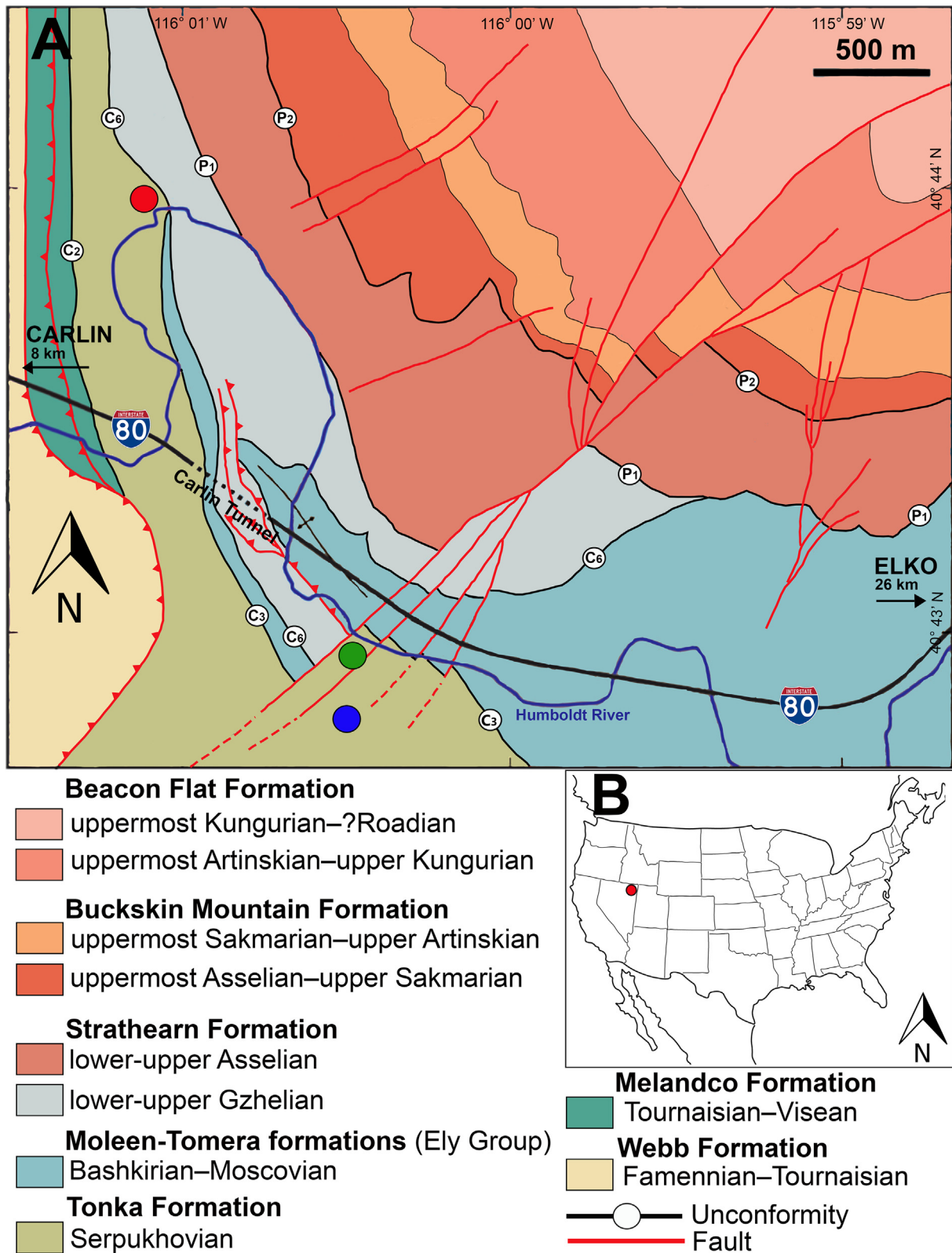


Fig. 2. Geographical and geological setting. (A) Geological map of study area in Carlin Canyon. Modified after [Beauchamp et al. \(2022\)](#). Red circle indicates the locality of sampling of the brachiopods and conodonts under study. Blue circle indicates the locality of provenance of the *Carlinia phillipsi* brachiopod assemblage collected by [Smith and Ketner \(1975\)](#), referred to the Late Mississippian. Green circle indicates the locality of provenance of the *Dictyoclostus coloradoensis* (= *Antiquatonia coloradoensis*) brachiopod assemblage collected by [Smith and Ketner \(1975\)](#), referred to the Lower Pennsylvanian. C₂ – middle Visean–late Visean unconformity; C₃ – Serpukhovian–Bashkirian unconformity; C₆ – Moscovian–early Gzhelian unconformity; P₁ – Gzhelian–early Asselian unconformity; P₂ – late Asselian–latest Asselian unconformity. (B) Geographical setting of the study area of Carlin Canyon in northeastern Nevada, USA.

3. Material and methods

The studied brachiopod assemblage consists of 53 specimens and fragments (Car5-2–54) collected at 40° 43'59.4"N, 116°01'13.6"W from two steeply dipping yellowish bioclastic marlstone beds in upper Tonka Formation (Fig. 1B), which are truncated below the C₆ unconformity by the lower member of the Strathearn Formation, along the Humboldt River in Carlin Canyon, north of the Interstate I-80, Elko, Nevada, USA (Fig. 2).

Brachiopod specimens were prepared for study with compressed air powered scribes in the laboratory of the Department of Earth Sciences “Ardito Desio” of the University of Milan. After systematic description and identification, the specimens were coated with smoked ammonium chloride and photographed with Nikon D3100 camera, with Nikon micro nikkor 105 mm macro lenses, under Kaiser rb 5000 dl lights on an IFF Super Repro copy stand.

Brachiopod supra-generic classification follows Brunton et al. (2000) for the Productida, Williams and Harper (2000) for the Orthotetida, Williams and Harper (2000) for the Orthida, Alvarez and Rong (2002) for the Athyridida, Carter et al. (2006) for the Spiriferida, Carter and Johnson (2006) for the Spiriferinida, and Lee et al. (2006) for the Terebratulida. Morphological terminology follows Williams and Brunton (1997).

The studied fossil brachiopod specimens are curated in the Palaeontological Museum of the Department of Earth Sciences “A. Desio” of the University of Milan, Milano (Italy), and registered with the prefix MPUM.

Two conodont samples (UC1352-26 and UC1352-28) were collected from two resistant bioclastic limestone beds in May 2016 by CMH, in the same locality as the brachiopods (Fig. 1B). The two samples weighed 5.47 and 4.35 kg respectively and both yielded a few conodont specimens and fish teeth. Processing of the samples started with crushing to 1 cm size and then dissolution in a 10% acetic acid solution over a two week period. The insoluble residue was washed and boiled in bleach for two hours to remove modern organic fibres. The insoluble residue was washed again and the 75 µm to 1.18 mm fraction was dried and then separated in heavy liquid at a specific gravity of 2.86. The heavy fraction was picked using a fine brush under a binocular microscope. The illustrated specimens were photographed with a back scatter detector on a tabletop SEM. The illustrated specimens are all from UC1352-26, which is from the higher of the two beds, and are stored at the Department of Earth, Energy and Environment collections, University of Calgary, Calgary (Alberta), on a micropaleontology slide with that label.

4. Brachiopod assemblage

The studied brachiopod assemblage comprises 13 species, representing 12 genera and seven orders: Productida (?*Antiquatonia* sp., *Flexaria* sp., ?*Marginatia* sp., *Echino-*

conchus sp.), Orthotetida (?*Orthotetes* sp.), Orthida (*Rhipidomella* sp., *Schizophoria* sp.), Athyridida (*Cleiothyridina* cf. *sublamellosa* Hall, 1858; *Composita sulcata* Weller, 1914), Spiriferida (*Anthracospirifer shawi shawi* Gordon, 1975; *Anthracospirifer* aff. *A. shawi*), Spiriferinida (*Punctospirifer* sp.), and Terebratulida (*Girtyella indianensis* Girty, 1909). Two small, poorly preserved linoproductoid ventral valves (Fig. 7G) and one undetermined genus and possibly two undetermined species of the Delthyridina were also identified.

Most productides and spiriferides in the assemblage are disarticulated, whereas athyridides occur as both articulated and disarticulated specimens. The articulation ratio for the total assemblage is 41.3%. Specimens commonly show shell abrasion, while the only species characterized by high degree of bioerosion is *Composita sulcata*, whose shells are characterised by irregular sinuous furrows possibly caused by bryozoans (Fig. 8C). No trace of predation was detected unless for one circular drill hole in the posterior part of the ventral valve of an articulated specimen of *Cleiothyridina* cf. *sublamellosa*, possibly made by a predator (cf. Hoffmeister et al., 2003; Mottequin and Sevastopulo, 2009). Specimens are frequently crushed and broken by compaction.

The assemblage comprises: (1) spinose, concavo-convex productides adapted to a semi-infaunal life-style on soft muddy substrates (e.g., Muir-Wood and Cooper, 1960; Thayer, 1975; Leighton et al., 1996); (2) ambitopic orthotetides, orthides, spiriferides, athyridides (*Cleiothyridina* cf. *sublamellosa*), and spiriferinides with morphologies with high surface/volume ratio, which lived free on the sea floor in the adult stage (Legrand-Blain, 1986; Harper and Jeffrey, 1996; Carniti et al., 2022); (3) pedicle-attached athyridides (*Composita sulcata*) and terebratulides adapted to a wide range of substrates (Brunton, 1987; Richardson, 1997).

The studied brachiopod assemblage also shows diverse suspension-feeding strategies with both productides with simple feeding mechanism with cilia attached to the dorsal brachial ridges (Muir-Wood and Cooper, 1960), orthotetides and orthides with simple lophophores, and athyridides, spiriferides, spiriferinides, and terebratulides with complex lophophores (Richardson, 1997). Taxa with a complex lophophore show a transverse shape and uniplacate commissure (*Composita sulcata*, *Anthracospirifer shawi shawi*, *Anthracospirifer* aff. *A. shawi*, *Punctospirifer* sp.), growth strategies addressed to increase the food-uptake area (cf. Viaretti et al., 2022) as well to avoid sinking on muddy substrates. All these groups were growing to similar medium-size (12–30 mm; see 8. Systematic palaeontology), with just some terebratulides and athyridides being smaller (5–12 mm).

The taphonomic characters of the studied brachiopod assemblage are indicative of a transported assemblage (sensu Brenchley and Harper, 1998), probably transported during the formation of wash-over fans. The high diversity of the brachiopod palaeocommunity was sustained by a wide spectrum of substrates from which the brachiopods

were transported, from coarse mobile substrates (sandy shoals) favouring pedicle-attached brachiopods to soft muddy substrates (muddy lagoons) colonized by semi-infaunal productides. Also, food supply was likely variable, but not high and concentrated, as this condition would have favoured the growth to large size of brachiopods with a complex lophophore (Pérez-Huerta and Sheldon, 2006; Angiolini, 2007; Carniti et al., 2022), while in the studied assemblage these are of the same size as productides and show growth adaptations to increase their food-uptake area.

5. Brachiopod assemblage correlation and age

Dott (1955) and later Smith and Ketner (1975) reported faunal lists for various brachiopod assemblages from the Tonka Formation in the area of Carlin Canyon, Elko, Nevada. The brachiopod fauna collected by Smith and Ketner (1975) from marly limestone in the Tonka Formation in east Carlin Canyon, on the Humboldt River southern bank (Fig. 2A) shares affinity with the one under study. Smith and Ketner (1975) considered the fauna as representing the *Diaphragmus phillipsi* (Norwood and Pratten, 1855) (= *Carlinia phillipsi*) assemblage of late Chesterian age (middle Serpukhovian, possibly uppermost MFZ18, Mamet Foraminifer Zone, Mamet et al., 1971; Gordon, 1975; Fig. 5), based on the presence of *C. phillipsi* and *Kozlowskia* sp. The assemblage under study does not include species of *Carlinia* and *Kozlowskia*, but it is close to the *C. phillipsi* assemblage in having species of *Flexaria*, *Echinoconchus*, *Schizophoria*, *Cleiothyridina*, *Composita*, *Anthracospirifer*, and *Punctospirifer*. The complete faunal list of Smith and Ketner (1975) and the taxa collected from the same locality by Dott (1955) are provided in Table 1.

The brachiopod assemblage under study and the corresponding fauna described by Smith and Ketner (1975) have affinities with the upper Chesterian (middle-upper Serpukhovian) *Rhipidomella nevadensis* Zone defined by Sadlick (1955; Fig. 5) in the Manning Canyon beds of the eastern Great Basin, and reported in various units of Utah and Nevada (upper MFZ18–MFZ19; Gordon and Duncan, 1970; Dutro et al., 1979; Poole and Sandberg, 1991). To be noted that Dott (1955) listed *R. nevadensis* from the Tonka Formation of east Carlin Canyon, while the specimen identified as *Rhipidomella* sp. from the brachiopod assemblage under study clearly differs from *R. nevadensis* (see 8. Systematic palaeontology).

In the Lake Point Limestone of the Oquirrh Mountains, northwestern Utah, a fauna referred to the *Rhipidomella nevadensis* Zone by Gordon and Duncan (1970) includes *Inflatia* spp., *Flexaria* sp., *Carlinia phillipsi*, *Carlinia diabolica* Gordon, 1971, *Rhipidomella nevadensis*, *Schizophoria* cf. *texana* Girty, 1927, *Ovatia* sp., *Cleiothyridina* cf. *sublamellosa*, *Composita* sp., *Spirifer brazerianus* Girty, 1927, *Anthracospirifer* sp., and *Beecheria* sp. The *R. nevadensis* Zone occurs also in the Granite Mountain, Confusion Range, western Utah (Morrow and Webster, 1992), Bird

Spring Formation in southern Nevada (Lane, 1963; Gordon and Poole, 1968), and the Manning Canyon Formation of the Samaria Mountain, along the Idaho–Utah border (Beus, 1968).

The brachiopod assemblage under study shows many affinities with the latest Chesterian fauna (MFZ19) from the Arco Hills Formation of east-central Idaho studied by Butts (2005, 2007) and referred as well to the *R. nevadensis* Zone. The Arco Hills fauna consists of 23 species belonging to 15 genera, and it is dominated by species of *Composita* and *Anthracospirifer*, including *C. subquadrata* (Hall, 1858), close to *C. sulcata*, and *A. shawi shawi*.

The assemblage under study is also very close to the *Composita*–*Anthracospirifer* dominated brachiopod faunas studied by Gordon (1975) from the Amsden Formation of Wyoming, and in particular to the Upper Mississippian Horseshoe Member *Carlinia amsdeniana* Subzone (*Inflatia lovei* Gordon, 1975; *Carlinia amsdeniana* Gordon, 1971; *Composita sigma* Gordon, 1975; *Anthracospirifer welleri welleri* Branson and Greger, 1918; *A. shawi shawi*; *Orthotetes kaskaskiensis bransorum* Gordon, 1975; *Flexaria* sp.; *Cleiothyridina hirsuta darwiniensis* Gordon, 1975; *Girtyella* cf. *G. indianensis*) in Fremont County, west-central Wyoming. The subzone is late Chesterian in age (upper MFZ18; Fig. 5) and represents the lower subzone of the *Anthracospirifer welleri-shawi* Zone.

Affinity between the brachiopod assemblage under study and the one from the Upper Mississippian mixed siliciclastic-limestone Big Snowy Group of Central Montana (Easton, 1962) is good at generic level, the Big Snowy Group fauna also being dominated by *Composita* and *Anthracospirifer*, but the affinity is low at specific level.

The brachiopod assemblage under study shows affinities with late Chesterian faunas of the Mississippian type area of the Upper Mississippi Valley in Iowa, Illinois, and Missouri (Weller, 1914, 1916, 1926). Carter (1990a) identified 17 brachiopod units in the Mississippian of North America, mainly based on brachiopod generic ranges in the Upper Mississippi Valley. The brachiopod assemblage under study is close to the upper Chesterian (middle-upper Serpukhovian) Unit 16 as it includes ?*Antiquatonia* sp., whose range starts in this unit. Unit 16 correlates to the Elvira Group in the Mississippian type region (Carter, 1990a, fig. 1), which is late Viséan–Serpukhovian in age according to Brenckle et al. (1977), Baxter and Brenckle (1982) and Lane and Brenckle (2005), and middle-late Serpukhovian according to Kulagina et al. (2008) and Cózar et al. (2019). Additional data from the Upper Mississippi Valley in support of a late Chesterian age are the species of *Orthotetes*, which are common in the uppermost Chesterian (Carter, 1990a); *Cleiothyridina sublamellosa* and *Composita sulcata* (Weller, 1914) which are common in the upper Chester Group of Illinois (Weller, 1926). *Girtyella indianensis* was considered characteristic of the Ste. Genevieve Limestone (lower Chesterian, Aretz et al., 2020; Angiolini et al., 2022a), but the species

Table 1

Faunal list of brachiopod assemblage from the Tonka Formation in northwest Carlin Canyon, Elko, Nevada, Humboldt River northern bank provided in this study, and faunal lists from the Tonka Formation in east Carlin Canyon, Humboldt River southern bank, by [Dott \(1955\)](#) and [Smith and Ketner \(1975\)](#) (Fig. 2A).

	This study	Dott (1955)	Smith and Ketner (1975) (<i>C. phillipsi</i> assemblage)
Chonetida			
<i>Neochonetes</i> (N.) cf. <i>granulifer</i> (Owen, 1852)		<i>Chonetes granulifer</i>	<i>Neochonetes</i> sp.
Productida			
<i>Inflatia</i> cf. <i>inflata</i> (McChesney, 1859)		<i>Dictyoclostus</i> cf. <i>D. inflatus</i>	<i>Inflatia</i> sp. A
<i>Carlinia phillipsi</i> (Norwood and Pratten, 1855)			<i>Diaphragmus phillipsi</i>
<i>Carlinia</i> aff. <i>phillipsi</i>			<i>Diaphragmus</i> n. sp. aff. <i>phillipsi</i>
<i>Kozłowska</i> sp.			X
? <i>Antiquatonia</i> sp.	X		
<i>Flexaria</i> sp.	X		X
? <i>Marginatia</i> sp.	X		<i>Inflatia</i> sp. B
<i>Echinoconchus</i> sp.	X	X	X
<i>Linoproductoidea</i> gen. et sp. indet.	X		<i>Ovatia</i> sp. A, sp. B
<i>Heteralosia</i> sp.			X
Orthotetida			
? <i>Orthotetes</i> sp.	X		<i>Schuchertella</i> sp.
Orthida			
<i>Rhipidomella</i> sp.	X	<i>R.</i> cf. <i>burlingtonensis</i> Hall, 1858	
<i>Schizophoria</i> sp.	X	<i>Schizophoria</i>	<i>Schizophoria</i> cf. <i>resupinoides</i> (Cox, 1857)
Rhynchonellida			
<i>Camarotoechia</i> sp.		X	X
Athyridida			
<i>Cleiothyridina</i> cf. <i>sublamellosa</i> (Hall, 1858)	X	<i>Cleiothyridina</i>	<i>Cleiothyridina</i> aff. <i>C. suborbicularia</i> (Hall, 1858)
<i>Composita sulcata</i> Weller, 1914	X	<i>Composita</i>	<i>Composita</i> sp.
<i>Nucleospira</i> sp.			X
Spiriferida			
<i>Anthracospirifer shawi shawi</i> Gordon, 1975	X	<i>Spirifer</i> aff. <i>opimus</i> Hall, 1858 (= <i>Anthracospirifer opimus</i>)	<i>Anthracospirifer</i> sp.
<i>Anthracospirifer</i> aff. <i>shawi</i> Gordon, 1975	X		
<i>Torynifer</i> cf. <i>setiger</i> (Hall)			X
<i>Delthyridina</i> gen. et sp. indet.	X		
Spiriferinida			
<i>Punctospirifer</i> sp.	X	X	<i>Punctospirifer transversus</i> (McChesney, 1859)
<i>Reticulariina spinosa</i> (Norwood and Pratten, 1855)			X
Terebratulida			
<i>Girtyella indianensis</i> (Girty, 1909)	X		<i>Beecheria?</i> sp.

was extensively recorded throughout the Osagean–upper Chesterian of North America ([Weller, 1931](#); [Maples and Waters, 1987](#); [Carter and Carter, 1970](#), and references therein).

There seems to be a clear distinction between Mississippian and Pennsylvanian brachiopod faunas in North America, with a few species ranging through the boundary

([Easton, 1962](#); [Gordon, 1975](#); [Sando et al., 1975](#); [Carter, 1990a](#)). The brachiopod assemblage under study includes some taxa ranging into the Lower Pennsylvanian (*Flexaria* sp.; *Composita sulcata*). However, it differs from Pennsylvanian faunas in western USA, such as the fauna described by [Pérez-Huerta \(2006\)](#) from lower Bashkirian–upper Moscovian units in the Great Basin, in lacking any species

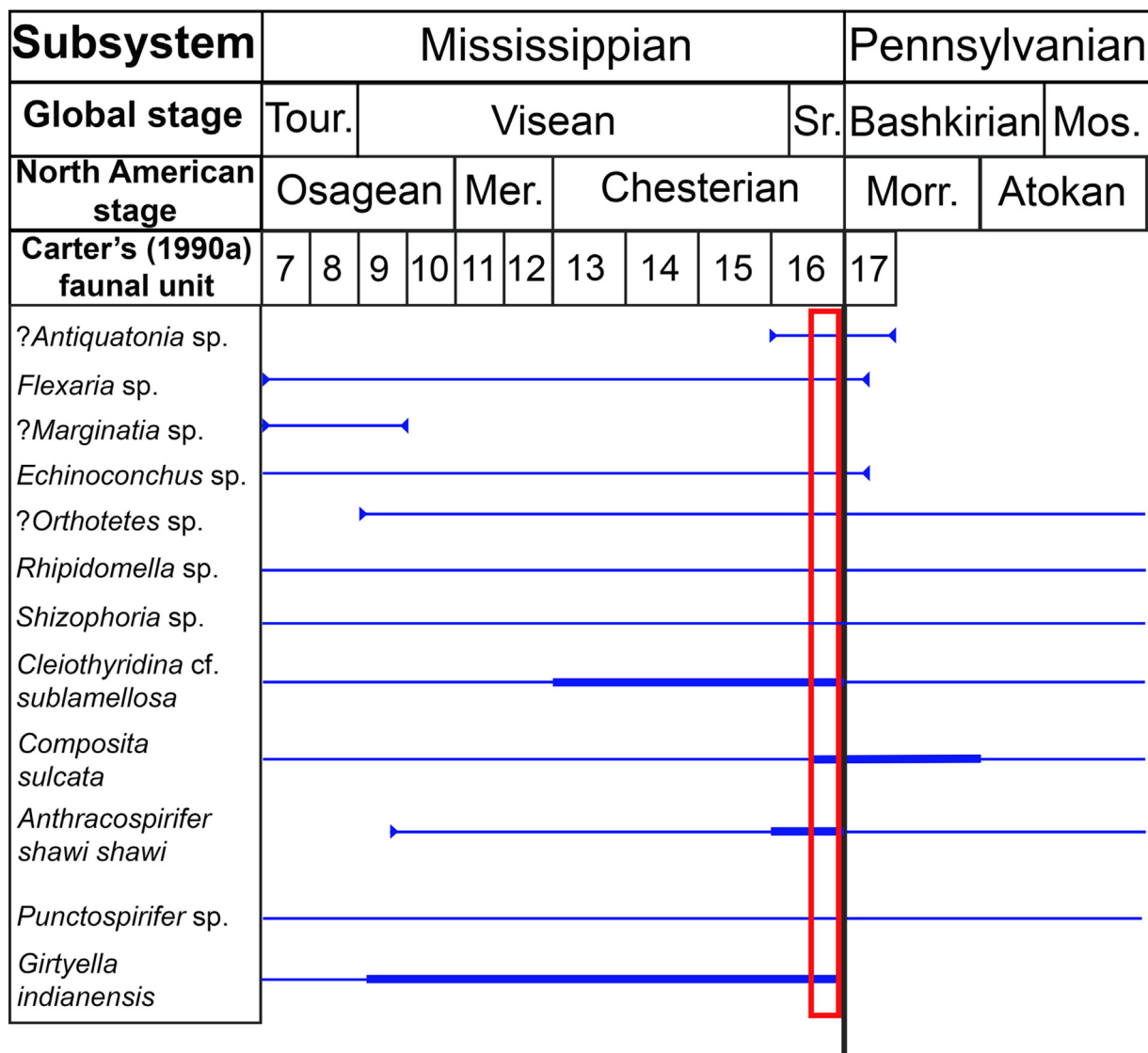


Fig. 3. Range chart for genera and species in the brachiopod assemblage under study from the Tonka Formation in northwest Carlin Canyon correlated with brachiopod units of Carter (1990a), Mississippian American and global stages. Unit 8 corresponds with the upper Burlington Limestone Formation (Carter, 1990a, fig. 1), and thus its upper boundary correlates with the Tournaisian–Visean boundary (cf. Lasemi et al., 1998, 2003). Generic and specific ranges from Carter and Carter (1970), Gordon (1975), Carter (1990a) and Pérez-Huerta (2006). The thicker line indicates the range of the species, the thinner the range of the genus. Base of the Serpukhovian plotted according to Lane and Brenckle (2005). Abbreviation: Tour. – Tournaisian; Sr. – Serpukhovian; Mos. – Moscovian; Mer. – Meramecian; Morr. – Morrowan.

of *Rugoclostus*, *Echinaria*, *Juresania*, *Linoproductus*, and *Neospirifer* (Gordon and Duncan, 1970; Gordon, 1975; Carter, 1990a; Pérez-Huerta, 2006). These genera characterize the lower Bashkirian *Antiquatonia coloradoensis* association in the Carlin Canyon (Smith and Ketner, 1975) and lower Bashkirian *Rugoclostus* Zone of the Oquirrh Mountains (Gordon and Duncan, 1970) and the Granite Mountain (Morrow and Webster, 1992) in Utah, as well as the lower Morrowan (lower Bashkirian) *Antiquatonia blackwelderii* (Gordon, 1975) Zone of the Amsden Formation in Wyoming (Gordon, 1975; Sando et al., 1975). Lower Pennsylvanian faunas also host abundant specimens of species of *Composita* and *Anthracospirifer*, but the typi-

cal Pennsylvanian species of *Anthracospirifer* (*A. birdspringensis* Lane, 1963; *A. curvilateralis* Easton, 1962; *A. occiduus* Sadlick, 1860; *A. opimus* Hall, 1858; *A. rawlinsensis* Gordon, 1975) show a pattern of bifurcation of ribs on flanks more developed than in *A. shawi* (Gordon, 1975; Pérez-Huerta, 2006), which is the species that characterizes the assemblage under study.

Species recorded in the brachiopod assemblage under study are restricted to North America. The genus *Flexaria* is restricted to North America (Muir-Wood and Cooper, 1960; Brunton et al., 2000), while *Anthracospirifer* is only rarely recorded outside the Americas (e.g. Libya, Mergl and Massa, 2000). The assemblage under study shares

some affinity at the generic level with the basal Itaituba Formation of the Amazon Basin, Brasil (Chen et al., 2005), which also hosts *Rhipidomella*, *Schizophoria*, *Anthracospirifer*, *Punctospirifer*, and *Composita*. This roughly confirms the affinity between Mississippian brachiopod faunas of western United States and the Amazon Basin (Langenheim, 1991; Chen et al., 2005). Overlap of generic and species ranges from the literature (e.g., Carter and Carter, 1970; Gordon, 1975; Carter, 1990a; Pérez-Huerta, 2006) for the brachiopod assemblage under study indicates a late Chesterian age (middle-late Serpukhovian; Fig. 3). However, typical Chesterian genera such as *Diaphragmus* and *Inflatia* are missing from the assemblage. The species with the most restricted range in the assemblage under study is *Composita sulcata*, a species occurring in the Amsden Formation in the upper Chesterian *Composita popsiensis* Subzone (uppermost MFZ18–MFZ19; Figs. 3, 5).

6. Conodont assemblage

The conodont assemblage is of low diversity consisting only of *Vogelgnathus postcampbelli* (Austin and Husri, 1974) (Fig. 4A–C). Actinopterygian fish teeth are common in the sample as well (Fig. 4D, E).

In the USA Midcontinent shallow-water faunas comprise *Hindeodus*, *Cavusgnathus*, and *Vogelgnathus*. As is typical of shallow-water conodonts, species tend to have long ranges and occur within low diversity assemblages. According to Barrick et al. (2022) *Vogelgnathus campbelli* (Rexroad, 1957; Norby and Rexroad, 1985) first occurs within Faunal Unit 10 (uppermost Viséan) of Lane and Brenckle (2005). Purnell and von Bitter (1992) demonstrated a phylogenetic lineage including *V. postcampbelli* developing from *V. campbelli* by suppression of posterior denticles; they indicated that *V. postcampbelli* occurred

within the British substage Brigantian (corresponding to the upper Viséan according to Aretz et al., 2020; Lucas et al., 2022 and to uppermost Viséan–lower Serpukhovian according to Cózar and Somerville, 2014, Sevastopulo and Barham, 2014, Barrick et al., 2022). The upper limits of the ranges of these species are poorly constrained but, according to Purnell and von Bitter (1992), are associated with *Adetognathus unicornis* in Arkansas (FU 12 of Lane and Brenckle, 2005; Serpukhovian; Fig. 5).

7. Conclusions

In conclusion, the brachiopod assemblage under study is close to the upper Chesterian (upper MFZ18, middle Serpukhovian, Upper Mississippian; Fig. 5) *Carlinia phillipsi* assemblage of the Great Basin and *Carlinia amsdeniana* Subzone of Wyoming, and it is correlative with Carter's (1990a) upper Chesterian Unit 16. The assemblage has some affinities with the uppermost Chesterian (uppermost MFZ18–MFZ19, Upper Mississippian) *Rhipidomella nevadensis* Zone of the Great Basin and *Composita popsiensis* Subzone of Wyoming, though it lacks specimens of *R. nevadensis*. The brachiopod assemblage is thus of late Chesterian age (upper MFZ18–lower MFZ19, middle-late Serpukhovian).

The associated conodont assemblage is represented by *Vogelgnathus postcampbelli* only, a species that occurs in the upper Viséan–Serpukhovian of North America. The late Chesterian (middle-late Serpukhovian) age of the brachiopod assemblage is thus supported. This study allows to correlate Carter's (1990a) brachiopod Unit 16 with the conodont and brachiopod zones defined from various regions of North America (Fig. 5; Gordon, 1975; Dutro et al., 1979): Unit 16 spans in western North America the upper Chesterian, corresponding to the upper Viséan Upper *Cavusgnathus*–*G. bilineatus* conodont Zone to upper Ser-



Fig. 4. Conodonts and fish teeth from the Tonka Formation, Upper Mississippian, Carlin Canyon, Elko, Nevada. (A–C) *Vogelgnathus postcampbelli* (Austin and Husri, 1974). (D, E) Two actinopterygian fish teeth. SEM photographs using BSD; all specimens are from sample UC1352-26.

Global stage	North American stage	Western European conodont zone	Western North American conodont zone	<i>V. postcampbelli</i> range	Brachiopod fauna	Global stage
Bashkirian (pars)	Morrowan (pars)	<i>Id. sinuatus</i>	<i>N. symmetricus</i> (pars)	V. postcampbelli North America	C. phillipsi assemblage R. nevadensis Zone C. amdeniana Subzone C. poposiensis Subzone Carter Unit 16 This study	Bashkirian (pars)
Serpukhovian	Chesterian	<i>D. noduliferus</i>	<i>Id. sinuatus</i>			Serpukhovian
		<i>G. postbilineatus</i>	<i>D. noduliferus</i>			
		<i>Gnathodus bollandensis</i>	<i>Rh. muricatus</i>			
		<i>Gnathodus bollandensis</i>	<i>Adetognathus unicornis</i>			
Visean (pars)		<i>Lochriea ziegleri</i>	<i>Cavusgnathus naviculus</i>			Visean (pars)
		<i>Lochriea nodosa</i>	<i>Gnathodus bilineatus</i>			
		<i>Gnathodus bilineatus</i>	Upper <i>Cavusgnathus</i>			

Fig. 5. Correlation chart between global Carboniferous stages, North American stages (Lucas et al., 2022), Western European conodont zones (Lucas et al., 2022), western North American conodont zones (Barrick et al., 2022), North American (Purnell and von Bitter, 1992, and references therein) *Vogelgnathus postcampbelli* range and selected brachiopod faunas and zones: *Carlinia phillipsi* assemblage from Tonka Formation (Smith and Ketner, 1975), *R. nevadensis* Zone from the Great Basin (Sadlick, 1955; Dutro et al., 1979), *Carlinia amdeniana* Subzone and *Composita poposiensis* Subzone from Amsden Formation, Wyoming (Gordon, 1975), Carter (1990a) Unit 16, assemblage under study. Correlation between global stages and European conodont zonations based on Lucas et al. (2022); correlation between North American stages and western North American conodont zonation based on Lane and Brenckle (2005) and Barrick et al. (2022).

pukhovian *R. muricatus* conodont Zone (Lane and Brenckle, 2005; Barrick et al., 2022).

The assemblage under study shares limited affinities with coeval faunas in western United States and South America, indicating poor connection with other paleogeographic domains and a high degree of endemism.

8. Systematic paleontology

All material from the upper Chesterian (middle-upper Serpukhovian) of the Tonka Formation, Carlin Canyon, Elko, Nevada (USA). Measures for the fauna are summarized in Table 2.

Class Strophomenata Williams, Carlson, Brunton, Holmer and Popov, 1996

Order Productida Sarytcheva and Sokolskaya, 1959

Suborder Productidina Waagen, 1883

Superfamily Productoidea Gray, 1840

Family Productidae Gray, 1840

Subfamily Productinae Gray, 1840

Tribe Retariini Muir-Wood and Cooper, 1960

Genus *Antiquatonia* Miloradovich, 1945

Type species: *Productus antiquatus* Sowerby, 1821 in 1821–1822.

Remarks: *Antiquatonia* ranges from the Visean to the lower Serpukhovian in western and eastern Europe, while it ranges from the uppermost Serpukhovian to Pennsylvanian in North America (Muir-Wood and Cooper, 1960; Carter, 1990a). Lazarev and Carter (2000) noted that all North American species assigned to *Antiquatonia* should not be included in the genus as they lack the typical shagreen texture in the inner ventral umbo, and that they should be thus referred to a new genus homeomorph to

Antiquatonia and related to the Bashkirian–Lower Permian North American genus *Reticulatia* Muir-Wood and Cooper, 1960 of the Dictyoclostinae Stehli, 1954. As Lazarev and Carter (2000) did not erect a new genus, in this study the name *Antiquatonia* is kept for North American species traditionally referred to it.

According to Carter (1990a) few genera of the Productinae occur in the Chesterian of North America: *Productus* Sowerby, 1814 in 1812–1815, *Carlinia* Gordon, 1971, and *Diaphragmus* Girty, 1910 of the Productini Gray, 1840, *Kozlowskia* Fredericks, 1933 and *Eomarginifera* Muir-Wood, 1930 of the Kozlowskiini Brunton, Lazarev and Grant, 1995, and *Antiquatonia*. *Antiquatonia* differs from North American Productini in having a slightly curved trail with straight flanks rather than spreading anteriorly, clear reticulation on visceral discs and characteristic ventral spine ridge flanking the ears (Brunton et al., 2000). *Antiquatonia* differs from the North American Kozlowskiini in being larger and in having more numerous fine spines (Muir-Wood and Cooper, 1960; Carniti et al., 2022). *Antiquatonia* differs from *Auloprotonia* Muir-Wood and Cooper, 1960 of the Dictyoclostinae Stehli, 1954, also occurring in the Chesterian of North America, in lacking a gutter anteriorly, having more clearly reticulate visceral discs, different disposition of ventral spines, rare spines on dorsal valve (Carniti et al., 2022) and lateral ridges diverging at a larger angle from the cardinal margin (Muir-Wood and Cooper, 1960). From *Dictyoclostus* Muir-Wood, 1930, also of the Dictyoclostinae, from the Visean of Western Europe, but also recorded in the Moscovian of the Great Basin (Pérez-Huerta, 2006), *Antiquatonia* differs in being usually smaller, in having ears well separated from the visceral disc by a groove and in having spines on flanks forming a row rather than patches (Brunton et al., 2000).

Table 2
Measurements for the studied brachiopod specimens from Tonka Formation, Carlin Canyon, Elko, Nevada. Abbreviation: dv – dorsal valve.

Taxon	Specimen number	Length (mm)	Width (mm)	Thickness (mm)
?Antiquatonia sp.	Car5-6	23.0	26.0	-
	Car5-9	31.0	30.0	-
Flexaria sp.	Car5-2	24.0	32.0	-
	Car5-38 (dv)	-	> 30.0	-
?Marginatia sp.	Car5-3	23.0	24.0	-
	Car5-8	25.5	34.5	-
	Car5-10	26.5	32.0	10.5
Echinoconchus sp.	Car5-51	25.0	28.0	-
?Orthotetes sp.	Car5-53	18.0	28.0	-
Rhipidomella sp.	Car5-46 (dv)	12.0	14.0	-
	Car5-48	19.8	20.7	-
Schizophoria sp.	Car5-50	-	> 40.0	-
Cleiothyridina cf. sublamellosa	Car5-47	13.8	17.5	5.5
	Car5-49	12.5	16.9	6.2
Composita sulcata	Car5-36a	14.5	17.0	-
	Car5-36d	11.2	11.6	-
	Car5-36e	10.0	13.0	-
	Car5-36f	8.5	12.0	-
Anthracospirifer shawi shawi	Car5-14	20.0	25.0	-
	Car5-16	16.0	21.0	-
	Car5-17	10.0	12.0	-
	Car5-19	16.5	16.0	-
	Car5-24	18.5	24.0	-
	Car5-25	17.0	21.0	-
	Car5-29	26.0	-	-
	Car5-34	17.5	17.0	-
Anthracospirifer aff. A. shawi	Car5-22	24.0	27.0	-
Delthyridina gen. et sp. indet.	Car5-15	16.0	18.0	-
	Car5-18	24.0	30.0	-
Punctospirifer sp.	Car5-54 (dv)	8.5	15.0	-
Girtyella indianensis	Car5-37	9.5	8.5	-

Other North American genera very close to *Antiquatonia* are *Keokukia* Carter, 1990b, restricted to the lower Viséan (upper Osagean; Carter, 1990a) and *Tesuquea* Sutherland and Harlow, 1973 (Bashkirian; Carter, 1990a). *Antiquatonia* differs from *Keokukia* in having a more transverse visceral disc and larger ears, (Carter, 1990b), from *Tesuquea* in being larger (Sutherland and Harlow, 1973).

?*Antiquatonia* sp.
(Fig. 6A, B)

Material: One articulated specimen: MPUM13413 (Car5-9). One ventral valve: MPUM13412 (Car5-6).

Description: Medium-sized, strongly convex geniculated ventral valve with elongate suboval outline. Cardinal margin wide, almost corresponding to the maximum width. Ears triangular, wide, flat, well separated from corpus and from trail. Cardinal extremities orthogonal. Visceral disc 12 mm long; geniculation subangular, geniculation angle 90°. Trail long, curved. Anterior commissure rectimarginate. Shell substance 1.6 mm thick.

Ornamentation of low, rounded ribs with rounded, commonly wide interspaces, starting from umbo. Ribs increasing in number by intercalation and becoming obsolete anteriorly on trail. They number 9–10 per 5.0 mm at

geniculation, 7–8 per 5.0 mm anteriorly on the trail. Ventral visceral disc and posterior portion of trail bear subquadrate, low rugae. Rugae stronger on flanks, increasing in number by bifurcation in the central part of the visceral disc, where intersection with ribs results in clearly reticulate ornamentation. Rugae intersect the cardinal margin at a 90° angle. Rugae number 5–6 per 5.0 mm. One row of posteriorly directed spines subparallel to cardinal margin on each ear. One big halteroid spine on each cardinal extremity, posteriorly directed. Two rows of erect spines on flanks, diverging with an angle of roughly 20° and 30° from the cardinal margin, the more posterior one being ill-defined. Erect spines also scattered on ventral valve on ribs posteriorly, more abundant and larger anteriorly on trail, where they are irregularly to quincuncially arranged.

Remarks: The specimens under examination are close to species of *Antiquatonia* in their dimensions, geniculated shell and arrangement of ventral spines in one row on the ears and at least in one curved row on flanks. However, they have a poorly defined second row of spines on the flanks and obsolete ribs anteriorly on trail, where quincuncially arranged large erect spines are reminiscent of species of *Dictyoclostus* (Muir-Wood and Cooper, 1960; Brunton et al., 2000).

Subfamily Buxtoniinae Muir-Wood and Cooper, 1960

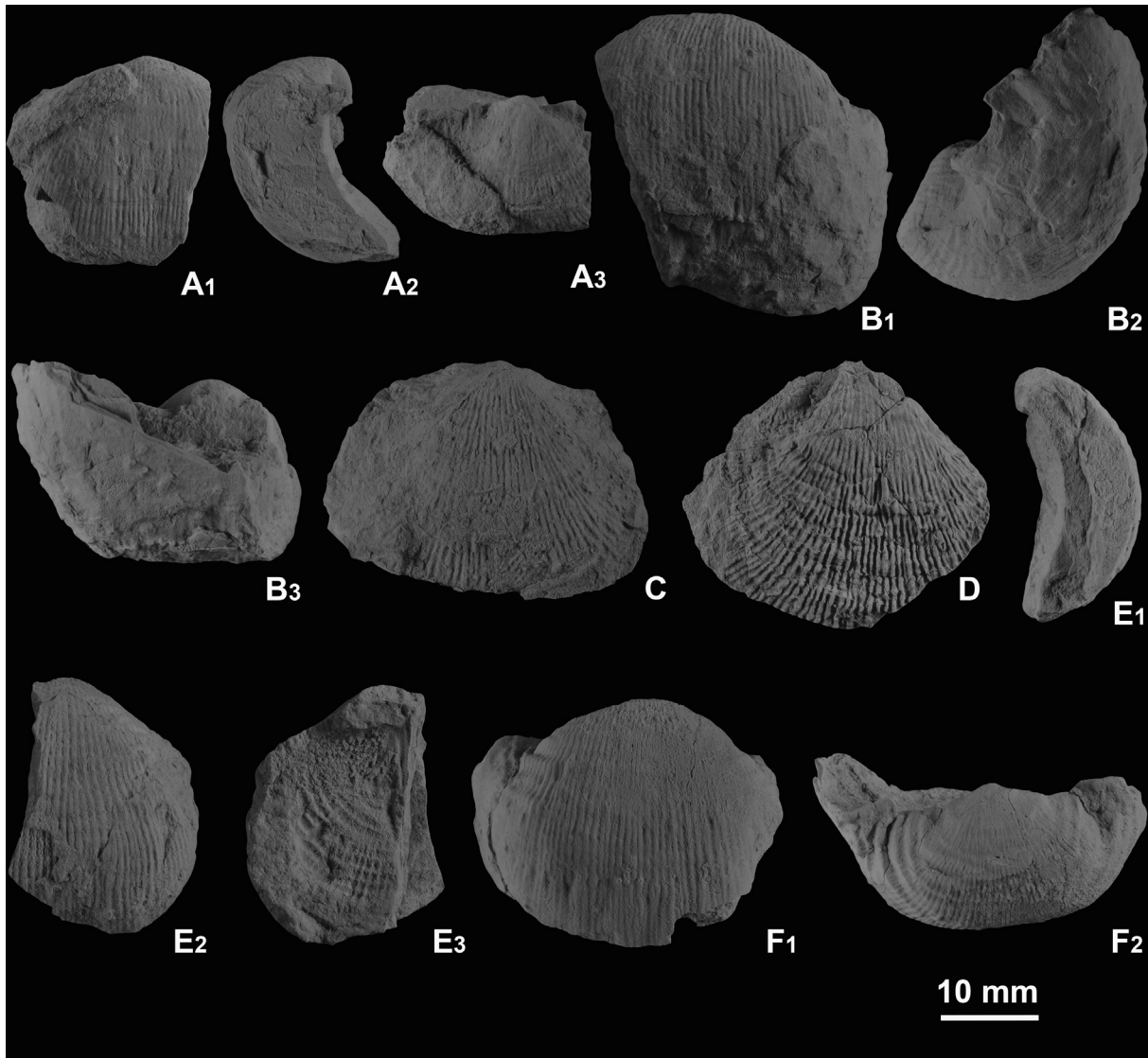


Fig. 6. Productides from the Tonka Formation, Upper Mississippian, Carlin Canyon, Elko, Nevada. (A, B) ?*Antiquatonia* sp.; (A) MPUM13412 (Car5-6), ventral valve, (A₁) ventral view, (A₂) lateral view, (A₃) posterior view; (B) MPUM13413 (Car5-9), articulated specimen, (B₁) ventral view, (B₂) lateral view, (B₃) anterior view. (C, D) *Flexaria* sp.; (C) MPUM13414 (Car5-2), articulated specimen, ventral view; (D) MPUM13415 (Car5-38), dorsal valve external cast. (E, F) ?*Marginatia* sp.; (E) MPUM13416 (Car5-10), articulated specimen, (E₁) lateral view, (E₂) ventral view, (E₃) dorsal view; (F) MPUM13419 (Car5-8), ventral valve, (F₁) ventral view, (F₂) posterior view, ventral valve down.

Tribe Buxtoniini Muir-Wood and Cooper, 1960

Genus *Flexaria* Muir-Wood and Cooper, 1960

Type species: *Productus arkansanus* Girty, 1910.

Remarks: Only three genera of the Buxtoniinae Muir-Wood and Cooper, 1960 occur in the Chesterian of North America (Carter, 1990a): *Buxtonia* Thomas, 1914, *Flexaria* Muir-Wood and Cooper, 1960, and *Setigerites* Girty, 1939. Of the three, *Flexaria* seems to be the most common (Girty, 1910, 1927; Muir-Wood and Cooper, 1960; Gordon, 1975). *Flexaria* differs from *Buxtonia* in commonly being smaller, in having more regular ribs and shorter lateral ridges (Muir-Wood and Cooper, 1960; Carniti et al., 2022).

Flexaria differs from *Setigerites* in having coarser spine-bearing ribs starting anterior to umbo, while the umbonal region and ears are covered by elongated spine bases only (Muir-Wood and Cooper, 1960). Another genus of the Buxtoniinae is *Buxtonioides* Mendes, 1959, an external homeomorph of *Buxtonia* occurring in the Bashkirian–Gzhelian of South America, Canada, and Russia (Mendes, 1959; Brunton et al., 2000; Chen et al., 2004), which is larger and with a coarser ornamentation.

Leighton and Maples (2002) proposed to include the Buxtoniinae in the Family Echinoconchidae Stehli, 1954, based on phylogenetic analyses of 14 genera of the two

groups; here we follow Brunton et al. (1995, 2000) in considering the Buxtoniinae part of the Productidae.

Flexaria sp.
(Fig. 6C, D)

Material: One articulated specimen: MPUM13414 (Car5-2). One dorsal valve external cast: MPUM13415 (Car5-38).

Description: Medium-sized, concavo-convex shell with transversely suboval outline. Cardinal margin wide. Anterior commissure rectimarginate. Ventral valve regularly convex.

Entire ventral valve covered by regular spine-bearing rounded ribs, with narrow interspaces, except for the umbonal flanks which are just covered by elongate spine bases in rough quincunx. Ribs increase in number anteriorly by bifurcation and intercalation. They number 6–7 per 5.0 mm near the anterior commissure. Low, very poorly defined rounded rugae posteriorly, spaced 1.0–4.0 mm. Dorsal valve also covered by ribs with wide interspaces, increasing in number anteriorly by bifurcation and intercalation. Subrounded rugae on flanks. Numerous elongated dimples in rib interspaces.

Remarks: The specimens under examination are assigned to an undetermined species of *Flexaria* based on their ornamentation of spine-bearing regular ribs.

Tribe Tolmatchoffiini Sarytcheva in Sarytcheva et al., 1963

Genus *Marginatia* Muir-Wood and Cooper, 1960

Type species: *Productus fernglenensis* Weller, 1909.

Remarks: *Marginatia* is restricted to the upper Tournaian–lower Viséan in North America, Europe, northern Africa and China (Carter, 1990a; Brunton et al., 2000; Chen and Shi, 2003; Shi et al., 2005). *Marginatia* differs from *Brasilioproductus* Mendes, 1959, described from the Middle Pennsylvanian of Brasil but also reported in the Upper Mississippian (Chesterian) of the Amazon Basin by Chen et al. (2005), in having smaller ears, less elongate outline, no or less strongly developed sulcus, and in lacking a row of spine bases on the ventral and dorsal ears. *Marginatia* is similar to *Inflatia* Muir-Wood and Cooper, 1960 of the Productellidae Schuchert, 1929, which is common in the Chesterian (upper Viséan–Serpukhovian) of North America (Carter, 1990a; Gordon et al., 1993), but differs from it in having a more transverse outline, less tubiform trail, in being commonly less deeply sulcate with ribs not converging medially in the sulcus but bifurcating anterior to spine bases on trail resulting in local fascicostellation (Muir-Wood and Cooper, 1960). Also, *Marginatia* lacks a row of spines on ears, which conversely always occur in species of *Inflatia* (Muir-Wood and Cooper, 1960; Gordon et al., 1993).

?*Marginatia* sp.
(Figs. 6E, F, 7A–E)

Material: One articulated specimen: MPUM13416 (Car5-10). Eleven ventral valves: MPUM13417 (Car5-1),

MPUM13418 (Car5-4), MPUM13419 (Car5-8), MPUM13420 (Car5-11), MPUM13421 (Car5-43), MPUM13422 (Car5-3, 5, 7, 39, 42, 52). Five fragments: MPUM13423 (Car5-44), MPUM13424 (Car5-6, 40, 41, 45).

Description: Medium-sized, concavo-convex shell with subquadrate to transversely sub-rectangular outline. Cardinal margin wide, almost corresponding to the maximum width. Cardinal extremities orthogonal. Corpus cavity shallow. Anterior commissure rectimarginate to slightly uniplicate. Shell substance up to 2.7 mm thick. Ventral valve regularly convex, enrolled, with very shallow broadly rounded sulcus in some specimens; trail long, curved, gently flaring anteriorly. Ears triangular, wide, flat, well separated from corpus. Dorsal valve convex.

Ornamentation consists of low, rounded ribs with narrow, rounded interspaces, becoming wide anteriorly. Ribs increasing in number anteriorly by bifurcation and intercalation. They number 7–8 per 5.0 mm near to the anterior commissure. Ventral visceral disc ornamented by subangular asymmetrical rugae, more prominent on flanks and increasing in number on visceral disc by intercalation. They number three per 5.0 mm length. Rugae intersect the cardinal margin with an acute angle. Erect spines scattered on ribs on the ventral valve, more abundant anteriorly. On the trail ribs bifurcate anterior to spine bases, resulting in local fascicostellation. One spine on each ear. Dorsal valve visceral disc reticulate: ribs number seven per 5.0 mm, rugae number 4–5 per 5.0 mm.

Remarks: The specimens under examination are close to those of species of *Marginatia* in their transverse outline with trail gently flaring anteriorly, in being commonly not sulcate, in having fascicostellation anteriorly to spine bases on trail and in lacking a row of spines on ears. The specimens under examination are similar to *Inflatia cooperi* Gordon, Henry and Treworgy, 1993, from the upper Chesterian of Oklahoma, in their poorly developed to absent shallow ventral sulcus, but differ in lacking any spine row on ears and in having ribs not converging medially in the sulcus and bifurcating anterior to spine bases. The specimens under examination may be similar to ?*Inflatia succincta* Gordon, Henry and Treworgy, 1993, from the upper Meramecian (upper Viséan) of Oklahoma, which commonly lacks a sulcus and has no spine row on ears, but they differ in having a regularly convex ventral valve and in having fascicostellation anterior to spines bases on trail.

Superfamily Echinoconchoidea Stehli, 1954

Family Echinoconchidae Stehli, 1954

Subfamily Echinoconchinae Stehli, 1954

Tribe Echinoconchini Stehli, 1954

Genus *Echinoconchus* Weller, 1914

Type species: *Productus punctatus* Sowerby, 1822 in 1821–1822.

Remarks: *Echinoconchus* differs from *Echinaria* Muir-Wood and Cooper, 1960, common in Pennsylvanian–Per-

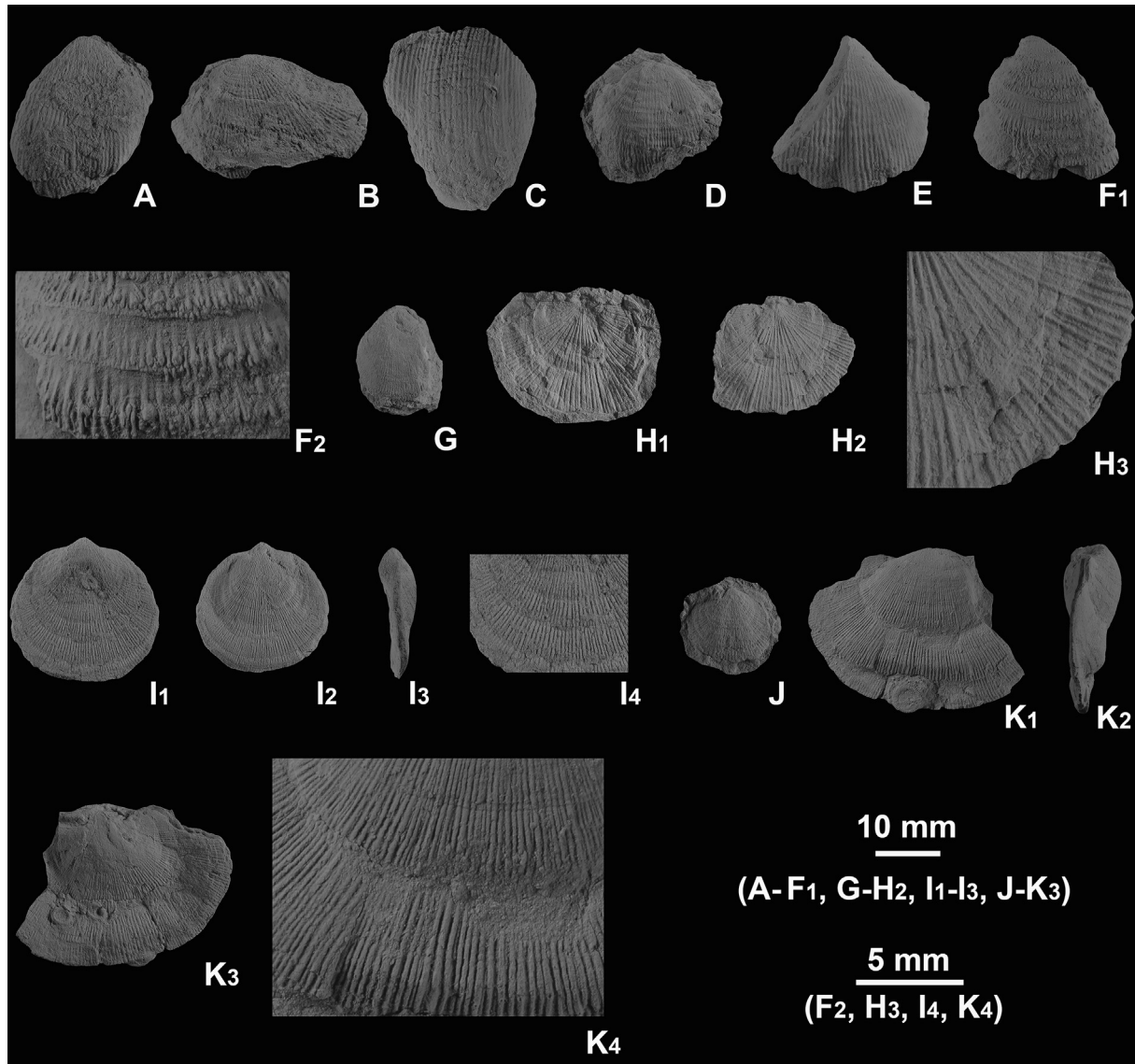


Fig. 7. Productides, orthotetides, and orthides from the Tonka Formation, Upper Mississippian, Carlin Canyon, Elko, Nevada. (A–E) *?Marginatia* sp.; (A) MPUM13418 (Car5-4), ventral valve; (B) MPUM13421 (Car5-43), ventral valve; (C) MPUM13423 (Car5-44), ventral valve fragment; (D) MPUM13417 (Car5-1), ventral valve; (E) MPUM13420 (Car5-11), ventral valve. (F) *Echinoconchus* sp., MPUM13425 (Car5-51), articulated specimen, (F₁) ventral view, (F₂) detail of the ornamentation of ventral valve. (G) *Linoproductoidea* gen. et sp. indet., MPUM13452 (Car5-12), ventral valve, ventral view. (H) *?Orthotetes* sp., MPUM13426 (Car5-53), (H₁) ventral valve external cast, (H₂) cast of ventral valve external cast, (H₃) detail of ornamentation of the cast of ventral valve external cast. (I, J) *Rhipidomella* sp.; (I) MPUM13428 (Car5-48), articulated specimen, (I₁) ventral view, (I₂) dorsal view, (I₃) lateral view, (I₄) detail of the ornamentation of the ventral valve; (J) MPUM13429 (Car5-46), dorsal valve. (K) *Schizophoria* sp., MPUM13427 (Car5-50), articulated specimen, (K₁) ventral view, (K₂) lateral view, (K₃) dorsal view, (K₄) detail of ornamentation of the ventral valve.

mian units of North America, in being smaller, more transverse, in having a less convex, not geniculated ventral valve, and fewer rows of spines on each lamella (Muir-Wood and Cooper, 1960; Carniti et al., 2022). It differs from *Karavankina* Ramovš, 1969, of the Karavankinini Ramovš, 1969 in being larger and in having spinose lamellae (Brunton et al., 2000). It differs from *Parajuresania* Lazarev, 1982, a genus erected to include North American Pennsylvanian–Permian species of the Juresaniinae Muir-Wood and Cooper, 1960 formerly attributed to *Juresania* Fredericks, 1928, in lacking a cicatrix, having lamellae

covering the entire surface of both valves, while in *Parajuresania* they are developed in the anterior part of the shell only (Brunton et al., 2000), and in lacking an antron at the base of the median septum (Leighton and Maples, 2002). *Echinoconchus* differs from *Stegacanthia* Muir-Wood and Cooper, 1960, of the Sentosiidae McKellar, 1970, from the middle Tournaisian–middle Visean of North America (Carter, 1990a), in having a planoconvex rather than shallow concavo-convex corpus, cuesta-like lamellae, and spines of two different diameters (Muir-Wood and Cooper, 1960; Brunton et al., 2000).

Echinoconchus sp.
(Fig. 7F)

Material: One articulated specimen: MPUM13425 (Car5-51).

Description: Medium-sized, convex, not geniculated ventral valve. Anterior commissure rectimarginate. Valve flattened medially in the anterior half of the shell.

Both valves covered by sub-imbricated lamellae, cuesta-like in profile, three to five per 10.0 mm length. Each lamella bears in the anterior half one to two irregularly staggered rows of prostrate rounded spines, 4.0–6.0 mm long, 10 per 5.0 mm width. Some spines start in the posterior half of the lamella. One row of smaller spine bases occurs anteriorly on each lamella, particularly evident in the posterior half of the valve. Microramentation of sinuous lirae.

Remarks: The specimen under examination is assigned to an undetermined species of *Echinoconchus* based on its entire lamellose ornamentation, cuesta-like in profile, with two orders of prostrate spines of different size (cf. Sutton, 1938; Muir-Wood and Cooper, 1960).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Orthotetidae Waagen, 1884

Genus *Orthotetes* Fischer de Waldheim, 1829

Type species: *Orthotetes radiata* Fischer de Waldheim, 1850.

Remarks: *Orthotetes* differs from *Werriea* Campbell, 1957 by its straight ventral umbo and internal characters. *Orthotetes* is a common genus in the Chesterian of North America (Carter, 1990a), but it might be that many North American species of *Orthotetes* are in fact species of *Werriea* as suggested by Campbell (1957).

?*Orthotetes* sp.
(Fig. 7H)

Material: One ventral valve external cast: MPUM13426 (Car5-53).

Description: Small, moderately convex ventral valve with sub-semicircular outline. Umbo straight. Cardinal margin straight, wide, possibly corresponding to maximum width. Anterior commissure rectimarginate.

Valve parvicostellate. Narrow, simple costae starting from umbo with broadly rounded to flat interspaces. Costellae intercalating at one-third shell length and then near to the anterior commissure. Collectively ribs number 10–11 per 5.0 mm at one-third shell length, 8–11 per 5.0 mm at the anterior commissure.

Remarks: The specimen is tentatively assigned to an undetermined species of *Orthotetes* based on its outline, straight ventral umbo and parvicostellate ornamentation. It is similar to the specimens from the Chesterian Amsden Formation of Wyoming assigned to *Orthotetes kaskaskiensis* bransorum Gordon, 1975 by Gordon (1975) in its dimensions, moderately convex ventral valve and ornamentation.

O. kaskaskiensis (McChesney, 1859) was assigned by Campbell (1957) to *Werriea*.

Class Rhynchonellata Williams, Carlson, Brunton, Holmer and Popov, 1996

Order Orthida Schuchert and Cooper, 1932

Suborder Dalmanellidina Moore, 1952

Superfamily Dalmanelloidea Schuchert, 1913

Family Rhipidomellidae Schuchert, 1913

Subfamily Rhipidomellinae Schuchert, 1913

Genus *Rhipidomella* Oehlert, 1890

Type species: *Terebratula michelini* Léveillé, 1835.

Remarks: Only three genera of Orthida are reported from North American Chesterian units (Carter, 1990a): *Rhipidomella*, *Perditocardinia* Schuchert and Cooper, 1931 of the Perditocardiinae Williams and Harper, 2000, and *Schizophoria* King, 1850 of the Enteletioidea Waagen, 1884. *Rhipidomella* differs from *Perditocardinia* in its orbicular rather than triangular outline and in having a ventral interarea, while it differs from *Schizophoria* in commonly being smaller and in having a shorter cardinal margin and more equidimensional outline.

Rhipidomella sp.
(Fig. 7I, J)

Material: One articulated specimen: MPUM13428 (Car5-48). One dorsal valve: MPUM13429 (Car5-46).

Description: Small biconvex shell with orbicular outline: ventribiconvex posteriorly, dorsibiconvex anteriorly. Cardinal margin straight, short; maximum width attained at shell mid-length. Cardinal extremities subangular, cardinal angles obtuse. Anterior commissure rectimarginate. Ventral valve convex posteriorly, flat anteriorly. Ventral umbo curved, overhanging interarea; apical angle 100°. Ventral interarea triangular, wider than long, apsacline. Dorsal umbo slightly curved, sealing ventral delthyrium.

Entire surface of both valves multicostellate. Ribs sub-cylindrical, with narrow interspaces. Ribs start at umbo, unless for rare bifurcating costellae. Ribs number 14–16 per 5.0 mm near the anterior commissure. Both valves also covered by few sub-imbricated lamellae, spaced 0.5–2.0 mm.

Remarks: The specimens under examination are assigned to an undetermined species of *Rhipidomella* based on their orbicular outline with short cardinal margin and dimensions. They differ from the specimen of *Rhipidomella* sp. reported by Easton (1962) from the Chesterian Heath Formation of Montana in being larger, orbicular rather than sub-quadrate, dorsibiconvex and in lacking a ventral sulcus. The specimens under examination differ from *R. nevadensis* (Meek, 1877) from the uppermost Chesterian–Morrowan (Lower Pennsylvanian) of eastern Nevada and western Utah, in being smaller (Meek reported *R. nevadensis* is 39.0 mm long, 33.5 mm wide, 24.0 mm thick), less thick, orbicular rather than sub-quadrate in outline and lacking any development of a fold-sulcus (cf. Meek, 1877, pl. 7, fig. 1a–d; Lane, 1962, pl. 125, fig. 20; Gordon and

Poole, 1968, pl. 1, figs. 1–3). From *R. penniana* (Derby, 1874), from the upper Chesterian of the Amazon Basin (Chen et al., 2005), the specimens under examination differ in being orbicular rather than elongate ovate in outline, in lacking a dorsal sulcus, and in the finer radial ornamentation.

The specimens under examination differ from the typically Pennsylvanian *R. carbonaria* (Shumard and Swallow, 1858) and *R. elyensis* Lane, 1962 in being larger, more transverse and less thick (cf. Gordon, 1975; Pérez-Huerta, 2006).

Superfamily Enteletoidea Waagen, 1884

Family Schizophoriidae Schuchert and LeVene, 1929

Genus *Schizophoria* King, 1850

Type species: *Conchyliolithus anomites (resupinatus)* Martin, 1809.

Schizophoria sp.
(Fig. 7K)

Material: One articulated specimen: MPUM13427 (Car5-50).

Description: Medium-sized, dorsibiconvex to resupinate shell. Anterior commissure rectimarginate. Shell substance 0.7 mm thick.

Entire surface of both valves multicostellate. Ribs sub-cylindrical, with narrow interspaces. Ribs increasing in number by frequent bifurcations. Ribs number 15–16 per 5.0 mm width at shell mid-length, 11–12 at the anterior commissure. Both valves also covered by few sub-imbricated lamellae, spaced 1.0–7.0 mm.

Strong socket ridges on dorsal valve interior. Ventral median septum not visible.

Remarks: The specimen under examination is assigned to an undetermined species of *Schizophoria* based on its dorsibiconvex to resupinate shape and multicostellate ornamentation (cf. Pocock, 1968; Butts, 2007). The specimen under examination is close in dimensions and morphology to the cosmopolitan type species *Schizophoria resupinata*, but it has a coarser radial ornamentation (cf. Pocock, 1968; Carniti et al., 2022). *S. resupinoides* is a junior synonym of *S. resupinata* according to Butts (2007). The specimen under examination differs from *S. depressa* Easton, 1962, in having a convex, rather than depressed, dorsal valve (Easton, 1962; Gordon, 1975; Butts, 2007), from *S. texana* Girty, 1927, in lacking a ventral sulcus.

Order Athyridida Boucot, Johnson and Staton, 1964

Suborder Athyrididina Boucot, Johnson and Staton, 1964

Superfamily Athyridoidea Davidson, 1881

Family Athyrididae Davidson, 1881

Subfamily Cleiothyridininae Alvarez, Rong and Boucot, 1998

Genus *Cleiothyridina* Buckman, 1906

Type species: *Atrypa pectinifera* Sowerby, 1840 in 1840–1846.

Remarks: *Cleiothyridina* differs from *Carteridina* Alvarez, Rong and Boucot, 1998 from the Tournaisian–Visean of southeastern USA in being less strongly uniplicate to rectimarginate, in having dental plates and a myophragm and narrower growth lamellae (cf. Alvarez et al., 1998). It differs from *Leiothyridina* Grunt, 1980 from the Upper Mississippian of Europe and eastern Asia in having more clearly differentiated dental plates. *Cleiothyridina* differs from *Bruntonathyris* Chen et al., 2003 from the upper Tournaisian–Visean of northwestern China, for its circular rather than transverse outline, equibiconvex profile, absence of sulcus and fold and concentric ornamentation of spinose lamellae, while *Bruntonathyris* has fine growth lines and a delicate radial pattern on exfoliated surfaces (Chen et al., 2003).

Cleiothyridina cf. *sublamellosa* (Hall, 1858)
(Fig. 8A, B)

Material: Two articulated specimens: MPUM13430 (Car5-47), MPUM13431 (Car5-49).

Description: Small, slightly ventribiconvex shell with suboval outline; cardinal margin straight, with obtuse subangular extremities; maximum width attained at shell mid-length. Anterior commissure rectimarginate. Shell substance impunctate, thick (0.5 mm). Ventral apical angle 100°. Ventral palintrope anacline, sealed by dorsal valve. Ventral valve flattened medially in the anterior portion of the valve.

Entire surface of both valves covered by more or less regularly concentric, imbricated lamellae, 9–12 per 5.0 mm length, extending anteriorly in a continuous row of sub-rectangular flat spines. Lamellae are 20 per 5.0 mm length at the anterior commissure, where spines are better preserved, 4 per 1.0 mm width.

Interior of ventral valve with short dental plates.

Remarks: The specimens under examination fit in the morphological and morphometric variability shown by the specimens assigned to *Cleiothyridina sublamellosa* from the Chesterian of Illinois by Weller (1914). Also, they have lamellae of comparable size to those of Weller's (1914) specimens. Specimens of *C. sublamellosa* from the upper Chesterian Arco Hills Formation of Idaho (Butts, 2007, fig. 5.17) seem to have much shorter lamellae. The specimens under examination differ from *C. atrypoides* (Girty, 1910), of the lower-middle Chesterian of North America (Easton, 1962; Gordon, 1975) in being less thick, more transverse, and in having longer lamellae and a rectimarginate commissure. They differ from other Chesterian species such as *C. hirsuta* (Hall, 1856) and *C. elegans* (Girty, 1910) in being larger and more transverse (cf. Easton, 1962; Gordon, 1975; Pérez-Huerta, 2006).

Age and distribution: *Cleiothyridina sublamellosa* occurs in the lower Chesterian (upper Visean) Moffat Trail Lime-

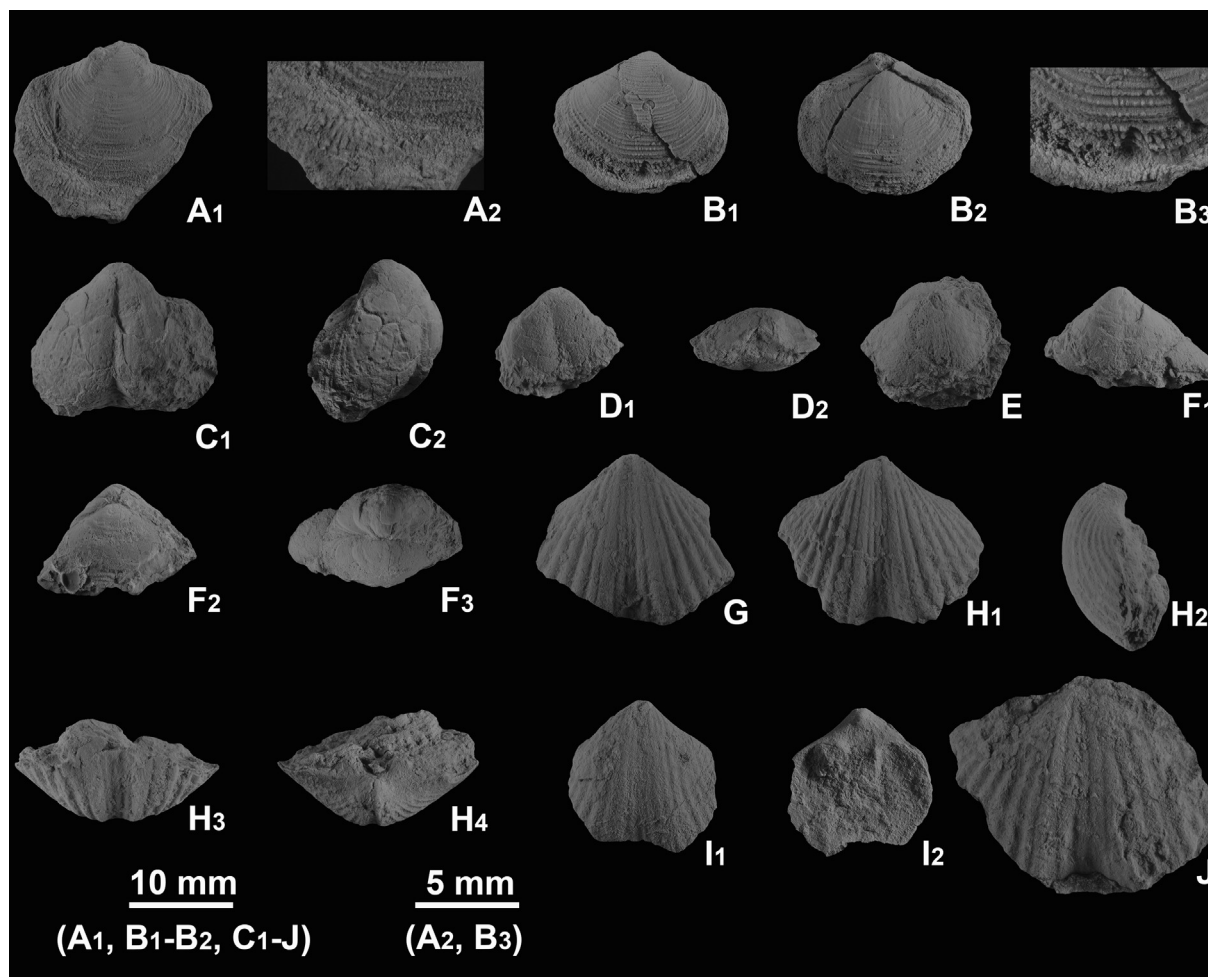


Fig. 8. Athyridides and spiriferides from the Tonka Formation, Upper Mississippian, Carlin Canyon, Elko, Nevada. (A, B) *Cleiothyridina* cf. *sublamellosa* (Hall, 1858); (A) MPUM13430 (Car5-47), articulated specimen, (A₁) ventral view, (A₂) detail of ornamentation of the anterior part of the ventral valve; (B) MPUM13431 (Car5-49), articulated specimen, (B₁) ventral view, (B₂) dorsal view, (B₃) detail of ornamentation of the anterior part of ventral valve. (C–F) *Composita sulcata* Weller, 1914; (C) MPUM13434 (Car5-36a), (C₁) ventral valve, (C₂) lateral view showing detail of bioerosion, possibly by bryozoans, on ventral valve flank; (D) MPUM13432 (Car5-36f), articulated specimen, (D₁) ventral view, (D₂) anterior view; (E) MPUM13435 (Car5-36e), ventral valve; (F) MPUM13433 (Car5-36d), articulated specimen, (F₁) ventral view, (F₂) dorsal view, (F₃) posterior view. (G–J) *Anthracospirifer shawi* Gordon, 1975; (G) MPUM13439 (Car5-16), ventral valve; (H) MPUM13441 (Car5-25), ventral valve, (H₁) ventral view, (H₂) lateral view, (H₃) anterior view, (H₄) posterior view; (I) MPUM13440 (Car5-19), ventral valve, (I₁) ventral view, (I₂) internal view; (J) MPUM13438 (Car5-14), ventral valve.

stone Member, Amsden Formation, of Wyoming (Gordon, 1975); in the upper Chesterian (upper Serpukhovian) Arco Hills Formation of Idaho (Butts, 2007); in the Chesterian Heath Formation of Montana (Easton, 1962). It is also recorded from the Chesterian units of Iowa (Hall, 1858), Illinois (Weller, 1914), Kentucky (Weller, 1931), Arkansas, Oklahoma, Arizona, Indiana, and Alberta (Carter and Carter, 1970, and references therein). It has also been recorded from the Visean of Mount Head Formation of western Canada (Nelson, 1961). Carter and Carter (1970) also reported some findings of *C. sublamellosa* from the Visean of central Asia and the Mississippian of Scotland (Reed, 1954), but these are unlikely to be correct attributions.

Subfamily Spirigerellinae Grunt, 1965

Genus *Composita* Brown, 1845

Type species: *Spirifer ambiguus* Sowerby, 1822 in 1821–1822.

Composita sulcata Weller, 1914
(Fig. 8C–F)

- ?1910 *Athyris subquadrata* var. *lateralis* – Girty, p. 222.
- 1914 *Composita sulcata* – Weller, p. 409, pl. 82, figs. 1–10.
- 1927 *Composita sulcata* – Girty, p. 64, pl. 23, figs. 28–33.
- 1954 *Composita subtilita* var. *ovata* Mather – Burk, p. 12 (pars), pl. 1, figs. 3, 11, non fig. 2, non fig. 4.
- 1954 *Composita subtilita* var. *subtilita* (Hall) – Burk, p. 12 (pars), pl. 1, non figs. 5–7, non fig. 12.
- 1962 *Composita sulcata* – Easton, p. 77, pl. 11, figs. 8, 9.
- ?1962 *Composita argentea* (Shepard) – Lane, p. 906, pl. 127, figs. 31–33.
- 1975 *Composita sulcata* – Gordon, p. D62, pl. 8, figs. 40–42, 44–48, 50–54.

2006 *Composita sulcata* – Pérez-Huerta, p. 127, pl. 7, figs. 1–5.

Material: Two articulated specimens: MPUM13432 (Car5-36f), MPUM13433 (Car5-36d). Three ventral valves: MPUM13434 (Car5-36a), MPUM13436 (Car5-36b), MPUM13435 (Car5-36e). One fragment: MPUM13437 (Car25-36c).

Description: Small, equally biconvex shell with slightly transverse sub-triangular outline. Maximum width anterior to shell mid-length. Anterior commissure uniplicate to parasulcate. Ventral umbo curved, palintrope low, apsacline, sealed by the dorsal valve. Foramen circular, permesothryd. Sulcus starting immediately anterior to the umbo, subrounded, shallow, narrow (2.0 mm wide), becoming wider (5.0 mm) and deeper near to the anterior commissure and extending into rounded tongue. Dorsal umbo gently curved, palintrope sealed by the ventral valve. Rounded fold restricted anteriorly on dorsal valve.

Sub-imbricated growth lamellae near to the anterior commissure.

Interior of ventral valve with dental plates visible on the abraded shell exterior.

Remarks: The specimens under examination belong to *Composita sulcata* based on their transverse outline, narrow sulcus in the posterior half of the ventral valve, uniplicate to parasulcate commissure, and lamellose ornamentation anteriorly. The specimens under examination differ from *C. ozarkana* Mather, 1915 in being sub-triangular and in lacking a median furrow on the dorsal fold (Easton, 1962). They differ from the common Chesterian species *C. subquadrata* (Hall, 1858) in having a transversely triangular rather than sub-quadrate outline, a sulcus starting near umbo and a more strongly uniplicate to parasulcate anterior commissure (Easton, 1962; Grinnell and Andrews, 1964). The specimens under examination differ from *C. subtilita* (Hall, 1852) and its varieties in having a deeper ventral sulcus. According to Gordon (1975) some of the specimens of *C. subtilita* described by Burk (1954) belong in fact to *C. sulcata*. The specimens under examination differ from *C. caimanensis* Chen et al., 2005, from the upper Chesterian of the Amazon Basin, Brasil, in being smaller, equally biconvex and in the stronger expression of the ventral sulcus posteriorly. The specimens under examination differ from the Pennsylvanian species *C. argentea* in having a ventral sulcus starting posteriorly near the umbo. According to Pérez-Huerta (2006) the specimens described as *Composita argentea* by Lane (1962) might instead belong to *C. sulcata*.

Age and distribution: *Composita sulcata* is common in upper Chesterian (Serpukhovian) to Morrowan (lower-middle Bashkirian) units of North America. It occurs in the upper Chesterian Heath Formation and the upper Chesterian–Lower Pennsylvanian Cameron Creek Formation and Alaska Bench Formation of Montana (Easton, 1962), the upper Chesterian Horseshoe Shale Member, Amsden Formation, of west-central Wyoming (Gordon, 1975), the ?upper Chesterian Yellow Pine Limestone and the Morrowan

(lower-middle Bashkirian) Ely Limestone of White Pine County, Great Basin, Nevada, USA (Pérez-Huerta, 2006). Also, Weller (1914) reported the species from the Chester Group of Illinois and Girty (1927) from the Mississippian Brazer Limestone of Idaho, but they did not give a precise stratigraphic distribution for the species.

Order Spiriferida Waagen, 1883

Suborder Spiriferidina Waagen, 1883

Superfamily Spiriferoidea King, 1846

Family Spiriferidae King, 1846

Subfamily Sergospiriferinae Carter in Carter et al., 1994

Genus *Anthracospirifer* Lane, 1963

Type species: *Anthracospirifer birdspringensis* Lane, 1963.

Remarks: Lane (1963) erected the genus *Anthracospirifer* to include North American spiriferides similar to *Spirifer* Sowerby, 1816 in 1815–1818, but with a simple median costa in the sulcus, lateral sulcal ribs arising from bifurcation of sulcus bounding costae and few simple to variably bifurcating ribs on flanks. The genus includes several species and subspecies ranging from the Osagean (Middle Mississippian) to Desmoinesian (Middle Pennsylvanian) of North America, many of which might need revision. *A. leidyi* (Norwood and Pratten, 1855) and *A. shoshonensis* (Branson and Greger, 1918) seem to fall outside the genus description of Lane (1963) in having a bifurcating median sulcal costa (Gordon, 1975; Butts, 2007). The genus differs from *Unispirifer* Campbell, 1957, and *Parallelora* Carter, 1974 of the Subfamily Prospirinae Carter, 1974, in being less transverse and having fewer costae on flanks. *Parallelora* is more lamellose and commonly has bifurcating costae on flanks, while *Anthracospirifer* commonly has mostly simple costae.

Anthracospirifer shawi shawi Gordon, 1975
(Figs. 8G–J, 9A)

1918 *Spirifer pellaensis* Weller – Branson and Greger, p. 317 (pars), pl. 18, fig. 7.

1975 *Anthracospirifer shawi shawi* – Gordon, p. D71, pl. 12, figs. 25, 29–33, 37–42.

?2007 *Anthracospirifer shawi shawi* – Butts, p. 59, fig. 5.42–5.44.

Material: Ten ventral valves: MPUM13438 (Car5-14), MPUM13439 (Car5-16), MPUM13440 (Car5-19), MPUM13441 (Car5-25), MPUM13442 (Car5-29), MPUM13443 (Car5-17, 21, 24, 28, 34). Three fragments: MPUM13444 (Car5-20, 23, 31).

Description: Medium-sized, transversely suboval shells. Anterior commissure uniplicate. Shell substance thick (0.8 mm in the anterior region). Ventral umbo curved, overhanging strongly apsacline, triangular, concave inter-area, as long as wide. Delthyrium triangular, longer than wide, closed by concave deltidial plate. Sulcus starting from the umbo, subrounded in section, widening anteriorly, extending in a rounded tongue anteriorly, 6.0–8.0 mm wide at the anterior commissure.

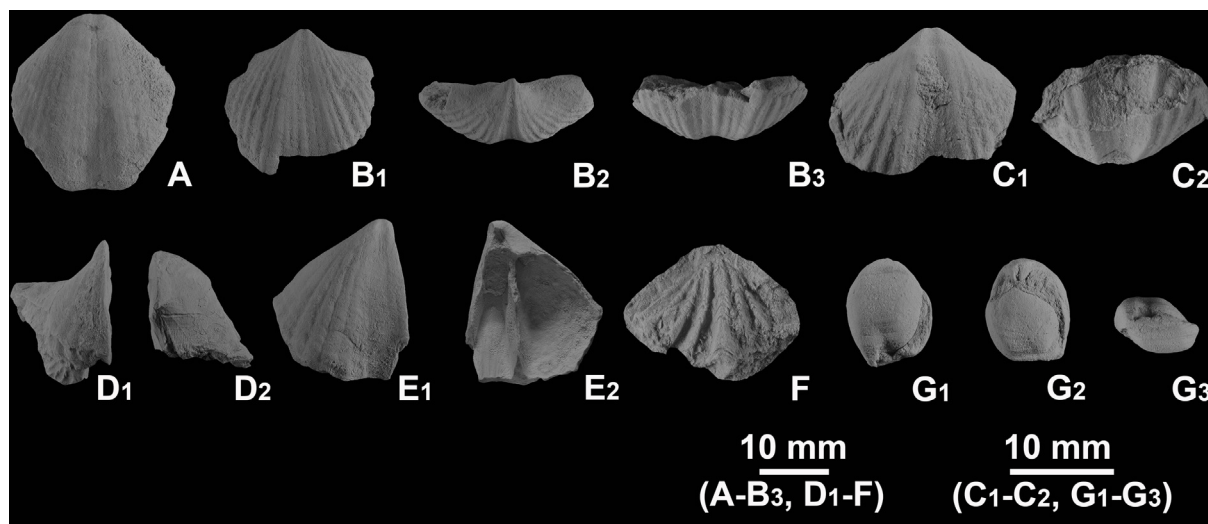


Fig. 9. Spiriferides, spiriferinides, and terebratulides from the Tonka Formation, Upper Mississippian, Carlin Canyon, Elko, Nevada. (A) *Anthracospirifer shawi shawi* Gordon, 1975, MPUM13442 (Car5-29), ventral valve. (B) *Anthracospirifer* aff. *A. shawi* Gordon, 1975, MPUM13445 (Car5-22), ventral valve, (B₁) ventral view, (B₂) posterior view, (B₃) anterior view. (C–E) Delthyridina gen. et sp. indet.; (C) MPUM13446 (Car5-15), ventral valve, (C₁) ventral view, (C₂) anterior view; (D) MPUM13448 (Car5-33), fragment of ventral valve, (D₁) ventral view, (D₂) postero-dorsal view, delthyrium partly closed by concave deltidial plate; (E) MPUM13447 (Car5-18), ventral valve, (E₁) ventral view; (E₂) internal view. (F) *Punctospirifer* sp., MPUM13450 (Car5-54), dorsal valve. (G) *Girtyella indianensis* (Girty, 1909), MPUM13451 (Car5-37), articulated specimen, (G₁) ventral view, (G₂) dorsal view, (G₃) anterior view.

Ornamentation of coarse, rounded ribs with narrow, subrounded interspaces. Three ribs in the sulcus: one median sulcal costa starting near umbo and two lateral sulcal ribs deriving from bifurcation of the sulcus bounding costae. Sulcus bounding costae starting from umbo, bifurcating at umbo towards the sulcus, giving rise to lateral sulcal ribs, and then at 1/3 shell length towards the flanks. Other ribs on flanks simple, 7–8 on each flank, numbering 3–4 per 5.0 mm at the anterior commissure.

Interior of ventral valve with strong, sub-quadrate teeth, supported by prominent, subparallel dental plates, extending the whole of valve length.

Remarks: Many species of *Anthracospirifer* have been defined in the Upper Mississippian of North America, and differentiated based on their outline, morphology, and pattern of ribbing. Specific attribution of the specimens under examination has been difficult due to the absence of dorsal valves and preserved cardinal extremities in the ventral valves. The specimens under examination are close to *A. shawi shawi*, from the lower Chesterian of Wyoming, in their dimensions, general morphology, and ornamentation. Butts (2007) assigned to this subspecies some specimens from the upper Chesterian Arco Hills Formation of Idaho, but these have a bifurcating sulcal median costa. The specimens under examination differ from *A. shawi exoletus* Gordon, 1975, in being smaller and in having fewer ribs. The specimens under examination differ from *A. welleri* Branson and Greger, 1918 in being larger and in having fewer, wider costae in the sulcus and on flanks which do not bifurcate.

The specimens under examination differ from other North American Chesterian species of *Anthracospirifer*,

such as *A. leidy* (Norwood and Pratten, 1855), *A. occiduus* (Sadlick, 1960), *A. curvilateralis* (Easton, 1962), *A. rawlinsonensis* Gordon, 1975, and *A. arcoensis* Butts, 2007 in the different number of ribs and pattern of their bifurcations on the flanks. Also, they lack the prominent angular sulcus bounding costae typical of *A. arcoensis*.

Dott (1955) reported *A. opimus* (Hall, 1858) from the Tonka Formation of Carlin Canyon. The specimens under examination share the same ribbing pattern of *A. opimus* as it was described and figured by Sturgeon and Hoare (1968, p. 62, fig. 9d). However, the specimens under examination differ from *A. opimus* in the more rounded section of the ventral sulcus. *A. opimus* as figured by Sturgeon and Hoare (1968, pl. 19, figs. 30–32) and Pérez-Huerta (2006, pl. 9, figs. 26–30, pl. 10, figs. 29, 30) is characterized by a flat bottomed sulcus. *A. opimus* is commonly reported from Middle Pennsylvanian units of the USA (e.g., Desmoinesian of Ohio, Sturgeon and Hoare, 1968; Atokan of the Great Basin, Nevada, Pérez-Huerta, 2006).

The specimens under examination are similar to *A. oliveirai* (Mendes, 1956), from the upper Chesterian of the Amazon Basin, Brasil (Chen et al., 2005), but differ in having sulcal bounding ribs bifurcating towards the flanks.

Age and distribution: *Anthracospirifer shawi shawi* is recorded from the upper Chesterian (middle Serpukhovian) Horseshoe Shale Member, Amsden Formation of west-central Wyoming (Gordon, 1975) and the upper Chesterian (upper Serpukhovian) Arco Hills Formation of Idaho (Butts, 2007).

Anthracospirifer aff. *A. shawi* Gordon, 1975 (Fig. 9B)

Material: One ventral valve: MPUM13445 (Car5-22).

Description: Medium-sized, equidimensional suboval shell. Anterior commissure uniplicate. Ventral umbo curved, overhanging apsacline, triangular, concave interarea. Low, rounded sulcus starting near umbo, becoming flat and wide anteriorly, 11.0 mm wide at the anterior commissure.

Ornamentation of coarse, subrounded ribs with narrow, subrounded interspaces. Sulcus with one median sulcal costa starting near umbo and four lateral sulcal ribs arising from bifurcation of prominent sulcus bounding costae. Median sulcal costa slightly thicker than other ribs in the sulcus. Each flank covered by 9–10 simple costae starting from the umbo, numbering 2–4 per 5.0 mm at the anterior commissure.

Remarks: The specimen under examination differs from those assigned to *Anthracospirifer shawi shawi* based on the wider, shallower sulcus and absence of bifurcating ribs on flanks. The specimen under examination is close to *A. shawi* Gordon, 1975 in having no bifurcation of costae on flanks, but differs from both subspecies (*A. shawi shawi* Gordon, 1975; *A. shawi exoletus* Gordon, 1975) in having a wider shallower sulcus. The specimen is also close to *A. welleri* (Branson and Greger, 1918), and particularly *A. welleri welleri* (Branson and Greger, 1918) in having a shallow sulcus and lacking bifurcating ribs on the flanks, but it is larger, with a wider sulcus and five rather than three ribs in the sulcus. The specimen under examination shows some similarities with *A. arcoensis* Butts, 2007 in having coarse sulcus bounding costae, but differs in having five rather than three ribs in the sulcus and in the pattern of ribs on flanks.

Suborder Delthyridina Ivanova, 1972

Delthyridina gen. et sp. indet.
(Fig. 9C–E)

Material: Two ventral valves: MPUM13446 (Car5-15), MPUM13447 (Car5-18). Three fragments: MPUM13448 (Car5-33), MPUM13449 (Car5-32, 35).

Description: Medium-sized, convex shell. Maximum width at shell mid-length. Anterior commissure uniplicate. Shell substance 1.3 mm thick at the anterior commissure. Ventral interarea high, apsacline to catacline, gently concave, wider than long, with a triangular delthyrium, closed by a concave deltidial plate. Low, rounded sulcus starting near umbo as a furrow between the two sulcal bounding costae, becoming wide and flat anteriorly and extending into a rounded tongue.

Ventral sulcus smooth. In Car5-15 the ornamentation on flanks consists of broadly rounded simple ribs with broadly rounded interspaces; they number four per 5.0 mm width at the anterior commissure. Sulcus bounding costae bifurcate towards the flanks near umbo. In Car5-18 the ornamentation consists of low, broadly rounded simple costae starting from umbo, with narrow rounded interspaces; they number two per 5.0 mm at the anterior com-

missure. Concentric sub-imbricated lamellae, two per 1.0 mm length.

Dental plates strong, long and slender, divergent anteriorly with an angle of 20° and bounding the sulcus. Radial muscular impressions between the two dental plates.

Remarks: The specimens under examination are likely representative of an undetermined genus and possibly two undetermined species of the Suborder Delthyridina, based on their shape, lamellose ornamentation and dental plates. They are close to the Tournaisian–Visean genus *Tylothyris* in their catacline interarea, ornamentation of broadly rounded simple ribs on flanks and smooth sulcus, but they have stronger dental plates and lack a median septum; nevertheless, it is known that in the species of *Tylothyris*, the septum might be buried in a callus (cf. Johnson et al., 2006).

Order Spiriferinida Ivanova, 1972

Suborder Spiriferinidina Ivanova, 1972

Superfamily Pennospiriferinoidea Dagys, 1972

Family Punctospiriferidae Waterhouse, 1975

Genus *Punctospirifer* North, 1920

Type species: *Punctospirifer scabricosta* North, 1920.

Remarks: *Punctospirifer* differs from the other Spiriferinida genera of the Carboniferous of North America by its transverse suboval outline, rounded ribs, imbricated lamellae, and capillate micror ornamentation. Common North American species attributed to the genus, as *P. transversus* (McChesney, 1859) from the Upper Mississippian–Lower Pennsylvanian of western North America, and *P. kentuckyensis* (Shumard, 1855), from the Pennsylvanian of eastern North America, are more transverse and have a higher number of costae than the type species. Also, both species have a wide, high dorsal fold with a shallow, narrow sulcus anteriorly (Easton, 1962, p. 80; Sturgeon and Hoare, 1968, pl. 22, figs. 1, 4; Pérez-Huerta, 2006, p. 145; Butts, 2007, p. 61) so they might represent a new genus, as already suggested by Easton (1962, p. 82)

Punctospirifer sp.
(Fig. 9F)

Material: One dorsal valve: MPUM13450 (Car5-54).

Description: Small-sized, transversely triangular shell. Cardinal margin long, straight. Anterior commissure slightly uniplicate. Shell substance punctate. Low, rounded fold starting from umbo, poorly delimited, widening anteriorly, 2.0 mm wide at the anterior commissure.

Flanks covered by coarse, simple, sub-rounded ribs with broad rounded interspaces, extending from the umbo, becoming lower and indistinct laterally. Costae number 4–5 on each flank. Entire surface of the valve covered by irregular imbricated lamellae, 5–10 per 1.0 mm length.

Remarks: The specimen under examination is assigned to an unidentified species of *Punctospirifer* because of its transverse shape, ribs density, and lamellose shell surface, though it differs from the type species *P. scabricosta* in having a narrower dorsal fold. The specimen under examina-

tion differs from ?*Punctospirifer transversus*, recorded in upper Chesterian units with a similar lithofacies of the Arco Hills Formation of Idaho by Butts (2007), in having a narrower fold and less numerous costae. The specimen under examination is close to *P. acutus* Carter, 1968 from the Osagean (upper Tournaisian–lower Visean) Burlington Limestone of Missouri, in its size, shape, and ornamentation of few rounded ribs.

Order Terebratulida Waagen, 1883

Suborder Terebratulidina Waagen, 1883

Superfamily Cryptonelloidea Thomson, 1926

Family Cranaenidae Cloud, 1942

Subfamily Girtyellinae Stehli, 1965

Genus *Girtyella* Weller, 1911

Type species: *Harttina indianensis* Girty, 1909.

Remarks: *Girtyella* differs from *Harttella* Bell, 1929 in having dental plates (Brunton, 1982); from *Gacina* Stehli, 1961 of the Cryptonellidae Thomson, 1926 in having a less strongly sub-pentagonal elongate outline. Also, *Girtyella* commonly has a broad sulcus in both valves with a median plication in the dorsal sulcus, resulting in a paraplicate anterior commissure (Weller, 1911; Easton, 1962).

Girtyella indianensis (Girty, 1909)

(Fig. 9G)

1891 *Terebratula turgida* (Hall) – Whitfield, p. 586, pl. 13, figs. 21, 22.

1895 *Terebratula turgida* – Whitfield, p. 473, pl. 9, figs. 21, 22.

1909 *Harttina indianensis* – Girty, p. 293, pl. 19, figs. 6–15.

1911 *Dielasma turgida* – Morse, p. 381, fig. 12a, b.

1911 *Girtyella indianensis* – Weller, p. 442, fig. 2a–i.

1914 *Girtyella indianensis* – Weller, p. 275, pl. 34, figs. 1–24.

1916 *Girtyella indianensis* – Weller, p. 246, pl. 16, figs. 9, 10.

1917 *Girtyella indianensis* – Butts, p. 62, pl. 15, figs. 34–36.

1918 *Girtyella indianensis* – Lee and Thomas, p. 613, pl. 12, figs. 12, 13.

1919 *Girtyella indianensis* – Miller, p. 133, pl. 60, figs. 34–36.

1925 *Girtyella indianensis* – Van Tuyl, pl. 6, figs. 17–19.

1931 *Girtyella indianensis* – Weller, pl. 34, fig. 5a–c.

1935 *Girtyella indianensis* – Hernon, p. 685, pl. 81, fig. 5.

?1937 ?*Girtyella indianensis* – Branson, p. 657.

1941 *Girtyella indianensis*? – Butts, p. 242, pl. 130, figs. 28–34.

1942 *Girtyella indianensis* – Easton, p. 100, pl. 6, fig. 11.

1944 *Girtyella indianensis* – Cooper, p. 365, pl. 143, figs. 24–26.

1961 *Girtyella indianensis* – Nelson, pl. 21, figs. 17–19.

1965 *Girtyella indianensis* – Stehli, fig. 614.2a, 614.2b.

?1975 *Girtyella* cf. *G. indianensis* – Gordon, p. D78, pl. 13, figs. 15–18, 21, 22.

2006 *Girtyella indianensis* – Jin and Lee, fig. 1337.4a–1337.4k.

Material: One articulated shell: MPUM13451 (Car5–37).

Description: Small, ventribiconvex shell with sub-pentagonal elongated outline. Maximum width at shell mid-length. Anterior commissure weakly paraplicate. Shell substance punctate. Ventral umbo strongly curved; palintrope anacline. Foramen permesothyrid. Shallow, broadly

rounded sulcus starting at shell mid-length. Dorsal palintrope anacline. Dorsal valve flattens in its middle part anteriorly.

Shell smooth, with growth lines and regularly concentric lamellae, spaced 0.1 mm.

Interior of ventral valve with dental plates longer than 2.0 mm, probably divergent.

Remarks: Hernon (1935) noted overlap in the morphological variability of three Chesterian species of *Girtyella*: *G. indianensis*, *G. brevibata* (Swallow, 1863), and *G. turgida* Weller, 1914; the specimen under examination is closer to *G. indianensis* in having a sub-pentagonal outline, a weak ventral sulcus and a paraplicate commissure and no dorsal fold or median rib. The specimen under examination differs from the specimens from the Chesterian Heat Formation of central Montana assigned by Easton (1962) to *G. woodworthi* Clark, 1917 in being smaller; it differs from the juvenile specimens of *G. woodworthi* (Easton, 1962, pl. 12, fig. 7) in being less elongate and in having a weak paraplicate rather than rectimarginate commissure.

Age and distribution: *Girtyella indianensis* ranges in North America from the middle Osagean (lower Visean) to the upper Chesterian (Serpukhovian; Maples and Waters, 1987; Kammer et al., 1990), though it seems to be most common in the upper Meramecian (middle-upper Visean; Weller, 1914; Cooper, 1944). It occurs in the Visean of Alberta, Canada (Nelson, 1961), the Osagean to Chesterian of Iowa, Illinois, and Missouri (Weller, 1914; Kammer et al., 1990), the upper Meramecian–Chesterian of Virginia (Englund, 1979; Christopher, 1990) and Kentucky (Weller, 1931), the lower Chesterian of Pennsylvania (Benson, 1934), Chesterian members of the Paradise Formation of Arizona (Hernon, 1935), the Chesterian of Arkansas (Easton, 1942).

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