Early Middle Devonian conodont faunas (Eifelian, *costatus–kockelianus* zones) from the Roberts Mountains and adjacent areas in central Nevada

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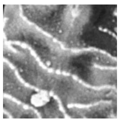

Conodont faunas from the uppermost part of the Coils Creek Member of the McColley Canyon Formation and primarily the lower part of the Denay Limestone (Middle Devonian, Eifelian) from the northern Roberts Mountains and adjacent central Nevada areas are the subjects of the present study. Four new species from the Denay Limestone (Eifelian, *costatus* and *australis* zones) are described herein: *Polygnathus salixensis* sp. nov., *P. holynensis* sp. nov., *P. robertsensis* sp. nov. and *P. damelei* sp. nov. These species add to the biostratigraphic resolution and characterization of the *costatus* and *australis* zones. The basal Denay Limestone in the northern Roberts Mountains is in the upper part of the *costatus* Zone, which directly overlies the upper Coils Creek Member in the *serotinus* Zone. Thus, the *patulus* and *partitus* zones are missing in this area. To the south in the northern Antelope Range and the northern Hot Creek Range, the *partitus* Zone sits directly on the *serotinus* Zone with the *patulus* Zone missing. • Key words: Middle Devonian, conodont biostratigraphy, Nevada, Roberts Mountains.

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Middle Devonian conodonts (Eifelian) from the Roberts Mountains (Nevada) and adjacent areas are the subject of the present research. The conodont faunas discussed come from the uppermost part of the Coils Creek Member (Murphy & Gronberg 1970) of the McColley Canyon Formation (Carlisle *et al.* 1957, Johnson 1966) and the lower part of the Denay Limestone (Johnson 1966, Murphy 1977). These two units crop out throughout the Roberts Mountains as well as other ranges in the limestone belt of central Nevada and by virtue of their contrasting lithologies the boundary between them is easily mapped.

Geological setting

Coils Creek Member, McColley Canyon Formation

The Coils Creek Member, the uppermost member of the McColley Canyon Formation (Murphy & Gronberg 1970), has been mapped at Red Hill in the northern Simpson Park Range, throughout the Roberts Mountains, in the southern Sulphur Springs Range, at the Lone Mountain, in the northern Antelope Range, and in the northern Hot Creek Range (Fig. 1). Historically, the McColley Canyon Formation has been treated as a deepening upward sequence with some fluctuations in all members and with the Kobeh (basal member of the formation) showing the most wave-generated structures, the Bartine (the middle member) fewer, and the Coils Creek few, if any, such structures. The Coils Creek Member consists of rather uniform, medium- to thick-bedded, medium- to light-gray, very fine-grained limestones, generally with very few identifiable macrofossils (Murphy & Gronberg 1970). Those authors interpreted the depositional environment of this member as outer shelf below storm wave base in relatively deep, quiet, but well-aerated water.

Denay Limestone

The name Denay Limestone was introduced by Johnson (1966) for then unnamed Middle Devonian strata in the

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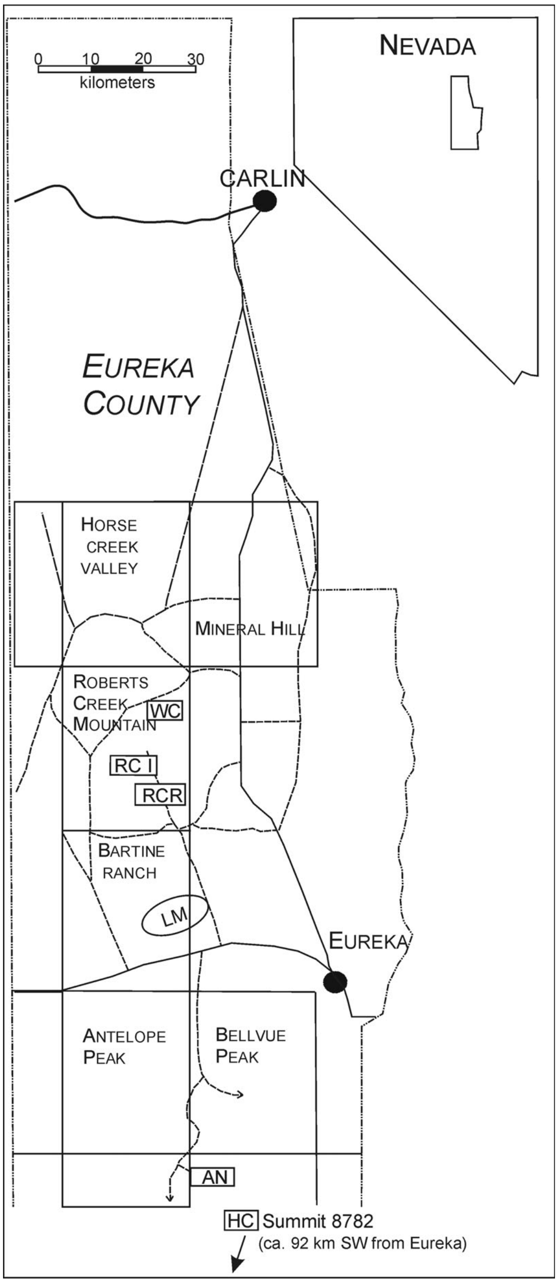


Figure 1. Schematic map showing locations of conodont localities in the northern Roberts Mountains and Eureka County, central Nevada. Abbreviations: WC – Willow Creek (see Fig. 2B for detailed map of Willow Creek sections), RC I – Roberts Creek, RCR – Roberts Creek Ranch, LM – Lone Mountain, AN – northern Antelope Range, HC – Hot Creek. Modified after Murphy & Gronberg (1970).

northern Roberts Mountains and northern Simpson Park Range lying between the McColley Canyon Formation and the Devils Gate Formation (Nolan *et al.* 1956). Morgan (1974, unpublished thesis), Murphy & Morgan (1974), and especially Murphy (1977) studied the lithologic development of the Denay Limestone. In comparison to rather uniform development of the underlying Coils Creek Member, the lithologic development of the Denay Limestone is much more diverse. Murphy (1977) informally divided the upward shoaling sequence of the Denay Limestone into three parts on the basis of the percentage of coarse-grained limestone beds (Fig. 2). The conodont faunas studied herein come from the first two parts of the Denay Limestone. The lower part of the formation is according to Murphy (1977) comprised of laminated, thin-bedded lime-mudstones with interbeds of graded or massive bioclastic packstones, grainstones and occasionally also intraformational breccias (debris flows deposits). The middle part of the formation is characterized by thick-bedded, coarse-grained wackestones, packstones, grainstones, rudstones and floatstones with abundant coral, stromatoporoid and brachiopod faunas (gravity flow deposits) interbedded with thin beds of laminated, fine-grained limestones. Murphy (1977) and Murphy & Morgan (1974) interpreted the depositional environment of the Denay Limestone as deep-water, shelf-slope, and basinal deposits. The first author studied the boundary between the Coils Creek Member and the Denay Limestone in the northern Roberts Mountains and northern Simpson Park Range in an attempt to characterize its nature and recorded a number of features suggesting an unconformity in most of the study area (abrupt lithological change, erosional contacts).

Previous studies on Lower and Middle Devonian (Emsian–Eifelian) conodont faunas from the Roberts Mountains and adjacent areas

The first study on conodont faunas from Lower and Middle Devonian strata of central Nevada was published by Clark & Ethington (1966), who described and figured a species of *Polygnathus* from the Lone Mountain section (Fig. 1), identified as *P. linguiformis* Hinde (1879). The Lone Mountain specimen illustrated on their plate 84, fig. 7, was later included by Klapper & Johnson (1975, p. 74) within their new Emsian species, *P. laticostatus*. [The other specimen identified as *P. linguiformis* by Clark & Ethington (1966, pl. 84, fig. 9) is indeed that species, but is from the Middle Devonian Simonson Formation in the Confusion Range, Utah.] Klapper & Johnson (1975, figs 3, 4) described an evolutionary sequence within *Polygnathus* from the McColley Canyon Formation and basal Denay Limestone in the Lone Mountain section and demonstrated the correlative value of species within this sequence with strata elsewhere in Nevada, Canada, Australia, Spain, and Germany. Conodonts from Red Hill (a short distance NW of the Roberts Mountains) were studied by Morgan (1974, unpublished thesis), who recognized two different conodont faunal assemblages in the Coils Creek Member and Denay Limestone (see below). Klapper (1977a) studied upper Emsian and Eifelian conodont biostratigraphy, recognizing the

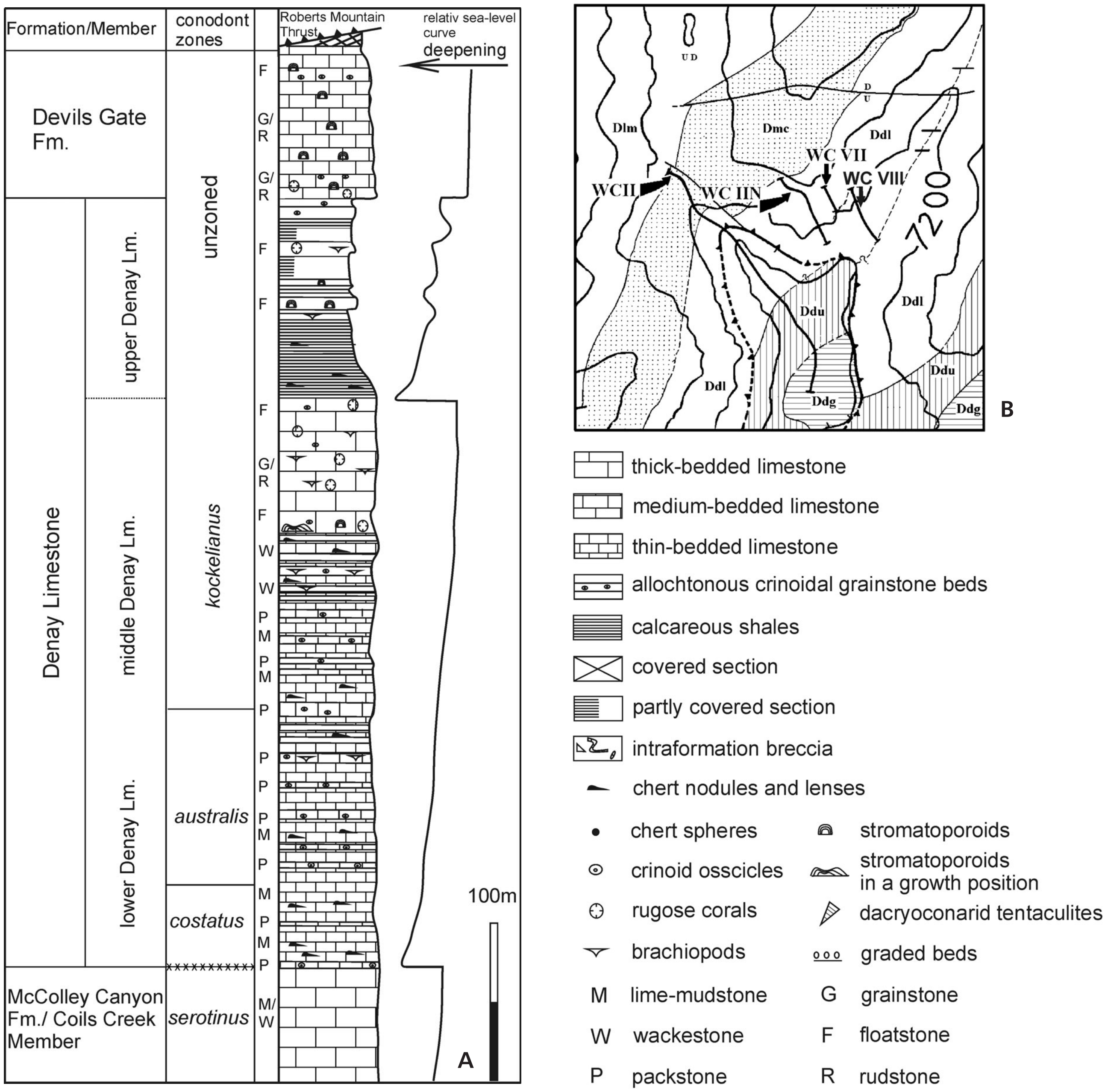


Figure 2. A • Willow Creek composite section with reconstructed relative sea-level curve. Mappable beds were followed between the partial sections (WC II, IIN, VII, VIII) in order to compile the composite. Slightly modified after Murphy (1977). B • Detailed map of Willow Creek with the position of WC II and WC IIN indicated. Sections WC VII and VIII, which are also indicated, were not a subject of our study.

serotinus, *costatus*, *australis* and *kockelianus* zones in central Nevada sections and discussed possible explanations for the missing *patulus* Zone (see below). Klapper & Johnson (1980), Klapper *in* Johnson *et al*. (1980) and *in* Johnson *et al*. (1996) identified conodonts from the northern Antelope Range (concentrating on section V in the latter paper), in which evidence for the conodont succession from the *serotinus* to the *kockelianus* zones was presented. The revision of the 1996 conodont collections by Klapper and critical new collections from section V by C.A. Sandberg revealed an absence of the *patulus* Zone in northern Antelope Range section V [Sandberg & Klapper *in* Elrick *et al.* 2009, p. 171, where the *partitus* Zone (sample VH6 in Johnson *et al*. 1996, table 2)] lies only 0.3 m of an unsampled shale interval above the *serotinus* Zone (sample VH5); see also Sandberg *in* Morrow 2007). Conodonts from the Givetian *varcus* Zone of the Denay Limestone at Willow Creek (WC II) were described by Ziegler *et al*. (1976).

Pedder (2010) studied the succession of rugose coral faunas from the *serotinus* Zone to the *costatus* Zone and

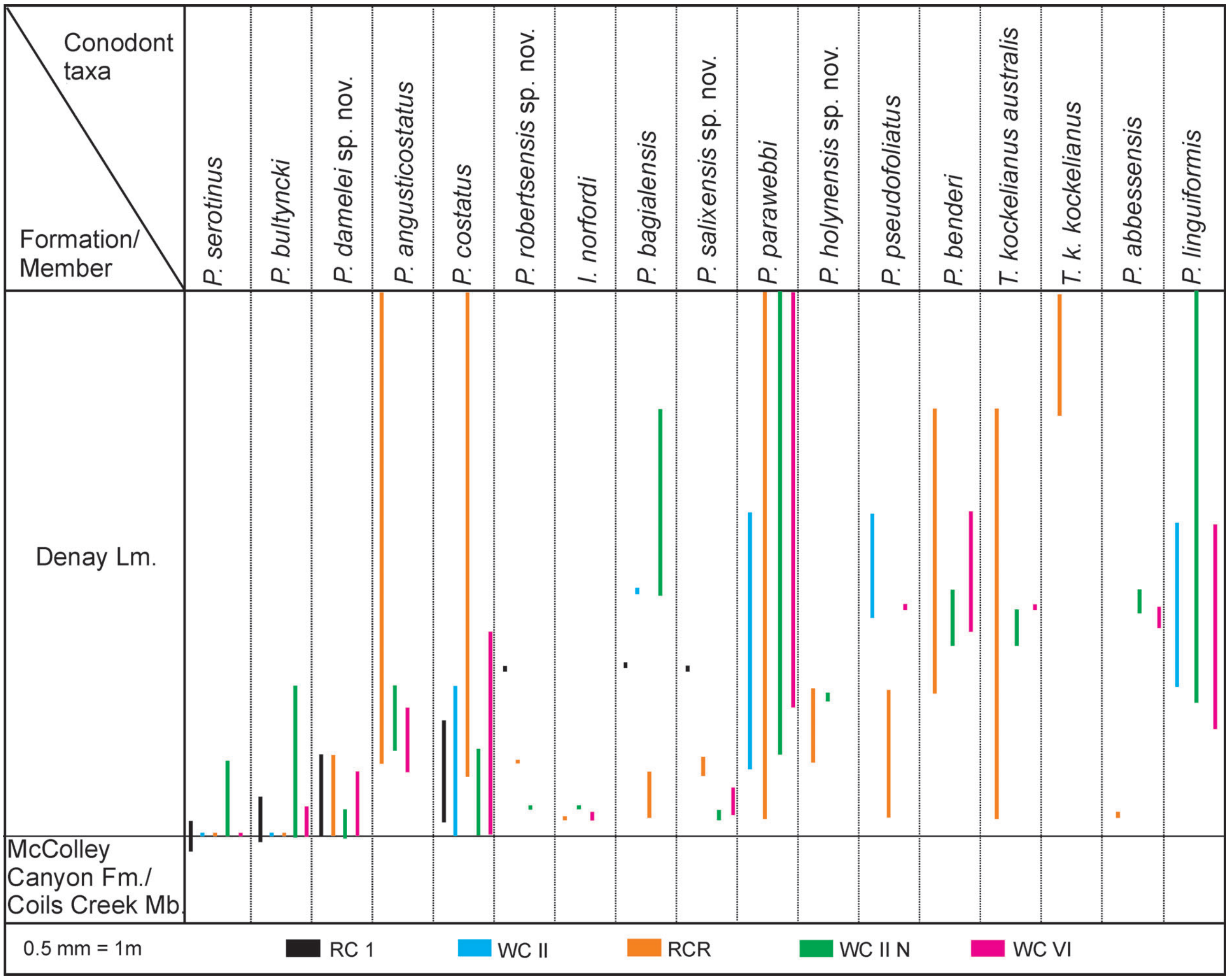


Figure 3. Stratigraphic distribution of conodont species in the Coils Creek Member and the Denay Limestone at individual sections.

provided new data from the northern Antelope Range and the southern Sulphur Spring Range.

Previous studies on the missing record in the Roberts Mountains

Johnson (1962) described a significant faunal break between the Lower Devonian *Eurekaspirifer pinyonensis* Zone (faunal intervals 10–12 *sensu* Johnson 1977, *gronbergi* and *inversus* zones) and Middle Devonian *circula* Zone (*costatus–kockelianus* zones, faunal units FI 13 and FI 15 *sensu* Johnson 1977), which according to Johnson (1966) also coincides with a lithologic break between these zones (argillaceous limestones of the *pinyonensis* Zone and siliceous platy gray limestones of the *Leptathyris circula* Zone). Murphy & Gronberg (1970) recorded the *Elythyna* faunal assemblage of the *pinyonensis* Zone (faunal interval 14 *sensu* Johnson 1977, *serotinus* Zone) in the upper part of Coils Creek Member and thus reduced the missing record. Although a faunal break between the Coils Creek Member of the McColley Canyon Formation and the Denay Limestone in the northern Roberts Mountains was apparent (Murphy 1977), no conclusive evidence in terms of exact biostratigraphic data existed then. Morgan (1974, unpublished thesis) recognized two different conodont assemblages in the upper Coils Creek Member and lower Denay Limestone in the Red Hill area and regarded the abrupt upper limit of the first and lower limit of the succeeding assemblage as a result of paraconformity, following the ideas of Johnson (1962). Klapper (1977a, pp. 44, 45) recorded the absence of the *patulus* Zone in central Nevada, attributing it either to a biostratigraphic hiatus corresponding to physical unconformity or, in the case of Lone Mountain, to sampling deficiencies. The *patulus* Zone was later identified in the northern Hot Creek Range (Johnson *et al*. 1986, table 8; Klapper & Ziegler 1979) and in the crinoidal member of the Sadler Ranch Formation at Modoc Peak (Johnson

& Murphy 1984), but these occurrences may be better interpreted now as belonging to the *partitus* Zone. The main evidence for the *patulus* Zone was from the Summit 8782 section in the northern Hot Creek Range. That section (Johnson *et al*. 1986, table 8) shows a lower fault block with the *serotinus*, *partitus*, and *costatus* zones overlain by an upper fault block with the *serotinus*, supposedly *patulus*, and *costatus* zones. We suspect that the upper block should be the same as the lower fault block and thus doubt the identification of the *patulus* Zone here because that zone is clearly missing in the northern Antelope section V. In summary, the *patulus* Zone is probably absent in the known outcrop areas in central Nevada that expose the contact of the Denay Limestone on the Coils Creek Member of the McColley Canyon Formation. Johnson & Murphy (1984, p. 1353) noted that the base of the Denay Limestone is in but not at the base of the *costatus* Zone. The missing interval in the northern Antelope Range was recently discussed by Pedder (2010).

Results

Missing record in the Roberts Mountains and adjacent areas

The faunas from the following sections were studied (Fig.1): Roberts Creek (RC1), Roberts Creek ranch (RCR) and three sections at Willow Creek (WC II, WC II N and WC VI). Additionally, faunas from northern Antelope section V and the Hot Creek Summit 8782 section are included in the Systematic Paleontology section. In the northern Antelope and Hot Creek sections the basal Eifelian *partitus* Zone intervenes between the underlying Emsian *serotinus* Zone and the overlying Eifelian *costatus* Zone*,* unlike the northern Roberts Mountains where there is no evidence for the *patulus* and *partitus* zones.

As Fig. 3 indicates, *Polygnathus serotinus* and *P. bultyncki* were recorded in the uppermost beds of the Coils Creek Member. Neither of these species is zonally diagnostic. *P. serotinus* (nominal species of the *serotinus* Zone) is long ranging, with the range being mostly recorded from the *serotinus* Zone to the *partitus* Zone (*e.g*., Belka *et al.* 1997, Berkyová 2009, Mawson 1987, Weddige 1977) and the lower part of the *costatus* Zone (Johnson *et al*. 1996, Klapper 1977a, Klapper *et al.* 1978, Lane & Ormiston 1979). The range of *P. bultyncki* is similar to that of *P. serotinus* occurring commonly from the *serotinus* Zone to the lower *costatus* Zone.

The lowermost part of the Denay Limestone in the northern Roberts Mountains yielded *Polygnathus costatus*, *P. serotinus* and *P. bultyncki*, thus indicating the *costatus* Zone. Neither the nominal species nor the accompanying faunas of the *patulus* and *partitus* zones have been found, which indicates absence of these conodont zones in the northern Roberts Mountains. In the lower Denay Limestone (interval from *ca* 5 m to 20 m), new faunal elements appear (Figs 3–5), *e.g. P. angusticostatus*, *P. bagialensis*, *P. parawebbi*, *P. pseudofoliatus* and *Tortodus kockelianus australis* representing the *australis* Zone. The occurrences of these species low in the Denay Limestone considerably reduce the thickness of the *costatus* Zone (5 m in the RCR section, Fig. 5). The differences in sedimentary rates and patterns at individual sections might partly account for the reduction of thickness of the *costatus* Zone. However, based on evidence for the missing *patulus* and *partitus* zones and the physical character of the Coils Creek/Denay Limestone boundary, the absence of these two zones and also of the lower part of the *costatus* Zone due to physical unconformity appears to be most probable.

Summary and concluding remarks

Conodonts from the top of the Coils Creek and the base of the Denay Limestone of northern Roberts Mountains and adjacent areas (central Nevada) were the subject of the recent study. Specifications of stratigraphic distribution and geographic occurrences of important conodont species are given here: *P. bagialensis* and *P. benderi* have been recorded from central Nevada for the first time. The upper range of *P. costatus* has been recorded as high as in the basal *kockelianus* Zone, which represents its highest published occurrence. Four new species are described herein: *Polygnathus holynensis* sp. nov., *Polygnathus salixensis* sp. nov. (*costatus* Group), *Polygnathus damelei* sp. nov. and *Polygnathus robertsensis* sp. nov. (*robertsensis* Group). Exact biostratigraphic data constrains precisely the conodont zones of the top of the Coils Creek Member of the McColley Canyon Formation and the base of the Denay Limestone. At all Roberts Mountains sections studied so far, the higher part of the Eifelian *costatus* Zone (inferred from the conodont associations, as shown in Fig. 3) in the lower Denay lies directly on the Emsian *serotinus* Zone in the upper Coils Creek. It is concluded that the *patulus and partitus* zones, as well as the lower part of the *costatus* Zone, are absent in the sequences in the northern Roberts Mountains. In the northern Antelope Range and the northern Hot Creek Range to the south, however, the *partitus* Zone intervenes between the *costatus* Zone above and the *serotinus* Zone below, with the *patulus* Zone missing.

Systematic section

Photography of the specimens was made in the Paleontological department of Natural History Museum (National Museum, Prague) using the Olympus SZX-12 (*e.g*., Fig. 10), Charles University in Prague using the JEOL

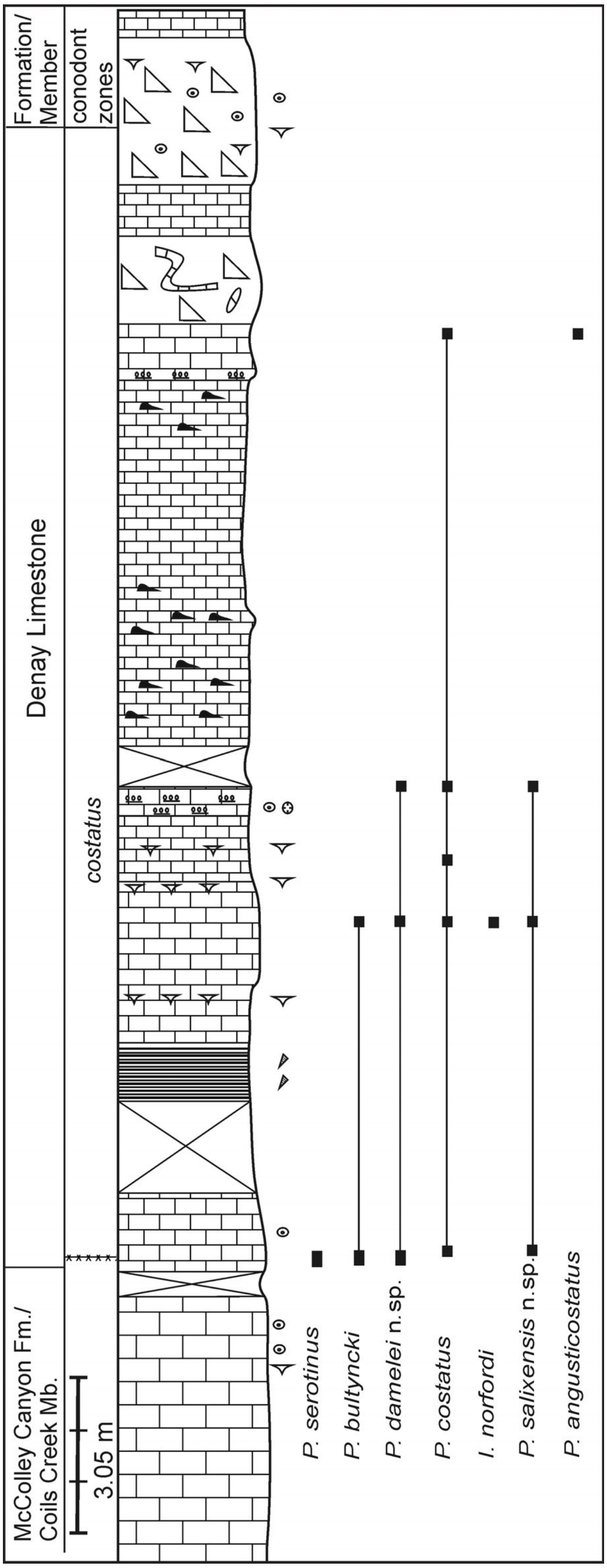


Figure 4. Lithological column of Willow Creek VI section with conodont species ranges. See legend in Fig. 2.

JSM-6380 (Figs 6F–H), Department of Earth Sciences, University of California at Riverside using a Leica MZ16 microscope mounted with a Leica DFC420 camera (*e.g.*, Fig. 11A, C, J – lateral views) and Department of Geoscience, University of Iowa using a Leitz Aristophot setup mounted with a Canon 50D camera (*e.g.*, Fig. 9B, C), and more recently with a Visionary Digital BK Lab System (http://www.visionarydigital.com/IntegratedSystems2.html) mounted with a Canon 7D digital camera (*e.g.*, Fig. 8C–G, I). All the photographs, except for Figs 6J–O, 8C–I, and 9, were stacked using the CombineZP software (http://www.hadleyweb.pwp.blueyonder.co.uk/). The specimens studied are deposited in the collection of Michael A. Murphy in the University of California, Riverside (UCR type numbers), of Stanislava Vodrážková in the Czech Geological Survey (SB3–SB5), and at the University of Iowa, Iowa City (SUI type numbers).

We recognize a *costatus* Group of species comprised of *Polygnathus costatus* Klapper, 1971, *P. holynensis* sp. nov., *P. salixensis* sp. nov., *P. partitus* Klapper, Ziegler & Mashkova, 1978, *P. patulus* Klapper, 1971, and *P. gilklapperi* Mawson & Talent, 1994. All of these are formally described herein except for *P. partitus* and *P. patulus*, which are listed in Appendix 1 that provides critical literature references to diagnoses and illustrations. In this paper, we elevate *P. costatus*, *P. partitus*, and *P. patulus* to the species level as the degree of their differences justifies this action. The three taxa were formerly treated as subspecies of *P. costatus.* We also recognize a *robertsensis* Group of species comprised of *P. robertsensis* sp. nov., *P. damelei* sp. nov., *P. zieglerianus* Weddige, 1977, *P. pinguis* Weddige, 1977, and *P.* aff. *P. pinguis.* To be consistent in our taxonomic practice, we elevate *P. pinguis* to the species level and no longer treat it as a subspecies of *P. linguiformis* Hinde, 1879.

As to terminology in the diagnoses and descriptions, adcarinal grooves differ from adcarinal troughs in that the grooves are either equant or deeper than they are wide and the troughs are wider than they are deep.

Genus *Polygnathus* Hinde, 1879

Type species. – *Polygnathus dubius* Hinde, 1879.

Polygnathus costatus **Klapper, 1971**
Figure 6A–I, K–L

1971 *Polygnathus costatus costatus* subsp. nov.; Klapper, p. 63, pl. 1, figs 30–36; pl. 2, figs 1–7 [figs 5–7 = holotype, reillustrated here on Fig. 6L].

1973 *Polygnathus costatus costatus* Klapper, 1971. – Klapper *in* Ziegler, pp. 347, 348, *Polygnathus* – plate 1, fig. 3 [reillustration of holotype; synonymy].

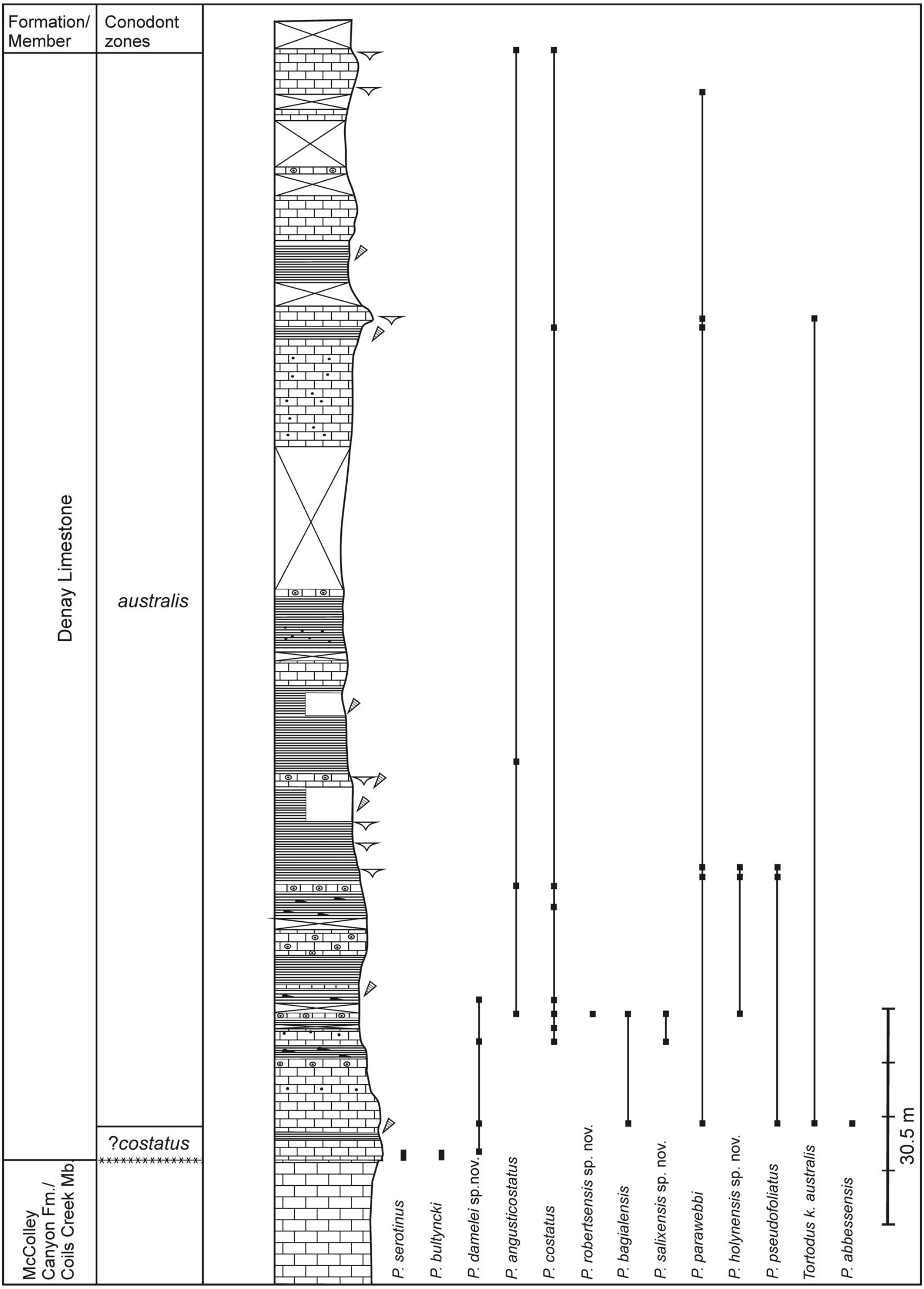


Figure 5. Lithological column of Roberts Creek Ranch section with conodont species ranges. See legend in Fig. 2.

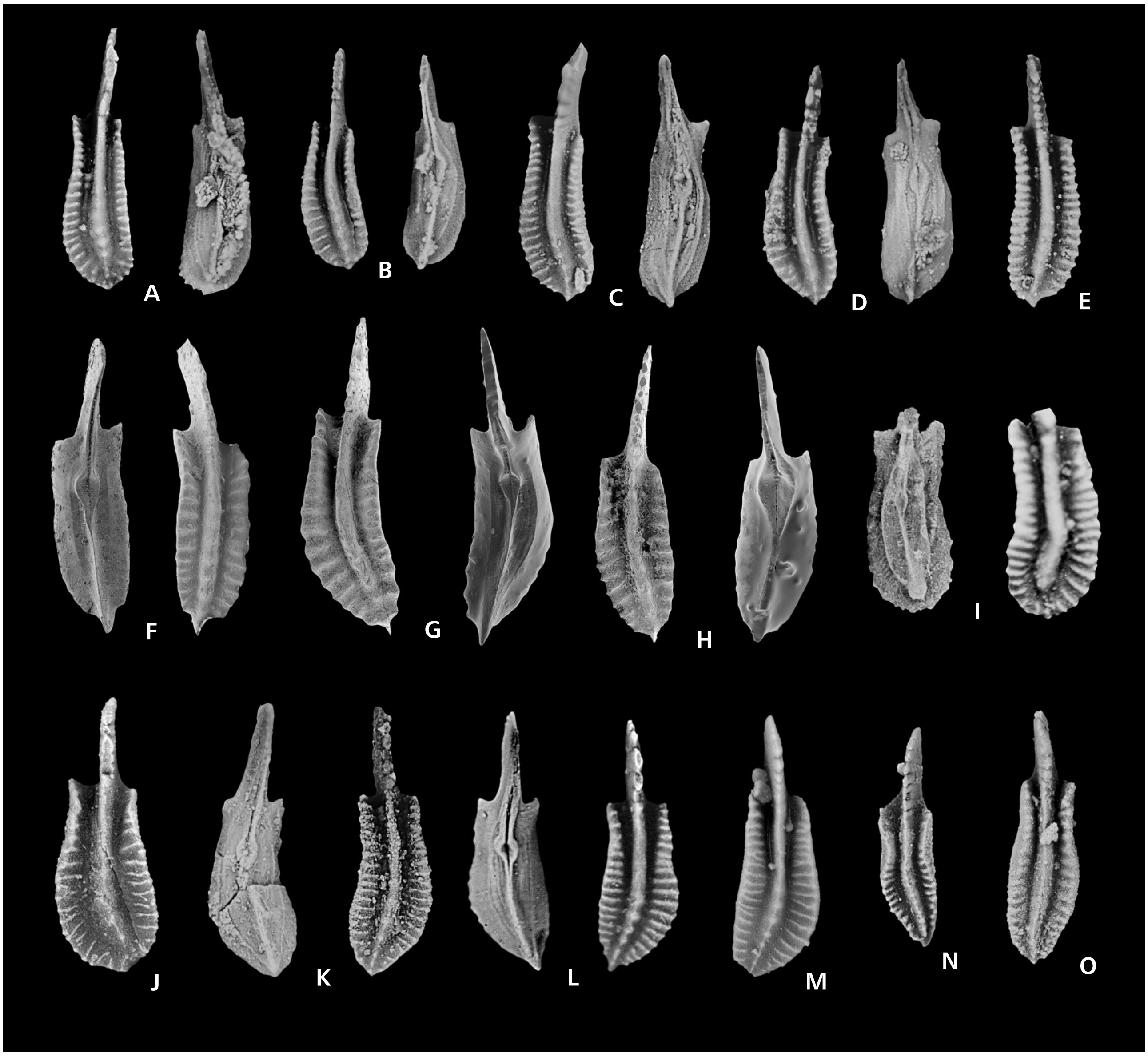


Figure 6. A–I, K–L – *Polygnathus costatus* Klapper, 1971. • A–C, E – RCR 22 I, *australis* Zone, upper and lower views of UCR 10989 X/3, UCR 10989 I/20, UCR 10989 I/30 and upper view of UCR 10989 X/3). • D – WC VI 2, *costatus* Zone, upper and lower views of UCR 10999 I/30. • F, G – Na Škrábku quarry, Prague Basin, 5 m above the base of the Choteč Limestone, *costatus* Zone, approximately × 40, lower and upper views of SB3, upper and lower views of SB4. • H – Na Škrábku quarry, Prague Basin, 7 m above the base of the Choteč Limestone, *costatus* Zone, approximately × 40, upper and lower views of SB5. • I – WC IIN 4, *costatus* Zone, lower and upper views of UCR 8700 I/40. • K – WC VI 5C-1', *costatus* Zone, lower and upper views of UCR 11004. • L –New York, Seneca Member, Onondaga Limestone, loc. 5, sample 2, *costatus* Zone (Klapper 1971, pl. 2, figs 5–7), new illustrations of lower and upper views of holotype SUI 35096, approximately × 33. • J – *Polygnathus* cf. *P. costatus*; Antelope Range, section V, sample VG-25, Coils Creek Member (Johnson *et al.* 1996, table 2), *costatus* Zone, upper view of SUI 126794, approximately × 26. • M – *Polygnathus patulus* Klapper, 1971. Antelope Range, section V, sample VH-8, Coils Creek Member (Johnson *et al.* 1996, table 2), *partitus* Zone, upper view of SUI 126795, posterior tip broken, approximately × 26. • N–O – *Polygnathus holynensis* sp. nov., Antelope Range, section V, samples VH-32, SB-26, Coils Creek Member (Johnson *et al.* 1996, table 2), *costatus* Zone, upper views of paratypes SUI 126796, 126797, approximately × 26. All magnifications approximately × 30, unless mentioned otherwise.

1978 *Polygnathus costatus costatus* Klapper, 1971. – Klapper, Ziegler & Mashkova, pp. 109, 114, pl. 2, figs 10–12.

1986 *Polygnathus* sp. nov. – Schönlaub, p. 368, pl. 4, figs 18, 19.

1994 *Polygnathus gilklapperi* sp. nov.; Mawson & Talent, pp. 46, 47, pl. 2, figs 5–8 [figs 6, 7 = *P. costatus* morphotype X].

2009 *Polygnathus costatus costatus* Klapper, 1971. – Berkyová, pp. 676, 678, figs 6I–K [see further synonymy].

species	platform character	carina	transverse ridges	adcarinal areas	
costatus	narrow p.,inner m. straight to slightly concave, then expanded. Outer m. nearly straight, then convex. Maximal width of p. slightly posterior of midlength	continuous, or ends shortly anterior of tip. Almost straight or slightly curved	closely, evenly spaced. Interspaces of the same size as ridges or slightly wider	narrow grooves continouos to tip	
partitus	narrow p., inner m. almost straight to 2/3 of p., then angles in a straith margin to tip. Outer m. almost straight or slightly concave, then convex taper to tip	almost straight, continuous, at least in forms of nodes	evenly spaced	narrow, deep grooves, shallow posteriorly, continuous to tip	
patulus	medium width, inner m. concave then convex, outer m. nearly straight or slightly convex, then convex to tip. Maximal width of p. at midlength or in posterior third	commonly does not reach posterior tip	evenly spaced, interspaces wider then ridges	moderately wide deep anterior troughs shallow posteriorly	
holynensis	irregular shape of p. Inner m. nearly straight to sinuous, outer m. expanded at midlength narrowing posteriorly	strong, slightly curved, continuous to tip or ends slightly anteriorly of tip. Recurved at tip	evenly and closely spaced with minimum of intercalations and branching	similar to that of *P. costatus*	
cf. *holynensis*	inner m. almost straight, outer m. bulges at midlength	similar to that of *P. holynensis*	irregular in size, spacing and orientation with intercalations, branching and interruptions	deep throughs pass into troughs of irregular width and ragged margins	
gilklapperi	medium width of p. Inner m. almost straight, outer m. biconvex	variable: continuous to tip in form of nodes or ends in posterior third of p.	intercalation of ridges possible	deep troughs tapers to midlength, shallow and fade out in posterior third	
salixensis	V to U shape in cross section. Medium width, margins subparallel or slightly diverging to 3/4 of p.,then taper to tip	continuous, almost straight	uniformly and closely spaced, branching and intercalations common	anterior troughs pass into grooves posteriorly	

Figure 7. Characteristic features of representatives of the *costatus* Group.

2010 *Polygnathus costatus* cf. *partitus* Klapper, Ziegler & Mashkova 1978. – Machado *et al.*, p. 445, pl. 2, fig. E [= *P. costatus* morphotype X].

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: narrow platform with strong transverse ridges separated from carina by narrow, deep adcarinal grooves continuous to posterior end and that shallow somewhat posteriorly; ridges uniform and closely spaced; anterior platform margins nearly parallel; inner platform margin nearly straight to slightly concave, then slightly expanded posterior of

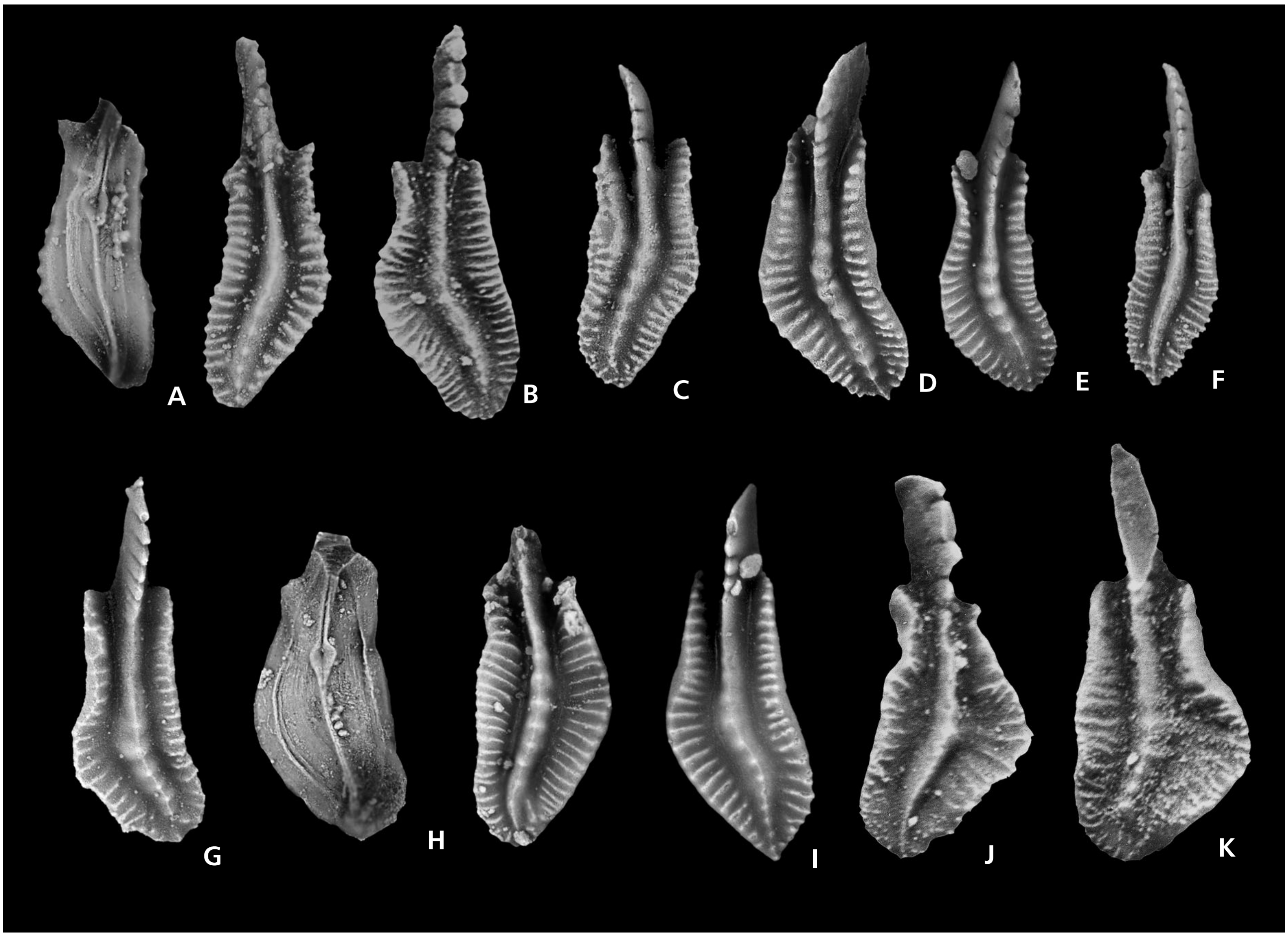


Figure 8. A–I – *Polygnathus holynensis* sp. nov. • A – RCR 19, *australis* Zone, lower and upper views of paratype UCR 10988 slide I/19 (free blade broken during manipulation of the specimen), approximately × 30. • B – WC IIN 6A+4', *costatus* Zone, upper view of holotype UCR 8706 I/30, approximately × 30. • C, F – Antelope Range, section V, sample VB-3, VH-32, Coils Creek Member (Johnson *et al.* 1996, table 2), *costatus* Zone, upper views of paratypes SUI 126798, 126799. • D–E, G, I – Hot Creek Range, Summit 8782, samples 11, 11, 8A, 11, Coils Creek Member (Johnson *et al.* 1986, fig. 7, table 8), *costatus* Zone, upper views of paratypes SUI 126800-126803. • H – RCR 31, *australis* Zone, lower and upper views of paratype UCR 11022 I/15, approximately × 30. • J, K – *Polygnathus* cf. P. *holynensis*. WC IIN 6A+4', *costatus* Zone, upper views of UCR 8706 I/30, UCR 8706 I/3, approximately × 30. All magnifications approximately × 26, unless mentioned otherwise.

the anterior third; outer margin in the anterior third nearly straight followed by a slightly expanded convex arc in the posterior two-thirds; widest part of platform slightly posterior of midlength; carina almost straight to slightly curved; posterior carina continuous to tip or ends shortly anterior of tip.

Description. – Pa element lower side: basal pit small with strong rims, located slightly anterior of platform midlength; anterior groove open, parallel-sided. Pa element upper side; anterior platform margins commonly meet free blade at almost a right angle; outer margin may have a weak sinus at the anterior third in a few specimens. Carina narrows to thinner nodes near the posterior end in some specimens and may extend shortly and distinctly beyond the posterior margins of the platform in some specimens. In exceptional specimens (Fig. 6I; also that of Schönlaub 1986, pl. 4, figs 18, 19) the adcarinal grooves extend in a circular arc around the posterior termination of the carina. Free blade with 5–6 compressed denticles. Unit is slightly arched.

Remarks. – *Polygnathus patulus* has a wider platform, adcarinal troughs instead of grooves, a generally shorter posterior carina, and more widely spaced transverse ridges, in contrast with that of *P. costatus* (slightly modified from Klapper 1971, p. 63). For a comparison of *P. costatus* with the closely similar *P. holynensis,* see under the latter. Specimens in Fig. 6F–H are regarded herein as a distinct morphotype of *P. costatus. P. costatus* morphotype X differs by having a conspicuous but small triangular tip posterior of the end of the carina, extending beyond the rest of the posterior platform margins and forming right angles with those margins. This feature is not to be confused with the

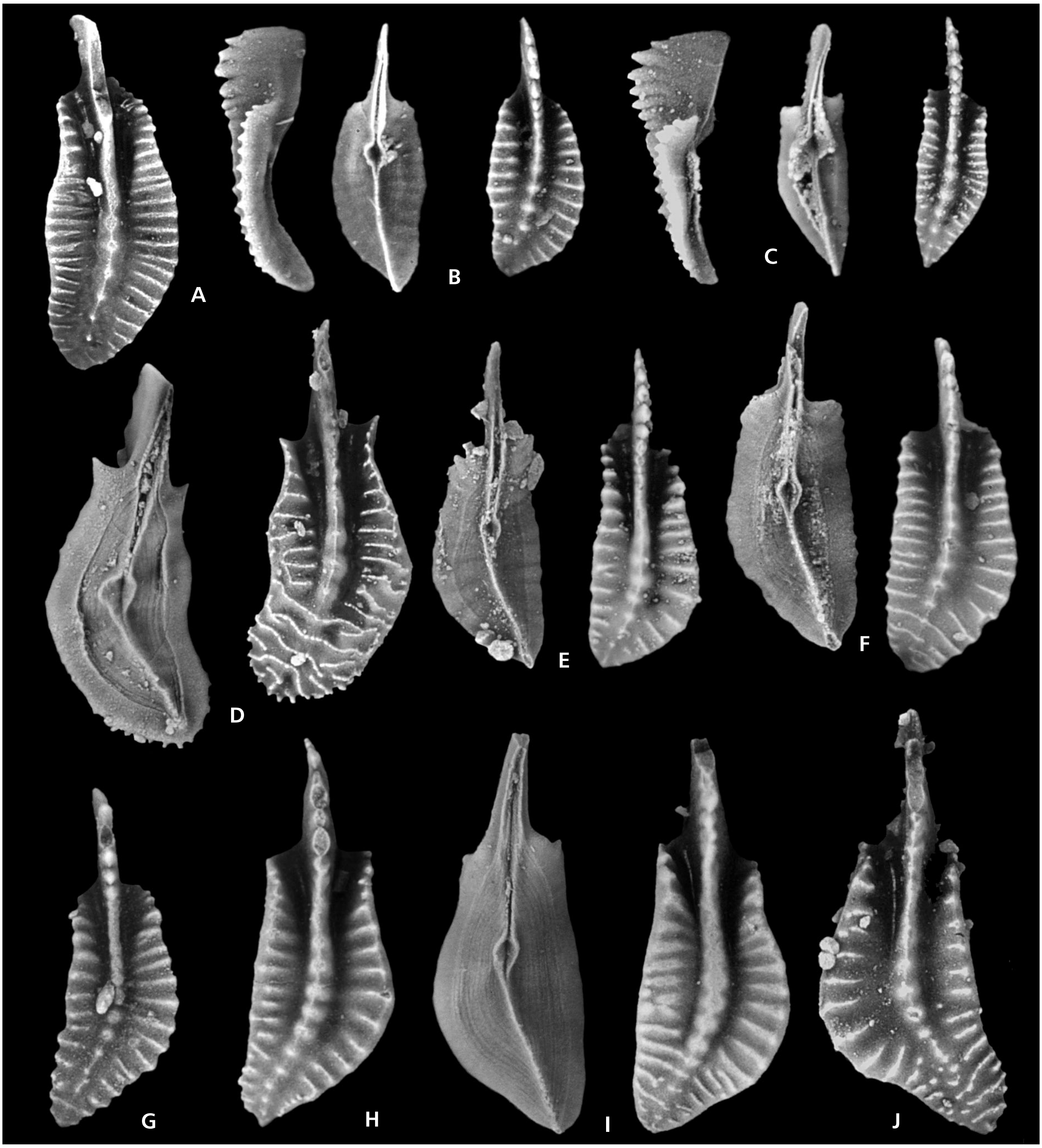


Figure 9. A, B – *Polygnathus patulus* Klapper, 1971. • A – Antelope Range, section V, sample VH-8, Coils Creek Member (Johnson *et al*. 1996, table 2), *partitus* Zone, upper view of SUI 126804, approximately × 34. • B – New York, Nedrow Member, Onondaga Limestone, loc. 8, sample 5 (Klapper 1971, pl. 1, figs 6, 7), *partitus* Zone, new illustrations of lateral, lower, and upper views of holotype SUI 35076. • C – *Polygnathus partitus* Klapper, Ziegler, and Mashkova, 1978, Hlubočepy, Choteč Limestone, 0.20–0.30 m above base (Klapper *et al*. 1978, pl. 2, fig. 5), *costatus* Zone, new illustrations of lateral, lower, and upper views of holotype SUI 44964. • D – *Polygnathus laticostatus* Klapper & Johnson, 1975, Lone Mountain, loc. 1, sample LM29, Coils Creek Member (Klapper & Johnson 1975, pl. 1, figs 31, 32), *inversus* Zone, new illustrations of lower and upper views of paratype SUI 38014. • E–J – *Polygnathus gilklapperi* Mawson & Talent, 1994. • E, F – Hot Creek Range, Summit 8782, sample 7, Coils Creek Member (Klapper & Johnson, 1980, figs 13, 14, 17, 18; Johnson *et al*. 1986, fig. 7, table 8), *serotinus* Zone, new illustrations of lower and upper views of holotype SUI 46304 and paratype SUI 46305. • G – Antelope Range, section V, sample VH-5, Coils Creek Member (Johnson *et al*. 1996, table 2), *serotinus* Zone, upper view of SUI 126805. • H–J – Hot Creek Range, Summit 8782, samples 10A, 10A, 7, Coils Creek Member (Johnson *et al*. 1986, fig. 7, table 8), *partitus* Zone, *serotinus* Zone, upper, lower and upper, upper views of SUI 126806–126808. All magnifications approximately × 40, unless mentioned otherwise.

tip of the carina, which extends in some specimens (*e.g*., Fig. 6B–E, L) beyond the rest of the posterior platform margins. We consider the specimens of Mawson & Talent (1994, pl. 2, figs 6, 7; those on their pl. 2, figs 5, 8 are closely related) and that of Machado *et al*. (2010, pl. 2, fig. E) to belong to morphotype X.

A specimen termed here as *Polygnathus* cf. *P. costatus* (Fig. 6J) has adcarinal troughs instead of grooves and shorter and irregularly developed transverse ridges. For the summary of diagnostic features of the *costatus* Group see Fig. 7.

Stratigraphic range and occurrences. – *Polygnathus costatus* has an almost 'cosmopolitan' distribution (note the qualification of this term in Klapper & Johnson 1980, p. 402, as Devonian conodonts were not then known in the large Malvinokaffric Realm and are not known there even as yet). The lowest occurrence of *P. costatus* in the Nevada sections was recorded at the base of the Denay Limestone at most of the sections studied (*costatus* Zone); the highest occurrence was recorded at about 150 m above the base of Denay Limestone at the RC 1 section, at the base of the *kockelianus* Zone, representing its highest known occurrence.

***Polygnathus holynensis* sp. nov.**
Figures 6N, O, 8A–I

Holotype. – The specimen in Fig. 8B, UCR 8706 I/30.

Etymology. – The name is derived from the Holyně village near Prague, where the first specimen of this species was found.

Material. – 3 specimens from the Roberts Creek Ranch and Willow Creek, 3 specimens from the Prague Basin and more than 50 specimens from the northern Antelope Range and Hot Creek Range.

Diagnosis. – A species of *Polygnathus* based on Pa elements with the following combination of characters: narrow to medium, irregularly shaped platform with strong, evenly spaced transverse ridges separated from carina by narrow, relatively deep adcarinal grooves to narrow troughs that are continuous to posterior end but that may change to shallow, nearly equant grooves near tip; ridges uniformly spaced; inner platform margin nearly straight to sinuous, outer margin expanded at midlength narrowing posteriorly; carina straight to slightly curved inwardly; posterior carina continuous to tip or ends shortly anterior of tip and thins posteriorly and is recurved outwardly.

Description. – Pa element lower side: basal pit small with strong rims, located slightly anterior of platform midlength; anterior groove open, parallel-sided. Pa element upper side; anterior platform margins commonly meet free blade almost at a right angle; outer margin sinuous in most specimens; some specimens have irregularly spaced transverse ridges and some have nodes replacing the ridges posteriorly. There can be an extremely narrow shelf on the outer margin just anterior of midlength. Carina narrows to thinner nodes near the posterior end in some specimens. Free blade with 4–6 compressed denticles. Unit is slightly arched. Maximum width normally at mid-length of the platform.

Remarks. – Pa elements of *Polygnathus holynensis* sp. nov. have sinuous platform margins, carinas, and keels, as opposed to the closely similar species *P. costatus* and the platform is relatively longer. Although the outer platform margin may be expanded at midlength in some specimens of *P. costatus,* the outer platform does not narrow appreciably from that point to the posterior end.

Specimens termed here as *Polygnathus* cf. *P. holynensis* (Fig. 8J, K) have a much wider outer platform at midlength, with more intercalations between the transverse ridges, and more branching of the transverse ridges than in *P. holynensis.* The ridges are also less numerous and shorter.

Stratigraphic range and occurrences. – The new species was recorded in the Prague Basin at Na Škrábku quarry in the *costatus* Zone; at the Holyně section near Prague and the Hostim section near Beroun it occurs in the basal *australis* Zone (joint occurrence with *P. pseudofoliatus*). In the Roberts Mountains sections *P. holynensis* was found in the *australis* Zone, but it occurs in the *costatus* Zone in the northern Antelope Range section V and the Summit 8782 section in the northern Hot Creek Range.

***Polygnathus gilklapperi* Mawson & Talent, 1994**
Figure 9E–J

1980 *Polygnathus* sp. nov. B Klapper, 1977. – Klapper & Johnson, p. 454, pl. 4, figs 13, 14, 17, 18 [see synonymy; figs 13, 14 = holotype selected by Mawson & Talent 1994, p. 46].
1986 *Polygnathus* sp. nov. B of Klapper. – Klapper *in* Johnson *et al*., tables 1, 8.
[not] 1994 *Polygnathus gilklapperi* sp. nov.; Mawson & Talent, pp. 46–47, pl. 2, figs 5–8 [Figs 5, 8 = *P. costatus* Klapper, 1971; figs 6, 7 = *P. costatus* morphotype X].
1996 *Polygnathus* sp. nov. B of Klapper. – Johnson, Klapper & Elrick, table 2.
2002 *Costapolygnathus gilklapperi* (Mawson & Talent, 1994). – Bardshev, Weddige & Ziegler, p. 415, text-fig. 14, fig. 28 [reillustration of holotype].

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: wide platform with strong transverse ridges in the anterior two thirds separated from carina by either adcarinal troughs or grooves (Fig. 9H, I), which terminate at the posterior third of the platform; ridges in posterior third may completely cross the platform, or be interrupted by nodes of the carina (Fig. 9E, G, H, I) or be partially replaced by lateral nodes (Fig. 9J) or some combination of these (Fig. 9F); transverse ridges are uniformly spaced, but some have much shorter ridges intercalated between those of normal length; anterior platform margins not parallel; inner platform margin nearly straight, outer platform margin expands into a convex curve posterior of midlength; widest part of platform and point of carina's curvature is at same point posterior of midlength; posterior carina either continuous to tip as a row of separate nodes or ends in the posterior third; basal pit located very slightly anterior of platform midlength.

Description. – Pa element lower side: moderate-sized basal pit with rims; anterior groove open, parallel-sided. Pa element upper side; anterior platform margins commonly meet free blade variably at a right to an acute angle; in a few specimens the outer margin may have a weak sinus at the anterior third (*e.g.*, Fig. 9G, I) and also in the posterior third of a few (Fig. 9I, J). Carina narrows to thinner nodes near the posterior end in some specimens. Short free blade with 3–5 compressed denticles. Unit is slightly arched.

Remarks. – The pit of the closely related *Polygnathus laticostatus* Klapper & Johnson, 1975 (Fig. 9D) has a distinctly larger pit with stronger rims than in the present species. The pit of *Polygnathus patulus* Klapper, 1971, is located closer to the anterior platform margin, about halfway between midlength and the anterior margin, as opposed to the Pa elements of *P. gilklapperi.*

In *Polygnathus cooperi* Klapper (1971, pl. 1, figs 17–22; Klapper *et al*. 1978, pl. 2, figs 21, 22, 29, 30) the anterior platform margins are parallel or close to parallel, the platform is narrower, and the transverse ridges in the anterior two-thirds of the platform are shorter than in *P. gilklapperi*.

As indicated in the synonymy list, Mawson & Talent (1994) designated the holotype of *P. gilklapperi* from a sample from the Summit 8782 section in the northern Hot Creek Range, central Nevada, illustrated by Klapper & Johnson (1980). However, the Australian specimens Mawson & Talent (1994, pl. 2, figs 5–8) attributed to their new species belong instead to *P. costatus*, based on differences in the platform outline, position of the pit, and distribution of ornament on the upper surface. In having a conspicuous but small triangular tip that extends posterior of the rest of the platform margins, their specimens in pl. 2, figs 6, 7 indicate identification with *P. costatus* morphotype X.

Stratigraphic range and occurrences. – *Polygnathus gilklapperi* occurs only in Nevada as far as is presently known. It does not occur in our Roberts Mountains collections, because the *costatus* Zone in the lower Denay Limestone lies unconformably on the *serotinus* Zone of the upper Coils Creek Member of the McColley Canyon Formation, where only a few samples were taken. The species occurs in the *serotinus* and *partitus* zones in the Summit 8782 section in the northern Hot Creek Range (Johnson *et al*. 1986, table 8) and in the same two zones in section V in the northern Antelope Range (Johnson *et al*. 1996, table 2; see revised zonal identifications of the *partitus* Zone for samples VH 6–8 in Elrick *et al*. 2009, p. 171).

***Polygnathus salixensis* sp. nov.**
Figure 10A–B, D–K

Holotype. – The specimen in Fig. 10G, UCR 11000 II/5.

Etymology. – *Salix* is Latin for willow; the species is named for Willow Creek, one of the main localities for Lower Eifelian conodonts in the Roberts Mountains, central Nevada.

Material. – 86 specimens.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: wide, subquadrate to lenticular platform with wide transverse ridges separated from the carina by narrow, deep adcarinal grooves anteriorly and posteriorly that are continuous to the posterior end; transverse ridges uniformly and closely spaced, but some are branched and some have much shorter ridges intercalated between those of normal length; open 'v' to 'u' – shaped platform cross section; platform margins roughly parallel until the posterior third where they converge to the pointed tip; carina continuous to posterior tip, almost straight to slightly curved.

Description. – Pa element lower side: basal pit small with rims, located slightly anterior of platform midlength; anterior grooves open. Pa element upper side; anterior platform margins meet free blade at almost a right angle; outer margin commonly a convex curve but a sinus may be developed in the posterior third, inner margin with a sinus at the anterior third followed by a convex curve to the tip. Depth of cross section variable from shallow to deep. Carina thins in the posterior third or fourth. Free blade short with about 4–5 compressed denticles. Unit is slightly arched.

Remarks. – Pa elements of the similar species, *P. costatus*, have a narrower anterior platform and the range of

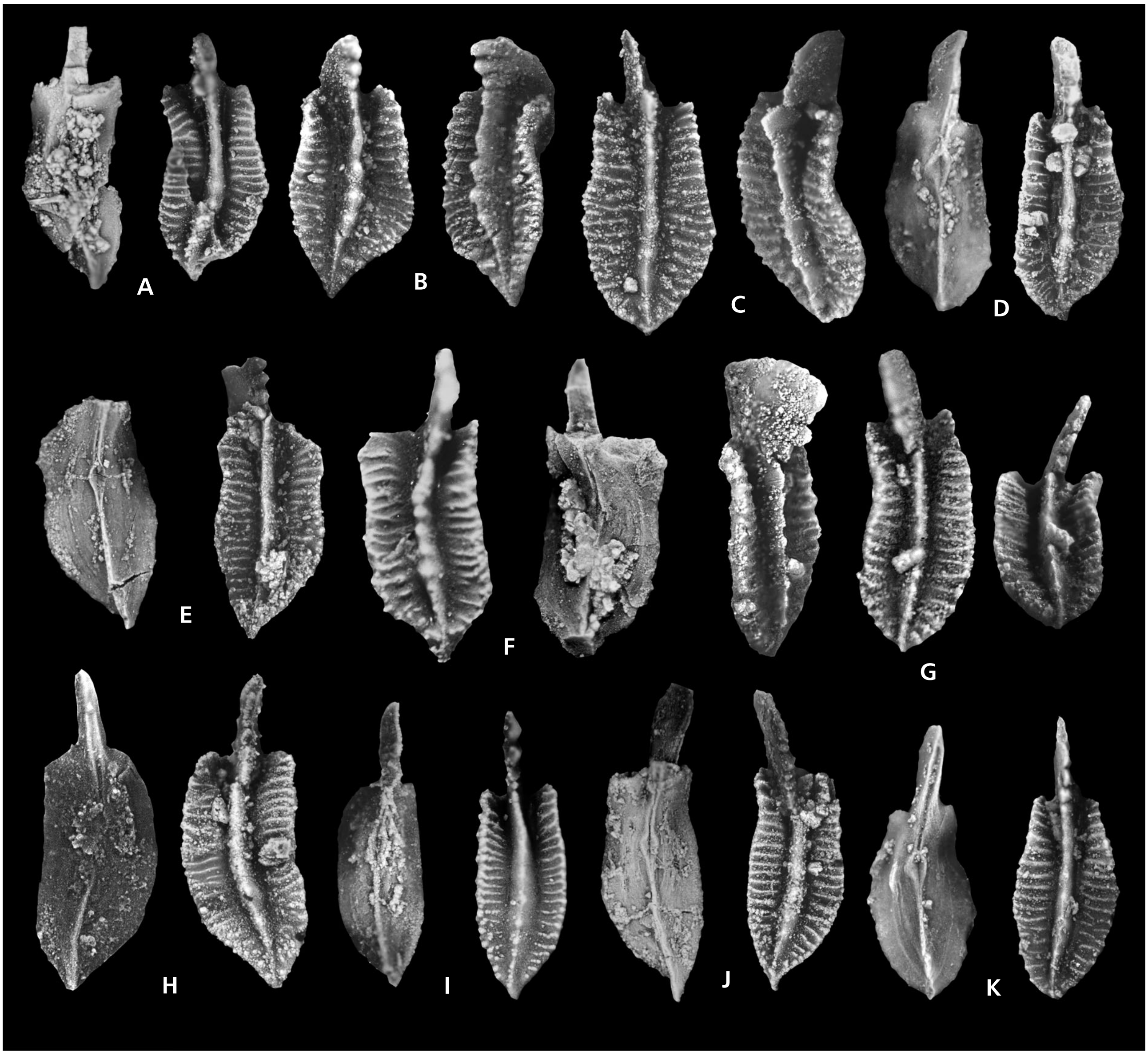


Figure 10. A–B, D–K – *Polygnathus salixensis* sp. nov. • A – RCR 17, *australis* Zone, lower and upper views of paratype UCR 10987 V/23). • B, D, G–H – WC VI 4A, *costatus* Zone, upper and oblique-lateral views of paratype UCR 11000 II/2, lower and upper views of paratype UCR 11000 I/15, oblique-lateral, upper, and posterior views of holotype UCR 11000 II/5, lower and upper views of paratype UCR 11000 I/16. • E, J – WC VI 5C-1', *costatus* Zone, lower and upper views of paratype UCR 11004 II/43 (free blade broken during manipulation of the specimen); lower and upper views of paratype UCR 11004 II/15. • F – WC IIN4, *costatus* Zone, upper and lower views of paratype UCR 8700 I/41. • I – RCR 22, *australis* Zone, lower and upper views of paratype UCR 10989 X/1. • K – WC VI 2, *costatus* Zone, lower and upper views of paratype UCR 10999 II/31. • C – *Polygnathus* cf. *salixensis*, WC VI 4A, *costatus* Zone, upper and oblique-lateral views of UCR 11000 II/3. All magnifications approximately × 30.

variation does not include a 'v' shaped platform cross section, as opposed to the new species. In *P. salixensis* sp. nov. the transverse ridges are wider because the platform is wider than in *P. costatus,* which lacks both the branched and intercalated ridges of the new species.

The form we identify as *P.* cf. *P. salixensis* (Fig. 10C) has much shallower posterior adcarinal grooves, thus flattening the posterior platform in contrast with the new species. The specimen in Fig. 10F is an end member of the new species in terms of the platform outline and the deeper adcarinal troughs and grooves.

Stratigraphic range and occurrences. – The new species has been recorded in the *costatus* and *australis* zones in the Roberts Mountains.

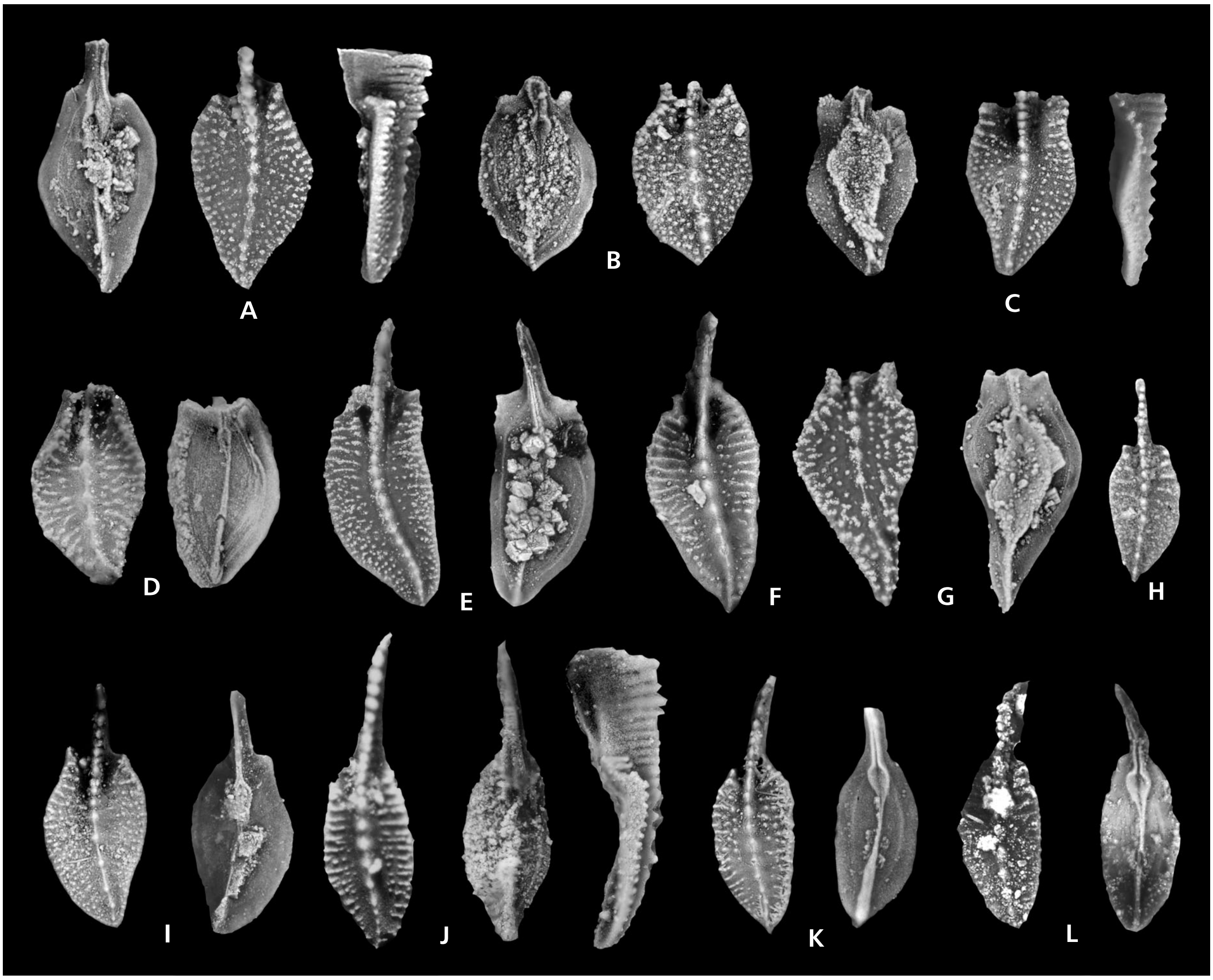


Figure 11. A–D, G, I –*Polygnathus abbessensis* Savage, 2011. • A–C, G – WC IIN 8+14 (UCR 8714), *australis* Zone, lower, upper and lateral views of UCR 8714I/1, lower and upper views of UCR 8714 II/45, lower, upper and lateral views of UCR 8714 II/23, upper and lower views of UCR 8714I/3. • D – WC IIN 8, *australis* Zone, upper and lower views of UCR 8714 III/1. • I – WC VI 17, *australis* Zone, upper and lower views of UCR 11045 I/13. • E–F, H, J–L –*Polygnathus benderi* Weddige, 1977. • E–F, H – WC IIN 8+14 (UCR 8714), *australis* Zone, upper and lower views of UCR 8714 I/5, upper views of UCR 6714 II/46, UCR 8714 II/47. • J – WC IIN 7, *australis* Zone, upper, lower and lateral views of UCR 8712 II/1. • K, L – RCR 45, *kockelianus* Zone, upper and lower views of UCR 11032 VIII/1, UCR 11032 V/1. All magnifications approximately × 30.

***Polygnathus benderi* Weddige, 1977**
Figure 11E, F, H, J–L

1977 *Polygnathus benderi* sp. nov. – Weddige, p. 308, pl. 3, figs 59–61 [fig. 59 = holotype].

1979 *Polygnathus benderi* Weddige, 1977. – Lane & Ormiston, p. 88, pl. 9, fig. 8.

1983 *Polygnathus benderi* Weddige, 1977. – Wang & Ziegler, p. 100, pl. 5, fig. 21.

(not) 1992 *Polygnathus benderi* Weddige, 1977. – Bardashev, p. 64, pl. 2, fig. 27.

1994 *Polygnathus benderi* Weddige. – Mawson & Talent, p. 54, pl. 2, fig. 14.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: elliptically shaped platform covered mostly or entirely with nodes; adcarinal grooves absent to weakly developed; platform widest at midlength; slightly curved carina continuous to posterior tip and slightly recurved outwardly near posterior tip.

Description. – Pa element lower side: basal pit small with rims, located slightly anterior of platform midlength in adult specimens, but closer to anterior end in juveniles including the holotype; anterior groove thin, parallel-sided. Pa element upper side: anterior platform margins commonly meet free blade at an acute angle; short transverse ridges or aligned nodes may be developed anteriorly and/or posteriorly in the Nevada specimens but not in the types. Margins are upturned anteriorly in the holotype, forming short anterior troughs. Such troughs are present in some of the Nevada specimens (*e.g.*, Fig. 11E, F), but are absent in others. The weakly developed adcarinal grooves posterior of the short troughs are narrow and very shallow. Carina may be replaced by fine nodes near the posterior end in a few specimens. Long free blade with about ten compressed denticles. Unit is slightly arched.

Remarks. – Pa elements of *P. abbessensis* Savage, 2011, have a shorter and wider platform with the basal pit very close to the anterior end, in contrast with *P. benderi* in which the pit is closer to midlength in adult specimens. The outer anterior margin in most specimens of *P. abbessensis* is constricted but not in the holotype nor in *P. benderi.*

The specimen of Bardashev (1992, pl. 2, fig. 27) differs from *P. benderi* in its platform outline and the presence of transverse ridges.

Stratigraphic range and occurrences. – See Klapper & Johnson (1980) and references therein. *Polygnathus benderi* occurs in the *australis* Zone in the Roberts Mountains.

***Polygnathus abbessensis* Savage, 2011**
Figure 11A–D, G, I

1977 *Polygnathus* sp. A; Savage, p. 1350, pl. 1, figs 13–18.
1977 *Polygnathus* sp. C; Savage, p. 1354, pl. 2, figs 5–8.
1980 *Polygnathus* sp. A Savage. – Klapper & Johnson, p. 454, pl. 4, fig. 10.
1995 *Polygnathus borealis* sp. nov.; Savage, p. 550, figs 6.10–6.12, fig. 8.11 [= holotype, reillustration of Savage, 1977, pl. 1, fig. 13; not fig. 8.10].
2011 *Polygnathus abbessensis* n. name; Savage, p. 810.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: oval-shaped but posteriorly pointed platform covered mostly with nodes and some transversely aligned nodes; very short adcarinal troughs present anteriorly; platform widest at midlength and flat posterior of the troughs without adcarinal grooves in mature specimens; carina almost straight to gently curved and continuous to posterior tip.

Description. – Pa element lower side: basal pit small with rims, located very close to the anterior margin of the platform; anterior groove thin, parallel-sided. Pa element upper side: anterior platform margins meet free blade at an obtuse angle directed diagonally to the posterior; incipient rostral ridges, built up with nodes, border the short anterior troughs. Short free blade with about five compressed denticles. Unit is slightly arched.

Remarks. – For a comparison with the closely similar *P. benderi,* see under the latter. We exclude from *P. abbessensis* a specimen illustrated by Savage (1995, fig. 8.10) because of the different platform outline and the anterior terminations of the platform margins, which are at a right angle. Also, the adcarinal troughs extend farther posteriorly in this specimen.

We interpret the specimen termed *Polygnathus* sp. C by Savage (1977) as an early ontogenetic stage of *P. abbessensis;* it is almost identical to the specimen illustrated by Klapper & Johnson (1980), which we also include in *P. abbessensis.*

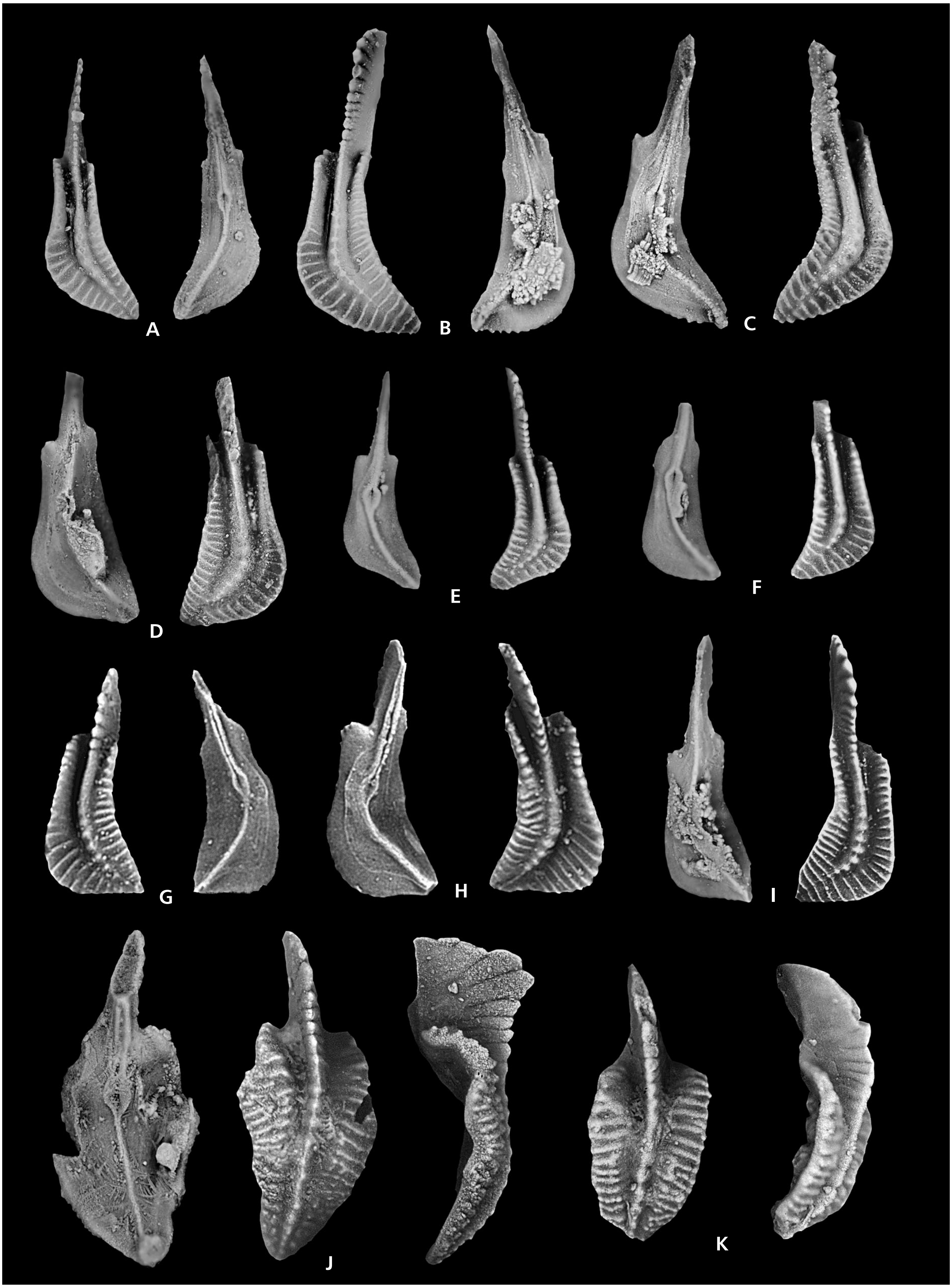
Polygnathus borealis Savage, 1995 is a junior homonym of *P. borealis* Nassedkina & Plotnikova, 1979. Savage (2011) proposed *P. abbessensis* as a replacement name.

Stratigraphic range and occurrences. – Savage (1977) reported this species from the *australis* Zone in Alaska. Klapper & Johnson (1980, table 8) reported this species from the *australis* and *kockelianus* zones, northern Antelope Range, and Klapper *in* Johnson *et al*. (1996, table 2) recorded it in the *australis* and basal *kockelianus* zones in Antelope section V. It occurs in the *australis* Zone in the Roberts Mountains.

***Polygnathus parawebbi* Chatterton, 1974**
Figure 12A–I

1974 *Polygnathus parawebbi* sp. nov.; Chatterton, pp. 1473, 1474, 1476, 1478, pl. 1, figs 12, 15–19, 25–27 [fig. 18 = holotype = alpha morph]; pl. 2, figs 1–9, pl. 3, figs 15–17.

Figure 12. A–I –*Polygnathus parawebbi* Chatterton, 1974. • A – WC IIN 10A-2, *australis* Zone, upper and lower views of UCR 8724/1. • B, C – WCIIN 8+14 (UCR 8714), *australis* Zone, upper and lower views of UCR 8714 II/8 and lower and upper views of UCR 8714 II/9. • D, I – WC VI 17, *australis* Zone, lower and upper views of UCR 11045 I/34 and UCR 8671 I/15. • E, F – RCR 14, *australis* Zone, lower and upper views of UCR 11045 I/21 and UCR 10986/2. • G, H – WC II 937, UCR 8671, *costatus* Zone, upper and lower views of UCR 8671 I/4 and lower and upper views of UCR 8671 I/9. • J, K – *Polygnathus bagialensis* Savage, 2011. J – RCR 14, *australis* Zone, lower, upper, and lateral views of UCR 10986 I/40. K – WC IIN 8+14, *australis* Zone, upper and lateral views of UCR 8714 II/5. All magnifications approximately × 30.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1977b *Polygnathus parawebbi* Chatterton, 1974. – Klapper *in* Ziegler, pp. 477–479, *Polygnathus* – pl. 11, figs 8–10 [fig. 10 = reillustration of holotype; synonymy].

1979 *Polygnathus parawebbi* Chatterton. – Chatterton, pp. 195–197, pl. 2, figs 1–17, 19–28 [figs 1–7, 19–28 = alpha morph, figs 8–17 = beta morph]; pl. 4, figs 4–7 [= gamma morph]; pl. 9, figs 9–11, 14–16 [figs 9–11 = alpha morph, figs 14–16 = beta morph].

1980 *Polygnathus parawebbi* Chatterton. – Klapper *in* Johnson *et al*., pp. 102, 103, pl. 4, figs 18–21 [figs 18, 19 = alpha morph, figs 20, 21 = beta morph].

1983 *Polygnathus parawebbi* Chatterton, 1974. – Klapper & Barrick, pp. 1239, 1240, figs 12Q, W, X, AA [beta morph].

1998 *Polygnathus parawebbi* Chatterton. – Uyeno, pp. 164, pl. 11, figs 1–3, 15, 16, 19; pl. 12, figs 6, 10–12, 24, 27; pl. 14, figs 15–18.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: platform narrow anteriorly and curved inward very strongly in posterior third; with strong transverse ridges separated from carina by relatively deep adcarinal grooves either continuous to posterior end or terminating anterior of the tongue; ridges more closely spaced anteriorly, most widely spaced at point of maximum curvature on the outer side; transverse ridges on anterior outer margin area tend to disappear in some specimens of both morphs; anterior platform margins nearly parallel, inner platform margin a shallow concave curve; outer anterior margin either straight followed by a sharp angular deflection inwardly to posterior tip (alpha morph) or it is slightly concave anteriorly then changes to a convex arc to the tip (beta morph); posterior carina either more or less continuous to tip (alpha) or commonly terminates anterior of the transverse ridges that cross the tongue (beta).

Description. – Pa element lower side: basal pit small with strong rims, located slightly anterior of platform midlength; anterior groove open, parallel-sided; keel strongly curved inwardly beginning slightly posterior of pit. Pa element upper side: anterior platform margins commonly meet free blade at almost a right angle; outer margin of two types as given in the diagnosis. In the alpha morph the posterior carina may be either continuous to the tip or replaced by a few separate nodes or a very narrow ridge. The beta morph commonly has transverse ridges that cross the tongue, but some specimens lack these ridges and instead have the carina continuous to the posterior tip (Chatterton 1979, pl. 9, fig. 14; Klapper & Barrick 1983, figs 12Q, W, X, AA). The two morphs, however, are distinguished mainly by the platform outline. Long free blade with 5–11 compressed denticles. Element is arched.

Remarks. – Two morphs of the Pa element of *Polygnathus parawebbi* recognized by Chatterton (1979) are also present in the Nevada collections (Fig. 12G–I = alpha morph, Fig. 12A–F = beta morph). They differ in the configuration of the outer platform outline, as given in the diagnosis. Furthermore, in the alpha morph the outer posterior margin adjacent to the beginning of the tongue is slightly higher than the opposite inner margin, whereas in the beta morph they are at the same height. In contrast, in *P. linguiformis* Hinde, 1879 s.s. (= gamma morph of authors) the outer posterior margin adjacent to the beginning of the tongue is much higher forming a flange, as opposed to the alpha morph of *P. parawebbi*. Chatterton (1974, 1979) has reconstructed the multielement apparatus of *Polygnathus parawebbi*.

Stratigraphic range and occurrences. – *Polygnathus parawebbi* has an almost "cosmopolitan" distribution reported from the *australis* to the *varcus* zones (Belka *et al*. 1997, Mawson & Talent 1989): North America (*e.g*., Klapper & Barrick 1983, Klapper & Johnson 1980 and references therein, Uyeno 1998); North Africa (Belka *et al*. 1997); Europe (Narkiewicz & Bultynck 2007), central Asia (*e.g*., Bardashev 1992), central Russian Platform (Kononova & Kim 2005), Australia (*e.g*., Mawson & Talent 1989). In the Roberts Mountains this species occurs in the *australis* and *kockelianus* zones.

***Polygnathus bagialensis* Savage, 2011**
Figure 12J, K

1971 *Polygnathus trigonicus* Bischoff & Ziegler, 1957. – Klapper, p. 66, pl. 3, figs 9, 10 [not figs 7, 8, 11, 12 = *P. trigonicus*]

1977 *Polygnathus trigonicus* Bischoff & Ziegler, 1957. – Savage, p. 1353, pl. 1, figs 1–12.

1992 *Polygnathus trigonicus* Bischoff & Ziegler, 1957. – Bardashev, p. 64, pl. 2, figs 37–40.

1995 *Polygnathus praetrigonicus* sp. nov.; Savage, p. 550, figs 8.8, 8.9 [reillustration of Savage 1977, pl. 1, figs 5, 9; fig. 8.8 = holotype].

2011 *Polygnathus bagialensis* n. name; Savage, p. 810.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: wide triangular platform with closely and uniformly spaced strong transverse ridges, separated at the anterior end from carina by short, deep adcarinal troughs that abruptly change to narrow adcarinal grooves shallowing posteriorly; the grooves reach or almost reach the posterior tip; transverse ridges may be replaced posteriorly by nodes; pit closer to midlength than anterior platform margin, unit strongly arched.

Description. – Pa element lower side: basal pit small with strong rims; anterior groove wide and deep, parallel-sided.

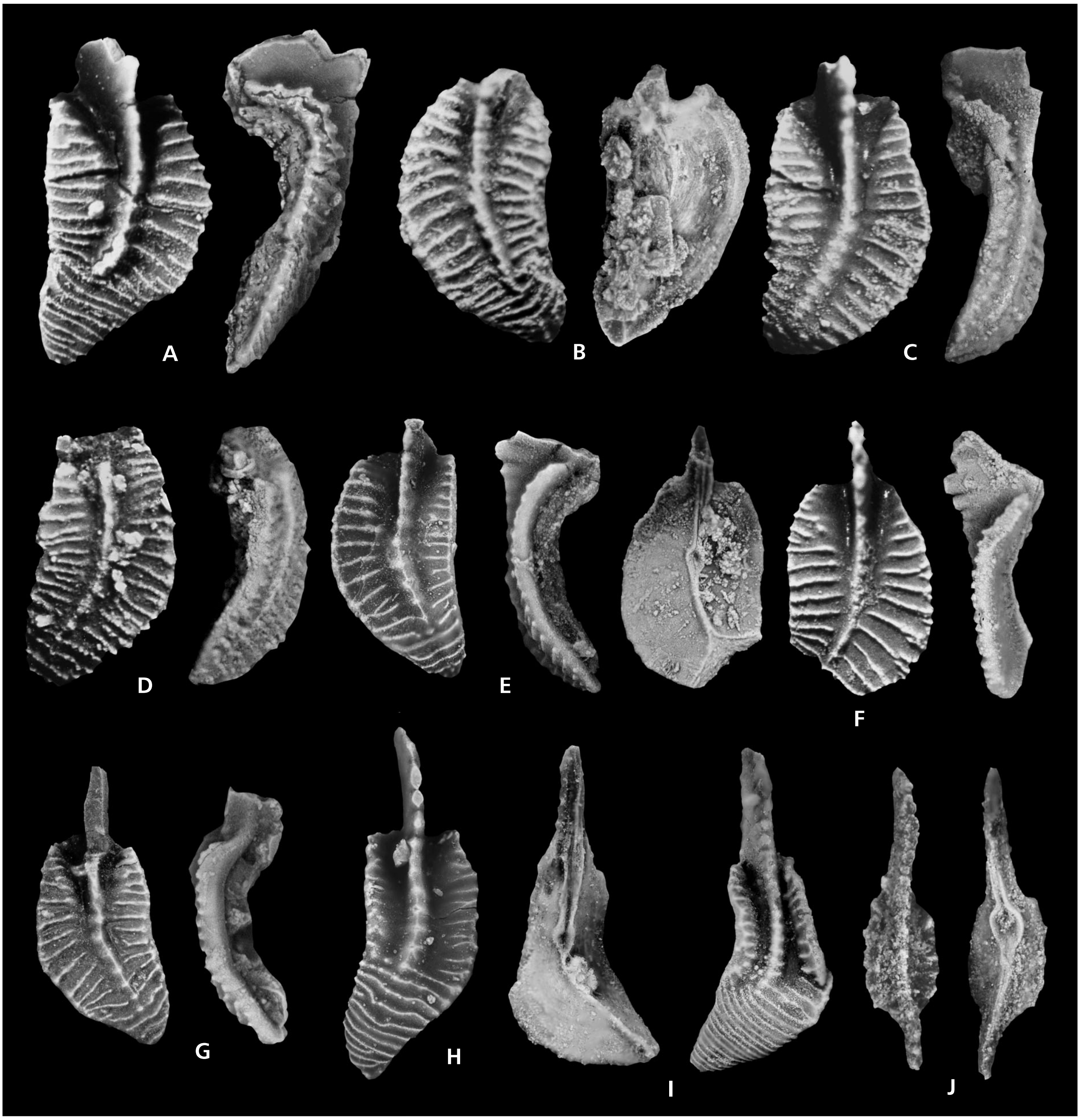

Figure 13. A–G – *Polygnathus robertsensis* sp. nov. • A, E–G – RCR 22, *australis* Zone, upper and lateral views of holotype UCR 10989/1, upper and lateral views of paratype UCR 10989 VI/30, lower, upper, and lateral views of paratype UCR 10989 II/18, upper and lateral views of paratype UCR UCR 10989 II/19. • B–D – WC IIN5, *costatus* Zone, upper and lower views of paratype UCR 10989 II/19, upper and lateral views of paratype UCR 8702 IV/1 and upper and lateral views of paratype UCR 8702 IV/2. • H, I –*Polygnathus bultyncki* Weddige, 1977. H – WC VI 32-3 +6'', *costatus* Zone, upper view of UCR 10991/1. I – WC IIN 6D, *costatus* Zone, lower and upper views of UCR 8710 I/30. • J –*Polygnathus angusticostatus* Wittekindt, 1966, WC VI 10, *costatus* Zone, upper and lower views of UCR 11040 I/29. All magnifications approximately × 30.

Pa element upper side: short anterior adcarinal troughs together form a v-shape and may be bordered on one side by a diagonal row of nodes; transverse ridges terminate at edge of both the adcarinal troughs and the adcarinal grooves; anterior platform margins meet free blade variably at almost a right to an acute angle. High, short free blade has 6–7 compressed denticles.

Remarks. – Pa elements of *Polygnathus bagialensis* Savage, 2011 are closely comparable to those of *P. trigonicus* but in that species the pit is situated at the anterior platform margin, the anterior adcarinal troughs are bordered by diagonal rows of nodes, which converge posteriorly, and the platform is less highly arched. Pa elements of *Polygnathus praetrigonicus* Bardashev 1992 (= *P.* aff. *P. trigonicus* Klapper, 1971 and later authors) have more widely spaced transverse ridges, the adcarinal troughs extend farther posteriorly, and the anterior platform margins characteristically meet the free blade at a right angle (Klapper & Vodrážková in prep.).

Polygnathus bagialensis Savage, 2011 occurs in the *costatus* and *australis* zones in Nevada and was originally described from the *australis* Zone in southeastern Alaska (Savage 1977, 1995). *P. praetrigonicus* Bardashev, 1992 occurs in the *partitus* and *costatus* zones in the northern Antelope Range, Nevada (Klapper & Vodrážková in prep.), the *costatus* Zone in New York (Klapper 1971), and the basal *costatus* Zone in the Prague Basin (Berkyová 2009, Klapper *et al*. 1978). Bardashev (1992) gives the range as *partitus* and *costatus* zones in Central Asia.

Polygnathus praetrigonicus Savage, 1995 is a junior homonym of *Polygnathus praetrigonicus* Bardashev, 1992 (= *P.* aff. *P. trigonicus* Klapper, 1971 and later authors). Savage (2011) proposed *P. bagialensis* as a replacement name.

Stratigraphic range and occurrences. – Specimens assigned herein to *Polygnathus bagialensis* were recorded in the *australis* Zone in southern Alaska (Savage 1977) and the *costatus* Zone in New York (Klapper 1971). The occurrence reported by Bardashev (1992) from central Asia is from the *australis* Zone. It occurs in the *australis* Zone in the Roberts Mountains.

Polygnathus robertsensis sp. nov.
Figure 13A–G

1980 *Polygnathus linguiformis linguiformis* Hinde theta morphotype; Klapper *in* Johnson, Klapper & Trojan, pp. 102, 114, pl. 4, figs 35, 36.

Holotype. – The specimen in Fig. 13A, UCR 10989/1.

Etymology. – The species name derives from the Roberts Mountains.

Material. – 11 specimens.

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: wide platform with strong transverse ridges separated at the anterior end from carina by v-shaped adcarinal troughs that abruptly shallow to narrow adcarinal grooves at mid-platform, terminating before the tongue; complete transverse ridges on tongue more closely spaced than those anteriorly; some transverse ridges are branched and some have much shorter ridges intercalated between those of normal length; inner platform margin nearly straight, outer margin a convex arc and nearly parallel to carina; platform widest at midlength; posterior carina incomplete but penetrates the tongue to a variable degree.

Description. – Pa element lower side: basal pit small with strong rims, slightly anterior of center of platform; anterior groove open, parallel-sided. Pa element upper side: anterior transverse ridges extend from margins to adcarinal troughs; at mid-platform adcarinal grooves are shallow and well defined; anterior platform margins commonly meet free blade at almost a right angle. High, short free blade has 3–4 compressed denticles. Unit is strongly arched.

Remarks. – Pa elements of *Polygnathus robertsensis* sp. nov. differ from those of *P. damelei* sp. nov. in lacking the conspicuous sinus in the outer posterior margin and in having a shorter free blade. *Polygnathus damelei* has wide, deep adcarinal troughs throughout the platform anterior of the tongue, as opposed to the abrupt narrowing of the troughs into shallow adcarinal grooves at mid-platform in *P. robertsensis.* Also, in *P. damelei* the anterior platform margins are more or less parallel as opposed to *P. robertsensis*. They are similar, however, in the disposition and spacing of the transverse ridges.

We have observed the basal pit in only a few specimens of the new species because the lower side of other specimens has the pit covered either by basal plate material or quartz grains.

Stratigraphic range and occurrences. – Polygnathus robertsensis is known only from Nevada. It was recorded by Klapper *in* Johnson *et al*. (1980) in the northern Antelope Range from the *costatus* Zone and by Klapper *in* Johnson *et al*. (1996, table 2) from the same zone in Antelope section V. It occurs in the *costatus* and basal *australis* zones in the Roberts Mountains.

Polygnathus damelei sp. nov.
Figure 14A–F

1986 *Polygnathus zieglerianus* Weddige. – Bultynck, p. 282, pl. 7, fig. 11 [not figs 10, 15, 16 = *P. zieglerianus* Weddige, 1977].

Holotype. – The specimen in Fig. 14E, UCR 11004 I/16.

Etymology. – The species is named for Roy D. Damele, who was the proprietor of the Willow Creek Ranch during the time that collections of the faunas from the Denay Limestone were being made by M.A. Murphy. Mr. Damele furnished accommodations at the ranch, logistical support in the field, maintenance and repair of equipment essential to our work.

Figure 14. A–F – *Polygnathus damelei* sp. nov. • A – RCR 14, *australis* Zone, lower and upper views of paratype UCR 10986 IV/1. • B – WC VI, H32-3+6'', *costatus* Zone, lower and upper views of paratype UCR 10992/2. • C – RCR 23, *australis* Zone, lower and upper views of paratype UCR 11051/1). • D, E – WC VI 5C-1'(UCR 11004), *costatus* Zone, lower and upper views of paratype UCR 11004 I/28 and holotype UCR 11004 I/16. • F – WC VI 2, *costatus* Zone, upper view of paratype UCR 10999/1. • G–H –*Polygnathus* aff. P. *pinguis* Weddige, 1977. G, I – WC VI 4A (UCR 11001), *costatus* Zone, upper and lower views of UCR 11001 IV/40, upper view of UCR 11001 IV/37). H – WC VI 5C-1', *costatus* Zone, upper and lower view of UCR 11004 I/18. All magnifications approximately × 30.

Material. – 74 specimens.

Diagnosis. – A species of *Polygnathus* based on Pa elements with the following combination of characters: wide platform with strong, equally spaced transverse ridges separated from carina on the anterior platform by wide, deep adcarinal troughs that terminate before the tongue; strong transverse ridges on tongue are generally more closely spaced than those anteriorly; anterior platform margins almost parallel; posterior carina incomplete but penetrates the tongue to a slight degree; a conspicuous sinus is present in outer posterior margin; outer posterior margin at about same height as opposite inner margin.

Description. – Pa element lower side: medium to small-sized basal pit slightly anterior of platform center in adult specimens, closer to the anterior in juvenile specimens, migrating posteriorly and decreasing in size with growth; anterior groove open, parallel-sided, deep. Pa element upper side: transverse ridges extend from anterior margins to adcarinal troughs which are deep and well defined anterior of the tongue; depth and width variable on mid-platform, anterior platform margins meet free blade at about a right angle. Free blade, about a third of the total length, has 6–7 compressed denticles. Unit is slightly arched.

Remarks. – In the parallel-sided anterior platform margins and the conspicuous sinus in the outer platform margin, the Pa element of *P. damelei* sp. nov. is distinguished from both *P. pinguis* Weddige, 1977, and the form we have identified here as *P.* aff. *P. pinguis. Polygnathus zieglerianus* Weddige (1977, pl. 6, figs 100, 101) lacks the conspicuous sinus in the outer posterior margin and the transverse ridges on the tongue are not as well developed as compared with *P. damelei*.

The platform outline of *P. linguiformis* Hinde, 1879 s.s. (= gamma morph of authors) has the outer posterior margin adjacent to the tongue developed as a high flange, in contrast with *P. damelei.* For a comparison with the closely related *P. robertsensis* sp. nov., see remarks under the latter.

Stratigraphic range and occurrences. – *P. damelei* was recorded from the *costatus* and basal *australis* zones in the Roberts Mountains. In a specimen we refer to *P. damelei*, Bultynck (1986, pl. 7, fig. 11) reported its occurrence in the *partitus* Zone from southern Morocco.

***Polygnathus* aff. *P. pinguis* Weddige, 1977**
Figure 14G–I

(aff.) 1977 *Polygnathus linguiformis pinguis* n. ssp.; Weddige, p. 316, pl. 5, figs 88, 89 [fig. 89 = holotype].

Diagnosis. – A species of *Polygnathus* based on a Pa element with the following combination of characters: wide platform with complete transverse ridges separated from carina on the anterior platform by wide, shallow to somewhat deeper adcarinal troughs (Fig. 14I) that shallow posteriorly and terminate before the tongue; distinct transverse ridges on tongue more closely spaced than those anteriorly; anterior platform margins variable and not parallel; inner margin slightly concave to convex, outer one forms a convex arc; carina slightly curved inwardly, penetrates tongue with a few nodes; outer platform margin lacking a sinus.

Description. – Pa element lower side: small basal pit slightly anterior of platform center; anterior groove open, parallel-sided. Pa element upper side: transverse ridges extend from anterior margins to deep adcarinal troughs; some shorter ridges are intercalated between the ones of normal width; anterior platform margins meet free blade about at a right angle. Free blade about a third of the total unit length, with 4–6 compressed denticles. Unit is strongly arched.

Remarks. – Pa elements of *P. pinguis* Weddige, 1977 differ from *P.* aff. *P. pinguis* by having much wider, shallower adcarinal troughs anterior of the tongue and thus the adjacent transverse ridges are shorter, confined closely to the margins. In *P.* aff. *P. pinguis* there are adcarinal troughs at midlength, as opposed to the narrow adcarinal grooves at midlength in *P. robertsensis.*

Stratigraphic range and occurrences. – In the Roberts Mountains *P.* aff. *P. pinguis* occurs in the *costatus* Zone.

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Appendix 1

Species illustrated in this paper, but not formally described in the Systematic section, are listed below with the original, as well as some representative references.

Polygnathus angusticostatus Wittekindt, 1966. Fig. 13J herein.
Polygnathus angusticostata sp. nov. Wittekindt, 1966, p. 631, pl. 1, figs 15–18.
Polygnathus angusticostatus Wittekindt; Klapper, 1971, p. 65, pl. 3, figs 21–25.
Polygnathus angusticostatus Wittekindt, 1966; Weddige, 1977, pp. 306, 307, pl. 6, figs 102–104.

Polygnathus bultyncki Weddige, 1977. Fig. 13H, I herein.
Polygnathus linguiformis Hinde, 1879, alpha forma nova Bultynck, 1970, p. 126, pl. 9, figs 1–7.
Polygnathus linguiformis bultyncki n. ssp. Weddige, 1977, pp. 313, 314, pl. 5, figs 90–92.
Polygnathus linguiformis bultyncki Weddige, 1977; Klapper, Ziegler & Mashkova, 1978, p. 112, pl. 1, figs 21, 22, 26–29.
Polygnathus bultyncki Weddige, 1977; Belka *et al*., 1999, p. 24, pl. 2, fig. 6.

Polygnathus partitus Klapper, Ziegler & Mashkova, 1978. Fig. 9C herein.
Polygnathus costatus partitus subsp. nov. Klapper, Ziegler & Mashkova, 1978, p. 109, pl. 2, Figs 1–5, 13.
Polygnathus costatus partitus Klapper, Ziegler & Mashkova, 1978; Bultynck, 1986, p. 270, pl. 8, figs 19, 20, 22.
Polygnathus costatus partitus Klapper, Ziegler & Mashkova, 1978; Berkyová, 2009, pp. 675, 676, figs 5E–I.

Polygnathus patulus Klapper, 1971. Figs 6M, 9A, B herein.
Polygnathus costatus patulus subsp. nov. Klapper, 1971, pp. 62, 63, pl. 1, figs 1–9, 29, pl. 3, figs 16–18.
Polygnathus costatus patulus Klapper, 1971; Weddige, 1977, pp. 310, 311, pl. 4, figs 73, 74.
Polygnathus costatus patulus Klapper, 1971; Klapper, Ziegler & Mashkova, 1978, p. 14, pl. 2, figs 6–9, 14–17, 19, 20 [figs 25, 31 transitional with *P. praetrigonicus* Bardashev, 1992].
Polygnathus costatus patulus Klapper, 1971; Bultynck, 1986, p. 270, pl. 8, figs 1–6.
Polygnathus costatus patulus Klapper, 1971; Berkyová, 2009, p. 675, figs 5A–D.

Appendix 2

Locality Register with list of conodont samples and their position relative to the base of the Denay Limestone. The asterisk stands for the footage below the base of the Denay Limestone.

Roberts Creek Ranch (RCR) Section Location
The Middle Devonian part of the RCR Section lies almost exactly 1 mile north slightly northeast of the Roberts Creek Ranch house slightly north of the boundary between sections 18 and 19, T22N, R51E near the southern edge of the Roberts Creek Mountain Quadrangle, 1/62,500, Nevada. It begins at the base of the Denay Limestone a little west of the 6800 foot contour line of the quadrangle map at its contact with the Coils Creek Member of the McColley Canyon Formation on the ridge paralleling the section boundary just to the north of it.

Roberts Creek (RC I) Section Location
The Roberts Creek Section is very poorly exposed in a northern tributary to Tank Canyon a main western tributary to Roberts Creek two miles north of the Roberts Creek Ranch house, Roberts Creek Mountain Quadrangle, 1/62,500, Nevada. At the head of Tank Canyon, there is a storage tank and watering trough for cattle where the canyon branches into its contributaries. The RC I section is in the north trending gully branching from the main canyon with its lower part in the upper Coils Creek Member of the McColley Canyon Formation and its upper part in the lower Denay Limestone. The section was marked in 1975 but it is not likely that the markings would survive for more than a few years. Resampling would require finding the Coils Creek-Denay contact and measuring away from it.

Willow Creek II (WC II), Willow Creek II North (WC IIN), Willow Creek VI (WC VI) Sections Location
The WC II section lies on the main ridge leading east from the mouth of Willow Creek to peak 7625. The section begins just below the 10–12 foot cliff at the base of the Denay Limestone which crosses the ridge at about the 7320 foot contour and continues to peak 7625. Only the lower part of the section from the upper part of the Coils Creek Member of the McColley Canyon Formation through the lower part of the Denay Limestone is discussed in this paper. The WC IIN section is on a subsidiary parallel-trending ridge a short distance to the north of the main ridge and begins at approximately the same level as in the WC II section. WC VI is on the east flank of Willow Creek in a small gully that builds a small fan into Willow Creek where it crosses the 6600 foot contour line on the 1/62500 Roberts Creek Mountain USGS topographic map.

Northern Hot Creek Range, Summit 8782, Morey Peak Quadrangle 1/24,000, Nye County, Nevada
The NHC, Summit 8782 Section is well exposed north and south of the minor peak labeled 8782 on the N-S trending ridge just east of Big Cow Canyon in the middle western third of the Morey Peak 1/24,000 Quadrangle, central Nevada. The section there exposes the McColley Canyon Formation and Denay Limestone and is one of the few sections in Nevada where identifiable dacryoconarids have

University of California Riverside Catalog #	Footage in the WCIIN Section	Murphy Field #
UCR 8697	* 0.6´ (0.18 m)	WCIIN 1
UCR 8698	0´	WCIIN 2
UCR 11052	0.2´ (0.06 m)	WCIIN 2A
UCR 8699	0.5´ (0.15 m)	WCIIN 3
UCR 8700	13.6´ (4.5 m)	WCIIN 4
UCR 8702	23.6´ (7.2 m)	WCIIN 5
UCR 8704	70.8´ (21.6 m)	WCIIN 6
UCR 8705	74.4´ (22.7 m)	WCIIN 6A
UCR 8706	81.7´ (24.9 m)	WCIIN 6A+4´
UCR 8708	129.2´ (39.4 m)	WCIIN 6C-2´
UCR 8710	139.7´ (42.6 m)	WCIIN 6D
UCR 8712	173.8´ (53 m)	WCIIN 7
UCR 8714	205.8´ (62.7 m)	WCIIN 8
UCR 8714	219.8´ (67 m)	WCIIN 8+14´
UCR 8716	385´ (117.4 m)	WCIIN 8C-6´ ´
UCR 8721	387´ (118 m)	WCIIN 8G
UCR 8722	390.4´ (119 m)	WCIIN 9
UCR 8724	525´ (160 m)	WCIIN 10A2

Meterage in the NHC Section	Murphy-Klapper Sample Number
24.8 m	7 – *serotinus* Zone
38.5 m	8A – *costatus* Zone
63 m	10A – *partitus* Zone
64.8 m	11 – *costatus* Zone

University of California Riverside Catalog #	Footage in the RCR Section	Murphy Field #
UCR 10983	0-0.5´ (0.152 m)	RCR 12
UCR 10984	1´ (0.305 m)	RCR 12A
UCR 10986	16´ (4.87 m)	RCR 14
UCR 10987	56.5´ (17.22 m)	RCR 17
UCR 10988	63´ (19.2 m)	RCR 19
UCR 10989	71.5-72´ (21.8 m)	RCR 22
UCR 11051	79.3´ (24.2 m)	RCR 23
UCR 11019	115.8´ (35.3 m)	RCR 28
UCR 11021	126.6´ (38.5 m)	RCR 30
UCR 11022	130.5´ (39.8 m)	RCR 31
UCR 11023	134.5´ (41 m)	RCR 32
UCR 11054	183.7´ (56 m)	RCR 36
UCR 11031	383.8´ (117 m)	RCR 44A
UCR 11032	389.7´ (118.8 m)	RCR 45
UCR 11036	492´ (150 m)	RCR 51
UCR 11035	494.7´ (150.8 m)	RCR 50

University of California Riverside Catalog #	Footage in the RCR Section	Murphy Field #
UCR 8651	0´	H6-1
UCR 8655	0.5´ (0.15 m)	H6-2
UCR 8654	65´ (19.8 m)	WCII 690
UCR 8656	66´ (20.13 m)	WCII 691
UCR 8657	136.8´ (14.7 m)	WCII 762
UCR 8658	177.8´ (42 m)	WCII 763
UCR 8660	203.4´ (62 m)	WCII 828
UCR 8662	223´ (68 m)	WCII 848
UCR 8663	225´ (68.6 m)	WCII 850
UCR 8667	283.13´ (86.3 m)	WCII 900+8´
UCR 8668	291´ (88.7 m)	WCII 916
UCR 8669	297´ (88.7 m)	WCII 922
UCR 8671	312.2´ (95 m)	WCII 937
UCR 8675	363.2´ (110.7 m)	WCII 988

University of California Riverside Catalog #	Footage in the WCVI Section	Murphy Field #
UCR 10991	0´	H-32-3, II
UCR 10991	0´	H-32-3, II
UCR 10991	0.5´ (0.15 m)	H-32-3+6´
UCR 10999	22.2´ (6.78 m)	WCVI 2
UCR 11001	30.6´ (9.35 m)	WCVI 4A
UCR 11000	31´ (9.5 m)	WCVI 4
UCR 11009	41.6´ (12.7 m)	WCVI 5D
UCR 11008	35.7´ (10.9 m)	WCVI 5D-6´ ´
UCR 11001	42.6´ (13 m)	WCVI 5C
UCR 11012	61.3´ (18.7 m)	WCVI 7A
UCR 11012A	63´ (19.2 m)	WCVI 8
UCR 11013	67.5´ (20.6 m)	WCVI 9
UCR 11015	68.5´ (20.9 m)	WCVI 9A
UCR 11040	96.8´ (29.5 m)	WCVI 10
UCR 11017	100.7´ (30.7 m)	WCVI 9C
UCR 11041	114.8´ (35 m)	WCVI 11A
UCR 11055	149.2´ (45.5 m)	WCVI 15
UCR 11056	156.2´ (47.6 m)	WCVI 15+7´ ´
UCR 11043	173.8´ (53 m)	WCVI 15A
UCR 11044	188.3´ (57.4 m)	WCVI 16A
UCR 11045	208.3´ (63.5 m)	WCVI 17
UCR 11046	285.4´ (87 m)	WCVI 19
UCR 11047	293.6´ (89.5 m)	WCVI 21
UCR 11049	504.2´ (153.7 m)	WCVI 27A
UCR 11050	506.2´ (154.3 m)	WCVI 27B

University of California Riverside Catalog #	Footage in the RCI Section	Murphy Field #
UCR 10967	*14.8´ (4.5 m)	RCI 2
UCR 10968	*3.28´ (1 m)	RCI 3
UCR 10969	0´	RCI 4
UCR 10970	2.6´ (0.8 m)	RCI 5
UCR 10971	11.5´ (3.5 m)	RCI 6
UCR 11053	36.7´ (11.2 m)	RCI 14

been recovered. A columnar diagram and the distribution of conodont species were shown for the Summit 8782 section in Johnson *et al.* (1986, fig. 7, table 8). A revision here is that sample 10A is now interpreted as being in the *partitus* Zone. A fault is recognized between the part of the section containing samples 7, 8A and that containing samples 10A, 11. These four samples provided specimens illustrated in the present study.

Northern Antelope Range, section V

Northern edge of NE1/4 sec. 21, T. 16 N., R.51 E., southern Eureka County, Nevada. Position of section and columnar diagrams are shown in Johnson *et al.* (1980, 1986, 1996). Distribution of conodont species is shown in Johnson *et al.* (1996, table 2). Several critical zonal identifications have changed since that paper, as noted by C.A. Sandberg and G. Klapper *in* Elrick *et al.* (2009, p. 171). Samples VH 6–9 are now known to belong to the *partitus* Zone, which closely overlies the *serotinus* Zone represented by sample VH-5. Samples that provided illustrated specimens for the present study are VH-5, 8, VG-25, SB-26, VB-3, and VH-32. Stratigraphic position of these samples is given in Johnson *et al.* (1996, table 2).

Appendix 3

Table showing occurrences of conodont species with the number of specimens indicated. < 5 = ●, 5–10 = ○, 11–20 = ■, 21–30 = □, > 30 = ×.

	P. serotinus	*P. bultyncki*	*P. bagialensis*	*P. damelei* sp. nov.	*P. angusticostatus*	*P. costatus*	*P. robertsensis* sp. nov.	*P. salixensis* sp. nov.	*P. parawebbi*	*P. holynensis* sp. nov.	*P. pseudofoliatus*	*P. eiflius*	*P. benderi*	*T. k. australis*	*T. k. kockelianus*	*P. abbessensis*	*P. linguiformis*
RCI																	
RCI-2	●																
RCI-3		●															
RCI-4	■	●		●													
RCI-5	●	●		●													
RCI-6	●	●				●											
RCI-14		●				●											
WCII																	
H6-1	□	●															
H6-2	●	○				○											
WCII, 690						●											
WCII, 691						●											
WCII, 762						●			●								●
WCII, 763									●								●
WCII, 763B																	●
WCII, 828									●		●						●
WCII, 848									□		●						●
WCII, 850									×		●						●
WCII, 900+8´											●	●					
WCII, 916-937									○								
WCII, 916									○								●
WCII, 922									■								
WCII, 937									×		●						
WCII, 988									●								
RCR																	
RCR 12	×	○															
RCR 12A	●	■		■													
RCR 14			●	●					●		●			●		●	
RCR 17				○		●		○		aff. ●							
RCR 19						●											
RCR 22			●		●	×	●	○		●							
RCR 23				●		●											
RCR 28						●											
RCR 30					●	○											
RCR 31										●							
RCR 32																	
RCR 36					●												
RCR 44A						●											
RCR 45																	
RCR 51			●		●	○											
RCR 50									●						●		
WCIIN																	
WCIIN 1		●		●													

	P. serotinus	*P. bultyncki*	*P. bagialensis*	*P. damelei* sp. nov.	*P. angusticostatus*	*P. costatus*	*P. robertsensis* sp. nov.	*P. salixensis* sp. nov.	*P. parawebbi*	*P. holynensis* sp. nov.	*P. pseudofoliatus*	*P. eiflius*	*P. benderi*	*T. k. australis*	*T. k. kockelianus*	*P. abbessensis*	*P. linguiformis*
WCIIN 2		○				●											
WCIIN 2A	○	○				●											
WCIIN 3	○	●				●			●								●
WCIIN 4						●			●								●
WCIIN 5				●		○	○										●
WCIIN 6	●					○			●		●						●
WCIIN 6A									□		●						●
WCIIN 6A+4´			●		■	■			×	●	●						●
WCIIN 6C-2´											●	●					
WCIIN 6D		●			●				○								
WCIIN 7									○								●
WCIIN 8									■							●	
WCIIN 8+14´			●						×				■			●	●
WCIIN 8G-6´ ´									●								
WCIIN 8G									×		●						
WCIIN 9									●								
WCIIN 10A2									□								●
WCVI																	
H32-3, II	×								●								
H32-3, I		○		●				○									
WCVI, H32-3+6´ ´	■	○		○		●											
WCVI XVI		■	●					●									
WCVI 2		○		○		×											
WCVI 3D						●											
WCVI 4A		●		□		■		□									
WCVI 4A						●											
WCVI 5D						●		■									
WCVI 5D-6´ ´						●											
WCVI 5C				○	●	●		□									
WCVI 7A					●	■											
WCVI 8				●		●											
WCVI 9						○											
WCVI 9A					●	×											
WCVI 10					●	●											
WCVI 9C						●											
WCVI 11A					●				●								
WCVI 15									●								
WCVI 15+7´									●								
WCVI 15A									●								●
WCVI 16A						●			●				●			●	
WCVI 17									○		●			●		●	
WCVI 19																	●
WCVI 21													●				
WCVI 27A									○								
WCVI 27B									○								