

# A new species of *Idiognathoides* (conodont) in the Lower Pennsylvanian Ladrões Limestone of the Alexander terrane, southeast Alaska, and its paleogeographic significance

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**ABSTRACT:** The Peratrovich Formation and overlying Ladrões Limestone in the Craig C4 quadrangle of the Prince of Wales Island, Alaska, record the accumulation of Carboniferous carbonates behind the remnants of a Late Devonian volcanic arc in the Alexander terrane. The occurrences of declinognathoid elements in the lower Ladrões Limestone suggest the possibility of a conformable Mississippian-Pennsylvanian boundary near the base of the Ladrões Limestone. The recovery of the Early Pennsylvanian conodont *Idiognathoides chaaguloos* n. sp. in the lower part of the Ladrões Limestone helps to constrain current models of the paleogeographic position of the Alexander terrane during the Carboniferous because of its limited occurrence within the Uralian Seaway. The presence of *Id. chaaguloos* n. sp. in the Alexander terrane, the Brooks Range of Alaska, and Novaya Zemlya indicates a species level biogeographic connection between these regions that shows that the Alexander terrane remained in the Uralian Seaway until at least the Middle Pennsylvanian.

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## INTRODUCTION

The geologic history of the Alexander terrane is encased in strata sparsely exposed in intertidal zones along the coastlines of the temperate rainforest and archipelago landscape that blankets southeastern Alaska. The Alexander terrane extends from southeastern Alaska northward into British Columbia and the Yukon Territory, as well as westward into the Wrangell Mountains (Blodgett et al. 2010) (text-fig. 1). Neoproterozoic to Triassic strata comprise two distinct components of the Alexander terrane. A southern component consists of Neoproterozoic to Triassic igneous, volcanic, and sedimentary rock, and a northern component contains Ordovician to Triassic siliciclastic and carbonate strata (White et al. 2016). The southern Banks Island assemblage includes Ordovician to Devonian metamorphosed marble and quartzite intervals that are genetically similar to shelf facies present in the Saint Elias Mountains of the northern partition of the Alexander terrane, suggesting a southward displacement of ~1800 km during the Late Jurassic-Early Cretaceous (Tochilin et al. 2014).

A significant gap in knowledge exists concerning the paleogeography of the Alexander terrane during the Carboniferous. Numerous authors have discussed the likely paleogeographic origins of the Alexander terrane and the paleobiogeographic affinities of the macrofauna in the lower to middle Paleozoic strata (e.g., Boucot et al. 2012; Antoshkina and Soja 2016). However, the paleogeography of the Alexander terrane and the biogeographic affinity of its Carboniferous fauna remain uncertain. Some paleogeographic diagrams for the combined Wrangellia-Alexander terrane even omit its presence in late Paleozoic reconstructions because of the lack of paleogeographic indicators for that time (e.g., Torsvik and Cocks 2017). Paleomagnetic data have not resolved the paleogeographic position of the Alexander terrane during the Mississippian-Penn-

sylvanian. The Devonian Wadleigh Limestone and Pennsylvanian Klawak Formation show secondary magnetization that is most likely a result of a complex history of chemical remagnetization (Butler et al. 1997). There are no reported paleolatitude estimates for the Pennsylvanian Ladrões Limestone.

The Prince of Wales Island and the surrounding, smaller islands preserve at least 11,500 m of rock of the Alexander terrane that represent a range of time from the Early Ordovician to the Late Permian (Eberlein and Churkin 1970). Recent fieldwork on the stratigraphy and sedimentology of Carboniferous strata in this region has yielded a small number of conodont faunas that provide a better time resolution for upper Mississippian to lower Pennsylvanian strata. More importantly, the recovery of P<sub>1</sub> elements of a new species of Early Pennsylvanian conodont genus *Idiognathoides* Harris and Hollingsworth 1933, presents the opportunity to constrain current paleogeographic models and re-evaluate the paleogeographic position of the Alexander terrane during the Carboniferous.

## GEOLOGIC SETTING

This paper is a part of recent stratigraphic, sedimentologic, and conodont biostratigraphic studies of Carboniferous carbonate sections of the Alexander terrane in the Ladrões Islands group, an area 11 km south-southeast of Craig, Alaska (text-fig. 2). Outcrop exposures are mostly along the shorelines of this archipelago landscape and are limited by three- to seven-meter mixed semidiurnal tidal swings and by the dense inland coverage of the southeastern Alaskan rainforest. A stratigraphic section of 411 m was measured along the coast of the southernmost Ladrões Islands under low-tide conditions, where 2 to 10 kg carbonate samples were taken at 3-meter intervals or at closer intervals where lithologic boundaries were observed (text-fig. 3).

The Mississippian Peratrovich Formation forms the base of the Ladrões Island stratigraphic section, where it is exposed along the northwestern shoreline of discrete islands and within an east-southeast plunging syncline that extends from the Madre de Dios Island (text-fig. 2). Previous workers have reported differing thicknesses for the Peratrovich Formation, ranging from 300 to 1100 m (Eberlein and Churkin 1970). The exposed upper part of the Peratrovich Formation is only 33 m thick at the Ladrões Island section. Lithofacies of the Peratrovich Formation mostly consist of organic-rich (TOC) skeletal wackestones to packstones. Two facies were resolved in the Peratrovich Formation at the Ladrões Island section. The base of the stratigraphic section is a siliceous wackestone that crops out as thin 0.5-meter-thick beds of black, silica-rich wackestone. This facies contains an abundance of organic-rich mud and numerous thin ostracode and rugose coral hashes, as well as minor amounts of endothyroid foraminifers. Intercalated with the siliceous wackestone are black cherts that crop out as 0.5-meter-thick beds. Cherts of this facies are primarily composed of sponge spicules and these cherts are the dominant constituent of the lower 38 meters of stratigraphic section. Previous age interpretations for the Peratrovich Formation utilized foraminifers and corals to infer a Kinderhookian-Osagean to Meramecian-Chesterian age (Armstrong 1970; Eberlein and Churkin 1970). Mamet et al. (1993) constructed zonations through the Ladrões Islands strata using occurrences of foraminifers. The base of the Peratrovich Formation in the Ladrões Island section corresponded to the global foraminiferal zone 18, which indicated a late Chesterian or Serpukhovian age for the lowermost exposed Peratrovich Formation on the Ladrões Islands.

The overlying Ladrões Limestone is a thick-to-massively bedded carbonate that crops out along the northwestern coasts of the southernmost islands within the Ladrões Island group. The Ladrões Limestone is exposed in the southeastern flank of a broad syncline that extends from the Madre de Dios Island to the northwest. Facies comprise cyclic deposits of peloidal wackestone/packstone to foram grainstone with varying amounts of dissolution and recrystallization of carbonate. Common dolomite and white chert interbeds also occur in the lower 20 meters and upper 40 meters of the Ladrões Limestone. Common faunal constituents are cryptostome bryozoans, productid and strophomenid brachiopods, solitary rugose corals, coiled nautiloids, ostracodes, and foraminifers. An age of Early Pennsylvanian to Middle Pennsylvanian for the Ladrões Limestone was inferred through fusulinids, endothyroid foraminifers, corals and brachiopods found in its type section (Eberlein and Churkin 1970).

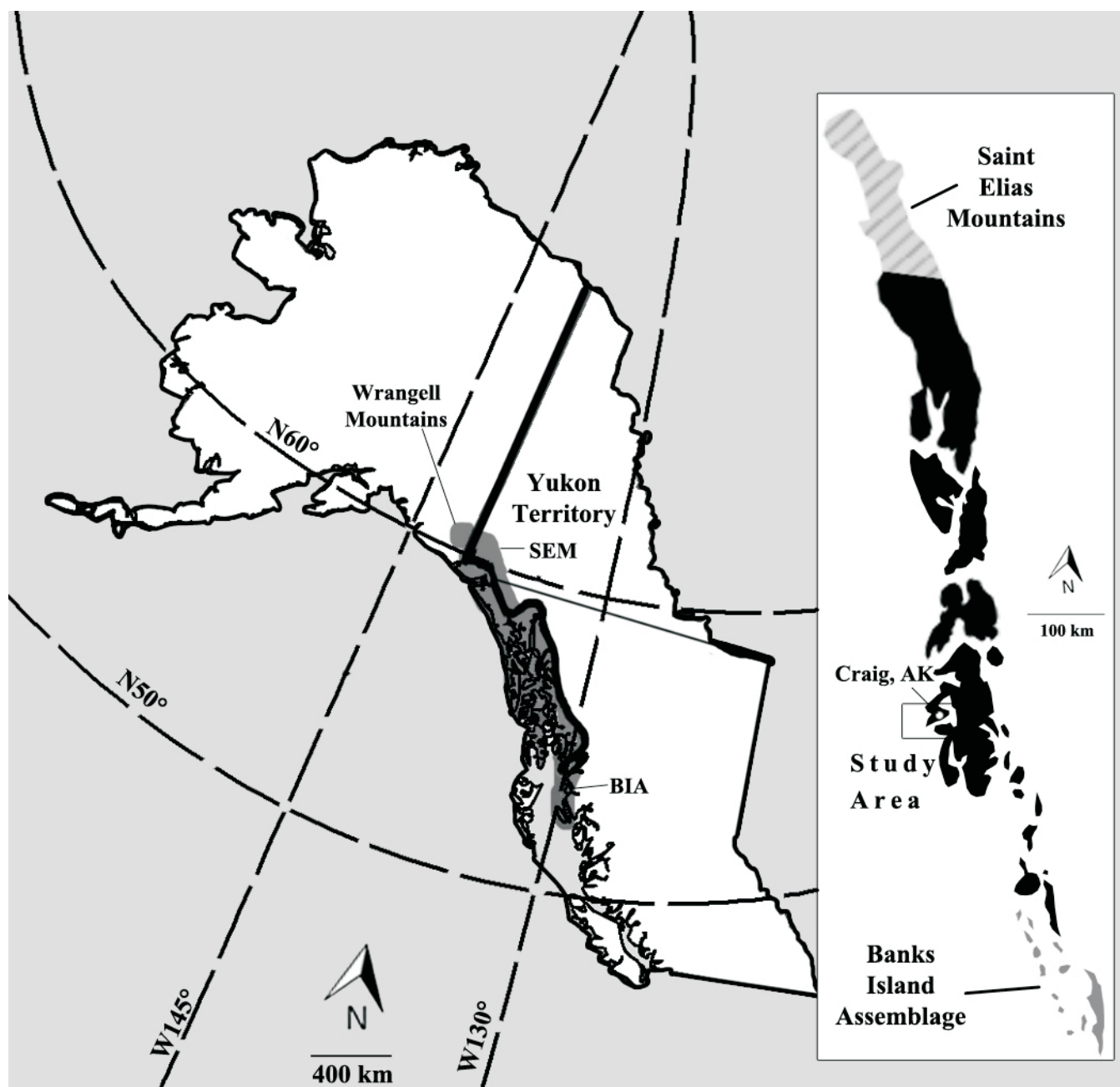
The contact between the Ladrões Limestone and the underlying Peratrovich Formation in the Ladrões Island section is in a 20-meter interval of cover. Southwards, in the Shelikof Island area, the Ladrões Limestone overlies an interval of massive limestone that is devoid of organic-rich mud and that contains a fossil fauna similar to that recovered from the Peratrovich Formation (Eberlein and Churkin 1970). Westwards, in the Madre de Dios Island area, massive, dolomitic limestone overlies intercalated chert and limestone beds of the underlying Peratrovich Formation. No further work was done in this interval, and the Ladrões Limestone was classified as entirely Pennsylvanian. This unobserved to ambiguous lithologic boundary between the Ladrões Limestone and Peratrovich Formation became the Mid-Carboniferous boundary in the southern-central region of the Alexander terrane.

## PALEOGEOGRAPHY OF THE ALEXANDER TERRANE

Buddington and Chapin (1929) and Eberlein and Churkin (1970) described the lithology and stratigraphic framework of the Alexander terrane that forms the foundation for discussing lithologic, stratigraphic, and faunal associations between the Alexander terrane and other regions. Churkin and Eberlein (1977) suggested that the Alexander terrane originated and evolved near its present position as a west-facing volcanic arc that subsequently accreted to North America during the Antler Orogeny. Other authors postulated that the Alexander terrane originated south of its present position in a volcanic arc along the western margin of North America, and that it was once contiguous with the Sierra-Klamath region (Jones et al. 1972; Schweikert 1976; Schweikert and Snyder 1981). Gehrels and Saleeby (1987) discussed a southern paleo-Pacific origin along the margin of Gondwana (eastern Australian Lochlan Fold Belt) and subsequent northward migration of the Alexander terrane through the latter stages of the Paleozoic. The most recent hypotheses propose a Paleo-Arctic origin for the Alexander terrane within the Uralian Seaway or in close proximity to present-day northeast Russia during the late Silurian-Early Devonian (Soja 1991; Bazard et al. 1995; Gehrels et al. 1996; Butler et al. 1997; Soja and Krutikov 2008; Colpron and Nelson 2009, 2010; Miller et al. 2011; Beranek et al. 2012, 2013a, 2013b; Antoshkina and Soja 2016; Blodgett et al. 2002; Blodgett et al. 2010; Boucot et al. 2012).

Geochronologic, isotopic, and paleomagnetic studies of the lower to middle Paleozoic strata of the Alexander terrane have suggested a geographic and lithologic affinity to Baltica and the subsequent trek of the terrane westward through the Uralian Seaway. Tochilin et al. (2014) and White et al. (2016) presented U-Pb and Hf data through detrital zircons recovered from the northern and southern portions of the Alexander terrane. Age groupings and Hf isotopic composition of samples collected from the late Silurian-Early Devonian Karheen Formation give maximum likelihood ages ranging from 449–436 Ma with juvenile epsilon Hf(t) values of +10 to +15 (White et al. 2016). A paleolatitude position of  $14^{\circ} \pm 5^{\circ}$  was derived from the Karheen Formation (Butler et al. 1997; Bazard et al. 1995). Bazard et al. (1995) recovered Archean-Proterozoic detrital zircons within the lower Karheen Formation, suggesting a nearby continental source. They indicated that Baltica was a likely source for the zircons, given the assumption of a northern hemisphere position (Bazard et al. 1995). Similarly, U-Pb and Hf isotope data from detrital zircon of the Alexander terrane have been used to suggest a connection with the Caledonides and the Devonian Old Red Sandstone during the Early Devonian (Beranek et al. 2012; Tochilin et al. 2014; Soja and White 2016). Similar age populations in Permian detrital zircons from Siberia and the Alexander terrane have been used to suggest that the Alexander terrane may have sourced sediment through a major fluvial system in close proximity to the Ural-Mongolian orogen (Ershova et al. 2016).

The middle Silurian to Lower Devonian Heceta Limestone, Karheen Formation, and Wadleigh Limestone of the Alexander terrane comprise a faunal and lithologic succession similar to that of the Khekandinskaya, Mirininskaya, and Krokhalinskaya suites of the Omulevsk Mountains in northeast Russia (Blodgett et al. 2010). Silurian to Devonian megafossil groups within the Alexander terrane also show a strong affinity to Siberia. These faunal and lithologic similarities have led some workers to suggest that the Alexander terrane may have originated as a rifted



TEXT-FIGURE 1

Geographic extent of Alexander terrane and its component assemblages. Inset map displays present configuration of Saint Elias Mountains (striped pattern) and Banks Island Assemblage (plain gray) from the rest of the southeast Alaskan Alexander terrane (black). Outline box illustrates extent of study area near Craig, AK. Inset map modified from White et al. (2016).

block derived from the present-day eastern margin of Siberia, in proximity to the Omulevska and Farewell terranes, during the Late Devonian and Early Carboniferous (Blodgett et al. 2010; Boucot et al. 2012). Conodont faunas of the Silurian and Devonian in the Alexander terrane appear to lack endemism, and are instead representatives of cosmopolitan, tropical to subtropical faunas (Ovenshine and Webster 1969, 1970; Savage 1983, 1984, 1985, 1990). Because the location of the Alexander terrane is poorly known, Chen et al. (2017) did not include

these faunas in their paleobiogeographic analysis of Early Silurian conodonts.

Not much is known of the paleogeographic or biogeographic affinities of the Alexander terrane during the Carboniferous. Rugose coral genera collected from the Mississippian Peratrovich Formation (*Lithostrotionella*, *Thysanophyllum*, and *Diphyphyllum*) have been found in northwest Canada, northwest Alaska, and in China, Russia and Ireland, loosely suggest-



ing a biogeographic affinity to those regions, or a cosmopolitan distribution (Armstrong 1970; Guo 1983; Somerville et al. 2007). Israel et al. (2014) concluded that the Wrangelia and Alexander terranes were tectonically and stratigraphically linked from at least as far back as the Late Devonian based on the geochemistry of gabbros and volcanics from arc and back-arc events in the two terranes. These authors show both terranes to be located north and east of the Arctic Alaska terrane during the Devonian and Mississippian (Israel et al. 2014, fig. 6C). Davydov (2016, fig. 2) proposed that Moscovian fusulinid faunas of the Wrangelia terrane indicate a paleogeographic position within the Alaska-Chukotka composite terrane, in contrast to the more common placement of the terrane along the Panthalassan margin of Laurentia. Novaya Zemlya is shown lying to the east of the Alaska-Chukotka composite terrane (Davydov 2016, fig. 2) and the Arctic Alaska terrane, which includes the Brooks Range, forms the western end of the composite terrane. Because the Wrangelia terrane and Alexander terrane may have been linked since the Late Devonian (Israel et al. 2014), it is possible that the Alexander terrane, like the Wrangelia terrane remained near the Uralian seaway until at least the Middle Pennsylvanian.

Mamet et al. (1993) provided further insight into the paleogeographic affinities of the region through use of foraminiferal diversity and phylogeny. Mixed microfauna of Tethyan and North American affinity were recovered from the Peratrovich Formation. These included genera of foraminifers such as *Janischewskina*, *Spinothyra*, *Viseidiscus*, *Mediocris*, *Banffella*, and *Zellerinella* (Mamet et al. 1993). Genera known from the Tethys region, such as *Omphalotis* were also recovered from the Peratrovich Formation, while genera commonly found in the Tethys (e.g., *Endostaffella*, *Forschia*, *Forschiella*) were not. The recovery of transitional forms within nearly complete phylogenetic sequences of *Endothyranopsis-Cribrospira-Janischewskina-Bradyina*, *Tetrataxis-Howchinia-Monotaxinoides-Eolasiodiscus*, and *Brunsia-Viseidiscus-“Permodiscus” Propermodiscus-Archaeodiscus* suggested a strong Tethyan influence upon the Alexander terrane and that the Alexander terrane may have served as a transitional region between the Tethyan and North American realms during the Mississippian to Pennsylvanian (Mamet et al. 1993).

Paleomagnetic data do little to resolve the geographic affinity of the Mississippian–Pennsylvanian units. Upper Devonian through Pennsylvanian strata in the central portion of the Alexander terrane show characteristic, secondary magnetization that is most likely a result of chemical remagnetization and cannot be used as reliable paleogeographic indicators alone (Butler et al. 1997). The collective paleomagnetic data from the Permian Pybus Formation and from the Permian Hunsaker Creek Formation of the Wallowa terrane indicate a likely paleolatitude of ~25–30° and constrain the likely geographic positions of the Alexander terrane during the Permian (Haussler et al. 1992; Harbert, Hillhouse and Vallier 1995).

Paleogeographic models based on detrital zircons (e.g., Colpron and Nelson 2010; White et al. 2016; Pecha et al. 2016) either illustrated the Alexander terrane off the western margin of Laurussia by the Pennsylvanian–early Permian or have suggested that the Alexander terrane developed along a subduction system on the Panthalassan margin of Laurentia during the Early Paleozoic (White et al. 2016; Pecha et al. 2016). This disregards macrofaunal and sedimentologic affinities towards

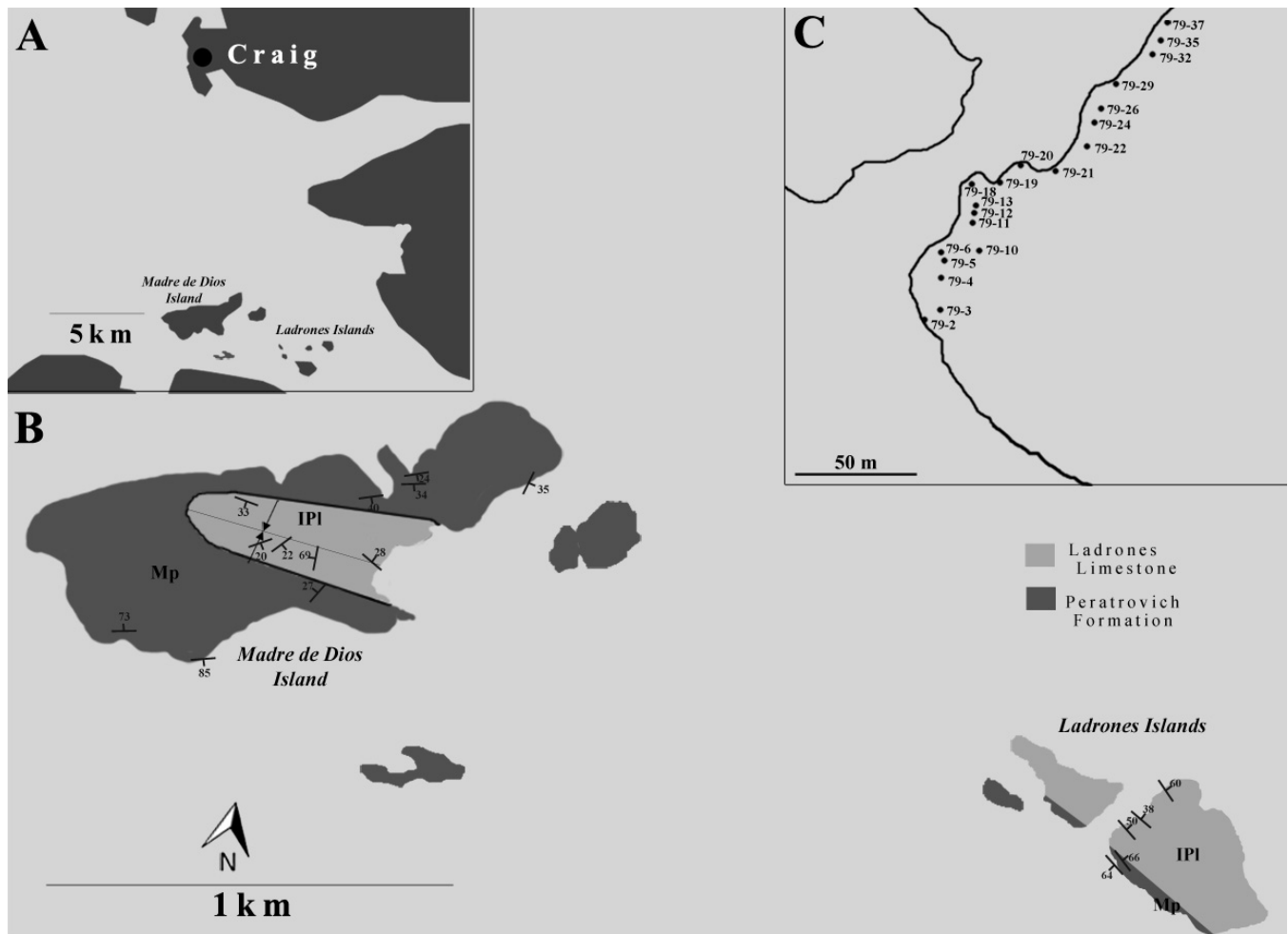
Baltica and Siberia that suggest that the Alexander terrane was within the Uralian Seaway during the late Silurian–Early Devonian, and perhaps into at least the Middle Pennsylvanian. In contrast, the detrital zircon provenance analysis of Ershova et al. (2016) provides a paleogeographic reconstruction that places the Alexander terrane along the northern margin of Baltica during the late Paleozoic.

## CONODONT BIOSTRATIGRAPHY AND PALEOGEOGRAPHY

Faulhaber (1977) described conodonts from three sections in the Peratrovich Formation exposed in the intertidal zone of Peratrovich Island, 21 km north of the Ladrões Islands. Conodonts recovered included species of *Taphrognathus*, *Cavusgnathus*, and *Gnathodus*. A maximum age of middle Osagean was inferred for the base of their stratigraphic section through the occurrence of *Taphrognathus varians* Branson and Mehl 1941. This level is now better assigned to Faunal Unit 7 (*texanus* Zone), which spans the Osagean–Meramecian boundary interval (early Visean) in the most recent revision of conodont faunas in the Mississippi Valley region (Lane and Brenckle 2001). The occurrences of *Cavusgnathus altus* Harris and Hollingsworth 1933 and *Gnathodus girtyi simplex* Dunn 1965 near the top of their stratigraphic section suggested a middle to late Chesterian age (Serpukhovian). These species range through most of the Chesterian in the Mississippi Valley succession (Lane and Brenckle 2001).

The Peratrovich Formation is poorly exposed in the Ladrões Islands, but the age of its exposed upper part can be constrained to the middle to late Chesterian through use of the low-abundance conodont fauna. *Cavusgnathus naviculus* (Hinde 1900) and *Lochriea commutata* (Branson and Mehl 1941), occur in the upper Peratrovich Formation, 9 m above the base of the Ladrões Island stratigraphic section. The presence of *C. naviculus* indicates an age no older than the middle Chesterian Faunal Unit 11 (*naviculus* Zone; Serpukhovian) of the Mississippi Valley succession (Lane and Brenckle 2001).

Savage and Barkeley (1985) described Early to Middle Pennsylvanian conodonts from the Klawak Formation at Peratrovich Island and nearby sections on Prince of Wales Island. The Klawak Formation, which rests on the Peratrovich Formation in that area, produced forms identified as *Idiognathoides noduliferous* (Ellison and Graves 1941), *Id. sulcatus* Higgins and Bouckaert, 1968, the new species *Id. pacificus* Savage and Barkeley 1985, as well as examples of *Neognathodus*, *Idiognathodus*, and other genera. The Klawak faunas were interpreted to range in age from the middle Morrowan through the Desmoinesian (Bashkirian–Moscovian), but an updated revision of these faunas may produce a narrower age range. Contrary to previous evidence from foraminiferal faunas that indicated stratigraphic continuity from the Peratrovich to the Klawak (Dutro 1979), Savage and Barkeley (1985) proposed that a stratigraphic break ranging from the middle Chesterian to middle Morrowan (Serpukhovian–early Bashkirian) exists between the two formations. A series of samples from Ladrões Limestone taken by Savage and Barkeley (1985) from along the shorelines of the Ladrões Islands yielded small faunas with many of the same species described from the Klawak Formation, including *Id. noduliferous*, *Id. sulcatus*, and *Id. pacificus*. Because some of the younger Klawak Formation species were absent from the Ladrões Limestone samples, Savage and Barkeley (1985) interpreted the Ladrões Limestone samples to



TEXT-FIGURE 2

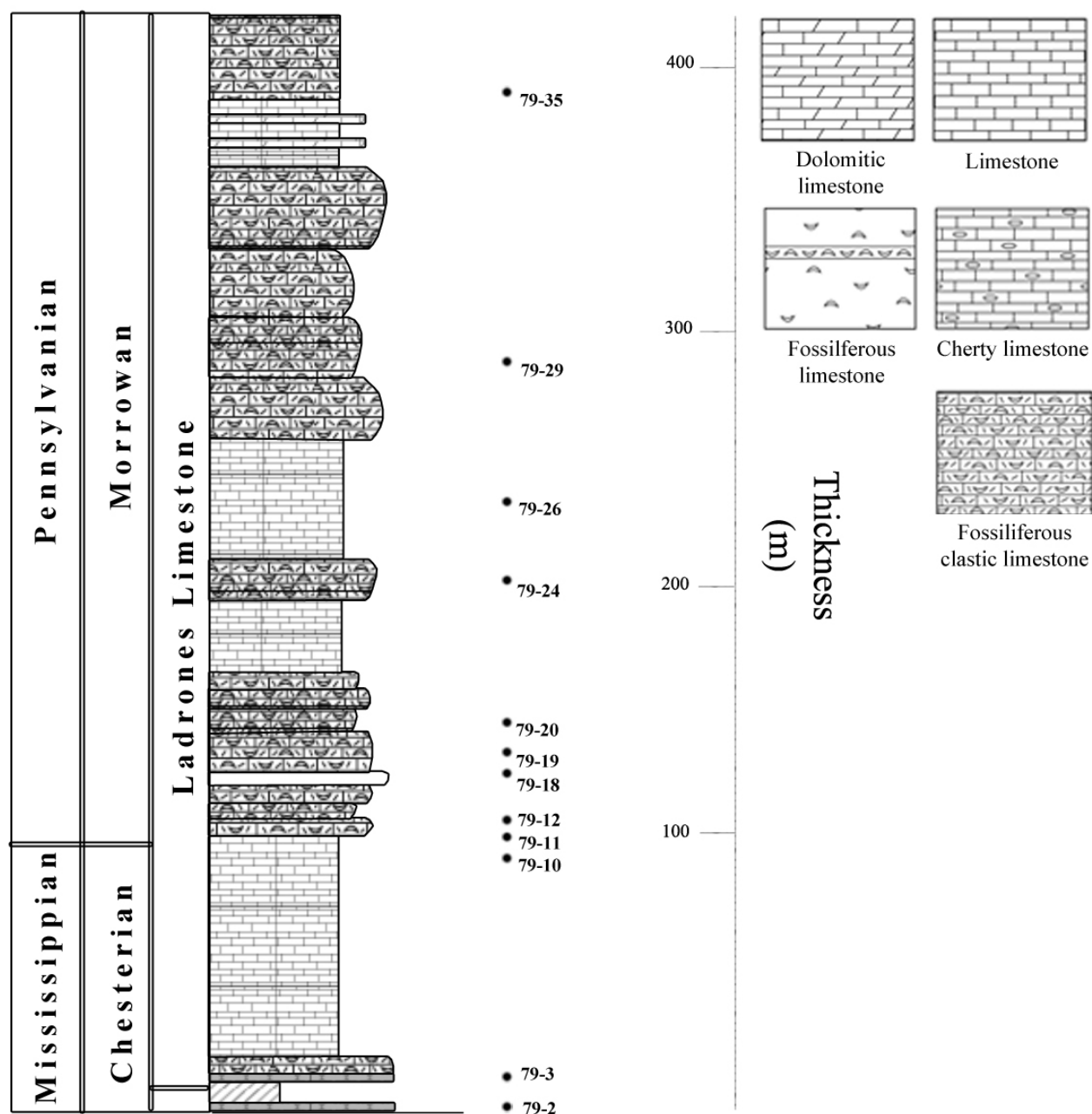
Geologic and collection maps of Madre de Dios and Ladrões Islands near Craig, AK. A) Geographic setting of study area ~5 km south of Craig, AK. B) Geologic map of Madre de Dios and Ladrões Islands, illustrating a southeast trending syncline. C) Collection map of southernmost Ladrões Island.

range in age from the middle Morrowan to middle Atokan (Bashkirian), and that the Ladrões Limestone was equivalent to the lower part of the Klawak Formation. The specimen identified as *N. roundyi* by Savage and Barkeley (1985, fig. 11:13-16) is more likely an example of *N. nataliae* Alekseev and Gerelzeg 2001 (in Alekseev and Goreva 2001), which is latest Morrowan to early Atokan (Bashkirian) in age (Barrick et al. 2013), which supports their interpretation.

In our Ladrões Island section, the lowermost conodont level of the Ladrões Limestone is the first occurrence of *Declinognathodus noduliferus noduliferus*, at 66.5 m above the base of the Ladrões Limestone. *Declinognathodus noduliferus noduliferus* appears at the base of the Morrowan (and the base of Pennsylvanian) and apparently ranges into the middle Atokan, or through much of the Bashkirian, (e.g., Qi et al. 2016), although its last occurrence level is not well known. The lowermost 66 m of the Ladrões Limestone did not produce conodonts and could be latest Mississippian to earliest Pennsylvanian in age. The first occurrence of “*Streptognathodus expansus*” Igo and Koike 1964 (M1, or primitive form of Qi et al. 2010, 2011, 2016), an undefined genus, 255 m above the

base of the Ladrões Limestone is indicative of the “*Streptognathodus preexpansus*” Zone of Qi et al. (2016), which appears to be late Morrowan to early Atokan (late Bashkirian) in age (Qi et al. 2016). The first appearance of *Idiognathoides corrugatus* (Harris and Hollingsworth 1933) occurs 349 m above the base of the Ladrões Limestone in the Ladrões Islands. This species occurs in upper Bashkirian strata in south China, appearing with and then ranging above “*S. expansus*” M1 (Qi et al. 2016; Hu, Qi, and Nemyrovska 2018). *Idiognathoides chaaguloosus* n. sp. is also a characteristic form in these sparse faunas. The Ladrões Limestone at the Ladrões Island section may be interpreted to range from the Morrowan into the Atokan and may span much of the Bashkirian. Because no conodonts were recovered from the base of the Ladrões Limestone, the level of the base of the Pennsylvanian is unknown and it is possible that the base of the Ladrões Limestone is latest Mississippian in age and that no unconformity exists here between the Ladrões and the underlying Peratrovich Formation.

Conodonts from the Mississippian Peratrovich Formation, Mississippian–Pennsylvanian Ladrões Limestone, and the Pennsylvanian Klawak Limestone were reported to have a



TEXT-FIGURE 3

Stratigraphic section measured from the northwest coast of southernmost island in the Ladrões Islands. Position of the level of the base of the Pennsylvanian is not well determined. Conodont-bearing samples are illustrated at their corresponding stratigraphic level. Exact levels of samples are given in Table 1.

cosmopolitan or North American affinity (Faulhaber 1977; Barkeley 1981; Savage and Barkley 1985). Faulhaber's (1977) collections from the Peratrovich Formation in the area of the Peratrovich Island recorded no strong biogeographic affinity. The conodont faunas described by Savage and Barkley (1985) from the Klawak Formation and Ladrões Limestone were interpreted to have no particular paleogeographic affinity outside of North America, except for two new species *Taphrognathus alaskensis* and *Idiognathoides pacificus*. Since then, *Id.*

*pacificus* has been recovered from uppermost Bashkirian strata of the Naqing section of South China (Qi et al. 2016).  $P_1$  elements of specimens illustrated as transitional forms from *Id. corrugatus* to *Id. pacificus* share similar features to *Id. chaaguloatus* n. sp. (Qi et al. 2016, fig. 8 H-J).

Early Pennsylvanian conodont faunas, collected within this study and recovered from the Ladrões Limestone, include species of *Declinognathodus* and several specimens of the new species

TABLE 1

Conodont specimens collected from the Peratrovich Formation and Ladrões Limestone of the Ladrões Island stratigraphic section. Included are total weights of samples processed in kilograms.

Sample	79-2	79-3	79-10	79-11	79-12	79-18	79-19	79-20	79-24	79-26	79-29	79-35	Total
Formation	Peratrovich	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	Ladrões	
Level (meters above base)	9	10	97	97.5	106	128	137.5	144	205.5	252	286	380	
Weight processed (Kg)	1.4	4.4	0.6	1.4	3.2	1.4	0.7	1.4	5.5	5.6	3	1.4	
Species recovered													
<i>Cauvognathus naviculus</i>	2												2
<i>Lochriea commutata</i>	2												2
<i>Declinognathodus</i> sp.			1		3	1	2		2				9
<i>Dec. noduliferous noduliferous</i>				1	1					2			4
<i>Dec. cf. noduliferous</i>					1								1
<i>Idiognathoides chaaguloootus</i> n. sp.					3			4	28	1	2	1	39
<i>Id. sp.</i>				2									2
<i>Id. corrugatus</i>												2	2
" <i>Streptognathodus</i> " <i>expansus</i>											1		1
<i>Hindeodus</i> sp.					1								1

cies *Idiognathoides chaaguloootus* n. sp. The  $P_1$  element of this new species bears a strong resemblance to  $P_1$  elements of the genus *Neolochriea* Mizuno, 1997 and to certain  $P_1$  elements previously reported as *Id. pacificus* by Savage and Barkeley (1985). The strong resemblance of  $P_1$  elements and the co-occurrence of *Idiognathoides pacificus* and *Id. chaaguloootus* n. sp. in the Ladrões Limestone suggest a close phylogenetic relationship. A robust button-like denticle is present on the ventral-caudal margins of dextral,  $P_1$  elements in both species. This denticle is completely isolated in *Id. chaaguloootus* but is attached to the transverse ornamentation of *Id. pacificus*. Specimens of *Id. pacificus* have been reported from Morrowan strata of the Lisburne Group in the Sadlerochit Mountains of the Northeast Brooks Range of Alaska, where the foraminiferal assemblages are of Eurasian origin (Harris et al. 1997). However, we interpret the illustrated specimens to be examples of *Id. chaaguloootus* n. sp. Sobolev and Nakrem (1996) also reported the occurrence of *Id. pacificus* from the Lower Bashkirian of Novaya Zemlya, but their illustrated specimens are additional examples of *Id. chaaguloootus* n. sp.

The occurrence of *Idiognathoides chaaguloootus* n. sp. in Bashkirian strata of the Alexander terrane, northern Alaska (Arctic Alaska terrane), and Novaya Zemlya suggests that these three regions were in close proximity in the Uralian Seaway and formed parts of the Boreal Province during the Early Pennsylvanian (text-fig.4). Also, neither *Id. pacificus* nor *Id. chaaguloootus* n. sp. have been reported from regions known to have occupied the western margin of Laurussia during the Carboniferous. Thus, paleogeographic reconstructions should show that the Alexander terrane remained in the Uralian seaway into the Early to Middle Pennsylvanian in a location near its Mississippian position (e.g., Colpron and Nelson 2009, fig. 14), and not far offshore in northern Panthalassa as commonly shown (e.g., Colpron and Nelson 2009, fig. 15).

## CONCLUSIONS

The conodont succession recovered from the Peratrovich Formation and Ladrões Limestone in the Craig C4 quadrangle of Prince of Wales Island reveals that Early Pennsylvanian conodonts first appear well above the base of the Ladrões Limestone. No unconformity is evident between the Mississippian Peratrovich Formation and the overlying Ladrões Limestone and it is possible that the lowermost Ladrões Limestone is also Mississippian in age. The occurrence of *Idiognathoides*

*chaaguloootus* n. sp. in the Bashkirian (late Morrowan-early Atokan) of the Alexander terrane, the Brooks Range of Alaska, and Novaya Zemlya strongly suggests proximity between these three regions and that the Alexander terrane remained in the Uralian seaway until at least the Middle Pennsylvanian.

## SYSTEMATIC PALEONTOLOGY

Conodonts collected as a part of this study are constituents of low abundance fauna. Sampling was done at 3 m intervals totaling 68 samples of 2 to 7 kg of carbonate rock. Of the 68 samples, 30 samples produced sparse, but well-preserved specimens of Mississippian and Pennsylvanian genera after processing in buffered formic acid.

Class CONODONTI Branson 1938  
Order OZARKODINIDA Dzik 1976

Family IDIOGNATHODONTIDAE Harris and Hollingsworth 1933

Genus *Idiognathoides* Harris and Hollingsworth 1933

*Diagnosis*: Narrow, lanceolate-shaped scaphate  $P_1$  elements with long free blade. Free blade attaches to platform lateral position and continues as a high, broad parapet to end of element. Medial groove of varying lengths and depths in different species is present in anterior portion of platform.

*Idiognathoides corrugatus* Harris and Hollingsworth 1933  
Plate 1, figure 1

*Idiognathoides corrugatus* HARRIS and HOLLINGSWORTH 1983, 202, pl. 1, figs. 7-8; – NEMYROVSKAYA and ALEKSEEV 1994, pl. 1, figs. 1, 13, 15; – NEMYROVSKAYA 1999, pl. 3, figs. 2, 4, 21; pl. 4, fig. 8; – HU et al. 2018, figs. 10 I, J.

*Diagnosis*: Long free blade attaches to platform in rostral margin position and continues as a broad parapet with coarse transverse ornamentation to middle portion of element. Deep, adcarinal groove extends short distance from ventral margin of element.

*Description*: Ovate to lanceolate-shaped pectiniform element with long free blade that attaches to rostral-ventral margin. Free blade continues as raised parapet that merges into center-rostral portion of platform. Adcarinal groove extends from ventral caudal margin to center of platform and forms a deep escarpment between a raised parapet and column of nodular ridges on ven-



tral caudal margin. Five to six transverse ridges extend across dorsal portion of platform and are slightly concave in shape.

**Remarks:** Differentiation between species of *Idiognathoides* can be made through the presence, length, and position of a medial sulcus. *Idiognathoides corrugatus* consists of a deeper and more pronounced medial sulcus than *Id. asiaticus* Nigmatdjanov and Nemyrovskaya 1993, and has less widely spaced transverse ridges than the latter. The short and deep adcarinal groove differentiates it from *Id. sinuatus* Harris and Hollingsworth 1933 and *Id. sulcatus* Higgins and Bouckaert 1968. It bears a resemblance to illustrated specimens of *Id. corrugatus* in Hu, Qi, and Nemyrovskaya (2018, fig. 10I-J).

**Material:** 1 small P<sub>1</sub> element

**Occurrence:** Ladrões Limestone, Ladrões Island stratigraphic section, samples 79-32, 79-35, 79-37.

***Idiognathoides chaaguloatus* Frederick and Barrick n. sp.**

Plate 1, figures 2, 3, 5–9

*Idiognathoides pacificus* SAVAGE and BARKELEY 1985, p. 1468, fig. 9:11–14 (only). – SOBOLEV and NAKREM 1996, p. 103, pl. 2, fig. f. – HARRIS et al. 1997, fig. 10:4, 5. – BERANEK et al. 2010, fig. 6:7.

**Diagnosis:** Asymmetric right and left P<sub>1</sub> elements consist of a long free blade that joins rostral margin of platform. Element lacks a dorsal medial groove. Ventral caudal margin consists of a button-like parapet that is offset from platform and carina.

**Description:** In oral view, platform of the sinistral P<sub>1</sub> element is slightly triangular in shape. The platform of the dextral P<sub>1</sub> element, though, has more offset of caudal and rostral platform margins, which creates the strong asymmetry between paired elements. Long, straight blade joins platform near ventral rostral margin and continues onto platform as a short, denticulate to nodular carina. No dorsal medial groove is present. The platform of the dextral P<sub>1</sub> element bears 9 to 10 uninterrupted transverse ridges and has a somewhat broadly elliptical profile, whereas the platform of sinistral P<sub>1</sub> element bears 5 to 6 transverse ridges and has a much narrower profile. Platforms of both elements taper and curve towards the caudal margin dorsally. A parapet or button-like denticle is present on both elements on the ventral caudal margin of the platform. In the sinistral P<sub>1</sub> element the rostral margin of the platform is constricted opposite to the parapet/denticle.

**Remarks:** *Idiognathoides chaaguloatus* n. sp. can be differentiated from other species of *Idiognathoides* by the presence of a large, isolated button-like denticle on the ventral caudal margin of both right and left P<sub>1</sub> elements. *Idiognathoides chaaguloatus* n. sp. most closely resembles *Id. pacificus* Savage and Berkeley 1985, in its general shape and the presence of a denticle on the caudal margin of its platform. *Idiognathoides chaaguloatus* n. sp. differs in the presence of a strong button-like denticle that is isolated from the transverse ridges in both right and left P<sub>1</sub> elements. A dorsal medial groove is also not present on either left or right elements of *Id. chaaguloatus* n. sp. The illustrated specimens of *Id. pacificus* in Sobolev and Nakrem (1996), Harris et al. (1997), and Beranek (2010) are all examples of *Id. chaaguloatus* n. sp. These specimens do not have the dorsal medial sulcus of *Id. pacificus* and possess a large button-like denticle on the ventral caudal margin.

*Idiognathoides chaaguloatus* n. sp. bears a resemblance to species of the genus *Neolochriea* Mizuno 1997. The P<sub>1</sub> elements of *Id. chaaguloatus* n. sp. and *Neolochriea* share some common traits, such as a lanceolate-shaped P<sub>1</sub> element with a wide basal cavity and the reduced to absent ventral sulcus. *Neolochriea* species differ from *Id. chaaguloatus* n. sp. in possessing a more mid-positioned carina (Hu, Qi, and Nemyrovskaya 2018). Furthermore, *Id. chaaguloatus* n. sp. does not resemble any other reported species of *Neolochriea* (Hu and Qi personal communication 2018). The comparison of P<sub>2</sub> elements appears to be a useful tool in the differentiation of species of *Neolochriea* from those of *Idiognathoides* (Hu and Qi personal communication 2018), but only P<sub>1</sub> elements were recovered in this study.

**Holotype:** dextral P<sub>1</sub> element, specimen UAMES 41478 (pl. 1, fig. 9), sample 79-24, Ladrões Island stratigraphic section.

**Etymology:** *chaaguloatus*— After the words Ch'áagu Lóot' in the Tlingit language meaning “long ago eel”.

**Material:** 39 dextral and sinistral P<sub>1</sub> elements.

**Occurrence:** Ladrões Limestone, Ladrões Island stratigraphic section, samples 79-12, 79-20, 79-24, 79-26, 79-29, 79-35.

***Idiognathoides* sp.**

Plate 1, figure 4

**Description:** Triangular-shaped pectiniform element with long free blade. Blade attaches to rostral margin of platform. Very shallow medial groove is present near center of platform and only extends for a short distance. Transverse ridges are present but very worn. Adcarinal parapet is present on ventral-caudal margin of platform. Very broad and open basal cavity extends beyond the width of oral surface and is smooth.

**Remarks:** *Idiognathoides* sp. resembles *Id. chaaguloatus* n. sp. in the presence of an adcarinal parapet. It differs from *Id. chaaguloatus* by the presence of a medial groove. *Idiognathoides* sp. also resembles *Idiognathoides pacificus* but differs by the presence of the adcarinal parapet on the sinistral element.

**Material:** 2 P<sub>1</sub> elements.

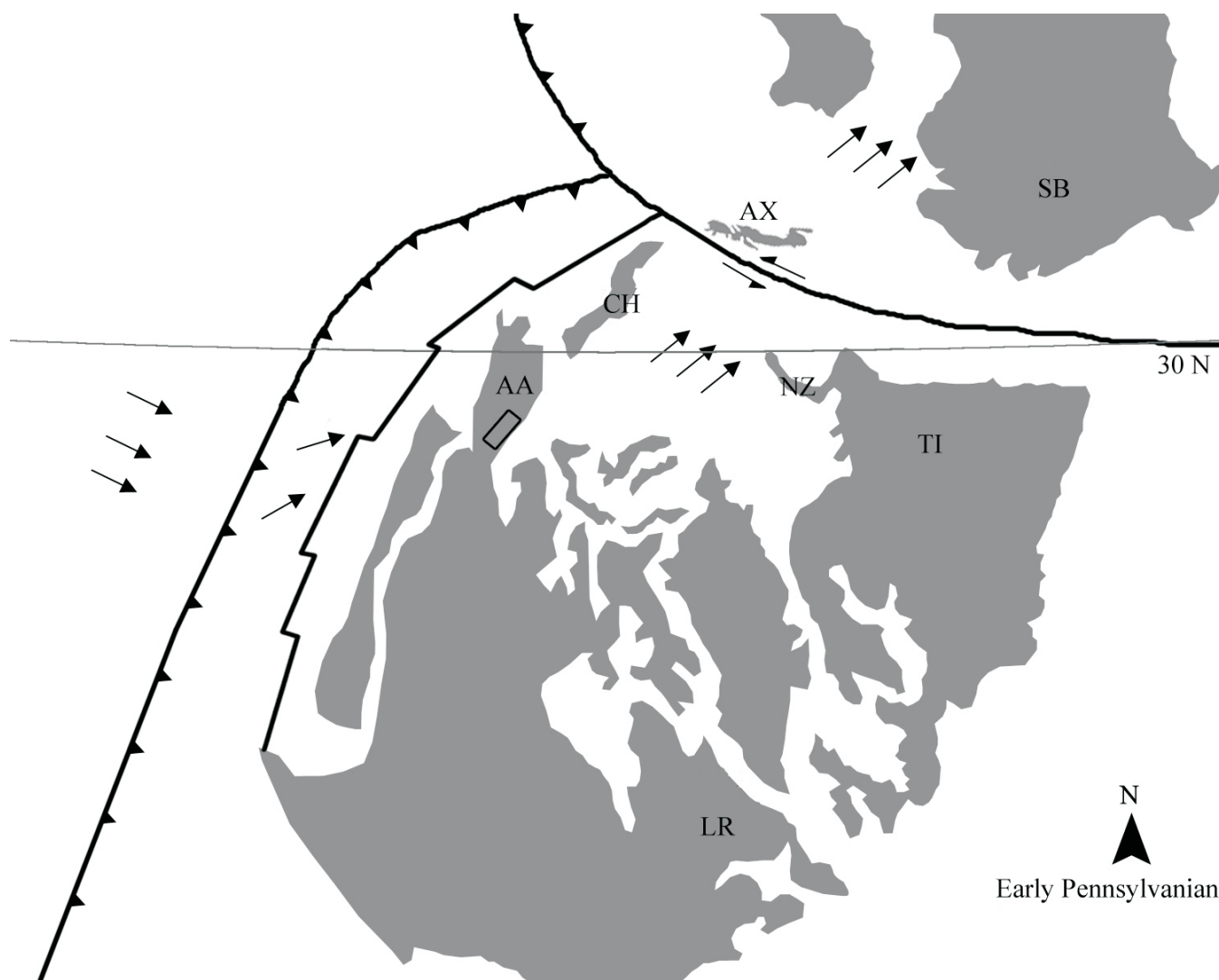
**Occurrence:** Ladrões Limestone, Ladrões Island stratigraphic section, sample 79-11.

**Genus *Declinognathodus* Dunn 1966**

**Diagnosis:** Paired, symmetrical carminiscaphate P<sub>1</sub> elements, lanceolate in shape, with medial junction of free blade. Free blade continues as carina of varied lengths in different subspecies that declines towards rostral margin of platform. Basal cavity is deep and asymmetrical.

**Remarks:** The diversification of *Declinognathodus* during the Bashkirian has led to numerous species being recognized and used to great effect in biostratigraphy (e.g., Sanz-López, Blanco-Ferrera and Sánchez de Posada 2013). A hierarchy of traits from length of carina and its subsequent declination towards the rostral margin to the presence or absence of a deep or shallow medial trough are used to distinguish species and subspecies. Many specimens recovered from the Ladrões Limestone are juvenile and do not express the species diagnostic traits.





TEXT-FIGURE 4

Paleogeographic and tectonic reconstruction of Uralian seaway during Early Pennsylvanian. AA (Arctic Alaska); AX (Alexander terrane); CH (Chukotka terrane); NZ (Novaya Zemlya); TI (Timanides); SB (Siberia); LR (Laurussia). Box on AA denotes approximate location of Brooks Range, Sadlerochit Mountains deposits of Krumhardt et al. (1996). Thin gray line denotes approximate position of 30°N paleolatitude. Arrows denote plate vectors as illustrated by Domier and Torsvik (2014). Base map modified from Domier and Torsvik (2014).

*Declinognathodus noduliferus noduliferus* (Ellison and Graves 1941)

Plate 1, figures 10-12

*Cavusgnathus nodulifera* ELLISON and GRAVES 1941, p. 4, pl. 3, fig. 4.

*Declinognathodus noduliferus* (Ellison and Graves). – NEMYROVSKA et al. 2011, p. 183, pl. 4, figs. 7, 8, 12–14, 19, 21, 22–24. (see for further synonymy).

**Diagnosis:** P<sub>1</sub> elements with a short carina that declines and merges with rostral margin. Adcarinal parapet is present on rostral margin of carina deflection and consists of 3 to 4 nodes. Wide medial groove extends to dorsal end of platform.

**Description:** Lanceolate-shaped pectiniform element with pointed dorsal end. Free blade is broken near junction to plat-

form. Short carina deflects towards and merges with broad node on rostral margin close to ventral margin of platform. Six to seven transverse ridges extend the width of the platform and are interrupted by a wide medial groove that extends to the dorsal end of element.

**Remarks:** The presence and number of nodes, the presence of an adcarinal trough, and the nature of the dorsal margin of the platform have been used by previous workers to differentiate between declinognathodid species (Nemyrovska 1999; Sanz-López et al. 2006; Nemyrovska et al. 2011; Sanz-López and Blanco-Ferrera 2013). *Declinognathodus noduliferus noduliferus* differs from *D. berneseae* Sanz-López, Blanco-Ferrera, García-López and Sánchez de Posada 2006 through the presence of a deeper and wider dorsal, medial groove and interrupted transverse ridges. *Declinognathodus noduliferus noduliferus* also exhibits a clear

adcarinal trough that separates three to four adcarinal nodes from the deflected carina. *D. praenoduliferus* Nigmatganov and Nemyrovska 1992 has a very short carina that joins the rostral margin at a near right angle and does not have a pronounced medial groove as observed in *D. noduliferus noduliferus*.

**Material:** 4 P<sub>1</sub> elements.

**Occurrence:** Ladrões Limestone, Ladrões Island stratigraphic section, sample 79-11, 79-12, 79-26.

***Declinognathodus* cf. *noduliferus*** (Ellison and Graves 1941)

*Declinognathodus* cf. *noduliferus* (Ellison and Graves 1941). – SANZ-LÓPEZ et al. 2013, fig. 4E

**Description:** Lanceolate-shaped P<sub>1</sub> element with pointed dorsal end. Free blade joins platform in medial position. Short carina deflects towards and merges with broad node on rostral margin. Three to four transverse ridges extend the width of the platform and are uninterrupted by shallow medial groove that extends towards dorsal end of platform.

**Remarks:** Sanz-López, Blanco-Ferrera and Sánchez de Posada (2013) described two morphoclines from *Declinognathodus berneseae* to *D. noduliferus* and *D. berneseae* to *D. inaequalis* in which a transitional morphotype, *D. cf. noduliferus*, was placed in the latter. *Declinognathodus* cf. *noduliferus* has a deeper medial trough than *D. berneseae*, but a much shallower trough than *D. noduliferus*. The transverse ridges of *D. cf. noduliferus* are not interrupted by its medial trough whereas those of *D. noduliferus* are interrupted.

**Material:** 1 P<sub>1</sub> element.

**Occurrence:** Ladrões Limestone, Ladrões Island stratigraphic section, sample 79-12.

***Declinognathodus* sp.**

Plate 1, figure 13

**Description:** Very small, lanceolate-shaped P<sub>1</sub> element with pointed posterior end. Free blade joins platform in medial position. Short carina deflects towards and merges with rostral margin. Three to four transverse ridges extend the width of the platform and are slightly deflected by shallow medial groove that extends towards dorsal end of platform.

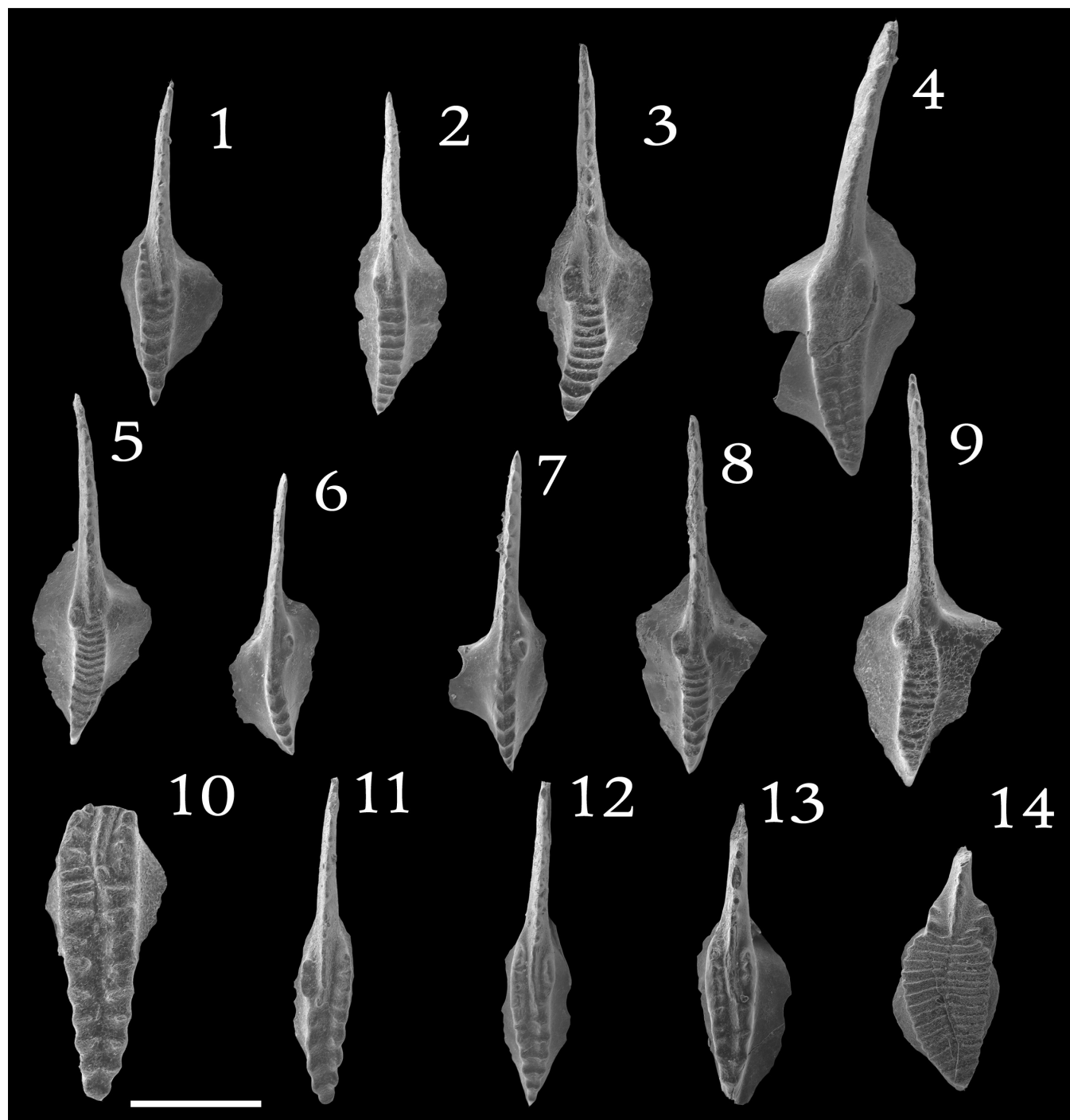
## PLATE 1

Conodonts from the Ladrões Limestone, southern Alaska.

All specimens are upper views of P<sub>1</sub> elements. Scale bar is 0.4mm. UAMES = University of Alaska, Fairbanks Museum.

Repository numbers are based on sample site, not individual specimens.

- 1 *Idiognathoides corrugatus* Harris and Hollingsworth 1933, UAMES 41486, Ladrões Limestone, 79-35, 380 m, Ladrões Island stratigraphic section
- 2 *Idiognathoides chaaguloatus* n. sp., UAMES 41475.1, Ladrões Limestone, 79-12, 106 m, Ladrões Island stratigraphic section
- 3 *Idiognathoides chaaguloatus* n. sp., UAMES 41478.2, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 4 *Idiognathoides chaaguloatus* n. sp., UAMES 41475.2, Ladrões Limestone, 79-12, 106 m, Ladrões Island stratigraphic section
- 5 *Idiognathoides chaaguloatus* n. sp., UAMES 41478.3, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 6 *Idiognathoides chaaguloatus* n. sp., UAMES 41478.4, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 7 *Idiognathoides chaaguloatus* n. sp., UAMES 41478.5, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 8 *Idiognathoides chaaguloatus* n. sp., UAMES 41478.6, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 9 *Idiognathoides chaaguloatus* n. sp., holotype, UAMES 41478.1, Ladrões Limestone, 79-24, 205.5 m, Ladrões Island stratigraphic section
- 10 *Declinognathodus noduliferus noduliferus* (Ellison and Graves 1941), UAMES 41470, Ladrões Limestone, 79-26, 252 m, Ladrões Island stratigraphic section
- 11 *Declinognathodus noduliferus noduliferus* (Ellison and Graves 1941), UAMES 41471, Ladrões Limestone, 79-11, 97.5 m, Ladrões Island stratigraphic section
- 12 *Declinognathodus noduliferus noduliferus* (Ellison and Graves 1941), UAMES 41472, Ladrões Limestone, 79-12, 106 m, Ladrões Island stratigraphic section
- 13 *Declinognathodus* sp., UAMES 41468, Ladrões Limestone, 79-19, 137.5 m, Ladrões Island stratigraphic section
- 14 “*Streptognathodus*” *expansus* Igo and Koike 1964 M1, UAMES 41484, Ladrões Limestone, 79-29, 286 m, Ladrões Island stratigraphic section



**Remarks:** *Declinognathodus* sp. lacks development of nodes present on an adcarinal parapet as observed in *D. noduliferus noduliferus*. Transverse ridges on the dorsal margin of *D. sp.* are only slightly interrupted by a much shallower medial groove than that of *D. noduliferus noduliferus*. The presence of a medial groove and slightly deflected transverse ridges on the dorsal portion of *D. sp.* readily distinguishes it from *D. berneseae*.

**Material:** 9 juvenile P<sub>1</sub> elements.

**Occurrence** Ladrone Limestone, Ladrone Island stratigraphic section, samples 79-10, 79-12, 79-18, 79-19, 79-24.

Genus “*Streptognathodus*” Gunnell 1933

**Remarks:** Early and Middle Pennsylvanian grooved idiognathodids are unrelated to the Late Pennsylvanian genus *Streptognathodus* Stauffer and Plummer 1932 (Lambert, Barrick, and Heckel, 2003), but no new genus has been erected that includes forms such as “*S. expansus* Igo and Koike 1964 or “*S. suberectus* Dunn 1966. Following Qi et al. (2016), Qi et al. (2017), Cardoso et al. (2017), and Nemyrovska (2017) we use quotes around *Streptognathodus* to indicate this group.

“*Streptognathodus*” *expansus* Igo and Koike 1964 M1 Plate 1, figure 14

*Streptognathodus expansus* IGO AND KOIKE 1964, 189, pl. 28, fig. 14. “*Streptognathodus*” *expansus* M1. – Qi et al. 2016, fig. 6H–J. – HU et al. 2017, fig. 7A, B.

**Diagnosis:** Broad, lanceolate-shaped element with medial blade attachment. Short and shallow medial groove extends from near mid-platform and interrupts dorsal transverse ridges.

**Description:** Broad, lanceolate-shaped pectiniform element. Blade is broken but attaches in medial position to platform. Attached blade is short and terminates against transverse ornamentation near ventral end of platform. Shallow and curved medial groove extends from end of attached blade towards dorsal end of platform and separates coarse transverse ornamentation on caudal and rostral sides. Shallow troughs border attached blade in ventral margin and are at an angle to attached blade. Basal cavity is wide and almost extends to the dorsal margin of the element.

**Remarks:** Two morphotypes of “*Streptognathodus*” *expansus* were described by Qi et al. (2016) and Hu et al. (2017). The Ladrone Island specimen corresponds to M1 and differs from M2 by means of a shallow and less pronounced medial groove. Its lack of carina, interrupted transverse ridges on the posterior portion of its platform, and the absence of lobes differentiates it from other species.

**Material:** 1 P<sub>1</sub> element.

**Occurrence:** Ladrone Limestone, Ladrone Island stratigraphic section, sample 79-29.

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## REFERENCES

- ALEKSEEV, A. S. and GOREVA, N. V., 2001. Chapter 9, Conodonts. In: Makhlina, M. Kh., Alekseev, A. S., Goreva, N. V., Goryunova, R. V., Isakova, T. N., Kossovaya, O. L., Lazarev, S. S., Lebedev, O. A. and Shkolin, A. A., Eds., *Middle Carboniferous of Moscow Syncline (southern part). Volume 2. Biostratigraphy*, 113–140. Moscow: Scientific World. [in Russian]
- ANTOSHKINA, A. I. and SOJA, C. M., 2016. Using fossil «fingerprints» to circumscribe the paleogeography of two Alaskan terranes along the Uralian seaway in the late Silurian. *Vestnik Instituta Geologii Komi Nauchnogo Tsentra Uro. Ran.* iss. 2:14–23.
- ARMSTRONG, A. K., 1970. *Mississippian Rugose corals, Peratrovich Formation, west coast, Prince of Wales Island, Southeastern Alaska*. Washington: U.S. Geological Survey Professional Paper, 534, 44 pp.
- BARKELEY, S. J., 1981. “Lower to Middle Pennsylvanian conodonts from the Klawak Formation and Ladrone Limestone, southeastern Alaska.” Unpublished M.S. thesis, University of Oregon, Eugene, Oregon, 97 pp.
- BARRICK, J. E., LAMBERT, L. L., HECKEL, P. H., ROSSCOE, S. J. and BOARDMAN, D.R., 2013. Midcontinent Pennsylvanian conodont zonation. *Stratigraphy*, 10: 55–72.
- BAZARD, D. R., BUTLER, R. F., GEHRELS, G. E. and SOJA, C. M., 1995. Early Devonian paleomagnetic data from the Lower Devonian Karheen Formation suggest Laurentia-Baltica connection for the Alexander terrane. *Geology*, 23: 707–710.
- BERANEK, L. P., MORTENSEN, J. K., ORCHARD, M. J. and ULLRICH, T., 2010. Provenance of North American Triassic strata from west-central and southeastern Yukon: correlations with coeval strata in the Western Canada Sedimentary Basin and Canadian Arctic Islands. *Canadian Journal of Earth Sciences*, 47: 53–73.
- BERANEK, L. P., VAN STAAL, C. R., GORDEE, S. M., MCCLELLAND, W. C., ISRAEL, S. and MIHALYNUK, M., 2012. Tectonic significance of Upper Cambrian–Middle Ordovician mafic volcanic rocks in the Alexander terrane, Saint Elias Mountains, northwestern Canada. *Journal of Geology*, 120: 293–314.
- , 2013a. Detrital zircon Hf isotopic compositions indicate a northern Caledonian connection for the Alexander terrane. *Lithosphere*, 5: 163–168.
- , 2013b. Baltican crustal provenance for Cambrian-Ordovician sandstones of the Alexander terrane, North American Cordillera: Evidence from detrital zircon U-Pb geochronology and Hf isotope geochemistry. *Journal of the Geological Society*, 170: 7–18.
- BLODGETT, R. B., BOUCOT, A. J., ROHR, D. M. and PEDDER, A. E. H., 2010. The Alexander terrane of Alaska – a displaced fragment of Northeast Russia? Evidence from Silurian-Middle Devonian megafossils and stratigraphy. *Memoirs of the Association of Australasian Palaeontologists* 39: 323–339.
- BLODGETT, R. B., ROHR, D. M. and BOUCOT, A. J., 2002. Paleozoic links among some Alaskan accreted terranes and Siberia based on megafossils. In: Miller, E. L., Grantz, A and Klemperer, Eds., *Tec-*



- tonic evolution of the Bering Shelf–Chukchi Sea — Arctic margin and adjacent landmasses, 273–290. Boulder: Geological Society of America Special Paper, 360.
- BOUCOT A. J., BLODGETT, R. B. and ROHR, D. M., 2012. *Strophatrypa*, a new genus of Brachiopoda (Atrypidae), from upper Silurian strata of the Alexander terrane, southeast Alaska. *Bulletin of Geosciences*, 87: 261–267.
- BRANSON, E. B., 1938. Stratigraphy and paleontology of the Lower Mississippian of Missouri. Part I. *University of Missouri Studies*, 13(3), 208 pp.
- BRANSON, E. B. and MEHL, M. G., 1941. New and little-known Carboniferous conodont genera. *Journal of Paleontology*, 15: 97–106.
- BUDDINGTON, A. F. and CHAPIN, T., 1929. *Geology and mineral deposits of southeastern Alaska*. Washington: U.S. Geological Survey Bulletin, 800, 398 pp.
- BUTLER, R. F., GEHRELS, G. E. and BAZARD, D. R., 1997. Paleomagnetism of Paleozoic strata of the Alexander terrane, southeastern Alaska. *Geological Society of America Bulletin*, 109: 1372–1388.
- CARDOSO, C. N., SANZ-LÓPEZ, J. and BLANCO-FERRERA, S., 2017. Pennsylvanian conodonts from the Tapajós Group (Amazonas Basin, Brazil). *Geobios*, 50: 75–95.
- CHEN, Z., MÄNNIK, P. and FAN, J., 2017. Llandovery (Silurian) conodont provincialism: An update based on quantitative analysis. *Palaeogeography Palaeoclimatology Palaeoecology*, 485: 661–672.
- CHURKIN, M., JR. and EBERLEIN, G. D., 1977. Ancient borderland terranes of the North American Cordillera; correlation and microplate tectonics. *Geological Society of America Bulletin*, 88: 769–786.
- COLPRON, M. and NELSON, J. L., 2009. A Paleozoic Northwest Passage: incursion of Caledonian, Baltican and Siberian terranes into eastern Panthalassa, and the early evolution of the North American Cordillera. In: Cawood, P. A. and Kröner, S. Eds., *Earth Accretionary systems in space and time*, 273–307. London: Geological Society of London Special Publications, 318.
- , 2010. A Palaeozoic NW Passage and the Timanian, Caledonian and Uralian connections of some exotic terranes in the North American Cordillera. In: Spencer, A. M., Embry, A. F., Gautier, D. L., Stoupakova, A. V. and Soresen, K., Eds., *Arctic Petroleum Geology*, 463–484. London: Geological Society of London Memoir, 35.
- DAVYDOV, V. I., 2014. Warm water benthic foraminifera document the Pennsylvanian–Permian warming and cooling events – the record from Western Pangea. *Palaeogeography Palaeoclimatology Palaeoecology*, 414: 284–295.
- , 2016. Biotic paleothermometry constraints on Arctic plates reconstructions: Carboniferous and Permian (Zhokhov Island, De-Longa Group Islands, New Siberian Archipelago). *Tectonics*, 35: 2158–2170.
- DAVYDOV, V. I. and CÓZAR, P., 2017. The formation of the Alleghenian Isthmus triggers the Bashkirian glaciation: constraints from warm-water benthic foraminifera. *Palaeogeography Palaeoclimatology Palaeoecology*, <http://dx.doi.org/10.1016/j.palaeo.2017.08.012>.
- DOMIER, M. and TORSVIK, T. H., 2014. Plate tectonics in the late Paleozoic. *Geoscience Frontiers*, 5: 303–350.
- DUNN, D. L., 1965. Late Mississippian conodonts from the Bird Spring Formation in Nevada. *Journal of Paleontology*, 39: 1145–1150.
- , 1966. New Pennsylvanian platform conodonts from southwestern United States. *Journal of Paleontology*, 40: 1294–1303.
- DUTRO, J. D., Jr., 1979. *The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States*. Washington: U. S. Geological Survey Professional Paper, 1110DD, 16 pp.
- DZIK, J., 1976. Remarks on the evolution of Ordovician conodonts. *Acta Palaeontologica Polonica*, 21: 395–455.
- EBERLEIN, G. D. and CHURKIN, M., JR., 1970. *Paleozoic Stratigraphy in the Northwest Coastal Area of Prince of Wales Island, Southeastern Alaska*. Washington: U.S. Geological Survey Bulletin, 1284, 67 pp.
- ELLISON, S. and GRAVES, R. W., JR., 1941. *Lower Pennsylvanian (Dimple Limestone) conodonts of the Marathon Region, Texas*. Rolla: University of Missouri School of Mines and Metallurgy, Technical Series Bulletin, 14(3), 21 pp.
- ERSHOVA, V. B., KHUDDOLEY, A. K., PROKOPIEV, A. V., TUCHKOVA, M. I., FEDOROV, P. V., KAZAKOVA, G. G., SHISHLOV, S. B. and O’SULLIVAN, P., 2016. Trans-Siberian Permian rivers: A key to understanding Arctic sedimentary provenance. *Tectonophysics*, 691: 220–233.
- FAULHABER, J. J., 1977. “Late Mississippian (Late Osagean through Chesterian) conodonts from the Peratrovich Formation, southeastern Alaska.” Unpublished M.S. thesis, University of Oregon, Eugene, Oregon, 171 pp.
- GEHRELS, G. E., BUTLER, R. F. and BAZARD, D. R., 1996. Detrital zircon geochronology of the Alexander terrane, southeastern Alaska. *Geological Society of America Bulletin*, 108: 722–734.
- GEHRELS, G. E. and SALEEBY, J. B., 1987. Geologic framework, tectonic evolution, and displacement history of the Alexander terrane. *Tectonics*, 6: 151–173.
- GUNNELL, F. H., 1933. Conodonts and fish remains from the Cherokee, Kansas City, and Wabaunsee groups of Missouri and Kansas. *Journal of Paleontology*, 7: 261–297.
- GUO, S., 1983. Middle and Upper Carboniferous rugose corals from southern Dahingnanling (Great Khingan Mountains). *Acta Palaeontologica Sinica*, 22: 220–230.
- HAEUSSLER, P. J., COE, R. S. and RENNE, P., 1992. Paleomagnetism and geochronology of 23 Ma gabbroic intrusions in the Keku Strait, Alaska, and implications for the Alexander terrane. *Journal of Geophysical Research*, 97: 19641–19649.
- HARBERT, W., HILLHOUSE, J. and VALLIER, T., 1995. Paleomagnetism of the Permian Wallowa terrane: Implications for terrane migration and orogeny. *Journal of Geophysical Research*, 100: 12573–12588.
- HARRIS, A. G., BRECKLE, P. L., BAESEMAN, J. F., KRUMHARDT, A. P. and GRUZLOVIC, P. D., 1997. Comparison of conodont and calcareous microfossil biostratigraphy and lithostratigraphy of the Lisburne Group (Carboniferous), Sadlerochit Mountains, northeast Brooks Range, Alaska. In: Dumoulin, J. A. and Gray, J. E., Eds., *Geologic Studies in Alaska by the U.S. Geological Survey*, 1995, 195–219. Washington: U.S. Geological Survey, Professional Paper, 1574.

- HARRIS, R. W. and HOLLINGSWORTH, R. V., 1933. New Pennsylvanian conodonts from Oklahoma. *American Journal of Science*, Series 5, 25: 193–204.
- HIGGINS, A. C. and BOUCKAERT, J., 1968. *Conodont stratigraphy and paleontology of the Namurian of Belgium*. Brussels: Service Géologique de Belgique, Mémoires pour servir à l'explication des cartes géologique et minières de la Belgique, 10, 64 pp.
- HINDE, G. J., 1900. Conodonts from the Carboniferous limestone strata of the west of Scotland. *Transactions of the Natural History Society of Glasgow*, 5, new series: 336–346.
- HU, K.-H., QI, Y.-P., WANG, Q.-L., NEMYROVSKA, T. I. and CHEN, J.-T., 2017. Early Pennsylvanian conodonts from the Luokun section of Luodian, Guizhou, South China. *Palaeoworld*, 26: 64–82.
- HU, K.-H., QI, Y.-P. and NEMYROVSKA, T., 2018. Mid-Carboniferous conodonts and their evolution: new evidence from Guizhou, South China. *Journal of Systematic Palaeontology*, 1–39.
- IGO, H. and KOIKE, T., 1964. Carboniferous conodonts from the Oni limestone, Niigata Prefecture, central Japan (Studies of Asian conodonts, Part I). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, 53: 179–193.
- ISRAEL, S., BERANEK, L., FRIEDMAN, R. M. and CROWLEY, J. L., 2014. New ties between the Alexander terrane and Wrangelia and implications for North America Cordilleran evolution. *Lithosphere*, 6: 270–276.
- JONES, D. L., IRWIN, W. P. and OVENSCHINE, A., T., 1972. Southeastern Alaska - A displaced continental fragment? *U.S. Geological Survey Professional Paper*, 800-B: B211–B217.
- LAMBERT, L. L., HECKEL, P. H. and BARRICK, J. E., 2003. *Swadelina* new genus (Pennsylvanian Conodonta), a taxon with potential chronostratigraphic significance. *Micropaleontology*, 49: 151–158.
- LANE, H. R. and BRECKLE, P. L., 2001. Type Mississippian Subdivisions and biostratigraphic succession. In: Heckel, P. H., Ed., *Stratigraphy and biostratigraphy of the Mississippian Subsystem (Carboniferous System) in its Type Region, the Mississippi Valley of Illinois, Missouri and Iowa*, 76–105. Champaign-Urbana: Illinois State Geological Survey Guidebook, 34.
- MAMET, B. L., PINARD, S. and ARMSTRONG, A. K., 1993. *Micropaleontological Zonation (Foraminifers, Algae) and Stratigraphy, Carboniferous Peratrovich Formation, Southeastern Alaska*. Washington. Washington: U.S. Geological Survey Bulletin, 2031, 65 pp.
- MILLER, E. L., KUZNETSOV, N., SOBOLEVA, A., UDORATINA, O., GROVE, M. J. and GEHRELS, G. E., 2011. Baltica in the Cordillera? *Geology*, 39: 791–794.
- MIZUNO, Y., 1997. Conodont faunas across the Mid-Carboniferous boundary in the Hina Limestone, Southwest Japan. *Paleontological Research*, 1: 237–259.
- NEMYROVSKA, T. I., 1999. Bashkirian conodonts of the Donets Basin. *Scripta Geologica*, 119, 115 pp.
- , 2017. Late Mississippian—Middle Pennsylvanian conodont zonation of Ukraine. *Stratigraphy*, 14: 299–318.
- NEMYROVSKA, T. I. AND ALEKSEEV, A. S., 1994. The Bashkirian conodonts of the Askyn section, Bashkirian Mountains, Russia. *Bulletin de la Société belge de Géologie*, 103: 109–133.
- NEMYROVSKA, T. I., WAGNER, R. H., WINKLER PRINS, C. F. and MONTANEZ, I., 2011. Conodont faunas across the mid-Carboniferous boundary from the Barcalientes Formation at La Lastra (Palentian Zone, Cantabrian Mountains, northwest Spain); geological setting, sedimentological characters and faunal descriptions. *Scripta Geologica*, 143: 127–183.
- NIGMADGANOV, I. and NEMYROVSKA, T. I., 1992. Mid-Carboniferous boundary conodonts from the Gissar Ridge, south Tianshan, middle Asia. *Courier Forschungsinstitut Senckenberg*, 154: 253–275.
- OVENSCHINE, A. T. and WEBSTER, G. D., 1969. Silurian conodonts from southeastern Alaska. *Geological Society of America Abstracts with Programs*, 3: 51.
- , 1970. Age and stratigraphy of the Heceta Limestone in northern Sea Otter Sound, southeastern Alaska. *US Geological Survey Professional Paper*, 700-C: C170–C174.
- PECHA, M. E., GEHRELS, G. E., MCCLELLAND, W. C., GIESLER, D., WHITE, C. and YOKELSON, I., 2016. Detrital zircon U-Pb geochronology and Hf isotope geochemistry of the Yukon-Tanana terrane, Coast Mountains, southeast Alaska. *Geosphere*, 12: 1556–1574.
- QI, Y. P., NEMIROVSKAYA, T. I., BARRICK, J. E., WANG, W. J., and ZHENG, Q. F., 2010. The stratigraphic distribution of conodonts in the Luokun Section. In: Wang, X. D., Qi, Y. P., Groves, J., Barrick, J. E., Nemirovskaya, T. I., Ueno, K., Wang, Y., Eds. *Carboniferous carbonate succession from shallow marine to slope in southern Guizhou*, 145–149. Nanjing: Field excursion guidebook for the SCCS Workshop on GSSPs of the Carboniferous System, 21–31 November 2010.
- QI, Y. P., WANG, X. D., LAMBERT, L. L., BARRICK, J. E., WANG, Z. H., HU, K. Y. and WANG, Q. L., 2011. Three potential levels for the Bashkirian-Moscovian boundary in the Naqing section based on conodonts. *Newsletter on Carboniferous Stratigraphy*, 29: 61–64.
- QI, Y. P., LAMBERT, L. L., NEMYROVSKA, T. I., WANG, X. D., HU, K. Y. and WANG, Q. L., 2016. Late Bashkirian and early Moscovian conodonts from the Naqing section, Luodian, Guizhou, South China. *Palaeoworld*, 25: 170–187.
- SANZ-LÓPEZ, J. and BLANCO-FERRERA, S., 2013. Early evolution of *Declinognathodus* close to the Mid-Carboniferous boundary interval in the Barcaliente type section (Spain). *Palaeontology*, 56: 927–946.
- SANZ-LÓPEZ, J., BLANCO-FERRERA, S. and SÁNCHEZ DE POSADA, L. C., 2013. Conodont chronostratigraphical resolution and *Declinognathodus* evolution close to the Mid-Carboniferous Boundary in the Barcalientes Formation type section, NW Spain. *Lethaia*, 46: 438–453.
- SANZ-LÓPEZ, J., BLANCO-FERRERA, S., SÁNCHEZ DE POSADA, L. C. and GARCÍA-LÓPEZ, S., 2006. The mid-Carboniferous boundary in northern Spain: difficulties for correlation of the global stratotype section and point. *Rivista Italiana di Paleontologia e Stratigrafia*, 112: 3–22.
- SAVAGE, N. M., 1983. Cosmopolitan and provincial faunas of the Alexander terrane, southeast Alaska, and the use of conodonts to fingerprint terranes. *Geological Society of America Abstracts with Programs*, 15: 386.
- , 1984. Provincial affinities of conodont faunas from the Alexander terrane, southeastern Alaska. *Geological Society of America Abstracts with Programs*, 16: 644–645.

- , 1985. Silurian (Llandoveryan-Wenlockian) conodonts from the base of the Heceta Limestone, southeastern Alaska. *Canadian Journal of Earth Sciences*, 22: 711–727.
- , 1990. Paleozoic faunal affinities of the Alexander terrane, SE Alaska. *Geological Society of America Abstracts with Programs*, 22: A321.
- SAVAGE, N. M. and BARKELEY, S. J., 1985. Early to Middle Pennsylvanian conodonts from the Klawak Formation and the Ladrones Limestone, Southeastern Alaska. *Journal of Paleontology*, 59: 1451–1475.
- SCHWEIKERT, R. A., 1976. Early Mesozoic rifting and fragmentation of the Cordilleran orogen in the western U.S.A. *Nature*, 260: 586–591.
- SCHWEIKERT, R. A. and SNYDER, W. S., 1981. Paleozoic plate tectonics of the Sierra Nevada and adjacent regions. In: Ernst, W. G., Ed., *The geotectonic development of California*, 183–201. Englewood Cliffs, New Jersey, Prentice-Hall.
- SMITH, JR., L. B. and READ, J. F., 2000. Rapid onset of late Paleozoic glaciation on Gondwana: Evidence from Upper Mississippian strata of the Midcontinent, United States. *Geology*, 28: 279–282.
- SOBOLEV, N. N. and NAKREM, H. A., 1996. *Middle Carboniferous–Lower Permian conodonts of Novaya Zemlya*. Oslo: Norsk Polarinstitutt Skrifter 199. 131 pp.
- SOJA, C. M., 1991. Origin of Silurian reefs in the Alexander terrane of southeastern Alaska. *Palaaios*, 6: 101–126.
- SOJA, C. M. and KRUTIKOV, L., 2008. Provenance, depositional setting, and tectonic implications of Silurian polymictic conglomerates in Alaska's Alexander terrane. In: Blodgett, R. B. and Stanley, G. D., Jr., Eds., *The terrane puzzle: New perspectives on paleontology and stratigraphy from the North American Cordillera*, 63–75. Boulder: Geological Society of America Special Paper, 442.
- SOJA, C. M. and WHITE, B., 2016. Lacustrine deposits in the Karheen Formation fortify links between Alaska's Alexander terrane and the Old Red Sandstone continent in the late Silurian–Early Devonian. *Journal of Sedimentary Research*, 86: 564–586.
- SOMERVILLE, I. D., COZAR, P. and RODRIGUEZ, S., 2007. Late Viséan rugose coral faunas from south-eastern Ireland: composition, depositional setting and palaeoecology of *Siphondendron* biostromes. In: Hubann, B. and W. E. Piller, W. E., Eds., *Fossil Corals and Sponges: proceedings of the 9th International Symposium on Fossil Cnidaria and Porifera, Graz, 2003*, 307–328. Vienna: Schriftenreihe der Erdwissenschaftlichen Kommission, Austrian Academy of Sciences, 17.
- STAUFFER, C. R. and PLUMMER, H. J., 1932. Texas Pennsylvanian conodonts and their stratigraphic relations. *University of Texas Bulletin*, 3201: 13–58.
- TOCHILIN, C. J., GEHRELS, G. E., NELSON, J. A. and MAHONEY, B. M., 2014. U Pb and Hf isotope analysis of detrital zircons in quartzites of the Banks Island assemblage to identify potential source terranes and origins. *Lithosphere*, 6: 200–215.
- TORSVIK, T. and COCKS, R., 2017. *Earth history and palaeogeography*. Cambridge: Cambridge University Press. 329 pp.
- WHITE, C., GEHRELS, G., PECHA, M., GIESLER, D., YOKELSON, I., MCCLELLAND, W. and BUTLER, R., 2016. U Pb and Hf isotope analysis of detrital zircons from Paleozoic strata of the southern Alexander terrane (southeast Alaska). *Lithosphere*, 8: 83–96.