Laurentian origin for the North Slope of Alaska: Implications for the tectonic evolution of the Arctic

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ABSTRACT

The composite Arctic Alaska–Chukotka terrane plays a central role in tectonic reconstructions of the Arctic. An exotic, non-Laurentian origin of Arctic Alaska–Chukotka has been proposed based on paleobiogeographic faunal affinities and various geochronological constraints from the southwestern portions of the terrane. Here, we report early Paleozoic trilobite and conodont taxa that support a Laurentian origin for parts of the Arctic Alaska–Chukotka terrane. The geology of the Arctic Alaska–Chukotka terrane has been divided into six subterranes, which are partly employed here for consistent descriptive purposes in line with previous publications (e.g., Moore et al., 1994; Dumoulin et al., 2002). We focus on the North Slope subterrane (referred to here as North Slope), grouping the remaining southwestern subterranes of the Arctic Alaska–Chukotka terrane as distinct from the North Slope. We acknowledge that the eastern and western segments of the North Slope may be geologically distinct from each other (e.g., Miller et al., 2011), but no unambiguous suture has been documented at this time. Pre-Mississippian strata of the North Slope comprise three distinct stratigraphic successions (Fig. 2B; Moore et al., 1994): a widely distributed but poorly understood Neoproterozoic(?)-Early Devonian basinal siliciclastic and volcanic sequence in the northeast Brooks Range and adjacent Yukon Territory (Fig. 2B; Moore et al., 1994; Lane, 2007), a Neoproterozoic–Late Ordovician platformal carbonate sequence exposed in the Shublik and Saldorochit Mountains (Fig. 2B; Macdonald et al., 2009), and a structurally complex sequence of Cambrian–Silurian arc-related volcanic and siliciclastic

INTRODUCTION

The Amerasian Basin of the Arctic Ocean (Fig. 1) remains the only major ocean basin for which the origin and tectonic history are still largely unknown (e.g., Miller et al., 2010). New and accurate geological data from the modern circum-Arctic margins are critical, not only for understanding the origin of “suspect” terranes embedded in the North American Cordillera and bordering the Arctic Ocean (e.g., Colpron and Nelson, 2011), but also for evaluating kinematic models for the Jurassic–Cretaceous opening of the Amerasian Basin (e.g., Grantz and May, 1983) and the development of its hydrocarbon-rich continental shelves. Currently, the use of potential Proterozoic and Paleozoic piercing points for constraining Mesozoic tectonic reconstructions is limited by a lack of geological constraints and uncertainty surrounding mid-Paleozoic terrane displacements.

The composite Arctic Alaska–Chukotka terrane covers an estimated 3,000,000 km² of the Arctic, encompassing the Brooks Range and North Slope of Alaska, the Chukotka Peninsula and Wrangel Island of Arctic Russia, and the adjacent continental shelves of the Beaufort and Chukchi Seas (Fig. 1; Miller et al., 2006; Amato et al., 2009). The identification of the modern continental margin to which the Arctic Alaska–Chukotka terrane restores to prior to the opening of the Amerasian Basin remains a critical question for understanding the tectonic evolution of the Arctic (e.g., Miller et al., 2010). Furthermore, the pre-Mesozoic origin and displacement history of this composite terrane and its relationship to the northwestern margin of Laurentia remain controversial (e.g., Miller et al., 2010; Colpron and Nelson, 2011). Several studies have suggested a Laurentian origin for parts of the Arctic Alaska–Chukotka terrane (e.g., Dutro et al., 1972; Grantz et al., 1991; Moore et al., 1994, 2011; Lane, 2007); however, contrasts in paleobiogeographic affinities of mega- and microfossils and various geochronological constraints suggest an exotic origin for the southwestern subterranes of the Arctic Alaska–Chukotka terrane (Dumoulin et al., 2002; Blodgett et al., 2002; Miller et al., 2006, 2010, 2011; Amato et al., 2009; Colpron and Nelson, 2011). Here, we place new early Paleozoic fossil collections and detrital zircon geochronology in a tectonostratigraphic framework that enables us to reevaluate the origin of the Arctic Alaska–Chukotka terrane and propose a revised model for its role in the Paleozoic tectonic evolution of the Arctic region.

GEOLOGICAL BACKGROUND

A variety of nomenclature systems have been employed to describe the geology of the Arctic Alaska–Chukotka terrane, and a review of these schemes is beyond the scope of this paper (see Dumoulin et al., 2002; Amato et al., 2009; Miller et al., 2010). The geology of the Arctic Alaskan portion of the Arctic Alaska–Chukotka terrane has been divided into six subterranes (Fig. 2A; e.g., Moore et al., 1994), which are partly employed here for consistent descriptive purposes in line with previous publications (e.g., Moore et al., 1994; Dumoulin et al., 2002). We focus on the North Slope subterrane (referred to here as North Slope), grouping the remaining southwestern subterranes of the Arctic Alaska–Chukotka terrane as distinct from the North Slope. We acknowledge that the eastern and western segments of the North Slope may be geologically distinct from each other (e.g., Miller et al., 2011), but no unambiguous suture has been documented at this time.
basin succession (Nilsen, 1981). In the northeastern Brooks Range and in the subsurface of the North Slope, undeformed Early–Middle Devonian mixed carbonate and siliciclastic rocks rest unconformably on older deformed strata and are themselves tilted and unconformably overlain by the Endicott Group (Fig. 2B; Ulungarait Formation of Anderson, 1991; Moore et al., 1994 and references therein).

The southwestern subterranes of the Arctic Alaska–Chukotka terrane (Fig. 2) include variably metamorphosed Neoproterozoic(?–Silurian carbonate and siliciclastic strata that overlie Neoproterozoic–Cambrian metasedimentary and crystalline basement (Fig. 2B; Miller et al., 2010, and references therein). They are both locally intruded by Devonian (ca. 402–366 Ma) granitoids (Amato et al., 2009, and references therein) and unconformably overlain by the Endicott Group. These subterranes have been variably interpreted as remnants of a large early Paleozoic carbonate platform that existed between Laurentia and Siberia based on faunal assemblages (Dumoulin et al., 2002) and as semicoherent fragments of the continental margin of Baltica based on detrital zircon provenance studies (Miller et al., 2011).

The Late Devonian–Mississippian Ellesmerian orogeny (sensu stricto) involved deposition of a southward-warding-prograding (present coordinates) clastic wedge across much of northern Laurentia, and it has been attributed to collision with a continental source terrane of uncertain origin (e.g., Embry, 1988; Beranek et al., 2010; Anfison et al., 2012). The Ellesmerian activity was preceded by Ordovician–Silurian accretion of arcs and continental fragments of the Pearya terrane (Fig. 1; Trettin, 1991; McClelland et al., 2012) and localized deformation of the pre–Middle Devonian Romanzof orogeny on the North Slope (Lane, 2007). These events indicate that Paleozoic orogenesis in Arctic Canada and Alaska involved a complex and protracted tectonic history that overlapped in time with the ca. 490–390 Ma multiphase Caledonian orogeny of northeastern Laurentia (Trettin, 1991; McKeever et al., 2000; McClelland et al., 2012).

**NEW INSIGHTS FROM THE NORTH SLOPE SUBTERRANE**

**Stratigraphy and Faunal Affinities**

The Katataukur Dolomite and overlying Nanook Limestone of the Shublik and Solderkotch Mountains (Fig. 2A) comprise an ~3.5-km-thick succession of Neoproterozoic–Late Ordovician platform carbonate that rests conformably on mixed siliciclastics, carbonate, and <800 Ma basalt (Fig. 2B; Macdonald et al., 2009, and references therein). In the Shublik Mountains, these deposits are tilted and unconformably overlain by the Early Devonian Mount Copleston Limestone, which is also tilted and unconformably overlain by the Endicott Group (Fig. 2B; Blodgett et al., 1988).

Recent biogeographic summaries (e.g., Blodgett et al., 2002) link the North Slope with the southwestern subterranes of the Arctic Alaska–Chukotka terrane and Siberia on the basis of Ordovician brachiopod and gastropod genera in the Nanook Limestone that, although common in Siberia, also occur in Laurentia (Blodgett et al., 1988). Our expanded collections confirm the presence of uniquely Laurentian species within the Lower Ordovician portion of the Nanook Limestone, including the conodont *Clavohamatus densus* and the trilobite *Plethopelis armatus* (Figs. 3A–3D and 3G); neither species has been reported from unequivocally non-Laurentian strata. *Plethopelis armatus* (Figs. 3A–3D), originally reported from the Nanook on only two exfoliated crania (Blodgett et al., 1986), is now represented by more than 25 specimens that conform in all respects to a significantly narrowed morphologic concept provided for that species by Ludvigsen et al. (1989). With that narrowed definition, the established distribution of *P. armatus* (aside from the Nanook) is limited to the outer-shelf and toe-of-slope facies of the central and northern Appalachians (Rasetti, 1959; Ludvigsen et al., 1989), although documentation of coeval faunas in adjacent areas of northern Laurentia (e.g., Arctic Canada) is currently inadequate. New collections from slightly higher in the Nanook also contain the uniquely Laurentian trilobite genus *Paraplethopelis* (Figs. 3E and 3F), which occurs at the base of the Stairsian Stage (Lower Ordovician) throughout western North America (Taylor et al., 2012) and Greenland (Fortey and Peel, 1989). Furthermore, scrutiny of material identified by Blodgett et al. (1986) as “*cf. Hystricurus? sainsburyi* Ross” has revealed that the Nanook species is neither conspecific nor congeneric with *H. sainsburyi*, a species described from the Seward Peninsular of Alaska (Ross, 1965). Thus, the updated faunal data from the Nanook Limestone, along with a previous report of Laurentian taxa in basinal clastics of the nearby British Mountains (Fig. 2; Dutro et al., 1972), contradict a Siberian origin and instead suggest that the North Slope is autochthonous with respect to northeastern (present coordinates) Laurentia.

**Detrital Zircon Geochronology**

New detrital zircon laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) U–Pb ages from pre-Mississippian...
strata of the North Slope can also be linked to Laurentia (Figs. 4 and 5). Eight samples (Fig. 4; GSA Data Repository1) were collected from sandstone underlying the <800 Ma basalt of the Shublik and Sadlerochit Mountains (Macdonald et al., 2009) and Cryogenian(?)-Cambrian sandstone in the British Mountains (Fig. 2). The ages of these strata are constrained by trace and body fossils (Lane, 2007) and overlying volcanic rocks interbedded with Upper Cambrian trilobite fauna (Dutro et al., 1972). The new samples yield zircon U-Pb age populations ranging from ca. 760 Ma to 3420 Ma, with prominent peaks at 1000–1200 Ma, 1400–1500 Ma, 1800–2000 Ma, and 2700–2800 Ma, and they lack zircons of the Laurentian magmatic gap (Fig. 4; Grove et al., 2008, and references therein). These populations are similar to common age distributions from coeval strata and older basement preserved along the northern margin of Laurentia (Figs. 1 and 4; Kirkland et al., 2009; Hadlari et al., 2012; Anfinson et al., 2012). The occurrence of a small number of Neoproterozoic (ca. 760–980 Ma) detrital zircons in sandstone from the Sadlerochit Mountains led some workers to suggest a potential exotic origin for the platform sequence of the North Slope (Macdonald et al., 2009; Moore et al., 2011). However, zircons of this age recently reported from autochthonous Laurentian strata of similar age (Hadlari et al., 2012; Rainbird, 2012) call into the question the claim that this population is unambiguously exotic.

1GSA Data Repository Item 2013251, a summary of analytical procedures, detailed sample descriptions, and U-Pb data tables, histograms, and concordia plots, is available at www.geosociety.org/pubs/ft2013.htm, or on request from editing@geosociety.org, Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA.
DISCUSSION

In sharp contrast to data presented here from the North Slope, the Neooproterozoic–Paleozoic basement and overlying sedimentary deposits of the southwestern subterrane of the Arctic Alaska–Chukotka terrane do not share affinities with Laurentia (Fig. 2B; Amato et al., 2009; Miller et al., 2010). These strata host exotic faunal assemblages, including conodonts and trilobites with Siberian affinity (Blodgett et al., 2002; Dumoulin et al., 2002, and references therein), and their pre-Mississippian stratigraphic architecture is also markedly different. For example, a pronounced mid-Ordovician transgression and thick accumulations of Silurian carbonate are characteristic components of the southwestern subterrane (Fig. 2B; Dumoulin et al., 2002). In contrast, on most Laurentian platforms, the mid-Ordovician is marked by a profound hiatus (i.e., Sauk-Tippecanoe unconformity; Taylor et al., 2012). The Nanook Limestone not only records a coeval disconformity, but it also completely lacks Silurian strata (Fig. 2B; Blodgett et al., 1988).

The new geochronological data presented here from the North Slope also differ greatly from those in previous studies of the southwestern subterrane (Fig. 5; Amato et al., 2009; Miller et al., 2010; Moore et al., 2011). The Paleozoic platform deposits of the southwestern subterrane overlie basement that is intruded by Neooproterozoic (ca. 750 ± 6 Ma and 970 Ma) magmatites in the Hammond subterrane and localized plutons ranging from ca. 540 Ma to 870 Ma on the Seward and Chukotka Peninsulas (Patrick and McClelland, 1995; Amato et al., 2009). Consequently, many workers have suggested an exotic origin for the western segment of the Arctic Alaska–Chukotka terrane, noting the lack of magmatism of this age in northwestern Laurentia (e.g., Patrick and McClelland, 1995; Amato et al., 2009; Miller et al., 2010, 2011). In contrast, exposed basement of the North Slope consists of <800 Ma basalts (Macdonald et al., 2009), which compare favorably with the ca. 780 Ma Gunbarrel and ca. 720 Ma Franklin large igneous provinces of northern Laurentia that extend from Yukon to Ellesmere Island (Harlan et al., 2003; Denysynz et al., 2009). Moreover, the provenance of Late Neooproterozoic–Ordovician (?) strata of the southwestern subterrane is clearly distinct from that of the North Slope, including overwhelming late Neooproterozoic–Ordovician detrital zircon age populations that lack classic 1800–2100 Ma and 2600–2800 Ma Laurentian signatures (Fig. 5; Amato et al., 2009).

These discrepancies can be explained by the independent evolution of the North Slope and southwestern subterrane and their juxtaposition sometime prior to deposition of the overlapping Late Devonian–Mississippian Endicott Group (Fig. 2B). We emphasize that this does not imply that the North Slope was fixed relative to the northwestern margin of Laurentia throughout the Neooproterozoic and Paleozoic (sensu Lane, 2007). We suggest instead that the North Slope is a continental fragment that originated from northeastern Laurentia and that the southwestern subterrane of the Arctic Alaska–Chukotka terrane evolved as a single or multiple crustal fragment(s) outboard of Laurentia (e.g., Dumoulin et al., 2002; Miller et al., 2010; Moore et al., 2011). Based on geochronological and stratigraphic arguments, other workers (Miller et al., 2010, 2011; Moore et al., 2011) have suggested that the southwestern portion of the Arctic Alaska–Chukotka terrane evolved as a part of Baltica and is currently separated from the eastern segment by an undocu-
m ented Caledonian suture. One putative suture between the North Slope and the southwestern subterranes is most likely marked by the prominent low-amplitude magnetic anomalies and a change in the aeromagnetic and gravity fabrics near the southern margin of the North Slope (Fig. 2A; Grantz et al., 1991); however, given the structural complexity and limited understanding of the Brooks Range basement (e.g., Moore et al., 1994), it is more likely that multiple sutures exist in the Brooks Range, indicating a protracted history of Caledonian terrane amalgamation between Baltic and Laurentia that extended through the Canadian Arctic. Importantly, Devonian–Mississippian juxtaposition of the southwestern subterranes with the North Slope along the Canadian Arctic margin provides the previously enigmatic source of exotic Neoproterozoic–Cambrian detritus in the Ellesmerian clastic wedge (e.g., Beranek et al., 2010; Anfinson et al., 2012) and potentially supports the foreland basin model of Nilsen (1981) for the Endicott Mountains subterranes of Arctic Alaska as an extension of this collisional basin.

Many studies use the data of Lane (2007) to provide an Early–Middle Devonian tie point between the Arctic Alaska–Chukotka terrane and the northwestern margin of Laurentia (e.g., Beranek et al., 2010; Colpron and Nelson, 2011). This conclusion hinges on the interpretation that no significant strike-slip displacement has occurred along the Kaltag-Poricpine-Rapid fault array (Fig. 2A; Lane, 2007). In contrast, Oldow et al. (1987) considered this fault system to be a major tectonic boundary separating autochthonous Laurentia from paraautochthonous and allochthonous crust. Restoration of the North Slope to a position adjacent to Banks and Melville Islands (Fig. 1) in the Devonian is consistent with the detrital zircon data and faunal assemblages described here, and it rectifies geological inconsistencies with Late Devonian strata in northern Yukon (e.g., Endicott Group proximal fluvial-deltaic deposits juxtaposed against coeval basin-floor fan deposits in northern Yukon) and aligns similar deformation ages, structural styles, and Late Devonian granitoid intrusions with patterns observed in Arctic Canada (Oldow et al., 1987; Trettin, 1991).

We suggest that the Doonerak arc complex, which hosts trilobites of apparent Siberian affinity (Duto et al., 1984) but is currently included with the North Slope, evolved independently from the North Slope paraautochthon and instead developed in a similar tectonic setting with the Pearly terrane outboard of the Franklinian Basin. In this scenario, juxtaposition of these arc terranes and subsequent oblique docking of the southwestern subterranes of the Arctic Alaska–Chukotka terrane with the Canadian Arctic margin of Laurentia were at least partly responsible for the protracted Devonian(?)–Mississippian Romanzof and Ellesmerian tectonism in northern Laurentia.

CONCLUSIONS

A lack of field-based observations and data from modern circum-Arctic margins has persisted controversy regarding the Mesozoic opening of the Amerasian Basin and the Paleozoic tectonic evolution of “suspect” terranes bordering the Arctic region. Here, we present coupled detrital zircon and paleontological data that better constrain the origin and travels of the Arctic Alaska–Chukotka terrane and demonstrate that it is composed of multiple continental fragments that were juxtaposed against northern Laurentia during the Devonian(?)–Mississippian. Subsequent establishment of the timing and kinematics of these mid-Paleozoic orogenic events within Arctic Alaska, Pearya, and on the Canadian Arctic margin of autochthonous Laurentia will provide key tie points for subsequent reconstructions of the Mesozoic opening of the Amerasian Basin of the Arctic Ocean.

ACKNOWLEDGMENTS

National Science Foundation (NSF) grants EAR-1049463 (FAM), EAR-1049398 (WCM), EAR-1032156 (AZ Laserchron Facility), and a NSF Graduate Research Fellowship awarded to Strauss supported this research. E. Kennedy, T. Gibson, and A. Gould aided with field work, and A. Breus, W. Ward, S. Malone, T. Barker, and M. Pecha provided laboratory assistance. Polar Field Services, K. Sweetert of Yukon Air Service, C. Cabanilla (RIP) of ERA Helicopters, and A.M. de la Rosa of the U.S. Fish and Wildlife Service were instrumental in providing access to our field area in the Arctic National Wildlife Refuge. We would like to thank J. Amato, D. Bradley, E. Miller, and A. Weil for constructive reviews.

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