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Foreword

The GEM 2 Western Arctic Project is tasked with re-establishing the geological framework for areas of the Canadian continental margin bordering the Arctic Ocean. On northern Ellesmere Island, Pearya Terrane is a unique geological feature forming the most northern part of Canada's landmass, adjacent to both Greenland and Lomonosov Ridge. The *Tectonics of Pearya Terrane and Sverdrup Basin* activity was proposed in order to advance geological knowledge of this important feature by undertaking fundamental boots on the ground fieldwork. During the summer of 2017 a team of GSC scientists were part of an international field camp to study the multiple stages of the history of Pearya terrane from Paleozoic collisional tectonics to Cretaceous formation of the Arctic Ocean and then Paleogene Eurekan deformation as Greenland impinged on Ellesmere Island.

Project Summary (plain language)

GSC scientists were part of an international team of researchers who visited bedrock outcrops on northernmost Ellesmere Island in the summer of 2017. The purpose of the expedition was to document and sample the rocks of Pearya terrane and study the tectonic history of the terrane in order to better reconstruct the past stages of continental drift that formed the Arctic Ocean.

Introduction

Rocks of the enigmatic Pearya terrane that are exposed on northernmost Ellesmere Island in the Canadian High Arctic (Fig. 1) are a key piece in the circum-Arctic puzzle presented by the current configuration of continents and ocean basins. The features of Pearya terrane that are distinct from the rest of the Canadian Arctic Islands are important clues for identifying a conjugate margin and therefore reconstructing how the Arctic Ocean formed. Pearya terrane, however, has many first-order uncertainties regarding its origin starting with the paleo-continental affinity of its oldest Precambrian rocks: if the oldest rock units were connected to other components of Pearya terrane prior to the Ordovician; which of those components are truly exotic to the North American continent; and how and when did Pearya terrane come to be in its present position on the northernmost edge of the North American continent? Fieldwork undertaken in the summer of 2017 is part of a reconnaissance-level study with a primary goal of identifying components of Pearya terrane that are exotic to North America in order to test hypotheses regarding the assembly of Pearya terrane in the Ordovician and Silurian.

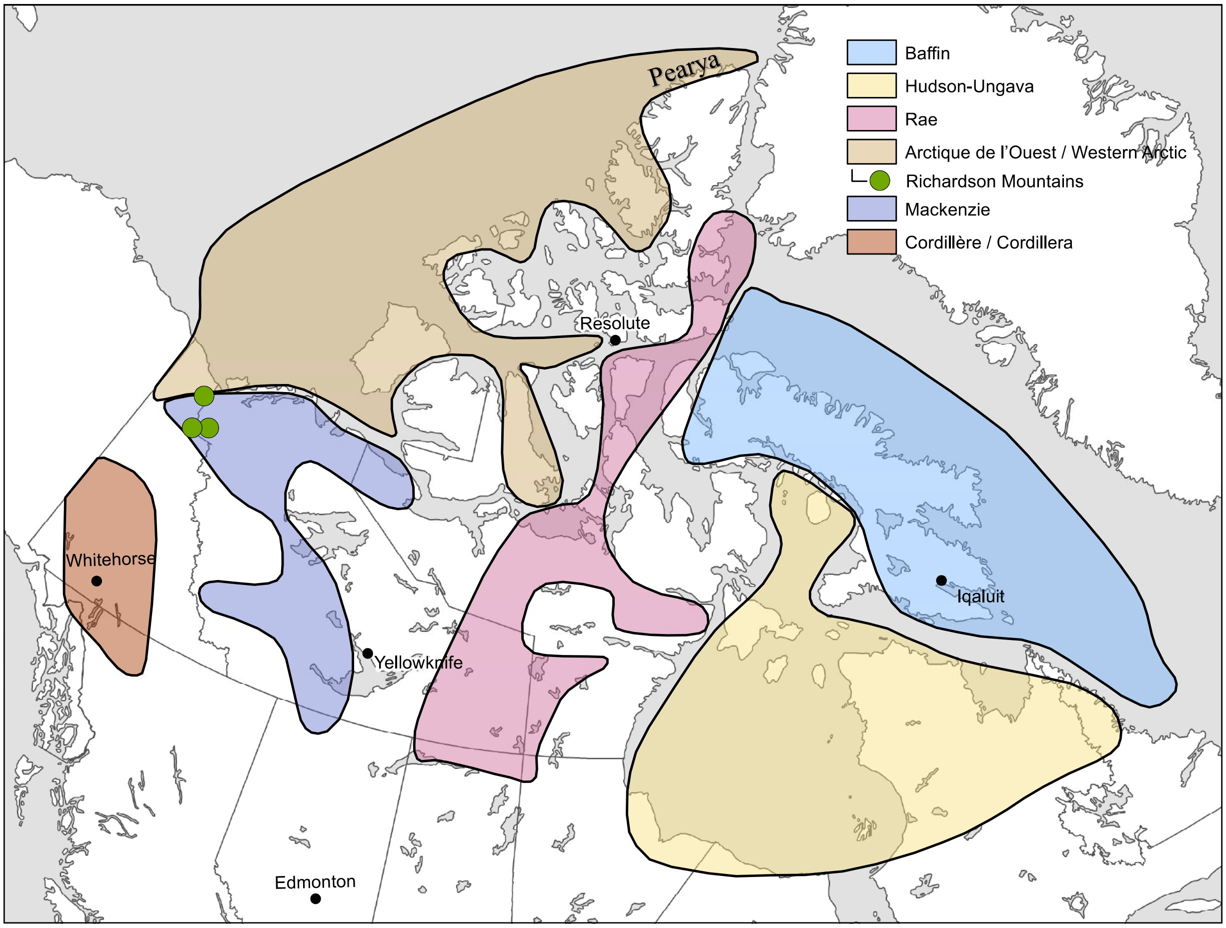

Figure 1: Map of Canada showing geographic areas of interest to the GEM-2 Program. Pearya terrane is Canada's most northerly exposed bedrock.

Objectives and methodology

At present, the published literature allows for large degrees of freedom in reconstructing how and when Pearya terrane came to be in its present position adjacent to the Franklinian Basin of Ellesmere Island by the end of the Devonian (Trettin, 1987; Trettin, 1998; Hadlari et al., 2014, Malone et al., 2014, 2017). Most if not all of Pearya terrane was subsequently covered by Late Paleozoic to Tertiary strata of the Sverdrup Basin and then uplifted in the Cenozoic. The older history of the rocks has been masked by significant deformation during the Eurekan orogeny, due to the indentation of Greenland forming a fold and thrust belt on Ellesmere Island in the Cenozoic. The main scientific questions in our study regarding the origin of Pearya terrane are:

1. What is the age of the Maskell Inlet Complex (Fig. 2) and was it part of Pearya terrane prior to the M'Clintock orogeny (approx. 475-460 Ma)? Our hypothesis is that the Maskell Inlet Complex was possibly a sliver of an Ordovician arc that was accreted to Pearya terrane in the Ordovician. There are almost no age constraints on the Maskell Inlet Complex, except that it is unconformably overlain by the Cape Discovery Formation which is approximately 450 Ma in age (Trettin, 1998; Hadlari et al., 2014). The Cape Discovery Formation also unconformably overlies upper Neoproterozoic-Cambrian strata that were deformed during the M'Clintock orogeny and that record an $^{40}Ar/^{39}Ar$ biotite cooling age of ca. 453 Ma (Trettin, 1998). The Cape Discovery Formation is apparently only affected significantly by Ellesmerian deformation in the Late Devonian-Early Carboniferous (Trettin, 1998).

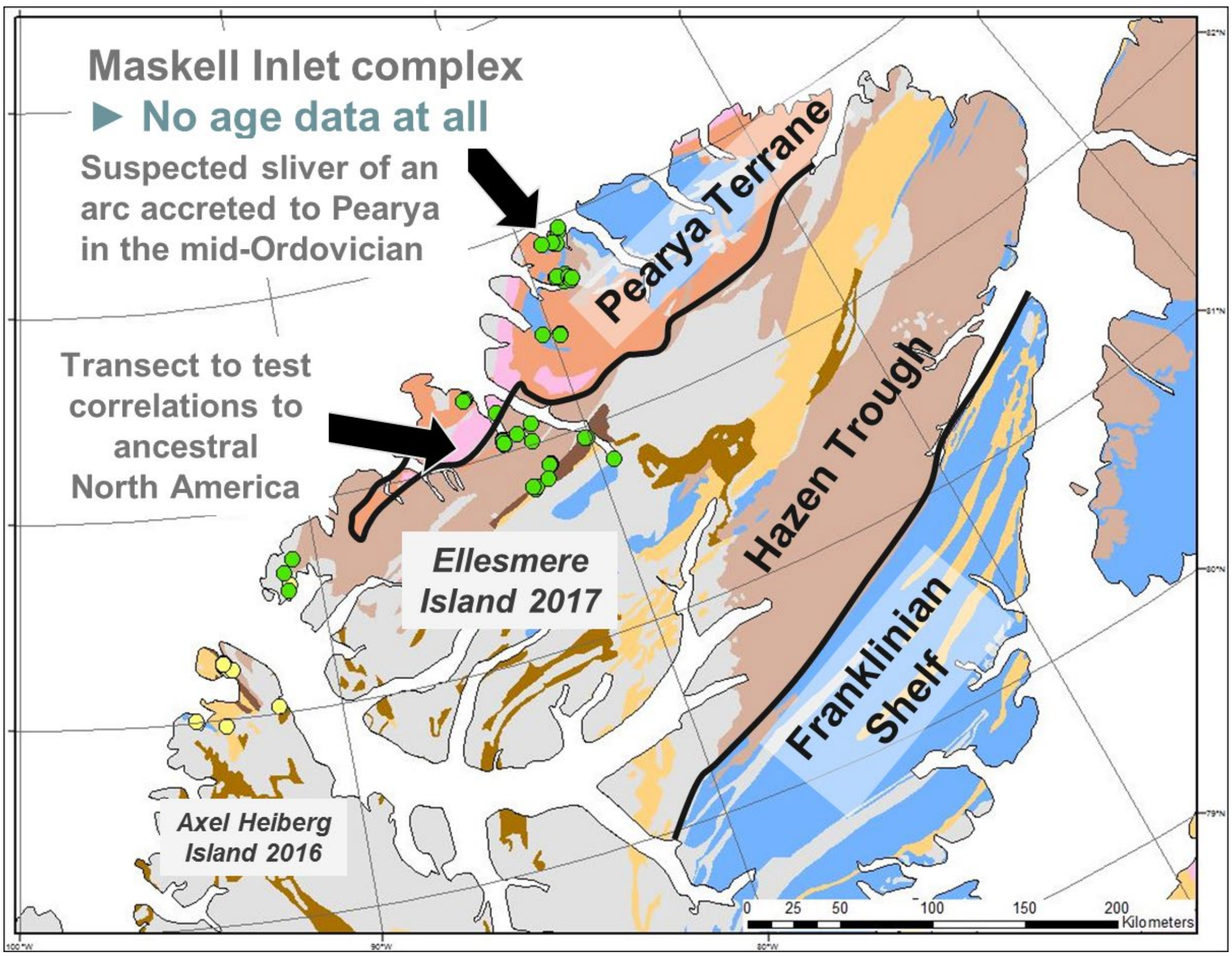

Figure 2: Map of northern Ellesmere Island. Outcrops that were visited in the summer of 2017 are indicated by green dots. Yellow dots are from the summer of 2016.

The potential scenario is that the Maskell Inlet Complex was a part of an arc that collided with Neoproterozoic-Cambrian Succession 2 rocks of Pearya terrane in the mid-Ordovician, and that the Late Ordovician Cape Discovery Formation is the overlap assemblage.

We visited localities west of M'Clintock Inlet where Succession 2 rocks of Pearya terrane are overlain by the Cape Discovery Formation, and to the east where the Cape Discovery Formation overlies the Maskell Inlet Complex. We will attempt to replicate the mid-Ordovician $^{40}Ar/^{39}Ar$ cooling age in Succession 2 strata below the Cape Discovery Formation. We sampled rhyolite flows at the base of the Cape Discovery Formation for U-Pb zircon geochronology to determine age constraints on the overlap assemblage.

2. Was the Tonian (lower Neoproterozoic) basement part of Pearya terrane prior to the M'Clintock orogeny? The rationale behind this question is that the Tonian detrital zircon ages are only present in metasedimentary rocks that can potentially be grouped with the basement (e.g., Map Unit A as designated by Trettin 1998), which would have been thrust over Succession 2 rocks of Pearya terrane. The upper Neoproterozoic to Cambrian strata of Pearya terrane do not contain significant amounts of Tonian detrital zircon (Malone et al., 2014), but Tonian detrital zircon are prominent Ordovician strata of Pearya terrane. Either the Tonian gneissic basement remained buried in the Neoproterozoic-Cambrian or was accreted during the M'Clintock orogeny.

Samples of Neoproterozoic-Cambrian strata were collected in locations inboard (south) of the Tonian gneisses and outboard (north). Detrital zircon analysis will test linkages across those rock units, as they pertain to tectonic associations before the Ordovician.

3. What is the age of the Yelverton Formation and how does it relate to Pearya terrane? The Yelverton Formation is part of the Franklinian succession within the Hazen Trough, or "deep water basin", and contains basalt flows and mafic sills.

We visited outcrops of the Yelverton Formation in the southwestern part of Yelverton Inlet. We found that the majority of igneous rocks are intrusive. The majority of sedimentary rocks are fine-grained and monotonous carbonates that were deposited in a relatively deep marine setting. Volcaniclastic sedimentary strata and quartzose sandstones are rare, but we collected a few samples of each for detrital zircon analysis with an aim to date the igneous rocks by proxy. We will compare these results to volcanic rocks of M2 from Pearya Terrane. The mafic igneous rocks in the Yelverton Inlet area should probably be referred to as the Yelverton Sill Complex.

Conclusions

The field activities from 2017 on Pearya terrane are part of a research project that is designed to reconstruct Pearya terrane at approximately 450 Ma. Our hypothesis is that the three components of Pearya terrane were assembled during the M'Clintock orogeny. As a test, the detrital zircon record of the overlap assemblage (Cape Discovery Formation and other Late Ordovician strata) should contain a record of the Tonian gneiss, Neoproterozoic-Cambrian metasedimentary rocks of Pearya Terrane, and the Maskell Inlet Complex. There are presently no radiometric age data from the Maskell Inlet Complex and so new detrital zircon results, potentially from our samples, are necessary to test the central hypothesis of this study.

Future work

Much of Pearya terrane is still described by informal stratigraphy mainly due to geochronological limitations that can only be improved with new outcrop samples for modern geochronological analysis. A robust stratigraphic framework is required for integration with the structural and magmatic record dated by radiometric techniques. Many of the faults that bound map units on Pearya terrane are Paleozoic but have been reactivated since, and so new observations coupled with new laboratory techniques in the field of thermochronology are necessary to resolve this multi-phase tectonic evolution.

The northern part of Pearya terrane between M'Clintock Inlet and Clements Markham Inlet contains (arrows in Fig. 3): Neoproterozoic strata that probably formed Cryogenian rift basins, which may be peri-Laurentian or exotic to North America; Ordovician granitic arc rocks; map units that are potentially slivers of arc terranes accreted in the Ordovician for which we have almost no information; and crystalline basement rocks that were also potentially accreted to the main part of Pearya terrane in the Ordovician.

We can reasonably deduce the Ordovician assembly of Pearya terrane in our present study, but relations to the Franklinian Basin and therefore to the rest of North America still remain highly uncertain and controversial. Future field-based work on northernmost Ellesmere Island can identify arc rocks, test affinities of potentially exotic crustal slivers, and study the terrane boundary at Clements Markham Inlet. This area would provide insight into relations between Ellesmere Island and Lomonosov Ridge that were established during the assembly of Pearya terrane, which were probably affected by Early Cretaceous opening of the Amerasia Basin, Late Cretaceous rifting to Paleogene opening of Baffin Bay (e.g., Hadlari and Issler, 2019), and Eocene opening of the Eurasia basin.

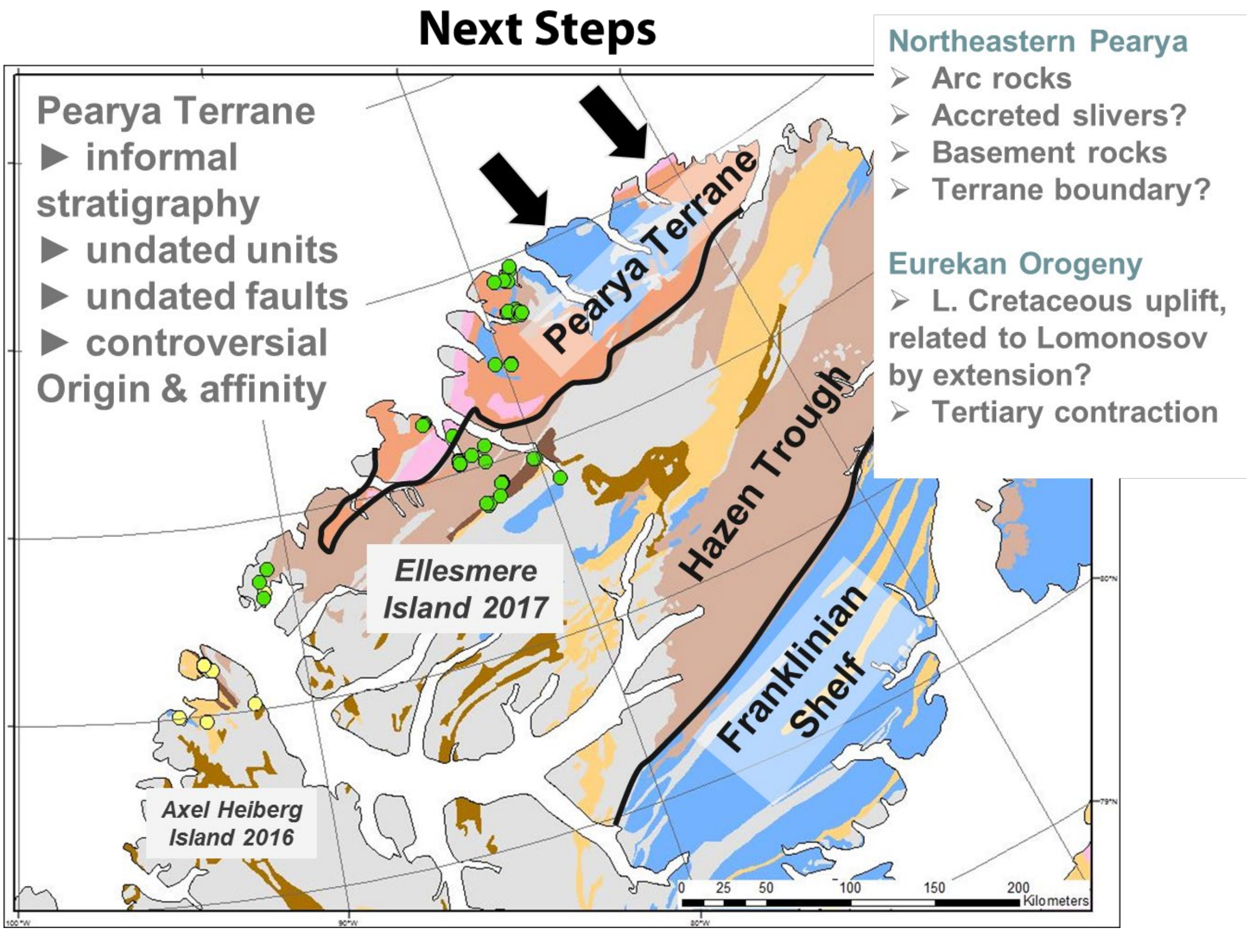

Figure 3: Map of northern Ellesmere Island showing the main tectonic associations.

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