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1.0 FORWARD

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to responsible land-use and resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the 2017 field season, research scientists from the GEM program successfully carried out 27 research activities, 26 of which will produce an activity report and 12 of which included fieldwork. Each activity included geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, Northerners and their institutions, academia and the private sector. GEM will continue to work with these key partners as the program advances.

2.0 PROJECT SUMMARY (PLAIN LANGUAGE)

We are conducting integrative and multi-disciplinary structural and stratigraphic research to precisely date the timing of structural deformation associated with the Eurekan deformation to provide new insight into the tectonic evolution of the Arctic. Our study is also expected to provide insight into Paleocene and Eocene climates of the Canadian High Arctic. This work is a contribution to the Pearya Activity within the Western Arctic Project of the GEM Program of the Geological Survey of Canada.

We conducted a 4-week field program in July and August 2017 on Ellesmere Island that was led by Bundesanstalt für Geowissenschaften und Rohstoffe (BGR; German Federal Institute for Geosciences and Natural Resources) and the Geological Survey of Canada. Two side camp locations were targeted for detailed structural and stratigraphic study: Stenkul Fiord (southern Ellesmere Island, NTS 049D/5) and Wootton Peninsula, northeastern Ellesmere Island (NTS 340F/4; Figures 1, 2). Our field-based mapping and detailed stratigraphic studies included sedimentology and collection of mudrock and sediments for isotopic, element geochemical, organic geochemical, paleontological, and palynological analyses.

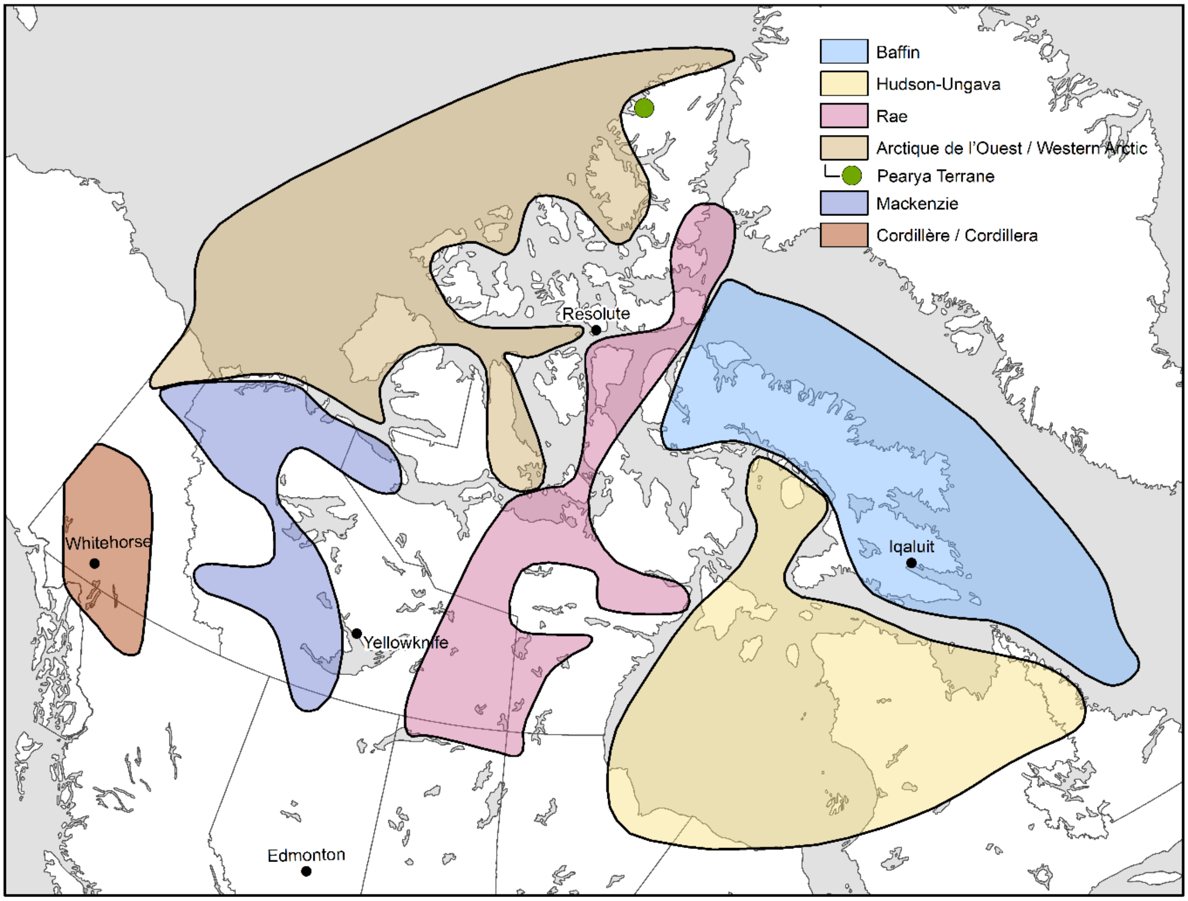

Figure 1: Map of the Geo-Mapping for Energy and Minerals Program Project study areas. This contribution falls under the Western Arctic Project

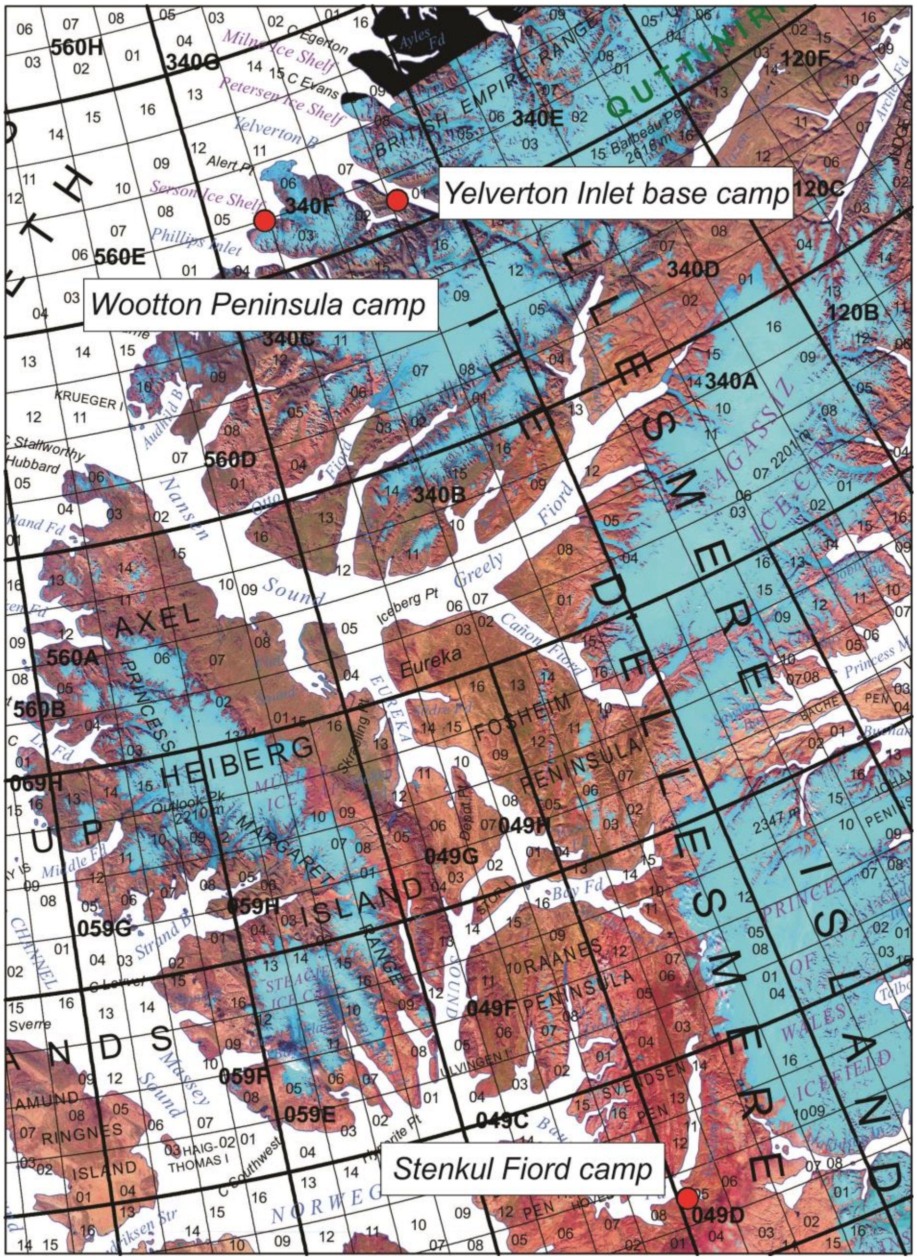

Figure 2. NTS map grid of Northeastern Ellesmere Island showing the locations and NTS map references for Yelverton Inlet base camp, Wootton Peninsula camp, and Stenkul Fiord camp

3.0 INTRODUCTION

Clastic Upper Cretaceous to Paleogene deposits of Ellesmere Island are preserved in mostly fault-bounded basins (Miall, 1986). These strata are interpreted as being syn-deformational with the Eurekan Orogeny (Miall, 1984; Ricketts and McIntryre, 1986) or post-depositionaly affected by Eurekan deformation (Piepjohn et al., 2015, 2016 and references therein). Despite abundant floral and faunal fossil remains (e.g., McIntyre 1992, 1994; Harrington et al., 2012; West et al., 2015 and references therein), the timing of deposition is not precisely constrained due to complex structural relationships. Dating of these strata will provide insight into the precise timing of Eurekan deformation and the tectonic history of the Arctic, as well as the impact of Paleogene hyperthermals on high-latitude ecosystems.

The mainly clastic sediments of the Margaret Formation of the Eureka Sound Group (stratigraphic nomenclature after Miall, 1986) are exposed at Stenkul Fiord (Figure 2). Here the Eureka Sound Group is up to 480 m thick and comprises predominantly non-marine sandstones, mudstones, coal, and minor siltstones (e.g., Riediger and Bustin, 1987). Four informal members are described by Riediger and Bustin (1987) and interpreted to have been deposited during two transgressive-regressive sequences that lasted from the early(?) Paleocene to late Paleocene and the second from late Paleocene to late Eocene. Reinhardt et al. (2017) and von Gosen et al. (submitted) also differentiate four units within the Margaret Formation at Stenkul Fiord based on geochronogy of volcanic ash layers, preserved in coals, and interpretative mapping. However, precise dating of stratigraphic units has remained problematic due to a protracted history of sedimentation, deformation, uplift, and erosion of strata associated with Eurekan deformation (von Gosen et al., submitted).

The Paleocene and Eocene was also a time of dynamic climate; the hyperthermals of the early Eocene are considered to be some of the most abrupt warming events of the Cenozoic (Zachos et al., 2008), when mean annual sea surface temperatures and mean annual air temperatures exceeded 8 °C to 18 °C (Weijers et al., 2007; Eldrett et al., 2009; Huber and Caballero, 2011; Pross et al., 2012; West et al., 2015). Climate warming at this time affected high latitude terrestrial vegetation comprised of Cupressaceae, palms, and even mangroves growing above 72 °N (Suan et al., 2017).

On Ellesmere Island, palynological studies reveal diverse vegetation consisting of Cupressaceae, Pinaceae, and angiosperms (McIntyre, 1994; Kalkreuth et al., 1996). These previous analyses show widely variable proportions of pollen and spores types. For example, angiosperm pollen ranges from 2-60% and Taxodiaceae pollen ranges from 7-87% at Stenkul Fiord (n=26 samples). This variability suggests that highly dynamic ecosystems existed during this time. Despite this previous palynological research, several questions remain including correlation to other sections, refined biostratigraphic age control, and high-latitude terrestrial vegetation composition that may be addressed through integration of quantitative palynology with the field-based structural study and planned geochemical, macrofloral, and other analyses. Emerging stratigraphic marker horizons and geochronological age control in coal-bearing estuarine and fluvial-deltaic sediments spanning the Paleocene/Eocene transition are reported by Reinhardt et al. (2010, 2013, 2017) and von Gosen et al. (submitted).

We returned to the site to conduct field-based interpretative mapping and to sample for additional ash layers as well as pollen, spores, and dinoflagellate cysts that are reported to be well-preserved in these sediments (McIntyre, 1994; Kalkreuth et al., 1996). Abundant and exceptionally well-preserved plant macrofossils also occur at this locality, but their precise stratigraphic context was previously unknown (West et al., 2015).

Farther north on Wootton Peninsula (Figure 2), much less was known regarding basic stratigraphy and structural relationships. Wottoon Peninsula and other localities on northeastern Ellesmere Island were visited by GSC scientists H.P. Trettin and T.O. Frisch for the purpose of sampling Upper Cretaceous Hansen Point volcanics (NTS map sheets 340C, 340F, 560D; Trettin, 1996). Volcanic strata at Wootton Peninsula are described as being overthrust from the southeast by Succession 1 of Pearya (Trettin, 1996). Fault blocks or Late Cretaceous-aged land-slides of map unit W3 are reported as occurring in the southwestern part of this area (Trettin, 1996). Upper Cretaceous and Cenozoic strata were investigated in the field by D.G. Wilson in 1975 (Wilson, 1976). Wilson (1976) reports Eureka Sound Formation as consisting of a minimum (base not exposed) of 500 m of interbedded clayey siltstone and sandstone that he separates, based on relative proportion of sandstone, into two units. In the lower part of the succession, siltstone predominates over sandstone while in the upper part sandstone predominates over siltstone. Samples were collected at that time by D.G. Wilson for paleontolgoical analysis for the purposes of biostratigrapic age control (Hopkins, 1975; Jeletzky, 1975). These fossils included palynomorphs and an ammonite fragment preserved in a concretion (Field No. 75-WR-13-4; 82^{0} 21‘10‘‘N, 84^{0} 32‘20‘‘W NTS-340F and 560E; GSC C-number C-55022). The ammonite fragment is identified by Jeletzky (1975) as being *Baculites*-like but he notes that the specimen does not exhibit any trace ammonite-like structures (e.g., suture lines) and is therefore rejected as being an ammonite. GSC Research Scientist Dr. David McNeil analyzed samples collected from northeastern Ellesmere Island identified as being sampled from Eureka Sound Group strata (sample locations, Field Nos., and GSC C-numbers as follows: 82^{0} 18‘50‘‘N, 84^{0} 30‘00‘‘, 75-WR-11-1, C-55015; 75-WR-11-3, C-55017 and 82^{0} 21‘10‘‘N, 84^{0} 32’30‘‘W 75-WR-13-1, C-55019; 75-WR-13-2, C-56020; 75-WR-13-3, C-55021) for microfossils (foraminifera). All samples were barren of microfossils (McNeil, 1998). GSC Research Scientist Dr. David McIntyre analyzed the same samples as reported in McNeil (1998) for palynomorphs. The samples contain few specimens of pollen, spores, and dinoflagellate cysts and these suggest a probable late Paleocene age. The author notes that the samples may range into the early Eocene (McIntyre, 1998). The presence of dinoflagellate cysts in the samples indicate deposition in a nearshore marine environment and some of the samples contain pollen of Maastrichtian age (also noted by Hopkins, 1976) and interpreted by McIntyre (1998) as being reworked into Paleocene strata.

We conducted a ~2 week field-based research program on Wootton Peninsula to collect basic information on stratigraphy and structural relationships that will be used to provide insight into the timing of Eurekan deformation on northernmost Ellesmere Island.

4.0 METHODOLOGY

While at the two field localities structural relationships were analyzed, ash layers were identified and collected for geochronological analyses (BGR), mudrock was collected for isotopic and geochemical analyses (BGR), and paleontological samples (microfossil teeth of vertebrates, fish remains, and macrofloral and palynological collections) were collected under a Class 2 Nunavut Territory Palaeontologist Permit No. 2017-093P by Dr. Jennifer Galloway. We report here only on palynology samples collected under this permit by GSC Research Scientist Dr. Jennifer Galloway and Masters of Science candidate Markus Sudermann (palynology, co-supervised by Dr. David Greenwood and Dr. Jennifer Galloway at Brandon University).

Small rock samples (~100 g) were collected for analysis of microscopic pollen, spores, and algal cysts (*n*=205 samples) from two measured sections at Stenkul Fiord through the Margaret Formation, one measured section at Wootton Peninsula through an unknown stratigraphic unit, and multiple grab samples at both localities for biostratigraphic age control. We were not able to precisely locate the localities of Wilson (1976) at Wootton Peninsula. Samples were transported to the Geological Survey of Canada, Calgary, for curation (on-going) and chemical digestion in the GSC Calgary Palynology Laboratory (pending). Following maceration, the samples will be analyzed for pollen, spores, and other palynomorphs using high-powered light microscopy to provide biostratigraphic age control of the material for integration with other chronostratigraphic techniques.

Larger (~1 kg) samples of clastic material were collected for isolation and identification of vertebrate teeth (*n*=2; to be conducted by Dr. Alex Dutchak at the University of Calgary).

We unexpectedly encountered fossil fish remains (*n*=5) at the Wootton Peninsula in strata of an unknown lithostratgraphic unit. Analyses will be focused on defining the age of host strata using palynology and identification of the fossil fish material (analyst to be determined).

5.0 ACKNOWLEDGEMENTS

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