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E.D. Ellefson[1,2], J.M. Galloway[1], T. Hadlari[1] , S.M. Hubbard[2], and M. Bringué[1]

[1]Geological Survey of Canada, 3303-33 Street NW, Calgary, Alberta T2L 2A7
[2]Department of Geoscience, University of Calgary, 2500 University Drive, Calgary, Alberta T2N 1N4

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1.0 FOREWORD

The Geo-Mapping for Energy and Minerals Program 2 (GEM-2) provided funding for the fieldwork completed during the summer of 2018 in support of the Richardson Mountains Activity led by Geological Survey of Canada (GSC) Research Scientist Thomas Hadlari, as part of the GEM Western Arctic Project (science co-leads GSC Research Scientists Jennifer Galloway and Keith Dewing; Project Manager Carl Ozyer). The Western Arctic Project of the GEM-2 Program has multiple objectives including establishing the stratigraphic and structural history of the margins of the Arctic Ocean and testing predictions for different tectonic models for the opening of the Arctic Ocean. Additional objectives include determination of the structural and stratigraphic architecture of the Canada Basin and testing predictions regarding the linkage and interaction between the northern Cordillera and the Arctic Islands. Furthermore geological maps of the Richardson Mountains Activity area are over 20 years old. Data produced by the GEM-2 Project is expected to generate new geoscience knowledge to be used to refine regional scale geologic knowledge and maps.

During the 2018 field season, research scientists from the Geological Survey of Canada, the University of Calgary and the University of Alberta associated with the GEM-2 Western Arctic Project, Richardson Mountains Activity, carried out a variety of field-based data and materials collection and research activities. Field activities included geological mapping, stratigraphic measurements and sample collection for a range of analyses including palynological sampling for biostratigraphy and sandstone sampling for geochronology and thermochronology. The research completed in the 2018 field season was conducted with the goals of providing updated regional geology and an integrated basin history study based on stratigraphy, biostratigraphy, geochronology, thermochronology and structural geology.

2.0 PROJECT SUMMARY

In July 2018 a 2-week field program was conducted in the Richardson Mountains in the northern Northwest Territories and Yukon (Figure 1). The field program was led by the Geological Survey of Canada, Calgary (Field Party Chief Dr. Thomas Hadlari) and also included researchers, students and wildlife monitors from the University of Calgary, the University of Alberta and the communities of Old Crow and Aklavik. The field party was based out of Aklavik, Northwest Territories, and daily flights via helicopter were made to various locations in the Richardson Mountains and the Mackenzie Delta. Five stratigraphic sections were targeted for detailed analysis including stratigraphic measurements, sedimentology and collection of material for various laboratory-based analyses upon return to the Geological Survey of Canada and University of Calgary.

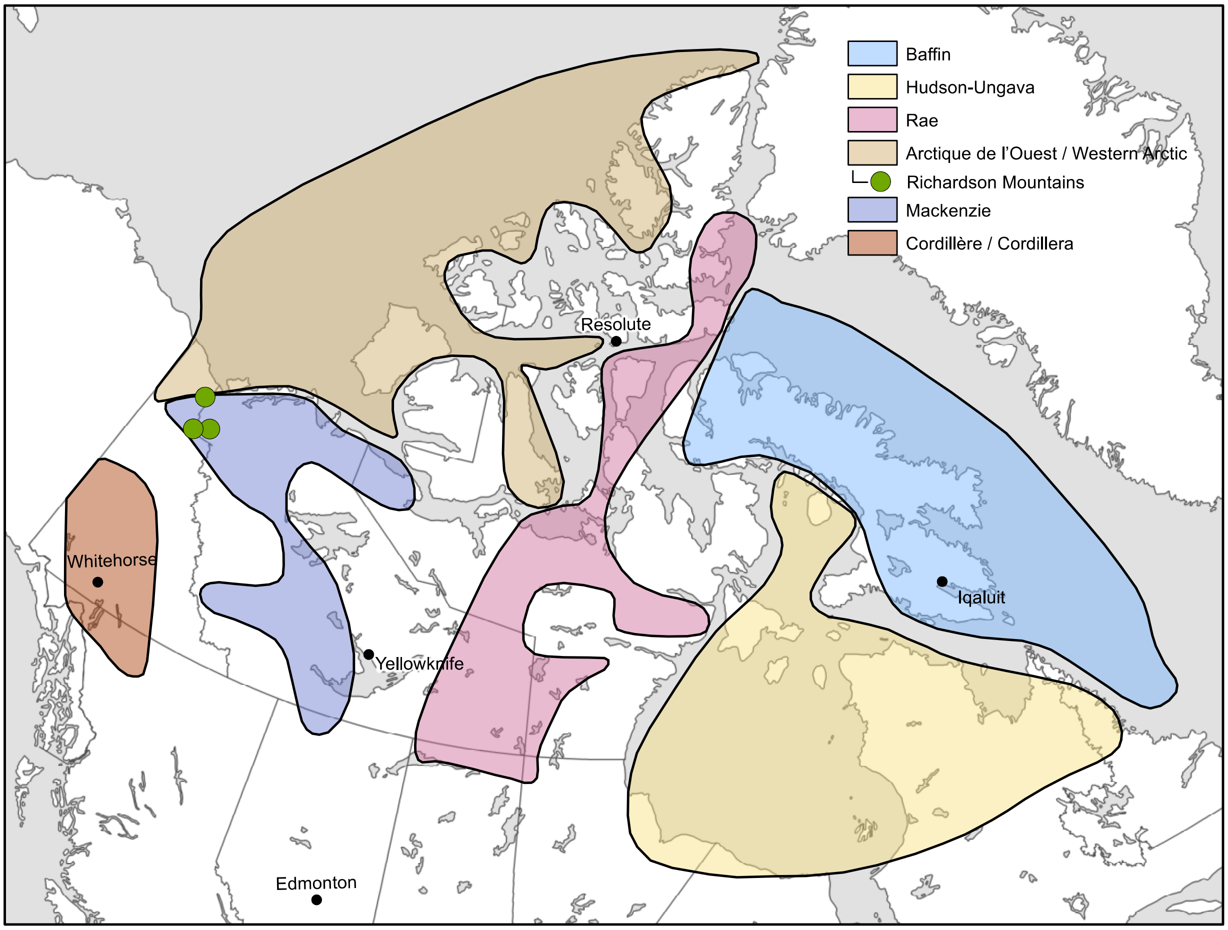

Figure 1: Map of Canada showing areas of interest to the GEM-2 Program, the locations that are the focus of this report are the Mackenzie (dark blue) and Richardson Mountains (green circles) areas.

3.0 INTRODUCTION

From the Berriasian to the Aptian (~145 – 113 Ma; Early Cretaceous), a broad shelf covered the majority of the District of Mackenzie and the northern Yukon. Shelf sedimentation processes dominated at this time and a shelfward progression of facies is observed from the Mackenzie Delta westward through the northern Richardson Mountains (Dixon, 1986; 1992). Cretaceous strata in this region are siliciclastic deposits with alternating sandstone and mudstone units. Within these Cretaceous strata there are 5 formations of interest: the Husky Formation (Jurassic – Berriasian), the Martin Creek Formation (upper Berriasian), The McGuire Formation (lower to middle Valanginian), the Kamik Formation (upper Valanginian to upper Hauterivian) and the Mount Goodenough Formation (late Hauterivian to Barremian; Dixon 1991; 1992).

The Husky Formation is divided into four informal members, the lower member, the arenaceous member, the red-weathering member and the upper member, however; only the last two are

Cretaceous in age (Jeletzky, 1967; Dixon, 1992). The red-weathering member is a mudstone-dominated unit, consisting of dark gray and rust colored mudstones with numerous ironstone concretions (Hedinger, 1993). The upper member consists of a large coarsening upward cycle with mudstone at the base grading into sandstones at the top of the succession (Hedinger, 1993). All members of the Husky Formation were deposited in a marine setting (Dixon, 1992). The Martin Creek Formation is a fine-grained sandstone dominant succession, weathering light yellow to orange and containing several upwards-coarsening cycles (Jeletzky 1958; Jeletzky 1960; Dixon and Jeletzky, 1991; Dixon 1991). It was deposited in a marine environment and the prevalence of sedimentary structures such as hummocky cross-stratification and swaley cross-stratification indicate deposition in a high-energy setting (Dixon and Jeletzky, 1991; Dixon 1991). The McGuire Formation is a mudstone-dominated succession, consisting of bluish gray fissile shale with numerous ironstone concretions (Jeletzky 1961; Dixon and Jeletzky, 1991; Dixon 1991). The succession grades upwards into mudstones followed by increase in sand content in the upper parts of the Formation, forming an overall coarsening-upward succession gradational with the overlaying Kamik Formation (Dixon and Jeletzky, 1991; Dixon 1991). The McGuire Formation was deposited in a marine environment and the prevalence of clay and silt in the succession indicates a low-energy depositional environment (Dixon and Jeletzky, 1991). The Kamik Formation is divided into two members, the upper member and the lower member (Jeletzky 1960; Dixon 1982; Dixon 1991). The lower member consists of thick sandstone beds and displays a fining upward trend with occasional interbedded mudstones (Dixon 1991; Dixon 1992). In contrast the upper member has a coarsening upwards trend where the base is fine-grained sand that grades into coarser sands (Dixon, 1991; Dixon 1992). The majority of the Formation was deposited in a marine environment, however the lower member also contains some deposits from deltaic and lagoonal environments (Dixon, 1991). The lower section of the Mount Goodenough Formation is dominated by black fissile shale with numerous ironstone concretions (Jeletzky 1958; Jeletzky 1960; Dixon and Jeletzky, 1991). These strata grade upwards into interbedded mudstone and sandstone in the upper part of the Formation (Dixon and Jeletzky, 1991; Dixon 1991). The Mount Goodenough Formation was deposited in a marine environment and the prevalence of clay and silt in the lower part of the succession indicates a low-energy depositional environment while the prevalence of sand in the upper part of the succession indicates a higher-energy depositional environment (Dixon and Jeletzky, 1991; Dixon, 1992).

The Jurassic to lower Aptian strata in northwest Canada were deposited under extensional tectonic settings and the beginnings of influence of the Cordilleran Orogen (Embry and Dixon, 1990; Dixon, 1993). Several major regional unconformities are present in the Cretaceous strata of northwest Canada (Dixon, 1993). At least eight major unconformities are recognized or inferred; most of these unconformities are recognized by their erosional relationships, however some are inferred based on the presence of maximum flooding surfaces (Dixon, 1993). One of the most prominent unconformities in the region is the middle-upper Hauterivian unconformity, which developed during a period of rifting and occurs erosionally at the base of the Mount Goodenough Formation (Dixon, 1991; 1992; 1993). However the exact age of this unconformity remains uncertain (Dixon, 1993). We aim to use palynological analyses to determine if the intra-Mount Goodenough Formation Hauterivian unconformity can be correlated with the sub-Hautervian (breakup unconformity; Hadlari et al., 2016) in the Sverdrup Basin to elucidate tectono-stratigraphic linkages with other Arctic areas.

4.0 METHODOLOGY

At five localities sandstone, siltstone and mudstone samples were collected under Northwest Territories Scientific Research License No. 16302 issued by the Aurora Research Institute (ARI) with permission from the Gwich'in Tribal Council and the Inuvialuit Environmental Impact Screening Committee. Samples were collected for palynological, geochronological and thermochronological analysis by Ph.D. candidate Benjamin Daniels (University of Calgary, supervised by Dr. Stephen Hubbard), M.Sc. candidate Ryan Millar (University of Alberta, supervised by Dr. Octavian Catuneanu) and M.Sc. candidate Emily Ellefson (University of Calgary, co-supervised by Dr. Jennifer Galloway, Dr. Stephen Hubbard and Dr. Manuel Bringué).

The following section will focus on the samples collected for palynology by M.Sc. candidate Emily Ellefson. Samples for palynological analyses (the analysis of microscopic pollen, spores and algal cysts) were collected by removing loose and weathered material and collecting small samples (~100g) of the underlying *in-situ* rock in Ziploc bags (*n* = 115 samples, Table 1). The majority of palynological samples were collected at a measured section near Martin Creek, termed the Martin Creek Section (*n* = 49 samples collected over 316.35 meters of section) where the Husky Formation was sampled. A large number of samples were also collected at a second exposure, termed the Mount Goodenough Section (*n* = 38 samples collected over 455.6 meters of section) where both the Husky Formation and the Mount Goodenough Formation were sampled. Additional palynological samples were also collected at a section exposed at Grizzly Gorge, termed the Grizzly Gorge Section (*n* = 17 samples collected over 102.95 meters of section) where the Martin Creek Formation, McGuire Formation and Mount Goodenough Formation were sampled. At a measured section exposed near Bug Creek, the Bug Creek Section (*n* = 4 samples collected over 99.88 meters of section) the Longstick Formation and Husky Formation were sampled. Finally samples were also collected from a section near Murray Ridge, termed the Murray Ridge Formation Section (*n* = 7 samples collected over 582.4 meters of section). The majority of samples collected were from formations that are Early Cretaceous in age with the exception of the samples from the Bug Creek Section, which are Permian in age and the Murray Ridge Section, which are Jurassic in age. After collection, samples were transported to the Geological Survey of Canada, Calgary for curation (Table 1) and preparation (pending) in the GSC Palynology Laboratory. Following standard palynological preparation samples will then be analyzed for pollen, spores and other palynomorphs using high-powered light microscopy.

The larger sandstone and siltstone samples collected will be analyzed for detrital zircons by PhD candidate Benjamin Daniels at the University of Calgary as well as apatite by MSc candidate Ryan McKay (supervised by Dr. Eva Enkelmann) at the University of Calgary. Resources will now be focused on the analysis and interpretation of data generated from the samples collected in summer 2018. When palynological analyses are complete they will be integrated with other stratigraphic analysis currently underway (including geochronology and thermochronology) along with a revised structural framework (Dr. Larry Lane, Geological Survey of Canada) to provide new insight into the timing and development of the margins of the Arctic Ocean.

Table 1. Palynology samples collected in the 2018 field season, from the Richardson Mountains Activity area, with corresponding GSC Curation Numbers and Section.

Sample Number	C-number	Section
1	C-629681	Grizzly Gorge Section
2	C-629682	Grizzly Gorge Section
3	C-629683	Grizzly Gorge Section
4	C-629684	Grizzly Gorge Section
5	C-629685	Grizzly Gorge Section
6	C-629686	Grizzly Gorge Section
7	C-629687	Grizzly Gorge Section
8	C-629688	Grizzly Gorge Section
9	C-629689	Grizzly Gorge Section
10	C-629690	Grizzly Gorge Section
11	C-629691	Grizzly Gorge Section
12	C-629692	Grizzly Gorge Section
13	C-629693	Grizzly Gorge Section
14	C-629694	Grizzly Gorge Section
15	C-629695	Grizzly Gorge Section
16	C-629696	Grizzly Gorge Section
17	C-629697	Grizzly Gorge Section
18	C-629698	Mount Goodenough Section
19	C-629699	Mount Goodenough Section
20	C-629700	Mount Goodenough Section
21	C-629701	Mount Goodenough Section
22	C-629702	Mount Goodenough Section
23	C-629703	Mount Goodenough Section
24	C-629704	Mount Goodenough Section
25	C-629705	Mount Goodenough Section
26	C-629706	Mount Goodenough Section
27	C-629707	Mount Goodenough Section
28	C-629708	Mount Goodenough Section
29	C-629709	Mount Goodenough Section
30	C-629710	Mount Goodenough Section
31	C-629711	Mount Goodenough Section
32	C-629712	Mount Goodenough Section
33	C-629713	Mount Goodenough Section
34	C-629714	Mount Goodenough Section
35	C-629715	Mount Goodenough Section
36	C-629716	Mount Goodenough Section
37	C-629717	Mount Goodenough Section
38	C-629718	Mount Goodenough Section
39	C-629719	Mount Goodenough Section
40	C-629720	Mount Goodenough Section
41	C-629721	Mount Goodenough Section
42	C-629722	Mount Goodenough Section
43	C-629723	Mount Goodenough Section
44	C-629724	Mount Goodenough Section
45	C-629725	Mount Goodenough Section
46	C-629726	Mount Goodenough Section
47	C-629727	Mount Goodenough Section
48	C-629728	Mount Goodenough Section
49	C-629729	Mount Goodenough Section

50	C-629730	Mount Goodenough Section
51	C-629731	Mount Goodenough Section
52	C-629732	Mount Goodenough Section
53	C-629733	Mount Goodenough Section
54	C-629734	Mount Goodenough Section
55	C-629735	Mount Goodenough Section
56	C-629736	Mount Goodenough Section
57	C-629737	Bug Creek Section
58	C-629738	Bug Creek Section
59	C-629739	Murray Ridge Section
60	C-629740	Murray Ridge Section
61	C-629741	Murray Ridge Section
62	C-629742	Murray Ridge Section
63	C-629743	Murray Ridge Section
64	C-629744	Murray Ridge Section
65	C-629745	Murray Ridge Section
66	C-629746	Martin Creek Section
67	C-629747	Martin Creek Section
68	C-629748	Martin Creek Section
69	C-629749	Martin Creek Section
70	C-629750	Martin Creek Section
71	C-629751	Martin Creek Section
72	C-629752	Martin Creek Section
73	C-629753	Martin Creek Section
74	C-629754	Martin Creek Section
75	C-629755	Martin Creek Section
76	C-629756	Martin Creek Section
77	C-629757	Martin Creek Section
78	C-629758	Martin Creek Section
79	C-629759	Martin Creek Section
80	C-629760	Martin Creek Section
81	C-629761	Martin Creek Section
82	C-629762	Martin Creek Section
83	C-629763	Martin Creek Section
84	C-629764	Martin Creek Section
85	C-629765	Martin Creek Section
86	C-629766	Martin Creek Section
87	C-629767	Martin Creek Section
88	C-629768	Martin Creek Section
89	C-629769	Martin Creek Section
90	C-629770	Martin Creek Section
91	C-629771	Martin Creek Section
92	C-629772	Martin Creek Section
93	C-629773	Martin Creek Section
94	C-629774	Martin Creek Section
95	C-629775	Martin Creek Section
96	C-629776	Martin Creek Section
97	C-629777	Martin Creek Section
98	C-629778	Martin Creek Section
99	C-629779	Martin Creek Section
100	C-629780	Martin Creek Section
101	C-629781	Martin Creek Section
102	C-629782	Martin Creek Section
103	C-629784	Martin Creek Section

104	C-629785	Martin Creek Section
105	C-629786	Martin Creek Section
106	C-629787	Martin Creek Section
107	C-629788	Martin Creek Section
108	C-629789	Martin Creek Section
109	C-629790	Martin Creek Section
110	C-629791	Martin Creek Section
111	C-629792	Martin Creek Section
112	C-629793	Martin Creek Section
113	C-629794	Martin Creek Section
114	C-629795	Bug Creek Section
115	C-629796	Bug Creek Section

*precise GPS coordinates and meterages are provided in the Geological Survey of Canada Sample Management Systems (SMS) database

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