

GEM 2 Hudson-Ungava Project: Stratigraphic investigations of the Hudson Bay Lowland, northeastern Manitoba

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1.0 Introduction

The Manitoba Geological Survey (MGS) is participating in the energy (hydrocarbon) component of the second phase of the Geo-mapping for Energy and Minerals (GEM-2) program's Hudson-Ungava project with the Geological Survey of Canada (GSC). The Hudson-Ungava project's hydrocarbon component involves the study of the Paleozoic strata of the Hudson Bay Basin, in the Hudson Bay Lowland (HBL) area, northeastern Manitoba.

This project builds on the first GEM program results (GEM Energy: Hudson Bay and Foxe Basins Project, which ran from 2008 to 2013), with the addition of more detailed stratigraphic and structural studies. Activities started this year include: 1) detailed logging of core and outcrop descriptions; 2) sampling of organic-rich beds and laminae for organic-geochemistry analysis by Rock-Eval 6™; 3) detailed profiling of δ¹³C and δ³⁴S stable isotopes on select core; 4) determining conodont, chitinozoan and micropalaeontological biostratigraphy; and 5) reconnaissance mapping of the Paleozoic outcrops along the Churchill River and Churchill coastal area.

This poster summarizes activities and preliminary results for items 1, 2 and 4 listed above. See Nicolas et al. (2014) and Nicolas and Young (2014) for more information on all the activities.

3.0 Churchill River and Churchill coastal area field work

The 2014 field component of the GEM-2 program in Manitoba consisted of visits to key outcrop locations along the Churchill River and in the Churchill coastal area (Figure 4). Lithostratigraphic type sections for the Upper Ordovician Portage Chute, Surprise Creek, Caution Creek, Chasm Creek and Red Head Rapids formations are all located along the Churchill River and its tributaries. All the type section localities were visited (Figure 5 to 9), with the exception of the type locality for the Caution Creek Formation (Figure 10); for this formation, exposures at other sites were visited, Figure 8). Lithological descriptions and samples were collected at each site, as well as joint and fracture measurements (Figure 11) and notes and samples of representative fossils (Figure 12 to 15).

The exposures visited around Churchill (Figure 16 and 17) provide a comparative section, demonstrating the stratigraphic complexities caused by proximity to the Proterozoic Churchill quartzite, which stood out as islands during the Ordovician. Visits to these sites provided a much-needed frame of reference to assist in understanding the complexities of the Churchill coastal area, and the long-distance correlations to subsurface core information from boreholes located in the southeastern half of the HBL in Manitoba.

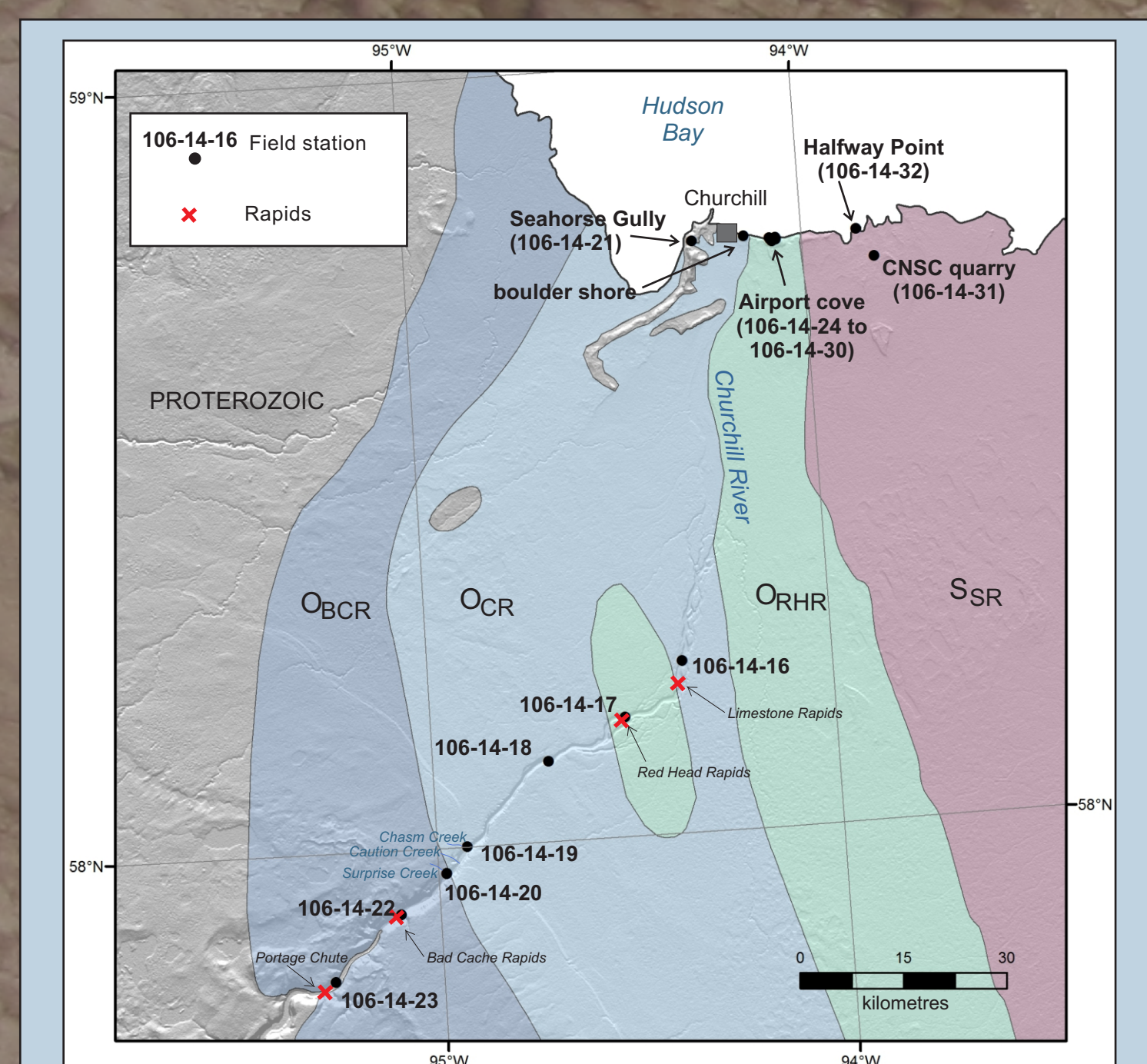


Figure 1: Time-stratigraphic framework of the Hudson Bay Lowland in northeastern Manitoba. Systems and stages are from the International Commission on Stratigraphy (2014), but their relationships to the formations are based on Zhang and Barnes (2007) for the Ordovician, Norford (1997) for the Silurian, and Sanford and Norris (1975) for the Devonian.

2.0 Core Investigations and biostratigraphy

Detailed core investigations on the formation assignments in the Foran Mining KK1 core confirmed a stratigraphic anomaly suspected from early geophysical surveys in the 1960s. According to previous reconnaissance-scale mapping, the Paleozoic formation that should have been present at the bedrock surface at the location of the KK1 borehole was the Attawapiskat Formation with the underlying Ekwan River Formation (Figure 1), but the core and biostratigraphic results indicate that both these formations are absent here, and that the Severn River Formation is at the bedrock surface. The Severn River Formation was confirmed with conodont biostratigraphic analysis. A re-interpretation of the formation edges was therefore required. Figure 2 shows the new interpreted mapping based on the KK1 borehole supporting a deep syncline in this area, as part of a complex series of synclines and anticlines between the Nelson River to just southeast of the Ontario border proposed by Nelson and Johnson (1966).

2.1 Organic geochemistry and source rocks

Previous organic geochemistry results have indicated that there are numerous thin organic-rich beds that are classified as good oil source rocks (Lavoie et al., 2013); these beds extend over a large geographic area. Most of these beds occur in strata that are suspected to be thermally mature in parts of the basin, perhaps sufficient to have produced oil, which is contrary to previous theories.

New samples collected and analysed by Rock Eval 6™ this year returned total organic contents (TOC) as high as 8.23 wt. % from the Ordovician Red Head Rapids Formation in the Merland et al. Whitebear Creek Prov. core, 5.65 wt. % in the Ordovician Surprise Creek Formation, and 3.87 wt. % in the Silurian Severn River Formation in the Houston Oils et al. Comeault Prov. No. 1 core (Figure 3).

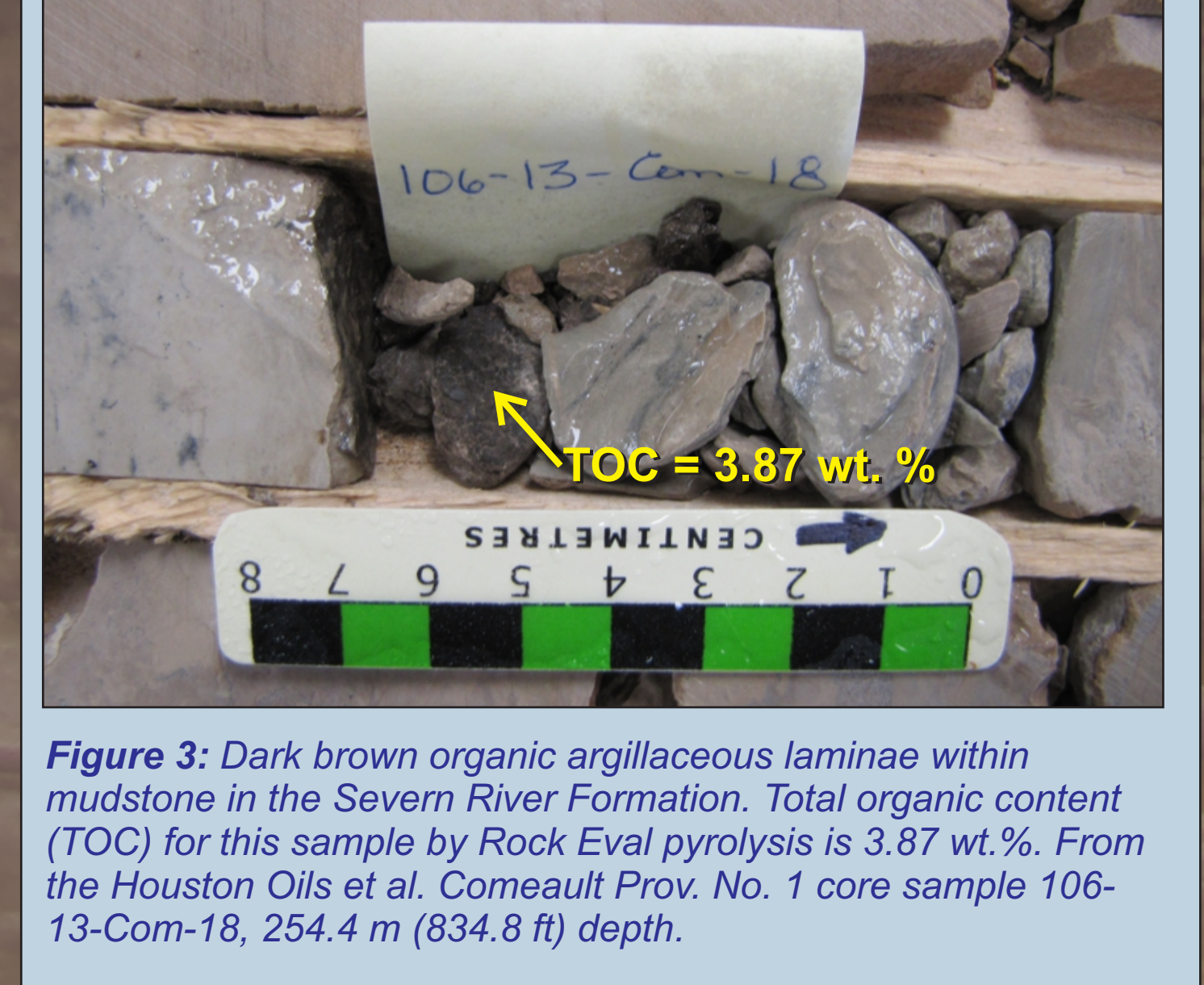


Figure 3: Dark brown organic argillaceous laminae within mudstone in the Severn River Formation. Total organic content (TOC) for this sample by Rock Eval pyrolysis is 3.87 wt.%. From the Houston Oils et al. Comeault Prov. No. 1 core sample 106-13-Com-18, 254.4 m (834.8 ft) depth.

Portage Chute Formation type section location

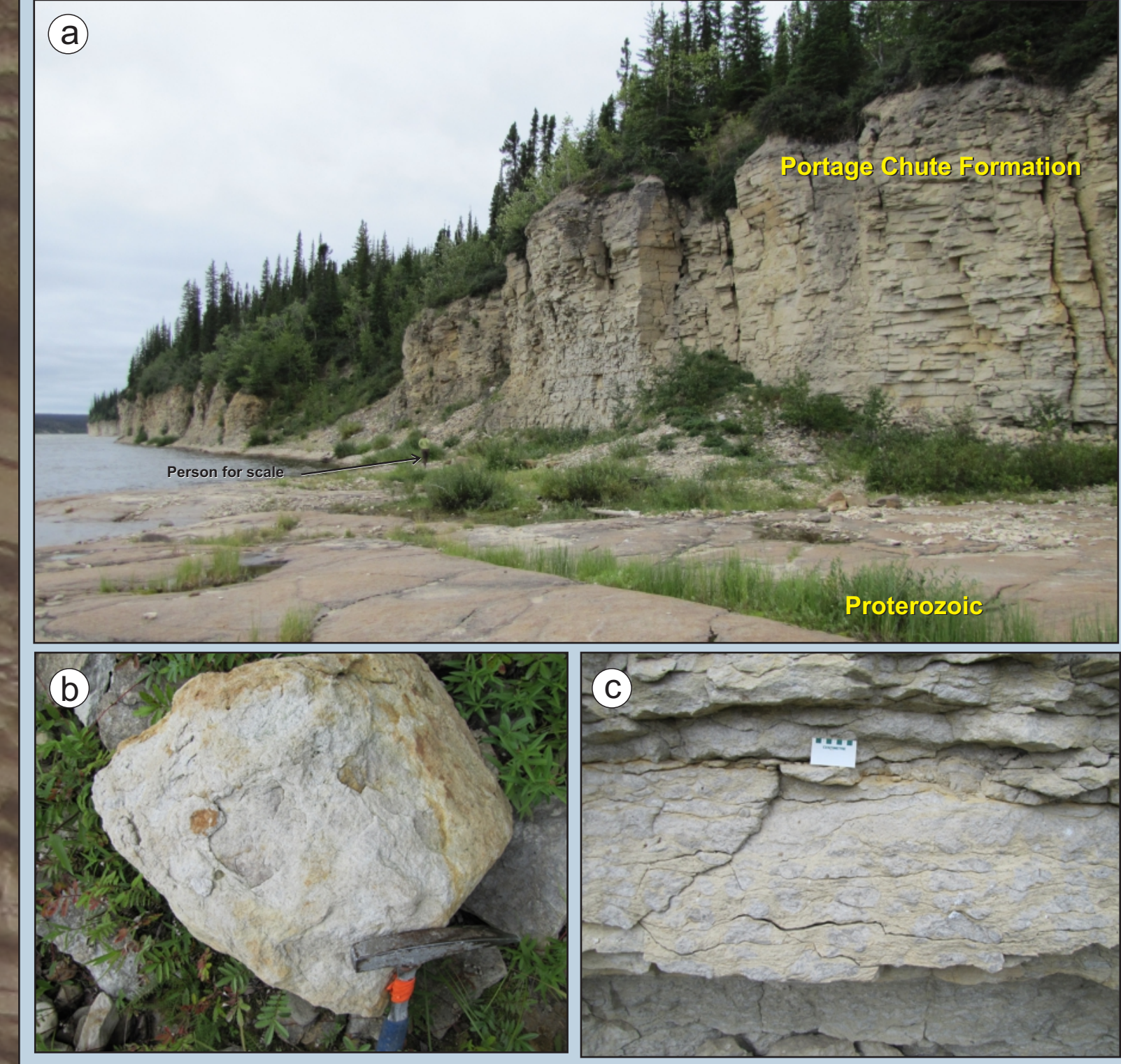


Figure 5: Exposure just downstream from Portage Chute at station 106-14-23 showing a) the vertical cliffs of the Portage Chute Formation directly overlying the Proterozoic granitic surface; b) close-up of a sandstone boulder from member 1 of the Portage Chute Formation; and c) close-up of nodular and argillaceous wackestone of member 2 of the Portage Chute Formation. Location of station 106-14-23 is shown in Figure 4.

Bad Cache Rapids Group type section location



Figure 6: Exposures of the Portage Chute Formation along the north bank of the Churchill River at Bad Cache Rapids, station 106-14-22. a) Portage Chute Formation forming vertical cliffs along river with fossil-rich scree slope; b) calcite-healed vertical fracture; and c) close-up of argillaceous nodular wackestone typical of the section. Location of station 106-14-22 is shown in Figure 4.

Chasm Creek Formation type section location

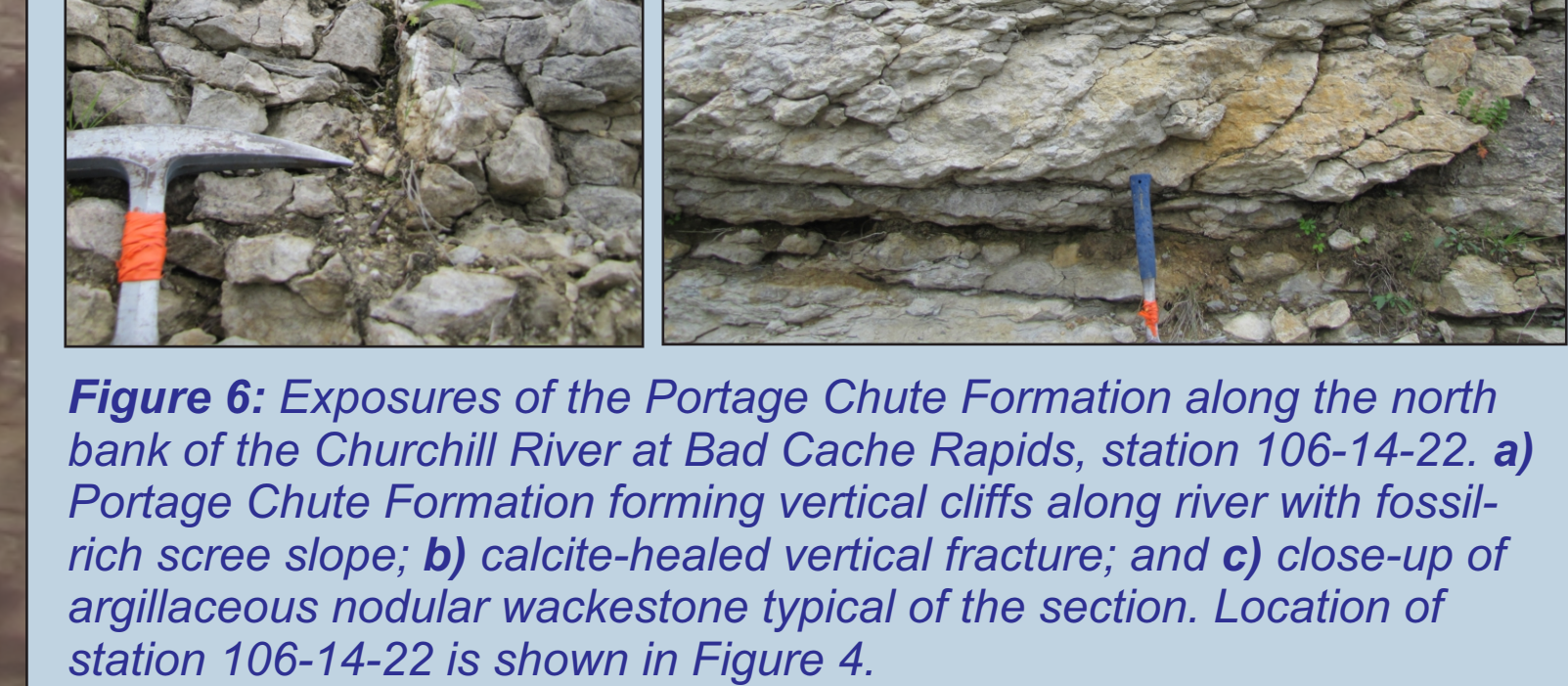


Figure 8: Exposure along Chasm Creek at station 106-14-19 showing a) the contact between the Caution Creek Formation and the overlying Chasm Creek Formation; b) close-up of the Caution Creek Formation; and c) bioclastic packstone of the Caution Creek Formation. Location of station 106-14-19 is shown in Figure 4.

Churchill Creek Formation type section location

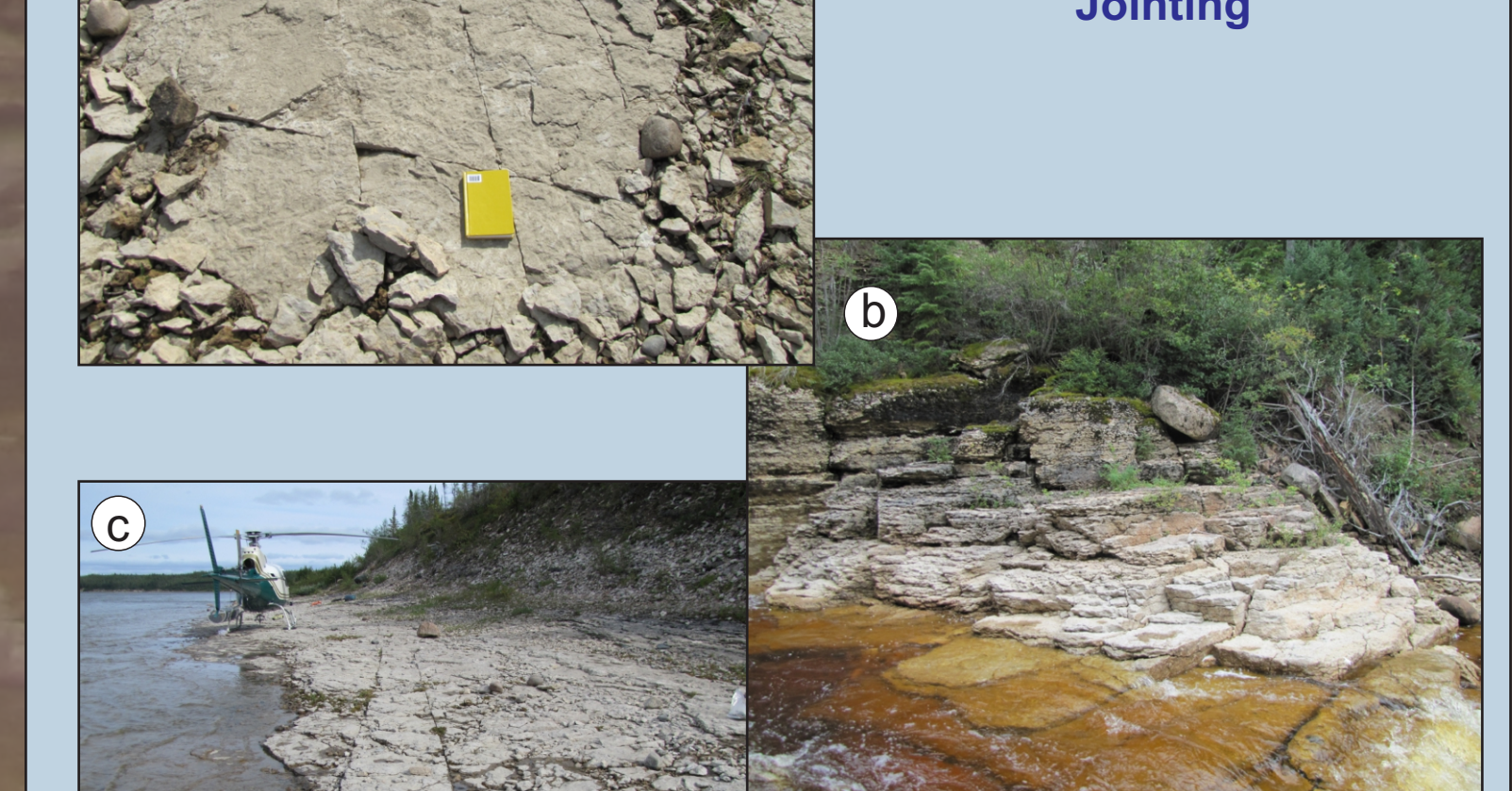


Figure 7: Exposures on Surprise Creek at station 106-14-20 showing a) the transitional beds making up the contact between the Portage Chute and Surprise Creek formations; b) a close-up of laminated mudstone of the Surprise Creek Formation with abundant chert lenses; and c) the contact between the Surprise Creek and Caution Creek formations at the waterfall. Location of station 106-14-20 is shown in Figure 4.



Figure 9: Exposure along the Churchill River at Red Head Rapids at station 106-14-17 showing a) the contact between the Chasm Creek Formation and the overlying Red Head Rapids Formation; b) a close-up of the mottled wackestone to packstone of the Chasm Creek Formation; and c) a close-up of the blue-grey mottled and laminated mudstone of the Red Head Rapids Formation. Location of station 106-14-17 is shown in Figure 4.

Caution Creek Formation type section location

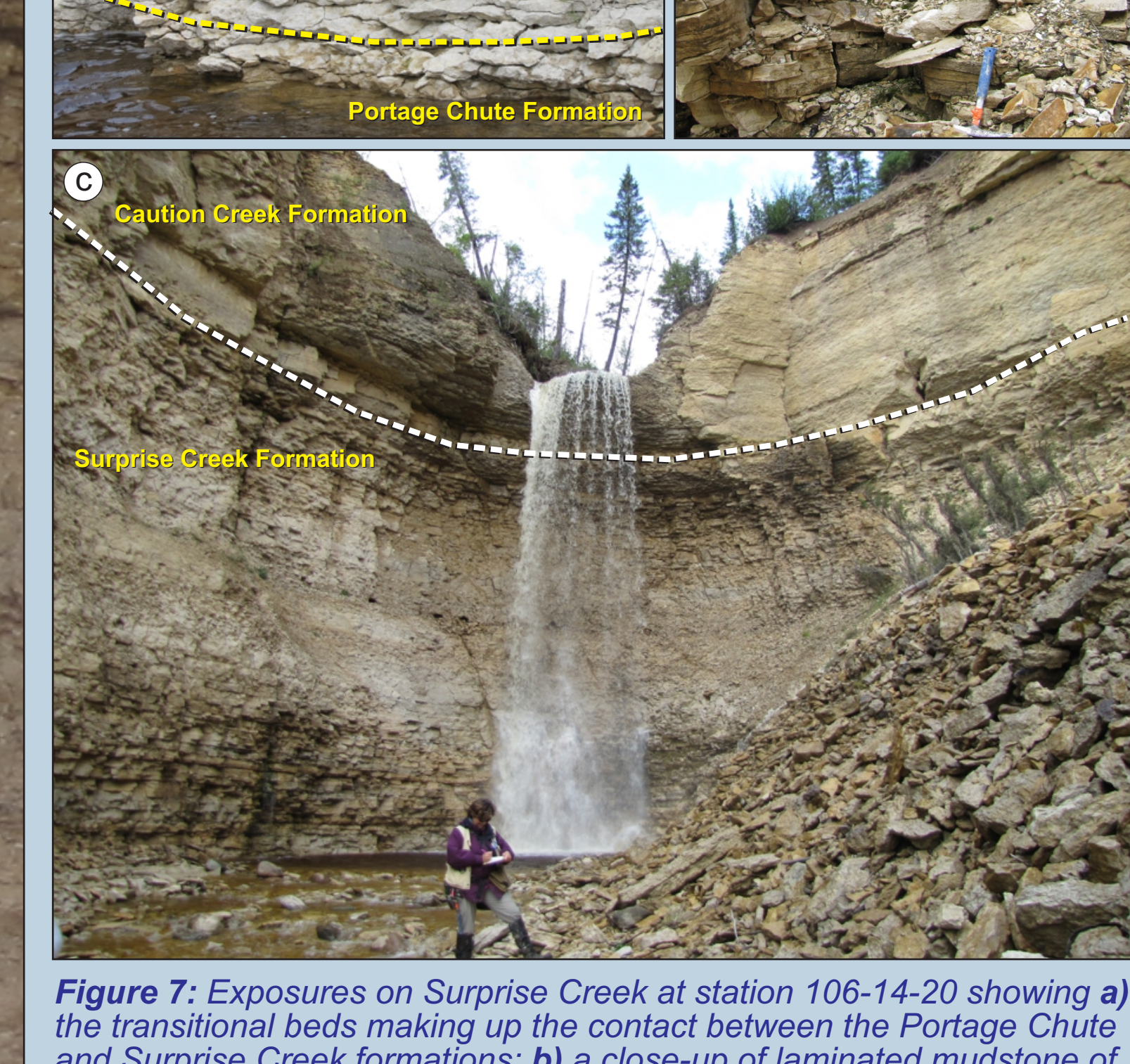


Figure 10: Helicopter fly-over of Caution Creek on the north-west bank of the Churchill River; view is looking east towards the Churchill River. This is the type locality for the Caution Creek Formation. Location of Caution Creek is shown in Figure 4.

Churchill coastal area



Figure 11: Well-developed joints are visible on all the exposures visited. a) Chasm Creek Formation, field station 106-14-16; b) Caution Creek Formation, field station 106-14-19; and c) Chasm Creek Formation, field station 106-14-18. Location of field stations are shown in Figure 4.

Churchill coastal area

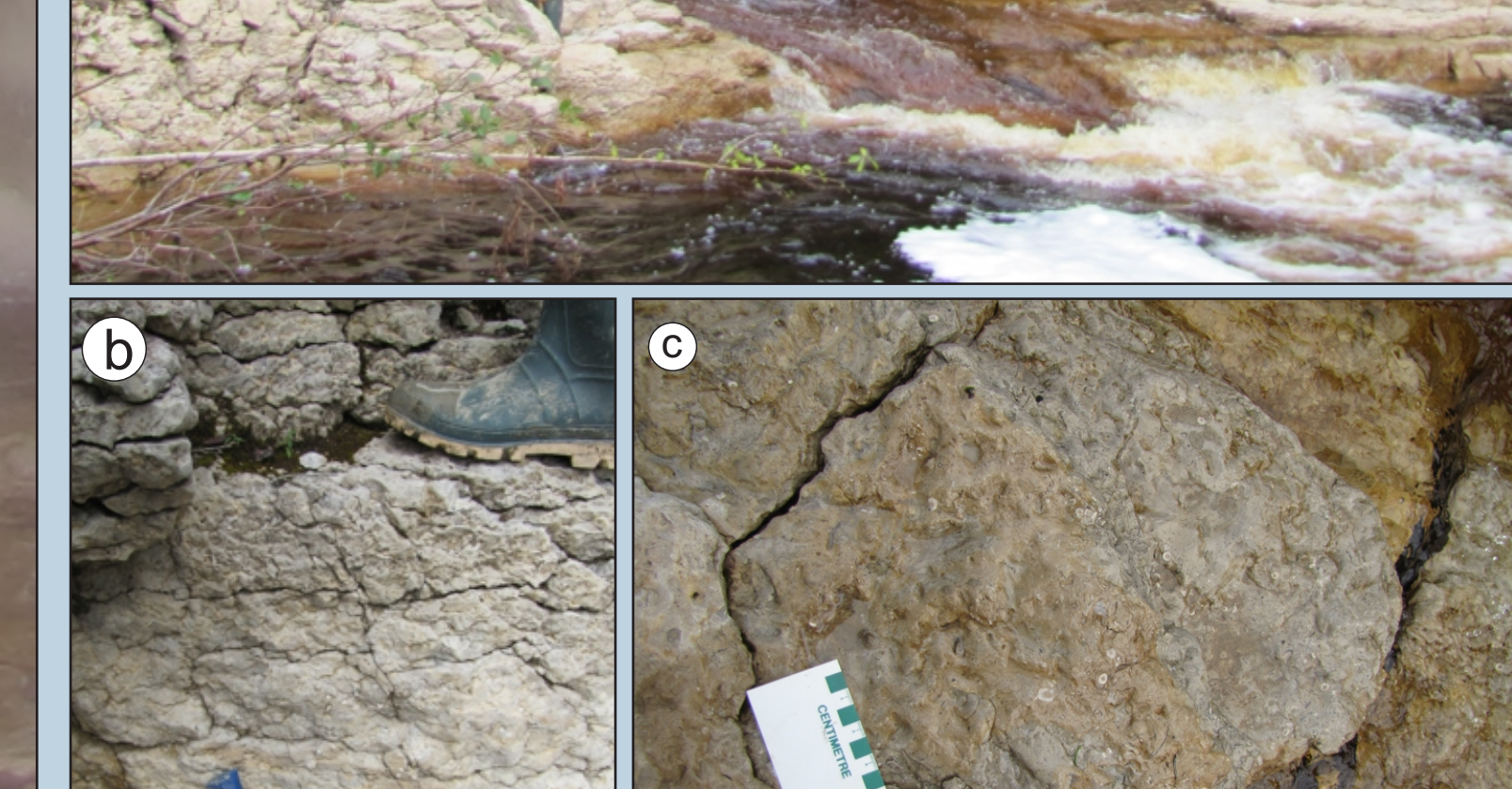


Figure 16: Aerial photograph showing the paleoshoreline at Seahorse Gully (station 106-14-21), where the basal sandstone of the Ordovician Churchill River Group is lapping directly onto the Proterozoic Churchill quartzite. Location of station 106-14-21 is shown in Figure 4.

Red Head Rapids Formation type section location

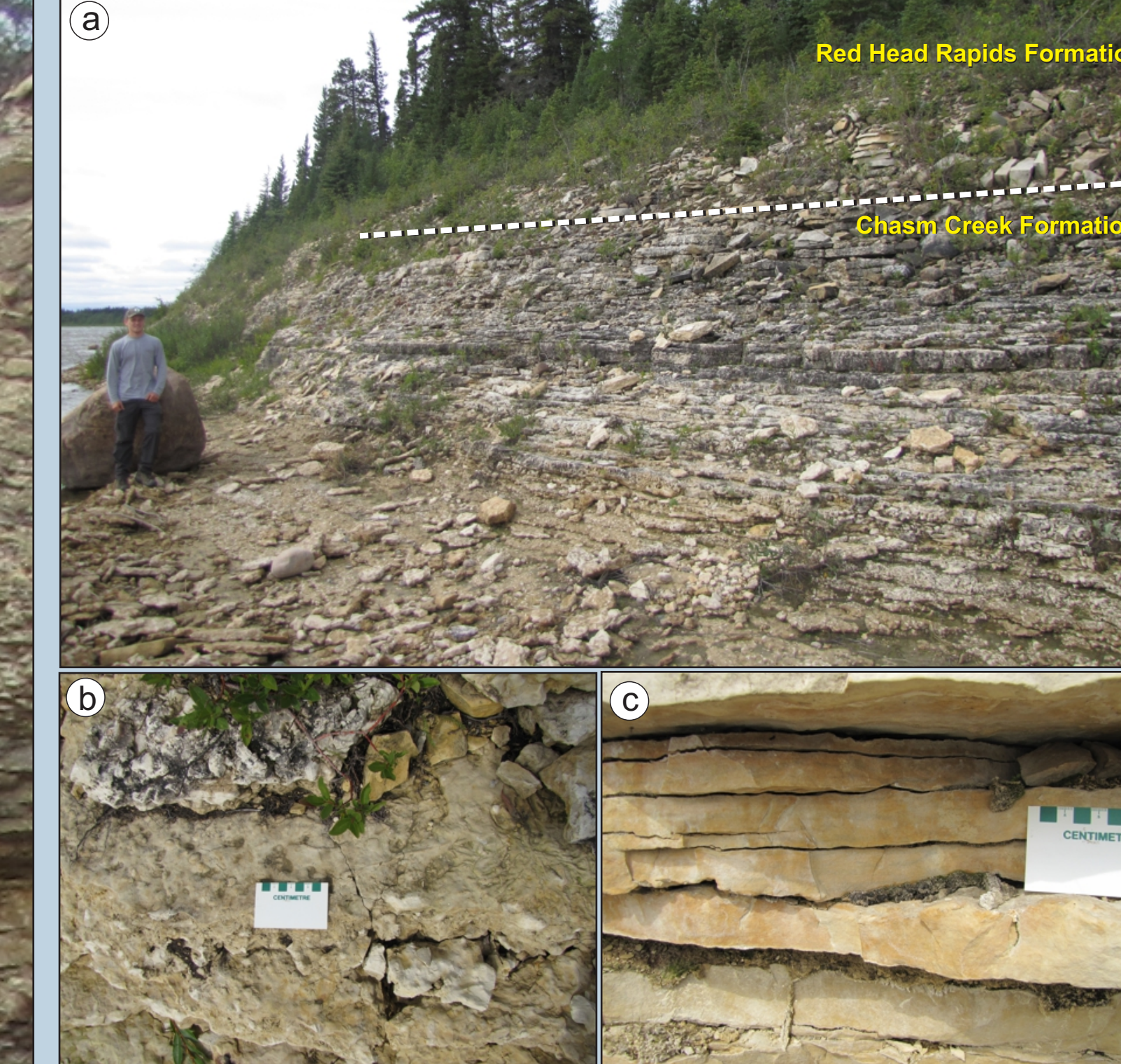


Figure 12: Oblique view of the broken surface of a colony of the tabulate coral *Calapocopia* sp., showing beautifully preserved walls, tabulae, and septa. Chasm Creek Formation, station 106-14-16 (marker is 12 mm wide).

Churchill coastal area

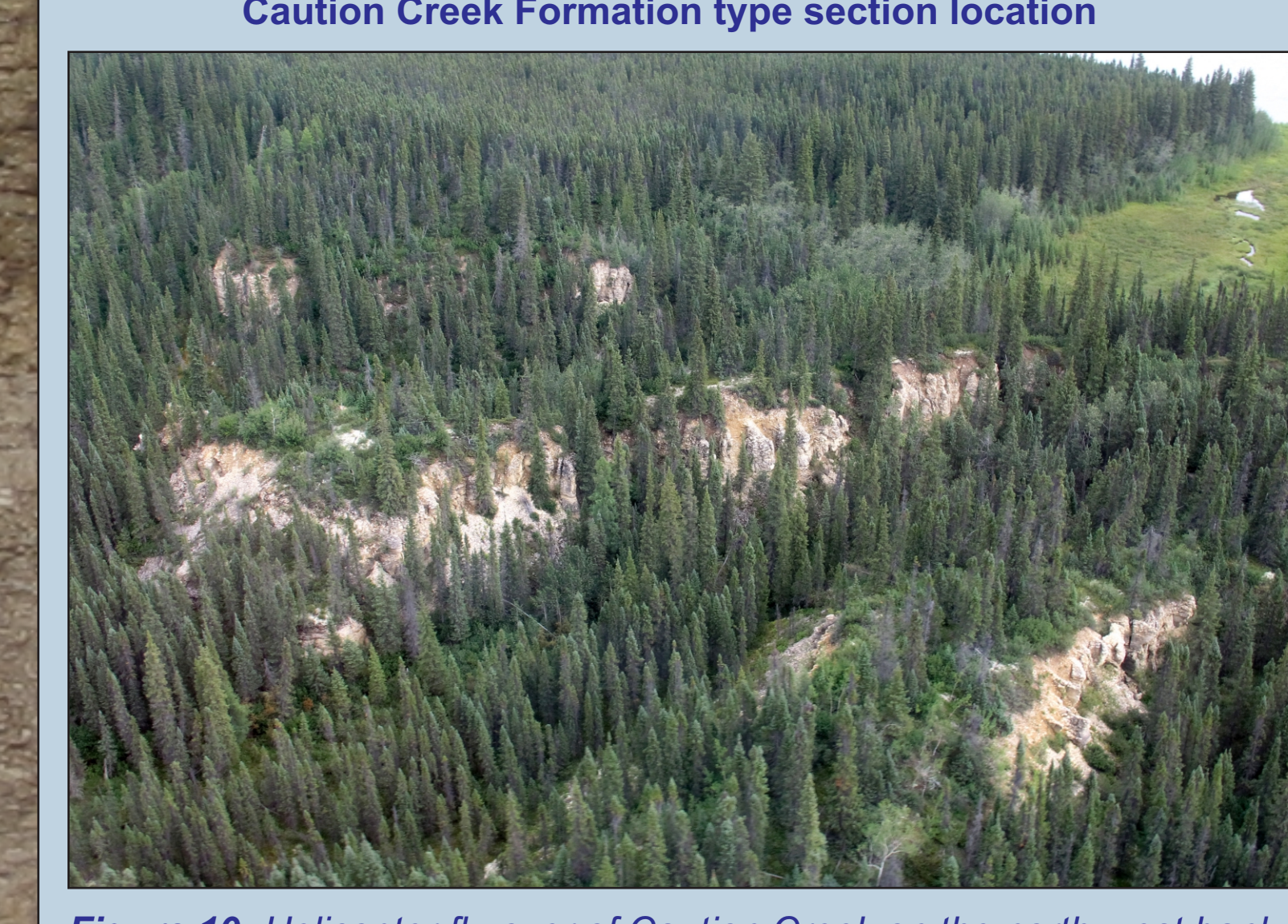


Figure 14: Brachiopods are very abundant in some beds. Here, numerous examples of strophomenid and rhynchonellid brachiopods are associated with gastropods. Surprise Creek Formation, station 106-14-20. Scale divisions are 10 mm.

Churchill coastal area



Figure 17: Aerial photograph showing the paleoshoreline at Airport Cove (stations 106-14-24 to 106-14-30), where there are exposures of the Churchill River Group, Red Head Rapids (Port Nelson) Formation and Severn River Formation. Location of stations 106-14-24 to 106-14-30 are shown in Figure 4.

Churchill coastal area

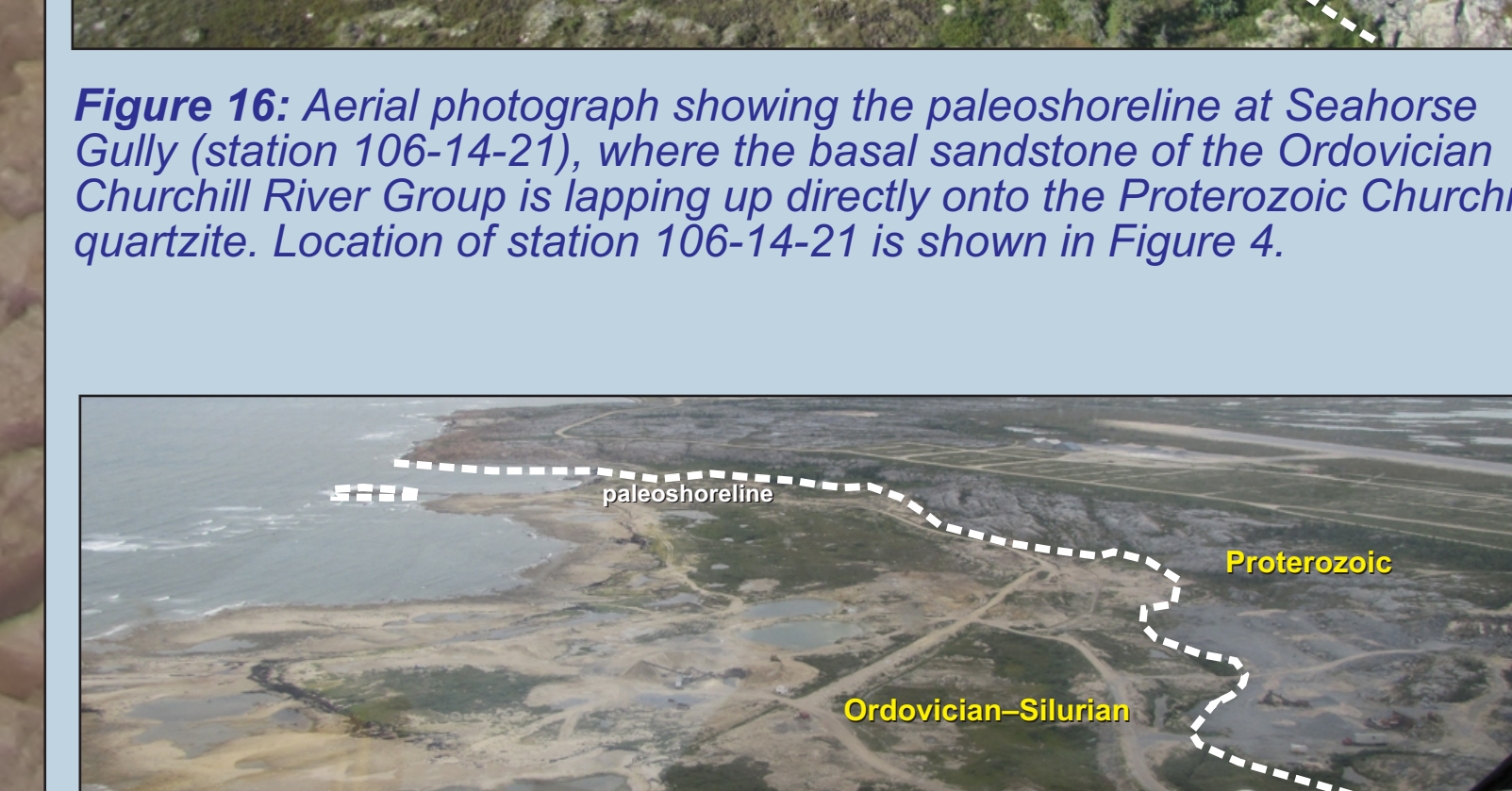


Figure 15: Abundant and large examples of the gastropod *Maclurina mantobensis* occur in the Portage Chute Formation, in association with other typically 'Arctic Ordovician' fossils such as receptaculitids and cephalopods. Station 106-14-23, below Portage Chute (scale division is 10 mm).

3.1 Paleontology

Most of the Upper Ordovician units studied contain diverse shelly fossils, which are abundant in places (the exception is the Red Head Rapids Formation, in which macrofossils are generally rare or absent). During the 2014 field work, numerous fossil samples were collected for future study. Examples of fossils are shown in Figures 12 to 15.

The faunas include examples of many groups associated with the Ordovician diversification of marine life: corals, bryozoans, brachiopods, gastropods, cephalopods, trilobites, echinoderms, and other fossils. Considered together, these give us a clear understanding of the varied life in warm tropical seas of this region. They are similar to Late Ordovician faunas found elsewhere, particularly those from southern Manitoba and parts of the Arctic.



Figure 13: Large examples of the cephalopod *Ammonoceras* sp., preserved on a bedding plane. Chasm Creek Formation, station 106-14-18 (helicopter skid on the left; marker is 135 mm long).

Churchill coastal area



Figure 18: Stratigraphic chart for the Hudson Bay Lowland along the Churchill River and Churchill coastal area, northeastern Manitoba. Stage usage is from Norris (1993), Norford (1997), Zhang and Barnes (2007), M.W. Demski, B.J. Wheaton, L.A. Stewart, R.J. Elias, G.A. Young, G.S. Nowlan and E.P. Dobrzanski (work in progress, 2014), and International Commission on Stratigraphy (2014). (Nicolas and Young, 2014)

3.2 Field work observations

The exposures of the Lower Paleozoic strata visited along the Churchill River correlate well with observations the authors have made in core from boreholes located in the southeastern half of the HBL (see Nicolas et al., 2014), and on Southampton Island, Nunavut (Zhang, 2010). This bodes well for successful long-distance lithostratigraphic correlation and definition of large-scale depositional trends in a large basin that has a minimal amount of subsurface information available.

In contrast to the river sections, the strata observed in the exposures around Churchill are different from those of similar age in other parts of the basin (Figure 18). This is due to the distinct micro-environments that formed around the Proterozoic paleoarchipelago and the resulting paleogeography, which delayed the start of marine deposition. An example of this is the presence of sandstone beds at the base of the Churchill River Group; in other parts of the basin sandstones have been restricted to the base of the older Bad Cache Rapids Group. Such differences suggest that definition of local stratigraphic members in the Churchill area may help to differentiate and understand them, permitting more accurate correlation with other parts of the basin.

Period	Stage	Churchill coastal area	Churchill River
SILURIAN	Telychian	Severn River Formation	
	Aeronian		
	Rhuddanian		
ORDOVICIAN	Hemantian	Red Head Rapids (Port Nelson) Formation	Red Head Rapids Formation
	Katian	Churchill River Group	Churchill River Group
			Chasm Creek Formation
		Caution Creek Formation	Caution Creek Formation
		Bad Cache Rapids Group	Bad Cache Rapids Group
			Surprise Creek Formation
			Portage Chute Formation
			member 2
			member 1
			PRECAMBRIAN (Proterozoic)

Figure 18: Stratigraphic chart for the Hudson Bay Lowland along the Churchill River and Churchill coastal area, northeastern Manitoba. Stage usage is from Norris (1993), Norford (1997), Zhang and Barnes (2007), M.W. Demski, B.J. Wheaton, L.A. Stewart, R.J. Elias, G.A. Young, G.S. Nowlan and E.P. Dobrzanski (work in progress, 2014), and International Commission on Stratigraphy (2014). (Nicolas and Young, 2014)

4.0 Economic considerations

The Hudson Bay Lowland in Manitoba is a large frontier area with good potential for local hydrocarbon accumulations. Simple geological models of the past are slowly being replaced by new, more complex models, as detailed information arises from new studies with better techniques. Through the collaborative work between the GSC and MGS, the GEM-2 Hudson-Ungava project (hydrocarbon component) will help resolve the detailed structure, stratigraphy and history of the HBL strata. This information will assist in identifying the best locations for hydrocarbon exploration and aid in land-use planning. Furthermore, this collaboration also provides the MGS access to expertise and services from world-class GSC laboratories, as well as training opportunities for students to develop themselves as new geoscience experts in Manitoba.

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