Report of Activities 2003
Published by:
Manitoba Industry, Economic Development and Mines
Manitoba Geological Survey, 2003.

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GS-23 Paleozoic drillcore from the Churchill area, northern Manitoba: preliminary results (NTS 54K and 54L)

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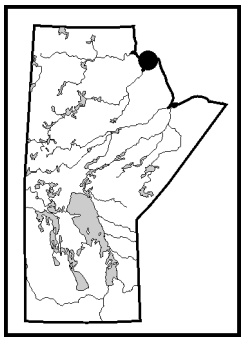

Young, G.A., Elias, R.J. and Dobrzanski, E.P. 2003: Paleozoic drillcore from the Churchill area, northern Manitoba: preliminary results (NTS 54K and 54L); *in* Report of Activities 2003, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 171–177.

Summary

Scattered outcrops of Upper Ordovician and Lower Silurian sedimentary rocks in the Churchill area represent shallow marine deposition around a tropical archipelago, the islands of which were formed by ridges of Proterozoic Churchill Quartzite. Drilling through the Paleozoic rocks was carried out in this area in 2003, and five cores were extracted. The purpose of this work is to establish correlations and facies successions of the Paleozoic rocks, to ascertain the nature of the Ordovician-Silurian boundary interval, and to determine the topography of the Precambrian bedrock surface. The Paleozoic strata in the drillcores are remarkable for their diversity and thickness; together they record substantial changes in sea level and other environmental factors.

Introduction

Bedrock exposed in the area around Churchill, Manitoba, consists of substantial elongated ridges of Proterozoic Churchill Quartzite and small, scattered outcrops of Upper Ordovician and Lower Silurian sedimentary rocks. Although the sedimentary rocks are insignificant in areal exposure, they have considerable scientific importance since they represent deposition in shoreline and nearshore environments around an archipelago of tropical islands (Nelson and Johnson, 2002). Shoreline deposits are rare in the geological record but they are significant because, as the transition zones between land and sea, they represent a great diversity of environments and adaptive niches. Thus, they have the potential to improve our understanding of depositional systems and the evolution of life. Not only does the Churchill area include some of the best Paleozoic shorelines known globally, but these are from a time interval which includes the Late Ordovician mass extinction, the causes of which are not well understood (Berry et al., 1995; Sheehan, 2001).

The corehole drilling described here is one of the final field portions of a large-scale collaborative project involving scientists from several institutions. Over six previous field seasons, we had determined the nature and extent of all Paleozoic exposures in this area, but the limited areal and stratigraphic extent of each exposure means that drillcore is essential to accurate correlation. A number of drill sites were selected, strategically placed throughout the Churchill area. In 2003, drilling was carried out by the Manitoba Geological Survey at the five highest priority sites (Fig. GS-23-1).

The 2003 field drilling program had several objectives: 1) to determine the topography and nature of Precambrian basement surfaces beneath Paleozoic strata; 2) to determine the stratigraphic relationships of Paleozoic beds observed in separated surface exposures; 3) to determine the nature of the Ordovician-Silurian boundary; and 4) to establish the succession and spatial relations of facies in this unique paleogeographic setting.

Previous work

Early geological exploration of the Hudson Bay Lowland (e.g., Tyrrell, 1897) was followed by larger field-based studies in the mid 20th century (e.g., Nelson, 1963, 1964; Sanford et al., 1968). A more recent regional synthesis by Norris (1993) draws on this work, combining it with field research on other parts of the Hudson Bay Basin, and drillcores from the Nelson River area and from the central part of the basin under Hudson Bay.

Studies of drillcore from the Nelson River area have resulted in the recognition of three lithostratigraphic units in the upper Upper Ordovician to lower Lower Silurian part of the succession. The upper Upper Ordovician (Richmondian) Churchill River Group consists of mottled, fossiliferous limestones. It is overlain, apparently conformably, by the Upper Ordovician to possibly Lower Silurian evaporitic dolostones of the Port Nelson Formation. The Lower Silurian (Llandovery) Severn River Formation, composed of heterogeneous carbonate and evaporite rocks, sits disconformably above the Port Nelson Formation (Norford, 1971; Norford et al., 1998).

In the immediate area around Churchill, limited exposures of fossiliferous Paleozoic rocks were noted by Tyrrell

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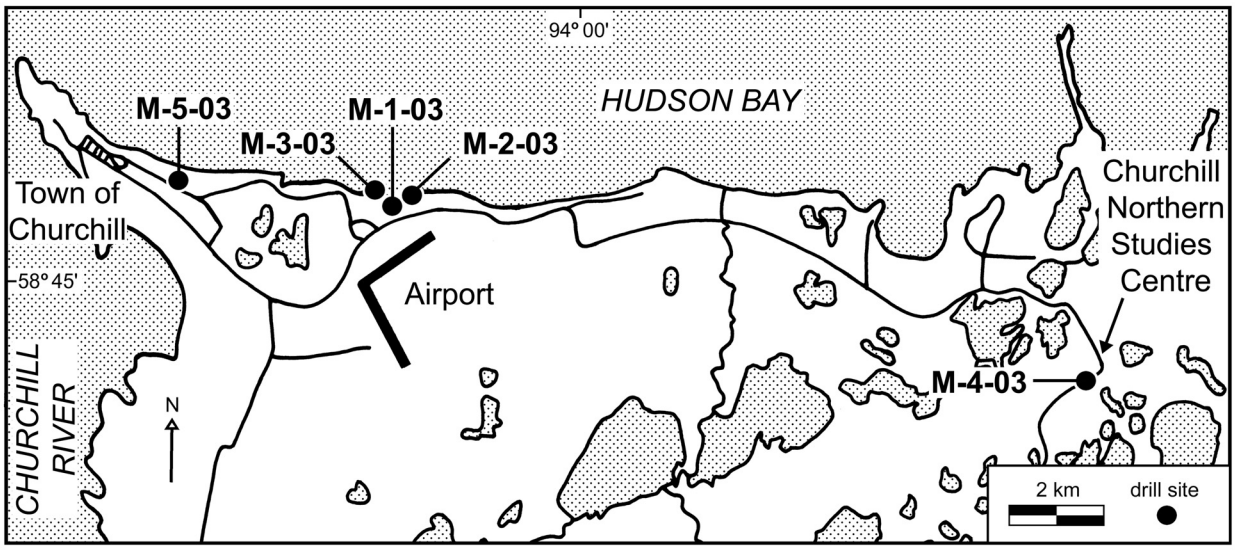

Figure GS-23-1: Map of the Churchill area showing the drill sites (coreholes M-1-03 to M-5-03).

(1897). Later studies in this area focused on a unique, three-dimensionally preserved Ordovician rocky shoreline east of the Town of Churchill (e.g., Norford, 1971; Johnson and Baarli, 1987; Johnson, 1988; Johnson et al., 1988). Other Paleozoic localities in the Churchill area have been noted (Elias et al., 1999; Nelson and Johnson, 2002) but these have not yet been documented in any detail.

As a result of our field seasons between 1996 and 2002, our research group has produced studies including a description of the first surface exposures of the Ordovician-Silurian boundary in the Hudson Bay Lowland (Elias et al., 1999), a systematic description and discussion of the world's largest fossil trilobite (Rudkin et al., 2003), and initial work on the highly diverse corals found on the ancient rocky shoreline (e.g., Elias and Young, 2000). Ongoing research will document the fossils, paleoecology and paleogeography in detail.

Progress to date

A number of potential drill sites were identified in the Churchill area during the 2002 summer field season. In the winter of 2002–2003, a plan for the drilling program was established, in collaboration with the Manitoba Geological Survey. Potential drill sites were prioritized based on several criteria: geographic coverage, road access, lack of overburden and location relative to ridges of Churchill Quartzite. It was considered essential to have holes near the easternmost and westernmost Paleozoic exposures because the sedimentary rocks dip gently from west to east; rocks at the surface around the westernmost drill site are Upper Ordovician, while all sedimentary bedrock exposed in the eastern part of the study area is Lower Silurian. Since the shapes of the buried flanks of quartzite ridges were unknown, we also wanted to drill sites on both the northern and southern sides of the east-trending ridges. The cove north of Churchill Airport was selected as a particular priority area because it contains the most complete set of surface exposures known in the region, including the Ordovician-Silurian boundary (Fig. GS-23-1; Elias et al., 1999).

Drilling was carried out during the last half of June, 2003. The drill rig was driven to Gillam, then shipped by train to Churchill. Despite the sometimes unfavourable northern conditions (arctic weather, ice in the drillholes), the drill crew managed to complete the extraction of core from five holes (coreholes M-1-03 to M-5-03 inclusive; Fig. GS-23-1; Table GS-23-1). After drilling was completed at the Churchill Northern Studies Centre quarry (site of corehole M-4-03), a series of thermocouples was placed in the hole by R. Bello (York University) for permafrost studies.

Preliminary logging of the core was done in the latter part of the summer of 2003. We can assign ages to most of the stratigraphic units based on contained macrofossils, relative stratigraphic position, and/or the macrofossils and microfossils previously documented from adjacent surface exposures. Nevertheless, we have not assigned the Paleozoic rocks to named stratigraphic units at this point. All of the Paleozoic units in the Hudson Bay Lowland were defined in areas some distance from Churchill. Since the Churchill area rocks were deposited in unusual settings, we wish to carry out a detailed study of the cores before assigning names and determining boundaries.

Table GS-23-1: Summary of Paleozoic drillcore data for the Churchill area, 2003. Elevations are relative to mean sea level.

Corehole no. and name	Location and elevation	Depth (m)	Time-stratigraphic unit	Lithology and fossils	Notes
M-1-03	beside quarry road in centre-south part of cove, north of Churchill Airport	0 - 0.75		gravel overburden (some core loss)	
Airport Cove Centre South	NAD 27, Zone 15V, 437941E, 6513687N; lat. 584539.0 N, long. 0940423.2 W	0.75 - 2.30	Lower Silurian	sandy carbonate rocks, burrow mottles and quartzite fragments in parts; grey sandstone	1
	elevation 3 m	2.30 - 3.90	Ordovician or Silurian	grey-buff clay, considerable sand content	2
		3.90 - 21.30	Upper Ordovician	carbonate rocks, laminated in places, darker stringers and pyrite at some levels, evaporite crystal moulds in some intervals; mostly lacking macrofossils; clay, sandstone and siltstone interbeds; sand becomes more common with depth; brecciated carbonate rocks at a few levels	3
		21.30 - 34.10	Upper Ordovician	mottled carbonate rocks, very sandy in some intervals; macrofossils include Late Ordovician rugose and tabulate corals	
		34.10 - 41.45	Upper Ordovician	boulders of Churchill Quartzite; coarse carbonate rocks between the boulders contain quartzite clasts, and fossils including articulate brachiopods and Late Ordovician rugose and tabulate corals	
M-2-03	on shore, near eastern end of cove, north of Churchill Airport	0 - 0.70	Lower Silurian	broken siltstone and carbonate rock	4
Airport Cove East	NAD 27, Zone 15V, 438357E, 6513891N; lat. 584545.8 N, long. 0940357.5 W	0.70 - 2.70	Ordovician or Silurian	grey clay	2
	elevation 2 m	2.70 - 31.50	Upper Ordovician	carbonate rocks, mottled in places, contain evaporite crystal moulds, dark stringers, sand and/or chert in some intervals; sandstone and clay interbeds; brecciated carbonate rocks at a few levels; quartzite clasts at some levels; Late Ordovician rugose and tabulate corals	
		31.50 - 79.30	Upper Ordovician	light-coloured mottled carbonate rocks, becoming sandier with depth, evaporite crystal moulds; fossiliferous in some intervals with Late Ordovician rugose and tabulate corals; lowest 2 m consists of sandy carbonate rocks and yellow to grey sandstones	
		79.30 - 97.00	unknown	grey sandstones with some pyritic horizons; some levels with small and large quartzite pebbles	
		97.00 - 100.00	Proterozoic	weathered Churchill Quartzite	
		100.00 - 102.70	Proterozoic	Churchill Quartzite	
M-3-03	on shore, near western end of cove, north of Churchill Airport	0 - 4.30	Lower Silurian	dolostones, mostly monotonous, some evaporite crystal moulds, thin sandy intervals with subangular quartz sand	
Airport Cove West	NAD 27, Zone 15V, 437604E, 6513981N; lat. 584548.2 N, long. 0940444.4 W	4.30 - 5.80	Ordovician or Silurian	light brown to dark grey clay, some sand and silt	2

Table GS-23-1: Summary of Paleozoic drillcore data for the Churchill area, 2003. Elevations are relative to mean sea level. (continued)

Corehole no. and name	Location and elevation	Depth (m)	Time-stratigraphic unit	Lithology and fossils	Notes
	elevation 3 m	5.80 - 35.00	Upper Ordovician	carbonate rocks, mottled or laminated in parts; abundant evaporite crystal moulds at some levels; some large patches of powdery chert; sandstone interbeds having subangular to mostly rounded grains; occasional thin clay horizons	3
		35.00 - 78.60	Upper Ordovician	mottled brown carbonate rocks, becoming sandier with depth; evaporite crystal moulds at some levels; chert at some levels; very fossiliferous in places, with cephalopods, crinoids and Late Ordovician rugose and tabulate corals; very sandy near base	
		78.60 - 80.25	unknown	boulders and cobbles of Churchill Quartzite, weathered quartzite and light-coloured quartz sand (subangular to subrounded grains)	
		80.25 - 92.25	unknown	variably weathered quartzites and clay	
		92.25 - 93.55	Proterozoic	Churchill Quartzite	
M-4-03	west of quarry, south of Churchill rocket range, near Churchill Northern Studies Centre	0 - 10.70	Silurian	dolostones, mostly monotonous, some laminated or mottled; occasional evaporite crystal moulds	5
Churchill Northern Studies Centre Quarry	NAD 27, Zone 15V, 452511E, 6510275N; lat. 584355.3 N, long. 0934914.0 W	10.70 - 11.00	Lower Paleozoic	pale buff clay	
	elevation 17 m	11.00 - 43.00	Lower Paleozoic	dolostones, mostly monotonous, some mottled or laminated; occasional fossils; quartzite clasts; sandier horizons; recurring grey clay horizons at 31.9 - 38.7 m	
		43.00 - 44.85	Lower Paleozoic	whitish clay (much material lost from interval)	
		44.85 - 78.15	Lower Paleozoic	fine-grained carbonate rocks; abundant vugs at some levels; some carbonate rocks are mottled, laminated, deformed or brecciated; chert horizons; sandstone interbeds with well sorted, subrounded grains	
		78.15 - 99.60	Lower Paleozoic	mottled buff to grey carbonate rocks; obvious burrows in some horizons; corals common in some intervals	
		99.60 - 101.40	Lower Paleozoic	boulders of Churchill Quartzite alternating with carbonate rocks containing sand, abundant fossil fragments, and some pyrite	
		101.40 - 102.80	Proterozoic	Churchill Quartzite	
M-5-03	west side of water pit for Boreal Gardens greenhouses	0 - 2.00		lost (overburden and broken bedrock)	
Boreal Gardens	NAD 27, Zone 15V, 433812E, 6514203N; lat. 584553.4 N, long. 0940840.6 W	2.00 - 19.15	Upper Ordovician	sandy carbonate rocks and quartz sandstones; pyritic stringers, mottles, fossil fragments or evaporite crystal moulds in some intervals; carbonate rocks are brecciated in places; large quartzite clasts present, become more common with depth; Late Ordovician rugose coral	6
	elevation 15 m	19.15 - 24.30	Upper Ordovician	boulders of Churchill Quartzite alternating with coarse sandstones, and with brown carbonate rocks containing abundant quartzite and fossil fragments; pyrite crystals on boulder surface; Late Ordovician tabulate corals	

Table GS-23-1: Summary of Paleozoic drillcore data for the Churchill area, 2003. Elevations are relative to mean sea level. (continued)

Corehole no. and name	Location and elevation	Depth (m)	Time-stratigraphic unit	Lithology and fossils	Notes
		24.30 - 26.55	Proterozoic	Churchill Quartzite; weathered at top and along fractures	
				Notes:	
				1 Early Silurian conodonts recovered from these beds in nearby quarry pit (Elias et al., 1999).	
				2 Several samples of the equivalent clay interval in surface deposits and quarry pit in this cove have not yielded diagnostic conodonts (Elias et al., 1999; G.S. Nowlan, pers comm, 1999, 2001, 2002).	
				3 Age interpretation based on stratigraphic position; Late Ordovician macrofossils and conodonts were collected and recovered from equivalent surface deposits in the same cove (Elias et al., 1999; G.S. Nowlan, pers comm, 1999, 2001).	
				4 Early Silurian conodonts were recovered from surface beds in this immediate area (G.S. Nowlan, pers comm, 2001).	
				5 In the adjacent quarry, these beds contain Silurian macrofossils.	
				6 Samples from the 2 m of rock exposed in the adjacent pit yielded Late Ordovician conodonts (G.S. Nowlan, pers comm, 2001) and a Late Ordovician rugose coral.	

Preliminary results

The initial core logs (Table GS-23-1) document a remarkable diversity of Paleozoic strata in the Churchill area cores: carbonate rocks, sandstones, siltstones, clay and boulder-field deposits. The carbonate rocks contain macrofossils, quartzite clasts, chert and evaporite crystal moulds. This variety of rocks and features represents sediment deposition in diverse shoreline and nearshore environments; each core is a record of substantial changes in sea level and other environmental factors.

Perhaps the most striking result is the remarkable thickness of the Paleozoic strata in close proximity to ridges of Proterozoic Churchill Quartzite, indicating that the flanks of these ridges, which are steep in surface exposure, continue to dip steeply in the subsurface. The drill sites are 60 to 340 m laterally from the exposed edges of the quartzite ridges. In the four holes that reached the quartzite bedrock, its upper surface was 24.3 to 101.4 m below the ground surface. The approximate average dips of quartzite surfaces are in the range of 16 to 21°; these numbers are similar for both the north and south sides of quartzite ridges. In the Early Paleozoic, these ridges would have formed small islands that were tall and steep sided.

Another remarkable finding is that substantial deposits of boulders and sandstone occur widely on the surfaces of the Churchill Quartzite, from west to east across the region and on the north and south flanks of the quartzite ridges. This is quite different from what was previously observed in surface exposures. Substantial amounts of sandstone outcrop are only observed at Seahorse Gully, the westernmost exposure, which is west of the Churchill River. Boulder fields occur at Seahorse Gully and at the rocky shoreline east of Churchill, but they have not been observed at the other localities. Core data indicate that both the sandstones and boulder-field deposits are much more widespread than was previously thought, demonstrating that outcrop exposures can be unreliable indicators of the distribution of past environments.

The drillcores will provide a useful window into the Ordovician-Silurian boundary interval in this region. Further work will include microfossil and macrofossil analyses, microscopic study of the sedimentary rocks, and geochemical research. These data will be combined with the detailed study of the rocks and fossils from surface exposures, based on material collected in previous field seasons.

Economic impact

The results of this project will fill a major gap in the basic knowledge of the stratigraphy of Manitoba, and may be applied to the understanding of the Hudson Bay Basin's geological history. The comprehensive synthesis of paleoenvironments at several unique fossil sites should encourage the development of new attractions that will benefit Churchill's emerging ecotourism industry. This knowledge may also contribute to land-use policies for this accessible northern area.

Acknowledgments

This research was supported by grants to G. Young and R. Elias from the Natural Sciences and Engineering Research Council of Canada. We are grateful to the MGS for its support of this collaboration, and to R. Bezys and D. Berk for facilitating the drilling plans. We particularly thank D. Berk, V. Varga and G. Benger for carrying out the field drilling in an enthusiastic and professional manner, even when the weather was extremely unpleasant. R. Syme, R. Bezys and J. Bamburak provided insightful comments during 2003 fieldwork. We thank D. Rudkin (Royal Ontario Museum) and G. Nowlan (Geological Survey of Canada) for many discussions of Churchill stratigraphy, and for their ongoing contributions to the understanding of the rocks and fossils of this area. Accommodation and logistical support were provided by the Churchill Northern Studies Centre.

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