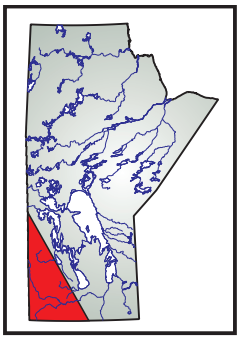
GS-15 Gammon Ferruginous Member of the Cretaceous Pierre Shale in southwestern Manitoba: distribution and mineral potential (parts of NTS 62F, G, J, K, N, O, 63C)

by J.D. Bamburak and M.P.B. Nicolas



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Summary

The Gammon Ferruginous Member of the Cretaceous Pierre Shale is present in hundreds of oilwells in southwestern Manitoba, where it reaches a maximum thickness of over 56 m. The Member has also been recognized in outcrop along the Manitoba Escarpment and in the Pembina River valley. Where it is present between the overlying Pembina Member of the Pierre Shale and the underlying Boyne Member of the Carlile Formation, in outcrop, the Gammon Ferruginous Member contains relatively anomalous concentrations of rare earth elements and other elements, such as Pt, Pd, Cu, Ni, V and Zn, compared with other Cretaceous shale horizons. Additional inorganic chemical and heavy mineral analyses of outcrop and oilwell chip samples from the Gammon Ferruginous Member may lead to the discovery of a new economic sedimentary deposit-type in Manitoba.

Introduction

The Gammon Ferruginous Member of the Pierre Shale (Figure GS-15-1) was named by Rubey (1930) for the numerous red-weathered ferruginous or sideritic concretions contained in the uniform, dark grey mudstone or silty shale occurring along Gammon Creek, on the northwest flank of the Black Hills in Wyoming (Twp. 57N, Rge. 67 and 68W, Crook County). Until 1970, the presence of the Gammon Ferruginous Member was not known in Manitoba. However, Bannatyne (1970, p. 26, 52, 53) recognized up to 54.9 m of Gammon Ferruginous Member in hundreds of oilwells in southwestern Manitoba (depicted by TGI Williston Basin Working Group 2008a, b). It occurred in the subsurface between calcareous speckled shale at the top of the Boyne Member of the Carlile Formation and the interbedded bentonite and black shale beds at the base of the Pembina Member of the Pierre Shale (Figure GS-15-1). The Gammon Ferruginous Member is equivalent to the Milk River Formation of Saskatchewan (Christopher and Yurkowski, 2007, p. 7, Figure 2; Nicolas, 2009, p. 11, Figure 2).

The presence of the Gammon Ferruginous Member was first recognized in outcrop in Manitoba by McNeil and Caldwell (1981, p. 65) at three adjacent localities (outcrop sections 76, 77, 78) along the Vermilion River on the north flank of Riding Mountain. At outcrop section 77, situated 17.5 km southwest of Dauphin (Figure GS-15-2a, locality 1; Table GS-15-1), they reported a Gammon Ferruginous Member thickness of 4.39 m. Subsequently, Bamburak (1996, p. 130) reported that thin (<1 m) ferruginous concretionary beds, possibly of the Gammon Ferruginous Member, above the Boyne Member and below the Pembina Member, occurred at several sites along the Manitoba Escarpment in the Pembina Hills area (Table GS-15-1). It should also be noted that Gill and Cobban (1965, Figure 5) had speculated that thin beds of shale and bentonite found at the base of the Pierre Shale, in a roadcut near the Pembina River in North Dakota (Figure GS-15-3), 10 km south of the border with Manitoba, "may be equivalent to the Gammon Ferruginous Member of the Pierre Shale" (Figure GS-15-2b, locality 13; Table GS-15-1).

McNeil and Caldwell (1981) also demonstrated in numerous cross-sections that the distribution of the Gammon Ferruginous Member is extremely erratic in the subsurface because it is bounded by upper and lower

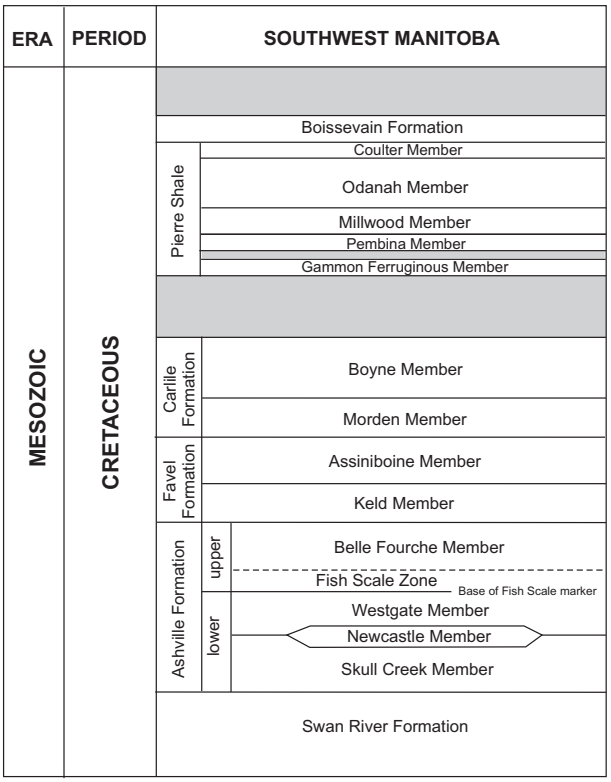

Figure GS-15-1: *Cretaceous stratigraphy of southwestern Manitoba.*

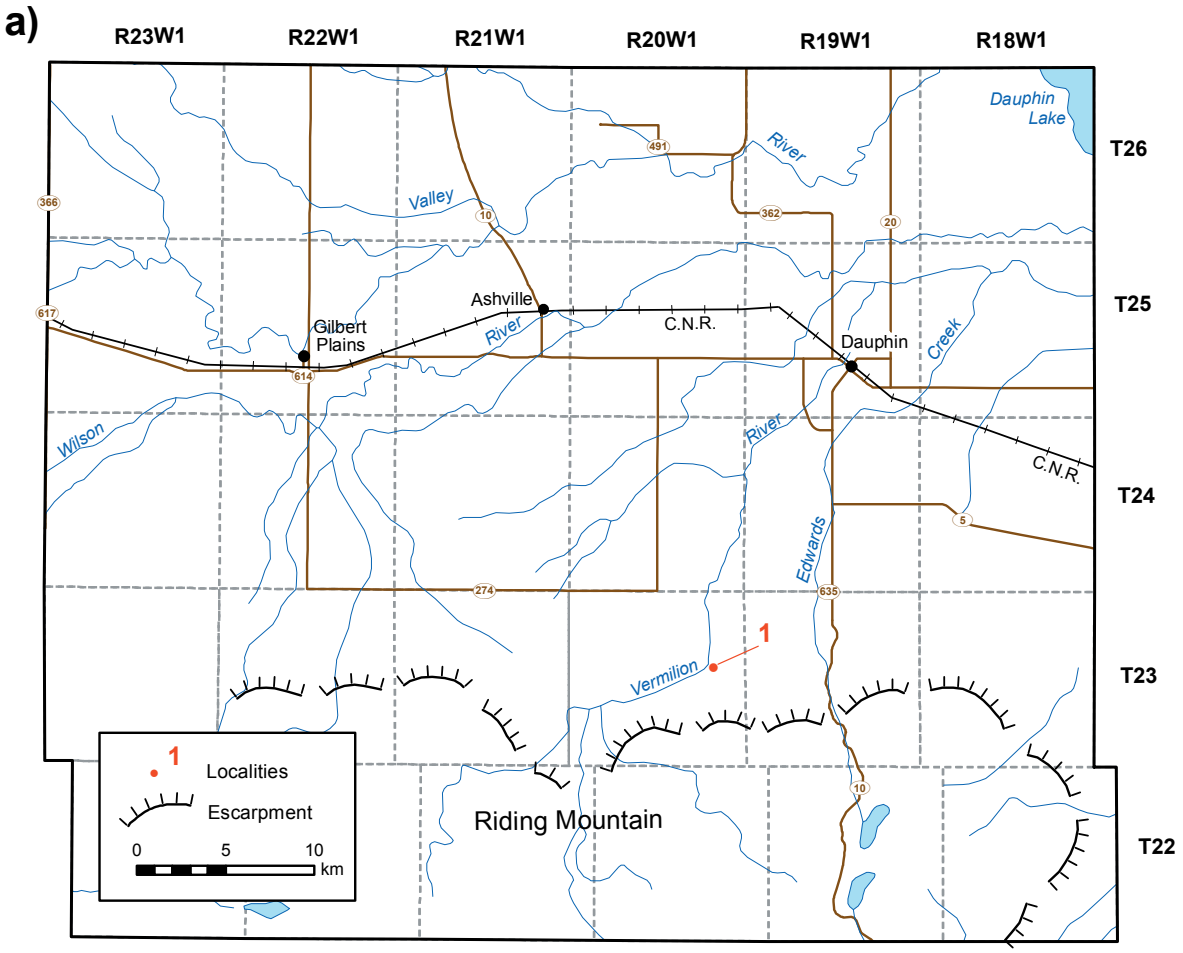

Figure GS-15-2a: *Gammon Ferruginous Member outcrop location map of the north flank of Riding Mountain.*

Cretaceous unconformities. Nondeposition, or subsequent erosion during the Cretaceous, of Gammon Ferruginous Member beds has resulted in unit thicknesses that can range from 0 m to a known maximum of 4.39 m along the Manitoba Escarpment (Table GS-15-1); and to over 56 m in the subsurface, west of Melita, in southwestern Manitoba (TGI Williston Basin Working Group, 2008a).

Previous inorganic geochemical analyses

Fedikow et al. (1997, 1998) and Bamburak et al. (1997) reported on the instrumental neutron activation analysis (INAA) and inductively coupled plasma–atomic emission spectrometry (ICP-AES) of Cretaceous black shale and other sedimentary rock from Manitoba outcrops and oilwell core and chips collected in southwestern Manitoba. These analyses, together with additional geochemical INAA and ICP-AES results from samples collected in 1999 and reported by Bamburak (1999), form the basis of the Manitoba Phanerozoic chemostratigraphic database conceived by Garrett et al. (2001), and described by Bamburak (2008a, b). Figure GS-14-2 (Nicolas et al., GS-14, this volume) shows a selective retrieval of data to 2008 (Bamburak, 2008a), from the Cretaceous portion of the chemostratigraphic database for the Pembina Hills area (as presented in MGS Data Repository Item DRI2010001[1]). In Figure GS-14-2 (Nicolas et al., GS-14, this volume), the Gammon Ferruginous Member can be seen to be relatively enriched in several rare earth elements (REE) and in Th and U compared with other Upper Cretaceous units in the southern part of the Manitoba Escarpment.

During the summers of 2008 and 2009, 95 new Cretaceous field samples were sent for INAA and ICP-ES analyses as part of the Shallow Unconventional Shale Gas Project (Bamburak, 2008b; Nicolas, 2008; Nicolas and Bamburak, 2009; Nicolas et al., GS-14, this volume). As a result of this work, three new anomalous Gammon

[1] MGS Data Repository Item DRI2010001, containing the data or other information sources used to compile this report, is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/web/freedownloads.html, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

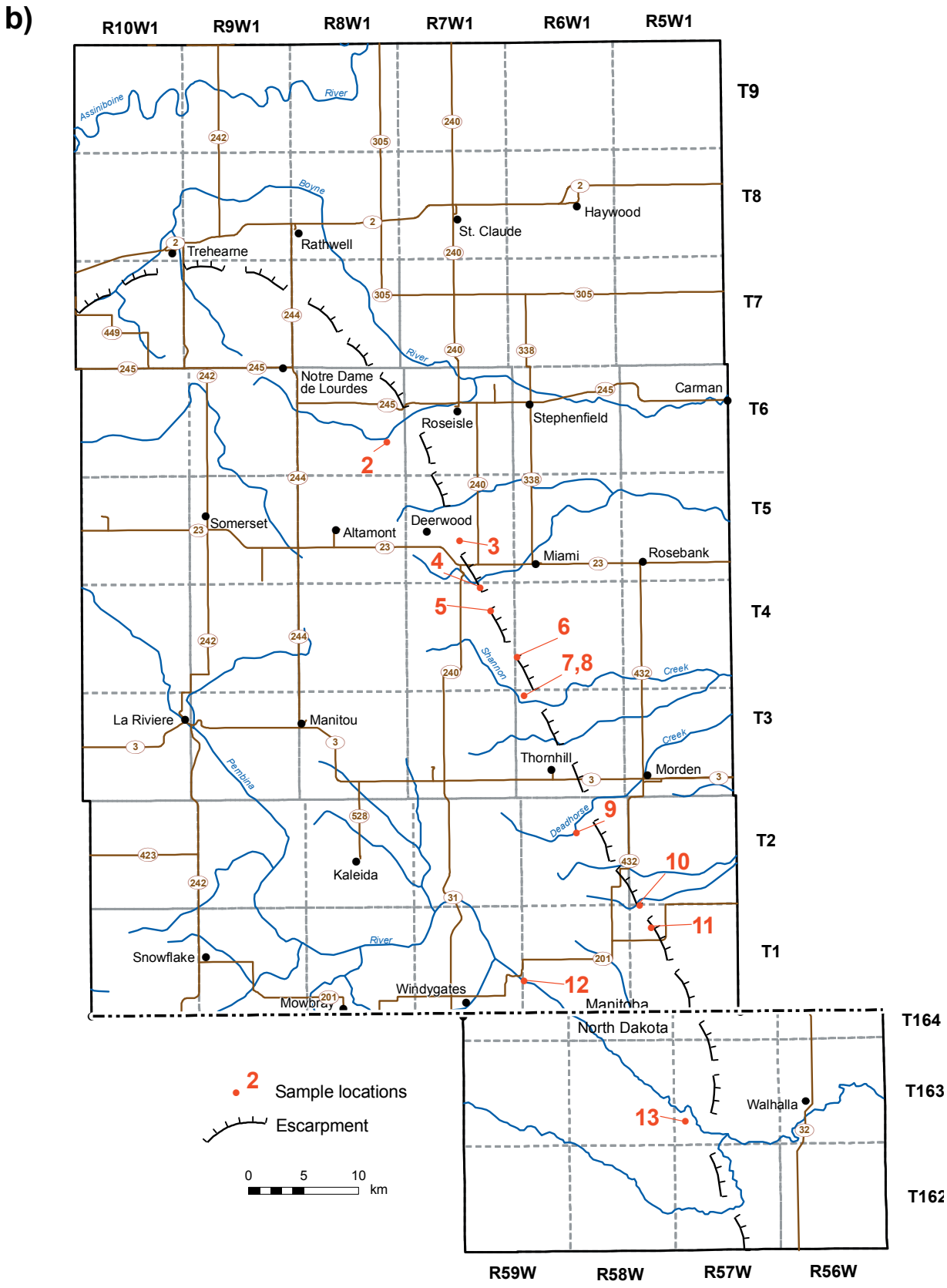

Figure GS-15-2b: *Gammon Ferruginous Member outcrop location map of the Pembina Hills area of southwestern Manitoba and northeastern North Dakota.*

Table GS-15-1: Gammon Ferruginous Member outcrop localities in the Riding Mountain and Pembina Hills areas.

Locality no.	Name	Location	Easting[1]	Northing[1]	Station no.	Thickness (m)
Riding Mountain area						
1	Vermilion River outcrop section 77	07-23-23-20W1	418125	5650125	99-99-RM-002	4.39
Pembina Hills area						
2	Roseisle Bridge	W13-11-06-08W1	539650	5480027	99-96-BR-20-1	0.4
					99-10-MI-009	
3	Arnold North	10-16-05-07W1	547233	5471635	99-96-BR-3-7	unknown
					99-10-MI-007	
4	South Tobacco Creek Tributary	NW13-34-04-07W1	547905	5466863	99-96-BR-28-1	0.24
					99-1--MI-016	
5	West Cox	14-26-04-07W1	550246	5465266	99-10-MI-012	0.3
6	Mount Nebo	04-19-04-06W1	553031	5460947	99-10-MI-008	0.18
7	Spencer's Ditch	15-31-03-06W1	553843	5457258	99-96-BR-23-3	3.0
					106-08-62G8-3	
					99-10-MI-001	
8	Spencer Pit - Shannon Creek	09-31-03-06W1	554183	5456744	99-10-MI-011	0.1
9	Stanley Park West	N13-21-02-06W1	556900	5443850	99-06-BR-31-3	0.5
10	Friesen Roadcut	04-07-02-05W1	563579	5439347	99-95-MI-5-8	0.2
					106-08-62G1-25	
					99-10-MI-002	
11	Mile Four North	SE1-29-01-05W1	566632	5434174	99-95-MI-5-4R	unknown
12	Holo Crossing	01-13-01-07W1	553407	5431337	106-08-62G1-11	0.2
					99-10-MI-004	
13	Pembina Gorge, North Dakota	SW30-163N-57W1	567221	5421884	99-10-WA-001	0.27

[1] NAD 83, Zone 14U

Figure GS-15-3: *Geological hammer marks the top of a 0.27 m thick unit interpreted to be the Gammon Ferruginous Member beneath the interbedded bentonite and black shale beds of the Pembina Member at the Pembina Gorge, North Dakota, outcrop locality 13, 10.5 km west of Walhalla. Upper part of the underlying Boyne Member of the Carlile Formation, beneath thin bentonite seam, has rust-stained fracture surfaces.*

Ferruginous Member analyses (Holo Crossing and Friesen Roadcut samples, MGS Data Repository Item DRI2010001) were added to the chemostratigraphic database.

In parallel to the above studies, Peck et al. (2000, p. 8) included the analyses of 36 Phanerozoic black shale outcrop and drillcore samples in their (generally Precambrian oriented) exploration database for platinum group elements in Manitoba. Concentrations of Au, Pt and Pd were determined by fire assay, using PbS as the collector, with an inductively coupled plasma–emission spectrometry (ICP-ES) finish at Activation Laboratories Ltd. (Ancaster, Ontario). According to Peck et al. (2000, p. 9), the results of the analyses indicated that there is a narrow range of concentrations for each of these elements in the black shale samples – Au ranges from <1 to 86 ppb, Pt from <0.1 to 14.8 ppb and Pd from <0.5 to 13.3 ppb. The highest Au analysis is from a drillcore sample (D127-COMRP 96-19) of undifferentiated Cretaceous shale and the highest Pt and Pd contents are documented from two outcrop samples (collected by Bamburak, 1996) as representing the Cretaceous Gammon Ferruginous and Pembina members of the Pierre Shale. The latter two samples were collected at the South Tobacco Creek Tributary locality 4 and the Arnold North locality 3 (Figure GS-15-2b, Table GS-15-1). The samples contain 11.6 ppb Pt and 13.3 ppb Pd and 14.8 ppb Pt and 12.5 ppb Pd, respectively (MGS Data Repository Item DRI2010001).

However, at the time of the Bamburak (1996) sampling, the Gammon Ferruginous Member was not believed to be present in the outcrop belt in the Pembina Hills area, as stated by McNeil and Caldwell (1981, p. 65). Since the Arnold North locality 3 'Pembina Member' sample was collected by Bamburak (1996) near the base of a Pembina Member outcrop section, it was, by default, included in the overlying Pembina Member. The sample is, herein, considered to be part of the underlying Gammon Ferruginous Member, as indicated in Table GS-15-1 and MGS Data Repository Item DRI2010001.

Current investigations

The results of the previous inorganic geochemical analyses of the Gammon Ferruginous Member of the Pierre Shale indicated that additional work should be undertaken in order to: locate new outcrops of the member; resample anomalous sites to confirm the previous analyses; and determine the mineral potential of the member, especially in the subsurface where its thickness increases dramatically towards the southwestern corner of the province (Bannatyne, 1970, p. 26, 52, 53).

During this past summer, four new localities with Gammon Ferruginous Member were found and sampled and six localities were resampled (Table GS-15-1). Preliminary results from 25 samples sent for INAA and ICP-ES inorganic chemical analyses showed that the Spencer's Ditch locality 7 (Figure GS-15-4) has the highest values for most REE and Th, U and P (Table GS-15-2) relative to all other Cretaceous shale analyses in the chemostratigraphic database. Similarly, the Holo Crossing locality 12 (Figure GS-15-5) has the highest values for Yb, Lu, Ni

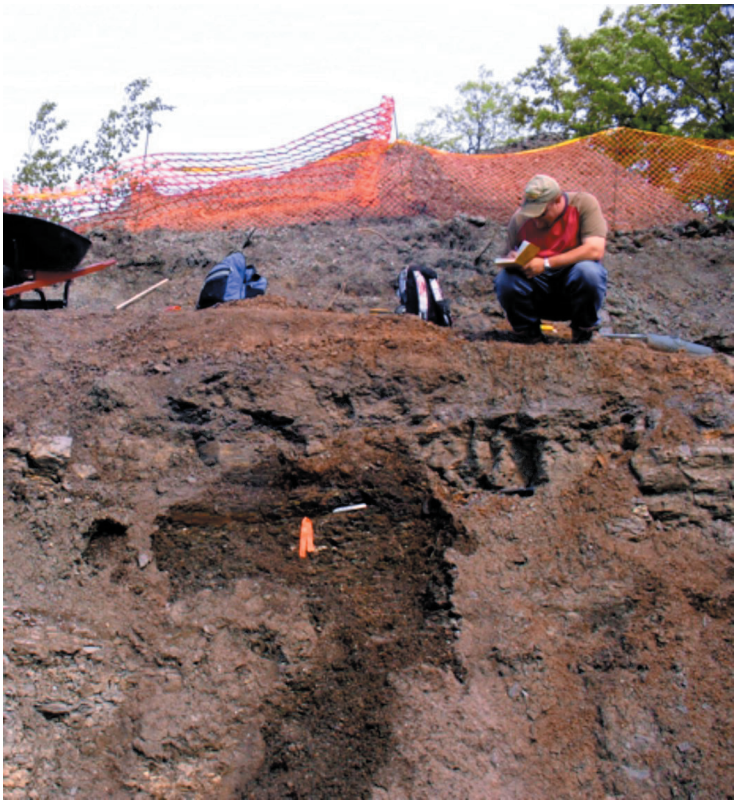

Figure GS-15-4: *J. Hatcher of the Canadian Fossil Discovery Centre recording his observations. Orange flagging tape marks the base of the 3.0 m thick Gammon Ferruginous Member at the Spencer's Ditch locality 7.*

Table GS-15-2: Gammon Ferruginous Member analytical update with 2010 data.

	Th (ppm)	U (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Y (ppm)	Cu (ppm)	Ni (ppm)	V (ppm)	Zn (ppm)	Fe (%)	P (%)
Detection limit	0.2	0.5	0.5	3	5	0.1	0.2	0.5	0.2	0.05	1	1	1	2	1	0.01	0.001
Analysis method	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP	MULT	TD-ICP	MULT	INAA	TD-ICP
1996–2007 sample analyses – Pembina Hills area																	
Average of 11 outcrop sample analyses[1]	15.2	73.8	170.1	228	128	2.5	7.5	5.3	18.6	3.08	319	96	115	641	230	8.69	1.307
Maximum values of above sample analyses	41.0	230.0	760.0	900	580	110.0	34.4	27.0	79.6	13.50	1656	159	180	1137	401	27.70	5.351
2010 sample analyses – several localities[2]																	
Maximum value from several localities	45.4	244.0	904.0	934	627	129.0	37.8	23.1	101.0	16.90	>1000	202	1290	1350	2800	14.0	5.430
Locality number (as in Table GS-15-1)[3]	7	7	7	7	7	7	7	7	12	12	7, 12	6	12	6	12	10	7

[1] Most of the data depicted for the Gammon Ferruginous Member in Nicolas et al. (Figure GS-14-2, this volume).

[2] MGS Data Repository Item DRI2010001, containing the data or other information sources used to compile this report, is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/web/freedownloads.html, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

[3] 6, Mount Nebo; 7, Spencer's Ditch; 10, Friesen Roadcut; 12, Holo Crossing

Abbreviations: INAA, instrumental neutron activation analysis; MULT, multi-element instrumental neutron activation analysis; TD-ICP-ES, inductively coupled plasma–emission spectrometry with total digestion.

Figure GS-15-5: *Sample bag and shovel mark bottom and top, respectively, of 0.2 m thick Gammon Ferruginous Member in the road base at the Holo Crossing locality 12.*

and Zn (Table GS-15-2), while the Mount Nebo locality 6 (Figure GS-15-6) has the highest Cu and V (Table GS-15-2).

To assist in the determination of the chemical composition of the Gammon Ferruginous Member in the subsurface in southwestern Manitoba, chip samples were collected in October 2010 by C. Campbell of Pinnacle Wellsite Consultants during the drilling of a petroleum development well in the Sinclair area (Twp. 7, Rge. 29, W 1st Mer.). Approximately 62 m of Gammon Ferruginous Member was encountered in the hole. Since geophysical log picks for the Gammon Ferruginous Member can be subjective, samples were collected over 5 m intervals between the top of the Pembina Member to the base of the Boyne Member (Figure GS-15-1) to capture the Gammon Ferruginous Member's full stratigraphic thickness. These samples will also be sent for INAA and ICP-ES inorganic chemical analyses.

Economic considerations

The Gammon Ferruginous Member of the Pierre Shale appears to be enriched in REE and other elements along the Manitoba Escarpment; but its thickness is quite variable, making it difficult to evaluate its mineral resource potential. However, in the subsurface, the thickness of the Gammon Ferruginous Member dramatically increases towards the southwest. If there is a corresponding increase in its mineral concentration, due to deep weathering of the member during the erosional interval following its deposition, then there is a possibility that new discoveries of mineable sedimentary deposits containing REE and/or other elements, such as Pt, Pd, Cu, Ni, V and Zn, could be made in southwestern Manitoba.

Acknowledgments

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Figure GS-15-6: *Head of geological hammer marks the top of 0.18 m thick Gammon Ferruginous Member at the Mount Nebo locality 6.*

pooling of geological knowledge with J.W. Hoganson of the North Dakota Geological Survey, during a visit to the Cretaceous outcrops west of Walhalla in North Dakota. Further, the authors would like to gratefully acknowledge D. Lobb, and his crew, of the Manitoba Soil Survey for the joint informal field trip to the South Tobacco Creek watershed. G. Matile is thanked for reviewing this report.

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