ERCB/AGS Open File Report 2011-07

Measured Outcrop Section T27-R17W4-01 of the Bearpaw and Horseshoe Canyon Formations, Dorothy, Red Deer River Valley, Southern Alberta (NTS 82P/08)

Energy Resources Conservation Board

Alberta Geological Survey

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Abstract

Measured outcrop section T27-R17W4-01, located 34 km southeast of Drumheller on the southwest side of the Red Deer River valley opposite the village of Dorothy, includes the upper part of the Bearpaw Formation and the lowermost part of the Horseshoe Canyon Formation. This report includes a graphic log of the measured section with an outcrop gamma-ray curve and a detailed description of the section (avoiding lithofacies interpretation but detailing stratigraphic context where appropriate) with selected photos.

The Bearpaw Formation interval includes the upper part of the Dorothy sandstone at the base of the section and the Dorothy bentonite. The bioturbated contact of the Dorothy sandstone with overlying mudstone is marked by the most pronounced increase in gamma-ray counts in the measured section. Gamma-ray counts and observed lithofacies for the Bearpaw Formation interval above the Dorothy sandstone define a series of coarsening-upward packages. Mean gamma-ray counts for the basal part of each coarsening-upward cycle become progressively lower up through the section. In the two best-defined cycles, grey-brown mudstone passes gradationally up into intervals dominated by hummocky cross-stratified, fine-grained sandstone units. The 11.9 m thick Dorothy bentonite shows relatively uniform gamma-ray counts in the middle range of values for the measured section. The base of the Horseshoe Canyon Formation is placed at the base of a thick (9.5 m exposed) swaley cross-stratified sandstone interval at the top of the measured section.

1 Introduction

Measured outcrop section T27-R17W4-01, located in the Red Deer River valley, 34 km southeast of Drumheller (Figures 1 and 2), includes the upper part of the Bearpaw Formation and the lowermost part of the Horseshoe Canyon Formation. The Bearpaw Formation interval includes the upper part of the 'Dorothy sandstone' and the 'Dorothy bentonite' of Given and Wall (1971). This report includes a graphic log of the measured section with an outcrop gamma-ray curve and a detailed description of the section (avoiding lithofacies interpretation but detailing stratigraphic context where appropriate) with selected photos. The section was measured in July 2009 using an Abney level attached to a 1.6 m Jacob staff.

2 Location

The measured section is located on the southwest side of the Red Deer River valley opposite the village of Dorothy (Figure 2). The base of the section is just above the level of the Red Deer River in Twp. 27, Rge. 17, W 4th Mer. (abbreviated T27-R17W4). There is 740 m lateral shift to the southeast at the base of the Dorothy bentonite (17.6 m in the measured section; Figures 2 and 3), and the remainder of the section is in Twp. 26, Rge. 17, W 4th Mer. (Figures 2 and 4).

3 Description

3.1 0 to 2.5 m: Bearpaw Formation – Dorothy Sandstone

The 2.5 m thick sandstone interval at the base of the measured section (Figures 3 and 5) represents the upper part of the unit informally named the Dorothy sandstone by Given and Wall (1971). Although the base of the sandstone is not exposed in measured section T27-R17W4-01, it does crop out along the Red Deer River to the southeast in Sec. 26, Twp. 26, Rge. 17, W 4th Mer., where Given and Wall (1971) measured a thickness of 20 ft. (6.1 m) for the unit. The sandstone is pale grey and fine to medium grained. It shows horizontal to low-angle planar stratification, with some trough cross-stratified lenses, and, at 2.0 m in the measured section, a well-exposed erosionally based swale (Figure 6). The sandstone contains sparse mudstone intraclasts (maximum dimension <1 cm) and carbonaceous fragments. Lenses of fine carbonaceous material are present in the uppermost part of the sandstone. The upper contact with overlying mudstone is intensely burrowed, with mud-filled *Thalassinoides* burrows up to 4 cm in diameter extending up to 35 cm down into the underlying sandstone (Figure 7). In places, the inner walls of the burrows show longitudinal grooves. The abundance and nature of these passively filled dwelling burrows indicates that they represent a firmground omission assemblage developed on the incipiently cemented (semilithified) top of the sandstone (*Glossifungites* ichnofacies; MacEachern et al., 1992; Pemberton et al., 2004).

3.2 2.5 to 17.6 m: Bearpaw Formation Mudstone

The interval from 2.5 to 17.6 m in the measured section (Figure 3) consists mainly of dark grey to grey-brown, blocky to nodular-weathering, slightly silty, noncalcareous mudstone. The mudstone generally appears to be thoroughly bioturbated, but rare millimetre-scale laminae and lenses of siltstone and very fine grained sandstone are present, and there are thicker sandstone units at 10.3 m (4 cm thick, green, fine to medium grained) and 11.9 m (2 to 3 cm thick, pale grey, very fine grained). There is a 10 cm thick, yellow-grey, waxy bentonite unit at 7.1 m in the section.

3.3 17.6 to 29.5 m: Bearpaw Formation – Dorothy Bentonite

The Dorothy bentonite of Given and Wall (1971) is 11.9 m thick in measured section T27-R17W4-01 (Figures 3 and 4), consistent with the thickness of 10 to 12 m measured in the area by Lerbekmo (2002). It consists largely of pale grey, slightly silty bentonite with a 'popcorn-weathering' exposed surface

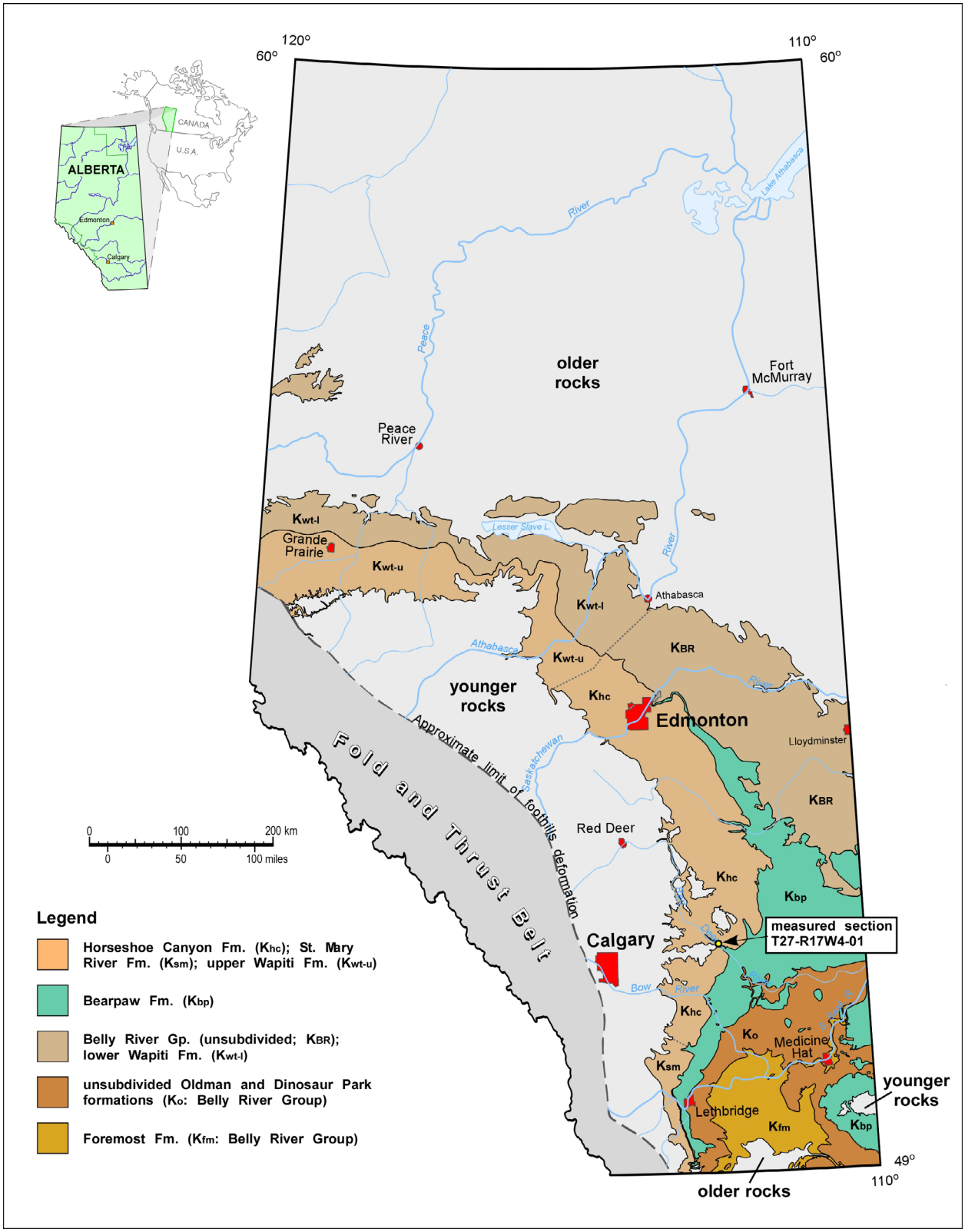


Figure 1. Simplified geological map (modified from Hamilton et al., 1999) showing the distribution of Bearpaw and Horseshoe Canyon formations and surrounding rocks in Alberta and the location of measured section T27-R17W4-01.

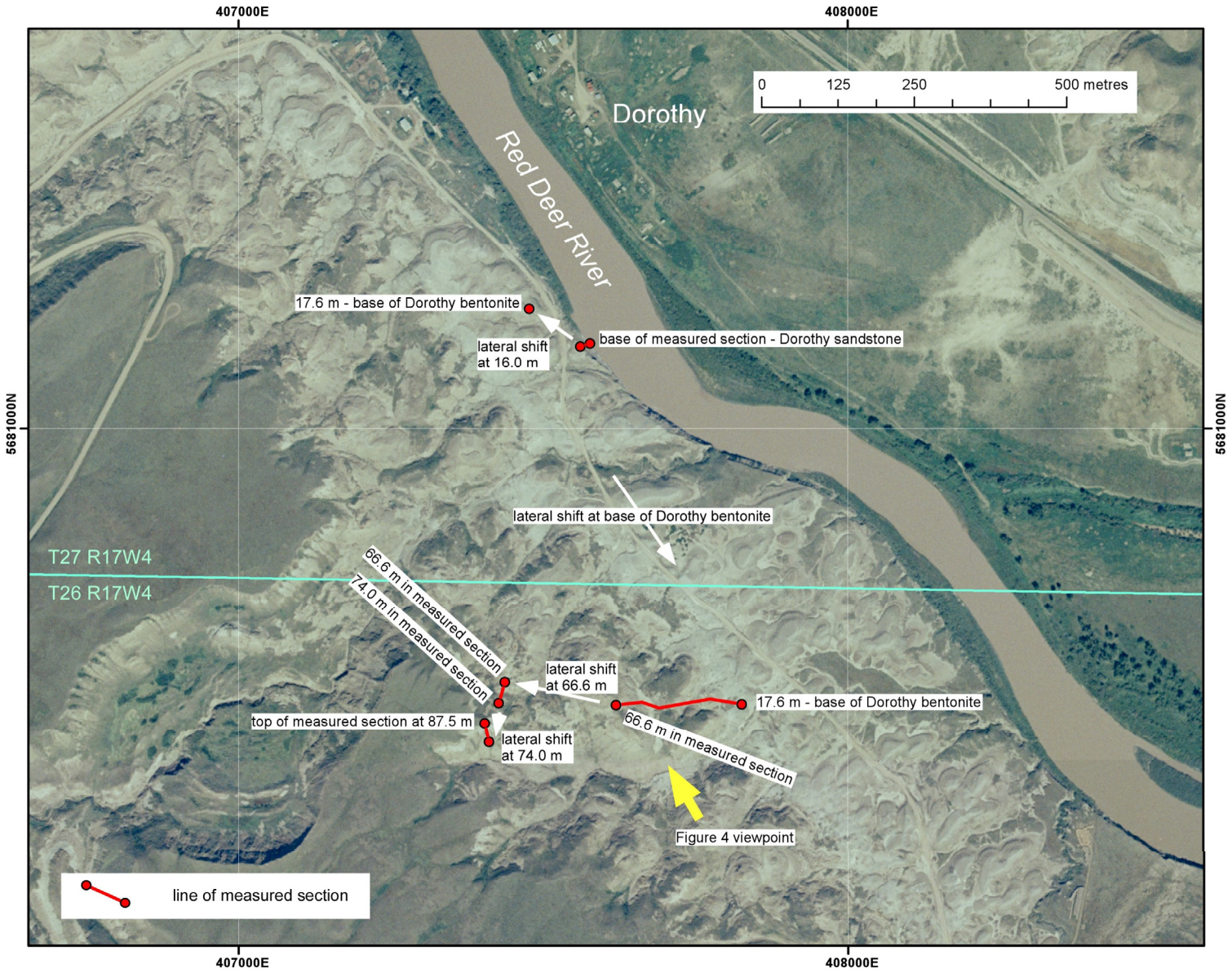


Figure 2. Location of measured section T27-R17W4-01 (southern Alberta) plotted on 1 m resolution orthorectified airphoto base with 1 km grid (UTM Zone 12, NAD 83).

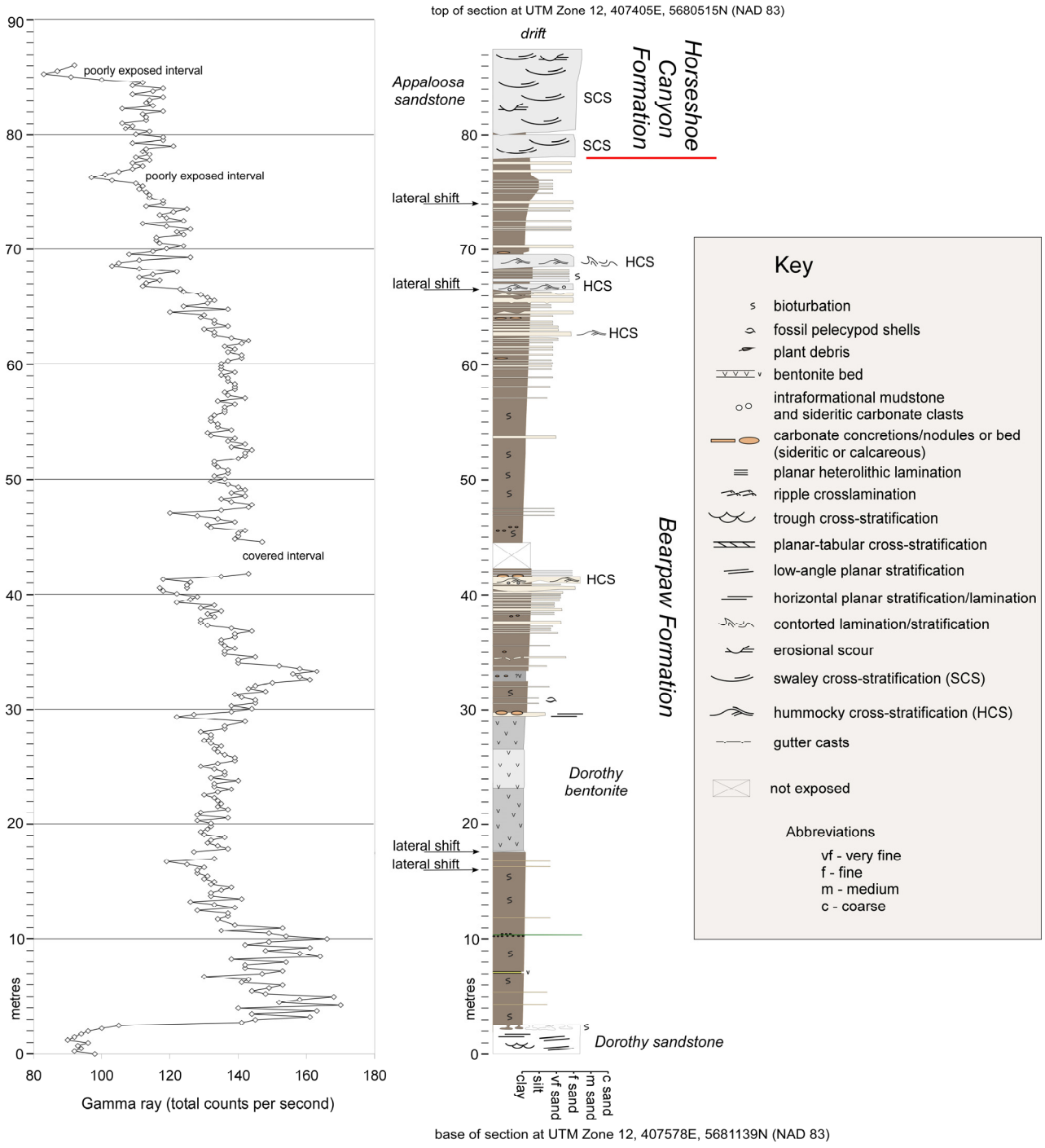


Figure 3. Graphic log of measured section T27-R17W4-01 (southern Alberta) with outcrop gamma-ray curve. See large-format version in Appendix 2 for descriptive notes.

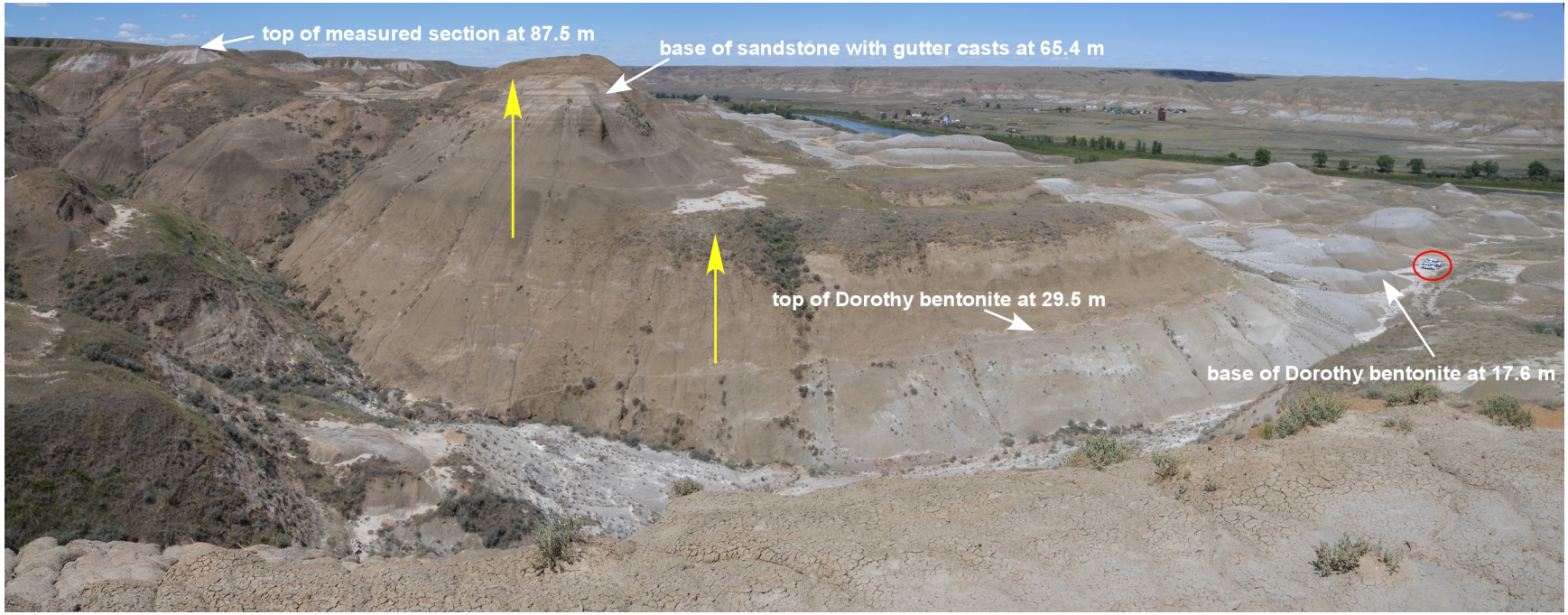


Figure 4. Panoramic view looking northwest (viewpoint at 407750E, 5680360N, UTM Zone 12, NAD 83) toward middle and upper part of measured section T27-R17W4-01 (above the lateral shift at the base of the Dorothy bentonite). Selected contacts are indicated, with their corresponding heights in the measured section. Vertical yellow arrows indicate coarsening-upward packages recognizable from observed lithofacies and outcrop gamma-ray data. The base of the section, with the Dorothy sandstone, is out of view on the near (southwest) bank of the Red Deer River. Vehicles at right (circled in red) for scale.

Figure 5. Dorothy sandstone exposed on the southwest bank of the Red Deer River. Arrows indicate top of sandstone. Base of measured section T27-R17W4-01 (southern Alberta) is below the arrow at the right-hand side of the photo.

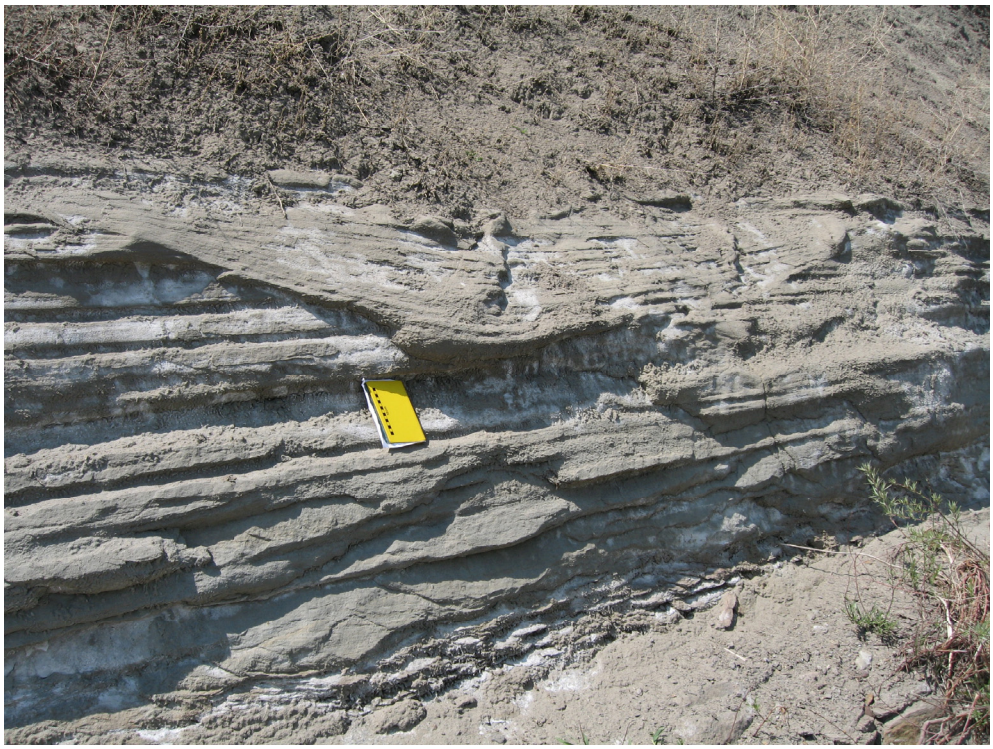


Figure 6. Erosionally based swale truncating horizontal planar stratification in the uppermost part of the Dorothy sandstone at 2 m in measured section T27-R17W4-01 (southern Alberta). Yellow notebook is 19 cm long.

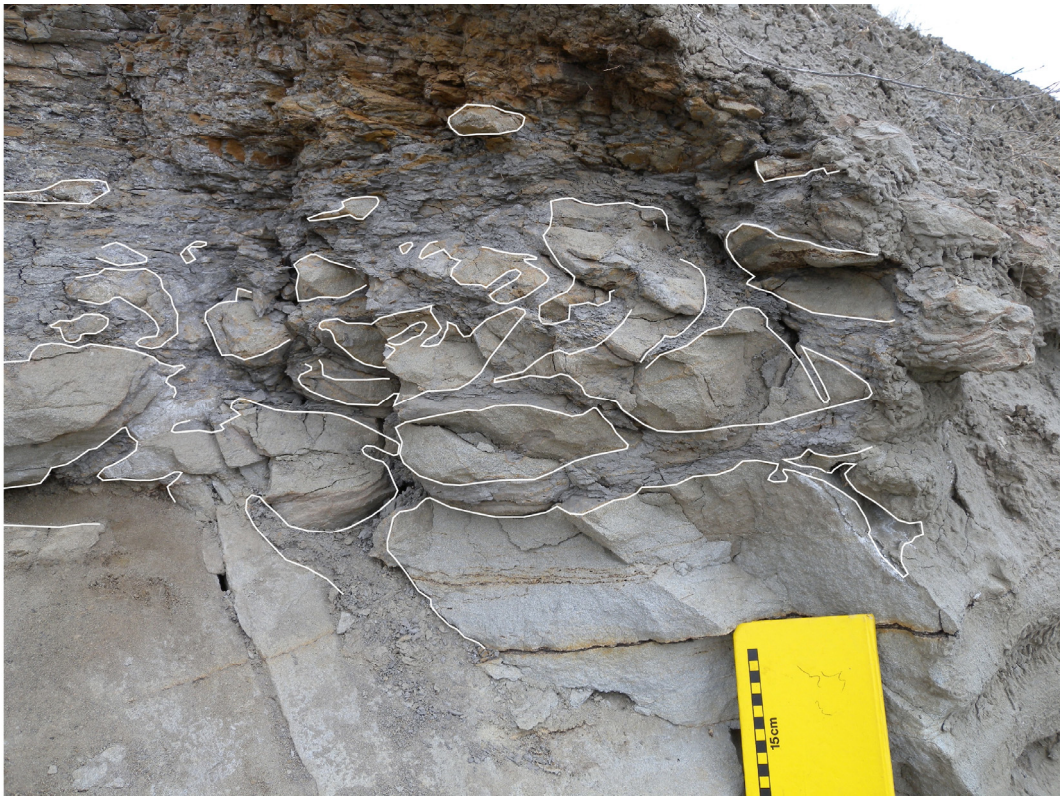


Figure 7. Bioturbated contact between the Dorothy sandstone and overlying mudstone at 2.5 m in measured section T27-R17W4-01 (southern Alberta). Mud-filled *Thalassinoides* burrows (outlined) extend down into the sandstone in the lower part of the photo. Notebook scale bar has 1 cm intervals.

(which tends to obscure details of the unit, including its upper and lower contacts). As noted by Lerbekmo (2002), the bentonite includes a thick (here 3.5 m), paler grey, more indurated, calcareous zone in the middle part, and a similar, but thinner (up to 25 cm thick), indurated zone at the base of the unit.

3.4 29.5 to 78.0 m: Bearpaw Formation Mudstone and Sandstone

The interval from 29.5 to 78.0 m in the measured section consists mainly of grey-brown, noncalcareous, silty mudstone and subordinate pale grey- to buff-weathering sandstone arranged in a number of coarsening- and thickening-upward packages (Figure 3).

At 29.5 m in the measured section, the Dorothy bentonite is overlain by a 50 cm thick unit of fine-grained, planar laminated sandstone with a horizon of buff carbonate concretions up to 50 cm thick at its top. The interval above this unit, up to 41.6 m, shows a well-developed coarsening- and thickening-upward trend, with bioturbated mudstone and minor, thin very fine to fine-grained sandstone units at the base passing up to a succession dominated by erosionally based, fine- to medium-grained sandstone units up to 60 cm thick at the top. The lower, mudstone-dominated part of this package includes an approximately 1 m thick interval of pale grey, probably bentonitic mudstone with a gradational base and top. The internal structure of the sandstone beds is generally obscured by weathering, but the uppermost and thickest sandstone in the coarsening- and thickening-upward package shows hummocky cross-stratification.

The lower 3 m of the next coarsening- and thickening-upward package, which extends up to 69.6 m (Figures 8 and 9), is largely unexposed. The lower part of the package again consists of grey-brown,

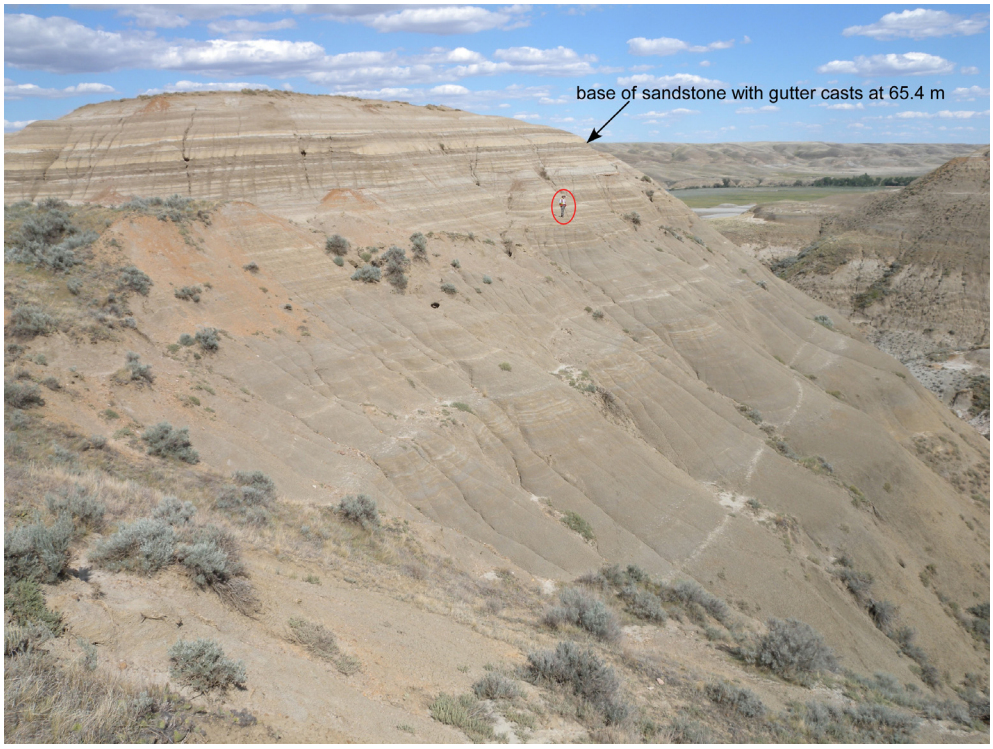


Figure 8. Upper part of coarsening- and thickening-upward mudstone and sandstone package extending up to 69.6 m (at the level of the top of the bluff in the photo) in measured section T27-R17W4-01 (southern Alberta). Figure (circled in red) for scale.

Figure 9. Detail of sandstone units in upper part of Figure 8 (measured section T27-R17W4-01, southern Alberta). Jacob staff (1.6 m long; circled in red) for scale.

bioturbated silty mudstone with rare very fine-grained sandstone units. Sandstone units show a relatively steady increase in abundance, thickness and grain-size (up to fine grained) above 58.0 m, with the thicker beds showing hummocky cross-stratification (Figure 10). Gutter casts occur at the sharp base of one sandstone unit (at 65.4 m) and some beds have sharp, upper erosional surfaces overlain by silty mudstone, which in some cases cut down through and completely remove the underlying sandstone (Figure 9). Siderite-cemented *Ophiomorpha* burrows are abundant in the upper parts of some sandstone beds. There is some synsedimentary folding in the upper part of the package and the 1.2 m thick, fine-grained, hummocky cross-stratified sandstone unit at the top locally shows ball-and-pillow soft-sediment deformation (Figure 11).

The interval from 69.6 to 78.0 m is dominated by grey-brown silty mudstone and muddy siltstone, with minor fine and very fine grained sandstone beds up to 20 cm thick. The upper part of the interval is poorly exposed and no clear coarsening-upward trend was noted at outcrop.

3.5 78.0 to 87.5 m: Horseshoe Canyon Formation Sandstone

In his definition of the Horseshoe Canyon Formation type section in the Red Deer River valley, Irish (1970) noted that the basal "contact is placed arbitrarily at the base of the first, thick, light grey-weathering sandstone unit above the chocolate-brown, sandy shales of the Bearpaw Formation." Hamblin (2004) refined that criterion, stating that "for consistency and ease of demarcation, that contact is placed at the base of the lowest thick sandstone body that is associated with coal above the chocolate-brown mudstone of the Bearpaw Formation." As noted by Hamblin (2004), the diachronous, interfingering relationship between the two formations allows this lithostratigraphic contact to be placed at varying levels in the stratigraphy, depending on location. Although there is no coal exposed in measured section

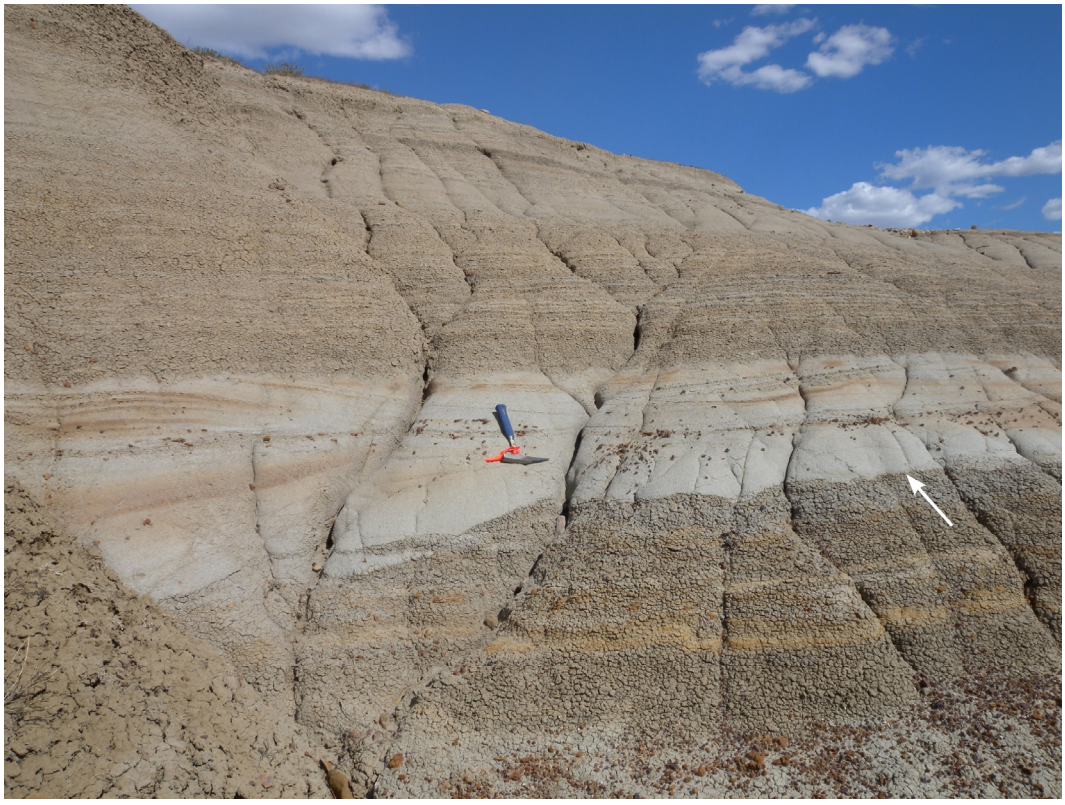


Figure 10. Hummocky cross-stratification in fine-grained sandstone bed. Base of unit (indicated by arrow) at 66.6 m in measured section T27-R17W4-01 (southern Alberta). Geological hammer (30 cm long) on sandstone unit for scale.

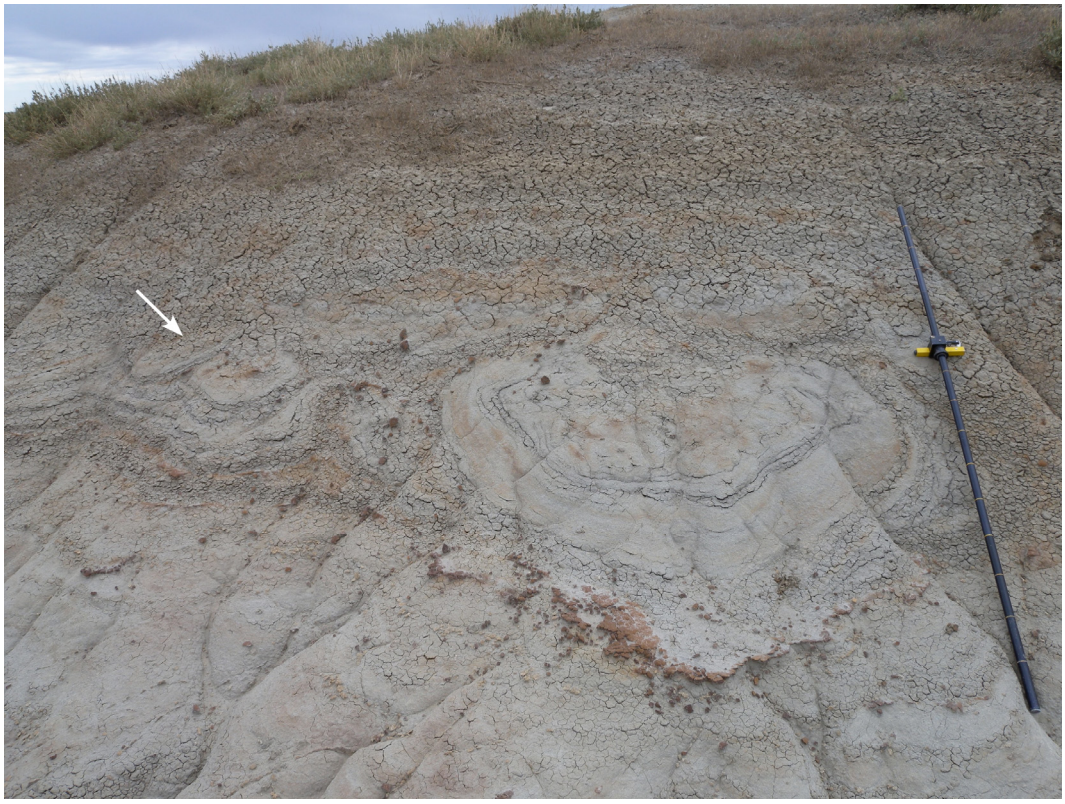


Figure 11. Ball-and-pillow soft-sediment deformation in sandstone at top of coarsening- and thickening-upward package. Top of unit (indicated by arrow) at 69.6 m in measured section T27-R17W4-01 (southern Alberta). Jacob staff (1.6 m long) for scale.

T27-R17W4-01 below the poorly exposed contact of the uppermost sandstone with drift at 87.5 m, it is present at the top of this sandstone unit in a section 1.7 km to the west-northwest (Saunders and Pemberton, 1986, Boot coulee section). Saunders and Pemberton (1986) informally named this sandstone interval, which "separates marine shales of the Bearpaw Formation from the overlying terrestrial coal-bearing strata of the Horseshoe Canyon Formation," the 'Appaloosa sandstone.'

In section T27-R17W4-01, the base of the Horseshoe Canyon Formation Appaloosa sandstone at 78.0 m (Figure 3) is poorly exposed and it is unclear whether the lower contact is sharp or gradational. The overlying interval consists of erosionally based, pale grey, fine-grained, amalgamated sandstone units up to 1.5 m thick, which generally show low-angle, undulatory, swaley cross-stratification (SCS; Figure 12). Individual sandstone units generally have finer grained, slightly silty tops, and at 80 m there is a 10 cm thick, laterally discontinuous fissile mudstone interval. Carbonaceous laminae are abundant and in the uppermost metre of the section the sandstone coarsens to medium grained.

4 Gamma-Ray Data

The methodology for collecting the outcrop gamma-ray data (shown in Figure 3) is detailed in Appendix 3.

There is a sharp increase in gamma-ray counts at 2.5 m, from low values within the Dorothy sandstone to some of the highest counts in the section in the overlying mudstone. The mudstone-dominated interval from 2.5 to 17.6 shows high gamma-ray values, with a well-defined upward decreasing trend, suggesting coarsening-upward, in the upper part of the interval.

Figure 12. Amalgamated, erosionally based, swaley cross-stratified, fine-grained sandstone units in the basal Horseshoe Canyon Formation 'Appaloosa sandstone' interval of measured section T27-R17W4-01 (southern Alberta). Jacob staff (1.6 m long) for scale.

Gamma-ray counts for the Dorothy bentonite (17.6 to 29.5 m) are in the middle range of values for the measured section, and show a consistency expected from the relatively uniform lithology of the unit. The overlying interval from 29.5 to 41.6 m shows a steady decrease in gamma-ray counts consistent with the observed coarsening- and thickening-upward trend, although the decrease is interrupted by high gamma-ray counts for the interval of pale grey, probably bentonitic, mudstone in the lower part of the package. The overlying mudstone and sandstone package, up to 69.6 m, again shows a decrease in gamma counts consistent with the coarsening- and thickening-upward trend. The rate of decrease is gentle and steady in the lower, mudstone-dominated part of the package, but increases sharply above 62.0 m as thicker sandstone beds become increasingly abundant.

Although no clear trend was observed at outcrop, upward decreasing gamma-ray counts for the interval from 69.6 to 78.0 m suggest coarsening upward. Anomalously low gamma-ray counts in the upper part of this interval may reflect the poor quality exposure. For the most part, the basal Horseshoe Canyon Formation sandstone, from 78.0 to 87.5 m in the section, shows gamma-ray counts similar to those for sandstones in the uppermost part of the 41.6 to 69.6 m coarsening-upward package. Gamma-ray counts for the topmost exposed part of the sandstone are lower, with values similar to those from the Dorothy sandstone, which may reflect the coarser grain-size.

Finally, it should be noted that mean gamma-ray counts for the basal part of each coarsening-upward cycle, from 2.5 m upward, are progressively lower up through the section.

5 Summary

Measured outcrop section T27-R17W4-01, located on the southwest side of the Red Deer River valley opposite the village of Dorothy, includes the upper part of the Bearpaw Formation and the lowermost part of the Horseshoe Canyon Formation. The uppermost 2.5 m of the Dorothy sandstone are exposed at the base of the section. The bioturbated contact of the sandstone with overlying mudstone is marked by the sharpest increase in gamma-ray counts in the measured section. Gamma-ray counts and observed lithofacies for the Bearpaw Formation interval above the Dorothy sandstone define a series of coarsening-upward packages. In the two best-defined packages, grey-brown mudstone passes gradationally up into intervals dominated by hummocky cross-stratified, fine-grained sandstone units. Within the Bearpaw Formation section, the 11.9 m thick Dorothy bentonite shows relatively uniform gamma-ray counts in the middle range of values for the measured section. The base of the Horseshoe Canyon Formation is placed at the base of a thick (9.5 m exposed) swaley cross-stratified sandstone interval at the top of the measured section.

6 References

Given, M. M. and Wall, J. H. (1971): Microfauna from the Upper Cretaceous Bearpaw Formation of south-central Alberta; Bulletin of Canadian Petroleum Geology, v. 19, no. 2, p. 502–544.

Hamblin, A.P. (2004): The Horseshoe Canyon Formation in southern Alberta: surface and subsurface stratigraphic architecture, sedimentology, and resource potential; Geological Survey of Canada, Bulletin 578, 180 p.

Hamilton, W.N., Langenberg, C.W., Price, M.C. and Chao, D.K., comp. (1999): Geological map of Alberta; Alberta Energy and Utilities Board, EUB/AGS Map 236, scale 1:1 000 000, URL <http://www.ags.gov.ab.ca/publications/abstracts/MAP_236.html> [May 2010].

Irish, E.J.W. (1970): The Edmonton Group of south-central Alberta; Bulletin of Canadian Petroleum Geology, v. 18, p. 125–155.

Lerbekmo, J.F. (2002): The Dorothy bentonite: an extraordinary case of secondary thickening in a late Campanian volcanic ash fall in central Alberta; Canadian Journal of Earth Sciences, v. 39, p. 1745–1754.

MacEachern, J.A., Raychaudhuri, I. and Pemberton, S.G. (1992): Stratigraphic applications of the *Glossifungites* ichnofacies: delineating discontinuities in the rock record; *in* Applications of ichnology to petroleum exploration, S.G. Pemberton (ed.), Society for Sedimentary Geology, SEPM Core Workshop 17, v. 17, p. 169–198.

Pemberton, S.G., MacEachern, J.A. and Saunders, T.D.A. (2004): Stratigraphic applications of substrate-specific ichnofacies: delineating discontinuities in the rock record; *in* The application of ichnology to palaeoenvironmental and stratigraphic analysis, D. McIlroy (ed.), Geological Society, London, Special Publication 2004, v. 228, p. 29–62.

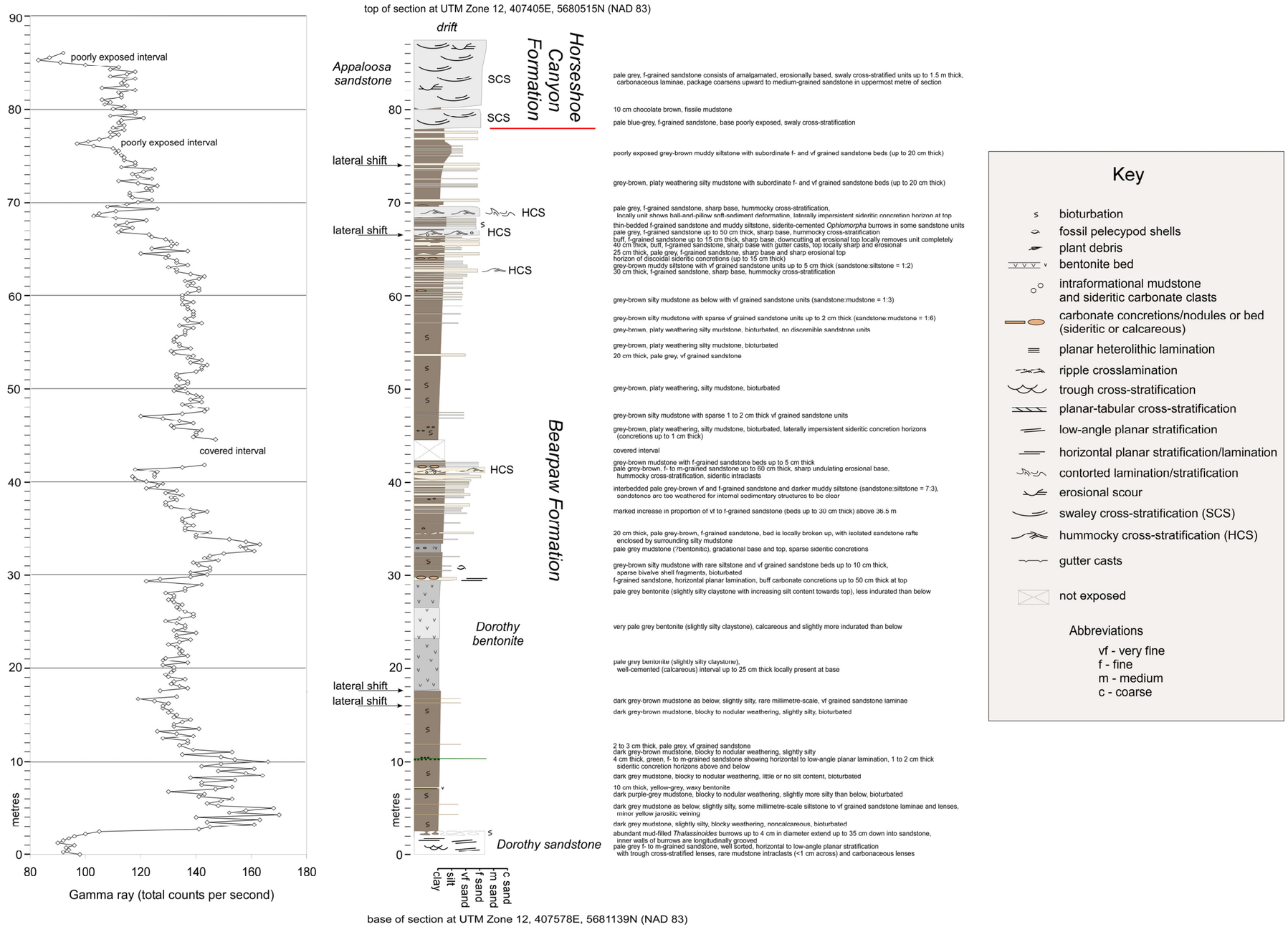
Saunders, T. and Pemberton, S.G. (1986): Trace fossils and sedimentology of the Appaloosa sandstone: Bearpaw-Horseshoe Canyon Formation transition, Dorothy, Alberta; Canadian Society of Petroleum Geologists, Field Trip Guide Book, 117 p.

Appendix 1 – GPS Location Data for Measured Outcrop Section T27-R17W4-01

The GPS location data for measured outcrop section T27-R17W4-01 in southern Alberta were obtained using Garmin® GPSMAP® 60CSx hand-held units. The UTM co-ordinates are NAD 83, Zone 12. The ± values indicate estimates of horizontal error generated by the GPS units.

Easting	Northing	Horizontal Error (±)	Elevation (m)	Comment
407578	5681139	8	670	base of measured section (0.0 m)
407562	5681134	7	688	16.0 m in measured section
407478	5681196	4	690	17.6 m in measured section – base of Dorothy bentonite before lateral shift
407827	5680546	0.7	686	17.6 m in measured section – base of Dorothy bentonite after lateral shift
407620	5680545	3.4	733	66.6 m in measured section before lateral shift
407438	5680582	1.4	734	66.6 m in measured section after lateral shift
407428	5680548	1.6	741	74.0 m in measured section before lateral shift
407412	5680484	n/a	737	74.0 m in measured section after lateral shift
407405	5680515	n/a	756	top of measured section at 87.5 m

Appendix 2 – Graphic Log of Measured Outcrop Section T27-R17W4-01 (Southern Alberta) with Outcrop Gamma-Ray Curve. Large-Format Version of Figure 3 with Descriptive Notes.



Appendix 3 – Outcrop Gamma-Ray Methodology

Gamma-ray values, in counts per second, were measured on outcrop section T27-R17W4-01 (southern Alberta) at nominal measurement intervals of 0.25 m using a hand-held GR-135 spectrometer. The counting time was 10 seconds and total counts were measured (above a lower threshold of 20 keV). Each measurement was obtained by placing the base of the front part of the GR-135 (near the detector) directly against the outcrop at the measurement location. Measurement locations were chosen to be as planar as possible over areas approximately 0.5 m in diameter. If necessary, loose material was scraped away to expose outcrop before the gamma-ray data were collected.

GR-135 Specifications

Manufacturer: SAIC (Mississauga, Ontario)
Model: Exploranium® GR-135 Plus "The Identifier" (GR-135GEO, geophysical model)
Year of Manufacture: 2007
Version: 6V01.02
Detector: sodium-iodide (thallium) [NaI(Tl)] detector with a 65 cm^3 (4.0 cu in.) volume (38 mm in diameter and 57 mm in length)
Stabilization: external cesium (^{137}Cs) source (stabilization completed daily)
Mode: manual (search mode)
Count Rate Measurement: counts per second
Sample Time: 10 seconds
Scan Window: total (above lower threshold of 20 keV)
Averaging: off
Channels: 1024