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**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 7840**

**Geological and geochemical data from the
Mackenzie Corridor. Part I: Devonian cored sections and
results for 2014 on geochemistry, $\delta^{13}\text{C}$ – $\delta^{18}\text{O}$, and
Rock-Eval™ 6 pyrolysis**

P. Kabanov

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INTRODUCTION

This paper reports on new data from the sub-Imperial Devonian succession (Lower to lowermost Upper Devonian) of the northern continuation of the West Canadian Sedimentary Basin in its eastern, less deformed to non-deformed subsurface part (Morrow, 2012). The studied wells have been drilled for hydrocarbon exploration starting in the 1960s and are located on plains along Mackenzie River and its drainage area between 62.317°N and 68.532°N, in physiographic divisions on Great Slave, Mackenzie, Peel and Anderson plains ([Figure 1](#); Morrow, 2012; Hannigan, 2012). The Mackenzie River Basin trends along the Cretaceous foreland basin (Hadlari et al., 2014) bordered to the west by the fold and thrust belt of the Mackenzie Mountains and in the east by the Laurentian Shield ([Figure 1](#); Morrow, 2012). The Devonian to lowermost Carboniferous succession subcrops under Cretaceous-Cenozoic siliciclastics. The younger part of the Devonian-Carboniferous succession (Imperial and Tuttle Formations and their southern equivalents; Hadlari et al., 2009; Dixon, 2012; Morrow, 2012) occurs at depths not exceeding 1600 m and crops out in many places in the Mackenzie Valley, adjacent plains and mountains (Morrow, 2012; Gal and Pyle, 2011, 2012). Older Devonian formations have fewer exposures. In the Mackenzie Plain, which is economically most prospective area, the Lower Devonian carbonate-dominated package is not exposed. The full Devonian succession crops out in the Mackenzie Mountains where it is used to study analogues for subsurface hydrocarbon plays (Gal et al., 2009; Pyle et al., 2011; Morrow, 2012; Pyle and Gal, 2013).

The best (longest) cored sections from exploration wells intersecting one or more formation boundaries have been selected to measure in detail and acquire multiproxy logs through certain formations and across stratigraphic boundaries. The goal of this work is to designate reference sections of the Devonian in the subsurface. These reference sections are being used to update the Devonian stratigraphic framework, support ongoing and future hydrocarbon exploration (AANDC, 2014) and bedrock geomapping (Canadian geoscience maps for NTS-97, NTS-96, NTS-95, NTS-106, NTS-107; Fallas et al., 2012).

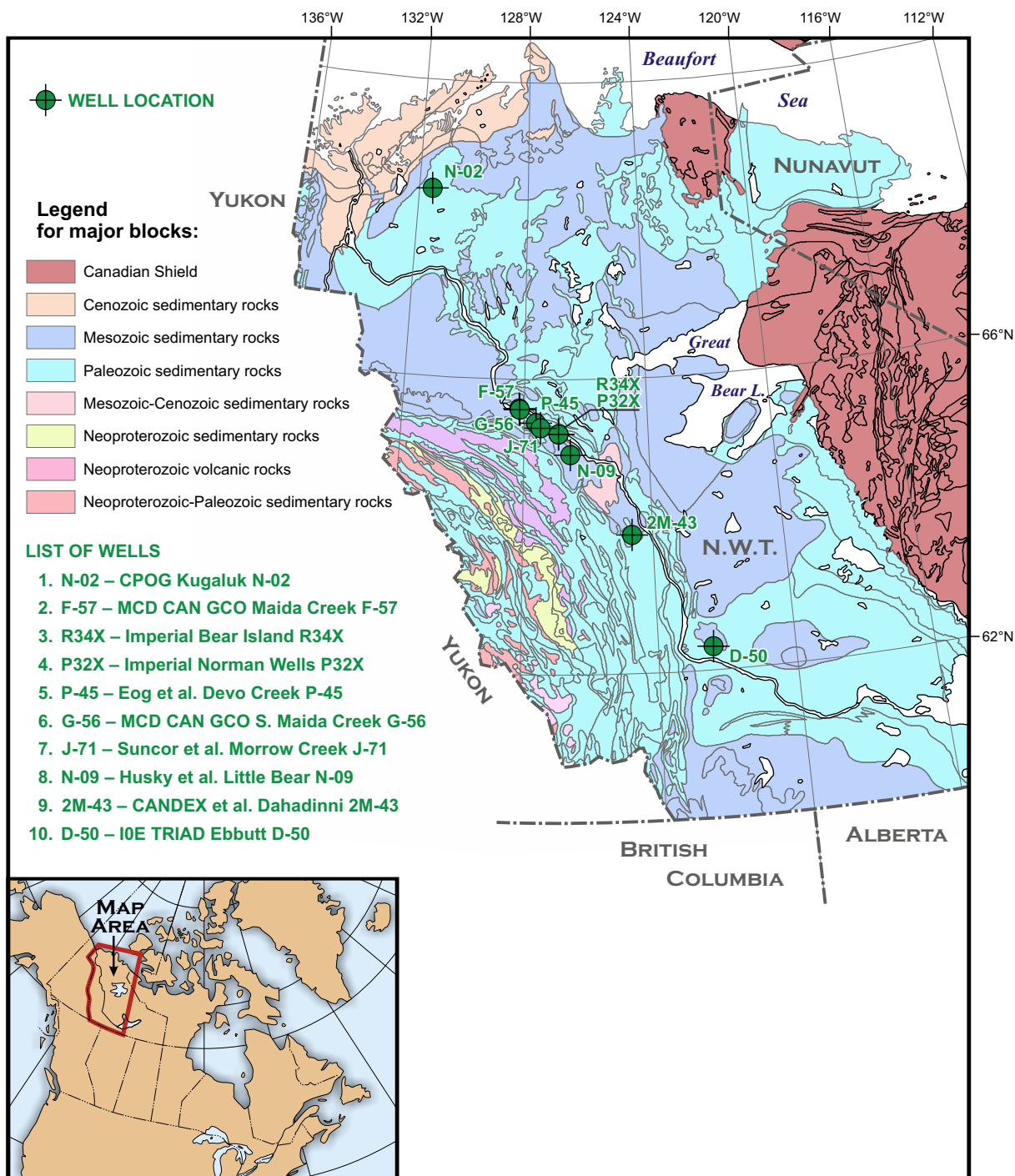


Figure 1. Studied wells on geological bedrock map of mainland Northwest Territories (based on Wheeler et al., 1997).

ECONOMIC PROSPECTIVITY OF DEVONIAN SUCCESSION

The economic prospectivity of the sub-Imperial Devonian is mostly tied to conventional and unconventional hydrocarbon plays. The Norman Wells oilfield is a giant mature oilfield with a microporous fractured carbonate reservoir in the Kee Scarp Member of the Ramparts Formation (Muir et al., 1984; Kaldi, 1989; Yose et al., 2001). The Kee Scarp reservoir is sealed by and sourced from the black shales of the Canol Formation (Snowdon et al., 1987; Hadlari, 2015). The original in-place oil volume in Norman Wells was estimated as $108 \times 10^6 \text{ m}^3$ (Yose et al., 2001). Other major conventional assets are the recently launched oil, gas, and condensate field of Summit Creek located in the Lower Devonian Bear Rock breccias and numerous oil and gas shows in Lower to lower Middle Devonian breccias, dolostones and limestones (Gal et al., 2009; Hannigan et al., 2011; Hannigan, 2012). To the south of the study area in the Liard Basin, a chain of fourteen gas fields produces gas from porous catagenetic (hydrothermal) saddle dolostone reservoirs (Manetoe facies) developed in Devonian-age carbonates (Morrow et al., 1990; Hannigan et al., 2011; Morrow, 2012).

Devonian carbonates of the Mackenzie Mountains host Pb-Zn mineralizations along fault zones with best showings in limestones of the Landry Formation. Further southwestward, in Selwyn Basin, SEDEX-type polymetal deposits occur in the Middle-Upper Devonian shales of the Besa River Group (Dewing et al., 2006; Ootes et al., 2013).

The black shales of the Middle-Upper Devonian Horn River Group were identified to host the largest unconventional hydrocarbon resource in the region (Hamblin, 2006) and have recently seen exploration investment in the central Mackenzie Plain (Hayes, 2011; AANDC, 2014). Referred to most recently as the Canol shale play (AANDC, 2014), this prospect consists of the thickest (up to 180 m) Canol Formation, with median TOC values of 4.6% and 17% maximum and the Bluefish Member of the Hare Indian Formation that is thinner (up to 23 m) and has 5.6% median value and maximum 10% TOC. The Canol Shale is also more brittle due to higher content of biogenic silica. The two organic-rich formations are divided by the informal “gray-shale member” (Morrow, 2012) Pyle et al. (2014) proposes to formalize this unit under the name Bell Creek Member. The Bell Creek (“gray-shale”) Member shows 1.5% median value of TOC and isolated carbonate platforms (banks and pinnacles) of the Ramparts Formation ([Figure 2](#)). The argillaceous-carbonate Headless Member of the Hume Formation is locally organic-rich and indicated as another potential source rock (Hannigan et al., 2011) that can be also tested for tight reservoir properties.

Most recent and complete thermal maturity, geochemical and mineralogical data from the Horn River Group outcrops and wells have been published by Pyle et al. (2011), Gal and Pyle (2012), and Pyle and Gal (2012, 2013). Available data indicate that the Horn River Group under the Mackenzie Plain occurs within and locally beyond the oil window with the thermal maturity gradient generally increasing to the west and south (Gal and Pyle, 2012). Thermal maturity data from Kugaluk N-02 well (northern corner of the study area; [Figure 2](#)) indicate that the Devonian succession there is overmature (Issler et al., 2012). Among issues impeding development of the Canol shale play, climate conditions, lack of infrastructure and resultant pressure on operations costs, as well as land regulation barriers are indicated as most detrimental (AANDC, 2014; Wohlberg, 2014).

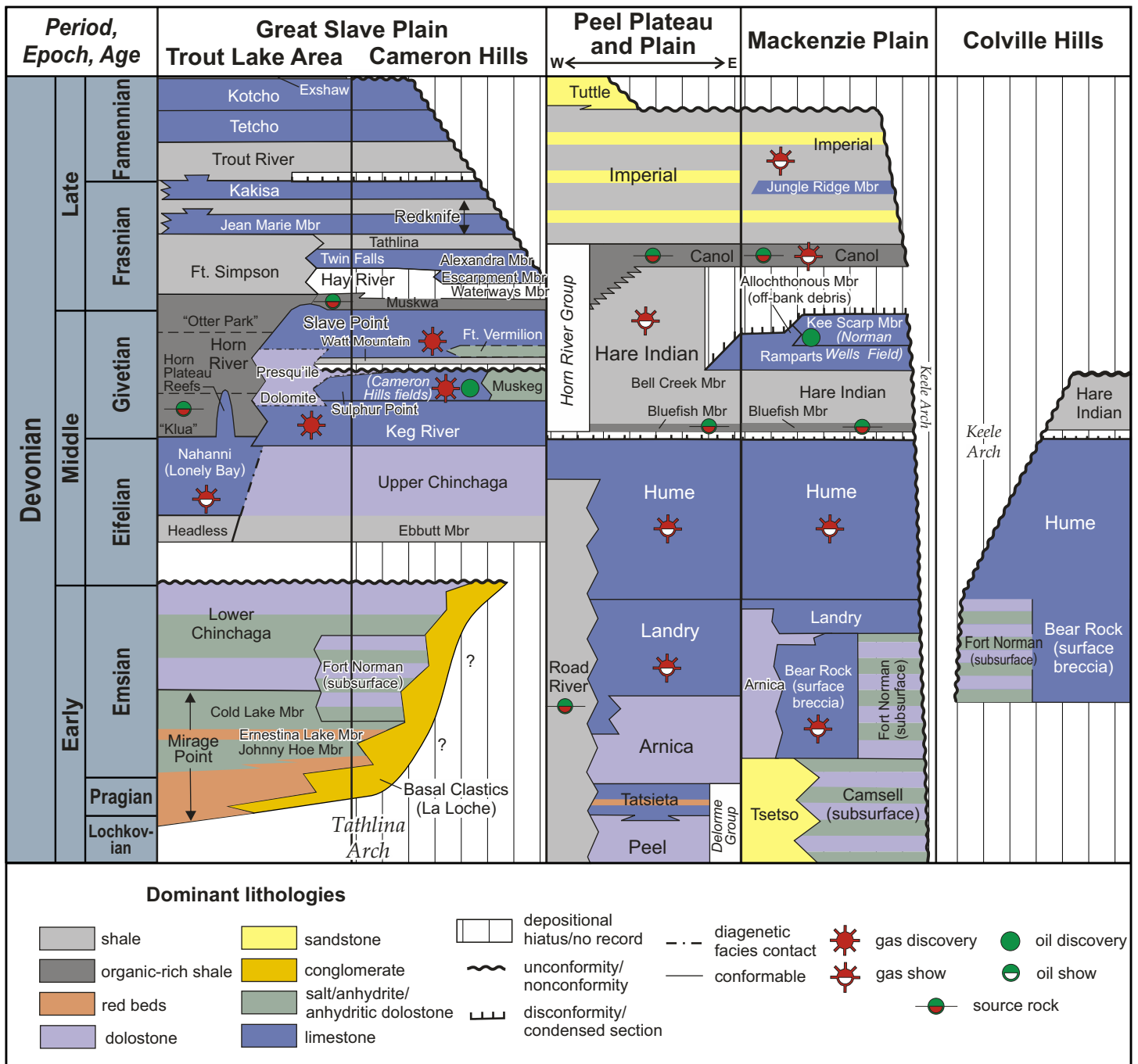


Figure 2. Table of Formations for the Devonian System of Northwest Territories (formally modified from Rocheleau and Fiess, 2014). Note that northern and southern extremities of the study region (Beaufort-Mackenzie Basin and Liard Basin) are not included. Correlation of stratigraphic units is retained from the source (Rocheleau and Fiess, 2014).

MATERIALS AND METHODS

Cored sections from five wells have been measured in 2014 ([Table 1](#)). [Table 1](#) is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab01.xlsx](#). Selected intervals from some of these cores and those measured in previous years have been sampled for thin sections and analyses with permissions granted by [NEB \(National Energy Board\)](#) in 2012-2014. Parts of sample sets have been collected to characterize stratigraphic units ([Figures 3, 4, 5, 6, 7, 8, and 9](#)), and other samples were collected across stratigraphic discontinuities to better understand their nature (e.g., across Kee Scarp/Canol and Hume/Bluefish contacts and across subaerial disconformities in the Landry Formation). Core descriptions in selected old wells are being augmented by spectral gamma ray (SGR) logs using RS-230 BGO tool ([Figure 3](#)).

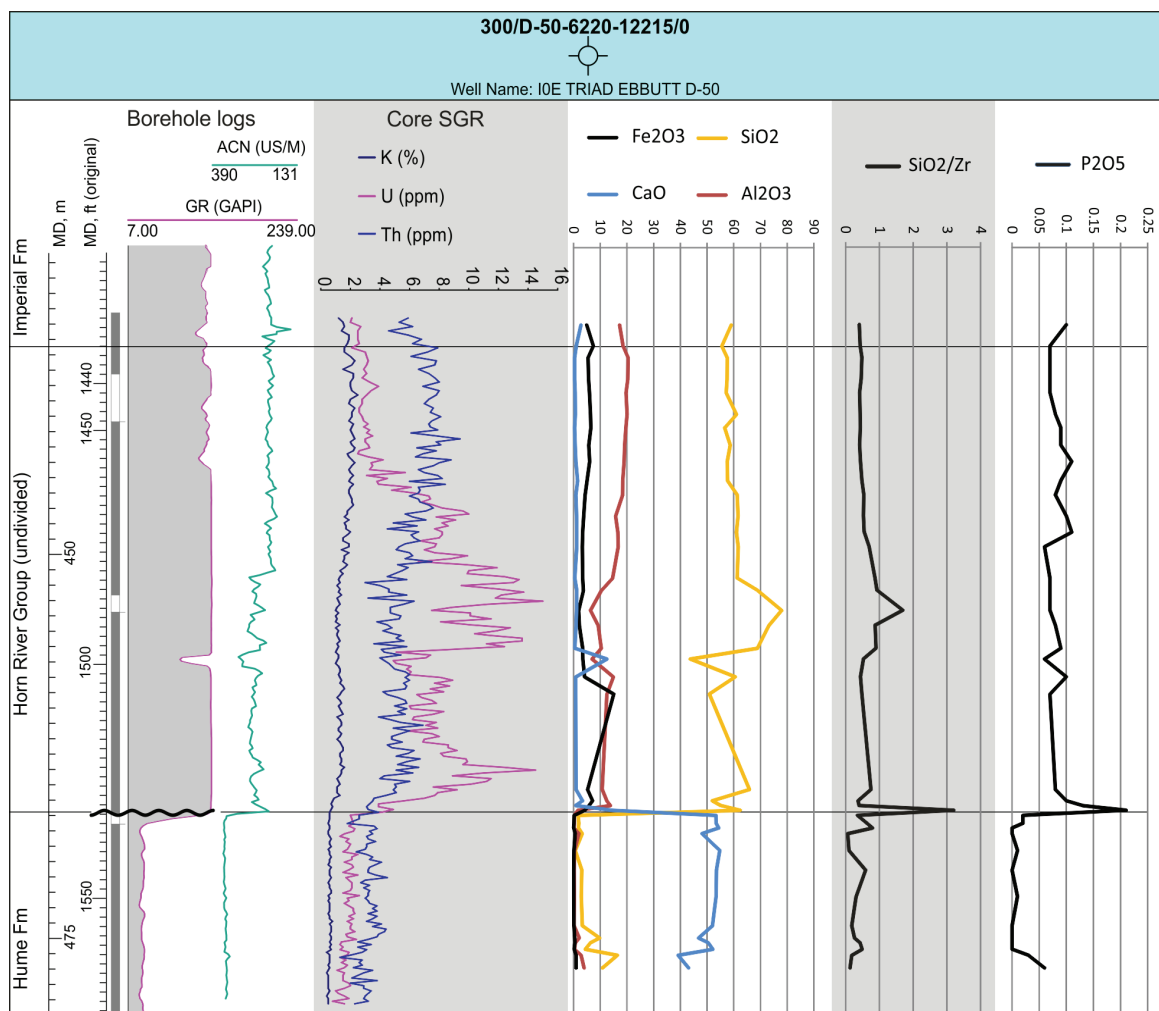


Figure 3. The Horn River Group in Ebbutt D-50 well. Geochemical logs based on new data: main (rock-forming) elements, SiO₂/Zr (proxy for biogenic silica vs. siliciclastics), and phosphorus. Available borehole gamma (truncated) is compared against the core spectral gamma log (SGR). See [Appendix 15](#) for SGR data.

Table 1

Well	UWID	Drilled to TD	Interval measured (m)	Year measured	Cored section deviation	Stratigraphic units measured	ICP-MS/ES	Rock-Eval™	$\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ from carbonates
CPOG Kugaluk N-02	300/N-02-6840-13130/0	1965	1172.0-1689.0	2014	vertical	Arnica Peel, and uppermost Mt. Kindle fms (Tatsieta unit not recognized).	N/A	N/A	N/A
IOE TRIAD Ebbutt D-50	300/D-50-6220-12215/0	1964	434.6-482.8	2014	vertical	Imperial, Canol, Hare Indian fms and Hume Fm.	83	N/A	32
Husky et al. Little Bear N-09	300/N-09-6500-12630/0	2012	1670-1837.4	2014	vertical	Canol, Hare Indian, Hume fms	N/A	N/A	N/A
MCD CAN GCO S. Maida Creek G-56	300/G-56-6540-12800/0 [NT]	1970	517.2-550.2	2014	vertical	Canol and Ramparts fms	15	N/A	18
PCI et al. Morrow Creek J-71	300/J-71-6530-12715/0	1984	861.0-897.60	2014	vertical	Canol and Ramparts fms	N/A	N/A	N/A
Eog et al. Devo Creek P-45	300/P-45-6530-12730/0	2002	327-345	2012-2013	vertical	Hume Fm.	N/A	N/A	N/A
Imperial Norman Wells P32X	304/M-46-6520-12645/0	1997	752.0 – 850.57	2012-2013	deviated	Canol and Ramparts fms	N/A	15	10
CPOG Kugaluk N-02	300/N-02-6840-13130/0	1965	794.6 - 1172.0	2012-2013	vertical	Imperial Fm, Horn River Gp (undivided); Hume and Landry fms.	70	38	46
MCD CAN GCO Maida Creek F-57	300/F-57-6540-12800/0	1970	464.2-491.9	2012-2013	vertical	Ramparts Fm	N/A	N/A	N/A
Imperial Bear Island R34X	302/E-46-6520-12645/0	1979	674.0-728.0	2012-2013	vertical	lower Ramparts and upper Hare Indian fms	N/A	N/A	N/A
CANDEX et al. Dahadinni 2M-43	302/M-43-6400-12430/0	1971	N/A	N/A	vertical	Landry Fm (sampled)	N/A	N/A	20

List of measured and sampled cored sections for 2012-2014. Core descriptions made in 2012-2013 are reported in (Kabanov, 2013), and those made in 2014 are published herewith. [Table 1](#) is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab01.xlsx](#).

Samples from the Landry Formation of Dahadinni 2M-43 well have been collected in order to make a more representative sample set for Landry facies. The new description of core from this well is not available yet.

Lithological descriptions of core

Cores from Devonian strata of the Mackenzie River Corridor were examined at the NEB Core and Sample Repository at the Geological Survey of Canada in Calgary. In most cases fine (millimetre to submillimetre scale) structures were more adequately revealed by grinding slabbed core surfaces with 35 µm silicon carbide powder (grit 400), subsequent etching of core face with 10% HCl for 1-2 seconds, and hand-lens examination under sprayed water cover.

Bulk-element geochemistry

The 5.5-7.0 gram samples were collected from core sides and loose chips. Each sample represents an averaged material collected from a stratigraphic interval exceeding 1 cm (typically 2-5 cm), i.e., none of the collected samples represents a single sedimentary lamina. The samples were analyzed at Acme Analytical Laboratories in Vancouver, B.C. with the induced coupled plasma (ICP) instrumentation technique ([Appendices 1, 2, 3, and 4](#)). All appendices are located in the "[of7840\appendices](#)" directory as Microsoft® Office Excel® 2010 files. Samples were run under LF200 (lithogeochemical whole-rock fusion) and AQ200 (geochemical aqua regia digestion) lab codes.

The LF200 code is described as follows. The prepared sample is mixed with $\text{LiBO}_2/\text{Li}_2\text{B}_4\text{O}_7$ flux. Crucibles were fused in a furnace. The cooled bead is dissolved in ACS grade nitric acid and analyzed by ICP and/or ICP-MS. Loss on ignition (LOI) is determined by igniting a sample split then measuring the weight loss.

In the AQ200 code, the prepared sample is digested with a modified Aqua Regia solution of equal parts concentrated HCl, HNO_3 and DIH_2O for one hour in a heating block or hot water bath. The sample then is made up to volume with dilute HCl. Sample splits of 0.5 g are analyzed.

In addition, total carbon and total sulphur were measured by Leco combustion (TC000 lab code). In this procedure, the induction flux is added to the prepared sample, then ignited in an induction furnace. A carrier gas sweeps up released carbon to be measured by adsorption in an infrared spectrometric cell. Results are total and attributed to the presence of carbon and sulphur in all forms.

Rock-Eval™ 6 pyrolysis

The pyrolysis-combustion tests ([Appendices 5 and 6](#)) were conducted using the Turbo Rock-Eval™ 6 device at the Organic Petrology and Geochemistry Laboratory of GSC (Calgary). The pyrograms are archived in [Appendix 7](#). The data is available as individual Adobe® PDF files in the "[of7840\appendices\of 7840 appendix07](#)" directory in either the "[Kugaluk N02 HornRv Hume Landry Fms](#)" folder or the "[P32X Kee Scarp-Canol contact](#)" folder. The method summary is given after Issler et al. (2012). The test must be an aliquot of a representative amount of rock. The smallest representative amount of sampled rock is roughly estimated as 0.5 g or 5 mm³ for

hydrocarbon-rich facies (e.g., black shales) and up to 2.5 g (1 cm³) for hydrocarbon-lean rocks such as limestones. Initially samples are heated at 300°C for 3 minutes to volatilize any free hydrocarbons (HC) and these are represented by the **S1** curve. Ideally, the area under the **S1** pyrolysis curve (mg HC/g of initial rock) represents hydrocarbons generated *in situ* over geologic time but sample impregnation by migrated hydrocarbons, expulsion and loss of hydrocarbons or organic drilling contaminants (e.g., oil-based drilling mud) can also affect the results.

Following this isothermal heating step, samples are heated linearly from 300°C to 650°C at 25°C/minute, yielding an **S2** curve on pyrograms ([Appendix 7](#)) that represents thermal cracking of sedimentary organic matter. Under ideal conditions, the area under the **S2** curve (mg HC/g of initial rock) represents the remaining potential of the rock sample to generate petroleum from kerogen at increased thermal maturity levels but results can be affected by migrated bitumen and organic drilling contaminants.

The temperature at peak generation on the **S2** pyrolysis curve (T_{peak}; [Figure 4](#)) is converted to the relative temperature and accepted thermal maturity parameter, **T_{max}** (in °C), which was established using the older Rock-Eval™ 2 technology.

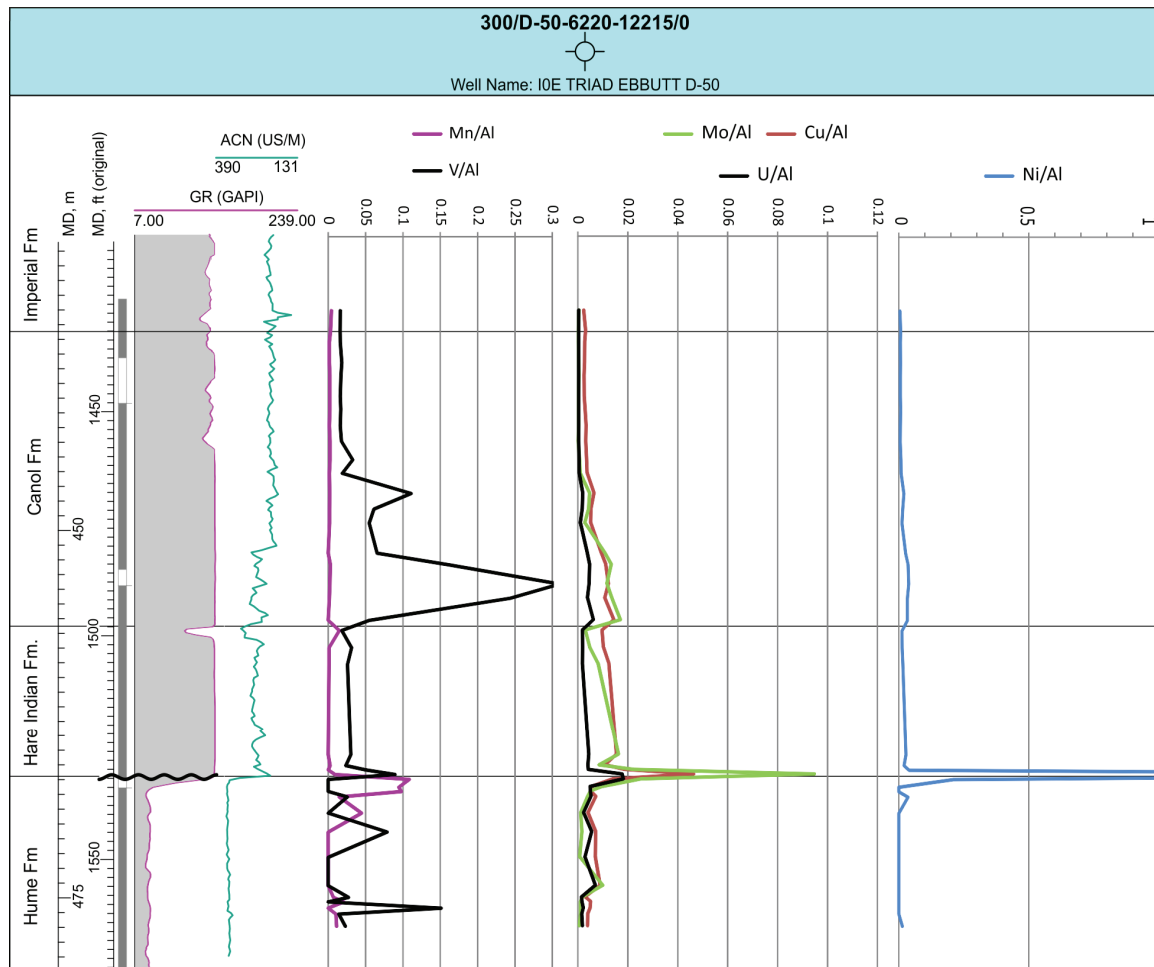


Figure 4. The Horn River Group in Ebbutt D-50 well. Proxies for redox (Mn/Al) and anoxic conditions normalized to alumina.

The **S3** curve corresponds to the amount of CO₂ (mg CO₂/g of initial rock) generated from organic matter during the initial isothermal heating step and the programmed heating phase up to 400°C. CO₂ generated between 400°C and 650°C is from the thermal decomposition of carbonate minerals. The Rock-Eval™ 6 instrument also records the amount of CO generated during pyrolysis and attributes various proportions to organic carbon and mineral sources, depending on sample temperature. The amount of pyrolysable organic carbon (**PC**) is determined by combining the S1, S2, S3 and CO contributions according to a specific formula. Pyrolysis mineral carbon is determined from the high temperature portions of the CO and CO₂ pyrolysis curves.

Following pyrolysis, samples are transferred to an oxidation oven where they were linearly heated from 300°C to 850°C to determine the amount of residual organic carbon (**RC**) and oxidation mineral carbon from CO and CO₂ generated during oxidation. The total organic carbon (**TOC** in weight %) is the sum of the pyrolysable and residual organic carbon. Similarly, mineral carbon (**MINC**) is the sum of the pyrolysis and oxidation mineral carbon.

Carbon and oxygen stable isotope analyses

The carbonate samples for $\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ ([Appendices 8, 9, 10, 11, 12, 13, and 14](#)) have been run at the G.G. Hatch Isotope Laboratory of the Faculty of Science (Earth Science) of the University of Ottawa. Samples were weighed into exetainers, 0.1 mL of H₃PO₄ (S.P. 1.91) was added to the side, exetainers were capped and Helium-flushed while horizontal. Reaction at 25.0°C for 24hrs (calcite) or 50.0°C for 24 hrs (dolomite) was followed by extraction in continuous flow. The measurements were performed on a Delta XP and a Gas Bench II, both from Thermo Finnigan. Analytical precision (2 sigma) is $\pm 0.1\text{‰}$.

Five samples for $\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ from the lower Landry Formation of the Kugaluk N-02 wells, including a thick paleosol at 1166.3 m (3826.4 ft.), have been run in both calcite ([Appendix 9](#)) and dolomite ([Appendix 10](#)) modes. These samples represented a mixture of calcite and dolomite in roughly equal proportion, and match between calcite and dolomite results was excellent for $\delta^{13}\text{C}$ (pearson $r = 0.99866184$) and reasonably good for $\delta^{18}\text{O}$ (pearson $r = 0.63582039$).

RESULTS

Raw data reported herein are currently under study. Certain preliminary observations are discussed below.

Horn River Group and Ramparts/Canol boundary

There were very few representative cored sections of the Hare Indian and Canol formations until recent exploration activity in the central Mackenzie Valley (Hayes, 2011). Most black-shale cores in the central Mackenzie Plain represented a few basal meters of Canol Formation on top of the Kee Scarp Member (e.g., Morrow Creek J-71 and Norman Wells P32X). The most complete cored sections repeatedly appeared in the literature are Kugaluk N-02 and Ebbutt D-50 on northern and southern extremities of the study area and away from the prospect area of the central-southern Mackenzie Plain ([Figure 1](#)).

Geochemical logs through the thin (30.5 m) black-shale section of the Ebbutt D-50 well ([Figures 3 and 4](#)) show a stratigraphic pattern that will allow for a subdivision of the Horn River Group in that section. [Table 2](#) (for a Microsoft® Office Excel® 2010 version of [Table 2](#), it is located in the “[of7840\tables](#)” directory as [of 7840 tab02.xlsx](#)) shows relative abundance of elements and their correlation matrix. More detailed stratigraphic subdivision, correlation, and reconstruction of sedimentary environments based on new data are subjects of the ongoing study.

A 9 m thick section of the Canol Formation recovered from Maida Creek G-56 well has also repeatedly appeared in publications as a unique section of a carbonate-platform slope. Most recently data from Maida Creek G-56 were published by Gal and Pyle (2012). The geochemical character of the Ramparts/Canol boundary through a so-called “Allochthonous member” of the Ramparts Formation is shown on [Figure 5](#). This thin (5 m) unit represents an apron of bioclastic debris shed downslope from the Kee Scarp carbonate bank (“Kee Scarp reef” in many publications; Muir et al., 1984; Kaldi, 1989; Al Aasm and Azmi, 1996). The dark shale matrix of calcarenites of the “Allochthonous member” shows more terrigenous material than the overlying Canol Shale, which is expressed in negative excursion in SiO_2/Zr and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ([Figure 5](#)). Trace metals (U, V, Mo, and Cu on [Figure 5](#)) are mostly bound in siliciclastics as suggested by negative excursion in their values normalized to Al^{3+} . These logs also indicate that the environment of allochthonous debris deposition avoided permanent anoxia.

Husky Little Bear N-09 ([Figure 6](#)) and Husky Little Bear N-64 are new cored sections from the exploration campaigns of 2011-2013 (AANDC, 2014) that became available to the public in 2014. More wells with cored Horn River Group are being released in 2015.

Headless Member of Hume Formation

The Headless Member is a regionally traced shale-rich lower part of the Hume Formation sometimes regarded in the formation status (Gal et al., 2009; Morrow, 2012). Observed lithofacies features in core from Kugaluk N-02 indicate an offshore character with suppressed bioturbation ([Figure 7](#); Kabanov, 2013, 2014). The spatial extent of this “headless drowning horizon” remains unknown until more observations from other sections are collected.

New geochemical data from the Headless interval of Kugaluk N-02 well indicate elevated aluminosilicate content ([Figure 8](#)), unequivocally pointing to terrigenous source. The Headless member is also characterized by elevated dolomite content (MgO curve on [Figure 8](#)). Manganese does not reach significant concentrations (max. 90 ppm of MnO), however, its negative covariation with anoxia-sensitive trace metals such as Cu, Pb, Zn, Ni, and V ([Figure 8](#) and [Table 3](#) ([Table 3](#) is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab03.xlsx](#)) may be an indication of moderate Mn accumulation in response to reduction-oxidation fluctuations at or just beneath the seafloor. Flat Al^{3+} -normalized logs for trace metals and essential absence of U ([Figures 9 and 10](#)) indicate that anoxia has not been achieved and that trace metals showing elevated values on [Figure 8](#) are mostly bound in siliciclastics. This combined visual and geochemical character of the Headless Member indicates that sedimentary conditions favorable for organic matter accumulation have not been achieved despite seafloor drowning.

Table 2

	Si	Al	Fe	Ca	Mg	K	Ba	Ti	Na	V	Zn	Mn	P	Sr	Rb	Ni	Zr	Cr	Mo	Cu	Ce
Si	1																				
Al	-0.3	1																			
Fe	-0.6	0.3	1																		
Ca	-0.5	-0.4	-0.1	1																	
Mg	-0.6	-0.3	-0.1	1	1																
K	-0.4	1	0.3	-0.4	-0.3	1															
Ba	0.1	-0.4	-0.1	-0	-0.1	-0.3	1														
Ti	-0.4	0.9	0.3	-0.3	-0.1	0.9	-0.4	1													
Na	-0.3	0.8	0.3	-0.5	-0.4	0.8	0	0.8	1												
V	0.7	-0.5	-0.5	-0.2	-0.3	-0.5	0.1	-0.6	-0.4	1											
Zn	0.6	-0.3	-0.5	-0.1	-0.2	-0.4	0.1	-0.5	-0.3	0.9	1										
Mn	-0.6	0.2	0	0.7	0.7	0.2	-0.5	0.4	-0.1	-0.4	-0.3	1									
P	0	0.2	-0	-0.2	-0.2	0.2	-0	0.3	0.5	-0	0	-0.1	1								
Sr	-0.6	-0.3	-0.1	0.9	0.9	-0.3	0.3	-0.3	-0.3	-0.3	-0.1	0.5	-0.2	1							
Rb	-0.3	1	0.2	-0.4	-0.3	1	-0.3	0.9	0.7	-0.4	-0.2	0.1	0.2	-0.3	1						
Ni	0.5	-0.5	-0.2	-0.3	-0.4	-0.5	0.4	-0.6	-0.2	0.6	0.5	-0.7	-0	-0.2	-0.4	1					
Zr	-0.5	0.8	0.4	-0.1	-0	0.8	-0.3	0.9	0.8	-0.6	-0.5	0.4	0.5	-0.1	0.7	-0.6	1				
Cr	-0.2	0.9	0.1	-0.5	-0.3	0.9	-0.3	0.9	0.8	-0.3	-0.3	0.1	0.3	-0.4	0.9	-0.4	0.8	1			
Mo	0.5	-0.7	-0.2	-0.1	-0.2	-0.7	0.5	-0.8	-0.4	0.4	0.3	-0.7	-0	-0.1	-0.7	0.9	-0.6	-0.6	1		
Cu	0.2	-0.6	0.1	-0.1	-0.2	-0.5	0.6	-0.6	-0.2	0.2	0.2	-0.7	0.1	-0	-0.6	0.8	-0.4	-0.5	0.89	1	
Ce	-0.5	0.9	0.4	-0.3	-0.2	0.9	-0.3	1	0.8	-0.7	-0.6	0.2	0.4	-0.2	0.9	-0.6	0.9	0.9	-0.6	-0.4	1

Pearson correlation matrix for elements composing the lower Imperial-Horn River shale section of Ebbutt D-50 well. Elements are sorted by their maximum values (largest values on the left of axis X). Only elements with maximum values ≥ 50 ppm are included. [Table 2](#) is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab02.xlsx](#).

Table 3

	Ca	Si	Al	K	Fe	Mg	Ti	Na	Ba	Mn	P	Sr	Zr	Rb	V	Cr	Zn	Ce	Ni
Ca	1																		
Si	-1	1																	
Al	-1	0.9	1																
K	-1	0.9	1	1															
Fe	-0.8	0.8	0.8	0.8	1														
Mg	-0.8	0.7	0.7	0.7	0.7	1													
Ti	-1	1	1	1	0.8	0.7	1												
Na	-1	0.9	1	0.9	0.8	0.6	0.9	1											
Ba	-1	1	1	1	0.8	0.7	1	1	1										
Mn	0.5	-0.5	-0.5	-0.6	-0.2	-0.2	-0.5	-0.4	-0.5	1									
P	-0.5	0.6	0.4	0.5	0.6	0.3	0.5	0.4	0.5	-0.3	1								
Sr	0.8	-0.8	-0.8	-0.8	-0.6	-0.6	-0.8	-0.8	-0.8	0.4	-0.5	1							
Zr	-0.8	0.9	0.7	0.7	0.7	0.6	0.8	0.7	0.7	-0.4	0.8	-0.6	1						
Rb	-1	0.9	1	1	0.8	0.7	1	1	1	-0.5	0.4	-0.8	0.7	1					
V	-1	0.9	1	1	0.8	0.7	1	1	1	-0.5	0.4	-0.8	0.7	1	1				
Cr	-1	0.9	1	1	0.8	0.7	1	1	1	-0.5	0.5	-0.8	0.7	1	1	1			
Zn	-0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.4	0.4	-0.3	0.2	-0.3	0.5	0.4	0.4	0.4	1		
Ce	-0.8	0.9	0.8	0.7	0.7	0.4	0.8	0.8	0.8	-0.3	0.6	-0.6	0.8	0.7	0.7	0.8	0.4	1	
Ni	-0.8	0.8	0.8	0.8	0.9	0.6	0.8	0.8	0.9	-0.3	0.5	-0.6	0.6	0.8	0.8	0.8	0.4	0.6	1

Pearson correlation matrix for elements composing the Headless Member of Kugaluk N-02 well. Elements are sorted by their maximum values (largest values on the left of axis X). Only elements with maximum values ≥ 50 ppm are included. [Table 3](#) is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab03.xlsx](#).

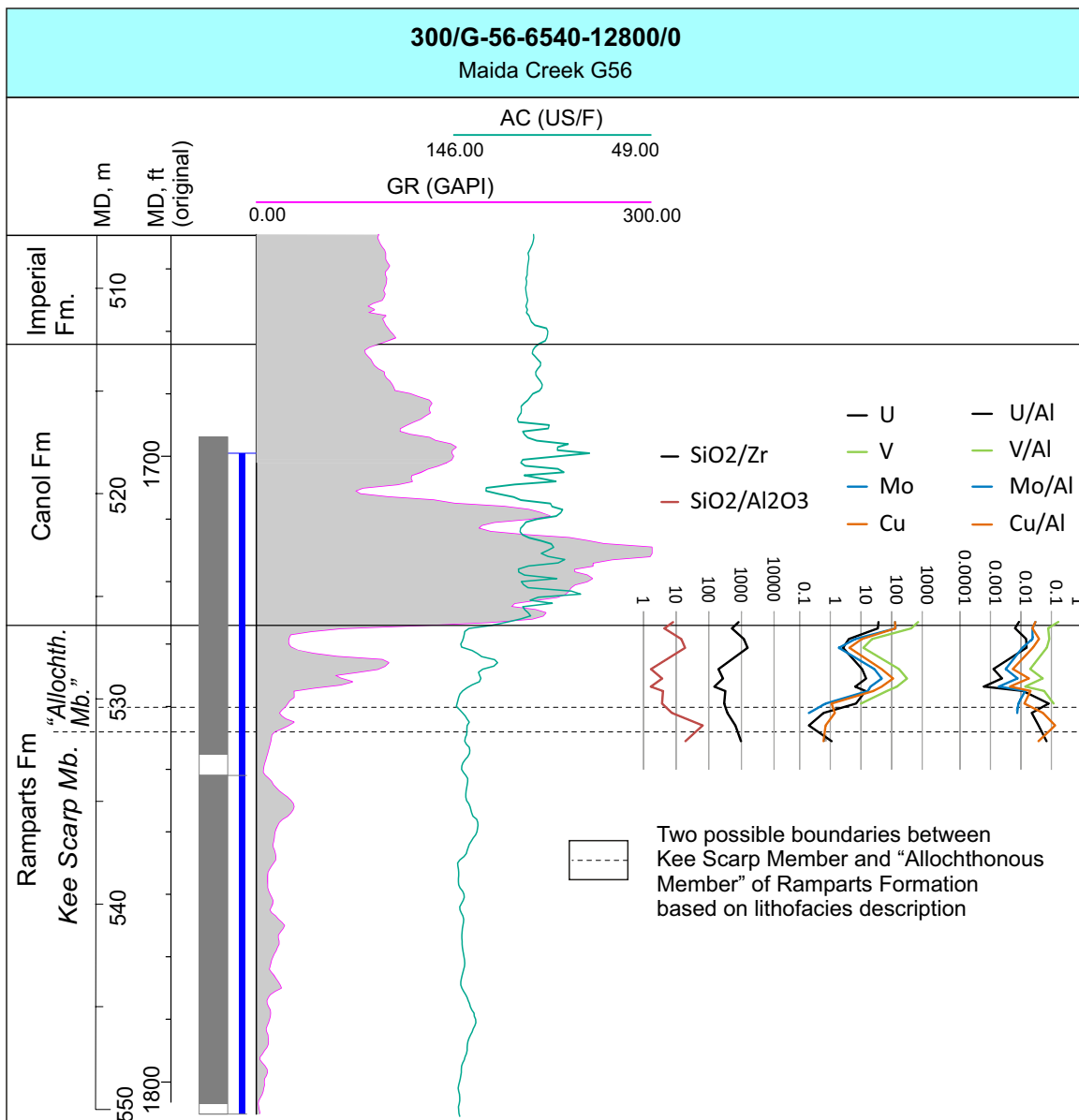


Figure 5. Maida Creek G-56. Selected geochemical logs across the Ramparts/Canol boundary based on new ICP-MS/ES data.

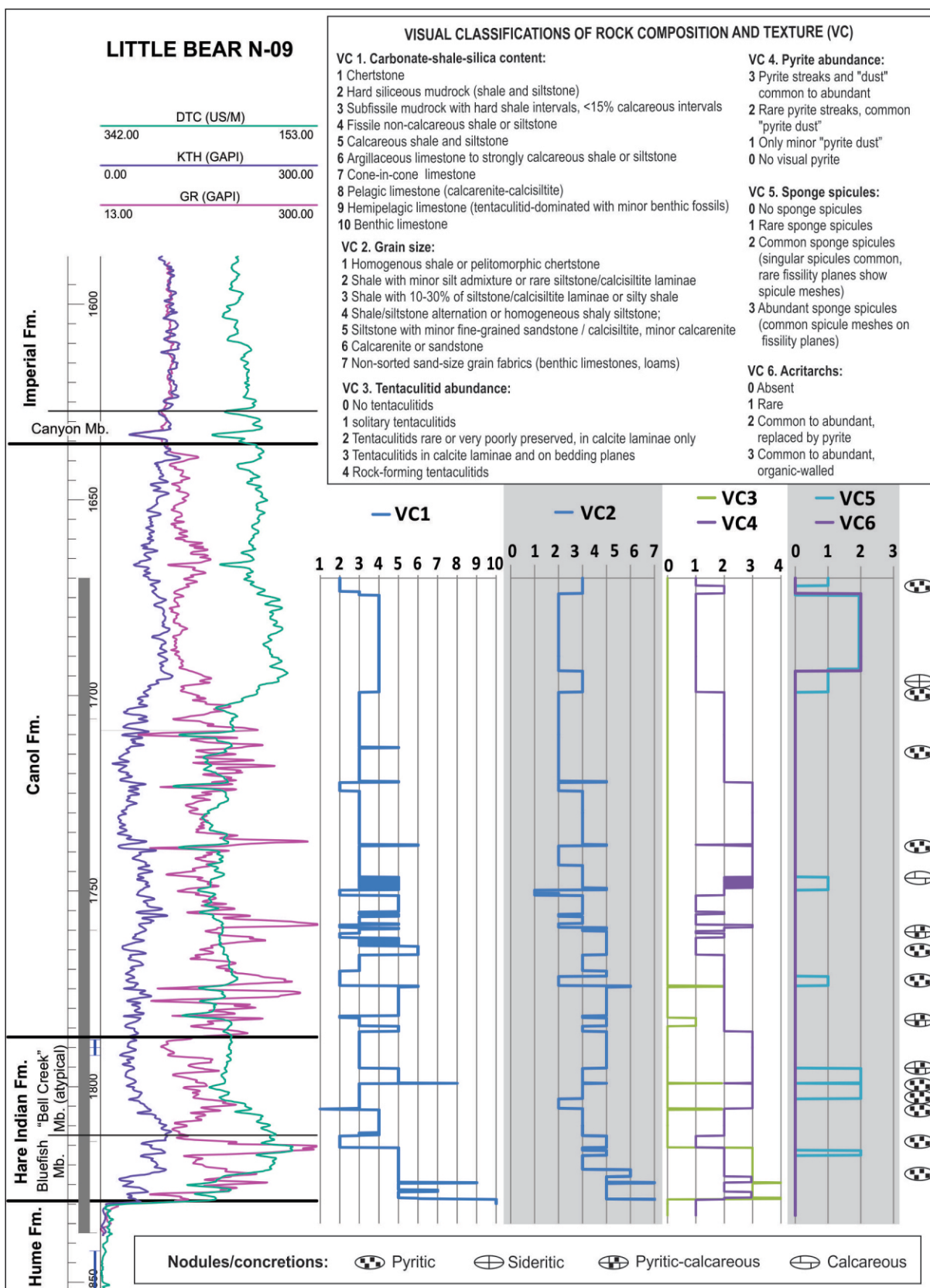


Figure 6. Cored section of Little Bear N-09 well. Borehole wirelogs and lithofacies striplog.

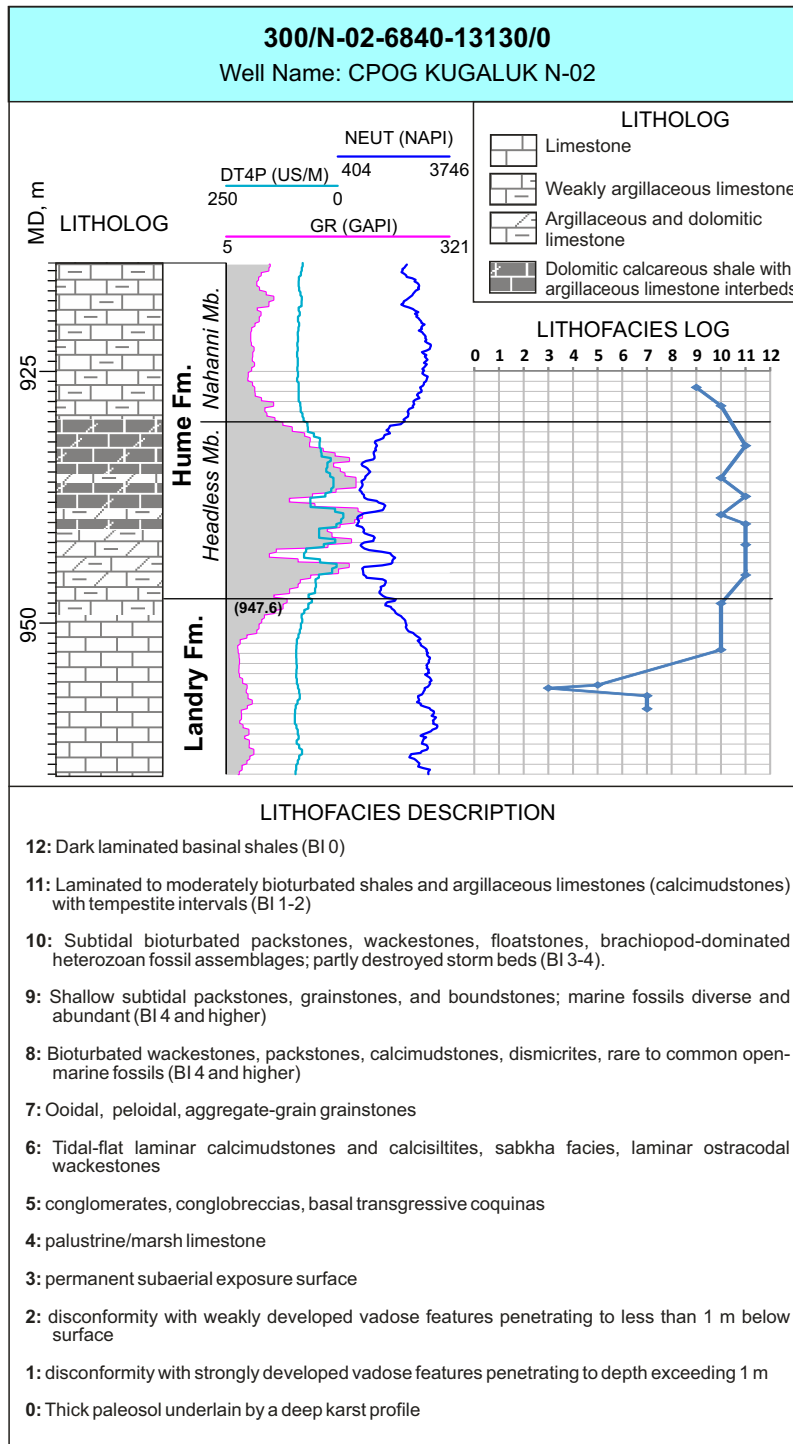


Figure 7. Headless Member of Hume Formation in Kugaluk N-02 well. Lithofacies log interpreted from published earlier core description (Kabanov, 2013). The system of lithofacies and ranks of subaerial surfaces (disconformities) are updated from (Kabanov, 2014). BI refers to Bioturbation index (Taylor et al., 2003).

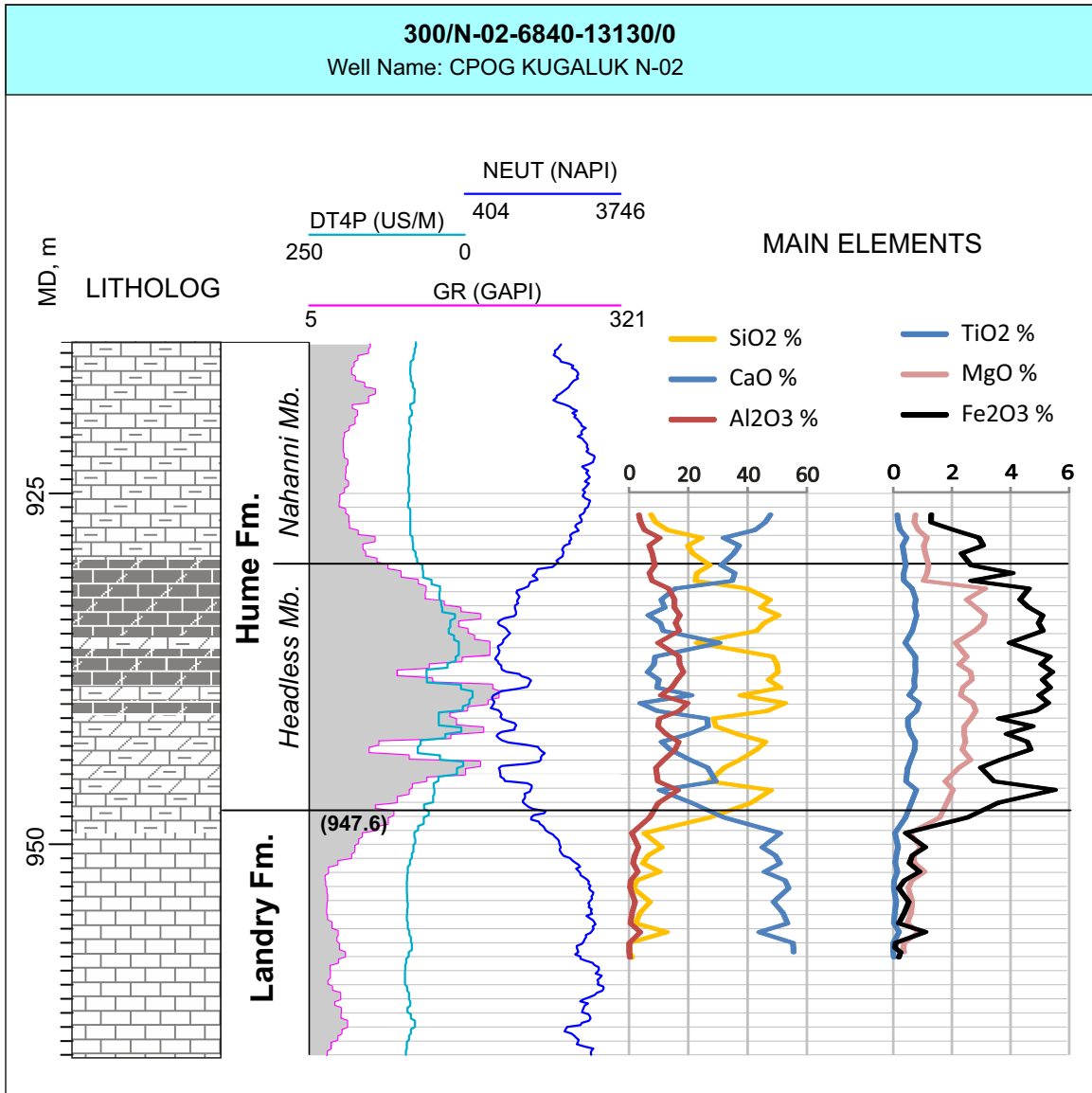


Figure 8. Headless Member of Hume Formation in Kugaluk N-02 well. Geochemical logs of main rock-forming elements. TiO₂ is given as terrigenous source proxy.

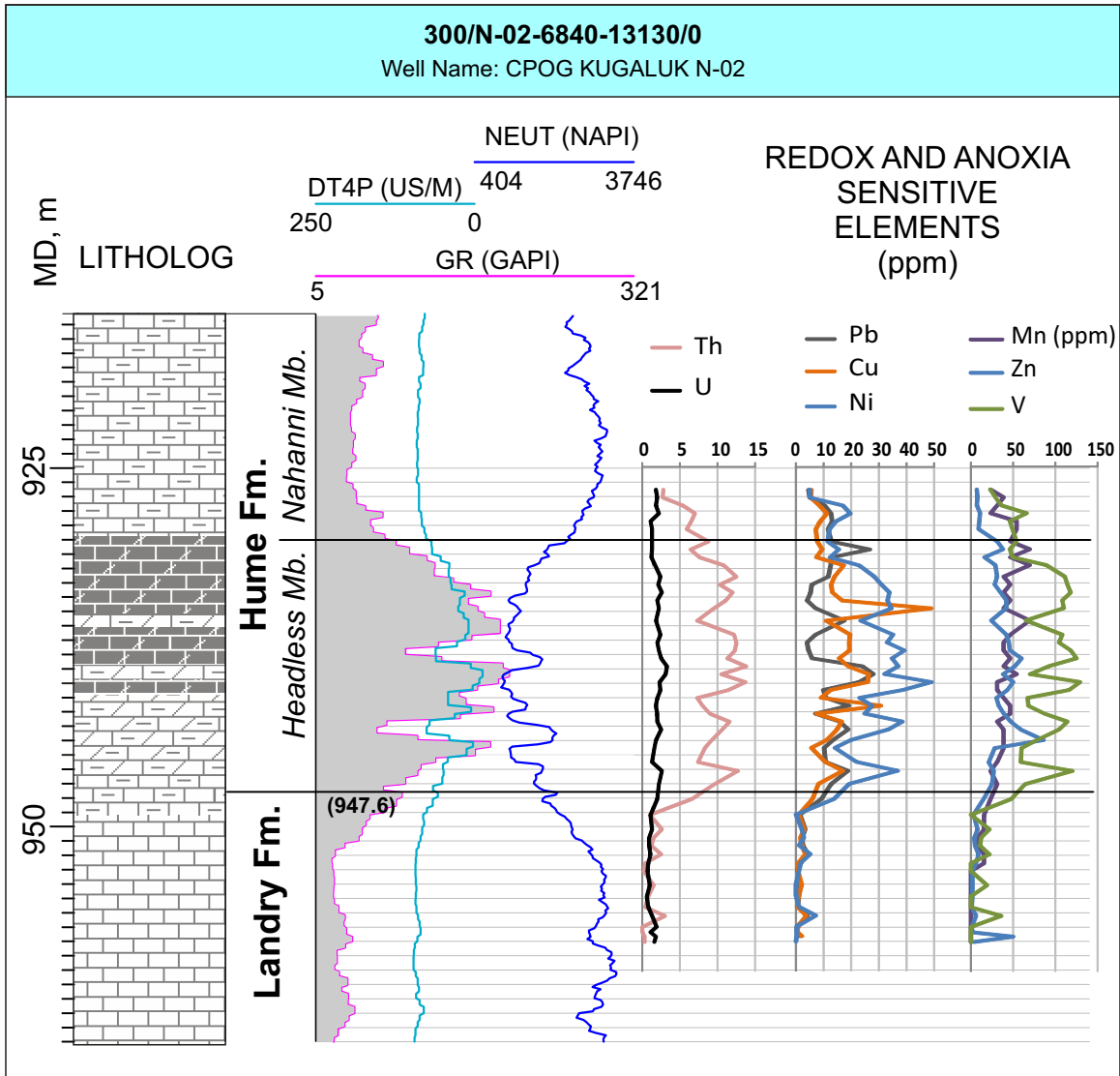


Figure 9. Headless Member of Hume Formation in Kugaluk N-02 well. Logs of characteristic trace metals.

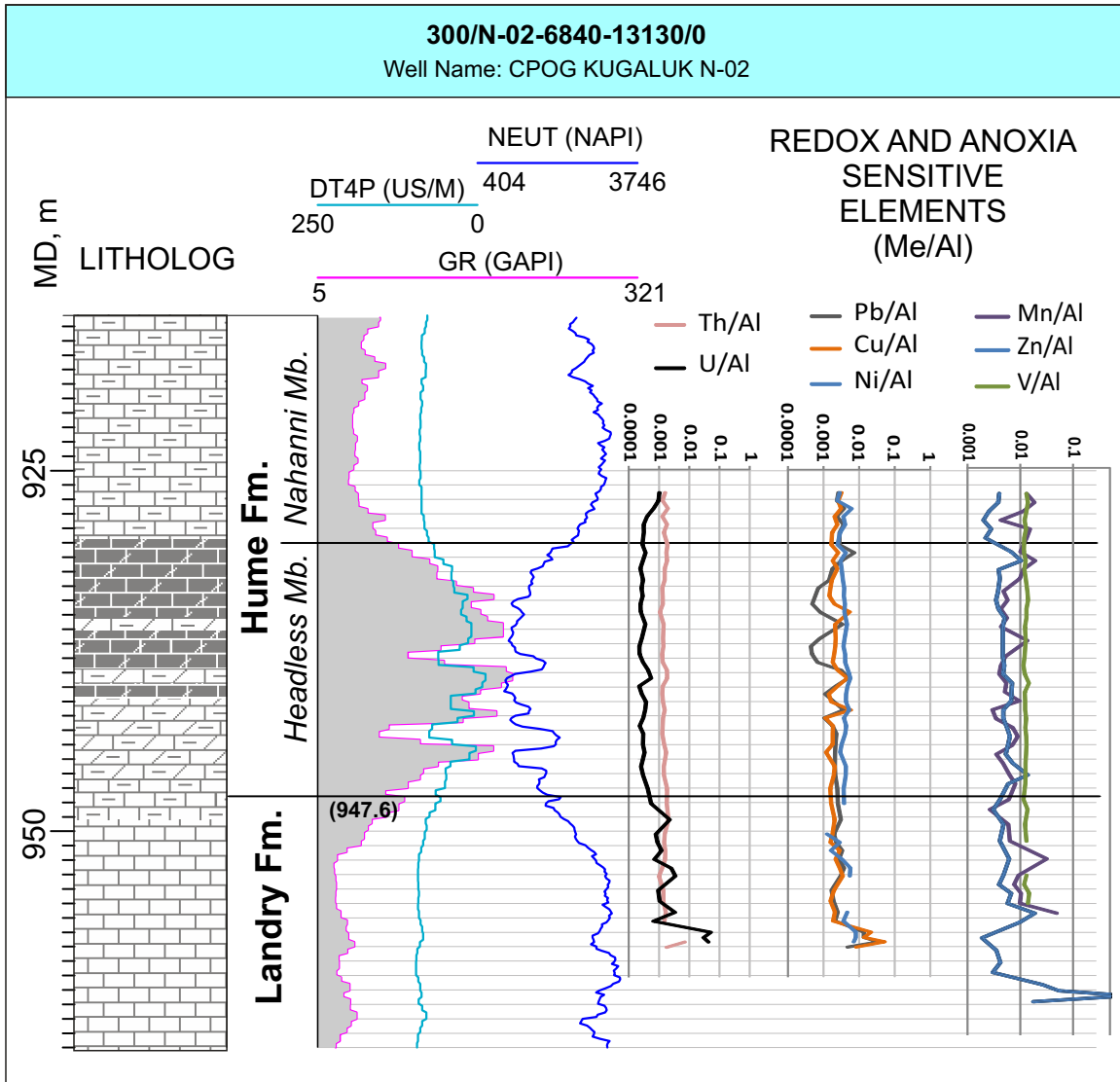


Figure 10. Headless Member of Hume Formation in Kugaluk N-02 well. Logs of characteristic trace metals normalized to Al³⁺. Featureless curves indicate that permanent bottom anoxia has not been achieved during the Headless sea-level highstand and that trace metals mostly reside in siliciclastics.

Subaerial Surfaces in Lower Devonian peritidal carbonates

The shallow-water carbonate packages (Peel, Tatsieta, Arnica and Landry formations and partly Hume Formation) contain hundreds of subaerial exposure surfaces ([Figure 11](#)). Although meter-scale cyclicity in this succession was known for many years (Morrow, 1991; Gal et al., 2009), permanent subaerial exposure surfaces have not been recognized. Visually these surfaces range from incipient stratigraphic discontinuities with solution vugs to paleokarst profiles of several meters in thickness and occasionally preserved rubbly paleosols (Kabanov, 2014). Paleokarsts are usually imprinted on tidal-flat laminites and in the Landry Formation are associated with thin shallow-water carbonate beds without marine fossils interpreted as palustrine facies (Kabanov, 2014). The succession of subaerial exposure surfaces and highstand intervals with relatively thick and conformable offshore intervals define a hierarchy of T-R sequences/parasequences ([Figure 11](#); Kabanov, 2014). The distinctive horizons in this succession, such as major highstands and major disconformities ([Figure 11](#)), can potentially be traced over long distances to augment the conventional lithostratigraphic framework.

The visual diagnostic features for subaerial exposure surfaces in the Arnica-Landry succession are shown on [Figures 12](#) and [13](#) and are discussed in more detail in (Kabanov, 2014). A set of stable isotope, Rock-Eval™, and geochemical analyses have been done from the shallow-water intervals in the Arnica-Landry succession containing subaerial exposure profiles ([Appendices 4, 5, 8, 9, and 10, and 14](#)).

The preliminary examination of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data from Landry limestone shows two main clusters, one from Dahadinni 2M-43 and another from Kugaluk N-02. However, systematic offsets between three major facies groupings are not observed ([Figure 14](#)). Sedimentary features from the sampled core of the Landry Formation were quite similar in both wells, but Dahadinni 2M-43, located in the Root Basin, has shown thicker sedimentary cycles and more severe late diagenetic imprint visually expressed in tectonic deformation and intense dolomite veining (Manetoe facies). This observation suggests that isotope composition of the Landry limestone in Dahadinni 2M-43 might have been pervasively altered. After exclusion of Dahadinni 2M-43 samples, the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values in marine and paleosol/paleokarst subsets lack any covariation (both Covar and Pearson functions very close to 0).

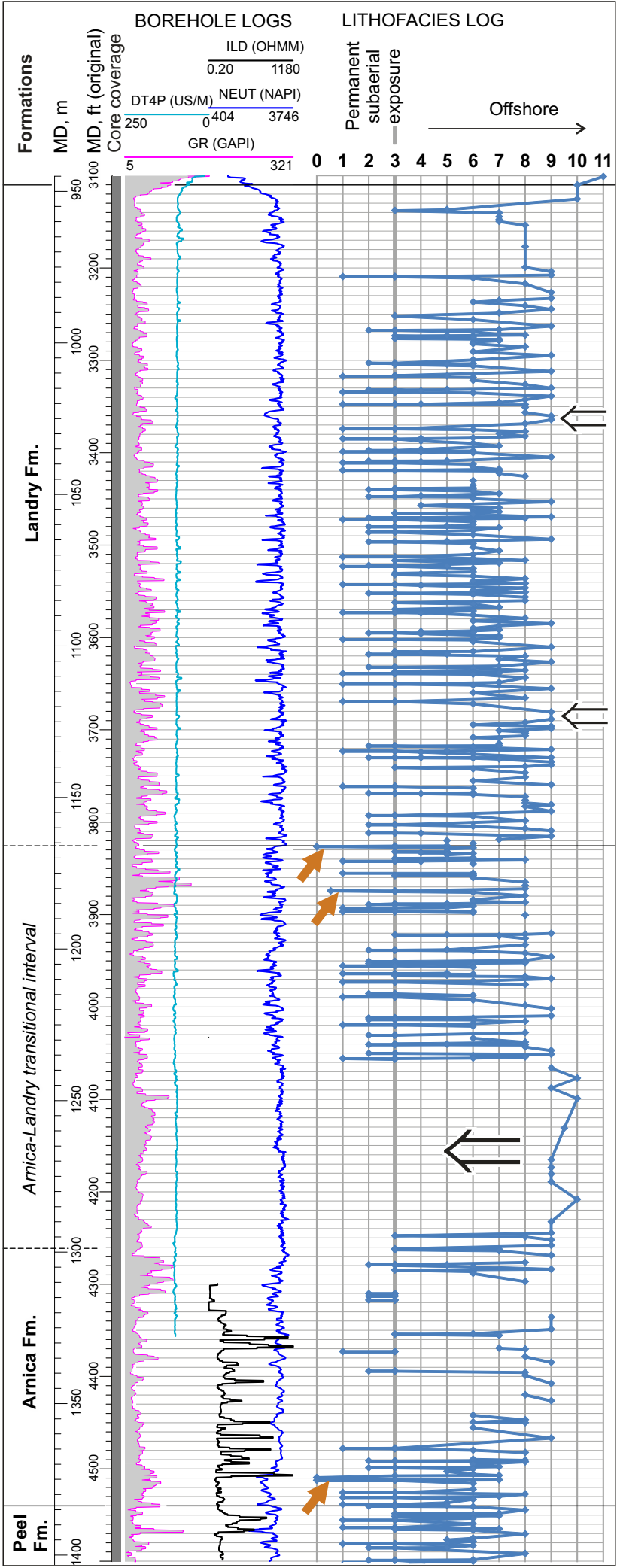


Figure 11. A lithofacies log for the Arnica-Landry succession of Kugaluk N-02 Well (partly published in Kabanov, 2014). The core is not adjusted to borehole logs; measured depth (MD) follows box markings found in the Well file. On the Lithofacies log, each facies point represents a mid-point of the descriptive interval, and most subaerial disconformities represent plain surfaces as they have no thickness. Lithofacies groups and ranks of subaerial disconformities are listed on Figure 11. Gaps in joint line indicate intervals with lost sedimentary structure due to fabric-destructive dolomitization and/or fractured "lost core" intervals. Black hollow arrows indicate prominent highstand intervals with thick offshore lithofacies and no disconformities. Orange arrows indicate deepest subaerial exposure profiles with preserved paleosols (Rank 0 disconformities of Kabanov, 2014).

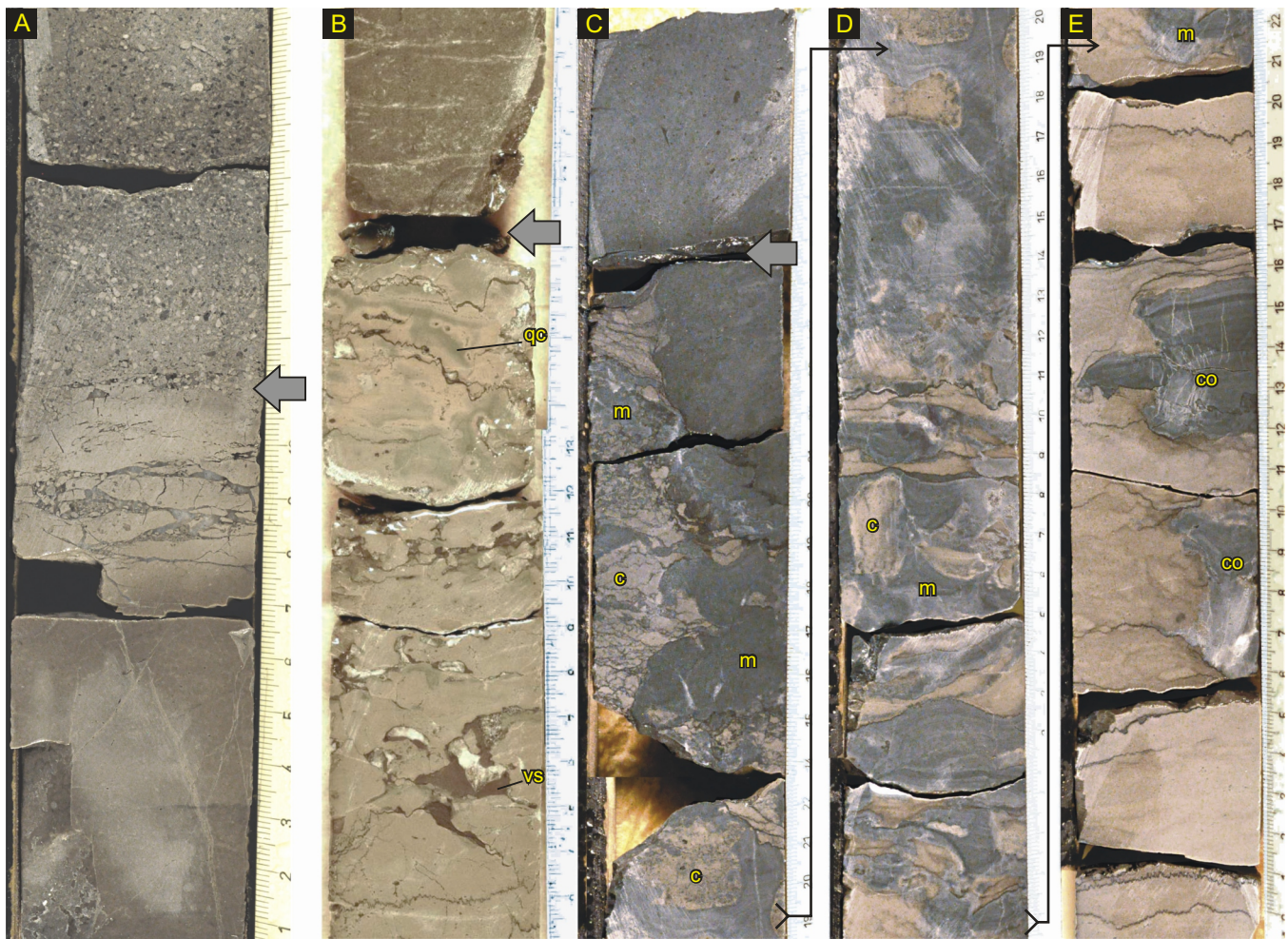


Figure 12. Paleosols and paleokarsts of Arnica-Landry succession, Kugaluk N-02 Well: A) A truncated paleokarst with brecciated top, overlain by a thick lithoclastic calcarenite (rank-2 or moderately developed disconformity with a shallow paleokarst profile), 1200.4 m (3938.2 ft.) MD. B) A paleokarst of rank 1 (well-developed vadose features, bedrock karstified to a depth exceeding 1 m), 978.3 m (3209.6 ft.) MD; top of this paleokarst is not preserved. C-E) A thick floatbreccia in claystone matrix identified as a paleosol of probably rank 1 or 0; overlapping of images is indicated by arrowed lines; 1180.8 m (3874.15 ft.) MD. Disconformity surfaces on (A-C) are marked by gray arrows. Ruler to the right of each core in millimetres. Ranking of subaerial exposure profiles according to Kabanov (2014).

A, B) A thick dolomitized paleosol at 1166.0 m TVD, close-up of a clay-rich (A) and clay-poor (B) horizons with matrix (m) and clasts (c). See (Kabanov, 2014) for the description and images of the entire paleosol profile.

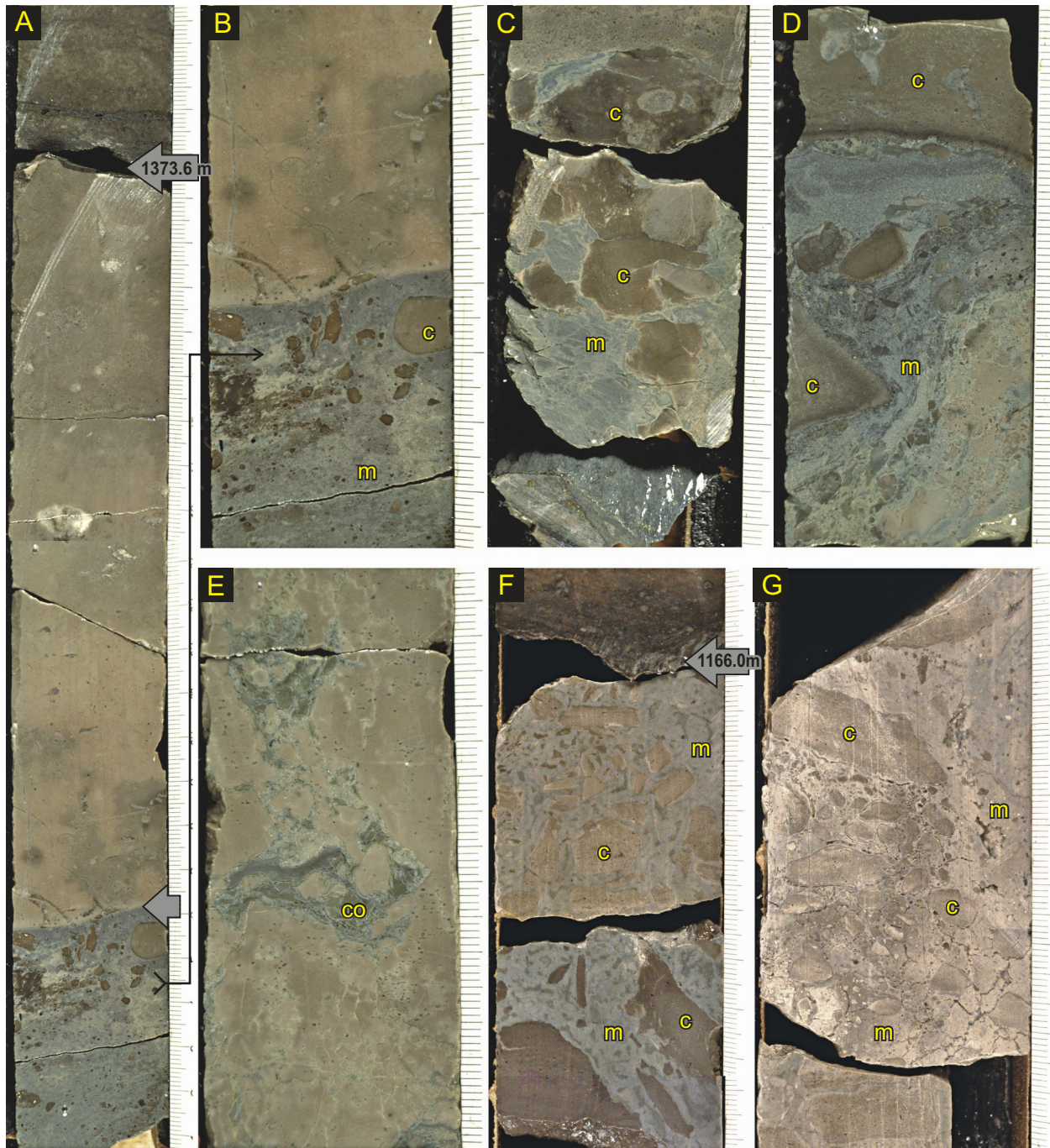


Figure 13. Details of thick paleosols of Arnica-Landry succession, Kugaluk N-02 Well (rank 0 subaerial exposure profiles of Kabanov, 2014): A-E) A composite paleosol developed on thoroughly karsted limestone from 1373.6 m (4506.4 ft.) down to at least 1386.2 m (4548 ft.): A) Paleosol top (gray arrow), the interval of the “upper limestone” (between upper and lower gray arrows), and the top of pedogenic dolomitized claystone grading to floatbreccia. The arrowed base of the “upper limestone” may correspond to a marine incursion on top of already formed paleosol. B-E) Close-up views: B) Dolomitized pedogenic claystone with residual limestone clasts; C) karst floatbreccia with thick slickensided claystone matrix, 1373.9 m MD; D) floatbreccia with dolomitized claystone matrix showing crudely laminar aspect typical of pedogenic coatings, 1376.9 m; E) karsted limestone with thick claystone infiltrations (pedogenic coatings), 1379.7 m. F-G) Paleosol at 1166.0 m MD (gray arrow), close-up views of an upper clay-rich (F) and lower clay-poor (G) horizons. See (Kabanov, 2014) for the description and additional images of this paleosol profile. On all images (m) are paleosol matrix, (c) residual bedrock clasts, and (co) are intra-cavern pedogenic coatings.

The three robust facies groupings include marine lithofacies, palustrine lithofacies, and paleosols/paleokarsts (Figure 14). The paleosol/paleokarst subset includes karstified bedrock (shallow-marine, usually peritidal carbonate facies altered in permanent vadose environments), three samples from the “vadose silt” (dark colored geopetal calcite deposit in solution vugs of paleokarst profiles; Figure 12B), and two samples from the paleosol matrix (Figure 15). Here the matrix refers to argillaceous or argillaceous-carbonate rock component, normally hosting residual bedrock fragments, developed in upper parts of thickest subaerial exposure profiles (Figure 13). These upper horizons of weathering profiles, or paleo-topsoils, exclude deeper infiltrations of pedogenic clay (argillaceous coatings) found in solution cavities (Figure 13E). The two samples from the argillaceous-carbonate matrix of a paleo-topsoil retrieved $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values within the range of karstified bedrocks and closer to heavier edge on the $\delta^{13}\text{C}$ axis, which is quite different from younger Phanerozoic and recent paleosols where pedogenic carbonate is usually depleted in ^{13}C due to its sequestration by terrestrial vegetation. However, more isotope data from paleosols are needed for reliable conclusions.

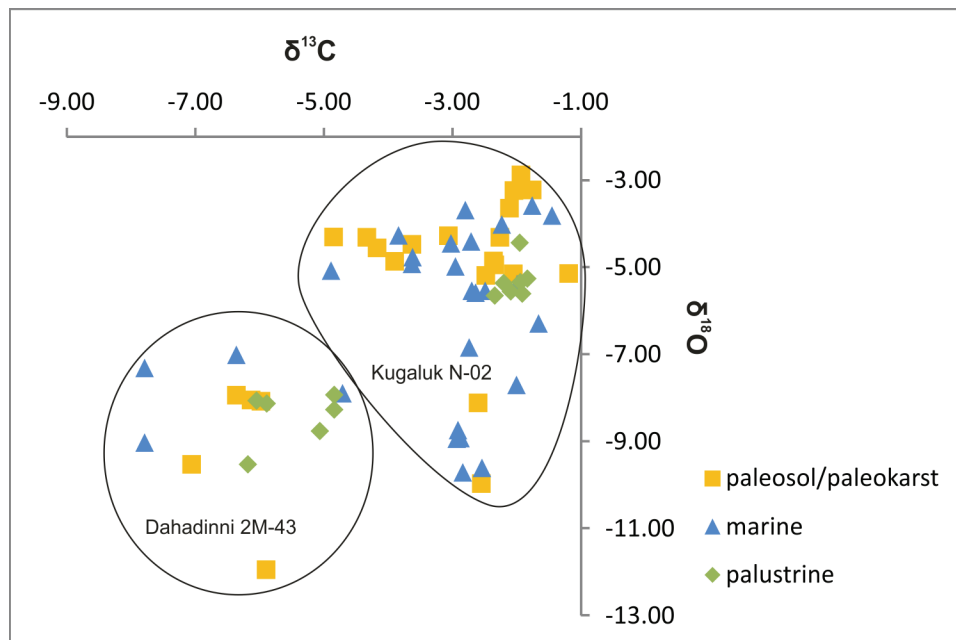


Figure 14. A cross-plot of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ for marine carbonate facies vs. subaerial exposure profiles vs. palustrine carbonate facies (data from Landry Formation of Kugaluk N-02 and Dahadinni 2M-43).

Grouping of $\delta^{13}\text{C}$ - $\delta^{18}\text{O}$ results into subtidal and intertidal subsets also fails to retrieve a systematic offset pattern (Figure 16). The subtidal group includes bioturbated and variously fossiliferous limestones (lithofacies 8-9), whereas the intertidal group contains laminites, often with buckled and disrupted lamination, poorly to non-fossiliferous, with occasionally preserved teepee structures and network of desiccation cracks (lithofacies 6 of Kabanov, 2014).

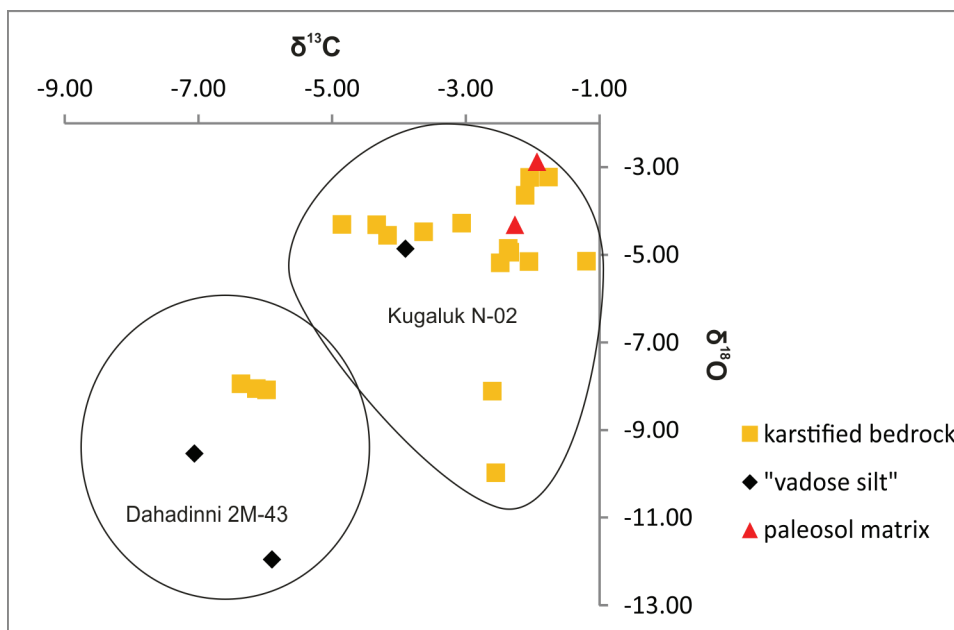


Figure 15. A cross-plot of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ for samples from subaerial exposure profiles (data from Landry Formation of Kugaluk N-02 and Dahadinni 2M-43). Samples are classified into the karsted bedrock, "vadose silt", and the paleosol matrix (Figures 12 and 13).

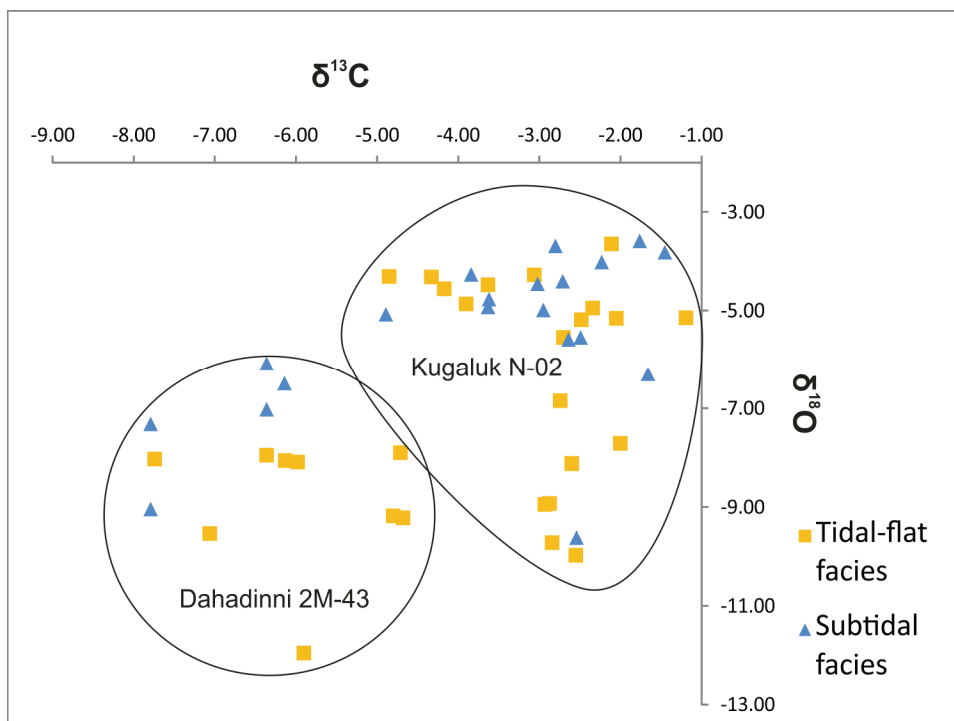


Figure 16. A cross-plot of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ for subtidal bioturbated vs. tidal-flat laminated facies (data from Landry Formation of Kugaluk N-02 and Dahadinni 2M-43).

Carbon and oxygen isotope signatures of Devonian formations

The $\delta^{13}\text{C}$ signature of the Landry Formation is clustered between -5 and -1 ‰ PDB (Kugaluk N-02 only) and does not seem to depend on facies or subaerial alteration of a sample (Figures 14, 15, and 16). The $\delta^{18}\text{O}$ values show wider range of -2.5 to -10 ‰ PDB and similarly no offsets between recognized lithofacies groupings (Figures 14, 15, 16, and 17). This lack of offset suggests that $\delta^{13}\text{C}$ signature can be time-characteristic irrespective of where (in what facies or paleosol) the sample had been collected. The samples from the Landry Limestone and the upper part of the Hume Limestone show almost complete overlap in $\delta^{13}\text{C}$. Oxygen isotope signature of the upper Hume Formation is shifted towards lighter values (Figure 17), which should be interpreted based on known dependence of ^{18}O content on temperature of ambient waters in the nearsurface (seawater or vadose) and burial (“hydrothermal”) environments.

Samples from the Kee Scarp carbonate buildup of Norman Wells P32X well are quite distinct from both Landry and upper Hume signatures by their heavier carbon (Figure 17) with $\delta^{13}\text{C}$ values found within the range of previously reported for Kee Scarp Member of Norman Wells (0.5 to 3.0 ‰ PDB; Al-Aasm and Azmy, 1996). Samples from the bioclastic calcarenite of the “Allochthonous member” are partly clustering with available samples from the in-situ carbonate bank (Figure 17; Al-Aasm and Azmy, 1996), and partly show tailing towards negative $\delta^{13}\text{C}$ values.

Three samples from a calcareous bed within the Canol Shale of Maida Creek G-56 well reveal a distinct carbon composition of -16 to -26 ‰ PDB (Figure 17). This bed is composed of authigenic microcrystalline calcite with pseudomorphs after radial coarsely crystalline aggregates (see core description). These $\delta^{13}\text{C}$ values may reflect anoxic methanogenic environment of carbonate growth.

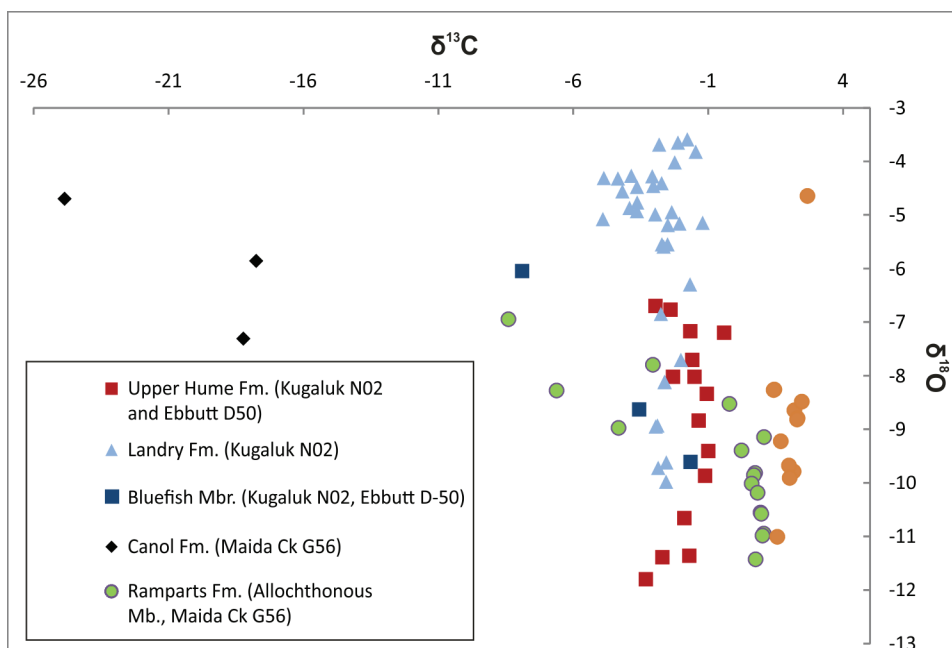


Figure 17. A cross-plot of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ for all sampled stratigraphic units. Data from Dahadinni 2M-43 showing systematic offset probably due to burial (catagenetic) replacement of carbon are excluded from analysis.

CORE DESCRIPTIONS

Kugaluk N-02

UWID: 300/N-02-6840-13130/0

Core diameter: switches from 2 inches to 1 inch at 4356.4 ft. MD.

Interval measured in 2014*: 1172.0-1569.7 m (3845-5150 ft.)*

*Notation in feet is retained in older wells reported in imperial units.

About 3 m (10 ft.) of core is missing between 1171.95 and 1175.0 m.

ARNICA (?) FORMATION

- 1175.0-1175.8 m (3855-3857.7 ft.) Dolostone with limestone patches in upper 0.4 m, limestone in lower 0.4 m: the upper dolostone is pale to dark gray, with crinkled, locally heavily contorted lamination, probably argillaceous, represents speleothem replacement/intracavern deposit; limestone patches are brownish gray calcimudstone making up 20-25% of rock and showing arcuate solution edges slightly dolomitized to depth 1-2 mm from surface; walls of small solution channels inside limestone blocks are lined with dark quasicrystalline coatings. These limestone patches represent walls of karstified host rock. The lower 0.4 m is a pale brownish gray fine-grained peloidal-calcispherical grainstone with web-like syndimentary micritic cement, grading to calcimudstone in base; minor dolomitization (1-2%) in the form of dispersed dolomite rhomboids; no macro-scale solution voids, interparticle porosity seems to be totally solution-enlarged (dispersed solution pattern). Top unknown. At the base, core incomplete, weak unconformity is possible.
- 1175.8-1177.15 m (3857.7-3862.0 ft.) Dolostone: pale gray, gradually darkens and becomes very calcareous downward from 0.8 m below top. Fabric-selective dolomitization preserved calcisphere-rich birds-eye texture with crude buckled lamination (grainstone to dismicrite). Spheres (calcispheres?) are thick-walled, 0.1-0.5 mm in diameter, agglutinated together in some laminae. In lower 0.5 m (dark gray calcareous dolostone to dolomitic limestone) sedimentary texture changes to more evenly laminated to massive (moderately bioturbated?), without fenestrae and less abundant spheres. No macrofossils. Base gradational.
- 1177.15 m-1178.75 m (3862.0-3867.3 ft.) Calcareous dolostone to dolomitic limestone: dark brownish gray, unevenly dolomitized; faintly laminated to massive (but weakly fissile) calcimudstone grading down into bioclastic wackestone with a few poorly preserved macrofossils (gastropods, brachiopod fragments). Moderate early diagenetic compaction expressed as dense network of black solution films. Base conformable or paraconformable.
- 1178.75-1179.4 m (3867.3-3869.4 ft.) Dolostone: calcareous to non-calcareous, pale brownish gray, mostly massive (upon calcimudstone?), in upper 0.18 m retaining original weakly laminated, birds-eye fabric, and in the middle penetrated by solution vugs and upright solution channels, some cemented and others empty (with drilling mud infiltrations).
- 1179.4-1180.85 m (3869.4-3874.15 ft.) Dolostone: very dark, almost black, probably moderately argillaceous, variously calcareous (residual matrix calcite between dolomite crystals), finely crystalline (50-80 µm). The primary limestone texture may be massive to weakly laminated calcimudstone. Thin weakly developed solution films. Rare fossils (spheres, "septate corals") are detected only in lower one-half of the bed; rare large (5-10 mm) solution vugs

with geopetals in upper 2/3 of the bed; laminated intervals mostly occur in lower 0.75 m; basal 0.3 m is enriched in sand-sized limestone clasts.

- 1180.85-1181.3 m (3874.15-3875.7 ft.) Dolostone-limestone floatbreccia: flattened and angular dissolved clasts of pale brown limestone in a thick matrix of bluish gray dolostone. Limestone clasts are vuggy calcimudstones, they are stylolitized and impregnated with dark mottles (sometimes distributed in a manner of quasicrystals). Matrix is vaguely laminar with laminae wrapping around limestone clasts and corroding into them. The dolomite probably replaces no less than 25% of original clasts.
- 1181.3-1183.5 m (3875.7-3882.8 ft.) Limestone: pale brownish gray, stylolitized, karstified from top, in upper 0.5 m with large solution cavities filled with the laminar bluish gray (argillaceous?) dolostone; massive, locally weakly laminated calcimudstone with bioclastic horizons in lower one-half (ostracods, gastropods). The abundance of ostracods increases to the base. Small (0.1-1 mm) "birds-eye" solution vugs throughout the bed.
- 1183.5-1184 m (3882.8-3884.6 ft.) Calcareous dolostone: pale gray, with mm-thick horizontal pinching stripes (flattened mottles) of very pale (almost white) medium-crystalline subhedral dolostone and residual windows of dolomitic limestone between these stripes. Dolomite makes up 60-70% of the rock in upper one-half and up to 90-95% in lower one-half of the interval. Texture of primary limestone: ostracodal wackestone, probably with partly preserved lamination.
- 1184-1184.5 m (3884.6-3886.0 ft.) Calcareous dolostone: dark gray, laminated, laminae composed of alternating very dark (almost black) argillaceous OM-rich dolostone, paler coarser-crystalline dolostone, and brownish-gray ostracodal limestone. Limestone occurs mostly in the lower one-half of the interval where makes up about 20-25% of the rock.
- 1184.5-1184.8 m (3886.0-3887.0 ft.) Calcareous dolostone: dark gray, with patchy dolomite replacement pattern over a bioturbated fossiliferous packstone and floatstone. Dolomite makes up to 60% of the rock, in lower one-half up to 85%. abundant ostracods, poorly preserved macrofossils (recrystallized tubular forms, cm-sized gastropods).
- 1184.8-1186.3 m (3887.0-3892.1 ft.) Dolostone: calcareous to almost non-calcareous, in the middle 15 cm of dolomitic limestone (up to 40% dolomite). Color gray to dark gray, lightens in lower 50 cm into pale brownish gray. Original texture in dolostone poorly preserved: upper 60 cm contains subrounded carbonate lithoclasts 0.5-20 mm in diameter; in 65 cm below the top possible disconformity; remains of churned-up flat-pebble stylolitized breccia just below the unconformity (poorly preserved in dolostone); limestone in lower one-half retains the texture of indistinctly laminated ostracodal wackestone (lamination even, laterally disappearing, locally seen only as horizontal orientation of bioclasts).
- 1186.3-1186.5 m (3892.1-3892.6 ft.) Dolostone: weakly calcareous, gray, retaining the texture of lithoclastic calcarenite; lithoclasts up to 2-3 mm in diameter, subangular to subrounded, their color varies from white to gray to almost black.
- 1186.5-1218 m (3892.6-3995.9 ft.) Dolostone: pale gray, in upper 40 cm darker due to dark gray buckled stripes and stylolites; sedimentary texture mostly lost, the upper 40 cm may have been originally laminated; lower part may represent original calcimudstone or wackestone.
- 1187.5-1187.7 m (3895.9-3896.7 ft.) Dolostone: brownish gray to gray, darker than above, locally with poorly preserved remains of buckled lamination and mm-sized limestone windows (micritic limestone with poorly preserved texture).
- 1187.7-1188.3 m (3896.7-3898.5 ft.) Dolostone: gray, very calcareous (40% calcite), with residual texture of limestone floatbreccia. Lithoclasts heavily corroded by dolomite, composed of light brownish gray limestone (wackestone-calcimudstone). Breccia matrix dolomitized throughout, probably significantly argillaceous. Paleokarst unconformity in top.
- 1188.3-1188.7 m (3898.5-3900 ft.) Breccia: rounded by a drill, cobble to pebble sized clasts of medium-crystalline dolostone and pale brownish gray dolomitic limestone (ostracod-rich wackestones, grainstones and calcimudstones). Open-fracture interval.

- 1188.7-1189 m (3900-3901 ft.) Limestone: pale brownish gray, ostracodal peloidal-bioclastic packstones and bioclastic wackestones with indistinct lamination preserved by 20-30%; mm-sized intraclasts of micritic limestone. Rare thin-shelled macrofossils (brachiopods or mollusks).
- 1189-1194.7 m (3901-3919.5 ft.) Breccia: small (pebble-sized) limestone and dolostone clasts rounded by a drill; very few material is available in box 506; dolostone is medium-crystalline (around 0.1 mm); limestone mostly microsparitic, dolomitized, with few preserved ostracods. Fractured zone in a formation.
- 1194.7-1195 m (3919.5-3920.7 ft.) Limestone: dolomitic, weakly nodular, dark brownish gray; dolomite distributed in patches and along dark solution seams, makes up 30% of the rock. Texture: bioclastic packstone with micro- and macrofossils (mass ostracods and other groups), bioturbated. Most diverse fossils occur in the middle, whereas in top and base gradations to ostracodal packstones with micritic matrix.
- 1195-1195.3 m (3920.7-3921.7 ft.) Dolostone: finely crystalline, non-calcareous in top to calcareous in lower one-half, probably argillaceous (especially in upper 10 cm). Texture changes from top to base: upper 13-15 cm is composed of homogeneous grey dolostone retaining some even sedimentary lamination. Below dolostone mottled (two phases of dolomite; photo), with small residual windows of brown micritic limestone; in base 3 cm of overcompacted argillaceous lithoclastic conglomerate (brownish subrounded micritic lime clasts) with about 20-30% of the rock replaced by dolomite. Base may be paraconformable.
- 1195.3-1196 m (3921.7-3924 ft.) Limestone: brownish gray, slightly lighter than above. Top sharp, overcompacted – paraconformity? Texture: dismicrite (wackestone-grainstone) with crude horizontal lamination in top 3 cm, grading downward into fine-grained rounded grainstones (oolithic?) with numerous spheres; the main part of the interval is composed of the alternation-intergradation of similar grainstones and agglutinated (clotted) micrites – apparently grainstones cemented by thick micritic cements. Regular frequent horizontal stylolites but no matrix compaction. Intraclasts present, no macrofossils. Base stylolitic, disconformable.
- 1196-1197.1 m (3924-3927.5 ft.) Limestone: pale brownish gray, weakly dolomitic in top, grading to calcareous medium-crystalline dolostone in lower 40-50 cm. Top stylolitic, the upper 15 cm show increased stylolitization. Texture: calcimudstone to wackestone mostly bioturbated, dominated by ostracods, with thin-shelled disarticulated brachiopods. Numerous spheres including charophyte gyrogonites. Rare vugs resembling birds-eye fenestrae. Mottles of pale grey dolostone in top. Small (0.2-2 mm) solution vugs. Weak matrix compaction; horizontal stylolites. Base probably conformable.
- 1197.1-1200.1 m (3927.5-3937.2 ft.) Dolomitic limestone to dolostone: dark brownish gray to dark gray, weakly fissile and may be weakly argillaceous. Peloidal-bioclastic fine to medium-grained bioturbated packstones, probably also some compacted grainstones with fitted fabric. Dolomite medium-crystalline (0.05-0.15 mm), occurs as replacive patches and horizontal stripes, makes up 40-50% of the rock in upper 40 cm and gradually grows to 70-90% in lower 2.1 m; lower 8 cm is dolostone with lost sedimentary texture and rare residual limestone windows. Macrofossils: disarticulated brachiopods in upper (limestone) part. The lower 2.1 m contain rare brachiopods and no distinct signatures of sedimentary lamination (only 'fluidality' probably resulted from pressure solution); the homogeneous dolostone fabric and rare windows of micritic limestone in these lower 2.1 m suggest original calcimudstone texture. Lower 5 cm contain poorly preserved mm-sized light-grey carbonate clasts. The dolostone is dissected by sigmoidal veins of coarse sparry calcite and locally brecciated – probably alterations associated with dolomitization. Base disconformable.
- 1200.1-1200.4 m (3937.2-3938.2 ft.) Calcareous dolostone: finely crystalline, pale gray, mimically replacing the micritic (pelitomorphic) rock with numerous sand-sized (0.2-2 mm) lithoclasts. Calcite is evenly preserved in matrix and lithoclasts (moderate and even HCl fizzing across the core face). These lithoclasts are subrounded to rounded, white, grey and almost black in color, often with even surficial rinds of different color. Matrix is bluish pale gray, mottled,

probably unevenly argillaceous, with spar-filled mm-sized vugs (very irregular dissolution walls). Lower one-half is composed of lithoclastic matrix-lean calcarenite. Base erosional.

- 1200.4-1201.8 m (3938.2-3943.0 ft.) Dolostone: pale brownish gray, fine to medium crystalline, weakly calcareous to non-calcareous, homogeneous, with rare poorly preserved biomolds after brachiopod (or mollusk) and ostracod fragments that become more numerous to the base. Locally developed are short sigmoidal spar-filled fractures and weak brecciation. Primary texture is probably bioturbated calcimudstone. In top 4 cm, dolostone preserves the texture of brecciated bioclastic bioturbated calcimudstone. Breccia of early karstic origin (packbreccia), with solution cavities floored with lithoclastic calcarenite (bed above) and cemented by clear sparry calcite.
- 1200.36-1201.83 m (3943.0-3950.6 ft.) Dolostone: dark gray, finely to medium crystalline, weakly to moderately calcareous, with fabric very similar to 1200.36-1201.83 m (only color is different). Rare poorly preserved remains of macrofossils: brachiopod or bivalve fragments, small "septate corals". In difference to 1200.36-1201.83 m, brecciation is relatively important: this is late diagenetic packbreccia, locally stylolitized, with fractures filled by milky white calcite spar, and may be genetically related to dolomitization. Rare brownish gray subangular lithoclasts in base.
- 1204.1-1204.3 m (3950.6-3951.0 ft.) Calcareous dolostone to dolomitic limestone: gray, mottled (striped) with dark and lighter gray stripes/mottles. Dolostone medium crystalline (0.1-0.2 mm), hypidiotopic, fabric-destructive. Complex fabric of rounded and elongated biomolds (some of them fenestrae?), thick geopetal sediments in these biomolds, and surrounding preferentially replaced micritic rock. Horizontal striping is imposed by horizontal orientation of biomolds or fenestrae. Important syngenetic brecciation. Geopetal sediments mostly avoided dolomite replacement, show clotted (to micropeloidal?) vaguely laminated micritic fabric. Top stylolitized, disconformable. High-amplitude crumbled out stylolite in base.
- 1204.3-1204.8 m (3951.0-3952.9 ft.) Dolostone: weakly calcareous to non-calcareous, dark brownish gray, finely to medium crystalline, massive. Sedimentary texture not preserved (supposedly bioturbated micritic limestone) except for carbonate lithoclasts that become especially numerous in base. Lithoclasts up to 2 mm in size, dark to pale gray, subangular to subrounded. Rare very poorly preserved bioclasts (crinoid ossicles?).
- 1204.8-1205.6 m (3952.9-3955.3 ft.) Dolostone: almost non-calcareous, tight, medium crystalline, pale gray in upper 15 cm and moderately darkens downward into gray. The upper 15 cm partly retains sedimentary fabric: moderately buckled uneven lamination disrupted by desiccation cracks and solution vugs; lamination disappears in basal one-half of these upper 15 cm where the rock retains most intense pre-dolomite solution vugs, some breccia, and numerous dark and pale gray carbonate clasts (up to a conglomerate texture in 15-18 cm below the top). The top is disconformable. Dolostone below is moderately stylolitized (weakly expressed nodularity), massive, enriched in lithoclasts (0.1-20 mm in size) in lower 10 cm. Thick stylolite in base.
- 1205.6-1206.4 m (3955.3-3958.0 ft.) Dolostone: very pale pinkish gray, tight, finely to medium crystalline, with poorly preserved fabric of partly laminated aggregate-grain grainstone to dismicrite in upper one-half and "microbial laminated calcimudstone" in lower one-half. Solution vugs and brecciated zones throughout the bed. Top disconformable, base likely conformable.
- 1206.4-1207.8 m (3958.0-3962.7 ft.) Dolostone: dark gray, finely to medium crystalline, massive, homogeneous, original facies features do not show. Base conformable.
- 1207.8-1208.1 m (3962.7-3963.7 ft.) Dolostone: dark brownish gray, medium crystalline, preserving the fabric of lithoclastic conglomerate (floatbreccia). Carbonate clasts are dark to light gray, subrounded to subangular, 0.5-30 mm in diameter. Base even, erosional, disconformable.
- 1208.1-1208.5 m (3963.7-3965.0 ft.) Dolostone: tight, calcareous, gray, retains most of the sedimentary texture. Top even, erosional. No compactional features except for stylolites. From top to base: (1) Argillaceous dolostone with sand-sized variegated carbonate clasts,

with vague wavy laminae (secondary, paleosol-related origin of these laminae is possible); in lower half of this interval a complex fabric of fenestrae and thick geopetal coatings-laminae ('polymud fabric') is developed; 7 cm. (2) Crudely laminar fenestral grainstone with subrounded fine to medium grained texture; grains totally dissolved/recrystallized inside (sparitic nuclei) encased in thick micritic coatings; fenestrae up to 10 mm in diameter, slightly oblate, many of them floored with bluish gray geopetal carbonate sediment; top stylolitic, base gradational; 10-12 cm. (3) dolostone vaguely laminar, finely crystalline, probably developed upon primary micritic limestone, with poorly preserved bioclasts and one convex-up large brachiopod valve; this valve is collapsed indicating significant matrix compaction - 15-17 cm.

- 1208.5-1208.8 m (3965.0-3966.0 ft.) Dolostone: argillaceous, tight, partly weakly calcareous, fabric retaining. Upper one-half consists of lithoclastic conglomerate (pale gray and blackened carbonate clasts). This conglomerate is divided in two parts by a stylolitized erosional surface: pack to float -conglomerate in top and float-conglomerate to marly rock with small half-dissolved white carbonate clasts in lower part; the latter part has micritic matrix riddled with solution vugs. The lower one-half is separated by a rugged dissolution top (disconformity) and is composed of pale brownish gray bioturbated bioclastic wackestone, very vuggy in upper 5 cm, and grading down into non-vuggy bioclastic wackestone with significant matrix compaction (collapsed brachiopod fragments) and rare large (up to 1.5 cm) light gray subangular carbonate clasts. Base paraconformable (weakly developed erosional surface).
- 1208.8-1209.3 m (3966.0-3967.6 ft.) Dolostone: brownish gray, weakly to non-calcareous, with solution vugs and minor solution breccia in upper one-half (vugs coated with black pyritized skins), with poorly preserved primary texture of bioturbated bioclastic wackestone and calcimudstone. Base gradational, by color change.
- 1209.3-1210.2 m (3967.6-3970.6 ft.) Dolostone: tight, dark brownish gray to almost black, finely to medium crystalline, with rare poorly preserved macrofossil remains (septate corals, brachiopod fragments); moderate burial-diagenetic brecciation fabric throughout the bed (may be related to dolomitization), high-amplitude stylolites. Original facies was probably bioturbated bioclastic wackestone. Base disconformable.
- 1210.2-1210.9 m (3970.6-3972.8 ft.) Dolostone: tight, gray to pale gray, weakly calcareous to non-calcareous, retaining robust sedimentary features: top rugged, upper 20-30 cm karstified, with thick black haloes around some solution channels. Stylolitized packbreccia is locally developed. Lower part has fewer but large (cm-sized) solution vugs. Sedimentary fabric is non-laminated (bioturbated calcimudstone?), with rare interbeds of vaguely laminar fenestral (birds-eye) dismicrite. One or more internal erosional surfaces. Base disconformable, enriched in sand-sized carbonate clasts.
- 1210.9-1212.6 m (3972.8-3978.4 ft.) Dolostone: tight, pale gray (in upper 10 cm), below slightly darker gray and faintly mottled. Top rugged, upper 10 cm light-colored and strongly karstified, separated by high-amplitude stylolite; solution channels are up to 10 mm in width, with some infiltrated geopetal carbonate sediment (also light-colored). The main part of the interval below is composed of finely to medium crystalline homogeneous dolostone with rare to frequent solution vugs and channels. The interval contains one or more disconformities and prominent quasicrystalline-like mottling on 1211.55-1212.19 m. Solution-enlarged thin-shelled brachiopods and mollusk biomolds in lower one-half of the interval. Sedimentary texture may comply to bioturbated calcimudstone, in lower one-half with increasingly important wackestone and ?biomorphic floatstone. Base conformable, by gradual color change.
- 1212.6-1213.7 m (3978.4-3982 ft.) Dolostone: tight, brownish gray to dark brownish gray, medium crystalline, homogeneous, with important diagenetic brecciation and rare small solution vugs in upper part. Breccia is cemented by gigantocrystalline brownish calcite. Base probably disconformable.

- 1213.7-1215.8 m (3982-3989 ft.) Dolostone: tight, medium-crystalline, mostly non-calcareous but with fractures cemented by calcite spar; light gray and riddled with small solution vugs in upper 0.61 m, gradually darkens below. A rugged disconformity in the middle with vuggy and "birds-eye" fabric extended to 0.46 m below this level. The interval is composed of two similar cycles. Important diagenetic brecciation in darker and less karstified lower portion of cycles. Even sedimentary lamination is preserved in the middle of the lower cycle.
- 1215.8-1217.8 m (3989-3995.4 ft.) Dolostone: tight, light gray, non-calcareous to calcareous, retaining solution vugs and channels and moderately buckled sedimentary lamination disrupted by desiccation cracks. Diagenetic brecciation is locally important. Top stylolitized, disconformable.
- 1217.8-1219.4 m (3995.4-4000.8 ft.) Dolostone: homogeneous, darkening to the base, with poorly preserved even sedimentary lamination at some intervals and rare very poorly preserved biomolds after macrofossils on other intervals. Lower 10 cm is very dark, compacted (dispersed solution films), probably contains minor argillaceous admixture. Base likely conformable.
- 1219.4-1220 m (4000.8-4002.5 ft.) Dolomitic limestone to dolostone: tight, brownish gray limestone with thick replacive mottles of medium-crystalline dolostone constituting 30% of rock in upper half and increasing to 60-70% to base. Sedimentary texture: bioturbated bioclastic wackestone and packstone with dense micritic matrix and severely disintegrated bioclastic material. Base stylolitic (stylobreccia), supposedly conformable or paraconformable.
- 1220-1221 m (4002.5-4005.8 ft.) Dolostone: tight, almost non-calcareous, bluish gray (argillaceous?) and finely crystalline in upper 15 cm, brownish gray and coarser crystalline below. Important multiphase brecciation throughout the interval; upper 15 cm with palimpsestic lamination and brecciation probably formed during dolomite growth. Sedimentary fabric not preserved.
- 1221-1221.3 m (4005.8-4007.0 ft.) Dolostone: tight, bluish gray to neutral gray, with breccia fabric (packbreccia to locally floatbreccia). Fragments angular, finely crystalline (microsparitic dolostone); matrix between fragments is composed of medium-crystalline (0.1-0.15 mm) brownish gray dolostone which fills fractures and corrodes into fragments. The floatbreccia patches are formed by patches and stringers of corrosive brownish gray dolostone phase ("breccia matrix"). The lower 5 cm is composed of a large fragment (or a karstified bedrock). Primary texture of the parent rock is probably a homogeneous non-laminated calcimudstone. Breccia probably marks significant disconformity or (less likely) formed by expanding growth of dolostone matrix inside diagenetically fractured substrate.
- 1221.3-1222.8 m (4007.0-4011.7 ft.) Dolostone: calcareous to non-calcareous, dark brownish gray to almost black, medium crystalline, with important diagenetic brecciation fabric. Fractures in breccia are filled with brownish coarsely crystalline dolostone (like in the overlying interval) and the post-dated phase of calcite spar. Dolostone fracture fills diminish to the middle of the interval. Large macrofossils are present: laminar to bulbous stromatoporoids, favositid corals (pachyporids?). Finer fossils or bioclastic texture has been destroyed by dolomitization. One non-replaced limestone window in 50 cm above base reveals bioturbated bioclastic packstone-wackestone with numerous amphiporas. Base disconformable.
- 1222.8-1222.9 m (4011.7-4012.3 ft.) Dolostone: pale brownish gray, finely to medium crystalline (crystals up to 0.1 mm), texture-retaining in upper 3 cm: vuggy, partly laminated bioclastic wackestone. Below the rock has floatbreccia fabric with multiphase crudely laminar dolomite injections/replacements and original rock texture preserved in very pale gray fragments (same texture as in bed top).
- 1222.9-1223.3 m (4012.3-4013.5 ft.) Dolostone: neutral gray, tight, homogeneous, finely crystalline, retaining mass sand-sized (mostly 0.2-2 mm, rare up to 5 mm) light-colored carbonate clasts. Base undulating, erosional, stylolitized.

- 1223.3-1224.2 m (4013.5-4016.4 ft.) Dolostone: light brownish gray, moderately darkens to base, finely crystalline, retaining sedimentary fabric: the upper 10 cm shows birds-eye finely buckled lamination with solution vugs and channels, below the rock is massive with rare solution vugs, probably primary calcimudstone.
- 1224.2-1225.1 m (4016.4-4019.2 ft.) Dolostone: light gray at top, grading downward to dark gray, showing depositional cycle very similar to the cycle at 1222.77-1223.28 m: karstified very light-colored tidal-flat laminite in upper 15 cm, grading down into brownish gray massive dolostone with vugs (20 cm), and below into dark gray vaguely brecciated dolostone with mass sand-sized carbonate clasts in lower 20 cm; lithoclasts locally form fining-upward subrounded grainstone beds. Base disconformable.
- 1225.1-1226.8 m (4019.2-4024.8 ft.) Dolostone: light brownish gray, weakly calcareous to non-calcareous, with rugged karsted top; upper 0.6 m is composed of vuggy tidal-flat laminite with buckled and disrupted (brecciated) lamination, the lower two-thirds of massive, partly vaguely nodular dolostone with rare solution vugs. Base diagenetically brecciated and stylolitized.
- 1226.8-1228.4 m (4024.8-4030.3 ft.) Dolostone: dark gray to almost black, variously calcareous and diagenetically brecciated, massive, locally with poorly preserved macrofossil fragments (brachiopods), and bioclasts (biomolds) showing bioturbated texture, in lower two-thirds slightly lighter colored and with cm-sized solution vugs. Base probably disconformable.
- 1228.4-1228.7 m (4030.3-4031.1 ft.) Dolostone: pale brownish gray, brecciated and stylolitized, homogeneous with rare solution vugs and rare quasiccoatings-like staining of matrix. Top and base of this core not preserved, top probably disconformable.
- 1228.7-1230.2 m (4031.1-4036.0 ft.) Dolostone: dark brownish gray to almost black, weakly calcareous to non-calcareous, with prominent preservation of microlamination. The lamination is mostly gently undulating, locally notably buckled and disrupted by desiccation cracks. Two or three discontinuity surfaces inside the interval. Stripes and patches of pale colored rock (stripes follow lamination) comprise 10-15% of the rock. Poorly preserved ostracods and very rare thin-shelled brachiopod remains.
- 1230.2-1231.3 m (4036.0-4039.7 ft.) Dolostone: dark gray to black, finely crystalline (50-100 μm), calcareous to non-calcareous, distinct from the overlying interval by lack of sedimentary lamination. Texture homogeneous, probably originally micritic (calcimudstones), with totally recrystallized unidentified macrofossil remains in lower one-half. Local catagenetic brecciation with fractures filled by milky white calcite. Top conformable, base disconformable.
- 1231.3-1231.5 m (4039.7-4040.5 ft.) Dolostone: gray, split by vertical catagenetic calcite vein, weakly calcareous, retaining the fabric of vuggy (vugs 0.1-1 mm in size), non-laminated, lithoclast-rich rock. The lithoclasts are subrounded and randomly oriented, many of them blackened. Top and base stylolitic, disconformable.
- 1231.5-1231.8 m (4040.5-4041.2 ft.) Dolostone: very pale gray, vuggy, tight, with important geopetal dark and pale gray sediments in large solution vugs, with curved upright channels 1-1.5 mm in diameter (solution-enlarged *Skolithos* burrows?). Sedimentary texture is indicated by poorly preserved randomly oriented bioclasts – bioturbated bioclastic wackestone. Top disconformable, base admitted by thick (5 cm) interval of unevenly laminated dolostone deposit with no sedimentary or subaerial diagenetic features preserved.
- 1231.8-1232.9 m (4041.2-4044.8 ft.) Dolostone: pale brownish gray (slightly darker than above), darkens to base, finely to medium crystalline (50-120 μm). Rare vugs filled with black (organic-rich) material and calcite spar; original texture very poorly preserved, only as rare thin-shell biomolds. Probably an original bioturbated calcimudstone to wackestone. Base conformable.
- 1232.9-1234.1 m (4044.8-4049.0 ft.) Dolomitic limestone to calcareous dolostone: dark brownish gray to black, with moderately and evenly compacted matrix; floatstones, wackestones, and

minor matrix-rich rudstones with diverse macrofossils: favositid and tabulate corals, brachiopod fragments, ?amphiporas, large gastropods; base disconformable.

- 1234.1-1234.4 m (4049.0-4050 ft.) Dolostone: calcareous to non-calcareous, finely-medium crystalline, pale brownish gray with rare solution vugs in upper two-thirds and dark gray in basal part. Primary facies poorly preserved: probably bioturbated bioclastic wackestones and calcimudstones.
- 1234.4-1235 m (4050-4051.8 ft.) Dolostone: calcareous to non-calcareous, brownish gray in upper one-half and gradually darkens below. Top karstic (rugged, with overhangs and sediment-filled pockets). Large (cm-sized) solution vugs throughout the bed. Original texture was totally bioturbated, bioclastic. Macrofossils are especially numerous in lower one-half, preserved as thick biomolds filled by calcite spar (corals or amphiporas) and collapsed brachiopod valves.
- 1235-1235.9 m (4051.8-4054.7 ft.) Dolostone: calcareous to non-calcareous, the upper 0.3 m is brownish-gray (intermediate lightness), below grades into dark brownish gray. The uppermost 10 cm has vague cloudy texture probably related to fabric-destructive dolomite growth. Below, even to finely buckled sedimentary lamination and birds-eye fabric is preserved down to 30-40 cm. The dark-colored dolostone below does not have sedimentary lamination, but subangular lithoclasts of lighter-colored dolostone are numerous. Sedimentary texture below the laminated fenestral interval is obscure, probably original bioturbated calcimudstone or wackestone. Disconformity in base.
- 1235.9-1236.4 m (4054.7-4056.4 ft.) Dolostone: upper 1/3 non-calcareous, with crenulated sedimentary lamination and birds-eye solution vugs cemented by sparry calcite, grading downward into brownish gray non-laminated vuggy dolostone. The lower 2/3 is composed of calcareous and probably argillaceous dolostone with complex palimpsestic texture: variegated floatbreccia (pale gray and dark gray fragments) in a cloudy matrix; it is possible that this lower interval is capped by a significant disconformity and represents the *in situ* paleosol.
- 1236.4-1236.8 m (4056.4-4057.8 ft.) Dolostone: brownish gray in upper 7-12 cm, darkens to almost black below, finely crystalline (up to 100 µm). Matrix weakly calcareous. Top rugged, dissolved, with pockets filled with dark dolostone. Sedimentary texture not preserved, probably bioturbated calcimudstone. Rare poorly preserved and randomly oriented bioclasts (ostracods, spheres, unidentified biomolds).
- 1236.8-1241.7 m (4057.8-4073.9 ft.) Limestone with dolostone intervals: alternation of dolostone and limestone in upper half, predominantly (70-80%) limestone in lower part; very dark brownish gray; bioclastic wackestones with minor calcimudstones, packstones and rudstones; no sedimentary lamination preserved, important and even matrix compaction (network of thin solution seams, moderately collapsed shells). Fossils diverse: large bulbous stromatoporans, brachiopods (bivalved and disarticulated), tabulate corals, gastropods and other mollusks, cm-sized thin-wall conic shells (tentaculites?), various thick spar-filled biomolds. Thin-wall forms incl. supposed tentaculites predominantly occur in lower 1 m of the bed. Dolomite distributed as massive mottles and rarely as dispersed "crystal dust" in micritic limestone. Basal 0.5 m dominated by calcimudstone with intercalation of bioclastic wackestone and packstone. Lower bioclastic beds show preferentially horizontal orientation of shell fragments, indicating suppressed bioturbation. Top and base conformable.
- 1241.7-1243.5 m (4073.9-4079.8 ft.) Limestone-dolostone alternation: very dark gray, almost black; calcimudstones with very rare bioclasts; even "basinal-type" lamination is preserved by 30-40%. Intraclasts of bioclastic packstone in base. No macrofossils. Dispersed pressure-solution films indicate moderate compaction. Base gradational.
- 1243.5-1248.2 m (4079.8-4095.0 ft.) Limestone: very dark brownish gray, with minor dolostone mottles and "crystal dust" of evenly dispersed dolomite crystals; bioturbated bioclastic packstones and wackestones with diverse fossil assemblages: brachiopods, amphiporids, bryozoans, gastropods, trilobites, pelmatozoans (disarticulated ossicles). Very rare

grainstone patches show isopachous cements in interparticle spaces; thick 0.1-2 mm layers of brownish radial(?) sparite in the intraskeletal cavities of larger brachiopods. Base gradational, only by partial decline of crinoid material and transition to purely micritic matrix.

1248.2-1250.5 m (4095.0-4102.6 ft.) Limestone: very dark brownish gray, micritic, unevenly dolomitized, distinct by mass brachiopod valves forming coquinas (storm beds?) and chaotically oriented accumulations. Wackestones, brachiopod floatstones, and minor packstones and matrix rich rudstones. Uneven, mostly light dolomitization throughout the interval. Macrofossils dominated by brachiopods, encountered one calcisponge (or alga?), infrequent crinoid ossicles, gastropods, trilobites, and bryozoans. Base and top conformable.

1250.5-1267.7 m (4102.6-4159.0 ft.) Limestone: very dark brownish gray, increasingly dolomitic to base (limestone-dolostone intercalation in lower 1.5 m). Bioclastic wackestone with diverse macrofossils: brachiopods, crinoid ossicles, trilobites, rare pachyporid corals, "septate" tabulates, and massive *in situ* stromatoporoids. No sedimentary lamination or marine cements except for isopachous rims in brachiopod intra-shell cavities. Basal 2.13 m is composed of alternating bioclastic packstones, wackestones, and brachiopod-mollusk coquinas. Dolomite is finely crystalline (about 50µm), comprises no more than 15-20% of the rock, distributed as mottles and "crystal dust" preferentially in micritic substrata. Transition to underlying interval very gradational.

1256.4-1267.7 m (4122.0-4159.0 ft.) Limestone: dark brownish gray, slightly lighter than above due to development of marine cements. Bioclastic packstones and rudstones (coquinas) dominated by mollusks (bivalves?) and brachiopods. Fossil assemblage also includes bryozoans, pelmatozoan ossicles, ostracods, and small trilobites. The main difference from the overlying interval is distinctly clotted matrix composed of micritic clots or micropeloids (0.2-0.5 mm in size) and light brownish gray cementing mass (primary marine cement?). No lamination except for a few cm-thick matrix-lean coquina beds (photo). Weak matrix compaction, weak nodular fabric. Base conformable, gradational.

1267.7-1271.4 m (4159.0-4171.2 ft.) Dolomitic limestone: very dark brownish gray (limestone) and brownish gray (dolostone). Dolostone finely crystalline, makes up 40-45% of the rock, distributed as thick mottles. Limestone texture: bioturbated bioclastic to biomorphic wackestones and floatstones with thin-shelled brachiopods, ostracods, pelmatozoan ossicles, mollusks, and rare favositid corals. Greater proportion of thin-shelled forms than below and above. Matrix dense micritic with very few clotted patches. Nodular fabric with thick black solution seams. Base conformable.

1271.4-1272.8 m (4171.2-4176 ft.) Limestone: dark brownish gray, with less dolomite (up to 20%). Bioturbated bioclastic packstones and minor rudstones (brachiopod-mollusk coquinas) with large *in situ* bulbous stromatoporoids, diverse corals, pelmatozoan fragments, etc. Matrix is composed of alternating dense and clotted micrites. Base conformable.

1272.8-1275.6 m (4176-4185 ft.) Limestone: very dark brownish gray, weakly nodular, with dolomite stripes and mottles not exceeding 10% of the rock. Bioclastic - biomorphic wackestones, matrix-rich packstones, and minor rudstones (coquinas). Macrofossil assemblage is dominated by brachiopods, mollusks, and large (3-4 cm) vesicular shelly fossils with recrystallized walls (photo). Matrix micritic, dense to indistinctly clotted. Base conformable.

1275.6-1278 m (4185-4193 ft.) Limestone: moderately dolomitic (20-25% of dolostone mottles), dark brownish gray, moderately nodular. Medium to coarse grained matrix-lean to matrix-rich bioclastic packstones, rudstones, and minor bafflestone. Macrofossils diverse: large *in situ* bulbous stromatoporoids, tabulate and rugose corals, brachiopods, mollusks, trilobites. Base conformable.

1278-1287.2 m (4193-4223 ft.) Dolomitic limestone: moderately to strongly dolomitic (20-40%), dark brownish gray in limestone patches and dark gray in dolostone patches, with weakly to moderately compacted matrix (indicated by collapsed thin shells). Dolomitization

increases downward. Coarse-grained matrix-rich bioclastic and biomorphic packstones, minor matrix-lean packstones. Very distinctive feature of this interval is copious (rock-forming) conical shells, apparently pelagic fossils (photo) that make up 70-90% of all bioclasts and biomorphs. Micritic matrix dense to weakly clotted. Rare large stromatoporoids and solitary Rugosa in upper 2.4 m, below only small tabulate corals and bryozoans. Common disarticulated brachiopods and pelmatozoan ossicles. No sedimentary lamination.

- 1287.2-1292.8 m (4223-4241.4 ft.) Dolomitic limestone: dark brownish gray (dolomite dark gray); biomorphic-bioclastic wackestones, minor matrix-rich packstones and floatstones; in contrast to the overlying interval, conical pelagic fossils are rare and sporadic. Dense to indistinctly clotted micritic matrix. No primary lamination. Common *in situ* thin-shelled brachiopods; mollusk fragments including small gastropods (preserved as spar-filled molds), various bryozoans (including encrusting forms). Infrequent large pachyporid corals, rare bulbous stromatoporoids. Base and top conformable.
- 1292.8-1294.6 m (4241.4-4247.3 ft.) Dolomitic limestone to dolostone: dark gray (dark brownish gray in limestone patches) bioclastic-biomorphic packstones, rudstones in upper one-half of the interval grade down into slightly finer-grained, more micritic packstones and minor wackestones. Distinct from the interval above by mass upturned (horizontal) amphiporas in upper 0.6 m and common amphiporas below. Rare *in situ* favositid corals and bulbous stromatoporoids, ?bulbous rhodophytes. A 30 cm-thick interval of bioclastic wackestone in the middle. Dolomite of the same type as above, preferentially replaces micritic components. Base not preserved in core, may (or may not) contain paraconformity or a weak disconformity.
- 1294.6-1295.3 m (4247.3-4249.7 ft.) Dolomitic limestone to dolostone: brownish gray, slightly lighter than above. Contains 40-50% of dolomite of same morphology as above. Massive bioturbated bioclastic calcimudstone with spar-filled solution channels. Bioclasts: mostly thin-shelled ostracods.
- 1295.3-1296.6 m (4249.7-4254 ft.) Calcareous dolostone: dark gray, with 70-80% of dolomite; non-replaced limestone windows show bioclastic wackestone and calcimudstone fabric and minor bioclastic packstones in base. Rare brachiopod fragments, in base corals and/or bryozoans. No sedimentary lamination.
- 1296.6-1298.9 m (4254-4261.5 ft.) Dolomitic limestone to dolostone: dark brownish gray, unevenly compacted. Dolomitized stripes are often overcompacted as indicated by collapsed shells. Bioturbated bioclastic packstones with common *in situ* pachyporid corals that are encrusted by stromatoporoids. Upturned amphiporas are locally abundant. Common pelmatozoan ossicles, brachiopod fragments, ostracods. Base strongly dolomitized, contains limestone clasts, with a thick stylolite along an erosional surface.
- 1298.9-1299.2 m (4261.5-4262.5 ft.) Limestone: brownish gray, strongly compacted (stylolitized) in upper 5 cm. Coated-grain (oid/oncoids/cortoid) rounded f/g to m/g grainstone in main lower part, in upper 7 cm transition to coarser-grained lithoclastic grainstone to rudstone (2-20 mm sized clasts). Pebble-sized coated clasts of grainstone apparently occur en masse in upper 7 cm and also in substantial quantity in the lower part of the bed. Some laminae in the uppermost 7 cm are composed of tiled essentially flat micritic flakes (reworked tidal-flat laminate). Coatings on larger grains are thick, micritic, vaguely laminated (oncoids). In the main lower part, grainstones with thin isopachous cement and weak intergrain compaction alternate with intervals where granular texture is poorly seen due to fitted fabric and/or development of micrite cement. Top and base stylolitic, probably disconformable.
- 1299.2-1299.9 m (4262.5-4264.7 ft.) Limestone: light brownish gray, in top slightly lighter than the grainstone above, moderately darkens to the base; moderately karstified from the top. Calcimudstone in upper 7 cm, grades downward into poorly sorted f/g grainstones and matrix-poor peloidal-bioclastic packstones. Gradation to wackestone in base. Bioturbation throughout the interval. Thin encrusting stromatoporoids form bindstone in 20 cm below top. Macrofossils sparse, include small upturned amphiporas, encrusting stromatoporoids,

collapsed small brachiopods, and ?small trilobites. Recognizable microfossils: ostracods and spheres. Moderate to strong matrix (intergranular) compaction, regular stylolite seams. Base probably conformable.

- 1299.9-1302.2 m (4264.7-4272.3 ft.) Calcareous dolostone: dark gray, with non-replaced windows of dark brownish gray limestone making up 30-40% of the core; lighter gray in upper 0.3 m. Dolomite medium-crystalline (0.1-0.125 mm), developed in a limestone matrix that is sometimes very dark, probably with some clay and/or OM admixture. Texture: alternation of skeletal wackestones, packstones, and bindstones built by thin lamellar stromatoporoids with minor large bulbous forms, amphiporas, and rare pachyporids. Several erosional surfaces divide the interval into fining-upward parasequences. The lower 0.76 m is composed of dolostone with thin seams of non-replaced limestone and preserved coarser reworked fragments of lamellar stromatoporoids and amphiporas. Indistinct lamination is locally preserved as indicated by horizontally oriented skeletal fragments. Medium to strong matrix compaction indicated by collapsed lamellar stromatoporoids and brachiopods.
- 1302.2-1302.7 m (4272.3-4273.8 ft.) Dolostone: gray (lighter than above and below), homogeneous, medium crystalline (0.1-0.125 mm). Primary limestone texture is not preserved except for rare small randomly oriented biomolds. Rare solution vugs may be present in upper part (unclear because of destructive dolomitization). Base with diagenetic 'flame structures' probably indicating introduction of dolomite into underlying darker-colored dolostone.
- 1302.7-1304.1 m (4273.8-4278.6 ft.) Dolostone: calcareous dark gray in upper part, grading in the middle to very dark gray and very weakly calcareous, in lower two-thirds weakly argillaceous. Distinct from the overlying interval by faint lamination formed by dark (almost black), laterally disappearing laminae or stripes. These laminae probably have increased clay content (argillaceous dolostone). Lamination is even, interpreted as subtidal and emphasized by compaction. Supposedly primary bioclastic wackestone or packstone with rare preserved amphiporas. Poorly preserved sand-sized carbonate lithoclasts in lower 0.3 m. Rare high-amplitude stylolites with thick (0.1-0.5 mm) shale linings. Base not preserved, probably disconformable.
- 1304.1-1305.9 m (4278.6-4284.5 ft.) Argillaceous dolostone: very dark gray, dark brownish gray and non-argillaceous in upper 20 cm. This uppermost part shows upright solution channels and massive texture with sand-sized light-colored carbonate clasts. This massive dolostone with solution channels rests on a rugged surface of a compacted argillaceous dolostone preserving crenulated lamination and wide desiccation cracks (30-35 cm) grading downward to argillaceous, evenly compacted dolostone (primary bioclastic wackestone) with rare lamellar stromatoporoids and poorly preserved macrofossils (mostly as biomolds). This most argillaceous part in lower 0.6 m grades into less compacted and less argillaceous calcareous dolostone preserving mass amphiporas and other macrofossils (e.g., rare pachyporid corals and bulbous stromatoporoids). Base probably disconformable.
- 1305.9-1306.9 m (4284.5-4287.7 ft.) Dolostone: mostly light gray, finely to medium crystalline. Upper 15 cm darker-colored, stylolitized, with poorly preserved syngenetically brecciated fabric. Below is dolostone light gray, medium crystalline, with gently buckled lamination in upper part and locally preserved even lamination in lower part. Rare solution vugs and unidentified bioclasts preserved as spar-filled biomolds. The basal 7-8 cm is dark (enriched in shale?), containing most diverse biomolds including lamellar stromatoporoids. Base stylolitized, erosional (paraconformity).
- 1306.9-1312.2 m (4287.7-4305.2 ft.) Argillaceous dolostone: dark gray, unevenly, mostly weakly argillaceous, unevenly calcareous to non-calcareous, with important catagenetically brecciated intervals (fractures filled with blocky calcite). Uppermost 25 cm shows distinct wavy to gently buckled lamination (alternation of pale gray and dark compacted laminae). The main interval below is composed of alternating thick (30-40 cm) laminated and non-laminated dolostones. Poorly preserved amphiporas and other bioclasts occur mostly in non-laminated intervals. Primary facies in non-laminated intervals: peloidal-bioclastic

packstones and poorly sorted grainstones. Base is enriched in shale, fissile, stylolitized, with preserved amphiporas.

1312.2-1317.2 m (4305.2-4321.4 ft.) Dolostone: pale brownish gray, massive, finely to medium crystalline, non-calcareous to weakly calcareous. Upper 20 cm darker colored, more calcareous, with faint brecciated fabric. The texture totally dia-catagenetic, probably related to displacive growth of dolomite. Karstic disconformity on precursor rock is not excluded. The main lower part contains several disconformities with solution vugs penetrated throughout. Most notable karstic disconformities occur at 1313.7 m, 1314.5 m, and 1315.8 m. Very rare remainders of sedimentary lamination, 95-98% of the interval is massive or vaguely brecciated. Base conformable, gradational.

1317.2-1318.7 m (4321.4-4326.5 ft.) Dolostone: dark gray, moderately argillaceous (indicated by some fissility), weakly calcareous to non-calcareous, finely crystalline. Bioclasts rare, poorly preserved: ostracods, echinoderm ossicles, and unrecognizable bioclasts. Primary texture probably conforms to bioturbated calcimudstone. Base diagenetic and stylolitic.

1318.7-1324.2 m (4326.5-4344.5 ft.) Calcareous dolostone to dolomitic limestone: very dark brownish gray, mottled (dolostone mottles and limestone intermottles). Sedimentary textures: alternation of bioturbated bioclastic-biomorphic wackestones, floatstones, and matrix-poor packstones. Patches of syndepositionally lithified dsmicrites. Diverse fossils: large bulbous stromatopores, amphiporas, diverse algae, brachiopods, ostracods, pelmatozoan ossicles, trilobites. The lower one-half is generally finer-grained, with overcompacted zones in limestone patches. Base diagenetic, through disappearance of limestone windows.

1324.2-1326.7 m (4344.5-4352.7 ft.) Dolostone: dark gray, medium crystalline (0.1-0.125 mm), weakly nodular (solution seams) and faintly mottled. Upper one-half is weakly to non calcareous, lower one-half calcareous and with windows of non-replaced limestone and rare limestone-dominated intervals. Texture in limestone windows: micritic, bioturbated, with thin-shelled bioclasts (wackestones and/or calcimudstones). The limestone-dominated intervals show less micritic texture with crude sedimentary bedding of thin-shelled coquinas (graded beds). Fossils: numerous thin-shelled brachiopods, ostracods, rare bulbous stromatoporoids. Base gradational.

1326.7-1327.1 m (4352.7-4353.9 ft.) Dolomitic limestone to calcareous dolostone: dark brownish gray, showing texture of partly laminated ostracodal packstones, peloidal-ostracodal grainstones, and wackestones. Lamination preserved by 40-60%. Dolomite occurs in stripes (emphasizing lamination) and as dispersed crystal 'dust' preferentially in micritic substrata. Rare limestone lithoclasts in disconformable base.

1327.1-1327.8 m (4353.9-4356.4 ft.) Limestone: brownish gray, strongly stylolitized in top, with regular stylolite seams below; alteration and intergradation of calcimudstone and vf/g peloidal grainstones; very faint sedimentary lamination alternates with massive-looking intervals. Dispersed, sub-mm sized solution vugs, but no large solution cavities. Microfossils: ostracods only.

At 1327.8 m core diameter changes from 2 in to 1 in. Well file reports on 0.9 m missing in Box 567 (1327.0-1330.15 m), most likely between 2" and 1" cores.

1327.8-1328.7 m (4356.4-4359.4 ft.) Missing

1328.7-1331.4 m (4359.4-4368 ft.) Dolostone: gray, medium crystalline (0.125-0.15 mm), non-calcareous to weakly calcareous, massive to evenly laminated. Original limestone texture is not preserved, but lamination most likely has sedimentary precursor. The lamination is composed of darker, finely crystalline compacted laminae (clay/OM admixture) and lighter-colored, coarser crystalline 'interlaminae'. In basal 0.3 m lamination is gently buckled and most distinct. Base unclear (totally replaced by dolostone).

1331.4-1331.8 m (4368-4369.5 ft.) Limestone: brownish gray (lighter than above), moderately dolomitic (dispersed rhomboids), evenly stylolitized; bioclastic-peloidal grainstones, mostly with fitted fabric, but locally held by thin isopachous cements; large disarticulated ostracods

(or thin-shelled juvenile brachiopods), very rare upturned amphiporas. Dispersed mm-sized solution vugs and enlarged intergranular pores in 5-7 cm below the top. Base conformable.

- 1331.8-1333.7 m (4369.5-4375.8 ft.) Dolostone: gray, weakly calcareous to non-calcareous, medium-crystalline, massive, faintly mottled. Septate corals and a large thin-shelled brachiopod valve are preserved only in top, below dolomitization destroyed sedimentary fabrics. Lower half is notably pale-colored and retains rare small vugs – disconformity(ies) inside the interval? Base is selected by color change.
- 1333.7-1337.6 m (4375.8-4388.4 ft.) Dolostone; dark gray, medium crystalline, weakly to non calcareous, massive in upper and lower 0.76 m and richly fossiliferous, locally brecciated in the middle part. Brecciation is catagenetic, fractures cemented by calcite spar. All macrofossils are poorly preserved as dolomite pseudomorphs and biomolds. In upper and lower massive parts, macrofossils are infrequent, some of them identified as upturned amphiporas. Sedimentary texture may conform to bioturbated wackestones and calcimudstones. The middle part is interpreted as stromatoporoid-coral bafflestones, bindstones, and matrix-rich bioclastic textures (packstones?). Identifiable fossils: diverse stromatoporoids, pachyporid corals, ?bryozoans, brachiopods, and locally cup-shaped thin-walled conical fossils. Top and base conformable.
- 1337.6-1339.2 m (4388.4-4393.8 ft.) Dolostone: dark gray, medium crystalline, non-calcareous. Alternation of laminated and non-laminated (bioturbated) intervals. The latter contain very poorly preserved fossils – ostracods and small amphiporas. Lamination even, undulating, 'flaser'. Base unclear (obliterative dolomitization), defined by gradual color lightening and decline of lamination.
- 1339.2-1340.1 m (4393.8-4396.6 ft.) Dolostone: light gray, medium crystalline, slightly darkening downward. Upper half massive, with no sedimentary textures preserved (original bioturbated calcimudstone?), with rare small (<1mm) vugs. Lower portion preserves ghostly biomolds and larger ostracods. Base conformable, gradational.
- 1340.1-1341.1 m (4396.6-4400 ft.) Dolostone: brownish gray to dark brownish gray, medium crystalline, faintly mottled (bioturbation) with rare cm-thick laminated intervals. The upper 20 cm preserves the bioclastic-biomorphic texture rich in ostracods and/or thin-shelled brachiopods (wackestone to floatstone). The lower 20 cm in a box is lighter-colored, massive dolostone similar to the overlying interval (4393.8-4396.6).
- 1341.1-1345.5 m (4400-4414.5 ft.) Dolostone: gray, calcareous, massive, medium to coarsely crystalline (0.15 mm), hypidiotopic, faintly mottled/nodular (weakly expressed solution seams and low-amplitude stylolites), contains ghost remains of coarser (>1 mm) randomly oriented bioclasts – brachiopod fragments, ostracods, pelmatozoan ossicles, ? poorly preserved stromatoporoids. Calcite resides in coarser non-dolomitized bioclasts and in matrix between dolomite crystals. Rare long upright and inclined fractures cemented by calcite spar.
- 1345.5-1346 m (4414.5-4416 ft.) Dolostone: dark gray, moderately argillaceous and calcareous, medium to coarsely crystalline, densely penetrated by black solution seams (also included into crystalline dolomite), contains rare very poorly preserved and small bioclasts. The original carbonate rock seems to be finer-grained than above and below. Base and top likely conformable.
- 1346-1348.2 m (4416-4423.1 ft.) Dolostone: medium to coarsely crystalline (around 0.15 mm), gray, in top dark gray (transitional to overlying argillaceous dolostone), hypidiotopic, moderately calcareous; alternation of bioturbated and likely partly laminated intervals. Lamination is even, emphasized by dark horizontal solution seams; bioturbation intervals are nodular. Poorly preserved bioclasts – brachiopod fragments, ostracods, ?amphiporas. Base by transition to totally bioturbated rock.

1348.2-1350 m (4423.1-4429 ft.) Dolostone: very similar to 4416.0-4423.1 m but no laminated intervals; upper 0.3 m is notably mottled, partly vaguely brecciated, probably originally bioturbated and with patchy early lithified micritic matrix. No preserved fossils.

1350-1351.2 m (4429-4433 ft.) Lost core: rounded fragments of gray weakly calcareous dolostone up to 2 cm in size.

1351.2-1352.9 m (4433-4438.5 ft.) Dolostone: medium to coarsely crystalline (around 0.15 mm), gray, hypidiotopic, calcareous, indistinctly nodular, locally dissected by thin curved catagenetic calcite veins. No obvious lamination.

N.B.: Local intercrystalline porosity (around 0.5% in average) starting from 1346.0 m downward.

1352.9-1354.7 m (4438.5-4444.5 ft.) Dolostone: medium to coarsely crystalline (0.15-0.2 mm), gray, laminated (defined by dark undulated horizontal stripes), calcareous in top to weakly and non calcareous below, hypidiotopic to minor idiotopic, calcareous, mostly porous. No fossils or obvious interpretable sedimentary structures. Lamination seems to be primary. Intercrystalline porosity resides in paler and coarser crystalline dolomite laminae/lenses (1-5%) sandwiched between tight dark gray, probably argillaceous laminae. The average porosity does not exceed 2%. An almost non-laminated interval with poorly preserved bioclasts and birds-eye fenestrae at 1353.5-1353.6 m. Thickness of laminae do not exceed 5 mm (one lamina is assigned for a pale-dark dolostone rhythm). Locally lamination resembles buckled and disrupted tidal-flat facies with flat lime mud clasts (photo). Base gradational.

1354.7-1355.9 m (4444.5-4448.5 ft.) Dolostone: gray to brownish gray, lighter than above, medium to coarsely crystalline, hypidiotopic, calcareous to non-calcareous, weakly porous (about 1%). Lamination is less developed, indicated by dark gray horizontal compacted seams; some intervals seem to be originally massive. Rare poorly preserved bioclasts (thin-shelled convex-up brachiopod valves). Top and base gradational.

1355.9-1356.1 m (4448.5-4449.3 ft.) Dolostone: laminated, weakly porous, very similar to 1352.85-1354.68 m.

1356.1-1356.4 m (4449.3-4450 ft.) Dolostone: pale brownish gray, medium crystalline, massive, with remain of a thin-shelled convex-up brachiopod valve.

1356.4-1357.7 m (4450-4454.5 ft.) Dolostone: dark gray, probably weakly argillaceous, finely crystalline (0.1 mm) in upper one-half and medium-crystalline in lower part, mottled due to thorough bioturbation pattern, with poorly preserved thick-shell bioclasts/biomolds; partly laminated interval in the middle; intercrystalline porosity of 0.5-1%. Core is fractured along upright fractures. These fractures are cemented by milky white calcite and likely have high formation porosity.

1357.7-1358 m (4454.5-4455.5 ft.) Dolostone: dark gray, hypidiotopic, finely to medium crystalline, probably weakly argillaceous, laminated (gently buckled lamination); lamination gradually disappears downward.

1358-1364.6 m (4455.5-4477.1 ft.) Dolostone: medium to coarsely crystalline (0.12-0.2 mm), dark gray, massive to mottled (expression of bioturbation), with regular subhorizontal stylolites, locally with low porosity. Ghost bioclasts are locally seen forming bioclast-rich intervals (photo). These intervals sometimes rest on erosional surfaces with finer-grained facies beneath. The best preserved erosional surface occurs at 1361.85 m (photo). Probably original alternation of bioclastic-biomorphic wackestones, packstones, floatstones, and rudstones. Bioclast-rich intervals contain numerous amphiporas and brachiopod fragments. The interval is dissected by upright and curved, tapering and widening calcite-filled fractures. The upper part (1358.04-1360.63 m) is disintegrated along upright fractures. The greatest fragmentation into cm-sized chips occurs at 1360.0-1360.3 m. This fragmentation indicated high open-fracture porosity in the formation. Very dark gray massive dolostone in base. The base erosional, disconformable.

1364.6-1364.8 m (4477.1-4477.8 ft.) Dolostone: distinctly mottled, with breccia-like fabric: pale brownish gray mottles (some of them are distinctly rock fragments) surrounded by dark gray, probably clay-enriched intermottle mass. Pale-colored mottles are coarser-crystalline (around 0.2 mm) and porous (sucrosic). One coarse (2 cm long) fragment with preserved lamination. Rare greenish clay-rich mottles. Paleosol interpretation is most probable. Top even, erosional, weakly stylolitized. High-amplitude stylolite with black shaly lining in base.

N.B.: Well file records only 1.5 m in Box 583, which is most likely a misread. Should be 1.8 or 2.1 m.

1364.8-1365.8 m (4477.8-4481 ft.) Dolostone: medium to coarsely crystalline, hypidiotopic to idiopic, locally weakly porous, brownish gray with a darkened interval at 1365.2-1365.5 m; weakly calcareous in top and base and strongly calcareous in the middle. Primary facies: laminated to non-laminated, in top with distinct buckled lamination. Retains paleokarst features: stylobrecciated rock with partly collapsed and geopetally filled vugs in upper 0.25 m; vugs are preserved throughout the interval. A blackened interval with clay-rich 'pedogenic-like' breccia at 1365.2-1365.5 m; below this breccia, an interval of strongly calcareous dolostone with very coarsely crystalline (0.2-0.3 mm) idiopic dolomite developed in brownish micritic limestone matrix (bioclastic wackestone); laminar to mottled coarsely crystalline tight dolostone below.

1365.8-1366.4 m (4481-4482.8 ft.) Dolostone: pale gray, weakly to non calcareous, standing out by complex packbreccia fabric preserved due to mimic replacement of original limestone. The packbreccia is developed upon a bioturbated fossiliferous facies with large thin-walled amphiporas, thin-shelled brachiopods, ostracods, and gastropods. Micritic finely brecciated crusts are also preserved. Breccia polygenic, with two or even three phases: syndimentary, dolomitization-related, and catagenetic. Coarsely crystalline fabric-destructive dolomite mosaic gradually restores from the middle downward to the base. The base likely followed the sedimentary discontinuity with brecciated fabric above and massive homogeneous micritic limestone below.

1366.4-1368.2 m (4482.8-4489 ft.) Dolostone: pale brownish gray, vaguely mottled, weakly calcareous, medium to coarsely crystalline (0.15-0.2 mm), with rare 2-5 cm thick laminated intervals (buckled lamination). No fossils preserved. In upper 0.3 m dolostone is slightly finer crystalline, penetrated by frequent microstylolites and partly 'overcompacted'.

1368.2-1368.4 m (4489-4489.5 ft.) Dolostone: pale brownish gray, stripy due to retained crude buckled lamination, coarsely crystalline, retaining empty vugs, probably after birds-eye fenestrae, and minor intercrystalline pores. Lamination at 10-12° angle to core perpendicular. Ghosts of tiled cm-sized rip-up clasts in base. Visible porosity is not exceeding 2%.

1368.4-1368.9 m (4489.5-4491 ft.) Dolostone: dark gray, calcareous, tight, coarsely crystalline (0.15-0.2 mm), massive, argillaceous. Shale content increases to base. The lower one-half is finer-crystalline and more argillaceous, contains brownish and darkened mm to cm sized subrounded carbonate clasts derived from the underlying paleokarst top. Top stylolitic, details obliterated by dolomitization. Rare amphipora fragments.

1368.9-1369.5 m (4491-4493 ft.) Dolostone: finely to medium crystalline, weakly to non-calcareous, mottled pale to dark gray (pale hue dominant). Original facies: non-laminated, apparently micritic (calcimudstone?). Retains paleokarst texture: karst breccia to moderately brecciated bedrock in upper one-half (stylolitized, stylobreccia), with bluish argillaceous patches in upper 10 cm (replacive and/or infiltrated paleosol clay); a large (over core diameter) solution cavity cemented by milky white calcite black occurs in the middle; "quasicoating style" mottling; lower 20 cm has breccia fabric with pale brownish gray rock fragments and dark gray matrix (float to packbreccia).

1369.5-1370.4 m (4493-4496 ft.) Dolostone: weakly calcareous to non-calcareous, very pale gray, medium crystalline, retaining birds-eye laminated fabric in upper 30 cm. Optically dense sedimentary laminae in these upper 30 cm indicate microcrystalline or opaque crystalline microfabric (sabkha facies?). Alternation of crudely laminated and non-laminated rock in

the underlying part of the interval. Numerous solution-enhanced fenestrae and/or vugs. Base by gradual darkening and disappearance of sedimentary lamination.

- 1370.4-1371.1 m (4496-4498.5 ft.) Dolostone: Medium to coarsely crystalline (0.15 m), tight, hypidiotopic, darker than above, stripy (dark staining along horizontal pressure solution seams); solution vugs probably present; no obvious sedimentary lamination; rare preserved upturned amphiporas. Basal 10 cm composed of slightly darker and more compacted dolostone with finely crystalline laminae and nodules – probably an internal sediment or ‘polymud fabric’ (photo). Base probably disconformable.
- 1371.1-1356.4 m (4498.5-4450 ft.) Dolostone: brownish gray, notably porous (intercrystalline porosity 1-5%), medium to coarsely crystalline, idiotopic.
- 1356.4-1356.5 m (4450-4450.6 ft.) Dolostone: brownish gray, tight, massive, medium crystalline, hypidiotopic. Few vugs with rugged walls – probably a solution vugs. No bioclasts preserved. Base probably disconformable.
- 1371.8-1372.1 m (4500.6-4501.6 ft.) Dolostone: Pale brownish gray, massive to moderately laminated, with few preserved fenestrae floored with geopetal blackened sediment; matrix is tight, some fenestrae contain open space. No distinct lamination. Base gradational or through a paraconformity.
- 1372.1-1372.9 m (4501.6-4504.2 ft.) Argillaceous dolostone: pigeon gray, very finely to medium crystalline in different intervals, weakly to non calcareous, retaining complex primary fabric: massive to laminated small-fenestral matrix embeds sand-sized carbonate clasts of different appearance: brownish gray recrystallized (most numerous), pale gray and blackened finely crystalline. Lamination is defined by dolomicritic finely crenulated and locally disrupted laminae. Rare ripped-up carbonate mud flakes. A 4 cm thick argillaceous limestone in base. This limestone has rounded-grain to clotted to dismicrite (“microbial-algal”) texture, weakly expressed lamination and fine syngenetic brecciation, and contains numerous brownish laminated carbonate clasts, blackened sand-sized clasts, and oncoids. Very early nearsurface lithification is indicated by lack of matrix compaction. Top likely contains one or more stylolitized discontinuity surfaces (paraconformities?). Base paraconformable.
- 1372.9-1373.6 m (4504.2-4506.4 ft.) Limestone: brownish gray, weakly argillaceous, micritic, may be partly chertified. Sedimentary texture changes from oncoidal rudstone with fitted-grain compactional fabric in top 10 cm to dismicrites with small oncoids, spheres, and minor grainstones below. Dismicrites locally grade into thromboid fabric. Rare buckled micritic laminae. Several levels with blackened sand-sized clasts and increased clay content indicate internal discontinuities. Base disconformable.
- 1373.6-1375 m (4506.4-4511 ft.) Limestone breccia: float to packbreccia in mottled green to bluish gray non-calcareous shale matrix. Limestone is light brownish gray, locally with blurred dark mottles. A thick paleosol profile. Shaly core is mostly disintegrated into flakes and crumbles. The uppermost 25 cm is a monolithic limestone (bioturbated very fine-grained peloidal grainstone to calcimudstone with ostracods). The top of this limestone is smooth, covered by a thin dark gray overcompacted shale with dark limestone clasts. Two interpretations of the upper limestone: (1) the karstic boulder in top of a paleosol profile; (3) incursive shallow-water limestone onlapping the thick paleosol and imprinted by subaerial alteration from top. The latter is favored by lack of large solution vugs and very few claystone coatings in pores. Below this upper limestone, the claystone breccia matrix has cloudy-laminar pattern characteristic of pedogenic coatings, locally dolomitized and contains brown rounded limestone clasts. The strongest dolomitization occurs in clayey matrix just below the upper limestone and in the interval base. The texture of host limestone varies between birds-eye laminite, very fine-grained grainstone, tight calcimudstone, and syndepositional conglomerate. Degree of brecciation is decreasing in lower one-half towards moderately brecciated to monolithic limestone with solution vugs and claystone stringers. Argillaceous and calcareous dolostone in base retains rare

carbonate clasts (dark and light colored), rare amphiporas, and rare poorly preserved bioclasts indicating transgressive erosion of the underlying paleosol.

1375-1375.3 m (4511-4512 ft.) Limestone: brownish gray, monolithic, riddled with mm-sized solution vugs (some of them contain argillans). Very fine-grained peloidal grainstones to packstones with ostracods. Significant stylolitization.

1375.3-1377.2 m (4512-4518.3 ft.) Limestone: brownish gray, mottled, weathered, brecciated, with local claystone-cemented breccia similar to 1373.55-1374.95 m. Claystone matrix is greenish to bluish gray, unevenly dolomitized (crystals of 0.1-0.15 mm in size dispersed in shale matrix). Thick claystone coatings occur in larger solution cavities. Sedimentary texture: birds-eye laminite with buckled lamination and some teepee structures, very fine-grained grainstone with ostracods, and tight massive calcimudstone. The difference from 1373.55-1374.95 m is more dolomitized and more distinctly laminated claystone matrix.

1377.2-1379.3 m (4518.3-4525.3 ft.) Anhydritic limestone: mottled brownish gray, weathered, birds-eye laminites interbedding with rounded peloidal – coated-grain grainstones; upper 20 cm dominated by medium to coarse grained (0.3-0.5 mm) grainstone. The limestone is fractured and riddled with solution-enlarged voids. Anhydrite finely crystalline, milky white, makes up 5-20% of the rock, occurs as bands/ laminae in fractures and larger fenestrae. Different from the overlying interval in very few claystone patches (only minor stringers and concentrations in overcompacted zones). Red-colored staining (streaks) along fractures in 10 cm above base (hematite preservation?). Weathered lithoclastic calcarenite in base.

1379.3-1380.2 m (4525.3-4528.3 ft.) Brecciated limestone: brownish gray, mottled (black staining), slightly lighter-colored in lower 2/3. The upper 30 cm is completely disintegrated stylolitized packbreccia with green claystone infill, below grading into moderately brecciated bedrock. Limestone has calcimudstone to bioclastic wackestone texture with no distinct lamination. Bioclasts: ostracods and fusiform biomolds 0.2-0.25 mm in size; Claystone infills locally show lamination and geopetal pattern (pedogenic sediments and coatings). Base by change in sedimentary texture.

1380.2-1380.8 m (4528.3-4530.3 ft.) Limestone: brecciated, brownish gray, vaguely mottled, weathered, with greenish claystone coatings and stringers. Sedimentary texture: alternation of peloidal-intraclastic grainstones, birds-eye laminites, and medium to coarse grained lithoclastic grainstones. The latter texture becomes dominant to the base and is formed by blackened and pale colored rounded limestone clasts. The basal 10 cm is also enriched in reworked clay (marly matrix). Base erosional, disconformable.

1380.8-1380.9 m (4530.3-4530.6 ft.) Limestone: mottled multiphase packbreccia of limestone, stylolitized, penetrated by braided shale seams that locally swell into claystone chambers (layered pedogenic coatings)

1380.9-1382 m (4530.6-4534.2 ft.) Limestone: very pale brownish gray calcimudstone brecciated from the top and penetrated by a network of claystone stringers. Local stylobreccia. Calcimudstone massive to weakly laminated (crenulated lamination), grading to partly laminated ostracodal wackestone in base.

N.B.: Extensive clay illuviation starting from 1373.5 m downward.

1382-1383.2 m (4534.2-4538 ft.) Limestone: weakly argillaceous and locally weakly anhydritic, pale gray to greenish gray (because of greenish shale stringers), finely nodular. Upper 0.3 m is coarse-grained (0.3-0.7 mm) rounded lithoclastic grainstone composed of very light to dark gray colored micritic lime clasts. Below syndepositionally brecciated fenestral laminite intercalated by intraclastic-lithoclastic grainstones. Rounded cm-sized intraclasts of grainstones indicate multiple reworking. Circumgranular cracks are common. Some fenestrae have solution aspect (vugs?). Clay makes up marly mm-thick intervals. Larger cavities show geopetal sediments with three main layers: (1) thin greenish to white shale (earliest), (2) thick sucrosic anhydrite, and (3) upper cavity filled by clear coarsely crystalline calcite spar. Base disconformable, admitted by increased clay content and larger (cm-sized) dark colored clasts of micritic limestone.

- 1383.2-1383.8 m (4538-4540 ft.) Limestone: weakly argillaceous and weakly anhydritic, pale gray. The upper one-half is finely brecciated and karsted massive calcimudstone with thick greenish clay coatings and geopetal sucrosic anhydrite; downward gradation into vaguely fissile light greenish gray limestone with layers of sand-sized to gravel-sized rounded micritic lithoclasts. No distinct fossils. Base probably disconformable.
- 1383.8-1385.9 m (4540-4547 ft.) Limestone: brownish gray in upper 0.3 m, below light brownish gray. Ten cm thick brecciated tidal-flat laminite in top; below massive stylobrecciated calcimudstone with massive texture; brecciation is karstic. Solution vugs contain thick green laminated clay coatings. Water-repelling core face indicate oil impregnation, however, without visible porosity. In lower one-half brecciation wanes to regularly stylolitized calcimudstone with rare fenestral laminated intervals. Randomly oriented ostracod valves in massive calcimudstone. Base likely conformable.
- 1385.9-1386.2 m (4547-4548 ft.) Argillaceous limestone: light brownish to greenish gray, with more argillaceous (greenish) lower part. Grainstone lithoclastic medium-grained with frequent coarse grains (dark and pale colored); reddish authigenic inclusions; the rock microbrecciated with dense network of anhydrite(?) filled cracks. Base disconformable.
- 1386.2-1387.1 m (4548-4551 ft.) Limestone: gray, a rhythmic interval composed of birds-eye laminite in upper one-half grading to cross-laminated rounded peloidal-lithoclastic grainstones in lower one-half. The upper laminite part has buckled and disrupted lamination and consists of the alternation-intergradation of peloidal grainstones, clotted/lacy micrites, and dense micritic laminae. The lower grainstone is medium to coarse grained (0.2-0.6 mm) in different laminae, composed of rounded micritic grains (pale gray and dark brownish gray) that in finer-grained laminae are bound by micritic cements. Birds-eye fenestrae are locally present, some of them floored by milky sucrosic anhydrite. The upper laminite is stylolitized. No distinct clay coatings but pressure solution seams are lined with green clay. Base not preserved, probably ravinement/paraconformity.
- 1387.1-1388.4 m (4551-4555 ft.) Limestone: pale brownish gray in upper 0.95 m, slightly darker in basal 0.3 m. The upper 0.95 m are composed of massive, rarely weakly laminated, bioclastic-peloidal wackestones, packstones, and clotted and tight calcimudstones. The bioclastic material is represented only by thin-shelled ostracods and fusiform (seed-like) biomolds (to be identified). A 4 cm thick bed in the middle of the interval is enriched in green shale and contains rare limestone clasts. The darker colored lower 0.3 m contains rare solution vugs and fenestrae floored with sucrosic anhydrite. The basal 3-4 cm is composed of a graded bed of the coarse lithoclastic grainstone in base and overcompacted marl with lithoclasts in top. Very rare small coatings of green claystone associated with stylolites. Base likely disconformable.
- 1388.4-1390.8 m (4555-4563 ft.) Limestone: pale gray, stylolitized, tight; moderately karstified. Solution cavities occur throughout the interval, include sub-mm scale solution vugs and very rare larger collapsed vugs with green laminated shale coatings or geopetal sediments. Sedimentary texture: upper 0.6 m is laminar calcimudstone with gently crenulated lamination and very small, solution-enlarged fenestrae; below is alternation of massive and laminated calcimudstone and minor bioclastic (ostracodal) wackestone. The basal 0.46 m is dominated in laminar calcimudstone with buckled and disrupted laminae; larger vugs in this lowermost portion are floored with milky white sucrosic anhydrite. Base likely conformable.
- 1390.8-1391.1 m (4563-4564 ft.) Argillaceous limestone: gray, partly weakly fissile, with greenish shale component showing as densely braided network of pressure solution films. Lithoclastic grainstones and packstones with fitted fabric, composed of subrounded fine to medium grained (0.18-0.35 mm) pale and dark gray limestone clasts. Matrix-rich (shaly) intervals complying to packstones alternate with matrix-poor grainstones. Rare buckled lamination. Base not preserved, apparently disconformable.
- 1391.1-1391.4 m (4564-4565 ft.) Limestone: weathered and stylolitized massive bioclastic wackestone in top, grading downward into pervasively compacted (fitted-fabric)

recrystallized grainy texture, probably original grainstones. Solution seams are lined with light salad colored shale. Upper wackestone is riddled with small solution vugs, contains ostracods and tiny seed-shaped biomolds. Base strongly stylolitized, can be an erosional surface.

- 1391.4-1393.9 m (4565-4573 ft.) Limestone: pale brownish gray, tight; karstified and stylolitized massive ostracodal calcimudstone. Large (mm-sized to over core diameter) solution cavities are collapsed under pressure and filled with thick green non-carbonate shale. Rare upright dolomitization zones developed along smaller clay-filled cavities. Upper 0.6 m contain intervals with lamination undulating at high angle – domal stromatolites? Base conformable.
- 1393.9-1394.8 m (4573-4576.2 ft.) Limestone: very pale brownish gray, with even to gently crenulated lamination. Laminae are up to 1-2 mm thick have normally graded aspect (photo) In base lamination is thicker and less distinct. Bioclasts: ostracods, seed-shaped biomolds, very rare amphiporas. Dispersed small spar-filled solution vugs and very rare collapsed shale-filled voids.
- 1394.8-1394.9 m (4576.2-4576.6 ft.) Limestone: dark brownish gray, weakly anhydritic (veins of sucrosic anhydrite), indistinctly coarse-grained, micritic, with mm to cm-sized pebbles of micritic limestone. Only 4 cm core is preserved, top and base unknown.
- 1394.9-1395.8 m (4576.6-4579.4 ft.) Limestone: pale brownish gray, tight; recrystallized (microsparitic) laminar calcimudstones, in top 10 cm non-recrystallized birds-eye laminite with numerous micritic intraclasts; intraclasts, buckled and disrupted lamination and teepee structures are common throughout the interval. Regular stylolites along lamination planes. Base not preserved, likely conformable.
- 1395.8-1396.2 m (4579.4-4580.7 ft.) Limestone: gray, weakly argillaceous, in basal 10-15 cm argillaceous and compacted (fissile). Poorly sorted fine to medium grained peloidal-lithoclastic grainstone. Limestone lithoclasts are normally coarser-grained (0.3-1.0 mm), variegated (pale gray to brownish gray to almost black). The basal argillaceous part comply to lithoclastic packstone (gravel-rich marl). No distinct fossils. Important unconformity in base.
- 1396.2-1397.3 m (4580.7-4584.3 ft.) Limestone: brownish gray in top to gray below, brecciated (strongly karstified) from top with imprinted strong stylolitization (stylobreccia). Sedimentary texture: massive calcimudstone with thin-shelled ostracods, laminated calcimudstone in basal 10 cm. Floatbreccia with non-carbonate green shale matrix in uppermost 10 cm, packbreccia to disrupted bedrock below. Solution vugs are usually collapsed and filled with thick laminated green shale. This shale contains residual brown limestone crumbles. Down the profile, green shale forms thick coatings (argillans). Dark mottling (quasiccoatings) in limestone blocks is especially distinct in the upper 15-20 cm.
- 1397.3-1397.5 m (4584.3-4585 ft.) Argillaceous limestone: medium to coarse grained lithoclastic grainstone very similar to 4579.4-4580.7; in shale-lean parts solution cavities are wrapped in milky white crystalline coatings (anhydrite or chalcedony). Base unconformable.
- 1397.5-1401.3 m (4585-4597.5 ft.) Limestone: pale brownish gray, moderately karstified (brecciated) from top. The uppermost 10 cm contain mm-sized solution vugs lined with milky white non-calcareous material. Clay is present in minor quantity in solution vugs and collapsed stringers. Below the upper 10 cm, milky white linings are not distinct and large solution vugs are filled with thick laminar green shale (argillans). Pale bluish gray sucrosic mottles in basal part, harder than anhydrite on scratch – dolomite? Sedimentary texture: ostracodal calcimudstone, in lower part alternation of wackestone and calcimudstone. Skeletal assemblage very poor, only thin-shelled ostracods and seed-like biomolds. Minor peloidal grainstones in conformable (?) base.
- 1401.3-1401.6 m (4597.5-4598.5 ft.) Limestone: finely mottled light to dark brownish gray, thromboidal, finely stylolitized, containing numerous intraclasts, weakly anhydritic due to development of sucrosic anhydrite geopotals. The basal core piece is argillaceous, fissile, with abundant sand-sized flakey and isodiametric dark brownish gray limestone clasts. The

thrombs/aggregates are 0.5-5 mm in size, isodiametric to slightly prolate and sometimes having shape of upward-facing fans; they have finely clotted, very weakly layered internal texture. The inter-thromb space is filled, sometimes geopetally, with a sequence of lighter colored micrite/microsparite, pale greenish clay, anhydrite, and catagenetic clear calcite spar. These infiltrated phases partly resemble polymud fabric. No macrofossils. A weak unconformity in base.

- 1401.6-1402.3 m (4598.5-4600.8 ft.) Limestone: pale gray in upper 15 cm (birds-eye calcimudstone/laminite with buckled lamination); alternation of darker and lighter brownish gray limestone below; this main part consists of alternating birds-eye laminites, lithoclastic calcarenites (grainstones to packstones), and palimpsestic lithoclast-rich rocks with multiphase syngenetic brecciation, circum-granular cracks, and shale stringers. No thick argillans. Milky white (anhydrite?) geopetals locally present. The laminite in top is riddled with solution-enlarged vugs/fenestrae, but in difference to unconformities above has no infiltrated green shale (only catagenetic sparite). Lithoclast-rich intervals contain pointed needle-like and curved dark brown non-calcareous fragments – phosphatic fish remains? A deep (over 15 cm) upright cavity in the middle filled with lithoclastic grainstone-packstone. This interval is overall distinct by lack of clay argillans.
- 1402.3-1405.6 m (4600.8-4611.5 ft.) Limestone: pale gray, tight; massive ostracodal calcimudstone in upper 0.46 m; the alternation of birds-eye laminites and massive calcimudstones below. Birds-eye laminites dominate in lower one-half where they are interbedded by thinner massive calcimudstones, rounded-grain lithoclastic grainstones-packstones and lithoclast/intraclast enriched laminites. The upper 1.7 m are largely stylobrecciated (especially in top) and contain collapsed solution vugs with thick green claystone. Base conformable.
- 1405.6-1406 m (4611.5-4613 ft.) Limestone: pale gray in top to darker brownish gray in base; a fining-upward rounded coated-grain grainstone, from coarse-grained (0.5-1.5 mm) oncoidal grainstone with fitted fabric in base to oncoidal-cortoidal medium-grained grainstone in upper half. The latter holds some intergranular space (cemented by clear spar) due to micritic cement bridges between grains. Some grains are also rimmed by thin isopachous sparitic cement. Nuclei of coated grains are structureless micritic. Base stylolitic, conformable or an erosional surface.
- 1406-1406.3 m (4613-4614 ft.) Limestone: pale gray, alternation and intergradation of 'lacy' birds-eye microbial laminites, coated-grain grainstones with oncoids up to 4 mm in size, and in lower one-half finer-grained peloidal grainstones and packstones with ostracods, grading to a weakly laminar clotted-matrix calcimudstone in base. Moderate stylolitization.
- 1406.3-1407.1 m (4614-4616.5 ft.) Limestone: pale brownish gray, laminar, with regular horizontal stylolites. Laminae up to 2 mm thick, show graded composition of very fine grained ostracodal-peloidal packstone in base to tight micrite in top. A 1 mm thick seam of fissile greenish shale in sole. A weak unconformity is possible in base.
- 1407.1-1408.8 m (4616.5-4622 ft.) Limestone: brownish gray stripy in upper 0.3 m, pale brownish gray below. A 4 cm long core in top shows micritic syngenetic breccia of a birds-eye laminite riddled with solution vugs. Two-feet interval below is a laminar and locally brecciated calcimudstone with small domal stromatolites. Below is gradation to the laminar fine-grained packstone to calcimudstone very similar to 4614.0-4616.5 m. Base not preserved in core. Regular stylolites throughout.
- 1408.8-1409.2 m (4622-4623.5 ft.) Limestone: moderately argillaceous, gray, syngenetically brecciated birds-eye laminites and rounded intraclastic/lithoclastic grainstones enriched in dark brown non-carbonate biogenic fragments, probably vertebrate sclerites (photo). Base conformable or paraconformable.
- 1409.2-1410.4 m (4623.5-4627.3 ft.) Limestone: brownish gray, partly argillaceous, birds-eye syngenetically brecciated laminites in upper one-half, grading downward to laminated packstone-calcimudstone rock without fenestrae. The upper fenestral part also contains solution vugs/enlarged fenestrae and slickensided, shale-lined oblique solution planes.

Larger solution cavities also contain a sequence of geopetal sediments: thin greenish shale overlain by sucrosic anhydrite, and the residual space above filled with brownish sparite. Small (<1 cm) limestone pebbles close to the base. The base erosional, probably paraconformity or a weak disconformity.

- 1410.4-1411.2 m (4627.3-4630 ft.) Limestone: pale brownish gray, stylobrecciated from top, massive to weakly and evenly laminar; calcimudstones with minor ostracodal wackestones. Ostracods, rare brachiopods, tiny seed-like biomolds. Meagre bluish clay partings and argillation spots developed in upper 0.6 m. Base not preserved.
- 1411.2-1411.6 m (4630-4631.3 ft.) Argillaceous dolostone: pigeon dark gray, finely crystalline (<0.05 mm), massive and monolithic, tight, locally with faint cloudy to laminar patterns. Base conformable, gradational.
- 1411.6-1412.4 m (4631.3-4633.7 ft.) Dolostone: pale gray, probably weakly argillaceous, finely crystalline, tight, retaining the depositional fabric of matrix-rich conglomerate with dark and pale gray subrounded carbonate lithoclasts up to 5 mm in size. The matrix is faintly mottled, locally showing syndepositional brecciation, disrupted laminae and birds-eye fenestrae, locally also pisoids surrounded by circum-granular cracks (photo). Base disconformable.
- 1412.4-1412.6 m (4633.7-4634.5 ft.) Argillaceous dolostone: bluish gray, tight, finely crystalline; in upper 5 cm with preserved texture of karst breccia with rubbly claystone fills of solution pockets. Downward this breccia grades into darker colored (more argillaceous) with obscure cloudy fabric and whitish subangular carbonate clasts. These clasts have clotted texture. No fossils. No signs of compaction other than infrequent shale-lined stylolites. Base disconformable.
- 1412.6-1108.7 m (4634.5-3637.5 ft.) Dolostone: pale brownish gray, grading to bluish gray (more argillaceous) in basal 0.15 m, medium to finely crystalline, fabric retaining: massive to laminated facies (calcimudstones?) karsted from the top, with patches and intervals of clay-rich breccia. Faint floatbreccia texture in basal 10-12 cm. Base disconformable.
- 1108.7-1414 m (3637.5-4639 ft.) Dolostone: pale gray to gray, slightly lighter brownish gray in top, finely crystalline, partly fabric retaining. Top rugged, dissolved, admitted by karst brecciation with brown infills of solution pockets. Subaerial alteration features fade out in 10-15 cm below top. Base diagenetic, by transition to fractures and porous dolostone.
- 1414-1414.4 m (4639-4640.5 ft.) Dolostone: pale brownish gray, medium crystalline, hypidiotopic, heavily fractured and with vuggy porosity up to 3-5%. Intercrystalline porosity may be also present. Vugs develop upon uncemented solution vugs in a precursor limestone (probably massive to laminated calcimudstone). Oil impregnation (still smelly). Larger vugs are filled with milky white sparry calcite. Fracturation decreases in base. The basal 3 cm is preserved in core: bluish gray argillaceous dolostone with whitish carbonate clasts. Base disconformable.
- 1414.4-1415.6 m (4640.5-4644.3 ft.) Dolostone: brownish gray to neutral gray, non-calcareous (except for catagenetic sparite cements), finely to medium crystalline, locally with very low intercrystalline and moldic porosity (<1%) and open fractures (shattered core). Whitish crenulated laminar crust in top. Primary fabric largely retained: laminites with gently buckled laminations, mostly with few or no birds-eye fenestrae. A 5 cm thick interval in the middle has a different complex fabric with cm-sized elliptical fenestrae and argillaceous veining. Base likely conformable, by disappearance of lamination.
- 1415.6-1355 m (4644.3-4445.6 ft.) Dolostone: gray, finely crystalline, probably weakly argillaceous, weakly fractured, retaining thin-shell and massive biomolds in random orientation (bioturbated interval).
- 1416-1416.4 m (4645.6-4647 ft.) Argillaceous dolostone: gray, finely crystalline, with ghost breccia or conglomerate fabric, with flakes (rarely certain pebbles) of green claystone. Carbonate clasts along with claystone clasts in basal 5 cm. Base disconformable.
- 1416.4-1417.2 m (4647-4649.5 ft.) Dolostone: gray, probably moderately argillaceous, non to weakly calcareous, distinctly laminar, finely crystalline to coarsely crystalline (up to 0.2 mm)

in different laminae. Lamination in upper 0.3 m is buckled and locally disrupted, with teepee and probably domal stromatolite structures; below it is gently buckled. Brownish fenestrae-like structures replaced by especially coarsely crystalline idiotopic dolomite. Base not preserved, supposedly conformable.

1417.2-1417.7 m (4649.5-4651.2 ft.) Argillaceous dolostone: bluish gray, massive, finely crystalline, with ghost wrinkled lamellar patterns, with tiny pyrite inclusions. Base disconformable, with flattened carbonate clasts (weathered and reworked tidal-flat laminae).

1417.7-1418.4 m (4651.2-4653.5 ft.) Dolostone: weakly(?) argillaceous, brownish gray, finely to medium crystalline, non-calcareous, laminar. Lamination is thin (<0.5 mm) and most buckled in top, grades downward to less distinct gently crenulated and even. Top rugged, erosional. However, no large-scale vadose features are observed under the top. Base conformable.

1418.4-1419.5 m (4653.5-4657 ft.) Argillaceous dolostone: bluish gray, finely crystalline, laminated to massive; lamination even to gently crenulated. Interval contains two internal discontinuities at 1418.7 m and 1418.9 m. These discontinuities divide cyclic units consisting of massive to wrinkled, darker colored dolostone (dolomarl) in base and laminated facies in top. A 2 cm thick core of distinctly laminated overcompacted dolomarl in base. The base disconformable.

1419.5-1421 m (4657-4662 ft.) Limestone: brownish gray, tight, karstified and penetrated by stringers, coatings, and geopetal sediments of green non-calcareous shale. Sedimentary facies: alternation of bioclastic calcimudstones, wackestones and packstones; intervals with buckled lamination make up no less than 50% of thickness in upper ½; the lower ½ lacks distinct lamination and is dominated in wackestones and packstones. Bioclasts: mass ostracods and seed-like microfossils. Larger solution cavities in lower ½ contain geopetals of sucrosic anhydrite post-dating green shale coatings. Abundant small (< 1mm) solution vugs and solution-enlarged biomolds, but karst breccia is not observed. Walls of solution vugs are usually bleached and possibly impregnated with silica.

1421-1421.1 m (4662-4662.5 ft.) Argillaceous limestone: brownish gray, lithoclastic conglomerate (packbreccia) composed of subangular fragments of micritic limestone and overcompacted pale green shale matrix.

1421.1-1422.3 m (4662.5-4666.5 ft.) Limestone: brownish gray in upper ½, slightly darker below, back to brownish gray in lower 0.15 m; lithoclastic-bioclastic calcarenite in disconformable base. Moderate karstification throughout, with green claystone partings, coatings, and stylolitized breccia in upper ½; the clay is overall meager, most solution vugs are clay-free, occluded by sparitic cement. Sedimentary textures: massive ostracodal calcimudstone to wackestone in top, below ostracodal wackestones with minor packstones and grainstones, occasionally preserved lamination; Fossils are almost entirely ostracods, also very rare small conical gastropods. Buckled lamination with flat-clast breccia is developed in lower 20 cm, and this laminated unit is underlain by the basal lithoclastic-ostracodal packstone with subangular cm-sized fragments of brown calcimudstone in the very base. The base disconformable.

1422.3-1423.2 m (4666.5-4669.2 ft.) Limestone: brownish gray, tight, moderately karstified. Infiltrated shale is generally meager, fills only large cavities and lines few slickensided partitions. A 1 cm thick bed of green claystone with brown limestone crumbles in top – in situ paleosol? Laminar alternation of ostracodal packstones and calcimudstones. Lamination thick (1-10 mm), even, with no buckled features or fenestrae. Base gradational.

1423.2-1424.3 m (4669.2-4672.8 ft.) Shale to argillaceous limestone: nodular rock with brownish gray (to dark gray) limestone nodules and paler bluish gray shale matrix. The interval is capped by fissile shale with almost no limestone nodules; several centimeters in base are mimically replaced by dolomite (flat-pebble float to packbreccia). Limestone nodules show bioturbated lithoclastic-bioclastic wackestone texture. Many (or most) nodules represent syngenetic breccia. An internal disconformity with undulating surface and distinct breccia

underneath is observed at 1424.0 m. Coarsely crystalline dolomite occurs in minor quantity in lower ½ of the interval, preferentially in shale matrix. Lithoclasts and bioclasts (mostly ostracods and small fish sclerites) occur both in limestone nodules and surrounding shale. Very rare thin-shelled brachiopods. Lithoclasts: subangular to rounded pale and dark brownish gray micritic and recrystallized sparitic limestones. Base erosional, undulating, disconformable.

1424.3-1425.1 m (4672.8-4675.6 ft.) Dolostone: brownish gray, darkening downward, weakly to non-calcareous, increasingly argillaceous in lower ½, medium-crystalline to finely crystalline in argillaceous parts. Retains crenulated lamination imprinted in upper 10 cm by karstic brecciation. Karst pockets show dark colored infill, apparently an original paleosol claystone. A wide (1 cm) upright vein of gigantocrystalline calcite in the middle of interval. Base by disappearance of lamination.

1425.1-1425.3 m (4675.6-4676.3 ft.) Argillaceous dolostone: gray, massive and with faint wrinkled pattern (dolomite growth pattern), with concentrate beds of fish sclerites (best preserved examples). These beds seem to be bioturbated and contain infrequent ostracods. Top and base conformable.

1425.3-1425.5 m (4676.3-4677 ft.) Argillaceous dolostone: gray, finely crystalline, with faint wrinkled to laminated pattern; in base grading to greenish claystone through downward looking tongues of coarsely crystalline idiotopic dolostone. Base likely disconformable.

1425.5-1426.3 m (4677-4679.3 ft.) Limestone: brownish gray, tight, moderately karstified, with meager greenish clay linings and geopetals in some solution cavities; upper 10 cm is syngenetically brecciated birds-eye laminite with buckled lamination and probably small-scale teepee structures; below gradation to peloidal-ostracodal packstone with clotted matrix and crude lamination expressed as alternation of ostracods coquinas and clotted micrites; brecciated and buckled lamination gradually restores in the lower 0.3 m. Massing ostracods, locally seed-like microfossil molds. Green non-calcareous shale with brown subrounded limestone clasts in disconformable base.

1426.3-1427.5 m (4679.3-4683.5 ft.) Limestone: strongly karstified (brecciated in top), with thick bluish shale fills of breccia and thick argillans below. Tray in upper portion of the interval contains crumbles of bluish slickensided shale indicating preserved topsoil. The host limestone is mottled (dark staining), showing partly laminated ostracodal wackestones and calcimudstones; lower ½ is dominated in massive to faintly laminated calcimudstones with ostracods and seed-like microfossils. Thin sucrosic anhydrite geopetals in lower ½. A layer of lithoclastic conglomerate at 1427.2 m; this pack-conglomerate consists of subrounded to subangular micritic lime clasts, minor fish debris, and lean pale greenish matrix. Base likely conformable, through facies change.

1427.5-1428.3 m (4683.5-4686 ft.) Limestone: brownish gray, partly argillaceous, impregnated with oil, shows dark bitumen stains; no macropores are seen, all hydrocarbon resides in microporosity. Bioturbated, with few lamination remains, fish debris - ostracodal packstones; locally enriched in limestone clasts. Base likely conformable.

1428.3-1429.2 m (4686-4689 ft.) Limestone: gray, weakly argillaceous, impregnated with oil (micropores); calcimudstones and wackestones with remarkable texture showing syngenetic microbrecciation, development of circum-granular cracks (patches of "diagenetic grainstone") and tiny fenestrae or vugs with smooth walls; locally with polymud fabric and enriched in micritic intraclasts and oncoids. Fish debris is abundant in top and infrequent in the main part of the interval; no ostracods; some fenestrae are cemented by reddish coarsely crystalline mineral; thin whitish non-calcareous coatings are common on walls of larger vugs/fenestrae. Infrequent upright spar-filled channels (burrows?); very rare inclined and upright tubular structures with laminar micritic walls, but definite branching rhizocretions are lacking. Provisional interpretation: pre-root palustrine carbonate. Base gradational.

1429.2-1430.4 m (4689-4692.8 ft.) Limestone: pale brownish gray, moderately impregnated with oil (microporosity, no visible pores); ostracodal wackestones, packstones and minor

calcimudstones with distinct buckled lamination in uppermost 15-20 cm; downward grades to evenly laminated to weakly bioturbated texture (BI 20-30%); ostracodal coquina are common; thin interbeds of ostracodal-peloidal grainstones; rare amphiporas in base (return of marine conditions). Base not preserved.

1430.4-1431 m (4692.8-4695 ft.) Argillaceous dolostone (dolomarl): pigeon gray, finely crystalline, massive, pelitomorphic; overcompacted conglomerate of subangular claystone pebbles/intraclasts in basal 5 cm. Base disconformable.

1431-1432.6 m (4695-4700 ft.) Argillaceous dolostone to dolomitic claystone: pigeon gray, massive, locally pelitomorphic and locally showing ostracod coquinas; overall BI is 30-60%. A brownish limestone (ostracodal wackestone-packstone) in top. This limestone has uneven top and is penetrated by pale green claystone partings/stringers, contains some solution vugs. A catagenetically (?) brecciated interval in the middle. Fish debris locally common; rare mollusks (recrystallized, probably gastropods). No typical marine fossils. Basal 10 cm are more argillaceous, showing complex "polymud" and partly slickensided fabric with coarsely crystalline (0.2-0.3 mm) idiotopic dolomite submerged in non-carbonate matrix of green clay.

N.B.: Boxes 612-613 (1427.7-1434.4 m) are impregnated with oil and cores are oily, although no pores are seen – microporosity or diesel spill?

1432.6-1432.9 m (4700-4701 ft.) Argillaceous-carbonate breccia: floatbreccia with green strongly dolomitized claystone matrix. Dolomite: same idiotopic crystals as in the base of the overlying interval. Limestone fragments: brownish gray, mottled, corroded, subrounded; ostracodal wackestones and calcimudstones; make up no more than 40% of rock. Provisional interpretation: topsoil.

1432.9-1434.1 m (4701-4704.9 ft.) Limestone: pale brownish gray, karstified throughout, converted into stylobreccia (packbreccia) in upper 15-20 cm. Meager partings of infiltrated green clay (collapsed and squeezed under pressure). Sedimentary texture: faintly laminar tight calcimudstones and minor ostracodal wackestones in upper part, grading downward into laminite (gently buckled laminae of alternating birds-eye clotted wackestones, packstones, and calcimudstones with minor fine-grained grainstones). Base diagenetic.

1434.1-1434.5 m (4704.9-4706.5 ft.) Argillaceous dolostone: bluish gray, with complex breccia texture, with several large fragments of brownish limestone (fine-grained peloidal grainstone). The lower 10-12 cm is composed of brecciated and collapsed argillaceous dolostone with microlaminated geopetal sediments of bluish very fine-grained dolomarl – cave sediment? Base diagenetic. The whole interval represents dolomitized karst breccia-speleothem.

1434.5-1438.3 m (4706.5-4718.8 ft.) Argillaceous dolostone: bluish gray, massive, rarely faintly laminated, finely to medium crystalline, hard, visually uncompacted (except for infrequent stylolites); locally preserves ostracod biomolds and unidentified angular fragments (also recrystallized); in upper 0.6 m locally retains fenestrae and microbrecciation typical of "palustrine" facies; below mostly pelitomorphic, with local catagenetic or dolomitization-related brecciation. Base likely disconformable (through breccia)

1438.3-1439.1 m (4718.8-4721.4 ft.) Argillaceous dolostone: bluish gray, tight, likely finely crystalline, with preserved disrupted lamination, locally with desiccation cracks and ripped-up "mud flakes". Basal 0.6 m is very faintly laminated to massive, slightly coarser crystalline. Base is destroyed in a brecciated interval.

1439.1-1439.6 m (4721.4-4723 ft.) Dolostone breccia: brownish gray and gray, dissected by wide veins of gigantocrystalline calcite; primary textures almost absent; pale brownish gray chunks preserve systems of solution vugs with geopetals and based on this disconformity is interpreted inside this interval. Base by transition to unbroken core.

1439.6-1439.9 m (4723-4724 ft.) Argillaceous dolostone: bluish gray, tight, finely crystalline, massive to faintly fenestral (palustrine-like texture). Early dolomitization is indicated by lack of pervasive compaction. Base not preserved.

- 1439.9-1441.1 m (4724-4728 ft.) Argillaceous dolostone: bluish gray, unevenly argillaceous, with cloudy (turbated) fabric: contorted and intermingled tongues of green shale and medium crystalline dolostone, locally with breccia aspect. No sedimentary features.
- 1441.1-1441.7 m (4728-4730 ft.) Argillaceous dolostone: bluish gray, finely crystalline, massive, with very faint cloudy pattern; randomly oriented ostracod biomolds are encountered. Very argillaceous dolostone with buckled lamination and faint breccia in basal 8 cm. Base unclear.
- 1441.7-1442.2 m (4730-4731.5 ft.) Dolostone: weakly argillaceous, gray, in base argillaceous and darker colored. The main upper part locally retains ostracod biomolds (bioturbated wackestone-calcimudstone); the basal 10 cm contains whitish sand-sized carbonate clasts in a dark gray pelitomorphic matrix. Base disconformable.
- 1442.2-1442.9 m (4731.5-4734 ft.) Argillaceous dolostone: in top paler gray, with faint relics of breccia texture; below gray, argillaceous, finely crystalline, with very few shows of lamination, pelitomorphic in upper 0.3 m and containing ostracod biomolds and seed-like microfossils below (ostracodal wackestones). Base likely disconformable.
- 1442.9-1444.5 m (4734-4739.1 ft.) Dolostone: variously (mostly weakly) argillaceous, tight, moderately fractured, mostly massive, fine to medium crystalline, brownish gray (in less argillaceous intervals) to dark gray (where more argillaceous). Sedimentary textures poorly preserved. No fossils other than rare ostracod molds. Buckled and disrupted laminite, rip-up clast breccia in top. An internal discontinuity is possible at 1443.7 m as indicated by dark gray, pyritic interval containing ghost carbonate lithoclasts. Base disconformable.
- 1444.5-1445.8 m (4739.1-4743.5 ft.) Dolostone: variously (mostly weakly) argillaceous, non-calcareous, similar to 1442.9-1444.5 m from which is separated by disconformity with overlying lithoclast-rich argillaceous dolostone and underlying breccia (packbreccia) with complex, probably karstic-pedogenic fabric; this breccia contains domal faintly laminated blocks resembling stromatolites. Textures massive to weakly laminated, with occasionally preserved ostracod biomolds. An interval 1445.4-1445.7 m shows grey dolostone with buckled lamination, microbrecciation, tiny fenestrae and smooth-walled vugs, spherical molds (charophyte gyrogonites?) and only rare ostracods. This interval resembles palustrine facies but without root traces. Base likely disconformable, dark colored, with small whitish carbonate clasts.
- 1445.8-1446.9 m (4743.5-4747 ft.) Dolostone: gray to brownish gray, finely crystalline, massive, non-calcareous. Sedimentary textures are partly preserved only in lower half: ostracodal wackestones with occasional non-disturbed pavements. At least one dark-colored interval with ghost carbonate clasts in the middle, overlain by a paler-colored dolostone with fabric resembling palustrine carbonate.
- 1446.9-1447.2 m (4747-4748 ft.) Argillaceous dolostone: gray, tight, breccia (pack to floatbreccia), with greenish argillaceous matrix replaced by coarser crystalline dolostone that finely crystalline fragments of parent rock. The interval is likely composed of two parts: in situ angular breccia and subangular to subrounded matrix-rich conglobreccia. Core here is mixed and incomplete. The interval contains disconformity.
- 1447.2-1448 m (4748-4750.5 ft.) Argillaceous dolostone: dark gray, non-calcareous, mostly massive, with ghost tiny biomolds and carbonate clasts in base. Base likely conformable.
- 1448-1448.9 m (4750.5-4753.7 ft.) Dolostone: weakly argillaceous to argillaceous, tight, finely to medium crystalline, with distinct gently crenulated lamination in upper part; lamination becomes less distinct downwards and vanishes in lower 0.21 m (bioturbated calcimudstones with ostracods); the base (1-2 cm) is laminated, contains thick dark laminae enriched in sand-sized greenish argillaceous and brownish carbonate lithoclasts. Base disconformable.
- 1448.9-1449.3 m (4753.7-4755 ft.) Dolostone: pale gray with dark partings, non-calcareous (except for catagenetic calcite veins), retaining breccia texture and solution vugs. Larger

vugs show thick geopetal sediments. Base by transition to homogeneous argillaceous dolostone.

- 1449.3-1450.5 m (4755-4759 ft.) Dolostone: weakly argillaceous, gray with paler brownish gray intervals, non-calcareous, massive to faintly laminated, with rare levels of pale colored carbonate clasts and occasionally preserved ostracod molds (showing some degree of bioturbation). Two brecciation intervals in upper half (lower part of karst profile developed from unconformity at 1448.93 m). Base likely conformable.
- 1450.5-1451.8 m (4759-4763 ft.) Argillaceous dolostone: gray, non-laminated, non-compacted, retaining texture of bioturbated ostracodal wackestone. Bioclasts are more diverse than above (massive ghost molds and seed-like molds), but large and thick-shelled forms are lacking. Several undulating erosional surface inside the interval. Base conformable.
- 1451.8-1452.5 m (4763-4765.4 ft.) Argillaceous dolostone: finely crystalline, gray, very dark and with pale carbonate clasts in base. A 20 cm thick interval with fine crenulated lamination in top. Below texture obscure, massive to faintly brecciated.
- 1452.5-1453.5 m (4765.4-4768.7 ft.) Dolostone: dark brownish gray, probably weakly argillaceous, finely to medium crystalline, with poorly preserved sedimentary fabric of moderately karstified laminite. Lamination fades out in lower one-half. Birds-eye fenestrae with thick whitish geopetal sediments (original anhydrite?) are common throughout the interval, and in top they are enlarged by solution and joined into a conduit system. Base by colour change.
- 1453.5-1454.7 m (4768.7-4772.5 ft.) Argillaceous dolostone: gray, paler than above, finely crystalline, mostly massive and pelitomorphic. Tray in upper portion contains chips of grey weakly fissile and slickensided very argillaceous dolostone. Fish debris are rare in upper part and more frequent in lower part. The core is fractured and grades into disintegrated breccia in base.
- 1454.7-1458.8 m (4772.5-4786 ft.) Dolostone breccia: formational fractured interval containing pieces of gray and pale brownish gray non-calcareous dolostone; some pieces preserve ostracod coquinas, in others sedimentary structure is lost. Base by transition to more integrated core.
- 1458.8-1459.7 m (4786-4789 ft.) Dolostone: gray, finely to medium crystalline, probably variously argillaceous, fractured and locally shattered into cm-sized pieces; overall disintegration less than in the overlying interval; composed mostly of cores longer than 5 cm. Sedimentary signatures: faintly laminated to massive, grainy (fine-grained grainstones?) to micritic; intervals with "polymud" fabric, smooth-walled fenestrae, and circumgranular cracks, resembling "rootless" palustrine facies. Rare fish debris. Base not preserved.
- 1459.7-1460.9 m (4789-4793 ft.) Dolostone: gray to dark gray, fractured, locally finely shattered; the upper one-half shows a 6 cm thick interval of pedogenic(?) floatbreccia composed of dark gray dolomite clasts intermingled with coarser crystalline argillaceous dolostone and claystone; pale green claystone clasts are also present. The dolostone beneath this breccia is also brecciated and contains greenish, light-colored clay-rich windows. The lower one-half shows laminated facies with gently buckled laminae and thick catagenetic calcite veins. Base disconformable.
- 1460.9-1461.3 m (4793-4794.2 ft.) Argillaceous dolostone breccia: pack to floatbreccia with signs of dissolution and multiphase brecciation; weakly calcareous; finer crystalline brownish gray dolostone clasts with obliterated sedimentary texture are surrounded by wrinkled, crudely layered matrix of coarser crystalline argillaceous dolostone and light greenish claystone. Base by transition to more integrated dolostone.
- 1461.3-1462 m (4794.2-4796.5 ft.) Dolostone: gray, medium crystalline, non-calcareous, showing brecciated intervals with whitish and greenish, faintly laminar matrix between clasts. Bedrock retains very faint thick lamination, partly massive. No fossils. Base disconformable, marked by breccia.

1462-1462.1 m (4796.5-4797 ft.) Dolostone: pale brownish gray, retaining the fabric of syngenetically brecciated and palimpsestic fine-grained rock with large elliptical solution vugs (upon fenestrae?) floored with whitish geopetal sediment; may contain one or more erosional surfaces, polymud fabric in top.

1462.1-1462.8 m (4797-4799.2 ft.) Argillaceous dolostone: brecciated, with complex fabric of pale green to gray argillaceous matrix and dolostone clasts showing different degrees of dissolution and conversion into greenish matrix. The lower part of the interval contains partings and crumbled flakes of non-dolomitized fissile and slickensided green shale. Sedimentary facies in bedrock: massive in top to buckled laminated in basal part. Base by transition to non-brecciated dolostone.

N.B.: The interval 4793.2 through 1463.0 m may represent one thick composite paleosol.

1462.8-1463.7 m (4799.2-4802.1 ft.) Dolostone: dark gray, massive, finely to medium crystalline, probably weakly argillaceous, with oblique fractures, retaining infrequent small solution vugs and locally faint complex texture resembling "rootless palustrine facies". No fossils. Base by transition to laminated facies.

1463.7-1465.2 m (4802.1-4807 ft.) Dolostone: dark gray to brownish gray, finely to medium crystalline, weakly to non calcareous; retaining in upper one-third an evenly laminated fabric (1-5 mm thick graded laminae); in lower two-thirds grading into paler brownish gray dolostone with faint syngenetic microbrecciation and few polymud features in the middle. This lower interval is also enriched in whitish subrounded sand-sized micritic lithoclasts. Breccia and laminated horizons inside this lower interval may indicate internal disconformities. Base disconformable.

1465.2-1465.8 m (4807-4809 ft.) Dolostone: brownish gray karstified in top, finely crystalline, fabric retaining, darkening to base, fabric selective; solution cavities under the top are filled with a sequence of milky white and dark dolomite; the early geopetal milky phase may represent replaced anhydrite. Sedimentary texture: mostly calcimudstone; complex fine-grained packstone to 'enterolithic' micritic fabric just under the top (indicating anhydrite growth in the sabkha setting). The lower 0.3 m retains buckled and disrupted whitish laminae locally reworked into 'mud flakes'. Base disconformable.

1465.8-1468.8 m (4809-4819 ft.) Dolostone: brownish gray to dark gray, probably weakly argillaceous, paler colored and with small solution vugs, many of them leached fenestrae; this upper part also shows moderate syngenetic brecciation and weak disrupted lamination; the interval at 1467.6-1468.2 m is dark colored, massive, pelitomorphic, devoid of fenestrae and syngenetic brecciation. No fossils. The core in lower 0.3 m is dissected by catagenetic calcite veins and shattered. Base unclear due to core disintegration.

1468.8-1470.8 m (4819-4825.5 ft.) Dolostone: dark brownish gray, finely crystalline, non to weakly calcareous, retaining the brecciated texture with mm to cm sized chambers geopetally filled with laminated whitish dolomite (replaced anhydrite?); locally 'enterolithic' character. Syngenetic brecciation gradually reduces downward, but occasional geopetally filled chambers and connecting them fractures-conduits filled with the same whitish material are present throughout the interval. No obvious fossils. Base conformable, picked by appearance of biomolds.

1470.8-1472.3 m (4825.5-4830.3 ft.) Dolostone: dark brownish gray, medium crystalline, mottled (weakly imprinted by brecciation/argillation), with solution vugs and poorly preserved randomly oriented biomolds – ostracods, rare thin-shelled brachiopods, small unidentifiable bioclasts (bioturbated wackestone and calcimudstone). Infrequent cm-sized Stromatactis-like chambers filled with thick pale-colored laminated geopetal sediment are present throughout. Base conformable, picked by disappearance of biomolds and intensified brecciation-polymud fabric.

1472.3-1472.8 m (4830.3-4832 ft.) Dolostone: gray, tight, faintly mottled (paler and darker patches), weakly to non calcareous, with Stromatactis (polymud) to faint syngenetically brecciated fabric. Distinct solution voids are lacking. Stromatactis-type structures are cm-sized, usually collapsed (stylolitized), composed of thick layered (dark to pale) geopetals

and the upper chambers filled with whitish coarser-crystalline dolomite with cloudy fabric. Rare poorly preserved biomolds. Base conformable, by transition to less polymud and more fossiliferous texture.

1472.8-1474.2 m (4832-4836.5 ft.) Dolostone: gray, tight, mottled, with fewer and smaller Stromatactis comparing to the preceding interval; with diverse poorly preserved biomolds indicating a wackestone texture (ostracod and/or brachiopod shells, rare bryozoans(?), massive unidentified biomolds). Base conformable.

1474.2-1476.1 m (4836.5-4842.8 ft.) Dolostone: gray, mottled, finely to medium crystalline, with important polymud/Stromatactis fabric and faint syngenetic brecciation; very poorly preserved biomolds define bioclastic wackestone to calcimudstone fabric.

N.B.: no signs of early (pre-dolomite) compaction on 1470.7-1476.1 m and no lamination except for laminar geopetals in Stromatactis. Base likely conformable.

1476.1-1476.5 m (4842.8-4844.2 ft.) Dolostone: brownish gray, mottled, medium crystalline, slightly lighter than above and below. Stromatactis small and rare, absent in central part of the interval; poorly preserved, partly empty biomolds define wackestone-mudstone texture. Solution vugs or enlarged biomolds may be present. No lamination. Base conformable.

1476.5-1480.1 m (4844.2-4856 ft.) Dolostone: gray to dark gray, tight to very weakly porous, medium crystalline (0.1-0.13 mm), massive to faintly mottled, with infrequent Stromatactis and oblique "Neptunian conduits" filled with the same pale colored, partly laminar geopetal sediments; tiny short curved cracks in the matrix, infrequent stylolites. The upper 0.6-0.9 m may contain weak argillaceous admixture betrayed by argillaceous partings along stylolitized Stromatactis. Biomolds and poorly preserved skeletons are common (shell fragments, bryozoans, spherical forms, etc.). Bryozoans are probably in situ, participating in automicritic boundstone fabric, rarely encountered (and better preserved) in pale-colored geopetals. Local syngenetic sediment deformation and brecciation fabrics. Rugged "microbial" growth surfaces are encountered. Rare wavy sedimentary laminae. Base conformable.

1480.3-1484.8 m (4856.5-4871.5 ft.) Dolostone: dark gray, finely crystalline, locally with weakly calcareous matrix; preserves larger (>0.5 mm) non-dolomitized and partly dolomitized bioclasts (brachiopods, echinoderm ossicles, bryozoans, ?trilobites). Rare collapsed Stromatactis and oblique fissures filled with the same whitish dolostone. Cloudy, patchy and faintly brecciated wackestone to calcimudstone texture without signs of early compaction. Bryozoans include fenestellids, some probably in situ and forming framework (bafflestone?).

1484.8-1485.1 m (4871.5-4872.3 ft.) Dolostone: lighter colored, brownish gray, massive to faintly mottled, finely crystalline; bioturbated bioclastic calcimudstone. An in situ bivalved brachiopod in top. Top and base conformable, gradational.

1485.1-1486.6 m (4872.3-4877.4 ft.) Dolostone: dark gray, finely crystalline, very similar to 1480.3-1484.8 m, retaining faint syngenetic breccia-like mottling and laminae. Sparse bioclasts (pelmatozoan ossicles, fenestellid bryozoans). No distinct fenestrae.

1486.6-1489.7 m (4877.4-4887.6 ft.) Dolostone: lighter colored, brownish gray, similar to 1484.8-1485.1 m, with minor darker-colored faintly mottled/brecciated intervals. These darker colored intervals bear stylolites with clay linings indicating weak argillaceous admixture. Mottling is also present in lighter colored brownish gray intervals, well developed in the middle and fades out to base. The mottles are defined by tight darker colored and finer-crystalline mottles and paler, coarser crystalline intermottles. Poorly preserved bioclasts and biomorphs: pelmatozoans, brachiopods, in situ bryozoans and ?tabulate corals, very rare gastropods, spherical forms, ostracods. Original calcimudstone texture in upper 0.6 m, progressively more fossiliferous (wackestone to bafflestone) in the middle mottled part (1487.4-1488.95-1489.0 m), less fossiliferous in base (wackestone-calcimudstone). No Stromatactis. Base conformable.

- 1489.7-1490.3 m (4887.6-4889.3 ft.) Dolostone: dark brownish gray, mottled, with faint breccia-like fabric, non-calcareous, medium crystalline, stylolitized. Primary texture likely conforms to bioturbated calcimudstone with rare pelmatozoan ossicles and other bioclasts. Base conformable.
- 1490.3-1494.4 m (4889.3-4902.8 ft.) Dolostone: slightly lighter colored, brownish gray, mottled, very similar to 1486.6-1489.7 m, also having more fossiliferous central part (wackestones and calcimudstones) and sparsely fossiliferous top and base (calcimudstones). Distinct mottling throughout. Base conformable.
- 1494.4-1496.4 m (4902.8-4909.5 ft.) Dolostone: darker colored (dark brownish gray), mottled, slightly lightening below 1494.9 m and getting back to dark gray distinctly mottled in lower 0.7m7 m; original calcimudstones with rare pelmatozoan ossicles and other bioclasts. The mottling is defined by lighter-colored mottles and dark intermottles, the pattern probably resulted from burrowing. No sedimentary laminae. No fenestrae.
- 1496.4-1501.6 m (4909.5-4926.5 ft.) Dolostone: brownish gray (slightly paler than above), mottled, locally nodular (mottles defined by darker areas with increased pressure solution); finely to medium crystalline, with rare poorly preserved fossils (ostracods, pelmatozoan ossicles, gastropods, probably bryozoans and thick amphipora-like forms with lost internal structure). Original bioturbated calcimudstones. Minor brownish gray intervals. Base conformable.
- 1501.6-1503.9 m (4926.5-4934.2 ft.) Dolostone: similar to the above (mottled to nodular) but with more numerous bioclast remains (mostly thin-shelled forms and small pelmatozoan ossicles). The core vaguely mottled, almost massive, with two or three thin (5-15 cm) nodular dolostones with black solution seams. Rare levels with 2-5% vuggy porosity (0.1-0.3 mm large vugs after dissolved bioclasts). Mostly original bioclastic wackestones. Fossil content increases to the base. The base contains several poorly preserved sedimentary discontinuities (erosional surfaces) overlain by richly fossiliferous texture with very poorly preserved finger-like forms (amphiporids?).
- 1503.9-1505.3 m (4934.2-4938.8 ft.) Dolostone: identical to 1496.4-1501.6 m, original bioturbated calcimudstone with sparse bioclasts that rarely concentrate into mm-thick seams. No sedimentary lamination is preserved. Base conformable, gradational.
- 1505.3-1512.7 m (4938.8-4962.8 ft.) Dolostone: dark brownish gray to brownish gray, mottled and faintly nodular, calcareous to non-calcareous, finely to medium crystalline, preserving the original texture of thoroughly bioturbated bioclastic wackestone with minor calcimudstone and packstone. Bioclastic texture (packstones and wackestone) predominate in central part (1507.5-1510.9 m). Braided solution seams locally form flaser fabric. Skeletal fragments mostly poorly preserved (different brachiopods, pelmatozoans, non-identifiable ghost fragments including possible bryozoans). No Stromatactis, nor massive coral or stromatoporoid like forms. Short irregular and sigmoidal fractures filled with sparitic calcite. Base conformable and gradational.
- 1512.7-1521.1 m (4962.8-4990.6 ft.) Dolostone: dark gray, homogeneous, medium crystalline (0.1-0.15 mm), non-calcareous with calcareous patches in the matrix, with original bioclastic calcimudstone texture. Rare mm to cm sized windows of whitish gigantocrystalline dolomite and calcite are probably leached and enlarged by solution fossils, in one spot preserving the shape of a cluster of thin-shelled in situ brachiopods (brachiopod bank). Rare pelmatozoan ossicles and fragments of thin-shelled brachiopods. Local faintly mottled texture from bioturbation. No sedimentary lamination is preserved. Base conformable.
- 1521.1-1522.5 m (4990.6-4995.2 ft.) Dolostone: mottled dark gray to gray, medium crystalline, with a 10 cm thick horizon of curved upright 5-6 mm thick burrows in top indicating sedimentation slowdown surface; below this upper horizon, mottling is very similar to 1505.3-1512.7 m with no upright burrows, and the rock is slightly lighter colored than at 1512.7-1521.1 m. In basal 0.3 m the rock darkens (more argillaceous/bituminous than above) and bears a cluster of whitish intermingled chert-calcite in 5-7 cm above the base

(photo). Rare poorly preserved pelmatozoan ossicles and thin-shelled brachiopods. Pre-dolomite texture: calcimudstone. A planar discontinuity surface in base (paraconformity?).

1522.5-1524.4 m (4995.2-5001.2 ft.) Dolostone: Gray to pale gray, medium crystalline, weakly to non calcareous, evenly laminated. The lamination is especially distinct in the middle and gradually declines to the base. Bioclasts are absent or not preserved. An upright stylolite is encountered at 4996.0 m indicating a lateral stress episode. Base conformable, by color change (darkening).

1524.4-1531 m (5001.2-5023 ft.) Dolostone: dark gray, finely crystalline (around 0.1 mm), mottled in the upper 2.70-2.45 m (paler gray mottles). Below it grades into uniformly dark gray as mottles lose their pale coloration. Sedimentary texture in this lower part is not changing: original bioturbated calcimudstones with very rare pelmatozoan ossicles and poorly preserved thin-shelled bioclasts. Compactional features: only stylolites in upper 1.2-1.56 m; black solution seams appear around 1526.1 m and locally define nodular fabric in lower 2/3 of the interval. Rare whitish chert nodules, some replacing bioclasts and biomorphs. Base conformable.

1531-1533 m (5023-5029.6 ft.) Dolostone: very dark gray, probably moderately argillaceous and bituminous, finely crystalline, locally with pyritic streaks. Sedimentary texture: alternation of evenly laminated and massive very homogeneous calcimudstone. Local presence of poorly preserved thin shells (ostracods?) and ossicles. Base conformable, by decline of lamination.

1533-1535.2 m (5029.6-5036.8 ft.) Dolostone: dark gray, in upper ½ faintly mottled bioturbated, with rare pelmatozoan ossicles, grades downward into laminated to very homogeneous massive very dark gray dolostone. Pre-dolomite texture: calcimudstone. Base conformable.

N.B.: Depth correction is indicated from 1525.2 m (5004 ft.) down to 1535.0 m (5036.0 ft.). This interval is double cored (depth repetition in boxes 655-659 and 659-663).

1532.8-1535.2 m (5029-5036.8 ft.) In the second core (Box 663), a chertified mesh of bryozoans and peloids is encountered at 1532.9 m, and stylolitized stromatoporoids at 1534.1 m.

1535.2-1536.6 m (5036.8-5041.4 ft.) Dolostone: dark brownish gray, distinctly laminated; the lamination is composed of paler medium crystalline (0.12-0.18 mm) brownish gray laminae and separating them finely crystalline dark gray laminae. These two types form mm to cm-thick fining-upward rhythms. Coarser grained and paler-colored parts of rhythms sometimes bear buckled features and intraclasts. Laminar sets are locally inclined at up to 10° with changing angle indicating cross-lamination in a calcarenite precursor (photo). The lower 2/3 show poorly preserved lamination with bioturbation disturbance. Ghost non-identifiable bioclasts, a chertified thin-shell coquina at 1536.1 m. Low intercrystalline porosity in coarse-crystalline laminae and patches. Base conformable.

1536.6-1537.3 m (5041.4-5043.6 ft.) Dolostone: uniformly gray to dark gray, finely laminated. The laminae are 0.5-1 mm thick, locally crenulated. No fossils. The core also contains upright stylolites. Base conformable.

1537.3-1543.2 m (5043.6-5063 ft.) Dolostone: dark brownish gray, tight, probably weakly argillaceous (shale-lined solution seams), mostly finely crystalline, with patches of lighter colored medium crystalline in the lower 1.0.9 m. Nodular bioturbated calcimudstone texture of the precursor limestone with very few or no shelly fossils. The lower 0.3 m is split by catagenetic calcite veins and shows very faint syngenetic breccia and pebbles. Base likely disconformable.

1543.2-1545.9 m (5063-5072 ft.) Dolostone: gray, probably argillaceous ('brick smell'), locally weakly calcareous, finely crystalline, with faint lamination in upper 0.5 m and progressively less laminated and mottled downward. The top is undulating, probably with solution sculpture, penetrated by deep (at least 30 cm) upright and branching fractures filled with dark gray dolomitized material (resembling neptunian dykes). Lamination returns in lower 0.6 m as thick (0.5-1 cm) brecciated (karsted?) laminae indicating possible presence of an internal paleokarst surface at 1545.3 m. Base conformable.

- 1545.9-1546.7 m (5072-5074.6 ft.) Dolostone: dark gray, very finely crystalline, probably with argillaceous admixture ('brick smell'), evenly laminated. Original calcimudstone. No fossils. Base likely corresponds to a weak unconformity.
- 1546.7-1548.1 m (5074.6-5079 ft.) Dolostone: gray, finely crystalline, slightly lighter colored than above and below; showing faint original fabric of gently buckled lamination locally disrupted by upright fractures and with some laminae converted into breccia. A 5 cm thick dark-colored breccia interval in 0.3 m above base. No fossils. Base conformable.
- 1548.1-1550.5 m (5079-5087 ft.) Dolostone: dark gray, tight, finely crystalline, locally weakly calcareous. Alternation of evenly laminated and brecciated intervals. The brecciated intervals show disrupted lamination. Minor mottled/nodular intervals with no or very sparse sedimentary lamination may be the originally bioturbated facies. Only these minor intervals contain rare and poorly preserved fossils (fragments of thick-shelled brachiopods). Internal discontinuity surfaces may be present at around 1549.0 m and 1550.2 m.
- 1550.5-1553.5 m (5087-5096.8 ft.) Dolostone: moderately and evenly argillaceous, very dark gray, finely crystalline, evenly laminated, locally with black collapsed fragments (coaly detritus?). Rare mottled lamination disturbance (BI = 2-3). Rare pyrite streaks. Original argillaceous calcimudstones. Lamination angle changes from normal to core (horizontal) to inclined at about 10° from core perpendicular, which probably results from burial soft-sediment deformation. Base conformable.
- 1553.5-1553.8 m (5096.8-5097.8 ft.) Dolostone: dark gray, tight, finely crystalline, with relict mottled to brecciated texture, with whitish chert stripes developed upon thin encrusting stromatoporoids and corals or encrusting bryozoans. Possible primary texture: bioclastic wackestone. Bioclasts are seen only locally and of poor, unrecognizable preservation. Base unclear (not preserved in core).
- 1553.8-1554.1 m (5097.8-5098.7 ft.) Dolostone: dark gray, distinctly mottled from preserved breccia (packbreccia) texture, probably argillaceous (at least argillaceous admixture in the breccia-cementing matrix). Rare mm-sized "cauliflower" chert patches.
- 1554.1-1557.8 m (5098.7-5111 ft.) Dolostone: gray, finely crystalline. The upper 0.3 m probably argillaceous, with unclear brecciated to laminar fabric. Below (1554.4-1555.7 m) is the alternating and intergrading buckled laminar fabric, syngenetic ripped-up breccias, and minor oncoidal fabrics. The portion below (1555.7-1557.8 m) is composed of laminite with distinct very fine (0.3-1.0 mm) thread-like crenulated lamination with rare ripped-up breccias. Lamination becomes even and less distinct in basal part. Base conformable.
- 1557.8-1564.8 m (5111-5134 ft.) Dolostone: dark gray, finely crystalline, weakly to non calcareous, retaining the sedimentary fabric of calcimudstone: thickly laminated (laminae are 1-15 mm thick), locally massive, with disrupted lamination (desiccation cracks) and cm-thick breccia interbeds (photo). Rare upright stylolites. No recognizable fossils. Rare Stromatactis-like cavities. Basal 15 cm are very dark, show faint rubbly fabric and chert windows, probably represent originally coarser-grained facies with carbonate clasts. Thick solution seam in base, likely unconformity.
- 1564.8-1566.6 m (5134-5139.7 ft.) Dolostone: gray, finely crystalline, weakly calcareous, moderately argillaceous, with tiny (<0.5 mm) pyrite inclusions. The upper 3 cm is separated from the underlying part by a poorly seen undulating erosional surface and contain sand-sized chalky white carbonate clasts. The dolostone below contains chains of small solution vugs to the depth of about 30 cm. Primary texture is poorly preserved, expressed in alternation of massive, weakly laminated, and laminated to brecciated rocks. No shelly fossils. At least 2 horizons of chalky sand-sized carbonate clasts inside the interval. The lower 1/3 contains rare oblique fractures filled with very dark gray coarser crystalline dolostone entrapping clasts of host paler-colored dolostone. Base probably conformable.
- 1566.6-1567 m (5139.7-5141.2 ft.) Dolostone: dark gray, finely to medium crystalline, locally calcareous, weakly argillaceous and with shale-lined solution seams. Calcimudstones and minor fine-grained ostracod packstones forming graded beds. BI 60-70%. The basal 4 cm

are argillaceous, strongly compacted, with a boudined seam of whitish chert. Base sharp, overcompacted.

- 1567-1567.9 m (5141.2-5144 ft.) Dolostone: gray, finely crystalline, probably weakly argillaceous, in upper 20 cm massive pelitomorphic with rare solution vugs, below showing buckled and brecciated lamination and occasional syngenetic solution vugs. No distinct fossils. Base likely conformable.
- 1567.9-1568.4 m (5144-5145.6 ft.) Dolostone: gray, partly slightly darker than above and below, massive, with ghost clotted fabric and darker structures looking like small shells or solution vugs. Base: probably a paraconformity or conformity based on lack of solution vugs developed from the top of the underlying unit.
- 1568.4-1569.7 m (5145.6-5150 ft.) Dolostone: gray, finely crystalline, very similar to 5156.7-1567.0-1567.9 m in primary fabric (buckled to crenulated lamination with breccia levels). Base conformable.
- 1569.7-1570.3 m (5150-5152 ft.) Dolostone: gray, weakly to non calcareous, homogeneous, faintly nodular and with no lamination preserved. The lamination partly returns in base where gently undulating non-disrupted laminae making up 10-20% of the interval.
- 1570.3-1571.6 m (5152-5156.2 ft.) Dolostone: gray, finely crystalline like above (about 50 μ m), weakly darkens to the base; top defined by residual ripped-up laminated fabric with some laminae and rip-up clasts distinctly lighter colored than the matrix. Buckled laminae with desiccation cracks are occasionally preserved throughout the interval. The lower 15 cm with faint cloudy pattern and probably light-colored mm-sized carbonate clasts. Base disconformable.
- 1571.6-1572.1 m (5156.2-5157.7 ft.) Dolostone: tight, gray (lighter than above), slightly darkens to base, locally weakly calcareous, with buckled and disrupted lamination, with rubble in top and rare cm-sized, partly collapsed solution cavities filled by light beige geopetal dolostone.
- 1572.1-1573.8 m (5157.7-5163.5 ft.) Dolostone: gray, homogeneous, massive to moderately laminated. The lamination is thick (2-5 mm), gently wavy, without desiccation fissures. Rare shear zones and features light-colored windows filled with light-beige dolostone – probably residual solution vugs. Fractured rubbly zone in base. Top and base apparently conformable.
- 1573.8-1574.4 m (5163.5-5165.5 ft.) Dolostone: gray to dark gray, with thick occasionally disrupted (ripped-up) lamination. The laminae are 5-8 mm thick. Occasional microlaminated horizons tend to be disrupted (microlaminated are horizons with ≤ 1 mm thick laminae). Rare horizons with preserved microbreccia. Regular stylolites. Base probably unconformable.
- 1574.4-1577 m (5165.5-5174 ft.) Dolostone: gray, moderately lighter than above. The fine rubble of argillaceous-dolomite rock and the integrated core of packbreccia in uppermost 10-15 cm. Breccia fill composed of greenish micritic dolomarl with vague cloudy-laminated pattern and abundant inclusions of coarsely crystalline dolomite - paleokarst probably with preserved clayey paleosol. This breccia grades down into pale gray dolostone with complex texture – an alternation of intervals with finely buckled (crenulated) microlamination and clotted contorted texture with dark mottles. The crenulated laminite contains common desiccation cracks and occasional windows of karst breccia. This facies grades down into a darker gray and thickly laminated dolostone identical to 1573.8-1574.4 m. Rare bivalved and disarticulated ostracods. Base not preserved, apparently disconformable.
- 1577-1578.1 m (5174-5177.5 ft.) Dolostone: gray to dark gray, tight, moderately fractured and with significant calcite veining (upright and oblique fracture-cementing veins of milky white sparry calcite). The upper 15 cm are composed of paler-gray dolostone with buckled and disrupted microlamination. Below is dolostone thickly laminated, similar to 5163.5-5165.5 ft. Rare 0.5-1 cm thick horizons of microbreccia in lower part.

- 1578.1-1580.1 m (5177.5-5184 ft.) Dolostone: fractured, gray in upper 30 cm and slightly lighter colored below; the lower 1.8 m is shattered into rubble with 1-3 cm sized fragments, and some core is probably lost. Primary texture: The upper 50-60 cm is the alternation of thickly laminar original calcimudstone(?) and compacted pack to float breccias; this upper part also contains several erosional disconformity surfaces. Below this alternation is grading into paler colored rock with residual buckled microlamination and the imprinted cloudy texture probably resulted from dolomitization. No fossils.
- 1580.1-1581.9 m (5184-5190 ft.) Dolostone: pale gray, moderately darkening in lower one-half. Texture: intervals with buckled microlamination alternate with thickly laminated and weakly brecciated intervals and vague cloudy diagenetic textures; darker colored lower part is dominated by thick lamination. Minor microbreccia horizons throughout the interval. Relatively coarse (1-2 cm) packbreccia in base. Probably original calcimudstone. No fossils.
- 1581.9-1582.2 m (5190-5191 ft.) Dolostone: brownish gray, tight or very weakly microporous, lightly coarser crystalline (0.15-0.2 mm) and more idiotopic than above, with rare small chert nodules; one nodule is replacing a small favositid coral. Pervasive network of solution seams or micro-stylolites indicates post-dolomitization collapse of a porous dolostone. Faint non-identifiable remains of benthic macrofossils in a dolostone. No obvious lamination. Top conformable, base unclear (probably conformity or paraconformity).
- 1582.2-1582.8 m (5191-5193 ft.) Dolostone: gray, massive to thickly laminated, finely crystalline (around 0.1-0.15 mm), preserves several undulating erosional surfaces and overlain by bioclastic-intraclastic calcarenites (identifiable bioclasts are small ostracod valves). The lower ½ preserves collapsed solution vugs filled with greenish gray, probably marly sediments and also probably replace marly mottles indicating that this interval may contain hidden surface of permanent subaerial exposure. Gently buckled lamination is more distinct in the lower part. Base may be disconformable.
- 1582.8-1583 m (5193-5193.7 ft.) Dolostone: gray, mottled due to preservation of the primary fabric: multiphase floatbreccia with dark gray structureless dolostone matrix, probably a paleosol.
- 1583-1584 m (5193.7-5197 ft.) Dolostone: light brownish gray, finely crystalline, retaining gently buckled thin lamination and solution vugs filled with greenish gray marly sediment. (both host rock and cave sediment completely dolomitized). Rare horizons of microbreccia. Base likely conformable.
- 1584-1584.5 m (5197-5198.5 ft.) Dolostone: brownish gray, finely crystalline, locally chertified. Sedimentary fabric massive to weakly laminated, with at least two levels of chalcidony developed upon bioclast-enriched horizons (thin-shelled ostracods and brachiopods). Between these bioclastic intervals, the rock is homogeneous (original calcimudstone) with very rare and small chalcidony nodules (Lithofacies 8).
- 1584.5-1586 m (5198.5-5203.5 ft.) Dolostone: light gray, in top 15 cm darker gray and preserving packbreccia fabric, hosting one thin-shelled chertified brachiopod; grading downward into gray dolostone with preserved lamination and few marl-filled solution vugs. The lamination: intervals with buckled microlamination interbed with thickly laminated and massive intervals both often brecciated. Rarely preserved ostracod and intraclast enriched levels. Base conformable.
- 1586-1586.8 m (5203.5-5206 ft.) Dolostone: brownish gray to gray, coarser crystalline than above, locally calcareous and cherty. The calcareous material comes from residual brownish micritic limestone and bioclasts. The bioclasts or benthic fossils mostly small and infrequent. Chert is developed as layered bluish chalcidony and tends to replace bioclasts. One distinct bed with chert-replaced oncoidal (?) texture in the middle of the interval. Internal structure of rounded grains from this bed is not preserved due to dolomite and chalcidony replacement. Original texture is dominated in wackestones probably with minor packstone-grainstones. BI is close to 3.

- 1586.8-1587.3 m (5206-5207.6 ft.) Dolostone: gray, finely crystalline, homogeneous, massive with local weak lamination. Rarely preserved ostracod bioclasts. BI probably close to 3.
- 1587.3-1588.6 m (5207.6-5211.8 ft.) Dolostone: gray, tight, finely crystalline (0.1-0.15 mm); original calcimudstone overprinted by faint cloudy texture; minor intervals with preserved lamination; several levels with solution features and light-colored greenish marl stringers and cavity fills (vadose cavities or dissolved anhydrite nodules?). Rare fish sclerites in base. The base conformable.
- 1588.6-1590.8 m (5211.8-5219.3 ft.) Dolostone: gray, homogeneous, slightly darkening to the base. Primary texture: fine gently undulating lamination without obvious buckled and desiccation-crack features, solution vugs or fenestrae. Zones of cloudy replacive fabric probably related to dolomite growth. No fossils. A weak unconformity in base.
- 1590.8-1592 m (5219.3-5223 ft.) Dolostone: gray, finely crystalline (≤ 50 μm), tight, very homogeneous, faintly nodular and with minor laminated intervals of the same kind as above. Original calcimudstone. The rock can be weakly argillaceous. Top distinctly laminated and brecciated; poorly preserved solution vugs with geopetal sediments in 15-20 cm below top. Rare fish sclerites and small detritus in lower part of the interval. Base conformable.
- 1592.1-1593.1 m (5223.5-5226.6 ft.) Dolostone: gray, non-calcareous; laminar to patchy alternation of finely crystalline (≤ 50 μm , original micritic), coarser crystalline (≤ 50 μm) idiotopic, and darker colored, probably argillaceous finely crystalline dolostones. Rare chertified laminae in basal 15 cm preserve oncoidal, peloidal, or cortoidal rounded-grain grainstone. The coarser crystalline dolostone laminae may represent original grainstones. Lamination preserves by 15-20% (BI 3-4).
- 1593.1-1593.8 m (5226.6-5229 ft.) Dolostone: very finely crystalline, preserving the texture of microbrecciated and sheared calcimudstone with fine locally preserved buckled microlamination. Tiny solution vugs, locally weakly developed polymud fabric. Rare ostracod valves. This facies is very similar to "palustrine carbonate" facies from the Landry Fm. But without root traces. Base by disappearance of microbrecciation. Base conformable.
- 1593.8-1597.3 m (5229-5240.6 ft.) Dolostone: dark gray, homogeneous, finely crystalline. Original calcimudstones. Alternation of predominantly bioturbated and predominantly laminate intervals. Lamination is gently undulating, composed of 2-10 mm thick laminae sometimes showing low-contrast rhythmicity (pale colored in bases to darker colored in tops). BI 2-3. Infrequent different-sized fish fragments.
- 1597.3-1598.9 m (5240.6-5245.8 ft.) Dolostone: finely crystalline, gray, grading to darker gray in base; preserves buckled lamination and horizons of rip-up breccias. Top and base seemingly gradational.
- 1598.9-1600.6 m (5245.8-5251.2 ft.) Dolostone: dark gray, finely crystalline (30-60 μm), preserving faint lenticular/nodular fabric and minor wavy sedimentary lamination. Interpreted as original moderately bioturbated calcimudstones (BI 3-4). Lower 0.5 m contain rare horizons of ghost structures that can be intraclasts, amphiporids, or burrows. Base disconformable, planar, erosional.
- 1600.6-1601.6 m (5251.2-5254.5 ft.) Dolostone: gray, finely crystalline, weakly to non-calcareous, fabric-retaining. Solution vugs abundant in top (upper 10 cm) and less numerous below; larger solution voids are floored with brownish geopetal sediments. An upright fissure (solution conduit or shear fracture?) in the middle of the interval filled with geopetal light brownish gray sediments and sparry calcite. Sedimentary texture: calcimudstone with gently buckled lamination in top grading downward to evenly laminated to massive micritic lithofacies. Rare fish teeth and scales in lower part. Base conformable, by color darkening and disappearance of solution vugs.
- 1601.6-1603.9 m (5254.5-5262.2 ft.) Dolostone: dark gray, weakly calcareous, coarser crystalline than above (0.08-0.12 mm) with finely crystalline (originally micritic) laminae, retaining

crude depositional features: bidirectional cross-lamination in upper part (photo) and unclear undulating lamination in lower part; the lamination seems to be disrupted by burrows and/or soft-sediment diking. The cross-laminated intervals retains one cm-sized intraclast confirming hydrodynamic nature of the cross lamination. Base uneven, pervasively compacted, showing ghosts of intraclasts or platy transported fossils. Primary texture: probably alternation of wackstones-calcmudstones and fine-grained packstones or grainstones. Black-colored fine sand sized fragments (conodonts?) and rare fish sclerites. BI is not exceeding 3 based on preservation of lamination. Intraclastic conglomerate in erosional base.

1603.9-1606.1 m (5262.2-5269.2 ft.) Dolostone: dark gray, slightly lighter in upper 50-70 cm, finely to medium crystalline (50 to 125 μm) in different intervals. The dolomite crystal size apparently depends on original grainy vs. muddy sediment texture. The upper 30 cm shows indistinct cloudy fabric. Original texture: evenly laminated to massive calcmudstones with minor possible grainstone beds in lower $\frac{1}{2}$. Pyrite content (small dispersed grains and their clusters) is more significant than above. A 15 cm thick bed with residual intraclasts, poorly preserved fossils, and coarser crystalline fabric at 1605.3 m (5266.6 ft.). This level also contains gently bucked laminae bounding abundant thin-shell bioclasts. The even to gently buckled lamination at 5266.8-5268.7 ft. Basal 15 cm with ghost rudstone texture. Fragments may represent intraclasts and/or fossils such as *Amphipora*. Rare fish sclerites throughout. No indication of subaerial exposure or solution in top. The base erosional, paraconformable.

1606.1-1606.9 m (5269.2-5272 ft.) Dolostone: dark gray, homogeneous, finely crystalline with few medium crystalline laminae. Primary texture: calcmudstone with thick gently undulating lamination. Rare fish sclerites. BI around 2. Base disconformable.

1606.9-1607.8 m (5272-5275 ft.) Dolostone: light gray mottled in top and slightly darkening to base. The upper 10-15 cm show mottled fabric with solution vugs and dark "quasicoatings" around them. Below contorted "cloudy" fabric probably resulted from massive dolomite growth inside originally laminated substrate. No fossils. Base conformable, by decline of "cloudy" fabric.

1607.8-1609 m (5275-5279 ft.) Dolostone: gray, finely to medium crystalline (50-100 μm), alternation of laminated and bioturbated intervals. The lamination is thick (2-5 mm), wavy but not buckled. Regular stylolites along lamination planes. Unevenly distributed fish sclerites, no other fossils. Basal 30 cm with "cloudy" fabric. Upright calcite veining. Base conformable.

1609-1610.7 m (5279-5284.4 ft.) Dolostone: very dark gray and somewhat heavier than above, finely to medium crystalline, notably pyritized. Pyrite as horizontal streaks and curved stringers, some dispersed micropyrte is possible. The lamination is poorly seen and very even in upper one-half. The lower part shows alternation of lighter-colored micritic and dark-colored, almost black and coarser crystalline laminae. Rare fish remains, no other fossils. Intraclastic conglomerate in paraconformable base.

1610.7-1611.5 m (5284.4-5287 ft.) Dolostone: mottled dark gray to gray, finely to coarsely crystalline, weakly to non-calcareous. The coarse-crystalline (180-250 μm) idiomorphic mosaic replaces darker colored, probably organic rich and more argillaceous zones. Domal stromatolite fabric in upper 10 cm with phosphatization crusts on some laminae. Undulating laminar pattern in the middle (overprinted by coarse dolomite) may also represent stromatolites. Rare fish remains. The laminar pattern disappears in the lower 10 cm.

N.B.: The interval 1610.7-1611.2 m is relatively heavy and may be enriched in pyrites and/or rare metal sulphides.

1611.5-1611.8 m (5287-5287.9 ft.) Dolostone: gray (lighter colored than above), finely crystalline (50-100 μm), retaining wavy to gently crenulated microlamination; no desiccation-crack features or rip-up breccias. Base by decline of lamination.

1611.8-1613.6 m (5287.9-5294 ft.) Dolostone: gray, slightly darkening in base; finely crystalline as above; massive, showing faint micronodular fabric and minor "cloudy" fabric; the upper

part also shows faint clotted fabric and uneven crystallinity probably resulted from bioclastic precursor limestone (packstone or wackestone). The lower two-thirds are probably original calcimudstones to wackestones. BI 4 or higher. Weak pyritization. Rarely preserved ostracods. Evenly dispersed black biogenic phosphate particles – fish teeth, plane and scales; the tiny particles may correspond to conodonts. Base likely conformable.

- 1613.6-1614.9 m (5294-5298.2 ft.) Dolostone: similar to the above but laminated. The lamination is wavy, thick, without desiccation features, with minor bioturbated horizons, emphasized by lighter colored and coarser crystalline (150 μ m) laminae interbedded with darker and finely crystalline inter-laminae. BI 2. Top and base conformable.
- 1614.9-1616.3 m (5298.2-5302.7 ft.) Dolostone: dark gray, finely crystalline (50-80 μ m), with slightly enhanced pyrite content in the upper one-half where pyritic streaks mark residual lamination and occur as short curved stringers. Faint burrowing textures. A non-replaced bryozoan fragment at 5298.8 ft. and rare brachiopod fragments. Original texture: bioclastic wackestones and calcimudstones. BI 4 or higher. The lower 0.5 m is composed of very homogeneous calcimudstone with residual lamination (BI 3-4).
- 1616.3-1616.8 m (5302.7-5304.5 ft.) Dolostone: gray, massive, finely crystalline, riddled with solution voids filled with black carbonate, brownish geopetals (in larger voids), and some whitish sparry calcite. No lamination. Local preservation of ostracods in chaotic orientation.
- 1616.8-1618.3 m (5304.5-5309.3 ft.) Dolostone: dark gray, finely to medium crystalline, moderately bioturbated (BI 2-3), with preserved wavy lamination. Rare pyritic streaks. Alternation of fine and medium crystalline laminae indicates original alternation of calcimudstones and probably very fine-grained calcarenites.
- 1618.3-1618.5 m (5309.3-5310 ft.) Dolostone: dark gray, preserving coarse conglomerate fabric with cm-sized pebbles of laminated carbonate (completely dolomitized) and rare light green claystone.
- 1618.5-1618.6 m (5310-5310.4 ft.) Claystone-dolostone: floatbreccia of dark gray dolostone in light greenish gray non-carbonate claystone matrix. The claystone matrix is compacted, retains complex laminar-brecciated fabric indicating multiple turbation-weathering – paleosol?
- 1618.6-1618.9 m (5310.4-5311.3 ft.) Dolostone: mottled, finely crystalline, with replacive mottles and stringers of claystone in upper part and poorly preserved solution vugs. Dark mottles resembling “quasicoatings”.
- 1618.9-1620.1 m (5311.3-5315.2 ft.) Dolostone: finely crystalline, tight, weakly to non-argillaceous, dark gray, with enhanced pyritization in upper 0.4 m, lighter gray with less pyrite in the middle, and darkening in basal 0.2 m. Gently undulating lamination is preserved by 10-20%. Common fish sclerites throughout the interval, from 0.1-0.2 mm (conodonts or fish?) up to cm-wide plates with preserved structure. Pyrite is finely crystalline, in darker colored rock grouped in faint streaks. The darker colored dolostone is argillaceous (producing smooth shale-lined solution seams) and probably organic-rich. Top and base conformable.
- 1620.1-1621.7 m (5315.2-5320.6 ft.) Dolostone: alternation of dark gray and gray finely crystalline dolostone similar 5311.3-5315.2 ft. but with lower BI and lamination preserved by 40-60%. Rare fish sclerites; one preserved mold from a small in situ brachiopod. Base not preserved, likely disconformable.
- 1621.7-1622.1 m (5320.6-5321.8 ft.) Argillaceous dolostone: breccia with light beige to greenish gray claystone matrix (or micritic anhydrite?); unevenly crystalline, with coarse (0.15-0.2 mm) idiotopic dolomite grown inside the original claystone (anhydrite?) matrix. The carbonate clasts are poorly preserved, sometimes overprinted by dolomite growth pattern; some fragments show weathering pattern and gradation to the claystone matrix. The upper 15 cm is floatbreccia, below packbreccia with angular carbonate fragments. The carbonate fragments retain massive to moderately laminar fabric.

- 1622.1-1622.8 m (5321.8-5324 ft.) Dolostone: unevenly gray to dark gray, with solution cavities developed from the top. These solution cavities are filled with thick dolomitized claystone showing geopetal laminated pattern. Claystone patches and stringers disappear in lower ½, but brecciation is traced to the interval base. Sedimentary textures unclear because of destructive dolomitization. Base by decline of fissures.
- 1622.8-1624.8 m (5324-5330.8 ft.) Dolostone: weakly to non calcareous, dark to lighter gray and brownish gray, finely to medium crystalline in different laminae, with the average BI of 3 and the lamination preserved by 20% to 60% in different intervals. Minor intervals with poorly preserved remains of macrofossils; rare fish sclerites. Brownish massive interbeds with abundant bivalved ostracods. Possible sedimentary textures: alternation of bioclastic packstones, wackestones and calcimudstones. A karst void with cavity filled with pale greenish gray geopetal sediment and light-colored "vadose silt" is encountered at 5326.5 ft. (karst void form overlying subaerial exposure surface). Base gradational.
- 1624.8-1625.1 m (5330.8-5331.7 ft.) Dolostone: dark gray, non-calcareous, unevenly crystalline and patchily colored due to unevenness of original limestone fabric. Primary texture very poorly preserved, apparently richly fossiliferous with thick-walled brachiopods and probably encrusting forms; microbial micritic deposits ("micritic cements") may have been also present (non-compacted, partly nodular fabric). Calcite is preserved only in rare veins and as a sparry cement in intraskeletal voids. Top and base conformable.
- 1625.1-1626.3 m (5331.7-5335.5 ft.) Dolostone: dark gray, very similar to 5324.0-5330.8 m, with rare intercalations of non-laminated fossiliferous fabrics. Base unclear.
- 1626.3-1628.6 m (5335.5-5343.2 ft.) Dolostone: dark gray, weakly to non calcareous, moderately anhydritic, preserving faint palimpsestic breccia fabric (lighter colored, sometimes brownish clasts submerged in darker colored cementing dolomite. These breccia intervals interbed with partly laminated and minor fossiliferous intervals. Another type of brecciation is anhydrite-dolomite breccia. Anhydrite makes up about 5% of the interval in the form of microcrystalline (50-100 µm) cement of dark gray dolostone breccia. A distinct floatbreccia with thick laminated anhydrite entrapping angular dolostone clasts occurs at 5336.0. Below this floatbreccia, anhydrite occurs as fissure fills and very rare breccia patches. The interval seems to contain several internal discontinuity surfaces. Base by decline of faint breccia in dolostone and transition to homogeneous dolostone.
- 1628.6-1631 m (5343.2-5351 ft.) Dolostone: dark gray, finely crystalline, massive, locally faintly nodular probably original calcimudstone; rare fish sclerites and very rare thin-shelled brachiopods. Local preservation of burrowing pattern and randomly oriented curved pyritic streaks. Rare steeply inclined fissures filled with geopetal finely crystalline anhydrite (as in breccias above).
- 1631-1632.1 m (5351-5354.5 ft.) Dolostone: brownish gray with darker gray intervals, coarser crystalline than above (0.1-0.15 mm), weakly to non-calcareous. Rare poorly preserved pre-dolomite brecciation. Coarser-crystalline layers locally bear remnants of intraclasts. Crude sedimentary lamination is preserved by 20-25%. Rare and thin horizons with buckled microlamination. Sedimentary texture or fossils are not preserved; probably alternation of grainstones and micritic lithologies. The rock is darker colored and more homogeneous in basal 30 cm. Sparse calcite veining.
- 1632.1-1633 m (5354.5-5357.7 ft.) Dolostone: moderately brecciated dolostone to packbreccia cemented by geopetally layered bluish white anhydrite. The dolostone is dark brownish gray, locally showing ghost syngenetic brecciation and locally preserving crude buckled lamination and rip-up clast fabric. Other intervals seem to be bioturbated, containing thin-shelled brachiopods and ostracods. Top and base likely gradational.
- 1633-1634 m (5357.7-5361 ft.) Dolostone: brownish gray, with dark gray stripes and patches; medium crystalline (0.1-0.17 mm), less brecciated than above and below, with wedging faintly laminar sets (reminder of ripple sets) and local rip-up breccias cemented by dolostone. The lower one-half is less laminated, with faint mottling indicating bioturbation.

Rare collapsed anhydrite-filled fenestrae (finely crystalline layered geopetal gypsum sediment). No macrofossils preserved.

- 1634-1636.5 m (5361-5369 ft.) Dolostone: brecciated to packbreccia, very similar to 5354.5-5357.7 m. Minor intervals with crude buckled lamination and syngenetic breccia fabric. Poorly preserved small brachiopod or large ostracod biomolds.
- 1636.5-1638 m (5369-5374 ft.) Dolostone: dark gray, homogeneous, hard and tight, non to weakly calcareous, finely crystalline, probably with moderate amount of matrix-dispersed micropyrrite. Alternation of weakly bioturbated (BI around 3) and laminated (BI 2 or less) intervals. The lamination is even, "basinal". One in situ poorly preserved brachiopod shell. Weak matrix compaction. Rare anhydrite stringers in upper part. Top and base conformable and gradational; the basal part is slightly lighter colored and may contain one or several erosional surfaces (overprinted by dolomitization).
- 1638-1638.7 m (5374-5376.3 ft.) Dolostone: gray to dark gray, mottled, finely to medium crystalline, with primary bioturbated texture, with rare veins of pale colored dolomitic anhydrite. Top and base conformable. Infrequent fish fragments.
- 1638.7-1639.9 m (5376.3-5380.3 ft.) Anhydritic dolostone: heterolithic rock composed of pale gray, brownish gray, and park gray patches of unevenly crystalline dolostone with texture ranging from moderately brecciated to solution collapse packbreccia of dolostone cemented by pale bluish gray finely crystalline layered anhydrite. The anhydrite content is greatest in the middle with 30-40% of anhydrite cements at some levels. This middle part also contains the solution collapsed breccia with variously tilted dolostone fragments. These fragments often contain mass poorly preserved ostracods. Rare patches with crude buckled lamination and rip-up breccia with wrapped (concave-up) carbonate clasts. The upper 20 cm is fossiliferous with poorly preserved dolostone casts of small thin-shelled brachiopods. Top and base likely conformable and gradational.
- 1639.9-1641.2 m (5380.3-5384.5 ft.) Dolostone: dark gray to brownish gray, finely to medium crystalline, homogeneous, with minor brecciated horizons and rare fenestrae filled with geopetal layered anhydrite. Locally preserved lamination. Infrequent small fish sclerites, no other fossils. Very poorly preserved even lamination at some intervals. Base conformable.
- 1641.2-1641.4 m (5384.5-5385.3 ft.) Dolostone: finely crystalline, preserving the texture of bioturbated bioclastic wackestone (ostracods and small fish fragments). Light colored patches/pebbles in base. Base disconformable.
- 1641.4-1642.2 m (5385.3-5387.8 ft.) Dolostone: gray, weakly mottled, preserving the texture of karstified from top massive micritic rock. The mottling is imparted by dark "quasicrystalline" type impregnations. Solution vugs are filled with dark pyritic carbonate. Top rugged, with solution pockets. Base conformable.
- 1642.2-1642.6 m (5387.8-5389.2 ft.) Dolostone: dark gray to brownish gray, with moderately argillaceous and overcompacted interbeds, locally brecciated with anhydrite fills. Mostly bioturbated with swarmed subhorizontal burrows. Base with signatures of syngenetic brecciation.
- 1642.6-1642.8 m (5389.2-5389.7 ft.) Conglomerate: heterolithic, with argillaceous matrix, unevenly overcompacted; overprinted by pre-compactional patches of coarsely crystalline (0.2-0.25 mm) hypidiotopic dolomite. The conglomerate includes subrounded pebbles of gray colored dolostone, dark colored non-calcareous rock, and squeezed pale gray anhydrite pebbles. This rock also crumbles out like shale. Base disconformable.
- 1642.8-1643.5 m (5389.7-5392 ft.) Dolostone: homogeneous, finely to medium crystalline (0.05-0.1 mm), dark-gray in upper 30 cm and lighter colored gray below; Brecciated to 5-7 cm from the top with fissures filled with heterolithic lithoclastic sand (composition as above). The upper 30 cm shows even gently undulated lamination; below the lamination changes to buckled with occasional desiccation features. Fossils: only rare poorly preserved ostracods molds. Base gradational.

N.B.: No bleaching in top of this karstified unit.

- 1643.5-1645.9 m (5392-5400 ft.) Dolostone: gray, finely crystalline, very homogeneous, with small dispersed finely crystalline pyrite streaks and patches; locally with faint mottling. Probably original bioturbated calcimudstone. A slightly darker colored interval with faint flaser fabric (or compacted burrowing fabric) at 5397.8-5399.0 ft. This interval is probably more argillaceous. Common tiny (<0.2 mm) biogenic phosphate grains, rare larger fragments. The tiny phosphate grains may represent conodonts. Rare pyritized ostracod molds. No other fossils preserved.
- 1645.9-1646.1 m (5400-5400.7 ft.) Anhydritic dolostone: laminated and partly brecciated, unevenly crystalline, with intervals of poorly preserved breccia or intraclastic conglomerate fabric.
- 1646.1-1646.6 m (5400.7-5402.1 ft.) Dolomitic anhydrite: brownish light gray and distinctly mottled, showing complex patchy fabric of intermingled finely crystalline anhydrite and finely to coarsely crystalline dolomite. The texture resembles breccia. The basal 10 cm with irregular streaks of brownish finely crystalline dolomite bounding chertified anhydrite resembles the chickenwire fabric. A 50-cm-long core piece with breccia of gray finely crystalline dolostone and heterolithic conglomerate in the middle of the interval. Top gradational, base not preserved.
- 1646.6-1648.2 m (5402.1-5407.5 ft.) Dolostone: gray (darker than above), homogeneous, non-calcareous, finely crystalline, with faint stringers of pale gray rock (dolomite or anhydrite?). Some pale gray stringers show layered geopetal texture indicating cavity fills (fenestrae?). No distinct lamination preserved. Fossils: common (in base abundant) fish teeth and scale; few levels with vague bioclastic texture and poorly preserved ostracods. Base erosional but without subaerial exposure features – paraconformity?
- 1648.2-1649 m (5407.5-5410 ft.) brownish gray, finely crystalline, retaining finely buckled microlamination, overprinted by late diagenetic brecciation with fissures filled with pale gray dolomite-anhydrite rock. Fossils: faint ostracods, rare fish sclerites. Base conformable.
- 1649-1653.5 m (5410-5425 ft.) Dolostone: brownish gray to dark brownish gray, similar to 5407.5-5410.0 m but without the buckled lamination. Low-contrast alternation of massive and poorly laminated intervals. Brecciation is persistent throughout: oblique and subhorizontal straight fissures filled with light-colored medium-crystalline anhydrite-dolomite rock; local development of floatbreccia (dark dolostone in light dolomite-anhydrite matrix). Fossils: rare to common fish sclerites; faint ostracods and non-identified bioclasts. Sedimentary facies is probably calcimudstone to wackestone. Base conformable or paraconformable.
- 1653.5-1654.1 m (5425-5426.7 ft.) Dolostone: light brownish gray, non-calcareous, massive to lamination. The lamination is uneven, in lower part domal (stromatolites). Multiphase brecciation (anhydrite-dolomite cement) and veining (sparry dolomite and calcite cements). The basal 5 cm composed of very dark gray, pyritic dolostone separated by a thick solution seam. This dark dolostone contains large fish sclerites. Base erosional, paraconformable, with rare small pebbles.
- 1654.1-1655.7 m (5426.7-5432.2 ft.) Dolostone: brownish gray microlaminated in top (2-3 cm), grading below to massive, very dark gray, pyritic (dispersed micropyrite and pyritized bioclasts). The lower one-half is the thick alternation and gray and dark gray, mostly massive dolostone, locally with partly destroyed even microlamination. One or more internal erosional surfaces (weak paraconformities). Common fish sclerites, poorly preserved bioclasts. Sedimentary texture: bioclastic calcimudstone. Same style of veining and brecciation. Base probably conformable.
- 1655.7-1656.7 m (5432.2-5435.3 ft.) Dolostone: gray, grading to light gray anhydritic and weakly argillaceous in lower 30 cm; distinct from the above by persisting crude (0.5-2.0 mm) undulating lamination. The lamination is distinct due to alternating pale gray coarser crystalline and dark gray finer crystalline laminae. Several levels with pale gray pyritized finely crystalline dolostone intraclasts. The anhydritic dolostone in basal 30 cm does not

show distinct lamination, it is coarsely crystalline (0.25-0.35 mm) idiotopic, with dolomite crystals submerged in earthy anhydrite matrix. This lower intervals also contains numerous intraclast-like patches of pale gray dolostone and small fish sclerites. No other fossils. Base sharp, probably erosional.

- 1656.7-1657.3 m (5435.3-5437.2 ft.) Dolostone: light gray to gray, massive, finely crystalline. The top is brecciated into the depth of 1 cm and stylolitized. Space between the fragments is filled with coarsely crystalline anhydritic dolostone. The light gray dolostone in the upper 12 cm is separated from the underlying darker gray dolostone by an erosional surface. Unidentifiable fragment of benthic fossils, small fish sclerites. Base gradational.
- 1657.3-1658.7 m (5437.2-5441.8 ft.) Dolostone: pale gray, partly anhydritic, darkening to base; with crude gently buckled lamination and several erosional surfaces, very similar to the upper part of 5432.2-5435.3 ft. interval. A 5 cm thick core with dolostone-anhydrite floatbreccia in the middle. In this breccia, angular dolostone fragments are tilted and chaotically piled in a thick laminated anhydrite matrix/cement. Base gradational.
- 1658.7-1661.1 m (5441.8-5449.7 ft.) Dolostone: dark gray, non-calcareous, finely crystalline, partly laminated (gently undulating disturbed laminae). Burrowing pattern is locally preserved (simple plunging burrows). The overall BI 3. Ostracod microcoquinas are discernible in some laminated intervals. Important brecciation: dolostone-anhydrite breccias cake up no less than 15-20% of the interval. The anhydrite cement is bluish pale gray, finely and unevenly crystalline, locally showing mm-thick geopetal lamination. Outside breccia intervals, anhydrite is encountered in numerous oblique veins/fractures. Base gradational.
- 1661.1-1662 m (5449.7-5452.6 ft.) Dolostone: brownish gray to gray, stripy to mottled, unevenly crystalline (0.07-0.2 mm), hypidiotopic to xenotopic, retaining crude sedimentary features: crude burrowing-disturbed lamination in upper one-half, unclear clotted and biomorphic texture below. The top by disappearance of dolomite-anhydrite breccias and appearance of biomorphs. The latter lost skeletal structure by destructive dolomitization, dominated by collapsed vesicle-shaped forms (gastropods and/or bivalves or small articulated brachiopods), sometimes elongated forms resembling bryozoans or corals. Biomorphs are distributed unevenly, tend to form bedded concentrates (storm redistribution?). Base erosional.
- 1662-1662.7 m (5452.6-5455 ft.) Dolostone: dark gray, finely crystalline, non-calcareous, light brownish gray in uppermost 5 cm (seemingly bleached from the top), massive and partly nodular (original calcimudstone or automicrite), with a Stromatactis at 15 cm below the top (the large, exceeding core diameter, cavity with rugged roof, floored with laminated dolostone, and with upper space filled with medium crystalline yellowish light gray anhydrite cement). Another smaller Stromatactis occurs in 0.5 m below the top. Very faint syngenetic brecciation pattern and rare overprinted by dolomitization birds-eye structures in lower 0.3 m (just above and below the lower Stromatactis). Singular small in situ brachiopods; no other fossils. Base conformable.
- 1662.7-1665.6 m (5455-5464.5 ft.) Anhydritic dolostone: mottled (dark to pale gray) tight rock composed of dark colored finely crystalline dolostone with numerous Stromatactis and early diagenetic fractures cemented by pale colored dolomite-anhydrite cement. The dolomite is unevenly crystalline, preserving only robust sedimentary structures: breccias, polymud fabric, rare to common unidentifiable benthic macrofossils (among them small brachiopods and large (3 mm in diameter) pelmatozoan ossicles). Fenestral network is complex, composed of interconnected "bird's eyes" to decimeter-size Stromatactis. Marine carbonate cements are not obvious, but the open clotted fabrics locally retain whitish isopachous dolomite bands that may represent replaced marine cements. Shear fractures and collapse breccias are common. The Stromatactis cement is typically composed of layered to massive medium-crystalline dolomite-anhydrite rock entrapping blackened (organic-rich?) angular fragments of anhydritic composition. Locally anhydrite seems to be replacive upon earlier dolostone. The proportion of anhydrite moderately grows to base. The base chosen on top of a thick dolomite-anhydrite interval.

- 1665.6-1666.6 m (5464.5-5468 ft.) Dolomitic anhydrite: pale gray to gray, variously calcareous, mottled, medium crystalline (a mesh of earthy anhydrite mass and idiotopic dolomite(?) crystals), showing contorted lamination and ghost breccia texture; locally enriched in clay (shale partings). Abundant crumbles of gray shale and dolomite in the middle (probably a carbonate boulder and shale speleothem infiltration). The base showing complex pattern of lamination-brecciation. The lower 30 cm is the alternation of dolostone with vague syngenetic brecciation fabric and biomorphs (collapsed rubbles?) and the pale gray "sucrosic" dolomite-anhydrite rock as above.
- 1666.6-1667.3 m (5468-5470 ft.) Dolostone: dark brownish gray, finely crystalline, massive to laminated ostracodal calcimudstone-wackstone. The lamination is even, expressed in non-disturbed ostracod micro-pavements. Several levels of collapse breccia cemented by sucrosic anhydrite.
- 1667.3-1667.4 m (5470-5470.6 ft.) Dolostone: gray, non-laminated, finely crystalline, with rare poorly preserved Stromatactis and early diagenetic shear planes. Smaller Stromatactis are totally dolomitized, larger are cemented by coarsely crystalline idiotopic dolomite and pelitomorphic anhydrite. Ghost high-angle shear planes (overprinted by dolomitization) and rugged discontinuities (automicrite growth patterns?). No fossils.
- 1667.4-1669.2 m (5470.6-5476.3 ft.) Dolostone: mottled, unevenly crystalline, dark gray with white and pale gray spots and stringers, preserving complex boundstone texture: vaguely laminated to cloudy matrix hosting in situ articulated brachiopods and encrusting features; the encrusting features vary from crudely wrinkled blades (resembling phylloid algae) to those resembling Stromatactis. Geopetal sediments are common. Isopachous crusts of whitish dolostone are also common indicating marine phreatic cementation. Lamination and encrusting features are curved and largely steeply inclined to the horizon (40-70°). The internal structure of encrusting features is lost due to dolomitization. Ghosty syngenetic breccia and shear fractures are common. Cavities filled by anhydrite are rare. Possible interpretation: platform-slope boundstone.
- 1669.2-1669.4 m (5476.3-5477 ft.) Dolomite-anhydrite rock: pale gray, showing crude buckled lamination and argillaceous partings/laminae, with upturned dolostone fragments; anhydritic matrix is riddled with idiotopic dolomite crystals. Interpretation: fill of a large frame cavity.
- 1669.4-1671.1 m (5477-5482.5 ft.) Dolostone: dark brownish gray, finely crystalline, relatively homogeneous (sedimentary calcimudstone or automicrite), with rare in situ brachiopods and gastropods. The matrix texture is mottled, locally vaguely brecciated to laminated with elongated features inclined at high angle to the horizon (40-60°). Rare open oblique fractures slumping or hearing features?) filled with gray earthy anhydrite cement. At least two levels of earthy anhydrite (also trending obliquely to the horizon). Base gradational.
- 1671.1-1672.7 m (5482.5-5488 ft.) Dolostone: very similar to 5470.6-5476.3 ft., retaining the boundstone texture. The encrusting and laminar features tend to stand upright; one recognizable bryozoan. The lower part contains windows and intervals (several cm thick) of grey earthy anhydrite.
- 1672.7-1673.3 m (5488-5489.7 ft.) Dolomite-anhydrite rock: massive to laminar gray earthy anhydrite hosting cm-sized fragments of dark gray dolostone; dolostone-anhydrite floatbreccia in basal 15 cm (photo). Base rugged, inclined at 35-40° to the horizon.
- Two possible interpretation of anhydrite: (1) catagenetic "hydrothermal" replacement; (2) cavity fills (cements).
- 1673.3-1674.3 m (5489.7-5493.0 ft.) Dolostone: dark brownish gray, very similar to 1669.4-1671.1 m (5477-5482.5 ft.).
- 1674.3-1675.1 m (5493.0-5495.8 ft.) Dolostone breccia: catagenetically brecciated dolostone with boundstone texture (similar to 1667.4-1669.2 m), with lamellar features inclined at 45-60° to the horizon. The intervals in top (10 cm) and in the middle (15 cm) are dominated by

sucrosic dolomite (floatbreccia with rare fragments of finely crystalline dolostone). Intense veining of milky white dolomite and calcite.

1675.1-1675.4 m (5495.8-5496.7 ft.) Dolostone: dark gray, finely crystalline, massive and homogeneous, with faint obliquely trending automicrite growth structures in base; the interval is fractured with calcite veins. No fossils.

1675.4-1676.9 m (5496.7-5501.5 ft.) Dolostone: gray, vaguely laminated to cloudy crystalline (0.2-0.4 mm) "sucrosic" dolomite with pebble to boulder sized angular fragments of dark gray dolostone. Ghost fragments of dolostone half-converted into anhydrite are also present. The dolomite blocks locally form floatbreccia; they are intensely fractured with sparitic calcite veins. Texture is dolostone is massive, very similar to the 1675.1-1675.4 m.

1676.9-1677.2 m (5501.5-5502.5 ft.) Dolostone: hard, gray, unevenly crystalline, with distinct floatbreccia texture (locally grading to packbreccia). Clasts: angular, up to 2-3 cm in size, dark gray finely crystalline dolostones sometimes with very faint laminar structures. Matrix: coarsely crystalline (0.25-0.4 mm) light gray idiopic-hypidiopic dolostone with minor anhydrite patches/streaks. The overall amount of anhydrite does not exceed 3%. Rare mammilar inclusions of chalcedony. Ghosts of smaller dolostone clasts overprinted by the coarsely crystalline matrix dolostone are very common indicating probably multiple replacive/metasomatic origin of the breccia.

1677.2-1677.9 m (5502.5-5505 ft.) Dolostone: hard, tight, dark gray finely to medium crystalline, with extensive calcite-dolomite veining, with minor bleached brecciated intervals (catagenetic breccia). The dark gray finely crystalline blocks retain the original fabric of massive to nodular micritic rock with very faint gravity-denying features (automicrites growth), with a 7 cm thick interval of boundstone composed of phylloid algae-like encrusting fossils; rare banks of in situ brachiopods. Base by transition into breccia.

1677.9- 1678.2 m (5505.0-5505.8 ft.) Dolostone: breccia very similar to 1677.2-1677.9 m.

1678.2-1679.4 m (5505.8-5509.7 ft.) Dolostone: dark gray, finely to medium crystalline (50-120 µm), extensively veined, with minor intervals of breccia with lost sedimentary fabric (breccia makes up 25-30% of the interval). Dolostones retain the sedimentary texture of massive micrite and boundstone with steep, almost upright trending phylloid algae-like fossils. Base diagenetic, by transition to breccia-dominated interval.

1679.4-1681.6 m (5509.7-5517 ft.) Anhydritic dolostone: breccia-dominated interval (floatbreccia) with clear pattern of in-situ anhydritization upon the precursor dark gray dolostone. The anhydrite is pale gray sucrosic with black streaks (to be identified) and fissile shale streaks, with complex vaguely laminar to cloudy fabric, locally chertified. The dolostone blocks are angular, finely to medium crystalline, homogeneous, locally unevenly bleached. Sedimentary texture was probably homogeneous micritic with no fossils or boundstone features. No definite sedimentary structures observed.

1681.6-1682.2 m (5517-5519 ft.) Dolostone: dark brownish gray, finely crystalline (88-100 µm), non to weakly calcareous, fractured and moderately veined, with white sparitic dolomite cement in veins/fractures. Rare very poorly preserved brachiopod valves and one articulated shell. No boundstone features. Base by transition to the anhydritic secondary rock.

1682.2-1682.8 m (5519-5520.9 ft.) Anhydrite: gray, dolomitic and unevenly argillaceous (streaks of fissile shale), with dark flakes/ streaks of pyritized material (to be identified), with complex secondary fabric of vague convolute lamination. Sedimentary textures or fossils are absent.

N.B.: This interval was previously labeled in the core box as the Mount Kindle top.

1682.8-1682.8 m (5520.9-5521.1 ft.) Dolostone: moderately anhydritic (replacive stringers of pelitomorphic anhydrite), unevenly crystalline, retaining the texture of subrounded conglomerate. The pebbles are composed of brownish gray dolostones with lost sedimentary structures; most pebbles are corroded from margins, some are merging with matrix. The matrix is argillaceous-anhydritic-dolomitic, with replacive patches of layered

yellowish chalcedony, with coarse (0.25-0.3 mm) idiomorphic zonal crystals of dolomite. Interpretation: transgressive basal conglomerate. Base is catagenetic (anhydritized), supposedly unconformable.

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1682.8-1683.6 m (5521.1-5523.5 ft.) Argillaceous anhydrite: similar to 5519.0-5520.9 ft. but seemingly more argillaceous, with bending shale films/partings and flakes/partings of dark pyritized material. Rare cm-sized fragments of bleached finely crystalline dolostone with lost sedimentary texture. The base is generally more argillaceous than the top. Interpretation: may represent a topsoil (weathering crust) overprinted by burial sulphatization.

1683.6-1683.9 m (5523.5-5524.5 ft.) Dolostone: dark gray to brownish gray, probably variously anhydritic, medium crystalline, partly retaining the texture of stromatolite entrapping large (1.0-1.5 cm) oncoids (photo). The rock is bleached and probably strongly sulphatized in lower one-half.

1683.9-1685.8 m (5524.5-5530.8 ft.) Dolostone to anhydritic dolostone: alteration of coarsely crystalline (0.4-0.6 mm) brownish gray dolostone and pale gray sucrosic anhydritized dolostone with lost sedimentary fabric. The dolostone preserves only crude sedimentary features: uppermost 10 cm shows dark brownish gray dolostone with randomly bending 2-3 mm thick cylindrical features with lost internal structure ("vermiform features") – can be burrows or in situ fossils (corals, sponges, or amphiporas). Below dolostones are even coarser crystalline, stylolitized and veined, retaining unrecognizable lamellar fossils, fenestrae or closed brachiopods with geopetals. Dolostones and anhydritic dolostones in nearly equal proportion. Base severely anhydritized, unclear.

1685.8-1689 m (5530.8-5541.5 ft.) Anhydritic dolostone: secondary, possibly multiphase breccia (floatbreccia in top, grading to packbreccia in lower part). Pale gray, medium to coarsely crystalline "sucrosic" matrix embeds darker gray finely crystalline angular clasts. Common stylolites. No sedimentary structures preserved.

Ebbutt D-50

UWID: 300/D-50-6220-12215/0

Core diameter: 3½ inch

Interval measured: 434.6-482.8 m (1426-1584 ft.)

Measured depth before correction to recovered core thickness

Core # 2

IMPERIAL FORMATION

434.6-440.3 m (1426-1444.4 ft.) Shale: gray, laminated, fissile, non-calcareous, hard to weakly slacking in water, with thick (0.1-2.0 cm) hard laminae. Some of these laminae are very faintly fissile (almost massive), brownish gray, sideritic. Fine (less than 0.3 mm) coaly detritus present in minor quantity in some intervals, but most of rock is detritus free. BI 2-3 in top of interval, diminishing to BI 1-2 towards base. Bioturbation: plane crawling tracks - "*Macaronichnus*"? (photo). Very gradual transition to underlying bed.

Core # 2-3

HORN RIVER GROUP (UNDIVIDED)

440.3-445.6 m (1444.4-1462 ft.) Shale: dark gray, strongly fissile, laminated, intercalated by thin (0.1-2 mm) laminae of black shale. Proportion of dark gray and black shale on this interval approximates to 3:1. Upright brick-red carbonate veins (hydrothermal), photo. Minor quantity of fine (less than 0.3 mm) coaly detritus. Sideritic laminae (0.5-2 mm thick) throughout the interval. Rare pyrite streaks. No distinct trace fossils. Even gradation to underlying bed.

445.6-450.5 m (1462-1478.1 ft.) Shale: mostly black with some very dark gray in top, laminated, mostly fissile and minor hard massive with conchoidal fracturing (siliceous), with numerous pyritic nodules and pyritized laminae; rare pyrobitumen laminae; no distinct coal detritus no bioturbation. Hardness and apparently SiO content increases to base marking gradation to the underlying interval.

450.5-452.6 m (1478.1-1485 ft.) Shale to chertstone: black, hard, laminated, probably silty (local siltstone), moderately fissile, non-calcareous, with characteristic conchoidal fractures. Lamination very even, parallel, locally emphasized by alternation of more and less pyritized laminae. Rare flattened pyritic nodules.

Core # 4

452.6-455.1 m (1485-1493.3 ft.) Shale: black to dark gray, variously calcareous (locally non-calcareous), probably locally silty, cherty, evenly laminated as above, with very small (< 0.5 cm) pyrite nodules. No fossils detected. Top and base gradational.

455.2-466.68 m (1493.3-1531.1 ft.) Shale: black, non-calcareous, evenly bioturbated, locally cherty, with small pyritic nodules. Less cherty intervals are fissile, more cherty ones tend to be hard and with conchoidal side fractures. Lamination emphasized by alternation of more and less pyritized laminae. Lamination becomes somewhat less even in basal 1.2-1.5 m (weak segregations of differential cementation?). Rare small obscure fossils occur in basal 0.3-0.6 m (collected and bagged by predecessors). Top and base gradational.

HUME FORMATION

466.68-467.1 m (1529.5-1532.5 ft.) Cherty limestone: with large, more than core diameter, chertstone nodules; black to very dark brownish gray, probably argillaceous, tight, rich in organic matter. Cherts are black (same color as host limestone), predominate in bed top; they mimically replace original limestone texture of bioturbated bioclastic wackestone to packstone; top sharp, cherty, undulating, with cm-deep shale pockets; the top admitted by a thin (1-2 cm) crust of enhanced pyritization and possible mineral impregnation (phosphatization?). Its submarine hardground nature is possible. Macrofossils: gastropods, brachiopods, one solitary rugose coral; a cluster of stromatopores and one pachyporid coral in lower 7 cm of the interval. Rare small (< mm) subangular lighter-colored limestone (derived from the bed below). No matrix compaction features in chert, weak matrix compaction in limestone; thick high-amplitude stylolites.

Core # 5

467.1-467.6 m (1532.5-1534 ft.) (core # 4) and 467.6-468.0 m (core # 5): Limestone: brownish-gray, tight, locally severely stylolitized; calcimudstone, in the upper 12 cm bioturbated (swirly burrowing patterns), with very rare thin-shelled fossils 1-2 mm in size (ostracods?); below is calcimudstone without any shelly fossils, with faint, very disrupted lamination; microtexture is by 60% clotted/finely peloidal and by 30-35% composed of thin laterally disappearing buckled crusts of dense micrite. Small (<3 mm) birds-eye fenestrae make up 3-10% of core faces. Zones of tubular rarely branching channels of about 1 mm in diameter occur throughout the bed. Intervals with rare vugs and no channels alternate with intervals with increased solution features and channel penetrations. In upper 20 cm most channels

occur in the form of tubules wrapped in pale coatings of micritic calcite, but some channels are devoid of coatings. Vadose features: solution vugs, especially well developed in upper 0.3 m (core #4). In upper 12 cm larger vugs are floored with dark gray speckled "vadose silt", below vugs sometimes lined by pale micritic calcite coatings. Sparitic cement filling vugs and channels is dark brown, contaminated by opaque inclusions in uppermost 5-7 cm and becomes clear downwards. Top is truncated by a high-amplitude stylolite.

468-468.2 m (1535.5-1536 ft.) Limestone: dark brownish gray, strongly compacted (nodular). In nodules, packstone bioclastic, bioturbated, with numerous spheres (foraminifers?) and tubular microfossils (kamaenacean syphoneans?). Thin-shelled brachiopods, some articulated and in life position. Thick solution seams are black, dolomitized. Corroded by stylolites septate corals in top. Both top and base are truncated by high-amplitude stylolites.

468.2-468.5 m (1536-1537.1 ft.) Limestone: pale brownish gray; upper 20 cm is faintly laminated calcimudstone identical to 1531-1532, locally penetrated by Mn dendrites, with numerous solution vugs; tubular channels are also present and wrapped in pale micritic coatings; downward gradation to calcimudstone massive, dense to clotted, with rare solution vugs, rare small fossils, and one stylolitized stromatoporoid. Increasingly compacted to base (solution seams). Base is conformable or paraconformable, marked by abrupt facies change. No distinct erosional surface is preserved though.

Top 35 cm of Pt.7/11 Limestone at 1561.0.

468.5-469.3 m (1537.1-1539.7 ft.) Limestone pale brownish gray: in upper 20 cm calcimudstone fenestral, with clotted matrix, with very rare small thin-shelled fossils, with residual very disrupted and buckled lamination, with solution vugs (solution-enhanced fenestrae) and variously oriented channels, some with micritic coatings. Roofs of fenestrae/vugs are locally lined by thin black crusts. Crenulated lamination is relatively well preserved at 15-20 cm below the top. Below gradation to calcimudstone bioturbated, with very rare macrofossils (tabulate corals, one stromatoporoid fragment), with zones of solution vugs (1537.7-1539.7). Infrequent high-amplitude stylolites throughout the bed. Thick high-amplitude stylolite in base.

469.3-469.8 m (1539.7-1541.2 ft.) Limestone: pale brownish gray, evenly and moderately stylolitized; calcimudstone/stromatolite with well-preserved finely crenulated microlamination, with rare lenses of dense "algal" micritic nodules (structureless under hand lens), with solution vugs, some lined with thick coating of pale micrite. Lamination is generally horizontal with few small (<2 cm) domes in lower part of bed. Minor flattened fenestrae are present. The solution vugs are most numerous in the uppermost 10 cm where they contain strongly pyritized geopetal sediments; below solution vugs are less frequent. Basal 7-8 cm is distinct by development of fine darker brown mottles of micritic carbonate. These mottles occur in thick clusters resembling *Epiphyton*, but without distinct dendritic pattern. These mottles may be a microbial carbonate thicket or diagenetic features. Base compacted, destroyed by core rotation.

469.8-471 m (1541.2-1545.3 ft.) Limestone: pale brownish gray, tight, with numerous dark solution seams (smoothened stylolites); calcimudstone by 60% massive (bioturbated), and 40% of intervals contain residual crenulated lamination disrupted by burrows. Pattern of bioturbation obscure. Massive and moderately laminated intervals grade to each other, some of them contain rounded birds-eye fenestrae and solution vugs (solution-enlarged fenestrae?) These fenestrae/vuggy intervals are less compacted (or even non-compacted). Thick solution seams are dolomitized and in upper part of bed contain rare ellipsoidal pyrite nodules 5-15 mm in diameter. Sparitic cements in fenestrae locally pyritized. Tiny (0.1 mm) spheres and local accumulations curved tubular microfossils (0.1-0.2 mm thick and 0.5-0.7 mm long), both predominantly in massive facies; no macrofossils. Base and top conformable.

471-471.3 m (1545.3-1546.3 ft.) Limestone: pale brownish gray, distinctly laminated, tight; lamination emphasized by abundant black stripes of bitumen or Mn impregnation (dendritic

impregnation). Lamination finely crenulated, with small-scale teepee structures, disruptions, and rare pavements of mud flakes (desiccation features). Solution vugs / fenestrae developed in less laminated (more massive) intervals. Base conformable.

471.3-471.8 m (1546.3-1547.8 ft.) Limestone: brownish gray, bioturbated, in lower part nodular and generally dark gray due to development of thick and dense solution seams. These seams are moderately dolomitized. Calcimudstone to wackestone bioclastic with a 10 cm thick boundstone interval at 471.6-471.7 m. Thin-shelled microfossils only: spheres, infrequent ostracods; boundstone is intensely compacted (originally argillaceous?), built by curved tubular microfossils 0.1-0.2 mm in diameter; these "vermiform" microfossils seem to have constrictions and/or horizontal partitions – syphonean algae or foraminifers? Base conformable.

471.8-472 m (1547.8-1548.7 ft.) Limestone: calcimudstone/stromatolite pale brownish gray, laminar, birds-eye, very similar to 471-471.3 m, but with less teepee structures. Interlayers of very fine-grained grainstone in basal 5 cm. Lamination is finely crenulated, locally emphasized by black impregnation, generally horizontal, with small (ca. 1 cm) and very low domal forms.

472-473.2 m (1548.7-1552.4 ft.) Limestone: pale brownish gray, darkens in base; calcimudstone fenestral, moderately laminated; upper 15 cm is wackestone to packstone bioclastic bioturbated; lamination also diminishes to bed base. Upper 15 cm (wackestone) is impregnated by black dendrites and penetrated by large (up to 2 cm) solution vugs floored by dark geopetal sediment. These geopetals contain tubular microfossils. Bioclasts in underlying calcimudstone are rare. Lamination there is notably thicker than at 471.8-472 m interval, disrupted by teepee structures and locally by burrows. Local development of dark dendritic staining. Basal 20 cm is calcimudstone nodular, massive, with thick dark dolomitic solution seams, with progressively more bioclasts towards the base. Nodules tend to be also stylolitized inside.

473.2-474.8 m (1552.4-1557.6 ft.) Limestone: dark gray, nodular, with thick dark dolomitized solution seams; wackestones and packstones bioclastic, bioturbated, with dense micritic matrix; Microfossils: spheres, bioclasts, tubular microfossils with constrictions; the latter locally form mass accumulations. Macrofossils: numerous gastropods, disarticulated thin-shelled brachiopods, ?bivalves. No lamination preserved.

474.8-475.7 m (1557.6-1560.8 ft.) Limestone: tight, pale brownish gray in upper half, darkens slightly to base; calcimudstone massive, partly nodular, with progressively more thick dolomitized solution seams towards base. A 5 cm thick laminated interval (crenulated microbial lamination) at 481.2 m. Minor solution vugs or fenestrae, calcite-filled fractures all over the bed; upright and bending biogenic channels, 1.5 mm in diameter, occur in plenty at 475.3 m and also rarely elsewhere in the bed; at 475.3 m one branching of such channel is seen. Possible interpretation of channels: *Skolithos* burrows or root traces. Matrix of calcimudstone is locally faintly mottled, with very weak dark bluish staining resembling quasicoatings. Microfossils rare (thin-shelled coiled forms), no macrofossils.

475.7-477.1 m (1560.8-1565.2 ft.) Limestone: tight, very dark (almost black), intercalated with thick (1-4 cm) "interlayers" or seams of overcompacted and probably dolomitized argillaceous limestone; locally these seams are wavy, defining nodularity. Bioclastic calcimudstones with dense uniform micritic matrix; minor wackestones. Bioclasts: small (<5 mm) and thin-shelled coiled fossils; occasional accumulations of crinoid ossicles; ostracods; BI 4, trace fossil patterns obscure; thin (1-2 m) crudely graded bioclastic beds, probably of storm origin, are locally preserved in lower half of bed, although these beds are rare. Top and base gradational.

477.1-478 m (1565.2-1568.1 ft.) Limestone: tight, very dark (almost black), intercalated by seams of overcompacted dolomitized limestone (these seams are thinner than in the overlying bed). Infrequent small (4-5 cm wide) whitish lenses of chertification. Wackestones bioclastic with rare interlayers of calcimudstone; bioclasts locally pile into packstones; rarely preserved crudely graded storm layers. Bioclasts mostly thin-shelled (ostracods,

gastropods, ?goniatite juveniles); frequent thick-shelled macrofossils, probably mollusks, preserved as sparite-filled biomolds; very small and thin-walled tabulates. Bioturbation slightly more intense than in the bed above (BI 4-5). Top and base conformable.

478-480.7 m (1568.1-1577 ft.) Limestone: tight, dark brownish gray, dissected by thick (1-3 cm) veins of milky white gigantocrystalline calcite and likely coarse gypsum. Veins are mostly upright, thin (1-2 mm) in top of interval and widen to 2-3 cm in 0.3-0.4 m below top; many veins preserve cm-sized intercrystalline voids, and core is mostly disintegrated into breccia. Sedimentary texture in host limestone: packstones and minor wackestones bioclastic, in 1.0-1.3 m below the top very gradually pass into alternation of packstones and stromatoporoid boundstones (floatstones-bindstones). Stromatoporoids: bulbous and thick lamellar forms; local piles of amphiporids. Bioclasts diverse: brachiopods, mollusks, ?bryozoans, small thin-shelled forms. The upper 1.0 m is enriched in gastropods and bivalves. Bioturbation intense (BI5), no primary lamination preserved. Solution seams in host limestone defining original nodularity are cross-cut by calcite veins pointing to post-compactional timing of their formation.

Core # 6

481.6-482.8 m (1580-1584 ft.) Limestone: dark brownish gray; matrix-rich packstones and amphiporid bafflestones, floatstones and rudstones; high-amplitude stylolites and unusual brecciation expressed in development of dolomitic and calcareous zones with encasing angular fragments of host limestone; these replacement zones contain clay-like insoluble residue on etched surfaces. Might these zones be related to hydrothermal gigantocrystalline veins of the overlying interval? High-amplitude stylolites are also present. Core top had been picked for faunal identification. Fossils diverse: mollusks, brachiopods, tabulate corals, mass amphiporids, rare bulbous and lamellar stromatoporoids. Base conformable.

Husky et al. Little Bear N-09

UWID: 300/N-09-6500-12630/0

Core diameter: 9 cm

Interval measured: 1670-1837.4 m

Core 1, 1670.00-1706.00

1.38 m per box, 0.65 m in box # 1 (packing from bottom to top).

CANOL FORMATION

1670.00-1674.00 Shale: Brownish black, faintly microlaminar (laminae defined by pyritic streaks) to almost massive (cryptolaminated) where pyritic streaks are not developed. Rare elliptical pyrite nodules (photo). Core relatively hard (7-15 cm thick chunks, with minor conchoid surfaces – increased Si content. Rare vertical formational fractures in upper part, some fractures are lined with brownish microsparitic calcite. Base by gradual increase in fissility.

1674.00-1693.8 Shale: dark gray, fissile, very homogeneous, non-calcareous. Slightly different from the overlying interval by more prominent fissility, lack of conchoid surfaces, and faster absorption of sprayed water indicating greater proportion of expandable clay. Also, pyrite streaks highlighting lamination in the overlying interval are lacking (or very rare) so the total interval may be less pyritic. Sub-mm sized, poorly preserved organic fragments (plant detritus) and rare pyrobitumen flakes on fissility planes.

Core 1, 1670.00-1706.00

Core 2, 1706.00-1760.25

- 1693.8-1699.2 Shale to mudrock: Brownish black, fissile, non-calcareous, with minor (<5%) lighter-colored grains (detrital?) of silt to very fine sand size. Most notable difference from the overlying interval is rare lighter-colored silt laminae 0.2-2 mm in thickness. Return to fissile homogeneous shale in lower one-half. Rare siderite(?) nodules producing slickensided impressions in surrounding shale.
- 1699.2-1713.3 Shale: Brownish black, faintly microlaminated (laminae defined by pyritic streaks), moderately fissile, slightly harder than the fissile shale above: thick (5-20 cm) monolithic cylinders of non-expanding siliceous shale alternate with more fissile shale. Rare pyritic streaks and small scattered pyrite nodules. Rare thin siltstone laminae including graded laminated beds up to 5 mm in thickness. A horizon of authigenic stellate calcareous aggregates at 1702.8-1702.9 m. Rare subhorizontal conchoid surfaces and rare upright pyrobitumen-lined fractures. At some intervals core looks very homogeneous.
- 1713.3-1713.45 Calcareous shale: brownish black, hard, non-expanding, microlaminated. Lamination defined by pyritic streaks and calcareous material – authigenic tiny (about 0.1 mm) crystal aggregates, some of them of stellate shape. No bioclastic material is present.
- 1713.45-1722.0 Shale: Brownish black, faintly microlaminated, relatively hard, with rare graded laminated beds of siltstone and likely rare authigenic aggregates of stellate calcite associated with siltstone laminae; these aggregates are the only calcareous material. This interval is very similar to 1699.2-1714.5 m.
- 1722.0-1722.3 Calcareous and siliceous shale: very hard, microlaminated; individual grains are not visible – fine calcareous silt? The interval is moderately and evenly calcareous, calcite may reside in grains or matrix. Upright fractures with thin skins of light brownish micritic calcite.
- 1722.3-1724.5 Siliceous shale: brownish black, hard and moderately fissile, non-calcareous, with tiny pyrite streaks highlighting lamination.
- 1724.5-1738.2 Shale and mudrock: alternation of hard shale similar to 1723.3-1724.5 m and laminated mudrock (silty shale). Laminae enriched in silt – very fine grained sand comprise about 5-10% of the interval. Rare upright bitumen-lined fractures and stylolites associated with boundaries of laminated siltstones and shales (photo). The interval is mostly non-calcareous, with rare horizons containing stellate aggregates of authigenic calcite (photo).
- 1738.2-1738.5 Calcareous shale to limestone: very hard, dark gray (lighter than above and below), distinctly laminated, with poorly preserved conical microfossils (styliolinids?) in the lower one-half. No microfossils are discernible in the upper half. This interval represents a fining-upward rhythm with very calcareous (calcsiltite) base and weakly calcareous to non-calcareous top. No pyrite streaks/laminae.
- 1738.5-1746.45 Shale: brownish black, siliceous, non-calcareous, laminated (emphasized by pyrite streaks). Very thin (< 1 mm) siltstone seams and lenses very rarely occur in basal 3 m. The rock is hard, monolithic to moderately fissile, almost non-expanding, preserves as 1-20 cm long cylinders. Rare large pyrite nodules/lenses and upright bitumen-lined fractures. A 10 cm thick moderately calcareous interval at 1741.6 m. Calcareous material there occurs as micrite encased in a siliceous shaly matrix as indicated by rapid decline of HCl fizzing (indicating that calcareous grains do not form interconnected framework in a matrix). Important feature in lower 3 m: rare large (10-20 cm across) calcareous nodules with diagenetic, probably sparitic-microsparitic, matrix (photo).
- 1746.45-1749.75 Shale: black, hard, weakly calcareous to non-calcareous, laminated as defined by pyrite streaks. Calcareous intervals (10-30 cm thick) alternate with non-calcareous shales. Calcite occurs in two forms: light gray microsparitic to finely sparitic grains dispersed in matrix of siliceous shale and micrite-sized (invisible) admixture in matrix. Lack of a continuous calcareous network in matrix is indicated by rapid decline of HCl fizzing

(especially rapid in intervals with micritic admixture). No fossils preserved. Proportion of calcareous intervals increases downward. The base is defined by a 50-60 cm thick calcareous interval with granular inclusions of calcite. Pyrite in calcareous intervals is less abundant than in non-calcareous. Base and top gradational.

- 1749.75-1751.2 Shale: black, siliceous, hard, non-calcareous, very homogeneous, with deviations into mudrock (silt admixture). Lamination is poorly visible because of very few pyrite streaks.
- 1751.2-1755.35 Shale: brownish black, weakly to moderately calcareous, with minor non-calcareous intervals, hard, subfissile, very homogeneous (lack of lamination-defining pyrite streaks). The lamination is best expressed in calcareous intervals where it is defined by light-colored calcite inclusions (50-70 μm in size, same as above). Fractured interval at 1755.2 m with oblique fractures at 70° angle to lamination lined by shear striations and thin calcite skin. This interval is calcareous and very hard.
- 1755.35-1756.0 Shale (mudrock): brownish black, very homogeneous, non-calcareous, relatively hard and subfissile (slightly more fissile than above), laminated (very poorly seen lamination), Almost no pyrite streaks.
- 1756.0-1756.6 Shale (mudrock): brownish black, very homogeneous, subfissile, similar to 1755.35-1756.0 m but weakly and evenly calcareous. Like in the interval above, pyrite streaks are absent, which makes sedimentary lamination indiscernible. Calcareous material probably micritic, encased in siliceous shale matrix.
- 1756.6-1758.4 Shale (mudrock): brownish black, very homogeneous, subfissile, hard, non-expanding, similar to the above but non-calcareous.
- 1758.4-1758.65 Shale (mudrock): brownish black, very homogeneous, subfissile, hard, non-expanding, similar to the above but weakly and evenly calcareous (identical to 1756.0-1756.6 m). No pyrite streaks or nodules.
- 1758.65-1759.4 Shale: brownish black, hard and less fissile (5-25 cm thick cylinders), siliceous, microlaminated, homogeneous, with tiny (<0.1 mm thick and <1 cm wide) pyrite streaks and isometric inclusions and very rare more continuous pyrite laminae, with rare cm-sized organic fragments (coaly particles?).
- 1759.4-1759.8 Shale: brownish black, weakly calcareous with non-calcareous intercalations. The lower part of the interval contains laminated calcisiltite likely composed of silt-sized carbonate particles (photo).
- 1759.8-1760.25 Shale: brownish black, hard and subfissile, non-calcareous, similar to 1758.65-1759.4 m; one weakly calcareous seam at 1760.15 m.
- Very few or no conchoid surfaces in 1738-1760 m interval.

Core 3, 1760.25-1814.45

- 1760.25-1760.9 Mudrock (silty shale to siltstone): black, weakly calcareous with non-calcareous intervals, hard and only weakly fissile (forming 3-25 cm thick cylinders), apparently very siliceous, homogeneous, lamination poorly seen, defined by depositional heterogeneities; no pyrite streaks. Calcareous material as micritic (invisible) components in matrix. A large (5 cm) calcareous-pyritic nodule near the top. The overall content of pyrite is moderate to low.
- 1760.9-1762.0 Mudrock (silty shale to siltstone): very similar to 1760.25-1760.9 m but non-calcareous, with only very rare calcareous laminae. Infrequent and tiny pyrite streaks.
- 1762.0-1764.2 Mudrock (silty shale to siltstone): very similar to the above; low-contrast alternation of weakly calcareous and non-calcareous 1-25 cm thick intervals. Lamination is generally more distinct in calcareous intervals. Fissility slightly increases to the base.
- No more 'stellate calcites' are seen downward from 1760.25.
- 1764.2-1766.4 Calcareous shale to mudrock: similar to the above, different by domination of calcareous intervals with relatively conspicuous microlamination and vertical fractures with

finely rugged walls; some intervals fizz vigorously (comply to argillaceous limestones or marls).

- 1766.4-1770.5 Shale: very homogeneous, black, hard and subfissile (as 1-12 cm thick cylinders), with obscure lamination, dominantly non-calcareous, with minor and thin calcareous interbeds (no more than 15% of the interval). Rare conchoid fractures and common upright formational fractures. Pyrite occurs as rare large nodules and tiny, relatively infrequent streaks along lamination.
- 1770.5-1771.9 Mudrock: black, hard, non-calcareous silty shale to siltstone; very homogeneous, with only faint traces of lamination defined by very weak differences between laminae. Pyrite streaks are notably rare and tiny (up to 1 mm long). Lamination planes very even.
- 1771.9-1774.25 Mudrock: black, hard, homogeneous, mostly non-calcareous with minor weakly calcareous intervals. Calcite occurs in micritic matrix form. Rare pyritic laminae, tiny streaks, and very rare small elliptical pyrite nodules. Upright formational fractures.
- 1774.25-1774.6 Limestone: very argillaceous and silty / finely sandy, very dark gray to black, more distinctly microlaminated due to laminar distribution of calcareous material. Proportion of calcite and siliciclastics is roughly 50/50. Calcite is dispersed in matrix and forms paler-colored laminae as recrystallized matrix and probably very poorly preserved, non-identifiable bioclasts and/or microfossils, all < 0.15 mm in size. Pyrite rare, occurs as tiny (<0.3 mm) aggregates. Smooth, low-amplitude stylolites are common on bedding planes. Black, very fine coaly detritus is present. Top and base very gradational.
- 1774.6-1778.5 Mudrock: black, hard, faintly laminated to almost homogenous shaly siltstones; weakly calcareous intervals alternate with non-calcareous intervals. As above, calcite occurs in matrix. Infrequent to common, evenly dispersed sand-sized coaly detritus (0.05-0.15 mm in size). Rare pyritic streaks.
- 1778.5-1782.0 Mudrock: black, hard, faintly laminated to almost homogenous, weakly to strongly calcareous shaly siltstones and silty shales (slightly finer-grained than above). Pyritized laminae and streaks are infrequent but generally more common than above. Calcareous material micritic and/or microsparitic, resides in matrix and defines lamination. Top and base defined by gradual decline/increase in calcareousness.
- 1782.0-1782.5 Mudrock to shale: black, mostly non-calcareous, with lamination defined by infrequent pyritic laminae. Upward gradation from mudrock (shaly siltstone) into shale (in upper 10 cm). Shale is distinct from the mudrock in conchoid fracturing surfaces (in difference to planar surfaces in all siltstones) and thick, horizontally stretched calcareous-pyritic nodules. Calcite in these nodules occurs in the form of coalesced stellate aggregates. Top gradational, defined by the top of the uppermost calcareous-pyritic nodule.
- 1782.5-1784.6 Mudrock: black, homogeneous, predominantly non-calcareous shaly siltstone with thin (0.1-3 cm) calcareous intervals. These intervals make up 3-5% of total thickness. Calcareous material occurs as microlaminae (matrix micrites) and as finely crystalline matrix in flattened nodules intermingled with pyrite. These nodules are similar to nodules in the top of 1782.0-1782.5 m interval, but stellate aggregates are not developed. Some calcareous intervals are laminar and transitional between nodules and primary sedimentary packages. Rare very poorly preserved conical fossils.
- 1784.6-1786.0 Calcareous mudrock: black, relatively hard; calcareous material resides in matrix and distributed in microlaminae. Lamination locally obscure and locally defined by pyritic streaks.

HARE INDIAN FORMATION

- 1786.0-1795.4 Mudrock: black, homogeneous shaly siltstone locally with pyrite streaks defining lamination, mostly non-calcareous, with minor (<5% of the interval) and thin (<5 cm thick) weakly calcareous seams. Rare 1-10 mm thick pyritized intervals incorporating several microlaminae. Calcite occurs as matrix admixture and defines lamination. The lower 1.0 m is non-calcareous except of one level of calcareous-pyritic nodules.

- 1795.4-1799.15 Mudrock to shale: black, homogeneous, variously (mostly weakly) calcareous; laminar distribution of calcareous material and rapid decline of HCl fizzing indicate that calcite is mostly sedimentary and resides in shaly matrix. Common pyritic streaks but no continuous pyritic laminae. Bedding planes are associated with pyritized and criss-crossing straight filaments, most likely sponge spicules. Lamination is slightly more distinct than above because of regular thicker (3-8 mm) graded laminae enriched in calcareous material. These laminae occasionally preserve tiny ostracods. Fine coaly detritus present.
- 1799.15-1799.3 Calcareous mudrock: dark gray, very hard, siliceous, distinctly laminated. Lamination emphasized by white calcareous-siliceous streaks (microphoto) that can represent recrystallized conical microfossils. Because of these calcite streaks the texture looks coarser-grained than above and below. Siliciclastic component is represented by common shaly micaceous silt. Top and base gradational.
- 1799.3-1803.15 Shale: brownish black, silty, generally more fissile than above (disintegrated into 'hockey pucks'); low-contrast alternation of non-calcareous and weakly calcareous intervals. Finer-grained (shalier) parts are weakly expanding in water; siltstone (mudrock) interbeds are often calcareous, locally contain same white calcareous streaks as in 1799.15-1799.3 m. Rare to numerous pyrite streaks and pyritized spicules on fissility planes, rare large pyrite nodules.
- 1803.15-1805.7 Shale: brownish black, subfissile to fissile, silty, heavy due to significant amount of pyrites; laminated, non-calcareous, siliceous, almost no expansion in water, producing conchoid surfaces along fissility planes. Infrequent large pyrite nodules, abundant pyrite streaks.
- 1805.7-1806.0 Shale-chertstone alternation: three beds of hard, weakly calcareous chertstone (cherty mudrock) with white streaks are separated by interbeds of fissile shale. Rare poorly preserved conical fossils are discernible among white streaks.
- 1806.0-1812.7 Shale: black, fissile, very silty, non-calcareous throughout, very gradually changes downward into a hard siliceous mudrock. Shale is weakly expanding in water. Microlamination is highlighted by slight differences in sedimentary textures/composition, rarely by pyrite streaks and laminae. Rare coarsely crystalline pyrite nodules.

BLUEFISH MEMBER

- 1812.7-1815.65 Mudrock: black, hard (3-30 cm thick cylinders), siliceous, non-calcareous with several weakly calcareous intervals. Shale-dominated intervals alternate with silt-dominated intervals with minor admixture of light-colored very fine sand grains. Lamination is mostly visible, in most homogeneous intervals obscure. Minor pyrite streaks and small nodules. Thin laminae of chertified poorly preserved thin-walled microfossils (<0.2 mm).
- 1815.65-1816.4 Mudrock: black, hard (3-30 cm thick cylinders), siliceous, variously calcareous. Locally laminae are enriched in thin-walled microfossils including conical forms up to 1 mm in size (photo). These fossiliferous intervals also contain coaly laminae composed of plant litter (photo). Calcite resides as micritic grains in matrix and in tiny microfossils, although the latter are partly chertified and pyritized.
- 1815.65-1816.4 Mudrock (shale): siliceous, hard (long cylinders) non-calcareous, with pyrite streaks defining lamination.
- 1816.4-1817.7 Mudrock: very similar to 1815.65-1816.4, variously calcareous, locally containing pyritized collapsed ostracods(?) and conical microfossils; infrequent and regularly spaced pyrite streaks.
- 1817.7-1821.25 Shale: more fissile than above, silty, weakly calcareous to almost non-calcareous, weakly expanding in water. Lamination is mostly defined by slight differences in lithology. Collapsed pyritized styliolinids (identifiable on lamination planes; photo) are common in upper part of the interval and increase to abundant in its lower part. Styliolinids

also carry some calcite (fizzing). Calcite is also dispersed in matrix as invisible (isolated) micritic grains (fizzing rapidly dies on core face).

- 1821.25-1823.1 Mudrock: black, hard, calcareous shaly siltstone to very fine-grained sandstone. Pyritized collapsed styliolinids are rare, increase to common in basal part; calcareousness also increases from weak (same as above) in upper half to moderate, longer-fizzing in lower half. Minor and low-contrast finer-grained shaly interbeds. Lamination is poorly seen, frequently obscure. Rare small pyrite nodules. A pyritized and strongly calcareous bed with non-collapsed styliolinids at 1822.65 m (photo).

N.B.: No more criss-crossing spicules are seen below 1805 m.

- 1823.1-1824.55 Calcareous shale: black, hard, silty, with very dark gray limestone intercalations, laminated. Limestone seams constitute 10-20% of the interval and consist of 0.1-3 cm thick graded beds of styliolinid coquinas; micritic calcite is also dispersed in shale matrix. A thick (20 cm) bed of black limestone occurs at 1824.1-1814.3 m. This bed is distinctly graded, with a 4 cm thick basal chaotic mesh of styliolinids (non-laminated!) lying on sharp shale surface. The styliolinid mesh grades upward into homogeneous microcrystalline calcite with tiny styliolinid lenses, practically no pyrite, and very faint lamination. This micrite is capped by an authigenic pyritic horizon (photo). In less calcareous intervals between limestone graded beds lamination is highlighted by pyritic streaks and collapsed, partly pyritized styliolinids. Top gradational, by downward transition from pyritized to non-pyritized styliolinids in graded beds. Base on top of a thick limestone bed that distinctly contain admixture of benthic bioclasts – brachiopod fragments, etc.
- 1824.55-1824.8 Limestone: black, argillaceous, silty and ?evenly cherty, composed of mass styliolinids and microcrystalline matrix; moderately bioturbated (random to swirly orientation of cones), apparently composed of two or three main churned-up graded beds. Lamination is partly preserved, mostly in top and base. No distinct erosional surfaces. This bed contains infrequent to common fragments of brachiopods, ostracods, maybe bryozoans, and other benthic skeletal forms, but no unbroken valves (transported debris). Defined in base and top by transition to regularly laminated and weakly calcareous shale.
- 1824.8-1826.45 Calcareous shale: very dark gray to black, hard, laminated, with alternating intervals of black fissile weakly calcareous shale with collapsed pyritized styliolinids and strongly calcareous, less pyritic and less distinctly laminated intervals where calcareous material resides in styliolinid shells and matrix. Basal 15 cm is mostly composed of this latter facies. Rare (in upper half) to common and abundant (in base) fragments of thin-walled bivalves, brachiopods, and possibly other benthic groups. These valves are collapsed and poorly preserved.
- 1826.45-1826.9 Argillaceous limestone: unusual dark gray hard rock bearing two levels of cone-in-cone calcite. These levels consist of fan-shaped aggregates of bladed coarsely-crystalline calcite divided by partitions of laminated shale. Lamination is gently whipping over cone terminations. Aggregates of fans are chevron-patterned (typical cone-in-cone) and in upper layers are suborganized into rough sheets. The upper level is the thickest (10 cm) and most coarsely crystalline (crystals up to 2 cm long in upper layers), occurring in top. The lower level is finer-crystalline (crystals up to 3-4 mm long) and only 2.5 cm thick, occurring in base. Crystals show growth perpendicular to lamination. Both cone-in-cone levels have coarsening-upward crystallinity. Between cone-in-cone levels, the rock is a strongly argillaceous finely crystalline (microsparitic?) laminated limestone with common non-compacted styliolinids grading downward (to the top of the lower cone-in-cone level) into a black laminated calcareous shale with compacted styliolinids. Rare poorly preserved debris of benthic fossils (Amphipora is the only identified fragment). Styliolinid cones occur separately and in thin (<1 mm) lenses. These lenses are gently buckled probably during authigenic growth of calcite. Weak pyritization.
- 1826.9-1828.75 Shale with limestone intercalations: black (limestones very dark gray), variously silty and with deviation into siltstone, laminated, hard to subfissile. Lamination is defined by skeletal calcite streaks and thin lenses (mass collapsed styliolinids) and less abundant

pyritic streaks developed on styliolinid streaks. Sand-sized pyrite grains are regularly dispersed in shale matrix. Minor conchoid fractures. In lower 0.7-0.8 m lamination is angling to horizon with the dip angle gradually building from subhorizontal at 1828.0 m to 20-22° at the base (probably dune overlapping). Limestone intercalations of two types: (1) thin, <1 cm, styliolinid coquinas and (2) horizons of finely crystalline authigenic calcites up to 10 cm in thickness. These horizons contain non-collapsed styliolinids, the least amount of pyrite, and less distinct lamination than in stronger pyritic shale.

1828.75-1828.9 Argillaceous limestone: hard, dark gray, crudely cross-laminated; styliolinid cones mostly occurring in randomly oriented mesh with poorly seen lamination trends. Obvious bioturbation is however lacking. Cones are cemented by pale brownish gray calcite cement – probably a finely crystalline marine cement (need thin section). Cross-lamination is bi- or multidirectional, probably forming mummocks or dunes/large ripples. No obvious benthic fossils. Minor low-amplitude stylolites mostly follow inclined bedding planes. Base unconformable.

HUME FORMATION

1828.9-1829.4 Limestone: brownish gray, tight, hard, intensely and palimpsestically bioturbated. Non-sorted bioclastic wackestones and packstones. Top rugged, presumably moderately phosphatized, penetrated by large (5 mm thick and up to 5 cm deep) curved borings or burrows. These borings/burrows are filled with greenish brown (phosphatic?) calcimudstone with weak and disappearing backfill patterns (photo). Sections of such borings also occur below the upper 5 cm. Bioturbation includes Scolicia/Asterosoma, ?very poorly preserved Zoophycos, and upright burrows. No signs of soft-sediment compaction. Skeletal assemblage includes (but not restricted to) thick finger-shaped bryozoans, rare pachyporid or alveolitid corals, rare crinoid ossicles, thin-shelled brachiopods and ostracods. Fossils are locally replaced by milky white chert stringers. No styliolinid cones are detected. Base paraconformable or conformable (on top of synsedimentary breccia). Abundant finely dispersed pyrite grains in 5-7 cm below top.

1829.3–1832.0 Limestone: brownish gray, hard, crudely nodular, bioturbated, nodular (different from 1828.9-1829.4 m by nodularity and presence of infrequent stromatoporoids). Bioclastic packstones with minor rudstones and wackestones. Mass fragments of mollusks locally form churned-up coquinas. Diverse lamellar and bulbous stromatoporoids, bryozoans, alveolinid or pachyporid corals, pelmatozoan ossicles, etc. Nodularity is formed by non-compacted rounded to angular rock fragments separated by dark overcompacted marly partitions. Nodularity is mostly catagenetic but may inherit synsedimentary brecciation. Numerous curved v-shaped and sigmoidal fractures (shear aspect deformation) cemented by milky white calcite. Top probably conformable, base very gradational.

1832.0-1834.75 Limestone: dark brownish gray, tight, fractured (same style of cemented fractures). Bioturbated bioclastic wackestones and matrix-rich packstones. Macrofossils: large infrequent corals and bryozoans in situ: Favosites, alveolinids, ?pachyporids; only one level with stromatoporoids – thin encrusting lamellar forms on syngenetically lithified surfaces. A bryozoan bafflestone with wackestone matrix occurs in 15 cm above base. Syngenetic lithification and episodic erosion of matrix is evidenced by intraclasts and rare encrusted benches (photo). Base gradational.

1833.75-1834.50 Limestone: dark brownish gray, tight, weakly nodular, locally fractured. Coarse to medium grained bioturbated bioclastic packstones. Rare large (4 cm) intraclasts; rare amphiporas.

1834.50-1836.9 Limestone: brownish gray (light gray stromatoporoids and dark gray matrix), nodular and stylolitized. Stromatoporoid boundstones, minor bioclastic packstones in the middle. Bioturbated bioclastic packstones to wackestones as boundstone matrix. Rare mottles of incomplete dolomitization (dolomite < 1% of rock volume). Boundstone texture is indicated by numerous encrusted benches with oblique surfaces and complete lack of matrix compaction inside nodules. Fossil assemblage very diverse: lamellar, oncoidal and

large bulbous stromatoporoids, rugose corals, diverse robust bryozoans, pachyporid corals, alveolitids, large amphiporas, tubular skeletal fossils, mollusks, minor brachiopods, ?charophytes. Various stromatoporoids dominate. Rare gravel-size lithoclasts in base. Base disconformable.

1836.9-1837.4 Limestone: tight, brownish gray, lighter than above. Bioturbated bioclastic calcimudstone to wackestone with amphiporas in life position. Matrix is rich in calcispheres that are very abundant on some intervals. The limestone is karsted from top, stylobrecciated in upper 0.3 m, riddled with solution vugs and channels; the largest (3-5 cm) solution voids are filled with bioturbated bioclastic sediment from the onlapping facies; smaller (mm-scale) cavities are filled with catagenetic clear sparite or contain geopetal sediments. Faint coloration mottling in matrix: weak black staining inside matrix, locally distinctly haloing around solution holes ('quasicoatings'). Stylolites bear black insoluble residues. Base conformable.

1837.4-1837.8 Limestone: riddled with solution cavities, very similar to 1836.9-1837.4 m but with gently buckled laminar fenestral fabric in upper 15 cm. Below the lamination grades to bioturbated limestone. Texture: bioclastic wackestone with thick amphiporas and small oncoidal stromatoporoids. Fenestrae are also developed in the lower non-laminated part of the interval.

MCD CAN GCO Maida Creek G-56

UWID: 300/G-5 Shell

6-6540-12800/0

Core diameter: 3½ inch

Interval measured: 517.2-550.2 m (1697-1805 ft.)

Measured depth corrected to recovered core thickness

Core #1 (4.9 ft./box)

CANOL FORMATION

517.2-519.9 m (1697-1705.8 ft.) Siltstone to silty shale (mudrock): dark brownish gray to black, well indurated, laminated, disintegrates with production of conchoidal fractures stretched along lamination (half-way to fissile fabric); minor very fine-grained sandstones; in basal 0.3 m grades into homogeneous pelitomorphous chertstone; dispersed finely crystalline (0.1-0.2 mm) making up no less than 5% of rock; occasional pyrobitumen seams along fissility planes; lamination defined by lighter-colored laminae (0.1-2 mm thick) of three compositions: (1) very fine to fine grained quartzose sandstone; (2) fine grained sandstone with black chert sand grains; and (3) very fine to fine grained, well-sorted, variously chertified and locally strongly pyritized calcarenites. Calcarenites form especially thick (up to 1 cm) layers that are strongly deformed (constricted, producing flame protrusions and detached elliptical balls. The mudrock matrix outside of these calcareous laminae is non-calcareous. In basal part thicker (>1 mm laminae) are generally more frequent.

519.9-520.4 m (1705.8-1707.5 ft.) Mudrock calcareous to limestone to sandstone: well-indurated interval defined by strong domination (60-80%) of calcareous rocks; dark to medium brownish gray in color; non-calcareous mudrocks similar to facies above make up no more than 20%; calcareous beds are thick (up to 10-12 cm), crudely laminated (tapering lamination), medium to very fine-grained, probably bioclastic but grains are very poorly preserved; these calcarenites contain chert stripes developed along lamination; sandstone

seams distinctly laminated; calcarenite beds contorted, with domal sole marks, flame structures, and occasional detached balls. Some calcareous intervals show accumulations of calcite pseudomorphs after replacive (authigenic) lath-like crystals (up to 2 mm wide and 2 cm long); these crystals form mesh and stellate aggregates (photo 192-198).

520.4-526.4 m (1707.5-1727 ft.) Shale (mudrock) dark brownish gray to almost black, homogenous, siliceous, obscurely laminated (due to lack of much contrast between laminae and pelitomorphous background); fabric a little bit more fissile comparing to the interval 517.2-519.9 m; rare chalcedony geodes; coarser grained laminae composed of very fine-grained, strongly chertified calcarenites and maybe some quartzose sand laminae. Sporadic black colored fish sclerites. Base conformable, through a 4 cm thick alternation of dark shale and very fine- to fine-grained, partly chertified, sorted crinoid calcarenites (packstones to grainstones); these calcarenites are strongly pyritized and weather rusty, contain collapsed and fragmented brachiopod shells.

RAMPARTS FORMATION, ALLOCHTHONOUS MEMBER

526.4-528.2 m (1727-1732.9 ft.) Limestone: gray coarse-grained encrinite (crinoidal packstone) poorly sorted, argillaceous, with moderate to strong matrix compaction; vague lamination locally seen at 7-12° to the horizon (in vertical core); solution seams run at same angle so lamination is assumed to be horizontal with inclined bedsets. Allochems in decreasing order: disintegrated pelmatozoan ossicles (no long stalks); black weakly calcareous pelitomorphous lithoclasts – shale clasts? (check in thin sections); attrited fragments of *Amphipora* and probably pachyporid corals; rare collapsed brachiopods. Base conformable.

528.2-528.6 m (1732.9-1734.4 ft.) Argillaceous limestone to shale: gray to dark gray, in lower one-half very dark gray; limestones form 0.1-2 cm thick laminae composed of fine to medium grained packstones apparently dominated by worn crinoid ossicles; these laminae are intercalated by brownish gray weakly calcareous to non-calcareous shale (0.1-0.5 cm thick), and in the lower one-half shale dominates; this lower part is especially finely laminated. Base abrupt (nonconformity?).

528.7-529.2 m (1734.5-1736.3 ft.) Limestone: encrinite (packstone) coarse grained, similar to 526.4-528.2 m. Differences: coarser and less worn fragments of *Amphipora* and higher angle cross lamination with maximum angle of up to 30° between two inclined laminae sets (photo 20-210). Top undulating, sharp, slickensided against overlying shale. Base through finer-grained and more argillaceous limestone (encrinite), also cross-laminated, intercalated by thin shale laminae.

529.2-529.4 m (1736.3-1737 ft.) Shale (mudrock): microlaminar, greenish gray silty non-calcareous to brownish dark gray weakly calcareous; the latter variety contains thin (up to 1 mm) encrinite laminae. Greenish gray shale dominates in upper one-half, it is hard, with conchoid fracture, locally strongly pyritized; may be cemented by siderite.

529.4-530.4 m (1737-1740 ft.) Limestone: brownish light gray, somewhat darker (argillaceous) in top; grainstones, packstones and rudstones medium-grained to very coarse grained, coral-stromatoporoid-crinoidal with diverse carbonate-bank fossils: pachyporid corals, infrequent bryozoans, *Amphipora* and diverse bulbous and lamellar stromatoporoids; crude inclined lamination at high angle (45-50, in base up to 65° to core perpendicular); several pinching laminae of dark shale in top 5 cm. Matrix of packstone may be moderately chalkified and microporous, oil impregnated. Top with discontinuity (downing surface) interpreted from sharp surface and *amphiporas* in life position protruding into overlying shale (photo 187-190).

530.4-531.4 m (1740-1743.55 ft.) Limestone: pale gray to white, notably tight; boundstone stromatoporoid-thamnoporan, with coarse grainstone matrix tightly cemented by radial isopachous poorly translucent cement – probably radial calcite. A thick (3-5 cm) crust of lamellar stromatoporoids in top (framestone); below boundstone mostly conforms to baffestone. Top rugged, stylolitized, inclined at 70° to core perpendicular. The boundstone

fabric features synsedimentary sheering planes and lamellar encrusters (mostly stromatoporoids) grown at high angle ($>60^\circ$) to core perpendicular; large (cm to dm sized) frame cavities geopetally filled by crudely layered dark brownish gray crinoid-rich packstones and wackestones (finer-grained infiltrations from facies at 1737.0-1740.0). Residual voids in top of frame cavities are filled with gigantocrystalline calcite. Geopetal level in a large cavity is inclined at 40° to core perpendicular. Cavity walls tend to be encrusted by either isopachous cement or discontinuous crusts of faintly laminar micrite (chasmolithic microbialite crusts). Skeletal assemblage diverse, includes master reef builders, rare bryozoans, and probably diverse microscopic calcareous algae. Base not preserved because of core destruction, two possible occurrences: (1) conformable, by demise of pervasive isopachous cementation; (2) sharp surface indicative of downslope sliding of the whole block of boundstone at 1740.0-1743.55 (olistolith).

RAMPARTS FORMATION (AUTOCHTHONOUS)

531.4-531.8 m (1743.55-1744.7 ft.) Limestone: coarse packbreccia of cm-sized limestone clasts. Breccia is strongly stylolitized; matrix of non-sorted crinoid-rich packstone, preserved only in few patches. Limestone clasts of three types: (1) fine bioclastic packstone and amphiporan floatstones with moderately chalkified fine-grained bioclastic matrix; (2) fragments of encrusting stromatoporoids, sometimes aggregated with patches of packstone; (3) large fragments of pachyporid corals. Smaller (1-10 mm) lithoclasts are represented by same types, Amphipora, and diverse skeletal debris from bank top. A seam of black homogeneous shale occurs in 7 cm above the breccia base; this shale, mostly destroyed by drilling, has sharp, undulating, stylolitic upper contact. Base conformable, through gradual dilution of breccia by packstone matrix (floatbreccia).

531.8-533.7 m (1744.6-1751 ft.) Limestone: brownish gray, homogeneous, with low matrix ("chalky") porosity (Norman Wells type chalkification). Floatstone and minor matrix-rich rudstone amphiporan-pachyporid, with diverse, apparently transported fossils: crinoid ossicles, Amphipora, pachyporid corals, thick trunk-like bryozoans, rare trilobites, disarticulated brachiopods; crude subhorizontal to gently inclined ($5-12^\circ$) lamination formed only by preferential orientation of flattened skeletal debris. Pachyporid-stromatoporoidal bindstone in core base. Moderate and pervasive matrix compaction with network of thin and disappearing solution films; rudstones with fragment to fragment contacts are stylolitized.

Core # 2 (4.9 ft./box)

533.7-538.3 m (1751-1766 ft.) Limestone: facies similar to 531.8-533.7 m of Core #1. Pachyporid-stromatoporoidal-bryozoan bindstone to rudstone in top; below bioclastic massive, (bioturbated) wackestones with minor floatstones-rudstones, rare bindstones (1-10 cm thick) formed by in situ pachyporids and stromatoporoids. Very faint lamination is present only in upper 0.3 m (at $3-5^\circ$ to core perpendicular). Large (20 cm thick) bulbous Parachaetetes in the middle. In situ thick lamellar and bulbous forms (bindstone-forming pachyporids and stromatoporoids) are more frequent in the lower one-half of the interval. Wackestone in the basal 0.5 m is enriched in disarticulated crinoid ossicles. Matrix compaction on this interval is mostly reduced to minimum; rare stylolitized and "flaser" horizons. Base disconformable.

538.3-541.1 m (1766-1775.3 ft.) Limestone: pale brownish gray, mottled from development of dark brown chalkified patches upon originally tight matrix. Stromatoporal boundstones (mostly bafflestones) with minor pachyporid corals; matrix tight, almost white, composed of bioclastic packstone. No isopachous cements are seen. Rare thin lenses of rounded-grain grainstone in lower 0.5 m. Top undulating, with solution pockets, chalkified to first millimeters and by that merging with overlying pervasively chalkified bed. Millimeter to centimeter sized solution vugs are present, some of them stretching along (mostly under) reef-building skeletons. Walls of these solution vugs are chalkified with destruction of original fabric, which makes it difficult to identify their margins; large open-space cavities,

probably original solution-enlarged frame voids, are occluded by gigantocrystalline calcite, some contain thin geopetal sediments. In lower one-half of interval geopetals are almost lacking in frame cavities. Chalkification tends to develop as mottles inside boundstone matrix and as crusts along fossil/matrix contact. Locally chalkification is inverse, converting amphiporas into dark chalky remains that are distinct on background of pale non-chalkified matrix. A 20 cm thick interval of pervasively chalkified packstone in 0.5 m above base. No compaction except for stylolites along solution cavities. No other signatures of vadose alteration – dissolution proceeded in marine setting?

- 541.1-543.6 m (1775.3-1783.5 ft.) Limestone: brownish gray to brown; matrix-rich bindstone to bafflestone; matrix composed of bioturbated bioclastic wackestone to packstone, weakly to moderately although pervasively chalkified and probably oil-impregnated; bindstones formed by encrusting stromatoporoids and (?)bryozoans, usually tightly intergrown with each other; bafflestones are formed by *Amphipora* and pachyporid corals (*Thamnopora*?); pressure solution accentuated in several overcompacted solution zones (solution seams); matrix is weakly compacted to non-compacted.
- 543.6-544.5 m (1783.5-1786.4 ft.) Limestone: brownish gray to brown, with matrix, degree of chalkification, and composition of reef builders very similar to core at 541.1-543.6 m; differences: very rare encrusting forms and almost no bindstones; here texture is alternation of massive bioclastic packstone, floatstone, and bafflestone. Basal 20 cm is marked by two thick (3-4 cm) lamellar *Parachaetetes* intergrown with tabulate corals. The lower colony lies on overcompacted and strongly chalkified amphiporan rudstone.
- 544.5-546.4 m (1786.4-1792.5 ft.) Limestone: mottled with brown chalkified components and cream white non-chalkified reef building skeletons, stromatoporoidal boundstone (framestone) with minor rudstones, with lean matrix composed of bioclastic packstones and minor rounded-grain grainstones; frame cavities are occluded by coarse (largely monocystal) calcite spar. Chalkification developed upon matrix; some crinoidal bioclasts are recrystallized into spar very similar to cavity-filling spar; frame builders are diverse stromatoporoids (excluding large domal *Stromatopora*) with about 50-60% of thick amphiporas. Framework locally collapsed under burial stress; the lower 0.5 m is especially strongly chalkified (brown in color) with very few residual cream white patches inside thick skeletons, and in this basal part the original boundstone-rudstone texture is strongly degraded; infrequent large (2-4 cm) intraclasts of micritic limestone. Base characterized by smooth discontinuity (erosional surface?) overlain by a coarse crinoid-rich packstone.
- 546.4-547 m (1792.5-1794.5 ft.) Limestone: brown mottled boundstone (framestone to bindstone) stromatoporoidal; lamellar stromatoporoids are alternating with bioclastic packstones. Sedimentary texture degraded by pervasive chalkification which is especially strong in unit's top. Top 15 cm: stylobrecciated, contain cm-sized poorly rounded fragments of *Amphipora* and intraclasts of micritic limestone and generally fewer lamellar stromatoporoid forms. Sedimentary texture in these top 15 cm is lost due to chalkification. Rare solitary tetracorals throughout the bed. Base conformable.
- 547-548.6 m (1794.5-1799.8 ft.) Limestone: brown, mottled, matrix-rich stromatoporoidal bafflestone with minor bindstone (lamellar forms) and bioclastic packstone; minor pachyporid corals and *Parachaetetes* in framework; matrix bioturbated, practically non-compacted, pervasively chalkified.
- 548.6-550.2 m (1799.8-1805 ft.) Limestone: brownish gray framestone stromatoporal, built by dm-sized domal *Stromatopora*/*Parachaetetes*, thick amphiporas, and other typical forms; framestone relatively lean in matrix so that accumulations of amphiporas locally compressed into fitted fabric; matrix preserved in patches – bioclastic packstone and packstone-grainstone; generally this interval is less chalkified than limestones above. Diverse fossil assemblage including large solitary tetracorals and oncoidal forms of lamellar stromatoporoids(?) that are not present above. Return to small-sized (cm-sized) reef building forms in basal 30 cm; this basal part is also enriched in packstone-grainstone matrix.

Suncor et al. Morrow Creek J-71

UWID: 300/J-71-6530-12715/0

Core diameter: 3½ inch

Interval measured: 861.0-897.60 m

Measured depth corrected to recovered core thickness

CANOL FORMATION

Core #1 (1.20 m fit in one box)

861.0-863.2: Mudrock: micaceous silty shale to shaly siltstone, very dark grey to black, apparently cherty, hard (well-lithified), with conchoid fracturing and very weak, only locally developed fissility. Lamination is faint, defined by two types of features: 0.1-0.4 mm thick pyritized seams and similarly thin calcareous laminae. Calcareous material is lacking at all in most of the core (probably replaced by silica). All types of laminae disappear laterally.

Core #2 (1.29 m per box 1-8 and 0.5 m in box 9)

863.2-874.0: Mudrock: almost identical to core at 861.0-863.2 m. Infrequent slickensided shear planes at 40-50° to core. Rare pyrite nodules. Very rare strongly pyritized thick (0.5-1.0 mm) laminae. Core at 870.0-873.0 m is a little bit more fissile than above and below, however, still dominated by conchoid rather than fissile fracture pattern.

RAMPARTS FORMATION

Core #3 (1.38 m per box 1-7 and 0.94 m in box 8)

887.0-887.3: Limestone: with dark brown mottles, coral boundstone (bindstone) with thick lamellar reef-building forms, probably pachyporids; brecciated packstone matrix; significant stylolitization. Lamellar skeletons occur at 30° to core perpendicular. Rare brachiopods, some in situ. Mottling is formed by tightly cemented matrix and irregular dark brown, probably microporous mottles impregnated with bitumen. Base conformable.

887.3-887.55: Limestone: gray to dark gray, stylolitized, with thick residual linings of black shale on stylolite planes; packstone coarse, non-sorted, rich in crinoid ossicles, with rare pachyporid corals; preferential orientation of elongated bioclasts reveals obscure lamination at 30° to core perpendicular; stylolites run roughly at same angle.

887.55-892.75: Limestone: light beige to gray, texture similar to 887.0-887.3 but slightly darker in color; framestone to bindstone stylolitized (up to development of stylobreccia); the lower one-half of the interval more large (dm-sized) bulging forms (pachyporid corals and minor Stromatopora); minor Amphipora in basal 1 m; base selected on transitional interval where lamellar encrusting forms stop dominating the reef-building association.

892.75-895.30: Limestone: light gray to neutral gray; matrix-rich stromatoporoid-dominated boundstone with patches of bioclastic packstone. Reef builders diverse: bulbous and lamellar stromatoporoids; pachyporid corals; thick oncoidal intergrowths of pachyporids and stromatoporoids; Parachaetetes with symbiotic tabulate corals. Significant stylolitization. Base conformable.

895.30-897.60: Limestone: brownish gray; amphiporan bafflestone with matrix of bioclastic packstone. All Ramparts Limestone is tight.

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Table 2. Pearson correlation matrix for elements composing the lower Imperial-Horn River shale section of Ebbutt D-50 well. Elements are sorted by their maximum values (largest values on the left of axis X). Only elements with maximum values ≥ 50 ppm are included. **Table 2** is also available in the “[of7840\tables](#)” directory as a Microsoft® Office Excel® 2010 file, [of 7840 tab02.xlsx](#).

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