The Parker Quarry Lagerstätte of Vermont – the first reported Burgess Shale-type fauna rediscovered

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SUPPLEMENTAL MATERIAL

Material and Methods

Sedimentology

Exposures from two freshly excavated trenches were logged in cm-scale detail in the field. The Parker Slate regionally has experienced extensive subsurface weathering that included oxidation of abundant sedimentary pyrite (Fig. 3A-C), and redistribution of prominent coatings of Fe-oxides along joints, cracks and other void spaces, including bedding surfaces (e.g., Fig. 2B-D). On vertical exposures, Fe-oxide coatings obscure most of the bed-type variation within the mudstones, which are best studied in polished slab and thin section. Only sandstone beds and laminae are consistently recognized in outcrop, with some event claystones evident in fresh breaks. Therefore, outcrop logs (Fig. S1), do not capture the prominent variability that is present within the mudstone facies (Fig. 3). More than 100 mudstone samples, collected from the two new excavations, were returned to the laboratory for detailed study.

In the lab, samples were cut perpendicular to bedding and polished to reveal variation in primary sedimentary attributes (grain size, grading, organic fragments, slump and slide features, and sedimentary pyrite), which were further constrained by preparing a suite of thin sections that, together, capture the range of variation observed. Polished slabs were imaged immersed in a pool of water on an Epson V19 flatbed scanner. Thin sections were studied under petrographic microscope and meso-scale features were imaged using an Epson V850 transparent media scanner. The locations of discrete fossils within depositional beds/laminae were determined using slices taken near the fossils from both part and counterpart, in some cases with the aid of thin sections.

Geochemistry

Mudstone samples were prepared as fused glass beads, following the method of Johnston et al. (1999) for analysis of major and trace element geochemistry using a PanAlytical Axios V X-Ray Fluorescence spectrometer at Pomona College. Sample powders of whole rock and of isolated gray claystones were first prepared with a Rocklabs shatterbox equipped with a tungsten carbide grinding head. 3.5 g of sample powders were then mixed with 7.0 g Li-Tetraborate flux, mixed, and placed in graphite crucibles for fusion at 1000°C for 10 minutes, then cooled to form glass. Glass beads were re-ground to powder, fused a second time at 1000°C for 10 minutes, and re-cooled. Resulting beads were polished, cleaned by ultrasound, and then analyzed. Replicate XRF measurements using multiple sediment standards revealed a precision within 2% of the certified values. For trace element data, enrichment factors (EF) of the aluminosilicate fraction (Calvert and Pedersen, 1993) were calculated by normalizing the concentration of the element to Al in the sample compared to the same ratio of average upper continental crust ($EF_{Mo} = Mo/Al \text{ sample} / (Mo/Al \text{ crust})$) (Wedepohl, 1995).

Taphonomy

A single slab bearing two soft-bodied fossils (Fig. 2G) was analyzed by SEM-EDS to determine the mode of preservation of soft-tissues. Analysis was performed by Sharon Lackie using an FEI Quanta 200 Environmental Scanning Electron Microscope with an EDAX Octane Plus detector at the University of Windsor.

Figure S1. Outcrop log of 2.3 m of continuous section exposed in freshly excavated trench P-1, and 0.6 m of continuous section in trench P-2. Field relationships indicate that P-1 is situated stratigraphically atop P-2. The apparent stratigraphic distance between the two trenches is <1m, however, numerous small faults with displacements of several 10s of cm cut the exposed intervals, rendering the absolute stratigraphic distance between the two trenches uncertain. Beds 4-12 mm in thickness comprised of very fine sand are shown in yellow. Two large-scale slumps dominate the lower portion of the P-1 section, and smaller-scale examples of soft-sediment deformation (Fig. 3E-F; Figs. S5-S7) occur throughout. Variation within the mudstone facies, shown here in gray, is not conspicuous in outcrop.

5 mm

5 mm

5 mm

Figure S2. Polished slabs from the P-2 trench, showing gray massive claystones of variable thicknesses intercalated with black silty mudstones. Ovoid pyrite clusters are largely concentrated in gray massive claystone beds. From top to bottom, specimen numbers are: YPM IP 239121, 239127, 239128.

Figure S3. Polished slab (YPM IP 239129) showing crude grading from very fine sand through silty claystone. Note high clay content (gray) of sand and silt-dominated horizons.

Figure S4. Polished slab (YPM IP 239130) showing soft sediment deformation of crudely graded very fine sand to silty claystone beds with large aggregations of pyrite developed in sandy horizons, and small pyrite ovoids hosted in mudstone horizons, particularly within massive claystone facies.

Figure S5. Polished slabs showing ductile soft-sediment deformation of very fine sand (light) and mudstone beds (gray and black). Brittle failure also occurs in the two lowermost images, at the right side of each. From top to bottom, specimen numbers are YPM IP 239131, 239132, and 239133.

Figure S6. Polished slabs showing combinations of brittle and ductile soft-sediment deformation in mudstone-dominated intervals. Disturbed very fine sand beds appear light in color. From top to bottom, specimen numbers are YPM IP 239124, 239134, 239135, and 239136.

Figure S7. Polished slabs showing synsedimentary mudstone clast breccias from within the excavated interval. Mudstone breccias are interpreted to have resulted from gravitational failure and brecciation of a firm, cohesive substrate. From top to bottom, specimen numbers are YPM IP 239125, 239137, and 239138.

Sample	Loss On Ignition (%)	SiO ₂ Si1 (%)	TiO ₂ Ti1 (%)	Al ₂ O ₃ Al1 (%)	Fe ₂ O ₃ Fe1 (%)	MnO Mn1 (%)	MgO Mg1 (%)	CaO Ca1 (%)	Na ₂ O Na1 (%)	K ₂ O K1 (%)	P ₂ O ₅ P1 (%)	Mo Mo (ppm)
P2 0	5.85	56.93	0.88	20.33	5.78	0.01	2.08	0.11	0.47	7.28	0.1	4
P2 0	5.76	56.97	0.88	20.35	5.79	0.01	2.08	0.11	0.47	7.29	0.1	4
P2 1	5.15	57.18	0.87	20.34	6.13	0.01	2.12	0.17	0.48	7.18	0.11	7
P2 1	5.11	57.17	0.87	20.39	6.13	0.01	2.12	0.16	0.49	7.19	0.11	7
P2 2	5.71	56.62	0.89	20.35	6.3	0.01	2.01	0.1	0.46	7.25	0.1	6
P2 2	5.77	56.6	0.89	20.31	6.3	0.01	2.01	0.1	0.47	7.24	0.1	6
P2-4	10.13	52.81	0.84	19.13	7.09	0.02	2.14	0.17	0.5	6.87	0.1	7
P2-4	10.07	52.83	0.85	19.14	7.1	0.02	2.13	0.17	0.49	6.89	0.1	6
P2 5	5.89	55.52	0.83	19.92	7.43	0.08	2.39	0.19	0.43	7	0.12	3
P2 5	5.99	55.52	0.83	19.88	7.42	0.08	2.38	0.19	0.43	6.99	0.13	4
P2 7	5.81	55.83	0.87	20.08	7.01	0.04	2.29	0.18	0.43	7.14	0.12	5
P2 7	5.62	55.97	0.87	20.12	7.01	0.04	2.29	0.18	0.43	7.14	0.13	5
P2 10	7.25	55.45	0.85	18.55	7.33	0.07	2.3	0.66	0.59	6.62	0.12	5
P2 10	7.17	55.51	0.85	18.57	7.33	0.07	2.31	0.66	0.59	6.62	0.12	5
P2 13	5.79	57.05	0.86	18.94	7.26	0.07	2.25	0.18	0.49	6.79	0.12	4
P2 13	5.65	57.15	0.87	18.96	7.28	0.07	2.25	0.18	0.49	6.78	0.12	4
P2 16	4.60	58.27	0.91	19.78	6.27	0.02	2.12	0.15	0.5	7.07	0.11	4
P2 16	4.61	58.24	0.91	19.83	6.27	0.02	2.1	0.15	0.49	7.06	0.11	4
P2 24	5.15	57.99	0.93	19.29	6.42	0.03	2.16	0.27	0.5	6.9	0.16	4
P2 24	5.14	58.05	0.92	19.27	6.42	0.03	2.15	0.26	0.5	6.9	0.16	4
P2 25	6.32	56.43	0.86	20.09	6.37	0.01	1.97	0.11	0.43	7.1	0.1	6
P2 25	6.28	56.42	0.86	20.13	6.37	0.01	1.98	0.1	0.43	7.11	0.1	7
P2-26	9.90	53.98	0.84	18.83	6.71	0.01	1.99	0.15	0.48	6.79	0.11	6
P2-26	9.66	54.12	0.84	18.91	6.72	0.01	2.01	0.15	0.48	6.79	0.11	6
P2 28	6.49	55.96	0.88	20.39	6.19	0.01	2	0.1	0.48	7.19	0.11	7
P2 28	6.57	55.93	0.88	20.35	6.19	0.01	1.99	0.1	0.48	7.19	0.11	6
P2 30	6.52	55.92	0.86	20.34	6.23	0.01	2.03	0.11	0.51	7.18	0.11	6
P2 30	6.49	55.93	0.86	20.35	6.23	0.01	2.04	0.11	0.51	7.18	0.11	6
P2 31	5.47	56.17	0.88	20.5	6.69	0.01	2.1	0.12	0.55	7.19	0.12	6
P2 31	5.52	56.12	0.88	20.48	6.69	0.01	2.1	0.12	0.55	7.2	0.12	4
P2-33	10.46	53.89	0.87	18.76	6.33	0.01	1.79	0.09	0.66	6.79	0.11	10
P2-33	10.49	53.85	0.86	18.76	6.34	0.01	1.78	0.1	0.66	6.79	0.11	10
P2 34	5.74	56.9	0.91	20.69	5.35	0.01	2.12	0.14	0.53	7.33	0.12	4
P2 34	5.87	56.79	0.91	20.67	5.34	0.01	2.12	0.13	0.52	7.34	0.12	3
P2 36	6.54	56.62	0.9	19.78	6.23	0.01	1.93	0.1	0.51	7.05	0.11	6
P2 36	6.50	56.64	0.9	19.8	6.23	0.01	1.93	0.1	0.49	7.05	0.11	6
P2-37	10.20	53.54	0.87	19.42	5.84	0.01	2.01	0.13	0.7	6.98	0.12	6
P2-37	10.23	53.57	0.87	19.36	5.84	0.01	2.02	0.13	0.7	6.98	0.12	6
P2 44	7.84	55.82	0.87	19.31	6.61	0.01	1.77	0.08	0.46	6.89	0.1	7
P2 44	7.83	55.83	0.87	19.31	6.62	0.01	1.77	0.08	0.45	6.9	0.1	7
P2 51	6.97	55.61	0.89	19.39	6.99	0.01	2.13	0.25	0.51	6.91	0.13	6
P2 51	6.93	55.67	0.89	19.37	6.99	0.01	2.13	0.25	0.51	6.9	0.13	6
P2 52	5.65	56.81	0.89	19.31	7.13	0.02	2.11	0.26	0.52	6.89	0.17	6
P2 52	5.52	56.86	0.89	19.37	7.14	0.02	2.12	0.26	0.52	6.9	0.16	6
P2-53	9.67	55.03	0.83	17.83	6.95	0.03	2.11	0.3	0.48	6.47	0.12	7
P2-53	9.55	55.13	0.84	17.83	6.95	0.03	2.11	0.29	0.48	6.46	0.12	7
P2 58	6.43	56.49	0.88	19.38	6.88	0.01	2.12	0.16	0.47	6.85	0.12	8
P2 58	6.46	56.47	0.88	19.36	6.88	0.01	2.12	0.16	0.46	6.85	0.12	7
AVERAGES	6.88	55.96	0.87	19.62	6.56	0.02	2.09	0.18	0.50	6.99	0.12	5.75

Table S1. Major element plus Molybdenum concentrations from 24 samples (duplicate analyses reported) analyzed by X-Ray Fluorescence (XRF). Samples were prepared as fused glass beads following the method of Johnston et al. (1999), and analyzed using a PanAnalytical Axios V XRF spectrometer at Pomona College.

Sample name	Mo (ppm)	Enrichment Factor
P2 0	4	2.54
P2 0	4	2.54
P2 1	7	4.45
P2 1	7	4.44
P2 2	6	3.81
P2 2	6	3.82
P2 4	7	4.73
P2 4	6	4.05
P2 5	3	1.95
P2 5	4	2.60
P2 7	5	3.22
P2 7	5	3.21
P2 10	5	3.48
P2 10	5	3.48
P2 13	4	2.73
P2 13	4	2.73
P2 16	4	2.61
P2 16	4	2.61
P2 24	4	2.68
P2 24	4	2.68
P2 25	6	3.86
P2 25	7	4.49
P2 26	6	4.12
P2 26	6	4.10
P2 28	7	4.44
P2 28	6	3.81
P2 30	6	3.81
P2 30	6	3.81
P2 31	6	3.78
P2 31	4	2.52
P2 33	10	6.89
P2 33	10	6.89
P2 34	4	2.50
P2 34	3	1.88
P2 36	6	3.92
P2 36	6	3.92
P2 37	6	3.99
P2 37	6	4.00
P2 44	7	4.68
P2 44	7	4.68
P2 51	6	4.00
P2 51	6	4.00
P2 52	6	4.01
P2 52	6	4.00
P2 53	7	5.07
P2 53	7	5.07
P2 58	8	5.33
P2 58	7	4.67
AVERAGES:	5.75	3.80

Figure S8. Enrichment Factor values for Molybdenum (Mo EF), plotted vs. stratigraphic height in the P-2 trench.

Table S2. Enrichment Factor values for Molybdenum (Mo EF), based on concentrations of Mo and Al in 24 samples from the P-2 trench. Enrichment factors were calculated as described in Material and Methods.

TAXON	Number
Trilobites	
<i>Bathynotus</i>	43
<i>Mesonacis vermontanus</i>	12
<i>Olenellus thompsoni</i>	8
<i>Olenellus transitans</i>	6
Other trilobites	7
Other shelly organisms	2
Soft-bodied organisms	
New bivalved arthropod	26
<i>Metaspriggina</i>	3
<i>Tuzoia</i>	5
Sponges	3
Other soft-bodied	4
	N=119

Table S3. Fossils discovered in the PQL during the field seasons 2016-2019.

REFERENCES CITED

Calvert, S.E., and Pedersen, T.F., 1993, Geochemistry of Recent oxic and anoxic marine sediments: implications for the geological record. In: Parkes, R.J., Westbroek, P., de Leeuw, J.W. (Eds.), Marine Sediments, Burial, Pore Water, Chemistry, Microbiology and Diagenesis. Marine Geology, p. 67-88.

Johnston, D., Hooper, P., Conrey, R., 1999, XRF analysis of rocks and minerals for major and trace elements on a single low dilution Li-tetraborate fused bead. Advances in X-Ray Analysis, v. 41, p. 843-867.

Wedepohl, K.H., 1995. The composition of the continental crust. Geochimica et Cosmochimica Acta, v. 59, p. 1217-1232.