PRECESSION CYCLE THICKNESS AT POLECAT BENCH AND RED BUTTE, BIGHORN BASIN, WYOMING

Polecat Bench - Clarks Fork Basin stratigraphic section in the northern Bighorn Basin

The Polecat Bench - Clarks Fork Basin (PCB-CFB) stratigraphic section studied here lies within paleomagnetic chron C24R (Butler et al., 1981; Gingerich, 2001). The precession cycle count for C24R has been established from an Ocean Drilling Project core on Walvis Ridge in the South Atlantic, and the duration calculated from this is 3,118 ± 52 kyr (Westerhold et al., 2007).

The top of C24R has not been found in the PCB-CFB stratigraphic section, but the levels of the base of C24R (1090 m), Paleocene-Eocene boundary (1506 m), and first appearance datum (FAD) of *Bunophorus* (2240 m) are known. The position of the top of C24R in the PCB-CFB section can be estimated by comparing these to the levels of the base of C24R (−460 m), the Paleocene-Eocene boundary (0 m), the *Bunophorus* first appearance datum (865 m), and the top C24R (940 m) in the Foster Gulch - McCullough Peaks (FG-MCP) stratigraphic section (Clyde et al., 1994, 2007), which is also in the northern Bighorn Basin. A relatively short extrapolation, shown in Figure 1, yields an estimated meter level of 2309 for the top of C24R in the PCB-CFB section.

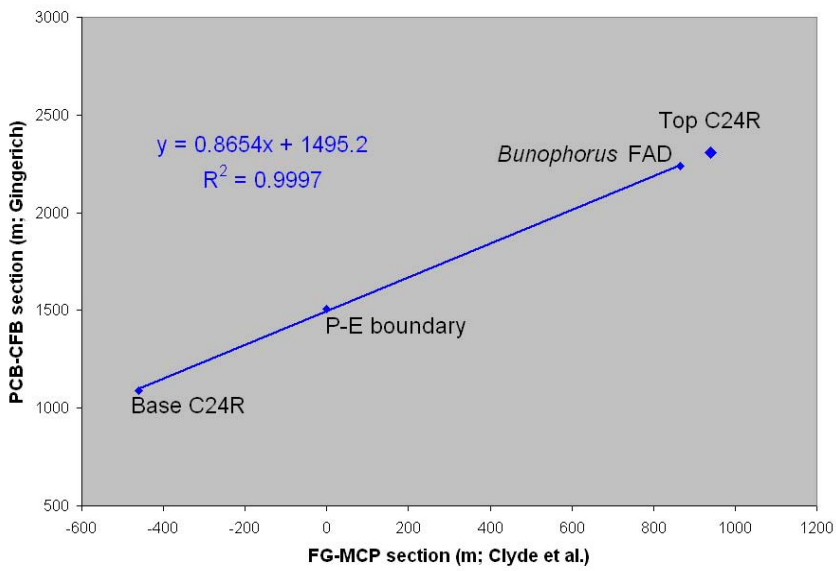

Figure 1. Extrapolation estimate (diamond) for the stratigraphic level of the top of chron C24R (2309 m) in the Polecat Bench - Clarks Fork Basin stratigraphic section. This is based on regression of levels for the base of C24R (1090 m), the Paleocene-Eocene boundary (1506 m), and the *Bunophorus* first appearance datum (2240 m) in the Polecat Bench - Clarks Fork Basin section (PB-CFB; Gingerich, 2001, 2003) on levels for the base of C24R (-460 m), the Paleocene-Eocene boundary (0 m), and the *Bunophorus* first appearance datum (865 m) in the Foster Gulch - McCullough Peaks stratigraphic section (FG-MCP; Clyde et al., 1994, 2007). Inserting the level for the top of C24R (940 m) in the FG-MCP section into the resulting equation yields a predicted level for the top of C24R in the PCB-CFB section of 2309 m.

The difference between the top of C24R (2309 m) and the base of C24R (1090 m) in the PB-CFB stratigraphic section is 1219 m. A 1219 m thickness for C24R and 3118 kyr duration for C24R corresponds to a long-term sediment accumulation rate of 391 m/myr. This means that **a single precession cycle of 21 kyr should represent approximately 8.2 m of sediment on Polecat Bench**.

Red Butte stratigraphic section in the central Bighorn Basin

Red Butte is in the middle of a large area of badlands yielding Wa-6 (Lysitean or *Heptodon* Range Zone) mammalian faunas in the central Bighorn Basin. Clyde et al. (2007: 856) state that sediment accumulation rates are considerably lower in the central part of the Bighorn Basin compared to the north, citing greater maturity of paleosols in the south. Greater maturity of paleosols can also be explained by accumulation a little higher on a floodplain where drainage is better. The only paleomagnetic constraints on sediment accumulation rates at Red Butte are provided by Tauxe et al. (1994) and these can be interpreted several ways (Clyde et al., 2007). The base of chron C24N (53.808 Ma; Ogg and Smith, 2004) at the 380 m level just above the first appearance of *Bunophorus* (Tauxe et al., 1994; Clyde et al., 2007) can be combined with the radiometric age of 52.8 Ma (Wing et al., 1991) at the 620 m level, to yield a long-term sediment accumulation rate of about 238 m/myr. Alternatively, the base of chron C24R at 380 m can be combined with the highest normal polarity sample at 680 m (Tauxe et al., 1994), interpreted as the top of C24N (52.648 Ma; Ogg and Smith, 2004), to yield a long-term sediment accumulation rate of about 259 m/myr. These mean that a single precession cycle of 21 kyr should represent approximately 5.0-5.4 m of sediment at Red Butte.

There are enough uncertainties in the Tauxe et al. (1994) paleomagnetic results (Clyde et al., 2007), and in the Wing et al. (1991) radiometric age (Smith et al., 2004), that these precession cycle thicknesses cannot be considered very precise. Sediment accumulation rates in the northern Bighorn Basin Polecat Bench and central Bighorn Basin Red Butte areas can be compared in a completely different and independent way by matching patterns of morphological change in evolutionary lineages found in both areas.

Haplomylus is a small condylarthran mammal that increased in tooth size and body size more or less monotonically through the early Eocene parts of both Bighorn Basin sections. This was documented in the central Bighorn Basin by Gingerich (1976) and in the northern Bighorn Basin by Gingerich (1985; see Figure 2). The *Haplomylus* lineage is the same in both areas, and its change in one area can be matched to change in the other area to see how sediment accumulation rates compare in the two areas.

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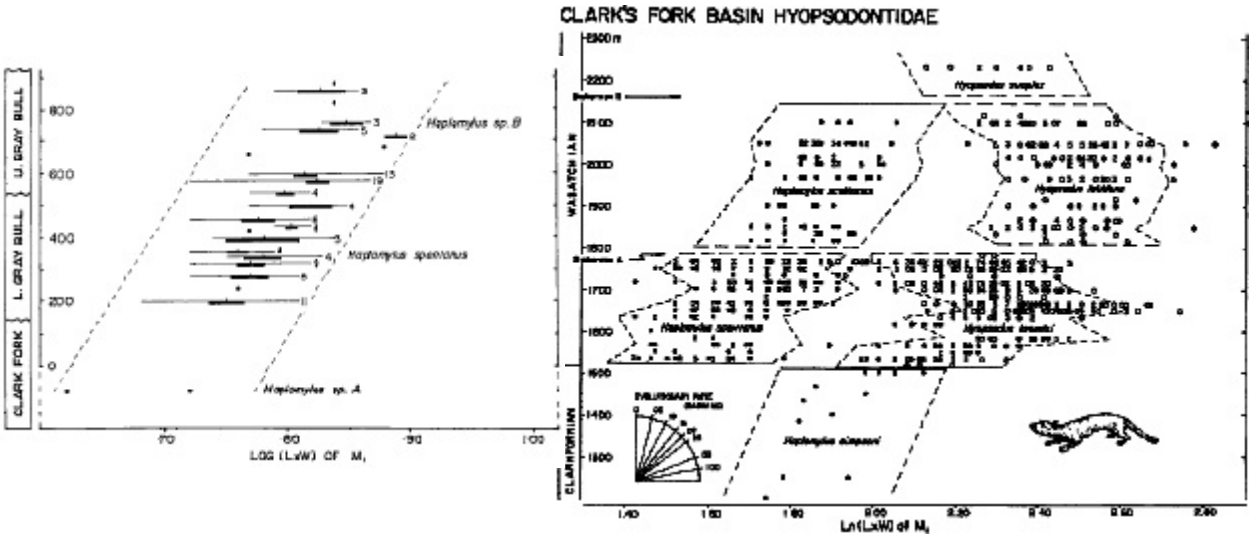

Figure 2. Comparison of *Haplomylus* evolution (*Haplomylus speirianus* and successor *Haplomylus* 'sp. B' or *H. scottianus*) in the central Bighorn Basin (lineage in figure at left; from Gingerich, 1976) and in the northern Bighorn Basin ('Clarks Fork Basin,' leftmost lineage in figure at right; from Gingerich, 1985). Vertical axis in each case is stratigraphic level (in feet, left; or meters, right). These lineages are compared quantitatively in Figure 3 (see below).

The *Haplomylus* lineage for each area is modeled as a linear trend in Figure 3. Blue circles are individual specimens from the northern Bighorn Basin, and red circles are individual specimens from the central Bighorn Basin. Tooth size is regressed on stratigraphic level for each area, with the blue line representing the northern Bighorn Basin and the red line representing the central Bighorn Basin. The northern Bighorn Basin stratigraphic section starts at the base of the Fort Union Formation and includes a thick section of Paleocene strata. The central Bighorn Basin stratigraphic section starts at the base of the Willwood Formation. To make the central Bighorn Basin record of *Haplomylus* change match that for the northern Bighorn Basin, central Bighorn Basin stratigraphic levels must be multiplied by 0.66, and 1600 m must be added. The multiplier indicates that sediment accumulated in the central Bighorn Basin at about 2/3 the rate of sediment accumulation in the northern Bighorn Basin (cf. rate of 1.2 for *Cantius* below).

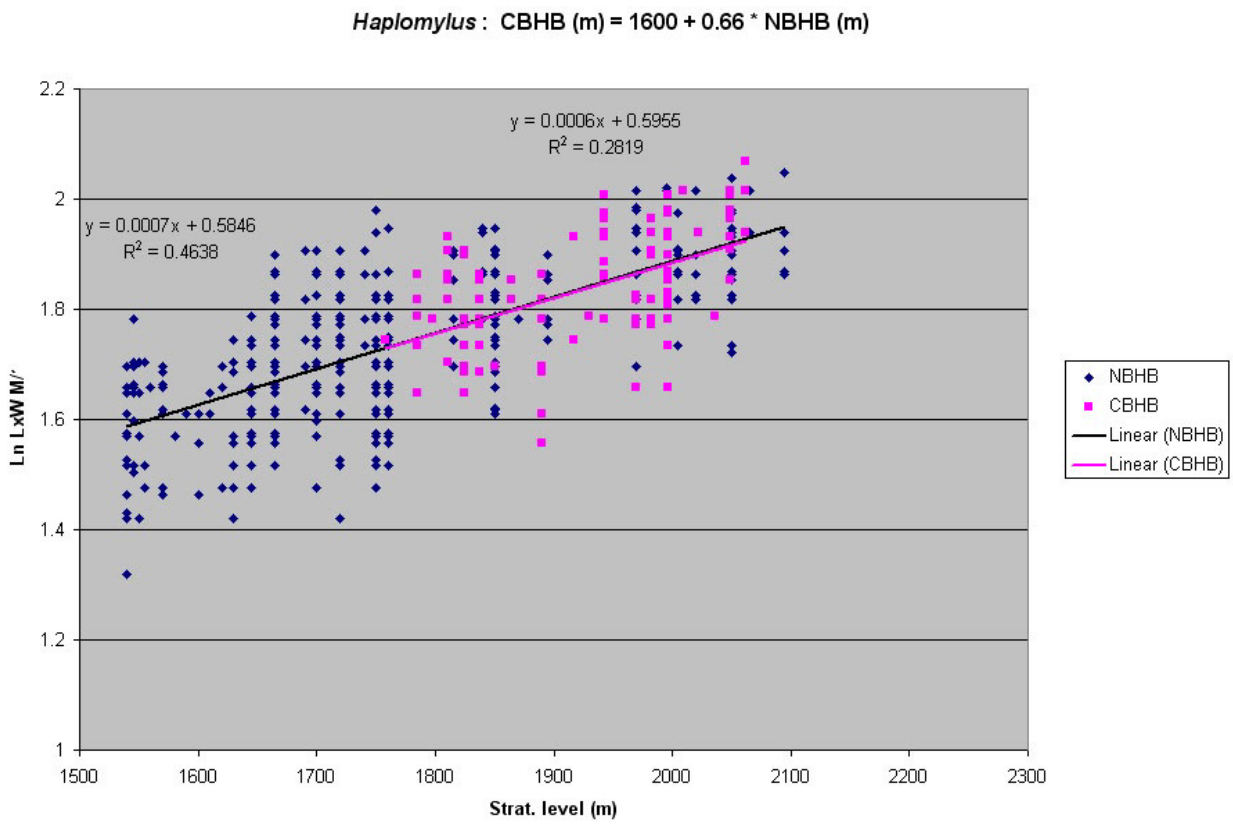

Figure 3. *Haplomylus speirianus* to *H. scottianus* lineage matched in the northern Bighorn Basin (NBHB; blue) and central Bighorn Basin (CBHB; red). Tooth size is regressed on stratigraphic level for each area, with the blue line representing the northern Bighorn Basin and the red line representing the central Bighorn Basin. To make the central Bighorn Basin record of *Haplomylus* change match that for the northern Bighorn Basin, central Bighorn Basin stratigraphic levels must be multiplied by 0.66 (to adjust slope), and 1600 m must be added (to standardize intercept). The 0.66 multiplier indicates that from this evidence sediment accumulated in the central Bighorn Basin at about 2/3 the rate of sediment accumulation in the northern Bighorn Basin.

The same comparison can be made using the *Cantius* lineage found in both the northern and central parts of the Bighorn Basin (Figure 4). *Cantius* is a small primate mammal that, like *Haplomylus*, increased in tooth size and body size more or less monotonically through the early Eocene parts of both Bighorn Basin sections. This was documented in the central Bighorn Basin by Gingerich (1976) and in the northern Bighorn Basin by Gingerich (1989; see Figure 4).

Here again, the *Cantius* lineage is the same in both areas, and its change in one area can be matched to change in the other area to see how sediment accumulation rates compare in the two areas. The *Cantius* lineage for each area is modeled as a linear trend in Figure 5. Blue circles are individual specimens from the northern Bighorn Basin and red circles are individual specimens from the central Bighorn Basin. Tooth size is regressed on stratigraphic level for each area, with the blue line representing the northern Bighorn Basin and the red line representing the central Bighorn Basin. To make the central Bighorn Basin record of *Haplomylus* change match that for the northern Bighorn Basin, central Bighorn Basin stratigraphic levels must be multiplied by 1.20, and 1630 m must be added. The multiplier indicates that sediment accumulated in the

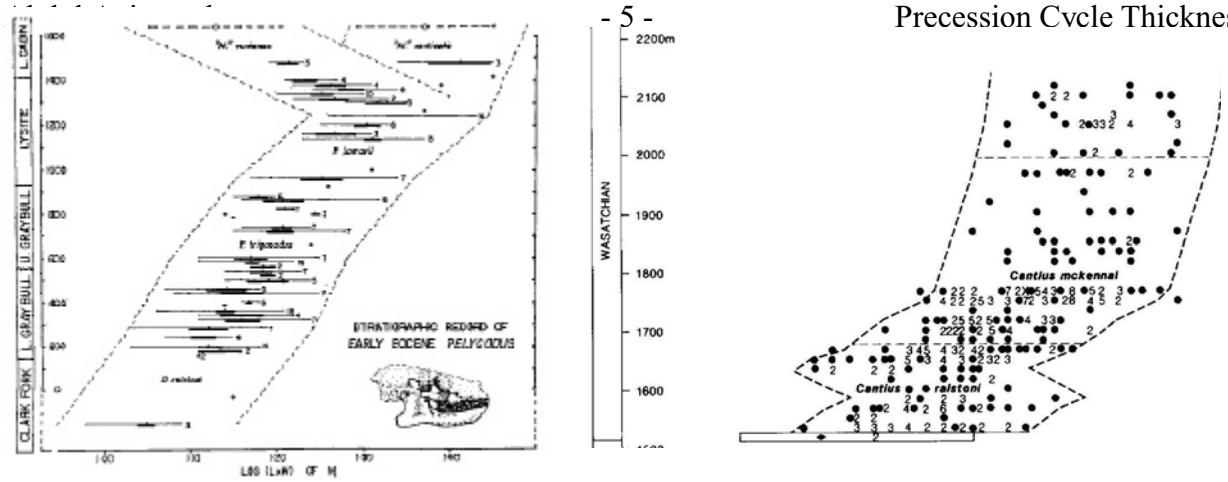

Figure 4. Comparison of *Cantius* evolution in the central Bighorn Basin (lineage in figure at left; from Gingerich, 1976) and in the northern Bighorn Basin ('Clarks Fork Basin,' lineage in figure at right; from Gingerich, 1989). Vertical axis in each case is stratigraphic level (in feet, left; or meters, right). These lineages are compared quantitatively in Figure 5.

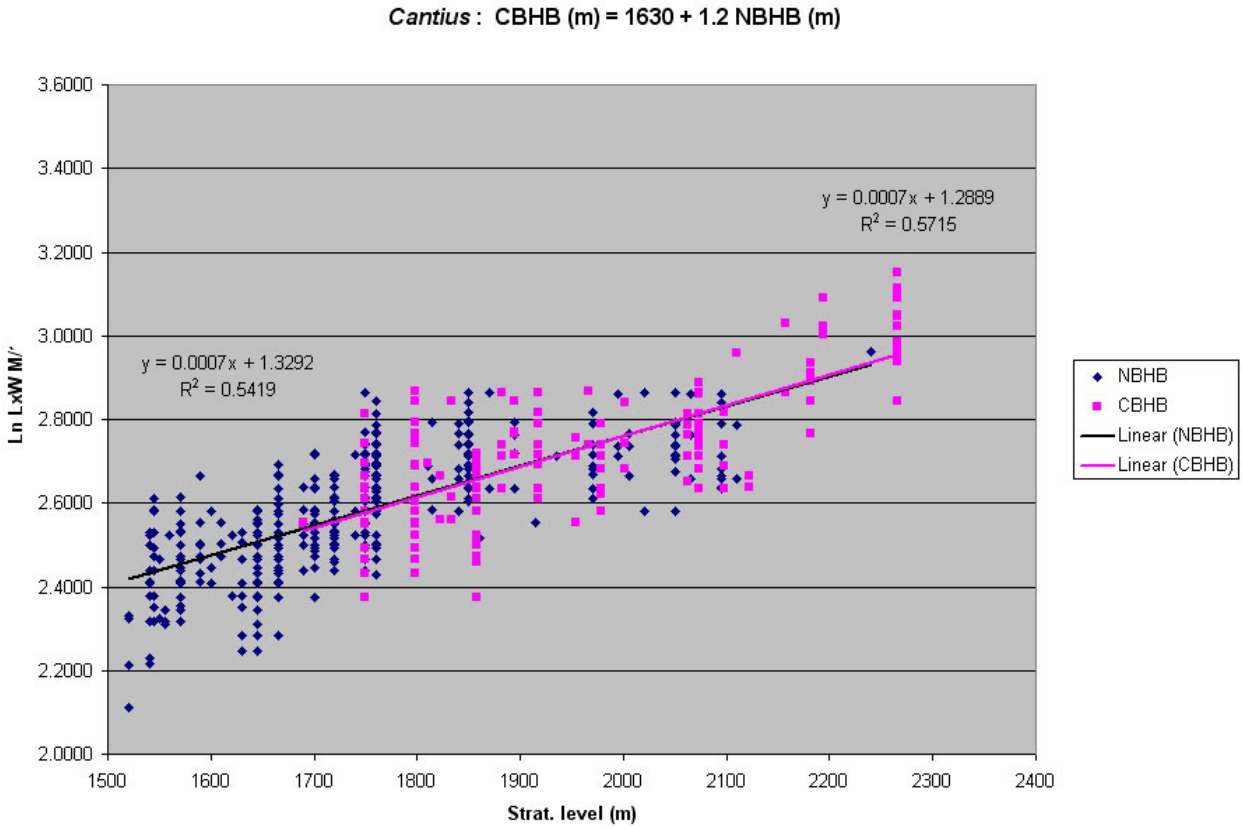

Figure 5. *Cantius* lineage matched in the northern Bighorn Basin (NBHB; blue) and central Bighorn Basin (CBHB; red). Tooth size is regressed on stratigraphic level for each area, as above. To make the central Bighorn Basin record of *Haplomylus* change match that for the northern Bighorn Basin, central Bighorn Basin stratigraphic levels must be multiplied by 1.20 (to adjust slope), and 1630 m must be added (to standardize intercept). The 1.20 multiplier indicates that from this evidence sediment accumulated in the central Bighorn Basin at about 1.2 times the rate of sediment accumulation in the northern Bighorn Basin.

central Bighorn Basin at about 1.2 the rate of sediment accumulation in the northern Bighorn Basin (cf. rate of 0.66 for *Haplomylus* above).

Taking the results for *Haplomylus* and *Cantius* together, the can expect that the rate of sediment accumulation in the northern and central parts of the Bighorn Basin will be approximately the same, because the average of 0.66 and 1.20, 0.93, is close to a value of 1.00 representing equal rates of sediment accumulation in the two basins. **These are long term averages in each case, and it is to be expected that there will be some variation in sediment accumulation rates in each area. Evidence from *Haplomylus* and *Cantius* suggests that lower Eocene sediment accumulated at approximately the same rate in both parts of the Bighorn Basin.** Hence precession cycle thickness, on the order of 5-8 m, should be approximately the same in the two areas.

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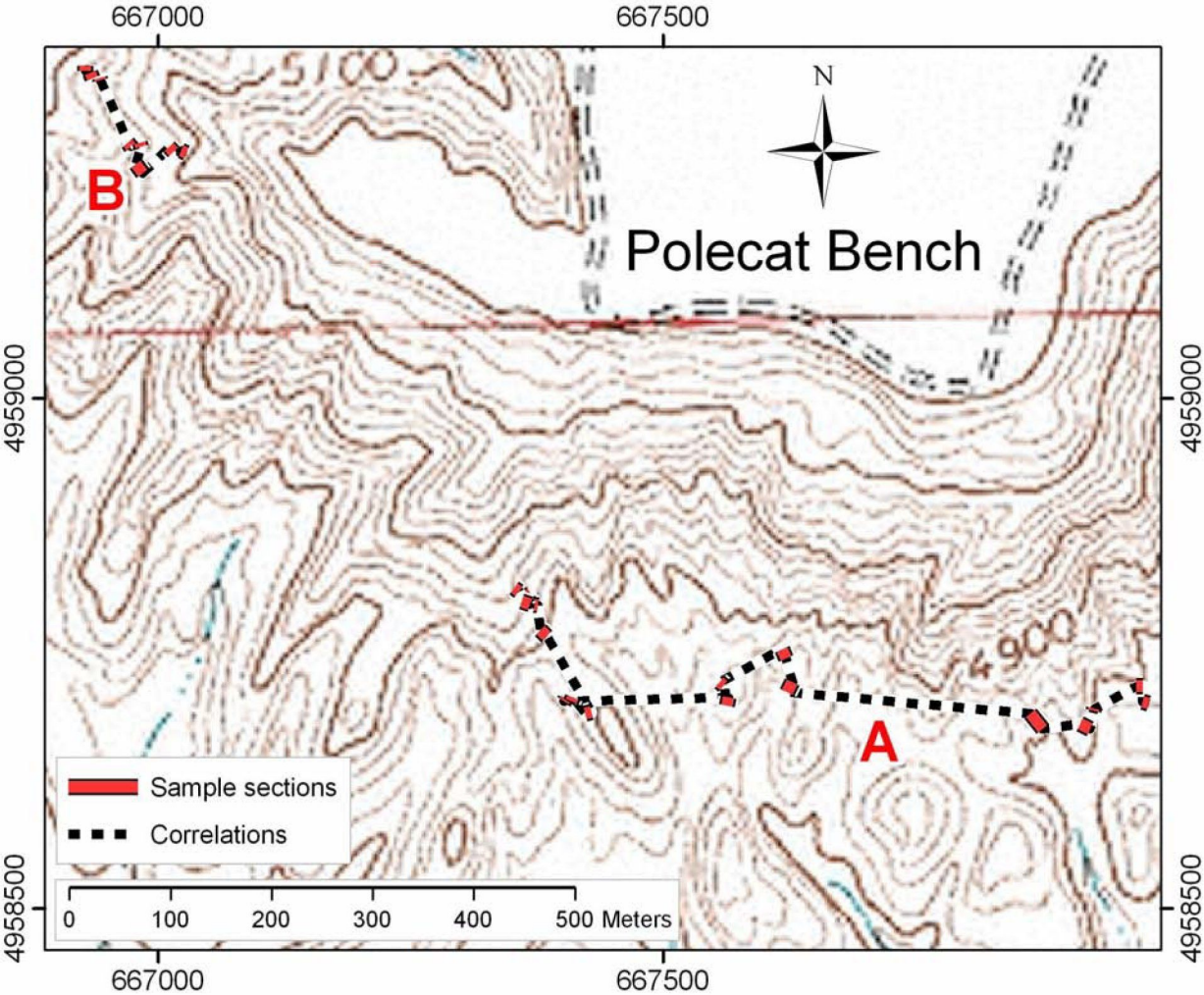

Figure DR1. Detailed location map of sample sections (red) for Polecat Bench area. Note that there are two sets of sample sections here (A and B). Beds at the top of set A can be traced lithologically to beds at the base of set B. General location of the area is shown in Figure 1 in the published text. Base map includes parts of USGS 7.5' quadrangles Elk Basin SW and Elk Basin SE, Park County, Wyoming. Coordinate system is NAD 1927 UTM zone 12N.

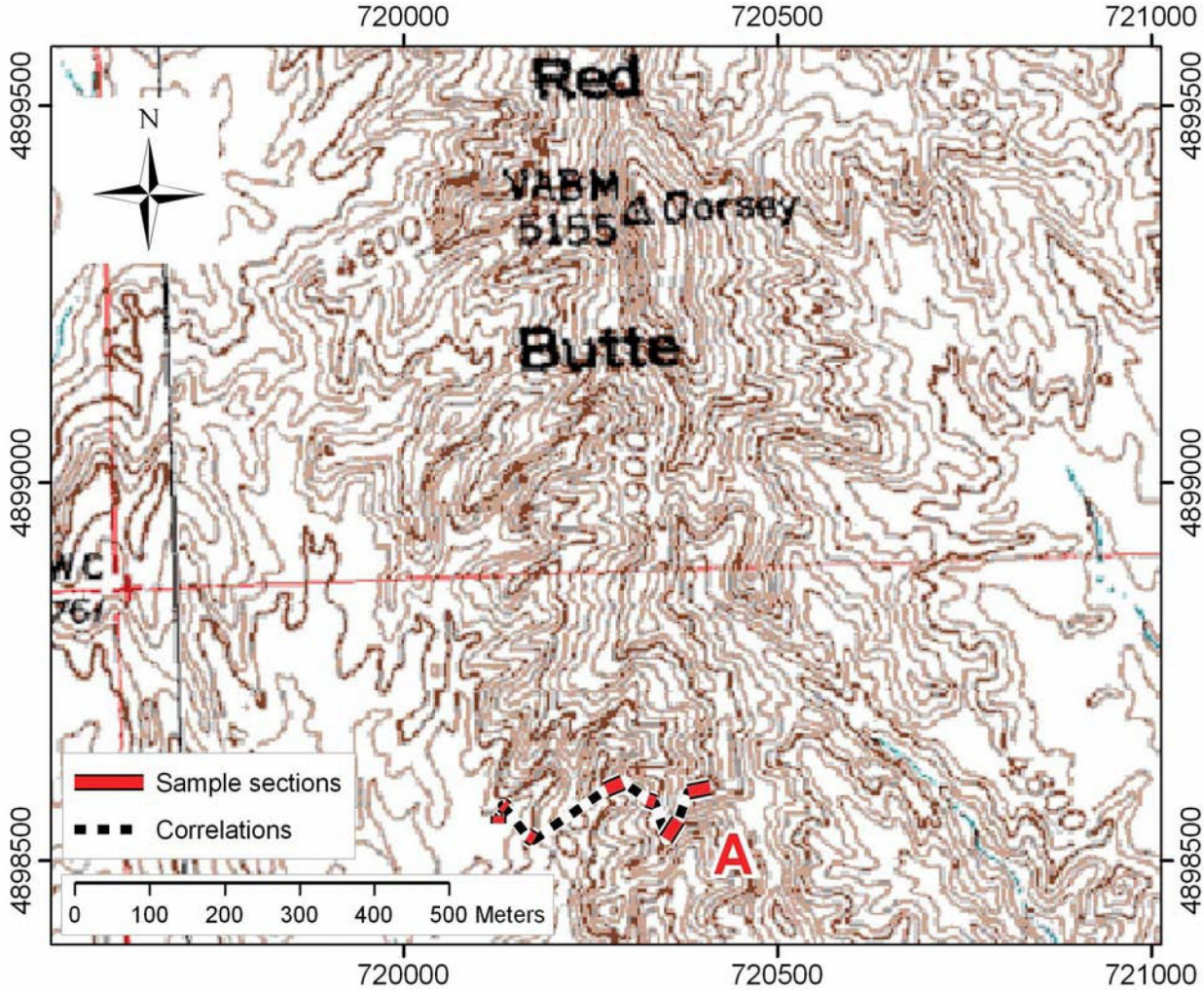

Figure DR2. Detailed location map of sample sections (red) for Red Butte area. Note that there is one set of sample sections here (A). General location of the area is shown in Figure 1 in the published text. Base map includes parts of USGS 7.5' quadrangles Sucker Dam and Schuster Flats NW, Bighorn County, Wyoming. Coordinate system is NAD 1927 UTM zone 12N.

TABLE DR3. RED (a*) COLOR MEASUREMENTS OF POLECAT BENCH

SL (m)	a*	SL (m)	a*	SL (m)	a*	L (m)	a*	SL (m)	a*
0.00	0.2168	7.08	1.7233	15.44	-0.2544	24.72	2.7675	33.60	-0.4380
0.13	0.1642	7.12	9.6305	15.59	0.5037	24.86	4.1384	33.79	5.1064
0.23	-0.0559	7.39	2.6418	15.75	0.1850	24.93	3.8083	33.89	8.3473
0.32	-0.6039	7.43	8.4252	15.90	0.1666	25.06	4.2920	34.07	9.9440
0.40	-0.6228	7.63	2.8314	16.08	0.0129	25.20	4.0476	34.24	5.5856
0.45	0.0910	7.93	2.5851	16.13	0.8415	25.29	4.3961	34.43	9.2350
0.47	0.0364	8.05	1.7429	16.29	1.1707	25.39	3.0275	34.60	8.9124
0.52	-0.0691	8.28	1.3291	16.44	0.6012	25.50	2.7094	34.63	9.0992
0.63	0.1107	8.44	1.5632	16.65	1.9193	25.66	3.2473	34.79	9.7714
0.74	4.6461	8.57	1.5662	16.82	0.6062	25.72	3.5329	34.84	-0.9992
0.86	6.3248	8.73	1.4791	17.15	0.8877	25.84	4.0486	34.94	10.0483
0.95	1.0081	8.84	1.9556	17.32	1.4910	25.92	4.3280	34.96	-0.2784
1.00	1.8404	9.02	1.2356	17.50	0.1315	26.02	3.0712	35.08	6.3664
1.07	1.1308	9.16	1.2055	17.60	0.2287	26.17	2.9855	35.12	7.6739
1.14	1.4403	9.28	0.9464	17.86	0.3517	26.31	2.8647	35.20	7.1499
1.20	1.6006	9.52	2.9845	18.11	0.5032	26.37	3.4647	35.32	7.0442
1.27	0.8038	9.67	2.1194	18.19	4.1678	26.58	1.5371	35.39	7.3749
1.38	1.0340	9.83	0.6648	18.21	2.7029	26.78	-0.3171	35.54	4.9744
1.43	2.6507	10.04	1.2547	18.38	8.3182	26.89	0.3148	35.55	8.0129
1.56	2.7696	10.18	0.7433	18.62	0.2349	27.07	0.7658	35.70	3.0514
1.66	1.3737	10.25	1.5252	18.77	0.9379	27.19	0.6962	35.72	3.8673
1.77	-0.0516	10.46	4.2995	19.01	-0.2833	27.31	0.0975	35.82	-0.3471
1.84	3.9522	10.50	4.4564	19.10	0.2472	27.36	4.8087	36.03	-0.0804
1.91	2.1603	10.68	0.7704	19.29	-0.1727	27.49	5.4964	36.16	-0.6488
2.20	3.1229	10.88	0.4229	19.42	0.4252	27.58	5.8358	36.35	-0.5834
2.34	2.5083	11.00	1.1535	19.55	0.1655	27.72	-0.3254	36.55	-0.5765
2.46	1.5760	11.16	0.9773	19.66	2.7108	27.96	0.3101	36.65	6.1715
2.55	4.9141	11.31	1.0505	19.75	2.2470	28.10	0.2763	36.83	-0.3432
2.66	4.7909	11.50	0.6121	19.93	0.5165	28.17	0.9500	37.02	-0.9449
2.73	4.8304	11.70	0.7909	20.20	1.2429	28.31	-0.3174	37.22	-0.6787
2.88	4.8109	11.80	0.1061	20.35	0.4551	28.33	1.8494	37.29	-0.1732
2.97	0.2869	11.90	3.1275	20.54	0.4978	28.43	3.8290	37.44	-0.6863
3.06	4.1648	12.05	0.4069	20.60	0.2635	28.55	1.5852	37.63	-0.3974
3.16	4.5634	12.19	0.4946	20.76	0.5038	28.78	0.4061	37.74	-0.7402
3.29	3.5853	12.40	0.0617	21.05	0.1958	28.96	-0.2963	37.78	-0.6998
3.40	3.3029	12.62	0.2327	21.27	0.0919	29.12	0.4295	37.86	4.7044
3.58	2.3381	12.77	0.0043	21.44	-0.2757	29.24	1.6286	37.98	-0.5815
3.74	4.7720	12.97	-0.3167	21.68	-0.3015	29.40	4.1944	37.98	6.8013
3.88	3.9785	13.12	-0.1232	21.83	-0.0193	29.55	3.2806	38.10	4.2174
4.08	3.9693	13.23	-0.2798	21.96	2.4678	29.63	2.6437	38.22	4.3089
4.27	5.0168	13.38	2.5863	22.08	2.7843	29.74	5.0532	38.42	6.6110
4.39	3.9435	13.47	-0.4307	22.23	1.8548	29.80	-0.9086	38.58	5.4874
4.47	3.2290	13.58	0.1928	22.33	1.2671	29.87	4.8048	38.65	4.7594
4.58	2.9428	13.77	0.3026	22.38	8.1121	29.96	-0.6190	38.77	5.3304
4.63	2.5575	13.86	-0.4148	22.39	4.9269	30.25	-0.1006	38.87	4.8438
4.72	1.5246	13.91	0.3390	22.41	5.2789	30.50	0.3851	39.01	4.2725
4.86	3.4064	14.04	0.9857	22.58	5.6362	30.63	-0.4382	39.10	3.1732
4.99	4.6058	14.16	1.3309	22.73	7.0285	30.82	-0.3928	39.29	5.3960
5.12	4.6693	14.21	9.8482	22.78	7.3652	30.95	0.1501	39.44	4.1277
5.22	0.8063	14.26	-0.0777	22.90	6.5363	31.22	-0.4483	39.50	1.9252
5.32	0.0314	14.34	-0.7974	23.03	6.0056	31.40	-0.1853	39.65	8.3003
5.46	-0.0194	14.35	3.5036	23.07	7.3289	31.52	0.3883	39.80	6.6520
5.56	7.4900	14.43	2.2592	23.25	0.9953	31.62	-0.0640	40.03	9.7000
5.68	6.7230	14.56	8.0533	23.31	0.6567	31.75	5.3145	40.15	2.2585
5.79	6.8907	14.62	10.1946	23.45	1.9697	31.88	7.4013	40.34	-0.0526
5.92	7.8483	14.62	-0.7992	23.56	2.9626	32.06	8.5481	40.34	-0.3835
5.99	8.3324	14.73	-0.6319	23.70	4.0517	32.15	4.6412	40.49	-0.2735
6.02	6.2878	14.76	-0.5309	23.77	2.2087	32.34	7.5323	40.61	-0.6094
6.11	1.1145	14.90	-0.3159	23.86	2.0721	32.58	7.3597	40.85	-0.1970
6.31	2.3560	14.96	-0.8412	24.00	2.5180	32.73	7.7273	41.04	-0.0981
6.40	1.9473	15.00	7.0526	24.05	1.6506	32.87	8.3193	41.14	-0.1016
6.55	1.3985	15.09	8.2224	24.19	2.6140	33.07	7.2737	41.32	0.3341
6.72	1.0751	15.13	6.3385	24.32	1.3942	33.18	2.5482	41.33	1.2910
6.92	2.2881	15.20	1.3620	24.47	0.6854	33.30	0.6769	41.44	3.8629
6.97	0.3711	15.29	7.3660	24.53	2.1643	33.43	0.1287	41.60	5.1317

TABLE DR3. *continued*

SL (m)	a*	SL (m)	a*	SL (m)	a*	SL (m)	a*	SL (m)	a*
41.81	3.9150	52.41	-0.2709	61.72	6.5951	72.92	0.3603	84.38	-0.8365
41.91	4.6035	52.52	-0.4408	61.88	6.5900	73.13	1.1319	84.61	0.1332
42.06	5.0283	52.72	0.7935	62.02	-0.4425	73.34	1.3239	84.76	2.2362
42.23	6.7166	52.80	1.2127	62.28	-0.0049	73.47	0.5282	84.90	0.7609
42.40	4.3963	52.85	7.9467	62.52	-0.2746	73.76	-0.0185	85.05	1.5547
42.55	5.0189	52.94	8.7150	62.65	0.6557	73.87	0.5314	85.19	0.7650
42.69	9.6550	53.08	4.6597	62.84	5.3988	73.97	3.1707	85.36	1.9801
42.81	4.3685	53.22	0.7017	63.13	5.7749	74.05	3.8942	85.62	1.6419
42.99	0.2184	53.41	5.5893	63.34	5.2388	74.07	3.9089	85.94	0.6714
43.13	0.1545	53.54	5.2624	63.45	5.3970	74.26	-0.5719	86.15	0.8972
43.18	5.1505	53.68	5.3376	63.64	5.1565	74.42	0.3586	86.49	1.7850
43.28	4.5024	53.83	-0.2596	63.72	5.5035	74.61	-0.3510	86.78	1.2177
43.46	-0.1742	53.99	1.0425	63.77	3.6685	74.75	4.3356	87.14	0.8360
43.73	-0.1696	54.03	3.0536	63.94	0.7415	74.92	-0.2111	87.42	1.2298
43.96	-0.2828	54.16	0.2903	64.09	2.5849	75.17	4.4758	87.62	0.9051
44.26	2.1187	54.36	8.4076	64.22	2.2936	75.29	7.6798	87.80	0.1528
44.30	-0.4849	54.56	8.5093	64.32	2.7120	75.43	6.0368	87.82	1.4756
44.50	-0.3181	54.79	7.9206	64.37	1.2229	75.54	6.0742	88.00	1.0612
44.69	3.8437	54.95	2.9624	64.66	0.7101	75.79	5.7365	88.23	1.2075
45.06	9.8032	55.03	7.0304	64.77	2.5078	75.97	2.8587	88.40	4.9209
45.29	9.3994	55.10	7.2743	64.97	-0.0969	76.18	0.5184	88.55	5.0773
45.49	2.2658	55.25	0.1123	65.12	0.1886	76.43	1.2836	88.66	7.0330
45.59	0.7748	55.30	1.3288	65.29	2.9965	76.63	-0.1573		
45.73	9.8297	55.45	1.1492	65.45	1.3308	76.78	0.3585		
45.88	8.2284	55.62	0.5453	65.65	2.3168	76.90	3.7313		
46.02	9.7474	55.84	0.3216	65.84	2.3140	77.03	3.1975		
46.22	8.7648	56.03	1.0368	65.94	3.9297	77.10	2.2218		
46.41	8.3185	56.16	0.9000	66.03	5.2639	77.22	3.2556		
46.59	-0.6957	56.22	4.1578	66.10	0.6540	77.40	-0.5478		
46.74	-0.2331	56.26	5.2569	66.29	1.5240	77.59	5.4126		
46.88	-0.4736	56.46	7.4286	66.51	1.2242	77.74	0.8925		
47.00	-0.0609	56.68	7.1434	66.80	1.4225	77.94	0.0738		
47.19	-0.0705	56.92	4.1897	67.16	0.2984	78.06	4.4892		
47.39	2.5063	57.08	8.8650	67.34	2.0745	78.25	4.2045		
47.46	8.8086	57.19	5.5753	67.64	1.1491	78.34	8.0375		
47.59	9.2432	57.30	5.4326	67.76	1.8522	78.48	2.7176		
47.79	9.7251	57.44	-0.3683	67.84	2.6079	78.60	1.6743		
47.92	10.9283	57.54	1.7243	67.99	0.7347	78.83	2.5714		
48.14	10.4364	57.67	7.2732	68.19	1.3705	79.05	3.0958		
48.34	10.9959	57.77	7.4966	68.32	1.0423	79.32	0.6452		
48.54	9.8077	57.80	1.1517	68.49	2.2968	79.44	1.2710		
48.76	10.6853	57.88	-0.0275	68.69	1.0134	79.63	0.7414		
48.94	10.8210	57.96	-0.3999	68.86	1.0034	79.90	0.1394		
49.15	11.5537	58.13	3.0259	69.01	0.4585	80.08	2.4150		
49.36	9.6285	58.26	0.9243	69.20	2.5015	80.22	2.2616		
49.54	9.2584	58.40	-0.2069	69.27	2.7691	80.45	1.8510		
49.87	5.0623	58.51	2.9869	69.40	4.3726	80.72	0.8183		
49.98	0.6125	58.58	0.3363	69.45	7.7485	80.96	0.6611		
50.10	1.3936	58.68	0.0568	69.54	3.4539	81.11	0.8566		
50.20	5.8223	58.81	-0.2358	69.68	2.9479	81.30	0.7167		
50.35	9.7559	58.97	-0.4972	69.90	1.0973	81.41	2.6145		
50.49	7.5584	59.21	-0.3568	70.12	0.4225	81.63	2.9124		
50.52	8.2628	59.46	-0.7119	70.28	0.0129	81.72	0.6099		
50.67	0.5043	59.62	-0.3890	70.47	0.1877	81.89	4.4717		
50.83	-0.4610	59.83	-0.7271	70.64	1.4605	82.04	0.2133		
50.99	-0.5473	59.99	5.5832	70.84	4.5591	82.31	0.0553		
51.14	3.7906	60.14	5.2126	71.04	6.8374	82.51	0.4005		
51.28	-0.4853	60.32	-0.1849	71.09	9.2975	82.52	-0.0911		
51.44	-0.1601	60.44	-0.6495	71.66	2.4983	82.72	0.5976		
51.60	7.3610	60.61	4.7674	71.83	3.9603	82.88	1.2863		
51.73	6.8044	60.76	4.3909	72.08	1.4250	83.03	0.0576		
51.91	8.9236	60.99	-0.2855	72.21	1.3149	83.21	0.1605		
52.00	6.8720	61.20	-0.2295	72.38	1.8215	83.39	-0.4599		
52.14	0.6394	61.35	6.3313	72.61	2.2215	83.81	-0.0723		
52.27	-0.4276	61.60	5.1626	72.84	0.0149	84.05	-0.1542		

TABLE DR4. RED (a*) COLOR MEASUREMENTS OF RED BUTTE

SL (m)	a*	SL (m)	a*	SL (m)	a*	SL (m)	a*	SL (m)	a*
0.05	-0.6906	11.95	10.4132	25.74	2.7503	40.34	4.2820	53.58	9.9950
0.15	-0.1459	12.21	11.2805	25.89	2.9452	40.58	0.0381	53.70	10.3080
0.24	0.1316	12.46	10.6486	26.19	4.6624	40.81	-0.8860	53.96	6.5214
0.36	0.1678	12.69	9.8871	26.49	5.7169	41.17	5.9984	54.31	5.9643
0.47	3.1231	12.92	0.0773	26.78	7.1443	41.34	5.8282	54.64	5.5016
0.65	5.5333	13.07	-0.2249	27.07	8.8313	41.49	6.8083	54.89	3.6292
0.83	4.7303	13.21	-0.7129	27.36	6.9831	41.58	7.0326	55.01	2.7262
0.98	4.3186	13.31	4.2042	27.64	7.1317	41.81	1.5578	55.16	6.4442
1.13	4.1918	13.41	8.3564	27.79	6.2097	41.91	4.0596	55.29	5.1510
1.34	7.0559	13.56	5.1705	27.94	5.0175	42.09	3.2289	55.47	5.2749
1.55	5.9295	13.70	7.2130	28.20	5.5193	42.30	5.4260	55.65	3.2108
1.73	8.4547	13.87	6.4494	28.45	5.6385	42.48	8.3951	55.90	3.0904
1.91	8.3144	14.03	8.0205	28.62	12.3907	42.62	6.6810	56.10	-1.1409
2.07	9.1206	14.25	7.7031	28.79	3.9385	42.72	7.2846	56.25	-0.5695
2.23	6.2298	14.46	8.1314	28.93	4.8932	43.02	8.7127	56.40	-0.8368
2.40	5.5324	14.67	9.1517	29.06	6.7196	43.20	7.4618	56.62	-1.2365
2.57	8.2862	14.88	9.5200	29.37	10.5005	43.31	10.3969	56.82	7.0452
2.69	9.6389	15.20	-0.5434	29.67	10.5885	43.52	5.3741	56.98	8.1846
2.81	8.5390	15.51	7.2826	29.86	9.8511	43.70	5.3300	57.20	-0.2525
2.99	8.3598	15.80	-0.7647	30.05	8.4909	43.92	5.6360	57.46	7.7726
3.31	0.7155	16.08	-0.7579	30.34	5.9010	44.18	1.5940	57.73	7.4528
3.45	6.4095	16.24	-0.9751	30.63	-0.5340	44.33	-0.5986	57.97	8.7800
3.58	6.9756	16.40	9.3278	30.87	8.4642	44.47	-0.0701	58.12	-0.0743
3.71	8.8022	16.61	8.2196	31.10	0.2891	44.52	9.2669	58.32	1.4029
3.97	8.0902	16.81	-0.2115	31.46	3.8230	44.78	9.7751	58.50	7.1726
4.22	0.7399	17.06	-0.4398	31.82	4.9487	44.97	5.5332	58.66	0.8563
4.53	-0.3679	17.31	8.9125	31.99	4.3404	45.11	5.0674	58.86	0.1909
4.83	-0.1899	17.49	8.7201	32.16	3.2163	45.30	9.7993	59.13	0.2945
5.15	-0.1458	17.66	9.7665	32.32	3.2172	45.52	9.8225	59.28	8.7398
5.47	-0.5933	17.80	9.5576	32.48	2.6909	45.75	11.2354	59.55	10.1492
5.76	-0.7111	17.93	5.1249	32.71	3.2260	45.98	11.4936	59.75	9.7716
6.04	9.0062	18.14	2.8464	32.93	-1.1145	46.19	7.7025	60.01	8.1722
6.21	10.3107	18.34	0.0995	33.16	-0.3058	46.30	6.4009	60.19	7.4567
6.37	6.7321	18.58	8.1146	33.38	-0.4480	46.51	5.2890	60.40	8.7497
6.51	7.5866	18.81	0.4436	33.63	-0.2267	46.64	7.1855	60.54	0.3876
6.65	7.1491	18.94	8.0105	33.87	0.7897	46.88	7.9055	60.69	11.6609
6.86	8.2475	19.07	10.4185	34.09	3.4904	47.13	5.7781	60.89	5.6937
7.06	-0.8406	19.29	11.3944	34.30	-0.4906	47.49	9.9624	61.11	5.8835
7.18	-1.0679	19.50	9.2293	34.55	1.9882	47.68	8.5622	61.35	4.5981
7.29	10.4050	19.78	10.5505	34.82	4.5475	47.81	0.0334	61.51	0.5721
7.46	-0.1788	20.06	7.9744	35.04	7.6067	47.91	7.9643	61.78	7.0736
7.63	9.6524	20.33	5.7280	35.31	5.9949	48.08	6.4653	62.04	7.3287
7.76	10.5454	20.59	6.6587	35.50	7.7820	48.23	-1.0018	62.29	8.4223
7.98	6.5920	20.79	6.7980	35.79	7.1502	48.36	1.9746	62.58	6.0331
8.15	8.0052	20.99	6.6893	36.12	8.1974	48.55	-0.0361	62.78	10.3404
8.32	5.8217	21.16	7.3414	36.45	6.5644	48.74	8.6706	63.11	7.7429
8.49	8.6818	21.33	7.2507	36.69	5.8094	48.85	0.2758	63.49	9.1602
8.66	8.2232	21.60	7.9117	36.92	7.9784	48.99	4.1444	63.73	6.5038
8.77	8.8215	21.86	5.0518	37.10	8.9959	49.24	0.0898	63.98	7.6183
8.87	0.2768	22.26	3.2532	37.27	10.5618	49.57	0.2104	64.21	6.1619
8.97	1.2488	22.57	4.1348	37.41	9.8999	49.86	6.2266	64.56	5.1410
9.07	8.5428	22.79	1.0255	37.54	9.9491	49.99	11.2841	64.74	5.0872
9.23	9.1605	23.00	-0.1460	37.76	10.4424	50.30	5.7879	65.08	1.5109
9.39	9.3274	23.24	-0.9734	37.97	9.3517	50.60	5.7458	65.33	8.8631
9.53	10.3971	23.47	2.1585	38.14	10.1005	50.82	5.2537	65.51	0.2900
9.67	10.3860	23.69	-0.0417	38.30	9.4070	51.15	6.1633	65.75	9.4974
9.82	9.0041	23.91	3.2656	38.50	9.1715	51.47	8.7013	65.99	9.9137
9.96	5.1856	24.07	4.3406	38.70	7.8545	51.61	9.5185	66.28	9.8640
10.17	0.0341	24.23	3.6342	38.96	7.6644	51.72	-0.1834	66.47	10.0525
10.38	-0.1012	24.47	-0.4233	39.22	3.6481	51.89	10.1386	66.65	1.4887
10.56	5.4270	24.70	-0.3688	39.42	-1.1593	52.19	10.2476	66.97	1.6714
10.74	8.0104	24.94	3.7459	39.62	6.0569	52.36	9.6368	67.14	3.2407
10.97	6.6597	25.18	2.6731	39.80	3.3240	52.55	10.0554	67.38	4.6234
11.20	7.0503	25.37	6.0901	39.97	2.7123	52.85	-0.6669	67.64	1.1970
11.58	10.1466	25.56	3.6209	40.16	-0.0292	53.12	9.5391	67.88	3.8264

TABLE DR4. *Continued*

SL (m)	a*
68.41	5.4862
68.58	4.8823
68.88	-0.3922
69.13	9.6383
69.27	8.9354
69.52	1.2677
69.68	-0.2480
69.79	1.0160
69.95	9.0458
70.13	11.5429
70.31	10.6843
70.42	9.2037
70.66	10.3578
71.84	11.7035
72.00	11.0852
72.20	11.9255
72.40	11.0779
72.62	12.1756
72.83	11.7844
72.98	-0.0468
73.18	-0.8057
73.42	10.3277
73.58	11.3743
73.73	11.8419
73.93	10.6431