Total Organic Carbon content and Rock Eval pyrolysis on outcrop samples across the Cretaceous/Tertiary boundary, Seymour Island, Antarctica

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Forty outcrop samples from Seymour Island, northeastern Antarctic Peninsula, were run for Total Organic Carbon (TOC) content and Rock Eval pyrolysis. These samples span 23.5 meters of section (figure 1) that includes the Cretaceous/Tertiary boundary as defined by dinoflagellate cysts (section B1, between samples 109 and 110, Askin 1988b). The aim was to evaluate preserved organic matter for quantity, quality, thermal maturity, and environment of deposition, to recognize changes in environmental conditions, if any, across the Cretaceous/Tertiary boundary.

These samples contain consistently low amounts of total organic carbon with similar poor quality (virtually no hydrocarbon generative potential) and are thermally immature (table, figure 1). No significant variations in analytic data were found across the Cretaceous/Tertiary boundary.

Outcrop samples were collected by F.C. Barbis and J.R. Robinson in December 1983, mostly at 0.5-meter intervals, from about 10–30 centimeters beneath the surface. Outcrop samples are subject to weathering which may have affected the TOC and pyrolysis results. The sediments are unconsolidated, mainly sandy silts and silty sands, with some glauconitic and more clayey beds (figure 1). All samples are rich in fossil palynomorphs (Askin 1988a, 1988b). Samples were analyzed by Exlog/Brown & Ruth Laboratories, Inc., Denver, Colorado.

TOC. TOC content of a sample includes the total sedimentary organic matter and is affected by the clastic sedimentation rate and the extent of degradation. Degradation includes oxidation in the depositional basin, diagenesis, and thermal alteration of organic matter due to burial depth or igneous activity, as well as subsequent weathering at the outcrop.

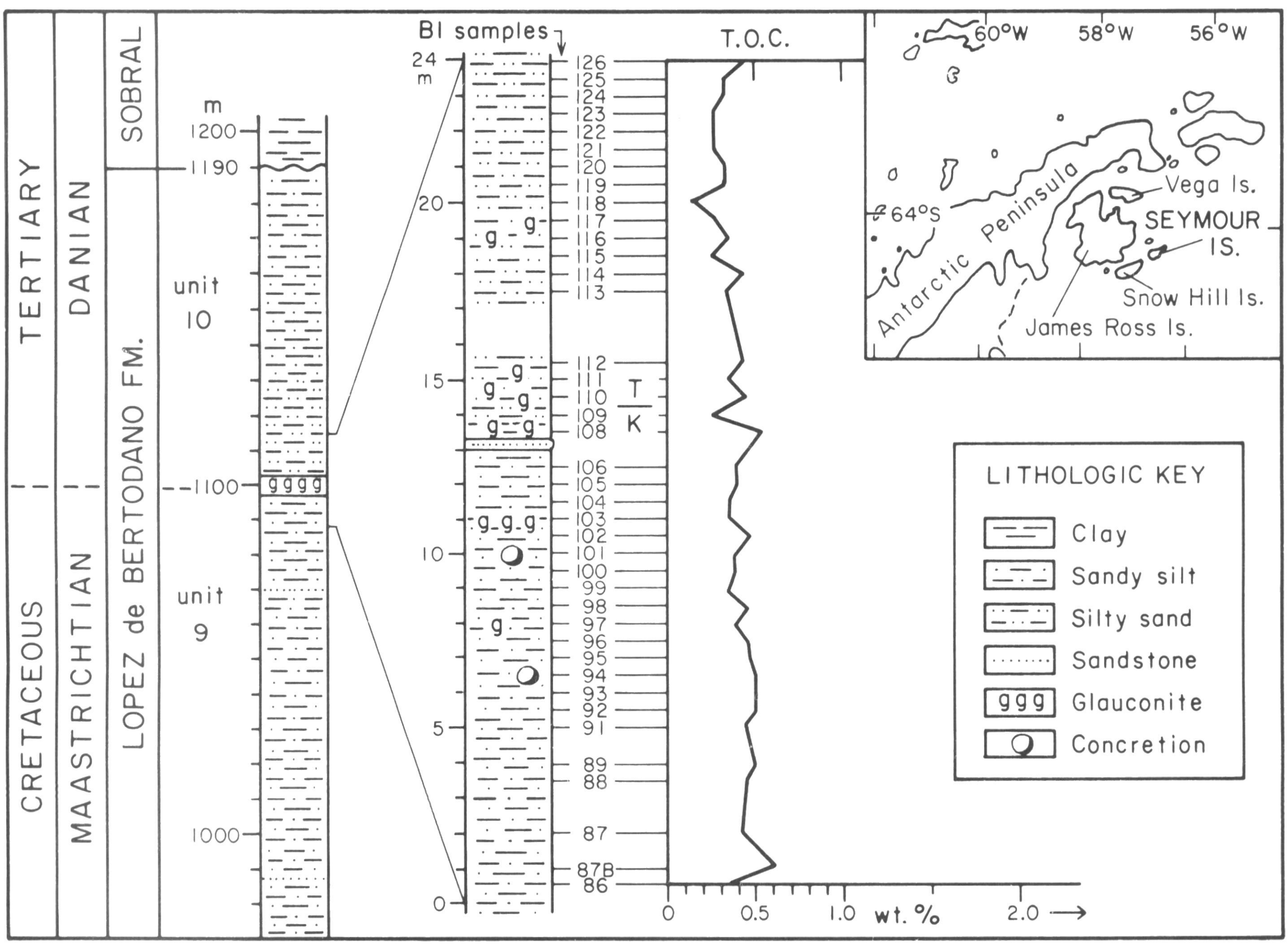

Figure 1. Location of Seymour Island, lithology in Cretaceous/Tertiary (K/T) boundary section B1, and TOC trend for 40 samples. (m denotes meter. T.O.C. denotes total organic carbon.)

Results of Total Organic Carbon (TOC) analysis and Rock Eval pyrolysis

Sample number	TOC[a]	S_1[b]	S_2[c]	S_3[d]	T_{max}[e]	Hydrogen Index[f]	Oxygen Index[g]
B1-126	0.44	<0.10	<0.10	0.66	—[h]	—	153
B1-125	0.33	—	—	—	—	—	—
B1-124	0.34	—	—	—	—	—	—
B1-123	0.28	—	—	—	—	—	—
B1-122	0.28	—	—	—	—	—	—
B1-121	0.28	—	—	—	—	—	—
B1-120	0.33	—	—	—	—	—	—
B1-119	0.34	—	—	—	—	—	—
B1-118	0.15	—	—	—	—	—	—
B1-117	0.28	—	—	—	—	—	—
B1-116	0.37	—	—	—	—	—	—
B1-115	0.27	—	—	—	—	—	—
B1-114	0.43	<0.10	<0.10	0.72	—[h]	—	167
B1-113	0.33	—	—	—	—	—	—
B1-112	0.43	<0.10	<0.10	0.62	—[h]	—	144
B1-111	0.37	—	—	—	—	—	—
B1-110	0.45	<0.10	0.21	0.79	—[h]	46	175
B1-109	0.27	—	—	—	—	—	—
B1-108	0.54	<0.10	0.21	0.71	—[h]	39	131
B1-106	0.40	—	—	—	—	—	—
B1-105	0.40	—	—	—	—	—	—
B1-104	0.37	—	—	—	—	—	—
B1-103	0.35	—	—	—	—	—	—
B1-102	0.48	<0.10	0.19	0.46	—[h]	39	97
B1-101	0.39	—	—	—	—	—	—
B1-100	0.39	—	—	—	—	—	—
B1-99	0.35	—	—	—	—	—	—
B1-98	0.46	<0.10	0.26	0.54	425	57	117
B1-97	0.39	—	—	—	—	—	—
B1-96	0.46	<0.10	0.19	0.44	—[h]	42	96
B1-95	0.47	<0.10	0.26	0.47	427	55	101
B1-94	0.50	<0.10	0.22	0.53	—[h]	44	106
B1-93	0.50	<0.10	<0.10	0.46	—[h]	—	93
B1-92	0.50	<0.10	0.20	0.53	—[h]	39	105
B1-91	0.44	<0.10	<0.10	0.43	—[h]	—	97
B1-89	0.50	<0.10	<0.10	0.52	—[h]	—	104
B1-88	0.45	<0.10	0.20	0.53	—[h]	46	117
B1-87	0.41	<0.10	0.22	0.51	—[h]	54	124
B1-87B	0.60	<0.10	0.23	0.78	—[h]	38	131
B1-86	0.34	—	—	—	—	—	—

[a] TOC is expressed in weight percent.
[b] S_1 denotes already generated hydrocarbons, in milligrams of hydrocarbons per gram of rock.
[c] S_2 denotes hydrocarbons generated from kerogen during pyrolysis, in milligrams of hydrocarbons per gram of rock.
[d] S_3 denotes carbon dioxide generated from kerogen, in milligrams of carbon dioxide per gram of rock.
[e] T_{max} denotes temperature at maximum pyrolysis, in degrees Celsius.
[f] Hydrogen Index equals $S_2 \times 100 \div$ TOC, in milligrams of hydrocarbons per gram of organic carbon.
[g] Oxygen Index equals $S_3 \times 100 \div$ TOC, in milligrams of carbon dioxide per gram of organic carbon.
[h] Insufficient S_2 yield for accurate determination.

TOC in all 40 samples varies from 0.15 to 0.60 weight percent ($\bar{x}$= 0.39) with 37 samples between 0.27 and 0.50 weight percent. Samples above the Cretaceous/Tertiary boundary are slightly leaner ($\bar{x}$ = 0.34, n = 17) than those below ($\bar{x}$ = 0.43, n = 23). This may reflect differences in organic matter input, organic matter dilution related to increased sandiness in the stratigraphically higher samples, or increased oxidation in nearer shore paleoenvironments above the boundary, as determined from palynomorph assemblages (Askin, unpublished data). TOC values of 0.50 and less are considered poor petroleum source rocks (Peters 1986).

In the sample (109) below the presumed Cretaceous/Tertiary boundary, TOC drops, then returns to the general trend in the sample above (110). This variation is noted but is small and probably not of sufficient magnitude to conclude confidently anything about a boundary event.

Rock Eval pyrolysis. The four measurements of Rock Eval pyrolysis are S_1, S_2, S_3, and T_{max} (see table for explanation). Parameters calculated from these analytic data evaluate the "quality" of the organic matter, its organic facies (*sensu* Jones 1987), and its extent of thermal maturation. In general, the analytical reliability of Rock Eval pyrolysis data is suspect for samples with TOC values less than 0.4 weight percent. Therefore, Rock Eval was not attempted on such samples. Seventeen of the 40 samples have TOC values of 0.41 to 0.60 weight percent and were analyzed by Rock Eval.

None of the 17 pyrolyzed samples produced detectable S_1. S_1 is a measure of mobile hydrocarbons in a rock sample. Eleven samples produced detectable S_2 (0.19–0.26), which measures hydrocarbons analytically pyrolyzed from kerogen. Two samples with sufficient S_2 to measure T_{max} showed the organic matter in these samples is thermally immature (i.e., no significant amounts of the organic matter have been converted to hydrocarbons). These maturity results are consistent with unmeasurable S_1 values, and confirm low thermal maturity based on yellow spore color (equivalent vitrinite reflectance of approximately 0.4 to 0.6 percent), despite sometimes abundant, more thermally mature reworked spores (R_o up to 0.9 percent). Fleming and Askin (1982) reported vitrinite reflectance values (0.28 and 0.30 percent R_o = thermally immature) for samples of a nearby Early Tertiary lignitic coal lens stratigraphically higher in the section. Vitrinite reflectance values of 0.69 percent R_o were reported (Palamarczuk et al. 1984) for two samples near(?) the Cretaceous/Tertiary boundary on Seymour Island, implying marginal maturity. The range of vitrinite reflectance values for the 24 Campanian to Paleocene samples analyzed by Palamarczuk et al. (1984) is 0.37 to 0.71 percent R_o, with the lower values from samples in the upper part of the section.

Organic facies. The term *organic facies* has been used many ways in the literature (Jones 1987). The definition of Jones and Demaison (1982) is followed here: "an organic facies is a mappable subdivision of a designated stratigraphic unit, distinguished from adjacent subdivisions on the basis of the character of its organic constituents without regard to the inorganic aspects of the sediment." Jones (1987) used hydrogen-to-carbon (H/C) and oxygen-to-carbon (O/C) atomic ratios, or equivalent Rock Eval pyrolysis parameters [Hydrogen Index (HI) and Oxygen Index (OI)] to categorize facies chemically. The values obtained here are plotted on a Van Krevelen type diagram (figure 2) to identify organic facies.

All 11 samples that provided both HI and OI data belong to organic facies CD to D of Jones (1987). This suggests that the environment of deposition (or the environment of preservation) was probably relatively rich in oxygen, an environment unfit for large accumulations of preserved organic matter. Kerogen analysis of these samples is consistent with the pyrolysis data, indicating vitrinite (woody material) and inertinite (oxidized organic matter) are usually the prevalent maceral groups.

Conclusions. The following interpretations are tentative because some or all of the samples could have been affected during outcrop weathering or shallow burial.

- Small amounts of organic matter are preserved in the 40 outcrop samples spanning 23.5 meters over the Cretaceous/Tertiary boundary.
- The organic matter is oxygen rich and hydrogen poor, suggesting a near shore oxic environment of deposition, or weathering.
- T_{max} and other data record a thermally immature environment, implying that the samples were never buried deeply enough to have generated significant amounts of hydrocarbons.
- No *major* break in trend for the data was noted at the Cretaceous/Tertiary boundary. A trend of slightly decreasing TOC, possibly within the margin of analytic and preservational error, occurs from uppermost Cretaceous to basal Tertiary. This trend, if real, is probably reflecting a sedimentological change toward increasing siliciclastic input, or toward more inshore, more oxic organic facies.

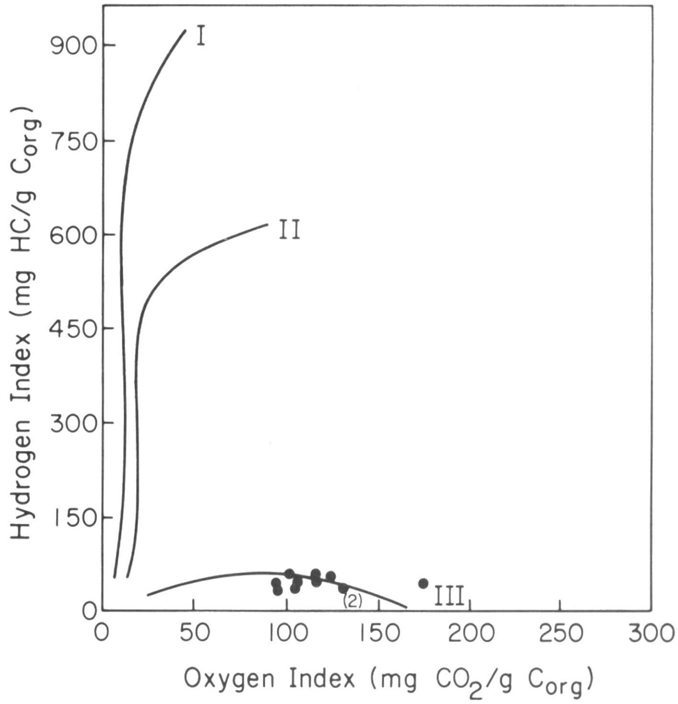

Figure 2. Van Krevelen type diagram for 11 samples, plotting whole rock Hydrogen Index vs. Oxygen Index. Pathways are labelled with kerogen types from which organic facies were determined. (mg HC/g C_{org} denotes milligrams of hydrocarbons per gram of organic carbon. mg CO_2/g C_{org} denotes milligrams of carbon dioxide per gram of organic carbon.)

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