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Mass Transfer of Elements in Middle Triassic Shale/Sandstone Sequences, Sverdrup Basin, Arctic Islands

Part 1: Mineralogy, composition, SEM character and Rock-Eval/TOC results, East Drake L-06 and Skybattle Bay M-11 cores

by

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Introduction

To date the main thrust in the study of catagenesis in shales and sandstones has been to observe mineralogical changes as detected by x-ray diffraction studies, and to and relate these transformations to burial depth or temperature. Additional work was carried out in relating the generation of hydrocarbons from source rocks to the disappearance of certain discrete layer silicates such as kaolinite, and the stepwise transformation of smectite to an interstratified 2:1 layer silicate such as an illite/smectite. An important aim was to define the oil generating window of organic-rich fine-grained source rocks. A vitrinite reflectance (Ro) of 0.5, which usually is related to the onset of the oil generation, was found to coincide with a d_{001} spacing of 12.5Å of the interstratified clays (Foscolos et al., 1976; Powell et al., 1978; Foscolos and Powell, 1980). This "sloughing-off" of the water, as observed from the d_{001} spacing migration from 15.8Å to 12.5Å, takes place around 100°C (Foscolos and Kodama, 1974).

Very recently, for the early stages of diagenesis of organic matter (eodiagenesis), the effect of organically derived, organic acids from thermal (<80°C) and bacterial decarboxylation of organic matter has been discussed (Surdham and Crossey, 1985, 1987; Gauthier et al., 1985), not only in relation to the dissolution of feldspars and the ensuing chelation and transportation of aluminum from the source rocks to sandstones, but also in connection with the creation of secondary porosity.

Since copious amounts of water and water-soluble acids evolve during diagenesis of organic matter and catagenesis of minerals of fine-grained organic-rich source rocks, substantial concentrations of elements may be transported to reservoir sandstones. Very little pertinent data concerning the influence of diagenesis and catagenesis on the elemental composition of shales and adjacent sandstones exists, however. The mass transfer of elements and the mechanism of transportation from source rocks to reservoir rocks, and its implication in understanding the compositional variation within the reservoir rocks, has not been investigated thoroughly.

As a result this research study was undertaken to attempt to understand the ultimate destination of the mobilized elements as a function of mineral dissolution including feldspars, and mineral transformation such as smectite being converted to 1 Md illite through the intermediate step of illite/ smectite interstratification process.

Geology

Cores from a portion of the Middle Triassic of the Sverdrup Basin were retrieved from two wells drilled in the Arctic Islands during 1985. The Eldridge Bay (Anisian) and Cape Caledonia (Ladinian) members of the Murray Harbour Formation were cored in Panarctic et al. East Drake L-06 and Panarctic et al. Skybattle Bay M-11. East Drake L-06 is a shut-in Jurassic gas well located at 76°25′35″ north and 107°33′11″ west, immediately east of the Drake gas field on Sabine Peninsula, Melville Island. The Skybattle Bay M-11 well is located at 77°10′56″ north and 105°06′44″ west, on the southern tip of Lougheed Island (Fig. 1). Though both wells were drilled for hydrocarbon exploration, the cores were cut and paid for by the Geological Survey of Canada for research purposes.

Regional Geology

The Sverdrup Basin is located in the Canadian Arctic Archipelago and is 300 x 1000 km (Fig. 1). It was a major depocentre from Carboniferous to early Tertiary time and contains up to 13,000 m of strata (Balkwill, 1978). Deformation and uplift occurred in the early Tertiary. The eastern portion of the basin is now folded and faulted. The intensity of deformation decreases westward, where only low relief anticlines occur.

Petroleum exploration in the basin began in 1969 and seventeen oil and/or gas fields have been discovered. The fields all occur in the western Sverdrup Basin on the crests of anticlines. The main reservoir strata are Jurassic in age but the petroleum source rocks are Middle to Late Triassic (Powell, 1978).

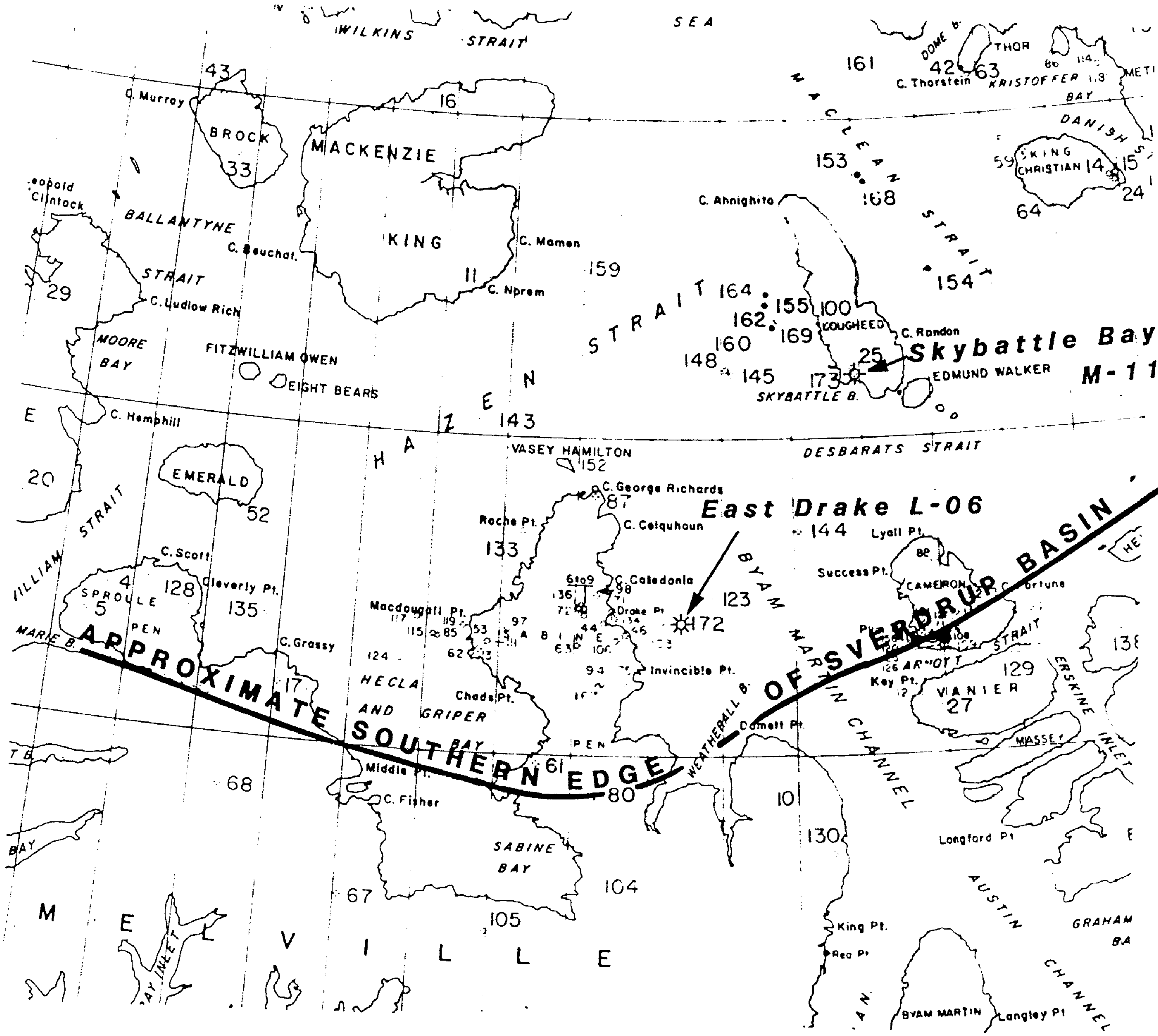

Figure 1. Location map, southwestern Sverdrup Basin, Arctic Islands.

Triassic strata in the basin consist mainly of sandstone, siltstone and shale with only minor limestone. The main source areas for the clastic sediments lay to the south and east of the basin with minor input from the northwest. Regional stratigraphy of the Triassic succession was established by Tozer (1961) on the basis of outcrop studies. Embry (1983a, b; 1984a, b; 1986) has enlarged the stratigraphic framework by incorporating the subsurface data obtained over the last eighteen years.

Embry (in press) reviewed the Triassic stratigraphy and depositional history of the Sverdrup Basin and emphasized trangressive-regressive (T-R) cycles as the basic building blocks of the succession. Along the basin margin a T-R cycle begins with a thin transgressive unit, commonly a calcareous sandstone or arenaceous limestone, which unconformably overlies strata of the preceding cycle. This unit is overlain by a thick regressive, progradation succession consisting of shale and siltstone in the lower part and sandstone in the upper part. A subaerial unconformity usually caps the sandstone unit. A submarine unconformity usually occurs on top of the basal transgressive unit. Basinward the transgressive unit thins and eventually disappears and the submarine unconformity surface forms the base of the cycle. The regressive sandstone unit and its capping subaerial unconformity also disappear basinward, and siltstones commonly form the upper portion of the cycle over much of the basin.

Ten T-R cycles have been recognized within the Triassic succession of the Sverdrup Basin, with two comprising the Middle Triassic which is the interval of interest in this report. Figure 2 illustrates the stratigraphy of the Middle Triassic interval of the western Sverdrup Basin, the location of the wells relative to basin setting, and the stratigraphic position of the two cores described. Note that both cores contain a portion of both Middle Triassic T-R cycles.

Both the East Drake L-06 and the Skybattle Bay M-11 cored intervals contain the Anisian-Ladinian unconformity and parts of both Middle Triassic T-R cycles, but in different environmental settings. The principal aim of this study is to analyse variations in diagenetic processes, that were caused by variations in depositional environment and post-depositional history, across the unconformity and across the Sverdrup Basin. These processes may be related to petroleum generation in potential source rocks and may control reservoir quality.

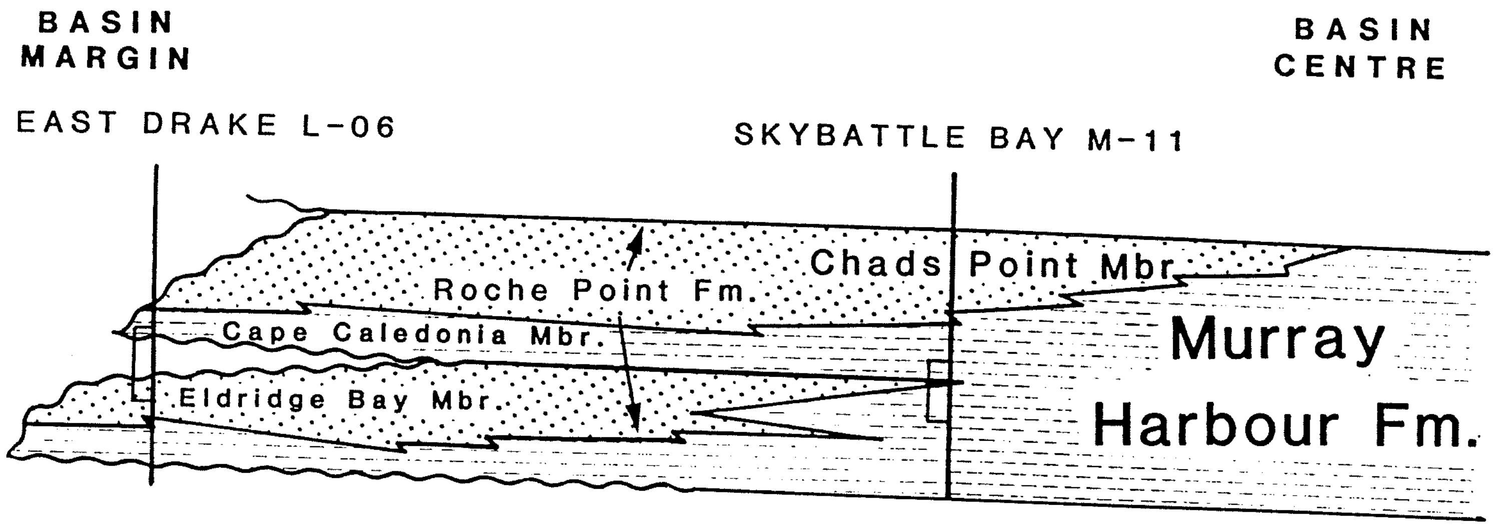

Figure 2. Schematic section, Middle Triassic stratigraphy, western Sverdrup Basin. Cored intervals shown.

The Cape Caldonia Member in the basin centre is a good potential source rock, with between 1 and 7% TOC. Hydrocarbon migration may have occurred through Eldridge Bay and Chads Point sandstones, toward equivalent thicker basin margin reservoir rocks. Structural, stratigraphic or combination traps may contain hydrocarbons in these sandstones near the basin margins.

General Core Description

Two continuous full diameter, 18 m cores were cut in the East Drake L-06 well, from 1122.6 to 1159.0 m; and one 18 m full diameter core was cut in the Skybattle Bay M-11 well, from 2520.0 to 2538.0 m. Both cores were slabbed to facilitate sampling and description.

The East Drake L-06 well is located near the southern edge of the Sverdrup Basin, in an area where the Eldridge Bay Member is well developed (Figs. 1 and 2). The top 36 m of this 153 m thick unit is cored in this well (Fig. 3). The cored interval consists of interbedded and interlaminated shallow marine lithologies, including: calcareous and dolomitic sandstone and siltstone; silty and sandy dolomitic limestone coquina; and silty and sandy, partly calcareous mudstone. Both low and high energy environments are represented in the cored interval. Beds deposited in low energy conditions (bay, lagoon, or low energy open shelf) are bioturbated or rippled mudstone, siltstone, and very fine-grained sandstone. Beds deposited in high energy conditions (bars, channels, or high energy open shelf) are: planar cross-bedded, fine- to coarse-grained sandstone, commonly with mudstone rip-up clasts; coquinoid sandstone; and sandy or silty dolomitic limestone coquina or grainstone. Carbonate cements and glauconite are common in all units.

Eldridge Bay sedimentation patterns in the East Drake L-06 well were probably influenced by rapid local changes in clastic sediment sources, caused by either distributary channel abandonment or storms. Coarsening-upward sequences, typical of shallow marine settings, are rare, thin, and incomplete. Instead, centimetre- to decimetre-thick units of sandstone, siltstone, mudstone and limestone are typically interbedded without regularity or cyclicity.

Eldridge Bay sediments were eroded and exposed to surface weathering prior to Cape Caledonia deposition. The top 5 m of the Eldridge Bay shows weathering effects, which include: red staining,

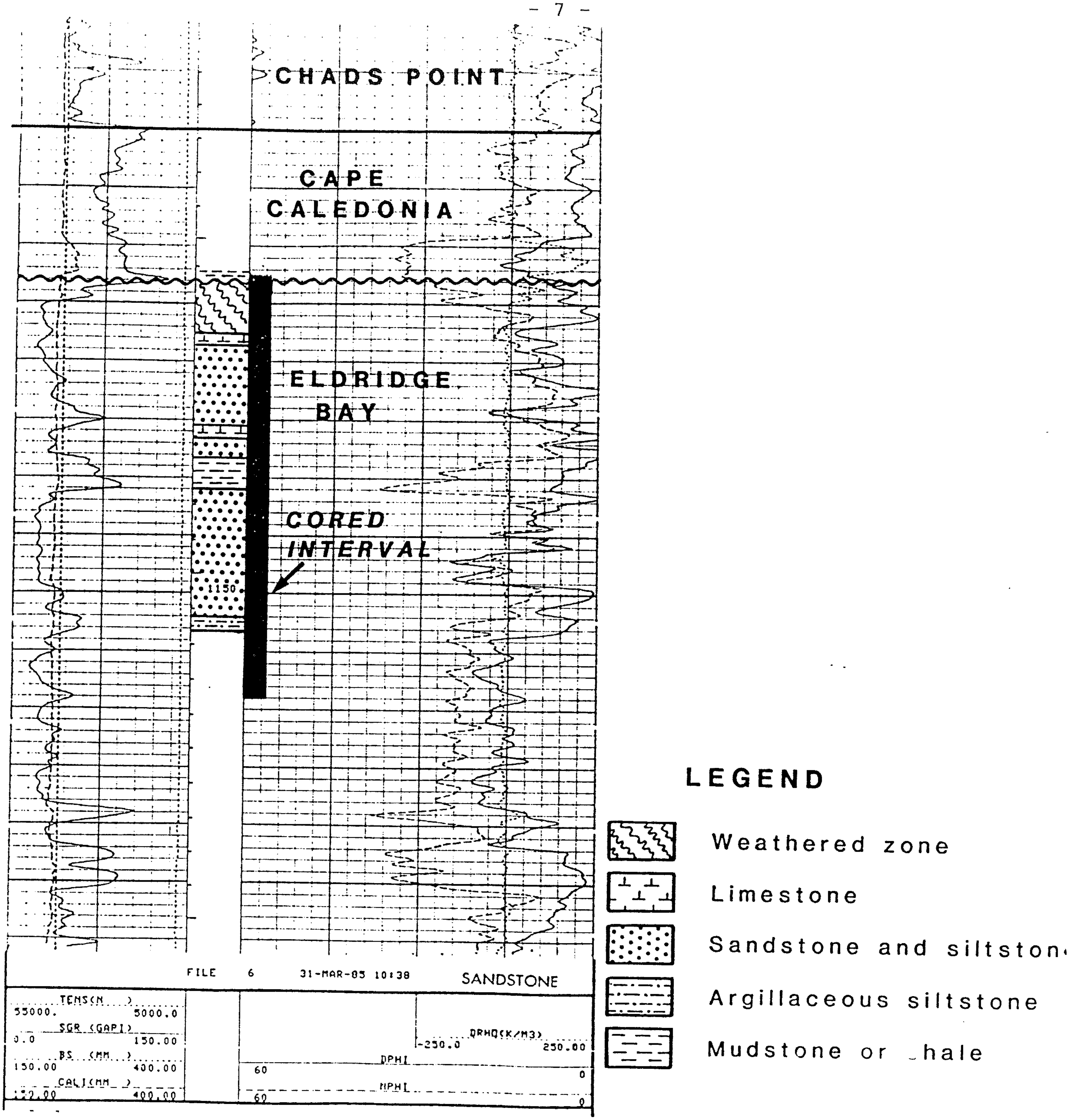

Figure 3. Generalized lithology, gamma ray, and compensated neutron-lithodensity log of cored interval, East Drake L-06.

dolomite cementation, brecciation, lack of bedding, and "veinlets" and a cap of waxy, light green mudstone. The contact of this weathered zone with the overlying Cape Caledonia is sharp and irregular, which is typical of an erosional unconformity surface.

The Cape Caledonia Member is a 13 m thick, marine, slightly micaceous, grey-brown mudstone that contains traces of calcareous shell debris. Only the basal 0.3 m of this unit are within the cored interval.

In contrast to the East Drake L-06 well, the Skybattle Bay M-11 well is located in the deeper, more central part of the Sverdrup Basin (Figs. 1 and 2). The coarse clastic and carbonate Eldridge Bay Member is represented in Skybattle Bay M-11 by a thin (0.5 m thick) very fine-grained calcareous sandstone that overlies a 165 m thick Murray Harbour mudstone sequence (Fig. 4). The unconformity that separates these rocks from the overlying Cape Caledonia Member does occur, but is in a submarine instead of a continental environment. The Cape Caledonia Member is 95 m thick, and grades upward into the Chads Point Member, which consists of coarse clastic rocks and limestones. The cored interval in this well includes the upper 6.8 m of the Murray Harbour-Eldridge Bay sequence, and the basal 11.2 m of the Cape Caledonia Member.

The Murray Harbour-Eldridge Bay sequence is an extensively bioturbated, dark and medium grey, silty and sandy mudstone that consists of several thin, coarsening-upward cycles. Within each cycle, the silt and very fine-grained sand content increases upward. These coarser components are in small discrete pods in the mudstone matrix, probably formed by the bioturbation of thin density flow beds. They occasionally contain relict ripple cross-laminations and calcite shell debris. They are commonly cemented by calcite. The uppermost cycle contains the thickest sandstone bed (0.54 m), and is lithologically similar to the Eldridge Bay units in the East Drake L-06 well.

The contact of this sandstone bed with the overlying Cape Caledonia Member is a submarine hardground developed on an eroded, irregular surface. The basal unit above the unconformity is a 0.11 m thick, transgressive phase, starved basin, phosphatic bone bed. The basal portion of this unit contains clasts of the underlying sandstone bed. The remainder consists of phosphatic bone

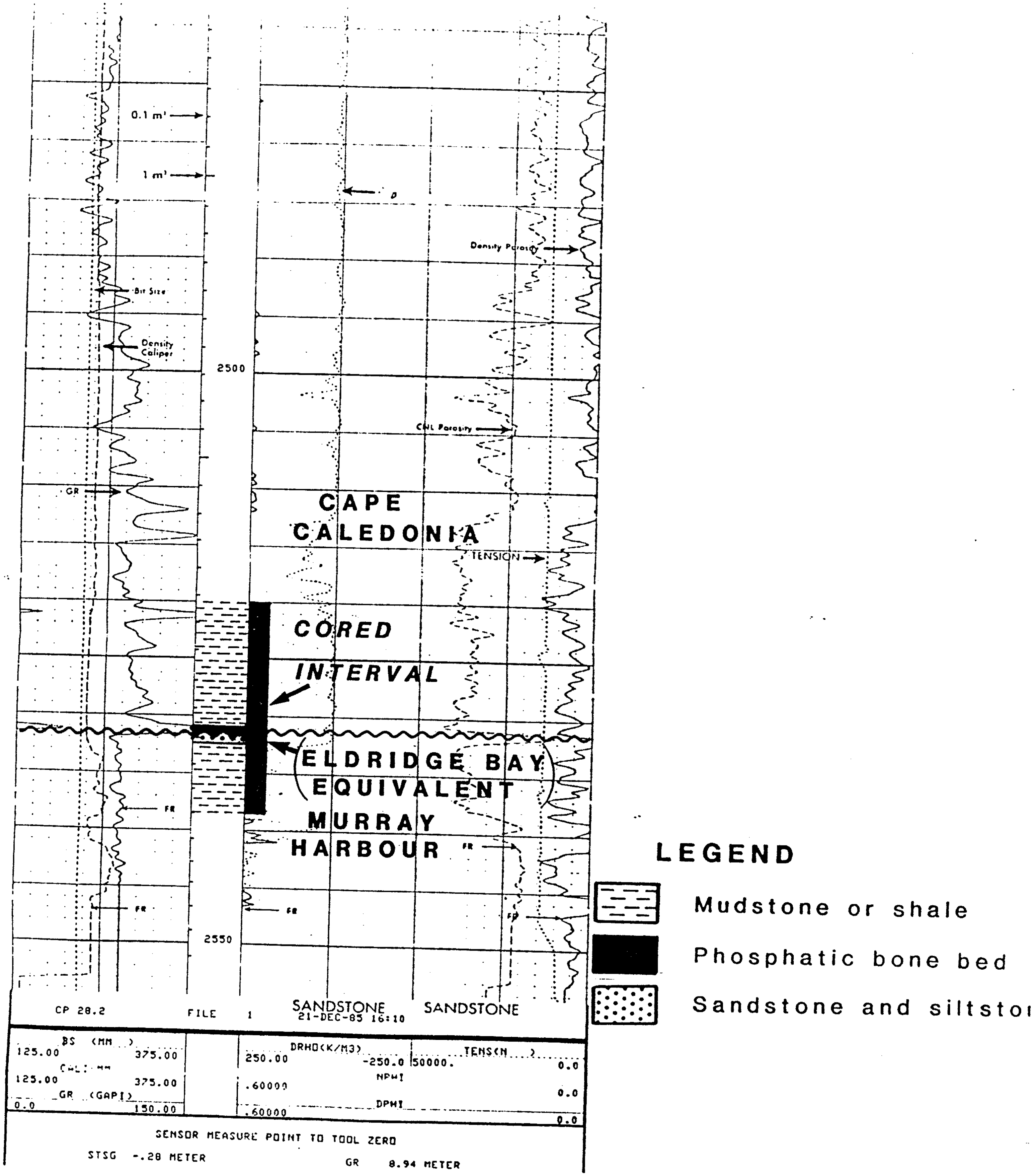

Figure 4. Generalized lithology, gamma ray, and compensated neutron-lithodensity log of cored interval, Skybattle Bay M-11.

fragments, phosphate nodules, and calcite shell debris, in a phosphatic, pyritic mudstone matrix. The upper contact of the bone bed is a submarine hardground.

A black, bituminous shale unit forms the remainder of the cored interval above the bone bed (Fig. 4). It consists dominantly of bituminous shale, with thin, discrete layers (<1 cm) of calcareous shell fragments and small phosphate and siderite nodules. Above the basal first metre of the unit, thin, argillaceous, phosphatic limestone coquina beds occur. They increase in content and thickness toward the top of the core, and may have been deposited by storms that interrupted the background shale sedimentation in the basin.

Sampling, Materials and Methods

Fifty-one core samples of calcareous shales, limestones, and calcareous sandstones were collected from the cores of the East Drake L-06 well and forty-four samples of similar texture were collected from the core of the Skybattle Bay M-11 well.

The samples were ground in a Bleuler mill for 20 seconds, leaving some chips for scanning microscope and thin section microscopy. The powdered samples were used in the following analysis.

All crystalline minerals present in the rock were determined by x-ray diffraction. One portion of the ground material was peletized and X-rayed with CoKα, radiation, iron filtered, settings of 45 Kv-20 ma, scanning speed of 1°20/min/2 cm, time constant 2 and range 4° to 40°20′. A second portion of the powdered sample was used to destroy the carbonates by 6N HCl. Subsequently $CaCl_2$ and $MgCl_2$ were removed by washing and clays were collected and suspended using 1N $(Na\,PO_3)_6$ +0.08 M Na_2CO_3 in order to stablize the suspension. After seven hours and fifty-two minutes the <2μ fraction was collected and 200 ml of Javex (trade name for 6% NaOCl) was added with constant stirring. The suspension was left overnight in a steam bath to destroy the organic matter and homoionically saturate the sample with sodium (Cassidy and Mankin, 1960). The excess sodium was washed out with distilled water and repeated centrifugation. Finally one portion of the Na clays was saturated with Ca^{2+} and another with K^+ by treating them with 1N $CaCl_2$ and 1N KCl, respectively.

After removal of the excess salt by washing and centrifuging, the samples were recovered by freeze-drying (Brydon et al., 1963). The samples are used for x-ray diffraction and chemical anlayses.

The sand and silt fraction after the removal of the $<2\mu$ fraction were pelletized and x-rayed to identify the type of tectosilicates present, specifically the feldspars.

The determination of major and trace elements in the whole rock was carried out by x-ray fluorescence using a Philips 1400 unit and applying a modified Trail and Lachance (1965) method. The powdered samples were fused to prepare glass beads. The mixture consisted of 1.00 g of sample, 1.00 g of oxidant (NH_4NO_3) and 5.30 g of flux (5.000 g of $Li_2B_4O_7$ + 0.30 g of LiF). The mixture was fused at 1000°C using a Claisse Fluxer apparatus. The advantages of using fused beads are: a homogeneous sample, elimination of mineral and grain size effects, minimum inter-elemental effects and common oxide forms for every element. The disadvantage of having a slight drop in intensity is counterbalanced by the advantages.

The spectrochemical conditions for the analysis of each element on the Philips 1400 are given in Appendix I.

Total carbon and sulphur on the whole rock were carried out on LECO units following a modified Foscolos and Barefoot (1970) method.

Samples were prepared for the Scanning Electron Microscope (SEM) by chipping small sections of material off the slabbed core. The small pieces were mounted on aluminum stubs, such that a relatively flat, newly fractured surface faced up. The samples were coated with a 40 micron layer of carbon to ensure good surface conductivity.

Scanning electron microscopy (SEM) of chips was carried out using a Cambridge stereoscan 150MK2 with an x-ray energy dispersive system (Kevex). SEM pictures were used to differentiate authigenic from detrital clays along with the analysis for relevant elements by Kevex. In addition the occurrence and morphological habits of clays in relation to pore space and adjacent grain surfaces was investigated.

Organic geochemical analysis was carried out using the Rock-Eval pyrolysis equipment along with total organic carbon (TOC) determination. Rock-Eval pyrolysis in conjunction with TOC provides the following data:

S1: the lower temperature peak which is obtained from the evolution of the pre-existing volatile hydrocarbon at 300°C. This value is measured as milligrams of hydrocarbon per gram of rock.

S2: the higher temperature peak resulting from the pyrolysis (300-600°C) of organically insoluble kerogen and organically soluble bitumen, measured as milligrams of hydrocarbon per gram of rock.

S3: the measure of CO_2 derived from the organic component as milligrams CO_2 per gram of rock. The 390°C temperature has been selected as a cut-off for the collection of CO_2 to avoid measuring material evolving from the breakdown of inorganic carbonates.

Tmax: the temperature (°C) recorded at the maximum hydrocarbon evolution rate, defining the S2 peak; an indicator of thermal maturation.

Hydrocarbon Potential (S1+S2): the total of all hydrocarbon products pyrolyzable from the rock, and a direct indicator of economic potential. The relative quality of the organic matter in the deposits is best determined by comparing the ratios of total yield to organic carbon content [(S1+S2)/%Corg], whereas the overall economic potential of a deposit is a function of both the type and amount of organic matter.

Hydrogen Index (HI): the ratio of S2 hydrocarbon to the organic carbon content. This ratio has been correlated to the atomic H/C ratio (Espitalié et al., 1977) and provides an indicator of kerogen type and maturation when interpreted in conjunction with Tmax and Oxygen Index.

Oxygen Index (OI): the ratio of the S3 (CO_2) peak to the organic carbon content,which correlates to the atomic O/C ratio (Espitalié et al., 1977), and is an indicator of kerogen type and maturity when interpreted with the Hydrogen Index and Tmax.

Production Index (PI): the ratio of volatile hydrocarbons (S1) to total, recoverable hydrocarbon (S1+S2), which is a direct indicator of thermal maturation and/or the presence of epigenetic (migrated) hydrocarbons.

The standard Rock-Eval program used for pyrolysis is discussed by Macauley et al. (1985).

Results

I. X-ray Diffraction on Whole Rock Samples

X-ray diffraction analysis on whole rock samples from the East Drake L-06 well reveals the following minerals. Calcite and dolomite are ubiquitous throughout the studied interval (Table 1). The same is true for quartz and feldspars. Shales, however, contain hydrous layer silicates whereas sandstones are devoid of clays as far as the x-ray analysis indicates. Apatite and pyrite occur commonly, and barite and anatase rarely. The shales examined contain substantial amounts of carbonates and thus should be termed calcareous shales. The sandstones also contain appreciable amounts of carbonate.

Mineral identifications by X-ray diffraction on Skybattle Bay M-11 samples show that layer silicates are more abundant than in the East Drake L-06 well. Calcite and dolomite are ubiquitous throughout the studied section, as are quartz and feldspar (Table 2). Pyrite and apatite are more abundant than in the East Drake L-06 well samples. The difference in pyrite concentration is more obvious if one compares Tables 3 and 4. These data are the result of carbonate and clay removal, in other words it is the mineral concentration in sand and silt fractions after the removal of carbonates using HCl and clays by elutriation. Tables 3 and 4 point also to a major difference between feldspars in the East Drake L-06 and Skybattle Bay M-11 wells. Alkali feldspars are the major feldspars in the East Drake L-06 well whereas plagioclases are more abundant in the Skybattle Bay M-11 well.

To summarize the differences between the two wells we can say that in the Skybattle Bay M-11 well calcite, pyrite, apatite and clays are more abundant than in the East Drake L-06 well.

II. Chemistry of Whole Rock Samples

The chemistry of whole rock samples reflects the mineral composition. In the East Drake L-06 well adsorbed H_2O ranged from 0.06 to 2.04%, SiO_2 ranges from 11.90 to 88.46%, Al_2O_3 from 0.21 to 13.10%, Fe_2O_3 from 0.43 to 4.15%, TiO_2 from 0.03 to 0.79%, CaO from 0.81 to 53.90%, MgO from 0.46

TABLE I

Semi-quantitative analysis by X-ray diffraction on Whole Rock
East Drake L-06 well

Depth in metres	Illite	Chlorite/ Kaolinite	Expandable and/or Mixed layer clays	Quartz	Feldspars	Calcite	Dolomite	Pyrite	Others	Lithology
1122.68-1122.71	7	3(K)	7	39	9	20	12	3	-	Brown shale
1122.76-1122.79	3	2	5	37	6	28	12	4	3-Apatite	Brown shale
1122.86-1122.89	2	-	4	20	2	21	49	2	-	Brown shale
1123.38-1123.40	12	-	11	53	13	8	-	3	-	Green shale
1124.02-1124.04	1	-	tr.	17	tr.	14	68	-	-	Green shale
1124.15-1124.18	tr.	-	-	17	-	10	73	-	-	Green shale
1124.53-1124.55	10	-	10	51	10	9	5	5	-	Green shale
1125.12-1125.15	-	-	-	11	tr.	10	79	-	-	Calcareous sandstone
1125.92-1125.95	-	-	-	12	tr.	27	61	-	-	Calcareous sandstone
1127.07-1127.10	-	-	-	21	1	25	53	-	-	Calcareous sandstone
1127.64-1127.66	-	-	-	14	-	72	14	-	-	Calcareous sandstone
1128.91-1128.93	-	-	-	13	-	81	6	-	-	Calcareous sandstone
1130.22-1130.93	-	-	-	22	2	73	3	-	-	Glauconitic sandstone
1130.93-1130.95	-	-	-	29	1	66	4	-	-	Glauconitic sandstone
1131.72-1131.74	-	-	-	42	3	34	21	tr.	tr.-Apatite	Argillaceous siltstone
1131.89-1131.91	-	-	-	22	-	75	3	tr.	-	Argillaceous siltstone
1132.26-1132.28	-	-	-	11	-	87	2	-	-	Argillaceous siltstone
1132.65-1132.67	-	-	-	26	2	66	6	tr.	-	Sandy limestone
1133.57-1133.59	-	-	-	43	tr.	54	1	-	2-Apatite	Glauconitic sandstone
1134.83-1134.85	1	2	tr.	23	tr.	23	47	4	-	Siltstone
1136.67-1136.70	-	-	-	15	-	85	-	tr.	-	Calcite
1136.70-1136.73	-	-	-	47	3	45	tr.	2	3-Apatite	Glauconitic sandstone
1137.47-1137.49	-	-	-	18	tr.	76	5	1	-	Sandy limestone
1137.82-1137.84	-	-	-	19	tr.	78	3	tr.	-	Brown calcareous shale
1138.50-1138.52	2	2	tr.	39	tr.	31	21	5	-	Brown calcareous shale
1139.06-1139.08	3	5	2	31	3	34	17	5	-	Brown calcareous shale
1140.03-1140.05	3	6	6	38	-	34	8	5	-	Brown calcareous shale
1141.03-1141.05	6	8	7	46	5	13	8	3	4-Anatase	Brown calcareous shale
1141.15-1141.17	5	3	6	39	3	19	17	5	3-Anatase	Brown calcareous shale
1141.34-1141.36	-	-	-	17	2	78	3	tr.	-	Glauconitic sandstone
1141.87-1141.90	2	3	tr.	29	3	28	30	5	-	Glauconitic sandstone
1143.73-1143.75	-	-	-	28	2	67	2	tr.	1-Apatite	Glauconitic sandstone
1144.10-1144.12	-	-	-	29	-	71	tr.	-	-	Sandy limestone
1144.49-1144.51	-	-	-	27	2	67	2	2	-	Sandy limestone
1146.08-1146.10	-	-	-	21	-	79	tr.	-	-	Calcareous sandstone
1146.99-1147.01	-	-	-	69	3	23	tr.	-	tr.-Apatite, 5-Baryte	Sandstone
1147.54-1147.56	-	-	-	59	9	24	3	-	2-Siderite?, 3-Baryte	Sandstone
1148.06-1148.08	-	-	-	48	8	42	2	-	tr.-Baryte	Silty shale
1148.38-1148.40	-	-	-	47	4	45	3	1	-	Silty shale
1148.76-1148.78	tr.	-	-	63	4	29	2	tr.	2-Baryte	Glauconitic sandstone
1149.57-1149.59	-	-	-	8	-	92	-	-	-	Limestone
1150.27-1150.29	-	-	-	21	3	68	8	-	-	Calcareous sandstone
1151.24-1151.26	-	-	-	41	1	53	5	tr.	tr.-Apatite	Calcareous sandstone
1151.63-1151.66	-	-	-	27	3	67	3	-	-	Calcareous sandstone
1151.94-1151.99	-	-	-	24	tr.	73	3	-	-	Calcareous sandstone
1152.66-1152.68	-	-	-	18	5	46	31	-	-	Calcareous sandstone
1153.14-1153.16	-	-	-	63	10	9	18	-	tr.-Apatite	Calcareous sandstone
1154.01-1154.03	-	-	-	65	10	8	17	-	-	Calcareous sandstone
1154.38-1154.40	-	-	-	55	10	26	9	-	-	Calcareous sandstone
1155.05-1155.07	-	-	-	54	14	18	12	2	-	Calcareous sandstone
1157.42-1157.44	-	-	-	55	4	27	14	-	-	Calcareous sandstone

TABLE 2

Semi-quantitative analysis by X-ray diffraction on Whole Rock
Skybattle Bay M-11 well

Depth in metres	Illite	Chlorite/ Kaolinite	Expandable and/or Mixed layer clays	Quartz	Feldspars	Calcite	Dolomite	Pyrite	Others	Lithology
2520.02	3	-	5	26	4	53	6	3	tr.-Apatite	Calcareous laminated shale
2520.51	1	-	-	17	2	69	7	2	2-Apatite	Calcareous laminated shale
2520.51	2	-	-	18	2	66	7	3	2-Apatite	Calcareous laminated shale
2520.58	3	-	3	23	3	56	7	.5	-	Calcareous laminated shale
2520.58	4	tr.	5	21	3	53	10	4	-	Calcareous laminated shale
2520.68[1]	2	-	tr.	18	2	70	5	3	-	Calcareous laminated shale
2520.68[1]	2	-	3	17	3	67	5	3	-	Calcareous laminated shale
2520.81	tr.	-	-	11	3	79	3	4	-	Calcareous laminated shale
2520.85	-	-	-	7	-	88	2	3	-	Calcareous laminated shale
2520.92	-	-	-	8	-	86	3	3	-	Calcareous laminated shale
2520.95	2	-	3	19	4	56	6	10	-	Calcareous laminated shale
2522.29	2	-	4	21	4	56	6	4	3-Apatite	Calcareous laminated shale
2522.41	tr.	-	-	16	3	61	4	2	14-Fluorapatite	Calcareous laminated shale
2522.61	-	-	-	22	3	56	5	4	10-Fluorapatite	Calcareous laminated shale
2522.65	3	-	5	25	4	51	6	4	2-Apatite	Calcareous laminated shale
2525.12	2	-	3	25	4	51	8	2	5-Apatite	Calcareous laminated shale
2526.00	4	-	5	27	6	47	8	3	-	Calcareous laminated shale
2527.08	3	-	tr.	22	5	55	6	2	7-Fluorapatite	Calcareous laminated shale
2527.79	2	-	-	25	5	49	13	3	3-Apatite	Calcareous laminated shale
2528.22	5	-	6	26	5	43	9	3	3-Apatite	Calcareous laminated shale
2528.54	4	-	5	27	4	45	9	3	3-Apatite	Calcareous laminated shale
2529.44	4	-	5	27	4	45	7	4	2-Apatite	Calcareous laminated shale
2530.04	3	-	tr.	21	4	62	7	3	-	Calcareous laminated shale
2530.14	-	-	-	13	2	48	31	2	3-Apatite	Calcareous laminated shale
2530.24	1	-	-	4	2	56	24	2	2-Apatite	Calcareous laminated shale
2530.27	3	-	4	20	2	46	18	2	5-Fluorapatite	Transition Zone
2531.16	5	-	7	28	6	43	7	4	-	Bone bed, major unconformity
2531.25	5	tr.	5	27	5	45	7	4	2-Apatite	Bone bed, major unconformity
2531.34	4	-	5	27	5	42	8	5	4-Apatite	Bone bed, major unconformity
2531.38	2	-	3	19	3	52	7	3	11-Fluorapatite	Bone bed, major unconformity
2531.44	-	-	-	19	tr.	56	3	3	19-Fluorapatite	Bone bed, major unconformity
2531.48	tr.	-	-	31	tr.	49	6	7	7-Fluorapatite	Bone bed, major unconformity
2531.53	-	-	-	31	3	61	5	tr.	tr.-Apatite	Bioturbated calcareous sandstone
2531.84	-	-	-	26	tr.	53	8(Ankerite)	2	3-Apatite	Bioturbated calcareous sandstone
2531.93	-	-	-	29	3	43	13	2	10-Fluorapatite	Bioturbated calcareous sandstone
2532.02	2	tr.	3	23	2	32	33	4	1-Apatite	Transition Zone
2532.08	3	tr.	3	19	3	18	48	4	2-Apatite	Calcareous silty shale or mudstone
2532.39	6	2(Chl)	6	18	3	17	44	4	-	Calcareous silty shale or mudstone
2532.65[1]	3	tr.	5	34	4	26	24	4	-	Calcareous silty shale or mudstone
2532.65[1]	4	2	4	30	4	26	26	4	-	Calcareous silty shale or mudstone
2533.50	5	3	7	31	4	29	16	5	-	Calcareous silty shale or mudstone
2538.08	3	2	7	43	4	28	8	5	-	Calcareous silty shale or mudstone
2534.30	5	3	6	32	5	34	12	3	-	Calcareous silty shale or mudstone
2536.35	3	tr.	5	32	4	45	7	4	-	Calcareous silty shale or mudstone

[1]means duplicate samples

TABLE 3

Semi-quantitative analysis by X-ray diffraction on
Residues after the Removal of Carbonates and Clays
East Drake L-06 well

Depth in metres	Expandable and/or Mixed layer clays	Illite	Chlorite and/or Kaolinite	Quartz	Feldspar Alkali	Feldspar Plagioclase	Pyrite	Others	Lithology
1122.68-1122.71	-	4	2(K)	73	5	10	6	-	Brown shale
1122.76-1122.79	-	2	2(K)	77	3	10	6	-	Brown shale
1122.86-1122.89	tr.	6	-	66	6	11	11	-	Brown shale
1123.38-1123.40	-	6	-	62	7	21	4	-	Green shale
1124.02-1124.04	-	2	-	82	8	4	4	-	Green shale
1124.15-1124.18	-	2	-	83	7	6	2	-	Green shale
1124.53-1124.55	-	6	-	79	6	4	5	-	Green shale
1125.12-1125.15	-	tr.	-	92	4	2	2	-	Calcareous sandstone
1125.92-1125.95	-	-	-	87	8	5	tr.	-	Calcareous sandstone
1127.07-1127.10	-	-	-	87	10	-	2	-	Calcareous sandstone
1127.64-1127.66	-	-	-	86	8	-	6	-	Calcareous sandstone
1128.91-1128.93	-	-	-	88	10	-	2	-	Calcareous sandstone
1130.22-1130.25	-	-	-	94	6	-	tr.	-	Glauconitic sandstone
1130.93-1130.95	-	-	-	93	7	-	tr.	-	Glauconitic sandstone
1131.72-1131.74	-	-	-	82	14	tr.	4	-	Argillaceous siltstone
1131.89-1131.91	-	-	-	81	11	3	5	tr.-Dolomite	Argillaceous siltstone
1132.26-1132.28	-	tr.	2(K)	76	2	4	15	-	Argillaceous siltstone
1132.65-1132.67	-	-	-	91	7	-	2	-	Sandy limestone
1134.83-1134.84	-	3	3	79	4	-	11	-	Glauconitic sandstone
1135.57-1135.59	-	-	-	97	3	-	-	-	Siltstone
1136.67-1136.70	-	-	-	93	tr.	-	7	-	Calcite
1136.70-1136.73	-	-	-	94	2	-	4	-	Glauconitic sandstone
1137.47-1137.49	-	-	-	84	4	-	12	-	Sandy limestone
1137.82-1137.84	-	-	-	94	3	-	3	-	Sandy limestone
1138.50-1138.52	tr.	3	3	71	8	-	15	-	Brown calcareous shale
1139.06-1139.08	-	4	5	74	4	-	13	-	Brown calcareous shale
1140.03-1140.05	tr.	4	6	70	8	-	9	3-Anatase	Brown calcareous shale
1141.03-1141.05	6	5	8	68	5	-	5	3-Anatase	Brown shale
1141.15-1141.17	-	6	5	73	3	-	10	3-Anatase	Glauconitic sandstone
1141.34-1141.36	-	-	-	88	9	-	3	-	Glauconitic sandstone
1141.87-1141.90	-	2	4	80	3	-	11	-	Glauconitic sandstone
1143.73-1143.75	-	-	-	96	4	-	tr.	-	Glauconitic sandstone
1144.10-1144.12	-	-	-	96	4	-	-	-	Sandy limestone
1144.49-1144.51	-	tr.	2(K)	83	7	-	8	-	Sandy limestone
1146.08-1146.10	-	-	-	89	8	-	3	-	Calcareous sandstone
1146.99-1147.01	-	-	-	95	tr.	-	-	5-Baryte	Sandstone
1147.54-1147.56	-	-	-	86	12	-	-	2-Baryte	Sandstone
1148.06-1148.08	-	-	-	95	5	-	-	-	Silty shale
1148.38-1148.40	-	-	-	88	10	-	2	tr.-Baryte	Silty shale
1148.76-1148.78	-	-	-	93	5	-	2	-	Glauconitic sandstone
1149.57-1149.59	-	-	-	95	3	-	2	-	Limestone
1150.27-1150.29	-	2	2(K)	88	7	-	1	-	Calcareous sandstone
1151.24-1151.26	-	-	-	93	7	-	-	-	Calcareous sandstone
1151.63-1151.66	-	-	-	94	6	-	tr.	-	Calcareous sandstone
1151.94-1151.96	-	-	-	96	tr.	-	-	-	Calcareous sandstone
1152.66-1152.68	-	1	2(K)	73	22	-	2	-	Calcareous sandstone
1153.14-1153.16	-	-	-	82	18	-	-	-	Calcareous sandstone
1154.01-1154.03	-	-	-	92	8	-	-	-	Calcareous sandstone
1154.38-1154.40	-	-	-	87	13	-	-	-	Calcareous sandstone
1155.05-1155.07	-	-	-	85	11	-	4	-	Calcareous sandstone
1157.42-1157.44	-	-	-	93	7	-	-	-	Calcareous sandstone

TABLE 4

Semi-quantitative analysis by X-ray diffraction on Residues after the Removal of Carbonates and Clays Skybattle Bay M-11 well

Depth in metres	Expandable and/or Mixed layer clays	Illite	Chlorite and/or Kaolinite	Quartz	Feldspars Alkali	Feldspars Plagioclase	Pyrite	Others	Lithology
2520.02	9	10	-	52	-	17	12	-	Calcareous laminated shale
2520.51	10	9	-	48	3	13	17	-	Calcareous laminated shale
2520.51	5	8	-	61	4	13	9	-	Calcareous laminated shale
2520.68	9	6	-	51	4	12	18	-	Calcareous laminated shale
2520.81	7	4	-	48	-	9	32	-	Calcareous laminated shale
2520.85	7	4	-	40	2	8	39	-	Calcareous laminated shale
2520.92	6	4	-	39	-	10	41	-	Calcareous laminated shale
2520.95	8	8	-	37	2	11	34	-	Calcareous laminated shale
2522.08	4	6	-	54	8	19	9	-	Calcareous laminated shale
2522.29	6	7	-	60	3	12	12	-	Calcareous laminated shale
2522.41	-	3	-	55	5	14	23	-	Calcareous laminated shale
2522.61	tr.	4	-	63	4	10	19	-	Calcareous laminated shale
2522.65	7	7	-	60	-	14	12	-	Calcareous laminated shale
2525.12	6	7	-	59	3	16	9	-	Calcareous laminated shale
2526.00	7	10	-	58	-	15	10	-	Calcareous laminated shale
2527.79	6	7	-	60	5	15	7	-	Calcareous laminated shale
2528.22	10	10	-	56	3	12	9	-	Calcareous laminated shale
2528.54	12	10	-	53	4	12	9	-	Calcareous laminated shale
2529.44	10	10	-	50	4	13	13	-	Calcareous laminated shale
2530.04	11	9	-	53	-	15	12	-	Calcareous laminated shale
2530.14	6	4	-	60	5	12	13	-	Calcareous laminated shale
2530.27	9	8	-	56	3	11	13	-	Transition Zone
2531.16	10	12	-	50	4	12	12	-	Major unconformity, bone bed
2531.25	10	11	-	52	3	12	12	-	Major unconformity, bone bed
2531.34	10	11	-	53	-	14	12	-	Major unconformity, bone bed
2531.38	6	5	-	56	3	10	20	-	Major unconformity, bone bed
2531.44	-	tr.	-	58	-	5	26	11-Baryte	Transition Zone
2531.48	-	2	-	72	-	7	19	-	Calcareous silty shale
2531.53	-	-	-	92	5	tr.	3	-	Calcareous silty shale
2531.84	-	-	-	91	4	-	5	-	Calcareous silty shale
2531.93	-	-	-	91	tr.	tr.	9	-	Calcareous silty shale
2532.03	-	3	-	68	4	7	18	-	Calcareous silty shale
2532.08	7	9	-	58	tr.	11	15	-	Calcareous silty shale
2532.39	6	12	-	54	3	12	13	-	Calcareous silty shale
2532.65	8	9	-	56	3	11	13	-	Calcareous silty shale
2533.50	7	9	-	60	tr.	10	14	-	Calcareous silty shale
2534.30	6	10	-	62	3	10	9	-	Calcareous silty shale
2536.35	-	4	-	72	8	8	8	-	Calcareous silty shale
2538.08	5	4	-	64	7	10	10	-	Calcareous silty shale

to 15.44%, Na_2O from 0.00 to 0.80%, K_2O from 0.07 to 4.10%, P_2O_5 from 0.02 to 1.75%, SO_3 from 0.02 to 1.75% and L.O.I. from 5.74 to 39.05% (Table 5).

In the Skybattle Bay M-11 well the adsorbed H_2O ranges from 0.20 to 1.43%, SiO_2 from 11.01 to 60.90%, Al_2O_3 from 1.19 to 11.31%, Fe_2O_3 from 1.24 to 6.34%, TiO_2 from 0.80 to 0.64%, CaO from 6.56 to 46.28%, MgO from 0.78 to 4.75%, Na_2O from 0.21 to 0.87%, K_2O from 0.28 to 2.61%, P_2O_5 from 0.05 to 16.64%, SO_3 from 0.07 to 3.08% and loss on ignition (L.O.I.) from 9.31 to 35.99% (Table 6).

Organic carbon, total sulphur and per cent ash in East Drake L-06 well range from 0.00 to 1.25%, 0.06 to 1.88% and 60.95 to 97.71% respectively (Table 7).

In the Skybattle Bay M-11 well organic carbon ranges from 0.00 to 4.57%, sulphur from 0.34 to 4.37% and ash from 64.01 to 90.69% (Table 8).

Trace element analysis on whole rock samples from the East Drake L-06 well shows the following range of concentrations: Pb 0-40 ppm, Zn 0-60 ppm, Cu 0-14 ppm, Ni 4 -932 ppm, Cr 47-835 ppm, Mn 38-412 ppm, Zr 35-252 ppm, Ba 33-8650 ppm, Rb 1-140 ppm and Y 1-59 ppm (Table 9).

Trace element analysis on whole rock samples from the Skybattle Bay M-11 well yield the following ranges of concentrations: Pb 0-46 ppm, Zn 1-729 ppm, Cu 0-74 ppm, Ni 25-252 ppm, Cr 46-196 ppm, Mn 163-566 ppm, Zr 51-255 ppm, Ba 56-16896 ppm, Sr 144-2029 ppm, Rb 12-118 ppm and Y 4-65 ppm (Table 10).

III. Scanning Electron Microscopy (SEM)

Scanning electron photomicrographs on carbon coated chips along with an analysis of the energy dispersive wavelengths yield similar mineralogical results to those obtained by x-ray and chemical analysis.

The composition of the major groups of authigenic clay minerals usually can be differentiated on the basis of characteristic morphologies, although it is necessary to utilize x-ray diffraction to rigorously identify a clay mineral. Using the KEVEX microanalyzer system, the presence of the following elements, when coupled with characteristic morphologies and compared to published standard spectral analysis, provides a reliable means of identifying the mineralogy of the clay being

TABLE 5

Whole Rock Percent Elemental Analysis on Dry Weight
by X-ray Fluorescence Spectroscopy
East Drake L-06 well

Depth in metres	H_2O	SiO_2	Al_2O_3	Fe_2O_3	TiO	CaO	MgO	Na_2O	K_2O	MnO	BaO	P_2O_5	SO_3	L.O.I.	Lithology
1122.68-1122.71	2.04	55.31	12.17	3.05	0.73	7.07	2.46	0.69	2.25	0.02	0.03	0.13	1.64	14.47	Brown shale
1122.76-1122.79	1.63	55.67	9.74	2.99	0.63	9.28	2.43	0.58	1.78	0.02	0.02	1.75	1.75	13.18	Brown shale
1122.86-1122.89	1.21	35.32	7.54	3.36	0.41	16.81	8.16	0.40	2.30	0.03	0.01	0.19	1.04	24.43	Brown shale
1123.38-1123.40	1.91	67.15	13.10	4.15	0.79	0.81	2.21	0.80	4.10	0.01	0.04	0.06	0.99	5.78	Green shale
1124.02-1124.04	0.66	29.63	4.27	1.82	0.22	20.55	11.65	0.24	1.34	0.03	0.01	0.03	0.30	29.93	Green shale
1124.15-1124.18	0.36	22.71	2.42	1.41	0.14	24.42	13.60	0.13	0.80	0.03	0.01	0.04	0.09	39.05	Green shale
1124.53-1124.55	1.54	72.40	10.51	3.66	0.47	1.27	1.94	0.41	3.20	0.02	0.03	0.04	0.31	5.74	Green shale
1125.12-1125.15	0.12	15.07	0.80	0.86	0.05	28.23	15.44	0.12	0.26	0.01	0.00	0.02	0.09	39.05	Calcareous sandstone
1125.92-1125.95	0.13	22.30	0.86	0.84	0.06	28.06	12.27	0.05	0.30	0.01	0.00	0.05	0.04	35.15	Calcareous sandstone
1127.07-1127.10	0.18	43.50	0.99	1.17	0.09	21.15	7.87	0.06	0.36	0.01	0.04	0.25	0.26	24.25	Calcareous sandstone
1127.64-1127.66	0.06	23.06	0.21	0.61	0.04	40.41	2.03	0.00	0.10	0.01	0.00	0.18	0.13	33.21	Calcareous sandstone
1128.91-1128.93	0.07	18.93	0.25	0.57	0.04	43.50	1.22	0.07	0.11	0.01	0.01	0.16	0.05	35.09	Calcareous sandstone
1130.22-1130.93	0.16	45.36	0.57	0.43	0.08	28.89	0.70	0.08	0.27	0.01	0.02	0.32	0.03	23.25	Glauconitic sandstone
1130.93-1130.95	1.98	49.73	0.57	0.51	0.08	24.80	0.89	0.08	0.30	0.01	0.03	0.31	0.07	22.62	Glauconitic sandstone
1131.72-1131.74	0.36	71.30	2.11	1.44	0.27	10.40	2.33	0.22	0.66	0.01	0.02	0.51	0.07	10.66	Argillaceous siltstone
1131.89-1131.91	0.18	33.77	0.90	0.92	0.11	34.86	0.91	0.17	0.29	0.01	0.00	0.35	0.16	27.56	Argillaceous siltstone
1132.26-1132.28	0.12	8.67	0.59	0.84	0.04	49.82	0.65	0.12	0.12	0.01	0.00	0.36	0.01	38.76	Argillaceous siltstone
1132.65-1132.67	0.12	55.45	0.73	0.57	0.10	23.11	0.72	0.01	0.25	0.01	0.01	0.39	0.05	18.60	Sandy limestone
1133.57-1133.59	0.14	60.19	0.75	0.64	0.11	25.16	0.79	0.06	0.28	0.01	0.01	0.43	0.09	11.48	Glauconitic sandstone
1134.83-1134.85	0.58	48.86	4.79	3.72	0.31	14.42	5.59	0.20	0.96	0.02	0.01	0.47	1.03	19.61	Siltstone
1136.67-1136.70	0.10	17.56	0.24	0.67	0.03	45.18	0.53	0.09	0.07	0.01	0.00	0.50	0.09	35.04	Calcite
1136.70-1136.73	0.27	72.85	1.15	1.29	0.09	12.64	0.46	0.08	0.32	0.01	0.13	1.19	0.40	9.39	Glauconitic sandstone
1137.47-1137.49	0.11	35.38	0.73	1.25	0.06	34.60	0.81	0.04	0.21	0.01	0.00	0.33	0.01	26.56	Sandy limestone
1137.82-1137.84	0.10	41.40	0.71	1.01	0.06	30.72	0.74	0.25	0.22	0.01	0.00	0.37	0.15	24.35	Sandy limestone
1138.50-1138.52	1.07	57.65	8.04	4.20	0.48	10.17	2.31	0.26	1.25	0.02	0.02	0.28	2.30	13.02	Brown calcareous shale
1139.06-1139.08	1.21	61.46	9.96	3.65	0.56	8.21	1.78	0.25	1.44	0.01	0.03	0.44	0.51	11.70	Brown calcareous shale
1140.03-1140.05	1.31	63.88	10.41	2.98	0.58	6.91	1.36	0.28	1.43	0.01	0.03	0.27	0.99	10.87	Brown calcareous shale
1141.03-1141.05	1.96	60.26	16.69	2.82	0.87	3.47	1.68	0.30	2.08	0.01	0.05	0.14	0.38	11.24	Brown calcareous shale
1141.15-1141.17	1.38	60.23	12.03	3.68	0.65	6.12	2.16	0.24	1.80	0.02	0.04	0.32	0.86	11.86	Brown calcareous shale
1141.34-1141.36	0.12	54.10	0.81	1.08	0.06	23.75	0.62	0.00	0.37	0.02	0.01	0.27	0.19	18.73	Glauconitic sandstone
1141.87-1141.90	0.73	53.90	7.39	4.03	0.42	12.08	3.93	0.11	1.52	0.02	0.02	0.34	0.05	16.19	Glauconitic sandstone
1143.73-1143.75	0.14	60.16	0.53	0.76	0.05	20.90	0.45	0.05	0.24	0.01	0.06	0.69	0.11	16.00	Glauconitic sandstone
1144.10-1144.12	0.12	58.42	0.53	0.63	0.06	22.02	0.41	0.03	0.21	0.01	0.01	0.47	0.03	17.17	Sandy limestone
1144.49-1144.51	0.36	54.69	2.85	1.91	0.17	20.62	0.75	0.08	0.68	0.02	0.03	0.30	0.66	17.23	Sandy limestone
1146.08-1146.10	0.10	24.22	0.53	0.94	0.05	40.77	0.56	0.08	0.18	0.02	0.00	0.39	0.04	32.23	Calcareous sandstone
1146.99-1147.01	0.12	87.29	0.64	0.59	0.09	4.52	0.29	0.14	0.21	0.01	1.16	0.50	0.28	4.28	Sandstone
1147.54-1147.56	0.16	86.07	0.76	0.66	0.08	4.96	0.47	0.25	0.40	0.01	1.23	0.41	0.02	4.70	Sandstone
1148.06-1148.08	0.17	78.01	0.84	0.78	0.08	9.95	0.52	0.17	0.42	0.01	0.33	0.33	0.08	8.48	Silty shale
1148.38-1148.40	0.19	77.42	1.07	0.86	0.10	10.05	0.59	0.12	0.51	0.01	0.15	0.34	0.13	8.65	Silty shale
1148.76-1148.78	0.21	83.95	1.19	1.02	0.09	5.77	0.53	0.09	0.47	0.01	0.61	0.42	0.12	5.73	Glauconitic sandstone
1149.57-1149.59	0.11	11.90	0.41	0.97	0.03	53.90	0.68	0.09	0.11	0.04	0.00	0.53	0.02	31.33	Limestone
1150.27-1150.29	0.22	40.70	1.59	1.06	0.12	29.34	1.44	0.00	0.47	0.03	0.01	0.38	0.01	24.85	Calcareous sandstone
1151.24-1151.26	1.03	72.38	0.87	0.58	0.06	12.65	0.84	0.05	0.28	0.02	0.06	0.45	0.04	11.72	Calcareous sandstone
1151.63-1151.66	0.13	53.88	0.67	0.72	0.06	23.77	0.75	0.02	0.25	0.02	0.02	0.46	0.09	19.28	Calcareous sandstone
1151.94-1151.99	0.10	55.25	0.62	0.58	0.04	23.19	0.55	0.00	0.22	0.03	0.01	0.37	0.06	19.08	Calcareous sandstone
1152.66-1152.68	0.16	43.52	2.00	1.48	0.10	23.81	4.18	0.04	1.00	0.05	0.01	0.13	0.23	23.46	Calcareous sandstone
1153.14-1153.16	0.09	87.14	1.21	0.68	0.08	3.62	1.40	0.12	0.75	0.01	0.23	0.24	0.12	4.40	Calcareous sandstone
1154.01-1154.03	0.08	88.46	1.08	0.62	0.10	3.14	1.20	0.26	0.68	0.01	0.32	0.22	0.09	3.83	Calcareous sandstone
1154.38-1154.40	0.16	82.89	1.01	0.56	0.08	6.76	1.01	0.19	0.64	0.01	0.24	0.22	0.11	6.29	Calcareous sandstone
1155.05-1155.07	0.30	83.62	1.47	1.20	0.14	5.20	1.20	0.22	0.74	0.01	0.28	0.53	0.18	5.21	Calcareous sandstone
1157.42-1157.44	0.22	76.20	1.07	0.73	0.11	9.78	1.54	0.10	0.48	0.02	0.21	0.06	0.10	9.60	Calcareous sandstone

TABLE 6

Whole Rock Percent Elemental Analysis on Dry Weight
by X-ray Fluorescence Spectroscopy
Skybattle Bay M-11 well

Depth in metres	H_2O	SiO_2	Al_2O_3	Fe_2O_3	TiO	CaO	MgO	Na_2O	K_2O	MnO	BaO	P_2O_5	SO_3	L.O.I.	Lithology
2520.02	0.98	42.03	9.55	2.77	0.50	16.95	2.31	0.87	2.07	0.02	0.02	0.79	0.68	21.44	Calcareous laminated shale
2520.51	0.49	27.00	4.16	1.70	0.23	33.18	1.83	0.58	0.98	0.03	0.00	1.57	0.73	28.00	Calcareous laminated shale
2520.58	0.94	37.47	8.76	3.64	0.45	20.51	2.42	0.83	1.98	0.03	0.01	0.23	1.47	22.21	Calcareous laminated shale
2520.68	0.73	29.11	5.90	2.72	0.29	29.59	1.87	0.66	1.33	0.02	0.00	0.39	1.16	26.96	Calcareous laminated shale
2520.81	0.66	19.43	4.06	3.16	0.20	40.99	1.39	0.50	0.87	0.06	0.00	0.05	1.53	26.76	Calcareous laminated shale
2520.85	0.28	11.01	2.31	2.10	0.11	46.28	1.22	0.32	0.50	0.03	0.00	0.05	0.07	35.99	Calcareous laminated shale
2520.92	0.28	12.11	2.53	2.59	0.12	43.81	1.28	0.39	0.55	0.03	0.00	0.10	1.61	34.88	Calcareous laminated shale
2520.95	0.79	34.48	7.92	6.34	0.36	20.72	2.20	0.64	1.74	0.02	0.01	0.25	6.40	18.91	Calcareous laminated shale
2522.29	0.58	38.66	6.27	2.72	0.37	23.35	1.94	0.74	1.45	0.02	0.01	2.26	1.28	20.93	Calcareous laminated shale
2522.41	0.32	22.48	2.55	2.71	0.16	38.08	1.03	0.96	0.61	0.02	0.01	10.76	1.42	19.22	Calcareous laminated shale
2522.61	0.60	33.82	4.91	3.13	0.29	29.04	1.51	0.62	1.17	0.02	0.01	6.50	0.72	18.26	Calcareous laminated shale
2522.65	0.87	42.98	7.52	2.81	0.45	19.59	2.11	0.81	1.76	0.02	0.01	2.19	0.07	19.67	Calcareous laminated shale
2525.12	0.67	42.06	6.29	2.46	0.37	21.39	2.26	0.90	1.56	0.03	0.01	2.69	0.97	19.00	Calcareous laminated shale
2526.00	0.91	48.62	9.17	2.93	0.51	15.24	2.43	0.90	2.18	0.03	0.02	0.74	0.13	17.10	Calcareous laminated shale
2527.08	0.57	39.52	5.95	2.45	0.35	23.87	1.77	0.82	1.38	0.03	0.01	4.77	0.96	18.12	Calcareous laminated shale
2527.79	0.59	44.35	6.65	2.29	0.40	19.61	2.83	0.86	1.58	0.03	0.02	1.26	0.72	19.39	Calcareous laminated shale
2528.22	0.98	47.17	9.95	3.13	0.53	13.73	2.73	0.75	2.30	0.03	0.02	1.00	0.91	17.77	Calcareous laminated shale
2528.54	0.95	46.26	9.94	3.10	0.53	14.46	2.60	0.88	2.29	0.03	0.02	0.94	0.61	18.33	Calcareous laminated shale
2529.44	0.90	46.67	9.98	3.41	0.51	13.87	2.40	0.90	2.29	0.03	0.02	0.74	1.66	17.51	Calcareous laminated shale
2530.04	0.77	36.76	8.12	2.85	0.41	22.25	2.31	0.93	1.81	0.02	0.01	0.42	0.40	23.70	Calcareous laminated shale
2530.14	0.40	23.55	3.94	2.33	0.20	33.08	3.78	0.50	0.94	0.04	0.00	1.96	0.61	29.06	Calcareous laminated shale
2530.24	0.40	21.29	4.02	2.16	0.21	35.05	3.58	0.44	0.93	0.04	0.00	1.12	0.11	31.05	Calcareous laminated shale
2530.27	0.79	34.17	7.21	2.75	0.37	24.37	3.14	0.70	1.60	0.03	0.01	3.25	0.11	22.29	Calcareous laminated shale
2531.16	1.20	46.38	11.21	3.59	0.56	12.95	2.40	0.85	2.55	0.03	0.02	0.67	0.28	18.51	Transition Zone
2531.25	1.13	45.71	10.70	3.50	0.55	13.52	2.47	0.76	2.43	0.03	0.02	0.88	0.79	18.64	Major unconformity, bone bed
2531.34	1.07	43.67	9.93	3.52	0.51	15.70	2.51	0.83	2.27	0.03	0.02	2.29	0.44	18.29	Major unconformity, bone bed
2531.38	0.87	31.96	5.63	3.65	0.27	28.92	1.54	0.62	1.22	0.03	0.10	9.81	1.12	15.14	Major unconformity, bone bed
2531.44	0.51	24.92	2.28	4.12	0.14	36.38	0.72	0.60	0.48	0.02	0.74	16.64	3.08	9.88	Major unconformity, bone bed
2531.48	0.59	53.14	3.55	3.92	0.20	18.94	1.22	0.40	0.77	0.02	0.01	5.08	2.11	10.64	Major unconformity, bone bed
2531.53	0.20	58.73	1.43	1.24	0.09	20.50	0.78	0.18	0.37	0.02	0.01	1.05	0.26	15.34	Bioturbated calcareous sandstone
2531.84	0.26	55.69	1.19	1.42	0.08	22.04	1.00	0.16	0.28	0.02	0.00	2.61	0.61	14.88	Bioturbated calcareous sandstone
2531.93	0.29	50.35	1.75	2.05	0.11	23.58	1.43	0.21	0.38	0.03	0.01	6.49	0.81	12.80	Bioturbated calcareous sandstone
2532.02	0.59	47.86	4.79	3.99	0.29	16.65	4.56	0.50	1.09	0.04	0.01	0.98	2.02	17.22	Bioturbated calcareous sandstone
2532.08	1.05	35.42	8.38	3.91	0.45	17.11	7.02	0.63	1.89	0.05	0.02	0.78	1.72	22.62	Transition Zone
2532.39	1.43	44.90	10.49	4.35	0.58	12.40	5.35	0.67	2.46	0.04	0.02	0.18	0.89	17.66	Calcareous silty shale
2532.65	1.18	46.58	10.06	4.26	0.57	12.36	4.75	0.73	2.30	0.04	0.02	0.22	1.60	16.52	Calcareous silty shale
2533.50	1.34	50.05	11.31	4.77	0.63	10.26	3.38	0.69	2.61	0.04	0.03	0.21	1.99	14.05	Calcareous silty shale
2534.30	1.30	60.90	8.09	3.73	0.53	6.56	2.00	0.62	1.80	0.02	0.03	0.23	1.93	13.55	Calcareous silty shale
2536.35	0.81	53.26	10.96	4.10	0.64	10.11	3.18	0.71	2.51	0.03	0.03	0.81	1.54	12.74	Calcareous silty shale
2538.08	1.06	62.35	7.30	3.24	0.52	12.07	2.19	0.62	1.67	0.03	0.02	0.27	0.42	9.31	Calcareous silty shale

TABLE 7

Per cent Total, Organic and Inorganic Carbon, Sulfur and Ash
East Drake L-06 well

Depth in metres	Lithology	Total Carbon	Organic Carbon	Inorganic Carbon	Total Sulfur	Ash
1122.68-1122.71	Brown shale	2.39	1.12	2.27	1.00	85.53
1122.76-1122.79	Brown shale	3.33	1.25	2.08	1.20	86.82
1122.86-1122.89	Brown shale	5.71	0.12	5.59	0.65	75.57
1123.38-1123.40	Green shale	0.26	0.00	0.26	0.71	94.22
1124.02-1124.04	Green shale	7.69	0.07	7.62	0.21	70.07
1124.15-1124.18	Green shale	8.90	0.05	8.85	0.12	60.95
1124.53-1124.55	Green shale	0.46	0.02	0.44	0.80	94.26
1125.12-1125.15	Calcareous sandstone	10.37	0.07	10.24	0.08	60.95
1125.92-1125.95	Calcareous sandstone	9.36	0.02	9.34	0.08	64.85
1127.02-1127.10	Calcareous sandstone	6.56	0.12	6.44	0.16	75.75
1127.64-1127.66	Calcareous sandstone	8.59	0.02	8.57	0.19	66.79
1128.91-1128.93	Calcareous sandstone	9.22	0.03	9.19	0.09	64.91
1130.22-1130.25	Glauconitic sandstone	6.24	0.07	6.17	0.07	76.75
1130.93-1130.95	Glauconitic sandstone	5.64	0.13	5.51	0.07	77.38
1131.72-1131.74	Argillaceous siltstone	3.12	0.37	2.75	0.31	89.34
1131.89-1131.91	Argillaceous siltstone	7.38	0.03	7.35	0.24	72.44
1132.26-1132.28	Argillaceous siltstone	10.15	0.04	10.11	0.29	61.24
1132.65-1132.67	Sandy limestone	4.86	0.01	4.85	0.10	81.40
1133.57-1133.59	Glauconitic sandstone	3.18	0.08	3.10	0.13	88.52
1134.83-1134.85	Siltstone	5.00	0.43	4.57	1.10	80.39
1136.67-1136.70	Calcite	9.28	0.02	9.26	0.17	64.96
1136.70-1136.73	Glauconitic sandstone	2.70	0.27	2.43	0.54	90.61
1137.47-1137.49	Sandy limestone	7.18	0.08	6.66	0.52	73.44
1137.82-1137.84	Brown calcareous shale	6.49	0.03	6.22	0.19	75.65
1138.50-1138.52	Brown calcareous shale	3.05	0.29	1.64	1.88	86.98
1139.06-1139.08	Brown calcareous shale	2.46	0.02	2.44	1.29	88.30
1140.03-1140.05	Brown calcareous shale	2.12	0.02	2.10	0.90	81.13
1141.03-1141.05	Brown calcareous shale	1.70	0.58	1.12	0.62	88.76
1141.15-1141.17	Brown calcareous shale	2.39	0.53	1.86	1.22	88.14
1141.34-1141.36	Glauconitic sandstone	5.00	0.04	4.96	0.30	81.27
1141.87-1141.90	Glauconitic sandstone	4.02	0.02	4.00	1.39	83.81
1143.73-1143.75	Glauconitic sandstone	4.36	0.14	4.22	0.18	84.00
1144.10-1144.12	Sandy limestone	4.45	0.13	4.32	0.11	82.83
1144.49-1144.51	Sandy limestone	4.72	0.16	4.56	0.78	82.77
1146.08-1146.10	Calcareous sandstone	8.12	0.00	0.00	0.19	67.77
1146.99-1147.01	Sandstone	1.10	0.00	0.00	0.32	95.72
1147.54-1147.56	Sandstone	1.28	0.09	1.19	0.19	95.30
1148.06-1148.08	Silty shale	2.20	0.12	2.08	0.17	91.52
1148.38-1148.40	Silty shale	2.40	0.20	2.20	0.22	91.35
1148.76-1148.78	Glauconitic sandstone	1.59	0.05	1.54	0.30	94.27
1149.57-1149.59	Limestone	9.96	0.02	9.94	0.09	68.67
1150.27-1150.29	Calcareous sandstone	6.49	0.04	6.45	0.08	75.15
1151.24-1151.26	Calcareous sandstone	3.02	0.16	2.86	0.06	88.28
1151.63-1151.66	Calcareous sandstone	5.01	0.17	4.84	0.11	80.72
1151.94-1151.96	Calcareous sandstone	5.31	0.50	4.81	0.06	80.92
1152.66-1152.68	Calcareous sandstone	6.19	0.04	6.15	0.29	76.54
1153.14-1153.16	Calcareous sandstone	1.12	0.04	1.08	0.25	95.60
1154.01-1154.03	Calcareous sandstone	0.93	0.03	0.90	0.17	96.17
1154.38-1154.40	Calcareous sandstone	1.64	0.02	1.62	0.14	97.71
1155.05-1155.07	Calcareous sandstone	1.29	0.14	1.15	0.58	95.79
1157.42-1157.44	Calcareous sandstone	2.47	0.01	2.46	0.38	90.40

TABLE 8

Per cent Total, Organic and Inorganic Carbon, Sulfur and Ash
Skybattle M-11 well

Depth in metres	Lithology	Total Carbon	Organic Carbon	Inorganic Carbon	Total Sulfur	Ash
2520.02	Calcareous laminated shale	8.27	4.57	3.70	1.17	78.56
2520.51	Calcareous laminated shale	8.05	1.30	6.75	0.80	72.00
2520.58	Calcareous laminated shale	7.66	3.11	4.55	1.93	77.79
2520.68	Calcareous laminated shale	8.60	2.30	6.30	1.46	73.04
2520.81	Calcareous laminated shale	9.45	1.86	7.59	1.53	73.24
2520.85	Calcareous laminated shale	10.21	0.00	0.00	1.24	64.01
2520.92	Calcareous laminated shale	10.18	0.00	0.00	1.56	65.12
2520.95	Calcareous laminated shale	7.60	3.21	4.39	4.37	81.09
2522.29	Calcareous laminated shale	7.56	2.94	4.62	1.41	79.07
2522.41	Calcareous laminated shale	6.40	1.19	5.21	1.77	80.78
2522.61	Calcareous laminated shale	6.47	1.81	4.66	1.83	81.74
2522.65	Calcareous laminated shale	7.08	3.47	3.61	1.34	80.33
2525.12	Calcareous laminated shale	6.05	1.89	4.16	1.08	81.00
2526.00	Calcareous laminated shale	5.64	2.10	3.54	1.23	82.90
2527.08	Calcareous laminated shale	6.17	2.04	4.13	1.19	81.88
2527.79	Calcareous laminated shale	5.83	1.30	4.53	0.87	80.61
2528.22	Calcareous laminated shale	5.90	2.93	2.97	1.22	82.23
2528.54	Calcareous laminated shale	6.40	2.99	3.41	1.28	81.67
2529.44	Calcareous laminated shale	6.12	2.82	3.30	1.52	82.49
2530.04	Calcareous laminated shale	8.43	3.28	5.15	1.30	76.30
2530.14	Calcareous laminated shale	8.44	1.88	6.56	0.83	70.94
2530.24	Calcareous laminated shale	9.13	2.40	6.73	0.81	68.95
2530.27	Transition Zone	7.77	2.86	4.91	1.28	77.71
2531.16	Major unconformity, bone bed	6.85	3.83	3.02	1.62	81.49
2531.25	Major unconformity, bone bed	6.66	3.75	2.91	1.41	81.36
2531.34	Major unconformity, bone bed	6.46	4.55	1.91	1.51	81.71
2531.38	Major unconformity, bone bed	4.56	0.45	4.11	2.06	84.86
2531.44	Transition Zone	4.39	0.82	3.57	3.24	90.12
2531.48	Calcareous silty shale	3.81	0.94	2.87	2.30	89.36
2531.53	Calcareous silty shale	4.31	0.25	4.06	0.34	84.66
2531.84	Calcareous silty shale	4.17	0.20	3.97	0.55	85.12
2531.93	Calcareous silty shale	3.95	0.68	3.27	0.91	87.20
2532.02	Calcareous silty shale	5.30	0.49	4.81	1.89	82.78
2532.08	Calcareous silty shale	6.07	0.46	5.51	1.29	77.38
2532.39	Calcareous silty shale	4.68	0.56	4.12	1.43	82.34
2532.65	Calcareous silty shale	4.70	0.63	4.07	1.56	83.48
2533.50	Calcareous silty shale	3.65	0.60	3.05	1.71	85.95
2534.30	Calcareous silty shale	3.50	0.50	3.00	1.11	86.45
2536.35	Calcareous silty shale	3.63	0.31	3.32	1.02	87.26
2538.08	Calcareous silty shale	2.69	0.43	2.26	1.52	90.69

TABLE 9

Trace Elements in ppm on Whole Rock
East Drake L-06 well

Depth in metres	Lithology	Pb	Zn	Cu	Ni	Cr	Mn	Zr	Ba	Sr	Rb	Y
1122.68-1122.71	Brown shale	0	32	12	36	96	130	140	280	267	108	18
1122.76-1122.79	Brown shale	1	24	6	42	104	108	149	291	281	92	59
1122.86-1122.89	Brown shale	2	18	5	20	59	215	186	164	669	78	10
1123.38-1123.40	Green shale	6	11	7	25	91	97	182	386	111	140	17
1124.02-1124.04	Green shale	0	0	0	21	47	202	213	71	1094	50	8
1124.15-1124.18	Green shale	4	6	0	11	53	225	252	95	1418	26	9
1124.53-1124.55	Green shale	0	0	3	22	91	107	112	301	102	125	14
1125.12-1125.15	Calcareous sandstone	0	0	0	16	51	194	126	74	738	11	2
1125.92-1125.95	Calcareous sandstone	1	0	0	17	73	82	115	144	647	10	4
1127.02-1127.10	Calcareous sandstone	0	0	0	10	80	84	123	617	512	11	5
1127.64-1127.66	Calcareous sandstone	3	0	0	8	73	38	116	166	382	3	3
1128.91-1128.93	Calcareous sandstone	5	0	0	23	59	69	92	1229	426	2	2
1130.22-1130.25	Glauconitic sandstone	0	0	0	4	96	52	123	435	192	7	7
1130.93-1130.95	Glauconitic sandstone	0	0	0	7	92	50	85	543	177	7	5
1131.72-1131.74	Argillaceous siltstone	2	4	3	38	101	60	173	178	145	22	14
1131.89-1131.91	Argillaceous siltstone	0	0	0	16	90	71	106	108	244	11	8
1132.26-1132.28	Argillaceous siltstone	1	4	0	73	90	71	58	99	396	6	1
1132.65-1132.67	Sandy limestone	0	0	0	8	64	58	101	223	163	10	8
1133.57-1133.59	Glauconitic sandstone	0	0	0	28	58	65	117	237	176	9	7
1134.83-1134.85	Siltstone	0	41	10	39	105	119	144	191	194	44	12
1136.67-1136.70	Calcite	0	0	0	66	108	74	51	149	383	1	4
1136.70-1136.73	Glauconitic sandstone	6	0	5	20	137	41	61	1222	201	10	17
1137.47-1137.49	Sandy limestone	0	4	0	8	54	117	54	148	222	8	5
1137.82-1137.84	Brown calcareous shale	0	0	0	18	59	114	41	93	197	9	5
1138.50-1138.52	Brown calcareous shale	3	47	8	30	117	120	143	251	174	62	16
1139.06-1139.08	Brown calcareous shale	2	50	0	47	117	86	132	308	169	71	18
1140.03-1140.05	Brown calcareous shale	5	31	8	31	103	77	129	283	159	70	14
1141.03-1141.05	Brown calcareous shale	4	60	7	41	124	74	125	439	166	109	17
1141.15-1141.17	Brown calcareous shale	9	43	4	38	110	100	172	367	176	90	19
1141.34-1141.36	Glauconitic sandstone	0	0	0	29	56	142	38	106	142	10	5
1141.87-1141.90	Glauconitic sandstone	1	16	0	22	174	155	153	277	151	65	14
1143.73-1143.75	Glauconitic sandstone	4	0	0	26	111	70	35	965	175	7	6
1144.10-1144.12	Sandy limestone	0	0	0	5	116	85	54	212	147	6	5
1144.49-1141.51	Sandy limestone	1	61	0	57	136	138	55	463	135	29	7
1146.08-1146.10	Calcareous sandstone	0	0	0	12	68	194	64	33	309	10	4
1146.99-1147.01	Sandstone	40	7	14	13	183	42	42	3650	163	5	5.
1147.54-1147.56	Sandstone	17	0	0	31	126	58	80	4270	109	11	6
1148.06-1148.08	Silty shale	9	0	1	11	165	72	56	2341	93	10	6
1148.38-1148.38	Silty shale	4	0	3	30	123	74	49	1317	89	15	6
1148.76-1148.78	Glauconitic sandstone	19	0	7	234	141	47	43	3102	99	16	7
1149.57-1149.59	Limestone	4	38	0	18	50	351	51	39	350	7	1
1150.27-1150.29	Calcareous sandstone	2	20	0	932	835	246	130	139	185	17	7
1151.24-1151.26	Calcareous sandstone	10	0	0	9	88	128	44	616	121	9	6
1151.63-1151.66	Calcareous sandstone	0	0	0	10	82	187	40	284	152	9	5
1151.94-1151.99	Calcareous sandstone	0	39	0	6	67	220	30	115	173	7	6
1152.66-1152.68	Calcareous sandstone	0	0	0	14	51	412	37	175	134	24	5
1153.14-1153.16	Calcareous sandstone	4	0	10	8	113	67	44	1572	64	14	5
1154.01-1154.03	Calcareous sandstone	5	0	0	13	113	67	99	1846	60	15	5
1154.38-1154.40	Calcareous sandstone	8	0	6	10	119	83	69	1680	69	14	4
1155.05-1155.07	Calcareous sandstone	13	0	12	24	98	81	185	1773	89	17	10
1157.42-1157.44	Calcareous sandstone	6	15	4	6	149	130	118	1605	77	11	4

TABLE 10

Trace Elements in ppm on Whole Rock
Skybattle Bay M-11 well

Depth in metres	Lithology	Pb	Zn	Cu	Ni	Cr	Mn	Zr	Ba	Sr	Rb	Y
2520.02	Calcareous laminated shale	46	190	27	65	183	171	149	230	534	96	27
2520.51	Calcareous laminated shale	3	27	0	31	73	261	152	153	575	47	18
2520.58	Calcareous laminated shale	5	101	21	62	121	217	135	227	499	98	18
2520.68	Calcareous laminated shale	7	122	29	73	109	184	141	160	582	70	23
2520.81	Calcareous laminated shale	3	30	17	65	61	566	71	115	343	51	9
2520.85	Calcareous laminated shale	3	27	0	56	46	279	51	56	286	27	4
2520.92	Calcareous laminated shale	5	84	14	102	47	252	54	93	298	31	8
2520.95	Calcareous laminated shale	9	173	68	252	104	200	126	193	408	94	19
2522.29	Calcareous laminated shale	3	94	30	65	152	209	153	249	479	67	31
2522.41	Calcareous laminated shale	0	59	21	55	100	218	184	332	826	29	62
2522.61	Calcareous laminated shale	7	106	35	55	142	206	169	252	627	57	37
2522.65	Calcareous laminated shale	4	107	2	58	193	183	151	268	439	81	41
2525.12	Calcareous laminated shale	0	77	20	43	131	253	158	227	388	71	25
2526.00	Calcareous laminated shale	0	106	12	43	147	235	138	293	313	92	22
2527.08	Calcareous laminated shale	0	88	19	48	115	209	176	213	501	92	22
2527.79	Calcareous laminated shale	0	59	7	33	104	273	161	267	311	66	23
2528.22	Calcareous laminated shale	0	110	23	55	168	203	111	267	301	102	25
2528.54	Calcareous laminated shale	0	129	26	57	164	209	113	293	316	104	27
2529.44	Calcareous laminated shale	3	109	34	57	140	223	128	243	269	101	24
2530.04	Calcareous laminated shale	1	182	27	62	153	205	117	200	449	88	19
2530.14	Calcareous laminated shale	0	40	10	38	100	388	114	92	479	42	21
2530.24	Calcareous laminated shale	0	49	12	32	101	369	106	143	516	42	19
2530.27	Transition Zone	0	112	0	51	155	272	122	155	480	79	48
2531.16	Major unconformity, bone bed	1	118	20	68	196	200	112	258	281	116	27
2531.25	Major unconformity, bone bed	5	125	31	68	173	203	116	271	287	113	27
2531.34	Major unconformity, bone bed	1	93	16	68	184	206	124	231	354	104	42
2531.38	Major unconformity, bone bed	7	343	30	66	162	227	168	740	2029	60	53
2531.44	Transition Zone	0	729	74	150	156	210	255	16896	1290	20	65
2531.48	Calcareous silty shale	1	94	46	70	177	163	109	148	419	38	54
2531.53	Calcareous silty shale	0	1	23	31	145	169	82	149	320	16	15
2531.84	Calcareous silty shale	0	14	0	15	109	197	87	92	420	12	31
2531.93	Calcareous silty shale	0	19	0	22	144	186	101	110	427	13	30
2532.02	Calcareous silty shale	5	37	2	26	114	313	109	210	235	50	17
2532.08	Calcareous silty shale	5	31	0	24	75	411	76	196	194	83	15
2532.39	Calcareous silty shale	3	49	5	30	87	313	89	237	161	107	17
2532.65	Calcareous silty shale	7	50	7	50	96	308	100	281	159	104	18
2533.50	Calcareous silty shale	12	61	17	34	88	281	108	276	153	118	20
2534.30	Calcareous silty shale	10	49	12	29	93	247	118	328	149	111	20
2536.35	Calcareous silty shale	3	284	5	25	126	207	172	271	194	70	18
2538.03	Calcareous silty shale	7	119	63	41	165	275	214	423	144	104	24

studied. Aluminum (Al) is abundant in kaolinite and other layer silicates: potassium (K) in illites; iron (Fe) and/or magnesium (Mg) in chlorites; and magnesium (Mg), calcium (Ca) and sodium (Na) in smectites.

Over 200 photographs and over 200 energy dispersive spectra reveal the presence of calcite, dolomite, quartz, feldspars, clays, pyrite and apatite in the East Drake L-06 and Skybattle Bay M-11 wells. The results are presented in Appendices II and III, respectively. Due to overabundance of carbonates the morphology of clays was impossible to recognize. However, authigenic quartz in the <2μ fraction was isolated (photos 077 and 078, Appendix II). The clay sample was isolated from a shale at a depth between 1141.15-1141.17 m and just above a glauconitic sandstone which is encountered between 1141.34 m and 1143.75 m.

IV. Rock-Eval/TOC Results

Skybattle Bay M-11. One hundred and sixty-seven samples of core material were analyzed by Rock-Eval/TOC over the interval between 2520.0 m and 2538.0 m (Fig. 5). The TOC values measured ranged from 6.08* to as low as zero, with the lower values in the bottom six metres of the core but with considerable variability on a centimetre by centimetre scale in the uppermost few metres of the core.

The Tmax (temperature of highest hydrocarbon yield during pyrolysis) was generally in the 445 to 450°C range which is approximately equivalent to a vitrinite reflectance range of 0.9 to 1.0% Ro, or just beyound the classical zone of peak oil generation. Current hydrocarbon generation and migration models suggest that this level of thermal maturation probably coincides with the time of decrease of maximum expulsion of liquid yields. Hydrocarbon saturation of the pores of fine-grained source rocks would be expected to be nearly saturated with bitumen at this point. Water which was present would be either chemically bound to mineral species or part of the 'irreducible' water content.

*Carbon concentration from additional samples not reported in the present work.

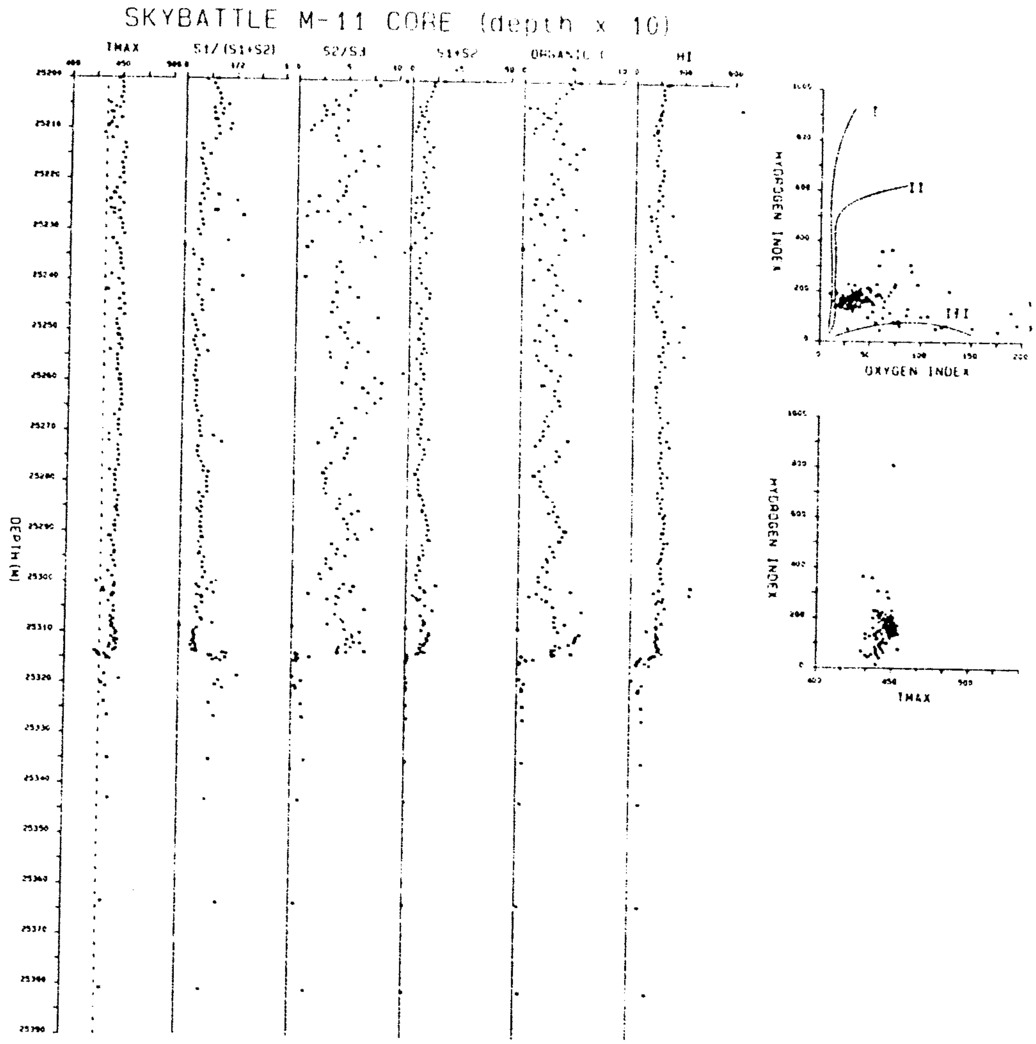

Figure 5. Rock-Eval logs, modified van Krevelen diagrams (Oxygen Index vs Hydrogen Index) and Tmax vs Hydrogen Index of Skybattle Bay M-11 core.

Production Index (Transformation Ratio, S1/S1 + S2) values are somewhat scattered, generally in the 10 to 30% range. This range is consistent with a mature source rock (that is, with an approximate vitrinite reflectance value of 0.7 to 0.8%), and the scatter and occasional extreme values may indicate local migration both into and out of layers within the core, that is on a very local scale.

It should be noted that the Tmax values from the bottom section of the core are somewhat lower than those from the upper two-thirds. This change in Tmax coincides with a downward change in the character of the organic matter towards Type III (terrestrial). The Tmax values in the marine dominated section may thus actually indicate a somewhat lower level of maturity than indicated above. Tmax values of about 445°C are observed for Type I (algal) kerogen at essentially any level of thermal maturity less than about 1.3% Ro equivalent.

The type of organic matter is inferred to be largely Type II, marine on the basis of the S2/S3 ratio and Hydrogen Index (S2/TOC). The level of thermal maturity is sufficiently advanced, however, to have caused significant shifts in both of these parameters and extrapolation to the original, unaltered character cannot be made with complete certainty. Thus, it is possible that the original organic matter in this stratigraphic section contained significant amounts of algal debris.

East Drake L-06. One hundred and twenty-one samples of the core taken at the East Drake L-06 well over the depth interval from 1120 m to 1154 m were analyzed using Rock-Eval/TOC (Fig. 6). The TOC content ranges from almost zero to 5.95%, with all of the higher values occurring in the uppermost 2 m of the core and corresponding to the section of the core dominated by fine-grained sediments.

The level of thermal maturity is again indicated to be somewhat higher in the upper section than in the terrestrially dominated sediments in the lower part of the core. Tmax values in the upper part (445 to 450°C) would be consistent with algal organic matter, and the Tmax values of about 435°C in the lower portion of the core would indicate a vitrinite reflectance level of about 0.7% Ro, or at the beginning of the classical oil window.

The organic matter type appears to be mixed Type II and Type III on the basis of Hydrogen Index. The S2/S3 ratio is widely scattered. There is essentially no indication of the presence of Type I (algal)

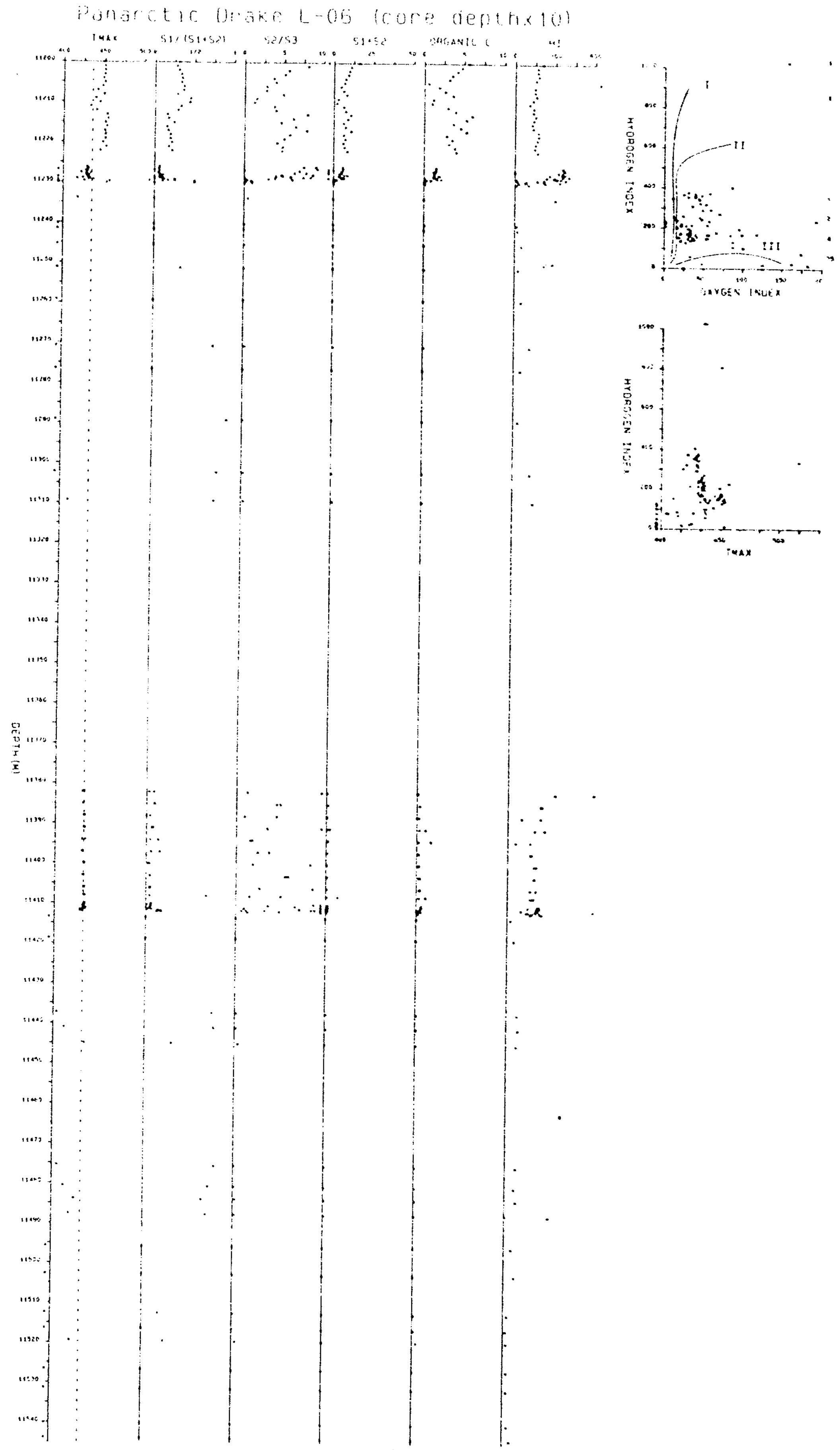

Figure 6. Rock-Eval logs, modified van Krevelen diagrams (Oxygen Index vs Hydrogen Index) and Tmax vis Hydrogen Index of Panarctic Drake L-06 core.

organic matter, and thus the anomalously high Tmax values in the upper 2 m of the core are problematic.

Discussion

Preliminary results demonstrate that both shales and sandstones are rich in carbonate minerals and thus it is not yet possible to draw any conclusions about the mass transfer of elements.

Preliminary x-ray analytical results on five (5) hydrous layer silicates which are concentrated in the $<2\mu$ fraction indicate diagenetic changes. Once the x-ray work and chemical analysis on the $<2\mu$ fraction is completed and thin section microscopy and SEM on the thin sections is completed, it should be possible to evaluate the extent of mass transfer of elements from shales to sandstones in both the East Drake L-06 and Skybattle Bay M-11 wells.

To complete the diagenetic study and the evaluation of elements transferred from shales to sandstones, the mineral identification on the already isolated clay fraction as well as the chemistry of the fine clays must be carried out, since it is the fine fraction which fingerprints the diagenetic changes and ensuing gain or loss of elements. These are the losses of H_2O, silica, iron, magnesium and calcium and the gains of aluminum and potassium.

In addition, petrography is needed to determine depositional environments, various source areas and different diagenetic events, especially as they are related to unconformities and breaks in deposition. SEM on thin sections will also yield additional valuable information concerning the mass transfer of elements, especially the transportation and genesis of authigenic silica across the shale/sandstone boundary. This has been shown to take place in the limited number of samples studied by SEM.

To summarize, the additional work to be done is clay mineralogy, clay chemistry, petrography and SEM on thin sections. Subsequently the data will be worked out to evaluate the transfer of elements from the calcareous shales to the calcareous sandstones in both wells, East Drake L-06 and Skybattle Bay M-11.

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APPENDIX I

X-RAY FLUORESCENCE CONDITIONS

FOR SPECTROCHEMICAL ANALYSIS

Element	Line	Filter	Colli- meter	Detect or	Crystal	Order	UPL	LWL	KV	MA	Angle	+Offs	-Offs
AL	KA	NO	F*	F***	P.E.T.	1	80	20	40	70	144.995	2.20	4.00
CU	KA	NO	F	FS****	LIF 200	1	80	20	55	50	44.995	1.50	2.00
FE	KA	NO	F	FS	LIF 200	1	80	20	50	55	57.505	2.00	2.60
SI	KA	NO	F	F	P.E.T.	1	80	20	40	70	109.160	2.80	3.20
CA	KA	NO	F	F	LIF 200	1	80	20	40	70	113.130	2.30	4.20
K	KA	NO	F	F	LIF 200	1	80	20	40	70	136.735	3.20	3.80
BR	KA	NO	F	FS	LIF 200	1	80	20	70	40	29.950	1.00	0.90
AL3	KA	NO	F	F	P.E.T.	1	80	20	35	25	145.095	0.00	0.00
MG3	KA	NO	F	F	P x 1	1	80	20	50	50	22.700	0.00	0.00
FE3	KA	NO	F	FS	LIF 200	1	80	20	25	10	57.540	0.00	0.00
CU3	KA	NO	F	S	LIF 200	1	80	20	25	15	45.030	0.00	0.00
AL2	KA	NO	F	F	TLAP	1	80	20	25	10	37.815	0.00	0.00
S	KA	NO	C	F	Ge	1	80	20	40	70	110.695	1.50	3.00
CL	KA	NO	C	F	Ge	1	80	20	40	70	92.740	2.20	1.80
NA	KA	NO	C	F	P x 1	1	80	20	40	70	27.245	2.80	1.70
MG	KA	NO	F	F	P x 1	1	80	20	40	70	22.670	1.30	1.70
F	KA	NO	C	F	TLAP	1	80	20	40	70	90.780	0.00	0.00
P	KA	NO	C	F	Ge	1	80	20	40	70	140.955	4.00	5.00
TI	KA	NO	F	FS	LIF 200	1	80	20	50	55	86.165	2.80	2.20
MN	KA	NO	C	FS	LIF 200	1	80	20	50	55	62.960	2.0	1.40
BA	LA	NO	C	FS	LIF 200	1	80	20	50	55	87.170	1.80	3.20
NI	KA	NO	F	FS	LIF 200	1	80	20	55	50	48.665	1.30	1.70
ZN	KA	NO	F	FS	LIF 200	1	80	20	55	50	41.775	1.20	1.90
PB	LB	NO	F	FS	LIF 200	1	80	20	70	40	28.255	1.00	1.10

*F = Fine; C** = Coarse; F*** = Flow; FS**** = Flow/Salinity

Element	Line	Filter	Colli-meter	Detector	Crystal	Order	UPL	LWL	KV	MA	Angle	+Offs	-Offs
AS	KA	NO	F	FS	LIF 200	1	80	20	70	40	33.925	1.00	1.50
RB	KA	NO	F	FS	LIF 200	1	80	20	75	35	26.610	0.50	0.60
SR	KA	NO	F	FS	LIF 200	1	80	20	75	35	25.135	0.90	0.60
Y	KA	NO	F	FS	LIF 200	1	80	20	75	35	23.815	0.70	0.70
ZR	KA	NO	F	FS	LIF 200	1	80	20	75	35	22.450	0.60	1.50
MO	KA	NO	F	FS	LIF 200	1	80	20	75	35	20.300	0.70	0.50
RH	KA	NO	F	FS	LIF 200	1	80	20	75	35	17.520	0.00	0.00
U	LA	NO	F	FS	LIF 200	1	80	20	95	30	26.155	1.50	1.50
FE2	KA	NO	F	FS	LIF 200	1	80	20	25	10	85.745	0.00	0.00
FE1	KA	NO	F	FS	Ge	1	80	20	25	10	34.490	0.00	0.00
F1	KA	NO	C	F	P x 1	1	80	20	40	70	42.360	2.00	1.50
RH1	KA	YE	F	FS	LIF 200	1	80	20	75	35	15.570	0.00	0.00
RH2	MA	NO	F	FS	LIF 200	1	80	20	0	0	35.730	0.00	0.00
MN1	KA	NO	C	FS	LIF 200	1	80	20	50	55	62.930	2.50	1.40
CR	KA	NO	C	FS	LIF 200	1	80	20	50	55	69.350	1.20	0.90
CR1	KA	NO	C	FS	LIF 200	1	80	20	50	55	69.325	1.20	0.90
BA1	LA	NO	F	FS	LIF 200	1	80	20	50	55	87.210	1.80	3.20

*F = Fine; C** = Coarse; F*** = Flow; FS**** = Flow/Salinity