SEDIMENTOLOGY, GEOCHEMISTRY AND GAS SHALE POTENITAL OF THE EARLY JURASSIC NORDEGG MEMBER, NORTHEASTERN BRITISH COLUMBIA

by

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ABSTRACT

The Early Jurassic Nordegg Member in north-eastern British Columbia (NEBC) is composed of 25-30 m of organic-rich marine strata. The unit was deposited in a restricted basinal environment, west of a high standing carbonate platform.

The Nordegg Member consists of four lithological facies: (A) a basal conglomeratic lag deposit; (B) a lower phosphatic marlstone that was deposited during highly productive conditions; (C) an overlying marlstone which represents an anoxic phase of sedimentation; and (D) an upper phosphatic mudstone reflecting a productive water column. Geochemical analysis reveals depositional conditions where high productivity is associated with enrichments of P and Fe, K, Ti, V, Cr and Zn and total organic carbon values (TOC) between 0-8 wt%, likely due to upwelling currents introduced nutrient-rich water increasing algal productivity during relative sea-level rise. The marlstone contains higher TOC (6-20 wt%) and reduced concentrations of P, Fe, K, Ti V, Cr and Zn. The elevated TOC's and lack of productivity-proxying elements (e.g. P) infers organic matter incorporation into the sediment was primarily controlled by redox conditions when basin conditions were persistently anoxic.

The TOC concentrations are a reflection of the depositional environment and have a strong influence on potential gas capacity. The TOC-rich samples have improved adsorption capacities compared to their organic-lean counterparts due to the highly microporous nature of organic matter to which the gas molecules physically adsorb to. Nordegg adsorbed gas capacities range from 0.05 cc/g to over 2 cc/g in organic-rich zones.

The relationship between TOC and adsorption is complicated by other geologic factors including moisture. Moisture competes for adsorption sites with methane and blocks pores and pore-throats, reducing the transmissibility of the methane to the microporosity of the organic matter.

Twenty to eighty percent of total gas storage is free gas (gas occupying open pores), ranging from 0.1 – 1.3 cc/g. Nordegg total gas-in-place ranges from 1 – 24 BCF/section. The greatest potential for gas shale production is to the south-west of the study area (93-P-5). TOC concentrations (up to 20 wt%), thickness, maturity and fracture-potential improve the gas shale potential in this region making it a prime gas exploration target.

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Chapter 1

Introduction

1.1 GENERAL STATEMENT

As the demand for natural gas increases, organic-rich strata including coal and shale are being investigated as potential resources of gas. Gas shales are classified as unconventional reservoirs, continuous type natural gas plays (USGS, 1995). Such reservoirs require no structural or stratigraphic control to retain the gas in place. In the US natural gas has been produced from shales and mudrocks since 1821. Estimates of shale gas in-place range from 497-783 tcf (Curtis, 2002). The substantial gas resources have lead to increased research into organic-rich units such as the Antrim, Ohio, New Albany, Barnett and Lewis shales. However the gas shale potential of analogous units in Canada is poorly known. Recent research has provided regional-scale assessments of various gas shale targets in the Western Canadian Sedimentary Basin (WCSB; Ramos, 2004) but more detailed work is required on specific horizons. The work presented here focuses on the Early Jurassic Nordegg Member in the WCSB.

The two major aspects of gas shale reservoir development (stratigraphy and adsorption capacity) are investigated in this thesis. Chapter two documents the sedimentology, stratigraphy and geochemistry and interprets the Nordegg depositional environment. Chapter three determines Nordegg total organic carbon (TOC) distributions across the study area using laboratory calibrated wireline logs. Chapter four evaluates the gas shale reservoir capacity of the Nordegg and factors which control reservoir quality. Chapter five briefly discusses the effect of particle size and sample preparation on methane adsorption. Chapter six investigates the controls and subsequent effects of moisture on gas capacity.

The regional stratigraphy and depositional environment for the Nordegg Member in Western Canada has been established by Frebold (1957), Stott (1967), Poulten (1984), Poulten *et al,* (1994), and Riediger & Bloch (1995). The research presented here extends the data-set by focusing on the Nordegg Member in northeastern British Columbia which differs considerably from the 'type' Nordegg section in south-western Alberta (Stott, 1967).

1.2 STRUCTURE OF THESIS

This thesis is presented as five stand-alone papers which may be read without reference to preceding chapters. Chapter two investigates the depositional controls on the Nordegg Member in northeastern British Columbia. The objectives of this chapter are to:

i. define the lithofacies within the Nordegg Member of NEBC and to document lateral and vertical compositional variations
ii. interpret the facies and facies associations
iii. propose a depositional model from lithofacies relationships and variability

Chapter three determines the vertical and lateral distribution of the Nordegg TOC contents across the study area. The objectives of this chapter are to:

i. evaluate the utility of wireline logs for TOC quantification

ii. develop a technique to determine TOC concentrations using ready available wireline logs

iii. to quantify TOC contents and map TOC facies of the Nordegg Member

iv. to compare results with previously established log-derived TOC models

Chapter four investigates the gas shale potential of the Nordegg Member and the relationship between gas capacity and various geologic conditions. The objectives of chapter four are to:

i. examine the gas adsorption capacity of various lithofacies

ii. investigate the relationship between gas adsorption and pressure, TOC, moisture and maturity

iii. examine pore-size distribution using mercury porosimetry

iv. assess free gas component

v. provide a regional assessment of gas-in-place estimations to determine areas of highest shale-gas potential

Chapter five discusses the effect of particle size and sample preparation on gas adsorption. The objectives of chapter five are to:

i. examine the effect of particle-size distributions on methane adsorption

ii. assess the particle-size effect on equilibrium moisture contents

Chapter six investigates the moisture effect on gas adsorption and the moisture association with organic and inorganic components. The objectives of chapter six are to:

i. determine controls on equilibrium moisture contents

ii. discuss the effect of moisture on methane adsorption

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Chapter 2

Palaeodepositional Conditions of the Early Jurassic Nordegg Member: A Combined Sedimentological and Geochemical Approach

2.1 ABSTRACT

Using a multi-disciplinary approach (sedimentology, organic petrology and geochemistry), palaeoenvironments during the Jurassic Nordegg Member sedimentation has been investigated. Four lithofacies are defined within the Nordegg in the Peace River Arch area of northeastern British Columbia (NE BC), interpreted as offshore marine deposits. In stratigraphic order the facies are: (A) mudstone conglomerate/breccia; (B) phosphatic marlstone; (C) marlstone; and (D) phosphatic mudstone. Geochemical analyses of organic-rich lithofacies B, C and D reflect the changing sedimentology of the individual lithofacies (termed litho-geochemical facies or LGF) which reveal evolving palaeooceanographic conditions.

LGF-B (lithofacies B) was deposited in a highly productive depositional setting, characterized by enrichments in the productivity proxying element P and total organic carbon (TOC) contents ranging between 0-7 wt%. The co-occurrence of the marine phosphate francolite and pyrite suggests conditions were transitional between dysoxic and anoxic. Open ocean conditions to the west allowed nutrient-rich deep waters to enter the basin, supplying nutrients leading to increased productivity. The increased basinal circulation recycled the settling organic matter, producing enrichments of matrix bituminite in LGF-B which preferentially concentrated V, Cr and Zn. A major shift in geochemistry took place at the onset of LGF-C (lithofacies C) deposition. LGF-C has

high TOC (6-20 wt%), pyritic and low concentrations of the productivity associated elements (P, V, Cr and Zn) and detrital proxying elements (K, Fe and Ti), suggesting LGF-C represents an anoxic stagnant phase of sedimentation with minor detrital input. Anoxic bottom waters developed in response to basin-silling (restricting lateral and vertical circulation). A second transgression disrupted the stratified water column once again, increasing productivity and depositing LGF-D (lithofacies D) which has similar sedimentological, petrological and geochemical characteristics as LGF-B (TOC contents range between 1-8 wt%).

Sulphur contents in all litho-geochemical facies do not correlate with the degree of organic matter preservation. The partitioning of sulphur between pyrite and organic matter was controlled by the ratio of reactive Fe to organic matter. Nordegg organic matter is sulphur-rich indicative of Fe-limited/highly sulfidic environmental conditions.

2.2 INTRODUCTION

Many factors have been proposed which influence the deposition of organic-rich marine sediments. These include anoxic/low oxygen bottom waters (Demaison and Moore, 1980; Demaison, 1991; Pelet, 1987; Erbacher *et al*, 2001), high primary production increasing the organic carbon flux to the sea-floor (Calvert, 1987; Pederson and Calvert, 1990; Ibach, 1982), primary productivity and export efficiency (Grimm *et al*, 1997), sedimentation rate (Pederson and Calvert, 1990), rapid burial thereby reducing the possibility to degrade the organic matter microbially (Muller and Suess, 1979), upwelling (Suess *et al*, 1987), "protective-sorption" of organic matter onto clay minerals (Hedges and Keil, 1995) and amount of dilution by inorganic components (Demaison and Moore, 1980). Other factors which could affect the preservation potential of organic matter include organic-matter type (more labile OM suffers greater degradation), water depth, salinity and distance from the continental margin (Calvert *et al*, 1996). However as noted by Stow and Bertrand (2001), isolating one factor responsible for the effective preservation of organic matter is difficult as organic-rich strata can be deposited by a combination of the afore mentioned processes.

The two prominent hypotheses for organic matter concentration in marine units are productivity and preservation. During times of increased productivity, high concentrations of organic matter are supplied to the underlying sediments (Calvert and Pederson, 1992). Eventually the demand for oxygen (from surface productivity) in the water column exceeds the supply (controlled by water circulation) producing dysoxic/anoxic conditions. As such, low O_2 conditions are a consequence, and not a cause, of the increased organic carbon flux to the sea-floor. In contrast, preservation models invoke anoxia as the cause of organic matter preservation (e.g. Demaison and Moore, 1980) where a strong density interface (pynocline) inhibits dissolved O_2 circulation in the water column.

In an attempt to better understand factors influencing the formation of organic-rich strata, a combined sedimentological, petrological and geochemical study on samples collected from the Nordegg Member, an Early Jurassic organic-rich marlstone sequence of Western Canada is used. TOC contents and distribution and factors influencing organic matter preservation (sedimentological and paleoenvironmental conditions which reveal the nature and development of redox conditions) are discussed.

2.3 STUDY AREA

The study area covers an area of approximately 30,000 km^2 in the Peace River district between 93-P-1 (south-east) and 94-A-13 (northwest). The area was chosen to constrain the depositional environment of the Nordegg Member specific to northeastern British Columbia (NEBC). Localities of all cores are shown in figure 2.1.

2.4 JURASSIC STRATIGRAPHY AND NOMENCLATURE

Jurassic strata in the WCSB are mainly composed of shales, siltstones and sandstones. Most of the Jurassic units in the Canadian Rockies are assigned to the Fernie Formation (Hamilton, 1962) which overlies a regional unconformity that truncates successively older Triassic tidal flat dolomites from west to east (Poulten, 1984; Poulten *et al*, 1990; Figure 2.2). The basal Fernie Formation consists of organic-rich marlstones, mudstones, shales, limestones and cherts (Nordegg Member and Poker Chip Shale). The

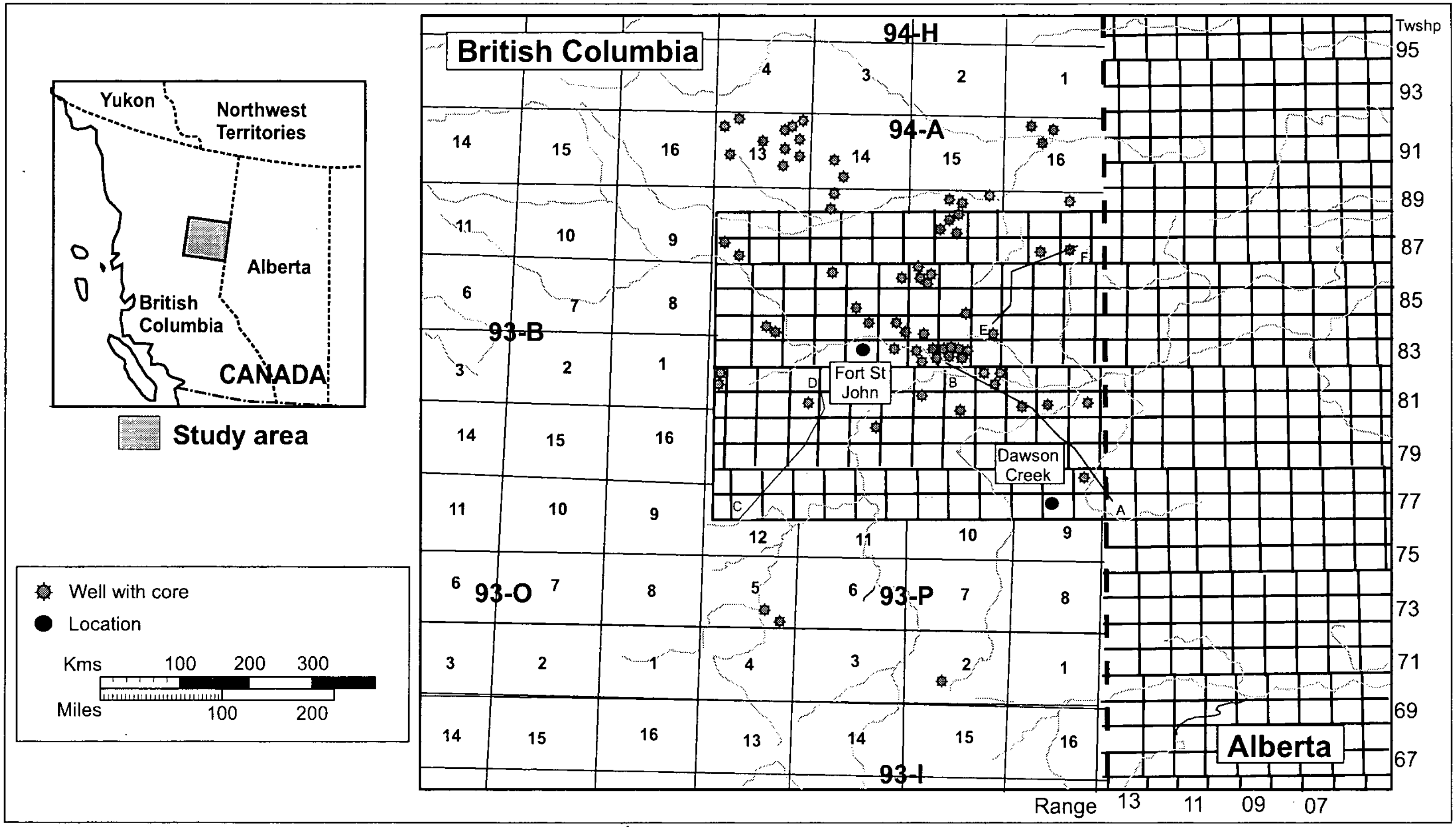


Figure 2.1: Map illustrating study area and well locations

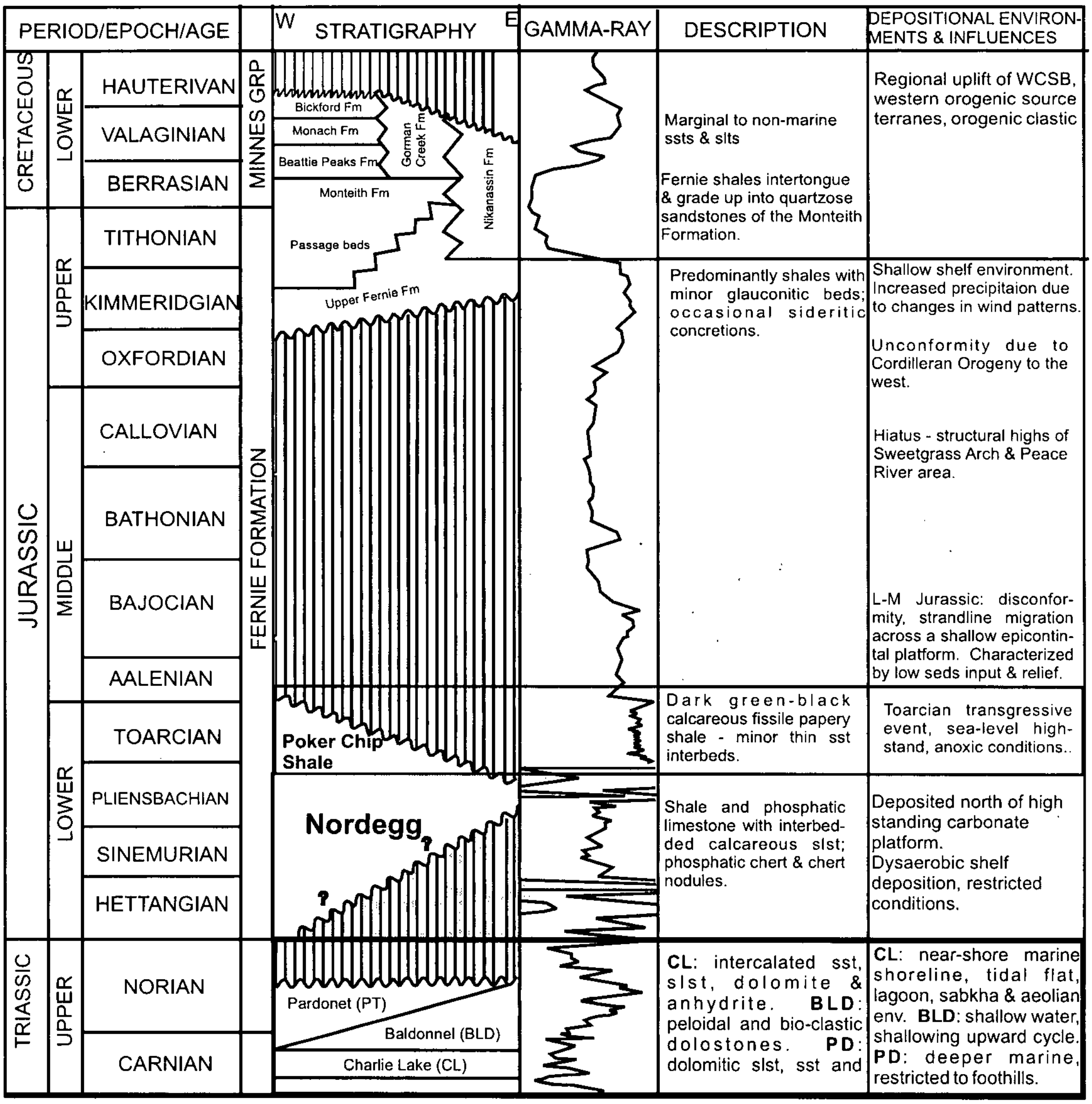


Figure 2.2: Stratigraphic chart of Jurassic units in northeastern British Columbia (modified from Stott (1967), Poulten *et al* (1990), Riediger (1990) and Poulten *et al* (1994).

uppermost Fernie Formation and Passage Beds are characterized by fine-grained siliciclastic deposits, primarily glauconitic shales. Overlying the Fernie Formation is the Minnes Group which includes Upper Jurassic and Lower Cretaceous sand/siltstone units of the Nikanassin Formation. A sedimentary hiatus occurred during the Middle Jurassic as NE BC was subjected to uplift and erosion as indicated by the absence of Middle Jurassic strata below the Late Jurassic regional unconformity (Davies and Poulten, 1986).

In NE BC, the Nordegg comprises of up to 25 m of organic-rich marlstones, mudstones and organic-lean argillaceous limestone. Descriptions of the Nordegg Member in the subsurface of British Columbia and west-central Alberta have been provided by Spivak (1949), Hamilton (1962), Carlson (1968), Poulten *et al* (1990) and Creaney and Allen (1992). Spivak (1949) did not define the Nordegg Member but described the basal Fernie Formation as calcareous platey shales and argillaceous limestone. Thompson and Crockford (1956), Peterson (1957), Frebold (1969) and Stronach (1984) describe the geology of Lower Jurassic units in the Rocky Mountains and Foothills. Published detailed geological investigations are limited to Riediger (1990), Stott (1998) and Asgar-Deen *et al* (2003) who present the most comprehensive overviews.

The shaley limestone in the Peace River district, north-eastern British Columbia was correlated with the Nordegg Member in its type section (Nordegg, south-western Alberta) due to comparable petrophysical responses (Springer *et al*, 1964). However the lithological correlative uncertainty between cherty limestones of the 'type' Nordegg and the marlstones and shales in NE BC lead authors to refer to the latter as the "Nordegg

Member"[1] (e.g. Poulten *et al*, 1990; Riediger *et al*, 1990). The BC-Alberta correlation has further come into question due to variation in ammonite faunal ages (Russell *et al*, 2000; Asgar-Deen *et al*, 2003). The Nordegg shales in west-central Alberta are Hettangain to late Toarcian in age (Asgar-Deen *et al*, 2003). Elsewhere the type Nordegg Member from the outcrop belt is Sinemurian-age and the 'basinal' equivalents are Pliensbachian (i.e. the Nordegg Member in this study; Russel *et al*, 2000).

2.5 GEOLOGICAL SETTING

The Early Jurassic was characterized by marine transgressions which produced relatively widespread, organic-rich deposits in the Arctic and Greenland margins, the Gulf Coast and western North America (Figure 2.3A; Ettensohn, 1997). Hettangian-Pliensbachian organic-rich mudrocks have also been reported in north-west Europe (Bailey *et al*, 2003).

On the western continental margin of North America, the Early Jurassic marked a change from terrane-specific volcanism, plutonic activity and sedimentation to the accretion of allochthonous terranes (Gabrielse and Yorath, 1991). A subsiding foreland basin formed along the Canadian Cordilleran margin (associated with the Nevadan Orogeny; Ettensohn, 1997). Despite terrane accretion, there was still ready access to marine waters on the western North American margin, indicated by the deposition of several organic-rich Jurassic units (Figure 2.3B; Poulten *et al*, 1993). Organic-rich mudrock deposition was constrained by the broad, shallow nature of the foreland basin (Veevers, 1994).

[1] Nordegg Member is used in this thesis but placed in quotation marks here to emphasize the correlative uncertainty which exists between the Nordegg in this study and the type-Nordegg in south-western Alberta.

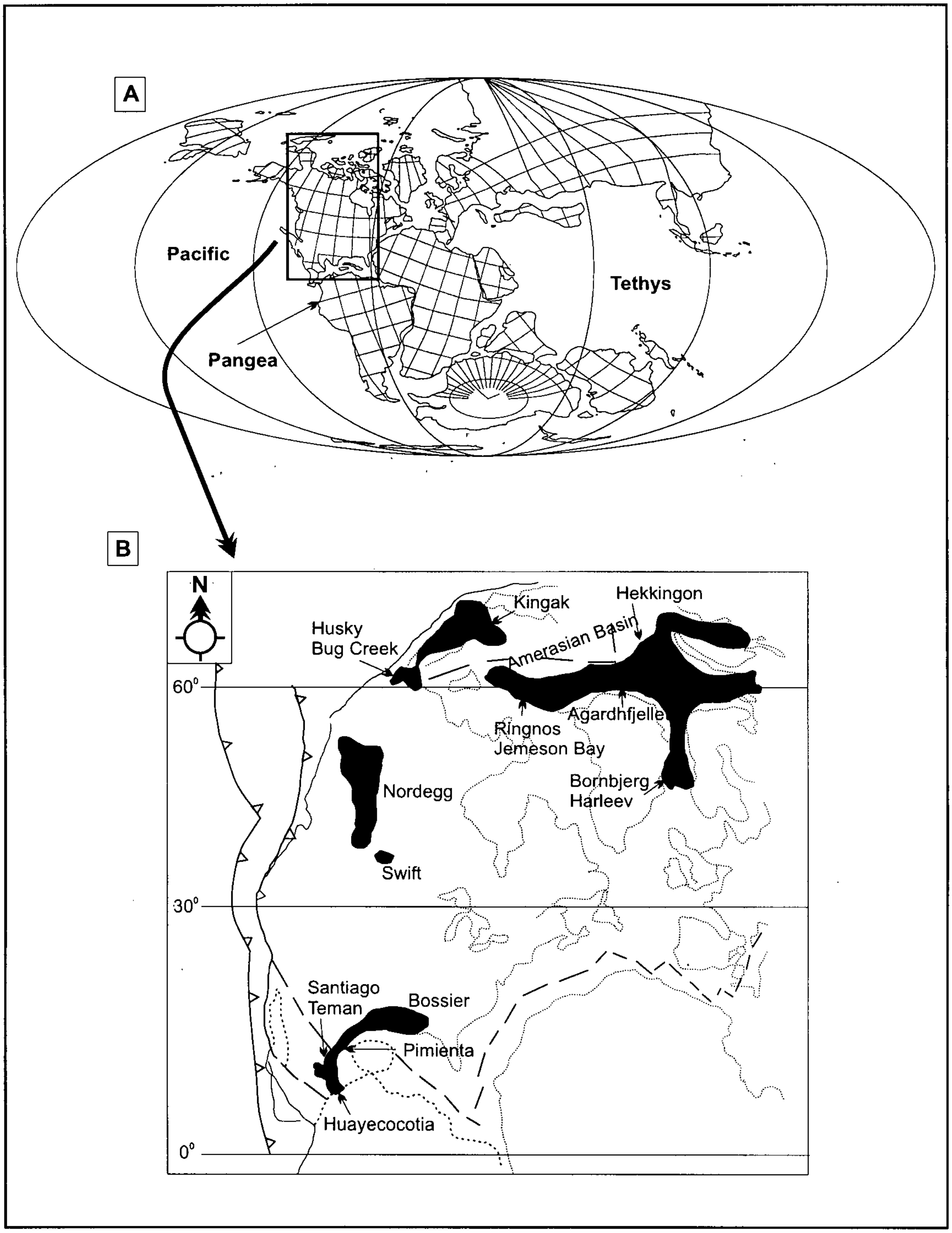


Figure 2.3: (A) Global paleogeography during the Lower Jurassic (Sinemurian - Toarcian; adapted from Jenkyns, 19880. (B) Marine black shale distribution across North America in the Jurassic (note: these units are not necessarily contemporaneous (adapted from Ettensohn, 1997).

The Jurassic rocks of the Western Canadian Sedimentary basin are located on platforms around the margins of the North American craton (Figure 2.4). During deposition of the Early Jurassic Nordegg Member, the western cratonic platform was stable (O'Connell, 1990). However the degree of stability of the craton has been questioned due to variation of juxtaposed units and depths of erosion at unconformities (Poulten *et al*, 1994). During the Early Jurassic, the Sweetgrass Arch was a structural high, separating the miogeocline and platform in the west, from the Williston Basin to the east (Poulten, 1984).

The tectono-stratigraphic setting of western Canada was further modified by the onset of the Columbian Orogeny in pre-Late Jurassic time (Poulten *et al,* 1990), causing local subsidence which significantly influenced Jurassic sedimentation patterns (Stronach, 1984). The Sweetgrass Arch subsequently subsided during the Middle Jurassic, linking the Williston Basin with the newly developed Alberta Trough.

Throughout Nordegg deposition, the North American continent drifted northwards (Cioppa *et al,* 2002). In the Early Jurassic the study area was located in a mid-high latitudinal position, in a sediment starved environment (Poulten *et al* 1994).

The areal extent of the study area is marked in the east by the sub-Cretaceous erosional edge and in the west by the Nordegg subcrop edge (Figure 2.5). The Nordegg has a constant thickness over most of the study area (Figure 2.6 and 2.7), averaging 20-25 m. Towards the northeast of the study area, the Nordegg Member is between 1-15 m thick and changes lithologically to a sandstone/siltstone-rich, marlstone/carbonaceous mudstone poor unit. The sands may be correlative with a Jurassic Limestone/sandstone unit found at Snake Indian Falls which lies 50km north of Jasper (Poulten *et al*, 1990).

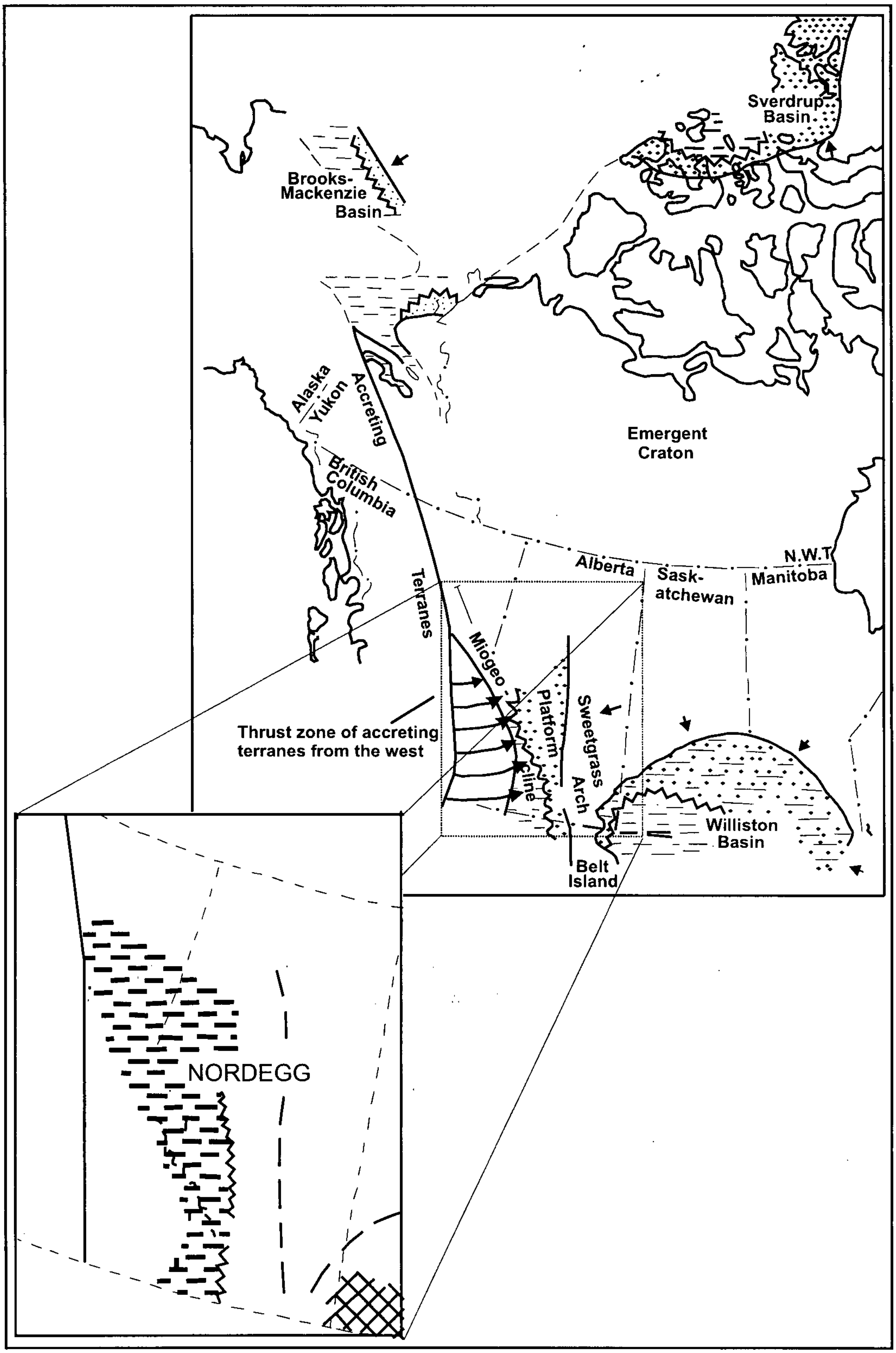


Figure 2.4: Tectonic map of western Canada during the Early Jurassic highlighting area of Nordegg deposition (adapted from Poulten ,1984).

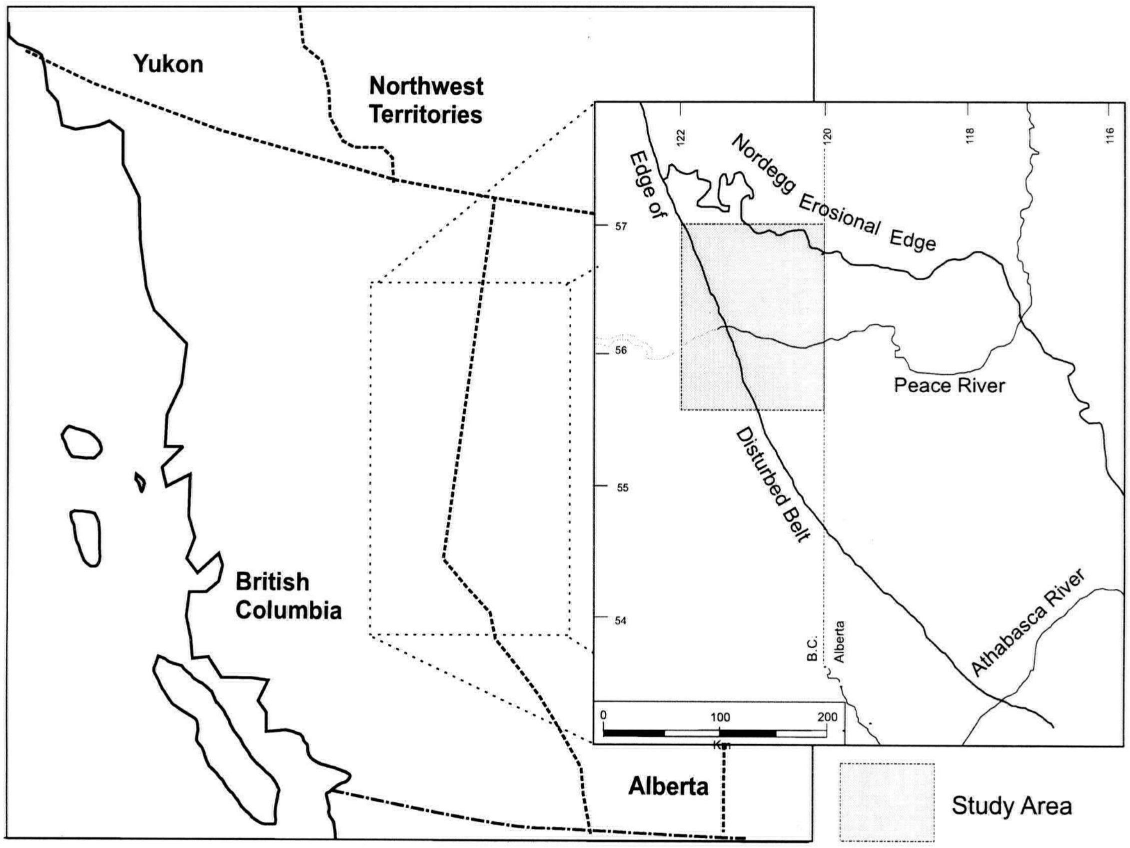


Figure 2.5: Map illustrating study area and eastern erosional limit of the Nordegg Member (adapted from Poulten *et al* 1990).

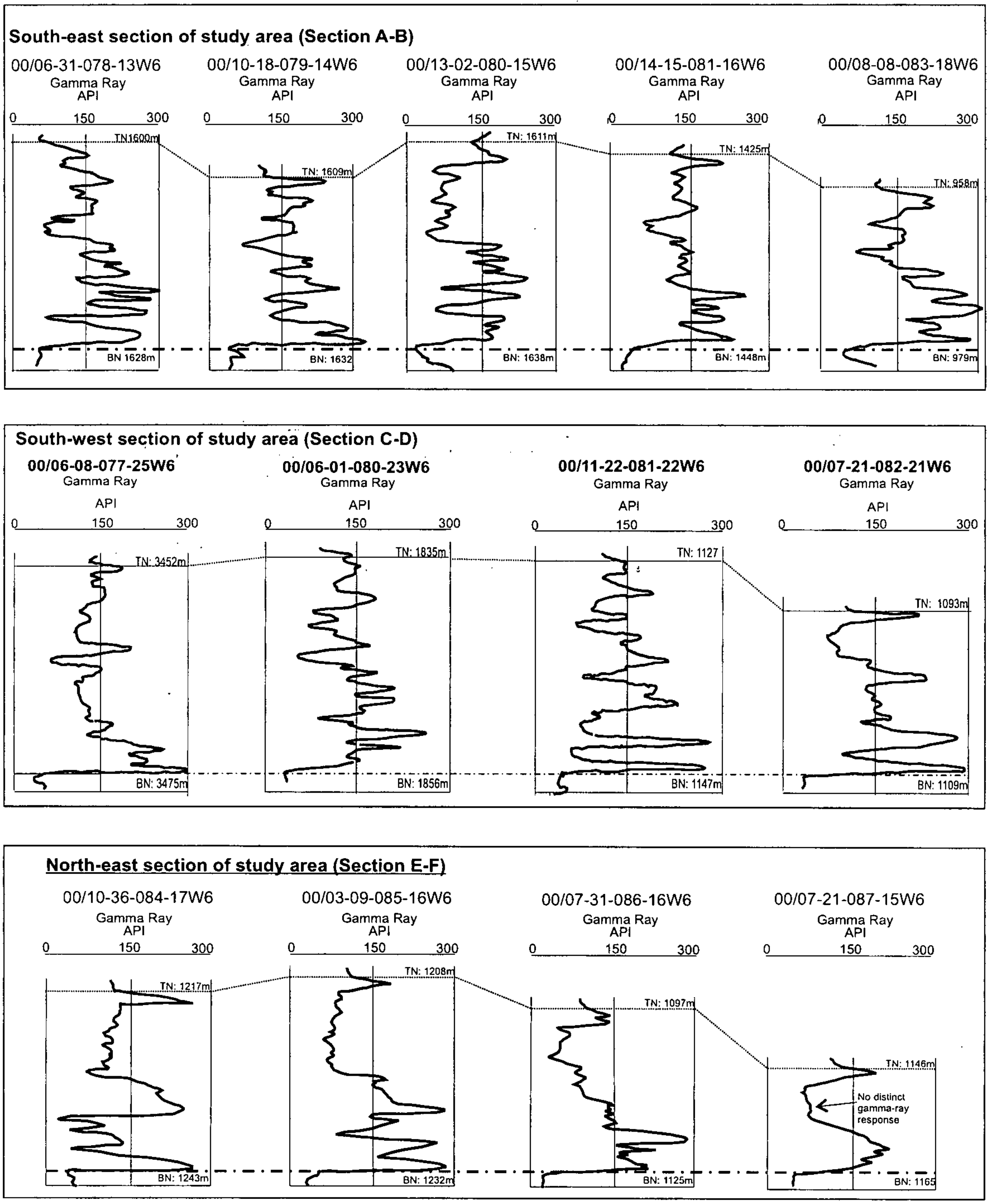


Figure 2.6: Nordegg thins towards the north-east (see map for well section locations). Datum = Baldonnel Formation.

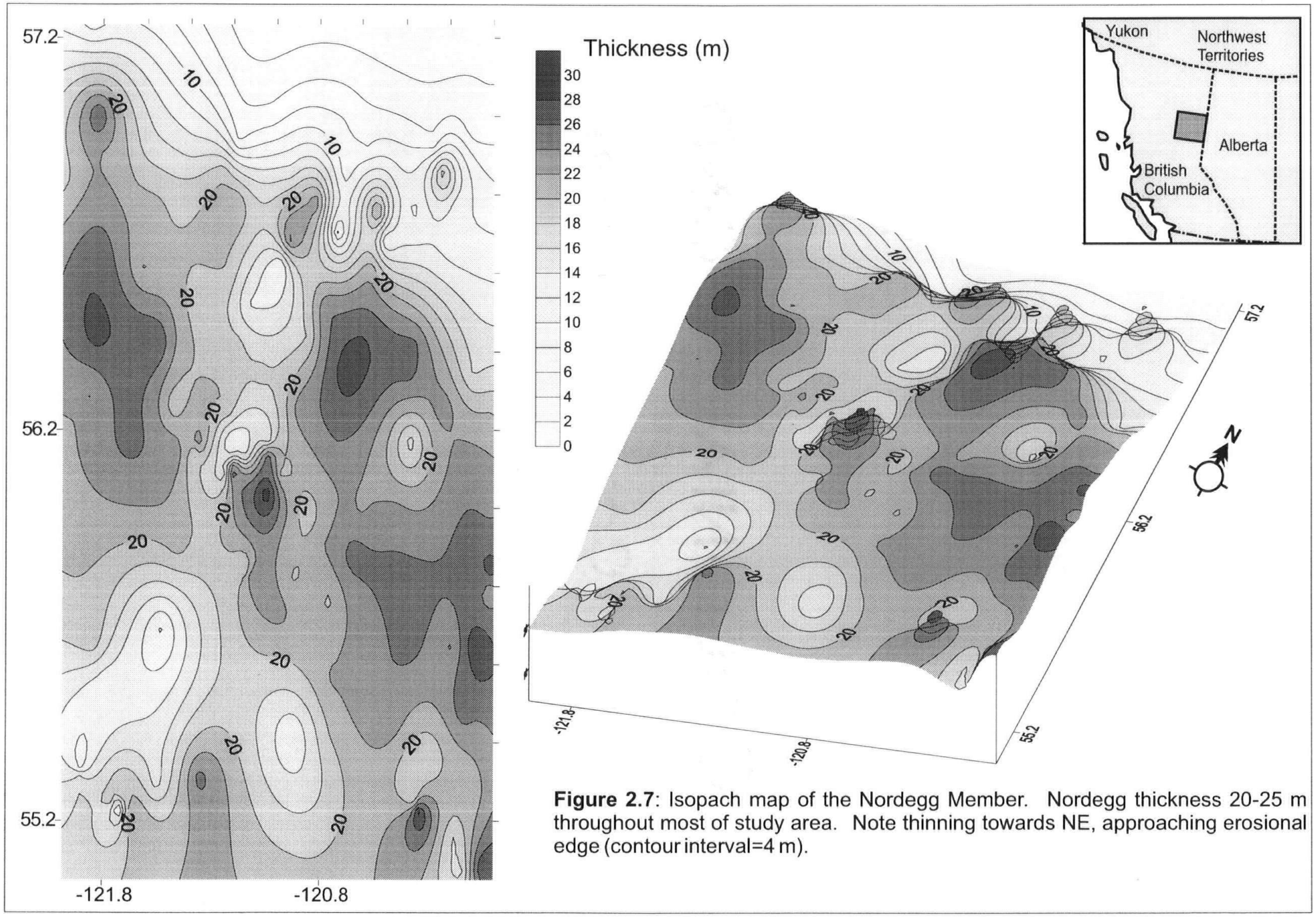


Figure 2.7: Isopach map of the Nordegg Member. Nordegg thickness 20-25 m throughout most of study area. Note thinning towards NE, approaching erosional edge (contour interval=4 m).

2.6 MATERIALS AND METHODS

Ninety-four cores of the Nordegg Member were described and sampled from NEBC. Many of the cores only intersected the basal section of the Nordegg Member (lowermost 3-8 m) making complete correlations with geophysical logs difficult. Only in well 200/d-088-H|094-A-13/00 was the Nordegg interval completely cored. Core analysis was supplemented with geophysical logs in order to produce cross-sections and isopach maps. Bulk mineralogy was determined by x-ray diffraction. Abundance of minerals was calculated semi-quantitatively using peak-intensity ratios. Identification of subtle lithological variations and detailed mudrock descriptions were augmented by thin-section examination under transmitted light.

The concentrations of total carbon, sulfur and nitrogen were established using a Carlo Erba® NA-1500 Analyzer. Inorganic (carbonate) carbon concentration values were generated from a CM5014 CO_2 coulometer. Fifteen to twenty-five milligrams of ground sample were weighed and reacted with HCl. The liberated CO_2 was titrated and the end point determined by a photodetector. $CaCO_3$ percentages, expressed as weight percent calcium carbonate, were calculated from the inorganic carbon (IC) content, assuming that all evolved CO_2 was derived from dissolution of $CaCO_3$, by the equation:

$$CaCO_3 \text{ wt\%} = 8.33 \times IC \text{ wt\%}$$

Total organic carbon values were determined by subtracting total inorganic carbon from total carbon values (TOC = TC-TIC).

Maturity data from T_{max} by Rock Eval pyrolysis (Espitalie *et al*, 1977) was performed on pulverized samples using standard procedures on a DELSI Rock-Eval

II/TOC apparatus. Elemental abundance of the samples was determined by X-ray fluorescence (XRF) for selected major (Si, Al, Fe, K, Ca, Mn, Mg, Ti, P, Na) and minor elements (V, Cr, Mn, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Ba, Pb, Nb). Geochemical analysis was conducted on the core from well 200/d-088-H 094-A-13 which was considered to be the type-section of the Nordegg in NEBC due to complete recovery and typical stratigraphy.

Loss-of-ignition (LOI) was calculated for all samples. This involved heating 1 gram of sample at 950 ^{0}C for 1 hour, placing the sample in a dessicator for 3 hours then measuring the sample weight loss. At temperatures >500 ^{0}C, all organic carbon is removed. For minor analysis, 4.00 g of powdered sample was hydraulically pressed into a pellet, mixed with boric acid (H_3BO_3) powder and analyzed using a sequential X-ray spectrometer (Philips PW2510) calibrated with synthetic standards. Precision of results are ±3% for the major elements (except Na which is ±7%) and ±5% for the minor elements (except Pb which is ±8%).

2.7 SEDIMENTOLOGY

2.7.1 Definitions

In this thesis, I use the classification by Pettijohn (1957, 1975) for mudstones, calcareous mudstones, marlstones and limestones. The term mudstone is defined as "a claystone which are neither fissile nor laminated but are blocky or massive" (Pettijohn, 1975). A mudstone with greater than 6% calcite is termed a calcareous mudstone, 35-80% calcite is deemed a marlstone and > 80% calcite is a limestone or an argillaceous limestone. The term shale is applied to fine grained, fissile rocks. As stated by Wignall (1994), the level of organic-richness is not used in the definition of mudrocks and shales.

2.7.2 Sedimentary Facies

Four stratigraphic units which are also distinct lithological facies are recognized within the Nordegg Member (Table 2.1) and are summarized as: (A) mudstone conglomerate/breccia; (B) phosphatic marlstone; (C) marlstone; and (D) phosphatic mudstone. Facies C has sub-facies of silty calcareous mudstone (C-1) and calcareous siltstone (C-2; Figure 2.8). In the following section, the lithology of the Nordegg is described in stratigraphic order.

2.7.2.1 Facies A: Mudstone conglomerate/breccia

The Nordegg Member unconformably overlies the dolomitic units of Baldonnel, Pardonet or Charlie Lake where, in most areas, a sharp low angle contact is overlain by conglomeratic or brecciated boundary (Figure 2.9A and 2.9B). The conglomerate contains quartz, chert and dolomitic clasts with minor phosphate grains. Near the base, a brecciated zone caused by solution effects is developed (Figure 2.9C) with mudstone clasts contorting laminations and abundant detrital quartz grains.

2.7.2.2 Facies B: Phosphatic Marlstone

Facies B is approximately 9 m of non-bioturbated, organic-rich, phosphatic carbonaceous marlstone. The predominantly calcareous unit contains occasional planar, non-calcareous beds (up to 4 cm thick; Figure 2.10A and 2.10B) and non-calcareous

Facies	Lithology	Thickness	Description
A	Mudstone Conglomerate/breccia	0.5 m	Granule to pebble congolomerate/breccia, Calcareous matrix-supported, mudstone clasts, semi-lithified deformation structures (solution breccia), rare shell debris
B	Phosphatic Marlstone	9 m	Dark grey to black marlstone, massive to laminated, abundant mm-diameter phosphate grains, rare shell-hash beds, several calcite and bituminite-filled fractures, occasional mud-clasts. Contains bands of medium-dark grey limestone, crypto -microcrystalline, micromicaceous, bituminous, stylolitic
C	Marlstone	12 m	Black marlstone, finely laminated, shell-hash beds common, fine disseminated pyrite, stylolitic, occasional siltstone beds containing bitumen -filled fractures
Sub-facies			
C-1	Silty calcareous mudstone (2 m)		Black calcareous mudstone, scattered silt-sized quartz grains
C-2	Siltstone (1 m)		Brown siltstone, calcareous, moderately bituminous, fractured, bioturbated (in NE)
D	Phosphatic Mudstone	2-3 m	Dark brown/black mudstone, massive to laminated (planar to wavy), occasional pyrite -rich laminae, mm-diameter phosphate grains, fractures lined with sulfate residue

Table 2.1: Summary of Nordegg Member facies and sub-facies

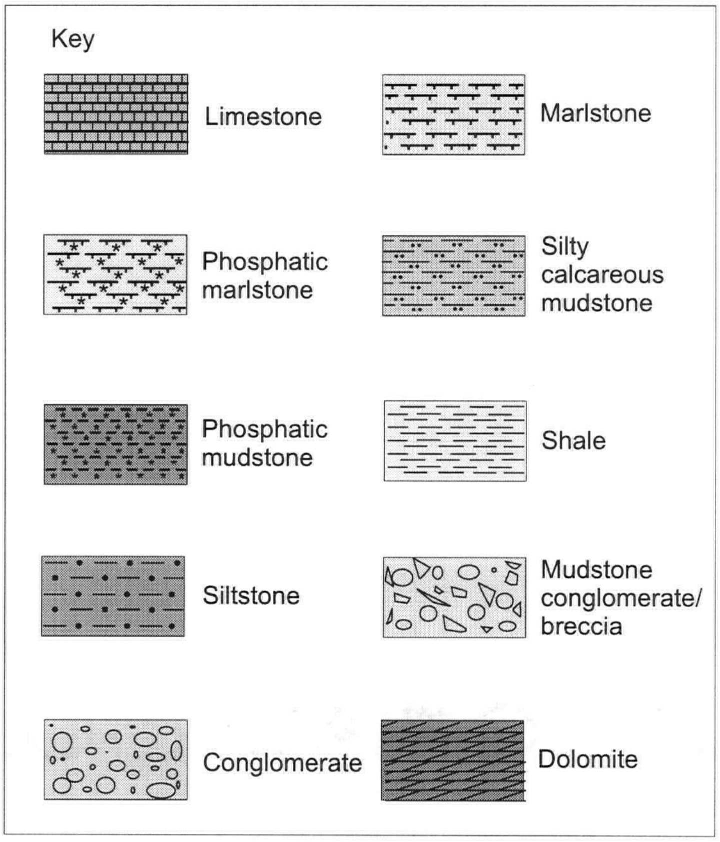


Figure 2.8: Key for all cores

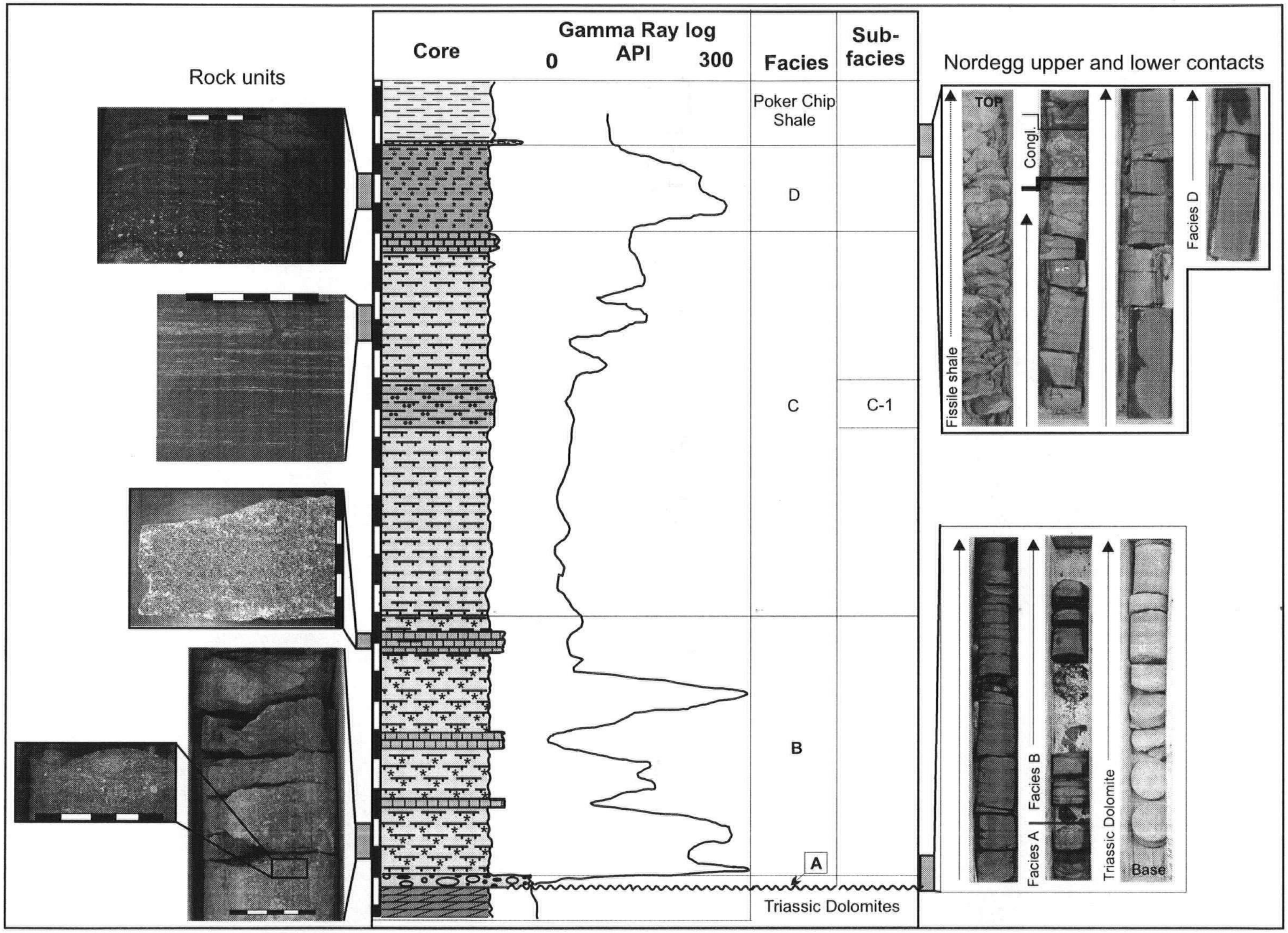


Figure 2.8 *continued (1)* : Complete core section of the Nordegg Member highlighting gamma-ray response to lithofacies (Well: 200/d-088-H 094-A-13)

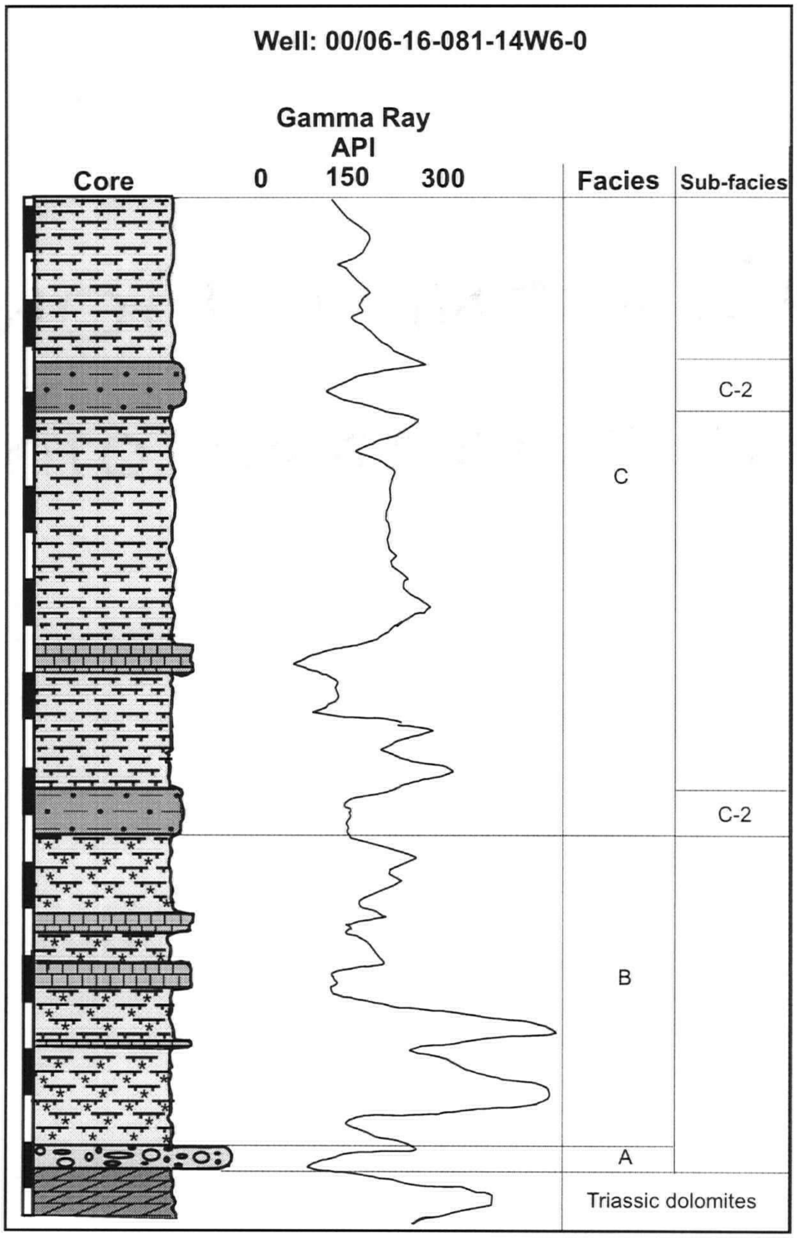


Figure 2.8 *continued (2)*: Facies associations of the Nordegg Member. Incomplete core from the eastern portion of the study area (81-14W6) - note siltstone facies (C-2) which are not present further west (e.g. Well: 200/d-088-H 094-A-13).

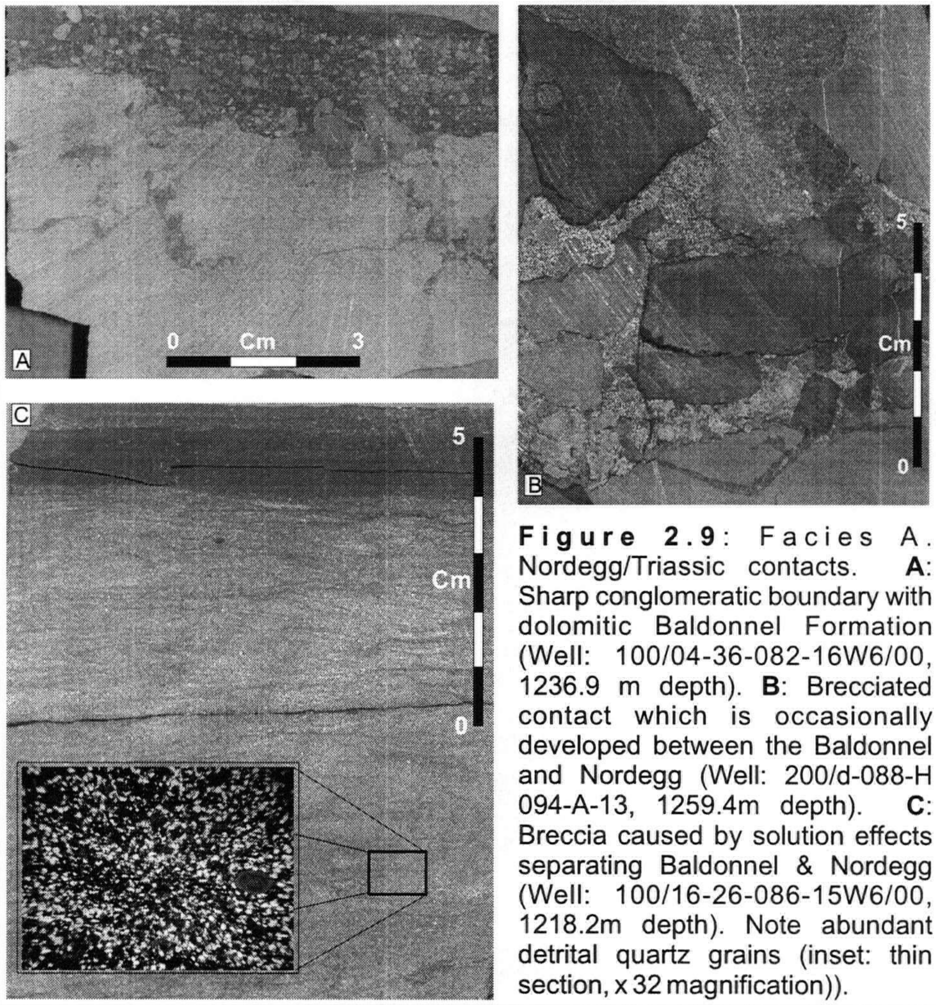


Figure 2.9: Facies A. Nordegg/Triassic contacts. **A**: Sharp conglomeratic boundary with dolomitic Baldonnel Formation (Well: 100/04-36-082-16W6/00, 1236.9 m depth). **B**: Brecciated contact which is occasionally developed between the Baldonnel and Nordegg (Well: 200/d-088-H 094-A-13, 1259.4m depth). **C**: Breccia caused by solution effects separating Baldonnel & Nordegg (Well: 100/16-26-086-15W6/00, 1218.2m depth). Note abundant detrital quartz grains (inset: thin section, x 32 magnification)).

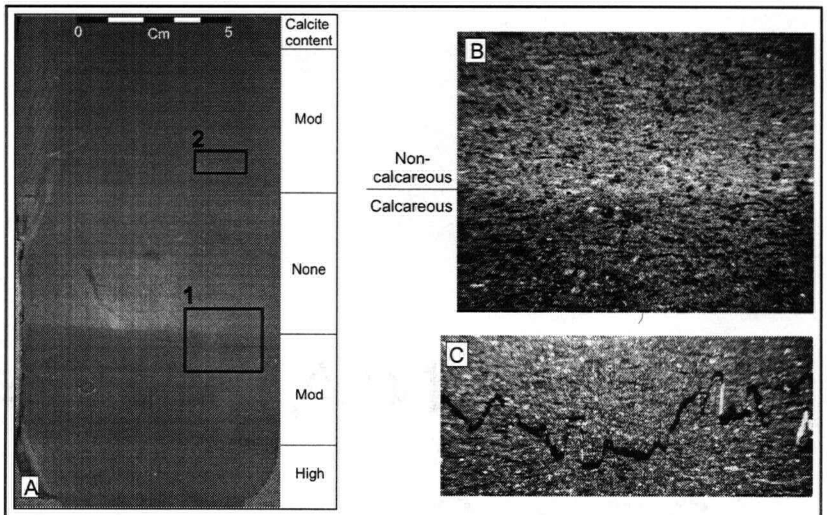


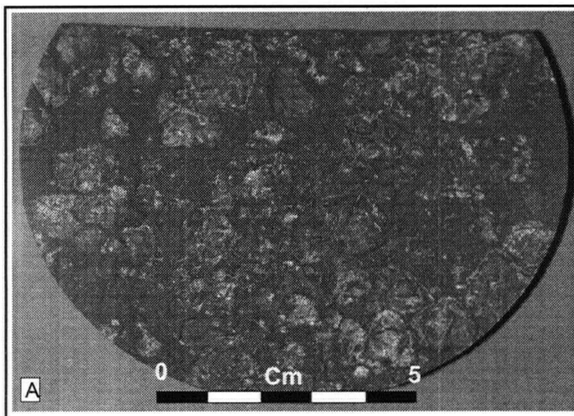
Figure 2.10: Faces B. **A**: Lower marlstone with variable calcite content. **B:** Photomicrograph of contact between calcareous and non-calcareous section in lower marlstone (x45 magnification). Note - Calcareous bands distinguished from non-calcareous bands by darker colour. **C:** Thin-section of stylolite within Facies B lined with organic/clay residue (x45 magnification).

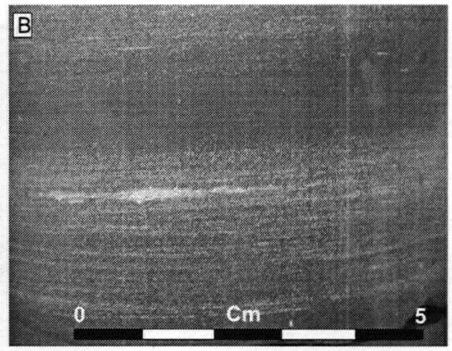
nodules. The calcareous sections have abundant low-amplitude stylolites (Figure 2.10C). Carbonate-rich sections are in part, coincident with 1 mm to 1 cm compacted shell beds (Figure 2.11A and 2.11B). Individual complete fossils were rare but bivalves and ammonite casts occur (Figure 2.11C). Fine phosphatic grains (sub-mm) are common in facies B, associated with fish bones/debris (Figure 2.12A). There is also a close relationship between phosphate and bitumen where solid bitumen occurs both in the centre of the phosphatic lenses and exuded to the edges (Figure 2.12B).

Based on XRD analysis, the mineralogical composition of facies B consists mainly of quartz (~ 40%) and calcite (~ 35%) with francolite and minor dolomite, feldspar and clay minerals (illite and smectite). Quartz occurs as detrital grains near the base, as an organic deposit (radiolarian (?); Figure 2.12C) and as an inorganic precipitate (as shown by colloidal silica; Figure 2.12D). TOC content averages 4.3 wt% (range 0-5 wt%) and is mainly type II kerogen (matrix bituminite dominated with minor alginite) and small concentrations of terrestrially derived Type IV (fusinite/semi-fusinite). Carbonate carbon values range from 5 – 58%, averaging 35%. The sulfur content averages 1.85 wt% (range 0.2 - 2.7 wt%).

Although facies B is extremely tight due to the high calcite content, fractures occur. The majority are horizontal with calcite cementation (Figure 2.13A). Some fractures have both calcite and bitumen in-filling with the bitumen occupying the centre of the fracture and calcite surrounding (Figure 2.13B), or bitumen only (Figure 2.13C).

Facies B includes 15-90 cm beds of argillaceous microcrystalline limestone (Figure 2.14A and 2.14C), containing abundant shelly material (Figure 2.14B). Contacts with surrounding marlstone are typically sharp (accentuated by compaction and pressure





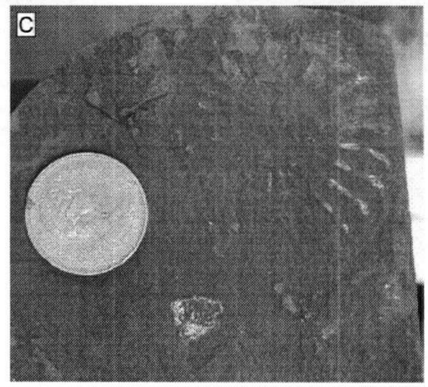
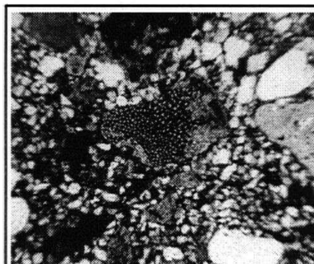
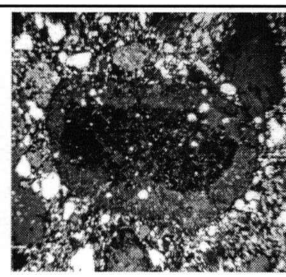


Figure 2.11: **A**: view of shell beds on bedding plane (Well: 200/d-088-H 094-A-13, 1235 m depth). **B**: Shell hash beds viewed parallel to bedding (Well: 200/d-088-H 094-A-13, 1244.35 m depth). **C**: Partial ammonite mold within Facies A. Photograph taken perpendicular to bedding.





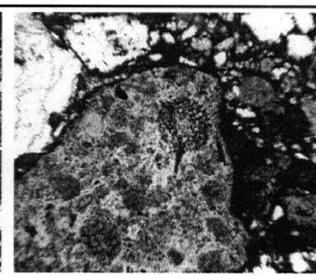
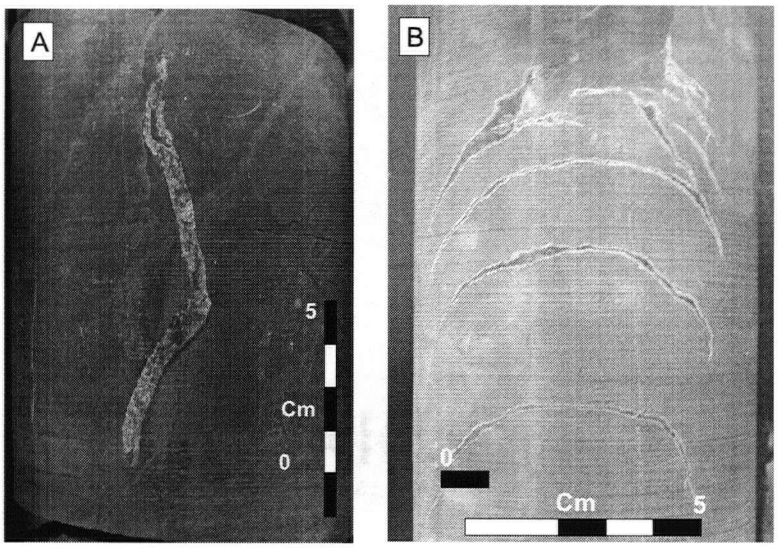


Figure 2.12: Nordegg thin-sections.
A: Fish bone/debris showing spongeous texture.
B: Phosphate pellet containing discrete OM.
C: Preserved radiolarian (?) within phosphatic grain.
D: Colloidal silica indicating inorganic precipitate. All photographs showing x45 magnification in plane polarized light.



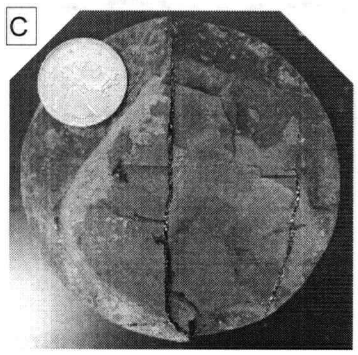


Figure 2.13: Fractures of the Nordegg Member. **A**: Major vertical fracture with calcite filling. **B**: Convex fractures with bitumen in-filling and calcite surrounding. **C**: Fractures with pure bitumen filling (viewed perpendicular to bedding; quarter coin for scale).

dissolution; Figure 2.14A) but vary in form from planar to convolute. Calcite predominantly occurs as authigenic, euhedral crystals (Figure 2.14D and 2.14E) which are occasionally twinned as a result of pressure effects (Adams *et al*, 1987). Fractured, calcite-lined clasts of non-calcareous mudstone within the limestone have an elongate horizontal form. TOC and sulfur values are low for the limestone bands (TOC ~ 0.2 wt% and S < 0.1 wt%).

2.7.2.3 Facies C: Marlstone

Facies C is a 12 m thick calcareous mudstone/marlstone which is finely laminated and more fossiliferous (shell-hash beds) than facies B. Within facies C there are thin interbeds (1-2 cm) of green silty-mudstone which are poorly indurated, non-calcareous and occasionally contain bitumen-filled fractures (Figure 2.15). Fractures are confined within the green silty beds.

Facies C mineralogy is rich in quartz and carbonate with a minor feldspars and clays. TOC values average 11 wt% (range 6 – 20 wt%), carbonate carbon values ranging from 5 - 47% and sulfur averages 2.5 wt%. Macerals are mainly alginite with lesser bituminite (Type II) and minor fusinite/semi-fusinite (Type IV).

2.7.2.4 Sub-Facies C-1: Silty calcareous mudstone

Sub-facies C-1 is a 2 m thick calcareous mudstone with scattered silt-sized quartz grains. The mineralogy is dominated by quartz (> 70%) and minor calcite, dolomite and smectite. There are trace amounts of francolite, pyrite, illite and potassium feldspar. Quartz occurs as lenses (Figure 2.16A) which were likely formed by the dissolution of

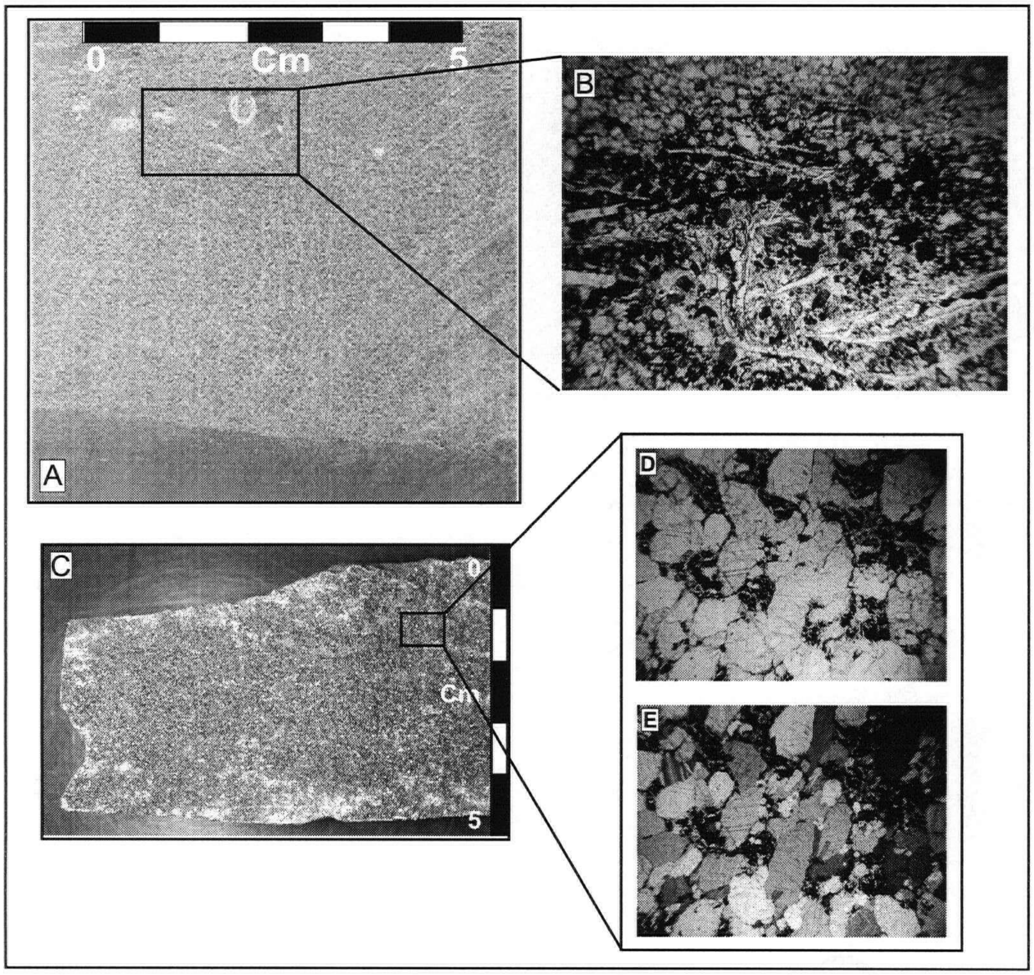


Figure 2.14: Facies B Limestone interbeds. **A**: Slabbed section of limestone/marlstone contact. **B**: Thin-section showing shell debris (x 45 magnification). **C** Non-slabbed microcrystalline argillaceous limestone (limestone sub-facies). **D**: Shows limestone which has been subjected to stress. Majority of calcite crystals are twinned caused as a result of pressure (ppl, x32 magnification). **E**: As D in xpl (x 32 magnification).

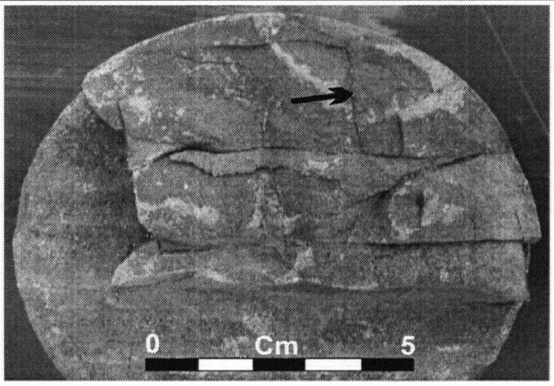


Figure 2.15: Green siltstone bed within facies C, view perpendicular to bedding. Arrow highlighting fractures filled with bitumen (Well: 200/c-074-J 094-A-10/00, 1083.8 m depth).

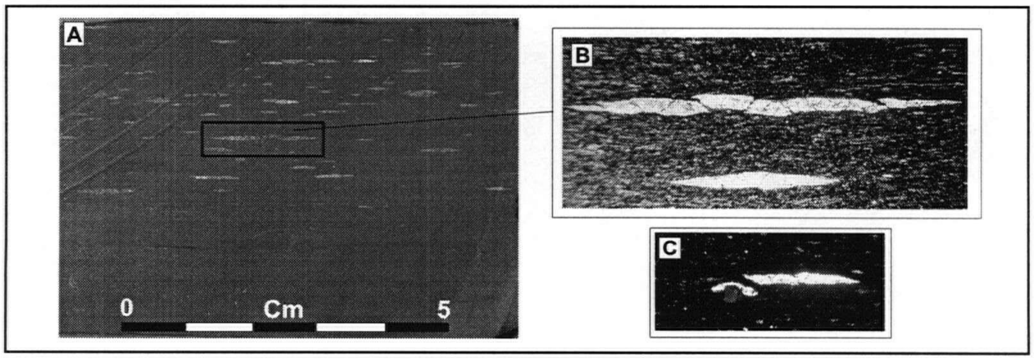


Figure 2.16: **A**: Diagenetic quartz lenses concentrated along bedding planes within sub-facies C-1(Well: 100/16-26-086-15W6/00, 1218.1 m depth). **B**: Thin section showing fracturing of quartz lenses (x 32 magnification). **C**: Curvilinear trace of lenses caused by compaction around phosphatic minerals.

detrital quartz (and/or biogenous silica) and subsequently reprecipitated along bedding planes. These lenses are fractured (Figure 2.16B) and contorted (Figure 2.16C).

The TOC content averages 12 wt% (range 7 – 19 wt%) which is primarily Type II (alginite-dominated) and minor type IV kerogen. Inorganic carbon values are low, ranging from 7-12 wt%. The sulfur content averages 2 wt%.

2.7.2.5 Sub-facies C-2: Siltstone

One metre siltstone units occur in the eastern region of the study area (81-14W6; Figure 2.8) which are generally massive, slightly calcareous with intergranular bitumen. TOC values associated with the siltstones are less than 1 wt%. Close to the subcrop belt, fine beds of facies C-2 are disrupted by rare bioturbation (wells 00/A-084-F/094-A-16/0, 00/A-058-K/094-A-16, 00/A-73-K/094-A-16; Figure 2.17A and 2.17B).

2.7.2.6 Facies D: Phosphatic Mudstone

A 2 m interval of finely laminated phosphatic mudstone-calcareous mudstone gradationally overlies the marlstone of facies C. Separating Facies D from facies C is a 60 cm band of argillaceous limestone (see facies B description for detail). Shell beds are occasionally present but less common than facies C. Facies D is quartz-rich (65 – 70%) with notable concentrations of calcite, francolite, pyrite, illite and potassium feldspar. Average TOC's are similar to facies B, averaging 5.6 wt% (range 4 – 8 wt%) with carbonate carbon values ranging from 25 ppm – 4%. Sulfur averages 1.9 wt% (range 0.5

– 2.8 wt%). The maceral composition is dominated by matrix bituminite and minor alginite and fusinite.

In the northeastern portion of the study area (wells 00/A-084-F/094-A-16/0, 00/A-058-K/094-A-16 and 00/A-73-K 094-A-16), facies D has pyritic layers and soft-sediment deformation features (Figure 2.17C).

2.7.2.7 Nordegg – Poker Chip Shale Contact

The Nordegg-Poker Chip Shale contact is a sharp, moderately indurated silty/sandy conglomerate and occurs in only 4 cores (Figure 2.18). The conglomerate is supported by a non-calcareous matrix with resedimented pyrite aggregates, irregular pyritic layers and lenses. Overlying the Nordegg is a dark grey/black – grey/green non-calcareous shale unit assigned to the Poker Chip shale.

2.8 GEOCHEMISTRY

2.8.1 Thermal Maturity

The thermal maturity of the Nordegg Member, based on Rock Eval T_{max}, increases towards the south-west (Figure 2.19). The maturity trends are as a result of the west to east propagation of deformation during the Laramide Orogeny (Bustin, 1991).

T_{max} values range from 440 ^{0}C in the north-east of the study area to greater than 550 ^{0}C in the southwest. T_{max} values less than 435 ^{0}C are considered immature, 435 ^{0}C to 455 ^{0}C indicates 'oil-window' conditions (i.e. mature) and 455 ^{0}C to 460 ^{0}C represent the overmature wet gas zone (Espitalie *et al*, 1985).

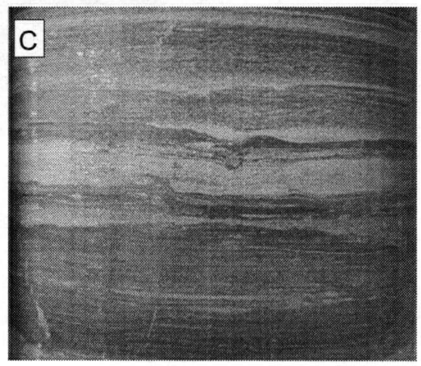


Figure 2.17: NE limit of Nordegg. **A & B**:Core photographs of the bioturbated fine sand/siltstone.
C: laminated mudstone of facies D with abundant pyrite and minor soft sediment deformation.

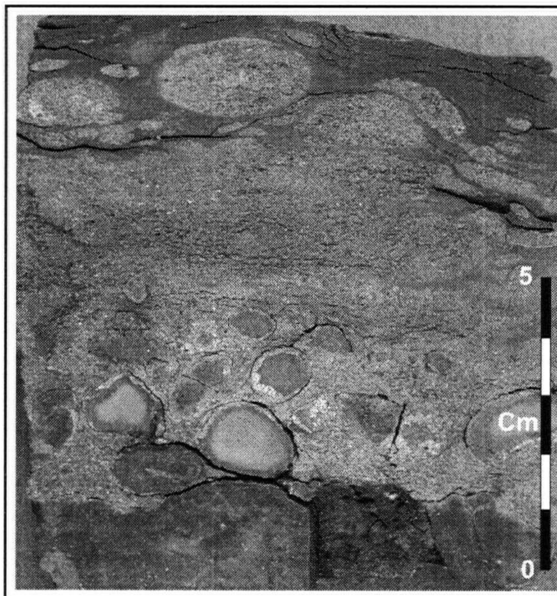


Figure 2.18: Silty/sandy conglomeratic contact between the Nordegg Member and Poker Chip Shale (Well: 100/06-05-088-15W6/00, 1082.7 m depth). Pyrite occurs as fine dissemenated particles or concentrated into clasts.

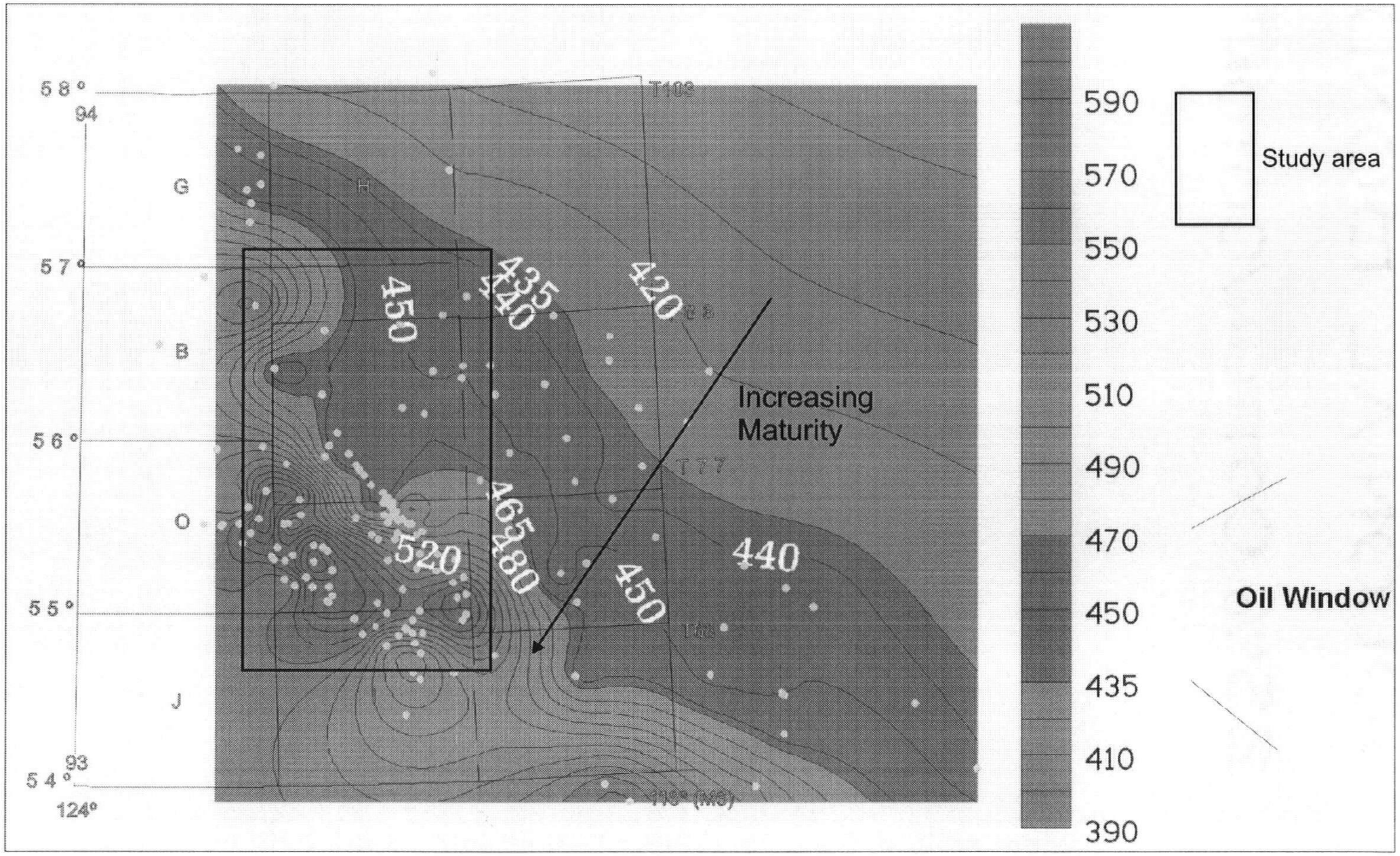


Figure 2.19: Maturity map of the Jurassic Nordegg Member across the Western Canadian Sedimentary Basin

2.8.2 Organic Carbon Distribution

Lithofacies B, C and D have distinct TOC contents. Due to the litho-geochemical association, the lithofacies are defined as litho-geochemical facies or LGF (using well 200/d-088-H 094-A-13 as the complete Nordegg section; Figure 2.20). LGF-B (facies B) has TOC contents ranging between 0-7 wt% with an average of 5.5 wt%, LGF-C (facies C) is richer in TOC with concentrations ranging between 6-20 wt%, averaging 11 wt%. LGF-D (facies D) has similar TOC concentrations to LGF-B, ranging between 1-8 wt%, averaging 5.6 wt%. The facies associations are readily distinguished on the gamma-ray log (increased gamma-ray response over LGF-B and LGF-D). Facies A is not included as it has insignificant TOC concentrations. In section 2.83, each litho-geochemical facies is discussed with reference to major and minor elemental concentrations and depositional environment.

2.8.3 Major and Minor Elemental Geochemistry

To determine the factors which influenced the organic matter distribution within the Nordegg, a variety of geochemical analyses were performed. The results of major and minor elemental analysis and carbon and sulfur concentrations for each of the three litho-geochemical facies are discussed. Major and minor elements were normalized to Al to investigate down-core variability in the composition of the detrital fraction. Therefore dilution effects by other sedimentary components (pyrite, organic matter) are eliminated as the Al represents the index of fine-grained aluminosilicate detritus in nearshore terrigenous sediments (Calvert, 1976). Carbonate-free basis normalization has also been used in limestones and marls (Baudin *et al,* 1999). However the level of Al

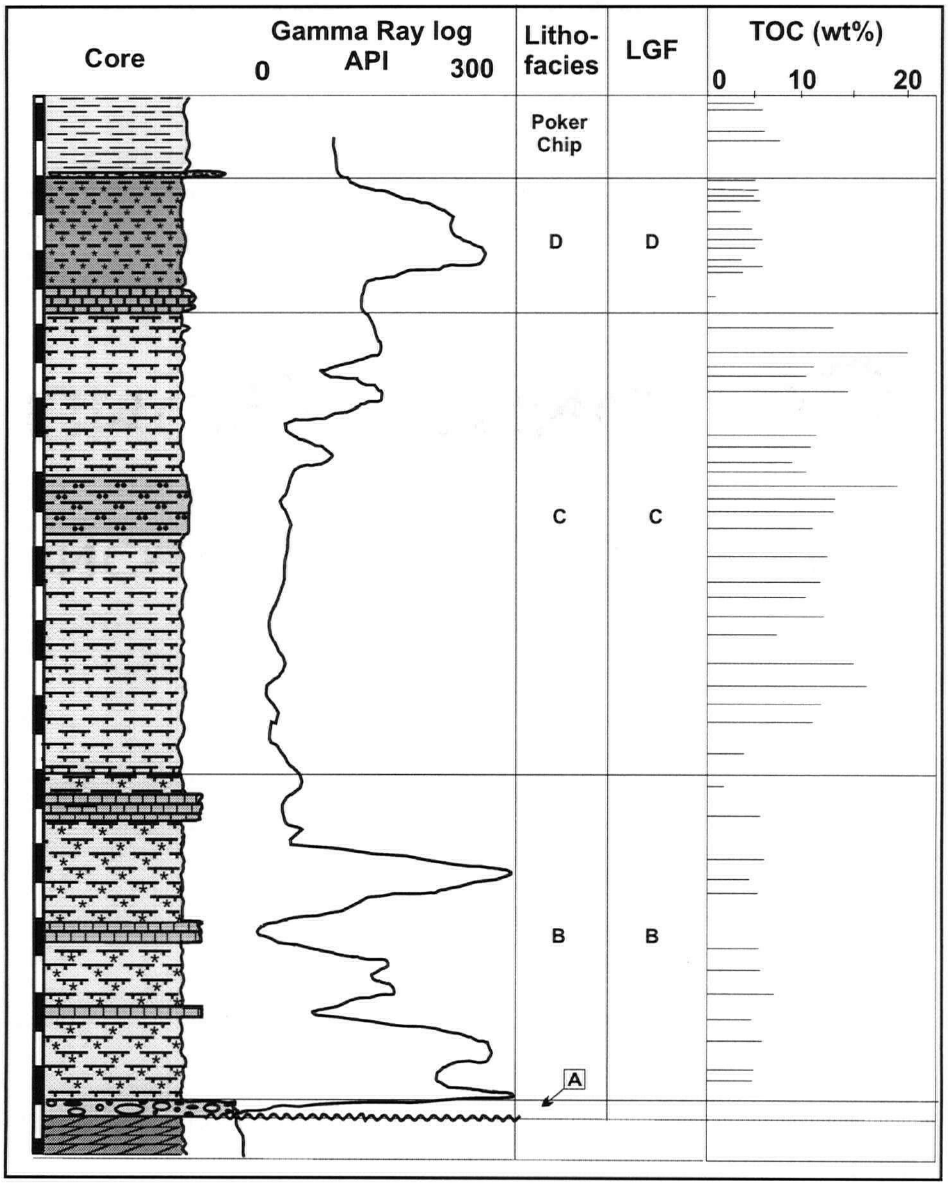


Figure 2.20: Litho-geochemical facies (LGF) of the Nordegg Member based on TOC concentrations (where facies B = LGF-B, facies C = LGF-C and facies D = LGF-D). Note the LGF are also recognizable from the gamma-ray log. Facies A is not included as it contains minor amounts of organic carbon.

concentration in the Nordegg reduces the possibility of artificially high element to Al ratios.

Major element concentrations provide an indication of clastic dilution levels into the depositional basin (e.g. Fe, K, and Si) or as grain-size indicators (e.g. Ti and Zr; Calvert *et al*, 1997). Many organic-rich rocks are further characterized by enrichments in certain trace metals, particularly Cd, Zn, V, Cu, and Ni (Dean and Arthur, 1986) which provide further insight into depositional conditions. Trace elements can be sygenetically enriched, either by plankton concentration from sea-water or absorbed onto the organic fraction that then accumulates in the sedimentary column (Vine and Tourtelot, 1970; Arthur et al 1990). Hypersaline marine environments can also cause enrichment of certain minor elements as has been suggested for the Kupferschiefer-Marl Slate deposits (Davidson, 1964). Many trace elements react and concentrate differently depending on oxygen levels in the sea water. Elements such as Cr and V have multiple valency states and varying solubilities (Calvert and Pederson, 1993) that change with oxic-anoxic conditions. Additionally, metals associated with organics are not necessarily lost through diagenesis, making the recognition and abundance of such elements an important indication of primary depositional conditions.

The elemental concentrations of the Nordegg are also compared with 'similar' organic-rich deposits from both modern and ancient settings including Cenomanian-Turonian black shales (CTBE shales; Arthur et al, 1990), Lower Aptian Fish Shale, (Hild and Brumsack, 1998) the Black Sea (Calvert, 1990) and the Gulf of California (Breheret and Brumsack, 2000).

2.8.3.1 Major Elements

The major element chemistry of the Nordegg Member is a mixture of carbonate and silica (Figure 2.21). A moderate-good inverse correlation coefficient (-0.66) exists between Ca and Si where silica contents vary between 4% (LGF-B) and 85% (LGF-C). All samples have a high SiO_2/Al_2O_3 ratio suggesting a minor clay-mineral component (Figure 2.22). An increase in the Si/Al ratio occurs in the central section of LGF-C (Figure 2.23) which correlates with the portion of LGF-C containing scattered quartz grains.

Ca correlates with the inorganic or carbonate carbon content ($r^2 = 0.82$; Figure 2.24A). Calcium and manganese have similar vertical trends in the core where the greatest concentration of Mn occurs within the limestone beds (Ca/Mn $r^2 = 0.68$), suggesting Mn fixation of carbonate phases (Hild and Brumsack, 1998). Mn/Al is slightly lower within the TOC-rich, silica-rich, carbonate poor samples (Figure 2.24B).

Fe, Ti and K correlate with Al and are related to the compositional variations of the aluminosilicate fraction (Figure 2.24, graphs C-E). LGF-B and LGF-D have a higher K/Al ratio due to the presence of minor potassium-feldspar and illite as identified by XRD.

The most significant stratigraphic shift in the bulk inorganic chemistry occurs in the upper portion of LGF-C. This interval is characterized by an increase in SiO_2. In the same interval, K/Al ratios decrease (proxy for illite content due to its importance as a potassium-bearing mineral phase) and Na/Al increases (proxy for smectite /montmorillonite; Figure 2.23)). The K vs. Na plot also shows a negative correlation (-

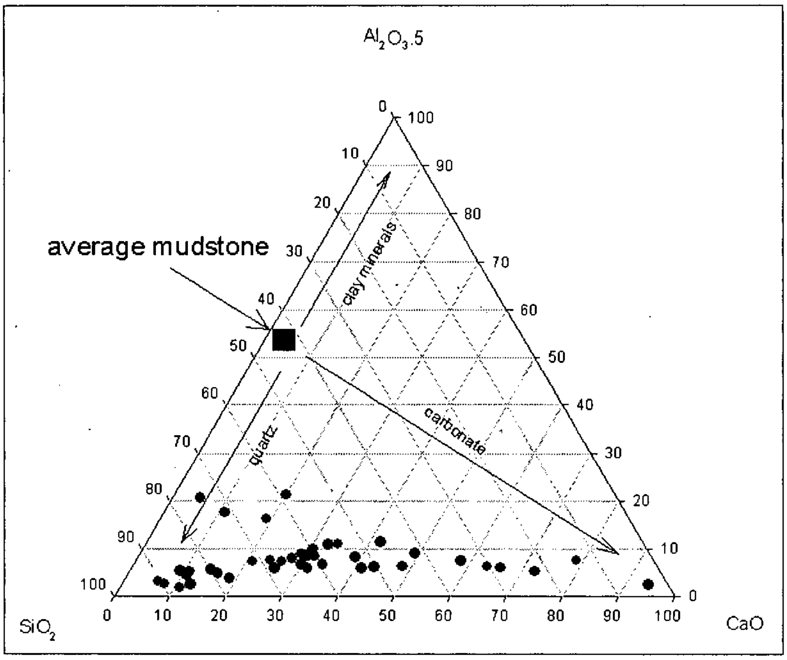


Figure 2.21: Al_2O_3 - SiO_2 - CaO ternary diagram of Nordegg core samples. Samples are characterized by a bimodal composition distribution of Si and Ca with low aluminosilicate fraction compared to average mudstone (average composition taken from Wedepohl, 1971).

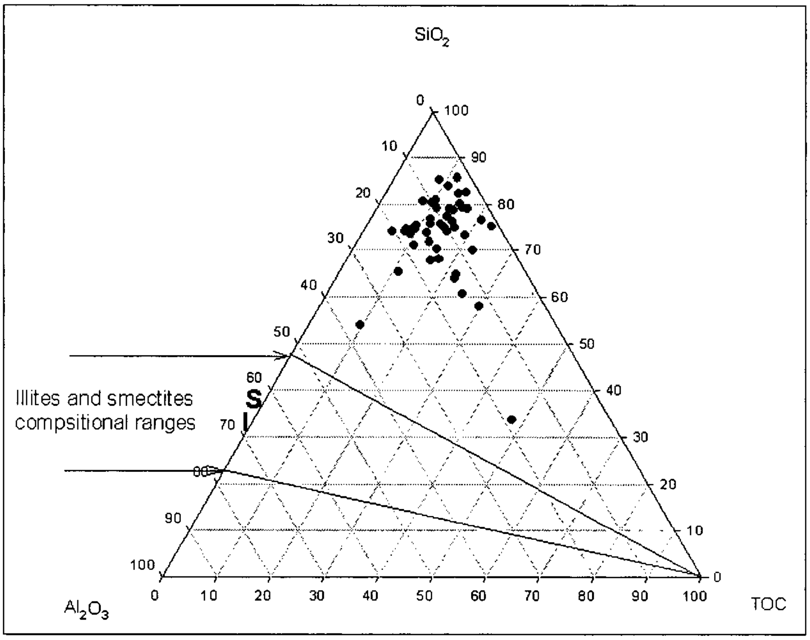


Figure 2.22:Three component system with elevated SiO_2 / Al_2O_3 ratio indicating low Illite, smectite and interstratified illite/smectite. (Clay mineral composition based on data from Weaver, 1989).

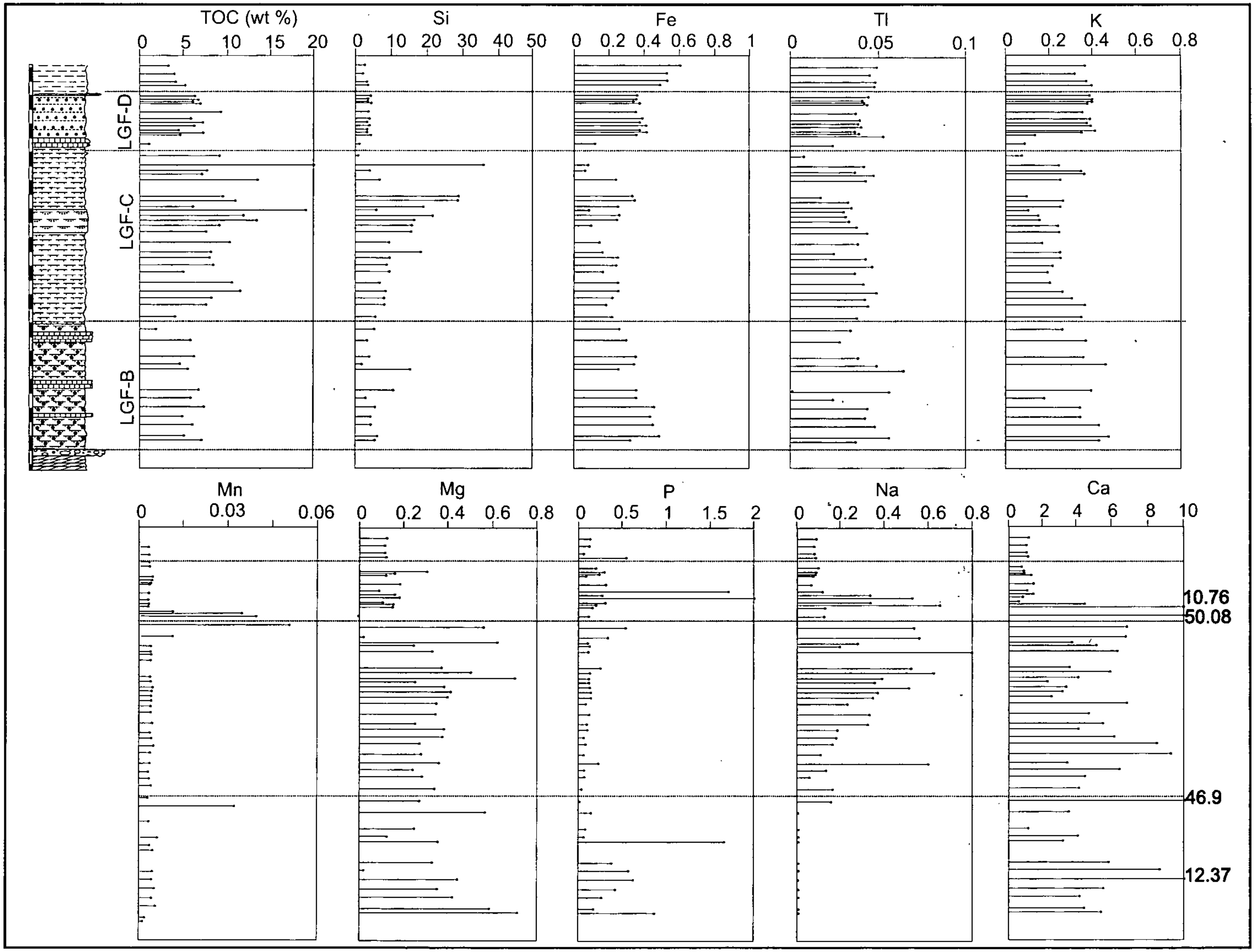


Figure 2.23: Vertical distribution of major elements (normalized to Al as %) in well 200/d-088-H 094-A-13

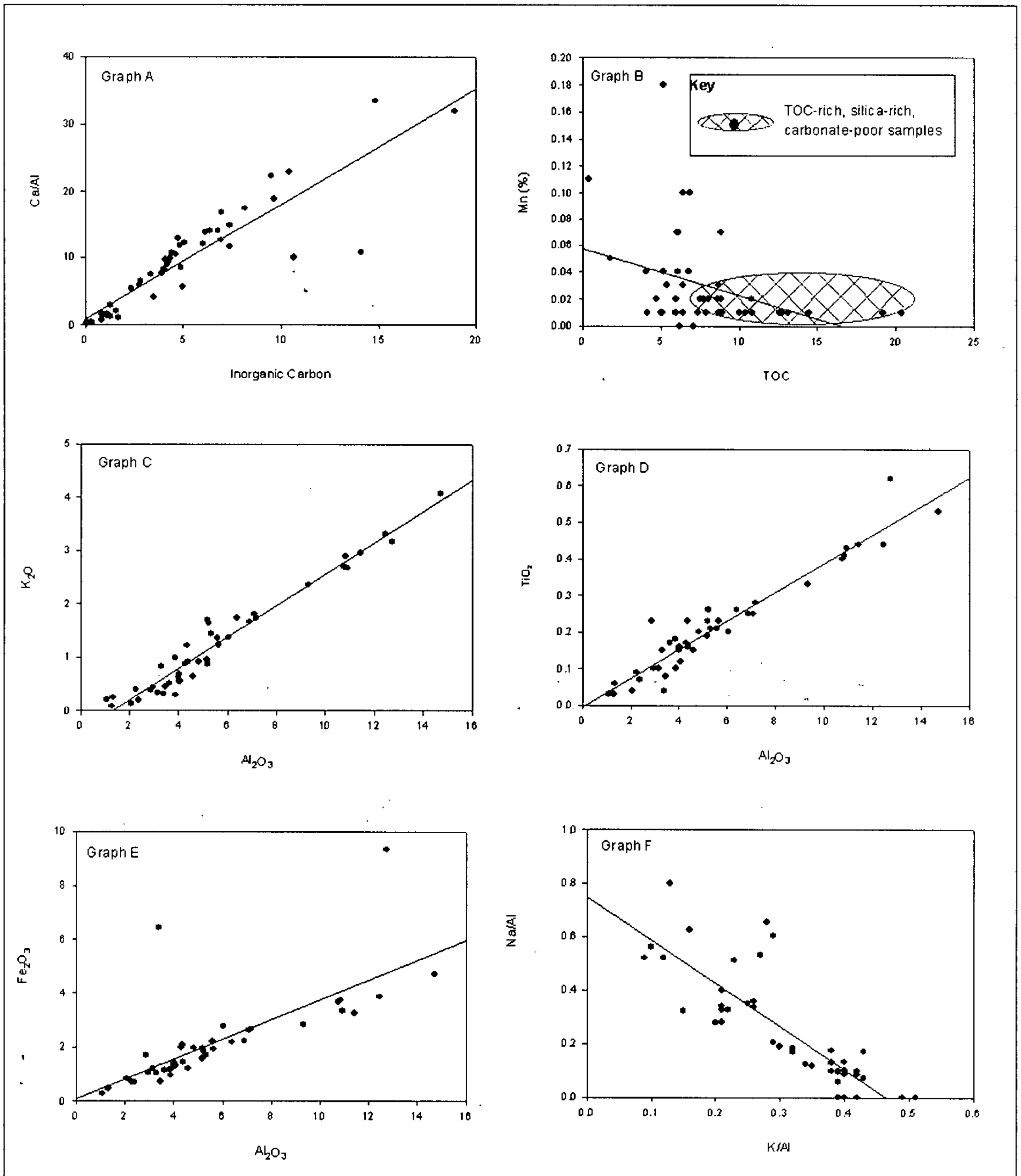


Figure 2.24: **A**: Strong correlation between inorganic carbon (measured by columetry) and CaO (XRF data). **B**: High TOC values associated with low Mn concentrations (low carbonate). **C-E**: K, Ti & Fe plotted against Al - good correlation with Al suggests these elements have a detrital source.
F: Inverse correlation between K and Na due to variable proportions of smectite and illite.

0.7; Figure 2.24F) where there is a change to a smectite or I/S mixed-layer assemblage at the expense of illite in LGF-C (based on XRD data).

P levels are higher in LGF-B and LGF-D which have slightly lower TOC values (Figure 2.23). The elevated phosphate is related to the concentration of francolite ($Ca_{10}(PO_4)_6F_2$) in these sections which are also enriched in uranium (as identified by spectral gamma-ray log; Figure 2.25).

Mg levels are slightly higher in LGF-C which inversely correlates with the P_2O_5 concentrations (associated with francolite). In modern marine environments, the rate of Mg phosphates nucleation is several orders of magnitude lower than that of Ca phosphates (Golubev *et al*, 2001). Therefore Mg suppresses phosphate precipitation. The concentrations of Mg can be in part attributed to dolomite (as within the basal Nordegg) and clay mineralogy (the Mg/K ratio increases in LGF-C which supports the XRD data as the smectite is Mg-rich).

2.8.3.2 Carbon – Sulfur - Fe Relationships

C/S plots have been used to decipher freshwater, marine and euxinic conditions (Berner and Raiswell, 1984; Leventhal, 1987). Sediments deposited under oxic conditions have a S/C ratio of 0.4 and a ratio above 0.4 is indicative of euxinic environments (Berner and Raiswell, 1984).

The S/C ratio for the Nordegg are higher in LGF-B and LGF-D than LGF-C – ranging between 0.4-0.6. LGF-C (greatest TOC population) has a S/C ratio of 0.2. A moderate-good correlation between Fe and S suggests pyrite is the most important phase for sulfur storage (Figure 2.26A) and accounts for the S distributions. A plot of carbon

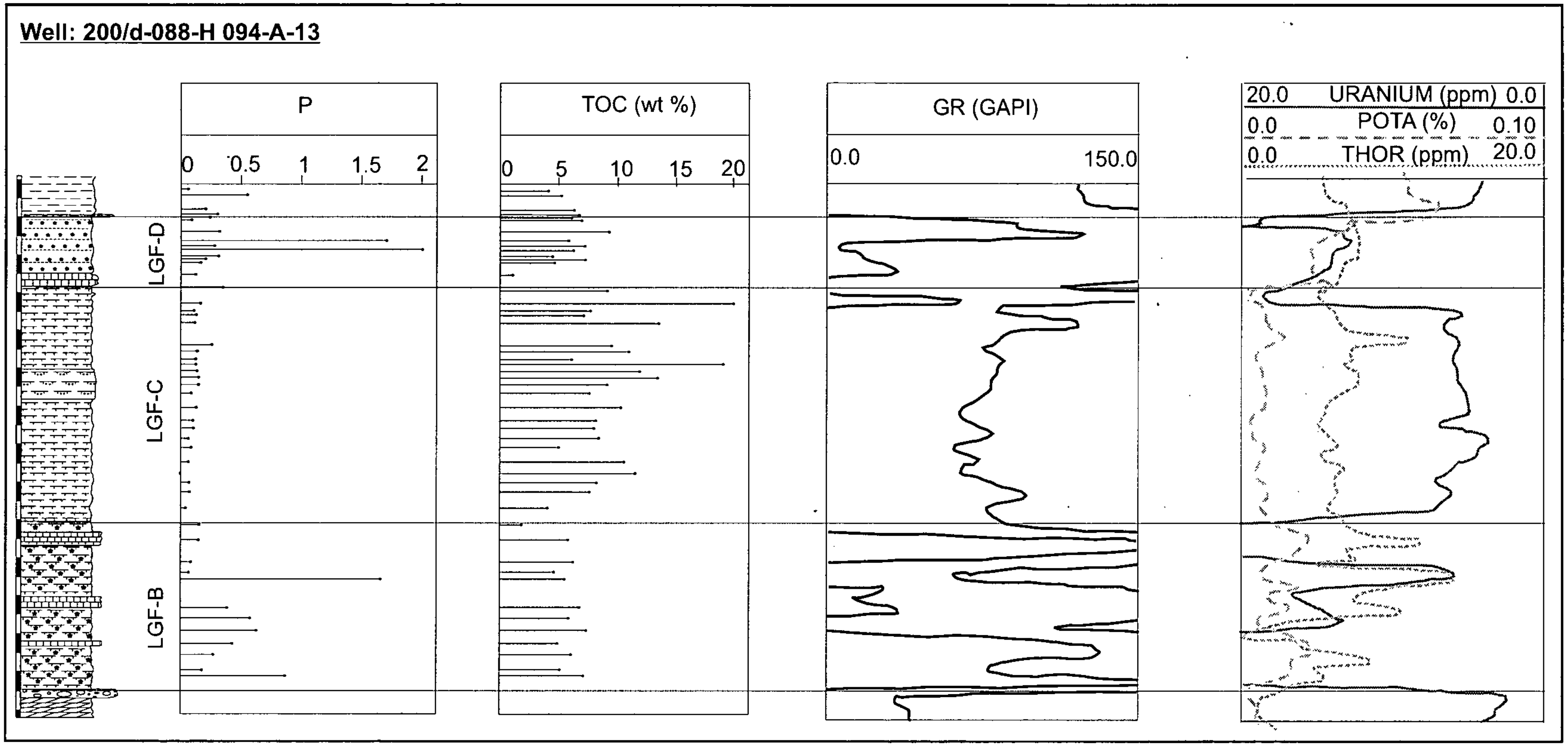


Figure 2.25: Relationship between phosphate, TOC and uranium concentrations

vs. sulfur shows no clear trend (Figure 2.26B) and most values plot below the normal marine line. The lack of correlation is probably caused by the non-uniformity of depositional conditions within the basin and Fe-limitation of pyrite formation.

TOC and S_{org} (calculated by subtracting 0.803 x $Fe2O_3$ from total S) show a moderately good correlation (Figure 2.26C). The organic-bound part of the S content only represents 20% of the total sulfur content. S_{org}/C_{org} ratios vary from 0.04 to 0.12 for most of the Nordegg. S_{org}/C_{org} ratios >0.04 are classified as sulfur-rich kerogen (Orr, 1986), characteristic of highly sulfuric marine conditions (Riediger and Bloch, 1995). The significant concentrations of organic matter in the Nordegg suggest sulfate reduction continued after all the Fe had been pyritized, producing S-rich OM. Samples from LGF-D have S_{org}/C_{org} ratios of 0 due to the higher Fe concentrations.

In a Fe-TOC-S diagram, Nordegg samples plot approximately on a line extending from the TOC corner to the Fe-S line (Figure 2.26D, ternary plot) indicating a constant Fe/S ratio and variable TOC content. The slight deviation of the TOC-S line towards the Fe corner indicates a minor portion of the available Fe was unreactive.

2.8.3.3 Minor Elements

LGF-B is enriched in V, Cr and Zn and both Cr and Zn show a good correlation with V (Figure 2.27). V concentrations decrease by an order of magnitude in LGF-C and increase slightly in LGF-D. When V, Cr and Zn concentrations of the Nordegg litho-geochemical facies from core 200/d-088-H 094-A-13/00 are compared with cores across the study area, comparable trends occur. Within LGF-B and LGF-D, there are enrichments of V, Cr and Zn, which are depleted in LGF-C.

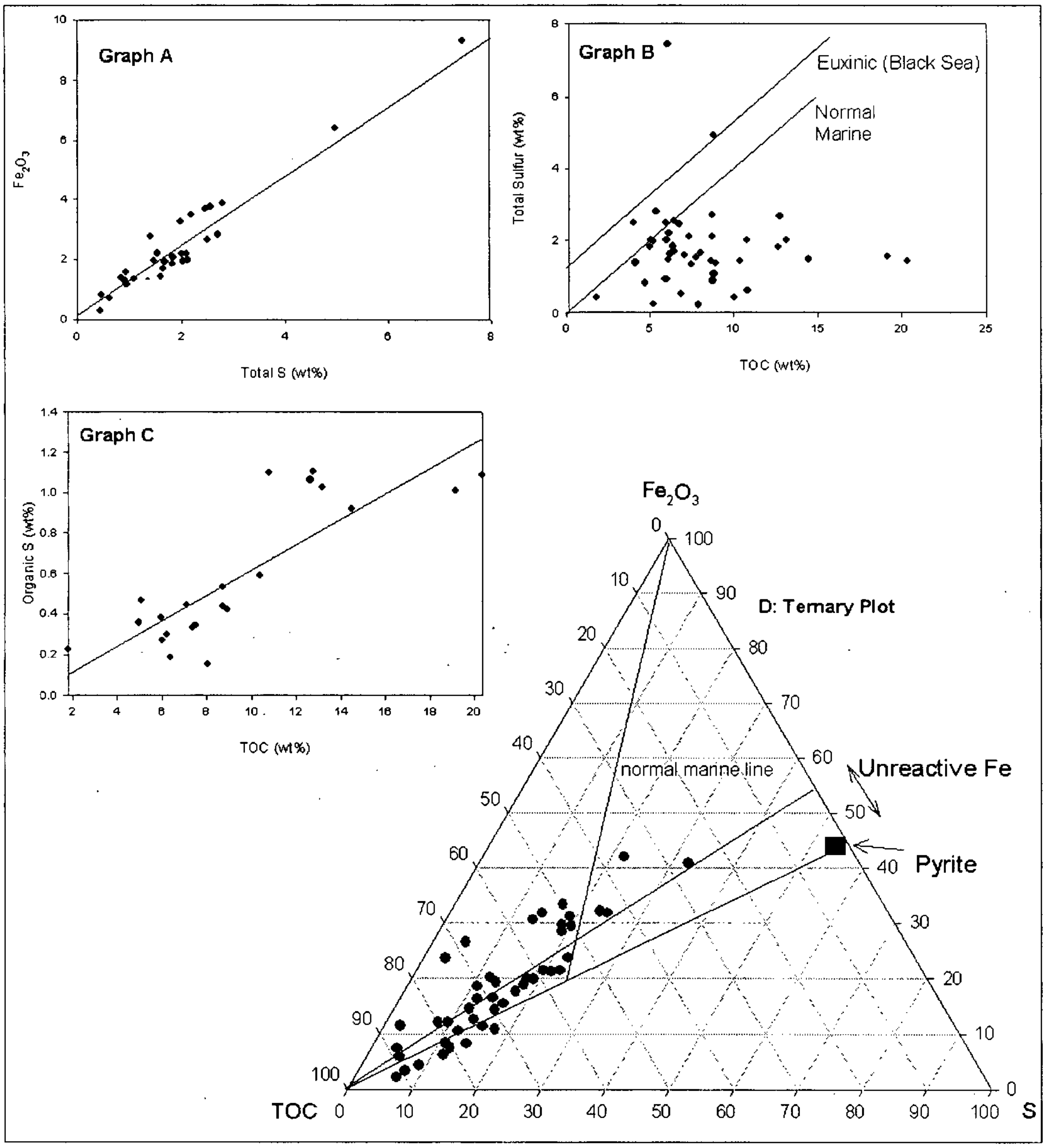


Figure 2.26: Fe-TOC-S relationships. **A**: Correlation between Fe and S suggesting pyrite being the important phase of sulphur storage. **B**: Carbon-sulfur plot - most samples plot below the normal marine line (see text for discussion; from Leventhal, 1987). **C**: Mod-good relationship between organic sulfur and TOC for the Nordegg. **D**: Fe-TOC-S ternary diagram indicating limitations of pyrite formation. The normal marine line (S/C = 0.4) and the pyrite line are displayed.

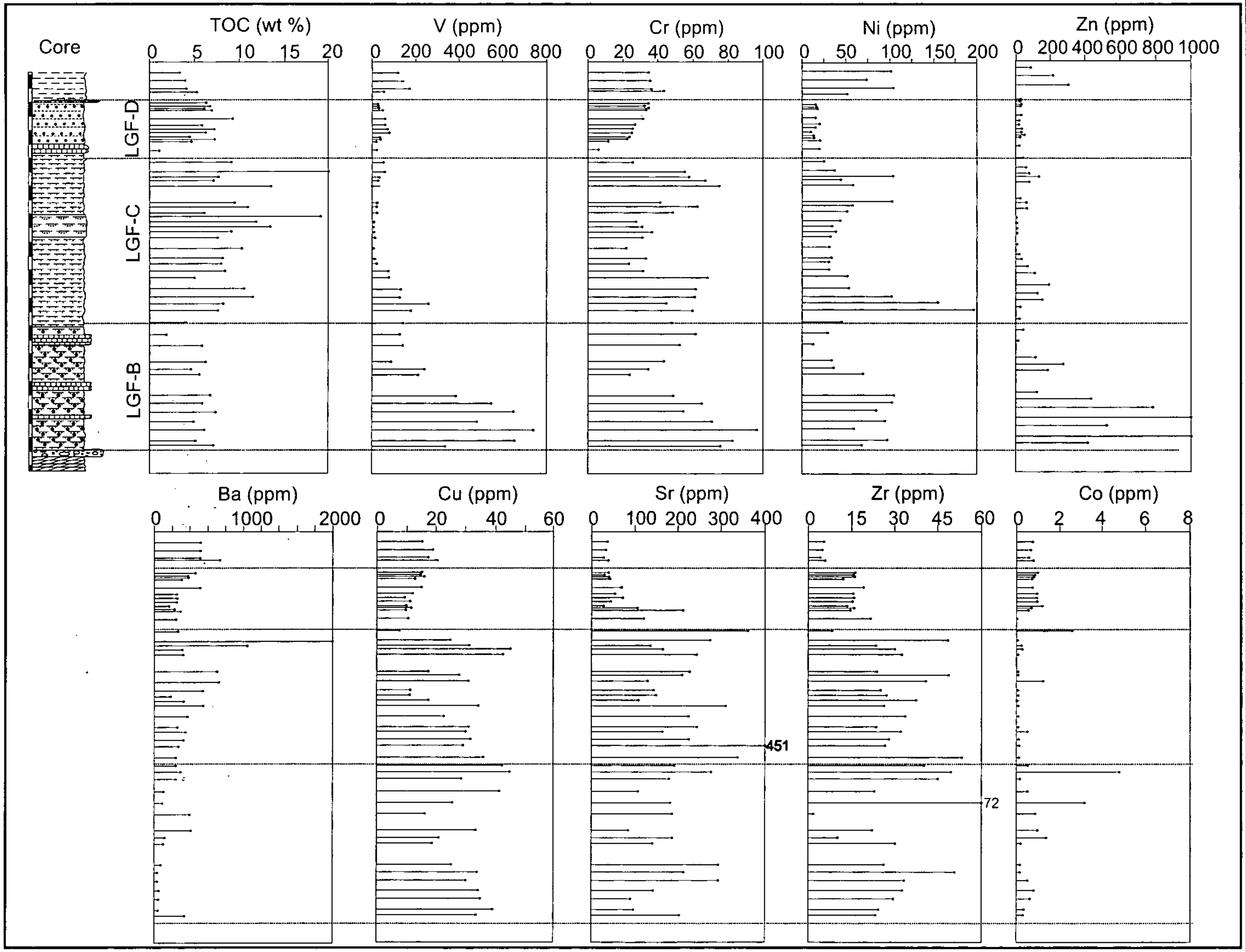


Figure 2.27: Depth profiles of carbonate, TOC and selected trace metals of well 200/d-088-H 094-A-13 (all elements normalised to Al).

Ni concentrations are variable throughout the Nordegg but, on average, are higher in LGF-B. Despite elevated Ni concentrations at the base of LGF-C, the Ni/Al ratio is similar in both LGF-C and LGF-D.

Barium concentrations of up to 1571 ppm were measured in the Nordegg Member, increasing steadily from approximately 350 ppm in LGF-B, to over 1500 ppm in LGF-C. Ba/Al ratios are four times greater in LGF-C compared to LGF-B and twice as much found in LGF-D.

A high Sr concentration in LGF-B and the lower portion of LGF-C reflects the higher carbonate concentrations (Figure 2.28A). Sr substitutes for Ca in the calcite lattice and is common in high-carbonate rocks (Wedepohl 1971). The upper LGF-C is siliceous (low carbonate) which correlates with a decrease in Sr. Low Sr in LGF-D is expected due to the low carbonate content of the mudstone.

A moderate correlation between Y/Al and P/Al exists ($r^2 = 0.69$). Yttrium is frequently found in phosphatic sediments, substituting for Ca in the inorganic phosphate mineral francolite (Calvert *et al*, 1996). Rb correlates well to K, Ti and Al (r^2=0.77; Figure 2.28B) suggesting a detrital origin. Co concentrations are higher in LGF-B and LGF-D compared to LGF-C reflecting a detrital origin.

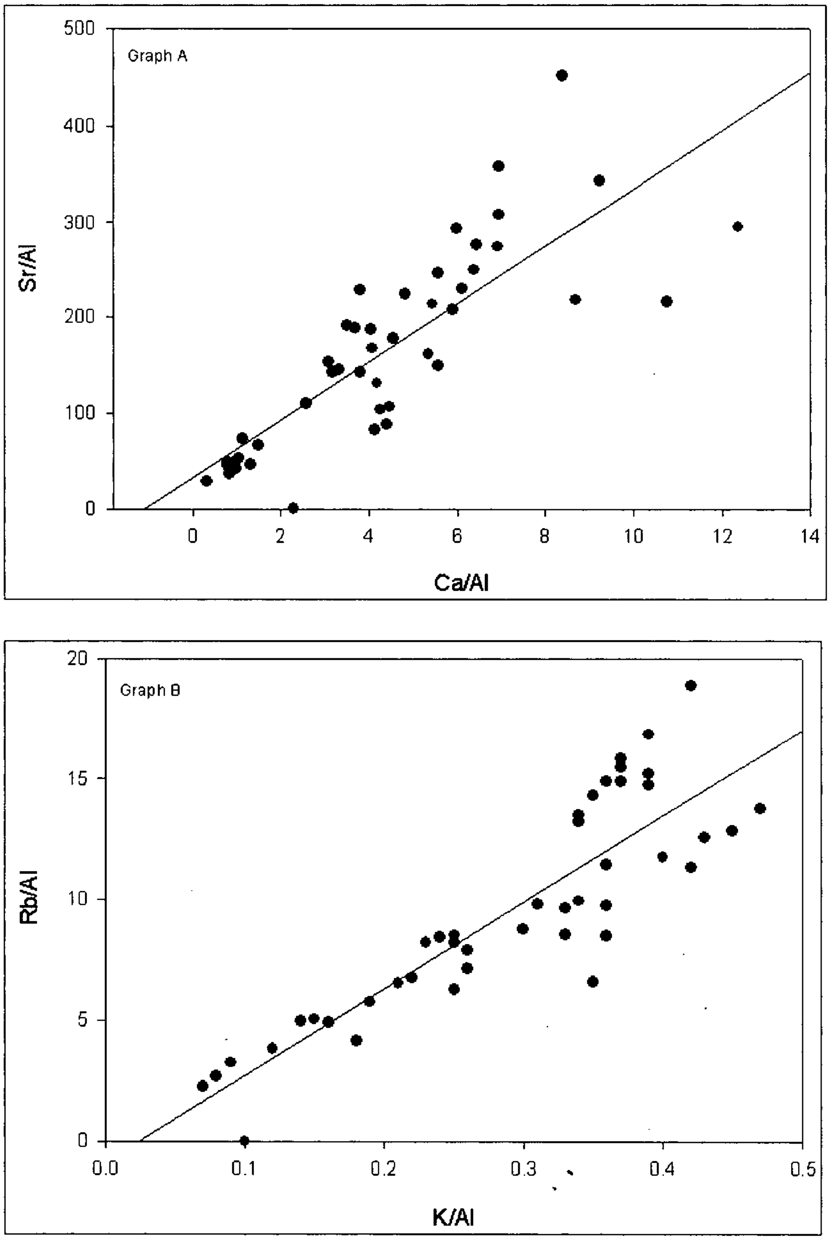


Figure 2.28: **A:** Correlation of Ca/Al with Sr/Al indicating Sr substitution for Ca in the calcite lattice which is common in high carbonate rocks. **B**: Good correlation between K/Al with Rb/Al for the Nordegg suggesting a detrital source for Rb

2.8.4 Geochemical Discussion

Using geochemical and mineralogical analysis, various aspects of depositional conditions can be interpreted for the Nordegg Member. Five observations are important for this discussion:

i) the highest TOC's are in Si-rich sections (LGF-C)

ii) lower TOC concentrations are associated with phosphate enrichments (LGF-B and LGF-D)

iii) LGF-C is characterized by low Al, Fe, K and Ti concentrations (detrital proxying elements) compared to LGF-B and LGF-D

iv) grain-size variations do not appear to have a significant control on the accumulation or preservation of OM

v) there is no correlation between IC and TOC, indicating carbonate dilution is not a factor in TOC variations

All Nordegg facies have mod-high TOC (4-20 wt%), fine parallel lamination, pyritic and rare bioturbation. For those reasons, other factors in conjunction with anoxia must exert a control on OM preservation in the Nordegg.

2.8.4.1 Discussion: Major Element Distributions

The enrichment of Si in TOC-rich sediments (LGF-C) is evidence against a detrital source for the quartz and points towards a diagenetic silica precipitate. Average Si concentrations in the Nordegg are three times as great as found in the organic-rich Fish

Scale (deposited in an anoxic/stagnant basin; Hild and Brumsack, 1998) and average shale (Wedepohl, 1971; see Table 2.2). The silt-sized nature of the quartz grains may represent a change in the pH of the porewater. At low pH, silica is less soluble than calcite thereby preserving biogenous silica which recrystallizes to quartz (Krauskopf, 1959).

Increased concentrations of Fe, K and Ti within LGF-B and LGF-D indicate clastic dilution (due to their good correlation with Al) was greatest during the initial and final stages of Nordegg deposition. The higher Ti/Al ratios in LGF-B and LGF-D may reflect the Ti associated with clay minerals within these sections. On average however, Ti and Fe are depleted in comparison with other organic-rich units (Table 2.2) indicating a consistent, lower detrital input/sediment starved conditions. Furthermore a constant Fe/S component represents an iron-limited sedimentary sequence (Arthur and Sageman, 1994) typical for oxygen-deficient, low detrital component environments at the time of deposition.

LGF-B and LGF-D contain elevated P, where francolite content is highest. Significant P_2O_5 concentrations suggest an environment with low-modest sedimentation rates, nutrient-rich (highly productive) and sub-oxic (Dypvik, 1984; Suess *et al*, 1987). P levels also correlate with uranium. In an anoxic environment, brief oxygenated episodes are required for francolite precipitation (formed in an early diagenetic marine environment; McClellan and Kauwenbergh, 1990) which subsequently takes up dissolved uranium (Fisher and Wignall, 2001) as U substitutes for Ca (Arabi and Khalifa, 2002).

The dysoxic conditions required for U enrichment in phosphate may have been produced by the initial transgression across the Baldonnel/Pardonet which disrupted the

Table 2.2: Inorganic geochemical comparison of TOC-rich rocks and sediments. Selected major elements and element/al ratios of the Nordegg Member, Cretaceous Black Shales, Gulf of California sediments, average shale and the Fish Shale from NW Germany.

	Nordegg								
Element	LGF-B*	LGF-C*	LGF-D*	Av: LGF-B + LGF-D**	CTBE[1]	Gulf of Calif[2]	Av. Shale[3]	Fish Shale[4]	Black Sea[5]
SiO2, %	43.7	62.1	49.2	46.45		62.6	58	27.5	
Al2O3, %	7.9	5.5	12.5	10.2	5.7	8.91	16.8	12	
Fe2O3, %	3	2	3.8	3.4		3.07	6.9	6.83	
K2O, %	1.8	0.8	2.9	2.35		1.66	3.4	1.49	
CaO, %	32.7	21.4	12.9	22.8		2.07	2.3		
MnO, %	0.03	0.028	0.114	0.072	0.018	0.019	0.11	0.122	
MgO, %	2.1	1.5	1.7	1.9		1.58	2.6		
TiO2, %	0.3	0.2	0.4	0.35		0.39	0.78	0.47	
P2O5, %	3.9	2.3	5.8	4.85					
Na2O, %	0.3	1.1	0.9	0.6			2.1		
TOC, %	5.9	10.2	5.6	5.75	9.3	4.35	0.2	4.56	3.89
S, %	1.9	1.63	1.9	1.9	1.8	0.56	0.2	3.64	1.05
Si/Al	5.7	13.5	4.7	5.2		6.3	3	2	2.86
Fe/Al	0.43	0.41	0.5	0.465		0.46	0.54	0.75	0.65
K/Al	0.36	0.23	0.4	0.38		0.29	0.32	0.25	0.25
Ca/Al	8.44	5.11	4.9	6.67		0.31	0.18	7.88	
Mn/Al	0.008	0.006	0.07	0.039	0.005	0.004	0.01	0.015	
Mg/Al	0.35	0.36	0.3	0.325		0.2	0.18	0.22	
Ti/Al	0.04	0.04	0	0.02		0.049	0.053	0.044	0.053
P/Al	0.53	0,2	0.5	0.515		0.022	0.008	0.006	0.013
Na/Al	0.09	0.09	0.1	0.095		0.23	0.18		

*/** This study (n=46; element concentrations and ratios on weight basis)

[1] Arthur *et al* (1990); Nijenhuis *et al* (1999)
[2] Breheret & Brumsack (2000)
[3] Hild & Brumsack (1998)
[4] Wedepohl (1971); Breheret & Brumsack (2000); Warning & Brumsack (2000)
[5] Brumsack (1988)

stratified water column causing a mixing effect, subsequently producing temporary dysoxic conditions. Dysoxic conditions could also result from times of lower productivity associated with a drop in the biological oxygen demand (Pufahl and Grimm, 2003). In these occasions, the oxic/anoxic boundary lowers into the sediment which provides an environment for sulfur-oxidizing, P-fixing bacteria. Release of P into dysoxic zones was induced by the microbial breakdown of OM which sources and transports phosphate to the sea-floor (Ingall and Van Cappellen, 1990; Filippelli, 2001). Dissolution of fish debris also contributed P during Nordegg diagenesis.

In modern marine environments, *Beggiatoa* spp. which oxidizes sulfur, occupies low O_2 bottom waters and stores the released P (Hagen and Nelson, 1997). The oxidation of sulfide provides a source of sulfate for sulfate-reducing bacteria, leading to anoxic conditions (Bruchert *et al*, 2003). This combined with increasing OM productivity (high BOD) in surface waters would raise the chemocline back to the sediment-water interface or even into the water column – producing a coupled productivity/redox cycle. The alternating redox conditions are suggested by the co-occurrence of francolite with pyrite and mod-high TOC's. During these times, phosphogenesis occurred at the oxic-Fe-reduction interface (MacQuaker, 1994). Francolite precipitation is initially restricted to the upper-parts of sediments as high carbonate alkalinity with depth reduces more phosphate formation (Glenn and Arthur, 1988).

Coeval phosphogenesis and minor sediment reworking during Nordegg deposition is indicated by the phosphatised lenses, fossil debris and detrital quartz inclusions (Follmi, 1996). Many phosphate pellets are elongate, indicating soft-sediment compaction effects. The size (mm size range) and nature (compaction) of the phosphate imply a relatively rapid transgression (with relatively high productivity) which would not allow sufficient time for proper phosphate generating conditions (Heckel, 1980).

High productivity likely occurred during the initial and final stages of Nordegg deposition (LGF-B and LGF-D) where nutrient availability was enhanced by upwelling currents from the west. Basinal conditions are still interpreted to have been slightly restricted as indicated by lower P_2O_5 and U concentrations compared to other phosphatic deposits (e.g. Red Sea and Nile Valley; Arabi & Khalifa, 2002). During LGF-B and LGF-D deposition, sedimentation rates were low, increasing the probability for the organic matter to be oxidized (Calvert, 1987). The increased oxygen levels accounts for the lower TOC values observed in LGF-B and LGF-D. LGF-C has lower phosphorous concentrations than LGF-B and LGF-D which may be the result of an O_2 restricted environment (as P can be released by sediments under reducing conditions; Kumar *et al*, 1996) and reduced input from upwelling nutrient-rich waters into the basin.

The presence of Mn-bearing carbonates, primarily within in LGF-B also implies times of dysoxia during Nordegg deposition. Mn carbonates typically form in environments where oxide-enriched surfaces overlay anoxic sediments (Calvert and Pederson, 1996). Oxide surfaces are common in many near-shore environments but the Mn-carbonate phase is more widespread. The TOC values of these limestone bands are low (< 1%) indicating OM could not be preserved. Low Mn concentrations within TOC-rich sections illustrates Mn was quickly fixed into the carbonate phase where at times, the sediments may have been undergoing intense bacterial sulphate reduction (Breheret and Brumsack, 2000). Mn removal from TOC-rich sediments would have only been made possible when sub-oxic water masses were removed from the Nordegg basin, likely caused by increasing sill-depths.

2.8.4.2 Discussion: Minor Element Distributions

LGF-B has a significantly high V accumulation similar to CTBE black shales and higher than the modern-day euxinic environment of the Black Sea (V/Al ~ 29; Brumsack, 1988; Table 2.3). Both Cr and Zn show good correlation with V indicating similar incorporative mechanisms (V/Cr r^2 = 0.63, V/Zn r^2 = 0.73). Reducing conditions typically favours the metallation of organic matter with V, Zn and Cr (Brumsack and Gieskes, 1983; Breit and Wanty, 1991). In such circumstances, for example, V is reduced to the vanadyl ion (V(IV)) which forms strong bonds with the OM (Wehrli and Stumm 1989). However, due to the phosphogenetic conditions which occurred during LGF-B, and high Co concentrations (across the O_2/H_2S boundary, transition metal concentrations (e.g. Co) increase due to the increased solubility of the reduced species; Emerson and Skei 1985) continuous anoxic bottom waters are unlikely.

The increased influx of metal-rich OM from upwelling during LGF-B deposition supported high levels of bacterial sulfate reduction in the sediment, releasing phosphate to precipitate francolite. At the same time, V, Cr and Zn remained strongly bound to the OM. LGF-D has comparable P levels to LGF-B but is not as significantly enriched in V, Cr and Zn. Therefore depletion does not appear to be strongly linked to nutrient level variation. The greater abundance of V, Cr and Zn within LGF-B to LGF-D probably reflects the greater availability of these elements to complex with the OM (i.e. sufficient concentrations in sea-water). Despite low concentrations of these elements in present-

Table 2.3: Selected minor elements and element/Al ratios of the Nordegg Member (subdivided into 3 organic facies) and Cretaceous Black Shales, Gulf of California sediments, average shale and the Fish Shale from NW Germany (for references see Table 2.2)

Element	Nordegg								
MINORS	**LGF-B***	**LGF-C***	**LGF-D***	**Av: LGF-B + LGF-D****	**CTBE[1]**	**Gulf of Calif[2]**	**Av. Shale[3]**	**Fish Shale[4]**	**Black Sea[5]**
V, ppm	1265	89	308	917	647	101	130	401	141 (415)
Cr, ppm	278	129	187	232	122	44	95	89	138
Zn, ppm	1666	198	190	928	1273	88	115	147	57
Co, ppm	3.8	2.15	5.8	4.8	38	7	19	15	27 (51)
Ni, ppm	244	186	102	173	145	38	68	102	97
Cu, ppm	122	91	82	102	190	27	39		87
Rb, ppm	38	23	98	68			150		
Sr, ppm	689	662	397	543	434	167	230		
Y, ppm	93	77	73	83					
Zr, ppm	116	112	105	110			200		
Ba, ppm	354	1464	1571	963	610	566	650	248	624 (1240)
Pb, ppm	32	37	28	30	16	17	22	51	
V/Al	675	44	61	368	268	21	15	63	
Cr/Al	130	62	66	82	46	9	11	14	
Zn/Al	647	44	55	344	460	19	13	23	
Co/Al	1.51	0.89	1.05	1.2	7.8	1.4	2.1	2.4	
Ni/Al	105	69	24	64	60	8	8	16	
Cu/Al	54	41	17	35	71	5.8	4.4		
Rb/Al	19	10	17	18		17			
Sr/Al	689	328	397	253	448	35	26		
Y/Al	93	41	73	30					
Zr/Al	58	43	22	40			22		
Ba/Al	164	799	347	256	279	121	73	39	
Pb/Al	14	20	8	11	5.3	2.5	8		

day sea-water, if the time period was long enough and sedimentation rates were low, trace metals can be efficiently concentrated at the O_2/H_2S boundary (Arthur *et al*, 1990). At the boundary, redox sensitive and stable sulfide forming elements can be trapped. There is no evidence of any volcanic or terrestrial detritus suggesting neither were important mechanisms for trace element enrichment (Nijenhuis *et al*, 1999). High Zn concentrations are not surprising as phytoplankton can concentrate up to 3000 ppm (Bostrome *et al*, 1974).

Increased concentrations of V, Cr and Zn occur in the same facies where bituminite is the dominant liptinite maceral (LGF-B and LGF-D). Samples which are bituminite-rich have approximately nine times the concentration of V and Zn and three times as much Cr. These trace elements adsorb onto the organic matter which in these litho-geochemical facies are the result of bacterial decay of the alginite precursors. Therefore the higher levels of certain trace elements may be the result of greater organic recycling and not necessarily low O_2 conditions. This is indicative of upwelling environments which occurred during initial and final stages of Nordegg deposition.

LGF-C has TOC ranging from 8-20%, higher than LGF-B and LGF-D. Elements such as V, Cr and Zn are also depleted in LGF-C whereby the supply of such trace metals to sea-water and low affinity to alginite were the controlling factors in metal-depletion.

Barium is high in LGF-C where concentrations are four times greater than LGF-B. The elevated Ba concentrations in LGF-C coincide with an increase in TOC and Si where there is a moderate correlation between TOC and Ba ($r^2 = 0.52$). As such, the Ba concentrations may be in part due to biogenic barite which gets delivered to the sea-floor in the form of a microcrystalline barite precipitate within organic matter (into the skeletons of siliceous planktonic organisms; Bishop, 1988). However, under reducing conditions, barite is secondarily solubilized when there is a lack of dissolved sulfate in porewaters (Brumsack, 1989). During LGF-C deposition, conditions were anoxic/reducing (as indicated by sulfur-rich OM and pyrite) and Ba remobilization likely occurred. Hence the biogenic barite only explains part of the Ba concentrations. The higher Ba/Al ratios in LGF-C may be further explained by the differences in the aluminosilicate fraction.

2.9 DEPOSITIONAL ENVIRONMENT

The Nordegg Member was deposited west of a high-standing carbonate platform (Poulten *et al*, 1990). In the study area, the Nordegg represents the basinal facies to the Nordegg platformal cherts and pure limestones to the southeast. A low gradient slope is suggested due to the lack of slump structures and turbidite deposits with a water depth < 200 m. This is primarily based on the assumption that the shell beds deposited from high-energy pulses would not likely reach depths greater than this (Oschmann, 1980).

The Nordegg unconformably overlies the Upper Triassic dolomites where the conglomeratic contact (lithofacies A) is interpreted to be a transgressive lag/reworked lowstand deposit. The upper portion of the underlying dolomite is brecciated, pointing to extensive dissolution (Kerans, 1988).

During the initial stages of Nordegg deposition (LGF-B) a major transgression introduced an inflow of cold, nutrient-rich, oxygen poor waters from the west suggested by enrichments of P and V, Cr, and Zn (Figure 2.29 – Stage 1). Cooling produced a greater lateral temperature gradient, increased circulation and coastal upwelling, increasing the phosphate flux to more basinal settings (Vincent and Berger, 1985). Oxygen levels oscillated between dysoxic (indicated by francolite, Mg-carbonate) and anoxic (pyrite formation).

TOC values up to 6% and alternating redox conditions suggests high levels of productivity played a significant role in the preservation of OM. In present-day environments, areas of significant phosphorite accumulation are associated with high primary productivity rates (Follmi, 1996). High vertical fluxes of organic matter with moderate basinal ventilation allowed for the re-utilization of P by marine ecosystems. The absorbed P was co-deposited with minor organic P from fish skeletons. The increased deposition of particulate OM to the sediment would have also served as an effective sink for trace metals (such as V and Zn). The high levels of metal-rich OM would also favour greater amounts of bacterial sulfate reduction which would release P to precipitate francolite where V, Zn and Cr were still strongly absorbed to the OM. High levels of phosphate in modern environments (from higher productivity levels) have been shown to remove metals from sea-water more efficiently (Balistieri *et al*, 1981). Scattered mud clasts in the lower portion of LGF-B suggest subtle movements of the storm wave-base during early deposition.

Conditions changed for LGF-C deposition where nutrients were increasingly depleted but TOC values increase (10-20 wt%). The reduction of productivity-associated elements (e.g. P, V, Cr and Zn), low Mn (indicating dysoxic conditions) and significant pyrite suggests anoxia rather than productivity was important for organic matter preservation. Throughout LGF-C deposition, the Nordegg basin may have been increasingly restricted due to western terrane accretion (Figure 2.29, Stage 2A). During

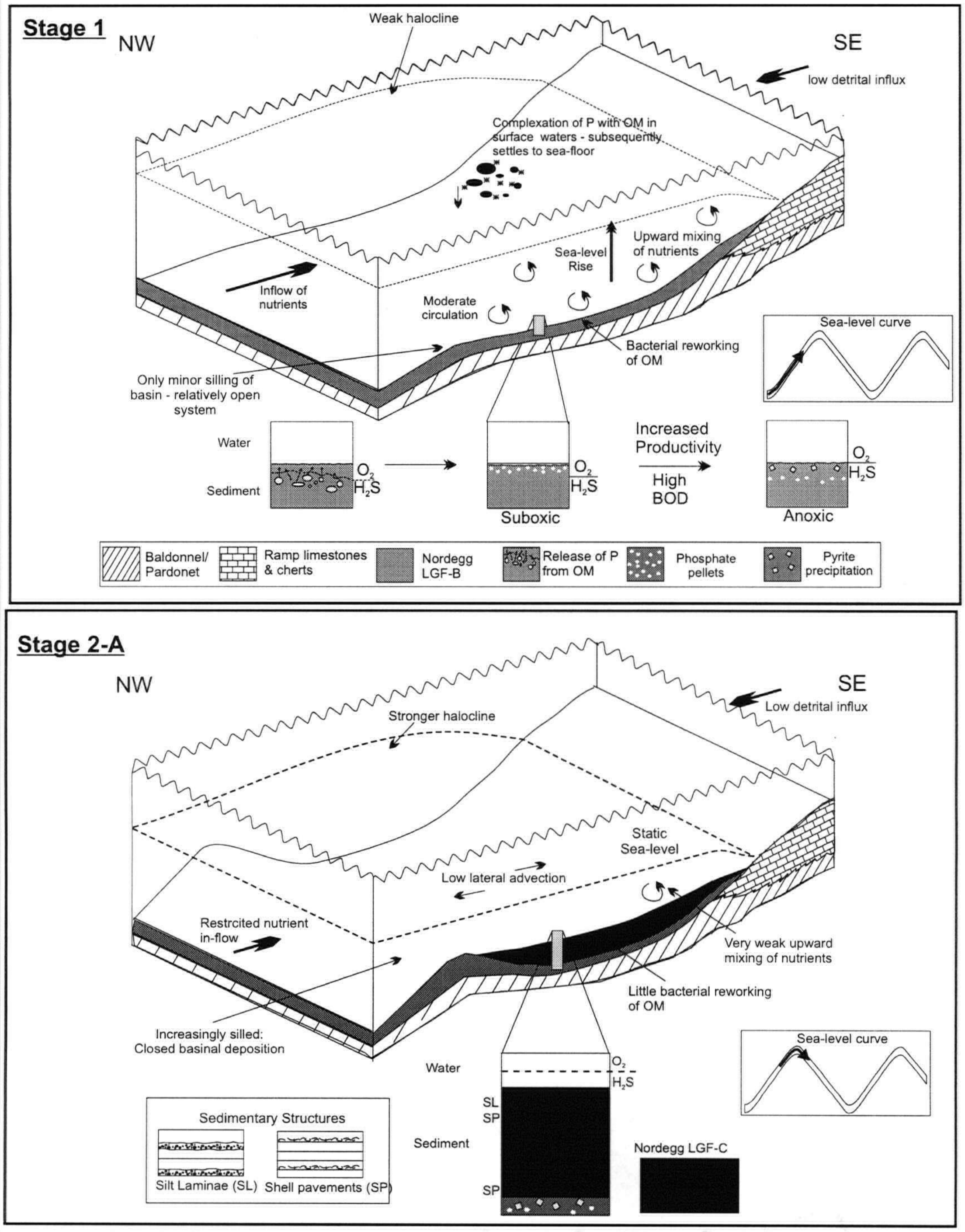


Figure 2.29: **Depositional environments of Nordegg litho-geochemical facies**

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Stage 1: Initial stages of Nordegg deposition (LGF-B). System was relatively open allowing nutrients to arrive from the west. Conditions varied between dysoxic and anoxic associated with productivity.

Stage 2-A: Terrane accretion of Wransgellia and Stikinia sills the Nordegg Basin. Flow from the west is restricted, reducing nutrient levels. Lack of water circulation produces a stagnant basin .

the Early Jurassic, western Canada was characterized by accretion of island arcs and oceanic terranes (Gabrielse and Yorath, 1991). The Stikine and Wrangellia terranes were in close proximity to one another (Aberhan, 1998) converging on the North American continent during Nordegg deposition. A silled basin formed, reducing the inflow of nutrients from the west and produced stagnant conditions. H_2S enrichment occurred in the substrate and perhaps, in the water column represented by the lack of planktic and benthic (autochthonous) organisms and absence of bioturbation.

A small connection between the basin and the open-ocean likely existed which allowed a low salinity surface water outflow and a high salinity deeper water inflow (Figure 2.30; Dickmann and Artuz, 1978). A permanent halocline (and thermocline) developed producing a stratified water column. No water mixing was possible resulting in anoxic conditions below the halocline. The earlier cooling, plus a shift to more saline waters and the silling of the basin would be important in causing a stratified basin. Similar temperature excursions have been described in Europe during the Pliensbachian (Bailey *et al*, 2003; Rosales *et al*, 2004).

LGF-C contains several fine shell beds (predominantly bivalves) with random alignment may suggest sporadic storm deposits. Most shells are moderately disarticulated and valves are convex-up suggesting allochthonous deposition. Similar shell "pavements" have been identified by Oschmann (1980) in the Upper Jurassic Kimmeridgian Clay where they were ascribed to short high energy events. The absence of benthic colonization and elevated TOC's suggests no O_2 was supplied during storm events. Distal storms could disrupt the stratified water column and rework the H_2S-enriched bottom waters to produce more toxic waters (Oschmann, 1988 and references within). Deposits generated by distal storm could have also supplied organic-rich-sediments into the Nordegg Basin as have been suggested for Miocene deposits off the South-West African coast (Huc, 1987). Consequently the excess sulfides were incorporated into the kerogen, producing sulfur-rich organic matter.

The shell material introduced into the basin may also be the primary source of carbonate which was subsequently diagenetically altered by compaction, indicated by sharp limestone/marlstone contacts and low relief stylolites (Ricken and Eder, 1991). Many of the limestone beds cannot be correlated across the study area, suggesting localized diagenetic alterations which are less likely to be consistent across a wide geographical extent (as opposed to a wide-scale biogenic production variation). However a contribution of carbonate from the adjacent carbonate platform cannot be discounted. Carbonate can be generated in shallow water regions and mobilized into the basin by seaward-directed currents (Elrick and Snider, 2002; Mattioli and Pittet, 2002).

Minor regressional events are better represented closer to the palaeoshoreline by 1 m thick siltstones (sub-lithofacies C-2). During these events, the coarser clastic fraction was restricted to proximal areas (Figure 2.31). Only OM, minor clays and silts were carried in suspension into the distal environments. TOC values in more proximal regions, associated with the siltstones, are low ranging between 1-2%. Thus regressional events during LGF-C deposition had limited effect in the deeper basinal settings.

LGF-C also contains fine interbeds of silt. Interlaminated siltstone beds and shales have been described by many authors (e.g. Caplan, 1997; Caplan and Moslow, 1999; Wignall, 1989). The siltstone beds are parallel laminated and show no scoured-base; therefore they are unlikely to be traction deposits. Such silty layers have been

Stage 2-A (*cont.*)

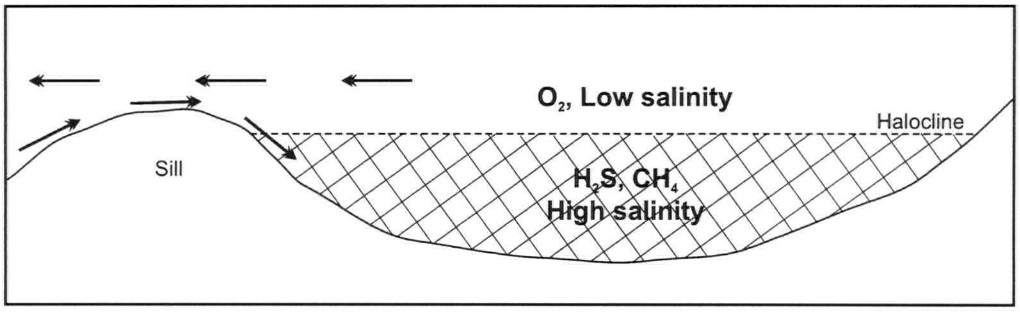

Figure 2.30: Restricted basinal setting for deposition of LGF-C. Positive water balance from low salinity water outflow and high salinity deep water inflow. Halocline produced from density variations between the flows, which consequently produces anoxic bottom waters. (Modified after Demaison & Moore, 1980; Oschmann, 1988).

Stage 2-B

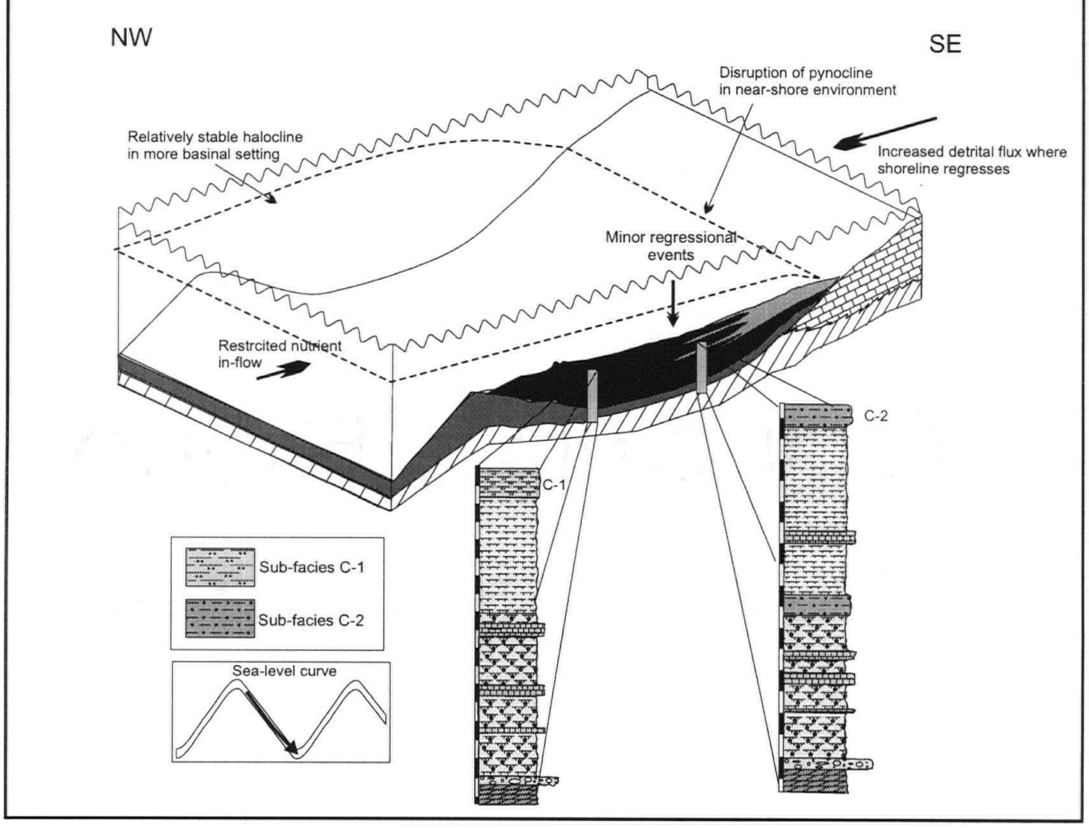

Figure 2.31: Minor regressions during LGF-C deposition, depositing sub-facies C-2 closer to the paleoshoreline (to the south-east).

attributed to distal remnants of low density turbidity currents related to storms (Stow and Bowen, 1980; Molgat and Arnott, 2001). The silty layers within the Nordegg reflect similar depositional conditions. A drop in water depth combined with increased energy of storms may account for the silty-layers. Some of these silt laminae may have been sourced from the west where exotic terranes were being accreted. They are less frequent than the shell bed deposits but show no signs of associated O_2 enrichment in the basin.

LGF-D was deposited in a major transgressional event which allowed a greater inflow of water into the basin and disruption of the stable stratified water column (Figure 2.32). More nutrients were supplied to the basin as indicated by higher P concentrations and moderate trace-element enrichments. A higher detrital influx is also suggested from Al, Fe and K levels. Francolite and pyrite again suggests alternating dysoxic/anoxic conditions.

TOC concentrations of LGF-B show a localised increase (Figure 2.33) which may represent subtle changes and irregularities in basin-floor topography. The depressions are sites of locally inhibited water circulation producing highly anoxic "pockets" (Hallam and Bradshaw, 1979) where OM is focused into these 'hydrodynamic quiescent regions' (Wignall, 1994). OM would be better preserved in these zones, surviving transportation and suffer limited diagenetic degradation.

Despite terrane accretion from the west, the Nordegg exhibits no significant thickness variations within the study area (only notable thickness variation is in the NE of study area due to sub-Cretaceous erosional front). This suggests that subsidence rates were constant throughout deposition and no syn-depositional faulting occurred.

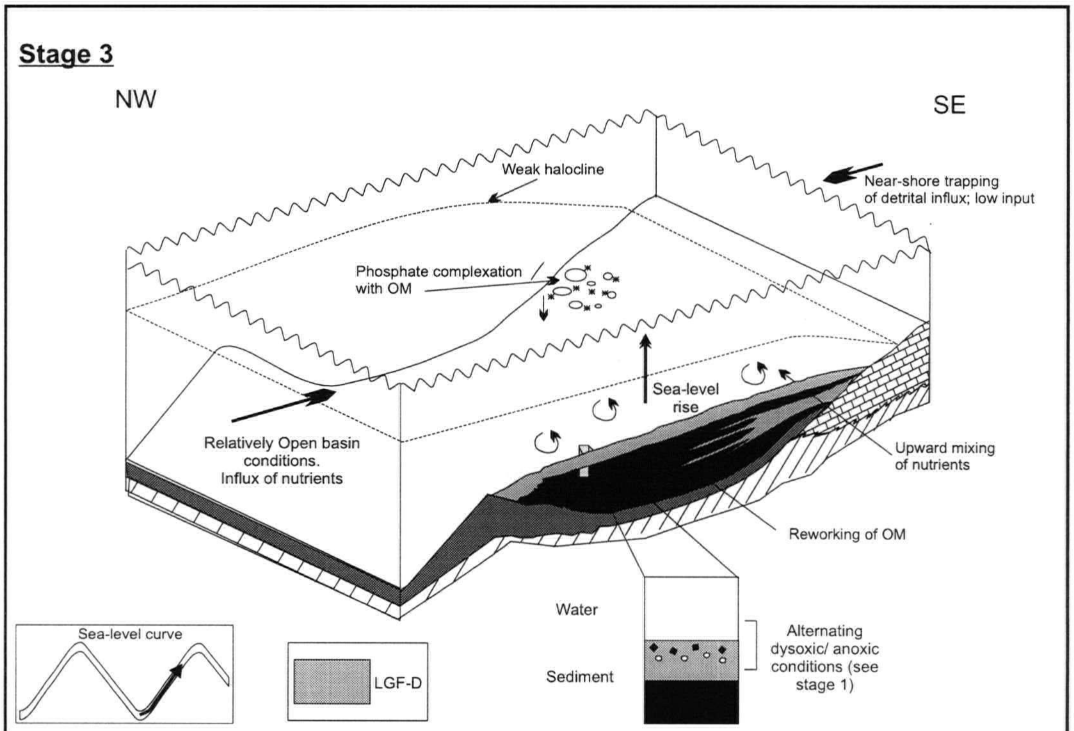

Figure 2.32: Deposition of LGF-D. Transgression opens up the basin to the west - allowing for inflow of nutrients and disturbs the stable water column. Increased surface productivity which subsequently produces an effective sink for phosphogenisis in bottom waters

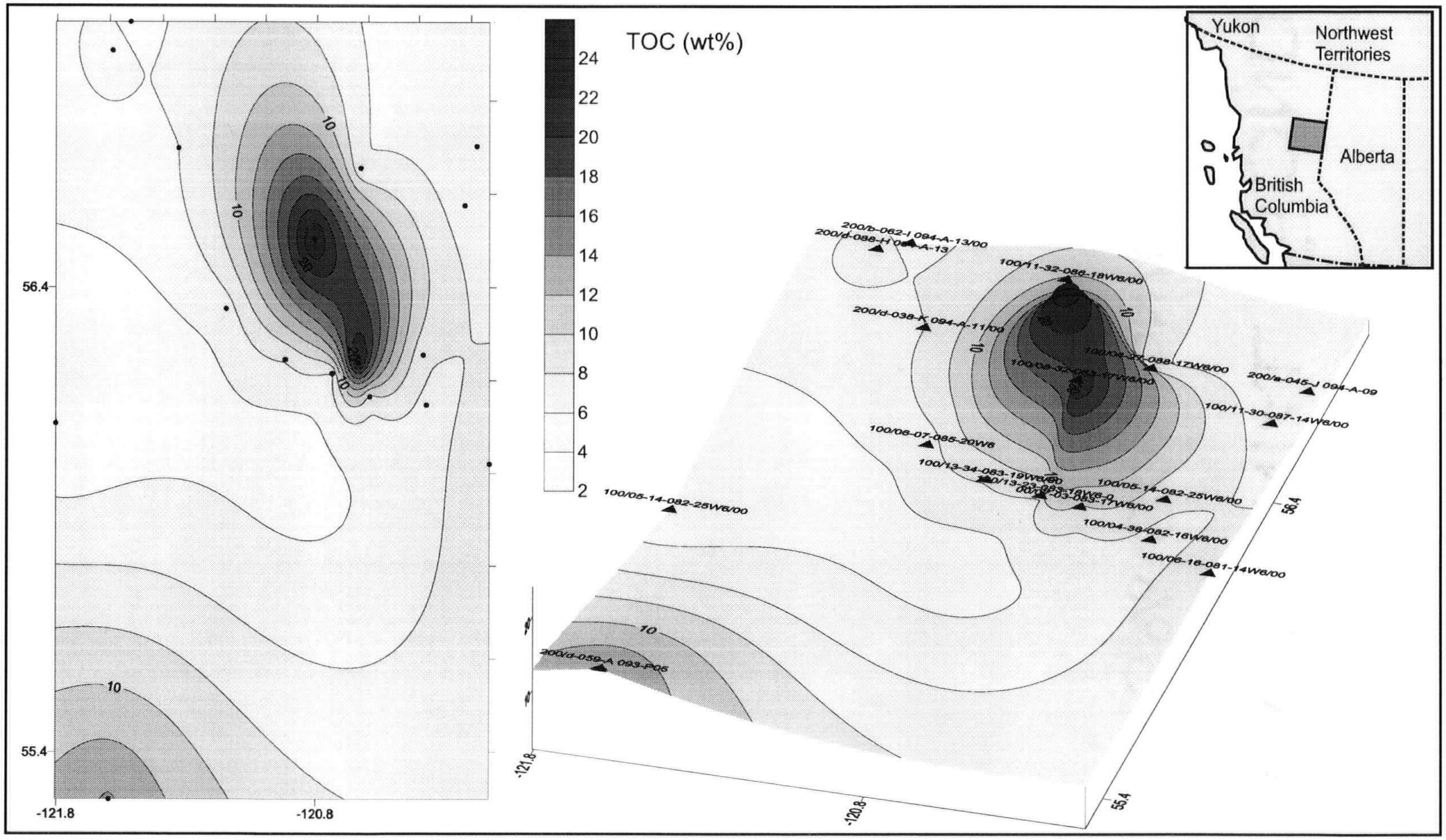

Figure 2.33: TOC distribution of the basal 10m Nordegg Member, NEBC reflecting irregular bottom floor topography during deposition. Core locations for TOC samples shown on 3-D map.

2.10 CONCLUSION

Sedimentological and geochemical analysis of Nordegg mudstones and marlstones imply organic-richness was controlled by times of varying primary production benthic anoxia. Two major transgressional events supplied nutrients into the basin which disrupted the stratified water column and replenished metal concentrations in bottom waters (LGF-B and LGF-D deposition). During sea-level rise, the environment was a coupled high productivity and anoxic system. The increasingly silled nature of the basin (due to terrane accretion to the west) and high productivity produced a stagnant basin with a strong chemo- and thermocline between the transgressions. The enclosed nature of the basin produced a quiescent period where OM was preserved due to low oxygenated conditions (LGF-C deposition). At the same time, minor regressional events had a greater effect on OM preservation to the east. Lower TOC concentrations surrounding minor siltstone facies are found in closer proximity to the shoreline. The regressions partially disrupted the stratified basin, circulating oxygen in the water column and destroying the marine biomass.

Farther into the basin, conditions were more stable. Despite deposition of allochthonous shell beds and silt laminae, TOC values are higher. Thus in the 'deeper' basin, the ability of such events to mix H_2S-rich waters and the development of a strong halocline meant less OM was degraded. Low clastic dilution was also a factor as indicated by Fe-limited conditions producing a sulfur-rich kerogen (H_2S conditions with low Fe). Since the H_2S is not fixed by reactive Fe, it returned to the marine water causing the O_2/H_2S boundary to rise, incorporating the sulfides into the organic matter. So-called redox-proxying elements are more correlatable with organic matter recycling (bituminite-rich LGF-B and LGF-D) rather than anoxic conditions (alginite-rich LGF-C) where stagnant conditions made metal complexation with OM less efficient.

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Chapter 3

Determination of Organic Carbon Content of the Nordegg Member by Wireline Logs

3.1 ABSTRACT

Total organic carbon (TOC) concentrations and distributions have been examined for the Nordegg Member in northeastern British Columbia (NE BC) using both laboratory and wireline log analysis. TOC-rich intervals are characterized by lower density, lower sonic transit time and higher resistivity than other intervals with similar lithological composition. These data show that organic carbon content computed from both density logs and combined sonic/resistivity is both reliable and accurate. Gamma-ray intensity and TOC concentrations do not correlate indicating anomalously high gamma-ray values are not the result of organic carbon enrichment.

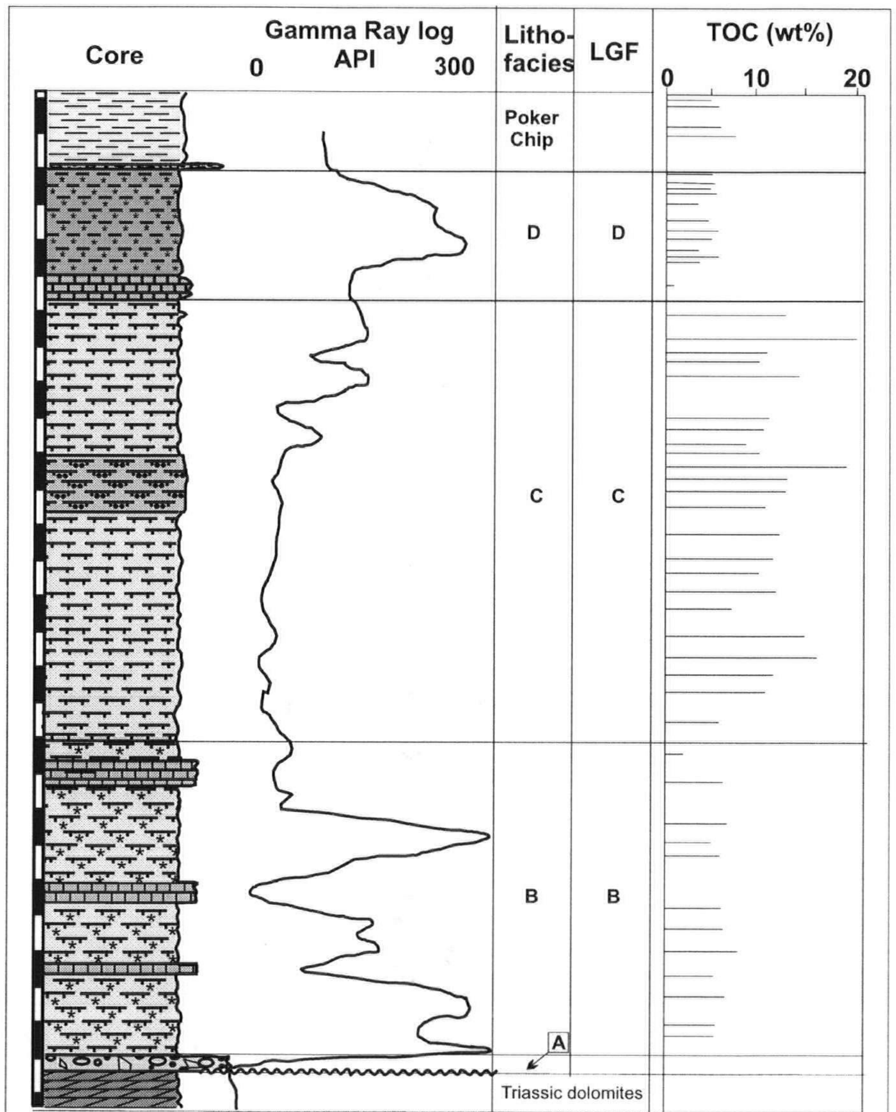
The organic carbon content based on a density log model, calculated at 157 locations in NEBC, averages 5% for the lower Nordegg Member (litho-geochemical facies B), 8% for the middle Nordegg member (litho-geochemical facies C) and 6.5% for the upper Nordegg Member (litho-geochemical facies D). To the northeast (94-A-16) there is a regional low of organic carbon. Available data indicate that the density method can be used over a wide area of NE BC as the overall increase in TOC contents to the south-west (93-P-4) is in good accordance with laboratory derived TOC.

3.2 INTRODUCTION

Gas shales are unique petroleum reservoirs as shales and mudrocks both source and reservoir the gas and no structural or stratigraphic trapping mechanisms are required (USGS, 1995). The gas is stored in a number of ways but primarily adsorbed to the organic fraction. Due to the strong physical adsorption between gas molecules and the organic matter, concentrations and distribution of organic carbon need to be characterized for gas shale reservoir evaluation.

One such potential gas reservoir is the Early Jurassic Nordegg Member, an organic-rich mudstone/marlstone sequence in the Western Canadian Sedimentary Basin (WCSB). In northeastern British Columbia (NE BC) the Nordegg consists of four stratigraphic units with distinct lithological facies: (A) mudstone conglomerate/breccia; (B) phosphatic marlstone; (C) marlstone; and (D) phosphatic mudstone. Facies C has sub-facies of silty marlstone (C-1) and calcareous siltstone (C-2). Facies B, C and D can further be distinguished through geochemical analysis which reveals three recognizable total organic carbon populations, defined as litho-geochemical facies (or LGF; Figure 3.1). Facies A is not included as it contains insignificant organic carbon concentrations. LGF-B (lithofacies B) and LGF-D (lithofacies D) contain 1-8 wt% TOC whilst LGF-C (lithofacies C) contains 6-20 wt% TOC. Cores which contain sections of siltstone (sub-facies C-2; Figure 3.2) have lower TOC values where such cores are only found in the eastern portion of the study area (e.g. 81-14W6).

Organic matter content can be determined directly from laboratory analyses of samples either by TOC analysis (through total carbon and inorganic carbon calculations) or pyrolysis. Both these processes are time consuming and expensive. Due to the ready



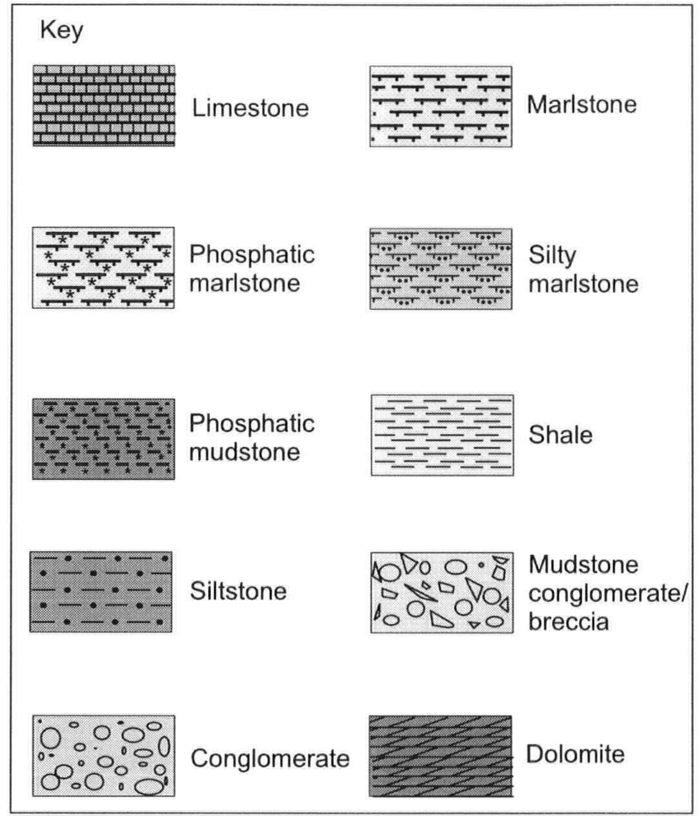


Figure 3.1: Litho-geochemical facies (LGF) of the Nordegg Member based on TOC concentrations (where lithofacies B = LGF-B, facies C = LGF-C and facies D = LGF-D). Note the LGF are also recognizable from the gamma-ray log. Facies A is not included as it contains low amounts of organic carbon.

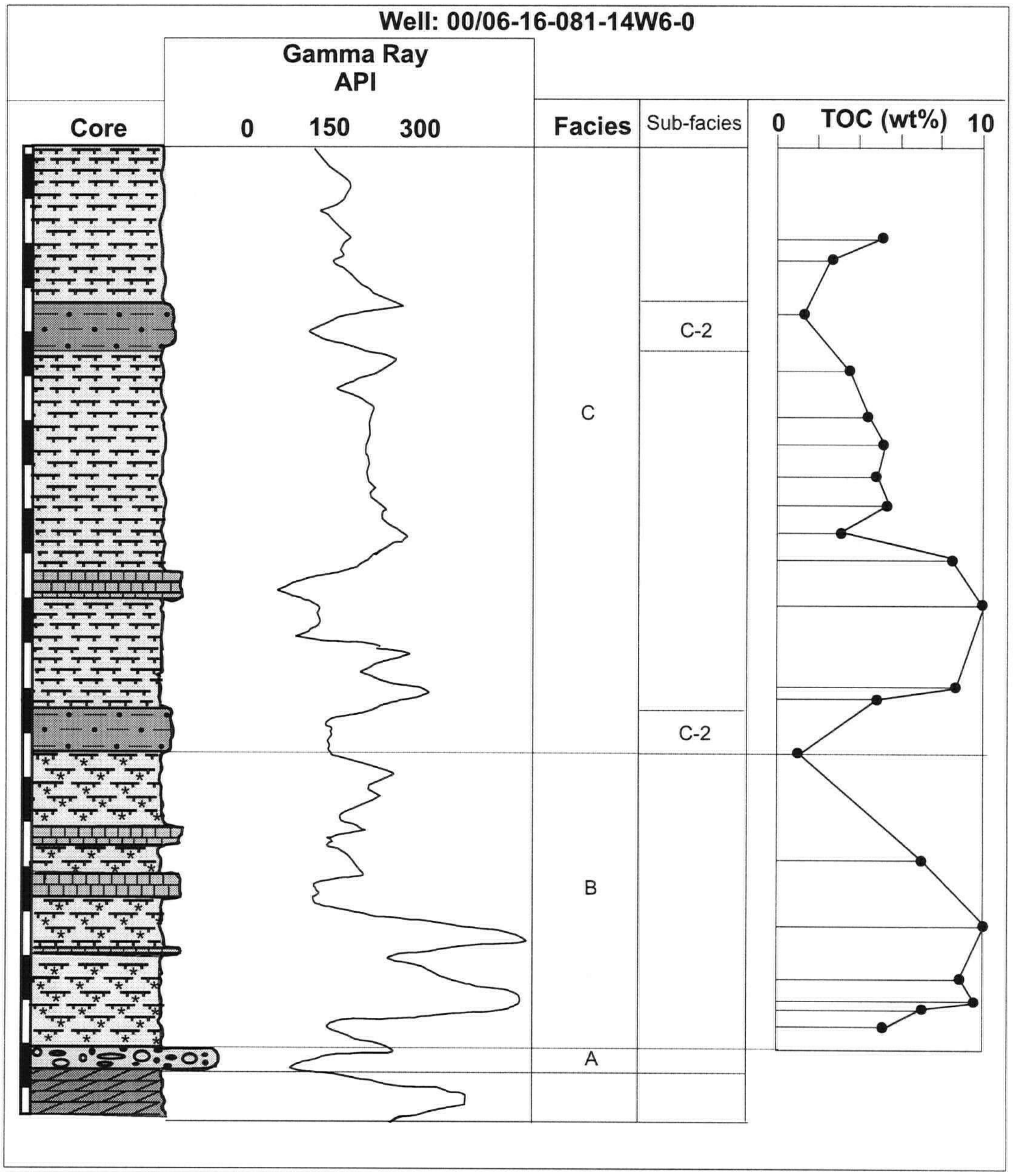


Figure 3.2: Incomplete core from the eastern portion of the study area (81-14W6) - note siltstone facies (C-2) with low TOC concentrations (see figure 3.1 for key)

availability of digital well data and wireline logs, a method for quantifying organic carbon contents from wireline logs is of great value. Therefore this paper compares Nordegg TOC data calculated in the laboratory with wireline data to provide a fast and cost-efficient method for deriving TOC. We propose a new density model (modified Schmoker & Hester, 1983; method) and compare our results with the Passey *et al* (1990) model which uses a different suite of logs.

3.3 LOG SUITE

3.3.1 Gamma-Ray Log

Many papers have attempted to provide a quantitative interpretation of organic matter content using the gamma-ray log (e.g. Schmoker, 1981; Meyer & Nederlof, 1983) due to the empirical relationship between uranium and organic matter (Swanson, 1960). To assess the applicability of gamma-ray derived TOC for the Nordegg, TOC contents were compared with uranium concentrations established from spectral gamma-ray logs.

LGF-B and LGF-D are characterized by high gamma-ray values. However the anomalous gamma-ray values are not associated with the organic matter (Figure 3.1). Indeed the uranium content of the Nordegg Member is inversely proportional to organic carbon content (high U in LGF-B and LGF-D). The U reflects the concentration of the marine phosphate mineral francolite ($Ca_{10}(PO_4)_6F_2$). LGF-B and LGF-C are enriched in P (associated with francolite; Figure 3.3) where during diagenesis, francolite can take up dissolved U, substituting for calcium in the mineral lattice (Fisher & Wignall, 2001) and

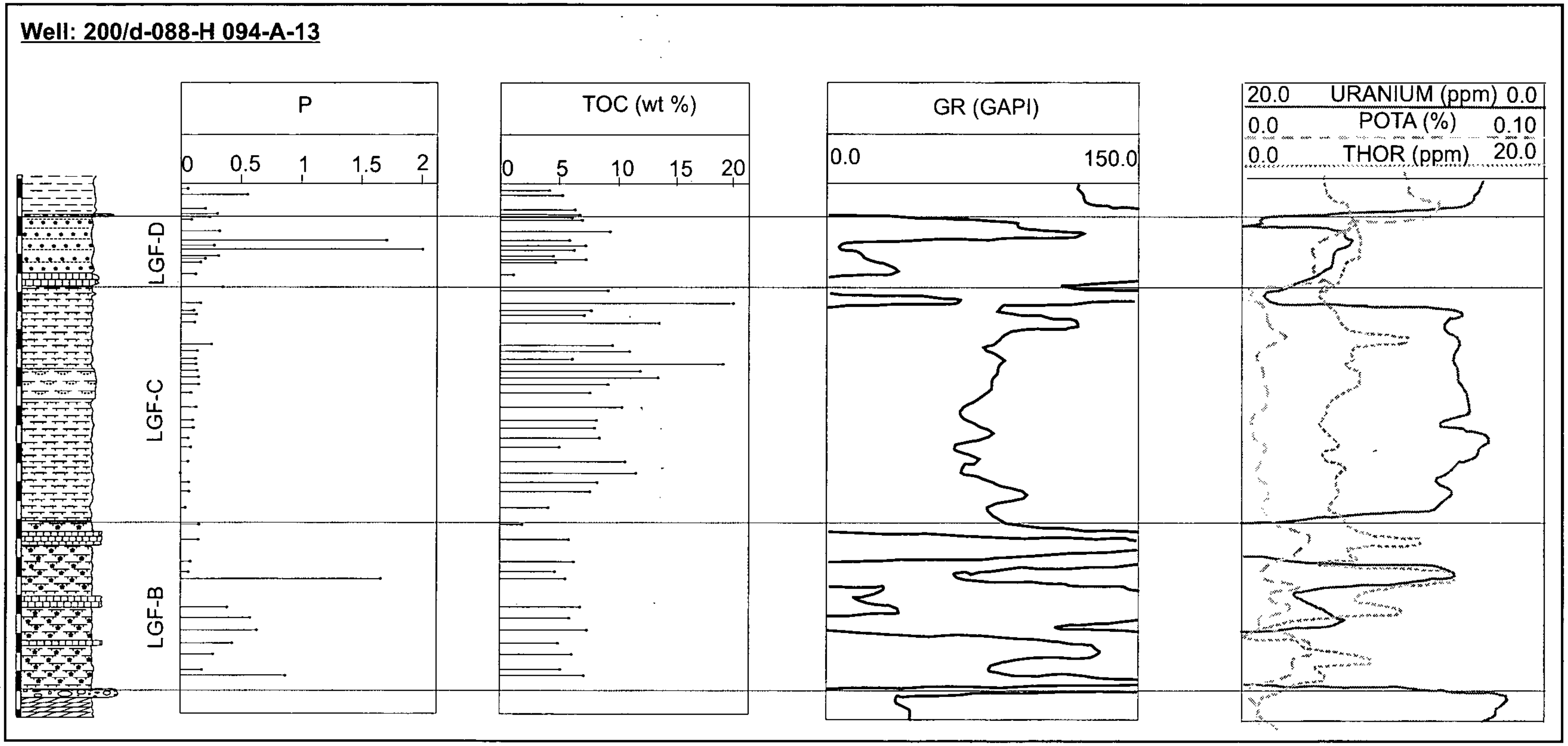


Figure 3.3: Relationship between phosphate, TOC and uranium concentrations

if the U was associated with the OM, an inverse correlation between gamma-ray and bulk density would exist as the density of organic material (~1.0g/cm^3) is significantly less than the average grain density (~2.7g/cm^3 ; Schmoker, 1981). However the gamma-ray intensity (primarily controlled by U content) is directly proportional to bulk formation density (Figure 3.4) owing to the greater density of francolite (~ 2.9 g/cm^3; Follmi, 1996). Therefore, use of the gamma-ray log to depict and quantify TOC-rich horizons appears of limited use for the Nordegg Member.

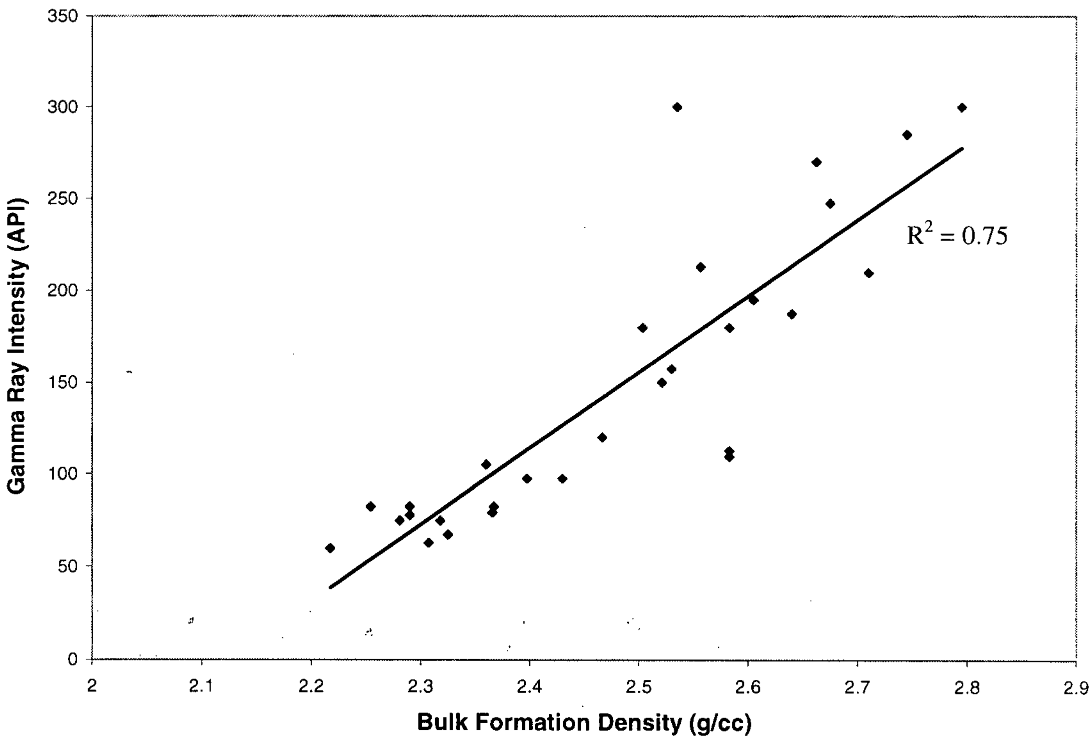


Figure 3.4: Correlation between gamma-ray intensity and bulk formation density

3.3.2 Density Log

The lower density associated with the TOC-rich horizon (LGF-C) suggests the density log may prove of significant value for determining TOC contents. Across organic-rich LGF-C, the density decreases from 2.6 cc/g to 2.3cc/g (Figure 3.5).

The density-log approach used here is similar that which Schmoker & Hester (1983) previously applied to the Bakken Formation in the Williston Basin. The strata are defined as a three component system comprised of rock matrix, organic matter and interstitial pores. In previous density log-TOC studies, pyrite is also accounted for as a separate component (Schmoker, 1978). Many organic-rich units have a linear increase in pyrite with organic matter due to the reducing conditions associated with both organic matter preservation and pyrite formation (e.g. Schmoker & Hester, 1983). However the pyrite concentrations show no such correlation with TOC in the Nordegg Member. For this reason, the pyrite content is included in the rock matrix component.

The total formation density is a function of the combined densities of the three different components:

$$(1) \quad \rho = \varnothing_o \rho_o + \varnothing_i \rho_i + (1 - \varnothing_o - \varnothing_i) \rho_m$$

where ρ is the total density, $\varnothing_o$ and $\varnothing_i$ are the fractional volumes of the organic matter and interstitial pores respectively and ρ_m is the density of the rock matrix.

Porosities for the Nordegg are low and are unlikely to alter the density log significantly (over the study area, mineralogy is dominated by quartz and calcite with minor clays, reducing the chance of altering porosity values by compaction). It is also assumed here that with low porosities, density differences between pore fluid types can be neglected.

Therefore equation 1 can be simplified to:

$$(2) \quad \rho = \varnothing_o \, \rho_o + (1 - \varnothing_o) \, \rho_m$$

Equation 2 can be re-arranged to:

$$(3) \quad \varnothing_o = \frac{\rho - \rho_m}{\rho_o - \rho_m}$$

The total organic carbon content (TOC) is measured on a weight percent basis and is related to the fractional volume of organic matter ($\varnothing_o$) by the equation:

$$(4) \quad TOC = \varnothing_o \, (100\rho_o) \, / \, (R \rho)$$

where R is the ratio of weight percent organic matter to weight percent organic carbon.

Equation 3 can be substituted into equation 4 to produce equation 5:

$$(5) \quad TOC = \frac{100\rho_o(\rho - \rho_m)}{R\rho(\rho_o - \rho_m)}$$

The values of ρ_o, ρ_m, and R are estimated from available data. The values used in this study are $\rho_o = 1.05$, $\rho_m = 2.48$ and $R = 1.7$.

3.3.3 Sonic – Resistivity Log

In sections of high organic carbon, the resistivity log increases (generation of hydrocarbons) and the sonic transit time also increases (due to presence of low density, low velocity organic carbon). Across organic-rich LGF-C, the resistivity increases from

1500 Ω to 2000 Ω, correlating with an increase in sonic transit time from 250 μs/m to 290 μs/m, indicating both logs are applicable for TOC determination (Figure 3.5). The Passey *et al* (1990) model concept is based on the identification of TOC-rich zones from the separation of the resistivity and sonic logs, known as Δ Log R. Δ Log R is a function of the maturity of the unit (as maturity affects both organic matter resistivity and density; Robert, 1988) and for this paper is inferred from regional maturity trends.

The formula used is:

$$\text{(6)} \quad TOC = (\Delta \text{ Log R}) \times 10^{(2.97 - 0.1688 \times LOM)}$$

where

$$\text{(7)} \quad \Delta \text{ Log R} = \log_{10} (R/R_{baseline}) + 0.02 \times (\Delta t - \Delta t_{baseline})$$

The baseline data used represent sections in the wireline log where the rock is interpreted to be a non-source rock (e.g. sandstone with no TOC).

3.4 LABORATORY VS. LOG-DERIVED TOC

One hundred and thirty-nine samples from six cores of the Nordegg Member were analyzed for TOC content, ranging from 1 to 20 wt%. Using the modified density model, a plot of laboratory derived TOC versus log-derived TOC shows a good correlation (Figure 3.6 and 3.7). The Passey model shows a moderate agreement with core data. As shown in figure 3.8 A-D, the TOC-rich horizons are reflected by an increase in sonic and resistivity separation.

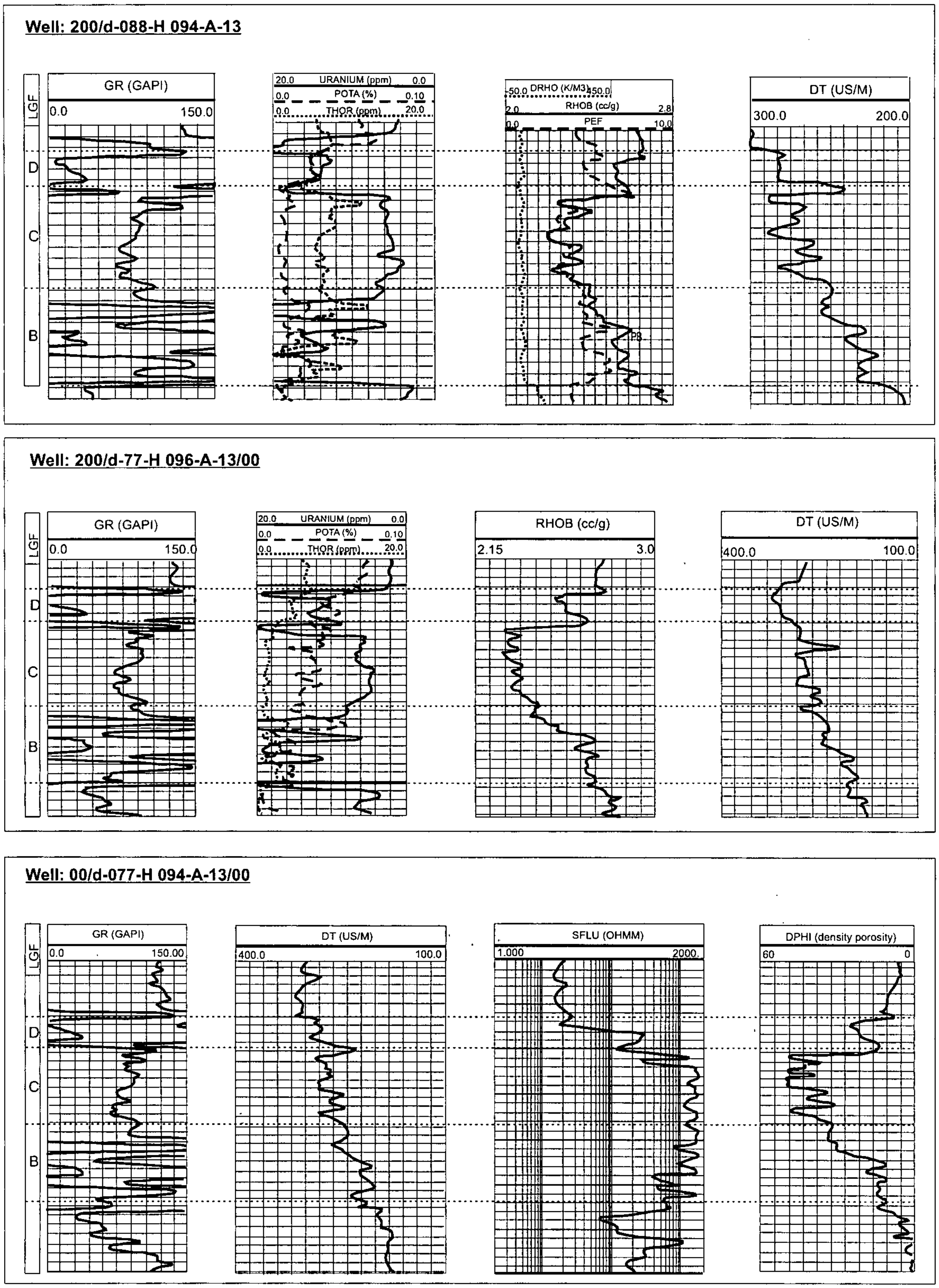


Figure 3.5 : Geophysical log responses for the Nordegg from various wells

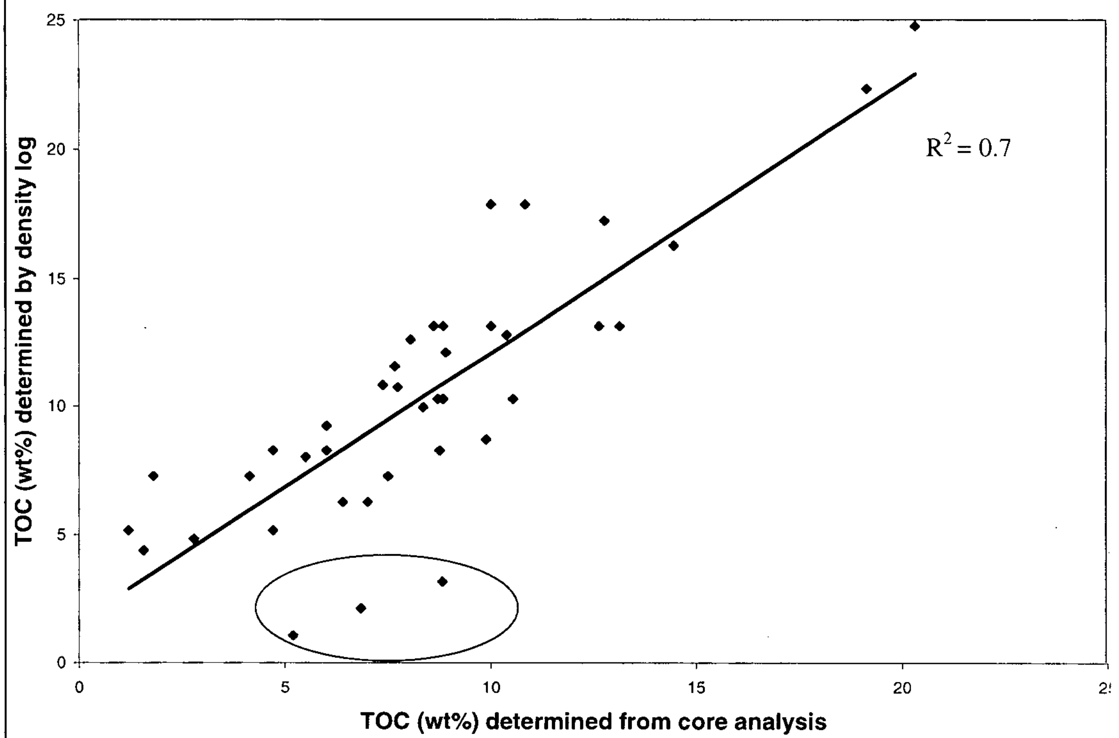


Figure 3.6: Comparison of lab and log-derived TOC based on density log

Erroneous density-log results can be accounted for by a number of factors, primarily the difficulty of matching samples taken from core to that of the density log making accurate correlations problematic. Miscorrelation between geochemical and petrophysical data can arise due to the thin-layer effect where a layer which was sampled may be organically lean but intercalated with organic-rich strata. Samples where log-derived TOC are lower than lab-derived TOC (Figure 3.6) may be explained by slight enrichments in pyrite. Pyrite-rich zones have a significant density increase (and result in a sonic velocity increase) which would underestimate the total organic carbon content in models using the density and sonic logs. Other sources of error may also include the variability of the organic matter density. For example in the southwest of the study area, the density of the organic matter increases as depth of burial increases. Greater thermal

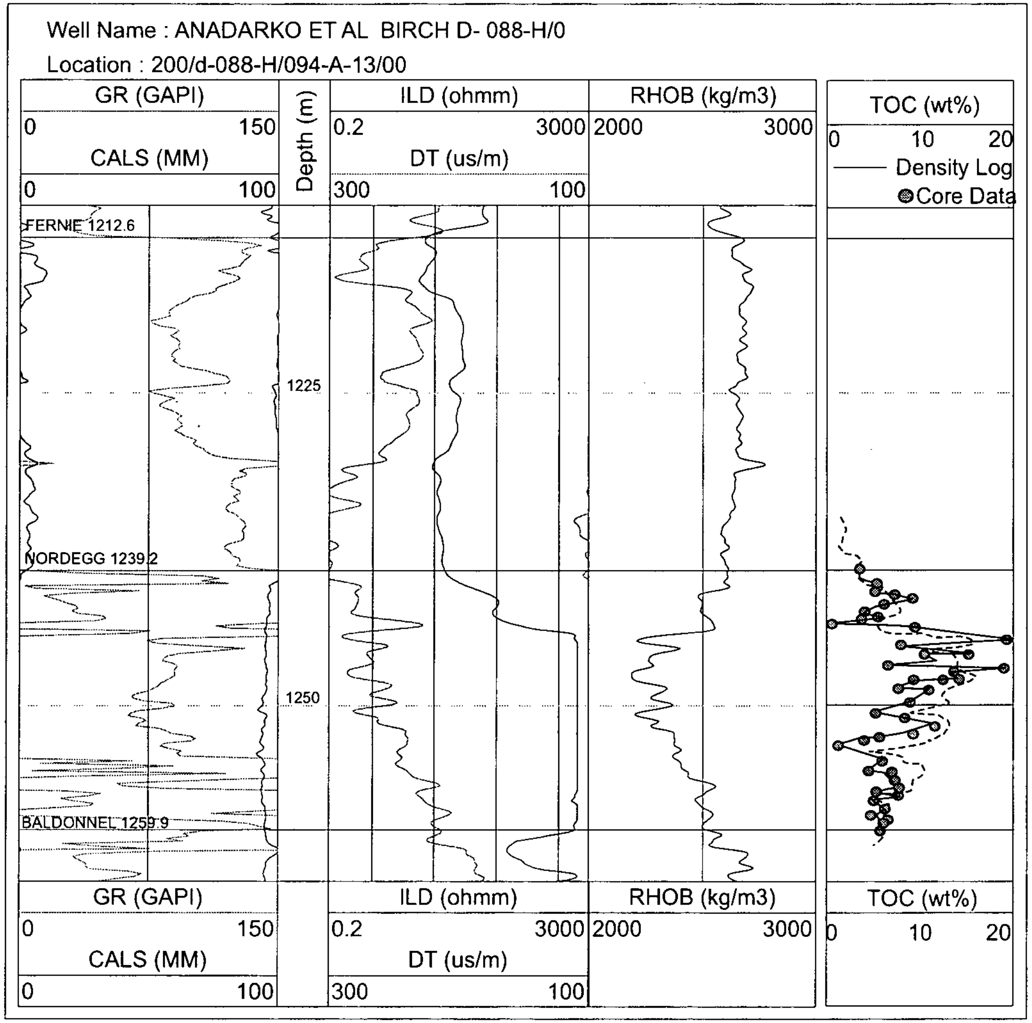


Figure 3.7: (A) Wire-line profile of complete Nordegg core. Figure illustrates drop in density over TOC-rich zone and comparison with calculated data using the Schmoker & Hester model (1983).

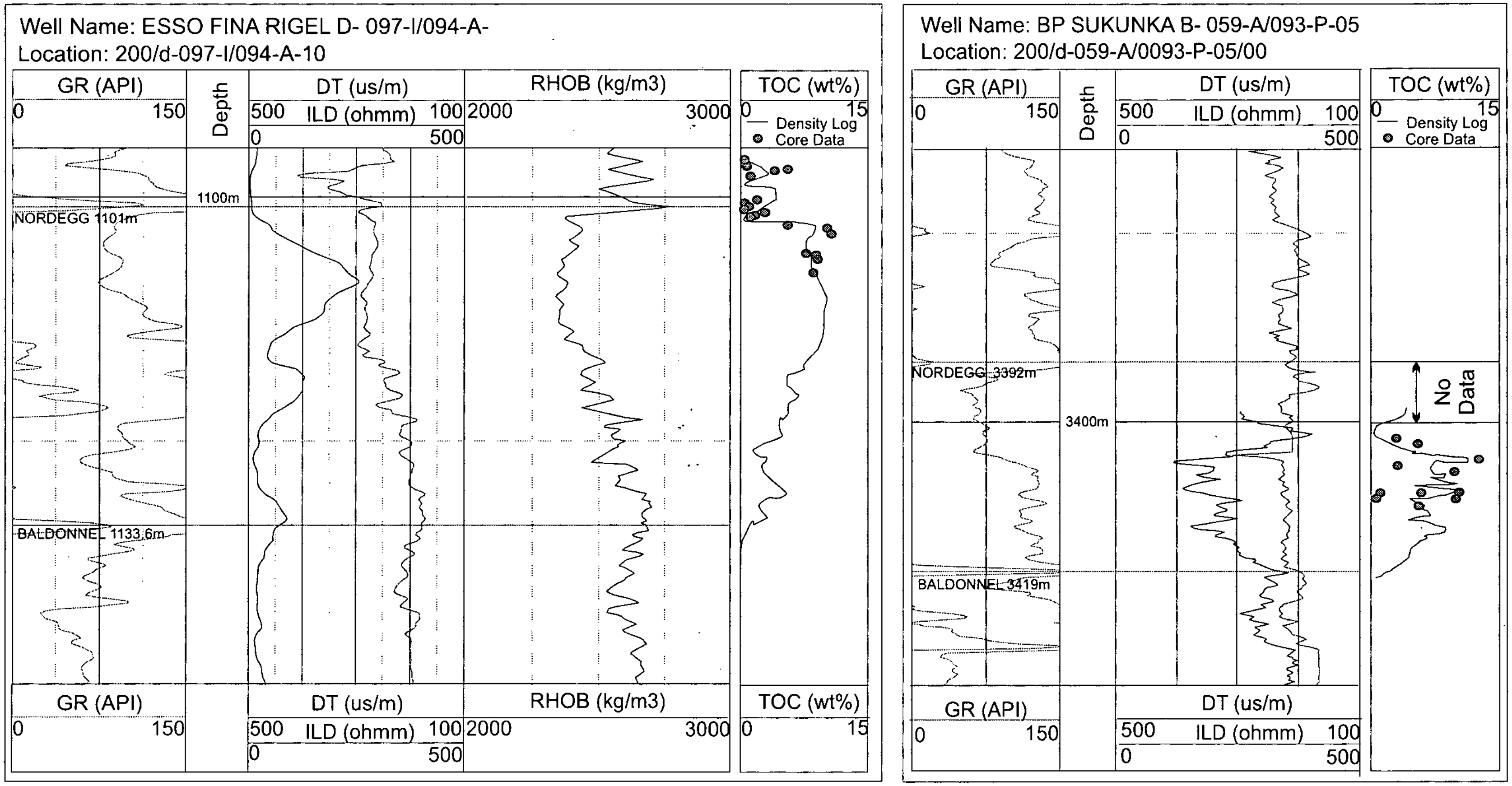


Figure 3.7 *continued* : (B + C) Correlation between laboratory and wire-line derived TOC

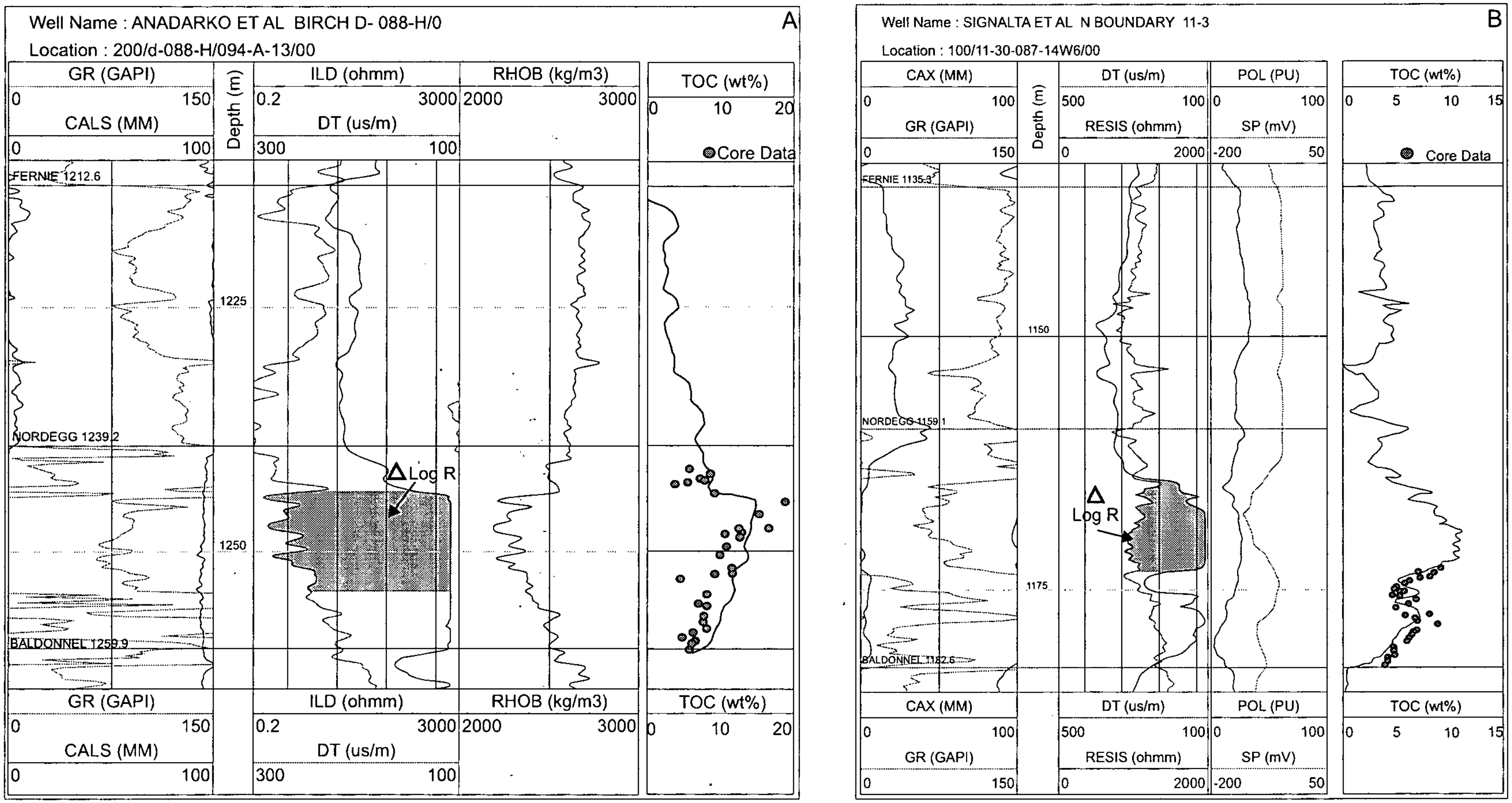


Figure 3.8, A-D: Core and log derived TOC comparison using Passey model. Separation of sonic and resistivity logs reveals TOC-rich zones which could not be calculated from laboratory analysis.

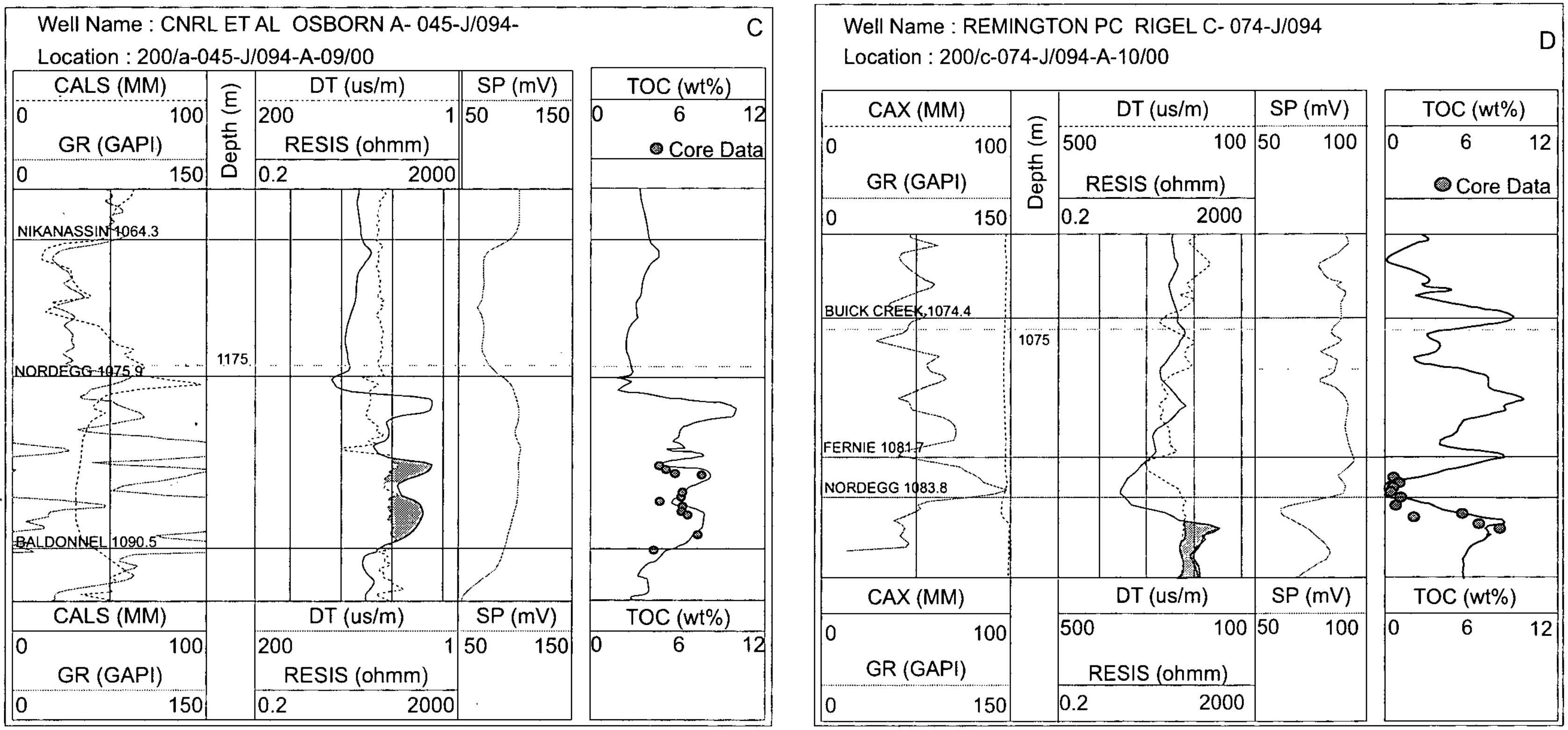


Figure 3.8 *continued*

maturity variability associated with increased burial depth may also explain erroneous data using the Passey *et al* model. The variation in correlation between the density and sonic/resistivity with lab-derived TOC may be due to the greater error associated with using two logs (Passey *et al*) as oppose to one (Schmoker & Hester). Recognition of organic-rich sections is also dependant on the vertical resolution of the tools used. The vertical resolution of a micro-resistivity tool is low (~ 61 cm) whereas the density log has a better vertical resolution (~38 cm; Meyer & Nederlof, 1984).

However it is apparent from log and lab data comparisons that the density-log model is an effective tool for quantifying TOC concentrations. The density model is primarily used for TOC distribution in section 3.4 due to the greater availability of digital density log.

3.5 TOC DISTRIBUTION – DISCUSSION

Average organic carbon content of the lower, middle, upper and complete Nordegg Member has been calculated from equation 5 at 157 locations in north-eastern British Columbia (Figure 3.9) based on density log measurements. LGF-C is rich in TOC across much of the study area, ranging between 1-16 wt%. Most of the organic carbon in LGF-B and LGF-D is in the thermally mature region to the southwest. The regional applicability of the density-log method is determined by comparing lab derived TOC concentrations (based on average TOC contents from the basal 10 m of the Nordegg Member) across the study area. The overall trend of increasing TOC content to the SW is in good accordance with the laboratory data (Figure 3.10). Therefore the data available indicates that the density model method is valid in an area of approximately 30, 000 km^2.

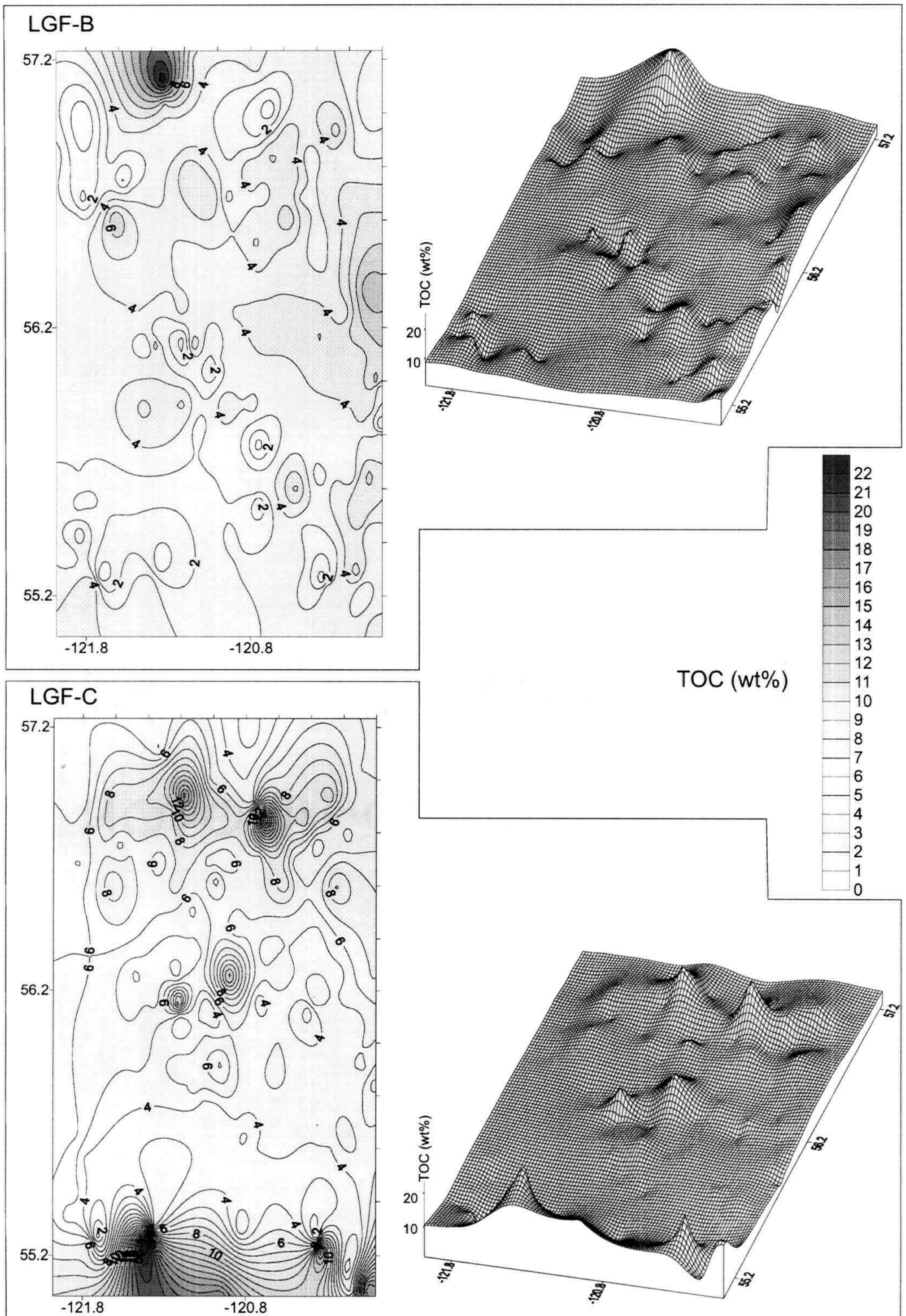


Figure 3.9: TOC distribution map for LGF-B and LGF-C based on density log calculation

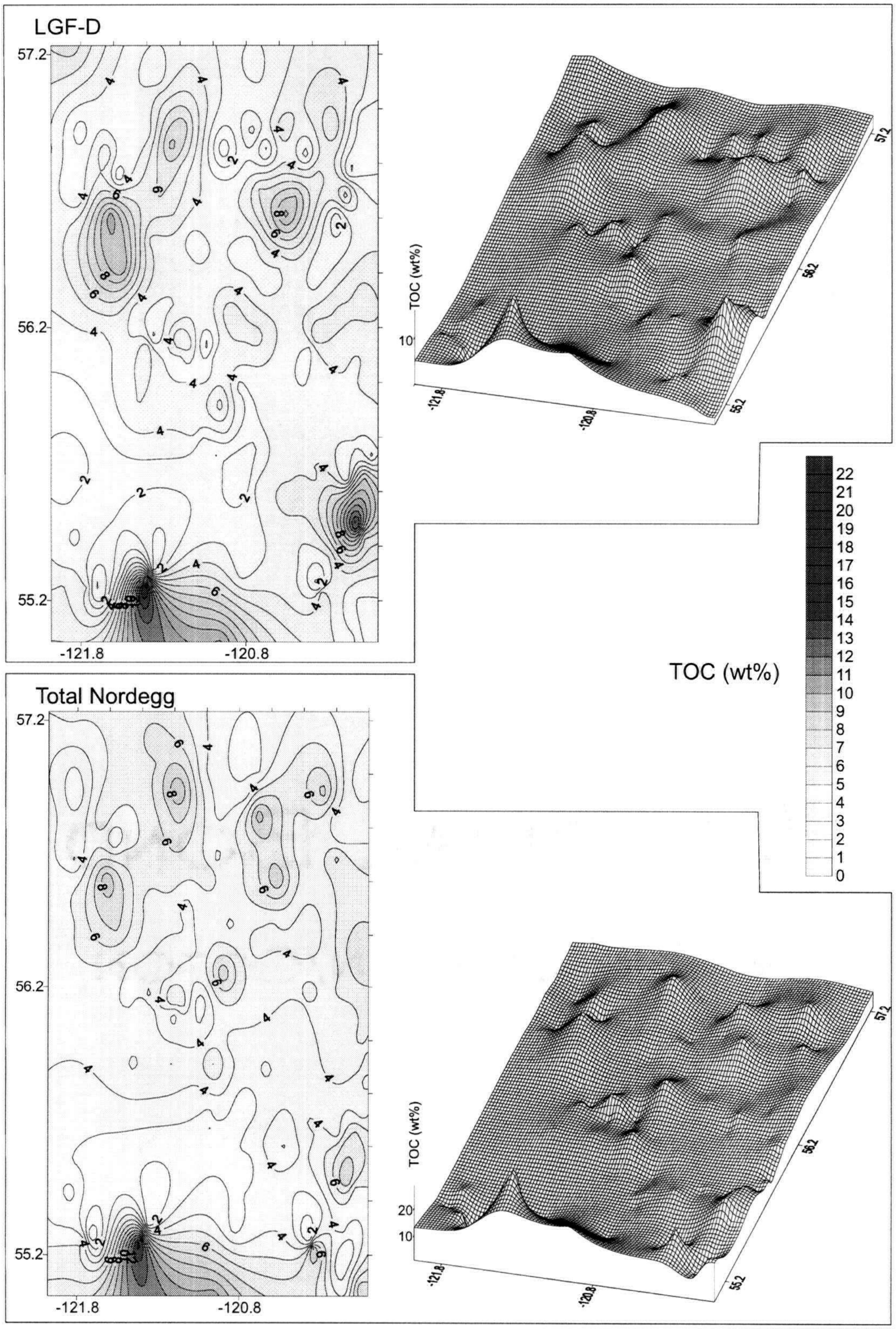


Figure 3.9 cont: TOC distribution map for LGF-D and total Nordegg

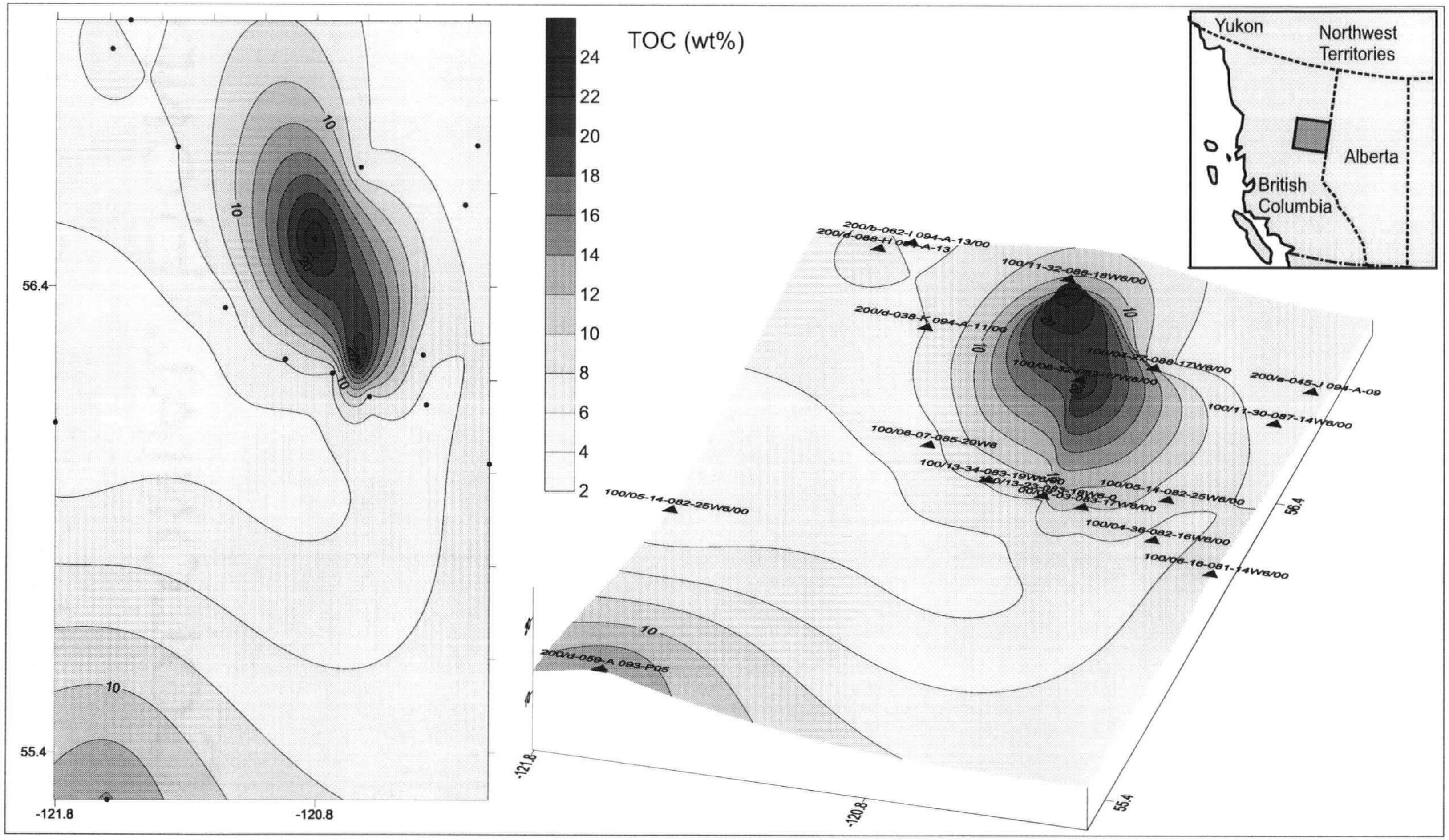


Figure 3.10: TOC distribution of the basal 10 m Nordegg Member, NEBC reflecting irregular bottom floor topography during deposition. Core locations of TOC samples shown in 3-D map.

Although beyond the scope of this paper, the regional TOC distribution trend may be explained by depositional conditions. The areas to the north-east were closer to the depositional edge, whereby organic matter would not be well preserved (e.g. high levels of clastic dilution or O_2-rich nearshore waters) . The high, 'bulls eye'-like TOC concentration to the NE may be the result of irregular bottom floor topography during deposition, similar to the 'puddle' model described by Wignall (1996).

3.6 CONCLUSIONS

Calibration of both density and combined sonic/resitivity logs to laboratory-derived TOC demonstrates the effectiveness of using wireline-logs for quantifying organic carbon concentrations. Errors associated with both models reflect the difficulty of precise correlation of data between laboratory analyses and digital wire-line data. The data presented here also emphasizes the need for caution when using gamma-ray logs to identify organic-rich horizons where mineralogy can exert a significant influence on wire-line log responses. High density minerals such as phosphate or pyrite, if sufficiently concentrated, have a strong influence on wireline log responses and are advantageous to cross-plot the density log with resistivity to identify intervals which differ from the norm due to mineralogical variations.

In deriving equation 5, care must also be taken when determining organic matter density, ρ_o, with increased burial (maturation), the density of organic matter increases. The maturity effect on organic matter density is difficult to assess due to lack of Rock Eval data and limited core availability in the southwest portion of the study area.

Despite the variability of absolute TOC values, both methods highlight TOC-rich zones which would not be determined from the gamma-ray log alone. The ability to map TOC becomes of great importance for gas shale exploration allowing TOC-rich horizons to be identified which could be of exploration interest.

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Chapter 4

Gas shale potential of the Early Jurassic Nordegg Member, Northeastern British Columbia

4.1 ABSTRACT

To assess gas shale resources, methane adsorption capacities of Jurassic Nordegg samples from the Peace River district (northeastern British Columbia) were investigated. The Early Jurassic Nordegg Member is an organic-rich, fine-grained mudrock and as such, is considered a potential gas shale target. Sorbed gas capacities of moisture-equilibrated samples increases with total organic carbon content (TOC) over a range of 0.5 – 14 wt%. Methane adsorption capacities range from 0.05 cc/g to over 2 cc/g in organic-rich zones (at 6.5 MPa and 30 ^{0}C). Moisture plays a significant role in the sorption of gases on Nordegg samples. Although a general decrease of methane adsorption with increasing moisture was observed, no direct relationship could be established between moisture and gas capacity, suggesting moisture has a greater importance than purely a competitor for methane adsorption sites. Pores and pore throats are likely blocked by moisture rendering many adsorption sites inaccessible to methane. Twenty to eighty percent of total gas storage is free gas (intergranular porosity), ranging from 0.1 – 1.3 cc/g. Total gas-in-place ranges from 1 – 24 BCF/section. The greatest potential for gas production is to the south-west of the study area (93-P-5). TOC concentrations (up to 20 wt%), thickness, maturity and fracture-potential improve the gas shale potential in this region making it a prime gas exploration target.

4.2 INTRODUCTION

The success of unconventional gas production from shales in the US has sparked major interest in similar, organic-rich units in the Western Canadian Sedimentary Basin (WCSB). Gas shales are unique in that shales and mudrocks both source and reservoir the gas and no structural or stratigraphic traps retain the gas in place (USGS, 1995). Unlike conventional gas reservoirs, unconventional gas is stored in a number of ways including: 1) adsorbed to organic matter and clay particles; 2) as free gas in the rock pores; and 3) in solution within bitumen and water. Due to the complex nature of gas storage, the detection, quantification and exploitation of unconventional reservoirs has proven difficult.

The Early Jurassic "Nordegg Member"[2] is one of the most organic matter-rich units in the WCSB and has the potential to be prospective gas shale. In this study, the adsorptive behaviour of a suite of organic-rich mudstones and marlstones of the Nordegg Member is reported. Pressure, moisture and total organic carbon content (TOC) will be characterized to assess the effect of these properties on methane adsorption. These results will be combined with other Nordegg characteristics (e.g., thickness variability, TOC distribution based on wire-line log calculations, maturity and porosity for free gas calculations) to evaluate the shale gas reservoir potential of the Nordegg Member in NEBC.

[2] Nordegg Member is used in this thesis but placed in quotation marks here to emphasize the correlative uncertainty which exists between the Nordegg in this study and the type-Nordegg in south-western Alberta.

4.3 THE NORDEGG MEMBER

The Early Jurassic Nordegg Member, the lowest unit of the Fernie Group, forms the base of the Jurassic strata in the WCSB. The Nordegg in NEBC was deposited during transgression/regression cycles in a partially silled basin. The Nordegg Member unconformably overlies the Triassic dolomite units of the Baldonnel, Pardonet and Charlie Lake –cross-cutting older strata from west to east (Figure 4.1). The Nordegg underlies the Toarcian Poker Chip Shale with apparent conformity.

Four stratigraphic units that are distinct lithological facies are recognized within the Nordegg Member: (A) mudstone conglomerate/breccia; (B) phosphatic marlstone (with limestone bands); (C) marlstone; and (D) phosphatic mudstone. Facies C has sub-facies of silty calcareous mudstone (C-1) and calcareous siltstone (C-2). Facies B, C and D can further be distinguished through geochemical analysis which reveals three recognizable total organic carbon populations, defined as litho-geochemical facies (or LGF; Figure 4.2). Facies A is not included as it contains low concentrations of organic carbon. LGF-B (lithofacies B) TOC content ranges between 1–7 wt% (5.5 wt% average), LGF-C (lithofacies C) contains 6–20 wt% (11 wt% average) whilst LGF-D (lithofacies D) contains 4-8 wt% TOC (5.6 wt% average).

The 'type' Nordegg Member in southern Alberta is somewhat lithologically and faunally different than the Nordegg in NEBC. The Nordegg shales in north-western Alberta are Hettangian-age which is the oldest age assigned. Elsewhere the Nordegg is Sinemurian age for the outcrop belt (the type Nordegg Member) and Pliensbachian-age for the 'basinal' equivalents (i.e., the Nordegg Member in this study; Russel *et al*, 2000). The highly radioactive unit in NEBC was assigned to the Nordegg by the petroleum

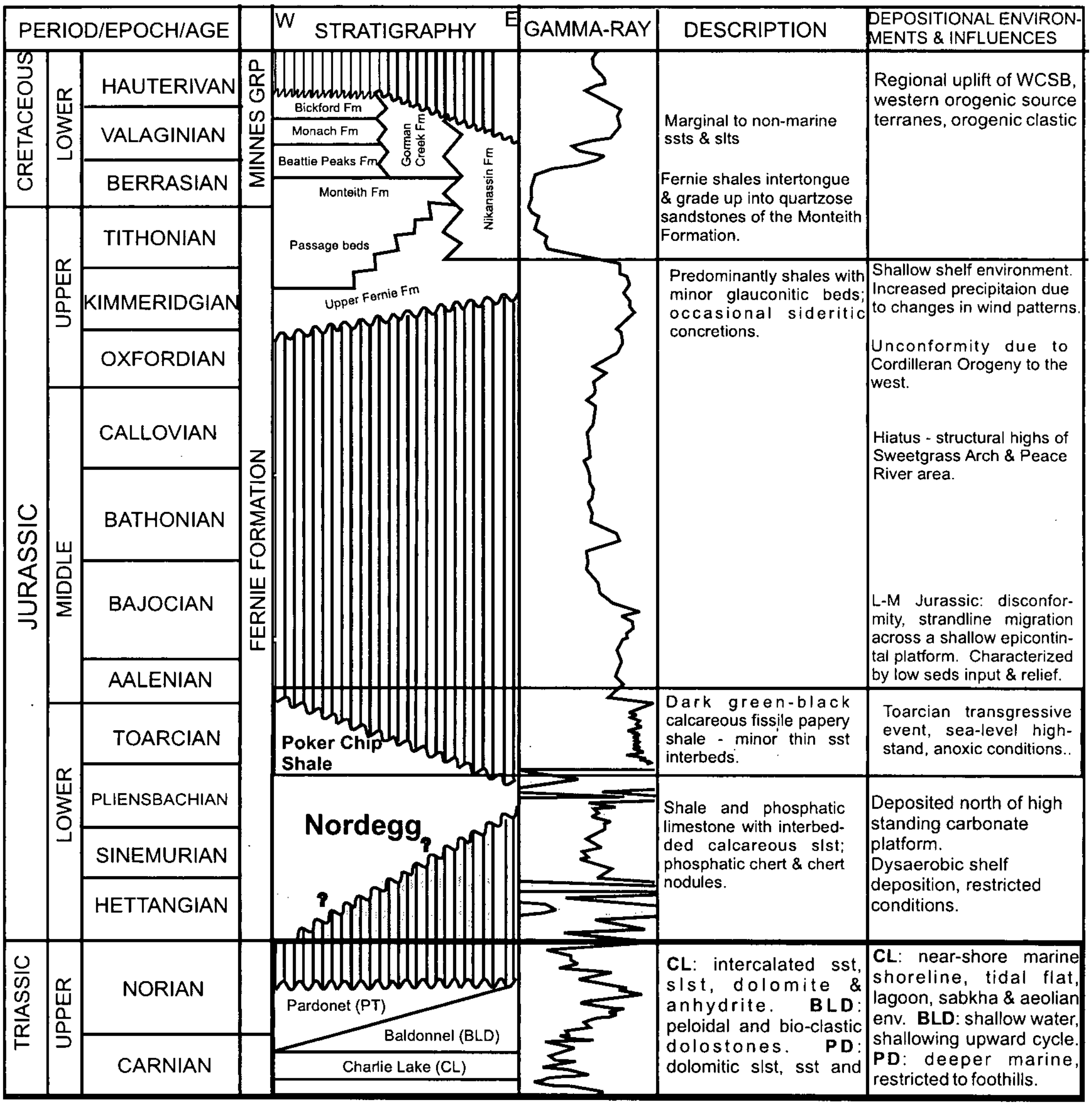
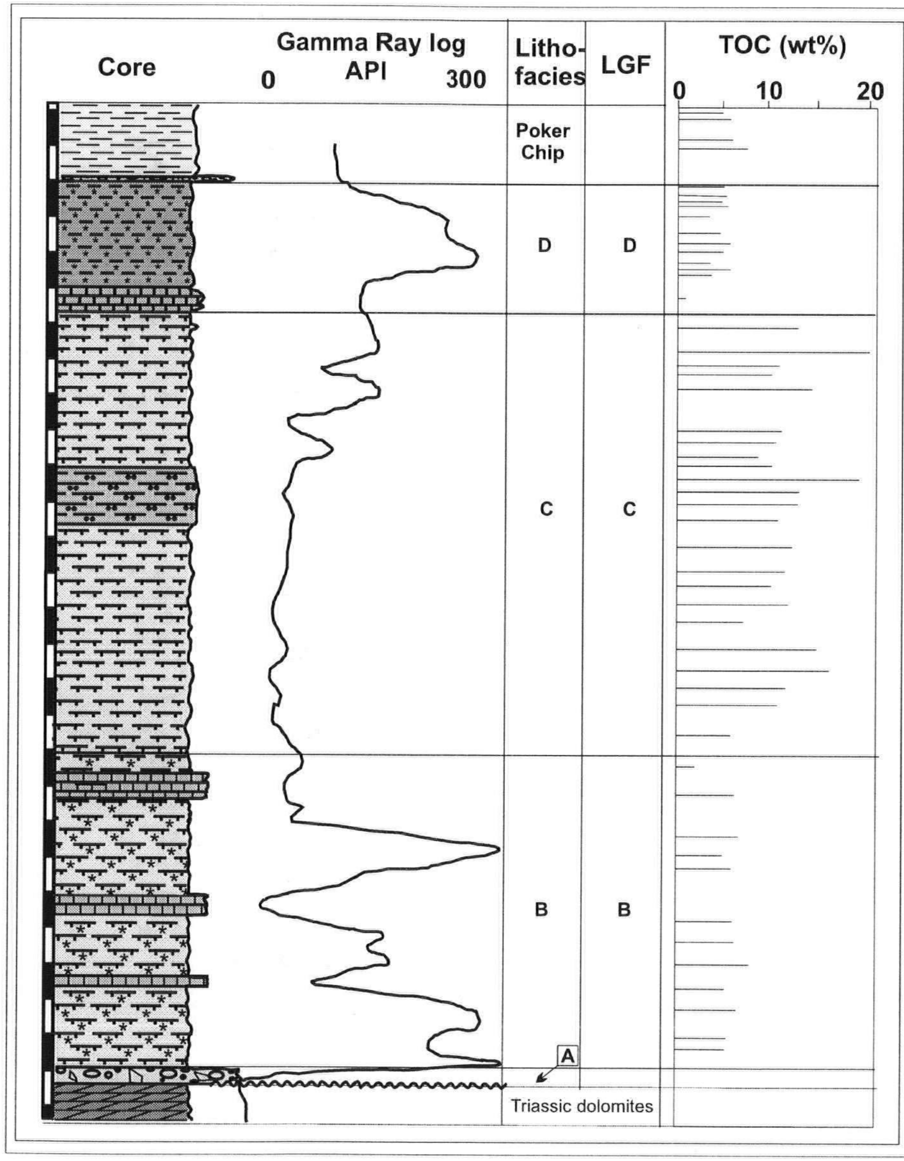


Figure 4.1: Stratigraphic chart of Jurassic units in northeastern British Columbia (modified from Stott (1967), Poulten *et al* (1990), Riediger (1990) and Poulten *et al* (1994).



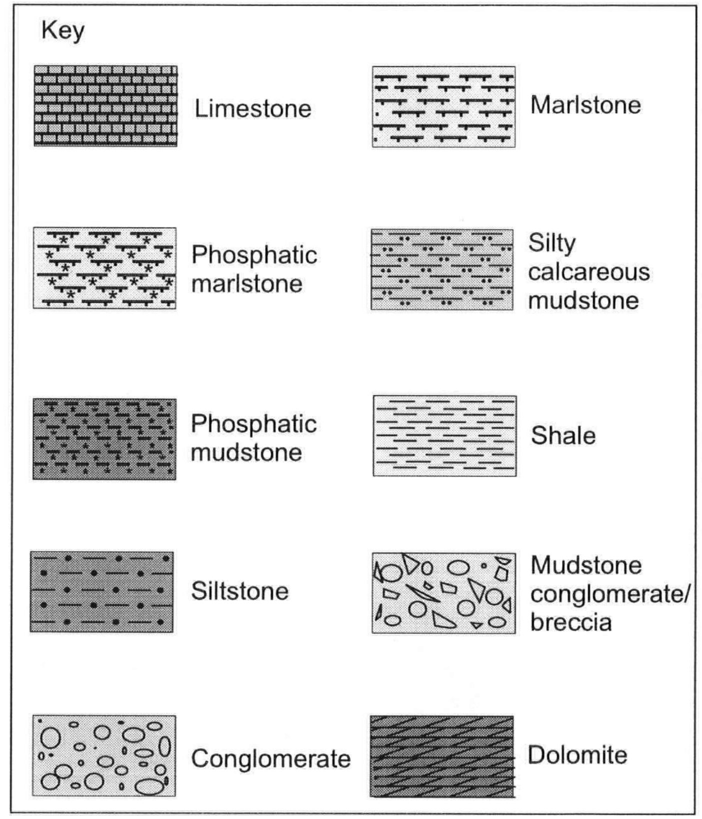


Figure 4.2: Relationship between Nordegg lithofacies and litho-geochemical facies (where lithofacies B = LGF-B, facies C = LGF-C and facies D = LGF-D). Note the LGF are also recognizable from the gamma-ray log. Facies A is not included as it contains low concentrations of organic carbon.

industry due to comparable petrophysical responses from the gamma ray log as the gamma-ray response maintains its identity throughout BC and Alberta.

4.4 EXPERIMENTAL

4.4.1 Samples

The material examined in this study were collected from 30 wells located in the Peace River District of northeastern British Columbia (between 93-P-1and 94-A-13; Figure 4.3). Samples were selected on the basis of core availability (depths ranged from ~1000 to ~3000 m) and total organic carbon content.

4.4.2 Methods

The concentrations of total carbon, sulfur and nitrogen content were determined by a Carlo Erba NA-1500 Analyzer for 430 samples. Fifty six of these samples were taken from core 200/d-100-H 094-A-13, the only core available through the entire Nordegg. Analytical precision was better than 2% for carbon, 5% for sulfur and 4% for nitrogen. Inorganic (carbonate) carbon concentration values were generated using a CM5014 CO_2 by coulometric titration following release of CO_2 with 2 N $HClO_4$. Total organic carbon was calculated as the difference between total and inorganic carbon values (i.e. TOC = TC-TIC). TOC analysis for total gas-in-place calculations was calculated using density wire-line logs (theory & methodology described in chapter 3).

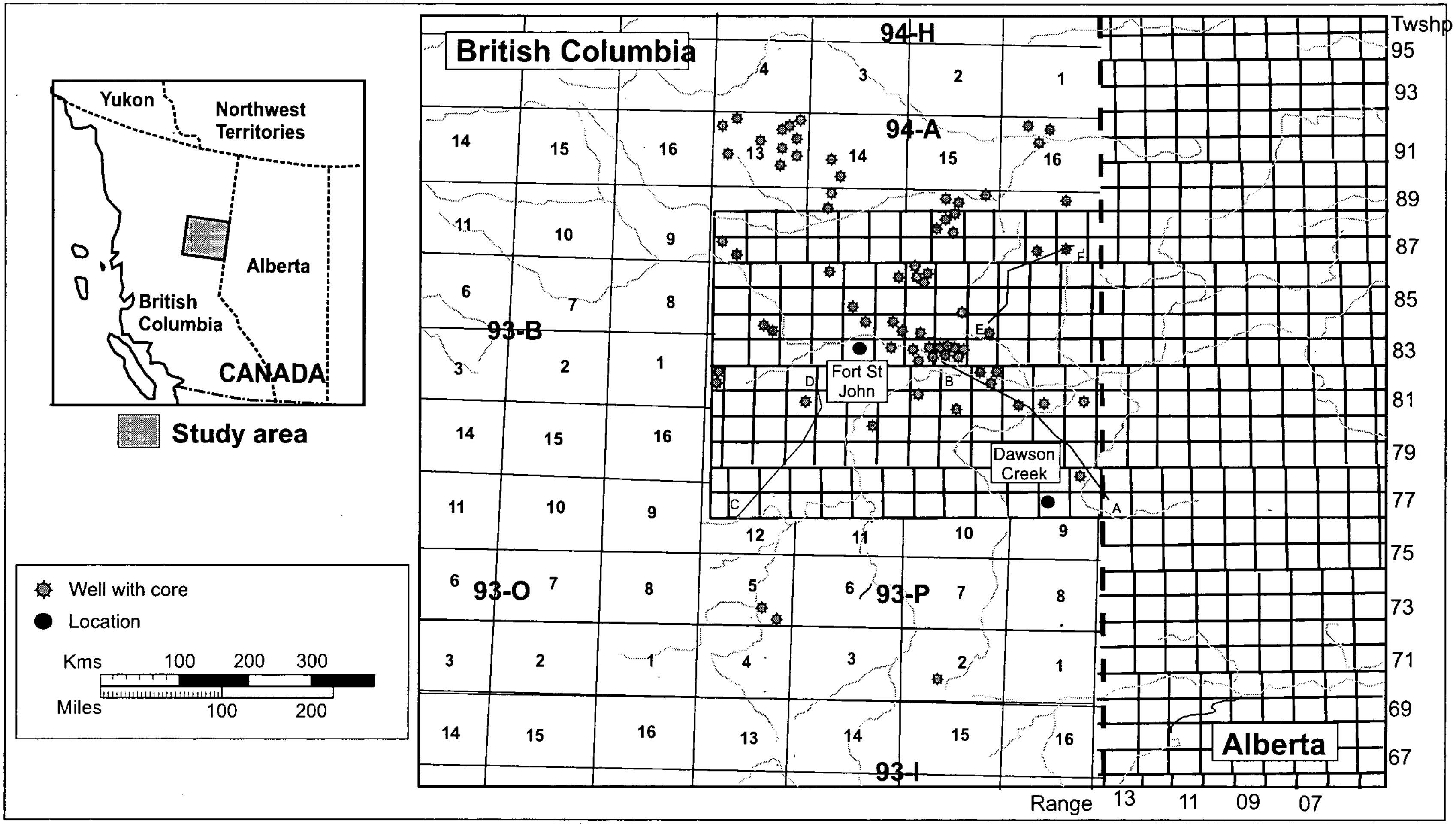


Figure 4.3: Map illustrating study area and well locations

Maturity data from T_{max} by Rock Eval pyrolysis (Espitalie *et al*, 1977) was performed on pulverized samples using standard procedures on a DELSI Rock-Eval II/TOC apparatus.

A volumetric, Boyles Law gas adsorption apparatus was used to measure high pressure methane isotherms at 30 ^{0}C. For each sample, pressure points were collected up to 9 MPa. Moisture equilibrated samples of ~150 g were crushed to 250 um in a ring-mill for adsorption analysis. Moisture capacities were determined by water saturation at 30 ^{0}C (ASTM D1412-85) which is recommended for moisture content under reservoir conditions. The method consisted of equilibrating dried shale samples over a saturated solution of potassium sulfate for more than 72 hours in a vacuum dessicator.

Total open pore volumes of mudrocks were determined from the difference in the densities between He (measured by pcycnometrey) and Hg (measured by Hg immersion based on Archimedes principle). Pore-size distributions were estimated by the intrusion of Hg at increasing pressures (0.52 psia to 30,000 psia in 45 pressure steps), utilizing the Washburn equation (Washburn, 1921). The samples were oven-dried at 110 ^{0}C for 1 hour prior to porosimetry analysis.

4.5 GAS ADSORPTION

4.5.1 Definitions

For clarification, the terms sorption, adsorption and absorption are defined as follows:

Adsorption: The physical adhesion of a gas molecule to the surface of solids or liquids by adsorption in microporosity (through pore-filling) or by completion of a monolayer. Both involve surface adsorption (after Greg & Sing, 1982).

Absorption: The physical process of the incorporation of gas molecules into the solids lattice.

Sorption: A generic term which includes surface adsorption and absorption.

4.5.2 Adsorption Isotherms

In unconventional reservoirs, gas primarily exists in a condensed phase (near liquid-density of the gas at boiling temperature at atmospheric pressure) due to physical absorption. Physical adsorption is a weak, reversible attraction due to Van Der Waals forces and is associated with a small heat of adsorption. When a gas adsorbs, it looses one of its three translational degrees of freedom (Rausch & Ammann, 2003). The kinetic energy lost by adsorption is converted to heat which is related to the heat of adsorption (see Greg & Sing, 1982 for further discussion). Chemical sorption is far stronger, slower and irreversible (Yee *et al*, 1993). Physical adsorption may produce multi-layering of the gas molecules as they are held less rigidly to the adsorbent. The adsorbate is normally restricted to a monolayer in chemical adsorption.

The volume of gas which can be stored in the sorbed state is a function of pressure and temperature. A sorption isotherm gives a quantitative measure between the sorbate gas pressure and the amount of sorbate accommodated at a constant temperature. Five basic adsorption isotherms were described by Brunauer, Deming, Deming and Teller (Type I, II, III, IV & V; Brunauer *et al*, 1940). Type I (Langmuir) is applied to microporous materials which have a small external surface area such as organic matter in mudrocks. From the Type I isotherm, gas sorption increases rapidly at relatively low pressures whilst sorption sites are continuously filled. The steep initial slope of the isotherm is caused by the overlapping adsorption potential between the pore-walls, with the adsorbate gas molecule diameter only slightly smaller than the pores (Lowell & Shields, 1984). Eventually the system will reach a saturation point at higher pressures and no more gas can be absorbed – a monolayer of absorbate is produced. The isotherm will plateau at that point. The microporosity is filled by a few layers of adsorbate where the pore size and shape controls any further adsorption.

The Langmuir Isotherm (Langmuir, 1918) can be written as:

$$(1) \qquad V_E = \frac{V_L P_g}{p_L + p_g}$$

where V_E is the volume of absorbed gas per unit volume of the reservoir in equilibrium at pressure p_g,, V_L is the Langmuir volume (based on monolayer adsorption), the maximum sorption capacity of the absorbent, p_g is the gas pressure, p_l is the Langmuir pressure, the pressure at which total volume absorbed and V_E, is equal to one half of the Langmuir volume, V_L.

4.5.3 Sorption Isotherm Uses

Adsorption analysis of gas shales is a critical element of reservoir analysis. There are three main uses:

1) Estimate the methane capacity *in situ*. The calculation is based on the assumption that the shale is saturated with CH_4
2) To asses the amount of CH_4 liberated as reservoir pressure decreases through on-going production
3) To determine the critical desorption pressure (CDP) and abandonment pressure. The CDP is the pressure from which gas will begin to desorb (i.e. below). The difference between the CDP and the abandonment pressure is the total producible gas.

4.6 RESULTS AND DISCUSSION

4.6.1 Methane Sorption

High pressure methane adsorption isotherms for selected Nordegg samples are shown in figure 4.4 and table 4.1. Methane reservoir capacities of the Nordegg Member range from 0.05 cc/g to 2 cc/g (at 6 MPa and 30 ^{0}C on moisture equilibrated samples).

4.6.2 Pressure Effects

The majority of methane isotherms for the Nordegg Member show a typical Langmuir-type behaviour up to pressures of 9 MPa. However some isotherms show a maximum adsorption capacity beyond these pressures, suggesting there may be multi-layering of the gas molecules onto the adsorbate (i.e. do not comply with the monolayer, or Type I, model of gas adsorption and deviates from the Langmuir equation at higher pressures).

4.6.3 Methane Capacity and TOC

There is relatively good correlation between methane storage capacity and total organic carbon content (Figures 4.5 & 4.6), indicating organic matter is an important factor responsible for adsorbed gas capacities. Figure 4.7 shows a down-core profile of methane adsorption in the Nordegg Member, highlighting greater sorption capacity with TOC-rich horizons.

4.6.4 Organic Matter Composition

The effect of maceral composition on gas adsorption is still debatable. Previous research has investigated the role maceral composition and gas sorption capacity with coals but limited data is available on the role of organic matter type with marine-dominated rocks. Ramos (Unpublished, 2004) found shale samples with a greater proportion of vitrinite have higher sorption capacities than samples which are Type II-rich with equivalent TOC contents and maturities. The Nordegg is composed primarily of alginite and matrix bituminite with minor fusinite/semi-fusinite and vitrinite. In the experiments reported here, the effects of maceral composition could not be discerned within the samples chosen because of the similar maceral composition in all samples.

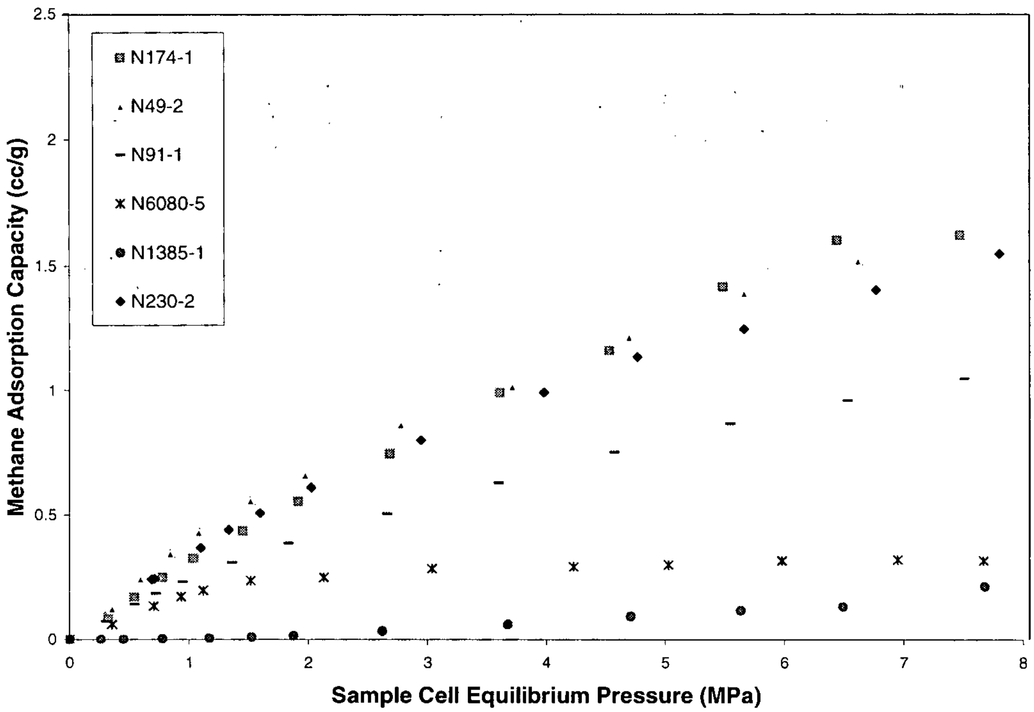


Figure 4.4 Sorption isotherms for methane on moisture equilibrated organic-rich mudrock

Sample #	Well Location	Depth (m)	TOC (wt %)	IC (wt %)	Moist (wt %)	Langmuir V @ 6MPa cc/g	scf/ton
N49-2	00/10-25-083-17W6-0	1268.60	10.00	2.64	2.26	1.52	48.74
N174-1	00/07-03-083-17W6/00	1168.40	11.83	1.70	1.65	1.70	54.52
N2709-1	00/11-29-088-17W6-0	1107.10	8.09	5.28	1.93	1.37	43.93
N6080-1	200/d-088-H 094-A-13	1240.00	4.25	0.26	8.49	0.20	6.41
N376-1	100/11-23-081-22W6/00	1104.80	1.44	8.10	0.74	0.01	0.32
N91-1	100/16-36-080-20W6/00	1630.20	10.15	1.83	0.63	0.96	30.79
N9351-1	A-58-K/94-A-16	1013.10	3.10	0.00	3.73	0.82	26.30
N89-1	200/b-078-C 094-A-14/00	1199.90	5.24	7.13	1.64	0.45	14.43
N6080-3	200/d-088-H 094-A-13	1250.10	7.48	4.30	1.76	0.53	17.00
N9682-1	A-73-K/94-A-16	1025.10	2.34	0.07	4.38	0.84	26.94
N2557-2	200/c-074-J 094-A-10/00	1084.10	3.05	0.49	2.27	0.13	4.17
N497/1m	200/d-053-G 094-A-13/00	1284.00	6.66	3.39	5.94	0.50	16.03
N72/1m	00/04-03-084-18W6	1248.00	6.93	3.64	3.17	0.69	22.05
N230-1	100/06-16-081-14W6/00	1472.50	7.09	3.77	2.48	0.59	18.92
N1385-1	100/06-28-088-17W6/00	1087.50	0.76	0.79	5.70	0.12	3.85
N6080-5	200/d-088-H 094-A-13	1259.00	6.68	3.61	2.35	0.31	9.94
N3098-3	100/11-30-087-14W6/00	1179.80	9.58	2.67	1.80	0.76	24.37
N8153-1	100/02-02-086-18W6/00	1129.00	10.45	4.76	1.69	0.59	18.92
N108-1	100/01-12-084-23W6/00	1134.70	3.64	2.62	1.58	0.76	24.37
N3793-1	200/a-65-B 93-P-05/00	2476.10	9.02	2.67	2.76	2.01	64.46
N3773-2	200/d-059-A 093-P05	3425.90	4.97	1.15	1.75	1.16	37.20
N6080-6	200/d-088-H 094-A-13	1244.90	5.63	0.26	1.82	0.44	14.11
N230-2	100/06-16-081-14W6/00	1484.90	10.67	3.73	1.77	1.40	44.90
N130-3	100/04-27-088-17W6/00	1111.00	9.49	3.20	2.20	0.50	16.03

Table 4.1: Langmuir volumes @ 6 MPa for representative Nordegg samples

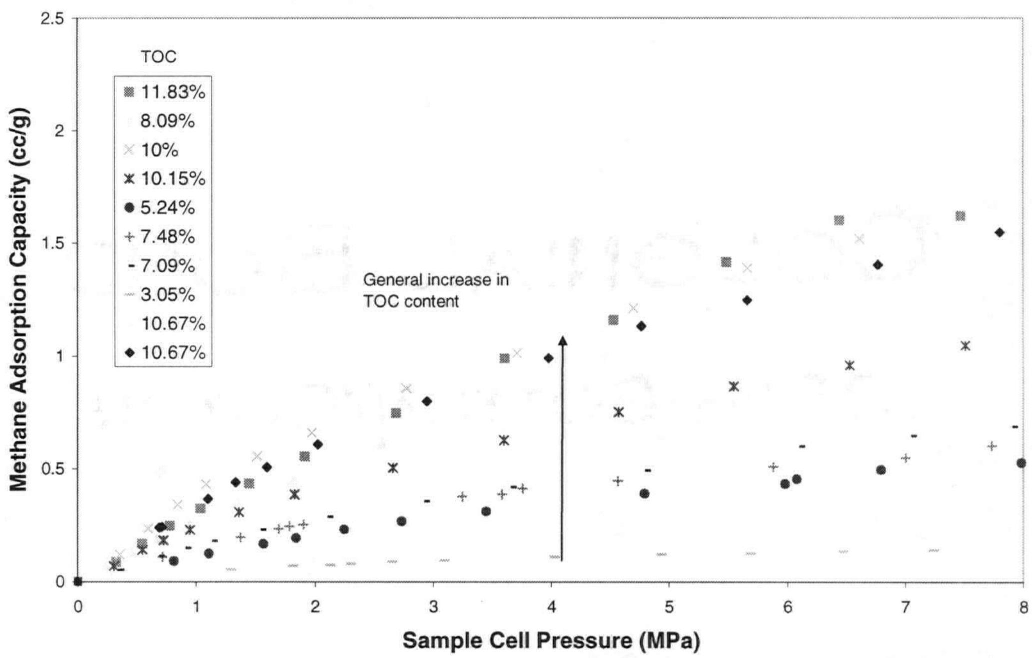


Figure 4.5: High pressure methane adsorption isotherms for selected Nordegg samples showing increase in sorption capacity with TOC

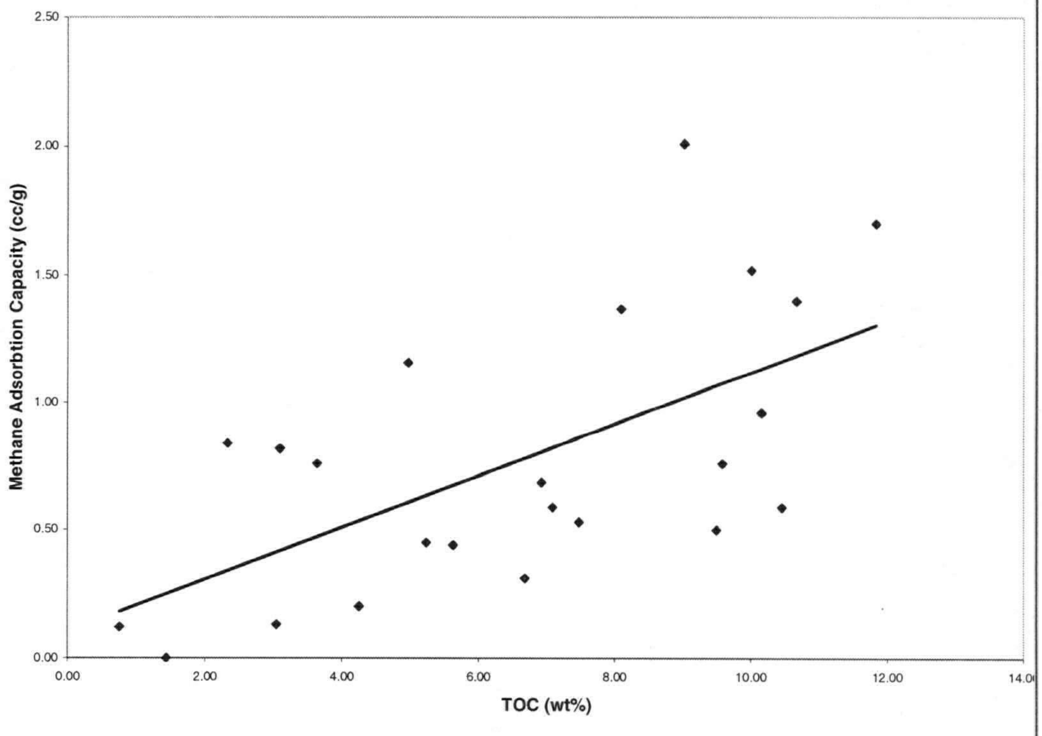


Figure 4.6: Plot of methane capacity at 6 MPa with varying TOC contents

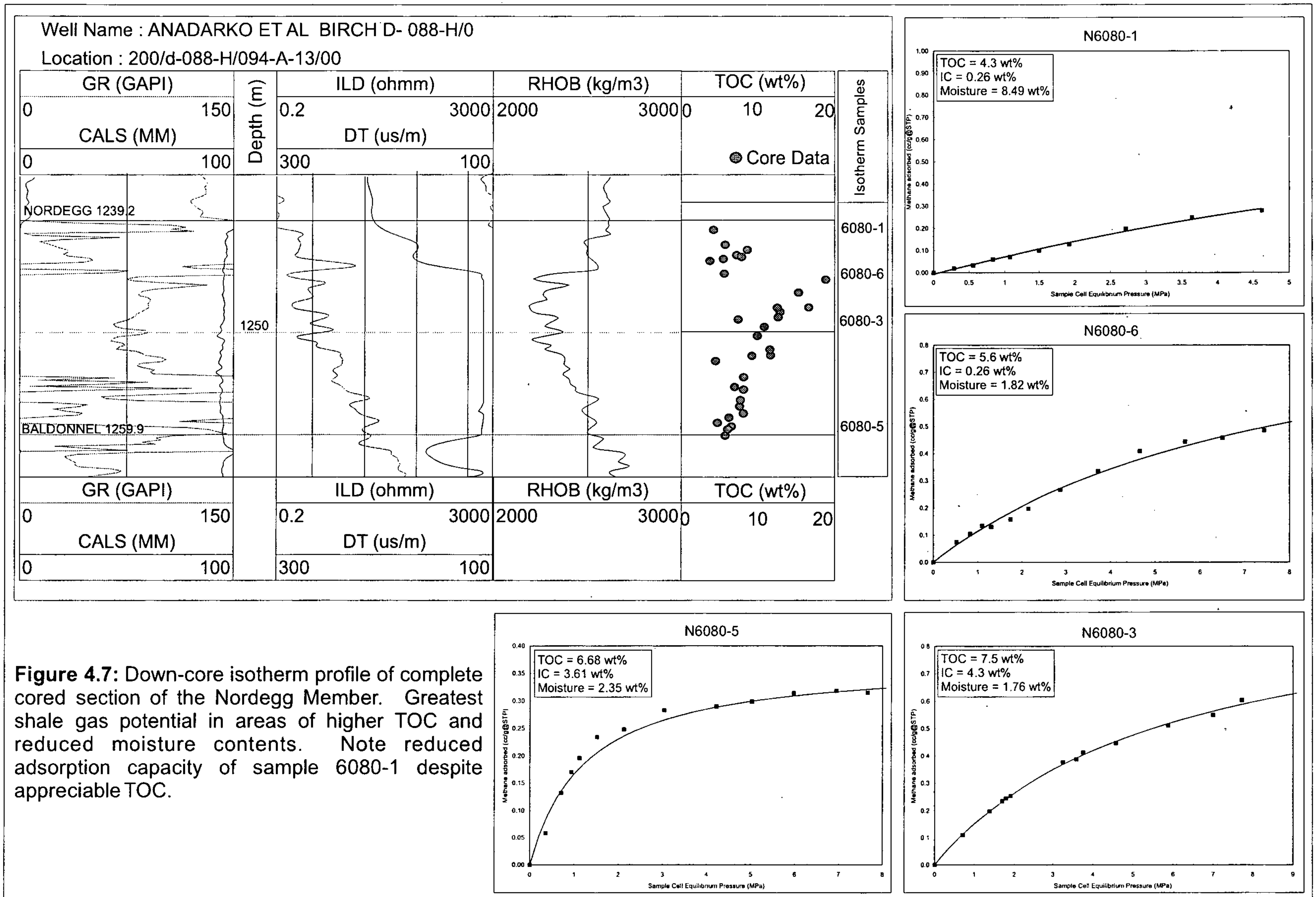


Figure 4.7: Down-core isotherm profile of complete cored section of the Nordegg Member. Greatest shale gas potential in areas of higher TOC and reduced moisture contents. Note reduced adsorption capacity of sample 6080-1 despite appreciable TOC.

4.6.5 Moisture Effect

Although no direct inverse correlation between moisture and methane capacity is observed, moisture does exert a significant influence on gas adsorption. Generally, higher moisture content inhibits methane adsorption despite varying TOC values (Figure 4.8). Methane adsorption capacities of moisture-equilibrated samples were lower by up to 30% than those for dry samples (Figure 4.9).

The relationship of moisture content and methane capacity can be quantified by comparing $EQ_{moisture}$ and dry samples. Methane content for Nordegg samples can be expressed as:

$$(2) \qquad V_d = V_m\,(1+0.30m)$$

where V_d and V_m are the methane capacities for dry and $EQ_{moisture}$ shale samples and *m* is the moisture content. For comparison, Levy *et al* (1997) suggested a multiplier of 0.39 for Bowen Basin coals whilst Ettinger *et al* (1958) used 0.31. This is to be expected due to the greater inherent moisture content of many coals compared to shales.

Previous unpublished data has shown the presence of moisture in shales is a major factor controlling methane capacity (Ramos, 2004). As moisture content increases towards a 'critical value', the ability to adsorb methane decreases (Joubert *et al*, 1973). A large proportion of the water is adsorbed and condenses within the pores of the organic matter in the shale whereby the ability of the molecules to occupy certain surfaces is controlled by thermodynamic equilibrium. The moisture competes with methane for available pore space. However as noted by Bustin & Clarkson (1998), the role of moisture is beyond that of a simple contaminant. The moisture also blocks pore-throats,

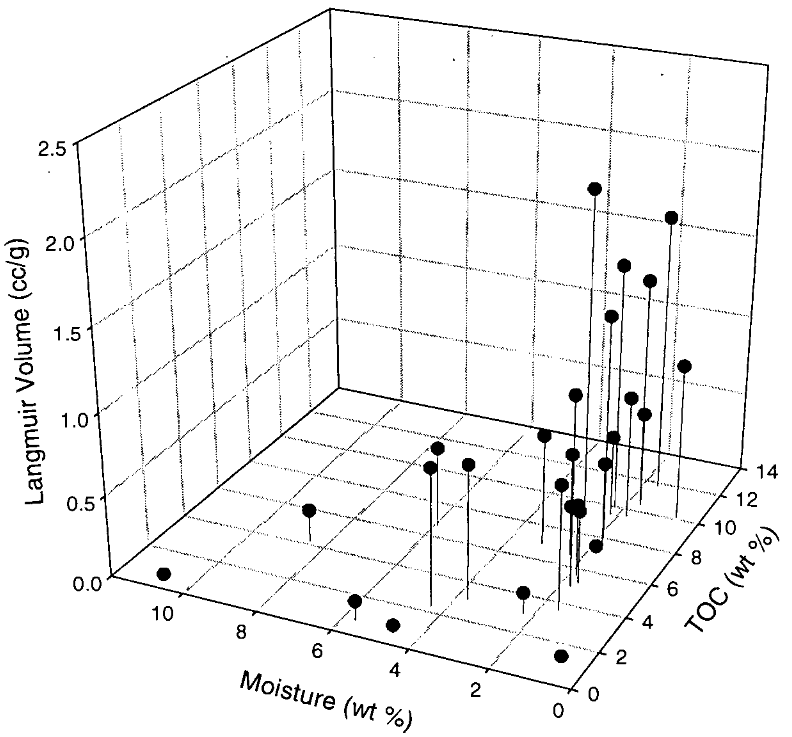


Figure 4.8: Plot showing importance of moisture content and TOC on adsorption capacity. Note significant increase in methane content with low moisture samples

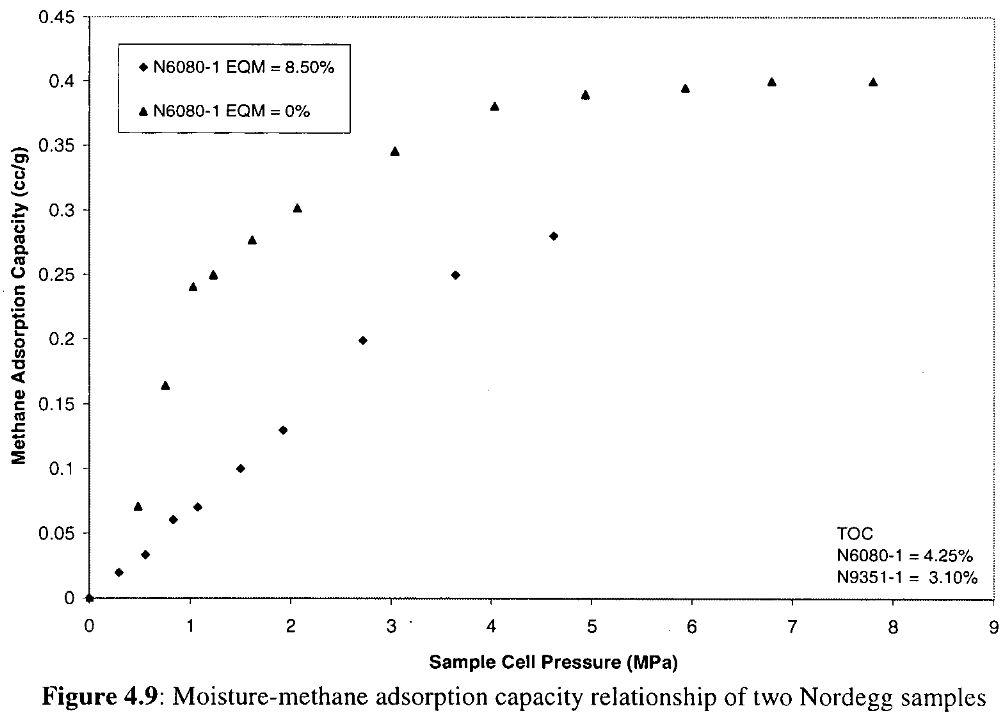


Figure 4.9: Moisture-methane adsorption capacity relationship of two Nordegg samples with similar TOC contents (EQM = equilibrium Moisture)

reducing the transmissibility of the methane to the microporosity (Yee *et al*, 1993).

4.6.6 Maturity effect

The maturity levels of the Nordegg Member increase from north-east to south west across the study area (Figure 4.10) – ranging from the base of the oil-window (~435 ^{0}C Tmax) to over-mature (> 560 ^{0}C Tmax). The region to the south west has attained the stage whereby thermogenic or late, dry-gas could be generated in significant quantities. Adsorption isotherm results indicate that methane capacities of samples with similar TOC contents increase with increasing maturity (Figure 4.11).

The adsorption capacity of many coals increases with higher maturity, despite maceral composition due to structural transformation of organic matter. The pore surface heterogeneity of the organic matter may decrease allowing more methane to absorb (Laxminarayana & Crosdale, 1999). However much debate still exists regarding maturity and adsorption as other research has shown no variation of pore volume, size or distribution occurring with increasing rank in coals (Bustin & Clarkson, 1998).

There have been few studies of gas shale capacity and maturity but research shows an increase in methane capacity with increasing maturity (Ramos, 2004). In mudrocks where clay minerals comprise a notable portion of the bulk rock composition, greater thermal maturity may result in structural transformation of minerals. For example, at high levels of maturity, smectite transforms to illite (illitisation) proceeding through a mixed-layer phase (Duba & Williams-Jones, 1983). At an early stage of diagenetic alteration to illite, smectite will loose its interlayer water. The loss of water associated with the transformation may increase sites available for methane adsorption.

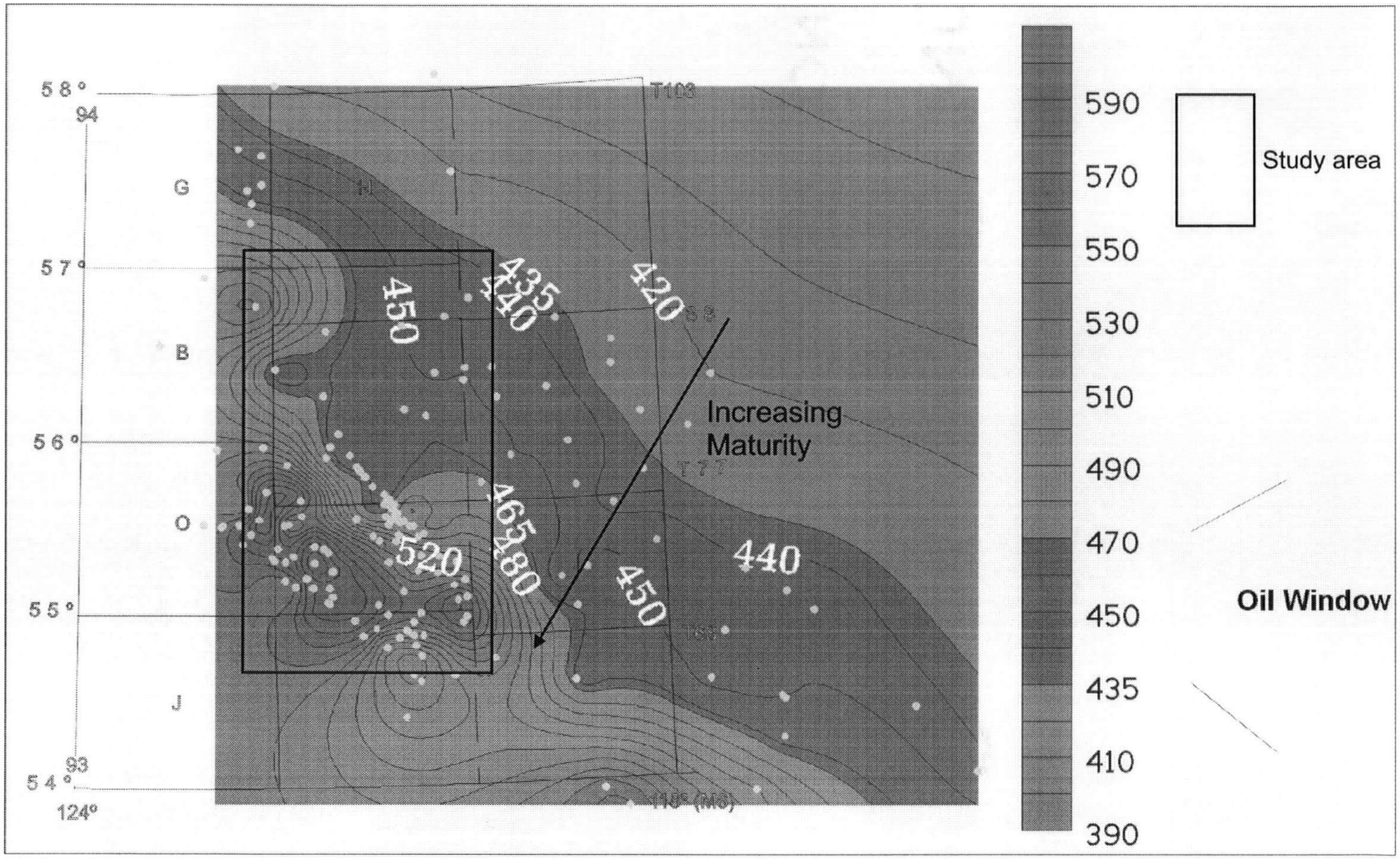


Figure 4.10: Maturity map of the Jurassic Nordegg Member across the Western Canadian Sedimentary Basin

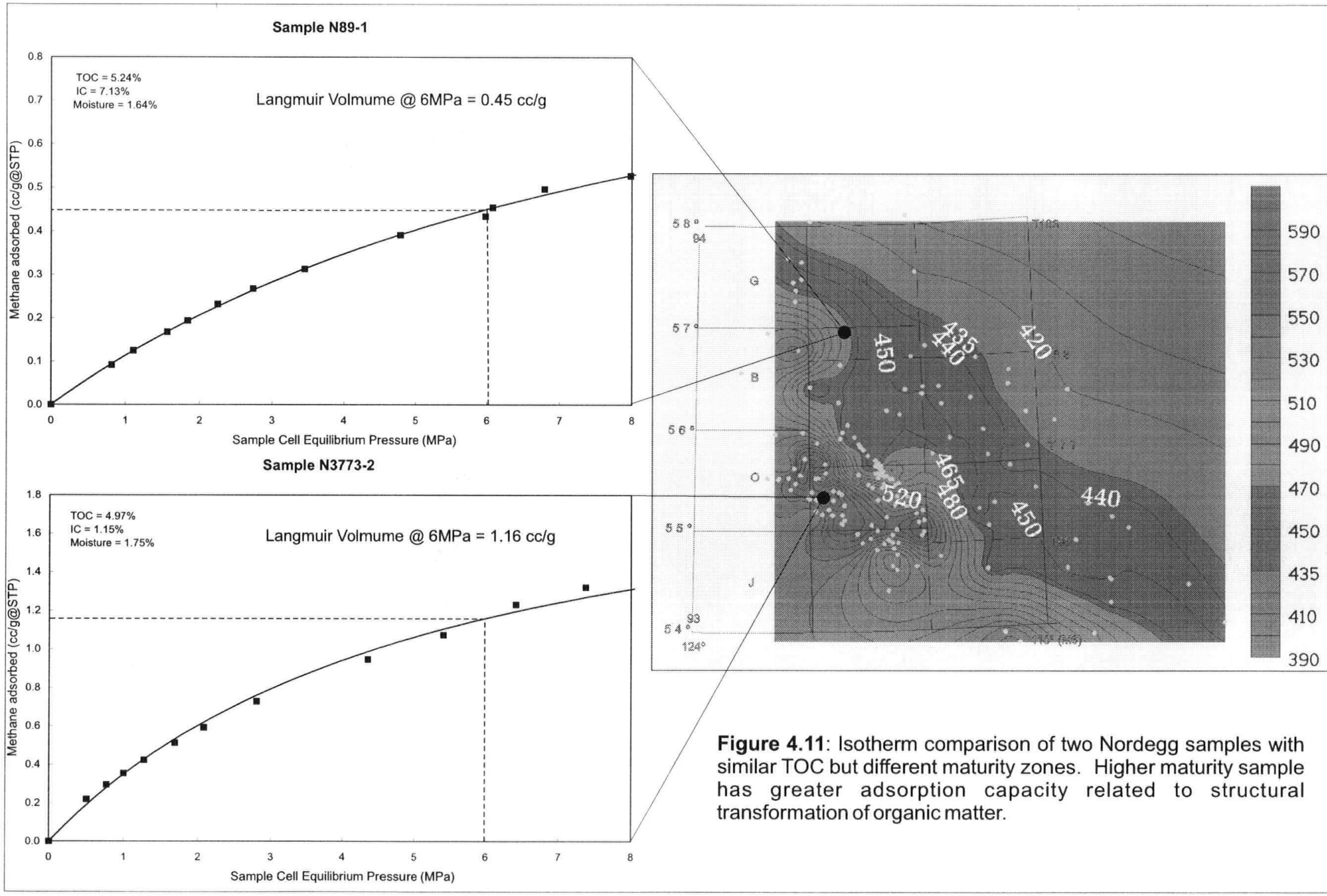


Figure 4.11: Isotherm comparison of two Nordegg samples with similar TOC but different maturity zones. Higher maturity sample has greater adsorption capacity related to structural transformation of organic matter.

4.6.7 Porosity Characteristics of the Nordegg Member

Determining porosity characteristics (both percentage of unit and size-distribution) are important in gas shale reservoir evaluations. At greater depths, and hence greater reservoir temperatures, a larger proportion of the gas may exist in the free-state (gas adsorption is an exothermic process) rather than the sorbed state. Therefore the free-gas proportion (gas molecule occupying open pores) of the gas in place may be significant depending on the porosity.

Total porosity values range from 0.7-7% with an average of 1.8% (Table 4.2). The typical Nordegg marlstones have a predominant pore-size of 0.01um (10 nm) which is within the meso-poresize[3] range (Figure 4.12A-C). The 10 nm pore-size may, in part, represent the proportion of fusinite/semi-fusinite organic matter which is meso-macro porous (Lamberson & Bustin, 1993). Argillaceous limestone has a predominant pore-size which is greater than the typical Nordegg marlstone (0.04-0.05 um or 40-50 nm/upper end of mesoporosity; Figure 4.12D). The limestone beds are typically more granular than the surrounding marlstone which would account for the coarser pore-size distribution.

Combining porosity data and adsorption data[4], the relative importance of the free gas component to the sorbed gas component can be investigated (at 6 MPa). In some samples (where porosities are typically greater than 3%), the free gas component is substantially greater than the sorbed gas component (Figure 4.13). The likely contribution of free gas in fractures to total gas storage appears minimal. Those which

[3] Porosity of shales is classified according to size using the IUAPC classification: micropores (<2nm), mesopores (2-50nm) and macropores (>50nm)

[4] Calculation involved taking porosity percentage as volume percentage of sample and subtracting from void volume.

Table 4.2: Porosity data with helium and mercury densities for selected Nordegg samples (IC = inorganic carbon, TOC = total organic carbon)

Sample #	Well ID	Depth (m)	Hg Bulk Density (g/cm3)	He Skeletal Density (g/cm3)	Open Porosity (%)	Total Open Pore Volume	IC	TOC
27-2	100/08-32-083-17W6/00	1253.6	2.56	2.64	3.212	0.013	7.32	20.14
27-5	100/08-32-083-17W6/01	1255.2	2.46	2.48	0.700	0.003	5.54	7.19
27-7	100/08-32-083-17W6/02	1255.9	2.54	2.59	2.100	0.008	10.01	24.96
55-1	100/05-14-082-25W6/00	1269.4	2.51	2.51	0.044	0.000	1.97	5.94
77-4	100/04-36-082-16W6/00	1232.5	2.54	2.60	2.255	0.009	8.79	4.20
77-14	100/04-36-082-16W6/01	1236.25	2.45	2.46	0.352	0.001	4.1	9.53
82-6	00/13-23-083-18W6-0	1164.35	2.73	2.78	1.785	0.007	0.97	2.90
121-3	200/d-038-K 094-A-11/00	1270.9	2.47	2.49	0.803	0.003	5.82	6.29
121-5	200/d-038-K 094-A-11/01	1271.35	2.41	2.47	2.513	0.010	7.34	7.88
130-4	100/04-27-088-17W6/00	1105.1	2.44	2.45	0.467	0.002	2.45	6.62
130-5	100/04-27-088-17W6/01	1105.5	2.47	2.54	2.589	0.010	10.1	5.65
130-19	100/04-27-088-17W6/02	1111.9	2.43	2.48	2.016	0.008	0.006	6.84
1257-1	200/a-045-J 094-A-09	1083.9	2.51	2.53	0.918	0.004	3.49	4.21
1257-8	200/a-045-J 094-A-10	1086.8	2.51	2.56	1.791	0.007	7.78	4.57
3773-6	200/d-059-A 093-P05	3422.2	2.54	2.58	1.550	0.006	1.31	12.80
5378-17	200/d-097-I 94-A-10/00	1105.6	2.36	2.38	0.783	0.003	0.0008	23.30
8354-12	100/11-32-086-18W6/00	1162.8	2.38	2.40	0.833	0.004	0.3	21.00
8354-16	100/11-32-086-18W6/01	1165.7	2.48	2.48	0.087	0.000	2.7	26.00
N2709-1	00/11-29-088-17W6-0	1107.1	2.48	2.48	0.039	0.000	5.28	8.09
N49-2	00/10-25-083-17W6-0	1268.6	2.48	2.48	0.175	0.001	2.64	10.00
N174-1	00/07-03-083-17W6/00	1168.4	2.23	2.38	6.224	0.028	1.7	11.83
N6080-1	200/d-088-H 094-A-13	1240	2.55	2.61	2.088	0.008	0.26	4.25
N376-1	100/11-23-081-22W6/00	1104.8	2.79	2.84	1.711	0.006	8.1	1.44
N9351-1	A-58-K/94-A-16	1013.1	2.56	2.57	0.470	0.002	0	3.10
N4941-1	200/d-075-I 094-A-13/00	1294.6	2.52	2.58	2.069	0.008	3.14	7.07
N91-1	100/16-36-080-20W6/00	1630.2	2.25	2.38	5.243	0.023	1.83	10.15
72-1	00/04-03-084-18W6	1248	2.51	2.60	3.231	0.013	3.64	6.93
497-2	200/d-053-G 094-A-13/00	1284	2.58	2.66	2.909	0.011	3.39	6.66

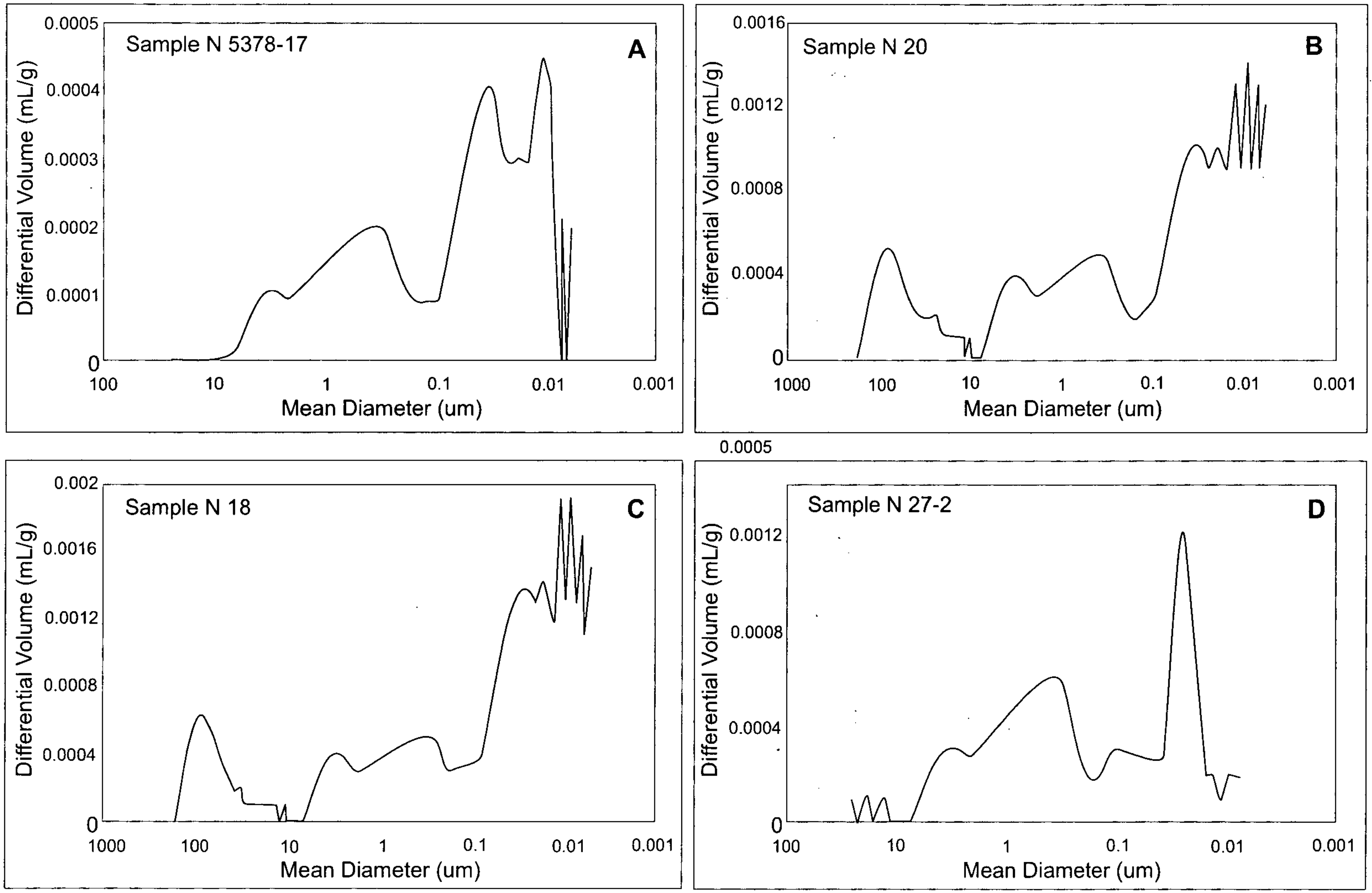


Figure 4.12, A-D: Differential Pore Volume vs. Mean Diameter for selected 'Nordegg' Samples. Most samples have a meso-macro pore size distribution. The lack of microporosity in samples likely reflects the inability of mercury to inject into the smallest pores.

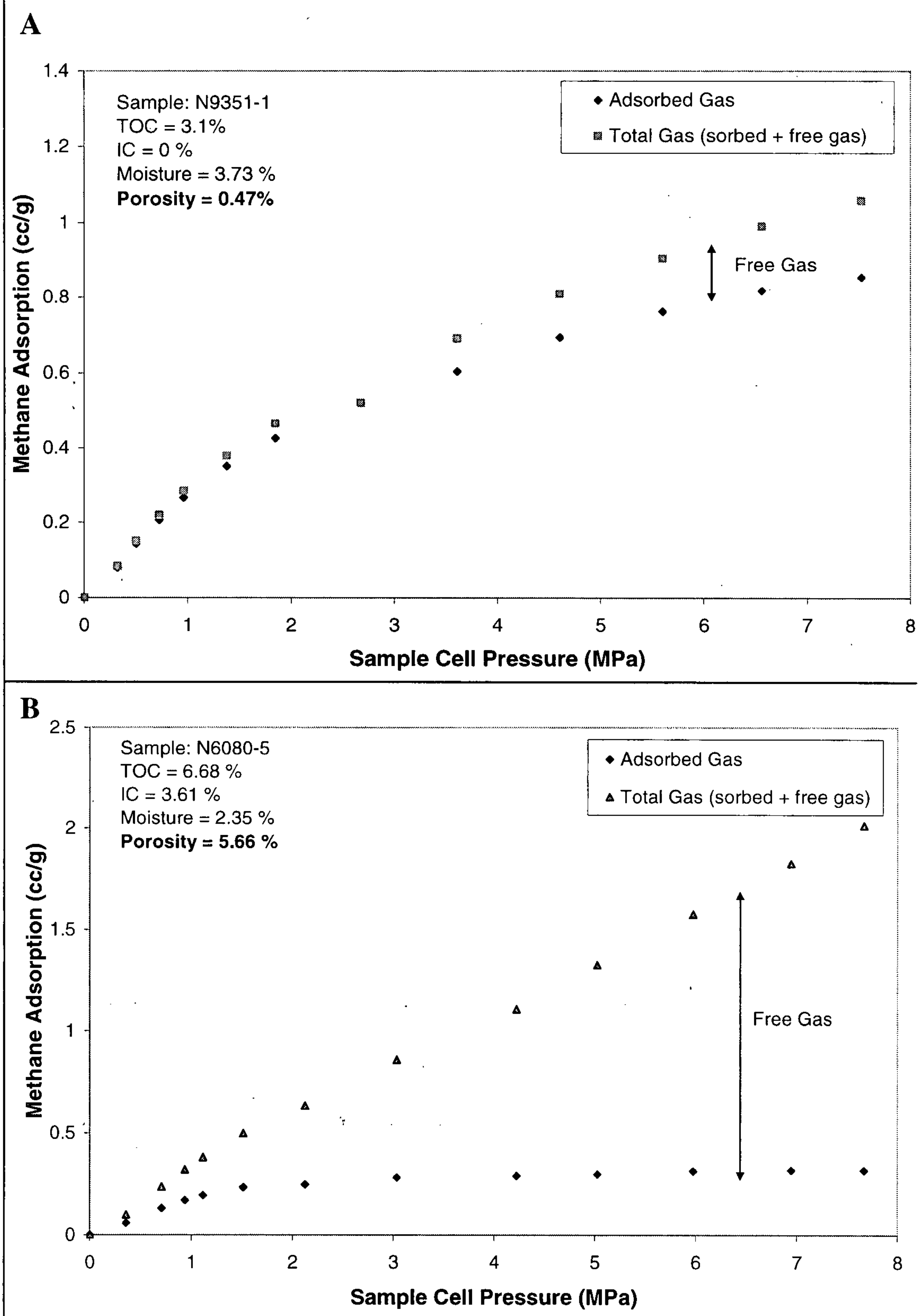


Figure 4.13: Variation of free-gas capacities and porosity. (A) 0.5 % porosity, free gas comprises 20 % of total gas. (B) 5 % porosity increases free gas component to 80 % of total gas

occur are horizontal with calcite cementation. Most fractures are calcite filled or have an early calcite and later bitumen in-filling with bitumen occupying the centre of the fracture and calcite surrounding.

4.7 GAS SHALE RESERVOIR EVALUATION

4.7.1 Nordegg Organic Matter and Gas Producing Capabilities

The Nordegg in the study area is characterized by both liptinite (alginite and bituminite or Type II organic matter) and inertinite (fusinite/semi-fusinite; Type IV organic matter) with rare vitrinite. A large proportion of the rock-matrix is bituminite which fluoresces a green/brown color in blue-light excitation. The admixture of Type II, III and IV organic matter (OM) indicates a good potential to generate gas as oppose to the oil-generative potential of Type II OM.

4.7.2 Nordegg Lateral Extent & Thickness

The Nordegg Member extends over an area of 90,000 km^2 in NE BC and adjacent parts of Alberta. Previous gas shale research has shown a good correlation between methane production and unit thickness in the US such as the Appalachian and Illinois Basins (Harris *et al*, 1978; Cluff & Dickerson, 1982). The lower and middle Nordegg Member (LGF-B and LGF-C) comprise the thickest sections (up to 13 m thick), thickening in the central and south-west portion of the study area (Figure 4.14). The upper Nordegg Member (LGF-D) is typically thinner, between 5-6 m. The Nordegg Member, on average, is 25 m across the study area but there is rapid thinning to the north-east towards due to the sub-Cretaceous erosional front.

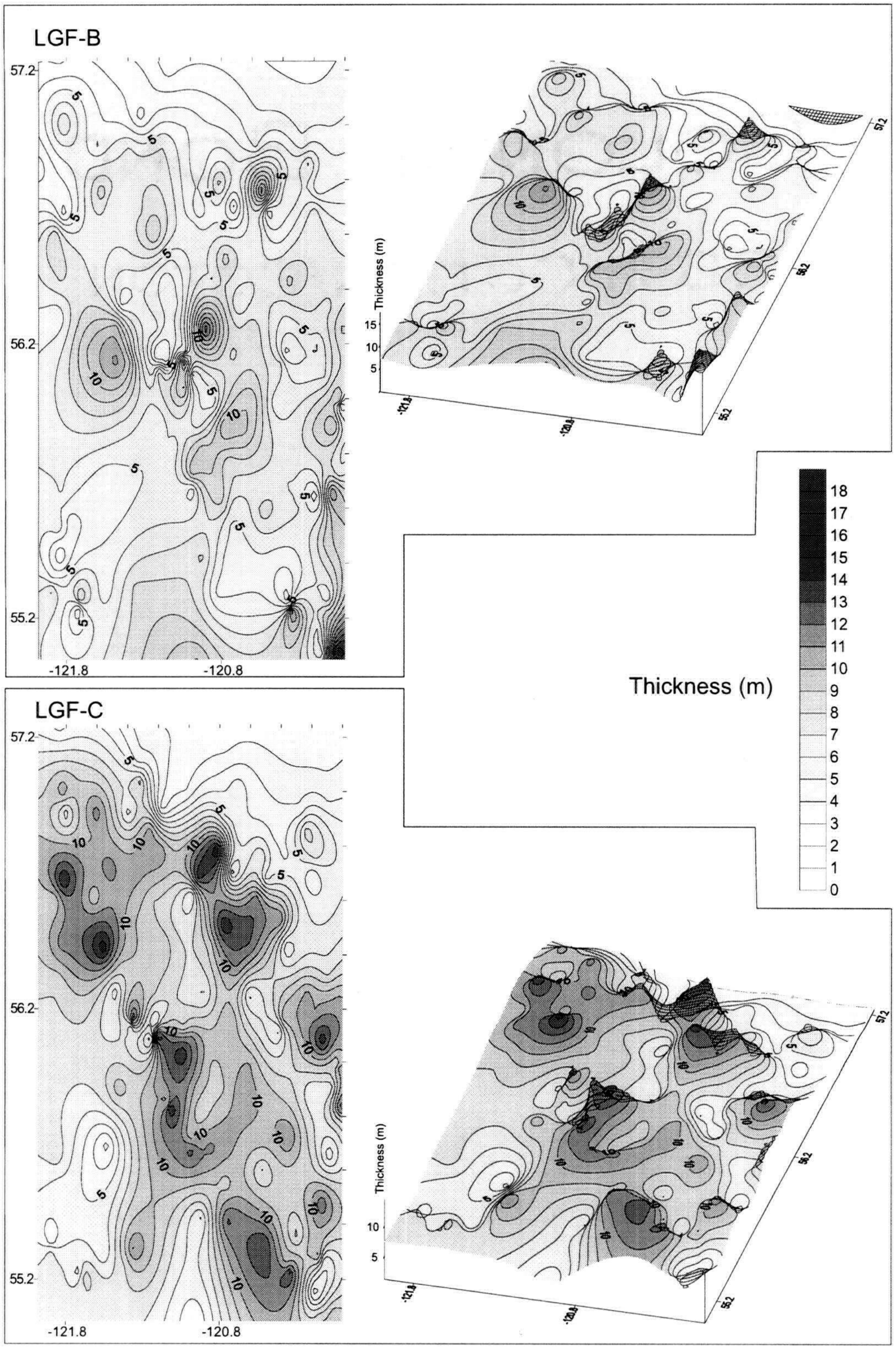


Figure 4.14 : Isopach maps of LGF-B and LGF-C

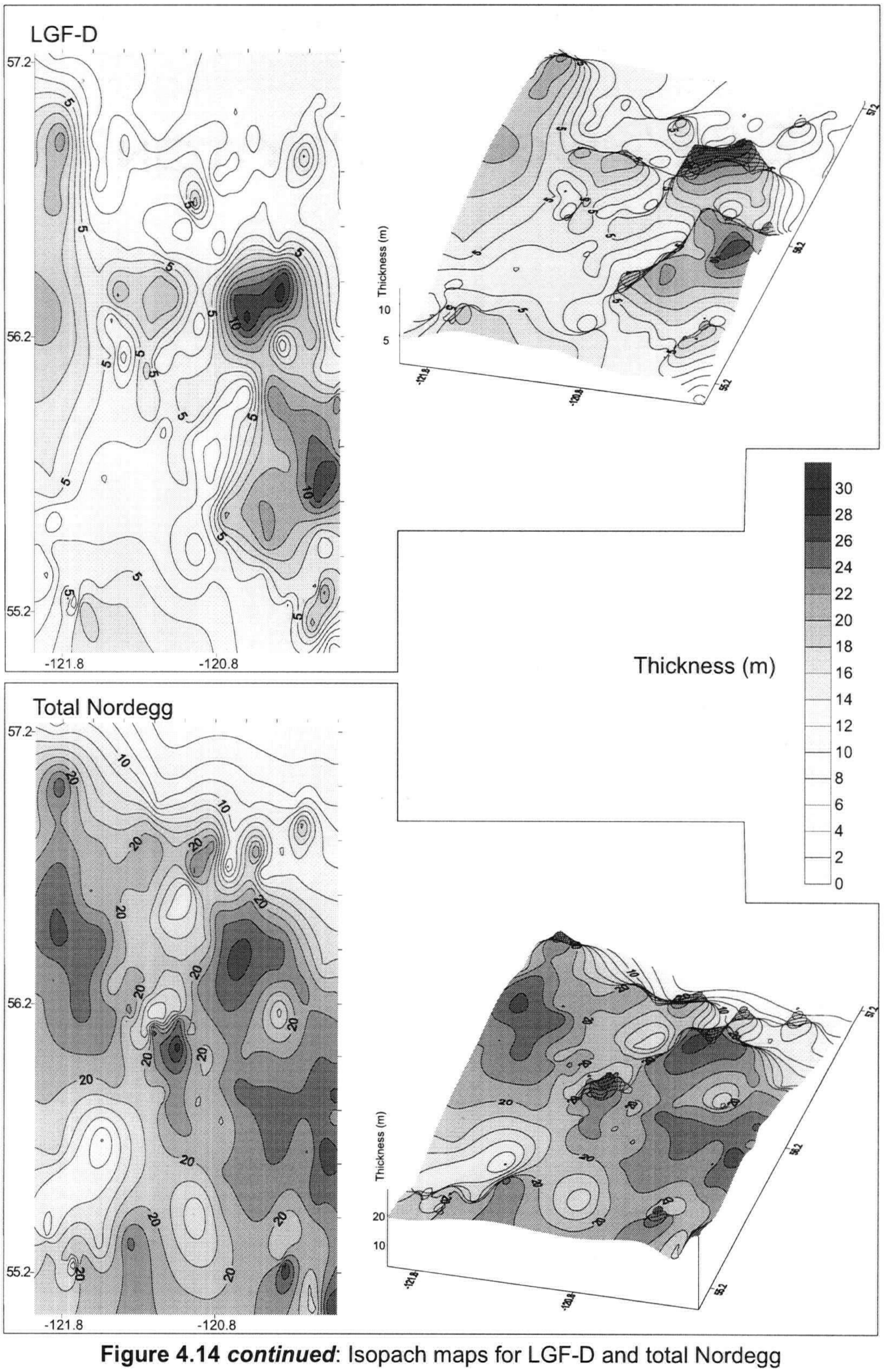


Figure 4.14 *continued*: Isopach maps for LGF-D and total Nordegg

4.7.3 Structure Considerations

The Nordegg Member has a dip of ~ 4^0 towards the southwest. The structure changes abruptly in the SW portion of the study area where the Nordegg dips sharply (Figure 4.15). The faulting associated with the Laramide Orogeny is likely responsible for changing dip. The only major faulting affecting the study area is located in the south-west of the study area (Figure 4.16).

The study area is located within the North American Mid-Plate Stress Province (Zoback & Zoback, 1980). Bell & McCallum (1990) suggest an east to west transformation of the stress regime across the Peace River Arch area. In the west, the stress regime is compressional where $S_{Hmax} > S_v > S_{Hmin}$ (S_{Hmax} = maximum horizontal stress; S_v = vertical stress; S_{Hmin} = minimum horizontal stress). Fault traces in the region are northwest-southeast but deflect to north-northwest over the Peace River Arch area (Figure 4.16). However the stress trajectories are not parallel to the fault orientations in the region. This "Peace River Arch Anomaly" will have a significant control on fracture orientation where induced fractures would be orientated anomalously to the NNE-SSW.

Mineralogy may also affect the Nordegg Member response to various stimulation treatments. XRD analysis of the Nordegg reveals high quartz content in organic-rich zones (TOCG2) with lesser carbonate. Quartz is more brittle than calcite in clay-rich rocks. Therefore induced fracturing will likely be more effective in the central sections of the Nordegg Member, coinciding with greater TOC contents and increased levels of gas adsorption.

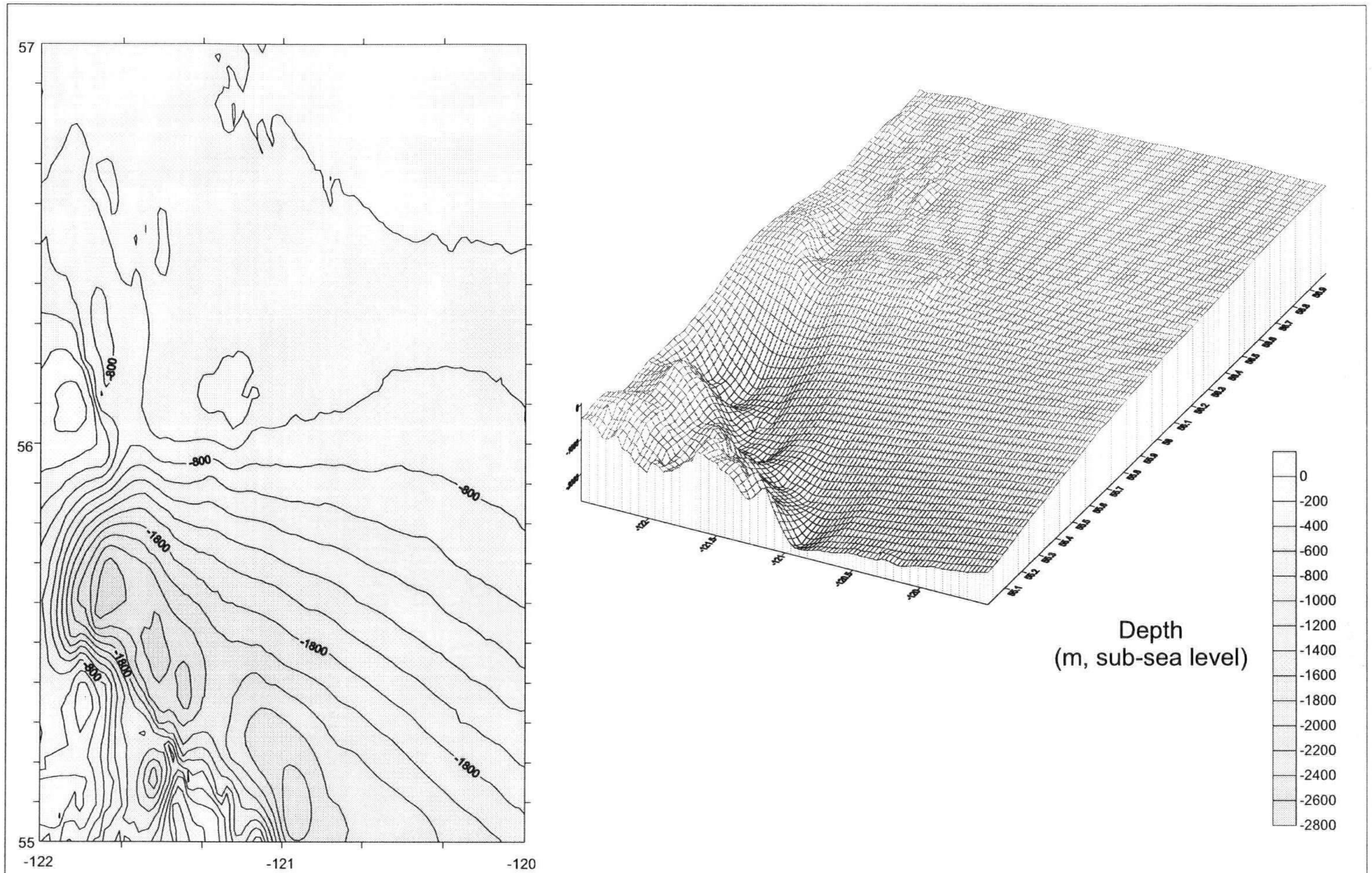


Figure 4.15 Structure map to the top surface of the Nordegg Member showing increased burial depth to the southwest of the study area.

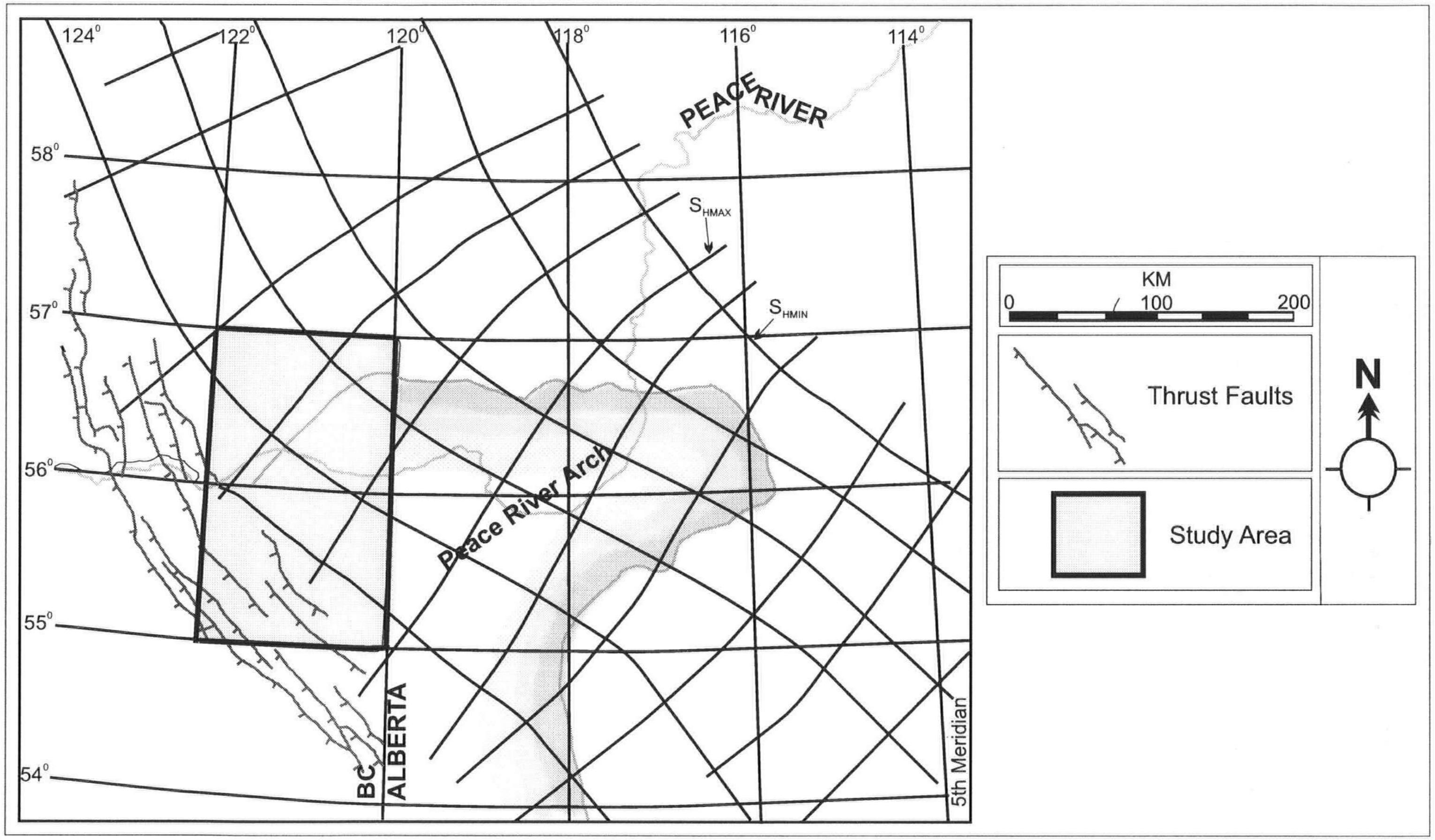


Figure 4.16: Map of thrust faults and stress trajectories in the Western Canadian Sedimentary Basin. Modified from Bell & McCallum (1990). Shaded area indicates Peace River Arch in NE BC.

4.7.4 Total Gas-In-Place (GIP) Across Study Area

TOC distributions of the Nordegg Member have been mapped using wireline logs (see chapter 3). The TOC data has been combined with adsorption capacities of various samples to produce a gas capacity map for LGF-B, LGF-C and LGF-D of the Nordegg Member. The methane adsorption capacities increase to the southwest, were the TOC contents are greater than 7% (Figure 4.17). On average, the methane capacities in this region reach up to 2 cc/g at 6 MPa. LGF-B and LGF-C have high GIP levels in the south-western portion of the study area (Figure 4.18). Here, gas content is primarily controlled by organic-richness (LGF-D) and a combination of organic-richness with increased thickness (LGF-C). The gas contents in the southwest of the study area may be greater than predicted due to the additional effect of maturity. Total gas reserves for the entire Nordegg Member (adsorbed + free gas) vary from 0.2 BCF/section to 24 BCF/section (Figure 4.19).

4.8 CONCLUSIONS

Methane adsorption isotherms on moisture-equilibrated organic-rich mudstones and marlstones of varying TOC contents were investigated. In the study, the Nordegg Member has gas shale potential in NEBC. Type II, IV & minor III organic matter occurs in various amounts across the study area which can generate significant quantities of natural gas. The moderate correlation between TOC and adsorption indicates gas adsorption capacity is strongly influenced by TOC content, with methane adsorbing onto the microporous organic matter. Variation of methane adsorption capacities at 6 MPa with similar TOC contents can in part be ascribed to differing maturity levels. At greater maturity, the organic matter becomes microporous improving adsorption between the

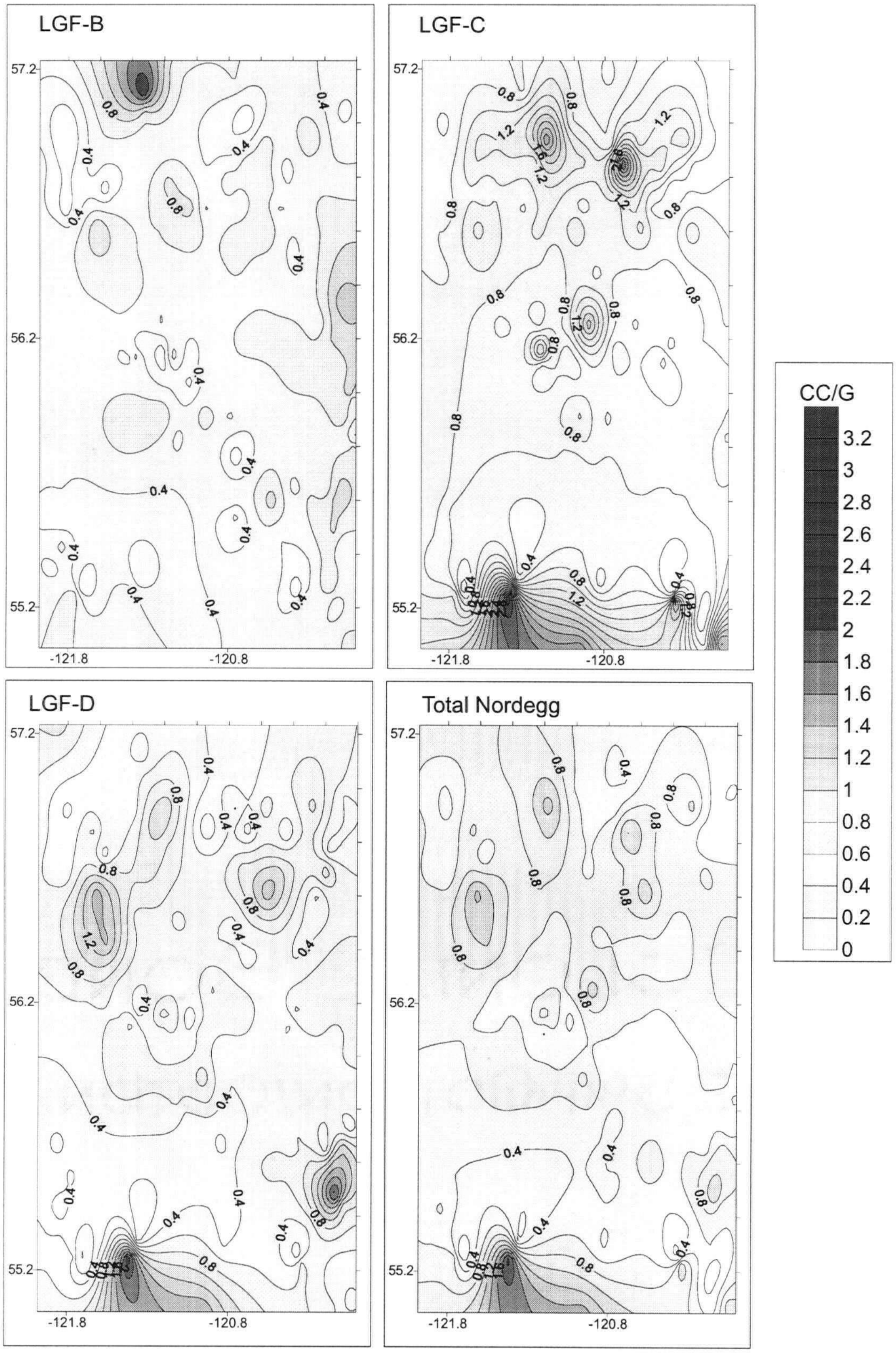


Figure 4.17: Gas capacities of the lower, middle, upper and total Nordegg Intervals across north-eastern British Columbia

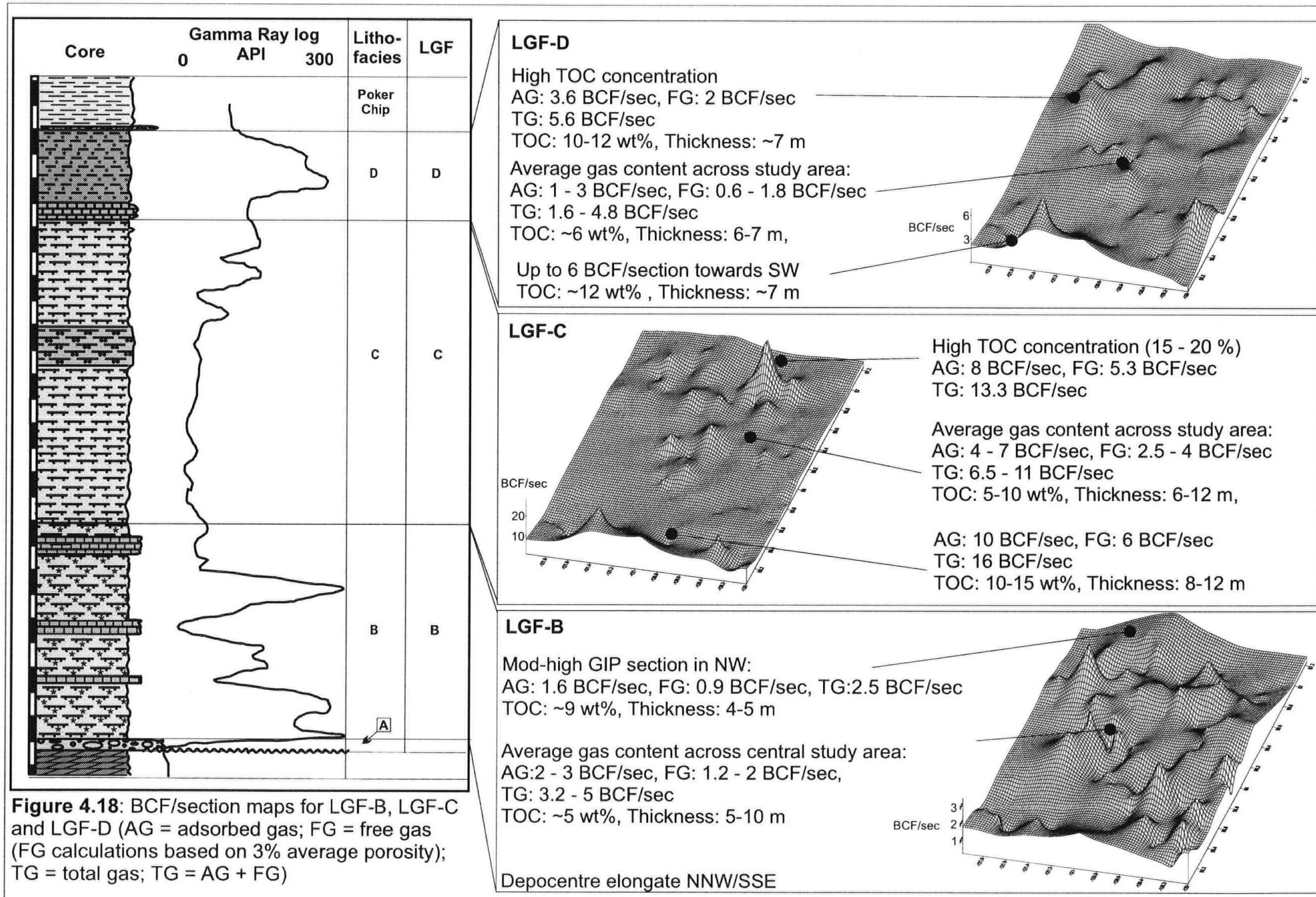


Figure 4.18: BCF/section maps for LGF-B, LGF-C and LGF-D (AG = adsorbed gas; FG = free gas (FG calculations based on 3% average porosity); TG = total gas; TG = AG + FG)

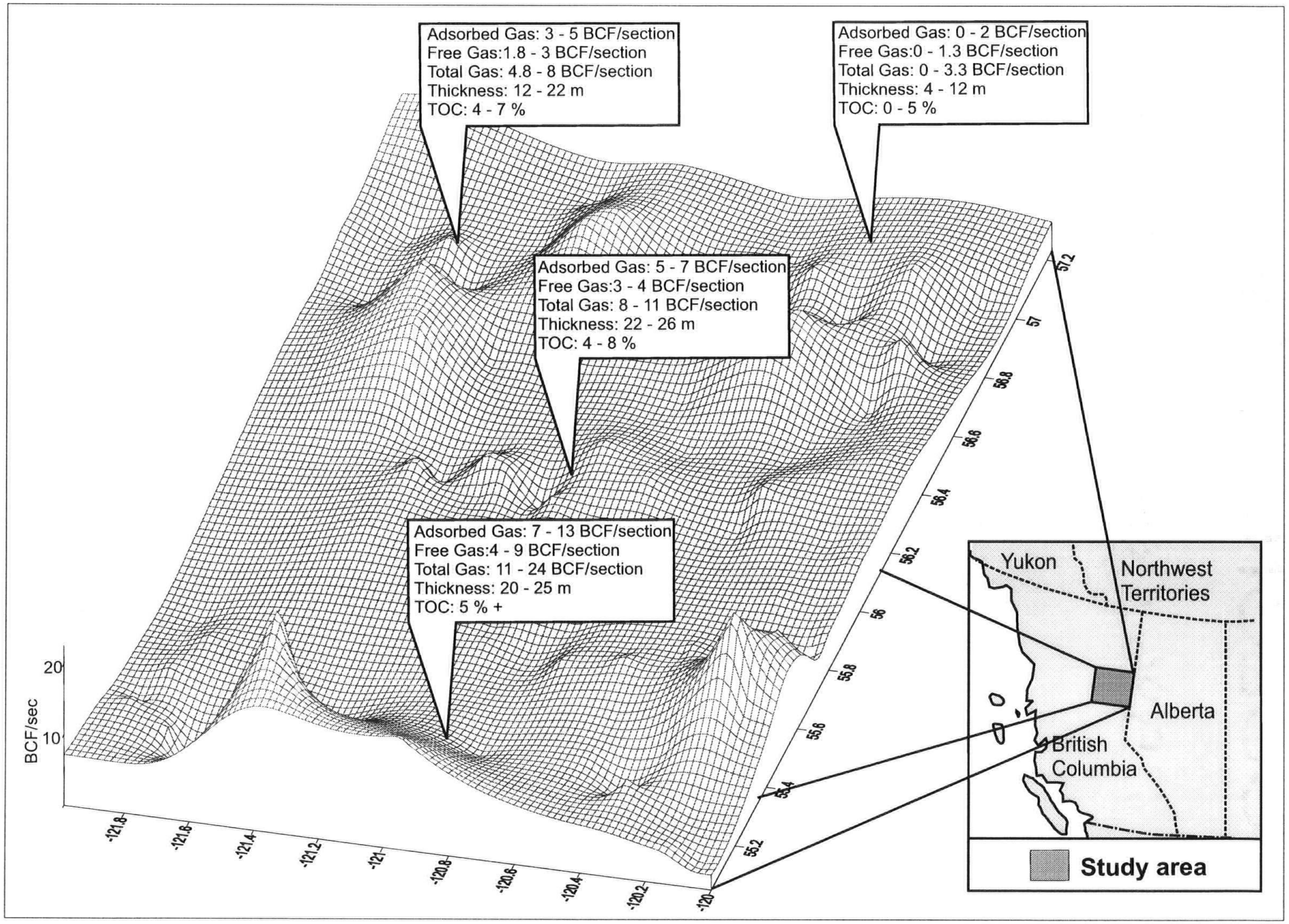


Figure 4.19: BCF/section map for total Nordegg Member (free gas calculated with 3% average porosity across study area)

adsorbent and adsorbate. Results of this investigation highlight the need to consider moisture content for estimating methane adsorption capacity. Moisture reduces the gas content of samples, not only sorbing onto organics and clays, but blocking pore-throats leaving areas inaccessible to methane. On a dry basis, methane adsorption is significantly higher than moisture-equilibrated samples. However, methane capacities of dry samples are of limited practical use as they do not represent in-situ reservoir conditions.

On a regional scale, the south-west of the study area would be a prime exploration target for shale gas within the Nordegg Member. Higher average TOC's (leading to increased methane adsorption capacities), greater unit thickness (BCF/section increases), thermally mature OM and extensive fracturing combine to produce an excellent prospect.

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Chapter 5

The Effect of Particle Size on Gas Adsorption

5.1 ABSTRACT

As no particle-size standard exists for samples to be analysed for sorption analysis, an experiment was conducted to assess the effect of various particle-size distributions on methane adsorption. Samples show an increased sorption capacity with decreasing particle size due to the greater surface area, hence greater adsorption, of finer grains. Samples with a smaller grain-size also have greater moisture content. The counter-intuitive nature of high methane adsorption, high moisture samples suggest some sites for adsorption may be more hydrophobic or hydrophilic than others. The ability of methane to penetrate and access adsorption sites may also be enhanced by finer particle sizes which allows for improved gas diffusion through the sample and ultimately increased gas adsorption.

5.2 INTRODUCTION

For both coalbed methane and gas shale analysis, sorption measurements are commonly ran on finely ground coal and shale samples. The fine-grained nature of adsorption samples enables a time-efficient equilibrium to be obtained between the sorbed and free gas phases (Yee *et al*, 1993). If equilibrium is not attained, the isotherm which represents the gas phase equilibrium will not be correct. A reason for non-equilibrium behaviour may be related to the variation of particle size of the adsorption sample. For example, Airey (1968) reported a significant increase in adsorption capacity with decreasing particle size which is a result of non-equilibrium due to diffusion and rapid adsorption takes place. However, Yalcin and Durucan (1991) found no difference between the methane adsorption capacity for a -65 + 100 mesh and -120 + 150 mesh and only a slight decrease in adsorption capacity for particles larger than 65 mesh size.

Due to the variability of sample preparation for gas adsorption analysis, an experiment was run to compare the adsorption capacity of samples with differing particle size as a result of various crushing times.

5.3 SAMPLES AND SAMPLE PREPARATION

The samples used in this study are taken from the Jurassic Nordegg Member, collected from wells located in the Peace River District of northeastern British Columbia (between 93-P-1and 94-A-13). Samples were selected on the basis of core availability (depths ranged from ~1000 to ~3000 m) and total organic carbon content. Two Nordegg samples were chosen with similar TOC (6.7 & 6.9 wt%) and porosity (2.91 and 3.23%).

Each sample was divided into two, one half ring-milled for 1 minute and the other for 20 minutes (e.g. 497/1 = 1 minute milling, 497/20 = 20 minute milling).

5.4 EXPERIMENTAL PROCEDURE

A volumetric, Boyles Law gas adsorption apparatus was used to measure high pressure methane isotherms at 30^{0}C modelled using the Type I Langmuir isotherm (1918). For each sample, pressure points were collected up to 9 MPa. Moisture equilibrated samples of ~150 g were crushed to 250 um in a ring-mill for adsorption analysis. Moisture capacities were determined by water saturation at 30^{0}C (ASTM D1412-85) which is recommended for moisture content under reservoir conditions. The method consisted of equilibrating dried shale samples over a saturated solution of potassium sulfate for more than 72 hours in a vacuum dessicator.

5.5 RESULTS AND DISUCSSION

The grain-size variability of the four samples is shown in table 5.1. Methane adsorption isotherms for N497 and N72 are given in figure 5.1 and table 5.2. With increased milling time (and resultant greater surface area where a greater proportion of the grain-size distribution is < 250 um), both sets of samples have an increased EQ moisture. N72 has the most significant moisture increase from 3.2 to 7.1%.

The moisture increase in both samples with finer grain-size is due to the greater surface area per unit mass, producing more sites for water adsorption. Previous research has also shown an inverse relationship between particle-size and moisture content (Jaber *et al*, 2001). Typically, water molecules compete for adsorption sites with methane

Sample #	>420um	420um - 354um	354um - 250um	250um - 120um	120um - 63um	<63um
N72/1min	19	5	12	14	10	40
N72/20min	2.5	2.5	10	20	15	50
N497/1min	26	3.15	11.25	19.35	11.25	29
N497/20min	1.2	1.2	3.6	18	16	60

Table 5.1: Grain-size variability of samples milled for 1 and 20 minutes

molecules and can block methane access to many pores (Joubert *et al*, 1973). Therefore higher moisture contents reduce the methane capacity everything else being equal. However the increase in moisture does not produce a decrease in methane adsorption for these samples. The excess surface area created has not only produced more moisture adsorption sites (saturation at 30 ^{0}C), but also more methane adsorption sites.

Dry samples have a markedly higher methane capacity compared to their moisture-equilibrated counterparts. The adsorption sites which were occupied by moisture have become available for methane, hence increasing the amount of methane adsorbed. Removal of moisture allows access of gas to the micropore system which would not have been previously available for sorption (Laxminarayana & Crosdale, 1999).

The ability of methane to be adsorbed in a sample is primarily a result of the highly microporous nature of the organic matter which has high internal surface area (e.g. Lamberson & Bustin, 1993). However the ability of the methane molecule to penetrate the micropores will also significantly influence how much methane can be adsorbed. For samples investigated here with a coarser grain-fraction (72/1 and 497/1), the methane could not access all the micropores in the pressure ranges applied in the laboratory. With greater milling time, adsorption sites which were previously unavailable are now accessible to the methane molecule. Therefore the increased methane capacities of fine-

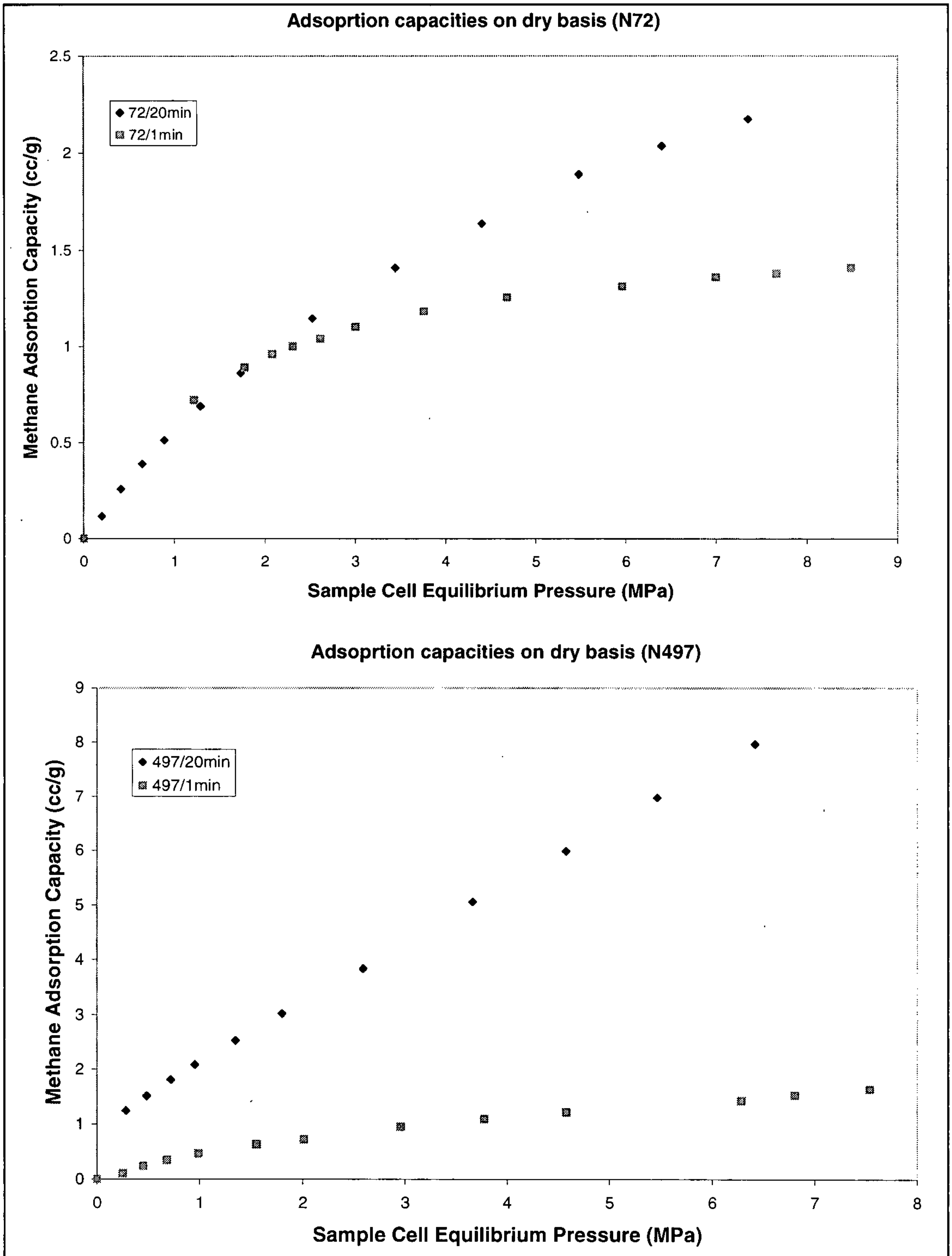

Figure 5.1: Effect of surface area (through varying crushing time) on methane adsorption capacity (1min – 1 minute milling time, 20min = 20 minutes milling time). Both samples show increase in gas capacity with finer particle size

Sample #	EQ moisture (EQM)	Adsorption capacity (@ EQM, 6 MPa)	Adsorption capacity (dry, 6 MPa)
N72/1min	3.17%	0.67 cc/g	1.3 cc/g
N72/20min	7.10%	1.08 cc/g	1.9 cc/g
N497/1min	5.95%	0.5 cc/g	1.3 cc/g
N497/20min	7.07%	0.94 cc/g	6.9 cc/g

Table 5.2: Adsorption data for various milling times

grained samples (72/20 and 497/20) may not only be a result of increased surface areas through excess milling, but may also be a result of full methane penetration to the adsorption sites.

5.6 CONCLUSIONS

Sample preparation has a significant influence on adsorption results in as particle grain-size controls the total surface area of the sample and the ability of methane to access adsorption sites on the micropores of organic matter. Heterogeneous grain-size distributions produces variable surface areas which affects both moisture and methane capacities which may not be indicative of in-situ conditions. To resolve erroneous adsorption calculations from particle size, an ASTM standard should be set so all adsorption samples are be milled and sieved to a common particle size.

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Chapter 6

The Cause and Effect of Moisture on Gas Shale Reservoirs

6.1 ABSTRACT

The moisture content of marine mudrocks is associated with both the organic matter and clay mineral fraction. In particular, illite and smectite adsorb appreciable amounts of water, which can account for over 50% of the total moisture content of shale. A large proportion of the clay moisture exists in the free-state between the individual silicate layers of the structural lattice rather than the sorbed state.

Adsorption measurements of moisture-equilibrated samples clearly indicate water reduces methane capacity; capacities of moisture-equilibrated samples were lower by up to 30% than those for dry samples. Not only does moisture compete for adsorption sites with methane, it blocks pores and pore throats restricting the diffusion of methane to potential adsorption sites. Despite the significant solubility of methane in water, no increase in methane capacity with increasing moisture content was observed indicating the moisture resides in locations which are inaccessible to the larger methane molecule.

6.2 INTRODUCTION

Moisture plays a significant role on the adsorption of gases in unconventional gas reservoirs (coalbed methane and gas shale reservoirs). In most coals studied, there is a linear decrease in methane adsorption with increasing moisture content (e.g. Joubert *et al*, 1974; Levy *et al*, 1997; Kroos *et al*, 2002;). Joubert *et al* (1974) found that moisture decreased methane adsorption until a 'critical' level of moisture was reached. The critical level is believed to be the water saturation of the sample whereby thereafter, moisture increase will not affect the adsorption capacity. However the factors which control moisture contents are not well understood. Maceral composition may play an important role, especially for vitrinites whereby the more open structure with hydrophilic groups in vitrinite accommodates large quantities of water (Levine, 1993). However Bustin and Clarkson (1998) found an inverse correlation between vitrinite and moisture contents for a suite of Australian Bulli isorank coals.

To date, there has been no systematic investigation on the controls and effects of moisture of marine organic matter (MOM) – rich shales and mudstones with respect to gas shale reservoir evaluation. Shales and mudrocks are assumed to exist at its inherent moisture at in-situ conditions. Therefore all samples analysed for gas shale adsorption should be measured at equilibrium moisture so in-situ conditions are met.

The object of this paper is to study the relationship between moisture and composition for organic-rich mudstones and marlstones which have similar maceral composition and to investigate the role of moisture on methane adsorption.

6.3 EXPERIMENTAL

6.3.1 Samples

The materials examined in this study were collected from wells located in the Peace River District of northeastern British Columbia (between 93-P-1and 94-A-13). Samples were selected on the basis of core availability (depths ranged from ~1000 to ~3000 m) and total organic carbon content. All samples studied have comparable maceral compositions, composed primarily of liptinite macerals (alginite and matrix bituminite) and minor fusinite/semi-fusinite and vitrinite.

6.3.2 Methods

The concentrations of total carbon, sulfur and nitrogen content were determined by a Carlo Erba NA-1500 Analyzer for 430 samples. Fifty six of these samples were taken from core 200/d-100-H 094-A-13, the only core available through the entire Nordegg. Analytical precision was better than 2% for carbon, 5% for sulfur and 4% for nitrogen. Inorganic (carbonate) carbon concentration values were generated using a CM5014 CO_2 by coulometric titration following release of CO_2 with 2 N $HClO_4$. Total organic carbon was calculated as the difference between total and inorganic carbon values (i.e. TOC = TC-TIC). TOC analysis for total gas-in-place calculations was calculated using density wire-line logs (theory & methodology described in section: 3.6 TOC QUANTIFICATION). Bulk mineralogy was determined by X-Ray Diffraction run on a Siemens D5000 X-Ray Powder Diffractometer. Relative abundance of minerals were calculated semiquantitatively using peak-intensity ratios. Clay minerals were concentrated for analyses by gravity separation. To determine illite/smectite concentrations, slides were suspended in a dessicator over ethylene glycol for one day before obtaining an X-ray pattern.

A volumetric, Boyles Law gas adsorption apparatus was used to measure high pressure methane isotherms at 30 ^{0}C. For each sample, pressure points were collected up to 9 MPa. Moisture equilibrated samples of ~150 g were crushed to 250 um in a ring-mill for adsorption analysis. Moisture capacities were determined by water saturation at 30 ^{0}C (ASTM D1412-85) which is recommended for moisture content under reservoir conditions. The method consisted of equilibrating dried shale samples over a saturated solution of potassium sulfate for more than 72 hours in a vacuum dessicator. Samples analyzed for equilibrium moisture on the non-organic fraction were oxidized using a combination of hydrogen peroxide (30%) and sodium pyrophosphate (0.1 M) to remove the organic matter prior moisture equilibration.

A micrometrics ASAP 2010® surface area analyzer was used to determine surface area by N_2 adsorption, using both single and multi point BET (Brunauer, Emmett, Teller) methods (Gregg and Sing, 1982). Prior to analysis, samples were oven dried for 1 hour at 100 ^{0}C and degassed at 350 ^{0}C for a minimum of 6 hours.

6.4 CONTROLS – RESULTS AND DISCUSSION

Moisture contents range from 0.6-8.5 % (average content by weight) and are comparable with other organic-rich deposits (Table 6.1).

The equilibrium moisture is compared to total organic carbon (TOC) from various Nordegg samples in figure 6.1. Generally the moisture content is inversely proportional

	USA	Morocco	Jordan	Brasil	China	Estonia	France	Nordegg'
Moisture Content	6-10	10	2.5	5.3	13	8-10	7	0.5-8.5

Table 6.1: Moisture variability of oil shale-deposits world-wide (Adapted from Jaber *et al*, 1997)

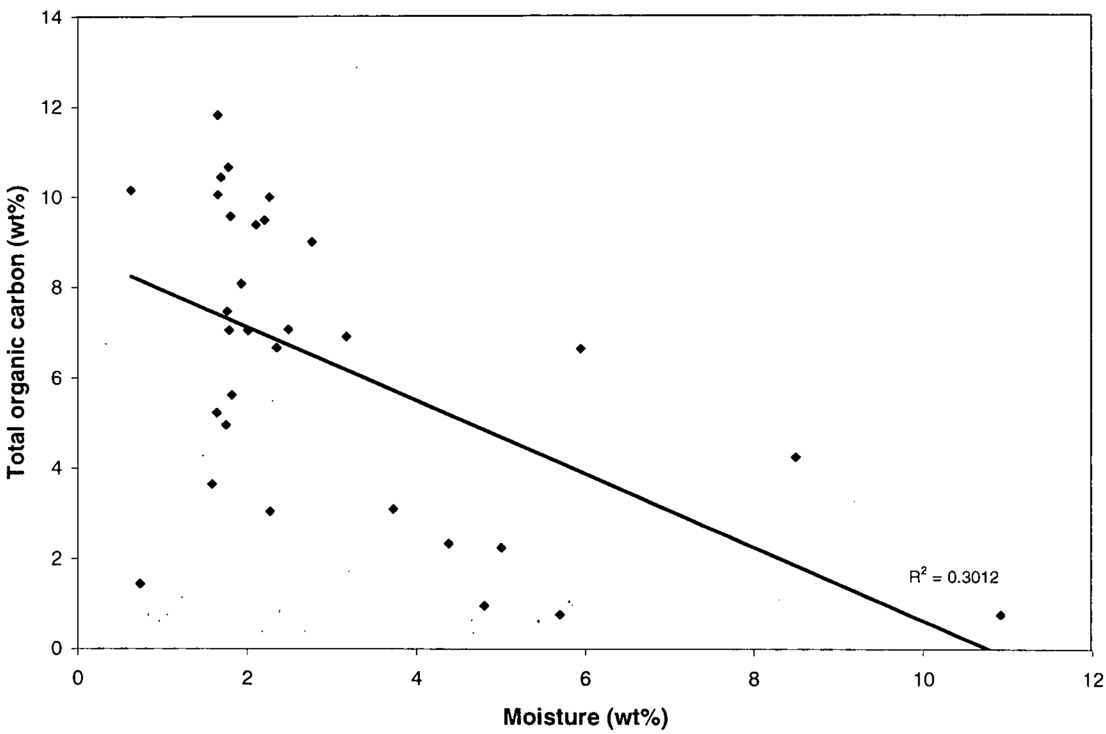

Figure 6.1 Variation in equilibrium moisture content with composition of Nordegg samples.

to TOC (r^2 = -0.3) where samples with greater equilibrium moisture contents are associated with samples which have a significant clay mineral component (Table 6.2).

The higher TOC content in sample 6080-1 may account for a proportion of the moisture content whereby moisture is adsorbed by organic materials (Wong & Wang, 1997). When equilibrium moisture contents were compared for samples prior and after organic matter removal, moisture contents decreased by 20 -59 wt% suggesting moisture has an equal affinity to both clays and organic matter (Figure 6.2).

Sample #	Moisture wt%	TOC	Clay Mineralogy	% Clays
6080-1	8.5	4.3	illite, smectite	6
5378-1	10.5	0.76	illite, smectite, kaolinite	11.9
376-1	0.74	1.4	illite	1

Table 6.2: Composition data of three selected Nordegg samples

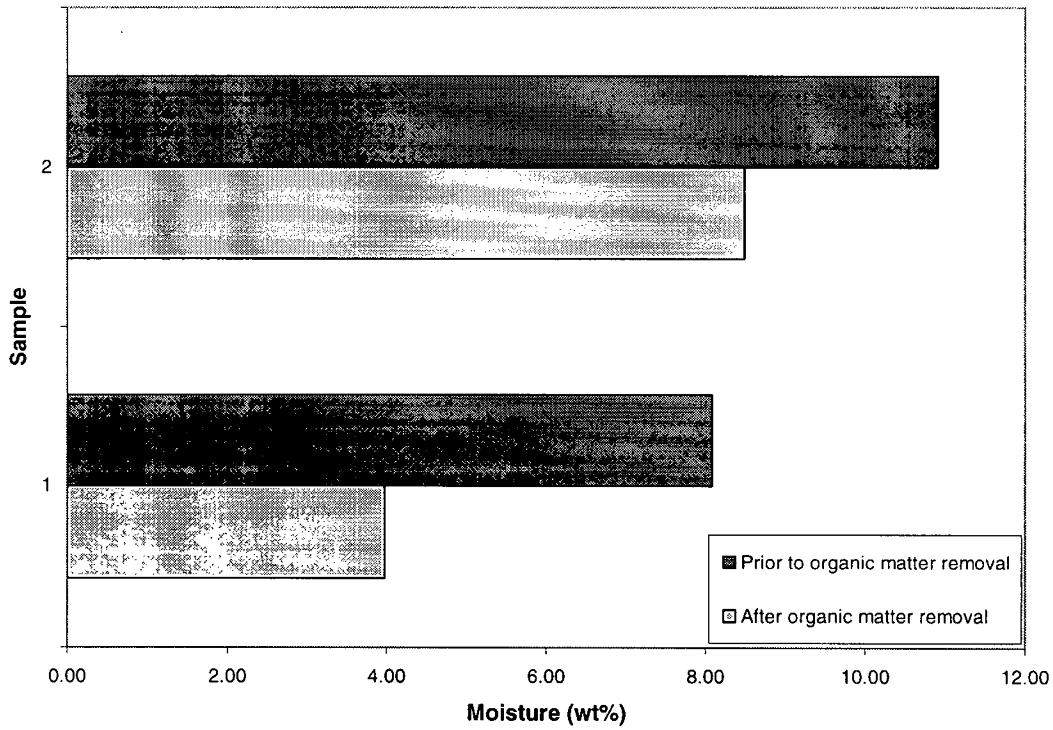

Figure 6.2: Equilibrium moisture of two Nordegg samples (1 = 6080-1, 2 = 5378-1) both prior and after organic matter removal. Reduction of equilibrium moisture of both samples after OM removal suggests part of moisture is incorporated into the organic fraction.

The XRD traces of these samples with high equilibrium moisture are shown in figure 6.3. Both samples have an asymmetrical illite peak at 0.9 nanometres, suggesting random interstratification of illite with smectite (Omotoso & Mikula, 2004). Sample 5378-1 also contains appreciable amounts of kaolinite (peak at 1.2 nanometres).

Moisture exists as both an interlamellar fraction (between clay particles; Wong & Wang, 1997) and an adsorbed fraction onto the clays. Water contains positively-charged cations which have a strong affinity to the clay mineral particles which carry negatively charged surfaces. Smectite and illite adsorb appreciable moisture (Figure 6.4) as opposed to other clay minerals due to their high surface area and cation exchange capacity (Table 6.3).

As shown by table 6.3, the equilibrium moisture content of smectite cannot be attributed to a high surface area (suggesting the moisture is not adsorbed) and moisture is may occur as free-moisture (Jaber *et al*, 2001) incorporated between individual silicate layers, resulting in swelling.

Mineral	Moisture %	Surface Area (Dry) m2/g	Exchange Capacity
Illite	5.87	29.96	0.27
Smectite	18.98	24.66	0.76
Kaolinite	2.93	7.07	0.038

Table 6.3: Moisture, surface area and cation exchange capacity of selected clay minerals (cation exchange capacity from Kahr and Madsen, 1995)

6.5 EFFECTS – RESULTS AND DISCUSSION

Although no direct inverse correlation between moisture and methane capacity is observed, moisture does exert a significant influence on gas adsorption. Generally, higher moisture content inhibits methane adsorption despite varying TOC values (Figure

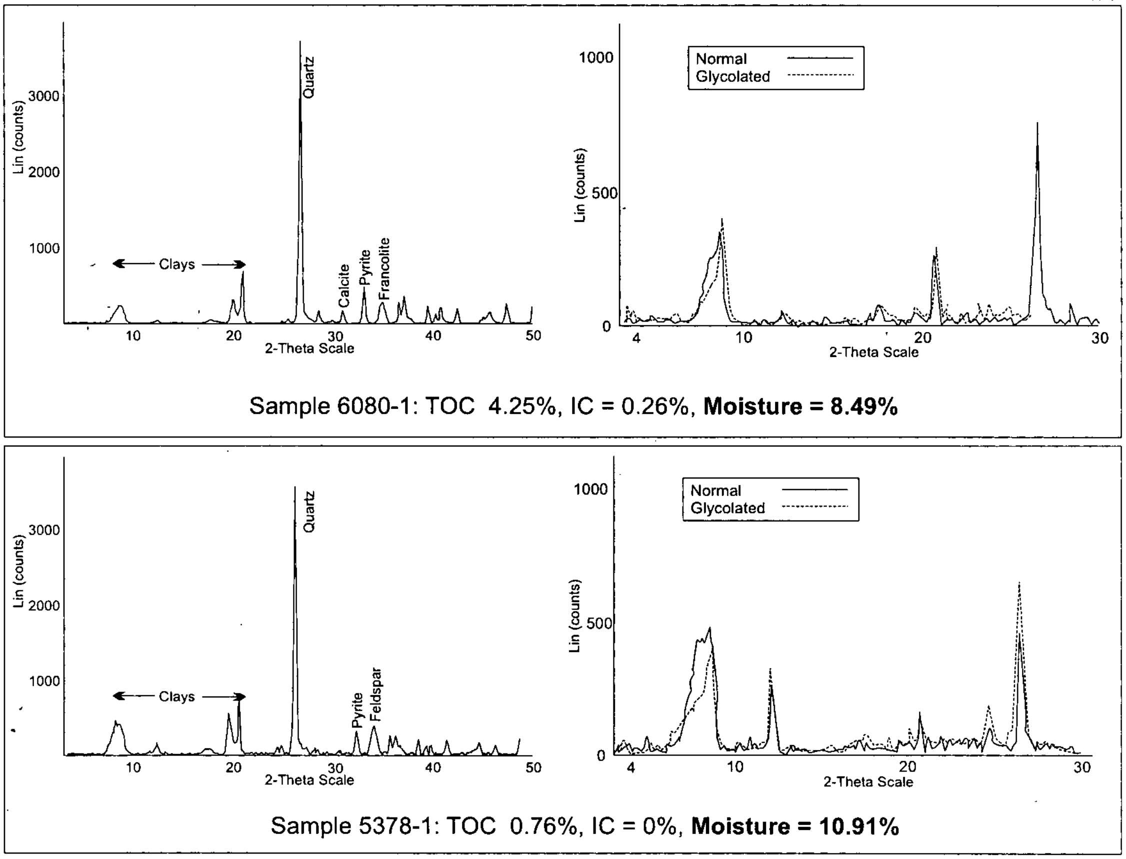

Figure 6.3: Diffraction patterns of selected samples Nordegg samples. Elevated moisture contents, in part, related to clay mineral component (primarily illite with minor interstratified smectite and kaolinite).

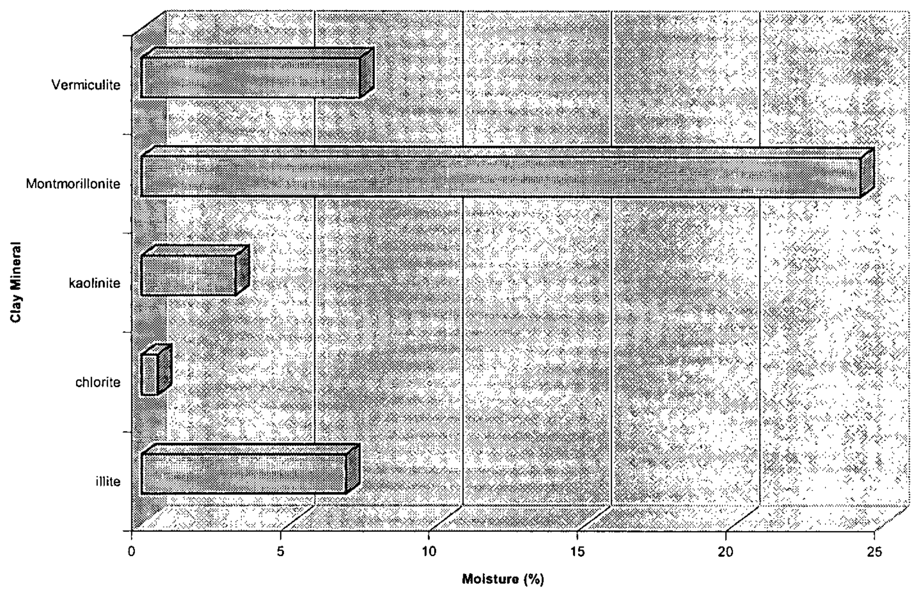

Figure 6.4: Moisture affinity for various clay minerals (samples saturated over a potassium-sulfate solution at 30 °C for three days. Montmorillonite can adsorb appreciable amounts of moisture into the inter-layer spacing.

6.5). Methane adsorption capacities were lower by 30 – 40% for moisture-equilibrated samples compared to dry samples (Figure 6.6).

The relationship of moisture content and methane capacity can be quantified by comparing $EQ_{moisture}$ and dry samples. Methane content for Nordegg samples can be expressed as:

$$(1) \quad V_d = V_m\,(1+0.30m)$$

where V_d and V_m are the methane capacities for dry and $EQ_{moisture}$ shale samples and m is the moisture content. For comparison, Levy *et al* (1997) suggested a multiplier of 0.39 for Bowen Basin coals whilst Ettinger *et al* (1958) used 0.31. This is to be expected due to the greater inherent moisture content of many coals compared to shales.

Previous unpublished data has shown the presence of moisture in shales is a major factor controlling methane capacity (Ramos, 2004). As moisture content increases towards a 'critical value', the ability to adsorb methane decreases (Joubert *et al*, 1973). A large proportion of the water is adsorbed and condenses within the pores of the organic matter in the shale whereby the ability of the molecules to occupy certain surfaces is controlled by thermodynamic equilibrium. The moisture competes with methane for available pore space. However as noted by Bustin & Clarkson (1998), the role of moisture is beyond that of a simple contaminant. The moisture also blocks pore-throats, reducing the transmissibility of the methane to the microporosity (Yee *et al*, 1993).

Sorbed gas storage capacity of shales has been shown to be significant despite low TOC values (Chun Lu *et al*, 1995) where methane adsorbs onto the clays as many clays have high surface areas (e.g. illite and smectite). The clay mineral fraction of the

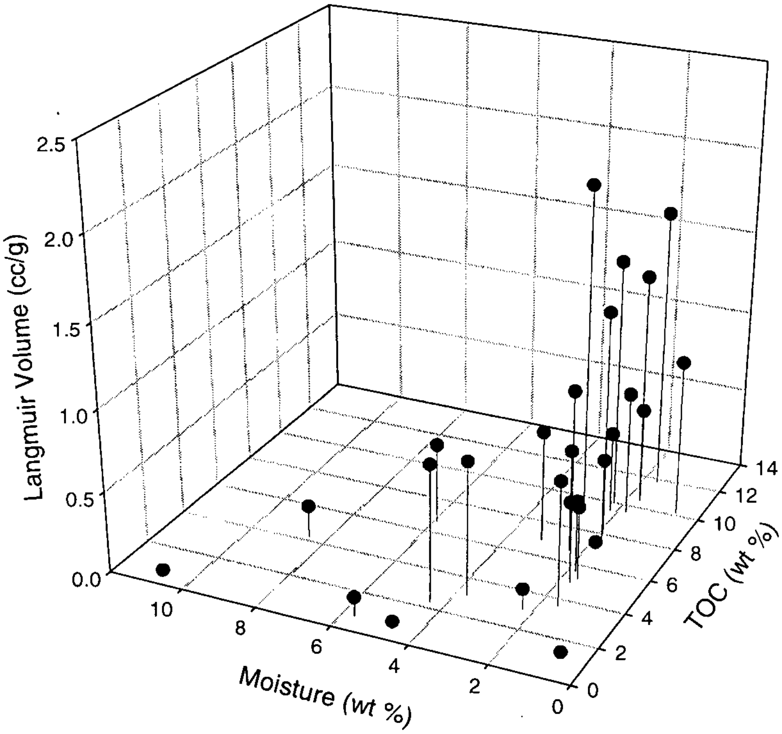

Figure 6.5: Plot showing importance of moisture content and TOC on adsorption capacity. Note significant increase in methane content with low moisture samples

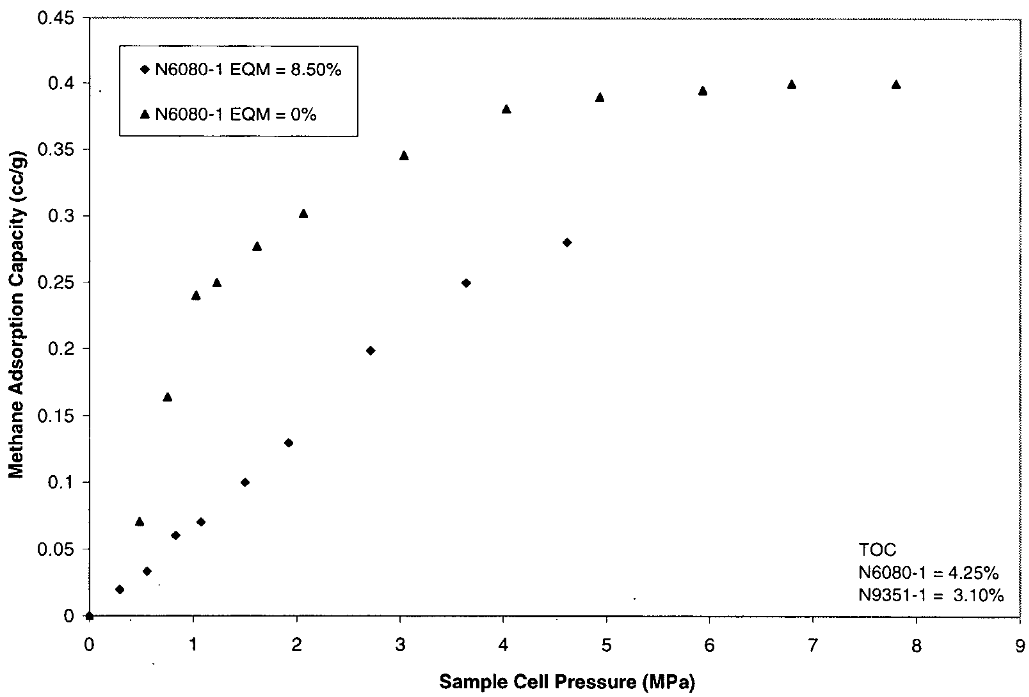

Figure 6.6: Moisture-methane adsorption capacity relationship of two Nordegg samples with similar TOC contents (EQM = equilibrium Moisture)

Nordegg Member appears to enhance moisture levels which reduce the methane capacity. Furthermore, adsorption isotherms for moisture equilibrated clay minerals indicate low adsorption capabilities (Figure 6.7). Moisture-equilibrated kaolinite adsorbs the greatest amount of methane but has the lowest surface area (7.07 m^2/g). The low moisture content of kaolinite (equilibrium moisture = 2.93 wt%) suggests that the inability of kaolinite to 'incorporate' significant moisture bears a strong influence on the amount of methane which can be adsorbed.

The high moisture content associated with the clays and low sorption capacities (associated with the organics) of the samples also implies a greater importance of moisture than a competitor of adsorption sites with methane molecules within the organic matrix. The particulate organic matter is intermixed with the clays whereby the moisture of the clays may block potential transmissibility pathways (i.e. pore throats) of the methane to the organic matter. If the clay minerals are not saturated with moisture, they may contribute a significant proportion to gas adsorption (Figure 6.8).

6.6 SOLUTION GAS

Methane can dissolve in water to form solutions whereby the concentration of a solute gas in a solution is directly proportional to the partial pressure of that gas above the solution (i.e. Henry's Law; Duffy *et al*, 1961). At 30 ^{0}C and 6 MPa, over 1.5 cc/g of methane can potentially dissolve in water (Figure 6.9). However the samples studied here with significant moisture show no such enrichment in methane capacity, suggesting methane is not able to move into solution (Table 6.4). Water molecules have a molecular diameter of 0.3 nm compared to the larger molecular diameter of methane (molecular

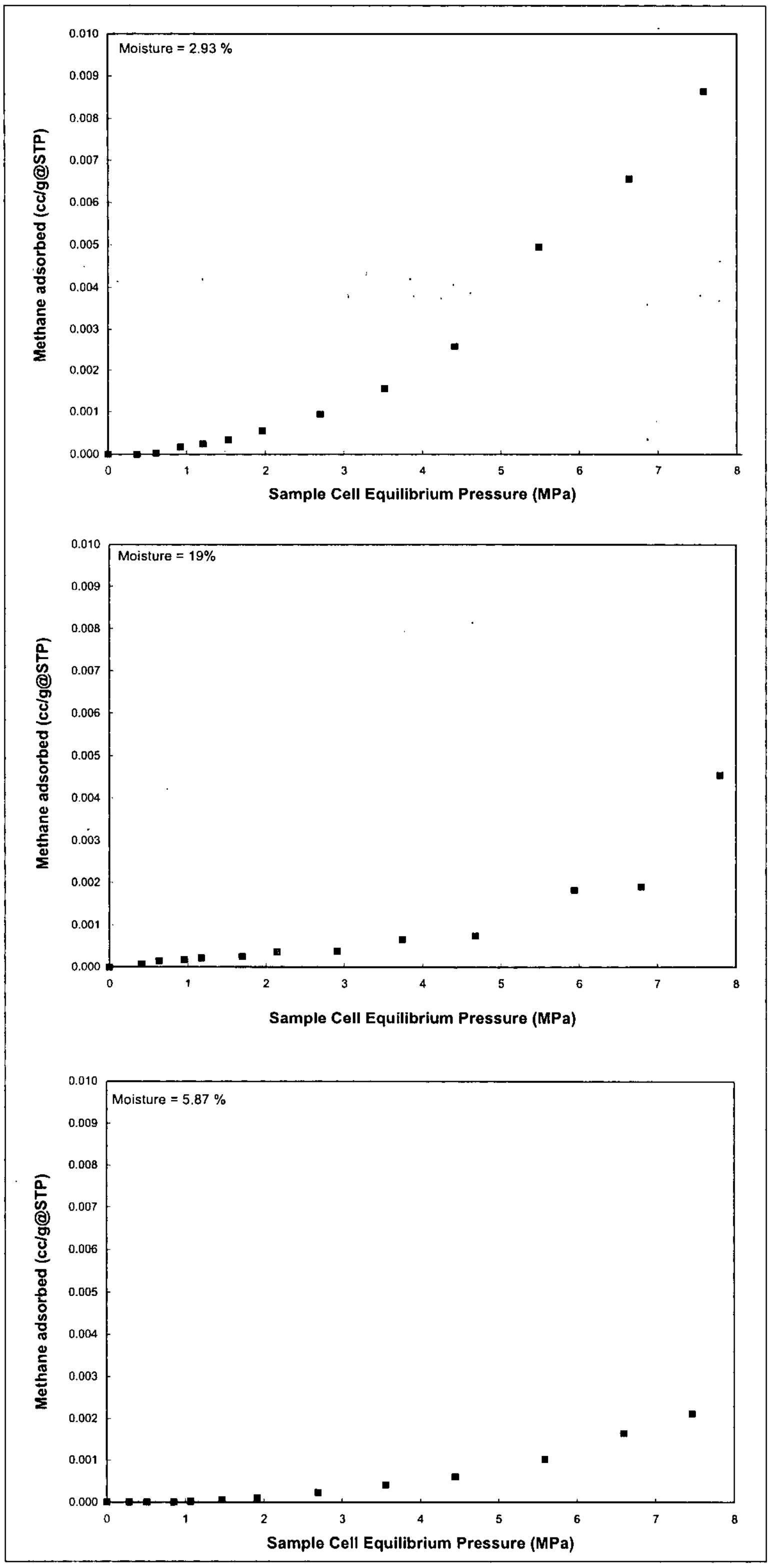

Figure 6.7: Adsorption isotherms for selected clay minerals (at equilibrium moisture)

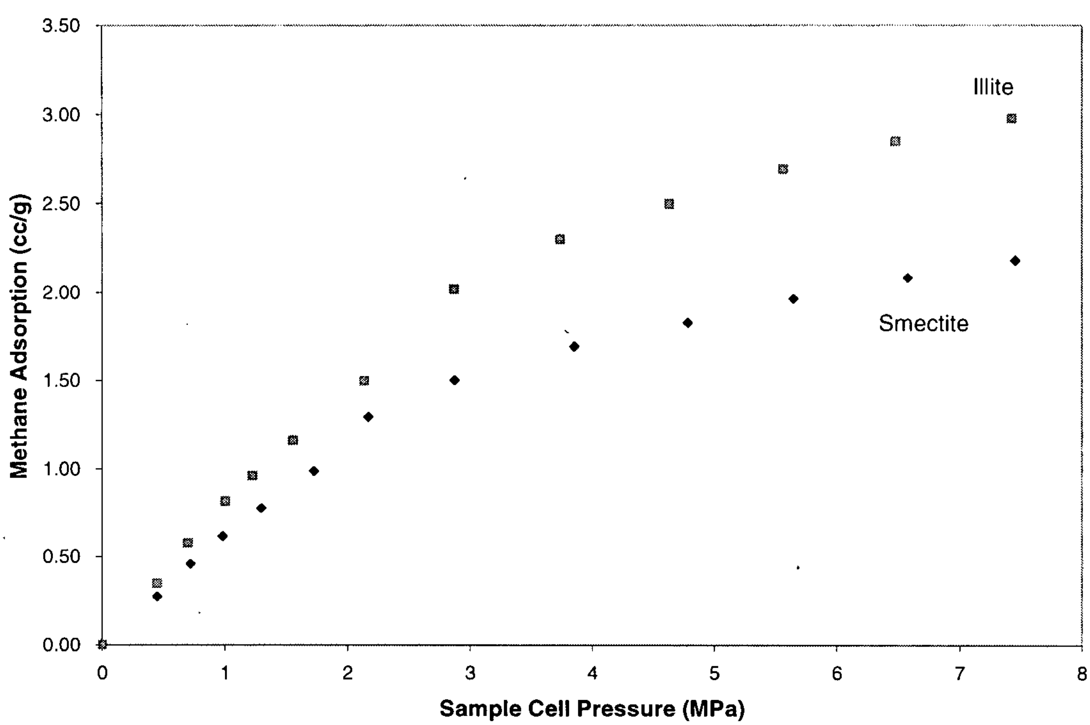

Figure 6.8: Adsorption capacity of dry illite and smectite

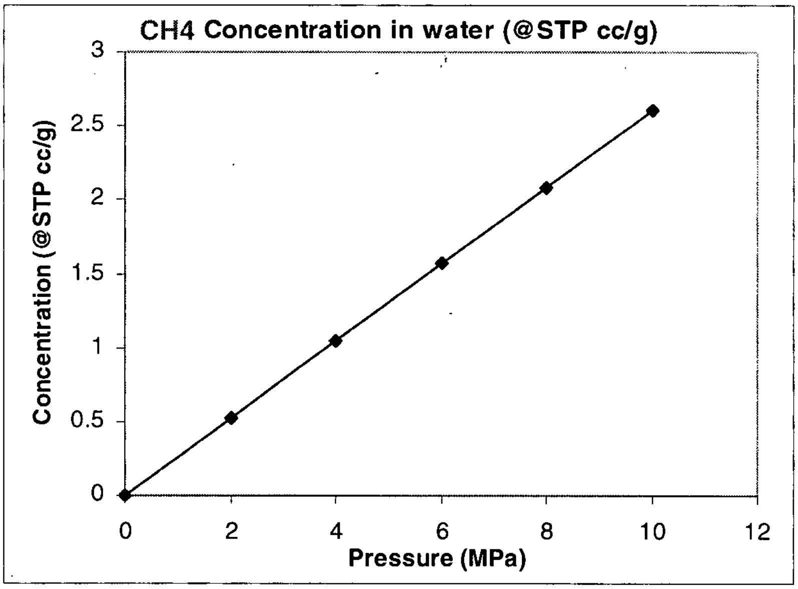

Figure 6.9: Solubility of methane at 30 ^{0}C for various pressure intervals

Sample Name	TOC	Moisture	Gas dissolved in water (where H2O=100% @ 6MPa, cc/g)	Gas Solution Potential (cc/g)	Actual Gas Content (cc/g)
Smectite	0	24.19	1.5	0.36	0.0018
Illite	0	5.87	1.5	0.09	0.00123
Kaolinite	0	3.15	1.5	0.05	0.006
5378-1	0.76	10.91	1.5	0.16	0.00129
2557-1	1.02	6.67	1.5	0.10	0.00194

Table 6.4 Comparison between the potential for gas to go into solution and actual gas capacities. Samples with high moisture contents have low adsorption capacities suggesting the water is not available/accessible to the methane molecule.

diameter ~ 0.38 nm). Therefore the lack of a dissolved gas component is likely due to the inability of the methane to interact with the moisture as the water can access smaller pores.

6.7 CONCLUSIONS

Greater equilibrium moisture contents can be in-part, attributed to high clay contents which are highly hydrophilic. The clay-swelling associated with moisture uptake may also inhibit/block zones for methane adsorption but do not contribute to the adsorbed gas capacity if at equilibrium moisture. Results of this investigation also highlight the need to consider moisture content for estimating methane adsorption capacity. Moisture reduces the gas content of samples, not only sorbing onto organics and clays, but blocking pore-throats leaving areas inaccessible to the gas molecule. Further research is required from an in-situ basis to determine the degree of moisture saturation as if undersaturated with respect to moisture, methane adsorption capacities will be greater than previously estimated.

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Chapter 7

Conclusions

7.1 CONCLUDING REMARKS

The Nordegg Member is divisible into four lithological facies: (A) mudstone conglomerate/breccia; (B) phosphatic marlstone (with intercalated limestone beds); (C) calcareous mudstone - marlstone; and (D) phosphatic marlstone. Within facies C there are subfacies of silty calcareous mudstone (C-1) and calcareous siltstone (C-2). Lithofacies of the Nordegg Member in northeastern British Columbia were deposited in a restricted basinal environment, characterized by a combination of productivity and fluctuating redox conditions.

The lithofacies can further be distinguished by geochemical composition, based primarily on TOC concentrations described as litho-geochemical facies (or LGF). LGF-B corresponds with lithofacies B, LGF-C with lithofacies C and LGF-D with lithofacies D. Lithofacies A is not included as it contains low concentrations of organic carbon. LGF-B and LGF-D are rich in productivity proxying elements such as V, Cr, Zn, and P and detrital elements Al, Fe and Ti with TOC contents ranging between 5-10 wt%. During LGF-B and LGF-D deposition, upwelling cells were governed by relative sea-level rise and supplied nutrients into the semi-restricted basin. Maceral composition is bituminite-dominated, a product of degraded alginite precursor where the degradation process preferentially concentrated V, Cr and Zn to the organic matter. Between LGF-B and LGF-D deposition, basin stagnicity occurred through a combination of basin-silling and consumption of dissolved oxygen by organic matter degradation. The resultant LGF-C unit is characterized by high TOC contents (5-20 wt%), alginitic organic matter and low productivity associated elements and detrital proxying elements. A coeval drop in sea-level affected the eastern portion of the study area, reflected by minor siltstone packages and lower TOC contents.

This study demonstrates that shale gas capacity is controlled by sedimentological and stratigraphic variabilities, primarily TOC, moisture and maturity. Gas adsorption capacities of representative Nordegg samples vary between 0.05 - 2 cc/g (measured at 30 ^{0}C and moisture equilibrated). Improved adsorption occurs with high TOC (8–12 wt%) and low moisture (0-4%). Moisture contents are controlled by organic matter and clay mineralogy but water does not have a dominant affinity to either. Adsorption isotherms for various clay minerals show, if water-saturated, they contribute little to the methane adsorption capacities and actually inhibit gas sorption. The moisture associated with the clays may block pores and pore throats making sorption sites inaccessible to methane.

Despite significant moisture contents, gas saturation dramatically increases when the free gas component is included in total gas in place calculations. The free gas component can be more significant than the sorbed component where porosities are greater than 3%. Total gas in place (adsorbed plus free gas) ranges from 0.2 BCF/section to 20 BCF/section where free gas can account for between 20-80% gas stored.

This study also provides both horizontal and vertical variations in Nordegg composition which effect gas adsorption which is fundamental for exploration and development of unconventional gas plays. The greatest shale-gas potential for the Nordegg Member is located in the southwest of the study area. Here average TOC, thickness and maturity are all greater, producing an improved gas shale reservoir. Although permeable strata are minor in the Nordegg, natural fractures occur in this region and may provide suitable permeability for gas production.

7.2 FUTURE WORK

The results of this study provide a detailed depositional model and evaluate the gas shale potential for the Nordegg Member in northeastern British Columbia. To further understand the controls which effect gas adsorption, more information is required from in-situ basis. Therefore the data set presented here would best be enhanced by on-site desorption analysis to determine the degree of gas saturation and critical desorption pressures. Sampling from well-site would give accurate moisture calculations to assess if the reservoir is fully saturated with water. Precise moisture data is extremely important because if under-saturated, gas-in-place calculations in the laboratory would be underestimated.

The controls on gas adsorption have been discussed but the role of moisture has not been adequately explained in the study or previous work. Additional investigations of the relationships between marine organic matter (MOM), mineralogy and the equilibrium moisture content need to be integrated into further studies. The affinity of MOM and moisture can be deciphered by examining the porosity characteristics which is lacking in current literature. The porosity data set needs to be improved for marine organic matter to better establish the controls of methane adsorption of Type II-rich, Type III- & IV-poor rocks. Mercury injection porosimetry cannot access the smaller pores, occurring often during this research. Therefore carbon dioxide low pressure isotherms could be used to calculate surface areas and micropore capacities. Furthermore, the ability of methane to go into solution needs to be investigated to establish whether solution-gas contributes to the adsorption isotherms.

Future exploitation of unconventional gas resources will also depend on the ability to identify well developed fractures or subtle facies variations. Due to the low-matrix permeability of shale-gas reservoirs, the degree of fracture development is a critical factor for estimating gas production (for the use in reservoir simulators). Therefore fracture determination from wire-line tools such as the FMI log (Formation Micro Imaging; Schlumberger) would be of immense benefit. Micro-imaging can be combined with seismic and structural data to delineate zones with good gas flow potential (highly fractured) and areas which would require additional fracturing (i.e. induced/artificial fracturing). Production of gas is known to be greater in areas where an extensive fracture network exists (Manger & Oliver, 1991).

Expanding the study area to the east (west-central and south-western Alberta) would also provide a more complete gas-shale reservoir evaluation of the Nordegg in the Western Canadian Sedimentary Basin.

7.3 REFERENCES

Manger, K.C. & Oliver, S.J.P. 1991. Geologic Influences on the Location and Production of Antrim Shale Gas, Michigan Basin. SPE 21854, p. 511-519.

APPENDICES

APPENDIX A – Well Locations and Sample Data

APPENDIX B – Core Descriptions

APPENDIX C – Total Organic Carbon (TOC) Data

APPENDIX D – Inorganic Geochemical Data

Appendix A

Well Locations & Sample Data

WA #	Well location	Sample depth (m)	Sample #	Interval	Isotherm
00023	100/07-15-081-15W6/00			B 2m	
00027	100/08-32-083-17W6/00	1254.8	27-1	B 10m	
		1260.2	27-2		
00030	00/01-15-084-19W6-0	1211	30-1	B	
00032	100/14-15-083-18W6/00	1118.5	32-1	B 4.9m	
		1120.8	32-2		
00033	100/13-34-083-19W6/00	1157.8	33-1	B 9.4m	
		1166.8	33-2		
00034	100/03-14-083-18W6/00	1141.6	34-1	B	
00036	100/13-11-081-17W6/00			B 1m	
00042	00/04-10-083-17W6/00			B 2.7m	
00044	100/04-11-085-17W6/00	1205.4	44-1	B 7.3m	
		1210.8	44-2		
00046	00/04-23-086-21W6-0	1346.1	46-1	B 2.3m	Y
00049	00/10-25-083-17W6-0	1267	49-1	B 3m	
		1268.6	49-2		Y
00052	00/08-05-083-17W6/00	1156.2	52-1	B 4.2m	
00053	100/05-14-082-25W6/00			B 6.6m	
00055	100/10-01-084-16W6/00	1271.8	55-1	B 8.8m	
		1276.8	55-2		
00057	100/03-33-081-18W6/00	1429.2	57-1	B 1.7m	
00060	00/10-33-082-17W6/00	1173.5	60-1	B 6.7m	
00063	100/01-02-084-19W6/00	1183.4	63-1	B 4.4m	
00072	00/04-03-084-18W6	1248	72-1	B 4m	Y
00074	00/01-20-083-18W6-0			B 3.5m	
00076	100/14-22-083-18W6/00			B 5.4 m	
00077	100/04-36-082-16W6/00	1236.2	77-1	B 7.6m	
00082	100/13-23-083-18W6/00	1164.2	82-1	B 5.2m	
00089	200/b-078-C 094-A-14/00	1199.9	89-1	B 8.5m	Y
00091	100/16-36-080-20W6/00	1630.2	91-1	B 2m	Y
00099	200/d-095-K 094-A-11/00	1171.4	99-1	B 6.2m	

00102	100/06-07-085-20W6/00	1323	102-1	B 5.5m	
		1326.6	102-2		
00108	100/01-12-084-23W6/00	1134.7	108-1	B 3.2m	Y
00114	100/10-01-082-25W6/00				
00121	200/d-038-K 094-A-11/00	1271.5	121-1	B 1.4m	
00130	100/04-27-088-17W6/00	1103.5	130-1	B 9.3m	
		1108.5	130-2		
		1111	130-3		Y
00134	00/04-23-086-19W6/00	1230.7	134-1	B 7.6m	Y
		1234.5	134-2		
00135	00/02-27-082-16W6/00	1211.9	135-1	B 6.8m	
		1214	135-2		
00139	100/06-27-084-20W6/00	1335.9	139-1	B 5.7m	
		1338	139-2		
00144	00/08-33-082-16W6/00	1191.9	144-1	B 3.9m	
00154	100/12-31-078-14W6/00	1713.9	154-1	B 3m	
00166	00/04-09-083-17W6-0	1167.9	166-1	B 1.6m	
00170	100/08-20-083-18W6/00	1133.2	170-1	B 2.4m	
00173	00/10-04-083-17W6/00	1160.7	173-1	B 2.8m	
00174	00/07-03-083-17W6/00	1168.4	174-1	4.7m	Y
		1169.6	174-2		
00176	200/a-009-L 094-A-05	1370.3	176-1	B 3.9m	
00182	00/08-11-087-25W6			B 1m	
00187	00/04-08-083-17W6-0			B 3.1m	
00230	100/06-16-081-14W6/00	1472.5	230-1	B 20.4m	Y
		1484.9	230-2		Y
		1491	230-3		
00290	200/c-034-E1094-A-14/00	1226.4	290-1	B 5.8m	
		1230.8	290-2		
00376	100/11-23-081-22W6/00	1104.8	376-1	B 13.8m	Y
00400	200/a-053-L 094-A-13/00	1441.6	400-1	B 4.3m	
00448	200/d-047-L 094-A-13/00	1402.5	448-1	B 6.7m	
		1405	448-2		
00497	200/d-053-G 094-A-13/00	1278	497-1	B 8.5m	
		1284	497-2		Y

00801	100/06-05-088-15W6-0	1178.2		B 2.6m	
00834	200/b-062-I 094-A-13/00	1218.6	834-1	B 14.8m	
		1222.5	834-2		
		1227.3	834-3		
01168	00/06-16-088-17W6/00	1086.7	1168-1	U (?) 6.8m	
		1090.1	1168-2		
01257	200/a-045-J 094-A-09	1084.7	1257-1	B 6.7m	
		1090.5	1257-2		
01385	100/06-28-088-17W6/00	1087.5	1385-1	U 6.4m	Y
02354	200/a-089-J 094-A-10/00	1059	2354-1 **(PK)**	U 3m	Y
		1065.4	2354-2		
02557	200/c-074-J 094-A-10/00	1082	2557-1 **(PK)**	U 1.7m	Y
		1084.1	2557-2		Y
02709	00/11-29-088-17W6-0	1107.1	2709-1	B 1.4m	Y
03098	100/11-30-087-14W6/00	1175	3098-1	B 7.9m	
		1176.8	3098-2		
		1179.8	3098-3		Y
03773	200/d-059-A 093-P05	3420.8	3773-1	7.6m	
		3425.9	3773-2		Y
03793	200/a-65-B 93-P-05/00	2476.1	3793-1	7.6m	Y
04941	200/d-075-I 094-A-13/00	1294.6	4941-1	B 2.9m	Y
05258		2477.6			
05348	200/d-011-J 094-A-13/00	1285.8	5348-1	B 3.2m	
05378	200/d-097-I 94-A-10/00	1102.5	5378-1 **(PK)**	U 10m	
		1105.5	5378-2		
		1112	5378-3		Y
05641	200/d-010-I 094-A-13/00	1249.9	5641-1	B 1.3m	
05733	200/d-100-H 094-A-13/00	1256.5	5733-1	B 2.8m	
06080	200/d-088-H 094-A-13	1240	6080-1	22m	Y
		1241	6080-2		
		1250.1	6080-3		Y
		1255	6080-4		
		1259	6080-5		Y
		1244.9	6080-6		Y
		1260	6080-7		
06100	200/d-077-H 096-A-13/00	1234	6100-1	B 5m	
		1234.2	6100-2		
		1237.2	6100-3		
06738	00/06-05-088-15W6-0	1081 (Fernie/PC)	6738-1 **(PK)**	U 3m	Y
		1083.2	6738-2		Y

07912	00/13-28-085-15W6-0	1253.3	7912-1	B 4.6m	
08153	100/02-02-086-18W6/00	1129	8153-1	B 10m	Y
08155	200/b-091-I 094-A-13/00	1220.25 1222.7	8155-1 8155-2	B 3.6m	
08262	00/04-12-086-18W6-0	1124.5	8262-1	B 7.2m	
08354	100/11-32-086-18W6/00	1156.5 1165.3	8354-1 8354-2	B 11.4m	
8676	200/D-073-C 093-I-15			Pard 8m	
9351	A-58-K/94-A-16	1013.1	9351-1		Y
9430	A-84-F/94-A-16	1006.8	9430-1		
9682	A-73-K/94-A-16	1025.1	9682-1		Y
14046	00/16-26-086-15W6-0	1217	14046-1	B 1.5m	
14270	100/10-30-086-18W6	1198.5 1201.5	14270-1 14270-2	B 6m	
14888	200/a-029-E 094-A-13/00	1485.8	14888-1	B 4.5m	

TOC		
WA #	Total core length	nos samples
27	9.7m	17
30	1.8m	6
32	4.9m	8
33	9.4m	17
36	1475.4	1
44	7.3m	8
46	2.3m	3
49	2.8m	6
52	4.4m	3
53	6.6m	7
54	1.6m	1
55	8.8m	12
60	6.7m	4
63	4.4m	8
72	4m	5
77	7.6m	15
82	5.2m	6
89	8.5m	8
91	2.2m	5
99	6.2m	2
102	5.5m	11
108	3.2m	7
121	4.7m	10
130	9.3m	19
134	7.6m	11
135	6.8m	11
139	5.7m	4
144	1191.1 (dull coal sample)	
154	3m	6
166	1.6m	3
173	2.8m	4
174	4.7m	10
176	3.9m	10
187	3.1m	4
230	20.4m	20
290	5.8m	20+
376	13.8m	9
400	4.3m	8
448	6.7m	9
497	8.5m	18
801	2.6m	7
834	14.8m	26
1168	6.8m	7
1257	6.7m	19
1385	6.4m	13+
2354	3m	23
2557	4m	10
2709	1.4m	3
3098	7.9m	13
3773	7.6m	20
3793	2474.6	8
4941	3m	8
5348	3.2m	6
5378	10m	28
5641	1.3m	2
5733	2.8m	3
6080	22m	56
6100	4.2m	7
6738	3m	8
7912	4.6m	3
8153	10m	6
8155	3.6m	7
8262	7.2m	11
8354	11.4m	16
9351	12m	3
14046	1.5m	3
14270	6m	16
14888	4.5m	5

Thin sections		
WA #	Depth	
27	1258	Brecciated lst with calcite-fill
33	1166.9	lst/shale contact
52	1154	shale clast within lst/calc band.
53	994.1	triangular calcite-filled void + fossils
54	1730	Base
60	1174.4	congl. Base
63	1185.3	contact
77	1238.4	Shale interbed within Bald.
89	1199	calcite-filled fracture mozaic
	1201.3	contact zone (within Baldonnel?)
91	1630.8	lst/shale conact (sh with chert and clay clasts)
102	1322.9	black chert clasts within shale
135	1214.3	fine congl. @ top of Baldonnel
170	1133.5	Bald/Nord contact
	1133.6	congl. & dolomite contact
290	1226.4	
	1487.4	
400	1442.9	
801	1178.8	shale/brecciated dol contact
	1178.9	brecciated dol & dol contact (sh between)
834	1226.3	shale clast within lst.
1168	1092.1	conact between light & dark grey lst
1257	1090.4	sh/dol. Interbds @ basal contact
	1091.35	breccia/sh stringers/bioturb in Bald.
1385	1088.5	shell concentration
2557	1083.2	upper congl. Within lower Fernie
2709	1108.4	brecciated dol and silt-sized calcite filling
3098	1173.6	crinoid (?)
	1179.8	top breccia/congl. In Nordegg
	1181	Top Baldonnel
3773	3421	ls/sh parallel interbeds
5733	1257.2	shale/sol. Breccia contact
6100	1238.2	1.5cm shredded/brecciated shale/calcite
6738		see core sheet
8153	1121.9	calc/blck & green sh/calc interbeds
	1129.8	shell hash
	1130.1	contact (Nord/Trias)
8155	1220.5	lst & bitumen stylolites
8354	1164	biotite in lst
	1164.3	coarse calcite band
	1166.1	contact (Nord/Trias)
9430	1003 (+ other sample)	
14046	1218	phosphate specks
14270	1198.45	interbedded chert/shale
	1198.5	stylolites in shale
	1199.15	lst/shale contact (flame-like structure)
	1202.1	contact

Appendix B

Core Descriptions

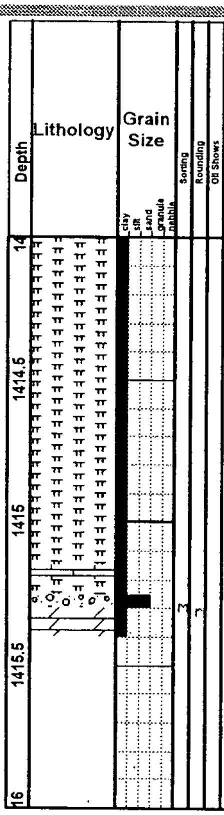
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Act Kiskatinaw No. 1 07-15
Location: 00/07-15-081-15W6-0
Licence Number: 00023
Region: British Columbia
Spud Date: 7/24/1951
Drilling Completed: 9/11/1951
Surface Coordinates: Lat: 56.019958
Long: -120.253502
Bottom Hole Coordinates: BH Lat: 56.019958
BH Long: -120.253502
Ground Elevation (m): 652.9
K.B. Elevation (m): 655.6
Logged Interval (m): 1414.2 To: 1415.2
Total Depth (m): 1434
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Section of core: 1.03m

UNIT: PHOSPHATIC MARLSTONE (100%) - black, highly calcareous, dense, strong petroliferous odour, minor interbeds of lst.

Thin (<1mm) discontinuous bands of calcite and interbeds of black chert.

SUB-UNIT: LIMESTONE (100%): dark grey/black, argillaceous, microcrystalline, mottled appearance, carbonaceous, sub-mm interbeds of mud.

UNIT: CONGLOMORATE at base with 1-2mm chert and quartz clasts, matrix supported with mud/shaley, non-calareous, argillaceous matrix.

UNIT: DOLOMITE: light grey, argillaceous, mod carbonaceous, micro-cryptocrystalline, minor pin-point & vuggy porosity - partially filled with calcite.

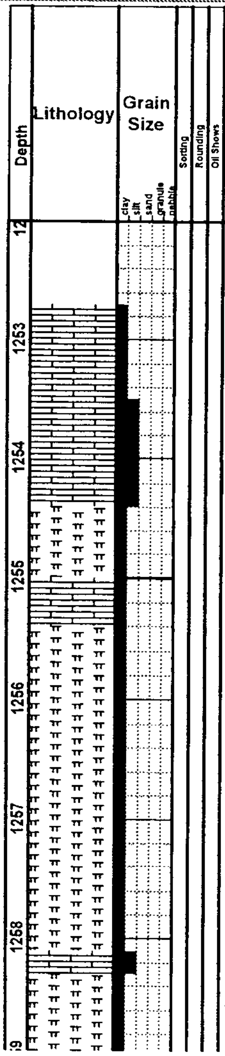
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Samson Airport 08-32-083-17
Location: 00/08-32-083-17W6-0
Licence Number: 00027
Region: British Columbia
Spud Date: 01/03/1952
Drilling Completed: 03/15/1952
Surface Coordinates: Long: 56.237331
Long: -120.638634
Bottom Hole Coordinates: BH Long: 56.237331
BH Long: -120.638634
Ground Elevation (m): 720.8m
K.B. Elevation (m): 723.3m
Logged Interval (m): 1252.7m To: 1262.4
Total Depth (m): 9.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - dark grey/brown, highly calcareous (microcrystallinity gives "speckled"/mottled appearance), argillaceous, mod carbonaceous, increasingly silty towards base. Finely interbedded with black shale. Strong petroliferous odour, low relief stylolites with insoluble organic residue.

Fractures: 2: near -vertical orientation, parallel. W4mm, L 40 & 80mm, completely filled with calcite (photo 3441)

Shell hash beds - occasional preservation of complete bivalve shells (photos 3443, 3444).

UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, brown streak, calcareous, bituminous. Gradational top contact. Vague lamination, bedding slightly inclined (~4 deg below horizontal), green shale interbed at 1254.8m, very friable, slightly silty.

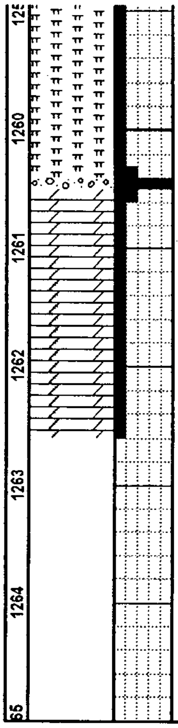
Lst, as above - base of marked by 1mm parallel lamination. Oil staining.

Marlstone, black to slightly brown, bedding planes contain pecten, occasional lst lenses.

Fractures: 2 orientated vertically. (L/W) (1) 10/0.6, (2) 6/0.3. Complete cementation with calcite (photo 3445).

Silty lst - 20cm band, poorly indurated, green/grey. Grain sizes range 88-125u. Upper contact with overlying shale marked by irregular, horizontal calcite laminae, also brecciated and subsequently calcite-filled (photo 3448). Vague parallel lamination (1mm) -calcite and shale. Green shale at base of lst, very poorly indurated, friable.

Marlstone, as above - slightly silty.



UNIT:CONGLOMORATE - matrix supported, matrix is dark grey/black, argillaceous, non-caclareous, (photo 3450), clasts of silty lst, subangular-subrounded, some elongate, 20-30mm diameter, argillaceous lst breccia.

UNIT: DOLOMITE - light grey/green, silty nature (gives "dirty"/gritty texture), minor calcite which can be interbedded. Finely interbedded 1mm bands of shale. Concentrated white granular beds (phosphate(?)). Moderate vuggy porosity, some vugs partly filled with calcite. Mildly petroliferous.

Stylolite - 8/0.1. Orientated horizontally across core and is bitumen-filled (photo 3451)

SAMPLES:

Sorption: 1254.8m, 1260.2m.

TOC: 1) 1252.9m, 2) 1253.6m, 3) 1254.3m, 4) 1254.7m, 5) 1255.2m, 6) 1255.3m, 7) 1255.9m, 8) 1256.3m, 9) 1256.7m, 10) 1256.8m, 11) 1257.1m, 12) 1258.7m, 13) 1259.0m, 14) 1259.2m, 15) 1259.7m, 16) 1260.0m, 17) 1260.3m (+ 1 original).

Thin-section: 1258m (Brecciated lst with calcite-fill)

Extra photos: (CD#3) - 4405 & 06 (Brecciated sh/lst with calcite-fill).

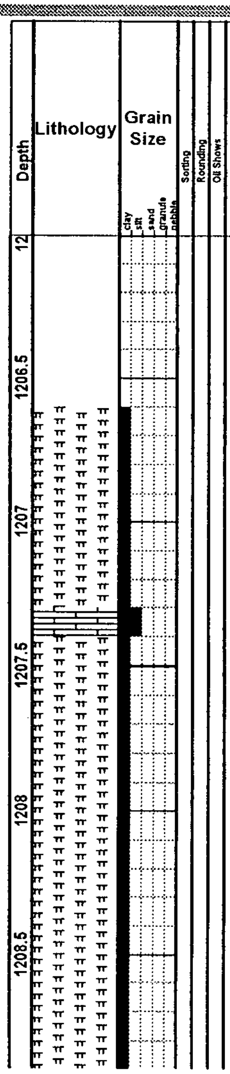
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: PEX WP Ft St John
Location: 00/01-15-084-19W6-0
Licence Number: 00030
Region: British Columbia
Spud Date: 03/08/1952
Drilling Completed: 09/01/1952
Surface Coordinates: BH lat: 56.277615
BH Long: -120.902115
Bottom Hole Coordinates: BH lat: 56.277615
BH Long: -120.902115
Ground Elevation (m): 725.9m
K.B. Elevation (m): 730.1m
Logged Interval (m): 1206.6m To: 1210.8m
Total Depth (m): 4.2m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

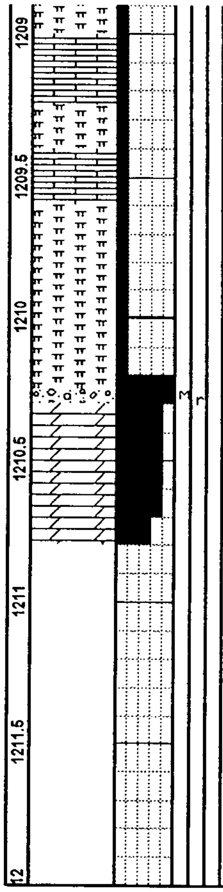
Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, brown streak, calcareous, hard, dense, disseminated plant fragments scattered throughout, very occasional near vertical fractures with oily/muddy residue, petroliferous odour, finely interbedded with lst in parts giving mottled texture, flattened shell hash bands.

SUB-UNIT: LIMESTONE (100%) - dark grey, argillaceous, calcite crystals in shaley matrix, microcrystalline, mottled-appearance, mod carbonaceous, interbeds of black shale (photo 3908).
Mrlst, as above - fossiliferous in parts, slickensided, white powdery sulfate residue, very minor vertical hairline fractures - calcite filled (photo 3909).



Lst, as above - slightly finer grained than previous lst unit, sharp lower contact/slightly diffuse upper contact, no fossils.

Mrlst, as above.

Lst, as above - sharp upper contact & diffuse lower.

UNIT: CONGLOMERATE - black cherty nodules at base (~4cm diameter), core fractured around them.

UNIT: DOLOMITE (50%) - med/dark grey, very argillaceous with med/dark grey stringers, 1cm nodules of silty lst, colour lightens downwards, hard, dense, non-porous, distorted bedding (due to solution collapse?), slightly silty and calcareous.
Dolomite (95%) - med/dark grey, argillaceous, hard, dense, crytpo-microcrystalline, slightly calcareous, fossiliferous (bivalves), fragments of crinoids, thick-bedded, massive, slight pin-point porosity, scattered/occasional nodules of chert (semi-opalescent, ~1.5cm diameter).

SAMPLES:
Sorption: 1211m, 1211.4m (use as TOC also)
TOC: 1) 1206.8m, 2) 1207.8m, 3) 1208.6m, 4) 1209.1m, 5) 1209.4m, 6) 1209.9m.

LITHOLOGY STRIP LOG

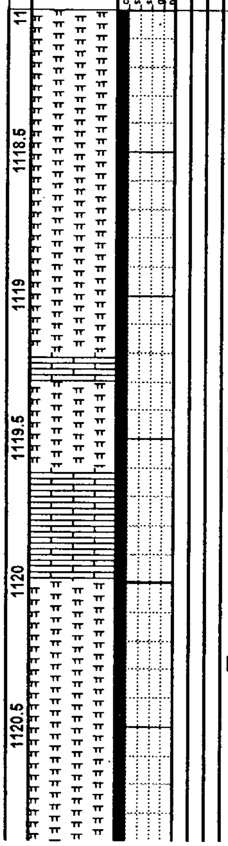
WellSight Systems

Scale 1:20 Metric

Well Name: Samson et al Ft St John 14-15-083-
Location: 00/14-15-083-18W6-00
Licence Number: 00032
Region: British Columbia
Spud Date: 3/24/1952
Drilling Completed: 6/1/1952
Surface Coordinates: Lat: 56.201107
Long: -120.757950
Bottom Hole Coordinates: BH Lat: 56.201107
BH Long: -120.757950
Ground Elevation (m): 622
K.B. Elevation (m): 625.1
Logged Interval (m): 1118 To: 1122.9
Total Depth (m): 4.9m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

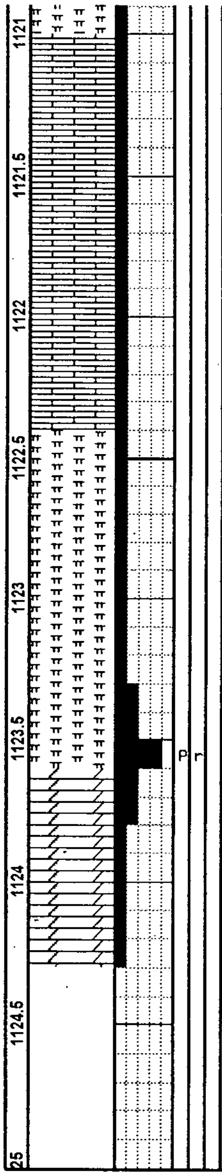
Depth	Lithology	Grain Size (clay, silt, sand, granule, pebble)	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: MARLSTONE (95%) - Black, calcareous, bituminous, carbonaceous, occasional fine interlaminations of argillaceous lst. Complete shells (pecten?) preserved (photo 3468).

UNIT: LIMESTONE (100%) - dark grey/black, microcrystalline, carboanceous, interbedded with finely laminated shale. Mottled appearance. Petroliferous odour. Irregular contact with shale unit (photo 3471). From contact, laminations become coarser (1-2mm). Top 15mm, 4 vertical calcite-filled fractures, slighty crenulated, 1 bifurcates upwards, 70mm apart, (W0.2mm, L ~100mm).

Mrlst, as above.



Lst - dark grey, dolomitic in places, less calcite than overlying lst (photo 3475). Fine interlaminations of dark black shale.

Mrlst, as above - base of overlying lst marked by angular rip-up like(?) clasts of mud (width 1-2mm), slightly less calcareous, shell hash common seen on horizontal broken surfaces in the core, occasional powder white residue (sulphate?). Base of marlst (lower 35mm) - slightly sandy, dark grey, argillaceous BRECCIA/very fine CONGLOMORARE, 1-2mm calcite crystals common

UNIT: TRIASSIC DOLOMITE - Light grey, microcrystalline, dense, brecciated (solution-breccia (?)) producing disrupted laminations of black shale in top few cm's (photo 3477). Below: minor vuggy porosity, petroliferous.

SAMPLES:

Soprtion - 1118.5m, 1120.8m

TOC - 1) 1119.1m, 2) 1119.8m, 3) 1120.1m, 4) 1120.6m, 5) 1121.35m, 6)1121.75m, 7) 1122.15m.

LITHOLOGY STRIP LOG

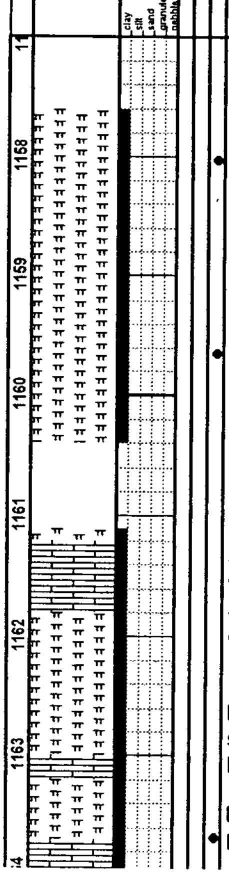
WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: NUMAC Wilder 13-34-083-19
Location: 00/13-34-083-19W6-0
Licence Number: 00033
Region: British Columbia
Spud Date: 5/12/1952
Drilling Completed: 10/4/1952
Surface Coordinates: Lat: 56.244812
Long: -120.921280
Bottom Hole Coordinates: BH Lat: 56.244812
BH Long: -120.921280
Ground Elevation (m): 677.5
K.B. Elevation (m): 681.2
Logged Interval (m): 1157.6 To: 1167
Total Depth (m): 9.4
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: PHOSPHATIC MARLSTONE (100%) - black, fine-grained, calcareous, fossiliferous (pecten?) interbedded with black limestone (2cm thick laminae which are calcite-rich, photo 3494) and poorly indurated green shale (photo 3496). Contains discrete zone of well round/mod sphericity mud clasts (?), 1-2cm in size (photo 3492). Vague laminations and caclcite "specks" (shell hash) (photo 3493).

Core missing: 1160.4m - 1161.1m

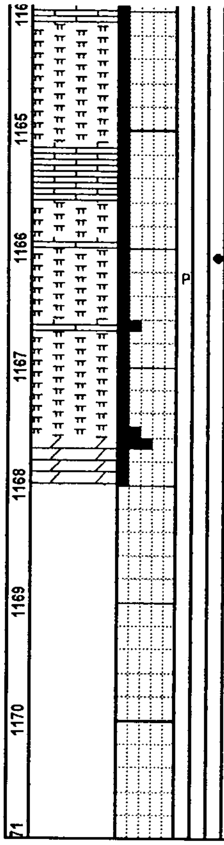
SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, carbonaceous, argillaceous, laminated, (up to 1mm with black shale). High calcite concentration gives white "speckly"/mottled appearance. Sharp contact with overlying shale (photo 3498). Stylolite fracture(?) : 1mm thick across core/irregular but horizontal, contains insoluble organic residue. Minor fractures run vertically from it with organic residue.

Mrlst, as above - brown streak, fissile, fossiliferous, lesser calcite "specks" than intial shale unit.

Lst, as above - coarsening upwards of calcite (?) (up to silt-sized grains), fossiliferous

Mrlst, as above.

Lst, as above - stylolite with insoluble organic-residue.



Mrlst, as above.

Lst, as above - brown, slightly more argillaceous, stylolites with organic residue (very low relief compared to previous), distinct fine interbeds of black shale(photo 3500).

Shale, as above - brittle, friable, sharp upper contact.

Lst - dark brown/black, upper contact is a diffuse, white "speckly" pattern. Calcite increases towards base - gives coarser appearance. Sharp contact with underlying mrlst (photo 3502).

Lst, as above - sharp horizontal basal contact with underlying shale, base marked by silt-sized calcite and sub mm "clasts" of black shale. Mrlst becomes med/dark grey towards base.

UNIT: DOLOMITE - light grey, microcrystalline, v. minor calcite content, minor vuggy porosity. Congl. contact with overlying shale (phosphate grains(?)), well rounded silty lst clasts (5-10mm diameter). Minor calcite. Clasts size~<1mm to 1.5mm (photo 3503), brecciated in part, minor horizontal fractures, some partially filled with calcite.

SAMPLES:

Sorption: 1157.8m, 1166.8m

TOC: 1)1157.8m, 2)1158.15, 3) 1158.95, 4) 1159.4m, 5) 1159.7m, 6) 1160.1m, 7)1160.5m (green shale interbed) 8) 1162.5m, 9) 1163.3m, 10) 1164.9m, 11) 1165.3m, 12) 1165.5m, 13) 1166m, 14) 1166.4m, 15) 1167.2m, 16) 1167.4m, 17) 1167.55m

Thin-sections: 1166.9m (lst/shale contact).

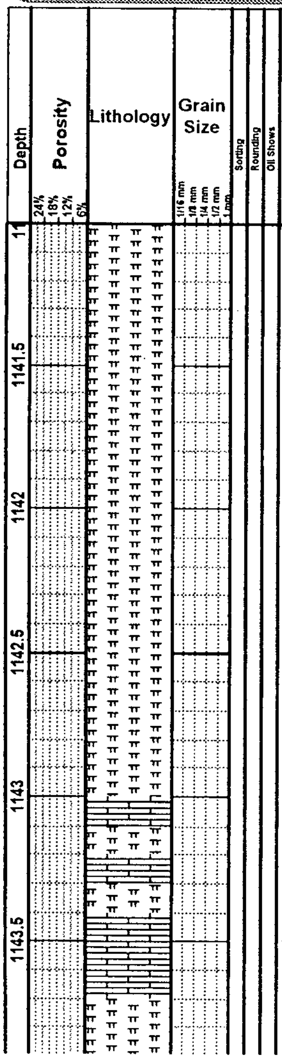
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: SAMSON FT St John 03-14-083-18
Location: 00/03-14-083-19W6-0
Licence Number: 00034
Region: British Columbia
Spud Date: 05/19/1952
Drilling Completed: 11/07/1952
Surface Coordinates: BH Lat: 56.190331
BH Long: -120.730644
Bottom Hole Coordinates: BH Lat: 56.190331
BH Long: -120.730644
Ground Elevation (m): 615m
K.B. Elevation (m): 618.7m
Logged Interval (m): 1141m To: 1145.7m
Total Depth (m): 4.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

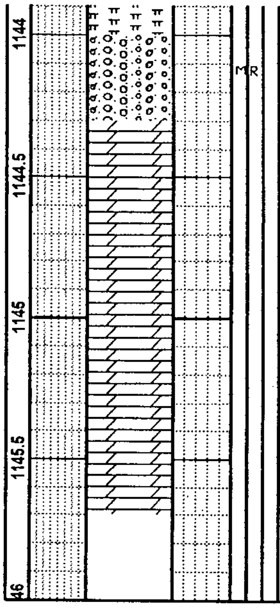


Geological Descriptions

Core photo: 3462

UNIT: PHOSPHATIC MARLSTONE (55%) - Black, fine-grained, calcareous, brown streak, strong petroliferous odour, top 50mm micromicaceous & remnants of green shale interbed, slightly silty in parts slightly fossiliferous. Becomes laminated at base (lower 30mm) with limestone (gives white "speckly laminated appearance), 1 open fracture (W2mm, L60mm, mechanincal ?).

SUB-UNIT: LIMESTONE (45%) - med-dark grey, microcrystalline, mottled appearance, petroliferous, interbedded with dark grey/black shale, increasingly argillaceous & conglomoratic towards base. Clasts range up to 4mm. Quartz (chert) & clay (light brown) clasts with minor calcite. Clay-clasts well rounded, quartz grains angular. Fine-grained, dolomitic matrix makes up approx 20%. Upper and lower contact missing from core box (photo 3465).



UNIT: CONGLOMORATE - coarsens downwards with silica-rich clasts (20-40mm width), opalescent blue quartz, chert, clay and Nordegg shale (?), 2-4mm diameters, matrix grades down from a argillaceous to slightly more arenaceous.

UNIT: DOLOMITE - Light grey, "dirty", silty unit (chalky texture) - argillaceous. Vague laminations. Solution enhanced porosity, producing vugs (minor calcite in-filling). Light, discrete zones of calcite - range from 2-3mm to 2cm. 5cm band of shells replaced by calcite.

SAMPLES:
Sorption - 1141.6m

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: PEX WP Pingel 13-17-081-17
Location: 00/13-17-081-17W6
Licence Number: 00036
Region: British Columbia
Spud Date: 6/5/1952
Drilling Completed: 11/24/1952
Surface Coordinates: Lat: 56.027107
Long: -120.631172
Bottom Hole Coordinates: BH Lat: 56.027107
BH Long: -120.631172
Ground Elevation (m): 802.4
K.B. Elevation (m): 805.5
Logged Interval (m): 1474.9 To: 1479
Total Depth (m): 4.1m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

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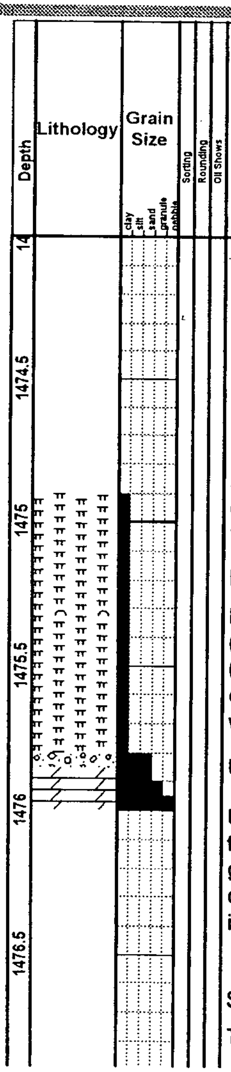


Geological Descriptions

Core photo 3397

UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, dense, calcareous, strong petroliferous odour. Minor horizontal caclite-filled veins/fractures, top 30mm shows bands of dirty green, slightly calcareous, fissile shale, ~6 deg dip below horizontal, occasional highly calcareous interbeds/bands (representing shell hash concentrations ?).

Bivalve shell concentration - little sign of disarticulation

Base of Mrlst marked by coarser zone (5% of core). Broken section of core 6cm long (photos 3398, 3401). Grains of quartz (1-2mm, angular & low sphericity) and phosphate (0.75-1cm, mod sphericity & low angularity). Bottom 1cm of core has high concentration of complete shells. Show preferred orientation across the core. Band of shells=15cm width

UNIT: CONGLOMORATE - clasts of silty lst and chert, matrix supported.

UNIT: DOLOMITE - med/dark grey, mod carbonaceous, argillaceous & calcareous. Minor fractures, poor-mod vuggy porosity, voids up to 2cm filled with calcite, grades into grey/brown dolomite, contains well rouneded chert and phosphate grains (2-10mm diameter), lingula (?) fragments common near contact, argillaceous bands near top, irregular/wavy, brecciated appearance..

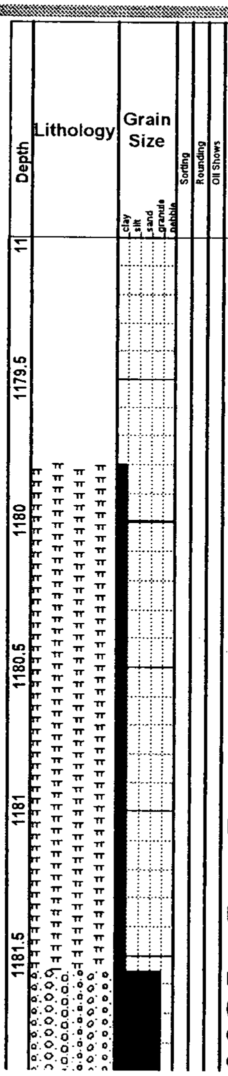
SAMPLES:

TOC - 1475.4m

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Samson Et Al Ft St John SE 04-10-0
Location: 00/04-10-083-17W6-0
Licence Number: 00042
Region: British Columbia
Spud Date: 09/07/1952
Drilling Completed: 12/14/1952
Surface Coordinates: Lat: 56.176929
Long: -120.606712
Bottom Hole Coordinates: BH Lat: 56.176929
BH Long: -120.606712
Ground Elevation (m): 631.9m
K.B. Elevation (m): 636.4m
Logged Interval (m): 1179.8m To: 1182.5m
Total Depth (m): 2.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

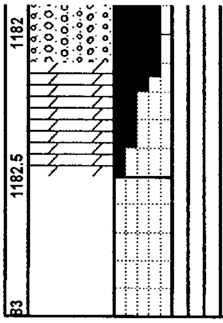
UNIT:PHOSPHATIC MARLSTONE (90%) - black, calcareous, petroliferous odour, fossiliferous, finely laminated, top 100mm interbedded with lsy giving mottled appearance.

Few horizontal calcite-filled fractures (W0.2-1.2mm, L80mm across core), very occasional vertical hairline fractures filled with calcite also (photo 3855).

Lower 800mm - black Mrlst interbedded with brown shale.

Bottom 20cm, non-calcareous Mrlst, colour grades from black down to dark grey.

UNIT: BRECCIATED CONGLOMERATE (100%) - clasts of chert, quartz & minor calcite (1-5mm) in med grey, argillaceous, non calcareous matrix, white "specks" (phopsphate) common. Disrupted bedding - produces stringers of black shale, direct contact with overlying shale missing from core box.



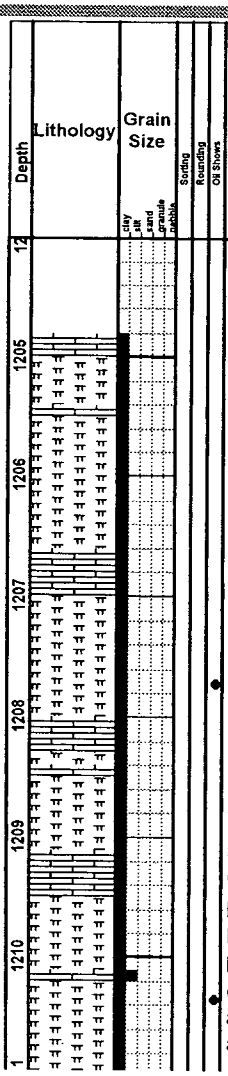
UNIT: DOLOMITE - med grey, mod argillaceous & carbonaceous, micro-cryptocrystalline, slightly congl. in parts, vuggy/fine intergranular porosity improving away from contact, partially calcite-cemented. Lower down unit - vuggy porosity partially bitumen-filled, fossiliferous, increasingly brecciated (flow breccia ?).

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Pacific Cecil Lake No. 1 04-11-08
Location: 00/04-11-085-17W6-0
Licence Number: 00044
Region: British Columbia
Spud Date: 9/23/1952
Drilling Completed: 1/5/1953
Surface Coordinates: Lat: 56.350067
Long: -120.578796
Bottom Hole Coordinates: BH Lat: 56.350067
Long: Long: -120.578796
Ground Elevation (m): 708.6
K.B. Elevation (m): 712.6
Logged Interval (m): 1204.8 To: 1212.1
Total Depth (m): 7.3
Formation: Nordegg
Type of Drilling Fluid:



Geological Descriptions

SUB-UNIT: LIMESTONE (85%) - med grey, microcrystalline, mottled appearance, argillaceous, laminated with interbedded black shale (<1mm), petroliferous. Second lst unit shows diffuse lower contact, sharp upper (photo 3545).

UNIT: PHOSPHATIC MARLSTONE (95%) - black, brown streak, calcareous, carbonaceous. Laminations more apparent in upper section. Discrete calcite-rich (i.e. black lst) zone (2cm thick) - sharp contacts (photo 3544). Strong H2S odour when split, occasional brown clay (?) nodules (~5mm diameter). Green shale interbed (friable) at 1205.6m).

Lst, as above - several stylolites - 0.2mm thick /bitumen -filled /x-cut laminations, low relief. VERTICAL fractures: more planer/0.25mm thick/x-cut laminations and horizontal fractures - therefore formed later. Calcite cement on outside of fractures co-occurs with bitumen in the centre (photo 3547), sharp basal contact (~35 deg below horizontal).

Mrlst, as above.

7cm Mrlst zone - irregular horizontal clacite filled fracture near base (photo 3548). Base of underlying lst marked by a more apparent microcrystalline texture - interbedded with underlying black Mrlst (photo 3550).

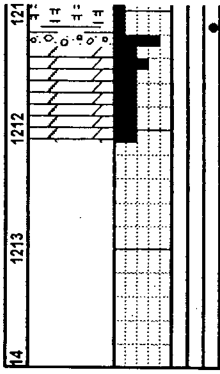
Lst - fines upwards, sharp lower/diffuse upper contact. Base contains "rip-up" -like clasts if black shale (~0.5mm).

Lst - 4 parallel convex fractures. Up to 0.5cm in thickest part. Internal fill is bitumen, calcite in edges (photo 3553, 3554).

Mrlst, as above - white powdery sulfate residue..

Lst, as above - sharp upper and lower contacts with shale.

Mrlst becomes less calcareous towards base, almost coaly White phosphate 'specks" common (<1mm). Dark brown/black, fine grained well rounded clasts (chert?), bigger and more common at base (photo 3557). Colour changes to grey/green, slightly argillaceous. Minor horizontal fractures



UNIT: CONGLOMERATE - well rounded chert clasts, matrix supported.

UNIT: DOLOMITE - light grey/green, argillaceous, low calcite, mod carbonaceous, minor fractures, top 10cm is fine CONGLOMORATE, 2-3mm clasts of grey chert scattered throughout, some calcareous inclusions, black shale clasts (Nordegg?) and stringers (photos 3555, 3556), occasional vugs, moldic porosity. Away from contact, dolomite us heavily oil-stained.

SAMPLES:

Sorption: 1205.4m, 1210.8m.

TOC: 1) 1205m, 2) 1205.6m (green shale), 3) 1206.2m, 4) 1206.35m, 5) 1207.95, 6) 1208.75m, 7) 1210.45m, 8) 1210.75m.

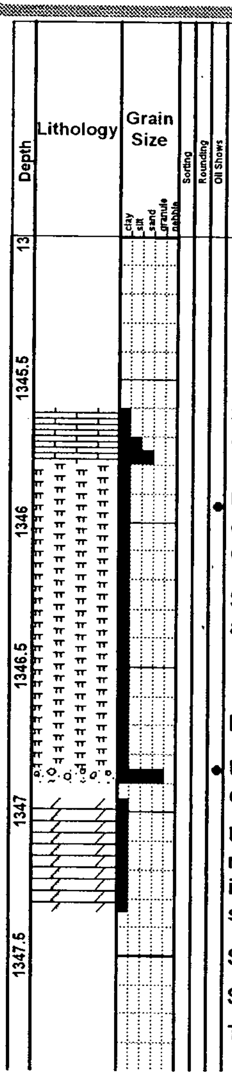
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Fort St John No. 11 04-23
Location: 00/04-23-086-21W6-0
Licence Number: 00046
Region: British Columbia
Spud Date: 12/30/1952
Drilling Completed: 05/26/1953
Surface Coordinates: Lat: 56.466084
Long: -121.209938
Bottom Hole Coordinates: BH Lat: 56.466084
BH Long: -121.209938
Ground Elevation (m): 845.2m
K.B. Elevation (m): 849.1m
Logged Interval (m): 1345m To: 1347.3m
Total Depth (m): 2.3m
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 3938

SUB-UNIT: LIMESTONE (15%) - dark grey, argillaceous, microcrystalline, mottled, calcite crystals fine upwards (calcite "sand" at base), mod carbonaceous.

UNIT:PHOSPHATIC MARLSTONE (85%) - black, calcareous, brown streak, petroliferous odour, fissile, finely laminated, dense, occasional interbeds of lst, sharp horizontal contact with overlying lst.

Slicken-side planes revealed 230mm above base, white powdery residue concentrated along horizontal fractures (sulphate?).

Mrlst is less calcareous.

UNIT: CONGLOMORATE - rounded clasts of dolomite and Nordegg shale (?), ~4mm diameter, dark grey, argillaceous matrix.

UNIT: DOLOMITE - med grey, very argillaceous, mod carbonaceous, dense, microcrystalline, stringers of black shale near contact, occasional stylolites with insoluble organic residue. Grades into a dolomite with crystalline calcite and sub mm scattered quartz, mod vuggy porosity, increasingly brecciated downwards.

SAMPLES:

SORPTION: 1346.1m

TOC - 1), 1345.9m, 2) 1346.7m, 3) 1346.9m

LITHOLOGY STRIP LOG

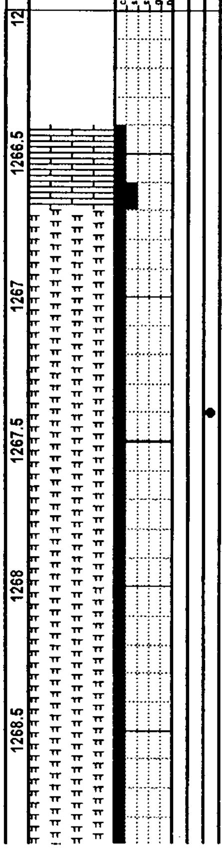
WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Fort St John No. 18 10-25
Location: 00/10-25-083-17W6-0
Licence Number: 00049
Region: British Columbia
Spud Date: 11/12/1952
Drilling Completed: 12/18/1952
Surface Coordinates: Lat: 56.226067
Long: -120.540321
Bottom Hole Coordinates: BH Lat: 56.226067
BH Long: -120.540321
Ground Elevation (m): 705.8m
K.B. Elevation (m): 709.8m
Logged Interval (m): 1266.4m To: 1269.6m
Total Depth (m): 2.8m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size (clay, silt, sand, granule, pebble)	Sorting	Rounding	Oil Shows	Geological Descriptions



SUB-UNIT: LIMESTONE (90%) - dark grey, microcrystalline, mottled, argillaceous, mod carbonaceous, finely interbedded with black shale, coarsening upwards of calcite (?), sharp contact at coarse end.

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, mod carbonaceous, fissile, fossiliferous in parts, micromicaceous, 3 discrete 10mm interbeds of lst, 1 band grades from light brown (bitumen-stained) up to milky white, calcite "specks" common throughout.

White powdery sulfate residue.

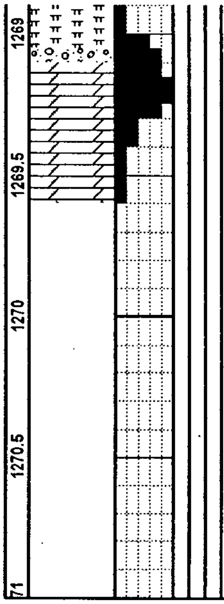
2 zones (~80mm each) of fractures:

1) 2 prominant vertical fractures, partially calcite-filled, (W 0.5mm, L 40mm), slickensided. Directly below, irregular (hor & vert.) calcite-filled fracture (W 1mm). (photos 3902, 03)

2) Fracture - near vertical, calcite-filled, W0.5-2mm, co-occurs with calcite-replaced shells (?) (photo 3904)

Mrlst - slightly siliceous/dolomitc towards base,

UNIT: CONGLOMERATE - black, argillaceous, non-calcareous matrix. clasts (1-15mm) of



chert, smaller phosphate grains, minor blue quartz, black chert nodules co-occur with minor scattered shell hash. Angled contact between fine congl. and underlying light grey unit.

UNIT: DOLOMITE - top brecciated conglomorate, angular clasts of cream dolomite (~15mm diameter), med/light grey, calcite-filled fractures cross-cut by stylolites with organic residue.

Dolomite - light grey, mod argillaceous & carbonaceous, silty, microcrystalline, increasingly fossiliferous away from contact, grades down to cream/buff colour, one prominant bitumen-lined fracture below contact, vertical calcite-filled fractures, mod vuggy porosity.

SAMPLES:

Sorption: 1267m, 1268.6m.

TOC: 1) 1266.7m, 2) 1267.1m, 3) 1267.3m, 4) 1268.1m, 5) 1268.7m, 6) 1269.1m (contact).

Extra photos: (CD#4) - 4443 (contact).

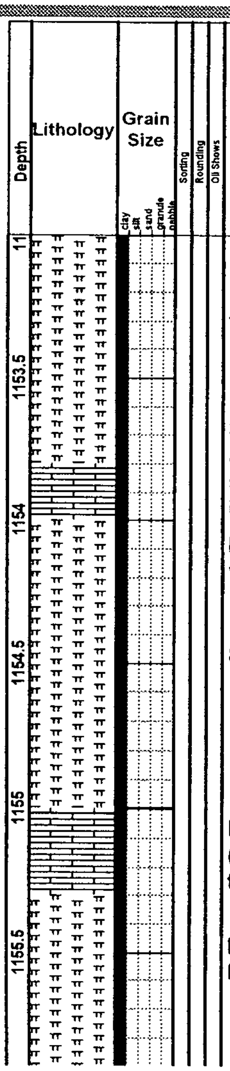
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Samson Et Al Ft St John SE 08-05-0
Location: 00/08-05-083-17W6-0
Licence Number: 00052
Region: British Columbia
Spud Date: 12/21/1952
Drilling Completed: 09/11/1968
Surface Coordinates: Lat: 56.166050
Long: -120.641167
Bottom Hole Coordinates: BH Lat: 56.166050
BH Long: -120.641167
Ground Elevation (m): 611.3m
K.B. Elevation (m): 615.4m
Logged Interval (m): 1153m To: 1157.4m
Total Depth (m): 4.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, mod petroliferous and carbonaceous, fossiliferous (plant fragments, bright - vitrinite-rich?), contains 9cm of finely interlaminated lst, gives mottled appearance, mod sharp lower and upper contacts, occasional calcite interbeds (horizontal/parallel with bedding, <0.5mm thick)

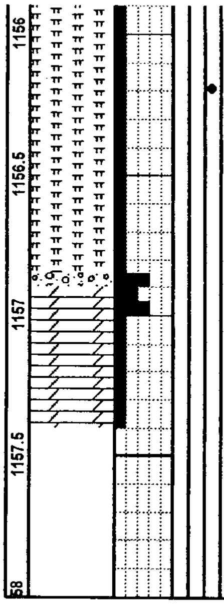
SUB-UNIT: LIMESTONE (95%) - dark grey/black, mod carbonaceous, microcrystalline, argillaceous, mottled, base marked by 4-20mm clasts of non-calcareous black shale, smaller clasts well rounded, larger clasts more angular (photo 3794), sharp/undulated lower contact.

Mrlst, as above - irregular non planar upper contact with lst, wavy/discontinuous calcite veins directly below.

8cm zone of interbedded lst, sharp non-planar lower contact.

Lst, as above - fractured, 2 calcite-filled fractures, vertical, 45mm apart, thicken upwards (W0.2-1.5mm, L90mm), joined horizontally by 7+ curvilinear calcite-filled fractures, fracture specing reduces upwards (photo 3795).

Mrlst, as above - dark grey, upper 15cm slightly silty, vague discontinuous interbeds of brown shale.



White powdery residue more apparent (sulfur?).

Bottom 5cm non-calcareous.

UNIT: CONGLOMORATE - med/dark grey shale matrix, argillaceous, white phosphate "specks" common, no grains/clasts larger than 1.5mm.

UNIT: DOLOMITE - light grey, dirty texture/silty, vuggy porosity (lessens away from contact), minor calcite-filled fractures, near contact - 2 angular black shale clasts (~2mm diameter, Nordegg?).

SAMPLES:

Sorption: 1156.2m

TOC: 1) 1155.8m, 2) 1156.3m, 3) 1153.3m

Thin-section: 1154m (shale clasts within lst/calc band)

Extra photos (CD#3) - shale clasts in calcite band 4243, calcite specks 4247.

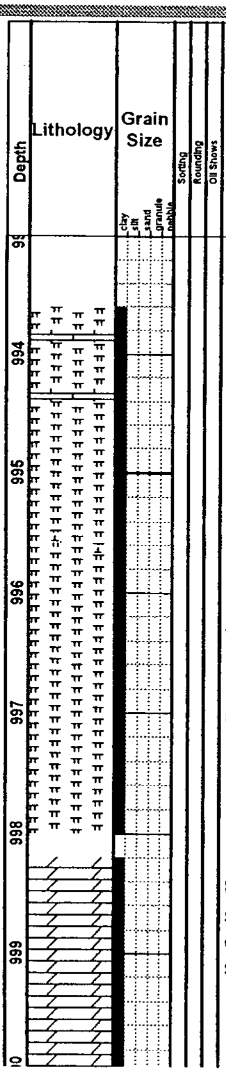
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	Pacific Gates No.1 05-14-082-25		
Location:	00/05-14-082-25W6-0		
Licence Number:	00053	Region:	British Columbia
Spud Date:	1/13/1953	Drilling Completed:	5/1/1953
Surface Coordinates:	Lat: 56.107895 Long: -121.804695		
Bottom Hole Coordinates:	BH Lat: 56.107895 BH Long: -121.804695		
Ground Elevation (m):	467.3m	K.B. Elevation (m):	470.6m
Logged Interval (m):	993.6m To: 1001.2m	Total Depth (m):	6.6m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Interval: 7.6m

UNIT: PHOSPHATIC MARLSTONE (95%) - dark grey/black, slightly calcareous & silty, argillceous, petroliferous, finely laminated. minor horizontal fractures filled with calcite.

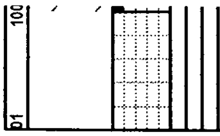
SUB-UNIT: LIMESTONE (5%) - dark grey/black, microcrystalline, mottled, argillaceous & mod carboanceous, occurs as 2 large (~100mm) interbeds within black shale.

Mrlst, as above - vertical stylolite-like fracture (?) with organic residue, cross-cuts horizontal calcite-filled fracture (~1mm thickness), also contains 1 triangular calcite-filled void (?).

Fractures: (1)irregular and curvylinear (photo 3435). total length 13cm, width 0.1-0.4cm. Predominantly filled with bitumen. Co-occurs with calcite which surrounds fracture when present. (2) 14/0.1-0.2 - near vertical orientation. Completely filled with calcite

Discrete zones of calcite (3-4cm "blebs") (photo 3436).

UNIT : DOLOMITE - light grey, mod carbonaceous & calcareous, argillaceous, (upper section more calcareous, lower section doloitized, photo 3440), vuggy porosity (leaching of shell fragments), fossiliferous, poor intercrystalline porosity, calcite-filled vugs, stylolites. Contact missing from core box (photo 3437).



SAMPLES:

TOC: 1) 993.6m, 2) 994.4m, 3) 995.8m, 4) 996.25m, 5) 996.4m, 6) 997.05m (+ original sample @ 997.55m)

Thin-section: 994.1m (triangular calcite-filled void & fossils)

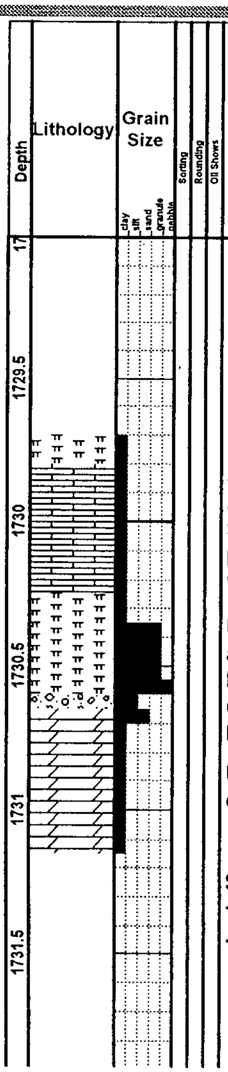
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Sunrise No.10 08-28-079-
Location: 00/08-28-079-16W6-0
Licence Number: 00054
Region: British Columbia
Spud Date: 1/10/1953
Drilling Completed: 4/25/1953
Surface Coordinates: Lat: 55.874012
Long: -120.429466
Bottom Hole Coordinates: BH Lat: 55.874012
BH Long: -120.429466
Ground Elevation (m): 805.5m
K.B. Elevation (m): 809.2m
Logged Interval (m): 1729.7m To: 1731.3m Total Depth (m): 1.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 3351

UNIT: PHOSPHATIC MARLSTONE (95%) - dark grey/black, fine-grained, pyritic, interbedded with light grey lst. Bitumen-filled fractures. Fractures show preffered orientation across the core sample. Fractures range in width from 0.25-0.75mm, length between 30-40mm.

SUB-UNIT: LIMESTONE (90%) - dark grey/black, microcrystalline (gives mottled appearance), argillaceous, mod carbonaceous, finely interbedded with black shale. Several calcite filled horizontal fractures (thickness ~ 0.2mm, length ~ 20mm).

Mrlst - Concentration of shell fragments into discrete zones (photo 3353). More white "speckles". Sits above a more argillaceous dolomite

UNIT: CONGLOMERATE - rounded grains of qtz, chert and minor calcite, angular-subrounded, 1-8mm diameter, intermixed with ribbons of chert (?) which are broken /fractured and filled (photo CD#3, 4118). Sharp contact between congl. and Mrlst units. Shale unit contains coarse-fill fractures (quartz) which cut through wavy laminations (photo 3354)

UNIT: DOLOMITE - light grey, argillaceous, slightly calcareous, dense. Contact with overlying shale marked by finely interbedded shale(?)), laminations irregular.

SAMPLES:

TOC: 1730.4m

Thin-section: 1730.6m (ribbon chert & congl. fill)

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:48 (25"=100') Metric

Well Name:	Pacific Beatton No. 1 10-01-084-1		
Location:	00/10-01-084-16W6-0		
Licence Number:	00055	Region:	British Columbia
Spud Date:	1/15/1953	Drilling Completed:	3/29/1957
Surface Coordinates:	Lat: 56.254581 Long: -120.383102		
Bottom Hole Coordinates:	BH Lat: 56.254581 BH Long: -120.383102		
Ground Elevation (m):	747.0m	K.B. Elevation (m):	750.7m
Logged Interval (m):	1269.4m To: 1278.2m	Total Depth (m):	8.8m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

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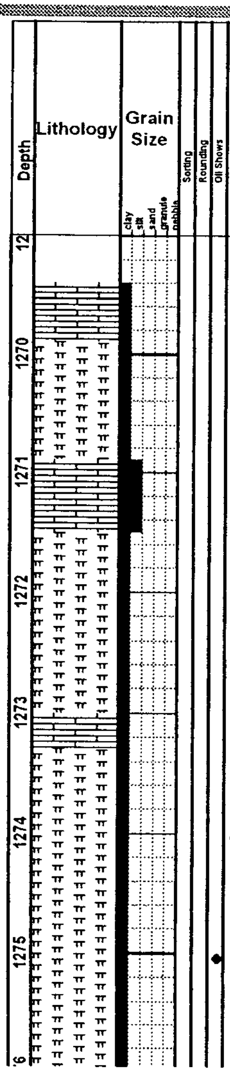


Geological Descriptions

SUB-UNIT: LIMESTONE (95%)- dark grey/black, carbonaceous, argillaceous, slightly silty, finely laminated (with shale), microcrystalline, mottled appearance, petroliferous. Horizontal calcite cemented fractures which are irregular and discontinuous (0.5mm thick, 20-30mm length).

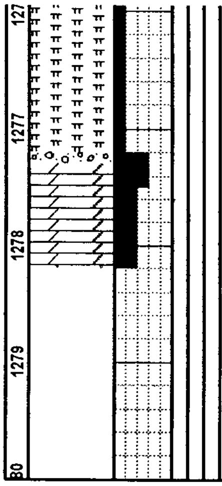
UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, brown streak, fine-grained, highly calcareous, strong petroliferous odour, fossiliferous (bivalves). Interbedded with green, poorly indurated silty-shale (broken fragments remain), green shale fractured with organic-rich fill (vitrinite?), 1mm thick/length across core. Calcite "specks" common (photos 3512, 3513), occasional organic-rich interbed, dull and very friable, rough texture.

Lst - from bright white appearance, higher calcite content that above lst (photo 3514), slightly coarser.

Mrlst, as above.

Lst, as above - sharp upper and lower conatacts with shale.

Mrlst - abundant horizontal calcite-filled fractures (width 1mm, length 30mm). 2 discrete lst interbeds - occurs as both a broad (7cm) or concentrated (1cm) bands. Contacts, where seen, are sharp.



UNIT: CONGLOMORATE - phosphate grains common (?), scattered sub mm calcite "specks" in slightly argillaceous, non-caclcareous matrix, can be brown and silty.

UNIT: DOLOMITE - light grey, micro- cryptocrystalline, brecciated, fractured, good moldic porosity, mod carbonaceous & argillaceous, contains light grey chert, calcareous in parts, silty. Exact contact with overlying shale is missing from core box.

SAMPLES:

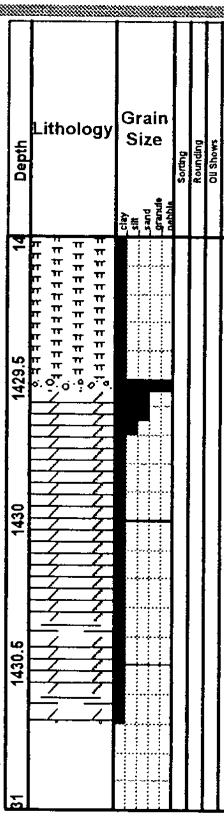
Sorption: 1271.8m, 1276.8m

TOC: 1) 1269.4m, 2) 1270m, 3) 1270.3m, 4) 1271.3m, 5) 1272.3m, 6) 1272.6m, 7) 1273.3m, 8) 1274.0m, 9) 1274.25m, 10) 1275.25, 11) 1276.0m, 12) 1276.6m

Other: 1270.2m (organic-rich interbed)

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Pacific Atlantic Pingel Creek No. 1
Location: 00/03-33-081-18W6
Licence Number: 00057
Region: British Columbia
Spud Date: 2/5/1953
Drilling Completed: 8/18/1953
Surface Coordinates: Lat: 56.060478
Long: -120.754906
Bottom Hole Coordinates: BH Lat: 56.060478
BH Long: -120.754906
Ground Elevation (m): 783.2m
K.B. Elevation (m): 786.3m
Logged Interval (m): 1429m To: 1430.7m
Total Depth (m): 1.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%)- dark grey/black, brown streak, very minor sub mm specks of phosphate, calcareous, mod carbonaceous, slightly fractured, strong petroliferous odour (photo 3387).

UNIT: CONGLOMERATE - chert and qtz pebbles (up to 2cm diameter), angular-subrounded Triassic (?) dolomite in med grey, argillaceous, shaley matrix, increasingly calcitic upwards.

UNIT: DOLOMITE - light brown, microcrystalline, good pin-point porosity, slightly brecciated, veins with calcite filling, scattered shell hash (also occurs as discrete flattened interbeds). (photos 3389, 3390, 3391)

Discontinuous quartz veins -horizontal orientation (2mm thick/40mm length)

Within dolomite, shaley bands with mottled texture (photo 3392) and wavy laminations. (photo 3395).

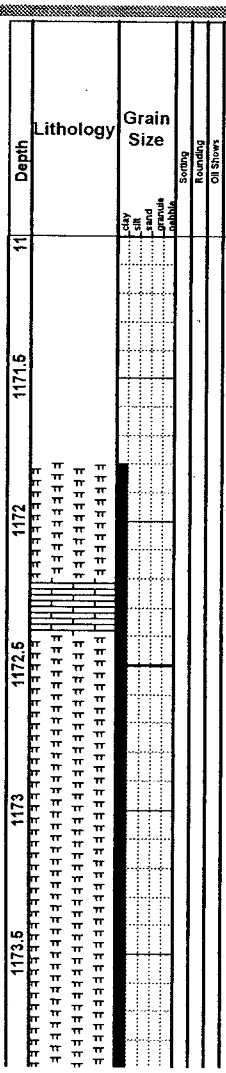
SAMPLES:
Sorption: 1429.2m

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Samson Ft St John SE 10-33-082-17
Location: 00/10-33-082-17W6-0
Licence Number: 00060
Region: British Columbia
Spud Date: 03/08/1953
Drilling Completed: 05/04/1953
Surface Coordinates: Lat: 56.154034
Long: -120.593422
Bottom Hole Coordinates: BH Lat: 56.154034
BH Long: -120.593422
Ground Elevation (m): 618.7m
K.B. Elevation (m): 622.7m
Logged Interval (m): 1171.9m To: 1178.6m
Total Depth (m): 6.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



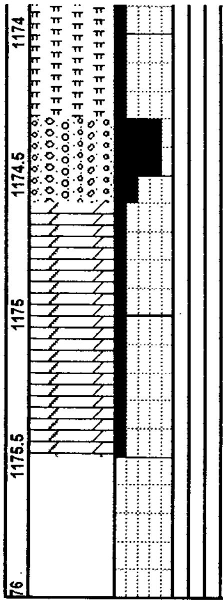
Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, thinly laminated, silty in parts, scattered white calcareous specks, contains 1 calcareous brown shale clast (35m length).

Fractures: 2, minor, both terminated by broken core, caclite-filled (0.5-1mm width).

SUB-UNIT: LIMESTONE (95%) - dark grey/black, crypto- microcrystalline, carbonaceous, sharp lower contact, finely interbedded with black shale.

Mrlst, as above - along fracture planes see bright lustre, high vitrinite content (bright coal ?).



UNIT: CONGLOMORATE - clasts of opalescent blue quartz, clay (brown) and phosphate, clasts (5-10mm) become more compacted towards bottom contact, upper 200mm of congl. has a fine-grained, black calcareous matrix, clasts generally have mod sphericity and roundness.

UNIT: TRIASSIC DOLOMITE - (to 1178.6m depth), med/light grey, mod carbonaceous, finely interbedded with black shale near contact, vuggy porosity.

Top 50mm massive, with 40mm finely laminated organic-rich laminae, cream dolomite, med grey silty dolomite, disrupted bedding, slightly wavy - almost ripple-like (?), laminations at base are thicker (change from 1mm-10mm), thicker cream/buff dolomtic laminae fractured and filled with organic residue, thicker laminae more irregular/non-planar. Below lamination, sharply changes to breccia (photo CD #3, misc folder, 4127)

SAMPLES:

Sorption - 1173.5m
TOC - 1) 1171.9m, 2) 1172.8m, 3) 1173.2m, 4) 1174.2m

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Pacific Fort St John No.25 01-02
Location: 00/01-02-084-19W6-00
Licence Number: 00063
Region: British Columbia
Spud Date: 4/18/1953
Drilling Completed: 7/8/1953
Surface Coordinates: Lat: 56.248127
Long: -120.874168
Bottom Hole Coordinates: BH Lat: 56.248127
BH Long: -120.874168
Ground Elevation (m): 648.8m
K.B. Elevation (m): 689.4m
Logged Interval (m): 1181.0m To: 1185.4m
Total Depth (m): 4.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

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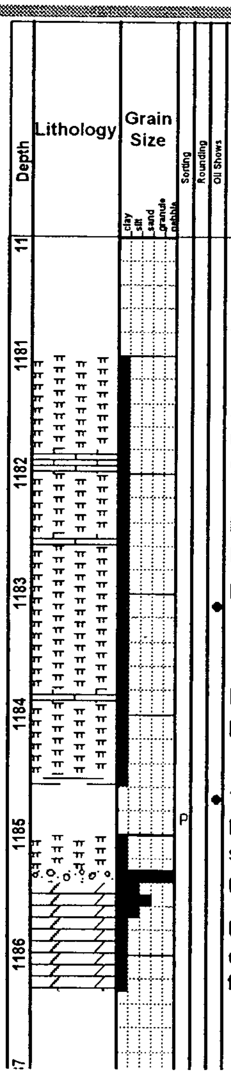

Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - black, fine grained, calcareous, petroliferous, fossiliferous. Vague, fine laminations with lst. Fractures: <1mm thick, calcite-filled, horizontal (photo 3510).

SUB-UNIT: LIMESTONE (90%) -dark grey/black (slightly green in places), microcrystalline, mottled appearance, argillaceous, mod carbonaceous, finely laminated (interbedded with shale, <1mm). <1mm horizontal calcite filled fractures/irregular form.

Mrlst, as above.

Lst, as above - sharp lower and upper contacts.

Mrlst, as above.

Lst, as above - sharp lower/diffuse upper contact.

Mrlst, as above.

1184.6-1185m core missing.

Basal Mrlst - argillaceous, calcareous, slightly coaly, sits atop of slightly argillaceous, siliceous/dolomitic shale (base Nordegg?),

UNIT: CONGLOMORATE - sub mm phosphate and chert grains, matrix supported.

UNIT: DOLOMITE : light grey, microcrystalline, mod carbonaceous, argillaceous and calcitic, brecciated, mod vuggy porosity, majority calcite-filled, horizontal 2-3mm fractures with bituminous lining, vertical calcite-filled fractures (W0.5mm, L 25mm).

118 / 1188 / 89					SAMPLES: Sorption: 1183.4m TOC: 1) 1181.2m, 2) 1182.0m, 3) 1182.5m, 4) 1183.3m, 5) 1183.75m, 6) 1184.05m, 7) 1184.15m, 8) 1184.85m. Thin-sections: 1185.3m (contact) Extra photos: (CD#4) - 4437 (contact)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Fort St John No. 28 09-03
Location: 00/09-03-084-18W6-0
Licence Number: 00072
Region: British Columbia
Spud Date: 07/10/1953
Drilling Completed: 08/10/1953
Surface Coordinates: Lat: 56.256569
Long: -120.742256
Bottom Hole Coordinates: BH Lat: 56.256569
BH Long: -120.742256
Ground Elevation (m): 648.8m
K.B. Elevation (m): 688.5m
Logged Interval (m): 1245m To: 1249m
Total Depth (m): 4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

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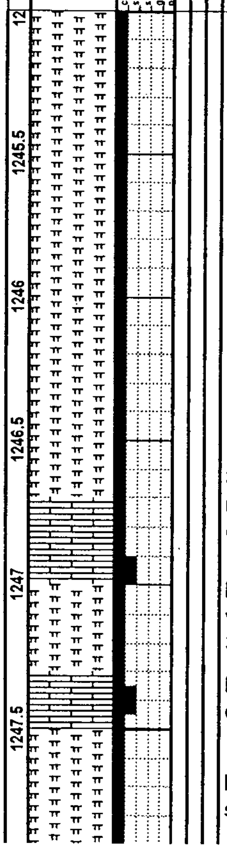
Depth | Lithology | Grain Size (clay, silt, sand, granule, pebble) | Sorting | Rounding | Oil Shows | Geological Descriptions



UNIT: PHOSPHATIC MARLSTONE (98%) - black, brown streak, calcareous, finely laminated with black chert, petroliferous odour, occasionaly interbedded with lst, slightly argillaceous.

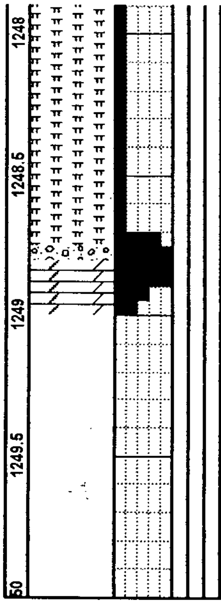
Contains 1 large (~60mm) "nodule" of lst/calcite sand, crystals bitumen stained, minor angular black chert clasts contorted around nodule (diameter ~3mm, photo 3905)

SUB-UNIT: LIMESTONE (90%) - dark grey/black, microcrystalline, mottled, argillaceous, mod carbonaceous, mod argillaceous, fining up of calcite, sharp lower and upper contacts, fine interbeds of black shale.

Mrlst, as above - fossiliferous in part (shell hash bands). 2 prominant fractures - 1 vertical & 2 horizontal, perpendicular to each other, bitumen-filled (?) (W0.5mm, L 30mm). (photo 3906)

Lst, as above, no fining up sequence, relatively diffuse lower and upper contacts, slight coarsening then fining upwards of calcite crystals.

Mrlst, as above - occasional brown clay nodules (~8mm), well rounded. White powdery sulfate residue at base, basal 10cm non-calcareous, siliceous/dolomitic, slickensided.



UNIT: CONGLOMORATE - sub mm qtz and chert grains, minor phosphate

UNIT: DOLOMITE - light/med grey, mod congl. near contact, poor-mod vuggy porosity, fine interbeds of shale, upper unit is very poorly sorted conglomorate, one 10cm clast of silty dolomite and 6cm white siliceous clast at contact, siliceous clast fractured and sunsequently filled with organic residue/black shale (?), mm blue quartz grains, little matrix, black, argillaceous (photo 3907).
Congl, sharply changes to light/med grey dolomite, brecciated, bituminous, argillaceous-arenaceous, occasional stringers of black shale, scattered cream/buff dolomitic clasts.

SAMPLES:
Sorption: 1248m
TOC: 1) 1245.8m, 2) 1247 (lst), 3) 1247.1m (shale directly below lst), 4) 1247.9m, 5) 1248.5m.
Extra photos: (CD#4) 4446 (contact)

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:48 (25"=100') Metric

Well Name:	Samson Et Al Ft St John 01-20-083-		
Location:	00/01-20-083-18W6-0		
Licence Number:	00074	Region:	British Columbia
Spud Date:	08/06/1953	Drilling Completed:	10/07/1953
Surface Coordinates:	Lat: 56.204964 Long: -120.799507		
Bottom Hole Coordinates:	BH Lat: 56.204964 BH Long: -120.799507		
Ground Elevation (m):	651.9m	K.B. Elevation (m):	653.5m
Logged Interval (m):	1132.3m To: 1135.8m	Total Depth (m):	3.5m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

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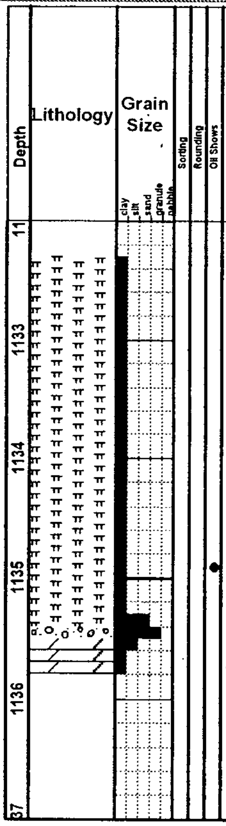


Geological Descriptions

UNIT:PHOSPHATIC MARLSTONE (90%) - black, calcareous, petroliferous odour, interbedded lst (dark grey/black, micromicaceous, microcrystalline) (30-50mm), .

Lst interbed zone, mod sharp lower and upper contacts angled at 20 deg below horizontal (photo 3900).

UNIT: CONGLOMORATE - (phosphate ~1mm), blue-ish qtz inclusions, chert & silty lst clasts (~ 5mm, slightly brown), argillaceous shaley matrix, dark grey/brown, low calcite content, stringers of black shale, white "specks" common (photo 3901).

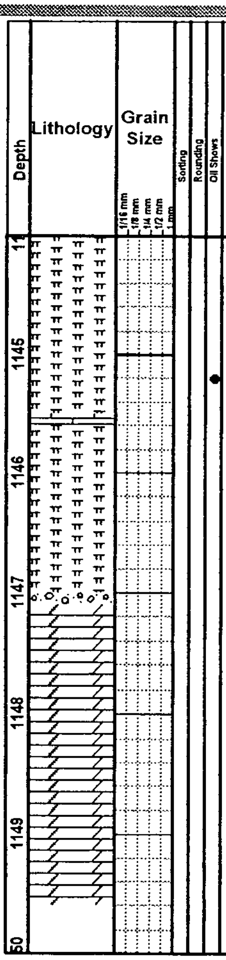
UNIT: DOLOMITE - cream/buff colour, congl. in parts, dense, argillaceous, horizontal fracturing near contact, poor vuggy porosity, occasionaly slightly calcareous, dolomitic layering, trace bitumen farther down unit.

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Samson Et Al FT St John 14-22-083
Location: 00/14-22-083-18W6-0
Licence Number: 00076
Region: British Columbia
Spud Date: 8/10/1953
Drilling Completed: 9/24/1953
Surface Coordinates: Lat: 56.214165
Long: -120.759155
Bottom Hole Coordinates: BH Lat: 56.214165
BH Long: -120.759155
Ground Elevation (m): 647.4m
K.B. Elevation (m): 651.1m
Logged Interval (m): 1144.8m To: 1149.4m
Total Depth (m): 5.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%)- dark grey/black, finely laminated, pyritic, calcareous (and concentrated laminations), petroliferous, Brown speckly appearance in some areas.

SUB-UNIT: LIMESTONE (5%) - dark grey/black, carboanceous, microcrystalline, mottled, sharp upper and lower contacts with shale.

Mrlst, as above.

UNIT: CONGLOMORATE - 4cm unit of 1-2mm qtz & chert grains which are sparse and unorientated, matrix supported, dark grey/black, sightly argillaceous, non-calcareous..

UNIT: TRIASSIC DOLOMITE - light grey, very argillaceous, dense, mod carbonaceous & calcitic. Becomes finer-grained away from contact area. Contact area marked by congl. Large phosphate grains - mod sphericity and angularity.

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Pacific Fort St John No.33 04-36
Location: 00/04-36-082-16W6/00
Licence Number: 00077
Region: British Columbia
Spud Date: 8/31/1953
Drilling Completed: 12/13/1953
Surface Coordinates: Lat: 56.147266
Long: -120.371269
Bottom Hole Coordinates: BH Lat: 56.147266
BH Long: -120.371269
Ground Elevation (m): 608.1m
K.B. Elevation (m): 611.7m
Logged Interval (m): 1231.0m To: 1238.6m
Total Depth (m): 7.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

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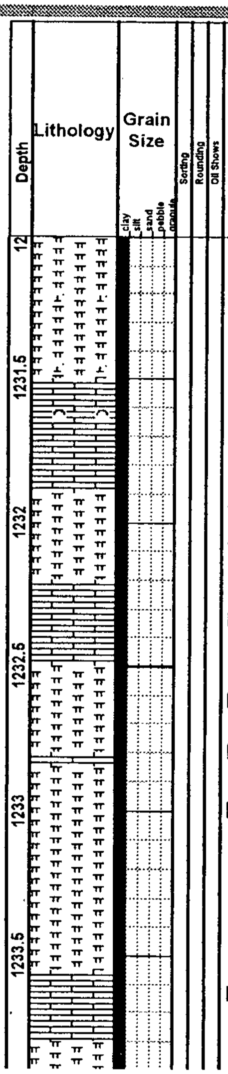


Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%)- dark grey/black, brown streak, calcareous, pyritic, finely interbedded with lst. Calcite veins orientated vertically through the core. Width <1mm. Absolute length cannot be determined due to incomplete core interval.

Bifurcated calcite vein (photo 3382)

SUB-UNIT: LIMESTONE (100%) - dark grey/black, highly petroliferous, carbonaceous, microcrystalline, mottled appearance. Preservation complete bivalve shells.

2cm Mrlst band with vertical calcite veins which are terminated by the overlying lst (photo 3371). Upper and lower contacts of lst extremely laminar.

Shale, as above - minor horizontal fractures: width 0.5mm, length 20-30mm, calcite lined

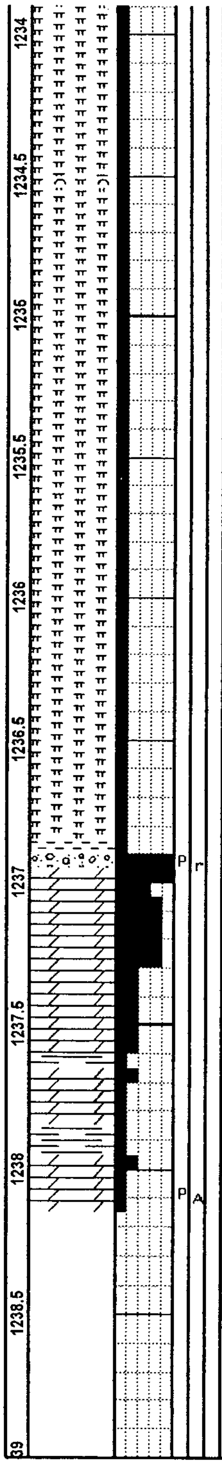
Lst, as above - Irregular, whispy interbedded nature between shale and lst.

Mrlst, as above - horizontal calcite veins (1mm thick).

Lst with dark basal contact from underlying shale (photo 3372).

Mrlst, as above.

Lst, as above - sharp lower and upper contacts.



Mrlst, as above.

Minor concentration of bivalve shells

Small pits (1mm thick, 3-4mm length) filled with quartz. Small concentration, randomly orientated. Pits surrounded by finer grained mud clasts - 1cm, well rounded/mod sphericity.

UNIT: CONGLOMORATIC (photo 3373) - black shaley non-calcareous matrix, 0.2-5mm grains of quartz and chert, occasional calcite, slight fining-up of conglomorate (photo 3377), grains angular-subangular & mod sphericity. Sharp, irregular contact with underlying med grey dolomite.

UNIT: DOLOMITE - light/med grey, slightly argillaceous, crytpocrystalline, mod petroliferous. Finely interbedded with black shale in some areas (photo 3383).

Top of dolomite - congl. - contains larger grains of quartz and chert, (av. 2.5-3mm), angular-subangular. Majority of clasts isolated in fine grained dolomitic matrix. Grades to med/light grey, bituminous, fractured, fossiliferous, mod vuggy and moldic porosity. Top 1m brecciated, laminated dolomite thereafter.

80mm bed of interbedded dolomite and shale, 15mm of fine conglomorate at base (quartz, chert, minor lithics) (photo).

Shale zone with irregular wavy laminations. Sharp contact at base (photo 3384). Concentration of quartz (1-2mm) and lithic clasts.

SAMPLES:

Sorption: 1236.2m

TOC: 1) 1231.2m, 2) 1231.5m, 3) 1232.0m, 4) 1232.5m, 5) 1232.85, 6) 1233.4, 7) 1233.7m, 8) 1234m, 9) 1234.4m, 10) 1234.8m, 11) 1235.1m, 12) 1235.4m, 13) 1235.85m, 14) 1236.25m, 15) 1237.05 (thin lime mud/green shale interbed within Bald.)

Thin-section: 1238.4m (shale interbed within Bald.)

Extra photos (CD#3): Stylolite (4305), congl. contact (4298), shale interbed (4302).

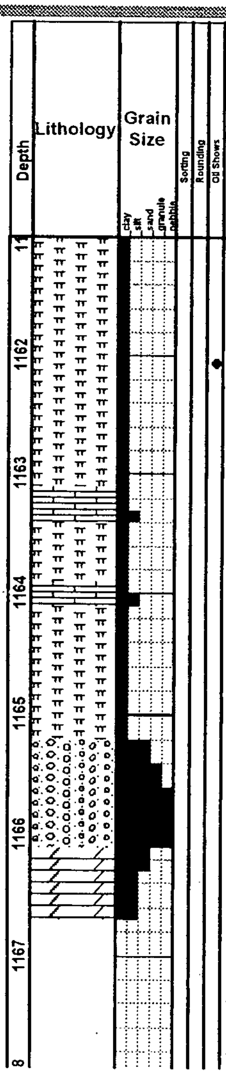
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Samson Et Al Ft St John 13-23-083
Location: 00/13-23-083-18W6-0
Licence Number: 00082
Region: British Columbia
Spud Date: 10/14/1953
Drilling Completed: 11/19/1953
Surface Coordinates: Lat: 56.214931
Long: -120.738838
Bottom Hole Coordinates: BH Lat: 56.214931
BH Long: Long: -120.738838
Ground Elevation (m): 653.4m
K.B. Elevation (m): 656.8m
Logged Interval (m): 1161.8m To: 1166.6m
Total Depth (m): 5.2m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - dark grey/black, brown streak, calcareous, strong petroliferous odour. Vague laminations. Interlaminated with lst (white "speckly" horizons) contacts can be both diffuse and concentrated.

2cm calcite -concentrated white interbed.

SUB-UNIT: LIMESTONE (90%) - dark grey/black, microcrystalline, mottled appearance, argillaceous, mod carbonaceous, occasional very fine interbeds of black shale. Sharp lower/diffuse upper contact.

Mrlst, as above - carbonaceous, 1x3mm bright plant (?) fragments.

Lst, as above - sharp contacts.

Mrlst, as above- slight honeycomb texture near base, white powdery sulfate residue.

UNIT: CONGLOMORATIC - Top 15cm, matrix dark grey, slightly argillceou Mrlst, carbonaceous, small (sub mm) qtz and phospate grains. Grades into dolomite, light/med grey, silty (top TRIASSIC DOLOMITE ?). Increasingly poorly sorted/ coarser conglomorate down. Brecciated, dolomite clasts, cream/med brown, subangular-subrounded, up to 15mm diameter, light grey silty dolomitic clasts, qtz and calcite inclusions. (photos 3484, 3485, 3486)

UNIT: DOLOMITE -light grey, argillaceous (dirty texture), mod moldic porosity, mod carbonaceous & calcitic, microcrystalline, brecciated in part, dense.

SAMPLES:

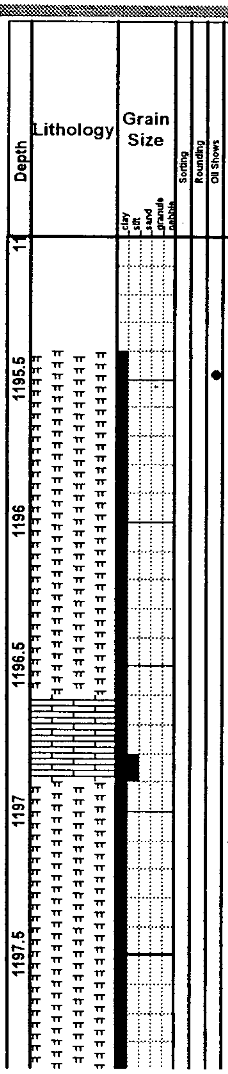
Sorption: 1164.2m

TOC: 1) 1162.9m, 2) 12663.5m, 3) 1163.45m, 4) 1163.85m (plant fragments), 5) 1164.25m, 6) 1164.35m (contact).

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name:	Samson W Bruick B- 078-C/094-A-14		
Location:	200/b-078-C 094-A-14/00		
Licence Number:	00089	Region:	British Columbia
Spud Date:	09/03/1954	Drilling Completed:	22/05/1954
Surface Coordinates:	Lat: 56.81124 Long: -121.34407		
Bottom Hole Coordinates:	BH Lat: 56.81124 BH Long: -121.34407		
Ground Elevation (m):		K.B. Elevation (m):	793.7m
Logged Interval (m):	1195.4m To: 1203.9m	Total Depth (m):	8.5m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



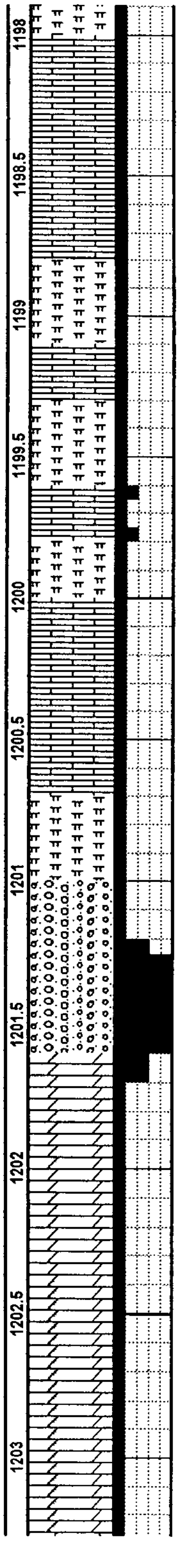
Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (90%) - black, calcareous, mod carbonaceous, finely laminated, slightly silty. Contains two zones of irregular/discontinuous caclite interlaminations (photos 3812, 13)

Phosphatic "specks" common at base, lense of coarse calcite "sand" (photo 3815), white powdery residue (sulfur?).

SUB-UNIT: LIMESTONE (100%) - med grey, mod carbonaceous, slightly argillaceous, microcrystalline, mottled, coarse calcite specks

Mrlst, as previous, lack of calcite "specks" and interlaminations, dolomitic in parts. Sharp, angled upper contact with overlying lst (photo 3816)



Lst - as above, minor horizontal/low relief stylolites bitumen-filled, 4 clasts (<1cm) of non-calcareous black shale, mod angularity and sphericity, finely interbedded with black shale.

Mrlst - as above, top marked with stringers of calcite (photo 3818), prominant calcite-filled fracture network, small clasts of black shale within fractures (W0.3-2mm, L80mm (photo 3819). Sharp upper contact.

Lst - as above, 2 prominant calcite-filled fractures, 1 near-vertical, 1convex, W1-2mm. 1 large calcite -filled fracture(?) beneath (photo 3820)

Mrlst, as above - calcite-rich band with well rounded clasts of calcareous black shale which contorts upper and lower calcite band contacts (photo)

Lst - as previous, coarse calcite "sand" at top and base, fines in centre, sharp angled contact (22 deg below hor) with shale at base, contact is undulated, 0.5mm black shale (?) band seperates calcite and shale, bitumen-filled fractures (W1mm, L200m) (photos 3821, 22, 23). Towards base, more bitumen-filled stylolites (7+), 10-100mm apart.

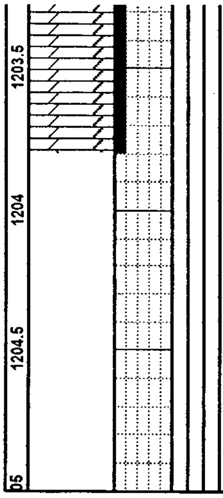
Lst, slighlty less microcrystalline than above lst, more micritic/argillaceous (?).

Near base, slickensided, 1 irregular concave calcite-filled fracture (photos 3824, 3825)

Mrlst, as above.

UNIT: CONGLOMORATE (100%)- slightly brecciated, top 140mm predominantly clasts of silty lst (varying 1-30mm diameter, larger clasts elongate horizontally, majority 5-10mm), matrix is dark grey, argillaceous, slightly calcareous, occasional sunangular phosphate grains. Lower 200mm, more brecciated/less large clasts, med/light grey matrix (top Trias?), argillaceous, slightly silty, calcareous matrix, phosphate grains more abundant, (photos 3826-29)
Organic-rich stringers common, orientated 20 deg below horizontal. Basal 80mm contains cherty/siliceous clasts, med/dark grey, angular-subangular, 10-40mm diameter, matrix as overlying brecciated zone.

UNIT: DOLOMITE - dark grey grading to buff, brecciated, cryptocrystalline, mod argillaceous, petroliferous & carbonaceous, dense, poor vuggy porosity, fossiliferous, bituminous, occasional fractures, slightly calcareous



SAMPLES:

Sorption: 1199.9m

TOC: 1) 1196m, 2) 1196.95m, 3) 1197.5m, 4) 1199.1m, 5) 1199.5m, 6) 1200.2m, 7) 1200.3m, 8) 1201.1m

Thin-sections: 1199m (calcite-filled fractue mozaic), 1201.3m (contact, Baldonnel?)

Extra pictures (CD #3): lst/shale sharp contact 4236, Trias contact 4238-4240.

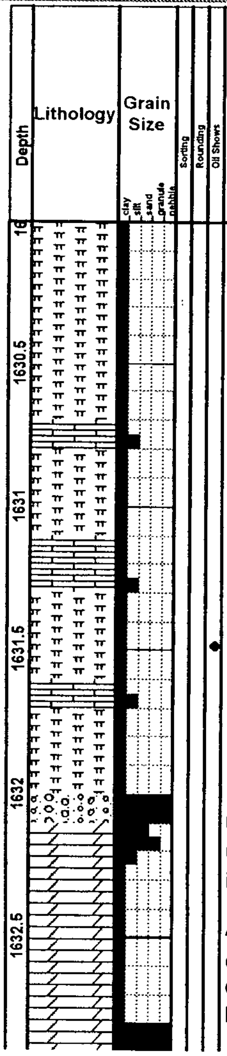
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Southern Product Atlantic B2-1 16
Location:	00/16-36-080-20W6-0
Licence Number:	00091
Region:	British Columbia
Spud Date:	3/23/1954
Drilling Completed:	7/27/1954
Surface Coordinates:	Lat: 55.983299 Long: -120.979958
Bottom Hole Coordinates:	BH Lat: 55.983299 BH Long: -120.979958
Ground Elevation (m):	915.8m
K.B. Elevation (m):	919.8m
Logged Interval (m):	1631.0m To: 1633.0m
Total Depth (m):	2m
Formation:	Nordegg/Baldonnel
Type of Drilling Fluid:	

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Entire core photo: 3345

UNIT: PHOSPHATIC MARLSTONE (100%)- dark grey/black, fine-grained, calcareous, highly petroliferous odour, slightly earthy appearance, occasional shell hash bands and brown clay clasts, interbeds of black chert. Minor, interlayered lst (lighter grey, mottled appearance).

SUB-UNIT: LIMESTONE (95%)- light/med grey, microcrsytalline, carbonaceous. Interbedded with fine black shale laminae (photo 3346). Sharp contacts at top and base.

Mrlst, as above - top 6cm contain brown clay & black chert clasts (~15mm diameter), fractured/brecciated in part, calcite-filled.

Lst, as above - cross-cutting, discontinuous calcite veins. Calcite also occurs as discrete blebs. Irregular surface either side of the lst. (photo 3347)

Mrlst, as above - occasional calcite "specks".

Lst, as above - sharp lower/diffuse upper contact.

Shale, as above.

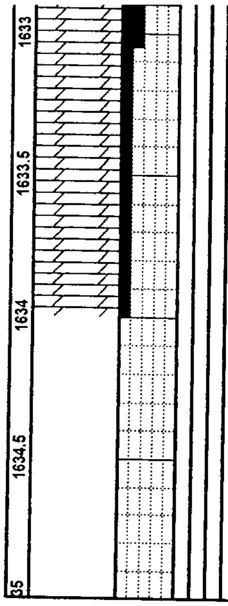
UNIT: CONGLOMORATE, 1-10 mm brown chert (?) clasts, black shale and dolomite nodules, occasionally rimmed with calcite, subangular-subrounded, point contacts, little matrix. Congl. marks top TRIASSIC.

UNIT: DOLOMITE: light grey grading to dark grey, cryptocrystalline, argillaceous, finely interbedded with shale and dolomite, mod carbonaceous & calcitic.

Abundant shell fragments (bivalves).

Calcite veins - 0.75mm width. Irregular and discontinuous.

Conglomorate - same composition as above congl., several fractures with bitumen lining.



Calcite rings - within highly fractured zone. Oil staining. Fractures concentrated in interlayers and calcite veins (photo 3350). Shells show two stage cementation - outer calcite layer white, inner cement layer is darker brown.

Zone of very coarse calcite crystallization. Occur as discrete blebs: 3-4cm. Below, coarser quartz and calcite crystallization - compose >80%. Rest is fine grained mud & clays.

SAMPLES:

Sorption: 1630.2m

TOC: 1) 1630.3m, 2) 1630.6m, 3) 1030.9m, 4) 1631.2m, 5) 1631.6m.

Thin-sectionss: 1630.8m (lst/shale contact and black chert/clay nodules in shale).

Extra photos: (CD#4) - 4441 (as thin section)

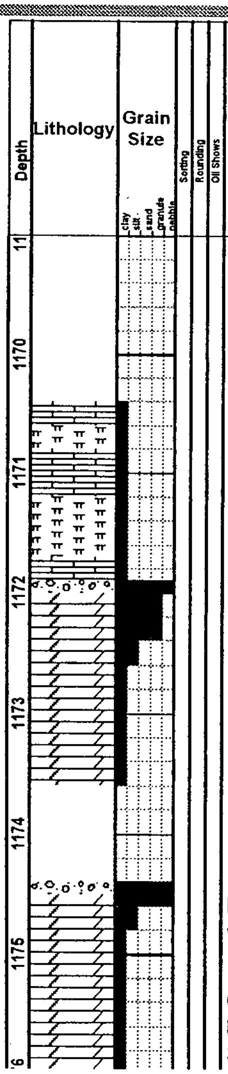
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Samson Et Al W Buick D- 095-K/094-A-11
Location: 200/d-095-K 094-A-11/00
Licence Number: 00099 — Region: British Columbia
Spud Date: 19/08/1954 — Drilling Completed: 24/09/1954
Surface Coordinates: Lat: 56.74705
Long: -121.30028
Bottom Hole Coordinates: BH Lat: 56.74705
BH Long: -121.30028
Ground Elevation (m): — K.B. Elevation (m): 742.5m
Logged Interval (m): 1170.4m To: 1176.6m Total Depth (m): 6.2m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

SUB-UNIT: LIMESTONE (90%) - dark grey, silty, argillaceous, fining-up sequence of calcite "sand", carbonaceous. Irregular, bitumen-filled stylolites at 45 degrees. Lower lst, med grey, finely interbedded with black shale, microcrystalline, mottled appearance, 2 prominant near-vertical fractures at base, bitumen-filled (photo 3699), slickensided. Ca-filled fractures oblique to bedding (0.2-1mm thick, 60-70mm length). 25 degree contact with underlying shale.

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, finely laminated, petroliferous, 1 oblique Ca-filled fracture (12 deg off vertical), 0.5mm thick, 12mm length), un-filled fractures parallel to bedding - mechanical (?), white powdery sulfate residue, scattered phosphate specks.

3rd Lst unit - finely interbedded with irregular, discontinuous laminae of black Mrlst, slightly brecciated.

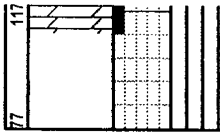
UNIT: CONGLOMORATE - clasts of brown chert, , (2mm-3cm diameter). More dolomitized towards base. Scattered sub mm qtz grains.

UNIT: DOLOMITE - cream/buff, crytpocrystalline, argillaceous, partly calcareous, brecciated, stylolites with organic residue lining, fossiliferous in parts, calcite blebs partially disolved leaving mod-good vuggy porosity.

1173.6m - 1174.4m missing from core box.

Lower dolomite - dark grey, micro-crystalline, mod argillaceous, brecciated texture, vuggy porosity, bitumen-filled stylolites

Contains congl. zone, angular clasts of calcite and dolomite, irregular fractures bitumen-filled, calcite-filled fractures, obliquity to bedding difficult to assertain (photo 3704).



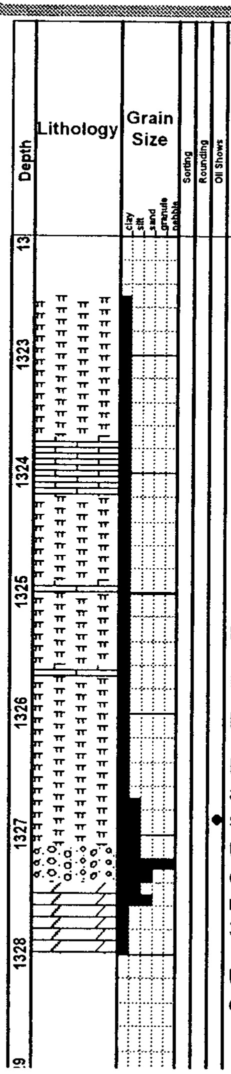
SAMPLES:
Sorption: 1171.4m
TOC: 1) 1170.8m, 2) 1171.6m, (+ original sample)
Extra photos (CD#4), contact 4521, 22

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	Penn West Red 06-07-085-20		
Location:	00/06-07-085-20W6		
Licence Number:	00102	Region:	British Columbia
Spud Date:	08/29/1954	Drilling Completed:	11/24/1954
Surface Coordinates:	Lat: 56.354023 Long: -121.153831		
Bottom Hole Coordinates:	BH Lat: 56.354023 BH Long: -121.153831		
Ground Elevation (m):	835.4m	K.B. Elevation (m):	839.4m
Logged Interval (m):	1322.5m To: 1328m	Total Depth (m):	5.5m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - black, brown streak, strong petroliferous odour, calcareous. Interbedded with lst (up to 6cm thick) - these contain 3cm, well rounded clasts of black chert (photo 3581), occasional shell hash bands (3mm thick).

SUB-UNIT: LIMESTONE (15%)- med-dark brown/grey, argillaceous, silty, highly petroliferous, mod carbonaceous. Upper and lower contacts missing from core box.

Mrlst, as above - scattered calcite "specks", occasional brown clay (?) clasts (~6mm diameter).

Lst, as above - sharp contacts at base and top. Very minor, horizontal, laterally discontinuous (3mm) fractures - calcite cemented.

Mrlst, as above, with shell hash, green shale interbed @ 1325.4m, very friable.

Lst, as above - sharp contacts (photo 3584)

Mrlst, finely interbedded with black chert.

Lower Mrlst - at base: flattened black clasts (?). White "specks" (phosphate) more abundant. Minor hor. calcite-filled fractures (<1mm thick) (photo 3588), white powdery sulfate residue.

UNIT: CONGLOMERATE - med/dark grey matrix, slightly calcareous, argillaceous, dolomitic, silty chert/siliceous clasts (~5cm diameter), black shale stringers, minor matrix. Phosphate grains common - silty lst clasts - well rounded (up to 40mm) (photos 3589, 3590), surrounded by stringers of black shale.

UNIT: DOLOMITE - top 10cm: med grey, argillaceous, dolomitic, scattered calcite crystals, slightly brecciated, contorted stringers of black shale (base Nordegg?).

132 1330 1331 32					Next 10cm: med/light grey dolomite, slightly calcareous, blebs of calcite with black shale stringers. Grades into DOLOMITE - grey/brown, argillaceous, mod carbonaceous, more calcareous towards top, dense, stylolites, 1 calcareous "bleb" (6cm diameter), fossil fragments in centre (?).. SAMPLES: Sorption: 1323.0m, 1326.6m, TOC: 1) 1322.95m, 2) 1323.25m, 3) 1323.55m, 4) 1324.05m, 5) 1324.05m, 6) 1324.6m, 7) 1325.1m, 8) 1325.15m, 9) 1325,75m, 10) 1326.35m (+1 original sample). Thin-section: 1322.9m (black chert clasts within shale).

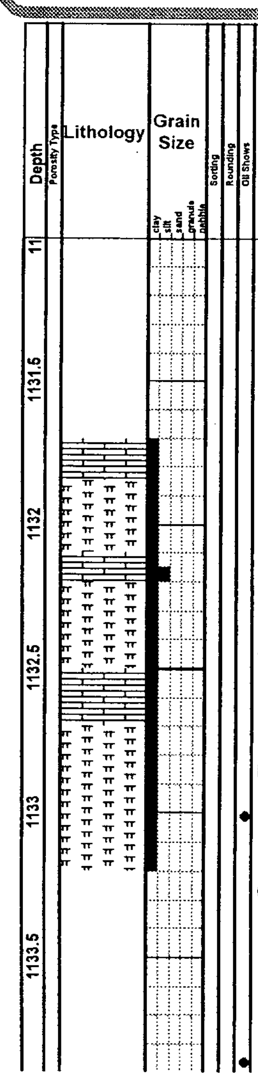
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Southern Production Canadia Atlanti
Location: 100/01-12-084-23W6/00
Licence Number: 00108
Region: British Columbia
Spud Date: 11/12/1954
Drilling Completed: 03/27/1955
Surface Coordinates: Lat: 56.262127
Long: -121.480530
Bottom Hole Coordinates: BH Lat: 56.262127
BH Long: -121.480530
Ground Elevation (m): 643m
K.B. Elevation (m): 646.8m
Logged Interval (m): 1131.7m To: 1134.9m
Total Depth (m): 3.2m
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - dark grey/green, microcrystalline, mottled texture, argillaceous, mod carbonaceous, parallel laminations (interbedded with black shale).

UNIT (100%): PHOSPHATIC MARLSTONE - black, fossiliferous, calcareous, petroliferous, scattered phosphate specks (photo 3532). Angular, planar contact with underlying lst (photo 3533).

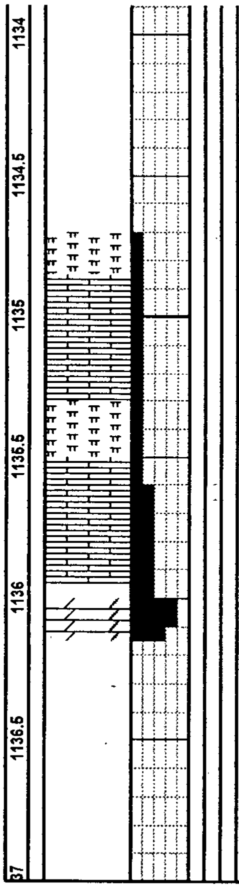
Lst, as above - sharp, horizontal contacts, silt-sized calcite at base.

Mrlst, as above - base marked by wavy laminae of phosphate (?) (photo 3535). Ammonite imprints preserved (photo 3538).

Lst, as above - scattered shell hash (photo 3536).

Mrlst, as above.

Core missing: 1133.2m - 1134.7m



Mrlst, as above - dark grey/black, mod calcareous, scattered disseminated carbonaceous matter, fossiliferous, slightly silty. (photo 3537)

Lst, as above - extremely fossiliferous.

Mrlst, as above - interbedded with black chert (~1mm).

Lst, as above - slightly silty, shell hash bitumen/oil - stained, slickensided, scattered calcite blebs (~1-2mm diameter).

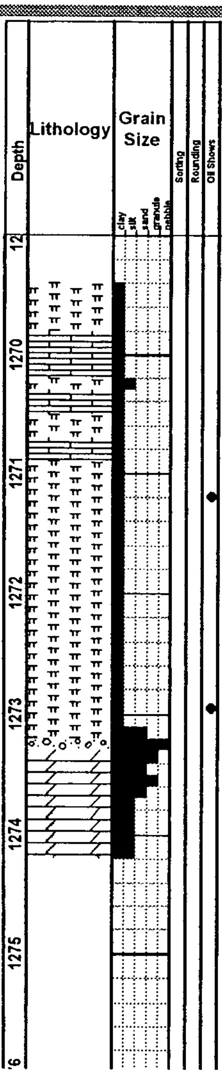
UNIT: DOLOMITE - 16cm of calcareous dolomite, disrupted interbeds of black shale (?), scattered sub mm shell hash, occasional clasts of black chert (~10mm diameter), rounded, contort shale/calcareous dolomite laminae (photo 3542) (photo 3543).

SAMPLES:
Sorption: 1134.7m
TOC: 1) 1134.8m, 2) 1135.1m, 3) 1135.9m, 4) 1136.15m.
Thin-sections: 1131.9m (calc shale/arg lst with fossils).

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:48 (25"=100') Metric

Well Name: Pacific Aitken Creek No. 1 D- 038-K/094-A-11
Location: 200/d-038-K 094-A-11/00
Licence Number: 00121 — Region: British Columbia
Spud Date: 13/01/1955 — Drilling Completed: 04/03/1955
Surface Coordinates: Lat: 56.69835
Long: -121.33944
Bottom Hole Coordinates: BH Lat: 56.69835
BH Long: -121.33944
Ground Elevation (m): — K.B. Elevation (m): 797.1m
Logged Interval (m): 1269.5m To: 1274.2m Total Depth (m): 4.7
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT:PHOSPAHTIC MARLSTONE (95%) - black, brown streak, occasional fine interbeds with black chert, calcareous, vague laminations, mod petroliferous, fossiliferous, silty in parts.

SUB-UNIT: LIMESTONE (95%) - med grey, crypto-microcrystalline, mottled appearance, argillaceous, mod carbonaceous, finely interlaminated with black shale.

Silty-Mrlst, 100mm thick, med grey/brown, carbonaceous.

Lst - slickensided, base very carbonaceous, very friable.

Mrlst - (as above), 2 finer calcite-rich intervals (10mm,13mm thick), one shows sharp lower & upper contact, other is diffuse. 3rd bed/band of calcite "sand", vague fining-up sequence. Other occasional fine interlaminations of calcite (sub mm, shell hash?), white powdery sulfate residue, occasional brown clay clasts towards base (~6mm diameter, well rounded).

Fractures: more apparent towards base of section - horizontal (parallel with bedding), calcite & bituminous filled, 0.5mm thick, 40mm length. Ca-filled fracture 45 degrees oblique to bedding (0.2mm thick).

Scattered black chert clasts at base of Mrlst (~4mm diameter).

UNIT: CONGLOMORATE - slightly brecciated, chert clasts/pebbles (10mm diameter), matrix supported - dark grey, non-calcareous, argillaceous, dolomitic shale (?), 2-3mm calcite blebs, prominent near-vertical bitumen filled fracture (0.5mm width, terminated wither end by core breakage), slickensided at contact.

UNIT: DOLOMITE - med grey, argillaceous, micro-cryptocrystalline, poor vuggy porosity.

SAMPLES:
Sorption: 1271.5m
TOC: 1) 1269.6m, 2) 1270.1m, 3) 1270.9m, 4) 1271.0m, 5) 1271.35m, 6) 1271.9m, 7) 1272.1m (lst), 8) 1272.4m, 9) 1272.7m, 10) 1273m (contact).

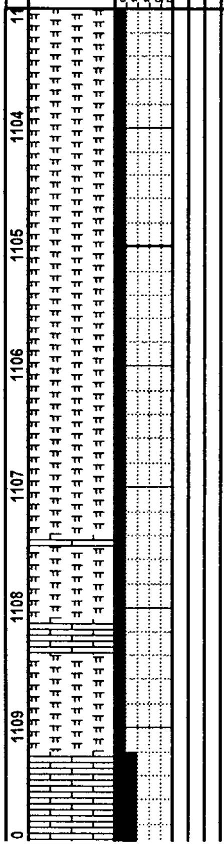
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: DECL Rigel 04-27-088-17
Location: 00/04-27-088-17W6-0
Licence Number: 00130
Region: British Columbia
Spud Date: 09/11/1955
Drilling Completed: 12/01/1955
Surface Coordinates: Lat: 56.655457
Long: -120.629616
Bottom Hole Coordinates: BH Lat: 56.655457
BH Long: -120.629616
Ground Elevation (m): 699.4m
K.B. Elevation (m): 702.8m
Logged Interval (m): 1103.3m To: 1112.6m
Total Depth (m): 9.3m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, brown streak, calcareous, mod petroliferous, occasionally interbedded with poorly indurated clayey green shale (10 mm thick at 1105.5m), lst interbeds (gives mottled laminae, 0.5-1cm thick), very minor calcite interlaminations (0.5mm thick, 5-10mm length - shell hash?).

Occasional white powdery streaks orientated horizontally (sulfur?)

Towards base of Mrlst unit, becomes more calcitic.

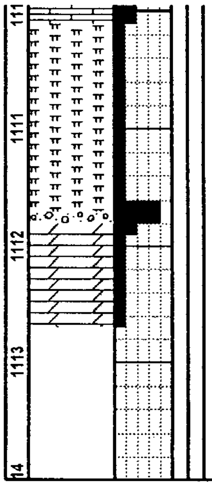
SUB-UNIT: LIMESTONE (98%) - dark grey/black, microcrystalline, mottled appearance, carbonaceous, strong petroliferous odour, interbedded with shale.

Mrlst, as above - extremely fossiliferous.

Lst, as above - sharp/planar horizontal contact

Mrlst, as above - slightly browner towards base.

Lst, as above - argillaceous, microcrystalline, bitumen (oil?) stained, interbeds of silty shale (rough textured).



Mrlst, contains 60mm interbed of extremely microcrystalline lst (fine sand sized crystals), strong sulfur odour.

UNIT: CONGLOMORATE - 1-2mm phosphate grains, brown clay and black shale (Nordegg?, very occasional, ~5mm diameter, well rounded), matrix is med dark grey, argillaceous, silty & very slightly calcareous (silty lst)

UNIT: DOLOMITE - med grey/brown, crypto -microcrystalline, mod carbonaceous, mod-good vuggy porosity, argillaceous, stylolites present, oil/bitumen stained.

SAMPLES:

Sorption: 1103.5m, 1108.5m, 1111.0m

TOC: 1) 1103.2m, 2) 1103.5m, 3) 1104.7m, 4) 1105.1m, 5) 1105.5m, 6) 1106.0m, 7) 1106.3m, 8) 1107.4m, 9) 1107.7, 10) 1107.9m, 11) 1108.2m, 12) 1108.6m, 13) 1109.0m, 14) 1109.3m, 15) 1109.6m, 16) 1110.6m, 17) 1111.4m, 18) 1111.6m, 19) 1111.9m

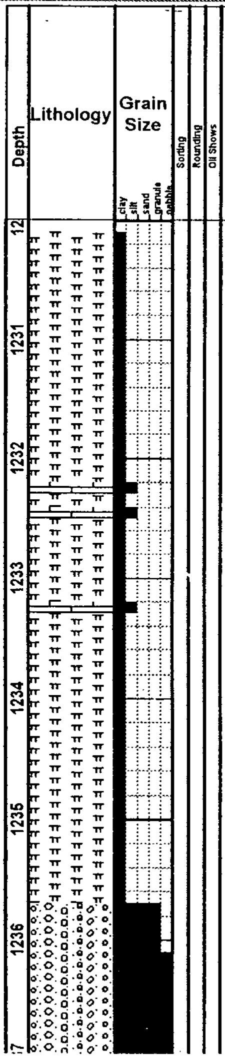
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Altair Et Al Stoddart 04-23-086-19
Location: 00/04-23-086-19W6
Licence Number: 00134
Region: British Columbia
Spud Date: 03/17/1955
Drilling Completed: 04/29/1955
Surface Coordinates: Lat: 56.465282
Long: -120.896980
Bottom Hole Coordinates: BH Lat: 56.465282
BH Long: -120.896980
Ground Elevation (m): 752.9m
K.B. Elevation (m): 756.5m
Logged Interval (m): 1230.1m To: 1237.7m
Total Depth (m): 7.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, with interbeds of lst (compose 5% of strat column), strong petroliferous odour, pyritic, occasional well rounded brown clay nodules (~6mm diameter).

SUB-UNIT: LIMESTONE (5%) - dark grey/black, microcrystalline, mottled, argillaceous, mod carbonaceous, sharp upper and lower contacts, extremely fine interbeds of black shale. Both lst units show slight fining-up of calcite (increasing micrite martrix upwards?), sharp basal contacts.

Mrlst, as above - at top contains "clasts" of overyling lst, large shell, calcite replaced (photo 3647), very occasional black chert nodules (?).

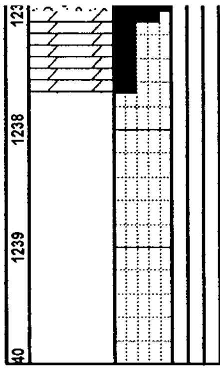
Lst, as above - sharp contcts.

Mrlst, as above - calcite occasionally occurs as fine (~0.2mm thick), discontinuous veins, parallel with bedding. Calcite "specks" in discrete zones.

White powdery sulfate residue common, occasional white phosphate specks.

(photo 3648)

UNIT: CONGLOMORATE - top 40cm: fine congl., black shale stringers common, calcareous matirx, med grey, low calcite content, mod fossilferous and argillaceous. Chert clasts, blue-quartz clasts, clay clasts (light brown). All well rounded & mod sphericity (~2-3mm diameter). Next 60cm - coarser congl., light grey/cream matrix, clasts of dolomite common (up to 50mm diameter), angular. Underlying 70cm - med grey, slightly congl., calcite specks common, mod vuggy porosity.



UNIT: DOLOMITE - med grey/brown, argillaceous, silty, micro-cryptocrystalline, low calcite content. Stylotization (with insoluble organic residue, minor fractures, mod vuggy porosity, finely laminated in parts, vuggy porosity improves.
(photo 3649)

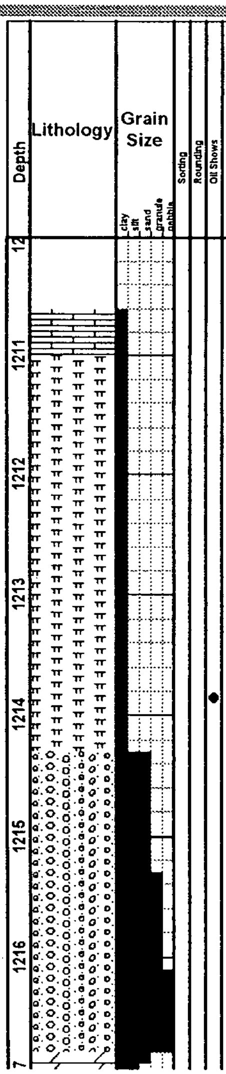
SAMPLES:

Sorption: 1230.7m, 1234.5m.

TOC: 1) 1230.9m, 2) 1231.5m, 3) 1232.3m, 4) 1232.7m, 5) 1233.0m, 6) 1233.35m, 7) 1233.9m, 8) 1234.0m, 9) 1234.3m, 10) 1234.7m, 11) 1235.1m, (+1 original sample).

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:48 (25"=100') Metric

Well Name: Penn West Numac Two Rivers 02-27-0
Location: 00/02-27-082-16W6-0
Licence Number: 00135 — Region: British Columbia
Spud Date: 03/24/1955 — Drilling Completed: 07/05/1955
Surface Coordinates: Lat: 56.133652
Long: -120.408203
Bottom Hole Coordinates: BH Long: -120.427483
BH Long: -120.408203
Ground Elevation (m): 587m — K.B. Elevation (m): 590.9m
Logged Interval (m): 1210.6m To: 1217.4m Total Depth (m): 6.8m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - med/dark grey, carbonaceous, microcrystalline, mottled, finely interbedded with black shale. Fracture: 1 prominant, near-vertical, caclite-filled (W0.5mm, L80mm)

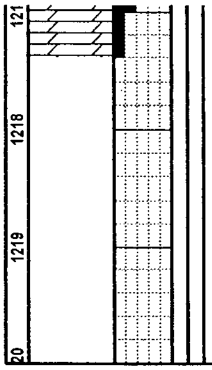
UNIT: PHOSPHATIC MARLSTONE (100%) - black (brown in parts), calcareous, slightly silty, fossiliferous, minor horizontal calcite discontinuous laminae (shell hash?). Sharp irregular contact with overlying lst, angled 15 deg below horizontal.

Mrlst, as previous - towards base, calcite "specks" common, co-occurs/surroundsclasts of non-calcareous black shale and silty lst (photos 3796, 98)

UNIT: CONGLOMORATE (marking top Triassic?) - top 1m: dark grey, chert clasts, quartz and minor calcite crystals, disrupted bedding producing stringer-like black shale within brown argillaceous /non-calcareous matrix, clasts up to 3mm length (photo 3799). Grades into a 30cm light grey, more poorly sorted congl. Clast composition as above but larger (15-20mm). Below this, 10cm pale green shale, fissile, highly fragmented.

40cm light grey congl. - clasts of grey dolomite (over 40mm), stringers of pale cream dolomite, shell fragments.
80cm of cream/buff dolomite, large angular clasts of grey dolomite within (up to 60mm).

Basal zone marked by clasts of cream/buff dolomite. Overall, congl. fines upwards. (photos 3800-06)



UNIT: DOLOMITE - cream/buff, micro - cryptocrystalline, slightly argillaceous, mod vuggy/ moldic porosity, discrete zones of quartz concentrations, minor fractures filled with calcite, traces of glauconite, disseminated bitumen, bitumen occasionally fills fractures.

SAMPLES:

Sorption: 1211.9m, 1214.0m

TOC: 1) 1210.75m, 2) 1211.45m, 3) 1211.95, 4) 1212.35, 5) 1212.75, 6) 1213.25m, 7) 1213.65m, 8) 1213.95m, 9) 1214.15, 10) 1214.3m, 11) 1214.8m (lime mud/green shale

Thin-section: 1214.3m (fine congl at top of Bald.)

Extra photos: CD#3, contact (4289, 90, 92).

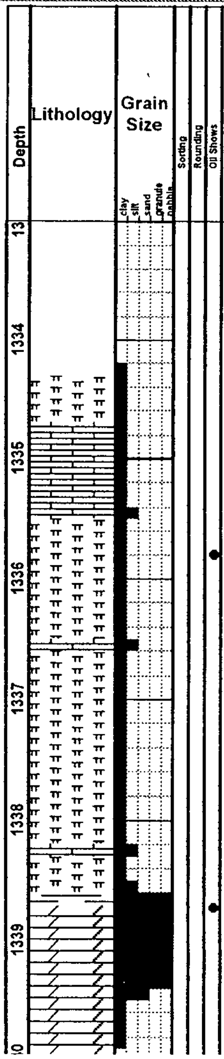
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	Pacific Fort St John No. 41 06-27		
Location:	00/06-27-084-20W6-0		
Licence Number:	00139	Region:	British Columbia
Spud Date:	05/25/1955	Drilling Completed:	07/9/1955
Surface Coordinates:	Lat: 56.310486 Long: -121.072990		
Bottom Hole Coordinates:	BH Lat: 56.310486 BH Long: -121.072990		
Ground Elevation (m):	841.5m	K.B. Elevation (m):	845.2m
Logged Interval (m):	1334.3m To: 1340.0m	Total Depth (m):	5.7m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, brown streak, finely laminated, calcareous, scattered calcite "specks" and occasional brown clay clasts (~8mm diameter), slickensided, petroliferous.

SUB-UNIT: LIMESTONE (90%)- med grey/brown, microcrystalline, mottled, argillaceous, silty, mod carbonaceous, petroliferous, gradational upper contact with overlying shale, slight fining-up of calcite sand, interbedded shale (photo 3518). Lst seperated by 5cm shale, top shale marked by 1mm black chert band (photo 3523), gradational lower contact with underlying lst, lower lst less silty, dark grey/black, fossiliferous.

Mrlst, as above.

Lst contact with underlying shale marked by 1mm calcite sand band, fines-upwards, minor shell hash (photo 3528).

Mrlst: interbedded black chert (photo 3529), calcite "specks".

Lst, as above - carbonaceous, slight fining-up, sharp/planar basal contact.

Basal Mrlst unit more siliceous/dolomitic, occasional black chert nodules (5mm) & sub mm phosphate grains (?) (photo 3530), slightly argillaceous, brecciated with lst (stylo-breccia), fragments of green shale interbed (glauconitic).

UNIT: TRIASSIC DOLOMITE - dark cream/buff, carbonaceous, mod argillaceous, calcitic (occurs as blebs), micro -cryptocrystalline, mod vuggy porosity, partially calcite-cemented, scattered silty lst clasts (~6mm), dense, stylolites, grades to dark grey. Contact missing from core box

134 1341 42					SAMPLES: Sorption: 1335.9m, 1338.0m. TOC: 1) 1234.5m, 2) 1234.9m, 3) 1237.3m, 4) 1238.3m (green shale interbed) (+2 original samples). Extra photos: (CD#4) 4462 (sharp shale/lst contact)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Pacific Fort St John No. 42 08-33
Location: 00/08-33-082-16W6-00
Licence Number: 00144
Region: British Columbia
Spud Date: 07/13/1955
Drilling Completed: 09/10/1955
Surface Coordinates: Lat: 56.150330
Long: -120.427483
Bottom Hole Coordinates: BH Lat: 56.150330
BH Long: -120.427483
Ground Elevation (m): 583.6m
K.B. Elevation (m): 587.3m
Logged Interval (m): 1191.1m To: 1195m
Total Depth (m): 3.9m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

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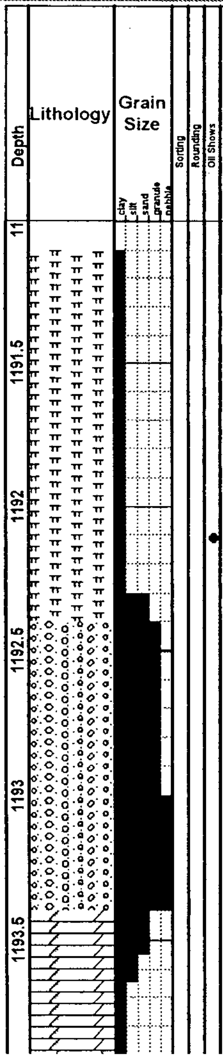


Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, silty in parts, mod carbonaceous, finely laminated, calcareous "specks" relatively common (scattered shell hash). 1-2cm interbed of dark green/black non-calcareous shale, very fissile, poorly indurated, 4cm from top of core - 3cm dull coal seam (?).

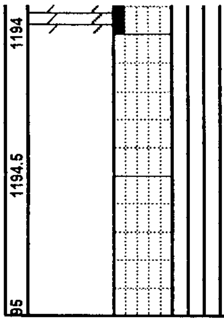
Fractures: 1 prominant, vertical, hairline fracture, calcite - filled, W0.3mm, L difficult to determine due to broken core.

Towards base of Mrlst unit, becomes less calcareous, 5-10mm clasts of non-calcareous black shale common, irregular calcite blebs (contact photo 3807)

UNIT: CONGLOMORATE - top 150mm: light grey/white clasts of chert, opalescent blue quartz (up to 1.5cm diameter, subangular-subrounded) & clay (brown) in dark grey argillaceous matrix/non-calcareous, congl. fines upwards, stringers of black shale common, clasts larger and more compacted towards base, sharp upper contact with shale (Marks top of Triassic?).

Dolomite - Lower congl - light grey - cream-buff: largely dolomitic matrix, large clasts (30mm+) of buff-coloured dolomite common, occasionaly interbedded with non-calcareous black shale.

UNIT: DOLOMITE - med grey/brown, argillaceous, microcrystalline, slightly calcareous, dense, some chert, mod petroliferous, good vuggy porosity but deteriorates away from contact.



SAMPLES:

Sorption: 1191.9m

TOC: 1) 1191.1m (Dull coal)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	FPC Kilkerran 12-31-078-14		
Location:	00/12-31-078-14W6-0		
Licence Number:	00154	Region:	British Columbia
Spud Date:	12/22/1955	Drilling Completed:	09/29/1956
Surface Coordinates:	Lat: 55.804974 Long: -120.167801		
Bottom Hole Coordinates:	BH Lat: 55.804974 BH Long: -120.167801		
Ground Elevation (m):	736m	K.B. Elevation (m):	741.5m
Logged Interval (m):	1712.9m To: 1715.9m	Total Depth (m):	3.0m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

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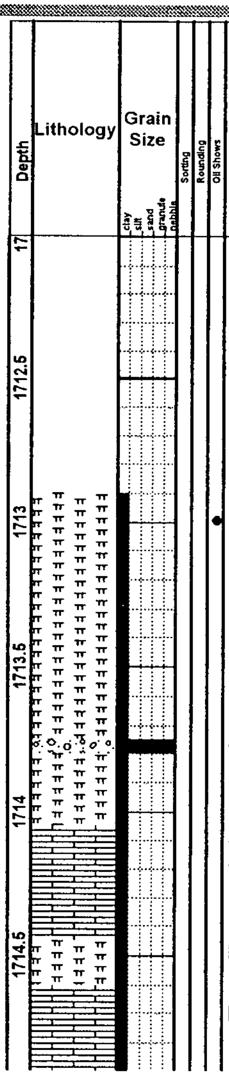


Geological Descriptions

Entire core secton photo: 3360

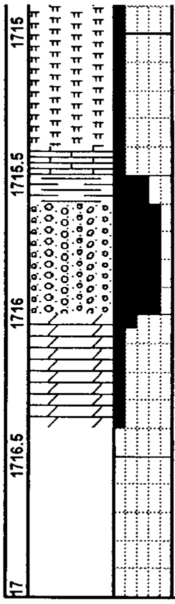
UNIT:PHOSPHATIC MARLSTONE (95%) - dark grey/black, brown streak, mod carbonaceous, fossiliferous, calcareous, finely laminated, fine interbeds of lst giving mottled appearance, very strong petroliferous odour.

Section of conglomerate (photo 3361). Angular clasts of cherty shale. Other grains range from 1-5mm in size. 8mm quartz inclusions, calcite occurs as blebs and as vein fillers (thickness <1cm), length: 3-4cm). Laminae contorted around clasts. Immediately underlain by siliceous/dolomitic shale.

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, argillaceous, silty, mod carbonaceous, mottled, fine interbeds of black shale (one 6cm interbed).

Fractures: 2, near vertical to bedding, calcite-filled, (W0.2mm, L 15-20mm).

Lst, as above.



Mrlst, as above - grades down into a more calcareous/lst unit.

Lst - becomes less calcareous towards base/more shaley.

UNIT: CONGLOMORATE, slightly silty and argillaceous matrix, microcrystalline with scattered qtz inclusions (sub mm), brecciated with silty lst (marks base Nordegg?).

UNIT: DOLOMITE - light grey, mod carbonaceous & argillaceous, micro-cryptocrystalline, minor calcite inclusions, fossiliferous, dense, interbedded black
Brecciated, fine at top, increasingly poorly sorted towards base, 1-2cm clasts of cream/buff dolomite, minor scattered qtz grains- sub-angular, matrix supported, argillaceous, non-calcareous. Grades down from med grey/brown to grey.

SAMPLES:
Sorption: 1713.9m
TOC: 1) 1713.1m, 2) 1713.7m, 3) 1713.9m, 4) 1714.4m (lst), 5) 1714.65m, 6) 1715.25m (contact).
Extra photos: (CD#4), 4482 (chert clast, top view), 4483 (brecciated congl @ 1713.8m)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Samson Et Al Ft St John SE 04-09-0
Location: 00/04-09-083-17W6-0
Licence Number: 00166
Spud Date: 04/02/1956
Surface Coordinates: Lat: 56.174580
Long: -120.632713
Bottom Hole Coordinates: BH Lat: 56.174580
BH Long: -120.632713
Ground Elevation (m): 623.5m
Logged Interval (m): 1167.0m To: 1168.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Region: British Columbia
Drilling Completed: 07/28/1992

K.B. Elevation (m): 627.2m
Total Depth (m): 1.6m

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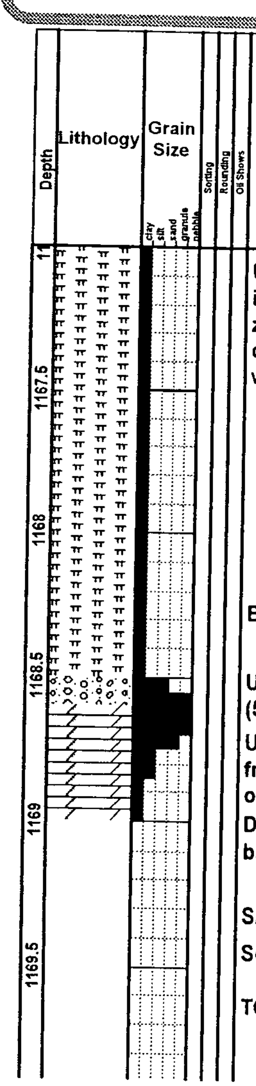


Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, petroliferous, finely interbedded with lst, minor calcite-filled fractures (horizontal) occuring in 1 discrete zone. 14cm from top of core: 14mm lst interbed (top 8mm more condensed calcite crystals, less coarse, basal band fossiliferous?) with occasional black shale lenses within, fining upwards, green shale band at base (photo 3898)

Basal Mrlst - dark grey, less calcareous, white powdery sulfate residue.

UNIT: CONGLOMERATE - clasts of phosphate, brown chert (~1mm), 1 large chert clast (50mm) (photo 3899).

UNIT: DOLOMITE - light/med grey, microcrystalline, argillaceous, brecciated, fractured, fractures subsequently filled with overlying conglomerate, calcareous in parts, organic-rich stringers, 1-1.5cm clasts of cream dolomite.

Dolomite - laminated cream and argillaceous dolomite, poor pin-point porosity, bitumen-filled fractures common.

SAMPLES:

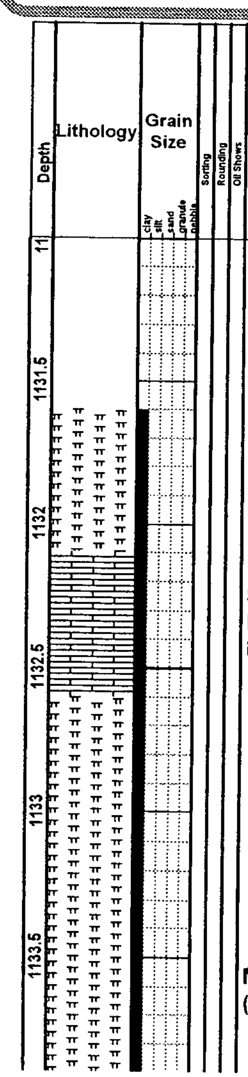
Sorption: 1167.9m

TOC: 1) 1167.3m, 2) 1167.75m, 3) 1168.55m.

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Samson Et Al Ft St John 08-20-083
Location: 00/08-20-083-18W6-0
Licence Number: 00170
Region: British Columbia
Spud Date: 05/06/1956
Drilling Completed:
Surface Coordinates: Lat: 56.208233
Long: -120.798416
Bottom Hole Coordinates: BH Lat: 56.208233
BH Long: -120.798416
Ground Elevation (m): 649.8m
K.B. Elevation (m): 653.8m
Logged Interval (m): 1131.7m To: 1134.1m
Total Depth (m): 2.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

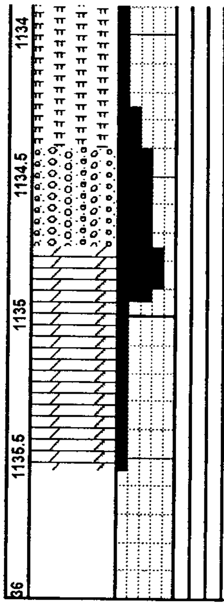


Geological Descriptions

UNIT : PHOSPHATIC MARLSTONE (90%) - black, mod carbocaceous, finely laminated (with microcrystalline lst), calcareous, petroliferous.

SUB - UNIT: LIMSTONE (90%) - light/med grey-green, mottled. Sharp upper contact. Fine interlaminations of black shale (1.5mm thick). Fracture: near vertical/0.5mm thick bitumen - filled (terminated by broken core).

Mrlst grades into argillaceous dolomite with distorted interbeds of shale and silty shale (top 18cm), occasional phosphate specks neat top.



Fine CONGLOMORATE, well sorted, matrix is argillaceous dolomite, grades up from med grey to dark grey, slightly silty at base, organic-rich stringers, 1mm chert and qtz grains, subangular-sunrounded, (photo 3508) (photo 3506).

UNIT: DOLOMITE - top 7cm brecciated and sunsequently filled with overlying fine conglomorate, several organic-rich stringers throughout, grades to light grey, argillaceous dolomite, cream dolomotic clasts, angular, 1mm-1cm diameter.

Dolomite - brown, cryptocrystalline, oocasional calcite veins, mod-poor vuggy porosity.

SAMPLES:

Sorption: 1133.2m

Thin-sections: 1133.5m (contact), 1133.6m (congl. & dolomite contact).

LITHOLOGY STRIP LOG

WellSight Systems

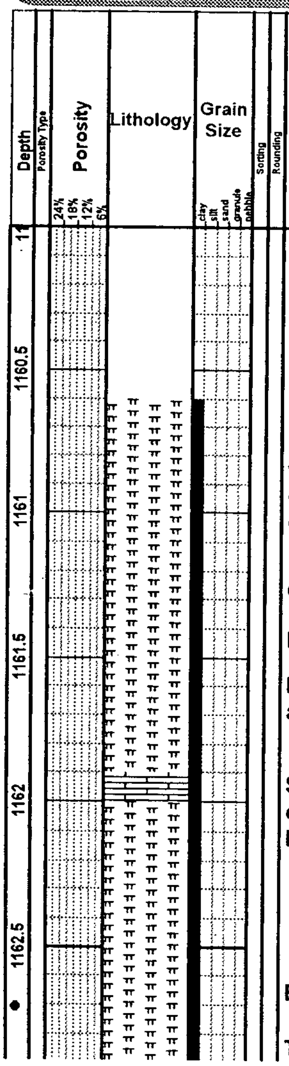
Scale 1:20 Metric

Well Name: Samson Et Al Ft St John SE 10-04-0
Location: 00/10-04-083-17W6-0
Licence Number: 00173
Spud Date: 05/18/1956
Surface Coordinates: Lat: 56.167709
Long: -120.618491
Bottom Hole Coordinates: BH Lat: 56.167709
BH Long: -120.618491
Ground Elevation (m): 620.5m
Logged Interval (m): 1160.6m To: 1163.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Region: British Columbia
Drilling Completed: 07/27/1956

K.B. Elevation (m): 624.5m
Total Depth (m): 2.8m

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 3857

UNIT: PHOSPHATIC MARLSTONE (94%) - black, brown streak, calcareous, finely laminated with black chert, mod carbonaceous, fossiliferous, occasionally interbedded with lst giving mottled appearance, calcite "specks" common, sharp contacts where observed.
Grades into an argillaceous lst with 1cm calcareous black shale interbed within.

Occasional calcite filled fractures, oblique to bedding (W1-2mm, L25mm) (photo 3858).

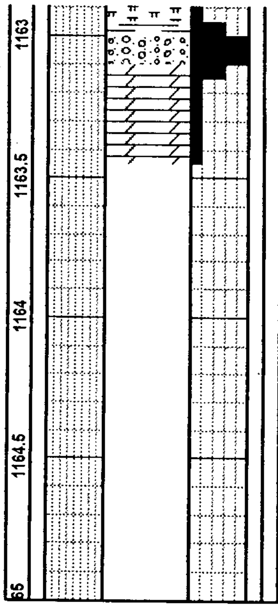
Lenses of lst (photo 3859).

Mrlst - with honeycomb texture, white powdery sulfate residue, slightly argillaceous/almost silty in parts.

SUB-UNIT: LIMESTONE (90%) - dark grey/black, argillaceous, microsrystalline, carbonaceous, mottled, finely interlaminated with black shale, contact is planar/25deg below horizontal (photo 3860).

Basal 20cm of Nordegg is slightly siliceous/dolomitic (dense), specks of phosphate (?).

Towards base - occasional calcite concretions which distort bedding (photo 3862).



UNIT: CONGLOMERATE - clasts of chert & opalescent blue quartz, subangular-subrounded- all within a dark grey/black, non-calcareous, argillaceous matrix, clasts concnetrated into a lag ontop of the underlying dolomite, fine congl. "veins: into underlying dolomite (result of brecciation?)

UNIT: DOLOMITE - light/med grey, crytpo-microcrystalline, slightly argillaceous, mottled, poor vuggy porosity, stylolites with organic residue lining, stringers of black shale common near contact.

SAMPLES:

Sorption: 1160.7m

TOC: 1) 1161.4m, 2) 1162.1m, 3) 1162.2m, 4) 1162.9m

Extra photos : Basal Nordegg (CD#4), 4511, 12.

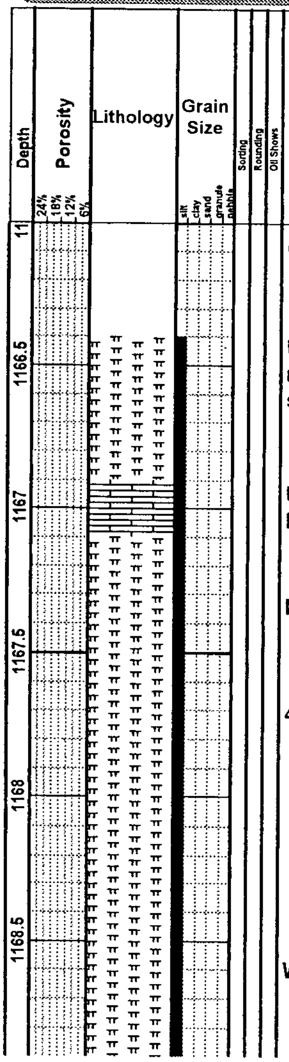
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Samson Et Al Ft St John SE 07-03-0		
Location:	00/07-03-083-17W6-0		
Licence Number:	00174	Region:	British Columbia
Spud Date:	05/30/1956	Drilling Completed:	08/26/1956
Surface Coordinates:	Lat: 56.164543 Long: -120.593140		
Bottom Hole Coordinates:	BH Lat: 56.164543 BH Long: -120.593140		
Ground Elevation (m):	621.9m	K.B. Elevation (m):	625.2m
Logged Interval (m):	1166.4m To: 1171.1m	Total Depth (m):	4.7m
Formation:	Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 3866

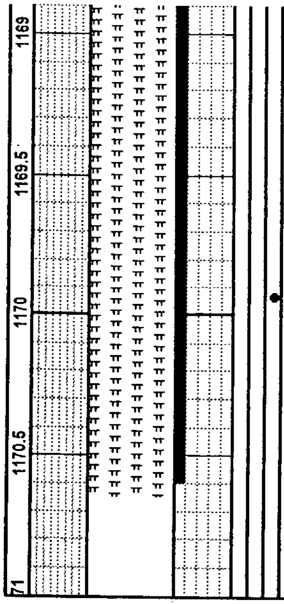
UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, coaly in parts, fossiliferous, mod carbonaceous, pyritic, upper section finely interbedded with calcite/limestone with sharp lower/diffuse upper contact (photo 3867).

UNIT: LIMESTONE (90%) - dark grey, microcrystalline, mottled, carbonaceous, finely laminated with black shale orientated 5 deg below horizontal.

Mrlst, as above - black chert nodules, scattered bands of shell hash.

4 discrete caclite-rich/interbedded lst zones (photos 3868-71).

White powdery sulfate residue.



5cm calcite-rich band, seperated into 4 bands, lowest band: 1cm, mod diffuse calcite, 1cm calcite silt/fine sand bed overyling, 1cm calcite-poor band, 1cm bed as seen at base, top band contains lenses of calcareous black shale (~5cm diameter) co-occuring with scattered shell hash.

1170.3m-1171.1m: majority of core missing. Fragments - upper shale calcareous, lower shaley_mudstone is dolomitic. Basal 5cm contains 5-10mm lst clasts with black, dolomitic (?) matrix, calcite stringers, white "specks" (phosphate) common (photo 3872) and black chert clasts.

SAMPLES:
Sorption: 1168.4m, 1169.6m
TOC: 1) 1166.55m, 2) 1166.9m, 3) 1167.35m, 4) 1167.65m, 5) 1168.65m, 6) 1169.25m, 7) 1169.75m, 8) 1170.15m, 9) 1170.55m, 10) 1170.95m
Extra photos: (CD#4), 4480 (lense of black shale in lst)

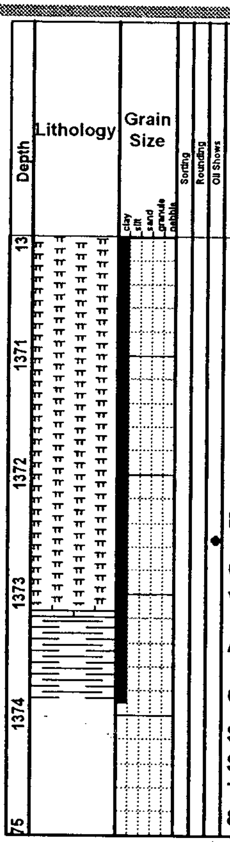
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Enermark Et Al Kobes A- 009-L/094-A-05
Location: 200/a-009-L 094-A-05/00
Licence Number: 00176
Region: British Columbia
Spud Date: 08/11/1956
Drilling Completed: 17/04/1957
Surface Coordinates: Lat: 56.41937
Long: -121.97812
Bottom Hole Coordinates: BH Lat: 56.41937
BH
Ground Elevation (m):
K.B. Elevation (m): 760.8m
Logged Interval (m): 1370.1m To: 1374m
Total Depth (m): 3.9m
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: MARLSTONE (100%) - black, brown streak, silty in parts, mod petroliferous & calcareous, scattered plant remains, slickensided..

Fractures: irregular, "stylolite"-like, near vertical, graphite luster in interior. Occasional near-horizontal & vertical fractures lined with calcite.

Mrlst progressively becomes more dolomitic/siliceous towards base.

Contains 5cm interbed of light grey-calcite rich zone, sharp/shallow angle contacts, vertical calcite-filled fractures emerge from top (photo 3705).

Along fracture planes, shale has a honeycomb texture (photo).

Core missing

SAMPLES:
Sorption: 1370.3m
TOC: 1) 1370.45, 2) 1370.8m, 3) 1371.3m, 4) 1372.1m, 5) 1372.4m, 6) 1373.2m, 7) 1373.3m, 8) 1374m, 9) 1374.1m, 10) 1374.8m

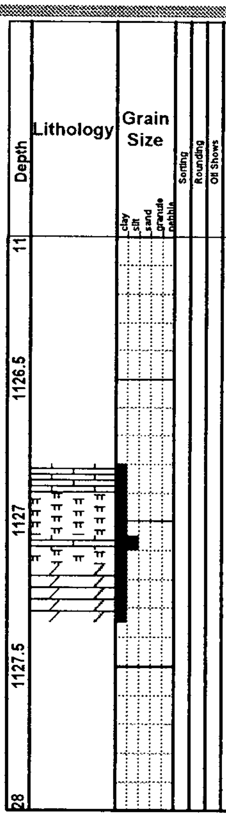
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Acel Et Al Halfway 08-11-087-25		
Location:	00/08-11-087-25W6		
Licence Number:	00182	Region:	British Columbia
Spud Date:	06/29/1956	Drilling Completed:	08/22/1999
Surface Coordinates:	Lat: 56.530403 Long: -121.856194		
Bottom Hole Coordinates:	BH Lat: 56.530403 BH Long: -121.856194		
Ground Elevation (m):	737.6m	K.B. Elevation (m):	741.2m
Logged Interval (m):	1126.8m To: 1127.7m	Total Depth (m):	0.9m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, mottled, carbonaceous, argillaceous, mod carbonaceous, occasional fine interbeds of black shale.

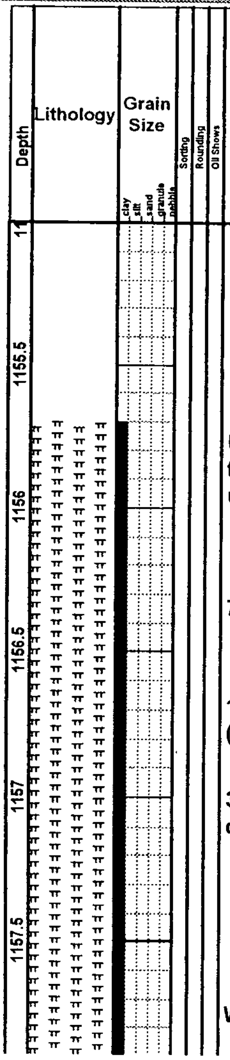
UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, finely laminated, strong petroliferous odour, occasional calcite "specks".
Lst, as above - slightly coarser calcite crystallinity, brown/black, very fossiliferous.

UNIT: TRIASSIC DOLOMITE - med grey/brown, microcrystalline, micro-cryptocrystalline, argillaceous, mod vuggy porosity.

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name:	Samson Ft St John SE 04-08-083-17		
Location:	00/04-08-083-17W6-0		
Licence Number:	00187	Region:	British Columbia
Spud Date:	08/06/1956	Drilling Completed:	09/14/1956
Surface Coordinates:	Lat: 56.174114 Long: -120.659241		
Bottom Hole Coordinates:	BH Lat: 56.174114 BH Long: -120.659241		
Ground Elevation (m):	608.6m	K.B. Elevation (m):	612.3m
Logged Interval (m):	1155.7m To: 1158.8m	Total Depth (m):	3.1m
Formation:	Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

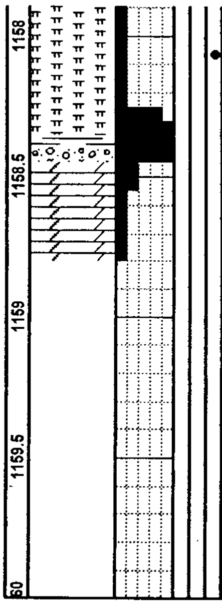
UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, strong petroliferous odour, finely-laminated, interbedded with lst (thickness range from 20-70mm, sharp lower and upper contacts), occasional black chert lenses and brown clay nodules, slickensided.

7cm lst interbed, sharp/near horizontal contacts.

100mm zone of calcite-filled fractures : 3 fractures, near vertical and cross cut bedding, (W0.2mm, L55-70mm).

3 calcite-rich bands, ~2.5cm thick, upper bands fine grained, lower band is slightly coarser in centre (flattened shell hash band?).

White powdery sulfate residue at base of Nordegg.



Basal Nordegg: black chert nodules (~2cm diameter) common, scattered white phosphatic specks.

UNIT: CONGLOERMATE - grains of phosphate, minor qzt and calcite, sub mm diameter, matrix is med/dark grey, slightly argillaceous, non-calcareous, minor silty lst clasts (~8mm diameter).
Next 3cm - dolomitic matrix, clasts/grains of chert and qtz, more poorly sorted/coarser downwards, matrix is med/light grey argillaceous dolomite. (photo 3897)

UNIT: DOLOMITE - cream/buff, argillaceous, vuggy porosity, slightly fractured with organic residue lining.

SAMPLES:

Sorption:

TOC: 1) 1157.5m, 2) 1158m, 3) 1158.1m, 4) 1158.4m (shale above congl.)

Extra Photos - (CD#4), 4513, 14 (contact)

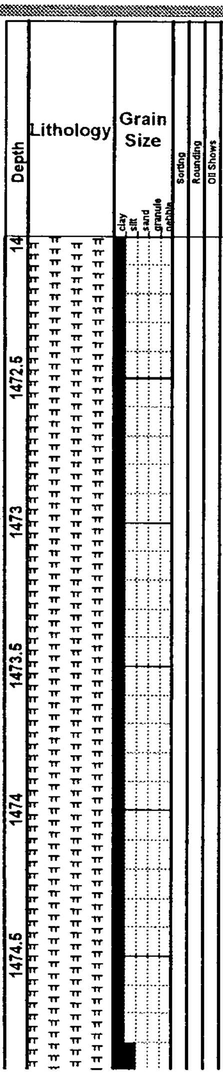
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Talisman Et Al Mica 06-16-081-14
Location: 00/06-16-081-14W6-0
Licence Number: 00230
Region: British Columbia
Spud Date: 01/23/1957
Drilling Completed: 11/26/1957
Surface Coordinates: Lat: 56.019890
Long: -120.129272
Bottom Hole Coordinates: BH Lat: 56.019890
BH Long: -120.129272
Ground Elevation (m): 734.1m
K.B. Elevation (m): 737.8m
Logged Interval (m): 1472.1m To: 1492.5m
Total Depth (m): 20.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

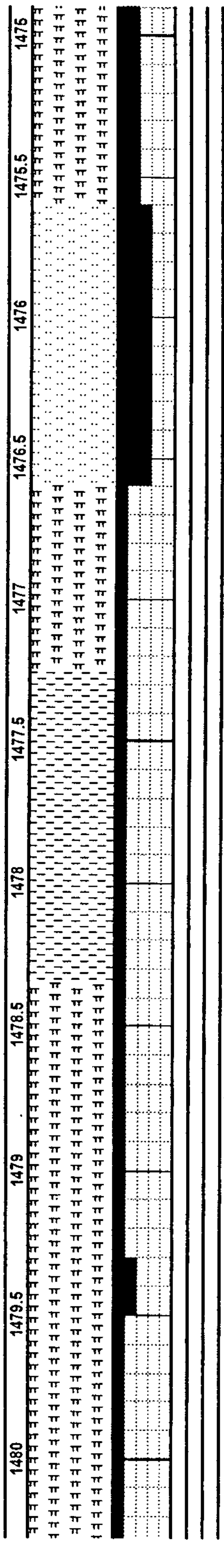


Geological Descriptions

Entire core photos: 4035-39

UNIT: MARLSTONE (95%) - black, calcareous, finely laminated, fossiliferous, slightly silty in parts, white "specks" in places, occasionally interbedded with carbonaceous lst (50-60mm thick), lst interbeds show fining-up sequence of calcite, sharp lower/diffuse upper contact.

Mrlst, powdery white residue (sulphate) on either side of several horizontal fractures (?),



Marlstone becomes slightly silty, med/dark brown, calcareous, dolomitic in parts, micromicaceous, slightly argillaceous, calcite "specks" concentrated into discrete zones (specks ~0.5mm diameter, band ~8mm thick), minor horizontal fractures/parallel with bedding (W~0.2mm, L40mm),

UNIT: SILTSTONE (to very fine sst) (100%) - med brown, calcareous, argillaceous, petroliferous odour, oil staining (?) slight fining-up sequence, micromicaceous. Near base: 3 stylolites (W0.3mm, L~60mm) with insolubale organic residue, base marked by fragmented fissile green shale (photo 4011, 12).

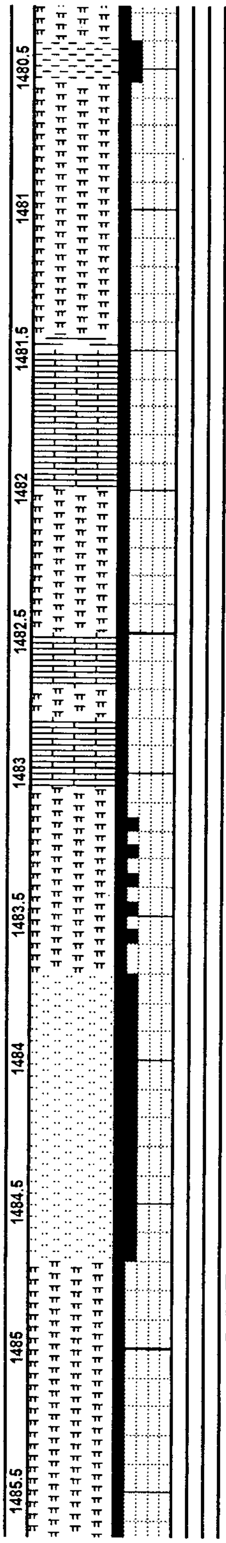
Mrlst, dark grey/black - as shale at 1472.1m, highly micromicaceous. Calcite content decreases towards underlying shale unit.

UNIT: CALCAREOUS MUDSTONE6%) - dark grey/brown, non-caclareous, slightly dolomitic (?), fossiliferous, trace pyrite, gradational contacts, lower 0.8m has missing core.

Mrlst - black, calcareous (slightly brown in parts), extremely fossiliferous, horizontal calcite veins common (W~0.4mm, L20-25mm), very occasional 2-3mm thick interbeds of non-calcareous green shale.

Silty-Mrlst: as 1474.8m-1475.8m

Mrlst - as 1478.3m-1479.3m



Silty-mudstone: green, non-calcareous, micaceous, fractured, sharp upper & lower contacts marked by 1-2mm black shale band (photo 4013).

Mrlst - as 1478.3m-1479.3m, contains 70mm interbed of silty green shale (see 1480.4m-1480.56m), within this a 30mm nodule of sst (fldsp, mica, calcite gs~250-350u, grains angular), light brown colour, fine black shale rim surrounding (photo 4015).

UNIT: LIMESTONE (95%) - dark grey, microcrystalline, carbonaceous, finely interbedded with black shale, 1 vertical bitumen-filled fracture (stylolite-like, W0.5mm, L30mm), slightly diffuse lower contact, sharp horizontal contact.

Mrlst - as 1478.3m-1479.3m

Lst - as 1481.5m, light brown calcite 30mm band, crystals more equant towards centre, clasts of silty lst within (3-10mm width, subangular-subrounded) (photo 4016).

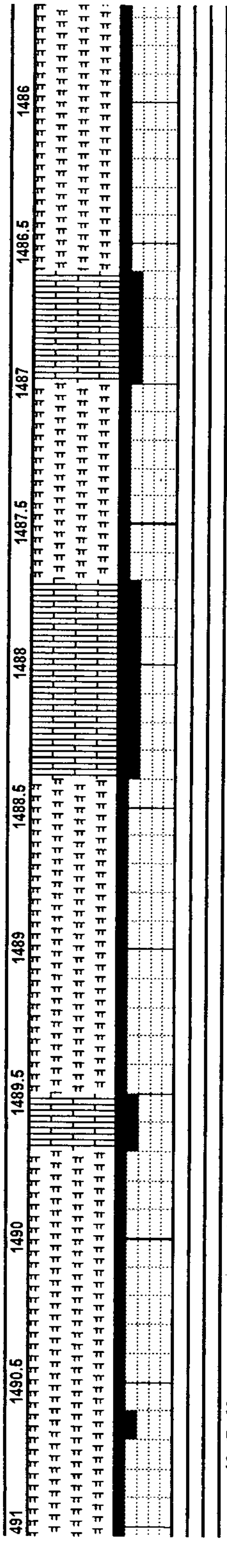
Mrlst - as 1478.3m-1479.3m, sharp upper contact with lst.

Lst - as 1481.5m, slightly coarse calcite at top, sharp /horizontal lower contact.

Mrlst - as 1478.3m-1479.3m, top marked by extremely calcite-rich zone, interbedded with green silty shale, bitumen fractures common in calcite zone (photos 4017-19).

Siltstone (100%) - med brown, micromicaceous, mod carbonaceous and argillaceous, slightly bituminous, occasional calcite-filled fracture, near vertical (W0.3mm, L terminated by core), lower portion of cored section missing, top contact marked by calcite sand with overlying 15mm green shale band, base contacts missing (photo 4022).

Mrlst - as 1478.3m-1479.3m, contains a 50mm zone of fine lst interbeds & 1 18mm thick lst interbed with sharp lower and upper contacts, diffuse white specks either side (photos 4023, 24), zone marked by high gamma ray peak on petrophysical log.



Lst - as 1481.5m, top 50mm shows slight fining-up sequence into diffuse upper contact with overlying shale, basal contact is sharp, 10 deg below horizontal, minor concentration of shell fragments (photos 4025, 26).

Mrlst - as 1478.3m-1479.3m, extremely fossiliferous, abundant horizontal calcite-filled hair-line fractures. At base, 15mm calcite "sand" interbed, sharp/slightly wavy contacts.

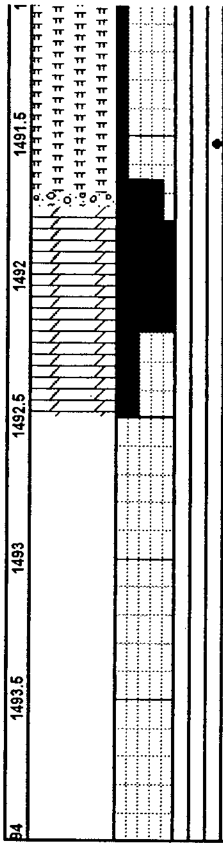
Lst - as 1481.5m, top 60mm marked by coarse calcite crystals, fossiliferous. 400mm through section: 2 calcareous balck shale clasts (?), mod roundness/low sphericity. Immediately below, 65mm black shale interbed, sharp/wavy upper contact, lower contact missing from core box (photo 4027).

Mrlst - as 1478.3m-1479.3m, contains 270mm section with abundant white "specks" (shell hash?) - extremely calcareous (photo 4028).

Lst - 1481.5m, 30mm black shale interbed, lower contact sharp/wavy.

Mrlst - as 1478.3m-1479.3m, contains 2 discrete calcite-rich zones, calcite "sand" occurs as 30mm interbed and 12mm lense, 80mm apart (photo 4029).

Silty-Mrlst: dark grey/brown, mod calcareous, sharp horizontal basal contact with underlying shale.
Shale - as 1478.3m-1479.3m



UNIT: CONGLOMERTE: dark grey (slightly brown in places), non-calcareous, contains several well rounded nodules of black shale (~8-15mm diameter), some calcareous, slightly siliceous/cherty, brown clay clasts (photo 4033).

UNIT: TRIASSIC DOLOMITE - light brown-cream/buff, micro-cryptocrystalline, fossiliferous, dense, argillaceous, mod carboanceous, upper part congl., clasts of opalescent blue quartz, dolomite, subangular-subrounded, 4-60mm diameter, matrix is dolomitic, stylolites with insoluble organic residue, mod vuggy porosity. Direct contact with overlying shale is missing from core-box.

SAMPLES:

Sorption: 1472.5m, 1484.9m, 1491m

TOC: 1) 1474m, 2) 1474.8m, 3) 1475.5m, 4) 1477.1m, 5) 1478.1m. 6) 1478.5m, 7) 1479m, 8) 1479.8m, 9) 1480.6m, 10) 1481.1m, 11) 1482.1m, 12) 1484m, 13) 1484.3m, 14) 1485.5, 15) 1487.8m, 16) 1488.6m, 17) 1489.4m, 18) 1492.0m 19) 1492.4m, (+ original samples)

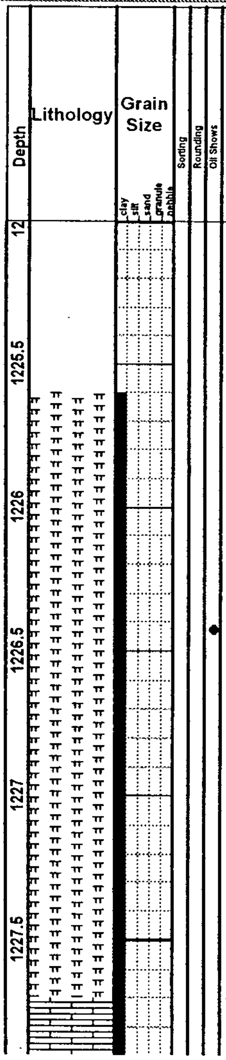
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Union Buick Creek C- 034-E/094-A-14		
Location:	200c/-034-E 094-A-14/00		
Licence Number:	00290	Region:	British Columbia
Spud Date:	17/11/1957	Drilling Completed:	29/12/1957
Surface Coordinates:	Lat: 56.86632 Long: -121.42183		
Bottom Hole Coordinates:	BH Lat: 56.86632 BH Long: -121.42183		
Ground Elevation (m):		K.B. Elevation (m):	818.7m
Logged Interval (m):	1225.6m To: 1231.4m	Total Depth (m):	5.8m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



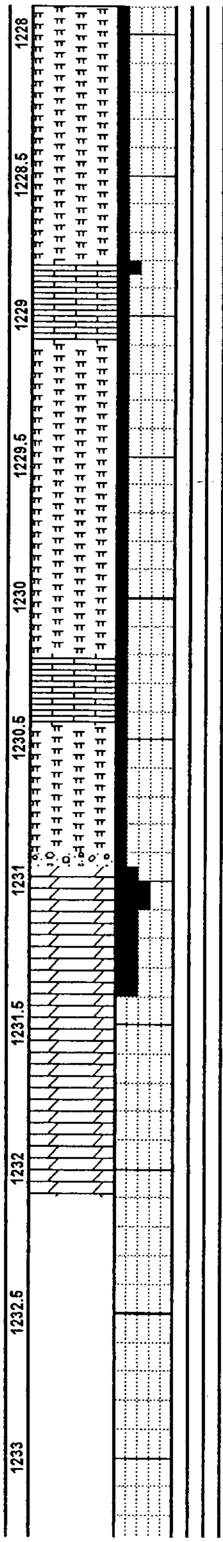
Geological Descriptions

Core photo: 4010

UNIT: PHOSPHATIC MARLSTONE (100%) - black with brown streak, calcareous, fissile, finely-laminated, calcite concentration in top 50mm (shell hash?).

Towards base of shale unit, horizontal calcite veins common (parallel with bedding, most likely to be shell hash concentration).

SUB-UNIT: LIMESTONE (90%) - dark grey/black, microcrystalline, mottled, angular contact with overlying shale (~15deb below horizontal, planar), diffuse upper/sharp lower contact. 1 near horizontal bitumen-filled fracture (W0.2mm. L20mm).



Mrlst, as above - slightly brown in parts, calcite "specks" common.

2 caclite-rich interbeds :
1)10-15mm thick, contains "nodules" of calcareous black shale (photo 4004).

2) 7mm thick, coarser calcite crystals than above, sharp contacts, irregular form (photo 4005), no shale clasts.

Lst, as above - slightly coarser calcite crystals near top - towards base, calcite more diffuse, interbedded with black shale, large (~30mm diameter) rounded nodules of black shale, sharp contact at base (20 deg below horizontal) (photo 4006).

Mrlst, as above - 20cm from top, two zones (6cm and 20cm thick) of black shale with 10mm angular clasts of black shale (?).

Lst, as above - fining upwards sequence of calcite (gs~350u at base), upper contact missing from core box.

Mrlst, as above - sharp, near horizontal contact with overlying lst, slightly brown in parts, contains non-calcareous black shale clasts (slightly silicified/dolomitic?), well rounded, ~10mm diameter, basal 3cm dolomitic.

UNIT: CONGLOMERATE - contains clasts of dolomitic shale (?), 10-15mm diameter, which have been fractured apart and sunsequently filled with calcite. Calcite also occurs as a 1mm band around the BASE of the clasts. One clast 45mm diameter, mod rounded, low sphericity and slightly elongate horizontally. Calcite has been occasionally disolved out.

UNIT: DOLOMITE - dark grey, mod argillaceous, carbonaceous, top 30cm is conglomoratic, matrix calcareous in parts, clasts of black shale and white/grey chert (up to 20mm diameter), stringers of black shale common, slightly brecciated. Grades into med brown dolomite, interbeds of grey silty dolomite, pure cream/buff dolomite and shaley dolomite, horizontal and vertical fractures common, partially calcite-filled.

SAMPLES:

Sorption: 1226.4m, 1230.8m.

TOC: 1) 1225.6m, 2) 1226.1m, 3) 1226.9m, 4) 1227.8m, 5) 1228.35, 6) 1229.15m, 7) 1229.45m, 8) 1229.85m, 9) 1230.35m, 10) 1231.15m.

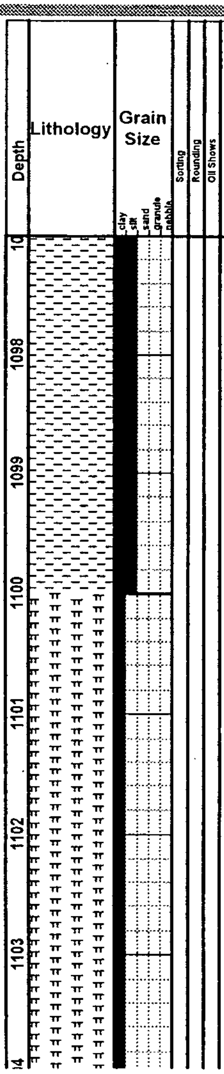
Thin-sections: 1230.6m (siliceous/glossy shale interbeds and clasts within black shale), 1231m (clasts of sh with calcite at base at Nord/Bald. contact).

Extra photos : (CD#3) - 4373, 75, 76, 77

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:48 (25"=100') Metric

Well Name:	Imperial Pacific Windy Creek No. 11		
Location:	00/11-23-081-22W6/00		
Licence Number:	00376	Region:	British Columbia
Spud Date:	08/21/1958	Drilling Completed:	11/29/1958
Surface Coordinates:	Lat: 56.037964 Long: -121.329422		
Bottom Hole Coordinates:	BH Lat: 56.037964 BH Long: -121.329422		
Ground Elevation (m):	692.7m	K.B. Elevation (m):	697m
Logged Interval (m):	1097.8m To: 1111.6m	Total Depth (m):	13.8m
Formation:	Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: MARLSOTNE - CALCAREOUS MUDSTONE- med grey, dolomitic, dense, argillaceous, silty.

Fractures: 2, irregular, near-vertical orientation, one bifurcates upwards, bitumen-filled, (W1.5mm, L120mm), 40mm apart. (photos: 3417, 3424)

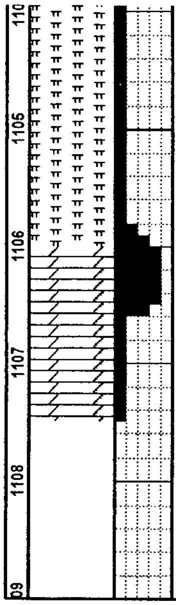
Irregular features: vertical concentration of calcite-filled voids (5cm length, 1cm wide). Minor calcite dissolution producing vuggy porosity (photo 3408)

UNIT: PHOSPHATIC MARLSTONE (100%) - dark grey/black, slightly dolomitic, more organic-rich than overlying Mrlst (darker colour, higher gamma ray-response).

Mrlst: as above - contains discrete zones of calcite "specks". Calcite also occurs as fine, near horizontal veins (parallel with bedding), thin (~0.2mm thick), and discontinuous (length ~10mm).

Several near-vertical crenulated fractures filled with insoluble organic residue, (W1mm, L 200mm).

Mrlst, slightly siliceous/cherty in places.



Base Nordegg marked by sub mm laminations (approx 20 deg below horizontal) of black shale, silty lst and med grey/brown slst, slightly wavy/rippled, occasional 1mm phosphate (?) grains. 1 extremely "sinuous" vertical fracture (?), with organic-residue (compacted to give extreme irregular shape?).

UNIT: DOLOMITE - med grey/buff, dense, micacoeus in parts, micro-cryptocrystalline, conglomoratic contact with clasts of cream/buff dolomite (1-15mm diameter) and silty lst within a dark grey argillaceous matrix, slightly carboncaeous, more laminations similar to those seen at base of Nordegg, stylolite with insoluble organic residue, direct contact with overlying shale unit is missing from the core box.

SAMPLES:

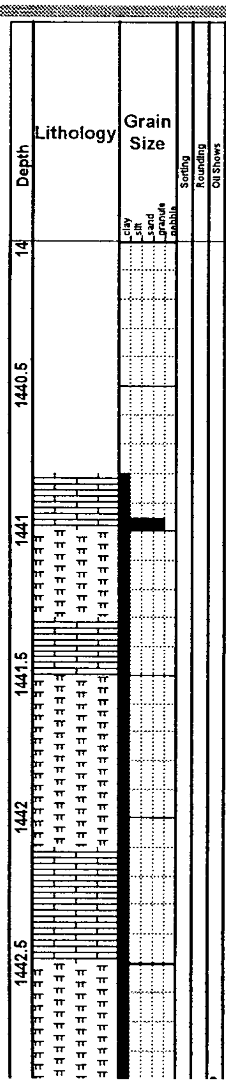
Sorption: 1104.2m

TOC: 1) 1098.4m, 2) 1099.2m, 3) 1100m, 4) 1100.7m, 5) 1101.1m, 6) 1102.7m, 7) 1104.3m, 8) 1105.1m, 9) 1105.9m

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Union Unit Aitken Creek A- 053-L/094-A-13
Location: 200/a-053-L 094-A-13/00
Licence Number: 00400 Region: British Columbia
Spud Date: 27/11/1958 Drilling Completed: 11/04/1959
Surface Coordinates: Lat: 56.96166
Long: -121.90594
Bottom Hole Coordinates: BH Lat: 56.96166
BH Long: -121.90594
Ground Elevation (m): K.B. Elevation (m): 955.9m
Logged Interval (m): 1440.8m To: 1444.5m Total Depth (m): 4.3m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 4003

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, mottled, carbonaceous, finely interbedded with black shale (horizontal laminations). Base of lst marked by nodules (1.5cm diameter) of calcareous black shale (photo 3995).

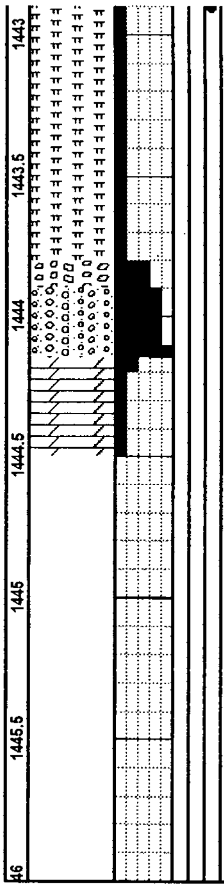
1 vertical fracture: (W0.2mm, L80mm), bitumen-lined.

UNIT: PHOSPHATIC MARLSTONE (90%) - black, brown streak, calcareous, finely laminated, slickensided, white powdery sulfate residue. Contains 1 calcite-rich interbed (~30mm thick), interbedded with black chert, bedding 25 deg below horizontal.

Lst, as above - gradational contact with overlying shale, laminations 25 deg below horizontal (photo 3996).
Mrlst, as above - slightly brown in places, upper contact with overlying lst missing. Interbeds of flattened fossil fragments, fractured at base - calcite-filled, parallel with bedding (W2.3mm, L terminated by broken core) (photo 3998).

Lst, as above - sharp upper and lower contacts angled at 35 deg below horizontal. Upper part of lst: 1 fracture, calcite-filled (slight bitumen-lining in centre), bifurcates downwards (W1mm (see photo 3998)), total length ~40cm, lower 30cm shows no calcite filling.

Mrlst, as above - occasional lst interbed (~10-15mm thick), angled 25 deg below horizontal, minor calcite "specks", increasingly siliceous/dolomitic towards base.



Contact area: 30cm of BRECCIATED lst and shale, very fine CONGLOMORATE with 1-2mm clasts of silty lst, sharp planar contact with overlying shale - marked by white sulfate streaks, basal 10cm contains occasional black chert clasts (~7mm diameter) which contort black shale/organic-rich stringers (photo 4000).

UNIT: CONGLOMERATEe - matrix brecciated as above, 2-4mm chert and opalescent blue quartz grains, 1 large (1cm) qtz inclusion (photo 4002), minor phosphate specks (marking base of Nordegg?).

5cm - coarse conglomorate, flattened pebbles of med grey, silty, calcareous dolomite, >6cm length within dark grey, argillaceous dolomitic matrix, scattered shell hash, pebbles fractured and sunsequently filled with surrounding matrix.

UNIT: DOLOMITE - light/med grey, dense, mod argillaceous & carbonaceous, abundant calcite inclusions, 10cm down, very fossiliferous with vertical fractures calcite-filled.

SAMPLES:

Sorption: 1441.6m

TOC: 1) 1441.1m, 2) 1441.4m, 3) 1441.6m, 4) 1442.2m, 5) 1442.4m, 6) 1443.2m, 7) 1443.5m, 8) 1443.9m (above brecciated lst/shale).

Extra photos: (CD#4), 4484, 85, 86, 87 (basal contact)

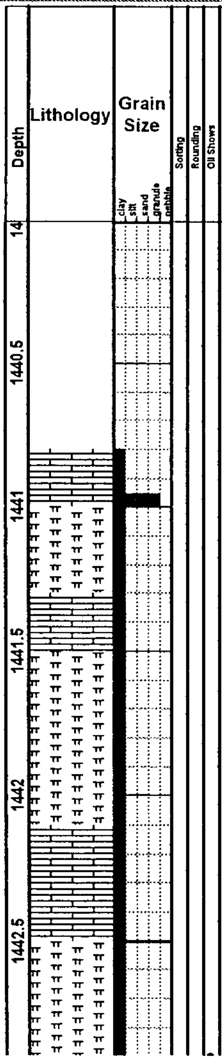
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Union Unit Aitken Creek A- 053-L/094-A-13
Location: 200/a-053-L 094-A-13/00
Licence Number: 00400 Region: British Columbia
Spud Date: 27/11/1958 Drilling Completed: 11/04/1959
Surface Coordinates: Lat: 56.96166
Long: -121.90594
Bottom Hole Coordinates: BH Lat: 56.96166
BH Long: -121.90594
Ground Elevation (m): K.B. Elevation (m): 955.9m
Logged Interval (m): 1440.8m To: 1444.5m Total Depth (m): 4.3m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 4003

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, mottled, carbonaceous, finely interbedded with black shale (horizontal laminations). Base of lst marked by nodules (1.5cm diameter) of calcareous black shale (photo 3995).

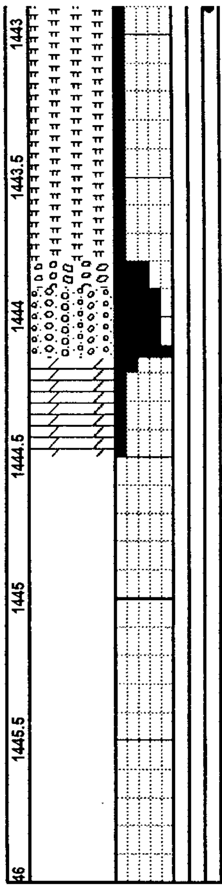
1 vertical fracture: (W0.2mm, L80mm), bitumen-lined.

UNIT: PHOSPHATIC MARLSTONE (90%) - black, brown streak, calcareous, finely laminated, slickensided, white powdery sulfate residue. Contains 1 calcite-rich interbed (~30mm thick), interbedded with black chert, bedding 25 deg below horizontal.

Lst, as above - gradational contact with overlying shale, laminations 25 deg below horizontal (photo 3996).
Mrlst, as above - slightly brown in places, upper contact with overlying lst missing. Interbeds of flattened fossil fragments, fractured at base - calcite-filled, parallel with bedding (W2.3mm, L terminated by broken core) (photo 3998).

Lst, as above - sharp upper and lower contacts angled at 35 deg below horizontal. Upper part of lst: 1 fracture, calcite-filled (slight bitumen-lining in centre), bifurcates downwards (W1mm (see photo 3998)), total length ~40cm, lower 30cm shows no calcite filling.

Mrlst, as above - occasional lst interbed (~10-15mm thick), angled 25 deg below horizontal, minor calcite "specks", increasingly siliceous/dolomitic towards base.



Contact area: 30cm of BRECCIATED lst and shale, very fine CONGLOMORATE with 1-2mm clasts of silty lst, sharp planar contact with overlying shale - marked by white sulfate streaks, basal 10cm contains occasional black chert clasts (~7mm diameter) which contort black shale/organic-rich stringers (photo 4000).

UNIT: CONGLOMERATEe - matrix brecciated as above, 2-4mm chert and opalescent blue quartz grains, 1 large (1cm) qtz inclusion (photo 4002), minor phosphate specks (marking base of Nordegg?).

5cm - coarse conglomorate, flattened pebbles of med grey, silty, calcareous dolomite, >6cm length within dark grey, argillaceous dolomitic matrix, scattered shell hash, pebbles fractured and sunsequently filled with surrounding matrix.

UNIT: DOLOMITE - light/med grey, dense, mod argillaceous & carbonaceous, abundant calcite inclusions, 10cm down, very fossiliferous with vertical fractures calcite-filled.

SAMPLES:

Sorption: 1441.6m

TOC: 1) 1441.1m, 2) 1441.4m, 3) 1441.6m, 4) 1442.2m, 5) 1442.4m, 6) 1443.2m, 7) 1443.5m, 8) 1443.9m (above brecciated lst/shale).

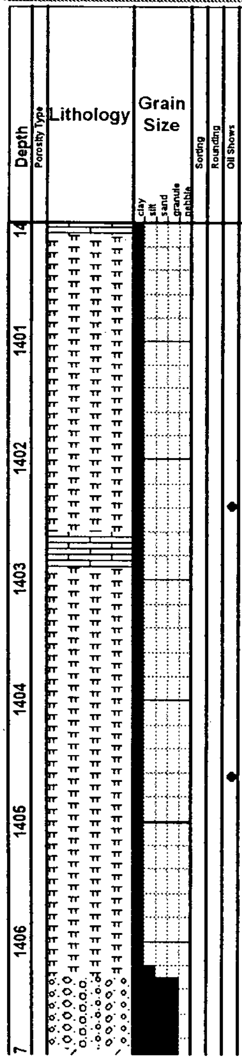
Extra photos: (CD#4), 4484, 85, 86, 87 (basal contact)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Fargo Et Al Highway D- 047-L/094-A-13
Location: 200/d-047-L 094-A-13/00
Licence Number: 00448 Region: British Columbia
Spud Date: 08/03/1958 Drilling Completed: 12/04/1959
Surface Coordinates: Lat: 56.95417
Long: -121.95624
Bottom Hole Coordinates: BH Lat: 56.95417
BH Long: -121.95624
Ground Elevation (m): K.B. Elevation (m): 907.7m
Logged Interval (m): 1400m To: 1406.7m Total Depth (m): 6.7m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

UNIT : PHOSPHATIC MARLSTONE (95%) - black, calcareous, mod carbonaceous, 2 discrete zones of finely interbedded lst (giving slight mottled appearance), mod silty in parts.

Fractures: 2, very minor, near-vertical, calcite-filled, 0.5mm width, 5mm length.

SUB-UNIT: LIMESTONE (90%) - dark grey/black, argillaceous, mod carbonaceous, microcrystalline, mottled-appearance, fine interbeds of black shale, slightly diffuse upper and lower and upper contacts.

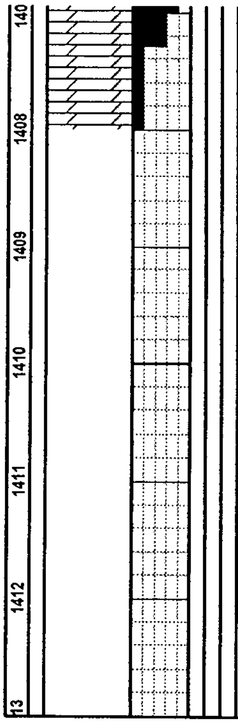
Fracture: 1, minor, orientated 45 deg from bedding, bitumen-filled, 0.75mm width/20mm length.

Mrlst- as above. Fractures: parallel woth bedding, calcite-filled, 0.5mm width/30mm length (bedding 15 deg below horizontal).

Lower Mrlst - med grey, irregularly interbedded with lst. Bottom 20cm has very low calcite content, more silicaeous.

UNIT - CONGLOMERATE - contains occasional well rounded brown clay(?) clasts (8mm diameter) and angular clasts (?) of non-calcareous (slightly silicic/dolomitic) black shaley mudstone (photo 3715).

40cm of black non-calcareous (silcic-dolomitic) shale, relatively sharp near-horizontal conact with overlying unit, soft sediment deformation (clay (?) clast "sinking" into underlying non-calcareous shale with calcareous black shaley sediment infilling after.



Top if section marked by white powdery sulfate streaks, basal region contains 10mm band of calcareous black shale clasts (?), 30cm below this - 15mm interbed of med/dark grey shale.

Basal 15cm slightly silty, med grey, calcareous in part.

UNIT: DOLOMITE - conglomeratic in part, fine, med grey, slightly calcareous, argillaceous matrix, brown silty in parts, similar brecciated texture as above, more prominant, black shale content decreases downwards, congl. slightly coarsens down, 2-4mm quartz grains, chert & clay clasts (brown), mod angularity & sphericity, lst matrix (photo 3718). Middle of section are 2 brown chert pebbles (40mm diameter, elongate horizontally), black shale stringers contort around.

Grades to a med/light grey, mod argillaceous & carbonaceous, mod vuggy porosity.

Fractures: horizontal, bitumen-filled (0.25mm width/15mm length).

SAMPLES:

Sorption: 1402.5m, 1405m

TOC: 1) 1401.5m, 2) 1402.9m, 3) 1403.1m, 4) 1403.6m, 5) 1404.4m, 6) 1404.65m, 7) 1404.95m, 8) 1405.2m, 9) 1405.7m.

Extra photos (CD#3) - 4350 (clay clast sinking into shale)

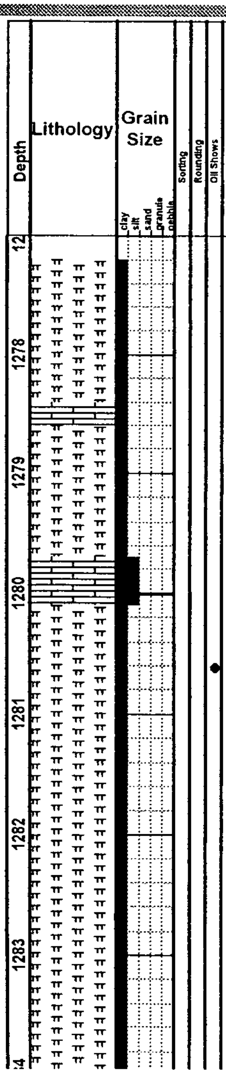
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Marathon Fireweed D- 053-G/094-A-13
Location: 200/d-053-G 094-A-13/00
Licence Number: 00497 **Region:** British Columbia
Spud Date: 02/10/1959 **Drilling Completed:** 29/11/1959
Surface Coordinates: Lat: 56.87947
Long: -121.65420
Bottom Hole Coordinates: BH Lat: 56.87947
BH Long: -121.65420
Ground Elevation (m): **K.B. Elevation (m):** 816.6m
Logged Interval (m): 1277.2m To: 1285.7m **Total Depth (m):** 8.5m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, minor calcite "flecks", mod bituminous, carbonaceous, fossiliferous (bivalves).

80mm of green shale, non-calcareous, fissile, friable (fragmented in core box), poorly indurated, micro-micaceous in part, slightly silty, .

SUB-UNIT: LIMESTONE (90%) - med-dark grey/black, microcrystalline, mottled, mod carbonaceous, argillaceous, finely interbedded with black shale.

Lst - med grey/brown, silty, dense, slightly fossiliferous, argillaceous, micro-micaceous, fines upwards, diffuse upper contact.

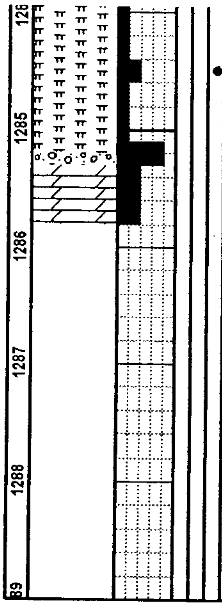
Mrlst - as above, minor interbeds of lst, calcite "flecks" relatively common (shell hash).

Mrlst - as above, slighty silty, more microcrystalline, 1 large irregular calcite band, sharp upper and lower contacts, wavy form, 40mm thick. (photo 3720)

Silty-Mrlst: med grey/brown, dirty appearance, calcareous, slightly micaceous, bituminous, mod argillaceous.

1 discrete calcite-rich lense (lst?) at base of silty-shale (photo 3723), thickness ~ 8mm, across core.

Mrlst - as above, silty in parts, interbedded with black chert (?), laminations slightly curvilinear(~3mm thickness), occasional shell hash band.



Bottom 50cm of shale - white powdery sulfate residue common (photos 3724, 3725, 3726), occasional calcareous "patch", gives shale mottled appearance.

UNIT: CONGLOMERATE - Contains 10mm calcite-rich band with siliceous/black chert nodules (~20mm diameter, subangular-subrounded). Occasional brown clay (?) nodules (~8mm diameter) scattered throughout. Slickenside near contact zone with underlying dolomite

UNIT: DOLOMITE - light grey, argillaceous, silty, mod carbonaceous, mod vuggy porosity, some interbeds of shale, quartz concentrated zones, calcite-filled voids which are concnetrated into discrete zones.

Direct contact with overlying shale is missing from core box.

SAMPLES:

Sorption: 1278m, 1284m.

TOC: 1) 1277.7m (green shale interbed), 2) 1278.1m, 3) 1278.6m, 4) 1279.4m, 5) 1279.7m, 6) 1280.35m, 7) 1280.45m, 8) 1280.75m, 9) 1281.05m, 10) 1281.85m, 11) 1282.05m, 12) 1282.45m, 13) 1283.45m, 14) 1283.55m, 15) 1284.05m, 16) 1284.25m, 17) 1284.65m, 18) 1280.05m.

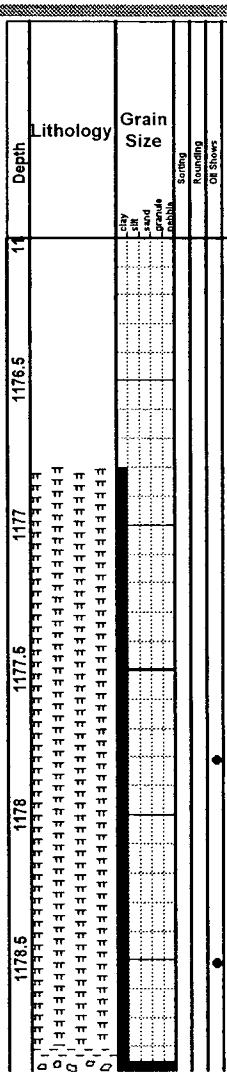
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Burlington Montney 06-05-087-18		
Location:	00/06-05-087-18W6-0		
Licence Number:	00801	Region:	British Columbia
Spud Date:	09/21/1961	Drilling Completed:	12/07/1961
Surface Coordinates:	Lat: 56.513737 Long: -120.835426		
Bottom Hole Coordinates:	BH Lat: 56.513737 BH Long: -120.835426		
Ground Elevation (m):	714.4m	K.B. Elevation (m):	717.8m
Logged Interval (m):	1176.8m To: 1179.4m	Total Depth (m):	2.6m
Formation:	Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

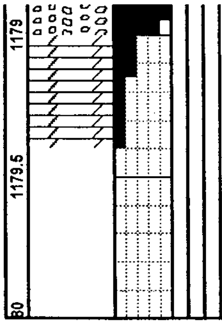


Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, finely laminated, petroliferous odour, slightly silty in parts, scattered disseminated carbonaceous matter, fossiliferous in part, very minor calcite-filled fractures, near vertical, flattened beds of shell hash (W0.1mm, L15mm). (photos 3952, 53), grades into lst, dark brown, speckled with calcite crystals, argillaceous, slightly silty and bituminous.

Basal 5cm is slightly siliceous/cherty - dolomitic.

UNIT: CONGLOMERATE/BRECCIA - slightly calcareous, disrupted interbeds of black shale (solution breccia?), nodules of silty lst (~8mm diameter), scattered brown chert nodules at base (~5mm diameter). Basal 3cm dolomitic (?) black shale, med/dark grey and black bands interbedded (~1mm thick), slightly wavy, white powdery sulfate residue, occasional chert nodules, beds contorted around lenses of med grey silty/argillaceous dolomite. (photo 3955)



UNIT: TRIASSIC DOLOMITE - med grey, argillaceous, micro-cryptocrystalline, calcareous, mod carbonaceous, oil-stained in parts. Top 15cm : stringers of black shale common, finely scattered qtz crystals (1mm diameter). Contact - sharp, 15 deg below horizontal, (photo 3956).

SAMPLES:
Sorption: 1178.2m
TOC: 1) 1177m, 2) 1177.3m, 3) 1177.6m, 4) 1177.7m, 5) 1177.95m, 6) 1178.4m, 7) 1178.7m
Thin-sections: 1) 1178.8m (shale/breccia dol contact), 2) 1178.9m, brecdol + dol contact).

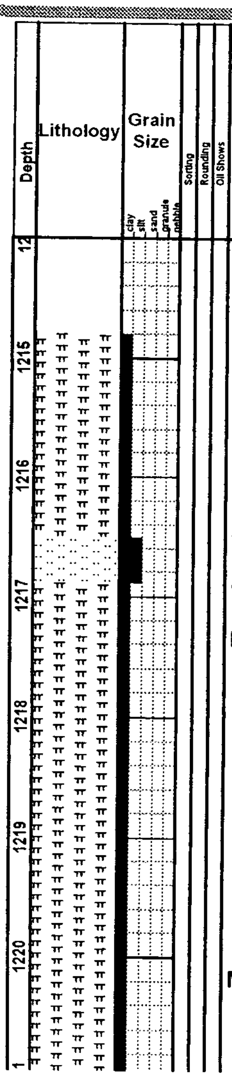
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	FJP Union Birch B- 062-I/094-A-13		
Location:	200/b-062-I 094-A-13/00		
Licence Number:	00834	Region:	British Columbia
Spud Date:	30/10/1961	Drilling Completed:	20/12/1961
Surface Coordinates:	Lat: 56.96875 Long: -121.52188		
Bottom Hole Coordinates:	BH Lat: 56.96875 BH Long: -121.52188		
Ground Elevation (m):		K.B. Elevation (m):	800.4m
Logged Interval (m):	1214.9m To: 1229.7m	Total Depth (m):	14.8m
Formation:	Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



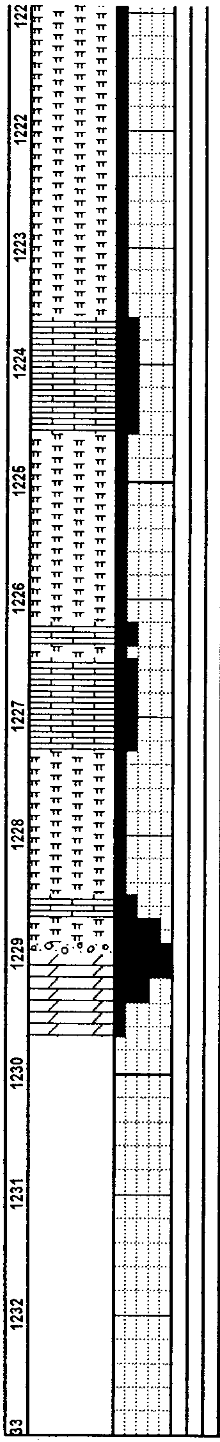
Geological Descriptions

UNIT: MARLSTONE (95%) - black, calcareous, mod petroliferous, fossileferous & silty in parts, vague laminations, two fractures broken to reveal organic-rich fracture fill, mod bright lustre.

Silty-Mrlst (100%) : dark brown, calcareous, finely laminated, 2 calcite-filled fractures (?), horizontal (parallel to bedding) 0.25-1mm width, 15-30mm length, contact missing from core box. (photo 3770)

Mrlst - black, as shale between 1215-1216.5m, laminations more prominant

Mrlst, 200mm, less calcareous (more dolomitic?), gradational contacts, slightly silty.



UNIT: PHOSPHATIC MARLSTONE - 20mm interbed of lst, plant remains - 1mm thick/ up to 10mm length, (photo 3771), occasional silt-sized calcite crystals.

Occasional white powdery residue across the core (sulfur?).

SUB-UNIT: LIMESTONE (100%) - med grey, microcrystalline, mottled, carbonaceous, mod argillceous, relatively planar/sharp upper contact, irregular sharp lower contact.

Mrlst - med/dark brown, calcite "specks" common (shell hash), contains 1 band (3.5 cm thick) of calcite "sand", sharp lower % upper contacts, strong sulfur odour.

Fracture: 1 prominant, near-vertical, sylolite-like, bitumen and calcite-filled (width 1.5mm, length 120mm, photo 3772), bifurcates at base.

Lst - slightly argillceous,planar angled contact with underlying shale, 25 deg below horizontal. Lst below - clasts of calcareous black shale, well rounded, 35mm, 1mm black rim around clast (photo 3776). Fractures: 1, 55 deg from horizontal, calcite-filled hairline fracture directly below stylolite-like bitumen filled fracture (W0.3mm, L70mm) (photo 3777). 1 prominant calcite-filled fracture at base, near-vertical, bifurcates, thins upwards (bitumen filled) (W0.2-1.5mm, L160mm) (photo 3779).

Mrlst - dark grey/brown, interbedded with black shale (bs), bs also occurs as discrete blebs (W2mm, L20mm). Contains 6cm interbed of calcite "sand", sharp lower and upper contacts. Calcite "flecks" more abundant towards base.

UNIT:CONGLOMORATIC, 15mm calcite-rich (shell hash?) with 2-10mm non-calcareous black mudstone clasts, calcite band has sharp contacts and occasionally contorts around shale clasts(photos 3780, 81, 82). 300mm from base is a 4cm band of opalescent blue quartz (photos 3783, 84)

UNIT: DOLOMITE - med grey, argillaceous, carbonaceous, vuggy porosity, large amounts of dissolution, voids up to 8mm width/15mm lengthmicrocrystalline, bitumen-filled fractures common near contact, direct contact missing from core box, generally a dirty, dense dolomite.

SAMPLES:

Sorption: 1218.6m, 1222.5m, 1227.3m

TOC: 1) 1215.4m, 2) 1215.8m, 3) 1216.1m, 4) 1216.4m, 5) 1216.8m, 6) 1217.1m, 7) 1218.5m, 8) 1218.55m, 9) 1219.35m, 10) 1219.45m, 11) 1221.0m, 12) 1222.1m, 13) 1222.7m, 14) 1223.1m, 15) 1223.4m, 16) 1224.3m, 17) 1224.6m, 18) 1225.0m, 19) 1225.4m, 20) 1225.8m, 21) 1226.1m, 22) 1226.5m, 23) 1227.3m, 24) 1228.5m, 25) 1228.9, 26) 1229.1m

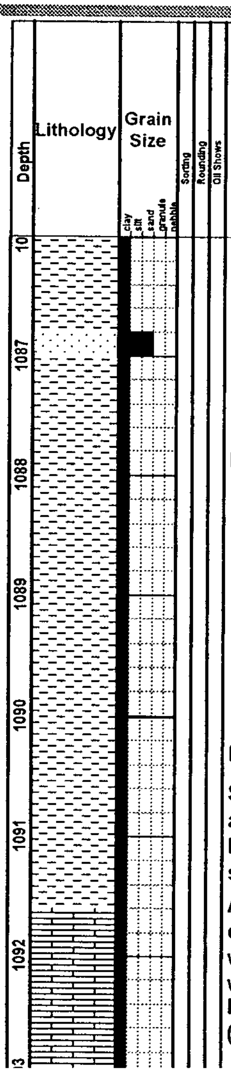
Thin-section: 1226.3m (mud clast within lst).

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: DECL Rigel 06-16-088-17
Location: 00/06-16-088-17W6
Licence Number: 01168
Region: British Columbia
Spud Date: 9/27/1962
Drilling Completed: 10/10/1962
Surface Coordinates: Lat: 56.630001
Long: -120.649544
Bottom Hole Coordinates: BH Lat: 56.630001
BH Long: -120.649544
Ground Elevation (m): 674.7
K.B. Elevation (m): 678.5
Logged Interval (m): 1086.6 To: 1093.4
Total Depth (m): 6.8
Formation: Fernie/Nordegg
Type of Drilling Fluid:



Geological Descriptions

UNIT: MUDSTONE (100%) - black, non-calcareous, petroliferous, silty in places, bituminous, fossiliferous (bivalves common throughout).

shaley sst interbed (100%) - med/dark brown, grains have mod angularity and sphericity (gs ~ 110u), oil stained, minor calcite, sharp contacts.

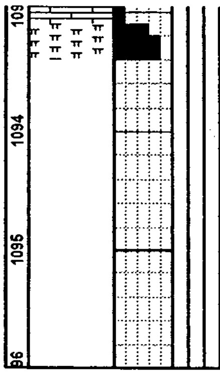
Mudstone, as above - white powdery sulfate residue common throughout section.

Basal 30cm of shale directly above overlying lst - microcrystalline, slightly pyritic.

SUB-UNIT: LIMESTONE (95%) - med grey, microcrystalline, mottled, mod carbonaceous, argillaceous, very fine interlaminations with shale, slightly silty in parts, bituminous. Partially filled calcite fractures cross-cut laminations (oblique), (photo 3659 slabbed section, photo 3660 top section).

At 1092m, lst changes from med grey to dark grey/brown (more carbonaceous/bituminous?), sharp irregular contact, clasts of light grey lst isolated within dark grey lst. Dark grey lst contains one compressed stylolite (oragnic residue within), low relief.

Fracture - 4mm thick in broadest section. Towards top of fracture calcite-filling splits (gap~0.25-0.5mm) - mechanical breakage?



UNIT: MARLSTONE - (95%) - black, as upper shale but increasingly calcareous, very occasional brown clay (?) clast, well rounded, ~10mm diameter.

-1095.7 core missing from core box.

SAMPLES:

Sorption: 1086.7m, 1090.1m.

TOC: 1) 1086.2m, 2) 1087.0m (sst), 3) 1087.55m, 4) 1087.85m, 5) 1088.25m, 6) 1088.95, 7) 1091.8m (lst) (+1 original)

Thin-section: 1092.1m (contact between light grey and dark grey lst)

Extra photos (CD#3): 4400 (as thin-section).

LITHOLOGY STRIP LOG

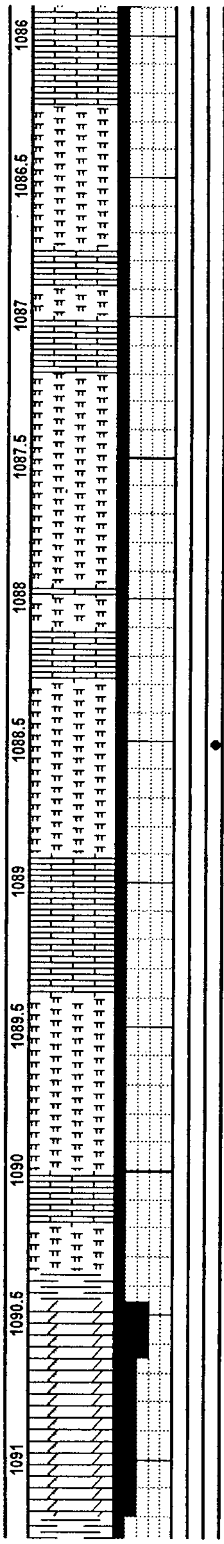
WellSight Systems

Scale 1:20 Metric

Well Name:	CNRL Et Al Osborn A- 045-J/094-A-09
Location:	200/a-045-J 094-A-09/00
Licence Number:	01257
Region:	British Columbia
Spud Date:	22/01/1963
Drilling Completed:	09/03/1963
Surface Coordinates:	Lat: 56.70209 Long: -120.17812
Bottom Hole Coordinates:	BH Lat: 56.70209 BH Long: -120.17812
Ground Elevation (m):	
K.B. Elevation (m):	767.7m
Logged Interval (m):	1083.9m To: 1090.6m
Total Depth (m):	6.7m
Formation:	Nordegg
Type of Drilling Fluid:	

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size (clay, silt, sand, granule, pebble)	Sorting	Rounding	Oil Shows	Geological Descriptions
10						
1083.5						
1084						UNIT: PHOSPHATIC MARLSTONE (100%) - black, calcareous, finely laminated, fossiliferous, abundant horizontal calcite veins - discontinuous and parallel to bedding (W0.2mm, L20mm), white "specks" throughout.
1084.5						
1085						SUB-UNIT: LIMESTONE (95%) - dark grey, microcrystalline, mottled, carbonaceous, occasionally finely interbedded with black shale, sharp lower/diffuse upper contact, near vertical calcite filled hairline fractures present.
						Mrlst, as above.
1085.5						Lst, as above - contains a minor non-calcareous black shale interbed with strong petroliferous odour, more shaley at base with brown clay (?) nodules (15mm diameter).
						Mrlst, as above - dark brown/black, non-calcareous, slightly silty, sharp upper and lower



contacts, grades brown to black at upper contact..

Lst, as above - 2 prominant fractures: near-vertical (W0.2-1mm, L50mm), bitumen-filled centre, calcite on outside (photo 3918).

Mrlst, as above - fractures in centre of unit, both horizontal and vertical (W0.3mm, L60mm), both filled with bitumen & calcite (photo 3919).

Lst, as above - sharp upper contact, angled 25 deg below horizontal.

Mrlst, as above

Lst, as above

Mrlst, as above - 50mm interbed of lst near top, diffuse upper and lower contacts, 1 prominant fracture through this zone (W1mm, L45mm), calcite & bitumen-filled (photo 3920).

Lst, as above - sharp lower and upper contacts.

Mrlst, as above

Lst, as above

Mrlst, as above - 1 irregular interbed of lst, thickness changes from 2-10mm (photo 3921).

Lst, as above - coarsens upwards, slightly oblique (but near-horizontal) bitumen-filled fracture (W0.5mm, L50mm). (photo 3923, 24).

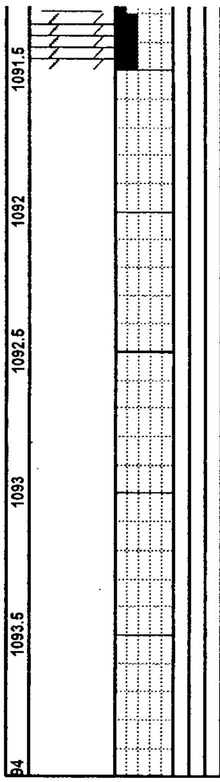
Mrlst, as above - slightly brown in parts, contains 4 discrete bands of calcite (20mm thick, 50mm apart), angled at 20 deg below horizontal, white "speckled" appearance (photo 3925).

Lst, as above - contains 1 curvilinear, convex fracture, calcite-filled (W2.5mm, L70mm), angled/planar upper contact with overlying shale, ~20 deg below horizontal (photo 3927).

Shaley-mudstone - dark grey/brown, non-calcareous, very fissile.

UNIT: DOLOMITE - top 14cm: med grey, interbedded black shale (disrupted bedding - solution brecciated ?), med grey dolomite and light grey calcite-rich laminae in upper 5cm, black shale laminae up to 4mm thick at top, thin away from contact, laminae slightly rippled, towards base of 5cm band, increasingly brecciated texture (lack of laminations), calcite-rich nodules (silty lst), stringers of black shale (photo 3928).

Next 15cm, light grey, very argillaceous, silty, brecciated, slightly more calcareous, abundant black shale stringers, appears bioturbated,



45cm: med/dark grey dolomite, little calcite, brecciated texture with black shale and silty dolomite, silty dolomitic nodules (~2mm diameter) occur within stringers of black shale. Central 20cm contains several black shale interbeds (up to 15mm thick), depressed by overlying nodules of light grey silty dolomite.

Basal 10cm, mrlst with white powdery residue (sulfate?), fine conglomerate directly above with signs og bioturbation.

20cm: brecciated dolomite as seen before.

SAMPLES:

Sorption: 1084.7m, 1090.5m.

TOC: 1) 1083.9m, 2) 1084.4m, 3) 1084.55m, 4) 1084.9m, 5) 1085.2m, 6) 1085.8m, 7) 1086.4m, 8) 1086.8m, 9) 1087.1m, 10) 1087.4m, 11) 1087.95m, 12) 1088.25m, 13) 1088.55m, 14) 1088.95m, 15) 1089.25m, 16) 1089.8m, 17) 1090.0m, 18) 1091.3m (shale interbed within Bald.), 19) 1090.3m (just above Trias contact).

Thin-sections: 1090.4m (shale/dolomite interbeds at contact), 1091.35m (breccia, shale stringers and bioturbation within Bald.).

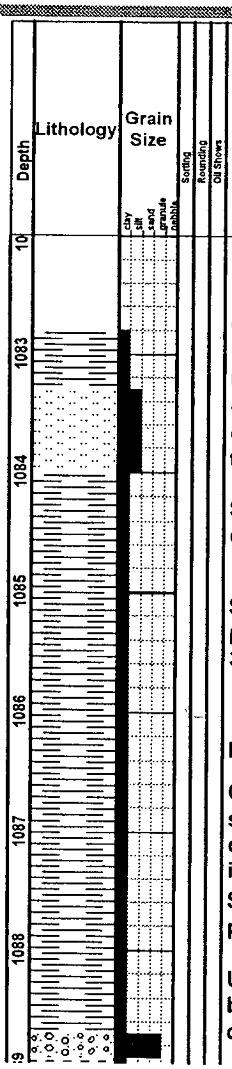
Extra photos (CD#3) - 4364 to 4370 (contact zone).

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Domcan Rigel 06-28-088-17
Location: 00/06-28-088-17W6-0
Licence Number: 01385
Region: British Columbia
Spud Date: 11/02/1963
Drilling Completed: 12/28/1963
Surface Coordinates: Lat: 56.659088
Long: -120.649529
Bottom Hole Coordinates: BH Lat: 56.659088
BH Long: -120.649529
Ground Elevation (m): 691.5m
K.B. Elevation (m): 694.8m
Logged Interval (m): 1082.9m To: 1089.3m
Total Depth (m): 6.4m
Formation: Fernie/Nordegg
Type of Drilling Fluid:



Geological Descriptions

UNIT: SHALE (95%) - dark grey, black, non-calcareous, petroliferous odour, finely laminated, dense/well indurated, pyritic. Base marked by 15mm green pyritic band at 30 deg below horizontal (photo 3911).

UNIT: SILTSTONE (100%) - med grey/brown, micromicaceous, horizontal fine sand-sized quartz-rich laminations, show gouging (?) which has been subsequently filled with finer, darker slst, slight coarsening upwards trend, dense, well indurated, sharp contacts at top and base.

Shale (100%) - black, very fissile, fragmented slicken-sides, well indurated, diffuse/patchy areas of green silty-sand, minor quartz.

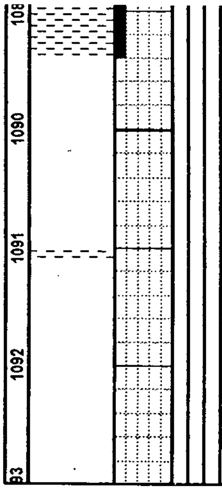
Shale (100%) - dark grey (green in parts), very friable, fissile, very poorly indurated, pyritic (framboids), contact with overlying shale marked by pyrite-rich zone (photos 3912, 13).

horizontal/linear white powdery residue (sulphate?)

Concentration of complete bivalve shells (lingula?), majority brown colour (bitumen staining?), some shells fractured (fractures filled with organic-rich residue) and partially dissolved leaving pitted texture, 10mm diameter(photo 4160, CD #3), induration improves downwards (photo 3914)

Shale (100%) - slightly silty, med grey grading down to green, becomes progressively poorly indurated towards base of section, bottom 50mm very green (photo 3915).

UNIT: CONGLOMERATE - matrix is dark grey/black, silty/earthy shale, pyritic, soft, well broken, clasts of clay & cherty shale common (high spher. & roundness), ~15mm diameter. Contact with FERNIE FORMATION/Poker Chip (?).



UNIT: MUDSTONE (100%) -dark brown/black, silty, dense, massive, greasy, extremely petroliferous, sharp upper contact with overlying congl., top100mm marked by interbeds with pyrite-rich laminae, upper laminations thinner and wavy, occasionally interbedded with green shale, dissolution (natural ?) leaving unfilled voids (2mm width, 15m length).

Bottom 1.6m mising from core-box

SAMPLES:

Sorption: 1087.5m

TOC: 1) 1083.1m, 2) 1083.9m, 3) 1084.15m, 4) 1084.6m, 5) 1084.9m, 6) 1085.05m, 7) 1085.6m, 8) 1086.2m, 9) 1086.5m, 10) 1086.9m, 11) 1087.3m, 12) 1088.5m, 13) 1089.0m

Thin-section: 1088.5m (shell concentration)

LITHOLOGY STRIP LOG

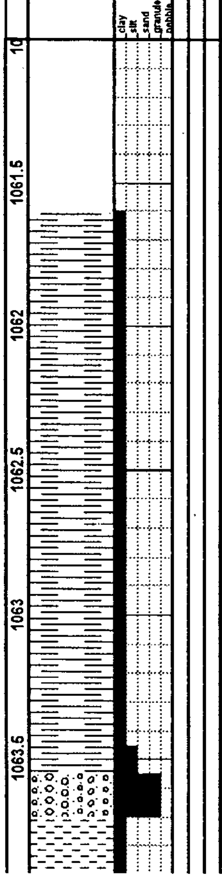
WellSight Systems

Scale 1:20 Metric

Well Name:	DECL Rigel A- 089-J/094-A-10		
Location:	200/a-089-J 094-A-10/00		
Licence Number:	02354	Region:	British Columbia
Spud Date:	22/07/1968	Drilling Completed:	04/08/1968
Surface Coordinates:	Lat: 56.73546 Long: -120.72812		
Bottom Hole Coordinates:	BH Lat: 56.73546 BH Long: -120.72812		
Ground Elevation (m):		K.B. Elevation (m):	696.2m
Logged Interval (m):	1061.6m To: 1064.6m	Total Depth (m):	3m
Formation:	Fernie/Nordegg		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



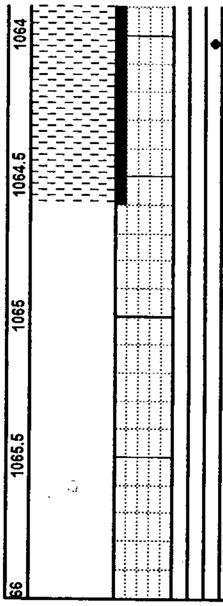
Core photo: 3967

UNIT: SHALE (100%, 4.8m) - dark grey/black, non-calcareous, fissile, disseminated pyrite, glauconitic.

UNIT: SHALE (100%, 1.25m) - black-grading down to green, non-calcareous, fissile, very pyritic, soft & friable in parts towards base (photo 3968), top 25cm mottled green with white powdery sulfate residue, slightly silty at base.

UNIT: CONGLOMORATIC - matrix supported (matrix as overlying shale), clasts of clay and black shale (slightly cherty(?)), 5-20mm diameter, angular-well rounded (angular clasts are darker) (photo 3969). Contact with FERNIE FORMATION (?).

UNIT: MUDSTONE (100%, 0.8m) - med/dark grey, non-calcareous, soft in parts, clayey



texture, mod pyritic, top 10mm of shale is slightly green (photo 3971).

SAMPLES:

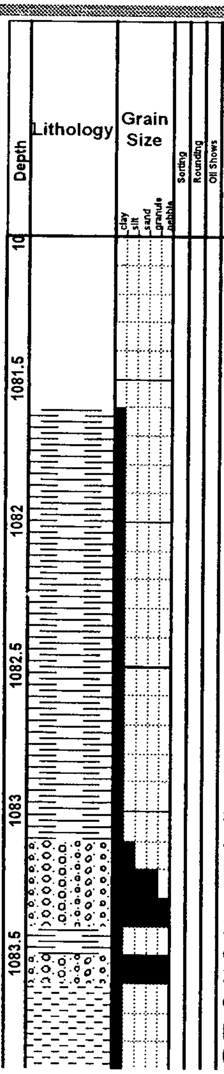
Sorption: 1059.0m, 1065.4m.

TOC: 1) 1057.8m, 2) 1058.0m, 3) 1058.4m, 4) 1059.0m, 5) 1059.8m, 6) 1060.3m, 7) 1060.6m, 8) 1060.9m, 9) 1061.3m, 10) 1061.6m, 11) 1061.85m, 12) 1062.25m, 13) 1062.7m, 14) 1062.9m, 15) 1063.3m, 16) 1063.7m (contact grey/green shale), 17) 1064.0m, 18) 1064.1m, 19) 1064.5m, 20) 1064.9m, 21) 1065.0m, 22) 1065.3m, 23) 1065.7m

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: Remington PC Rigel C- 074-J/094-A-10
Location: 200/c-074-J 094-A-10/00
Licence Number: 02557
Region: British Columbia
Spud Date: 10/08/1969
Drilling Completed: 19/08/1969
Surface Coordinates: Lat: 56.73125
Long: -120.67185
Bottom Hole Coordinates: BH Lat: 56.73125
BH Long: -120.67185
Ground Elevation (m):
K.B. Elevation (m): 687.9m
Logged Interval (m): 1081.6m To: 1085.3m Total Depth (m): 1.7m
Formation: Fernie/Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

Core photo: 3976

Shale (100%, 1.10m) - dark grey, non-calcareous, fissile, well indurated, pyritic, scattered plant fragments (1 large plant fragment, ~2.5cm, bright, vitrinite), slickensided.

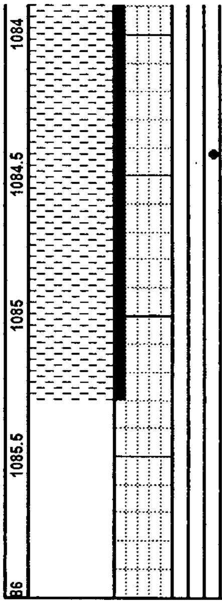
Shale (100%, 0.95m) - dark grey (slightly brown in places), silty, mottled appearance, soft & friable, pyritic, induration improves towards base of unit.

Fragments of grey/green shale interbed at 1082.4m.

2 conglomoratic zones:

UNIT: CONGLOMERATE - black shale stringers (photo 3973), congl. is matrix supported, matrix is dark grey, argillaceous, non-calcareous, clasts of brown silty-shale (1-1.5cm), angular, occasional larger pebbles (~4cm), subangular.. Complete bivalve shells, partially disolved, bitumen-stained, some shells have pyritic rims.

2 congl. zones seperated by 100mm of extremely soft dark green, silty shale, direct contacts missing from core box.
2nd -lower, matrix supported, matrix is green, argillaceous, non-calcareous, dissemninated pyrite, clasts as above, up to 40mm diameter, well indurated, stringers of pyrite-rich bands distorted around clasts (photo 3974), matrix and clasts fractured (mechanical?). Marks contact with FERNIE FORMATION (?).



UNIT: MUDSTONE (100%, 1.6m) - dark brown/black, non-calcareous, well indurated, fissile, occasional interbeds of pyrite-rich/green layers, also occur as "blebs" (~5mm diameter), fine interbeds of dark brown/black cherty shale, (photo 3975).

White powdery sulfate residue, occasional lenses of disseminated pyrite.

Bottom 1.2m missing from core-box.

SAMPLES:

Sorption: 1082m, 1084.1m.

TOC: 1) 1081.6m, 2) 1082m, 3) 1082.4m, 4) 1082.5m, 5) 1082.8m, 6) 1083.4m (shale between congl.), 7) 1083.6m (shale directly below 2nd congl.), 8) 1083.9m, 9) 1084.2m, 10) 1084.6m. (+ pebble samples from 2nd congl.)

Thin-section: 1083.2m (upper congl.)

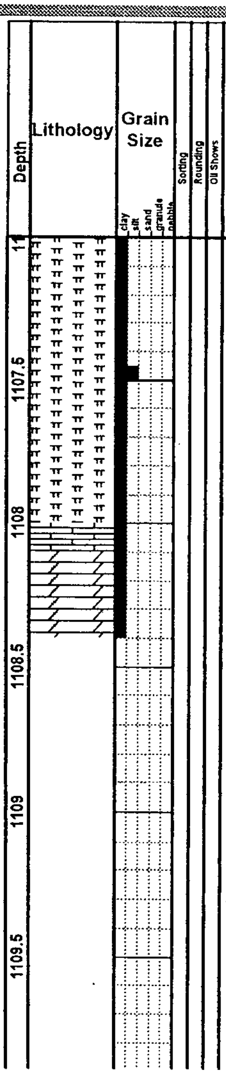
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Remington Et Al Rigel 11-29-088-17
Location: 00/11-29-088-17W6-0
Licence Number: 02709 **Region:** British Columbia
Spud Date: 05/24/1970 **Drilling Completed:** 06/06/1970
Surface Coordinates: Lat: 56.662186
Long: -120.674171
Bottom Hole Coordinates: BH Lat: 56.662186
BH Long: -120.674171
Ground Elevation (m): 678.6m **K.B. Elevation (m):** 682.7m
Logged Interval (m): 1107m **To:** 1108.4m **Total Depth (m):** 1.4m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (85%) - dark brown/black, calcareous, finely laminated with siliceous/cherty black shale, petroliferous odour, interbeds of flattened shell hash.

Contains a 20mm calcite-rich interbed (photo 3916), sharp upper and lower contacts, calcite slightly coarser upwards from silt-size, white powdery sulfate residue.

SUB-UNIT: LIMESTONE (15%) - dark grey/black, microcrystalline, mottled, argillaceous, mod carbonaceous, (photo 3917).

UNIT: DOLOMITE - med/light grey, mod carbonaceous & argillaceous, discontinuous interbeds of light grey calcareous dolomite and dark brown argillaceous dolomite, top 2cm contains lenses of dark brown/black shale (~8mm length). 5cm below, dolomite slightly brecciated with fractures filled with silt-sized calcite crystals, 2 vugs (~1cm diameter), one partially and other completely filled with calcite, bitumen-filled fractures common near contact.

SAMPLES:

Sorption: 1107.1m

TOC: 1) 1107.1m, 2) 1107.8m, 3) 1108.0m.

Thin-section: 1108.4m (brecciated dolomite and calcite filling).

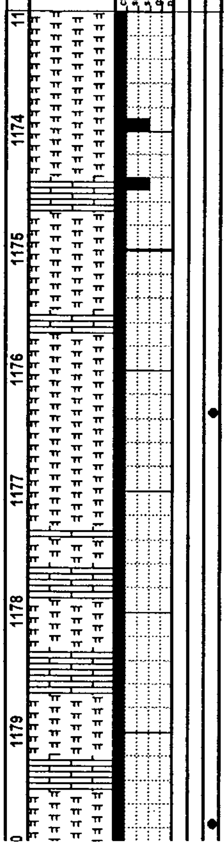
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Murphy Et Al N Boundary 11-30-087-
Location: 00/11-30-087-14W6-0
Licence Number: 03098
Region: British Columbia
Spud Date: 02/14/1972
Drilling Completed: 03/02/1982
Surface Coordinates: Lat: 56.575420
Long: -120.224625
Bottom Hole Coordinates: BH Lat: 56.575420
BH Long: -120.224625
Ground Elevation (m): 789.6m
K.B. Elevation (m): 793.7m
Logged Interval (m): 1173.4m To: 1181.3m
Total Depth (m): 7.9m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Depth	Lithology	Grain Size (clay, silt, sand, granule, pebble)	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, petroliferous, interbedded with lst (mottled textural bands -5-40mm thick). Calcite replaced shells (?) common (photo 3651). Calcite-filled fractures (6+) - (W0.1-1mm, L35mm), "spider" like appearance i.e. -perpedicular/horizontal and oblique to bedding, converge into 1 point (photo 3652). 1 lst interbed, calcite-sand fines upwards, sharp basal contact, underneath - 15mm of carbonaceous shale (very friable), shell hash bands.

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, mottled laminated appearance, mod petroliferous, finely interbedded with shales (1-5mm) (photo 3653), 15mm calcite sand marks top.

Mrlst, as above - interbedded green shale, 20mm thick, very bituminous, poorly indurated, low calcite content.

Lst, as above - microcrystalline, contains 1 coarse calcite bed (?), 3mm thick, horizontal (photo 3654).

Mrlst, as above - powdery white residue common (sulfur?).

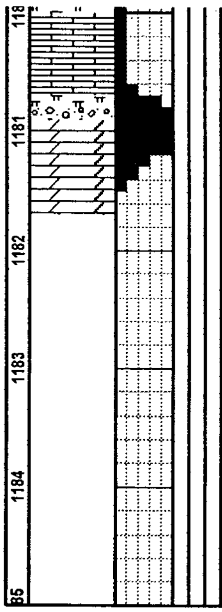
Lst - dark grey-black, dense.

Mrlst -brecciated with a mozaic of fractures filled with calcite, angular clasts of shale encased within calcite (1-25mm diameter) (photo 3655)

Mrlst, as above - lst interbed with 2 fractures, cross-cut each other, 1) orientated 25 deg above horizontal, 2) orientated 55 deg below horizontal, (W~1.5mm, L across core), partially bitumen-filled, minor calcite filling surrounding (photo 3657).

Lst, as above.

Mrlst, as above - irregualr lst interbed contact (photo 3656)



UNIT: CONGLOMORATE - brecciated appearance, soft clay (brown) clasts, <15mm, well-rounded. Phosphate grains common, more dolomitized towards base, calcite laminae (?) contort around clasts. At base, shale bed - sharp/irregular contacts, slightly "soupy" sediment at time of Ist deposition (?).

UNIT: DOLOMITE - light grey, dense, argillaceous, cryptocrystalline, occasional chert nodules, vuggy porosity more abundant away from contact, partially calcite-cemented, 60mm siliceous clasts (containing shell fragments) and minor lst in med grey, argillaceous, non-calcareous matrix - likely marks top of unit (?), sharp contact with overlying shale, 10 deg below horizontal.

SAMPLES:

Sorption: 1175m, 1176.8m, 1179.8m

TOC: 1) 1173.2m, 2) 1174.1m, 3) 1174.35m (green shale), 4) 1174.95, 5) 1175.95m, 6) 1176.95m, 7) 1177.2m, 8) 1177.9m, 9) 1178.6m, 10) 1179.2m, 11) 1180.1m, 12) 1180.5m, 13) 1180.8m

Thin-sections: 1173.6m (crinoid?), 1179.8m (top breccia/congl., 1181.0m (base Nord/top Bald.)

Extra photos (CD #3): Crinoid type structure 4268, brecc/fracs 4269, shell hash 4273, base contact 4274-4278.

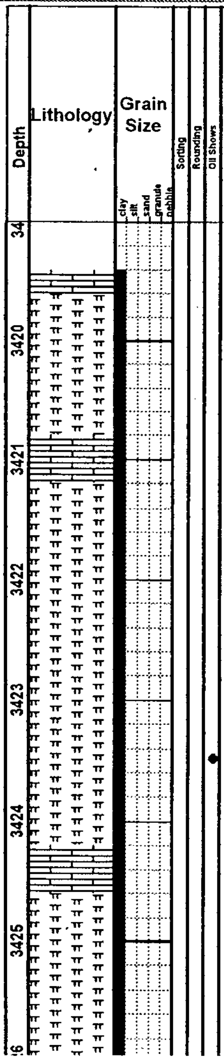
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: BP Sukunka B- 059-A/093-P-05
Location: 200/d-059-A 093-P-05/00
Licence Number: 03773 Region: British Columbia
Spud Date: 02/09/1976 Drilling Completed: 10/08/1977
Surface Coordinates: Lat: 55.29817
Long: -121.60115
Bottom Hole Coordinates: BH Lat: 55.29817
BH Long: -121.60115
Ground Elevation (m): K.B. Elevation (m): 1133.9m
Logged Interval (m): 3419.6m To: 3427.2m Total Depth (m): 7.6m
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: MARLSTONE (95%) - dark grey/black, mod calcareous, very carbonaceous, pyritic, petroliferous, finely interbedded with lst and calcite (interbeds 2mm thick) (photo 3668). Pyrite can be concentrated into sub mm laminae (orientated 10 deg below horizontal).

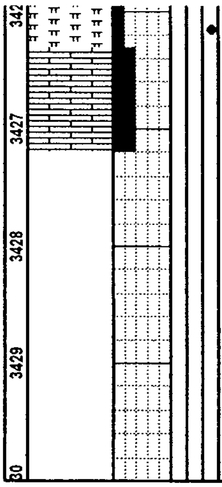
Fractures: parallel with bedding, partially calcite-filled, coninuous across the width of core (70mm), 0.5mm thick.

SUB-UNIT: LIMESTONE (90%) -dark grey/black, carbonaceous, finely laminated with black shale, microcrystalline, mottled appearance, petroliferous odour, sharp upper and lower contacts, slickensided.

Mrlst, as above - shows minor concentrations of shells (<1mm) in 10mm bands, calcite dissolved out on places to leave vuggy (?) porosity (photo 3671).

Lst, as above - sharp upper and lower contacts, contains 1 prominant fracture, near vertical, bitumen-filled, (W0.2mm, L50mm), slightly irregular form.

Mrlst, as above - varying calcite content.



Lst - as above - slightly silty, large interbeds (2cm thick) of med grey/green silty-shale. Shale is mod pyritic, non-calcareous, sharp contact (photo 3674).

60mm interbed of black Mrlst (which itself is interbedded with calcite - 0.5mm thick, 35-40mm length), bedding 25 deg below horizontal, sharp /angled upper contact, parallel with bedding (25 deg below horizontal) (photo 3675).

3427.2m+ missing from core box.

SAMPLES:

Sorption: 3420.8m, 3425.9m.

TOC: 1) 3419.5m, 2) 3420.3m, 3) 3420.7m, 4) 3421.1m, 5) 3421.4m, 6) 3422.2m, 7) 3422.8m, 8) 3423.2m, 9) 3423.55m, 10) 3423.65m, 11) 3424.05m, 12) 3424.45m, 13) 3424.85m, 14) 3425.25m, 15) 3426.05m, 16) 3426.2m, 17) 3426.6m, 18) 3427m, 19) 3427.1m, 20) 3427.9m.

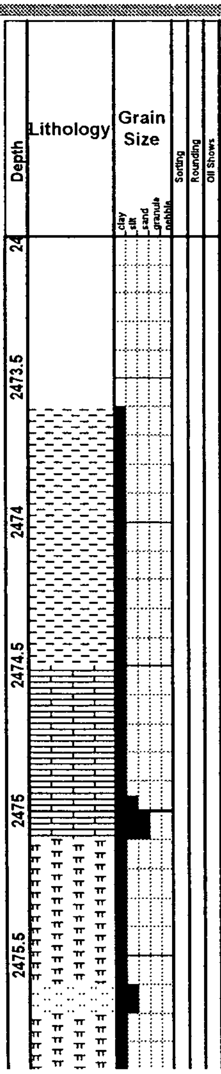
Thin-sections: 3421m (lst/shale - parallel lamination)

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Talisman Sukunka B- 065-B/093-P-05		
Location:	200/a-065-B 093-P-05/00		
Licence Number:	03793	Region:	British Columbia
Spud Date:	21/09/1976	Drilling Completed:	23/03/1977
Surface Coordinates:	Lat: 55.30396 Long: -121.68003		
Bottom Hole Coordinates:	BH Lat: 55.30396 BH Long: -121.68003		
Ground Elevation (m):		K.B. Elevation (m):	730.6m
Logged Interval (m):	2473.5m To: 2480.1m	Total Depth (m):	7.6m
Formation:	Nordegg		
Type of Drilling Fluid:			



Geological Descriptions

UNIT: MUDSTONE (100%) - black, almost coaly, mod-calcareous, finely laminated, slight dissolution along bedding planes, very thin (<0.5mm) calcite-filled fractures - along bedding plane (approx 25 deg to horizontal), slickensided.

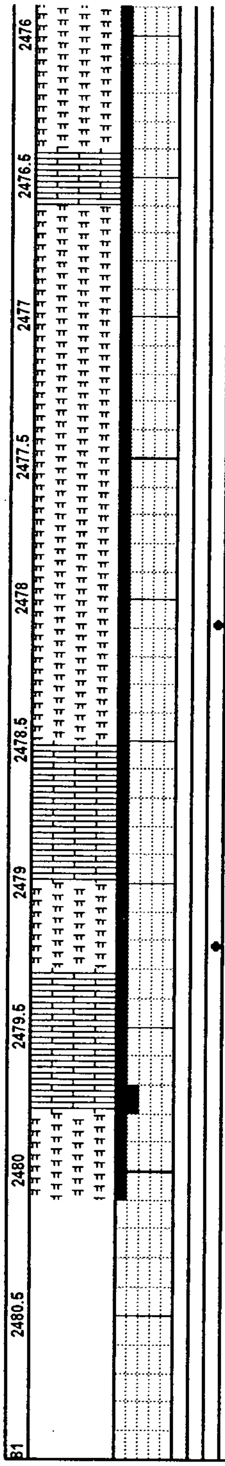
Mudstone becomes increasingly calcareous towards base.

UNIT: LIMESTONE (95%) - med grey, microcrystalline, mottled appearance, carbonaceous, slightly argillaceous, sharp upper and lower contact with shale (approx 30 deg below horizontal), calcite sand at base, slight fining-up sequence, 1 prominant fracture, 15 deg off vertical (cross-cuts bedding), core partly broken along fracture to reveal a graphite lustre (photo 3677, 4041, 42, 43).

UNIT: MARLSTONE (100%) - as above, calcite-filled fractures (up to 1mm), parallel to 25 deg bedding, section extremely fractured, calcite-fill, 1-2mm clasts of black shale within - brecciated appearance (photo 4052 in second photo folder).

20mm SILTY-MARLSTONE (100%), dark grey, vertical and horizontal calcite-filled fractures, bitumen-filled fractures are shorter, discontinuous, near vertical.

Mrlst - larger (1.5-2mm thick) calcite-filled fractures, parallel with bedding (approx 30 deg below horizontal), aprrox 8+, range from 15mm apart to 80mm, cross-cut by 1



near-vertical calcite filled fracture (25deg off vertical), 0.8mm thick, length - at least 100mm, horizontal fractures are displaced by 2mm, terminated by broken core (photos: 3678, 3680, 4044.) Very occasional black chert pebbles.

Lst - as above, 25 deg contact with shale, 2 near vertical fractures, 1-3mm thick, length ~70mm, terminated at lst boundary with underlying shale, calcite & bitumen-filled, calcite slightly coarse in parts, 40mm apart, (photo 3684).

Mrlst - as above, top 1.15m calcareous, calcite & bitumen-filled fractures parallel to bedding (25 deg from horizontal), 35+ fractures, planar & irregular/wavy, across entire core, very minor near-vertical fractures.

Mrlst - lower 400mm, less calcareous, very few horizontal fractures. Parallel to bedding where present, up to 0.4mm thick/20mm length (shorter than upper fractures).

Mrlst section - photos 3685, 3686, 3687, 3688, 3689, 3690, 3691, 3692, 3693.

Lst - as above - contains 2 dolomitic-silicified black shale interbeds (almost black chert, 5mm & 30mm thick, 30mm apart) (photos 3694, 3695), 4 crenulated bitumen-filled fractures, perpendicular and parallel with bedding, 1-2mm thick), sightly diffuse upper contact, contacts ~25 deb below horizontal (photo 4048), slickensided.

Mrlst, as above - bottom 100mm more cherty/siliceous /dolomitic (lenses of black chert and lst). Stylolites with organic residue, 2 horizontal fractures, calcite-filled, parallel with 25 deg bedding. Fragments of bentonite (?) within core box.

Lst, as above - black shale interbeds (1cm) at top. At base, calcite grains become coarser (photo 3697), 2 near vertical bitumen-filled fractures, perpinicular to bedding, (W0.41mm, L 100mm), slightly crenulated, terminates at caclite "sand" base (photo 4049).

Mrlst, as above - , non-calcareous/dolomitic, approaches black chert at base, slightly silty in parts, fractures (2mm thick), 5-6mm apart, calcite filled, parallel to 25 deg bedding (photo 3698), some fractures slightly open, partial calcite-filling.

SAMPLES:

Sorption: 2476.1m

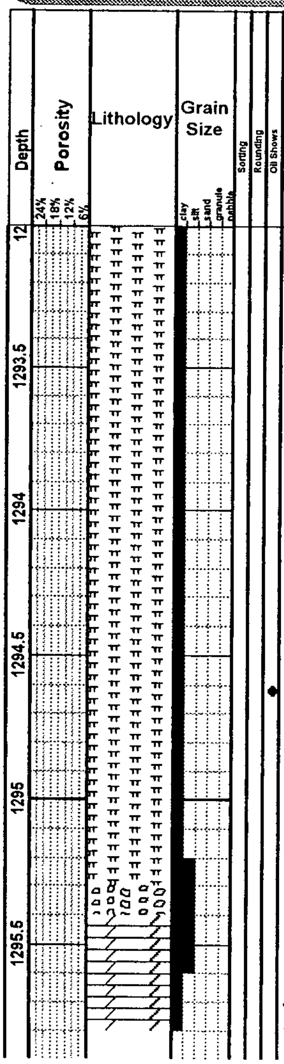
TOC: 1) 2473.0m, 2) 2474.6m, 3) 2476.3m, 4) 2476.7m, 5) 2477.5m, 6) 2478.3m, 7) 2478.5m, 8) 2480.1m.

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: CNRL Et Al Birch D- 075-I/094-A-13
Location: 200/d-075-I 094-A-13/00
Licence Number: 04941 — Region: British Columbia
Spud Date: 10/07/1979 — Drilling Completed: 07/08/1979
Surface Coordinates: Lat: 56.98107
Long: -121.55253
Bottom Hole Coordinates: BH Lat: 56.98107
BH Long: -121.55253
Ground Elevation (m): — K.B. Elevation (m): 869.3m
Logged Interval (m): 1293m To: 1295.9m Total Depth (m): 2.9m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

Core photo: 3982

UNIT: PHOSPHATIC MARLSTONE (95%) - (top 60cm rubble rubble in core box which is friable/soft, very absorbant), black, calcareous, finely laminated with black chert, 3 deg below horizontal, abundant fine;y disseminated plant fragments - needle like (250 microns length, 20 microns width, mod fissile, fossiliferous in part.

Contains 30mm calcite-rich band (speckled appearance, fossiliferous bed?), sharp lower and upper contacts (photo 3977), 2mm black chert band at base with scattered 2mm balck chert nodules, white powdery sulfate residue.

100mm of finely white "speckled" shale with clasts of black Mrlst, range in length from 15mm-50mm, subangular-subrounded, some elongate horizontally, more elongate clasts cross-cut bedding (photo 3978).

Slickensided.

Mrlst - med/dark grey, calcareous, slightly brecciated appearance, argillaceous, silty in parts, occasionaly microcrystalline, mottled (more lst-like), minor calcite-filled fractures, some near-vertical, others 45 deg oblique to bedding, (W0.1mm, L 5-10mm), some white "specks" of phosphate, bottom 50mm characterized by black shale stringers (photos 3979, 80).

Contact: 10cm - Argillaceous dolomite to silty lst with distorted bedding, organic-rich stringers (solution breccia?), sub mm scattered qtz grains.

UNIT: DOLOMITE - med/dark grey/brown, crypto-microcrystalline, fractured with biotuminous lining, mod argillaceous & carbonaceous, good vuggy porosity, fossiliferous, top 30cm very fossiliferous (Brachiopods?), stylolites with organic residue lining.

1296

Grades to dark brown microcrystalline dolomite, good pin-point porosity, fossiliferous, oil-stained in parts, slighty cherty and brecciated in palces.

SAMPLES:

Sorption: 1294.6m

1296.5

TOC: 1) 1293m, 2) 1293.4m, 3) 1293.7m, 4) 1293.9m, 5) 1294.2m, 6) 1294.6m, 7) 1195.6m (Top Bald.), 8) 1195.9m (within Bald.).

97

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name:	ACEL Et Al Birch D- 011-J/094-A-13
Location:	200/d-011-J 094-A-13/00
Licence Number:	05348
Region:	British Columbia
Spud Date:	11/01/1982
Drilling Completed:	04/02/1982
Surface Coordinates:	Lat: 56.93124 Long: -121.62816
Bottom Hole Coordinates:	BH Lat: 56.93124 BH Long: -121.62816
Ground Elevation (m):	
K.B. Elevation (m):	819.4m
Logged Interval (m):	1284m To: 1287.2m
Total Depth (m):	3.2m
Formation:	Nordegg/Baldonnel
Type of Drilling Fluid:	

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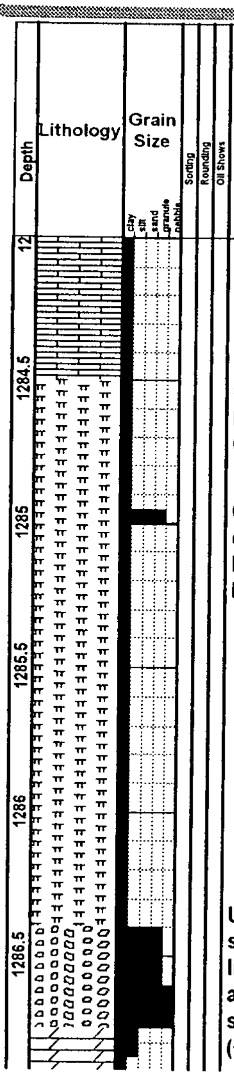


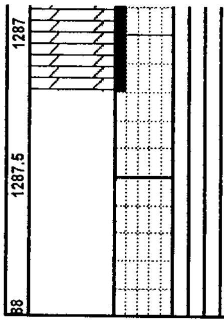
Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - dark grey/black, argillcaeous, carbonaceous, finely interbedded with black shale, microcrystalline, mottled appearance.

UNIT:PHOSPHATIC MARLSTONE (100%) - black, calcareous, finely interbedded with black chert (occasionally lensoid), minor horizontal and vertical calcite-filled fractures. Contains discrete areas of caclite "sand" laminae (15mm thick) with sharp contacts,

Clasts of non-calcareous black chert concentrated into 60mm zone, surrounded by calcite/lst matrix, 2-10mm diameter, clasts angular-well rounded, some elongate (~50mm length, near vertical orientation) random orientation (photo 3808). Base - stringers of black shale.

UNIT: BRECCIA/CONGLOMERATE - solution-brecciated argillaceous dolomite, disrupted shale interbeds, scattered white phosphatic (?) specks within top 10cm, progressively lightens in colour towards base, increasingly poorly sorted at base, 2-3cm clasts of argillaceous dolomite, 1cm qtz grains and dark grey chert clasts, subangular-subrounded (~1cm diameter). Large med grey/brown dolomite clast at base (~5cm), fractured and subsequently filled with upper fine conglomerate/matrix.



UNIT: DOLOMITE - pale cream/buff, mod argillaceous & carbonaceous, microcrystalline, mod vuggy porosity lined with calcite, brecciated with calcite-filling fractures, bitumen-filled stylolites common near contact.

LITHOLOGY STRIP LOG

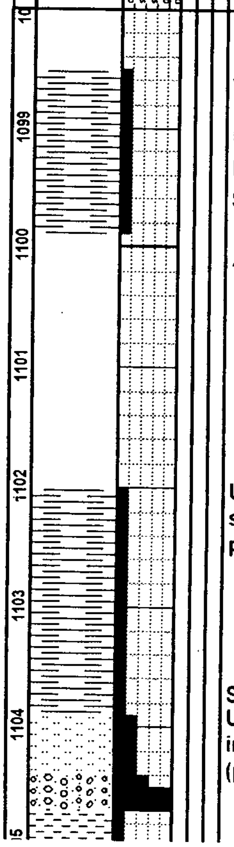
WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: ESSO Fina Rigel D- 097-I/094-A-10
Location: 200/d-097-I 094-A-10/00
Licence Number: 05378
Region: British Columbia
Spud Date: 08/06/1980
Drilling Completed: 26/06/1980
Surface Coordinates: Lat: 56.74701
Long: -120.57533
Bottom Hole Coordinates: BH Lat: 56.74701
BH Long: -120.57533
Ground Elevation (m):
K.B. Elevation (m): 747.8m
Logged Interval (m): 1102m To: 1112m
Total Depth (m): 10m
Formation: Fernie/Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size (clay, silt, sand, granule, pebble)	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: SHALE (100%) - dark grey/green, disseminated pyrite, non-calcareous, fissile. 300mm from top is clasts of well rounded black shale (10mm diameter) and pyrite framboids (10-15mm diameter).

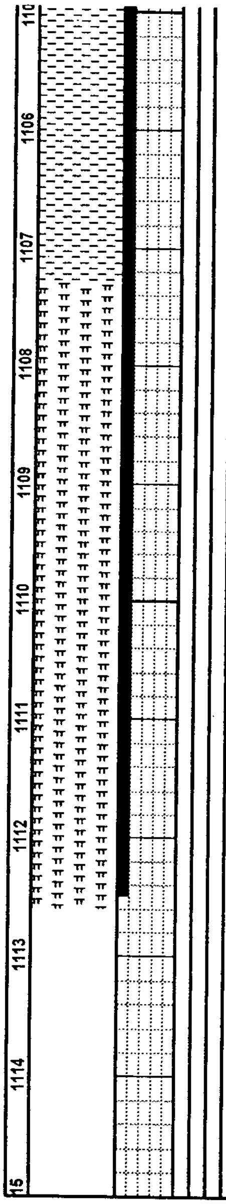
UNIT: SHALE (100%) - black, non-calcareous, fissile, friable (fragmented in core box), pyritic.

Shale, as 1098.5m - contains plant fragments (vitrinite?).

1099.8m - 1102m missing from core box

UNIT: SHALE (95%) - black, non-calcareous, fissile, poorly indurated, pyritic, occasional silty laminae. Towards base, shale becomes silty. Silt - grey/brown, well indurated, petroliferous.

Siltstone/silty shale: med grey, carbonaceous (coal-flecks ~1mm)
UNIT: CONGLOEMRATE - 30cm zone of congl. Green, pyritic, extremely poorly indurated, clasts of shale & clay (brown, soft), 0.5-4cm size in green silty shale matrix (photo 3676). Marks contact with FERNIE FORMATION/Poker Chip (?)



UNIT:MUDSTONE (100%) - dark brown/black, sub-fissile, well indurated, non-calcareous, interbedded with very fine laminae of calcite, petroliferous.

UNIT: MARLSTONE (100%) - black, brown streak, dense, as above shale, very calcareous, finely laminated (majority planar, some very slightly wavy). Minor fractures (0.25mm thick), orientated vertical and horizontal to bedding, calcite-cemented.

1112m+ missing from core box.

SAMPLES:

Sorption: 1102.5m, 1105.5m (non-calcareous), 1112m

TOC: 1) 1098.5m, 2) 1098.8m, 3) 1099.1m, 4) 1099.3m, 5) 1099.7m, 6) 1102m, 7) 1102.3m, 8) 1102.6m, 9) 1102.8m, 10) 1103.1m, 11) 1103.4m, 12) 1103.5m, 13) 1104.1m (above congl. contact), 14) 1104.6m, 15) 1104.9m, 16) 1105m, 17) 1105.6m, 18) 1106m, 19) 1106.85, 20) 1107.15m, 21) 1107.45, 22) 1107.9m, 23) 1108.1m, 24) 1108.7m, 25) 1108.85, 26) 1109.3m, 27) 1109.7m, 28) 1110.3m.

Others: 1099.5m (plant fragments), 1109m (showing laminations).

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	ACEL Et Al Birch D- 010-I/094-A-13		
Location:	200/d-010-I 094-A-13/00		
Licence Number:	05641	Region:	British Columbia
Spud Date:	06/06/1981	Drilling Completed:	23/06/1981
Surface Coordinates:	Lat: 56.92284 Long: -121.61654		
Bottom Hole Coordinates:	BH Lat: 56.92284 BH Long: -121.61654		
Ground Elevation (m):		K.B. Elevation (m):	787.9m
Logged Interval (m):	1249.4m To: 1250.7m	Total Depth (m):	1.3m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

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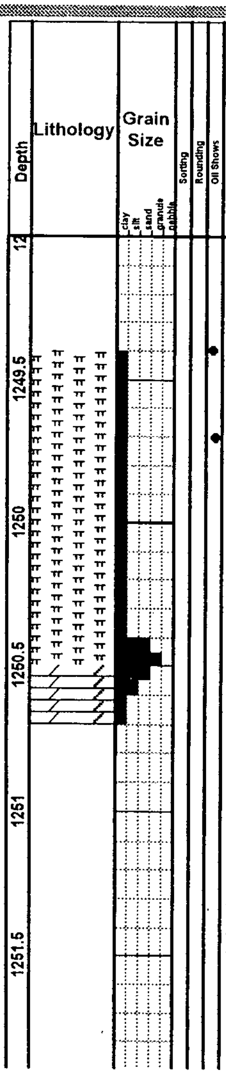

Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, brown streak, mod carbonaceous, calcareous, sub-fissile, strong petroliferous odour, finely laminated with black chert, flattened shell hash bands, white powdery sulfate residue.

Top 100mm: 2 fractures - 1) horizontal, calcite-filled (W0.5mm, L80mm). 2) vertical, bitumen-filled (?) (W0.4mm, L75mm). (Photo 3957).

Mrlst slickensided towards base.

UNIT: CONGLOMERATE - Basal 20cm of Mrlst, clasts of slightly cherty black shale (~2mm diameter), also occur as elongate blebs, fine scattered phosphate specks. Underlying 6cm, shale is siliceous/cherty - dolomitic (photo 3959).

UNIT: DOLOMITE - light grey, cryptocrystalline, mottled near contact, mod argillaceous & carbonaceous, poor-mod vuggy porosity, top 3cm very argillaceous, sub mm scattered opalescent blue qtz, calcite blebs, calcareous in upper 8cm, slightly brecciated in upper 20cm, massive dolomite underneath, black shale stringers common.

SAMPLES:
Sorption: 1249.9m
TOC: Both at 1250.4m, 1) calc shale sample, 2) non-calc shale sample.

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	ACEL Et Al Birch D- 100-H/094-A-13
Location:	200/d-100-H 094-A-13/00
Licence Number:	05733
Region:	British Columbia
Spud Date:	07/02/1982
Drilling Completed:	24/02/1982
Surface Coordinates:	Lat: 56.91646 Long: -121.61522
Bottom Hole Coordinates:	BH Lat: 56.91646 BH Long: -121.61522
Ground Elevation (m):	
K.B. Elevation (m):	791.6
Logged Interval (m):	1255.0m To: 1257.8m
Total Depth (m):	2.8m
Formation:	Nordegg/Baldonnel
Type of Drilling Fluid:	

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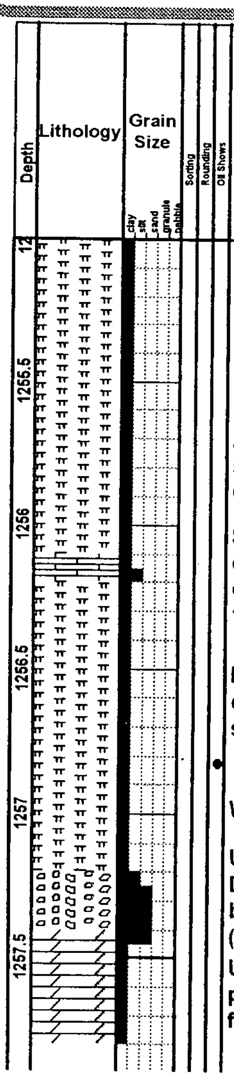


Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE(100%) - black, calcareous, finely laminated, fossiliferous in part, mod carbonaceous, 8mm band of flattened shell hash, top 40mm slightly silty/brown colour

200mm down unit: 2 prominant fractures, curvilnear trace, corss-cuts bedding (W1mm, L60mm), 5mm apart, bitumen fills centre, calcite surrounding (photo 3961).

At 1255.4m, shale - slightly brown/black, contains interbeds and lenses of black chert, sharp upper contact (photo 3962).
Calcite concentrated into 5mm interbed (photo 3963)

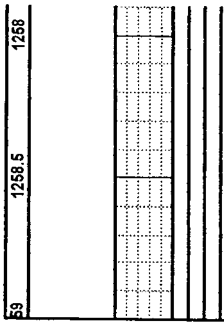
SUB-UNIT: LIMESTONE (90%) - dark grey/black, argillaceous, microcrystalline, mottled, carbonaceous, sharp lower and upper contacts, shell hash concentrated at base, clasts of black shale within 10mm of base, orientated and elongate in the horizontal direction, 1-2mm width, 2-15mm length (photo 3964).

Mrlst, as at 1250m - upper part is calcite-rich with 2 large clasts (~35mm diameter) of cherty black shale, well rounded, mod-high sphericity (photos 3965), more calcareous shale surrounding clasts, slightly coarser calcite towards base.

White powdery sulfate residue.

UNIT: BRECCIA/CONGLOEMRATE - Mrlst sits sharply on med grey argillaceous DOLOMITE, calcareous, disrupted bedding of shale and calcareous dolomite (solution breccia), silty lst clasts, whispy texture, scattered mm grains of opalescent blue quartz (photo 3966).

UNIT: DOLOMITE - light/med grey, argillaceous, slightly calcareous in parts, mod-poor pin-point porosity, brecciated leaving fractures subsequently filled with calcite, fossiliferous,



Core photo: 3960

SAMPLES:

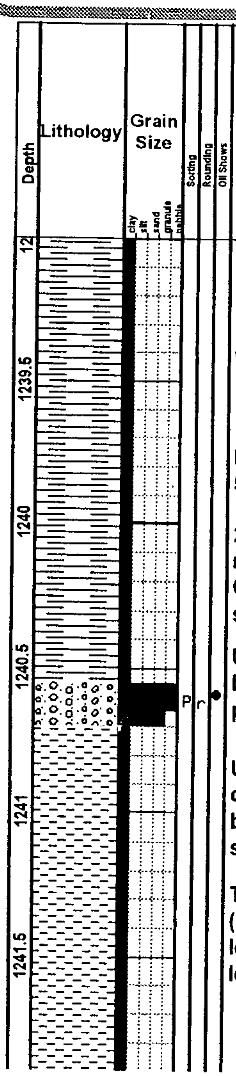
Sorption: 1256.5m

TOC: 1) 1255m. 2) 1256.1m, 3) 1257.1m (+ 1 original sample).

Thin-section: 1257.2m (shale contact with brecciated dolomite).

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

Well Name: CNRL Et Al Birch D- 088-H/094-A-13
Location: 200/d-088-H 094-A-13/00
Licence Number: 06080
Region: British Columbia
Spud Date: 14/10/1984
Drilling Completed: 26/10/1984
Surface Coordinates: Lat: 56.90708
Long: -121.58979
Bottom Hole Coordinates: BH Lat: 56.90708
BH Long: -121.58979
Ground Elevation (m):
K.B. Elevation (m): 796.9m
Logged Interval (m): 1239m To: 1260.9m Total Depth (m): 21.9m
Formation: Nordegg
Type of Drilling Fluid:



Geological Descriptions

UNIT: SHALE (100%) - dark brown/black, non-calcareous, very fissile, friable, carbonaceous, micro-micaceous in part, slickensided, fossilferous (belemnites, photo 3738).

White-powdery streaks (sulfate) - horizontal, concentrated in top 60cm.

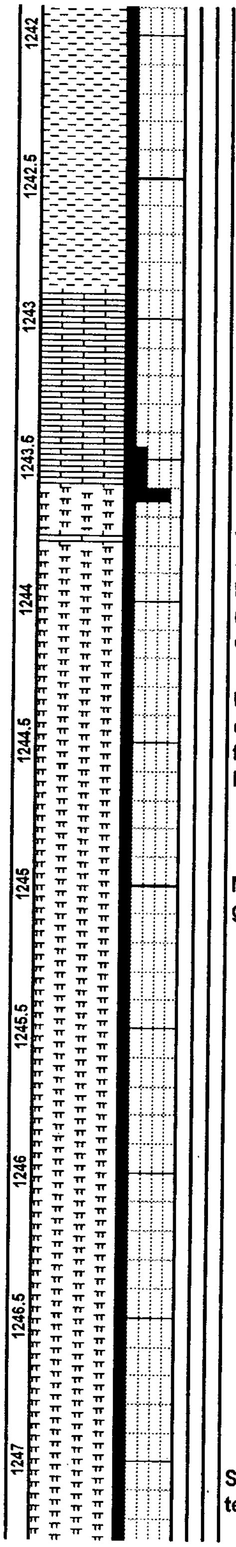
Fractures: calcite-filled, horizontal, parallel with bedding, 5+, (W0.2mm, L30mm), 5-10mm apart.

25cm light/med brown shale, soft & friable, micromicaceous, upper shale slightly more massive, scattered carbonaceous fossil imprints, fossiliferous (ammonites - photo CD#4), irregular laminations at top & base - interbeds of silty (?) brown and black shale, slightly wavy with 2 lenses of silty brown shale (~8mm length),

UNIT: CONGLOMORATE: Well rounded, 3cm clay clasts at top, disseminated pyrite at base, several (10+) minor horizontal and vertical fractures (W0.2mm, L10mm), slight pitted texture in parts (photo 3740). contact with FERNIE FORMATION/POKER-CHIP (?).

UNIT: PHOSPHATIC MUDSTONE (95%) - black, slightly calcareous, disseminated carbonaceous matter throughout, scattered brown inclusions, fossiliferous in part, bituminous residue, calcite "specks" common (likely representing cross sections of shell hash concentrations), more dense than overlying shale.

Towards base - brown, mottled texture, traces of siderite, interbedded black chert (?) (lensoid in parts - 4mm), bedding distorted around thin, horizontally-elongate shale lenses. 1.5cm band & 1 lense of sand-sized calcite (shell hash?), 10mm thick, 50mm length, piches out, sharp lower and upper contact. (photos 3742, 3743).



SUB-UNIT: LIMESTONE (90%) - dark grey/black, argillaceous, microcrystalline, mottled, carbonaceous, dark brown clay (?) lenses, coarser calcite at top and base, sharp contacts, highly fractured at base of section. Top 300mm marked by horizontal and vertical bitumen-filled stylolite-like fractures (W0.2mm, L70mm). Vertical bitumen-filled fractures in top 150mm, horizontal at base. 1 large clast of coarse grained calcite.

Fracture zone: brecciated, horizontal and vertical, braided-like, calcite & occasionally bitumen filled (bitumen in centre), some fracture - filling partially disolved. Thickness ranges from 0.5-7mm (length ~ 50mm). Towards base of lst, brown/black cherty clasts, 2-20mm thick, mod angularity.

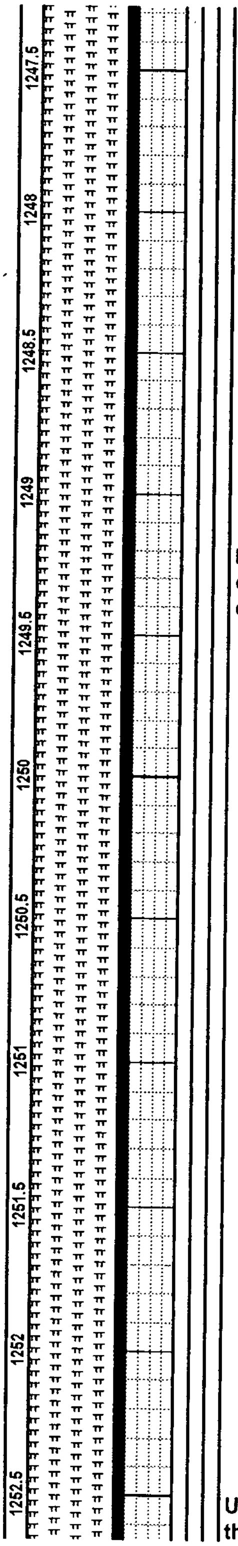
Lowest 20cm, grades into extremely carbonaceous mudstone, poorly indurated, scattered chert nodules in top 3cm (4-6mm diameter), very calcitic at base, shell hash with interbeds of black shale, bedding 15 deg below horizontal, fossiliferous. (photos 3744-3750)

Lst @ 1243.75m - distorted interbeds of lst and black/brown shale, slightly brecciated (similar to brecciated zone at NORDEGG & BALDONNEL contact), occasional 8mm black chert nodules.

UNIT: MARLSTONE (100%) - black (slightly brown in places), mod calcareous, carbonaceous, sub fissile, fine interbeds of calcite, bedding near horizontal, fossiliferous, 30mm concentration of shell fragments (calcite-replaced) with nodules of black, cherty shale, 5-10mm diameter, well rounded, high sphericity. (photos 3751, 3752)

Mrlst - horizontal calcite "flecks" common (shell hash), interbedded with brown shale, gives slight mottled appearance, mod bituminous (photo 3753).

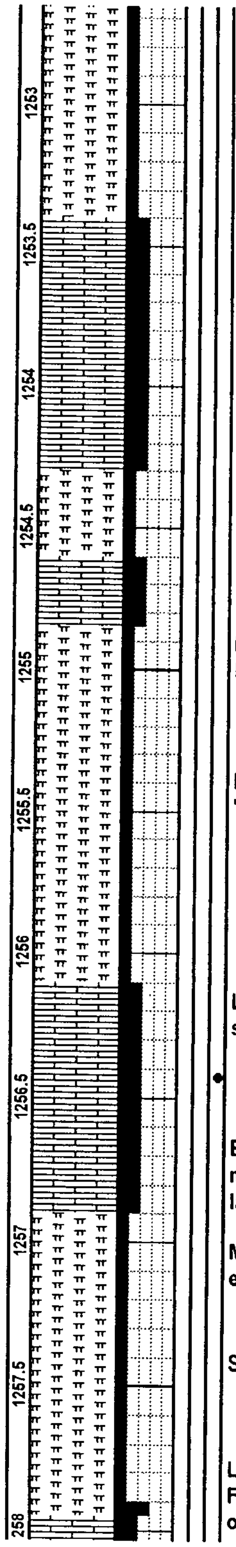
SUB-UNIT: SILTY CALCAREOUS MUDSTONE/MARLSTONE - Mrlst, as above - mottled texture, intermixed calcite and shale (for 1.2m), fine scattered qtz grains.



Mrlst, as above - flattened beds of shell hash common.

Mrlst, as above - interbedded with black chert (also occurs as thin (0.1mm), discontinuous (up to 40mm length) interlaminations), shell hash bands, (photo 3754)., calcite "specks" common, micromicaceous, carbonaceous, trace bitumen-residue,

UNIT: PHOSPHATIC MARLSTONE - as marsltone with scattered white phosphatic specks throughout.



Lst - dark grey, very argillceous, silty, slighty dirty appearance, sharp lower and upper contacts, no fractures.

Mrlst - as previous, laminated, mod petroliferous, grades to brown shale, one 25mm interbed of lst.

Lst, as above.

Mrlst, as above - interbeds of black and brown shale, grades into browner shale towards base, silty in parts.

Fracture: 1 prominant, near-vertical, calcite-filled, (W0.3mm, L60mm), more white "specks" towards base. 1 clast of non-calcareous black shale (photo 3755).

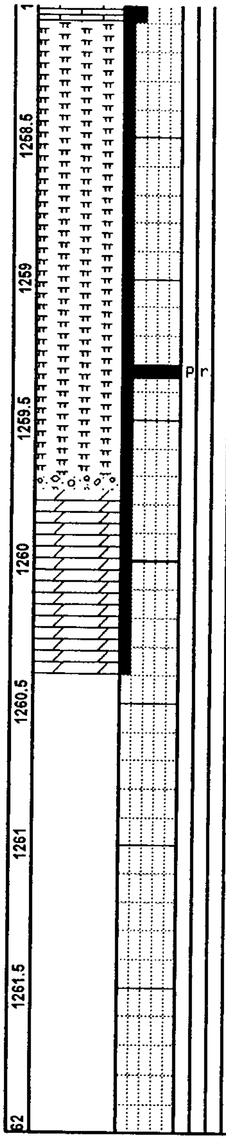
Lst - med grey, fine interbeds of black shale common, 80mm section of "speckled black" shale.

Basal lst -occasional clasts composed of coarser calcite, ~15mm diameter, well rounded, mod-high sphericity, calcite "flecks" common, continuous and discontinuous laminations of black shale (photo 3756).

Mrlst - black (brown in parts), very calcareous, lense-like black cherty shale and calcite encased within brown shale, also occur as irregular interbeds (photo 3578).

Sand-sized calcite interbed (photo 3760).

Lst - extremely microcrystalline, very carbonaceous, silt-fine sand sized calcite at top. Fracture - 1 prominant, calcite-filled, (W2mm, L30mm), 30 deg below horizontal, oblique ot bedding, Sharp horizontal contacts (photo 3761).



Mrlst - contains 2 calcite rich zones with clasts of non-calcareous black shale (very similar to 1257.5m & 1258.3m) (photos 3762, 3763).

UNIT: CONGLOMORATE (5cm thick) - very silliceous, clasts of quartz, chert. Size range: 2-20mm, subangular-subrounded, some elongate, matrix is mod calcareous. Fractures: 2, terminated by congl. at top, continue again above congl. Thicker at base (3mm/1mm at top), fractures within cream/buff dolomite, lower fractures filled with argillaceous, microcrystalline matrix from overlying conglomorate (photos 3765-3768)

UNIT: DOLOMITE - light grey/cream, calcareous, micro-cryptocrystalline, mod argillaceous & carbonaceous, poor vuggy porosity, partially calcite filled (minor bitumen-residue), sylolite near contact. Grading to mod pin-point & vuggy porosity, oil-stained.
Grading farther to med grey/brown DOLOMITE, microcrystalline, mod - good pin point & vuggy porosity (up to 2cm diameter), partially lined with calcite and bitumen residue, overlies dark brown DOLOMITE, slightly fractured/brecciated, calcite-lined fractures.

SAMPLES:

Sorption: 1240m, 1241m, 1244.9m, 1250.1m, 1255m, 1258m, 1259m

TOC: 1) 1239m, 2) 1239.4m, 3) 1239.7m (+ belmenite), 4) 1239.8m, 5) 1240.1m, 6) 1240.5m, 7) 1240.6m, 8) 1240.85m, 9) 1241.1m, 10) 1241.2m, 11) 1241.6m, 12) 1242m, 13) 1242.15m, 14) 1242.35m, 15) 1242.75m, 16) 1242.85m, 17) 1243.05m, 18) 1243.55 (lst), 19) 1243.85m, 20) 1244.35m, 21) 1244.65m, 22) 1245.15m, 23) 1245.35m, 24) 1245.65m, 25) 1245.95m, 26) 1246.3m, 27) 1246.7m, 28) 1247m, 29) 1247.4m, 30) 1247.65m, 31) 1247.95m, 32) 1248.35m, 33) 1248.85m, 34) 1249.1m, 35) 1249.6m, 36) 1249.95m.

37) 1250.25m, 38) 1250.55m, 39) 1251.15m, 40) 1251.4m, 41) 1251.8m, 42) 1252.1m, 43) 1252.5m, 44) 1252.9m, 45) 1253.8m, 46) 1254.2m, 47) 1254.5m, 48) 1254.9m, 49) 1255.2m, 50) 1256.1m, 51) 1256.6m, 52) 1257m, 53) 1257.3m, 54) 1257.8m, 55) 1258.7m, 56) 1259.3m.

Thin-sections: 1259.4m (contact).

Extra photos: ammonite (CD#4).

LITHOLOGY STRIP LOG
WellSight Systems
Scale 1:20 Metric

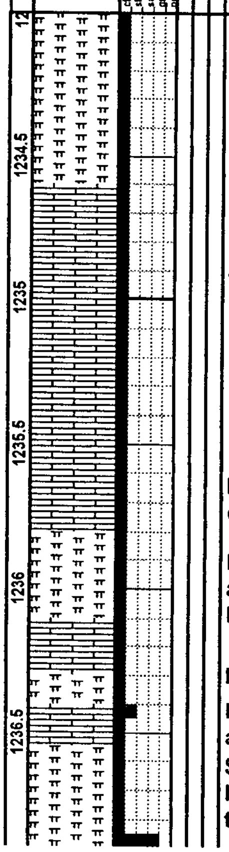
Well Name:
Location: 00/d-077-h 94-H-13
Licence Number: 6100
Region: British Columbia
Spud Date:
Drilling Completed:
Surface Coordinates:

Bottom Hole Coordinates:

Ground Elevation (m):
K.B. Elevation (m):
Logged Interval (m): **To:**
Total Depth (m):
Formation:
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth | Lithology | Grain Size (clay, silt, sand, granule, pebble) | Sorting | Rounding | Oil Shows | Geological Descriptions



UNIT: PHOSPHATIC MARLSTONE (98%) - dark grey/black, carboncaeous, calcareous, contains 10mm lenses of calcite-rich shale (white "speckled"), fossiliferous in parts (scattered zones of shell hash), 1-2mm interbeds of black cherty shale (photo 4054).

SUB-UNIT: LIMESTONE (100%) - dark grey, microstyalline, mottled, argillaceous, mod carbonaceous, contains 4+ near-vertical stylolite-like fractures lined with organic residue (W1mm, L60-90mm), 1 vertical calcite-filled hairline fracture, unit becomes slightly silty towards (photo 4503) base

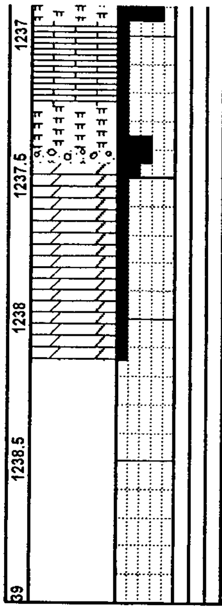
Mrlst, as above - brown streak, scattered calcite inclusions, finely interbedded with black chert (occasionaly lensoid), slickensided, white powdery sulfate residue.

Lst, as above - 50mm band of conglomorate, 15-20mm clasts of silty lst, well rounded, abundant calcareous "specks' surrounding, slight fining-up of calcite, sharp horizontal lower contact (photo 4055).

Mrlst, as above - irregularly thickening interbeds of black chert.

Lst, as above - stylolites, low relief, lined with organic residue, slightly argillaceous/silty at top.

Shaley-mudstone/marlstone - siliceous/dolomitic, top 10cm finely laminated, underlain by massive dark grey/black shale a calcite-rich interbeds, phosphate grains scattered throughout, occasional brown clay clast.



Conglomoratic, 15-20mm clasts brown/black cherty shale, well rounded, abundant calcareous "specks' surrounding, slight fining-up of calcite, sharp horizontal lower contact (photo 4055).

Lst - silty, argillaceous, minor shell hash flattened into interbeds.

Mrlst - slightly silty, contains 2cm dolomitic/silicified shale with 2mm calcite-filled fractures extending across core, 1.2cm band of shredded/brecciated shale & calcite in top 9cm,

UNIT: CONGLOMERATE - lower 9cm is finely conglomoratic, slightly silty, sub mm brown chert, phosphate and calcite grains, base marked by 2 horizontal black cherty shale bands, slightly wavy.

UNIT: DOLOMITE - cream/buff colour, mod argillaceous & carbonaceous, poor vuggy porosity, dense, scattered calcite inclusions, stylolite near conact lined with organic residue.

SAMPLES:

Sorption: 1234.2m, 1237.2m

TOC: 1) 1234.1m; 2) 1235.9m, 3) 1236.3m, 4) 1236.7m, 5) 1236.9m, 6) 1237.7m, 7) 1238.35m (Baldonnel)

Thin-section: 1238.2m (1.5cm shredded/brecciated shale & calcite).

EXtra photos: (CD#4) 4468-71 (basal contact region)

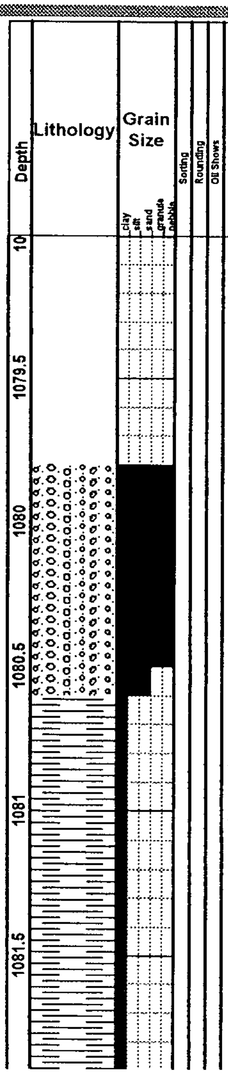
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Remington Lagarde 06-05-088-15		
Location:	00/06-05-088-15W6-0		
Licence Number:	06738	Region:	British Columbia
Spud Date:	10/20/1987	Drilling Completed:	11/12/1987
Surface Coordinates:	Lat: 56.600285 Long: -120.358124		
Bottom Hole Coordinates:	BH Lat: 56.600285 BH Long: -120.358124		
Ground Elevation (m):	696.9m	K.B. Elevation (m):	701.3m
Logged Interval (m):	1079.8m To: 1082.8m	Total Depth (m):	3m
Formation:	Cadomin/Fernie		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

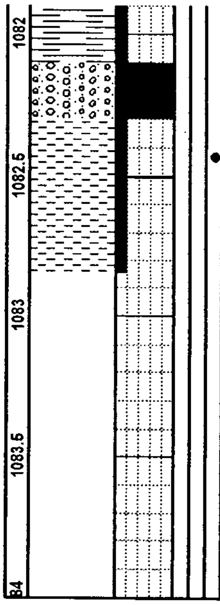
Core photo: 3940

UNIT : CRETACEOUS (?) CONGLOMERATE - med/dark grey with sandstone, top 200mm is very poorly indurated (sugary conglomerate), induration improves basewards, congl. is matrix supported, arenaceous-argillaceous, matrix med grey, argillaceous, clasts of quartz and chert (?), brown clay clasts, majority 3-5mm diameter, some 10-30mm diameter, angular-sub rounded, low-mod sphericity, some elongate horizontally. Sst fine-coarse grained, predominantly quartz, minor mica and feldspar.

In centre of unit, shale/clay/coaly interbeds, brown colour.

Base, congl. is finer, more organic-rich, irregular wavy stringers of black shale (photos 3941-43), fragments of green shale.

UNIT: SHALE (95%) - dark grey, green in parts, glauconitic, non-calcareous, fissile, mod-poorly indurated, disseminated pyrite, interbeds of light brown coaly/clay (?) - occur as discontinuous horizontal "blebs", occasional interbeds of green shale (photos 3944, 46).



UNIT: CONGLOEMRATE - sharp upper contact with overlying shale. silty/sandy matrix, dark grey/green, pyritic. micro-micaceous, mod indurated, clasts of well indurated clay (?), siliceous clasts (~8mm diameter), subangular-rounded, mod sphericity (photos 3950). contact with FERNIE FORMATION (?)

UNIT: MUDSTONE (100%) - Top NORDEGG (?), dark brown/black, non-calcareous, silicaeous/cherty, well indurated, contains 2 interbeds of poorly indurated green shale (2mm & 15mm thick) (photos 3947, 48), white powdery sulfate residue.

1082.5m+ not available

SAMPLES:

Sorption: 1081m (Fernie/PC), 1083.2m (Upper Nordegg)

TOC: 1) 1080.6m, 2) 1081m, 3) 1081.4m, 4) 1081.6m, 5) 1081.9m, 6) 1082.2m, 7) 1082.55m, 8) 1082.95m.

Extra samples: 1) Cret (?) conglomorate (1079.9m), 2) interbedded shale & brown shale (1081m), 3) Conglomorate of Basal Fernie/PC (1082.7m), 4) Contact between Cret congl. & Fernie/PC (1080.6m).

Extra Photos:

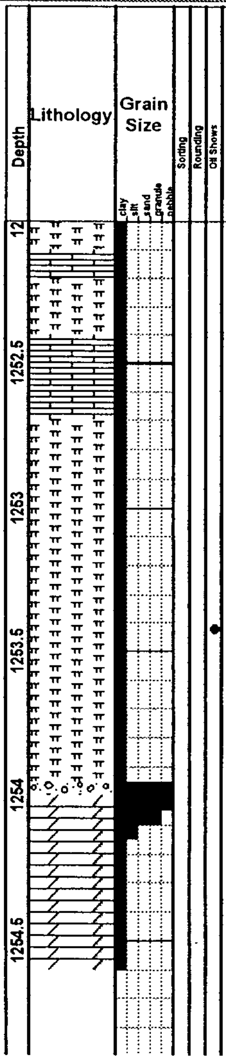
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Triquest Paradise 13-28-085-15
Location: 00/13-28-085-15W6-0
Licence Number: 07912
Region: British Columbia
Spud Date: 06/24/1992
Drilling Completed: 07/03/1992
Surface Coordinates: Lat: 56.403950
Long: -120.314163
Bottom Hole Coordinates: BH Lat: 56.403950
BH Long: -120.314163
Ground Elevation (m): 763.1m
K.B. Elevation (m): 767.6m
Logged Interval (m): 1252.0m To: 1254.6m
Total Depth (m): 4.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, mod carnonaceous & petroliferous, finely interbedded with black chert, occasional black chert nodules (~7mm diameter).

SUB-UNIT: LIMESTONE (100%) - dark grey, microcrystalline, mottled, argillaceous, mod petroliferous, occasionaly finely interbedded with black shale, sharp lower & upper contacts, base marked by 2mm green shale (?) band.

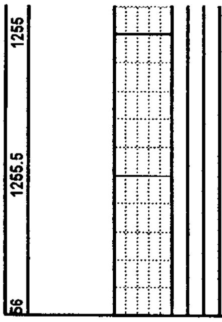
Mrlst, as above - occasionally finely interbedded with lst, calcite specks, minor vertical hairline fractures filled with calcite (W 0.2mm, L 20mm).

UNIT: CONGLOMERATE - chert nodules (~15mm diameter), scattered phosphatic (?) white specks, (photos 3884, 85, 86), white powdery sulfate residue.

UNIT: DOLOMITE - very argillaceous, top 5cm: med grey, disrupted bedding (solution breccia?), slightly calcareous, base marked by 15mm lag deposit, 1-2mm grains of opalescent blue quartz and chert.

UNIT: DOLOMITE - med/light grey, argillaceous, mod carbonaceous, good vuggy porosity, stringers of black shale common near contact, 60cm down - brecciated with fractures filled with calcite..

(Core photo - 3888)



SAMPLES:
Sorption: 1253.5m
TOC: 1) 1252.1m, 2) 1253.5m, 3) 1253.9m
Extra sample: 1252.7m (base lst with green shale band at base).

LITHOLOGY STRIP LOG

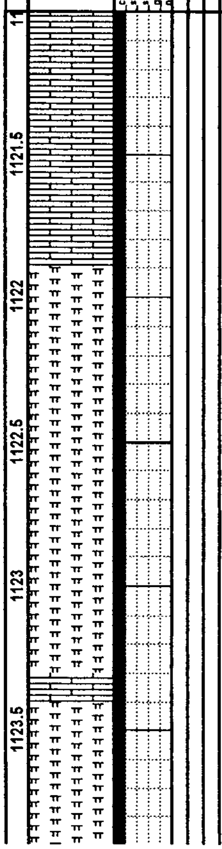
WellSight Systems

Scale 1:20 Metric

Well Name: Calpine Et al Oak 02-02-086-18
Location: 00/02-02-086-18W6-00
Licence Number: 08153
Region: British Columbia
Spud Date: 07/11/1993
Drilling Completed: 07/20/1953
Surface Coordinates: Lat: 56.423767
Long: -120.722618
Bottom Hole Coordinates: BH Lat: 56.423767
BH Long: -120.722618
Ground Elevation (m): 654.4m
K.B. Elevation (m): 658.9m
Logged Interval (m): 1121m To: 1131m
Total Depth (m): 10m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



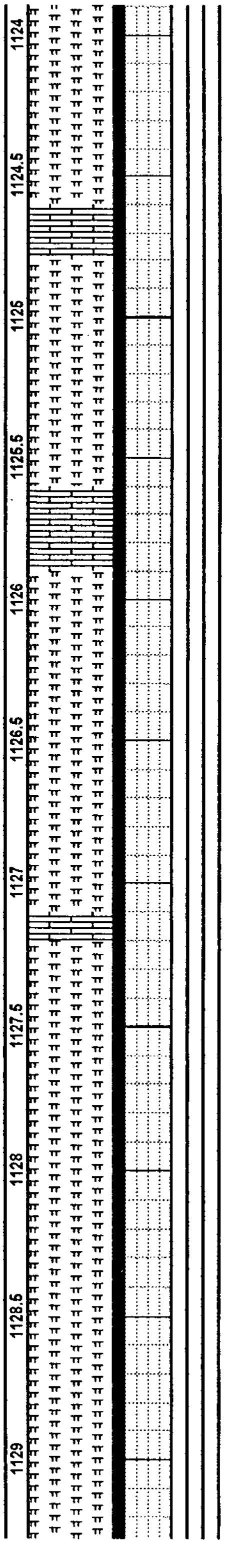
SUB-UNIT: LIMESTONE (100%) - dark grey/black, carbonaceous, strong petroliferous odour, microcrystalline, mottled appearance, 10mm shell hash band, tainted brown (bitumen stained?). Base of lst marked by 15mm concentration of coarse calcite.

UNIT: PHOSPHATIC MARLSTONE (98%) - black, calcareous, petroliferous, interbedded with lst, fossiliferous in parts. Sparse, interlaminations with irregular/discontinuous calcite (shell hash - 0.5mm thick, 20mm length). White speckles common throughout. Interbedded dark grey/brown shale (very friable, fragmented in core box) (photos 3564, 3568). Contains 1 calcite "nodule", highly spherical, 10mm diameter, slightly bitumen-stained.

30mm section - 8mm coarse calcite band, 4mm blackMrlst, 5mm green shale, 15mm of calcite (coarsening up towards green shale, silt/fine sand grain size) (photo 4216, CD #3).

Lst, as above - sharp contacts, 10 deg below horizontal.

Mrlst, as above - interbedded with black (almost platey?) shale. White powdery residue common (sulfur?), shell hash common.



Lst, as above.

Mrlst, as above - minor calcite "specks".

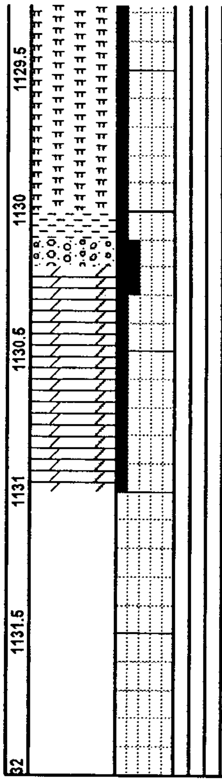
Lst, as above - 2 near vertical fractures, calcite filled (minor bitumen-filling within centre of fracture (?)), W0.2mm, L~25mm, 15mm apart.

Mrlst, as above - Pecten (?) preserved (photo 3579).

Lst, as above - sharp lower/slightly diffuse upper contact with shale.

Mrlst, as above - phosphatic and calcareous rich, slightly pitted texture (dissolution - from drilling?), shell hash common, bitumen/oil stained.

UNIT: CONGLOMERATE, med grey matrix - non-calcareous and argillaceous, non-calcareous black shale occurs as occasional 4mm horizontal interbeds (slightly



wavy) and occasional well rounded clasts, 5mm diameter, clay clasts (brown) & silty lst clasts - 5-10mm diameter, slightly elongate horizontally. Near base, clay clast terminates bedding whereas 30mm above, shale clast contorts bedding (photos 4209, 13, 14, 15, CD #3).

Interbeds of shale and silty lst occur as micro-clinoforms (?), these structures become less distincy farther up in section (photos). Top of unit marked by silt-fine sand sized calcite, sharp upper contact, 20 deg below horizontal.

UNIT: DOLOMITE - med brown, marginaly arenaceous -argillaceous, microcrystalline, minor calcite, disseminated bitumen, fossiliferous, cherty in part (white/brown). Cryptocrystalline away from contact, carbonaceous in part. Shows good vuggy porosity with minor fractures filled with calcite. Top of unit is also a fine conglomorate, 1-2mm chert, clay and shale clasts (Nordegg?), subangular, slightly calcareous matrix.

Contact with Nordegg is sharp, slightly curvilinear, orgainc-rich stringers penetrate top 3-4mm of Triassic Unit.

SAMPLES:

Sorption: 1129m

TOC: 1) 1122.9m (green shale interbed), 2) 1123.3m, 3) 1128.0m, 4) 1129.5m, + 2 original samples (1128.8m & 1129.9m)

Thin-sections: 1121.9m (calc/blck shale/green shale/calc interbeds), 1129.8m (shell hash), 1130.1m (Contact).

LITHOLOGY STRIP LOG

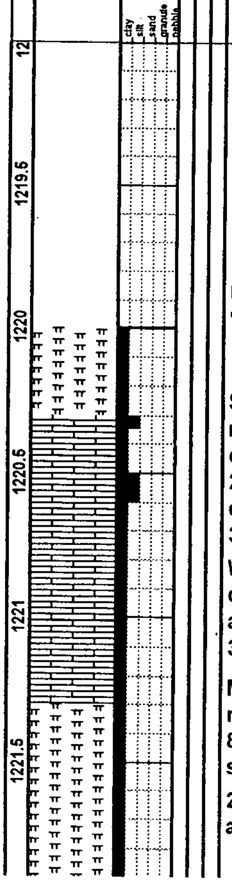
WellSight Systems

Scale 1:20 Metric

Well Name: CNRL Et Al Birch B- 091-I/094-A-13
Location: 200/b-091-I 094-A-13/00
Licence Number: 08155
Region: British Columbia
Spud Date: 07/06/1993
Drilling Completed: 16/06/1993
Surface Coordinates: Lat: 56.99509
Long: -121.50927
Bottom Hole Coordinates: BH Lat: 56.99509
BH Long: -121.50927
Ground Elevation (m):
K.B. Elevation (m): 793.1m
Logged Interval (m): 1220m To: 1223.6m Total Depth (m): 3.6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



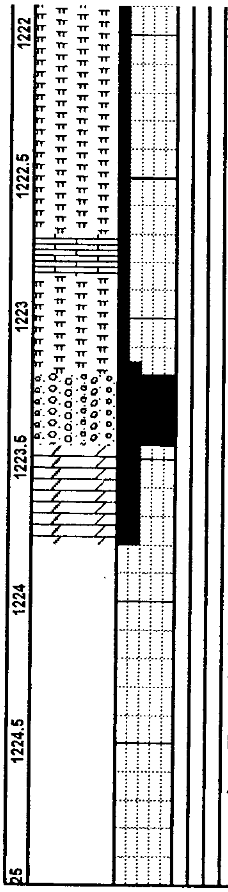
UNIT:PHOSPHATIC MARLSTONE (100%) - black, calcareous, petroliferous odour, calcite "specks" near top of unit, fractured, white powdery sulfate residue.

SUB-UNIT: LIMESTONE (95%) - dark grey/black, carbonaceous, microcrystalline, mottled, finely interbedded with black shale, upper contact marked by 10mm concentrated calcite band, angled at 10 deg below horizontal (photo 3983), overlying 2mm black chert and minor shale hash, massive lst underlying, contains 1 black shale clast (~6mm diameter), 1cm shale interbed @ 1220.5m, lst coarsens then fines upwards, 30mm lense of black shale, distorts surrounding stylolites.

Within top 300mm, several stylolites, low relief, (W~0.2mm). Lower lst - vertical fractures dominant, non-planar (L~60-80mm), occasional oblique fractures, 15 deg off vertical. Lst also contains slightly silty bands (~30m thick). Fining-up of calcite at base. (photos 3984, 85).

Mrlst, as above - slightly brown in parts with interbedded black chert, occasional chert nodules, upper conact with overlying lst marked by coarse calcite band (3mm thick). 80mm below contact - 25mm calcite band with relatively diffuse upper contact, sharp/irregular lower contact, scoured appearance (photos 3986, 87).

20mm, bracciated Mrlst, calcite-fill, (W0.1mm, L15mm) (photo 3988), 3 black shale clasts at top, calcitic rims, 1.5-15mm diameter, slightly elongate horizontally.



10mm calcite band, irregular sharp upper and lower contacts, nodules of well rounded, black chert (photo 3989)

Slickensides.

Lst, as above - shaley towards base, very finely laminated.

UNIT: BRECCIA/CONGLOMORATE - med/dark grey, top marked by irregular horizontal stringers of black shale (top Nordegg?), matrix is argillaceous and non-calcareous, carbonaceous, clasts of silty lst (25mm diameter) & dolomite, well rounded, 20cm of sub mm qtz and calcite grains. Sharp lower contact with underlying light grey dolomitic unit (photos 3990, 91, 92).

UNIT: DOLOMITE - light/med grey, mod argillaceous & carbonaceous, excellant vuggy and moldic porosity, calcitic in parts, fractures lined with bitumen near contact.

SAMPLES:

Sorption: 1220.25m, 1222.7m.

TOC: 1) 1220.3m, 2) 1221.7m, 3) 1222.1m, 4) 1222.4m, 5) 1222.6m, 6) 1222.8m, 7) 1223.2m.

Extra photos: (CD#4) 4450-57

Thin-section: 1220.5m (lst with bitumen stylolites)

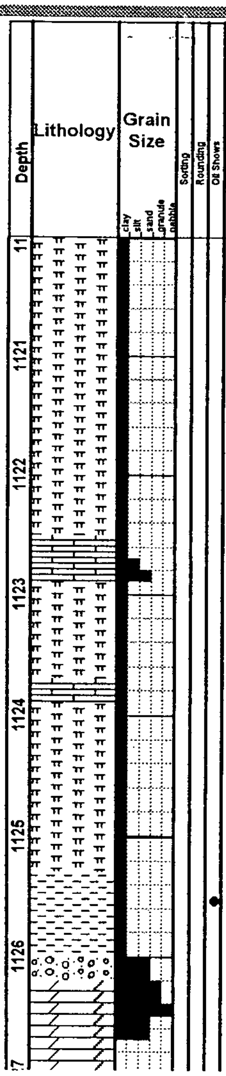
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	Calpine Et Al Oak 04-12-086-18		
Location:	00/04-12-086-18W6-0		
Licence Number:	08262	Region:	British Columbia
Spud Date:	11/06/1993	Drilling Completed:	01/26/1994
Surface Coordinates:	Lat: 56.438568 Long: -120.709244		
Bottom Hole Coordinates:	BH Lat: 56.438568 BH Long: -120.709244		
Ground Elevation (m):	648.9m	K.B. Elevation (m):	653.7m
Logged Interval (m):	1120.0m To: 1127.2m	Total Depth (m):	7.2m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - dark brown/black, calcareous, finely laminated, fossiliferous, grades to lst in part, discrete bands of lst (10-15mm thick) underlain by 3mm green shale band, horizontal calcite-filled fractures(?) (W 0.3mm, L 15mm) (photos 3889, 90). 250mm from top of core - remains of med green shale interbed.

White powdery residue common.

SUB-UNIT: LIMESTONE (100%) - dark grey, microcrystalline, mottled, slightly argilaceous, carbonaceous, fining-upwards of calcite, sharp lower contact/mod diffuse upper (gs~ 350u). (photo 3891)

Mrlst, as above.

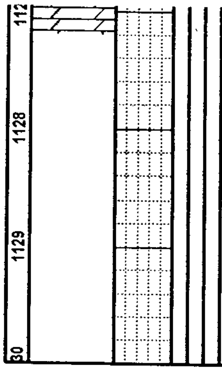
Lst - dark brown/grey, slightly silty, finer grained than above lst unit (gs~ 125u), no fining up sequence, sharp lower & upper contacts.

Mrlst, as above.

Lowest 55cm is less calcareous, lst/calcite stringers relatively common (irregular & discontinuous), lst nodules (~15mm diameter), scattered phosphate specks, base Nordegg marked by a near horizontal 20mm non-calcareous black shale bed ontop of fine congl (of underlying Triassic?).

UNIT: CONGLOEMRATE - matrix supported, chert/mudstone nodules, well rounded, phosphatic specks common.

UNIT: DOLOMITE - dark grey, microcrystalline, mod argillaceous & carbonaceous, poor vuggy porosity. Top 30cm is a fining-up conglomorate with abundant chert nodules (white/light grey, 2-3mm diameter), slightly fractured.



Grades down into a med/light grey, argillaceous, mod calcareous congl. Larger chert (white/grey) clasts with mod roundness & low sphericity, occasional stringers of black shale (photos 3893-96), bituminous, stylolites, improvement of vuggy porosity.

SAMPLES:

Sorption: 1124.5m

TOC: 1) 1120.2m, 2) 1120.5m, 3) 1121.1m, 4) 1121.9m, 5) 1123.5m, 6) 1124.0m, 7) 1124.8m, 8) 1125.2m, 9) 1126m, 10) 1126.5m (+ original sample @ 1125m)

Extra photos (CD#3) : Base Nordegg (4316), Bald. congl.(4317) & Ist fining-up sequence (4319).

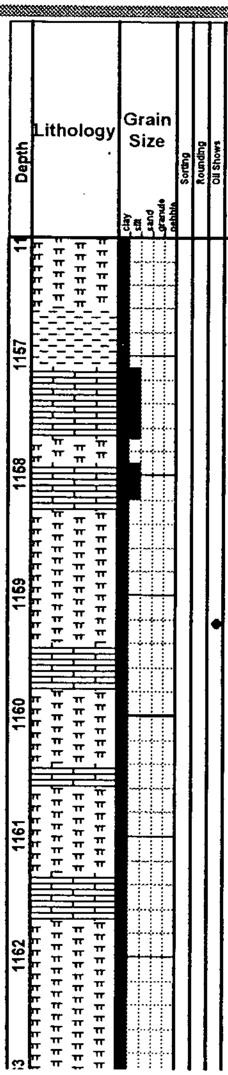
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Calpine Et Al Oak 11-32-086-18
Location: 00/11-32-086-18W6
Licence Number: 08354
Region: Britsh Columbia
Spud Date: 12/19/1993
Drilling Completed: 12/27/1993
Surface Coordinates: Lat: 56.503201
Long: -120.809212
Bottom Hole Coordinates: BH Lat: 56.503201
BH Long: -120.809212
Ground Elevation (m): 692.6
K.B. Elevation (m): 697
Logged Interval (m): 1156.0 To: 1167.4
Total Depth (m): 11.4
Formation: Nordegg
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE(100%) - black, calcareous, pyritic and sometimes carbonaceous, fossiliferous. Interbedded with fine laminations of lst (mottled appearance).

MUDSTONE (100%) - dark green, non-calcareous.

SUB-UNIT: LIMESTONE (95%) - light grey, microcrystalline, mottled, mod petroliferous, slightly argillaceous & carbonaceous. Interbeds of black shale and calcite-rich laminae (shell hash?), calcite fines upwards, sharp /horizontal lower and upper contacts.

Mrlst - green shale interbeds (very friable, wavy appearance, silt-sized calcite either side of the green shale interbeds), green shale interbeds fractured and filled with bitumen (very bright - vitrinite rich?, (photo 4193, CD#3) occasional black platey (shale?) blebs orientated horizontally (photo 3640)

Shell hash concentrated into 15mm band (photo 3637)

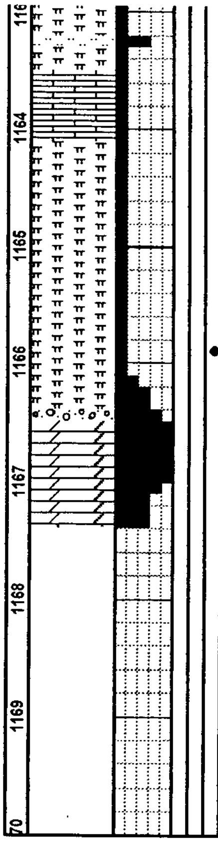
Mrlst, lst interbed with vertical irregular calcite-filled fractures (0.7mm thick, up to 70mm length, photo 3641)

Lst - crinoids common, 2 calcite-filled fractures (slightly bitumen-stained), near vertical (W1mm, L40&70mm)

Mrlst, slightly silty in places with 4 stylolite-like features with insoluble organic residue, orientated 20 deg below horizontal.

Lst, abundant brown platey specks (biotite?).

Mrlst, as above.



Silty sandy bed - coarse (siliceous cherty fragments?)

Mrlst, black platey interbeds and lenses, 30 deg below horizontal, 2-5mm thick.

Lst - light brown platy fragments (?) horizontally alligned. <0.5mm thick, ~3mm length (photo 3642), fining upwards sequence of calcite grains, base marked by 3mm pale green shale (?) band.

Mrlst, dark brown/black, with lst interbed (photo 3644)

UNIT: CONGLOMERATE - 50mm of interbedded (sub-mm) black shale, silty lst intermixed with 1-2mm phosphate grains and clasts of black shale, 1-2mm diameter, subrounded-subangular. Within 50mm zone laminae more planar at top & more wavy/irregular at base.

UNIT: DOLOMITE (9%) - light grey, argillaceous, slightly microcrystalline, petroliferous odour, moldic porosity common but partially filled with calcite, vague horizontal bedding. Petroliferous odour. Upper 70mm poorly sorted congl. Clasts of chert and phosphate. Irregularly interbedded black shale (photo 3645), fractures with calcite-fill cross cut upper unit and terminate against base of Nordegg..

SAMPLES:

Sorption: 1156.5m, 1165.3m

TOC: 1) 1156.2m, 2) 1156.6m, 3) 1156.9m, 4) 1157.3m, 5) 1157.9m, 6) 1158.7m, 7) 1159.1m, 8) 1159.8m, 9) 1160.5m, 10) 1160.8m, 11) 1161.8m, 12) 1162.8m, 13) 1163.5m, 14) 1163.8m, 15) 1165.3m, 16) 1165.7m.

Thin-sections: 1) 1164m (biotite in lst), 2) 1164.3m (coarse calcite band), 3) 1166.1m (contact Nord/Trias)

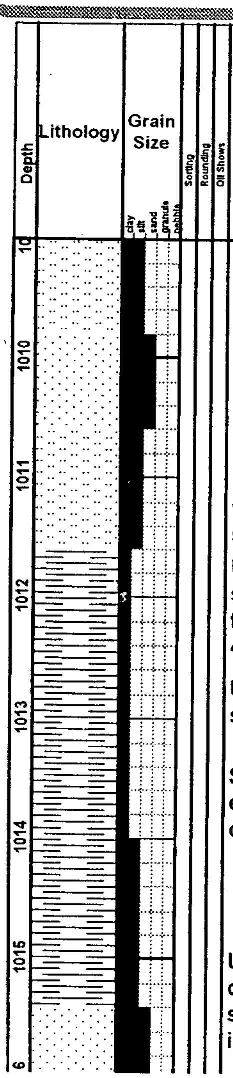
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name:	CNRL Doig A-058-K/094-A-16		
Location:	A-58-k/094-A-16		
Licence Number:	09351	Region:	British Columbia
Spud Date:	03/09/1995	Drilling Completed:	03/18/1995
Surface Coordinates:	BH Lat: 56.958378 BH Long: -120.341690		
Bottom Hole Coordinates:	BH Lat: 56.958378 BH Long: -120.341690		
Ground Elevation (m):	730m	K.B. Elevation (m):	734.4m
Logged Interval (m):	1009m To: 1021.8m	Total Depth (m):	12.8m
Formation:	Gething/Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: SILTSTONE (95%)- med grey, slightly carbonaceous and argillaceous, pyritic, upper section contains 30mm zone of coarse quartz grains and clays (?), occasional interbeds of very fine sst, med brown, shale interbeds, dark grey/black, organic-rich stringers common.

UNIT: SANDSTONE (100%) - light grey/brown, framboids of pyrite common, occasional coarse quartz grains, fine interbeds of slst, med brown/grey, slightly sideritic, silica cement, quartz overgrowths, slightly bituminous.

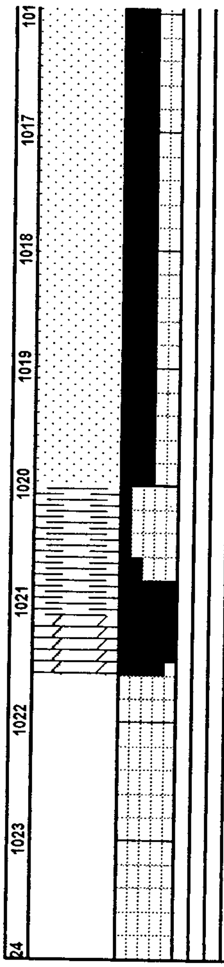
UNIT: SILTSTONE - (95%, 0.5m) light grey/brown, argillaceous, pyritic, thin/irregular interbeds of black shale, micromicaceous, occasional sst interbeds, light grey/cream, very fine-grained, framboids of pyrite (20mm diameter), unit shows a slight fining-up sequence.

UNIT: SILTSTONE - (100%, 0.6m) - med grey/brown, sharp upper contact with overlying sltst, marked by vertical burrows infilled with overlying slst, slst above slightly coarser, fine interbeds of dark grey/black shale, large pyrite framboids (40mm diameter) (photo 4101).

UNIT: SHALE - MUDSTONE (100%) dark grey, non-calcareous, pyritic, interbedded with slst, med brown, argillaceous, increasingly silty towards base (light grey colour).

Shale (100%, 2.8m) - black, non-calcareous, pyritic, interbedded with med grey slst, extremely friable in parts, black coal laminae (70mm thick) near top (photo), gradational contact to overlying shale (photo 4102), contains 80mm green shale band, very fissile.

UNIT: SANDSTONE - (90%, 2m) med grey, very fine grained, slightly pyritic, minor clay content, upper 30mm marked by fine CONGLOMORATE, predominantly quartz (2-3mm), siliceous, slightly argillaceous, cherty, pyritic, slightly carbonaceous, occasional interbeds of black shale thoughout the sst (photo 4107).



UNIT: SANDSTONE - (100%, 0.9m) light grey/cream, sharp/very angular contact with overlying sst, occasionally interbedded with black shale and ned grey/brown slst, vuggy porosity (?), occasional open fractures, shows compressional deformation with contorted bands of med brown slst, clasts (10-15mm) of dark grey slst, partially disolved out (photos 4108, 09).

UNIT: SANDSTONE - (1.8m) med grey, quartzose, slightly bituminous, finely interbedded with black shale, occasional light brown clasts of slightly coarser sst (10mm diameter, well rounded), clasts of light grey/cream sst which are fractured and filled with dark grey very fine sst/slst, occasional interbeds of cream sst (80mm thick), fractured and filled with sst unit. Base of sst: clasts of quartz/chert, blue, 2-8mm diameter, subangular-subrounded, low sphercity (photo 4110), bioclastic debris.

Improvement of intergranular porosity towards base, PELECYPOD shell debris (?), interbeds of brown sst.

UNIT : SHALE (100%, 0.8m) - sst grades into med/dark grey shale, flame structured (injected?) med brown very fine-grained sst, becomes more dolomitic towards base-more brown, large silica-rich fossiliferous clasts (70mm diameter) with black shale beds contorting around, occasional dark grey slst clasts, pyritic, silica clasts show blue zoning, some clasts partially dissolved leaving mod vuggy porosity, also fractured/brecciated (photos 4111-13).

UNIT: DOLOMITE (100%) - med brown, microcrystalline, silty, poor vuggy porosity, occasional shale interbeds, stylolite near contact, chert clasts common (~80mm diameter), argillaceous, shell debris (Gastropods/Crinoids/ Pelecypod ?), sharp contact with overlying shale.

SAMPLES:

Sorption: 1013.1m

TOC: 1) 1013.8, 2) 1014.6m, 3) 1015m.

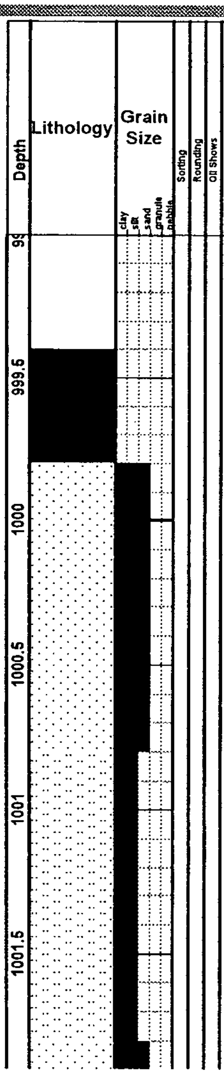
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Calpine Et Al Doig
Location: A-084-F/094-A-16
Licence Number: 09430 — Region: British Columbia
Spud Date: 09/01/1995 — Drilling Completed: 09/10/1995
Surface Coordinates: BH Lat: 56.902298
BH Long: -120.290092
Bottom Hole Coordinates: BH Lat: 56.902298
BH Long: -120.290092
Ground Elevation (m): 700.5m — K.B. Elevation (m): 704.7m
Logged Interval (m): 999.4m To: 1010.4m Total Depth (m): 10m
Formation: Gething/Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

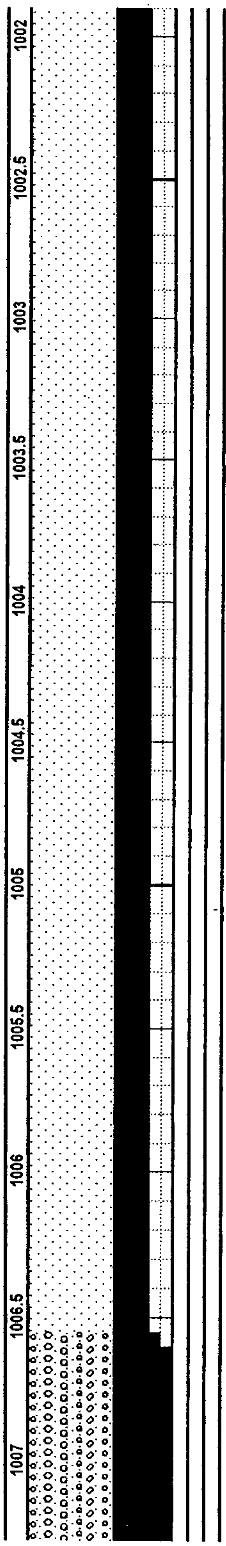
UNIT: COAL (100%) - grades from bright down to dull at base, clarain-rich, dense, arenaceous towards base (very fine white specks), sandy.

UNIT: SANDSTONE (100%) - very fine grained, med/dark grey, argillaceous, gradational contact with overlying coal, upper section shows coal spar (2-3mm width, 40mm length), towards base - sst med/light grey, more brecciated and siliceous, rip-up clasts of fine grained slst/mudstone (dark grey), shows differential compaction, fine sst clasts (10-15mm diameter) which have dark slst "halos" (diagenetic?), fractured at base, carbonaceous slickensides showing, partially lined with silica.

Slightly oil-stained.

UNIT: SANDY-SILTSTONE (100%) - med/dark grey, mottled with dark slst and slightly coarser/lighter sst, intergranular pyrobitumen, base marked by rip-up clasts of dark sitly mud with injection of coarse silty sst. Upper contact sharp and near horizontal.

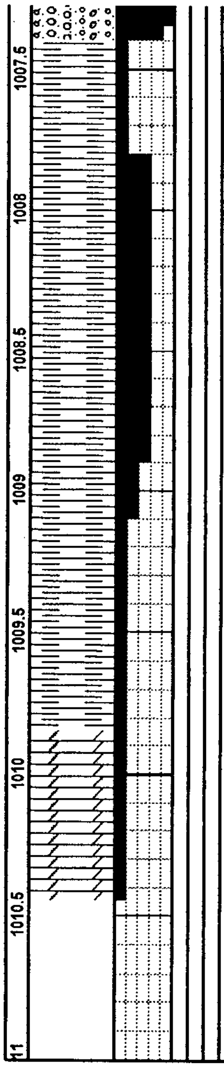
UNIT: SANDSTONE (100%) - dark grey, fine grained, brecciated, injenctions of cream fine



sst, also occurs as interbeds, occasionally contains clasts of dark grey, fine silty sst, angular (2-10mm), microfractured.

UNIT: SANDSTONE (100%) - med grey/brown, fine-grained, extremely brecciated and congl., sst injections common, rip-up (?) clasts of dark grey slst (2-5mm)orientated on a plane 30 deg above horizontal, larger (~10mm) of dark grey slst, slightly calcitic, occasional stringers of dark shale (?), gives fibrous texture.

Conglomerate - fine dark grey sst matrix, 7-45mm silica clasts, subangular-subrounded, slightly calcitic within the clasts, organic-rich stringers common towards base of unit.



UNIT: SHALE (100%) - med/dark grey, silty in parts, occasional slickensides, contact with overlying congl missing from core box. Non-calcareous, upper 200mm marked by interbedded slst orientated 30 deg below horizontal, white phosphatic (?) grains common.

Extremely brecciated/conlg farther down, silica-rich clasts up to 60mm diameter, sst nodules and sst injections, some have a slight blue rim surrounding, clasts occasionally partially disolved leaving unfilled voids, slightly dolomitic near base.

Light grey, fine grained stringers of sst, interbedded with shale, soft sediment deformation, some buff coloured clasts (dolomite?), angular, 30-40mm which are cross-cut by calcite filled fractures.

UNIT: DOLOMITE (100%) - cream/buff, microcrystalline, silty in parts, interbeds of dolomitic slst, mod argillaceous and carbonaceous, horizontal stylolite with insoluble organic-rich residue, poor vuggy porosity, slight oil-staining.

SAMPLES:

Sorption: 1006.8m

LITHOLOGY STRIP LOG

WellSight Systems

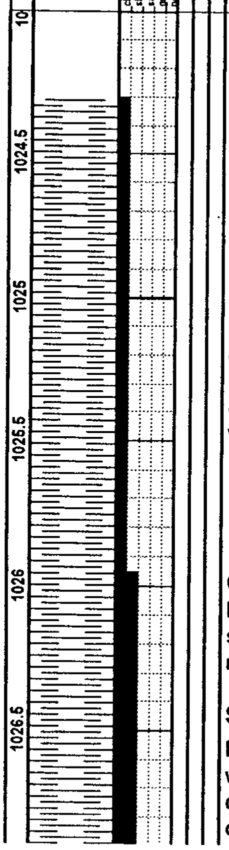
Scale 1:20 Metric

Well Name: PIONEER DOIG A- 073-K/094-A-16
Location: 200/a-073-K 094-A-16/00
Licence Number: 9682
Spud Date: 1997/02/02
Surface Coordinates:
Region: British Columbia
Drilling Completed: 1997/02/10

Bottom Hole Coordinates: BH LAT: 56°58'39.036" N
BH LON:120°16'48.720" W
Ground Elevation (m):
K.B. Elevation (m): 746.5m
Logged Interval (m): To:
Total Depth (m):
Formation:
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com

Depth	Lithology	Grain Size	Sorting	Rounding	Oil Shows	Geological Descriptions



UNIT: SHALE (100%) - black, non-calcareous, sub-fissile, slightly carbonceous, dark lithic & glauconite grains, extremely pyritic which occurs as framboids (30mm diamater) and interbeds (up to 8mm thick). One 1mm framboid of pyrite showing soft sediment deformation with laminae conorted around base, planar lamination across the top.

Contains 100mm section showing bioturbation, vertical, extremely sinuous, some discontinuous, thickness ranges from 1-4mm, length 60-70mm, infilled with pyrite and other argillaceous material, slightly silty (med grey/brown colour) .

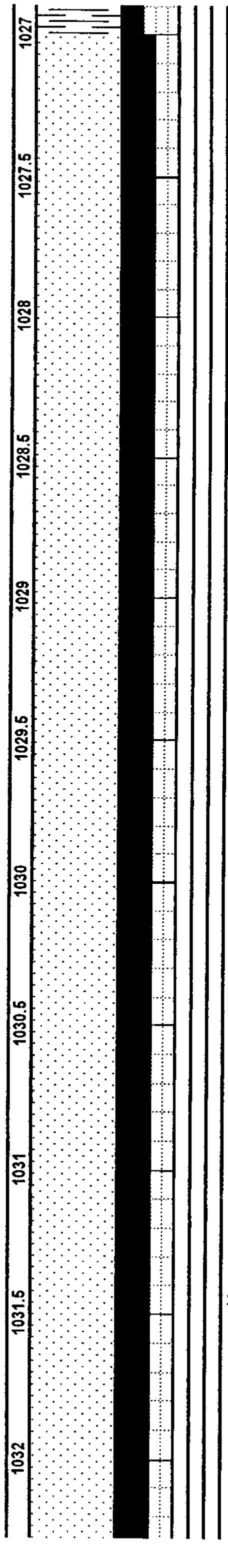
(photos: 4079, 80)

80mm section with 1 prominant vertical fracture, white filled, non calcareous, very soft, width ~1mm, length terminated by core.

Grades into med brown silty shale - argillaceous, mod carbonaceous, occasional sand lenses (gs 250-450 u) and as interbeds, quartz rich, occasional interbeds of black shale, slst-fine sand near base, dolomitic cement in parts (?). Sst intermixture gives silty-shale mottled/patchy appearance (photos 4083, 84).

Silty shale grades to med/dark grey.

Bottom 90mm, marked by fine CONGLOMORATE, intermixture of organic-rich material with cream/buff fine grained sst, angular clasts of slst (1-2mm diameter), grey/brown chert & lithic grains, black organic rich laminations contorted around large angular clast of silty sst (70mm diameter), showing soft sediment deformation /compressional

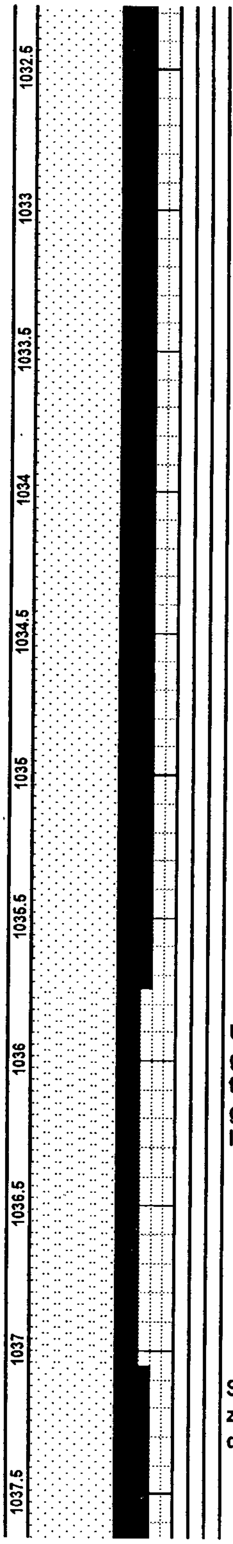


features, slightly pyritic (photo 4086).

UNIT: SANDSTONE (100%) - cream/buff, fine grained, low density, organic-rich stringers throughout, pitted texture in discrete zones and green specks (small clasts of green shale?, 1-2mm) (photo 4087), mod intergranular porosity.

UNIT: SANDSTONE (100%) - dark cream/light grey, fine grained, mod argilaceous, organic-rich stringers common.

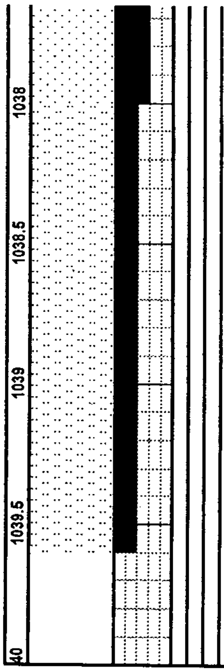
Sst, fine grained, cream/buff - as sst at 1027m.



Sst - med/dark grey, fine grained, fine interbeds of dark grey/black shale, slightly pyritic, chert and lithic grains common (mm scale), soft-sediment deformation (slump structures ?), matrix can be shaley in parts, slightly cleaner sst than above (mod intergranular porosity).

UNIT: SILTSTONE (95%) - gradational contact with overlying sst, dark grey, contains green shale clasts (?), well rounded (~5mm diameter), abundant lime green/soapy textured stringers (serpentinite/glauconite (?)), grades down into brecciated texture, lime green stringers contain brown silty clasts, elongate horizontally (4-5mm width, 15-20mm length) (photos 4089, 90).

Sst, fine grained, med brown, sharp/straight contact, 25 deg below horizontal, contact zone marked by intermixture of cream/buff med-fine grained sst, med brown fine sst and dark grey silty-sst, slightly conglomoratic with med-fine grained brown sst.



UNIT: SILTSTONE (100%) - dark grey, fine sandy (cream/buff) stringers, horizontal, 4-5mm length, 1mm thick, bottom 700mm changes sharply into a coarse conglomorate, silica-rich clasts, 50-60mm diameter, subangular-subrounded, green limey material surrounds some clasts, very little dark grey slst as seen above, very brecciated/fractured, silica clasts broken into smaller (1-2mm), more angular clasts which "float" in lime green matrix, occasional interbeds of pyritic green shale (photo 4091).

SAMPLES:
Sorption: 1025.1m

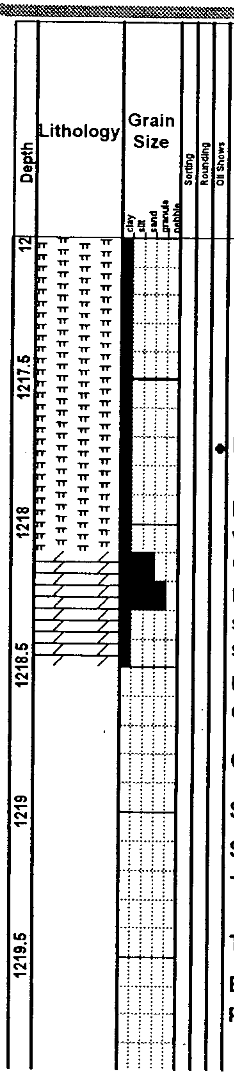
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name: Calahoo Montney 16-26-086-19
Location: 00/16-26-086-19W6-0
Licence Number: 14046
Region: British Columbia
Spud Date: 08/18/2001
Drilling Completed: n/a
Surface Coordinates: Lat: 56.491161
Long: -120.877068
Bottom Hole Coordinates: BH Lat: 56.491161
BH Long: -120.877068
Ground Elevation (m): 741.7m
K.B. Elevation (m): 745.8m
Logged Interval (m): 1217m To: 1218.5m
Total Depth (m): 1.5m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (100%) - black, brown streak, calcareous, mod carboanceous, slightly silty, mod petroliferous odour, scattered shell hash. Contains 10cm of dark grey non-calcareous shale (rubble), soft, friable.

Near base, concentration of phosphatic flecks horizontally alligned (photo 3933).

Mrlst- basal 3cm siliceous-cherty/dolomitic (photo 3934).

Mrlst sits sharply upon 13cm of argillaceous DOLOMITE, dark brown, disrupted bedding with black shale (solution breccia?), sub mm qtz crystals scattered throughout, some chert (photo 3937).

UNIT: DOLOMITE - med/light brown, texture as above, 8mm of silliceous black shale seperating from upper dolomite, stringers of black shale common away from contact, sharp contact with underlying massive DOLOMITE

UNIT:DOLOMITE - cream/buff colour, extremely argillaceous, poorpin-point porosity, oil-stained.

Core photo: 3932

SAMPLES:

Sorption: 1217m

TOC: 1) 1217.2m (non calcreous friable dark grey shale), 2) 1217.6m, 3) 1218.1m.

Thin-section: 1218m (phosphate flecks?)

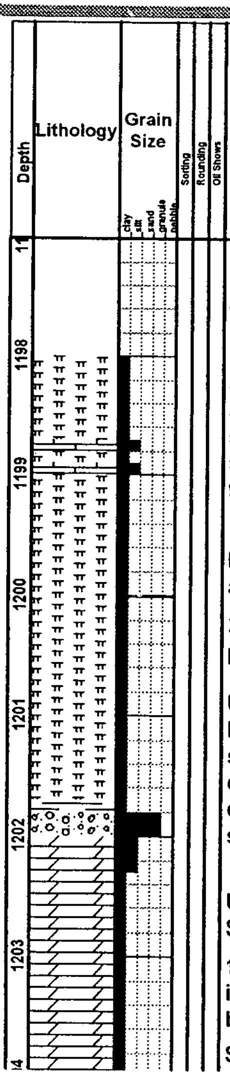
Extra sample: 1218.2m (upper brecciated dolomite zone, 13cm slabbed, below phosphate flecks).

LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:48 (25"=100') Metric

Well Name: Calahoo Montney 10-30-086-18
Location: 00/10-30-086-18W6-00
Licence Number: 14270
Region: British Columbia
Spud Date: 08/29/2001
Drilling Completed: n/a
Surface Coordinates: Lat: 56.487000
Long: -120.826706
Bottom Hole Coordinates: BH Lat: 56.487000
BH Long: -120.826706
Ground Elevation (m): 726.9m
K.B. Elevation (m): 730.9m
Logged Interval (m): 1198m To: 1204m
Total Depth (m): 6m
Formation: Nordegg/Baldonnel
Type of Drilling Fluid:



Geological Descriptions

UNIT: PHOSPHATIC MARLSTONE (95%) - dark grey/black, calcareous, highly petroliferous, finely laminated. Interbedded with black chert (?) (laminae thickens and thins irregularly, occasionally lensoid, photo 3621). Horizontal fractures, 25mm width/10mm length, calcite filled, 15mm apart.

SUB-UNIT: LIMESTONE (95%) - dark grey/black, microcrystalline, carbonaceous, mottled appearance, mod petroliferous, finely interbedded with black shale, laminae slightly wavy. Sharp planar upper contact with shale - approx 20 deg below hprizontal, sharp irregular lower contact (photo 3626). Upper lst contains 1cm blocky plant (?) fragment (photo), dull. 2nd lst has sharp lower contact, almost flame-like (photo).

Mrlst, as above - contains 40mm interbeds of poorly indurated green shale (photo 3630), abundant white "specks" in shale directly below green shale.

2cm calcite band, sharp planar contacts, intermixed with shell hash.

Mrlst becomes less calcareous towards base.

UNIT: CONGLOEMRATE top 1cm is finely laminated shale and lst, slightly rippled, 2cm below: massive shale, dark grey, slightly dolomitic/siliceous, mod argillaceous, scattered nodules of brown chert (?), 2-4mm diameter, subangular-subrounded, dissolution at base leaving pitted texture. 80mm: black shale, sharp irregular upper contact, 1 black chert (?) clast, ~8mm diameter, subangular. 1cm: interbedded black shale and silty lst, one 15mm clast of dark brown chert (?), laminations contort around.

UNIT: DOLOMITE
Scattered phosphate grains

1cm: slightly argillaceous shale, dark grey, dissolution texture as seen previously. 2cm: interbedded black shale and silty lst, discontinuous and wavy (stringers), base marked by 4mm black chert (?) band.

Sharp change to fine CONGLOMORATE (marking top of TRIASSIC ?), med brown argillaceous matrix, stringers of black shale, sub mm chert and qtz grains, congl. coarsens downwards, angular black shale clasts (Nordegg?), up to 10mm diameter, blue quartz rich near base.

Grades into DOLOMITE - light grey, argillaceous, mod carbonaceous & calcitic, mod vuggy porosity (partially infilled with calcite).

SAMPLES:

Sorption: 1198.5m, 1201.5m.

TOC: 1) 1198m, 2) 1198.45m (showing shale/chert interbed), 3) 1198.75, 4) 1198.85m, 5) 1199.15m (shale/lst contact, flame-like structure), 6) 1199.45m, 7) 1199.75m, 8) 1200.05m, 9) 1200.2m, 10) 1200.6m, 11) 1201.0m, 12) 1201.3m, 13) 1201.5m, 14) 1201.7m, 15) 1201.8m, 16) 1202m.

Thin-sections: 1198.45 (chert/shale interbed), 1199.15m (lst/shale contact, flame-like structure), 1198.5m (stylolites in shale), 1202.1m (contact).

Extra sample - 1200.6m (lst/calcite interbed within shale).

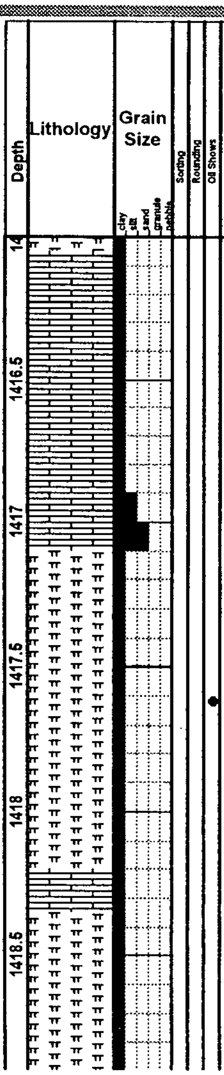
LITHOLOGY STRIP LOG

WellSight Systems

Scale 1:20 Metric

Well Name:	Progress Blueberry A- 029-E/094-A-13		
Location:	200/a-029-E 094-A-13/00		
Licence Number:	14888	Region:	British Colmbia
Spud Date:	13/06/2002	Drilling Completed:	03/07/2002
Surface Coordinates:	Lat: 56.85355 Long: -121.98087		
Bottom Hole Coordinates:	BH Lat: 56.85355 BH Long: -121.98087		
Ground Elevation (m):		K.B. Elevation (m):	953.3m
Logged Interval (m):	1416m To: 1420.5m	Total Depth (m):	4.5m
Formation:	Nordegg/Baldonnel		
Type of Drilling Fluid:			

Printed by STRIP.LOG from WellSight Systems 1-800-447-1534 www.WellSight.com



Geological Descriptions

SUB-UNIT: LIMESTONE (95%) - dark grey/black, carbonaceous, microcrystalline, mottled-appearance, finely interbedded with black shale.

Fracture: 1 prominant, near vertical, bitumen-filled, 0.5mm width/140mm length (photo 3711).

Calcite "sand" towards base - fines upwards (photo 3707).

UNIT: PHOSPHATIC MARLSTONE (95%) - black, calcareous, mod petrilferous, finely laminated. 25 deg contact below horizontal. Upper contact with lst marked by calcite "sand" (fining-up sequence) (photo 3707), top of black shale extremely fractured - filled with silt-sized calcite (photo 4198, CD3#).

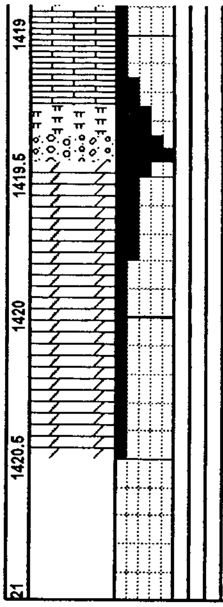
Fracture: 1 prominant, near-vertical, calcite-filled, 3mm width in thickest part/60mm length (photo 3708).

40mm interbed of lst, basal contact marked by 1mm clay (?) band, then fining-up sequenceof calcite "sand", top of bed shows slight coarsening-up sequence (photo 3709).

Lst - as above, sharp, horizontal lower and upper contacts.

Mrlst- as above, less calcareous towards base and more white "specks" (phosphate).

White powdery residue (sulfur?)



UNIT: CONGLOMORATE/BRECCIA). Bottom 300mm is med grey, irregular discontinuous fine laminations of black shale, slightly/fine CONGLOMORATE /BRECCIATED, white "specks" more common, 25mm clasts of silty lst, matrix supported, matrix dark grey, slightly argillaceous & calcareous. Congl. coarser at base (photo 3713).

UNIT: DOLOMITE - light grey, mod carbonaceous & argillaceous, fossiliferous in parts, crypto-microcrystalline, voggy porosity partially calcite-filled.

SAMPLES:
Sorption: 1418.8m
TOC: 1) 1417.2m, 2) 1417.8m, 3) 1418.4m, 4) 1419.3m, 5) 1419.5m

Appendix C

TOC Data

WA# 27

100/08-32-083-17W6/00

Sample interval: B10m

Sample #	Depth		IC	N	C	TOC
	m	ft	wt %	wt %	wt %	wt %
N 27-1	1252.9	4110.8	0.42	0.134	8.804	**8.384**
N 27-2	1253.6	4113.1	7.32	0.096	27.457	**20.137**
N 27-3	1254.3	4115.4	7.81	0.243	47.588	**39.778**
N 27-4	1254.7	4116.7	0.97	0.202	30.223	**29.253**
N 27-5	1255.2	4118.3	5.54	0.253	12.731	**7.191**
N 27-6	1255.3	4118.6	3.97	0.221	25.831	**21.861**
N 27-7	1255.9	4120.6	10.01	0.058	34.969	**24.959**
N 27-8	1256.3	4121.9	5.25	0.202	31.328	**26.078**
N 27-9	1256.7	4123.2	5.16	0.215	12.173	**7.013**
N 27-10	1256.8	4123.6	2.64	0.106	29.549	**26.909**
N 27-11	1257.1	4124.5	0.85	0.107	28.701	**27.851**
N 27-12	1258.7	4129.8	10.55	0.051	36.822	**26.272**
N 27-13	1259	4130.8	7.18	0.097	31.005	**23.825**
N 27-14	1259.2	4131.4	7.12	0.124	34.306	**27.186**
N 27-15	1259.7	4133.1	1.48	0.099	18.504	**17.024**
N 27-16	1260	4134.1	3.03	0.222	31.647	**28.617**
N 27-17	1260.3	4135.0	3.17	0.257	36.281	**33.111**
					Av:	**23.262**
						TOC RANGE: 7-39%

WA# 33
100/13-34-083-19W6/00
Sample interval: B9.4m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 33-1	1157.8	3798.7	0.26	0.326	3.942	2.668	**3.682**
N 33-2	1158.15	3799.9	1.49	0.278	7.507	2.377	**6.017**
N 33-3	1158.95	3802.5	3.21	0.284	9.888	3.353	**6.678**
N 33-4	1159.4	3804.0	3.15	0.336	12.637	3.791	**9.487**
N 33-5	1159.7	3805.0	3.85	0.299	13.905	3.654	**10.055**
N 33-6	1160.1	3806.3	0.16	0.377	1.770	5.808	**1.610**
N 33-7	1160.5	3807.6	0	0.384	1.338	2.605	**1.338**
N 33-8	1162.5	3814.2	5.95	0.174	13.304	1.408	**7.354**
N 33-9	1163.3	3816.8	4.68	0.145	10.092	1.792	**5.412**
N 33-10	1164.9	3822.0	4.65	0.267	13.033	2.117	**8.383**
N 33-11	1165.3	3823.3	4.02	0.248	11.204	0.993	**7.184**
N 33-12	1165.5	3824.0	6.99	0.152	12.865	1.902	**5.875**
N 33-13	1166	3825.6	10.05	0.034	11.273	0.278	**1.223**
N 33-14	1166.4	3827.0	4.95	0.349	18.520	5.174	**13.570**
N 33-15	1167.2	3829.6	5.56	0.128	10.296	1.351	**4.736**
N 33-16	1167.4	3830.2	3.07	0.196	10.015	2.821	**6.945**
N 33-17	1167.55	3830.7	1.11	0.176	6.674	2.434	**5.564**
						Av:	**6.183**

TOC RANGE: 1.2-13.6%

WA# 53

Well: 100/05-14-082-25W6/00

Sample Interval:

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 53-1	993.6	3260.0	8.71	n/a	9.197	n/a	**0.487**
N 53-2	994.4	3262.6	5.51	n/a	12.677	n/a	**7.167**
N 53-4	996.25	3268.7	5.51	0.053	6.242	0.055	**0.732**
N 53-5	996.4	3269.2	7.03	0.039	7.675	n/a	**0.645**
N 53-6	997.05	3271.3	3.56	0.045	4.317	0.048	**0.757**
						Av:	**1.958**

TOC RANGE: 0.48%

WA# 55

100/05-14-082-25W6/00

Sample Interval: B8.8m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 55-1	1269.4	4164.9	1.97	0.239	7.910	3.166	**5.940**
N 55-2	1270	4166.9	3.86				
N 55-3	1270.3	4167.9	3.21	0.275	11.454	2.745	**8.244**
N 55-4	1271.3	4171.1	3.71				
N 55-5	1272.3	4174.4	3.38	0.238	9.551	1.160	**6.171**
N 55-6	1272.6	4175.4	2.8				
N 55-7	1273.3	4177.7	3.5	0.196	8.578	1.435	**5.078**
N 55-8	1274	4180.0	3.1				
N 55-9	1274.25	4180.8	3.34	0.167	7.815	1.984	**4.475**
N 55-10	1275.25	4184.1	5.27	0.195	11.521	1.042	**6.251**
N 55-11	1276	4186.6	5.39				
N 55-12	1276.6	4188.5	4.79	0.178	15.064	0.224	**10.274**
						Av:	**6.519**
							TOC RANGE: 4-10%

WA # 77

100/04-36-082-16W6/00

Sample Interval: B7.6m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 77-1	1231.2	4039.6	2.49	0.165	5.618	1.308	3.128
N 77-2	1231.5	4040.6	10.52	0.057	12.434	0.279	1.914
N 77-3	1232	4042.2	2.05	0.284	8.097	1.265	6.047
N 77-4	1232.5	4043.8	8.79	0.105	12.989	0.343	4.199
N 77-5	1232.85	4045.0	3.27	0.184	6.944	2.121	3.674
N 77-6	1233.4	4046.8	1.77	0.199	12.233	1.251	10.463
N 77-7	1233.7	4047.8	3.86	0.165	8.849	2.592	4.989
N 77-8	1234	4048.8	3.54	0.187	8.751	1.806	5.211
N 77-9	1234.4	4050.1	4.82	0.174	9.888	1.705	5.068
N 77-10	1234.8	4051.4	2.34	0.160	9.731	2.342	7.391
N 77-11	1235.1	4052.4	2.14	0.197	7.260	2.596	5.120
N 77-12	1235.4	4053.3	4.41	0.158	9.622	1.579	5.212
N 77-13	1235.85	4054.8	2.7	0.134	7.665	1.459	4.965
N 77-14	1236.25	4056.1	4.1	0.216	13.627	2.415	9.527
N 77-15	1237.05	4058.8	1.32	0.077	2.073	6.172	0.753
						Av:	5.495

TOC RANGE: 0.7-10.4%

WA # 82

Well: 00/13-23-083-18W6-0

Sample Interval: B 5m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 82-1	1162.9	3815.5	6.98	0.135	12.823	0.681	**5.843**
N 82-2	1163.35	3817.0	3.15	0.250	8.093	2.454	**4.943**
N 82-3	1163.45	3817.3	3.25	0.188	10.748	2.093	**7.498**
N 82-4	1163.85	3818.6	4.13	0.250	12.454	2.462	**8.324**
N 82-5	1164.25	3819.9	0.17	0.151	5.818	2.196	**5.648**
N 82-6	1164.35	3820.2	0.97	0.068	3.893	2.057	**2.923**
						Av:	**5.863**

TOC RANGE: 3-8%

WA # 102

Well: 00/06-07-085-20W6

Sample Interval: B 6m

Sample #	Depth		%IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 102-1	1322.95	4340.6	4.09	0.137	8.520	0.479	**4.430**
N 102-2	1323.25	4341.6	6.83	0.146	12.635	0.124	**5.805**
N 102-3	1323.55	4342.6	10.2	0.086	15.748	0.104	**5.548**
N 102-4	1324.05	4344.2	7.79	0.128	13.397	0.099	**5.607**
N 102-6	1324.6	4346.0	6.33	0.169	12.451	0.123	**6.121**
N 102-7	1325.1	4347.7	1.07	0.230	4.365	4.950	**3.295**
N 102-8	1325.15	4347.8	3.76	0.202	11.929	2.134	**8.169**
N 102-9	1325.75	4349.8	0.8	0.201	7.440	2.499	**6.640**
N 102-10	1326.35	4351.8	6.99	0.131	12.748	0.188	**5.758**
						Av:	**5.997**
							TOC RANGE: 3.3-8.1%

WA# 121

200/d-038-K 094-A-11/00

1.4m section

Sample #	Depth		IC	N	C	S	TOC
	ft	m	wt %	wt %	wt %	wt %	wt %
N 121-1	1269.6	4165.6	0.68	0.153	12.166	1.417	**11.486**
N 121-2	1270.1	4167.2	3.68	0.266	8.230	2.262	**4.550**
N 121-3	1270.9	4169.8	5.82	0.217	12.110	1.406	**6.290**
N 121-4	1271	4170.2	4.52	0.184	9.165	2.239	**4.645**
N 121-5	1271.35	4171.3	7.34	0.193	15.220	0.943	**7.880**
N 121-6	1271.9	4173.1	2.89	0.114	10.771	0.747	**7.881**
N 121-7	1272.1	4173.8	7.11	0.144	11.507	1.236	**4.397**
N 121-8	1272.4	4174.7	4.16	0.281	8.439	4.538	**4.279**
N 121-9	1272.7	4175.7	3.13	0.181	9.951	1.801	**6.821**
N 121-10	1273	4176.7	1.46	0.361	6.011	3.221	**4.551**
						Av:	**5.968**
							TOC RANGE: 4-11%

WA# 130 100/04-27-088-17W6/00 Sample Interval: B9.3m								
Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 130-1	1103.2	3619.6	0.78	0.309	8.387	1.776	7.607
N 130-2	1103.5	3620.6	2.05	0.273	8.300	1.676	6.250
N 130-3	1104.7	3624.5	1.34	0.369	5.671	2.327	4.331
N 130-4	1105.1	3625.8	2.45	0.323	9.067	1.337	6.617
N 130-5	1105.5	3627.1	1.54	0.320	7.187	1.874	5.647
N 130-6	1106	3628.8	1.51	0.390	5.904	3.727	4.394
N 130-7	1106.3	3629.8	2.17	0.148	9.727	2.082	7.557
N 130-8	1107.4	3633.4	6.64	0.168	11.253	0.528	4.613
N 130-9	1107.7	3634.4	6.38	0.268	15.237	1.427	8.857
N 130-10	1107.9	3635.0	4.08	0.309	11.797	2.461	7.717
N 130-11	1108.2	3636.0	4.78	0.304	13.122	1.015	8.342
N 130-12	1108.6	3637.3	3.33	0.280	11.452	0.810	8.122
N 130-13	1109	3638.6	1.89	0.122	10.373	0.399	8.483
N 130-14	1109.3	3639.6	3.6	0.124	9.750	0.696	6.150
N 130-15	1109.6	3640.6	10.5	0.072	14.268	0.124	3.768
N 130-16	1110.6	3643.9	10.58	0.084	14.608	0.096	4.028
N 130-17	1111.4	3646.5	3.21	0.275	10.619	2.083	7.409
N 130-18	1111.6	3647.2	2.87	0.295	12.637	2.512	9.767
N 130-19	1111.9	3648.1	0.06	0.310	6.903	1.275	6.843
						Av:	6.327
							TOC RANGE: 3.8-9.8%

WA# 174
00/07-03-083-17W6/00
Sample Interval: 4.7m

Sample #	Depth		N	C	S	IC	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 174-1	1166.55	3827.5	0.188	13.389	1.832	2.46	**10.929**
N 174-2	1166.9	3828.6	0.190	16.725	1.987	8.1	**8.625**
N 174-3	1167.35	3830.1	0.247	14.647	2.135	1.91	**12.737**
N 174-4	1167.65	3831.1	0.226	15.177	2.239	2.91	**12.267**
N 174-6	1169.25	3836.3	0.171	13.647	1.831	4.99	**8.657**
N 174-7	1169.75	3837.9	0.238	12.896	3.103	2.6	**10.296**
N 174-8	1170.15	3839.3	0.120	4.373	2.000	0.51	**3.863**
N 174-9	1170.55	3840.6	0.233	11.554	2.636	1.62	**9.934**
N 174-10	1170.95	3841.9	0.088	3.762	2.689	0.58	**3.182**
						Av:	**7.186**
							TOC RANGE: 3-13%

WA# 230
100/06-16-081-14W6/00
Section: B 20.4m

Sample #	Depth		N	C	S	%IC	TOC	
	m	ft	wt %	wt %	wt %	wt %	wt %	
N 230-1	1474	4836.2	0.266	9.351	2.268	3.88	5.471	
N 230-2	1474.8	4838.8	0.160	8.058	2.209	5.5	2.558	
N 230-3	1475.5	4841.1	0.083	9.551		7.97	1.581	
N 230-4	1477.1	4846.4	0.161	9.026	2.254	5.27	3.756	
N 230-5	1478.1	4849.6	0.486	4.877	3.923	0.734	4.143	
N 230-6	1478.5	4851.0	0.336	6.197	1.759	1.41	4.787	
N 230-7	1479	4852.6	0.345	7.832	3.390	3.1	4.732	
N 230-8	1479.8	4855.2	0.326	7.064	3.388	1.58	5.484	
N 230-9	1480.6	4857.8	0.245	6.958	1.747	3.44	3.518	
N 230-10	1481.1	4859.5	0.200	11.911	2.140	3.46	8.451	B10m
N 230-11	1482.1	4862.8	0.199	13.299	1.509	2.84	10.459	10.459
N 230-12	1484	4869.0	0.197	12.663	1.532	4.34	8.323	8.323
N 230-13	1484.3	4870.0	0.313	6.489	2.765	1.47	5.019	5.019
N 230-14	1485.5	4873.9	0.037	11.693	0.257	10.75	0.943	0.943
N 230-15	1487.8	4881.5	0.208	11.581	1.060	4.42	7.161	7.161
N 230-16	1488.6	4884.1	0.536	14.085	1.956	2.12	11.965	11.965
N 230-17	1489.4	4886.7	0.134	14.550	0.140	5.75	8.800	8.800
N 230-18	1492	4895.3	0.178	13.699	0.806	4.18	9.519	9.519
N 230-19	1492.4	4896.6	0.181	13.377	1.501	6.15	7.227	7.227
						Av:	7.603	7.713
							TOC RANGE: 1-12%	

WA# 834

200/b-062-I 094-A-13/00

Sample Interval: B 14.8m

Sample #	Depth		IC	N	C	S	TOC	
	m	ft	wt %	wt %	wt %	wt %	wt %	B10m
N 834-1	1215.4	3987.7	1.26	0.255	15.734	1.209	**14.474**	
N 834-2	1215.8	3989.0	2.38	0.244	12.698	1.629	**10.318**	
N 834-4	1216.4	3991.0	3.9266	0.260	16.007	1.082	**12.081**	
N 834-5	1216.8	3992.3	3.92	0.180	7.703	1.213	**3.783**	
N 834-6	1217.1	3993.3	4.1357	0.330	14.408	0.992	**10.272**	
N 834-7	1218.5	3997.9	2.91	0.517	14.194	1.917	**11.284**	
N 834-8	1218.55	3998.1	2.8505	0.471	16.277	1.608	**13.426**	
N 834-9	1219.35	4000.7	3.85	0.257	15.961	1.202	**12.111**	**12.111**
N 834-10	1219.45	4001.0	3.83	0.257	11.429	0.490	**7.599**	**7.599**
N 834-12	1222.1	4009.7	4.55	0.335	12.505	1.434	**7.955**	**7.955**
N 834-13	1222.7	4011.7	5.11	0.090	8.371	0.743	**3.261**	**3.261**
N 834-14	1223.1	4013.0	2.4	0.206	7.142	0.873	**4.742**	**4.742**
N 834-15	1223.4	4014.0	6.849	0.070	8.995	0.522	**2.146**	**2.146**
N 834-16	1224.3	4016.9	7.34	0.095	8.973	0.296	**1.633**	**1.633**
N 834-17	1224.6	4017.9	2.74	0.204	6.115	0.713	**3.375**	**3.375**
N 834-18	1225	4019.2	2.82	0.205	6.655	0.615	**3.835**	**3.835**
N 834-19	1225.4	4020.5	3.56	0.264	7.606	0.808	**4.046**	**4.046**
N 834-20	1225.8	4021.8	4.41	0.292	11.055	1.234	**6.645**	**6.645**
N 834-21	1226.1	4022.8	2.73	0.281	8.130	missing	**5.400**	**5.400**
N 834-22	1226.5	4024.1	7.22	0.077	9.320	0.670	**2.100**	**2.100**
N 834-23	1227.3	4026.8	4.917	0.240	13.007	1.049	**8.090**	**8.090**
N 834-24	1228.5	4030.7	7.82	0.123	11.932	0.532	**4.112**	**4.112**
N 834-25	1228.9	4032.0	3.58	0.266	10.326	2.049	**6.746**	**6.746**
N 834-26	1229.1	4032.7	0.9701	0.286	8.323	1.126	**7.353**	**7.353**
						Av:	**6.897**	**5.362**

TOC RANGE: 1.6-13%

WA# 1257

Well: 200/a-045-J 094-A-09

Sample Interval: B 6.7m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 1257-1	1083.9	3556.3	3.49	0.223	7.696	1.563	**4.206**
N 1257-2	1084.4	3557.9	3.25	0.248	7.776	1.129	**4.526**
N 1257-3	1084.55	3558.4	2.8	0.254	8.051	1.700	**5.251**
N 1257-4	1084.9	3559.6	9.99	0.075	12.094	0.398	**2.104**
N 1257-5	1085.2	3560.5	2.78	0.215	6.755	1.267	**3.975**
N 1257-6	1085.8	3562.5	4.26	0.275	10.223	1.519	**5.963**
N 1257-7	1086.4	3564.5	5.15	0.257	11.659	2.993	**6.509**
N 1257-8	1086.8	3565.8	7.78	0.161	12.350	1.424	**4.570**
N 1257-9	1087.1	3566.8	6.61	0.223	12.762	1.834	**6.152**
N 1257-10	1087.4	3567.8	1.84	0.114	7.952	0.708	**6.112**
N 1257-11	1087.95	3569.6	5.74	0.247	12.032	1.890	**6.292**
N 1257-12	1088.25	3570.5	5.65	0.155	9.882	0.834	**4.232**
N 1257-13	1088.55	3571.5	6.17	0.151	9.954	0.852	**3.784**
N 1257-14	108.95	357.5	6.25	0.183	10.267	0.481	**4.017**
N 1257-15	1089.25	3573.8	4.91	0.132	8.442	0.607	**3.532**
N 1257-16	1089.8	3575.6	5.24	0.193	9.510	1.924	**4.270**
N 1257-17	1090	3576.3	2.79	0.193	9.510	1.924	**6.720**
N 1257-18	1091.3	3580.6	0.17	0.360	4.456	2.021	**4.286**
N 1257-19	1090.3	3577.3	3.04	0.330	8.009	5.131	**4.969**
						Av:	**4.633**
							TOC RANGE: 2-6.5%

WA# 2354

200/a-089-J 094-A-10/00

Sample Interval: U3m

Sample #	**Depth**		**N**	**C**	**S**	**IC**	**TOC**
	m	ft	wt %	wt %	wt %	wt %	**wt %**
1	1057.8	3470.6	0.192	2.248	4.667	0	**2.2**
5	1059.8	3477.2	0.240	0.910	4.897	0	**0.9**
6	1060.3	3478.8	0.185	2.032	2.227	0	**2.0**
10	1061.6	3483.1	0.176	1.831	7.042	0.003	**1.8**
12	1062.25	3485.2	0.206	1.828	2.595	0	**1.8**
17	1064	3491.0	0.184	0.359	11.895	0	**0.4**
18	1064.1	3491.3	0.212	0.403	5.189	0	**0.4**
19	1064.5	3492.6	0.236	0.383	6.259	0.002	**0.4**
21	1065	3494.3	0.168	0.995	4.216	0.5004	**0.5**
22	1065.3	3495.2	0.194	0.677	1.986	0.303	**0.4**
23	1065.7	3496.6	0.186	0.903	4.101	0.34	**0.6**
						Av:	**0.443**
							TOC RANGE: 0.4-0.6%

WA# 2557
200/c-074-J 094-A-10/00
Sample interval: U1.7m

Sample #	Depth		N	C	S	IC	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
PK 2557-1	1081.6	3548.7	0.276	0.390	5.984	0	**0.390**
PK 2557-2	1082	3550.0	0.274	0.926	3.352	0	**0.926**
PK 2557-3	1082.4	3551.4	0.257	0.625	6.603	0	**0.625**
PK 2557-4	1082.5	3551.7	0.249	0.757	6.734	0.19	**0.567**
PK 2557-5	1082.8	3552.7	0.240	0.910	4.897	0.09	**0.820**
PK 2557-6	1083.4	3554.6	0.185	2.032	2.227	1.49	**0.542**
N 2557-7	1083.6	3555.3	0.203	6.054	11.549	0.62	**5.434**
N 2557-8	1083.9	3556.3	0.071	2.388	1.019	0.3	**2.088**
N 2557-9	1084.2	3557.3	0.197	7.704	2.535	1.2	**6.504**
N 2557-10	1084.6	3558.6	0.217	9.824	2.091	1.12	**8.704**
						Av:	**4.015**

TOC RANGE: 2-9%

WA# 3098

100/11-30-087-14W6/00

Sample interval: B7.9m

Sample #	Depth		IC	N	C	S	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
N 3098-1	1173.2	3849.3	0.654	0.430	9.162	2.452	**8.508**
N 3098-2	1174.1	3852.2	10.85	0.065	13.510	0.314	**2.660**
N 3098-3 (green silty shale)	1174.35	3853.0	0.2416	0.617	0.939	10.617	**0.697**
N 3098-4	1174.95	3855.0	2.9691	0.329	10.387	2.101	**7.418**
N 3098-5	1175.95	3858.3	4.42	0.279	12.222	1.574	**7.802**
N 3098-6	1176.95	3861.6	3.7486	0.189	10.470	1.631	**6.721**
N 3098-7	1177.2	3862.4	5	0.177	10.844	1.239	**5.844**
N 3098-8	1177.9	3864.7	5.17	0.180	10.172	2.516	**5.002**
N 3098-9	1178.6	3867.0	10.1291	0.063	12.854	0.519	**2.725**
N 3098-10	1179.2	3869.0	5.4348	0.165	10.060	2.114	**4.625**
N 3098-11	1180.1	3871.9	1.909	0.291	8.957	1.089	**7.048**
N 3098-12	1180.5	3873.2	0.88	0.248	5.864	14.584	**4.984**
N 3098-13	1180.8	3874.2	0.28	0.334	6.203	2.048	**5.923**
						Av:	**5.051**

TOC RANGE: 2.7-8.5%

WA# 3773
200/d-059-A 093-P05
Sample interval: 7.6m

Sample #	Depth		IC	N	C	TOC
	m	ft	wt %	wt %	wt %	wt %
N 3773-1	3419.5	11219.4	0.99	0.095	3.838	**2.848**
N 3773-2	3420.3	11222.0	1.9245	0.082	7.471	**5.547**
N 3773-3	3420.7	11223.3	0.6202	0.068	21.401	**20.781**
N 3773-4	3421.1	11224.6	4.42	0.089	24.918	**20.498**
N 3773-5	3421.4	11225.6	2.21	0.105	18.254	**16.044**
N 3773-6	3422.2	11228.2	1.3121	0.155	14.141	**12.829**
N 3773-7	3422.8	11230.2	0.965	0.220	4.018	**3.053**
N 3773-8	3423.2	11231.5	2.1512	0.116	21.299	**19.148**
N 3773-9	3423.55	11232.7	1.68	0.118	17.568	**15.888**
N 3773-10	3423.65	11233.0	0.94	0.164	10.692	**9.752**
N 3773-11	3424.05	11234.3	1.82	0.188	17.529	**15.709**
N 3773-12	3424.65	11236.3	5.96	0.134	32.293	**26.333**
N 3773-13	3424.85	11236.9	3.82	0.126	25.803	**21.983**
N 3773-14	3425.25	11238.2	3.67	0.141	27.248	**23.578**
N 3773-15	3426.05	11240.9	0.89	0.172	11.385	**10.495**
N 3773-16	3426.2	11241.4	1.0682	0.203	6.919	**5.850**
N 3773-17	3426.6	11242.7	0.01	0.287	0.870	**0.860**
N 3773-18	3427	11244.0	0.013	0.282	0.543	**0.530**
N 3773-19	3427.1	11244.3	2.18	0.237	12.104	**9.924**
N 3773-20	3427.9	11246.9	5.09	0.148	10.455	**5.365**
					Av:	**14.280**
						TOC RANGE: 0.5-26%

WA# 5378 200/d-097-I 94-A-10/00 Interval: U 10m							
Sample #	**Depth**		**IC**	**N**	**C**	**S**	**TOC**
	m	ft	wt %	wt %	wt %	wt %	**wt %**
PK 5378-1	1098.5	3604.2	0	0.227	0.548	8.714	**0.5**
PK 5378-2	1098.8	3605.2	0	0.257	0.706	5.557	**0.7**
PK 5378-3	1099.1	3606.1	0	0.178	5.267		**5.3**
PK 5378-4	1099.3	3606.8	0	0.203	4.068		**4.1**
PK 5378-5	1099.7	3608.1	0	0.242	1.062	5.619	**1.1**
PK 5378-6	1102	3615.7	0	0.215	1.926		**1.9**
PK 5378-7	1102.3	3616.6	0	0.224	0.658	4.248	**0.7**
PK 5378-8	1102.6	3617.6	0	0.235	0.676	3.956	**0.7**
PK 5378-9	1102.8	3618.3	0	0.233	0.654	3.382	**0.7**
N 5378-10	1103.1	3619.3	0.137	0.218	2.916		**2.8**
N 5378-11	1103.4	3620.3	0	0.208	1.563	3.458	**1.6**
N 5378-12	1103.5	3620.6	0	0.207	1.203	4.151	**1.2**
N 5378-13	1104.1	3622.6	0.211	0.183	5.705		**5.5**
N 5378-14	1104.6	3624.2	0.2007	0.282	10.077	3.523	**9.9**
N 5378-15	1104.9	3625.2	0.124	0.280	28.156		**28.0**
N 5378-16	1105	3625.5	0.2	0.296	10.737	4.020	**10.5**
N 5378-17	1105.6	3627.5	0.000823	0.248	23.288		**23.3**
N 5378-18	1106	3628.8	0.943	0.184	24.546		**23.6**
N 5378-19	1106.85	3631.6	1.1077	0.226	8.765	1.720	**7.7**
N 5378-20	1107.15	3632.6	0.39	0.236	9.225	1.878	**8.8**
N 5378-21	1107.45	3633.5	1.32	0.238	10.146	1.616	**8.8**
N 5378-22	1107.9	3635.0	1.202	0.212	27.516		**26.3**
N 5378-23	1108.1	3635.7	0.901	0.237	29.787		**28.9**
N 5378-24	1108.7	3637.6	2.9	0.240	11.249	1.968	**8.3**
N 5378-25	1108.85	3638.1	0.56	0.240	27.605		**27.0**
N 5378-26	1109.3	3639.6	1.0034	0.249	29.250		**28.2**
N 5378-27	1109.7	3640.9	0.7553	0.235	29.093		**28.3**
N 5378-28	1110.3	3642.9	0.717	0.262	28.424		**27.7**
						Av:	**24.762**
							TOC RANGE: 5.5-28%

WA# 6080
200/d-088-H 094-A-13
Section : complete

Sample #	Depth		N	C	S	IC	TOC
	m	ft	wt %	wt %	wt %	wt %	wt %
PK 6080-1	1239	4065.2	0.225	3.86	4.22	0.18	**3.68**
PK 6080-2	1239.4	4066.5	0.224	4.34		0.22	**4.12**
PK 6080-4	1239.8	4067.8	0.212	4.11	3.80	0.29	**3.82**
PK 6080-5	1240.1	4068.8	0.205	5.21	3.28	0.28	**4.93**
N 6080-7	1240.6	4070.4	0.215	7.42	1.71	1.01	**6.41**
N 6080-8	1240.85	4071.2	0.224	7.12	2.19	0.98	**6.13**
N 6080-9	1241.1	4072.0	0.218	6.26	1.98	1.08	**5.17**
N 6080-10	1241.2	4072.4	0.230	8.09	1.48	2.00	**6.09**
N 6080-11	1241.6	4073.7	0.257	9.31	2.70	0.61	**8.70**
N 6080-12	1242	4075.0	0.261	7.33	2.56	0.90	**6.43**
N 6080-13	1242.15	4075.5	0.253	8.13	2.46	1.37	**6.76**
N 6080-14	1242.35	4076.2	0.297	5.86	2.80	0.49	**5.37**
N 6080-15	1242.75	4077.5	0.281	4.31	2.48	0.28	**4.03**
N 6080-16	1242.85	4077.8	0.177	9.36	0.52	2.53	**6.83**
N 6080-17	1243.05	4078.4	0.100	11.02	0.25	5.84	**5.19**
N 6080-18	1243.55	4080.1	0.049	11.46	n/a	11.11	**0.35**
N 6080-19	1243.85	4081.1	0.136	11.12	4.96	2.30	**8.82**
N 6080-21	1244.65	4083.7	0.411	21.81	1.46	1.49	**20.32**
N 6080-22	1245.15	4085.3	0.310	11.77	1.54	4.04	**7.73**
N 6080-23	1245.35	4086.0	0.351	12.40	1.68	4.36	**8.04**
N 6080-24	1245.65	4087.0	0.231	16.26	1.50	1.81	**14.45**
N 6080-25	1245.95	4088.0	0.147	11.08	0.45	1.08	**10.00**
N 6080-26	1246.3	4089.1	0.248	13.11	0.62	2.28	**10.83**
N 6080-27	1246.7	4090.4	0.270	8.76	0.93	2.76	**6.00**
N 6080-28	1247	4091.4	0.146	20.03	1.56	0.88	**19.15**
N 6080-29	1247.4	4092.7	0.192	14.21	1.82	1.59	**12.63**
N 6080-30	1247.65	4093.5	0.216	14.65	2.00	1.49	**13.16**
N 6080-31	1247.95	4094.5	0.239	10.12	0.89	1.37	**8.75**
N 6080-32	1248.35	4095.8	0.258	11.25	1.36	3.76	**7.49**

WA# 6080 *cont*								
N 6080-33	1248.85	4097.5	0.206	13.01	1.44	2.63	10.38	B10m
N 6080-34	1249.1	4098.3	0.286	11.90	1.09	3.07	8.83	8.831333
N 6080-35	1249.6	4099.9	0.385	11.88	1.46	3.24	8.64	8.640467
N 6080-36	1249.95	4101.1	0.304	12.94	1.39	4.01	8.93	8.926497
N 6080-37	1250.25	4102.1	0.226	10.41	0.84	5.71	4.70	4.700361
N 6080-39	1251.15	4105.0	0.327	15.16	2.01	4.36	10.80	10.80143
N 6080-40	1251.4	4105.8	0.498	15.08	2.68	2.32	12.76	12.75765
N 6080-41	1251.8	4107.2	0.339	13.34	2.12	4.62	8.71	8.711569
N 6080-42	1252.1	4108.1	0.360	11.53	2.10	4.16	7.37	7.367695
N 6080-43	1252.5	4109.5	0.281	8.22	1.40	4.09	4.13	4.12848
N 6080-44	1252.9	4110.8	0.087	12.25	0.44	10.45	1.80	1.801875
N 6080-45	1253.8	4113.7	0.336	10.27	2.49	4.31	5.96	5.963758
N 6080-46	1254.2	4115.0	0.412	6.98	7.43	0.92	6.06	6.061984
N 6080-48	1254.9	4117.3	0.168	7.13	1.30	2.39	4.74	4.74317
N 6080-49	1255.2	4118.3	0.175	7.50	1.84	1.12	6.38	6.383848
N 6080-50	1256.1	4121.3	0.165	9.85	1.60	2.76	7.09	7.092395
N 6080-51	1256.6	4122.9	0.168	11.55	0.94	5.62	5.93	5.927622
N 6080-52	1257	4124.2	0.183	14.87	0.23	7.01	7.86	7.864807
N 6080-53	1257.3	4125.2	0.174	9.63	1.83	4.64	4.99	4.98685
N 6080-54	1257.8	4126.8	0.198	9.61	2.02	3.61	6.00	5.995337
N 6080-55	1258.7	4129.8	0.192	9.31	2.02	4.23	5.08	5.084872
N 6080-56	1259.3	4131.8	0.221	10.12	1.65	3.91	6.20	6.203962
						Av:	6.011	6.808379
							TOC RANGE: 0.35-20%	

WA# 8354

100/11-32-086-18W6/00

Interval: B 11m

Sample #	Depth		IC	N	C	TOC
	m	ft	wt %	wt %	wt %	wt %
N 8354-1	1156.2	3793.5	3.37	0.210	37.265	**33.895**
N 8354-2	1156.6	3794.8	2.85	0.231	22.266	**19.416**
N 8354-3	1156.9	3795.8	0.0099962	0.598	1.448	**1.438**
N 8354-4	1157.3	3797.1	5.23	0.328	43.061	**37.831**
N 8354-5	1157.9	3799.1	4.28	0.352	40.719	**36.439**
N 8354-6	1158.7	3801.7	0.007499	0.561	3.680	**3.673**
N 8354-7	1159.1	3803.0	3.22	0.174	26.887	**23.667**
N 8354-8	1159.8	3805.3	0.26	0.034	10.974	**10.714**
N 8354-9	1160.5	3807.6	3.26	0.180	21.497	**18.237**
N 8354-10	1160.8	3808.6	1.2	0.379	11.260	**10.060**
N 8354-11	1161.8	3811.9	10.48	0.055	37.095	**26.615**
N 8354-12	1162.8	3815.1	0.3	0.078	21.341	**21.041**
N 8354-13	1163.5	3817.4	10.81	0.067	38.451	**27.641**
N 8354-14	1163.8	3818.4	10.44	0.059	37.492	**27.052**
N 8354-15	1165.3	3823.3	10.42	0.225	29.344	**18.924**
N 8354-16	1165.7	3824.7	2.7	0.240	28.703	**26.003**
					Av:	**24.546**

TOC RANGE: 10-37%

Appendix D

Inorganic Geochemical Data

Sample #	CaO (%)	Fe2O3 (%)	K2O (%)	MgO (%)	Mn3O4 (%)	Na2O (%)	P2O5 (%)	SiO2 (%)	TiO2 (%)	Al2O3 (%)
PK6080-1	0.9332	7.3449	3.8107	1.7455	0.0510	0.6567	0.1979	53.0730	0.6965	16.0895
PK6080-2	1.1785	7.0794	3.5870	1.7720	0.0619	0.2237	0.2598	53.9087	0.6692	16.8599
PK6080-4	1.1861	6.3117	3.6017	1.9134	0.0554	0.0000	0.1472	55.6536	0.6416	14.7532
PK6080-5	3.1357	4.9828	3.3505	1.9330	0.0619	0.6873	1.3376	56.0906	0.5593	13.2731
N6080-7	6.5353	3.7850	2.6158	2.9018	0.1295	0.7149	2.3559	51.9379	0.4113	10.5642
N6080-8	7.7228	3.5036	3.0042	1.7892	0.0949	0.7323	2.4808	49.9403	0.4494	11.8755
N6080-9	9.3409	3.2458	2.9485	1.4123	0.0562	0.7103	2.5421	48.8685	0.4443	11.4305
N6080-10	10.3705	3.3255	2.6686	1.7489	0.0501	0.7636	0.9172	50.2513	0.4327	10.9288
N6080-11	11.7746	2.8160	2.3549	1.2516	0.0395	0.6670	6.7651	45.7810	0.3318	9.3209
N6080-12	8.8973	3.7498	2.8793	1.6489	0.0360	0.7533	2.9554	50.4293	0.4051	10.8392
N6080-13	12.6510	3.6784	2.6877	2.0950	0.0455	0.7470	4.1615	42.8980	0.3987	10.7590
N6080-14	7.8856	3.8741	3.3072	1.3658	0.0369	0.7559	4.1026	50.9731	0.4389	12.4641
N6080-15	3.6117	4.7056	4.0632	1.9535	0.0573	0.7553	1.7798	53.2988	0.5279	14.7160
N6080-16	26.3836	2.6517	1.7287	1.1811	0.1283	0.6570	2.9215	29.4107	0.2839	7.1728
N6080-17	40.2771	1.6823	0.3789	0.5759	0.2326	0.6972	10.5160	12.4052	0.2281	2.8721
N6080-18	51.7469	0.4648	0.0765	0.6471	0.1412	0.4824	0.4483	1.9237	0.0271	1.3001
N6080-19	35.3874	6.4177	0.3134	0.3761	0.0948	0.7758	17.8857	6.1904	0.0400	3.3852
N6080-21	8.1136	0.4557	0.2441	0.7487	0.0081	0.6266	0.5884	65.1854	0.0578	1.3428
N6080-22	21.7959	2.2094	1.6590	1.7813	0.0306	0.6422	1.9510	34.5095	0.2523	6.9034
N6080-23	21.1887	1.9066	1.2196	1.5901	0.0232	0.4940	1.1563	40.4939	0.2323	5.6426
N6080-24	11.6056	0.7185	0.3892	0.8582	0.0100	0.8582	0.4930	79.4428	0.0948	2.2652
N6080-25	6.2302	0.8318	0.1273	1.0610	0.0110	0.8318	1.4846	72.1140	0.0373	2.0796
N6080-26	11.8450	0.7145	0.4446	1.7307	0.0127	0.6828	1.2115	57.7086	0.0802	3.4614
N6080-27	18.7765	1.5741	0.9477	1.4616	0.0209	0.7549	0.9549	47.4471	0.1855	5.1720
N6080-28	4.8625	0.6899	0.1912	0.9642	0.0125	1.3632	0.5611	69.9122	0.0748	2.3855
N6080-29	8.1331	0.9413	0.2890	1.2303	0.0182	1.4450	0.7010	63.0092	0.0958	3.8890
N6080-30	7.8331	1.2145	0.3260	1.2716	0.0179	1.4101	1.1020	61.4911	0.1003	3.1626

Table A: Major oxides - elements corrected for Loss-of-Ignition (LOI)

Sample #	CaO (%)	Fe2O3 (%)	K2O (%)	MgO (%)	Mn3O4 (%)	Na2O (%)	P2O5 (%)	SiO2 (%)	TiO2 (%)	Al2O3 (%)
N6080-31	7.0896	1.3104	0.5460	1.1508	0.0168	1.1592	0.6098	66.3096	0.1243	4.0740
N6080-32	21.8297	1.2660	0.6445	1.2891	0.0199	0.9975	0.8970	43.4062	0.1481	3.9976
N6080-33	14.8945	1.0560	0.4258	0.9368	0.0170	1.0815	0.8678	61.7751	0.1013	2.9636
N6080-34	18.0149	1.3482	0.6780	1.5374	0.0205	1.0328	0.9894	47.7770	0.1577	4.0366
N6080-35	16.7193	1.9487	0.8670	1.8612	0.0286	1.2488	1.2034	47.4456	0.2346	5.2019
N6080-36	20.8797	1.2013	0.6307	1.1262	0.0173	0.9160	0.5413	43.7116	0.1524	4.5949
N6080-37	28.3743	1.3973	0.5471	1.1533	0.0259	0.9389	0.7674	33.0171	0.1641	4.0292
N6080-39	25.9746	1.1410	0.5071	1.2044	0.0268	0.8452	0.5001	33.4261	0.1683	3.6342
N6080-40	14.0919	1.9631	0.9131	1.2098	0.0190	0.6544	2.1069	47.9900	0.2047	4.8393
N6080-41	22.2018	1.9779	0.8816	1.1186	0.0185	0.5630	0.5171	38.9290	0.1711	4.3115
N6080-42	20.0187	2.1980	1.3509	1.7477	0.0153	0.6945	0.4816	40.2817	0.2053	5.5790
N6080-43	19.8274	2.7710	1.3570	1.4789	0.0171	0.5038	0.3372	42.4502	0.2032	6.0457
N6080-44	11.1194	0.2702	0.1981	0.6064	0.0702	0.4683	0.0630	5.3316	0.0324	1.0867
N6080-45	21.4363	2.6343	1.7964	1.7662	0.0181	0.6718	1.2628	36.9324	0.2529	7.0876
N6080-46	12.0756	9.3217	3.1554	1.4372	0.0963	0.5139	0.6736	35.3035	0.6166	12.7420
N6080-49	11.3055	2.0555	1.2061	1.3930	0.0136	0.5351	0.4757	62.2440	0.2336	4.3744
N6080-50	34.5463	1.4419	0.9054	0.9221	0.0059	0.5281	16.1566	20.4126	0.1593	4.3759
N6080-51	29.8139	1.1643	0.9751	2.0157	0.0109	0.0000	3.3576	28.0310	0.1754	3.8641
N6080-52	36.2658	1.0352	0.8255	1.3735	0.0081		3.0860	15.4129	0.1461	3.2950
N6080-53	24.7411	1.8315	1.6280	2.2933	0.0102	0.0000	2.8662	33.7109	0.2575	5.2363
N6080-54	19.7934	2.1754	1.7312	3.4930	0.0146		2.0651	38.7136	0.2604	6.4038
N6080-55	18.2500	1.9433	1.6769	3.5340	0.0102	0.0000	1.0869	42.2360	0.2625	5.1953
N6080-56	29.1196	1.6816	1.4305	1.0729	0.0015	0.0000	7.7079	24.7064	0.2077	5.3339

Table A *continued*

Sample #	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (%)	Na (%)	P (%)	Si (%)	Ti (%)	Al (%)
PK6080-1	0.6673	5.1267	3.1629	1.0525	0.0395	0.4873	0.0863	24.7851	0.4172	8.5275
PK6080-2	0.8426	4.9415	2.9772	1.0685	0.0479	0.1659	0.1133	25.1754	0.4009	8.9358
PK6080-4	0.8481	4.4056	2.9894	1.1538	0.0429	0.0000	0.0642	25.9902	0.3843	7.8192
PK6080-5	2.2420	3.4780	2.7809	1.1656	0.0479	0.5100	0.5832	26.1943	0.3350	7.0347
N6080-7	4.6728	2.6419	2.1711	1.7498	0.1003	0.5305	1.0272	24.2550	0.2464	5.5990
N6080-8	5.5218	2.4455	2.4935	1.0789	0.0734	0.5434	1.0816	23.3221	0.2692	6.2940
N6080-9	6.6788	2.2656	2.4472	0.8516	0.0435	0.5270	1.1084	22.8216	0.2662	6.0581
N6080-10	7.4149	2.3212	2.2149	1.0546	0.0388	0.5666	0.3999	23.4674	0.2592	5.7923
N6080-11	8.4189	1.9656	1.9546	0.7547	0.0306	0.4949	2.9496	21.3797	0.1988	4.9401
N6080-12	6.3616	2.6173	2.3898	0.9943	0.0279	0.5589	1.2886	23.5505	0.2427	5.7447
N6080-13	9.0454	2.5675	2.2308	1.2633	0.0352	0.5543	1.8144	20.0333	0.2388	5.7023
N6080-14	5.6382	2.7041	2.7449	0.8236	0.0286	0.5609	1.7887	23.8044	0.2629	6.6060
N6080-15	2.5824	3.2845	3.3724	1.1779	0.0444	0.5605	0.7760	24.8905	0.3162	7.7995
N6080-16	18.8643	1.8509	1.4348	0.7122	0.0993	0.4875	1.2738	13.7348	0.1701	3.8016
N6080-17	28.7981	1.1743	0.3145	0.3473	0.1801	0.5173	4.5850	5.7932	0.1366	1.5222
N6080-18	36.9990	0.3244	0.0635	0.3902	0.1093	0.3579	0.1955	0.8984	0.0162	0.6891
N6080-19	25.3020	4.4795	0.2602	0.2268	0.0734	0.5756	7.7982	2.8909	0.0239	1.7941
N6080-21	5.8012	0.3181	0.2026	0.4515	0.0063	0.4650	0.2565	30.4416	0.0346	0.7117
N6080-22	15.5841	1.5422	1.3769	1.0741	0.0237	0.4765	0.8506	16.1160	0.1511	3.6588
N6080-23	15.1499	1.3308	1.0123	0.9588	0.0179	0.3666	0.5041	18.9106	0.1392	2.9906
N6080-24	8.2980	0.5015	0.3230	0.5175	0.0077	0.6368	0.2149	37.0998	0.0568	1.2006
N6080-25	4.4546	0.5806	0.1057	0.6398	0.0085	0.6172	0.6473	33.6773	0.0224	1.1022
N6080-26	8.4692	0.4987	0.3690	1.0436	0.0098	0.5066	0.5282	26.9499	0.0480	1.8345
N6080-27	13.4252	1.0987	0.7866	0.8814	0.0162	0.5601	0.4163	22.1578	0.1111	2.7411
N6080-28	3.4767	0.4815	0.1587	0.5814	0.0097	1.0115	0.2446	32.6490	0.0448	1.2643
N6080-29	5.8152	0.6570	0.2399	0.7419	0.0141	1.0722	0.3056	29.4253	0.0574	2.0612
N6080-30	5.6007	0.8477	0.2706	0.7667	0.0139	1.0463	0.4805	28.7164	0.0601	1.6762

Table B: Elemental Majors

Sample #	Ca (%)	Fe (%)	K (%)	Mg (%)	Mn (%)	Na (%)	P (%)	Si (%)	Ti (%)	Al (%)
N6080-31	5.0691	0.9147	0.4532	0.6939	0.0130	0.8601	0.2659	30.9666	0.0745	2.1592
N6080-32	15.6082	0.8837	0.5350	0.7773	0.0154	0.7401	0.3911	20.2707	0.0887	2.1187
N6080-33	10.6496	0.7371	0.3534	0.5649	0.0132	0.8025	0.3784	28.8490	0.0607	1.5707
N6080-34	12.8807	0.9410	0.5628	0.9270	0.0159	0.7663	0.4314	22.3119	0.0945	2.1394
N6080-35	11.9543	1.3602	0.7196	1.1223	0.0222	0.9266	0.5247	22.1571	0.1406	2.7570
N6080-36	14.9290	0.8385	0.5235	0.6791	0.0134	0.6797	0.2360	20.4133	0.0913	2.4353
N6080-37	20.2876	0.9753	0.4541	0.6954	0.0200	0.6967	0.3346	15.4190	0.0983	2.1355
N6080-39	18.5718	0.7964	0.4209	0.7262	0.0207	0.6271	0.2180	15.6100	0.1008	1.9261
N6080-40	10.0757	1.3703	0.7579	0.7295	0.0147	0.4855	0.9186	22.4113	0.1226	2.5648
N6080-41	15.8743	1.3806	0.7317	0.6745	0.0143	0.4178	0.2254	18.1799	0.1025	2.2851
N6080-42	14.3134	1.5342	1.1212	1.0539	0.0118	0.5153	0.2100	18.8116	0.1230	2.9569
N6080-43	14.1766	1.9341	1.1263	0.8918	0.0132	0.3738	0.1470	19.8243	0.1217	3.2042
N6080-44	7.9504	0.1886	0.1644	0.3657	0.0544	0.3475	0.0275	2.4898	0.0194	0.5760
N6080-45	15.3270	1.8387	1.4910	1.0650	0.0140	0.4985	0.5506	17.2474	0.1515	3.7564
N6080-46	8.6341	6.5065	2.6190	0.8666	0.0746	0.3813	0.2937	16.4867	0.3694	6.7533
N6080-49	8.0834	1.4348	1.0011	0.8400	0.0105	0.3971	0.2074	29.0680	0.1399	2.3184
N6080-50	24.7006	1.0064	0.7515	0.5560	0.0045	0.3919	7.0443	9.5327	0.0954	2.3192
N6080-51	21.3169	0.8127	0.8093	1.2155	0.0084	0.0000	1.4639	13.0905	0.1051	2.0480
N6080-52	25.9300	0.7226	0.6851	0.8282	0.0063	0.0000	1.3455	7.1978	0.0875	1.7464
N6080-53	17.6899	1.2784	1.3513	1.3829	0.0079	0.0000	1.2497	15.7430	0.1542	2.7752
N6080-54	14.1523	1.5185	1.4369	2.1063	0.0113	0.0000	0.9004	18.0793	0.1560	3.3940
N6080-55	13.0488	1.3564	1.3918	2.1310	0.0079	0.0000	0.4739	19.7242	0.1572	2.7535
N6080-56	20.8205	1.1737	1.1873	0.6469	0.0012	0.0000	3.3607	11.5379	0.1244	2.8270

Table B *continued*

Sample #	P/Al	Si/Al	Fe/Al	K/Al	Ti/Al	Ca/Al	Mn/Al	Mg/Al	Na/Al	Ca/Al
PK6080-1	0.0101	2.9065	0.6012	0.3709	0.0489	0.0782	0.0046	0.1234	0.0571	0.0000
PK6080-2	0.0127	2.8174	0.5530	0.3332	0.0449	0.0943	0.0054	0.1196	0.0186	0.0000
PK6080-4	0.0082	3.3239	0.5634	0.3823	0.0491	0.1085	0.0055	0.1476	0.0000	0.0000
PK6080-5	0.0829	3.7236	0.4944	0.3953	0.0476	0.3187	0.0068	0.1657	0.0725	0.0000
N6080-7	0.1835	4.3320	0.4718	0.3878	0.0440	0.8346	0.0179	0.3125	0.0947	0.8346
N6080-8	0.1718	3.7054	0.3885	0.3962	0.0428	0.8773	0.0117	0.1714	0.0863	0.8773
N6080-9	0.1830	3.7671	0.3740	0.4040	0.0439	1.1024	0.0072	0.1406	0.0870	1.1024
N6080-10	0.0690	4.0515	0.4007	0.3824	0.0447	1.2801	0.0067	0.1821	0.0978	1.2801
N6080-11	0.5971	4.3278	0.3979	0.3957	0.0402	1.7042	0.0062	0.1528	0.1002	1.7042
N6080-12	0.2243	4.0995	0.4556	0.4160	0.0422	1.1074	0.0048	0.1731	0.0973	1.1074
N6080-13	0.3182	3.5132	0.4503	0.3912	0.0419	1.5863	0.0062	0.2215	0.0972	1.5863
N6080-14	0.2708	3.6035	0.4093	0.4155	0.0398	0.8535	0.0043	0.1247	0.0849	0.8535
N6080-15	0.0995	3.1913	0.4211	0.4324	0.0405	0.3311	0.0057	0.1510	0.0719	0.3311
N6080-16	0.3351	3.6129	0.4869	0.3774	0.0447	4.9622	0.0261	0.1873	0.1282	4.9622
N6080-17	3.0121	3.8058	0.7714	0.2066	0.0898	18.9188	0.1183	0.2281	0.3398	18.9188
N6080-18	0.2836	1.3038	0.4708	0.0921	0.0235	53.6937	0.1586	0.5663	0.5195	53.6937
N6080-19	4.3465	1.6113	2.4968	0.1450	0.0133	14.1026	0.0409	0.1264	0.3208	14.1026
N6080-21	0.3605	42.7750	0.4470	0.2847	0.0486	8.1516	0.0089	0.6344	0.6533	8.1516
N6080-22	0.2325	4.4047	0.4215	0.3763	0.0413	4.2593	0.0065	0.2936	0.1302	4.2593
N6080-23	0.1686	6.3234	0.4450	0.3385	0.0465	5.0659	0.0060	0.3206	0.1226	5.0659
N6080-24	0.1790	30.9017	0.4177	0.2691	0.0473	6.9117	0.0064	0.4310	0.5304	6.9117
N6080-25	0.5873	30.5555	0.5268	0.0959	0.0203	4.0417	0.0077	0.5805	0.5600	4.0417
N6080-26	0.2879	14.6903	0.2719	0.2011	0.0262	4.6165	0.0054	0.5689	0.2761	4.6165
N6080-27	0.1519	8.0834	0.4008	0.2869	0.0405	4.8977	0.0059	0.3215	0.2043	4.8977
N6080-28	0.1935	25.8230	0.3809	0.1255	0.0354	2.7498	0.0076	0.4599	0.8000	2.7498
N6080-29	0.1483	14.2758	0.3188	0.1164	0.0278	2.8213	0.0068	0.3599	0.5202	2.8213
N6080-30	0.2867	17.1321	0.5057	0.1614	0.0358	3.3413	0.0083	0.4574	0.6242	3.3413

Table C: Major elements normalized to aluminium

Sample #	P/Al	Si/Al	Fe/Al	K/Al	Ti/Al	Ca/Al	Mn/Al	Mg/Al	Na/Al	Ca/Al
N6080-31	0.1231	14.3416	0.4236	0.2099	0.0345	2.3476	0.0060	0.3214	0.3984	2.3476
N6080-32	0.1846	9.5673	0.4171	0.2525	0.0419	7.3667	0.0073	0.3669	0.3493	7.3667
N6080-33	0.2409	18.3670	0.4693	0.2250	0.0386	6.7802	0.0084	0.3596	0.5109	6.7802
N6080-34	0.2016	10.4290	0.4399	0.2630	0.0441	6.0207	0.0074	0.4333	0.3582	6.0207
N6080-35	0.1903	8.0366	0.4934	0.2610	0.0510	4.3360	0.0080	0.4071	0.3361	4.3360
N6080-36	0.0969	8.3823	0.3443	0.2149	0.0375	6.1303	0.0055	0.2789	0.2791	6.1303
N6080-37	0.1567	7.2204	0.4567	0.2126	0.0460	9.5003	0.0094	0.3257	0.3262	9.5003
N6080-39	0.1132	8.1044	0.4135	0.2185	0.0523	9.6421	0.0108	0.3770	0.3256	9.6421
N6080-40	0.3582	8.7379	0.5342	0.2955	0.0478	3.9284	0.0057	0.2844	0.1893	3.9284
N6080-41	0.0987	7.9559	0.6042	0.3202	0.0449	6.9469	0.0063	0.2952	0.1828	6.9469
N6080-42	0.0710	6.3620	0.5189	0.3792	0.0416	4.8407	0.0040	0.3564	0.1743	4.8407
N6080-43	0.0459	6.1869	0.6036	0.3515	0.0380	4.4243	0.0041	0.2783	0.1167	4.4243
N6080-44	0.0477	4.3229	0.3274	0.2855	0.0337	13.8036	0.0944	0.6349	0.6033	13.8036
N6080-45	0.1466	4.5915	0.4895	0.3969	0.0403	4.0802	0.0037	0.2835	0.1327	4.0802
N6080-46	0.0435	2.4413	0.9635	0.3878	0.0547	1.2785	0.0110	0.1283	0.0565	1.2785
N6080-49	0.0895	12.5377	0.6189	0.4318	0.0603	3.4866	0.0045	0.3623	0.1713	3.4866
N6080-50	3.0373	4.1103	0.4339	0.3240	0.0411	10.6503	0.0020	0.2398	0.1690	10.6503
N6080-51	0.7148	6.3919	0.3968	0.3952	0.0513	10.4088	0.0041	0.3200	0.0000	10.4088
N6080-52	0.7704	4.1216	0.4138	0.3923	0.0501	14.8479	0.0036	0.4743	0.0000	14.8479
N6080-53	0.4503	5.6727	0.4606	0.4869	0.0556	6.3742	0.0028	0.3200	0.0000	6.3742
N6080-54	0.2653	5.3268	0.4474	0.4234	0.0460	4.1698	0.0033	0.4500	0.0000	4.1698
N6080-55	0.1721	7.1634	0.4926	0.5055	0.0571	4.7390	0.0029	0.3500	0.0000	4.7390
N6080-56	1.1888	4.0814	0.4152	0.4200	0.0440	7.3650	0.0004	0.2288	0.0000	7.3650

Table C *continued*

Sample #	Total S	Pyrite S	Organic S	Sorg/Corg
N6080-12	2.6982	2.2613	0.4369	0.0502
N6080-22	1.4554	0.3659	1.0894	0.0536
N6080-24	1.6808	1.5310	0.1498	0.0186
N6080-25	1.4956	0.5769	0.9187	0.0636
N6080-27	0.6216	0.5738	0.0478	0.0044
N6080-29	1.5650	0.5540	1.0110	0.0528
N6080-30	1.8188	0.7559	1.0629	0.0842
N6080-31	2.0004	0.9752	1.0252	0.0779
N6080-33	1.3581	1.0166	0.3414	0.0456
N6080-34	1.4391	0.8480	0.5911	0.0569
N6080-35	1.0851	1.0826	0.0026	0.0003
N6080-37	1.3871	0.9646	0.4225	0.0473
N6080-40	2.0132	0.9162	1.0970	0.1016
N6080-41	2.6828	1.5764	1.1064	0.0867
N6080-42	2.1204	1.5883	0.5322	0.0611
N6080-43	2.0960	1.7650	0.3310	0.0449
N6080-45	0.4396	0.2170	0.2226	0.1235
N6080-46	2.4938	2.1153	0.3785	0.0635
N6080-50	1.8387	1.6506	0.1880	0.0295
N6080-51	1.6002	1.1578	0.4423	0.0624
N6080-52	0.9434	0.9349	0.0085	0.0014
N6080-54	1.8278	1.4707	0.3570	0.0716
N6080-55	2.0161	1.7469	0.2692	0.0449
N6080-56	2.0248	1.5605	0.4644	0.0913

Table D: Pyrite and organic sulphur calculations

Sample #	V (ppm)	Cr (ppm)	Zn (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Ba (ppm)	Pb (ppm)	Nb (ppm)
N6080-7	180.6	245.5	175.3	7.3	103.7	98.2	108.4	310.9	97.6	118.5	1618	34.1	11.9
N6080-8	255.2	266.9	215	7	120.4	112.6	119.1	295.8	103	126.3	1583.2	23.6	11.4
N6080-9	324.5	285.4	215.8	6.2	125.4	125.4	122.7	340.8	100.3	136	1619.5	26	12
N6080-10	334.2	232.5	140.3	5	94.8	90.9	101	312.5	50.1	88.9	1013.3	27.9	12.1
N6080-11	392.8	217.9	231.1	5	131.2	107.1	97.7	458.1	106.7	127.4	3564.7	22.2	13.2
N6080-12	415.2	202.6	167.7	7.5	111.4	88.7	123.5	383.5	66.1	115.8	1940.4	30.8	12.6
N6080-13	460.4	195.4	152.8	7.1	96.1	69.8	119	495.6	73.8	126.8	1890.8	27	14.8
N6080-14	621.9	212.2	299.1	8.1	123.2	96.2	125.4	404.4	87.9	126.8	1954.5	30.8	12.2
N6080-15	352.9	222.9	277.8	11.3	112	89.5	176.2	266.5	67.9	127	1291.7	31.8	11
N6080-16	228.2	119.9	254	3.7	120.6	61.5	71.6	576	49.4	80.9	1109.4	35.9	14.3
N6080-17	106.2	39.6	121	1.6	65.4	33.4	13.5	765.6	68	76.6	1014.4	38.7	14.7
N6080-18	33.8	8.6	32.8	0	31.5	12.9	3.3	155.2	10.9	9.8	262.4	17.7	2.8
N6080-19	85.8	121.4	214.3	12.5	158.9	36.5	10.4	1669.6	325.7	241.7	12149.5	126.4	23.4
N6080-21	59.6	57.2	57.8	0	108.5	25.9	8.7	281.8	31.1	25.2	1045.4	34.3	7.9
N6080-22	161.9	308.6	387.1	2.8	232.7	170.9	53.2	761.3	107	159.7	1799.4	35.2	18
N6080-23	117.6	251.7	513.2	1.6	247	168.8	41.9	590.5	88.1	118.3	1286.4	27.6	15.5
N6080-24	60.5	98.9	109.2	0	133.9	55.4	10.7	323.8	31.2	30.2	882.7	39.6	11.1
N6080-25	38.9	58	41.1	0	86.2	24.4	4.5	316.1	98.3	70.5	1042.9	48.8	10.8
N6080-26	56.4	112	99.5	0	96.4	53.3	14.3	375.5	72.8	74.5	1050.1	29.6	12.4
N6080-27	107.7	198.2	268.5	0.5	162.2	124.8	32.9	523.4	69.4	103.3	721	27.9	17
N6080-28	38	60.2	20.6	0	81.2	22.9	10.5	308.3	51.6	58.8	722.2	33.3	12.5
N6080-29	34.1	69.9	28.4	0	92.4	27	11.2	339.2	89.8	82.6	1297.5	36.9	13.6
N6080-30	39.1	87.3	36.5	0	79.2	40.1	19.3	256.3	49.5	58.5	889.2	31	11.8

Table E: Minor elements of the Nordegg Member

Sample #	V (ppm)	Cr (ppm)	Zn (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Rb (ppm)	Sr (ppm)	Y (ppm)	Zr (ppm)	Ba (ppm)	Pb (ppm)	Nb (ppm)
N6080-31	52.6	92.4	54.2	0	99.3	100.1	24.7	902.7	63.7	101.4	720.6	21.5	22.7
N6080-32	35.3	53	40.8	0	94.5	56.3	12.7	582	52.9	58.4	910.7	31.1	16.9
N6080-33	56.2	95.9	51	0	99.4	92.5	24.1	721.9	72.1	96.1	876	32.8	19.9
N6080-34	88	116.5	92.6	2	115.3	107.1	31.4	616.9	91.9	104.6	1010.8	21.4	17.5
N6080-35	247.1	225.8	232.9	0	174.2	104.8	22	746.3	51.9	90.4	818.3	28.7	21.6
N6080-36	235.5	201.8	344.2	0.2	165.7	97.2	18.8	1476.3	72.8	165.5	830.8	20.4	34.3
N6080-37	381.5	174.1	570.5	0	308.3	103.9	18.6	981.2	50	110.3	810.4	20.3	21.2
N6080-39	514.8	170.8	475.9	2.5	596.3	163.6	27.1	724.8	109.5	186.4	977.9	20.5	12.5
N6080-40	893.6	196.3	512.3	2.7	662.6	151.1	29.1	916	54.6	149.8	364.9	32	12.5
N6080-41	715.8	202.4	121.9	2.4	193.2	118.3	40.1	735.2	52.2	94.4	373.6	32.7	16.8
N6080-42	695.1	251.1	99.7	20.1	117.2	169	55.4	425.8	25.1	299.4	1639.8	92	42.7
N6080-43	163	60.2	52.3	0	47.3	30.5	7.2	212.8	13.6	1.3	83.3	5.2	3.8
N6080-44	795.8	237.8	99	3.3	126.7	98.3	47	1042.2	67.6	124.1	363.6	30.1	23.4
N6080-45	920	330.6	563.2	29.6	134.1	294.9	62.1	690.4	43.1	97.8	680.2	129.2	12.7
N6080-46	555	111.3	652.7	1.9	275.4	48	29.5	431.5	31.8	68.9	220.4	24.2	10.5
N6080-49	629.5	117.7	546.8	2.5	307.9	54.5	35.3	427.2	34.9	82.2	171.2	24.9	9.6
N6080-50	1879.7	245.8	594.3	0.9	234.5	118.6	20.5	1444.5	339.3	280.9	268.5	27.2	24.1
N6080-51	1836.1	324.6	1464.5	0	210.1	117.2	32.4	733.1	77.1	105.1	190.6	25.9	13.3
N6080-52	2012.6	270.9	2437.8	0	258.2	93.7	26.5	912.2	62.9	100.2	118.3	24.7	15.3
N6080-53	1985.7	357.2	4254.8	1.7	368.6	138.2	50.9	604.6	78.2	118.5	212.6	30.3	11.4
N6080-54	3315.5	490.6	2409.8	2.8	269.1	153.1	50.8	370.4	105.4	108.6	111.3	21.6	6.2
N6080-55	2488.5	414.8	4868.2	2.2	359	149.4	51.9	332.3	63.9	89.8	94.1	24.3	3.7
N6080-56	1733.8	376.3	2049.7	1.4	347.5	167.9	49.3	1075.9	198.7	215.7	1736.3	26	17.3

Table E *continued*

Sample #	V/Al	Cr/Al	Zn/Al	Co/Al	Ni/Al	Cu/Al	Rb/Al	Sr/Al	Y/Al	Zr/Al	Ba/Al	Pb/Al	Nb/Al
N6080-7	32.2556	43.8468	31.3090	1.3038	18.5211	17.5387	19.3605	55.5274	17.4316	21.1644	288.9784	6.0903	2.1254
N6080-8	40.5465	42.4054	34.1595	1.1122	19.1293	17.8900	18.9227	46.9971	16.3648	20.0667	251.5407	3.7496	1.8112
N6080-9	53.5643	47.1102	35.6215	1.0234	20.6994	20.6994	20.2537	56.2549	16.5562	22.4491	267.3262	4.2917	1.9808
N6080-10	57.6974	40.1396	24.2219	0.8632	16.3666	15.6933	17.4370	53.9511	8.6494	15.3480	174.9396	4.8168	2.0890
N6080-11	79.5130	44.1087	46.7807	1.0121	26.5583	21.6799	19.7770	92.7315	21.5989	25.7891	721.5889	4.4939	2.6720
N6080-12	72.2747	35.2670	29.1919	1.3055	19.3916	15.4402	21.4979	66.7566	11.5062	20.1575	337.7693	5.3614	2.1933
N6080-13	80.7398	34.2671	26.7963	1.2451	16.8529	12.2407	20.8689	86.9128	12.9422	22.2368	331.5872	4.7350	2.5955
N6080-14	94.1421	32.1225	45.2772	1.2262	18.6498	14.5626	18.9828	61.2174	13.3062	19.1948	295.8688	4.6625	1.8468
N6080-15	45.2466	28.5788	35.6178	1.4488	14.3599	11.4751	22.5913	34.1690	8.7057	16.2831	165.6137	4.0772	1.4104
N6080-16	60.0278	31.5396	66.8145	0.9733	31.7237	16.1775	18.8343	151.5163	12.9946	21.2807	291.8268	9.4435	3.7616
N6080-17	69.7678	26.0151	79.4906	1.0511	42.9643	21.9420	8.8688	502.9586	44.6724	50.3221	666.4070	25.4238	9.6571
N6080-18	49.0512	12.4805	47.6000	0.0000	45.7134	18.7207	4.7890	225.2292	15.8183	14.2219	380.7999	25.6866	4.0634
N6080-19	47.8226	67.6651	119.4450	6.9672	88.5666	20.3441	5.7967	930.5900	181.5364	134.7171	6771.8037	70.4520	13.0425
N6080-21	83.7469	80.3745	81.2176	0.0000	152.4587	36.3934	12.2248	395.9711	43.7001	35.4098	1468.9432	48.1966	11.1007
N6080-22	44.2492	84.3441	105.7991	0.7653	63.5997	46.7090	14.5402	208.0725	29.2444	43.6479	491.7978	9.6206	4.9196
N6080-23	39.3236	84.1645	171.6060	0.5350	82.5929	56.4440	14.0107	197.4539	29.4592	39.5576	430.1518	9.2290	5.1830
N6080-24	50.3926	82.3773	90.9565	0.0000	111.5300	46.1446	8.9124	269.7044	25.9876	25.1546	735.2320	32.9842	9.2456
N6080-25	35.2941	52.6236	37.2902	0.0000	78.2096	22.1382	4.0829	286.7987	89.1880	63.9649	946.2270	44.2764	9.7989
N6080-26	30.7433	61.0506	54.2369	0.0000	52.5471	29.0535	7.7949	204.6830	39.6829	40.6095	572.4038	16.1348	6.7592
N6080-27	39.2902	72.3057	97.9519	0.1824	59.1724	45.5285	12.0023	190.9424	25.3179	37.6850	263.0292	10.1782	6.2018
N6080-28	30.0552	47.6138	16.2931	0.0000	64.2233	18.1122	8.3047	243.8430	40.8119	46.5065	571.2079	26.3379	9.8866
N6080-29	16.5438	33.9124	13.7784	0.0000	44.8284	13.0992	5.4337	164.5647	43.5670	40.0738	629.4892	17.9022	6.5981
N6080-30	23.3270	52.0830	21.7758	0.0000	47.2505	23.9236	11.5143	152.9080	29.5316	34.9010	530.4946	18.4945	7.0399

Table F: Minor elements normalized to aluminium

Sample #	V/Al	Cr/Al	Zn/Al	Co/Al	Ni/Al	Cu/Al	Rb/Al	Sr/Al	Y/Al	Zr/Al	Ba/Al	Pb/Al	Nb/Al
N6080-31	24.3606	42.7932	25.1017	0.0000	45.9888	46.3593	11.4393	418.0676	29.5014	46.9614	333.7316	9.9573	10.5131
N6080-32	16.6608	25.0148	19.2567	0.0000	44.6019	26.5723	5.9941	274.6909	24.9676	27.5635	429.8298	14.6785	7.9764
N6080-33	35.7804	61.0559	32.4698	0.0000	63.2842	58.8913	15.3436	459.6066	45.9034	61.1833	557.7163	20.8825	12.6696
N6080-34	41.1330	54.4545	43.2831	0.9348	53.8936	50.0607	14.6770	288.3516	42.9559	48.8922	472.4684	10.0028	8.1799
N6080-35	89.6259	81.9002	84.4754	0.0000	63.1843	38.0121	7.9796	270.6913	18.8247	32.7891	296.8065	10.4098	7.8346
N6080-36	96.7029	82.8647	141.3381	0.0821	68.0410	39.9130	7.7198	606.2100	29.8937	67.9589	341.1497	8.3768	14.0845
N6080-37	178.6494	81.5278	267.1545	0.0000	144.3712	48.6544	8.7100	459.4777	23.4141	51.6514	379.4953	9.5061	9.9276
N6080-39	267.2731	88.6757	247.0771	1.2979	309.5862	84.9376	14.0697	376.3006	56.8501	96.7749	507.7047	10.6432	6.4897
N6080-40	348.4036	76.5349	199.7394	1.0527	258.3395	58.9120	11.3457	357.1370	21.2879	58.4052	142.2700	12.4764	4.8736
N6080-41	313.2506	88.5749	53.3462	1.0503	84.5488	51.7708	17.5487	321.7405	22.8439	41.3116	163.4960	14.3103	7.3521
N6080-42	235.0800	84.9210	33.7181	6.7977	39.6366	57.1551	18.7361	144.0038	8.4887	101.2559	554.5737	31.1140	14.4410
N6080-43	50.8700	18.7876	16.3221	0.0000	14.7617	9.5186	2.2470	66.4119	4.2444	0.4057	25.9968	1.6228	1.1859
N6080-44	1381.6842	412.8732	171.8858	5.7295	219.9791	170.6705	81.6024	1809.4890	117.3685	215.4650	631.2898	52.2602	40.6276
N6080-45	244.9145	88.0095	149.9303	7.8799	35.6989	78.5057	16.5317	183.7923	11.4737	26.0355	181.0770	34.3945	3.3809
N6080-46	82.1824	16.4809	96.6494	0.2813	40.7802	7.1077	4.3683	63.8950	4.7088	10.2025	32.6360	3.5834	1.5548
N6080-49	271.5191	50.7670	235.8485	1.0783	132.8050	23.5072	15.2258	184.2620	15.0532	35.4549	73.8428	10.7400	4.1407
N6080-50	810.4807	105.9830	256.2477	0.3881	101.1107	51.1374	8.8391	622.8331	146.2979	121.1172	115.7706	11.7280	10.3913
N6080-51	896.5480	158.4987	715.0997	0.0000	102.5896	57.2275	15.8206	357.9649	37.6471	51.3192	93.0679	12.6467	6.4942
N6080-52	1152.4462	155.1216	1395.9223	0.0000	147.8493	53.6541	15.1743	522.3400	36.0175	57.3761	67.7404	14.1436	8.7610
N6080-53	715.5110	128.7105	1533.1401	0.6126	132.8183	49.7979	18.3409	217.8567	28.1780	42.6993	76.6066	10.9181	4.1078
N6080-54	976.8730	144.5495	710.0192	0.8250	79.2871	45.1091	14.9676	109.1340	31.0549	31.9977	32.7932	6.3642	1.8268
N6080-55	903.7615	150.6451	1768.0095	0.7990	130.3799	54.2584	18.8488	120.6831	23.2069	32.6131	34.1748	8.8252	1.3437
N6080-56	613.3064	133.1106	725.0515	0.4952	122.9231	59.3922	17.4392	380.5839	70.2872	76.3007	614.1908	9.1971	6.1196

Table F *continued*

	Mg	Mn	Na	K	Si	Fe	Ti	Ca	P	AL	V	Cr	Zn	Co	Ni	Cu	Rb	Sr	Y	Zr	Ba	Pb	Nb	C	N	S	TOC	TIC
Mg																												
Mn	0.06																											
Na	0.4	0.11																										
K	0.22	-0.14	**-0.7**																									
Si	0.36	-0.04	0.49	-0.2																								
Fe	0.08	0.03	0.01	0.03	-0.03																							
Ti	-0.04	0.02	0.11	0.2	-0.02	0.03																						
Ca	0.14	**0.69**	0.07	-0.16	-0.02	0.02	-0.02																					
P	-0.06	0.08	0.01	-0.04	0.08	0.49	0.01	0.08																				
Al	**-0.56**	-0.09	-0.41	0.39	-0.25		0.01	-0.24	-0.04																			
V	0.06	0.02	-0.08	0.14	-0.05	-0.01	0.04	0.03	0.01	-0.06																		
Cr	0.16	0.02	0.01	0.03	-0.12	-0.01	0.01	0.01	0.01	-0.12	**0.71**																	
Zn	0.01	0.02	-0.18	0.2	0.03	-0.01	0.01	0.01	0.01	-0.02	**0.53**	0.2																
Co	-0.02	0.03	-0.01	0.02	-0.09	0.2	-0.03	0.01	0.07	0.01	0.03	0.12	-0.01															
Ni	0.15	0.01	0.02	-0.11	0.03	0	0.03	0.03	0.01	-0.26	0.28	0.33	0.15	0.02														
Cu	0.16	0.02	0.02	0.12	-0.13	-0.03	0.02	0.01	-0.01	-0.19	0.43	**0.77**	0.07	0.15	0.44													
Rb	0.01	0.05	-0.01	0.13	0.05	-0.04	0.01	-0.01	-0.03	0.01	0.28	**0.58**	0.01	0.18	0.06	0.45												
Sr	0.12	0.16	0.14	-0.1	0.11	0.06	-0.02	0.11	0.14	-0.29	0.25	**0.55**	0.01	0.13	0.27	**0.52**	0.311											
Y	0.02	0.04	0.09	-0.14	0.12	0.27	-0.13	0.05	**0.56**	-0.19	0.1	0.17	0.01	0.09	0.12	0.12	0.02	0.52										
Zr	0.07	0.06	0.08	0.06	-0.1	0.07	-0.04	0.04	0.17	-0.22	0.26	**0.52**	0.01	0.24	0.31	**0.53**	0.28	**0.79**	**0.63**									
Ba	-0.01	0.03	0.06	-0.13	0.13	**0.77**	-0.18	0.03	**0.46**	-0.05	-0.03	-0.01	-0.02	0.19	0.01	-0.01	-0.01	0.14	0.45	0.16								
Pb	0.2	0.14	0.36	-0.24	0.18	0.27	-0.13	0.11	0.19	-0.33	0.01	0.11	-0.02	0.29	0.06	0.11	0.03	0.37	0.41	0.34	0.48							
Nb	0.23	0.11	0.3	-0.15	0.04	0.03	-0.04	0.05	0.02	-0.32	0.14	**0.51**	-0.02	0.13	0.16	**0.511**	0.34	**0.84**	0.32	**0.73**	0.06	0.4						
C	0.43	0.01	0.46	-0.3	0.47	-0.01	-0.01	0.04	0.01	**-0.56**	0.01	0.04	0	-0.02	0.23	0.08	-0.01	0.1	0.05	0.06	0.02	0.24	-0.1					
N	-0.15	-0.33	-0.14	0.11	-0.02	-0.02	0.01	-0.28	-0.12	0.18	-0.07	-0.06	-0.02	0.01	-0.01	-0.01	-0.04	-0.14	-0.2	-0.08	-0.04	-0.15	-0.1	-0.01				
S	-0.26	0.03	-0.06	0.04	-0.06	0.3	-0.1	0.1	0.02	0.24	-0.03	0.07	-0.03	0.07	0.02	-0.09	-0.03	0.04	0	-0.01	0.1	0	-0.08	-0.07	0.23			
TOC	0.11	-0.13	0.33	-0.17	**0.65**	0	-0.02	-0.08	0.01	-0.13	-0.08	-0.03	-0.04	-0.05	0.04	-0.01	-0.1	-0.01	0.01	-0.01	0.03	0.08	0.1	0	0.01	-0.01		
TIC	0.18	0.41	0.1	0.02	-0.08	-0.02	0.12	**0.6**	0.01	0.26	0.28	0.32	0.11	0.03	0.14	0.36	0.1	0.29	0.03	0.17	-0.01	0.06	0.22	0.03	-0.12	-0.16	-0.2	

Table G: Correlation coefficients of major and minor elements