EXPLORATION ASSESSMENT OF DEEP DEVONIAN GAS PLAYS, NORTHEASTERN BRITISH COLUMBIA

for

British Columbia Ministry of Energy and Mines
Resource Development Division
New Ventures Branch

May, 2003

Petrel Robertson

EXECUTIVE SUMMARY

Deep Devonian reservoirs in northeastern British Columbia, including the Chinchaga, Keg River, Sulphur Point and Slave Point formations, have been prolific gas producers since the 1950's. However, there is still abundant potential for high-impact gas discoveries along new and established exploration fairways, as outlined in this report.

Working from existing Petrel Robertson studies and the published literature, we review the Lower to Middle Devonian stratigraphic framework of northeastern B.C., and illustrate key units with a grid of regional cross-sections and gross isopach and porosity maps. This information is used to interpret depositional environments and to reconstruct regional paleogeography for each of the four major producing units.

A comprehensive reconstruction of the structural framework of the area is critical to understanding petroleum prospectivity. Using regional aeromagnetic intensity mapping, surface lineaments, and offsets mapped in younger strata, we have identified regional networks of southwest-northeast and northwest-southeast faults, in addition to the Bovie Lake Fault Zone in the northwest and the Hay River Fault Zone in the southeast. Reactivation of deep-seated faults appears to have exerted control over trends of large-scale features such as platform margins and interior platform embayments, and over smaller features such as isolated reefal buildups. Fault movements, particularly those involving strike-slip motion, have also allowed deep-sourced fluids access to Devonian reservoirs, causing widespread reservoir enhancement, primarily through hydrothermal dolomitization and associated solution and brecciation.

Exploration potential can be classified into several play types for each producing formation, depending upon the reservoir characteristics and regional paleogeography of each. The most exciting potential occurs in the deep Plains and outer Foothills to the west, where westerly platform edges and potential reefal buildups offer deep, highly-pressured, unexploited reservoir trends. Platform embayments in the Slave Point and Keg River are also highly prospective, with the 2000 Ladyfern discovery being an excellent example of the potential rewards.

Geological Survey of Canada and Canadian Gas Potential Committee assessments of remaining gas potential in the Devonian of northeastern B.C. range from 6.7 to 10.2 TCF. We project that even more gas potential exists, and will be realized with the drilling of new exploratory trends.

TABLE OF CONTENTS

LIST OF MAPS & CROSS-SECTIONS

INTRODUCTION

This report summarizes an assessment of deep Devonian gas production and exploration potential in British Columbia, undertaken by Petrel Robertson Consulting Ltd. for the British Columbia Ministry of Energy and Mines, Resource Development Division, New Ventures Branch. It draws extensively from Petrel's existing studies (1990, 1992), and highlights the importance of hydrothermal dolomite reservoirs as a key component of Devonian exploration potential.

Logs from more than 500 wells were interpreted, including all wells penetrating the entire Devonian section, and the database was augmented with data from Petrel's existing studies. A stratigraphic framework was constructed, based upon established lithostratigraphy (e.g., Griffin, 1967; Meijer Drees, 1994; Oldale and Munday, 1994), using a regional correlation network of 13 cross-sections – seven east-west, three north-south, and three chosen to illustrate specific paleogeographic features (Map 1). Formation tops were picked for each well, and well logs were used to calculate net porosity values, using a cut-off of 5%. Formation picks and lithological interpretations were checked using core and sample descriptions from Petrel studies and wellsite reports. A suite of isopach, porosity, structural and paleogeographic maps was created to illustrate interpretations and conclusions.

This report addresses several key issues:

- ✓ Regional lithostratigraphic framework of Devonian units, and the distribution of economically important strata;
- ✓ Paleoenvironments and paleogeographic setting of key units;
- ✓ Present structural configuration, and the impact of the basement and structural lineaments on deposition and diagenesis;
- ✓ Dolomitization trends in the Slave Point, Sulphur Point, Keg River, and Upper Chinchaga reservoirs;
- ✓ Key stratigraphic and structural features, and how the integration of these elements can be used for exploration.

STRATIGRAPHY AND DEPOSITIONAL HISTORY

LOWER ELK POINT GROUP

The Lower Elk Point Group comprises four units: the "Basal Red Beds", Ernestina Lake, Cold Lake, and Chinchaga formations (Fig. 1). The three basal units are recognized in northern Alberta, but are not mapped separately in northeastern B.C., as they are penetrated by very few wells (e.g., Cross-Section V-V'). They consist of evaporitic lithofacies, deposited in restricted environments during early flooding of the profound pre-Elk Point unconformity surface (Meijer Drees, 1994). The basal units appear to be thickest in regional topographic lows (Fig. 2).

Chinchaga Formation

The Chinchaga consists of lower and upper units, divided by a regional unconformity, which formed during a period of uplift and adjustment, and was followed by an influx of clastic deposition across the basin which deposited a characteristic clastic cycle known as the Ebbut marker (Belyea and Norris, 1962) (Fig. 1).

The ***Lower Chinchaga*** represents a marine transgression that overstepped the Cold Lake evaporite basin. However, it may be thin or absent over the most prominent highs. In a regional sense, it thickens to the northwest to about 70 metres in a relatively open marine environment (Cross-Section A-A').

The ***Upper Chinchaga*** (Map 2, 3) is marked by renewed marine transgression, which drowned most of the topographic relief created by the mid-Chinchaga uplift. It contains a wide variety of lithofacies, including fine and coarse clastics, dense very fine crystalline anhydrite and dolomite cycles, more marine intertidal laminites, stromatolites, very fine-grained peloidal wackestones and packstones with birdseye fabrics, pebble breccias and desiccation fractures (Plates 1-3). Coarse clastic strata become dominant southward towards the Peace River Arch (Fig. 2, Map 3, Cross-Section A-A'). South of the zero edge on Map 2, the Chinchaga can no longer be mapped as a separate unit.

To the northwest, the Upper Chinchaga thickens and becomes more marine, and is characterized by *Amphipora* and bulbous stromatoporoid floatstones, particularly at the base of depositional cycles. The Bovie Lake Fault appears to have moved syndepositionally, as shown by the abrupt westward thickening of

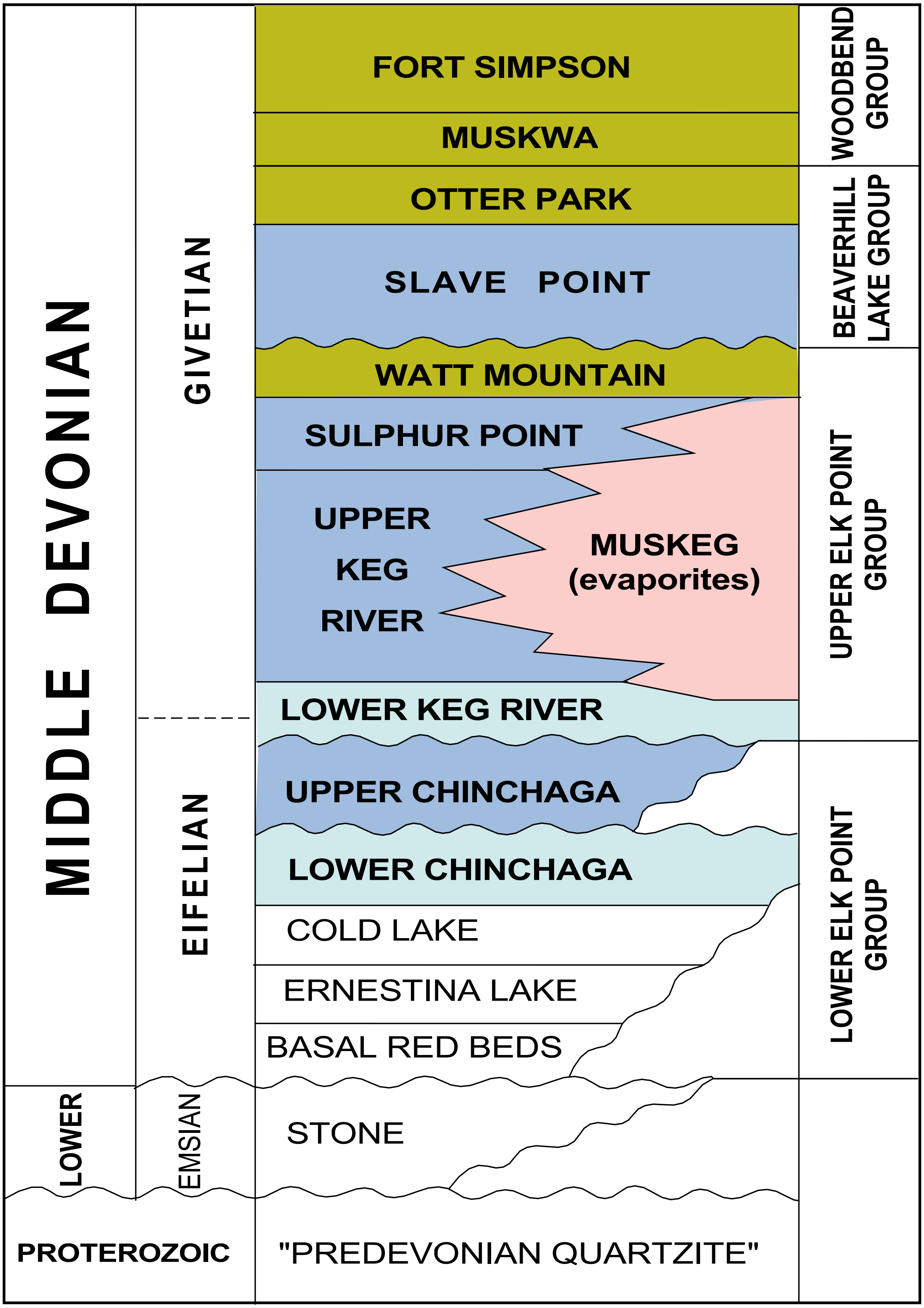


Figure 1 : Stratigraphic nomenclature.

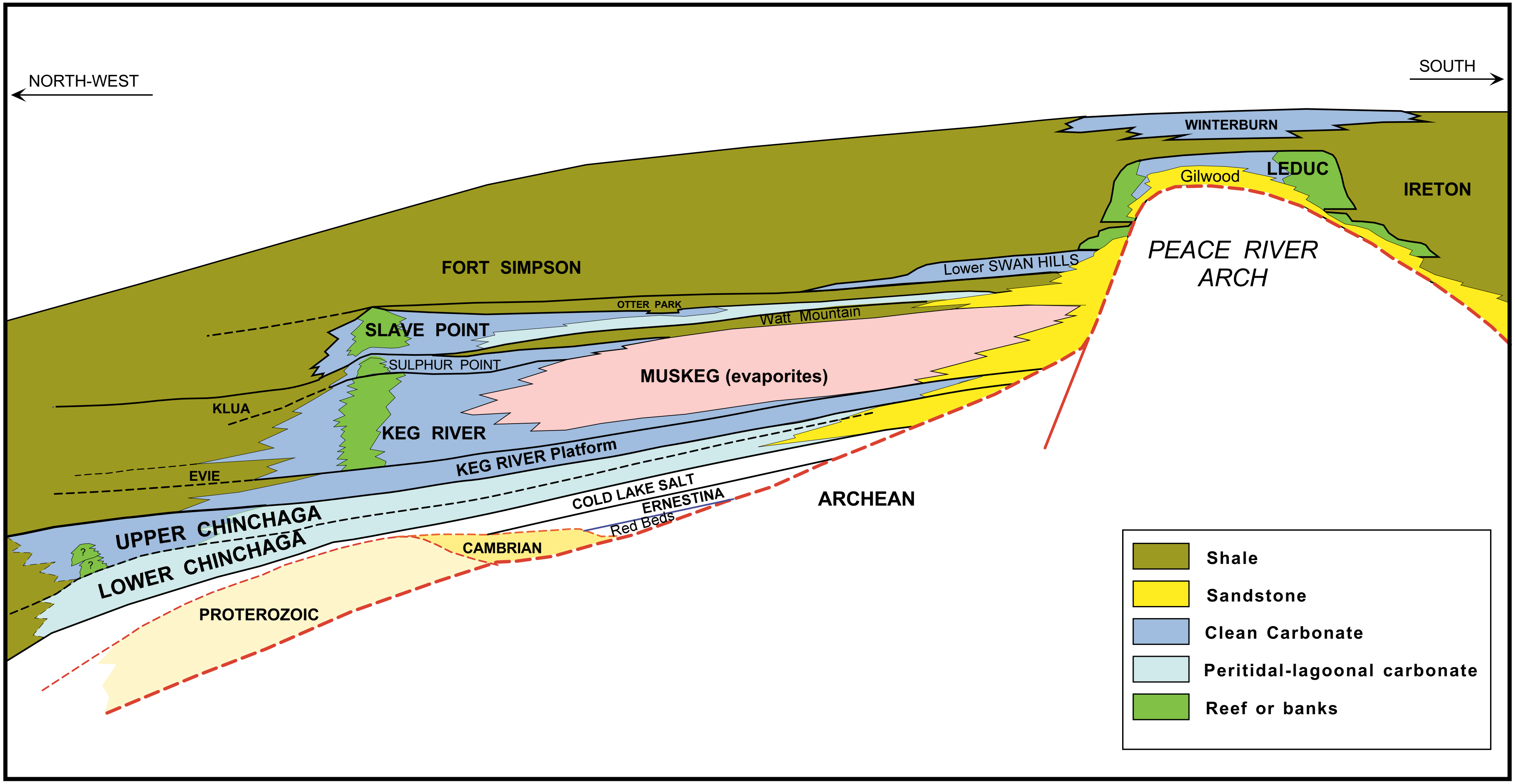


Figure 2: Stratigraphic architecture of the Middle Devonian in northeast British Columbia.

the Upper Chinchaga (Map 2). Upper Chinchaga carbonates shale out northwest of the study area, west of Beaver River and Pointed Mountain fields (Fig. 2, Map 3) (Petrel Robertson, 1992; Morrow and Potter, 1998).

UPPER ELK POINT GROUP

The Upper Elk Group comprises a number of lithostratigraphic units deposited in a rimmed carbonate platform setting (Fig. 1, 2). The bounding reef topography has traditionally been lumped as the Pine Point (Presqu'ile) Formation where dolomitized, and mapped as the "Presqu'ile Barrier". This terminology is not used in this report, as it is based upon diagenetic facies, and fails to recognize the stratigraphic significance of the constituent units.

Lower Keg River Formation

The Lower Keg River (Keg River Platform) is relatively uniform across much of northeastern British Columbia, with thicknesses ranging from 20 to 50 metres (Cross-Sections IV-IV', C-C'). North of Clarke Lake, Evie shales interdigitate with the upper part of the Keg River Platform. Southward towards the Peace River Arch, carbonates are gradually replaced by clastic deposits (Fig. 2).

The Lower Keg River marks the beginning of a widespread marine transgression with relatively deep-water deposits, represented by nodular and wavy-bedded mudstones and wackestones with crinoid debris, rare corals, and brachiopods. Keg River strata are typically dolomitized, and show a sharp contact with the underlying Chinchaga evaporites. In outcrop to the west, the Keg River platform rests directly on the Lower Devonian Stone Formation, demonstrating the existence of a substantial unconformity, and hence the potential presence of a westerly highland (Petrel Robertson, 1992, 2003).

Upper Keg River Formation

Upper Keg River carbonate banks form the northern wall of the Elk Point restricted basin, reaching thicknesses of over 200 metres (Map 4, 5). They pass southward into Muskeg evaporites, so that Upper Keg River carbonates are very thin or absent south of a line running from 94-G-14 to 94-I-1, and may not be readily distinguished from the Lower Keg River (Map 5, Cross-Section B-B', C-C'). Upper Keg River strata consist of stacked cycles, each with a shaly base, shoaling upward to a thick high-energy carbonate at top (Plate 4) (Petrel Robertson, 1992).

The reef margin appears to be an amalgamation of several bank masses, separated by embayments filled with argillaceous facies (Cross-Section V-V').

Maps 4 and 5 demonstrate these relationships on a regional basis, but detailed (prospect-level) paleogeography remains to be mapped, because of poor core control and the limited number of wells penetrating the full Keg River section. Detailed mapping of relationships with equivalent Muskeg evaporites and younger Sulphur Point carbonates also awaits more well and core control.

Outboard of the main reef margin, isolated Upper Keg River buildups are found at Yoyo, Sierra, and Evie (Cross-Section A-A’) (Map 5). It appears that elevated fault blocks may have nucleated reef growth in these locations.

To the southwest, outcrops of Keg River reefal facies in the mountains and Keg River penetrations in the Foothills and deep Plains (e.g., c-4-G/94-G-7, Cross-Sections A-A’ and II-II’) represent carbonate banks that may have formed the westerly margin of the restricted Elk Point basin (Map 5) (Petrel Robertson, 1992, 2003). Muskeg evaporite thins (Map 6) and the presence of equivalent clastic strata (e.g., b-10-J/94-G-7) indicate that ancestral highlands may have nucleated regional bank development in this area.

Muskeg Formation

The Muskeg Formation consists of interbedded anhydrite, dolostone and possibly halite, deposited within the restricted Elk Point basin (Petrel Robertson, 1992; Meijer Drees, 1994) (Fig. 2). Contacts with the underlying Keg River Platform and overlying Sulphur Point carbonates are sharp and easily distinguished on formation density logs. In the north, approaching the Keg River margin, dolomites thicken at the expense of evaporites, and small-scale cycles become more apparent.

Map 6 shows the Muskeg to range in excess of 200 metres in an area of maximum subsidence paralleling the Hay River Fault Zone. Two other thicks extend southwestward from 94-G-16 into 94-G-11, and from NW/94-J-2 into 94-G-12, and appear to coincide with subsiding blocks along major strike slip faults, separating Clarke Lake from the Adsett area, and Adsett from Bougie-Trutch. These trends are also apparent at Slave Point level, suggesting control by fault block reactivation.

Sulphur Point Formation

Sulphur Point carbonates were deposited during a relatively subtle regional transgression over the Keg River. The Sulphur Point is mappable over much of the study area southeast of the Horn River Basin, and is relatively uniform on regional cross-sections (Maps 7, 8). In the south, the basal contact is sharp, as relatively high-energy peloidal grainstone-wackestones transgress the evaporitic Muskeg. These facies are commonly dolomitized where they are in contact with the Muskeg (Plate 5b). To the north, slightly argillaceous facies mark the Sulphur Point / Upper Keg River contact (Cross-Section IV-IV'). Here, the Sulphur Point is generally limestone, particularly on the basinward side of the Keg River barrier.

At the Keg River margin, Sulphur Point reefs may step over tongues of basinal shale (a-75-K/94-J-3, Cross-Section IV-IV'), or may conform closely to the Keg River edge, as in the vicinity of the Klua Embayment (Maps 7, 8; a-65-J/94-J-9, Cross-Section V-V'). Outboard of the Keg River margin, isolated Sulphur Point buildups or shoals may occur on top of Keg River isolated buildups or banks (Plate 5a), but it is often difficult to distinguish the two (Cross-Section A-A').

Watt Mountain Formation

The Watt Mountain Formation is characterized by waxy green shales, but contains a variety of other sediments including arkosic or quartzose sandstone, nodular and argillaceous limestone or dolostone, limestone breccia, and weathered regolith strata (Meijer Drees, 1988). It forms a distinct stratigraphic break between the Sulphur Point and Slave Point carbonates, and because of its mappability, it has been chosen as a datum for the regional cross-sections.

The base of Watt Mountain marks a low-relief regional unconformity, resulting from a basin-wide tectonic adjustment and uplift on the Peace River Arch and other highs in the west (Meijer Drees, 1988). Watt Mountain strata thicken southward toward the Peace River Arch, reflecting proximity to a coarse clastic source area (Fig. 2, Cross-Sections A-A', B-B', C-C').

BEAVERHILL LAKE GROUP

Slave Point Formation

The Slave Point Formation was deposited in the early stages of a basinwide transgression, which ultimately drowned the Middle Devonian carbonate platforms of northeastern British Columbia and Alberta (Oldale and Munday, 1994). It forms a thick and complex carbonate platform comprising several stacked shallowing-upward cycles. Reefal buildups and high-energy carbonate banks occur along the edges of the main platform, and also along the margins of platform-interior embayments (Fig. 2; Map 8, 9) (Cross-Sections D-D', E-E', F-F').

The basal cycle of the Slave Point (correlated on the regional Cross-Sections as the Fort Vermilion Member) was deposited during the initial transgression over the Watt Mountain Formation. It infills the paleo-topography with argillaceous subtidal facies in the lows, and cleaner carbonates across the highs (Petrel

Robertson, 1992). Southward, it grades to clastic facies near the Peace River Arch (Fig. 2, Cross-Section C-C').

The succeeding Slave Point cycle can be correlated regionally, and typically consists of argillaceous, nodular, wavy-bedded, brachiopod-crinoid mudstone and wackestone passing upward to *Amphipora* floatstone and stromatoporoid-*Amphipora* wackestone (Plate 7, 8) (Petrel Robertson, 1992). This cycle established the substrate on which subsequent carbonate banks developed. The oldest of these is found at Adsett, where isolated stromatoporoid boundstones are capped by coarse-grained grainstones. Subsequent Slave Point cycles display a wide variety of lithologies and reefal morphologies (Plates 9 to 13) (Petrel Robertson, 1990, 1992).

The gross isopach map shows that maximum thicknesses of the Slave Point occur in reefal buildups bordering the Horn River Basin in the northwest, and the Cordova Embayment in the northeast (Morrow et al., 2002) (Map 8, 9). Buildup margin morphologies show strong parallelism with basement structures, and with major faults mapped in younger strata (Map 10; Petrel Robertson, 1995). By extension, in areas of relatively poor well control, such as the western flank of the Adsett Platform, strong magnetic lineaments suggest that isopach mapping should be adjusted to fit the inferred basement faults.

Local and regional thins on the Slave Point isopach map are highly suggestive of embayments, isolating various platformal areas over the larger Slave Point carbonate platform. For example, the Adsett area is flanked by embayments which appear to be controlled by the same basement structural features that earlier influenced Muskeg deposition. Embayment trends are poorly controlled by drilling, and their margins are highly prospective for the development of thick reef facies. Fault movements could have occurred at any time during Slave Point deposition, and thus prospective buildups may have formed at various levels throughout the Slave Point, not just at the top.

In the southeast, the margins of the Hotchkiss Embayment have been the focus of intensive exploration following the Ladyfern discovery (Oldale and Munday, 1994; Boreen, 2001, 2003a, b). The embayment is evident as a thick in the overlying Otter Park (Waterways) shales, but is not as obvious on the Slave Point isopach, as the platform thins on the southern margin of the embayment toward the Peace River Arch (Cross-Section C-C'). Continued subsidence (earlier noted in the Muskeg Formation) along the Hay River Fault Zone appears to have been a major control of the Hotchkiss Embayment trend (Map 8, 9, 10).

Along the edges of the Hotchkiss Embayment to the east, Slave Point bioherms are relatively thin, and appear to be limited to one depositional sequence. The reef margin is therefore quite narrow – less than 1.5 kilometres at Cranberry (Petrel Robertson, 1992) – and reef flank facies are consequently an important component of the reservoirs.

To the west in the deep Plains and Foothills, there must have been a westerly margin to the Slave Point platform. Reefal buildups may have existed, although they were not required to provide a restricted basinal setting, such as for the Muskeg evaporites in Keg River time. Scanty outcrop data suggest the existence of Slave Point reefs in southwestern 94-G (Petrel Robertson, 1992).

Middle Devonian Shales

Gray and Kassube (1963) established the original nomenclature for Middle Devonian shales of northeastern British Columbia. Basinal shales in the northwestern Horn River Basin were assigned to the Horn River Formation, and subdivided into three members (from oldest to youngest): the Evie, Otter Park, and Muskwa. The Klua Shale was interpreted as being a basinal equivalent of the Keg River, and was recognized in the Klua Embayment and adjacent areas.

Morrow et al. (2002) reviewed Devonian shale nomenclature in northeastern B.C., noting that the Horn River has been elevated to group status, and the constituent members to formation status. They recognized that certain basin-filling shale units could be related to specific shelfal equivalents, although depositional patterns and hence nomenclature vary between the Horn River Basin and Cordova Embayment.

In this study, the Klua Shale is correlated with Elk Point (Keg River and Sulphur Point) carbonates. Dark, radioactive Evie shales represent a starved basin facies, deposited when Keg River buildups restricted water circulation, and cut off the interior evaporitic (Muskeg) platform. The Otter Park is part of the Beaverhill Lake Group, and includes shales that filled Slave Point embayments and capped the Slave Point platform (Oldale and Munday, 1994). The Muskwa Shale was included as part of the Horn River Formation by Grey and Kassube (1963), but is more properly assigned to the Upper Devonian Woodbend Group, where it represents the distal starved basin component of the Fort Simpson basin-filling shales (Petrel Robertson, 1992).

Detailed mapping and interpretation of basinal shale – carbonate platform relationships holds promise for refining concepts of platform and reef growth, and hence improving understanding of Devonian reefal reservoirs and traps. Petrel Robertson (1992) undertook such efforts for the Otter Park / Slave Point succession. As our knowledge improves, exploration for more subtle and intricate targets will be possible, similar to the exploration situation during the past thirty years along Woodbend / Winterburn reef trends in Alberta.

STRUCTURAL FRAMEWORK

Structure, both syndepositional and post-depositional, played a major role in shaping the paleogeography and reservoir development of northeastern British Columbia during Devonian time. Basin margins and bank edges were preferentially located along deep-seated faults that were active during deposition (Morrow et al., 2002). Hydrothermal fluids migrated along these same faults, focusing diagenetic processes which enhanced reservoir quality. Faults can be mapped based on seismic interpretation, surface lineaments or regional isopach maps, and are coincident in many place with aeromagnetic anomalies interpreted as major basement discontinuities (Map 10).

Four main basement magnetic domains – Liard Terrane, Nahanni Terrane, Fort Simpson High, and Hotah Terrane – have been identified within the study area (Ross, 1990; Peirce et al.,1998) (Map 10). Sharp magnetic gradients can be interpreted as domain boundaries and basement fault trends, such as the Hay River Fault Zone and Bovie Lake Fault Zone (Fig. 3, Map 10).

Significant movements on the Bovie Fault began near the end of Devonian time, contemporaneous with Kotcho (Wabamun) deposition. The throw of the fault increases from 700 metres at Muskwa level to 1500 metres at Exshaw level, indicating differential western subsidence. This culminates in the preservation of a very thick (> 2000 metres) Mississippian section in the Maxhamish and Liard Plateau areas (94-N, O) (Monahan, 1999; Morrow et al., 2001). There is also evidence of down-to-the-northwest displacement along the fault during Chinchaga deposition (Map 2).

The Hay River Fault Zone has experienced numerous periods of reactivation and complex block faulting, from Proterozoic to Cretaceous times (Petrel Robertson, 1995, 1997). During the Devonian, long-term subsidence along the Hay River Fault Zone is shown by a regional thick in the Muskeg evaporites (Map 6), which is overlain by relatively deep-water facies of the Hotchkiss Embayment during Slave Point time (Map 8, 9).

Morrow et al. (2002) invoked movement on basement faults as a controlling influence in the position of the Cordova Embayment, which retained its character as a reef-rimmed basin throughout Keg River to Slave Point time (Map 5, 8). These faults are clearly expressed on the magnetic intensity map along the eastern side of the embayment, while the western flank of the embayment and the eastern margin of the Horn River Basin cross-cut basement features at a low angle (Map 10). In the southwest, high magnetic gradients along the western margin of the Fort Simpson high indicate a potential basement influence on the position of the postulated western margin to the restricted Elk Point basin (Map 10; Fig. 3).

At a more local scale, areas such as the Adsett Platform exhibit sharp geographic limits, which appear to coincide with magnetic lineaments and/or faults defined in younger strata (Map 8, 9). Numerous smaller-scale faults coincide with individual production trends and overall morphology of the Clarke Lake barrier margin. Isolated Keg River (and younger) buildups such as Yoyo and Sierra are defined by intersecting fault lineaments (Map 4, 5). Along the eastern margin of the Horn River Basin, linear, northwest-southeast trending pools and porosity trends within the Slave Point suggest that the bank margin is offset by a number of local faults paralleling the regional northeast-southwest fault trend (Map 10). Similarly, Morrow et al. (2001) suggested that basement structures influenced development of individual Slave Point productive reef edges along this margin in the Northwest Territories.

Figure 3. Interpretation of Fort Simpson High as "push-up" structure in a left stepping right-lateral strike-slip fault zone.

HYDROTHERMAL DOLOMITE RESERVOIRS

Hydrothermal dolomites (HTD), characterized by coarse-crystalline white saddle dolomite, and commonly associated with collapse and brecciation, form important components of many Devonian reservoirs in northeastern British Columbia (Nadjiwon and Morrow, 2001) (Plates 14-19). Key western Canadian discoveries have also been made during the past decade in the Nahanni Formation at Fort Liard (initial productivities up to 70 MMCF/D), and in the Swan Hills Formation at Simonette (Duggan et al., 2001). Further afield, hydrothermal dolomite reservoirs are currently very active exploration targets in the lower Paleozoic of southwestern Ontario and the northeastern United States (Davies et al., 2003).

Three factors are important in the genesis of hydrothermal dolomites:

- Carbonate facies with preserved primary porosity and permeability;
- An extensional tectonic setting, giving rise to normal and strike-slip fault motions;
- An elevated geothermal gradient, providing a source for hydrothermal fluids.

Primary lithofacies have a significant influence on the development of HTD reservoirs. In strata with good initial effective permeability and porosity, such as reefal buildups, dolomitization enhances reservoir quality over broad areas (Lonnee and Machel, 2001). At Clarke Lake, pervasive dolomitization occurred in reefal facies near the platform margin, apparently along a major strike-slip fault. In contrast, where hydrothermal dolomitization occurs within lithofacies with poor primary reservoir quality, such as tight shaly limestone, reservoir enhancement may be restricted to a narrow corridor along the fault zone.

Hydrothermal dolomites commonly occur along wrench or strike-slip fault systems, as intensive fracturing in fault blocks bounded by strike-slip faults is particularly conducive to the introduction of hydrothermal fluids (Berger and Davies, 1999). Regarding the Slave Point at Ladyfern, Boreen (2003b) noted: *"In areas of maximum extension proximal to fault intersections, intense dissolution, brecciation and hydrothermal dolomitization have resulted in seismically resolvable collapse synclines at the Muskeg and Slave Point levels. The thickest and best reservoir sections … are directly associated with these 'collapses'… Collapse synclines occur along some faults in a 'string of pearls' configuration and also in proximity to fault intersections"* (Fig. 4). The best wells at Ladyfern exhibit initial productive potential of greater than 100 MMCF/D because of porosity enhancement, fracturing, and brecciation.

Prospective areas can thus be delineated by mapping primary reservoir trends such as reef margins, and plotting intersections with major fault trends. Once primary areas of interest are identified, detailed mapping can be undertaken to identify the presence and distribution of HTD's. At the prospect level, good seismic control is critical in the delineation of key faults and reservoir characteristics. Boreen (2003a) noted that 3D seismic control was critical at Ladyfern in the delineation of Slave Point collapse features associated with hydrothermal dolomite emplacement and reservoir solution (Fig. 4).

In this study, net porosity isopachs have been mapped using a 5% log cutoff. Where possible, the presence of porosity has been verified in sample and/or core descriptions, and the primary lithologies noted (e.g., leached limestone, hydrothermal dolomite – see paleogeography / porosity maps).

Morrow et al. (2001) inferred that massive hydrothermal dolomites should be found at the intersections of northeast-trending fault zones with porous Slave Point and Keg River shelf margins in the Northwest Territories. Numerous similar situations occur in adjacent northeastern B.C. – for example, along the eastern Slave Point margin of the Horn River Basin (Map 9).

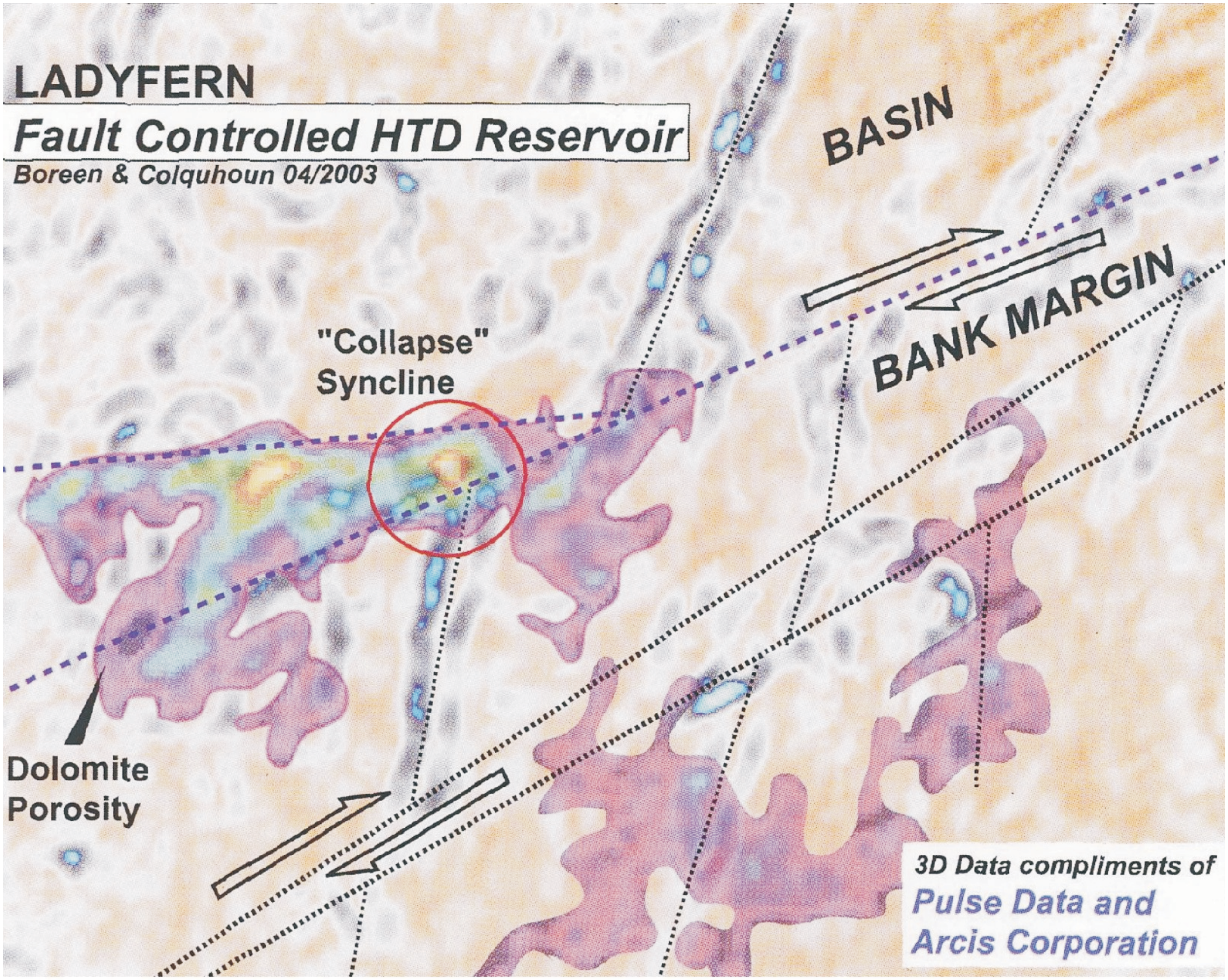


Fig. 4. Hydrothermal dolomitization associated with faulting at Ladyfern (from Boreen, 2003).

HYDROCARBON POTENTIAL

Torrie (1973) outlined tremendous hydrocarbon potential in deep Devonian strata of northeastern British Columbia, based upon the few major discoveries and limited drilling of the time. Exploration during the past 30 years has uncovered new reserves, and demonstrated that much more remains to be found. Deep Devonian reservoirs host up to 14 TCF of established gas in place in northeastern British Columbia and adjacent regions, and hold tremendous potential for additional discoveries along traditional exploration fairways, and in more remote, lightly-explored areas (Reinson et al., 1993; Canadian Gas Potential Committee, 2001; Petrel Robertson Consulting Ltd., 2003).

Discovery of the Ladyfern Slave Point gas field in 2000 gave a tremendous boost to Canada's total gas production, and dramatically accelerated Devonian exploration in B.C. The maps presented in this study illustrate numerous exploration fairways, along which comparable discoveries will be made.

Chinchaga Formation

Chinchaga carbonates produce gas at Beaver River (and to the north at Kotaneelee, Pointed Mountain, and Fort Liard), primarily from hydrothermal dolomite reservoirs and structural traps (Morrow and Davies, 2001).

The Chinchaga platform is prospective in northernmost British Columbia where fenestral and intrafossil vug porosity has been observed (Plate 2a), and where hydrothermal dolomites occur along fault trends (Map 3). Numerous gas shows occur in the Chinchaga (and younger formations) along the eastern upthrown margin of the Bovie Lake Fault in B.C. and the Northwest Territories, as large volumes of gas appear to have been preferentially transported along the axis of the fault, and trapped locally in structures.

A second play fairway may exist where Chinchaga carbonates (assigned to the Nahanni Formation) shale out northwestward toward the Yukon Territory (Map 3). The Chinchaga carbonate platform is fully developed at Beaver River, but is absent or drastically thinned northwest of Kotaneelee and Pointed Mountain (Morrow and Potter, 1998). Reefal buildups may occur along the carbonate bank edge (which may be associated with the Liard Fault), and would offer more effective matrix porosity and permeability than the fractured reservoirs at Beaver River, Kotaneelee, and Pointed Mountain Fields. Hydrothermal dolomitization would further enhance reservoir potential on this trend.

Keg River / Sulphur Point Formations

The Keg River produces gas from isolated reefal buildups controlled by basement horst blocks, such as at Yoyo and Sierra fields, and from smaller structural/stratigraphic pools along the major basinal margins (Reinson et al., 1993) (Map 5). It is difficult to assign productive intervals precisely in many of these pools, as most development wells penetrate only the upper productive section, and many are not logged to total depth.

Sulphur Point strata are difficult to distinguish from the Keg River in many areas, and hence their exploration potential can be assessed jointly. In general, however, the Sulphur Point is regarded as a more homogeneous regional aquifer, and trapping situations may not occur as abundantly as in the Keg River.

Keg River / Sulphur Point carbonates are prospective in at least four settings:

- Isolated platform margin reservoirs associated with cross-cutting faults;
- Buildups along the flanks of platform embayments;
- Stratigraphic traps within the southern transition to Muskeg evaporites;
- Carbonate banks flanking western highlands, along the western side of the restricted Elk Point Basin.

Faulted Platform Margins – Conceptually, wherever faults cut across a continuous platform margin at a high angle, a potential structural trapping situation is set up. If the fault is deep-seated, and/or was active near the time of deposition, it may have influenced reef growth and subsequent diagenetic processes. Morrow et al. (2001) discussed this type of prospect for the Keg River and Slave Point margins in the adjacent Northwest Territories.

Such traps will likely be small – up to several spacing units and tens of BCF – but highly productive.

Flanks of Platform Embayments – Fault lineaments and a poorly-controlled Keg River thin indicate the possible presence of a southwest-northeast embayment cutting across the Keg River platform through 94-J-3 and 94-J-7 (Map 5, 6). By analogy with the Hotchkiss Embayment (at Slave Point level), Keg River and Sulphur Point reef buildups along the margins may be prospective. Other embayment trends, not mappable on current well control, may exist.

Discoveries of this type could range up to several hundred BCF reserves in thick buildup sections, with high productivities from dolomitized reefal buildups.

Southern Depositional Limit – Isolated stratigraphic traps may occur where Keg River carbonates pass southward to Muskeg evaporites. However, reservoir quality and continuity would likely be poor, unless fault-related dolomitization provided local reservoir enhancement, as reservoir-quality reefal buildups are not expected to occur in this back-margin setting.

Conceptually, discoveries could be large, but it appears more likely that they would be relatively small (50 BCF or less), and less productive than the dolomitized reefal buildups targeted in the other play types.

Western Carbonate Banks – As discussed above, the restricted Elk Point (Muskeg) evaporite basin must have had a western margin; limited outcrop and well data indicate the possible presence of highlands and associated Keg River reefal buildups. Maps 4 and 5 suggest that prospective buildups flanked highland areas, but a more continuous reefal rim may have existed (Petrel Robertson, 2003). Displacement along regional southwest-northeast fault trends may have elevated particular structural blocks, thus influencing the paleogeography of the margin trend. Later movement, during the Antler Orogeny, would have influenced fluid movements and hence diagenetic trends (Petrel Robertson, 1992, 1995).

Keg River / Sulphur Point discoveries on the western margin could range up to Clarke Lake size (hundreds of BCF to more than a TCF) with production rates comparable to the best Clarke Lake or Ladyfern wells (100 MMCF/D+). Although mapping would be difficult and drilling expensive for deeply-buried targets along this play trend, high reservoir pressures would augment reserves and productivity.

Slave Point Formation

Slave Point exploration potential is controlled by many of the same factors as Keg River/Sulphur Point potential, and hence is conceptually very similar. However, capping shales provide better seals for Slave Point reservoirs, and allow better seismic imaging in many cases.

Slave Point carbonates produce from a variety of settings:

- Large barrier buildups at Clarke Lake;
- Smaller fault-bounded barrier traps along the Horn River and Cordova Embayment margins (e.g., Tsea, Cabin, Louise, Helmet);
- Embayment margins in the platform interior (Ladyfern);
- Lower depositional cycles on isolated platform blocks (Adsett) (Map 9, 10).

Each of these play types offers considerable additional potential for substantial discoveries.

Barrier Buildups – The Horn River Basin and Cordova Embayment margins have been drilled fairly extensively, and it is unlikely that large buildups resembling Clarke Lake will be found along these trends in B.C. However, the postulated western margin of the Slave Point platform is essentially unknown, and may be prospective.

As for the Keg River / Sulphur Point, discoveries in this area will be difficult to map, but reserves could be on the TCF scale, with initial well productivities ranging in excess of 100 MMCF/D.

Faulted Platform Margins – Deep-seated faults cross-cutting platform margins offer smaller-scale potential reserves, but high productivities where reservoirs are diagenetically enhanced. Morrow et al. (2001) discussed this type of prospect for the Keg River and Slave Point margins in the adjacent Northwest Territories.

Interior Embayment Margins – The Ladyfern discovery extended prospectivity from Cranberry in Alberta, along the Hotchkiss Embayment margin, westward into B.C. Isolated Slave Point buildups within embayments, such as Hamburg, may also be prospective. In addition to defining the limits of the embayment, faults along the Hay River Fault Zone have linked deep hydrothermal fluids to Slave Point reservoirs. Exploration along the embayment margins should thus be guided by the presence of faults, as indicated by seismic, reactivation at higher stratigraphic levels (Petrel Robertson, 1997), and basement magnetic anomalies. Ladyfern itself is coincident with a strong magnetic feature (Map 10).

Further west, along the northern flank of the Hotchkiss Embayment at Julienne Creek, a core from c-14-L/94-B-16 exhibits a rich fossil fauna in the Slave Point, indicative of a backreef subtidal lagoon setting (Plate 12a). There has been extensive matrix dolomitization, but no evidence of dissolution. This well may indicate proximity to a prospective reef along the embayment margin.

Other Slave Point interior embayments have been mapped in 94-G and 94-J, but have not been extensively explored at the Slave Point level. Several porosity anomalies in flanking wells suggest that opportunity exists for embayment margin plays to be developed (Map 9).

Since the Ladyfern discovery, the Hotchkiss Embayment has been the focus of relatively intense Slave Point exploration activity. Various operators have announced Slave Point discoveries as far west as 94-H-5, but most appear to be limited in reserve size and initial productivity. However, drilling is still sparse, and potential remains for the discovery of new fields on the scale of Ladyfern.

Lower Slave Point Cycles – Discrete fault-bounded areas within the Slave Point platform may develop additional cycles of reef growth, as at Adsett, given appropriate timing of movements on the faults. Detection of these cycles may be difficult without fairly extensive well control, but moderate reservoir potential may occur under the appropriate structural/diagenetic conditions.

Exploration Summary

The Deep Devonian of northeastern B.C. has been explored thoroughly only along a few play trends, and thus offers abundant potential for high-reserve, high-productivity discoveries along several established and postulated fairways.

A key recommendation that arises from this project is to carefully map and assess regional fault trends, particularly those that appear to be deep-seated, and that were reactivated throughout Phanerozoic time. Major faults have played a large role in nucleating reef growth along major platform margins, and in determining the locations of intra-platform embayments and isolated carbonate buildups. Deep-seated faults, particularly strike-slip shear zones containing small fault blocks prone to reactivation, have also promoted the movement of deep hydrothermal fluids, accelerating reservoir-enhancing diagenetic processes in carbonate facies. The Hay River Fault Zone is a prime example of such a trend, but several other faults have probably exhibited similar behaviour.

Paleogeography / porosity maps in this report highlight areas where porosity has been observed on well logs. Some of these areas correspond to known production, but others provide leads to prospectivity in new areas, and require evaluation in terms of the play types outlined above.

Resource Assessment Statistics – The Geological Survey of Canada (Reinson et al., 1993) and Canadian Gas Potential Committee (2001) have summarized discovered reserves and expected discoveries for Canadian gas plays. The following volumes have been tabulated for Devonian plays of northeastern B.C. (all figures are raw initial gas in place):

- Geological Survey of Canada (Reinson et al., 1993)
  - Discovered 283 e^9m^3 (10.0 TCF)
  - Ultimate Resource 572 e^9m^3 (20.2 TCF)

- Canadian Gas Potential Committee (2001)
  - Discovered 401 e^9m^3 (14.1 TCF)
  - Ultimate Resource 589 e^9m^3 (20.8 TCF)

In both cases, discovered and ultimate volumes include those associated with play trends extending into adjacent Alberta and Northwest Territories.

Gas volumes remaining to be discovered are considerable under both assessment schemes. In addition, the CGPC recognized that potential may occur in Chinchaga and older reservoirs, while the GSC noted that other unspecified gas plays may exist at various stratigraphic levels. Resource potential for these conceptual plays cannot be quantified, but is thought to be large (TCF scale).

When considering estimates of resources yet to be discovered, one must take into account the definition of play types and fairways. With increased well control and knowledge, a more detailed breakdown of plays can be developed, and hence a more accurate projection of resource potential may be justified. At the present time, we question the statistical validity of projections for some play types in which large portions of prospective fairways have not been sampled. For example – there has been no assessment of the western barrier margin of the Keg River / Sulphur Point and Slave Point platforms; the Hotchkiss Embayment is only now being explored; and platform interior embayment margin plays are not even considered as a potential play type in either assessment.

We conclude that although the remaining gas resource potential for the Devonian of northeastern B.C. is estimated to be very large, it may be even larger with exploration of new and expanded play trends.

REFERENCES

Belyea, H., and A.W. Norris, 1962. Middle Devonian and older Paleozoic formations of Southern District of Mackenzie and adjacent area. Geological Survey of Canada Paper 62-15, p. 76-79.

Berger, Z., and G. Davies, 1999. The development of linear dolomite (HTD) reservoir facies along wrench or strike slip fault systems in the western Canadian sedimentary basin.

Boreen, T., 2001. Ladyfern, N.E.B.C.: Major gas discovery in the Devonian Slave Point Formation. Proceedings, CSPG Annual Convention.

Boreen, T., 2003a. Exploration and Technology update: Ladyfern. CSPG Reservoir, v.30, #5, p.34-36.

Boreen, T.,2003b. The Ladyfern Gas Field – Canada is still hiding mammoths. Proceedings, AAPG Annual Convention.

Canadian Gas Potential Committee, 2001. Natural gas potential in Canada, 2001.

Davies, G., 2003. Hydrothermal (thermobaric) dolomite reservoir project, Alberta, BC, NWT, Yukon. (website:http://ursu.uregina.ca/~geol/shortcrs.html).

Duggan, J.P., E.W. Mountjoy, and L.D. Stasiuk, 2001. Fault-controlled dolomitization at Swan Hills Simonette oil field (Devonian), deep basin west-central Alberta, Canada. Sedimentology, v. 48, p. 301-323.

Gray, F.F. and Kassube, J.R. 1963. Geology and stratigraphy of Clarke Lake gas Field, British Columbia. AAPG Bulletin, v. 47, p. 467-483.

Griffin, D.L., 1967. Devonian of northeastern British Columbia. In: International Symposium on the Devonian System, edited by D.H. Oswald. Alberta Society of Petroleum Geologists.

Hickman, R.G., W.N. Kent, M. Odegard, N. Henshaw, and J. Martin, 2003. Hydrothermal Dolomite Reservoirs--A Play Whose Time Has Come. Proceedings, AAPG Annual Meeting.

Lonnee, J.S., and H.G. Machel, 2001. Reservoir Enhancement in the Clarke Lake Field, British Columbia: Facies Control on Diagenesis in the Middle Devonian Slave Point Formation. Proceedings, AAPG Annual Meeting.

Meijer Drees, N.C., 1988. The Middle Devonian sub-Watt Mountain unconformity across the Tathlina Uplift; District of Mackenzie and northern Alberta, Canada. In: Devonian of the World, CSPG Memoir 14, v. 2, p. 477-494.

Meijer Drees, N.C., 1994. Devonian Elk Point Group of the Western Canada Sedimentary Basin. In: Geological Atlas of the Western Canada Sedimentary Basin, edited by G.D. Mossop and I. Shetsen. Canadian Society of Petroleum Geologists / Alberta Research Council.

Monahan, P., 1999. Stratigraphy and potential hydrocarbon objectives of Mississippian to Lower Cretaceous strata in the eastern Liard Basin area. British Columbia Dept. of Energy, Mines, and Mineral Resources, consulting report.

Morrow, D.W., G.L. Cumming, and K.L. Aulstead, 1990. The gas-bearing Devonian Manetoe Facies, Yukon and Northwest Territories. Geological Survey of Canada Bulletin 400.

Morrow, D.W., and G.D. Davies, 2001. The Liard Basin Manetoe Dolomite: a new look at a frontier deep gas play. Proceedings, CSPG Rock the Foundation Convention.

Morrow, D.W., B.C. MacLean and L.S. Lane, 2001. Liard Basin and Trout Plain: tectonic evolution and petroleum potential, NWT. Proceedings, CSPG Rock the Foundation convention.

Morrow, D.W., and J.D. Potter, 1998. Internal stratigraphy, petrography, and porosity development of the Manetoe Dolomite in the region of the Pointed Mountain and Kotaneelee gas fields. In: Oil and Gas Pools of the Western Canada Sedimentary Basin, edited by J.R. Hogg, p. 137-161.

Morrow, D.W., M. Zhao, and L.D. Stasiuk, 2002. The gas-bearing Devonian Presqu'ile Dolomite of the Cordova Embayment region of British Columbia, Canada: dolomitization and the stratigraphic template. AAPG Bulletin, v. 86, #9, p. 1609-1638.

Nadjiwon, L., and D.W. Morrow, 2001. Brecciation and hydrothermal dolomitization of the Middle Devonian Dunedin, Keg River, and Slave Point formations of northeastern British Columbia. Proceedings, CSPG Rock the Foundation Convention.

Oldale, H.S., and R.J. Munday, 1994. Devonian Beaverhill Lake Group of the Western Canada Sedimentary Basin. In: Geological Atlas of the Western Canada Sedimentary Basin, edited by G.D. Mossop and I. Shetsen. Canadian Society of Petroleum Geologists / Alberta Research Council.

Peirce, J.W., E. Ebner, and N. Marchand, 1998. High resolution aeromagnetic interpretation over Sierra and Yoyo reefs, northeastern British Columbia. In: Geologic applications of gravity and magnetics: case histories. AAPG Studies in Geology #43, p. 93-101.

Petrel Robertson Ltd., 1990. Regional Geological-Geophysical Paleozoic Study. Non-exclusive study.

Petrel Robertson Ltd., 1992. Regional Geological Devonian Study, Blocks 94-B, G.J, and O. Non-exclusive study.

Petrel Robertson Ltd., 1995. An Integrated Geological, Geophysical and Hydrodynamic Evaluation of the Mississippian in northeast British Columbia. Non-exclusive study.

Petrel Robertson Ltd., 1997. Exploration and Development Assessment of the Lower Cretaceous section, Buick Creek-Laprise area, northeastern British Columbia. Non-exclusive study.

Petrel Robertson Consulting Ltd., 2003. Petroleum Resource Assessment, Muskwa-Kechika Management Area. Report for B.C. Ministry of Energy and Mines.

Reinson, G.E., P.J. Lee, W. Warters, K.G. Osadetz, L.L. Bell, P.R. Price, F. Trollope, R.I. Campbell, and J.E. Barclay, 1993. Devonian gas resources of the Western Canada Sedimentary Basin. Geological Survey of Canada Bulletin 452.

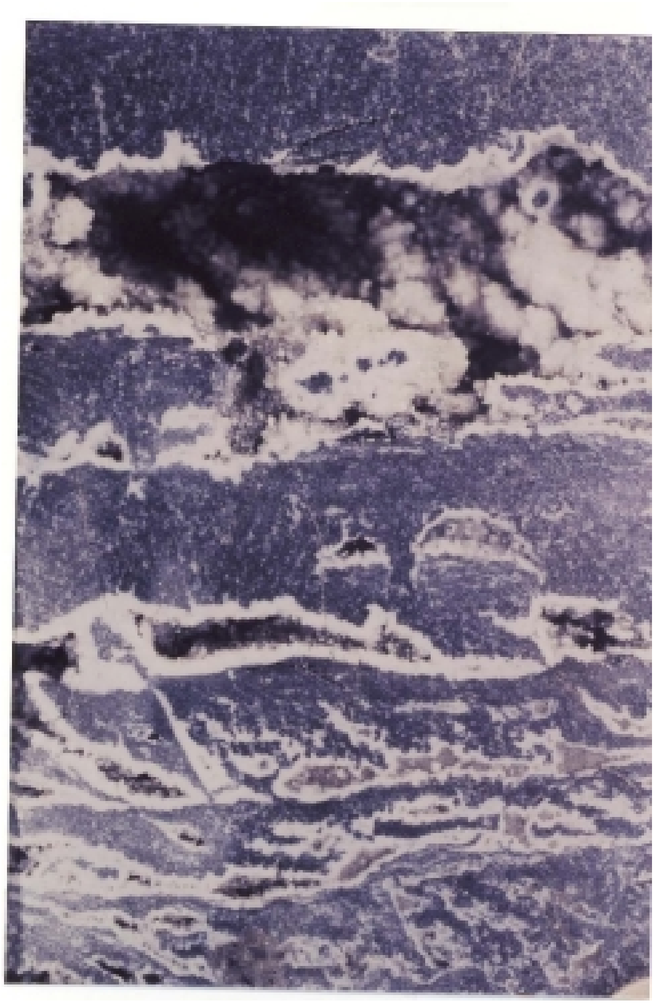
Ross, G.M., 1990. Deep crust and basement structure of the Peace River Arch region: constraints on mechanism of formation. Bulletin of Canadian Petroleum Geology, v. 38A, p. 25-35.

Torrie, J.E., 1973. Northeastern British Columbia. In: The Future Petroleum Provinces of Canada – their Geology and Potential, edited by R.G. McCrossan. CSPG Memoir 1, p. 151-186.

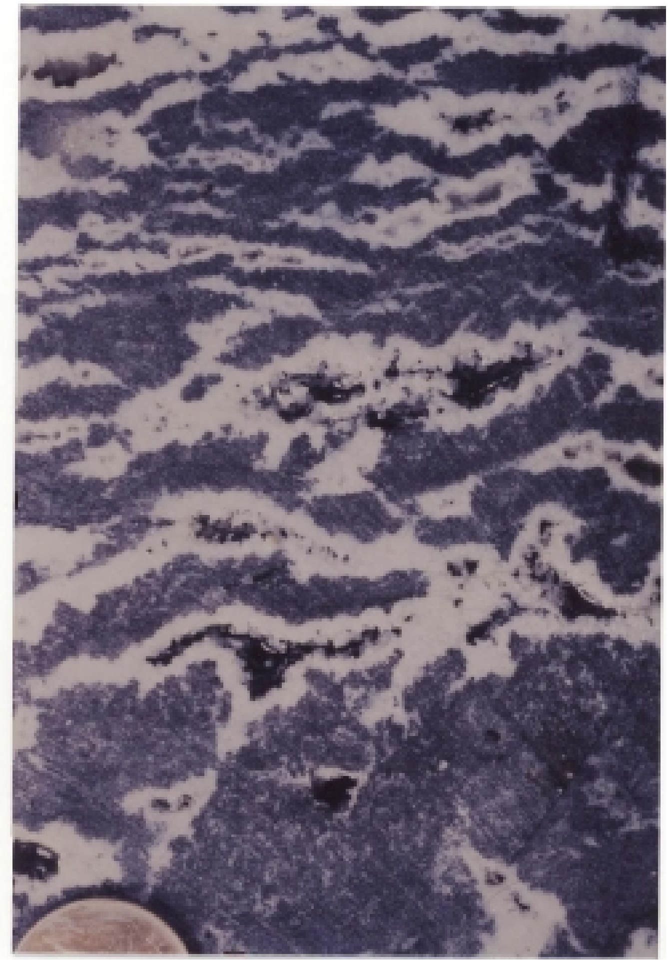
APPENDIX I

Core Photographs

PLATE 1 – UPPER CHINCHAGA

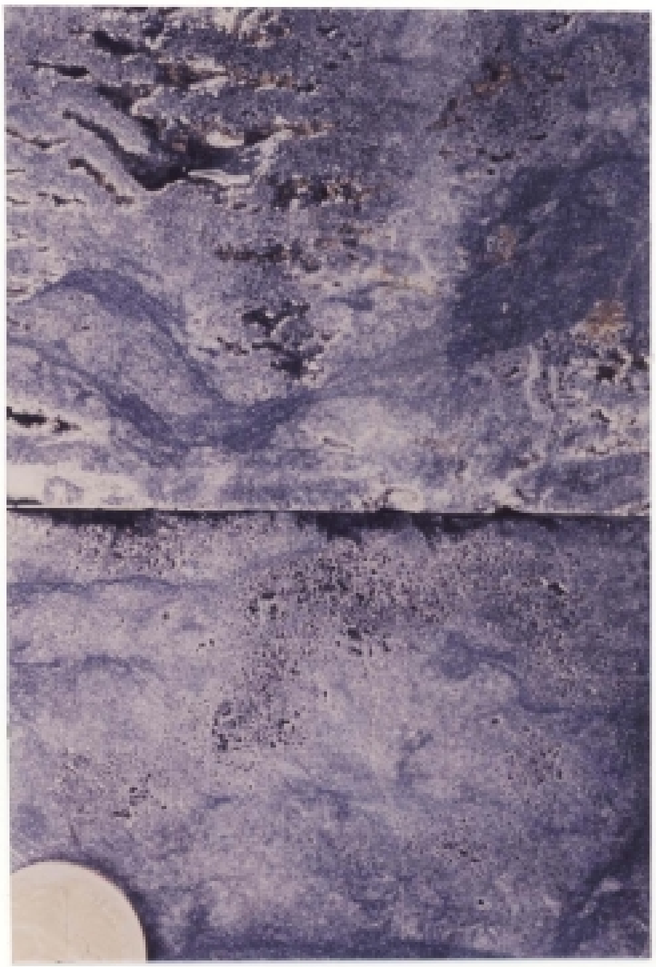


a. b-14-A/94-O-1 7713.0 ft. Upper Chinchaga
Peloid packstone with fenestral fabric. Note large nodular voids may be a result of anhydrite dissolution.



b. b-21-G/94-O-6 8691.0 ft. Upper Chinchaga
Peloid grainstone and mudstone, saddle dolomite cemented with vuggy porosity. The disrupted nature of the banding is the result of replacive anhydrite cement corroding the fenestral carbonate. Dissolution of anhydrite leaves a fragmented banded texture.

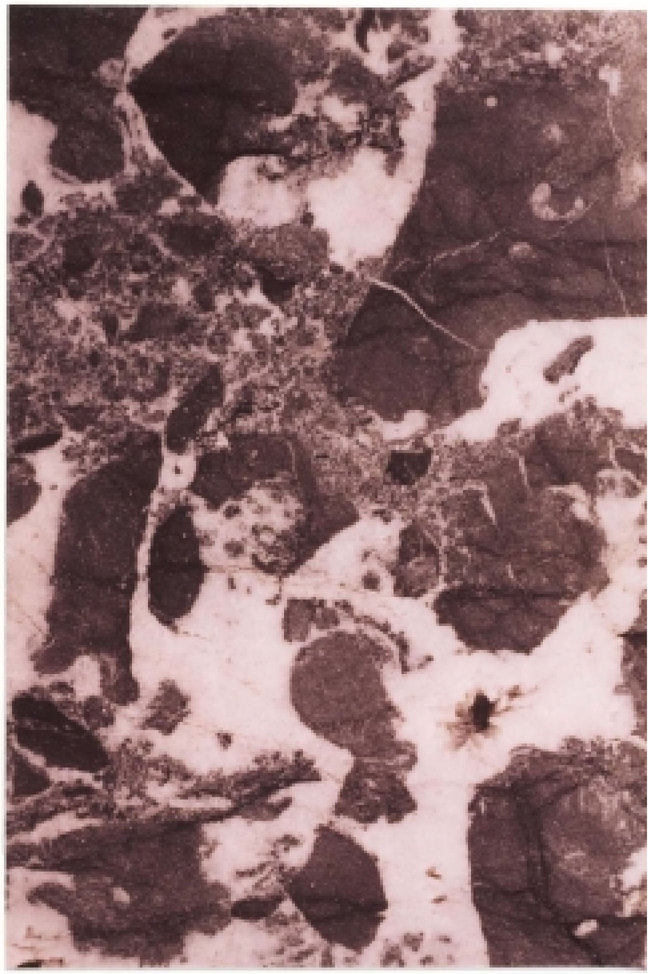
PLATE 2 – CHINCHAGA FORMATION



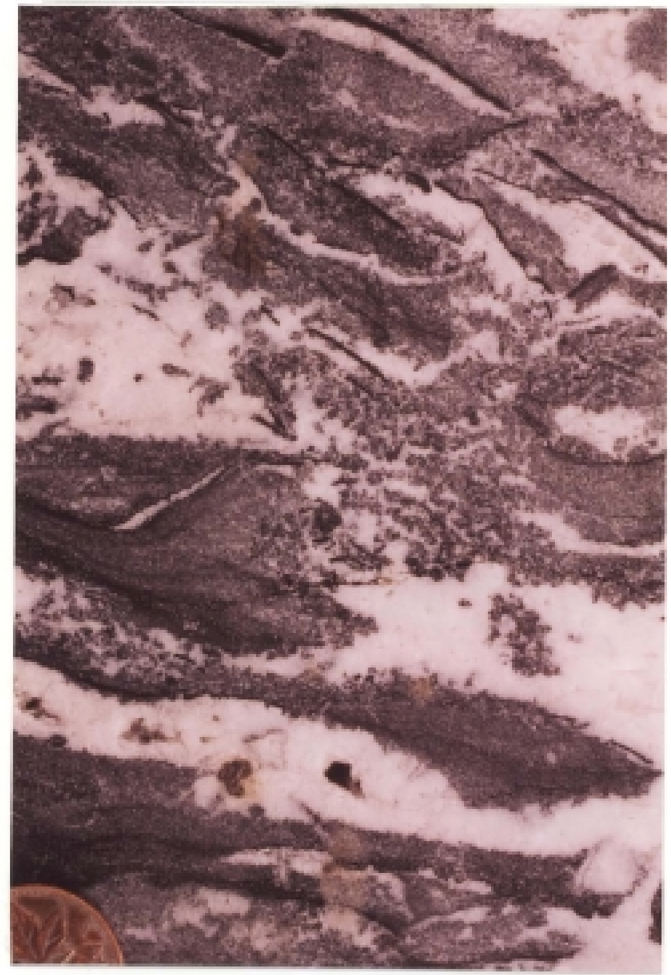
a. c-15-I/94-O-6 8742.0 ft. Upper Chinchaga
Peloid grainstone and dark mudstone with pinpoint vuggy porosity and fenestral fabric. Note complete lack of cementation in this example except for a trace at the midpoint of the core.

b. a-67-D/94-O-13 17,113.0 ft. Chinchaga
Dolomite microcrystalline breccia. Dark bioturbated mudstone disrupted angular fragments, some internal sediment of fine angular chips, rimmed by fine layer saddle dolomite, infilled by calcite.

PLATE 3 – CHINCHAGA FORMATION



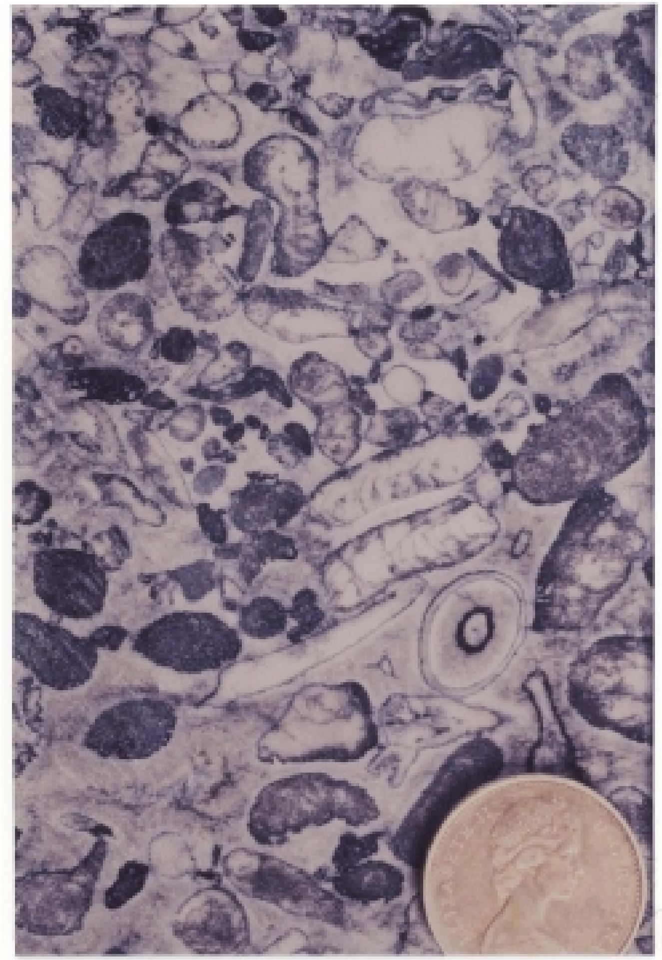
a. a-67-D/94-O-13 17,138.0 ft. Chinchaga
Breccia, microcrystalline dolomite matrix, white saddle dolomite cement, dissolution breccia pipe.



b. a-67-D/94-O-13 17,140.0 ft. Chinchaga
Algal laminate and peloid grainstone. Disrupted fabric caused by displacive, replacive anhydrite cement now white saddle dolomite.

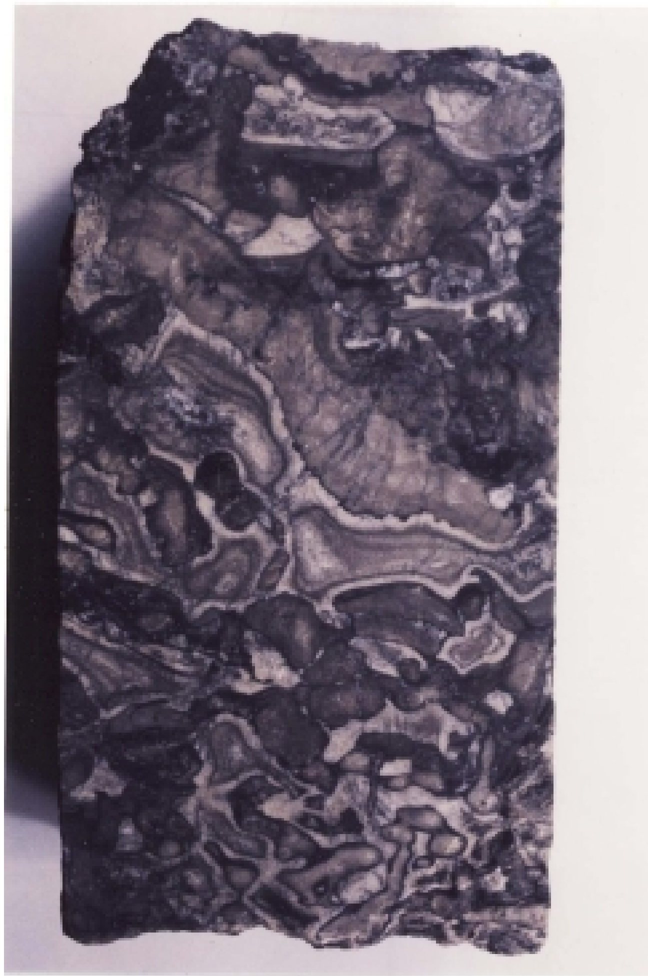
PLATE 4 - KEG RIVER

a. b-89-E/94-J-15 7348.5 ft. Upper Keg River
Dendroid and massive stromatoporoid boundstone. Skeletal grainstone matrix pyrobitumen "saturated"; presumably degraded oil saturation.

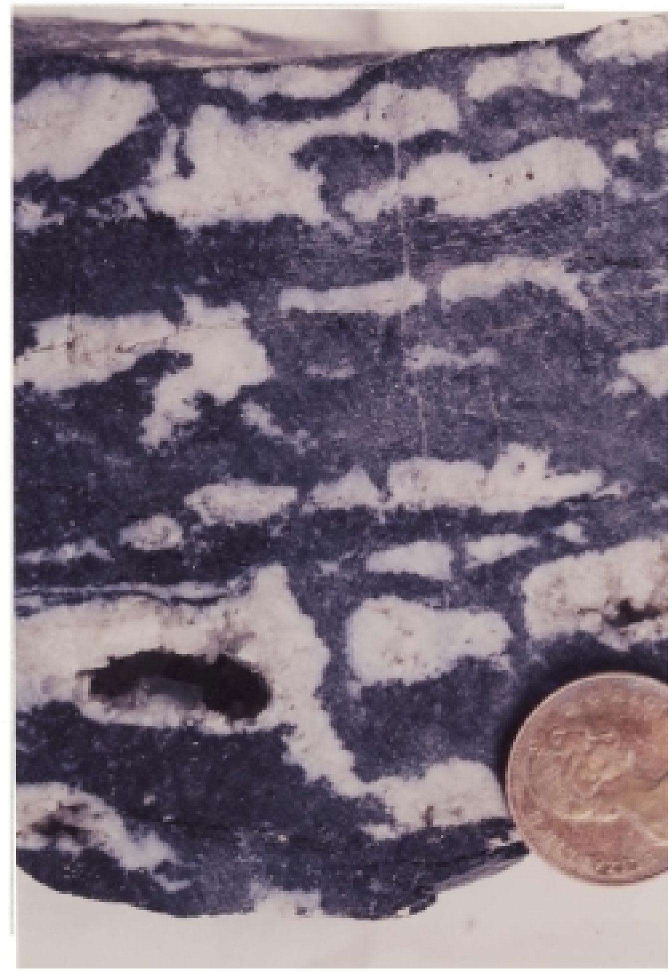


b. d-51-A/94-O-8 2232.0m Upper Keg River
Coarse skeletal grainstone in micritised stromatoporoid grains; mainly fragments of dendroid stromatoporoid, very well sorted.

PLATE 5 – SULPHUR POINT

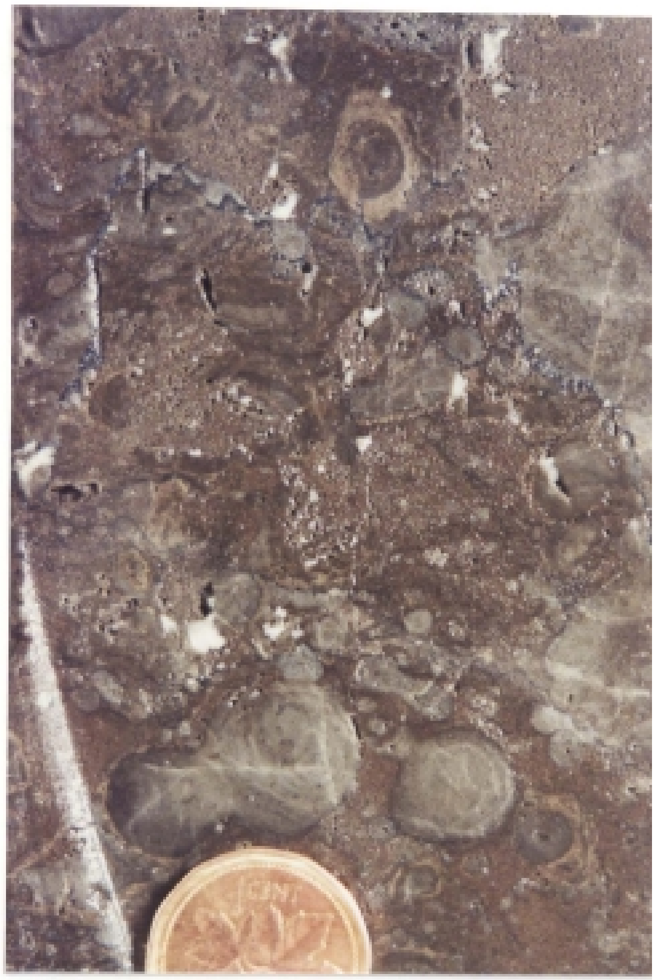


a. b-89-E/94-J-15 6731.0 ft. Sulphur Point
Dendroid and laminar stromatoporoid boundstone.



b. a-75-C/94-G-16 9564.5 ft. Sulphur Point
Dark grey microcrystalline dolomite peloid packstone with sabkha-type anhydrite nodules replaced by white saddle dolomite with some residual vugs.

PLATE 6 – SULPHUR POINT



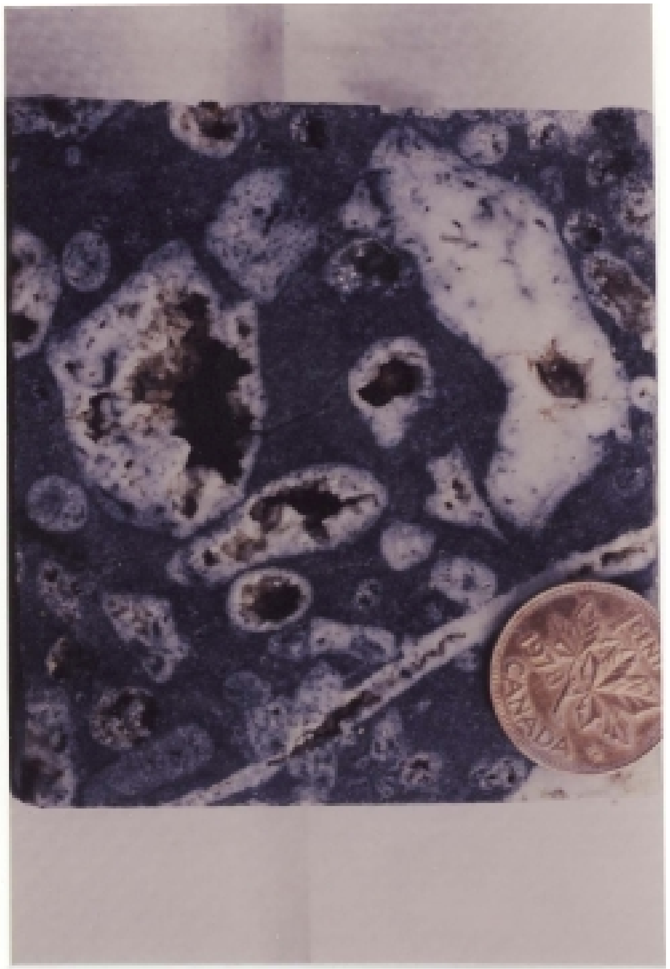
a. c-60-E/94-I-11 6957.0 ft. Sulphur Point
Dendroid stromatoporoid floatstone in Amphipora. Note leached intrafossil vugs lined by isopachous white saddle dolomite cement. Some vugs remain open uncemented. Matrix with some intercrystalline porosity.

PLATE7 – SLAVE POINT - DEEP SUBTIDAL

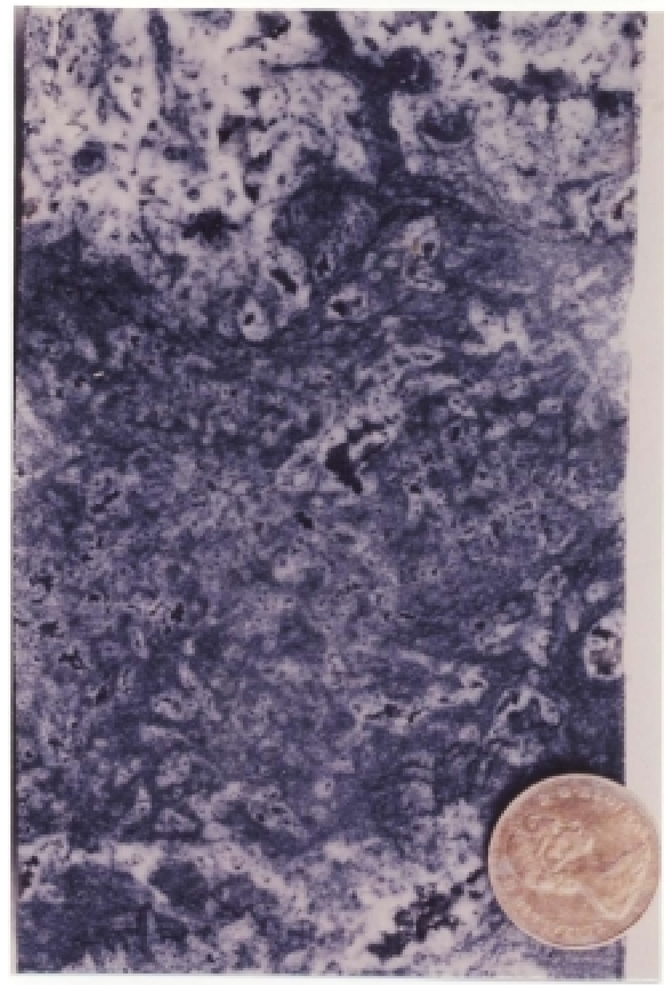
a. 7-5-97-4W6M 2222.8m Slave Point
Unfossiliferous argillaceous mudstone with nodular boudinage.

b. 11-4-97-5W4M 2283.3m Slave Point
Skeletal wackestone with nodular boudinage structure and sparse crinoids and brachiopods.

PLATE 8 – SLAVE POINT FORMATION

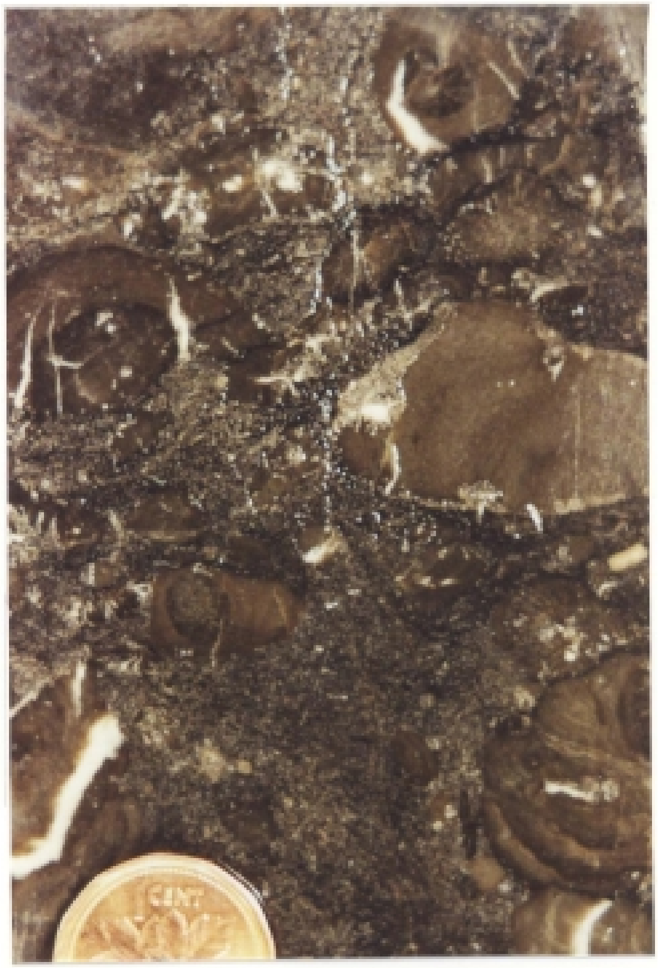


a. c-82-B/94-J-6 2862.3m Slave Point
Dendroid and bulbous stromatoporoid floatstone with intrafossil porosity. Three generations of dolomite. Dark grey microcrystalline matrix, bladed replacement in fossil coenostea and white cement.

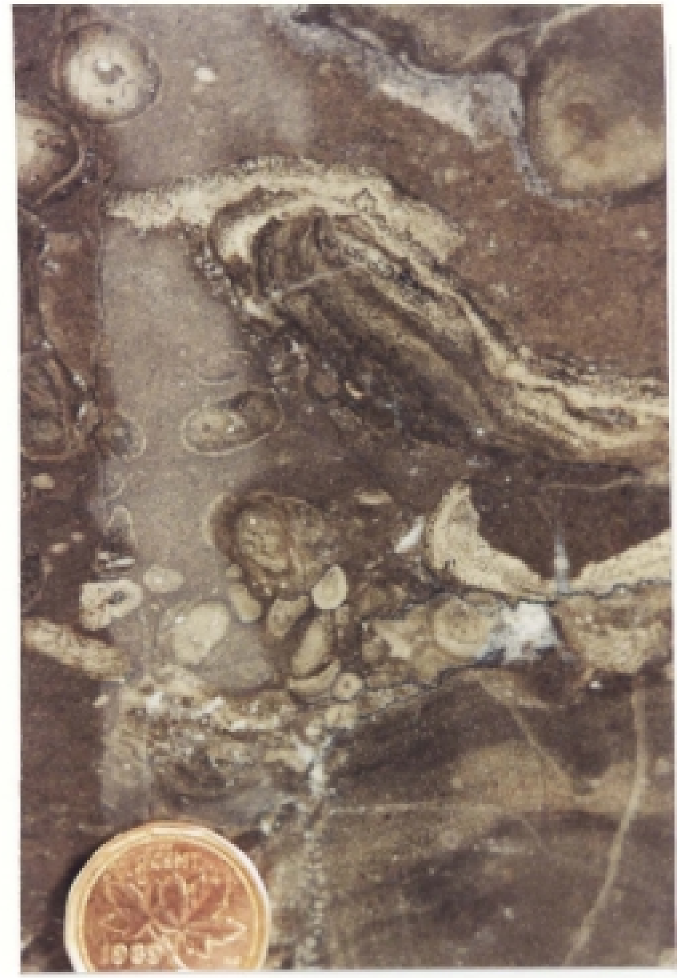


b. c-82-B/94-J-6 2867.3m Slave Point
Amphipora boundstone. Note shadowy texture preserved in fabric preserving dolomite with white saddle dolomite in intrafossil vugs.

PLATE 9 – SLAVE POINT - FORE REEF SUBTIDAL



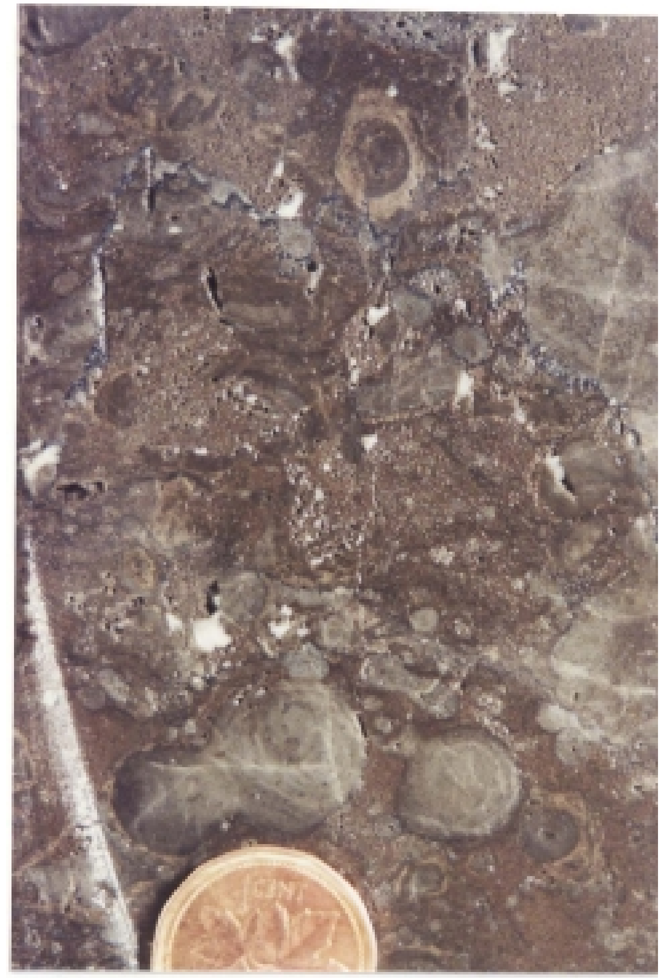
a. 2-6-97-11W6M 2511.0m Slave Point
Thamnopora, bulbous stromatoporoid floatstone, bituminous skeletal packstone matrix.



b. 3-35-96-11W4M 2548.30m Slave Point
Laminar and bulbous stromatoporoid floatstone.

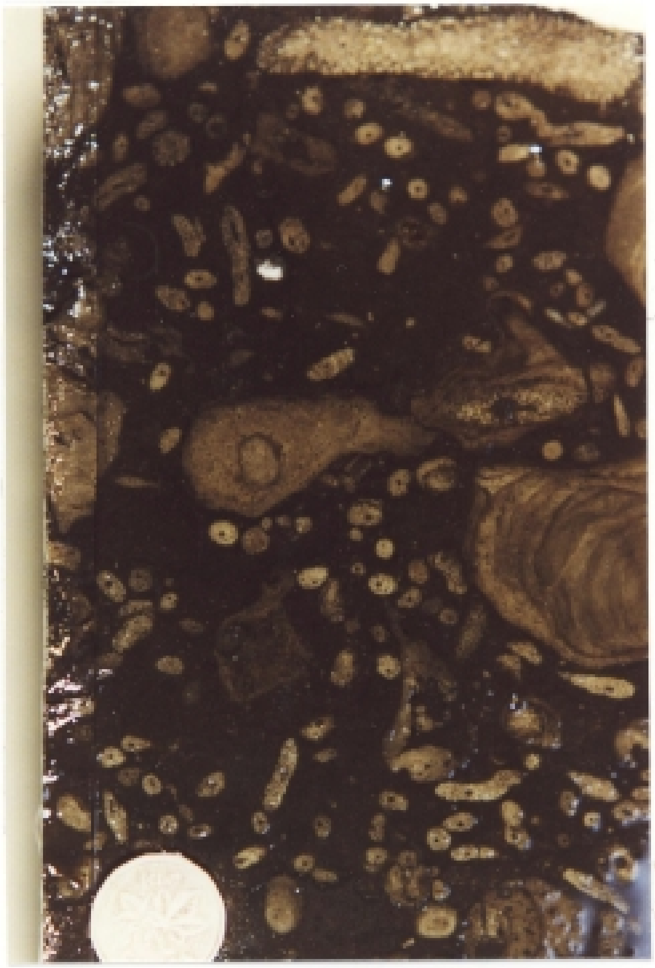
PLATE 10 – SLAVE POINT REEF

a. d-37-B/94-I-7 6453.3 ft. Slave Point
Dendroid stromatoporoid boundstone with skeletal peloid grainstone to packstone matrix.



b. 3-33-96-11W6M 2517.5m Slave Point
Bulbous to dendroid stromatoporoid floatstone in dolomitized matrix. This example has a minimum of intrafossil leaching but has good intercrystalline porosity in matrix.

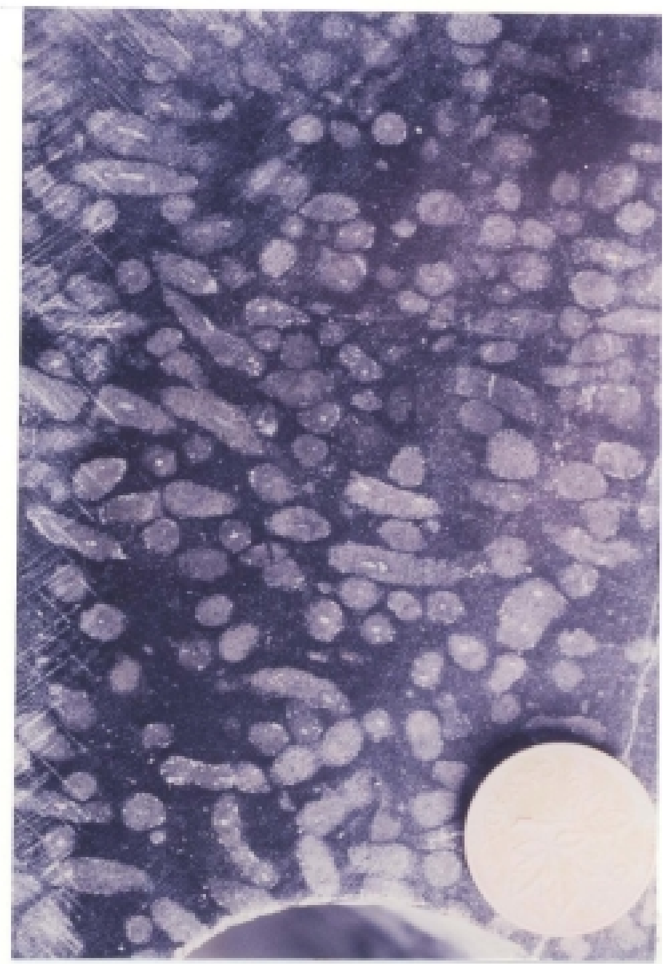
PLATE 11 – SLAVE POINT - BACK REEF SUBTIDAL



a. d-37-B/94-I-7 6458.7 ft. Slave Point
Dendroid stromatoporoid floatstone with peloid packstone matrix.

b. c-3-C/94-J-11 6420.5 ft. Slave Point
Dendroid and bulbous stromatoporoid with coated grains and *Amphipora* rudstone in bituminous mudstone.

PLATE 12 – SLAVE POINT - BACKREEF LAGOON SUBTIDAL

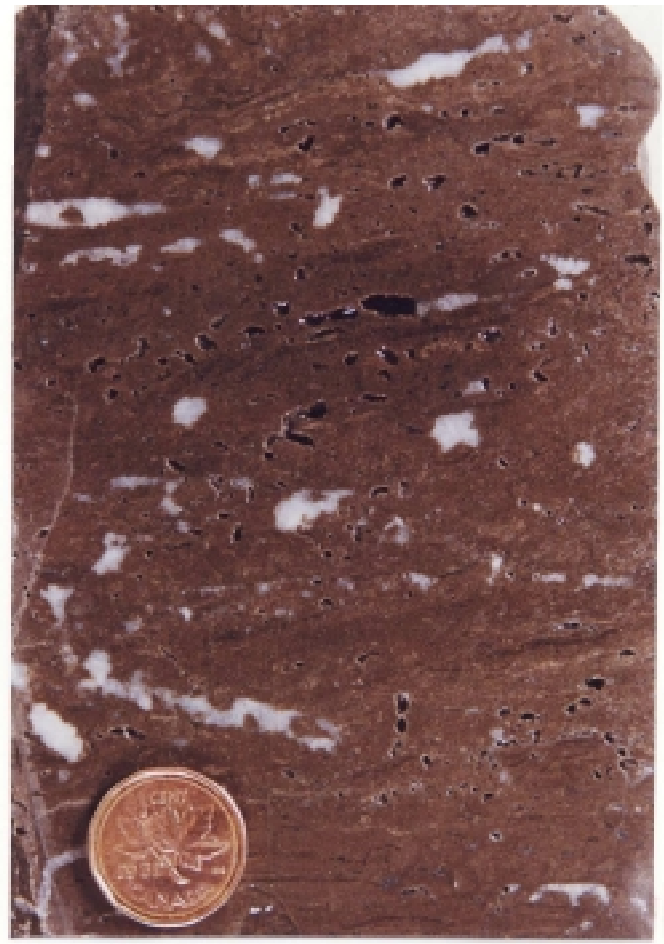


a. c-14-L/94-B-16 3855.0 ft. Slave Point
Amphipora boundstone with fine muddy peloidal matrix. Coenostea appear to be in partial growth position.

b. c-56-L/94-J-9 6425.5 ft. Slave Point
Amphipora, Thamnopora floatstone with dense bed of *Amphipora* rudstone with replacive fabric destructive saddle dolomite.

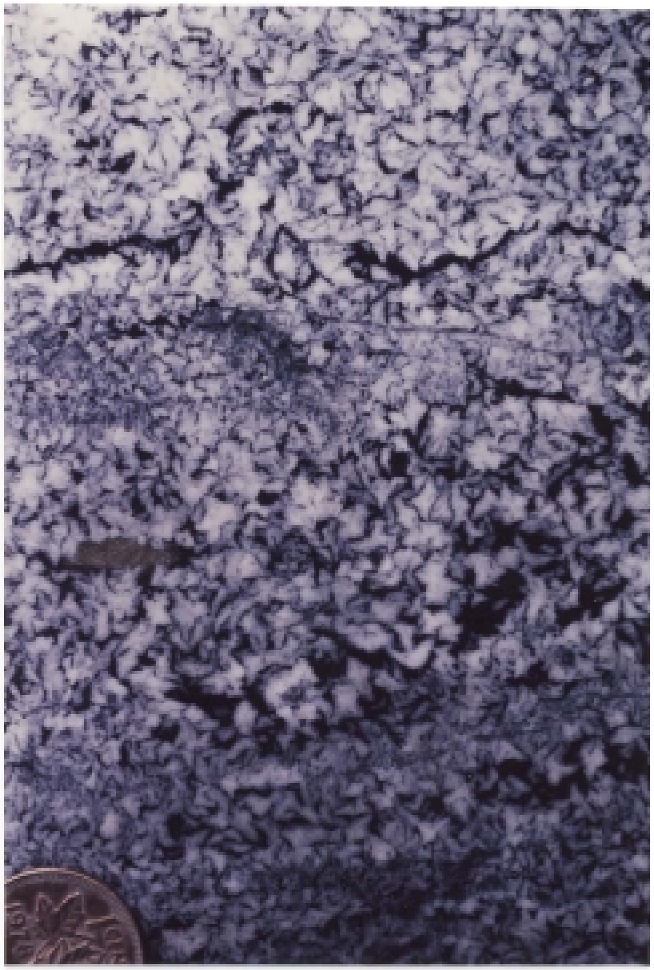
PLATE 13 – SLAVE POINT - INTERTIDAL – SUBTIDAL

a. 10-7-99-8W6M 2272.30m Middle Slave Point
Finely laminated peloid packstone and grainstone with fenestral fabric cemented by white sparry calcite.



b. 10-7-99-8W6M 2276.30m Middle Slave Point
Peloid packstone and grainstone with fenestral fabric; white sparry calcite cemented and open leached vugs.

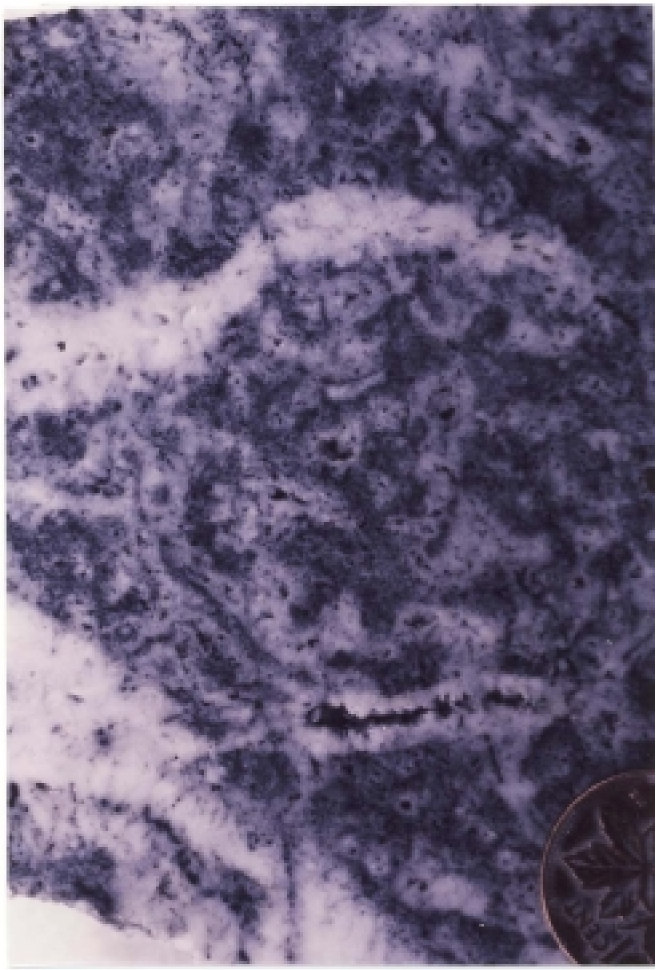
PLATE 14 – SADDLE DOLOMITE



a. a-25-D/94-G-15 10,164.0 ft. Watt Mountain
Coarse fabric destructive replacive saddle dolomite. The saddle dolomite crystal growth post dates prominent stylolite surfaces. Note that insolubles from stylolite surface are disrupted into interstitial component of the mosaic.

b. a-99-K/94-P-4 6926.3 ft. Slave Point
Grey fabric destructive dolomite with characteristic dark interstitial bitumen. Note the gradation in grain size away from stylolite surface where replacement was initiated. Also total destruction of earlier fabric of limestone other than vestigial and disrupted solution planes.

PLATE 15 – SADDLE DOLOMITE



a. c-94-L/94-J-9 6434.5.0 ft. Upper Slave Point
Three generations of dolomite:
1) Dark fine crystalline rhombic matrix, early burial type dolomite.
2) Light grey bladed metasomatic dolomite replacing some relict fossil coenostea.
3) White megacrystalline dolomite cement infilling void space created by dissolution of calcite.

b. c-94-L/94-J-7 6476.5 ft. Upper Slave Point
Pseudobreccia with three phases of dolomite. Fabric preserving skeletal peloid grainstone with some areas light grey pyrobitumen speckled destructive replacement dolomite with areas of dissolution infilled by white cement. Note fragmentary pyrobitumen caught up in cement.

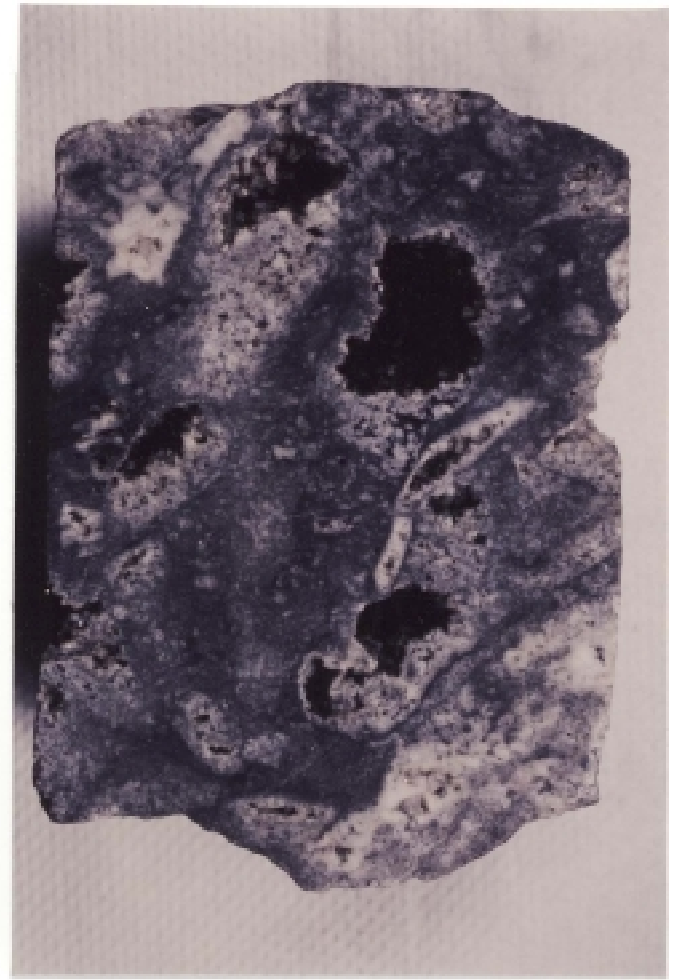
PLATE 16 – SADDLE DOLOMITE

a. c-14-G/94-J-13 9987.5 ft. Chinchaga
Coarse white megacrystalline dolomite composes eighty percent (80%) of the rock, but the cement overgrows a delicate web of earlier dolomite which appears to be the destructive replacive phase. This fabric might be inherited from anhydrite.

b. c-14-G/94-J-13 9987.5 ft. Chinchaga
The same example as Plate 59(c) viewed by upper surface. Note vertical distribution of vugs in white dolomite.

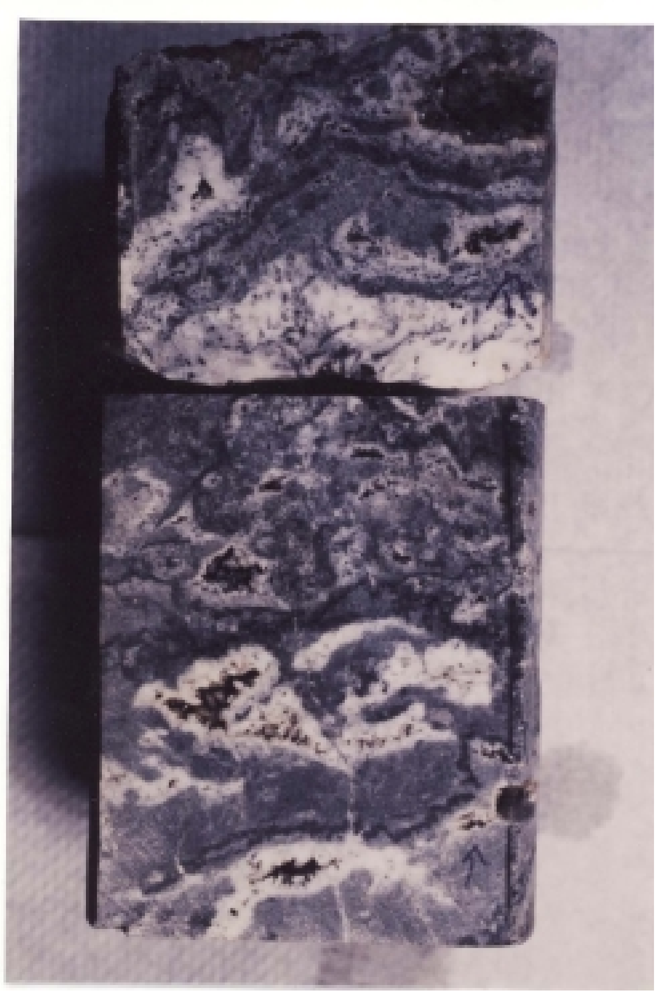
PLATE 17 – KEG RIVER - HYDROTHERMAL DOLOMITE

a. b-89-E/94-J-15 7429.8 ft. Upper Keg River
Dolomite dark grey fabric preserving with some thin rims of light grey destructive replacive cement and coarse white cement infill following dissolution of stromatoporoid.



b. b-89-E/94-J-15 7432.0 ft. Upper Keg River
Dark grey fabric preserving dolomite. Skeletal wackestone with sparse crinoid. Light grey patches of bladed fabric destructive replacing fossil structures, bulbous dendroid stromatoporoid. Sparse white megacrystalline cement.

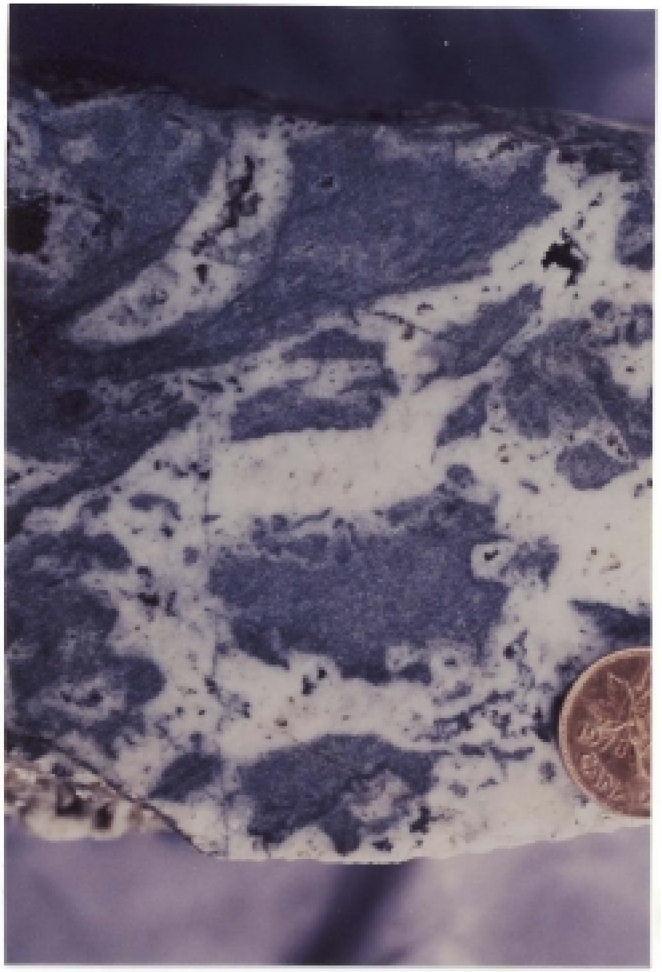
PLATE 18 – SLAVE POINT FORMATION - HYDROTHERMAL DOLOMITE



a. c-94-L/94-J-9 6491.0 ft. Slave Point
Dolomite, three generations. Early fabric preserving with intrafossil voids. Bladed destructive replacement of fossils, and white cement in intrafossil vugs. Bulbous to dendroid and laminar stromatoporoid floatstone.

b. a-61-F/94-J-10 6706.0 ft. Middle Slave Point
Dolomite with relict grey fabric preserving dolomite and extensive intrafossil cementation by white saddle dolomite. Dendroid stromatoporoid boundstone.

PLATE 19 – SLAVE POINT FORMATION - HYDROTHERMAL DOLOMITE, COLLAPSE BRECCIA



a. c-37-A/94-J-11 7878.0 ft. Slave Point
Collapse dissolution breccia indicated by fragmentation of dark grey dolomite fabric. *Amphipora* floatstone.

b. c-5-A/94-J-11 7953.0 ft. Basal Slave Point
Dissolution collapse breccia. Early fabric preserving dark grey microcrystalline dolomite with peloidal fabric and coarse bladed replacement dolomite (top) in coarse white dolomite cement. Observe fragmentation and collapse of stylolite surface (centre). At lower left a fine high frequency stylolite is rotated into vertical position.

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY
GAS PIPELINES

Kilometres
0 10 20 30
0 10 20
Miles

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

INDEX MAP

MAP 1

Geologist : Achour J. Madi — APRIL 2003

1:500,000

Kilometres
0 10 20 30
0 10 20
Miles

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

UPPER CHINCHAGA GROSS ISOPACH

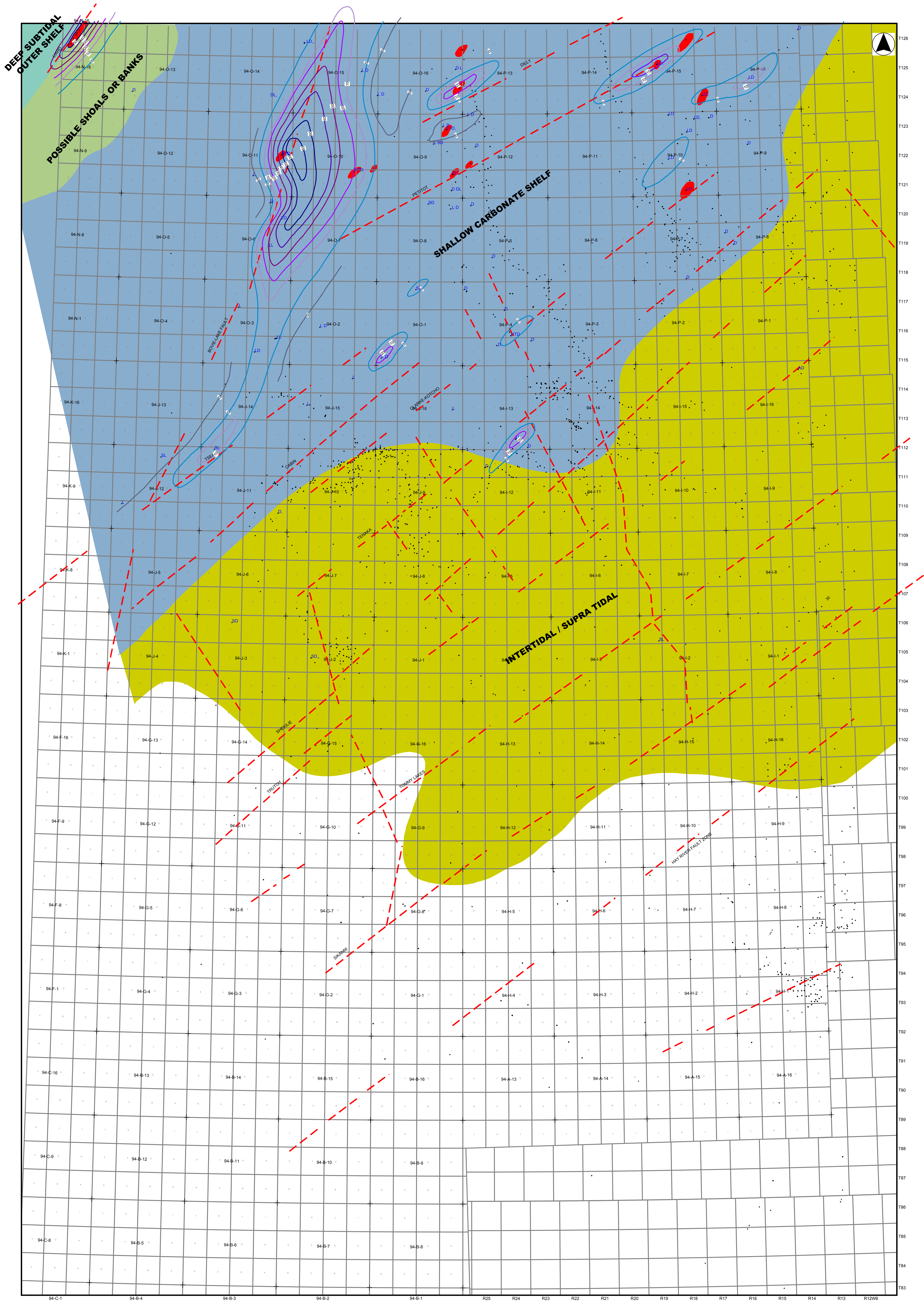
C.I. = 20m

MAP 2

Geologist : Achour J. Madi

APRIL 2003

1:500,000



COMMENTARIES CODES	
L	= limestone
LL	= leached limestone
SL	= shaly limestone
HTD	= hydrothermal dolomite
D	= dolostone (may include HTD)
DL	= dolomitized limestone
LDL	= leached dolomitized limestone
Sh	= shales
SS	= sandstone/siltstone
Ah	= Anhydrite
Ad	= Anhydritic dolostone

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY.
POSITY VALUES : ISOPACH >5% POROSITY (METRES)
SELECTED FAULT TRENDS

Kilometres 0 10 20 30
0 10 20
Miles

LEGEND

- SUBTIDAL
- BANKS/REEFS
- LAGOON
- INTERTIDAL / SUPRATIDAL
- INTERTIDAL DOMAIN
- SABKHA
- PEACE RIVER ARCH
- EMBAYMENTS
- SHALLOW CARBONATE REEF

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

UPPER-CHINCHAGA PALEOGEOGRAPHY AND POROSITY

C.I. = 10m

MAP 3

Geologist : Achour Madi

MAY 2003

1:500,000

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY.

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

UPPER KEG RIVER GROSS ISOPACH

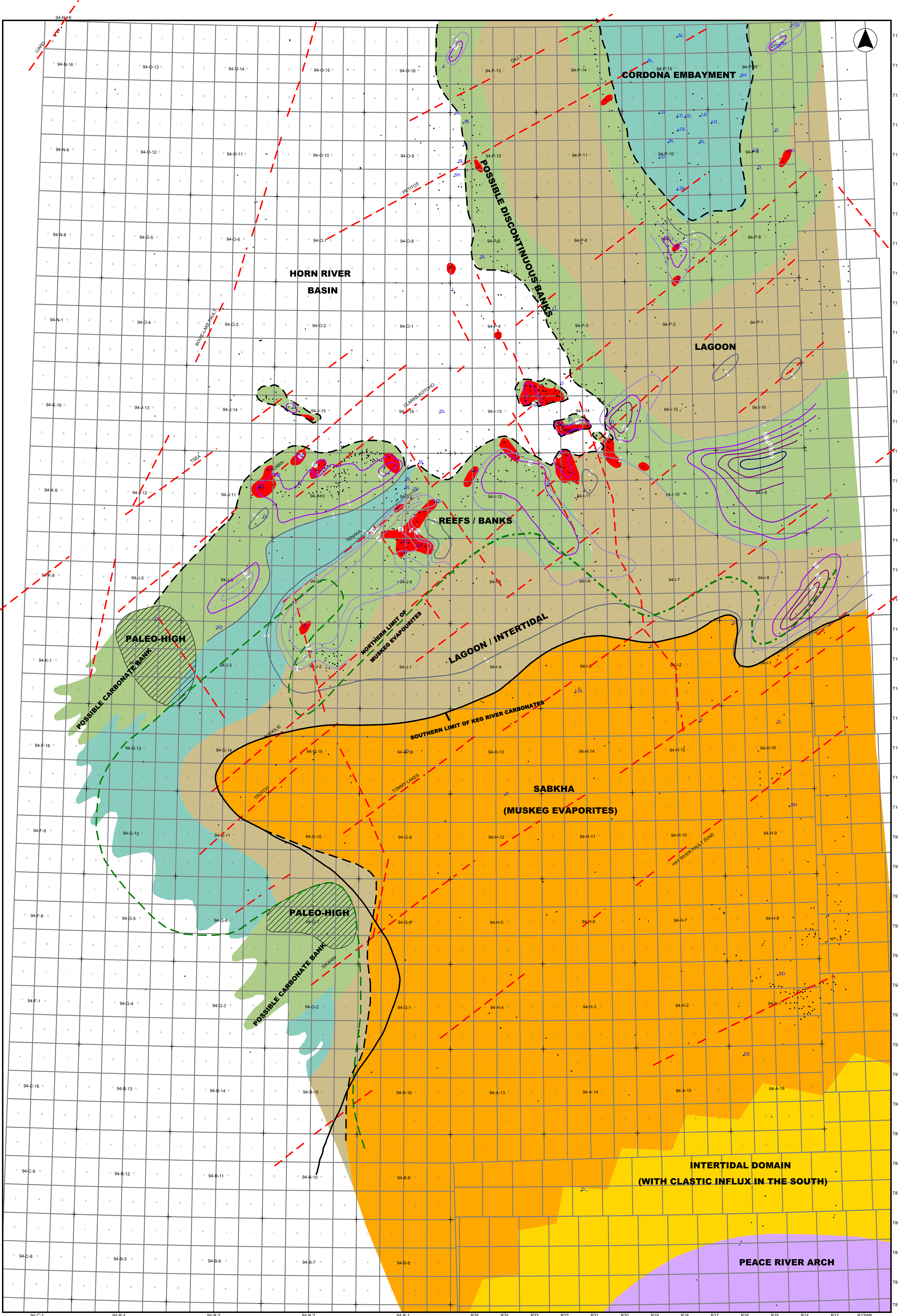
C.I. = 50m

MAP 4

Geologist : Achour Madi

APRIL 2003

1:500,000



COMMENTARIES CODES	
L	= limestone
LL	= leached limestone
SL	= shaly limestone
HTD	= hydrothermal dolomite
D	= dolostone (may include HTD)
DL	= dolomitized limestone
LDL	= leached dolomitized limestone
Sh	= shales
SS	= sandstone/siltstone
Ah	= Anhydrite
Ad	= Anhydritic dolostone

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY
POROSITY VALUES : ISOPACH >5% POROSITY (METRES)
SELECTED FAULT TRENDS

Kilometres 0 10 20 30
0 10 20 Miles

LEGEND

- SUBTIDAL
- BANKS/REEFS
- LAGOON
- INTERTIDAL / SUPRATIDAL
- INTERTIDAL DOMAIN
- SABKHA
- PEACE RIVER ARCH
- EMBAYMENTS
- SHALLOW CARBONATE REEF

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

KEG RIVER PALEOGEOGRAPHY AND POROSITY

C.I. = 5m **MAP 5**

Geologist : Achour J. Madi MAY 2003

1 : 500,000

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

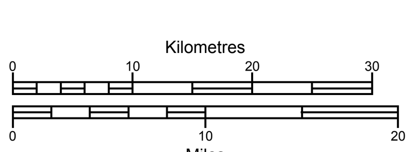
MUSKEG GROSS ISOPACH

C.I. = 50m **MAP 6**

Geologist : Achour Madi APRIL 2003

1:500,000

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY



Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

SULPHUR POINT GROSS ISOPACH

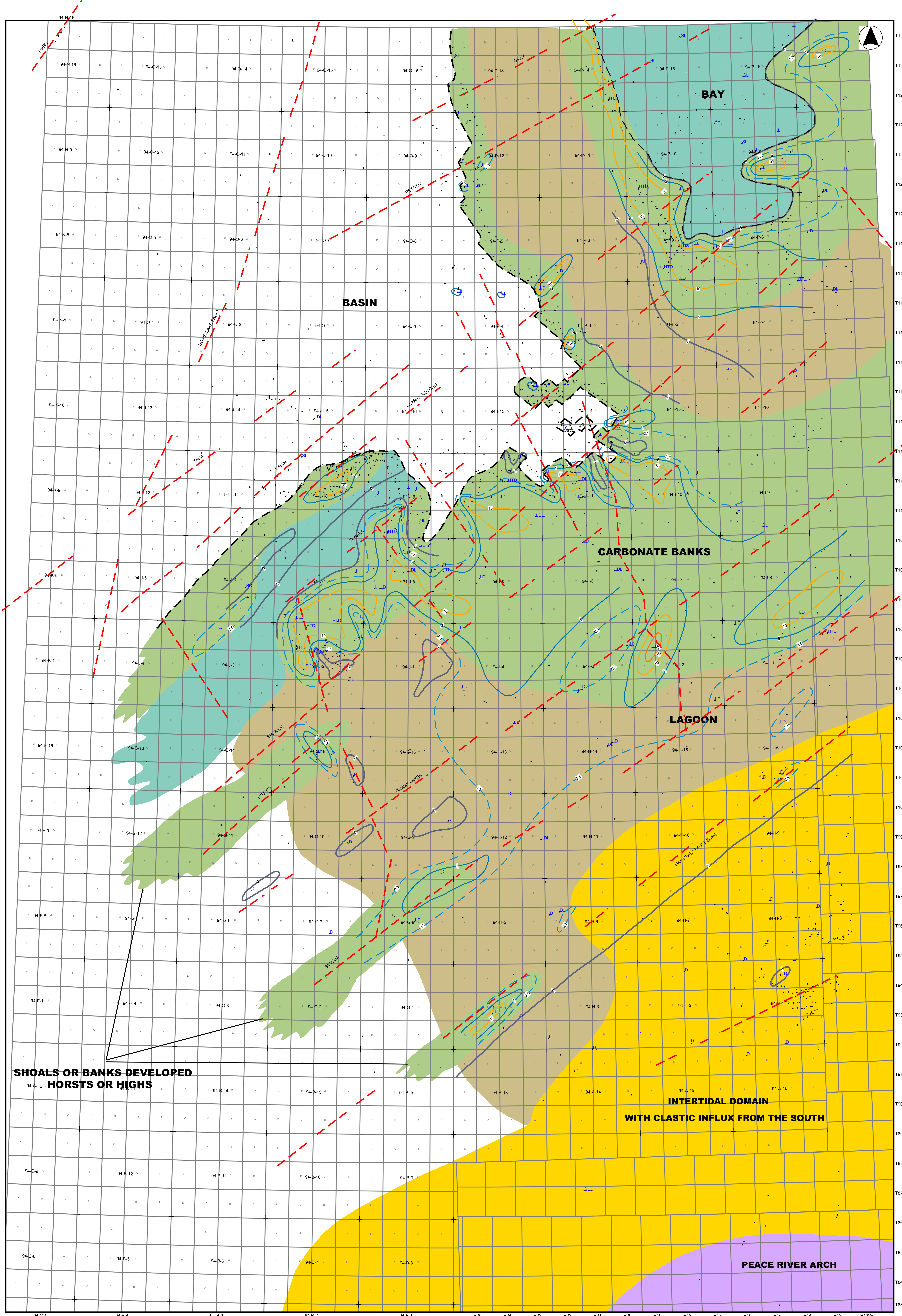
C.I. = 10m

MAP 7

Geologist : Achour Madi

APRIL 2003

1:500,000



COMMENTARIES CODES	
L	= limestone
LL	= leached limestone
SL	= shaly limestone
HTD	= hydrothermal dolomite
D	= dolostone (may include HTD)
DL	= dolomitized limestone
LDL	= leached dolomitized limestone
Sh	= shales
SS	= sandstone/siltstone
Ah	= Anhydrite
Ad	= Anhydritic dolostone

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY

Kilometres 0 10 20 30
Miles 0 10 20

LEGEND

- SUBTIDAL
- BANKS/REEFS
- LAGOON
- INTERTIDAL / SUPRATIDAL
- INTERTIDAL DOMAIN (WITH CLASTIC INFLUX FROM THE SOUTH)
- SABKHA
- PEACE RIVER ARCH
- EMBAYMENTS
- SHALLOW CARBONATE REEF
- POSSIBLE BANKS

Petrel Robertson

EXPLORATION ASSESSMENT OF DEEP DEVONIAN GAS PLAYS FOR NORTH EASTERN BRITISH COLUMBIA

SULPHUR POINT PALEOGEOGRAPHY

C.I. = 5m MAP 8

Geologist : Achour Madi MAY 2003

1:500,000

Kilometres 0 10 20 30

Miles 0 10 20

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY.

Petrel Robertson

EXPLORATION ASSESSMENT OF
DEEP DEVONIAN GAS PLAYS
FOR NORTH EASTERN BRITISH COLUMBIA

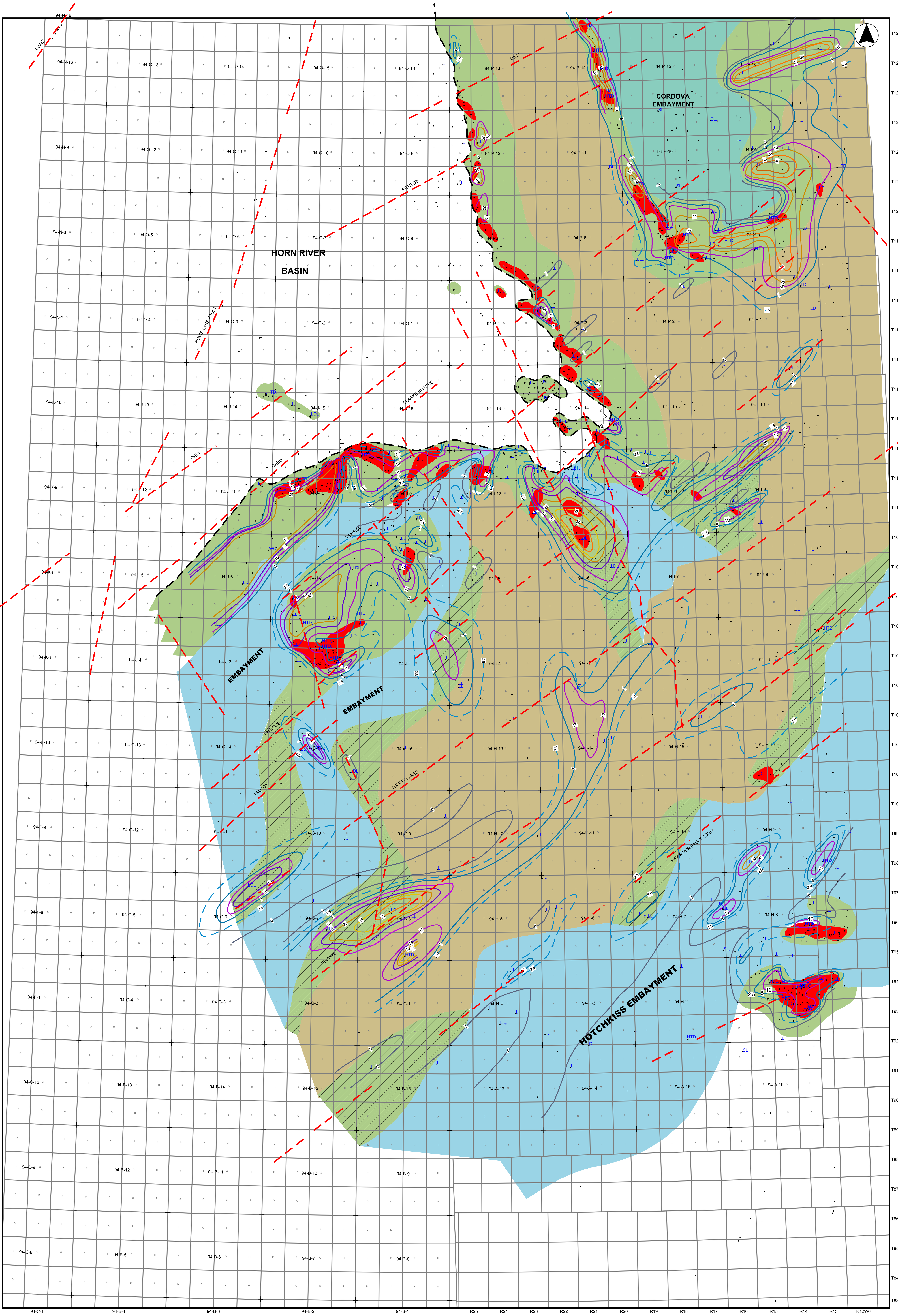
SLAVE POINT GROSS ISOPACH

C.I. = 10m

MAP 8

Geologist : Achour Madi — APRIL 2003

1:500,000



COMMENTARIES CODES	
L	= limestone
LL	= leached limestone
SL	= shaly limestone
HTD	= hydrothermal dolomite
D	= dolostone (may include HTD)
DL	= dolomitized limestone
LDL	= leached dolomitized limestone
Sh	= shales
SS	= sandstone/siltstone
Ah	= Anhydrite
Ad	= Anhydritic dolostone

WELL SYMBOLS : DEVONIAN PENETRATIONS ONLY
POROSITY VALUES : ISOPACH >5% POROSITY (METRES)
SELECTED FAULT TRENDS

Kilometres
0 10 20 30
0 10 20
Miles

LEGEND

- SUBTIDAL
- BANKS/REEFS
- LAGOON
- INTERTIDAL / SUPRATIDAL
- INTERTIDAL DOMAIN (WITH CLASTIC INFLUX FROM THE SOUTH)
- SABKHA
- PEACE RIVER ARCH
- EMBAYMENTS
- SHALLOW CARBONATE REEF
- POSSIBLE BANKS

Petrel Robertson

EXPLORATION ASSESSMENT OF DEEP DEVONIAN GAS PLAYS FOR NORTH EASTERN BRITISH COLUMBIA

SLAVE POINT PALEOGEOGRAPHY AND POROSITY

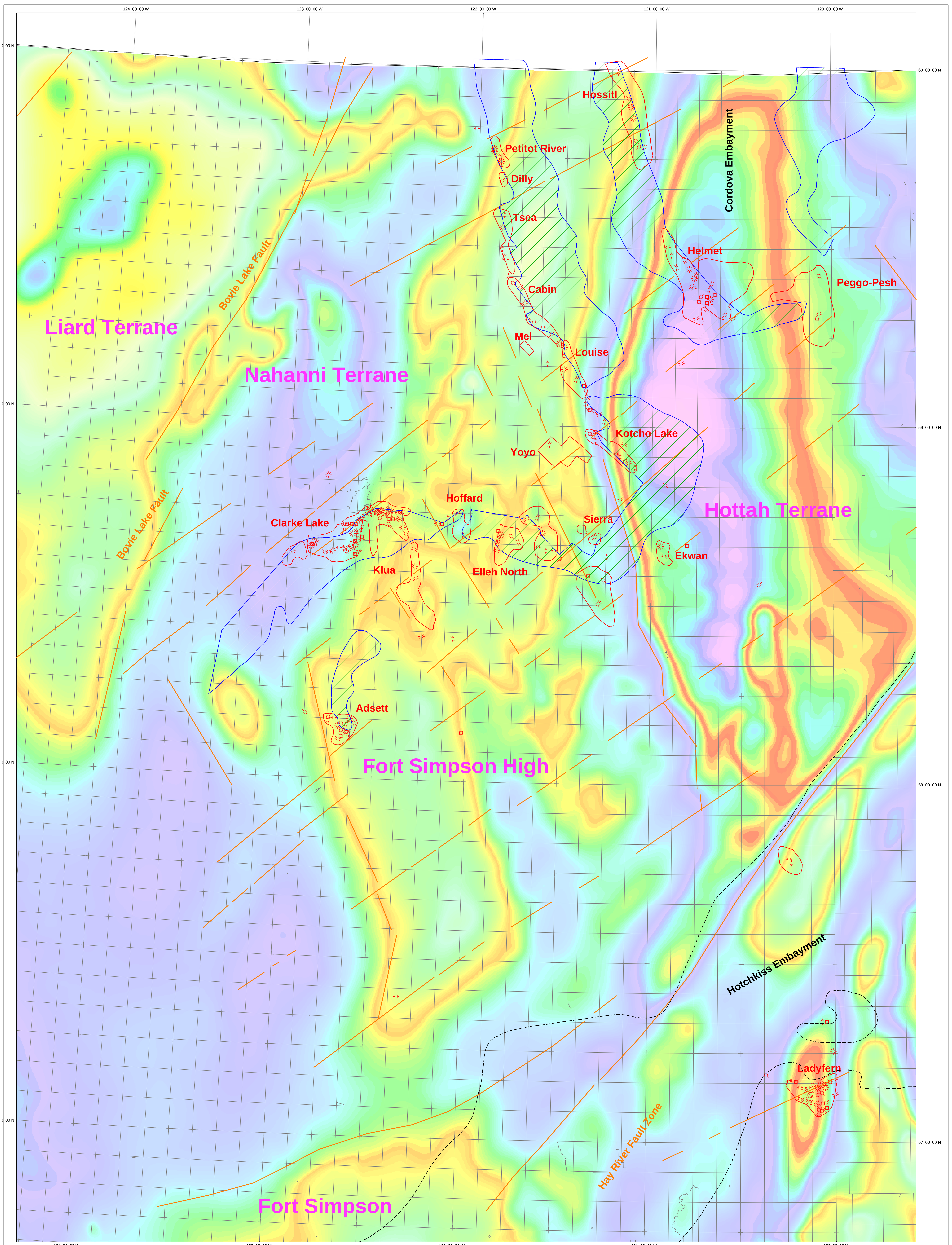
C.I. = 5m

MAP 10

Geologist : Achour J. Madi

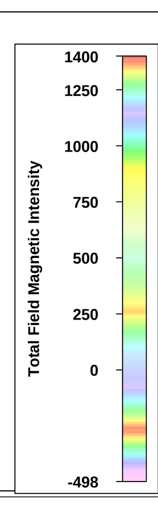
MAY 2003

1:500,000



LEGEND

- PHYSIOGRAPHY AND LITHOLOGY BASED LINEAMENT
- EMBAYMENT
- SLAVE POINT FIELDS
- SLAVE POINT GAS WELLS
- SLAVE POINT BANK EDGE



N

TRUE NORTH IS SHOWN
FOR THE CENTRE OF THE MAP

1:500000

0 10 20 30 40 50

KILOMETRES

Residual Total Field Magnetic Intensity Grid
Natural Resources Canada

Petrel Robertson Consulting Ltd

Exploration Assessment of Deep Devonian
Gas Plays for NE BC

Structural Elements

Geologist	MAP 11	
Alula Damte		April 2003

Fault-associated hydrothermally-dolomitized reservoirs (HTD) in Devonian strata of northeastern British Columbia: A large-scale geological exploration concept.

Authors: Achour J. Madi, PhD, P.Geol.*, A.Damte, PhD, P.Geol.*, B.Hayes PhD, P.Geol.* [*] Petrel Robertson Consulting Ltd.
Mark Hayes, P.Geol. Manager, Petroleum Resource Geology, B.C. Ministry of Energy & Mines.

INTRODUCTION

Deep Devonian reservoirs in northeastern British Columbia (Fig. 1), including the Chinchaga, Keg River, Sulphur Point and Slave Point formations, have been prolific gas producers since the 1950's. However, there is still abundant potential for high-impact gas discoveries along new and established exploration fairways.

Petrel Robertson Consulting Ltd. has undertaken an assessment of deep Devonian gas production and exploration potential in British Columbia for the British Columbia Ministry of Energy and Mines, Resource Development Division, New Ventures Branch. It highlights the importance of hydrothermal dolomite reservoirs as a key component of Devonian exploration potential.

Working from existing Petrel Robertson studies, new data from more than 500 wells and the published literature, this project addresses several key issues:

- Regional lithostratigraphic framework of Devonian units, and the distribution of economically important strata
- Paleoenvironments and paleogeographic setting of key units
- Present structural configuration, and the impact of the basement and structural lineaments on sedimentation and reservoir quality
- Dolomitization trends in the Slave Point, Sulphur Point, Upper and Lower Keg River, and Upper Chinchaga reservoirs
- Key stratigraphic and structural features, and how the integration of these elements can be used as an exploration tool.

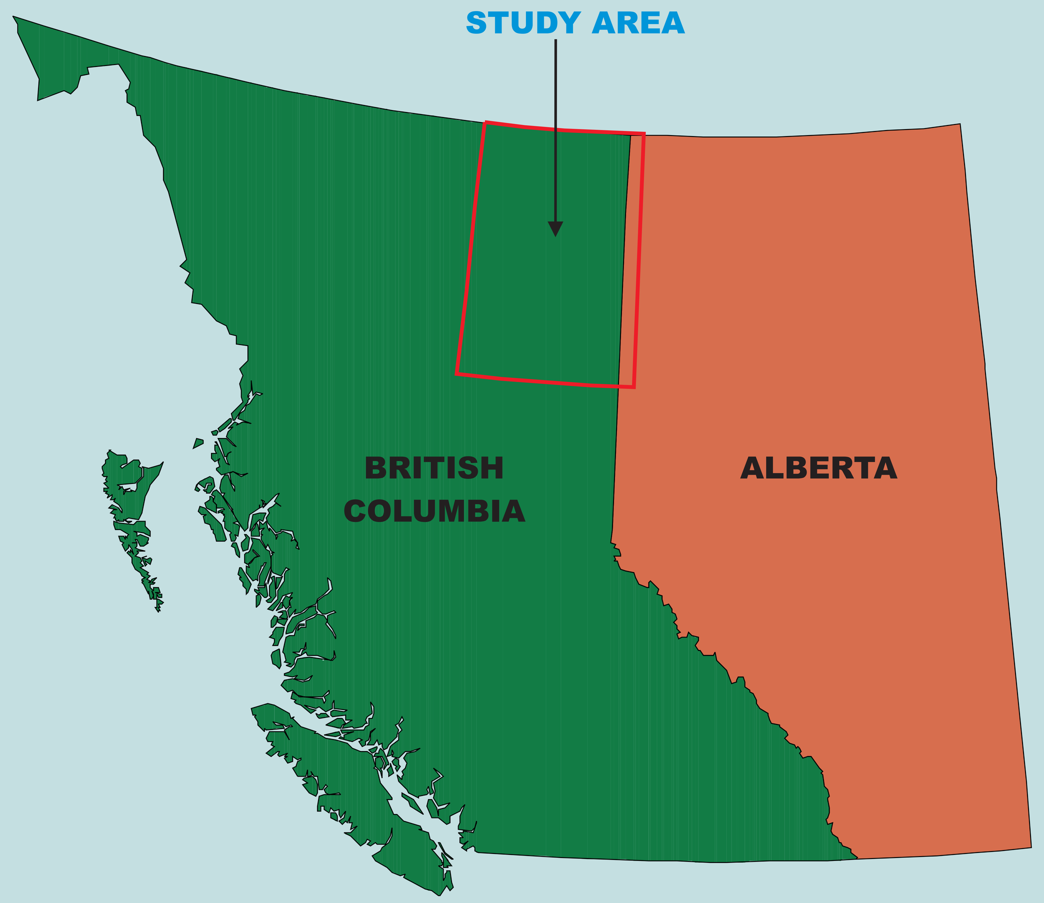
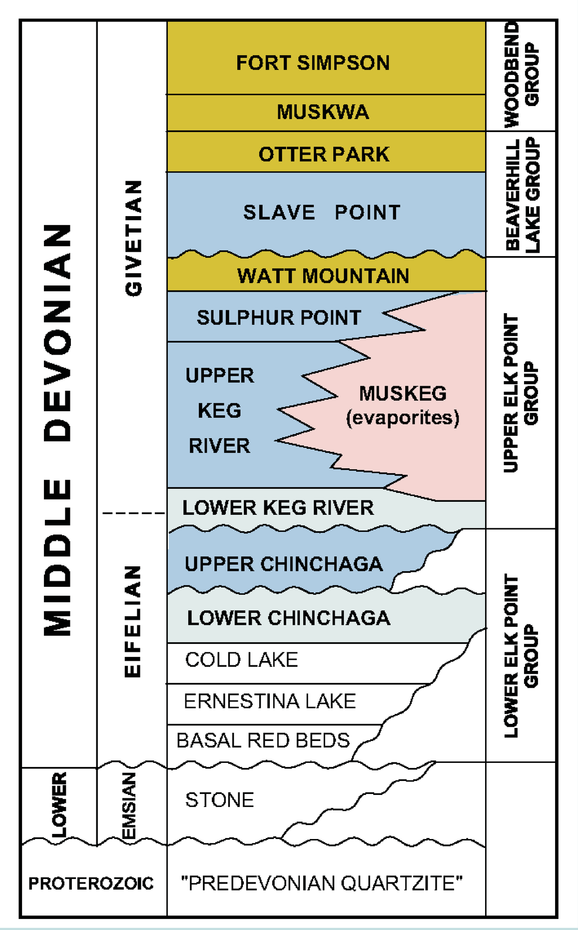


FIG. 1 - LOCATION OF STUDY AREA.



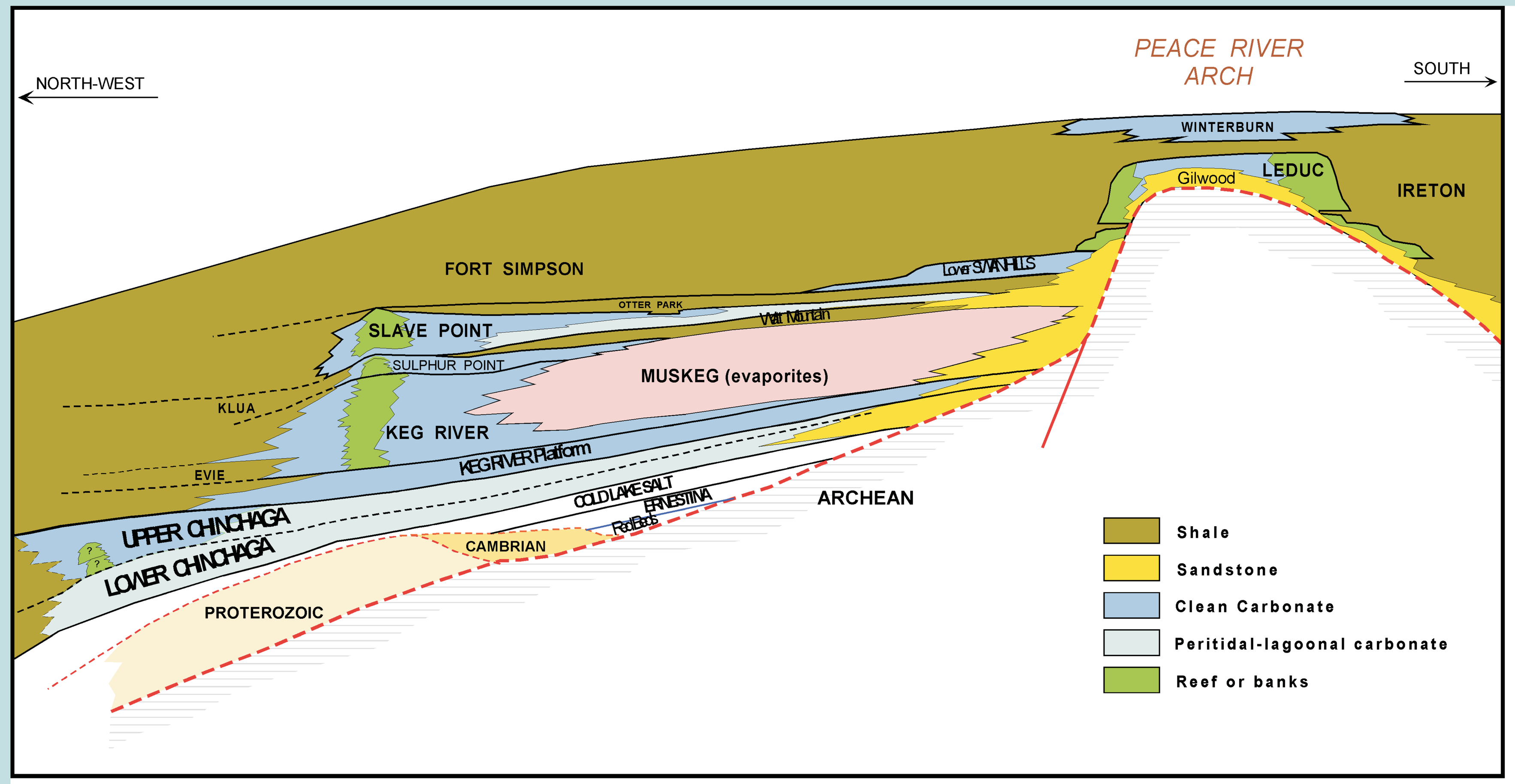


FIG. 2 - STRATIGRAPHIC ARCHITECTURE OF THE MIDDLE DEVONIAN IN N.E. BRITISH COLOUMBIA

THE LOWER ELK GROUP is comprised of four units: the "Basal Red Beds", Ernestina Lake, Cold Lake and Chinchaga formations, formed by restricted and evaporitic lithofacies, and deposited within the topographic lows between the pre-Devonian Quartzite highs.

THE CHINCHAGA FORMATION is subdivided into two units by a regional unconformity, which follows a period of uplift and adjustment in the basin with a renewed influx of clastic deposition across the basin.

THE UPPER ELK GROUP comprises a number of lithostratigraphic units deposited in a rimmed carbonate platform setting. The bounding reef topography has traditionally been lumped as the Pine Point (Presqu'ile) Formation where dolomitized, and mapped as the "Presqu'ile Barrier".

THE LOWER KEG RIVER (Keg River Platform) is relatively uniform across much of N.E. British Columbia, with thicknesses ranging from 20 to 50 metres (Fig. 4). The Lower Keg River marks the beginning of a widespread marine transgression with relatively deep-water deposits, represented by nodular and wavy-bedded mudstones-wackestones and are typically dolomitized.

THE UPPER KEG RIVER carbonate banks form the northern wall of the Elk Point restricted basin, reaching thicknesses of over 200 metres. Upper Keg River strata consist of stacked cycles, each with a shaly base, shoaling upward to a thick high-energy carbonate at top.

THE MUSKEG FORMATION ranges in excess of 200 metres in an area of maximum subsidence paralleling the Hay River Fault Zone and consists of interbedded anhydrite, dolostone and possibly halite, deposited within the restricted Elk Point basin. In the north, approaching the Keg River margin, dolomites thicken at the expense of evaporites, and small-scale cycles become more apparent.

THE SULPHUR POINT carbonates were deposited during a regional transgression over the Keg River and is mappable over much of the study area. In the south, the basal contact is sharp, as relatively high-energy peloidal grainstone-wackestones transgress the evaporitic Muskeg.

THE WATT MOUNTAIN FORMATION forms a distinct stratigraphic break between the Sulphur Point and Slave Point carbonates and is characterized by waxy green shales. The base of Watt Mountain marks a low-relief regional unconformity, resulting from a basin-wide tectonic adjustment and uplift on the Peace River Arch and other highs in the west.

THE SLAVE POINT FORMATION was deposited during a basinwide transgression, which ultimately drowned the Middle Devonian carbonate platforms of northeastern British Columbia and Alberta. It forms a thick and complex carbonate platform comprising several stacked shallowing-upward cycles. Reefal buildups and high-energy carbonate banks occur along the edges of the main platform (Fig. 4), and also along the margins of platform-interior embayments.

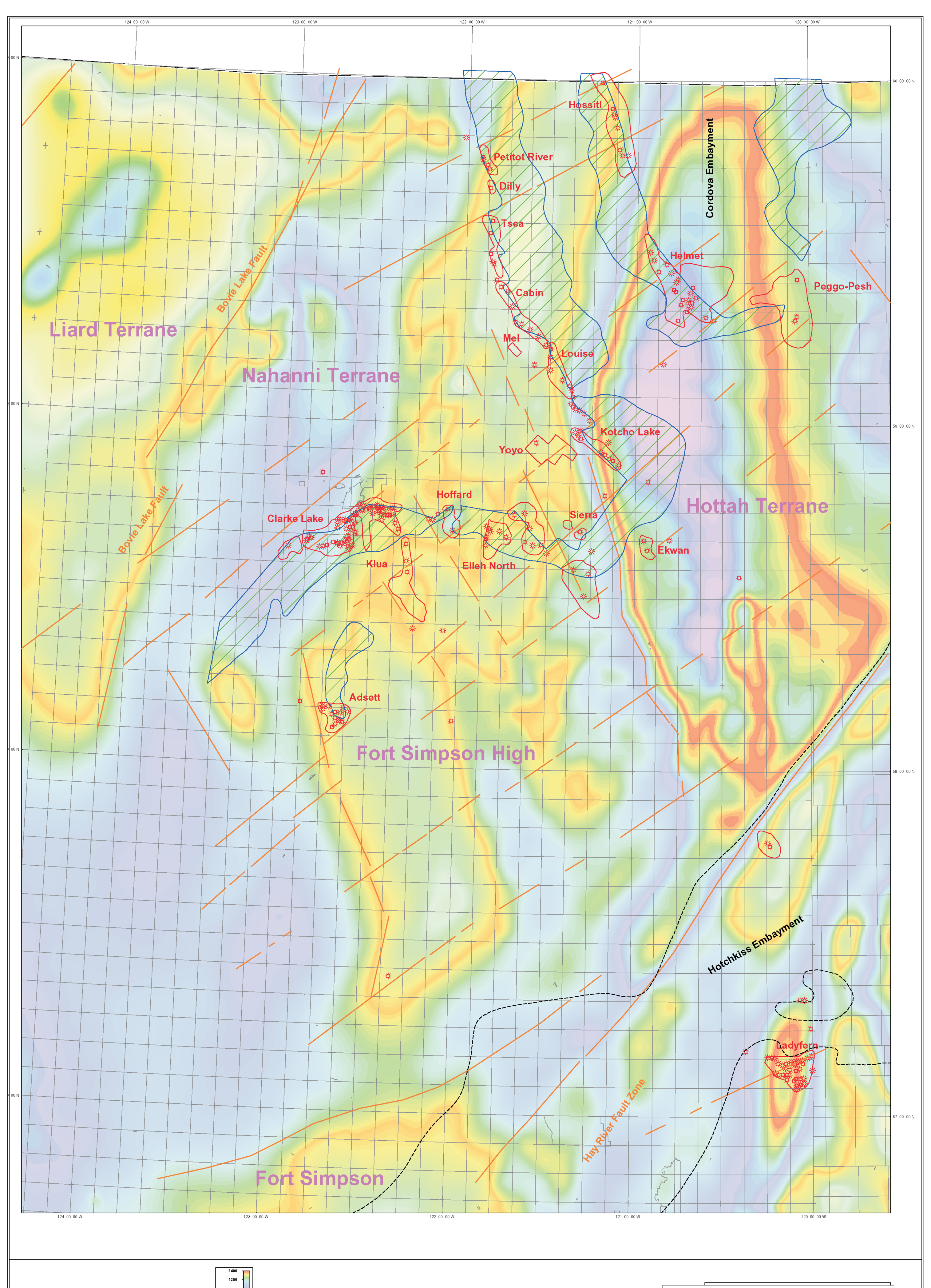


FIG. 3
STRUCTURAL ELEMENTS

Four main basement magnetic domains Liard Terrane, Nahanni Terrane, Fort Simpson High, and Hotah Terrane have been identified within the study area. Sharp magnetic gradients can be identified as domain boundaries and basement fault trends, such as the Hay River Fault Zone and Bovie Lake Fault Zone. In addition to these two zones, we have identified regional networks of SW-NE and NW-SE faults.

Structure played a major role in shaping the paleo-geography and reservoir development of northeastern British Columbia during Devonian time. Basin margins and bank edges were preferentially located along deep-seated faults that were active during deposition. Reactivation of deep-seated fault trends has exerted control over large-scale features such as platform margins and interior platform embayments, and over smaller features such as localization of isolated reefal buildups.

The Hay River Fault Zone has experienced numerous periods of reactivation and complex block faulting, from Proterozoic to Cretaceous times. During the Devonian, long-term subsidence along the Hay River Fault Zone recorded a regional thick in the Muskeg evaporites, argillaceous lower Slave Point time, and thick Otter Park-Muskwa shales.

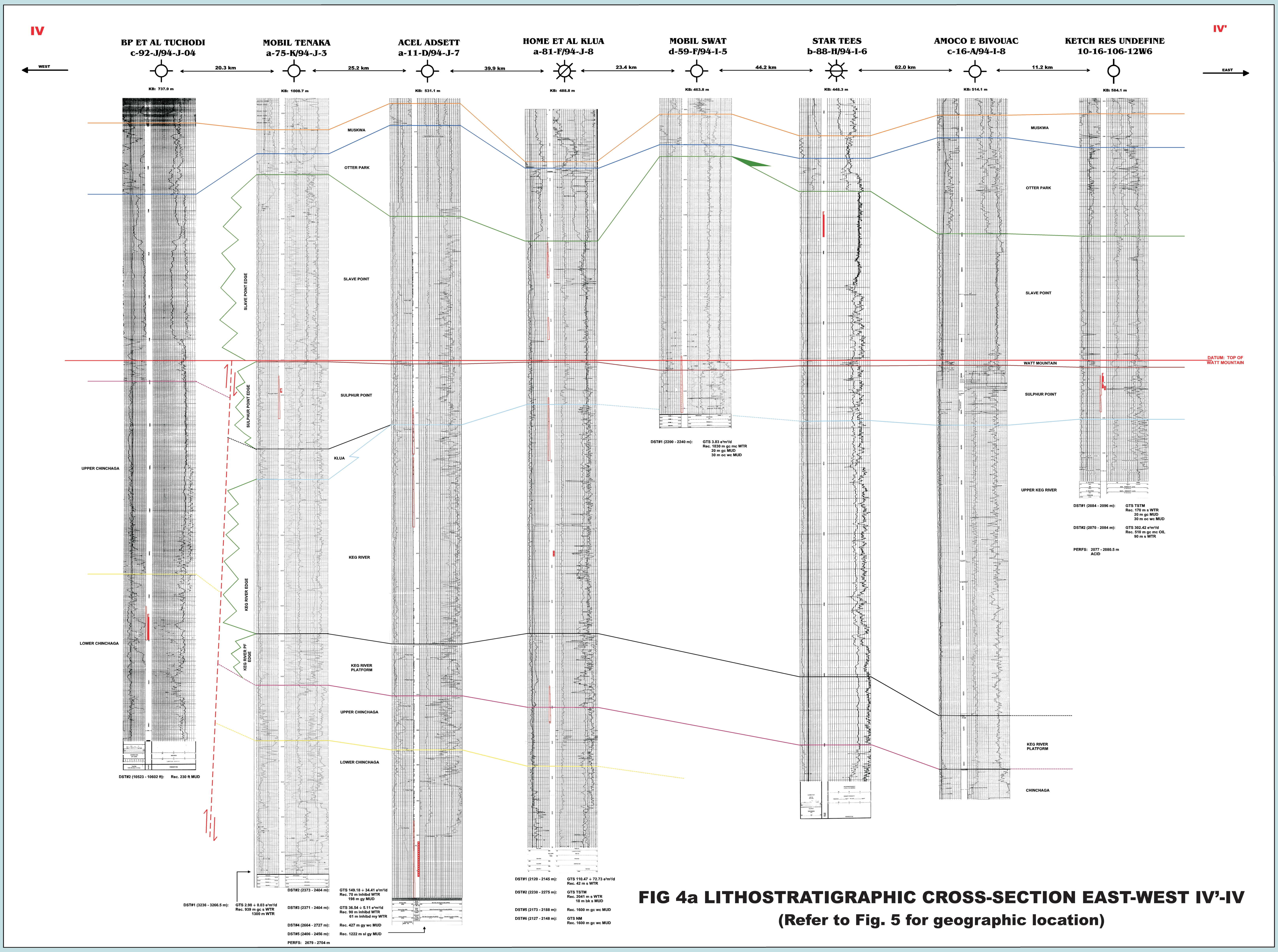


FIG 4a LITHOSTRATIGRAPHIC CROSS-SECTION EAST-WEST IV'-IV

(Refer to Fig. 5 for geographic location)

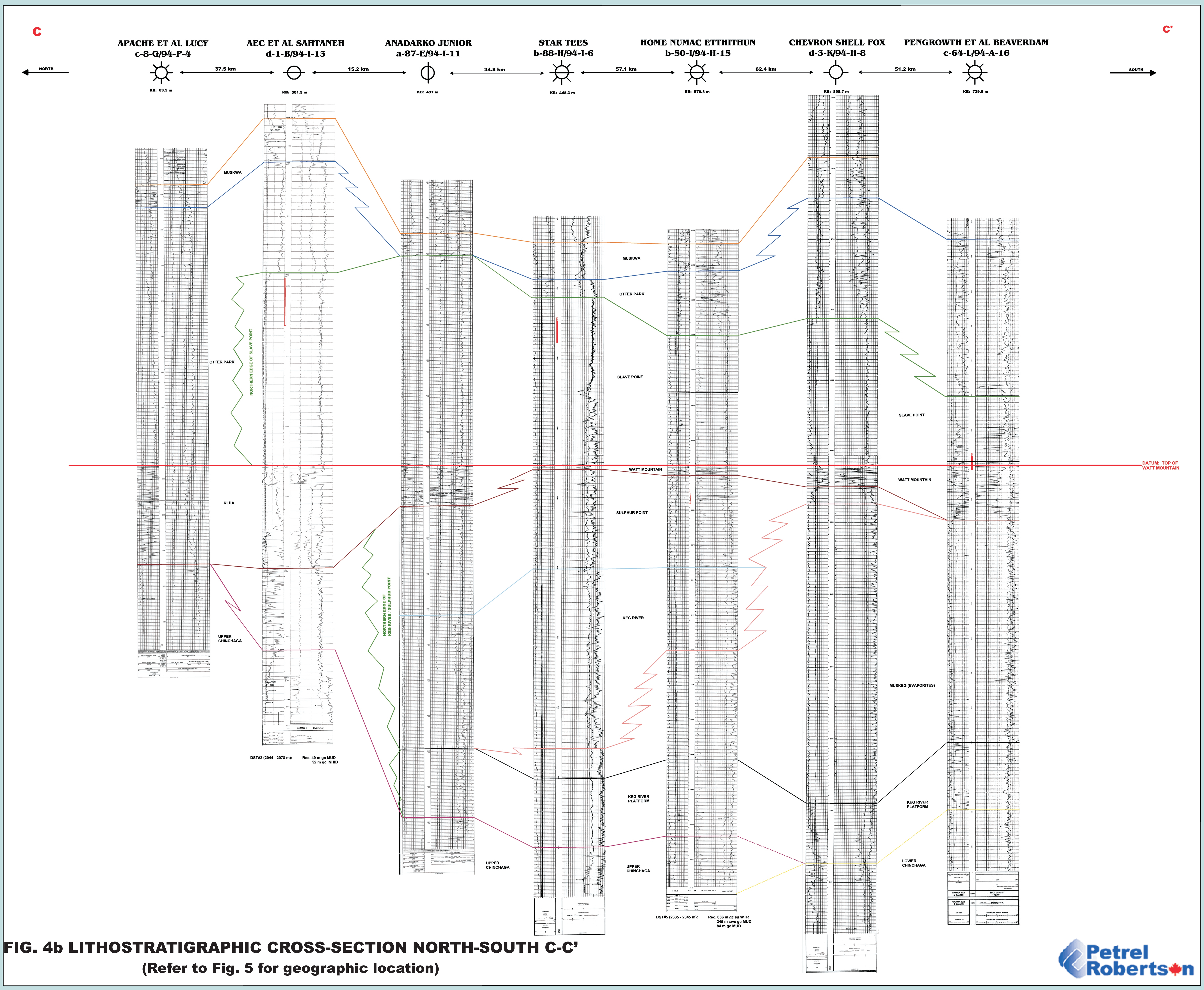


FIG. 4b LITHOSTRATIGRAPHIC CROSS-SECTION NORTH-SOUTH C-C'

(Refer to Fig. 5 for geographic location)

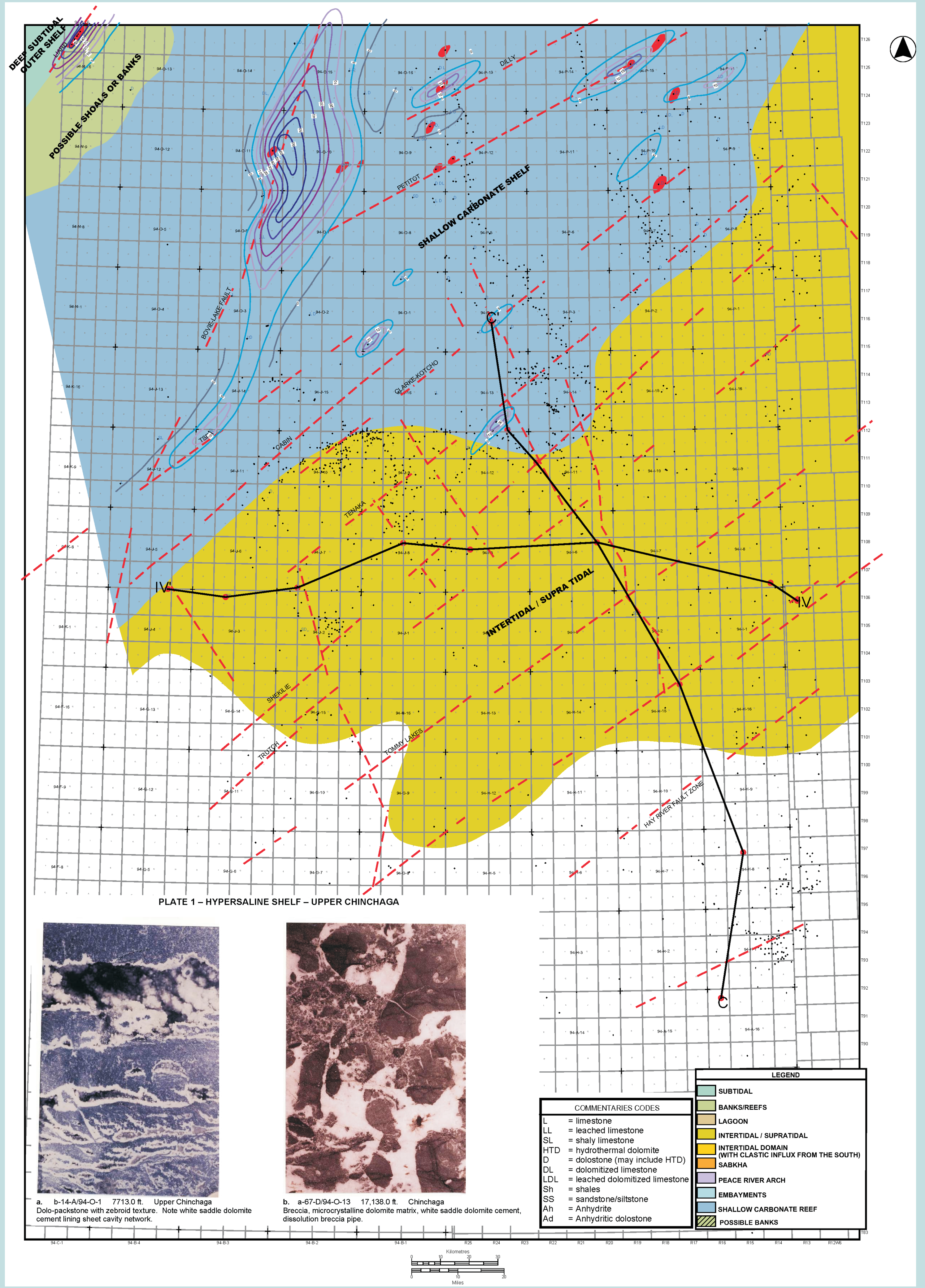


Fig. 5 - UPPER - CHINCHAGA PALEO-GEOGRAPHY AND POROSITY

The Chinchaga contains a wide variety of lithofacies including very fine-grained peloidal wackestones and packstones with birdseye fabrics, pebble breccias and dessication fractures.

Chinchaga carbonates produce gas at Beaver River (and to the north at Kotaneelee, Pointed Mountain, and Fort Liard), primarily from hydrothermal dolomite reservoirs and structural traps.
The Chinchaga is prospective in northernmost British Columbia where fenestral and intrafossil vug porosity has been observed in platformal facies, and hydrothermal dolomites (Plate 1) occur along several fault trends. Numerous gas shows occur in the Chinchaga (and younger formations) along the eastern upthrown margin of the Bovie Lake Fault in B.C. and the NWT, as large volumes of gas appear to have been preferentially transported along the axis of the fault, and trapped locally in areas where HTD is well developed.

Another potential play may exist where Chinchaga carbonates shale out northwestward toward the Yukon Territory. The Chinchaga carbonate platform is fully developed at Beaver River, but is absent or drastically thinned northwest of Kotaneelee and Pointed Mountain. Reefal buildups may occur along the carbonate bank edge and would offer more effective matrix porosity and permeability than the fractured reservoirs at Beaver River, Kotaneelee, and Pointed Mountain Fields. Hydrothermal dolomitization would further enhance reservoir potential on this trend.

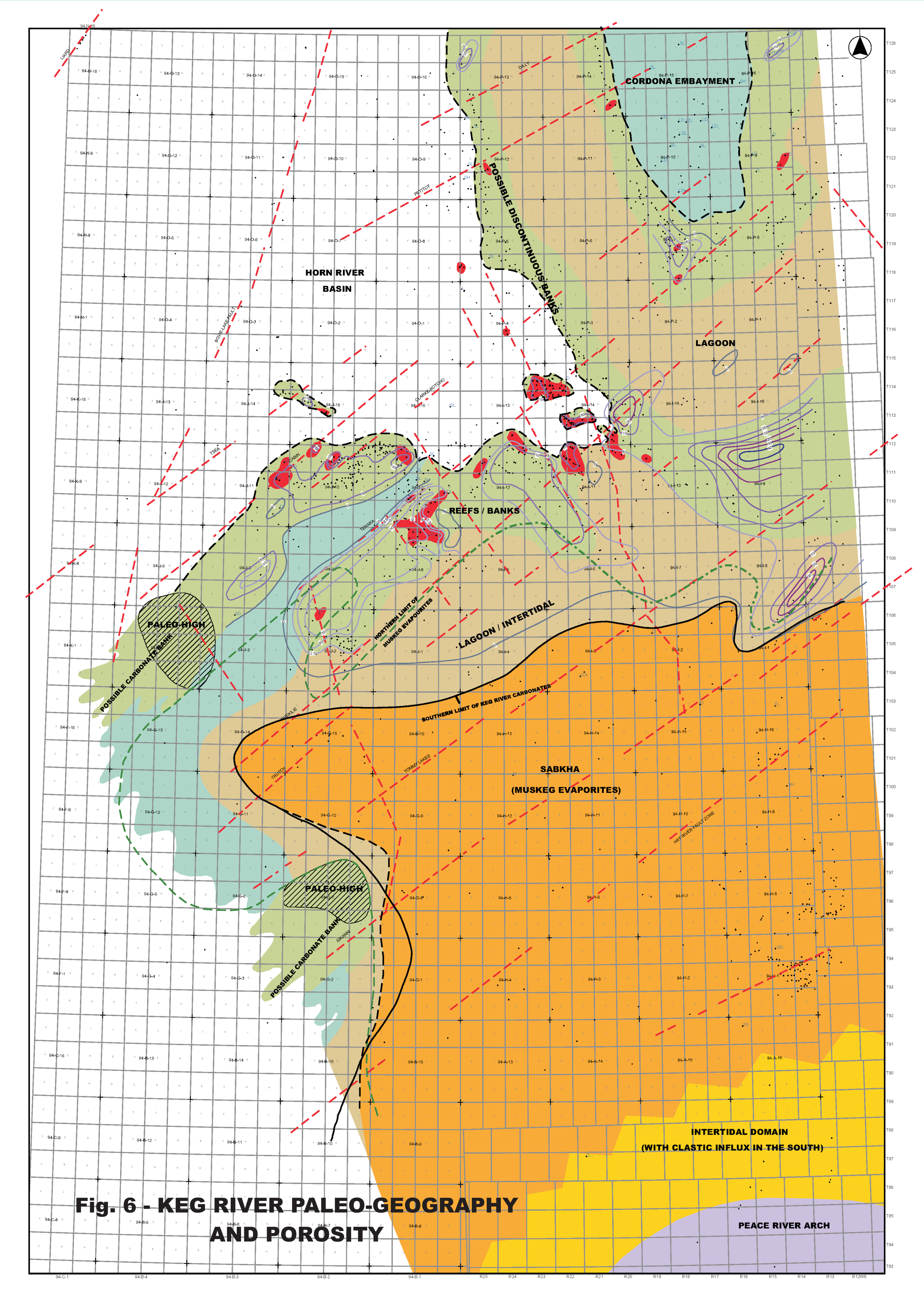


Fig. 6 - KEG RIVER PALEO-GEOGRAPHY AND POROSITY

The Keg River produces gas from isolated reefal buildups controlled by basement horst blocks, such as at Yoyo and Sierra fields, and from smaller structural/stratigraphic pools along the major basinal margins.

Sulphur Point strata are difficult to distinguish from the Keg River in many areas so their exploration potential can be assessed jointly. Generally, the Sulphur Point is regarded as a more homogeneous regional aquifer, and trapping situations may not occur as abundantly as in the Keg River.

Keg River / Sulphur Point carbonates are prospective in at least four settings:·

Faulted Platform Margins Conceptually, wherever faults cut across a continuous platform margin at a high angle, a potential structural trapping situation is set up. If the fault is deep-seated, and/or was active near the time of deposition, it may have influenced reef growth and subsequent diagenetic processes. Such traps will likely be small up to several spacing units and tens of BCF but highly productive.

Flanks of Platform and Embayments Fault lineaments and a poorly-controlled Keg River thin indicate the possible presence of a SW-NE embayment cutting across the Keg River platform. By analogy with the Hotchkiss Embayment (at Slave Point level), Keg River and Sulphur Point reef buildups along the margins may be prospective.

Discoveries of this type could range up to several hundred BCF reserves in thick buildup sections, with high productivities from dolomitized reefal buildups.

Western Carbonate Banks The restricted Elk Point (Muskeg) evaporite basin must have had a western margin. Displacement along regional SW-NE fault trends may have elevated particular structural blocks, thus influencing the paleogeography of the margin trend. Later movement, during the Antler Orogeny, may have influenced fluid movements and hence diagenetic trends.

Keg River / Sulphur Point discoveries on the western margin could range up to Clarke Lake size (hundreds of BCF to more than a TCF). Although mapping would be difficult and drilling expensive for deeply-buried targets along this play trend, high reservoir pressures would augment reserves and productivity.

Antler Structural traps The Sulphur Point occurs over a considerable portion of the platform. Because of its role as the major regional aquifer, it was not generally considered to be prospective but now, since Antler age deformation is seriously considered, the Sulphur Point can be regarded as a prospective reservoir where it occurs on structure, particularly south of the reefal front where it is sealed by Watt Mountain and or lower Slave Point (Fort Vermilion "Member") shales.

Such traps will likely be small up to several spacing units and tens of BCF but could be very productive in the vicinity of strike-slip faults.

PLATE 2 – KEG RIVER – HYDROTHERMAL DOLOMITE

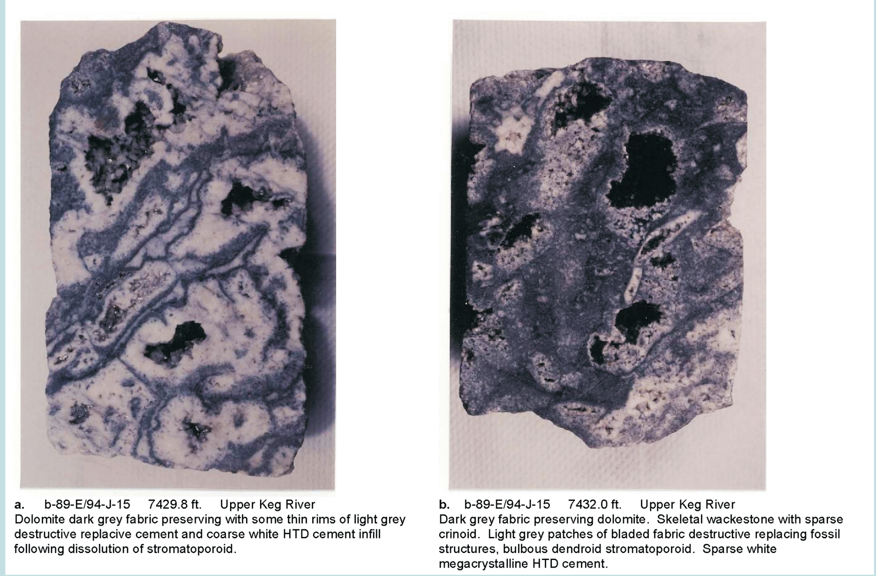


PLATE 4 – SLAVE POINT FORMATION

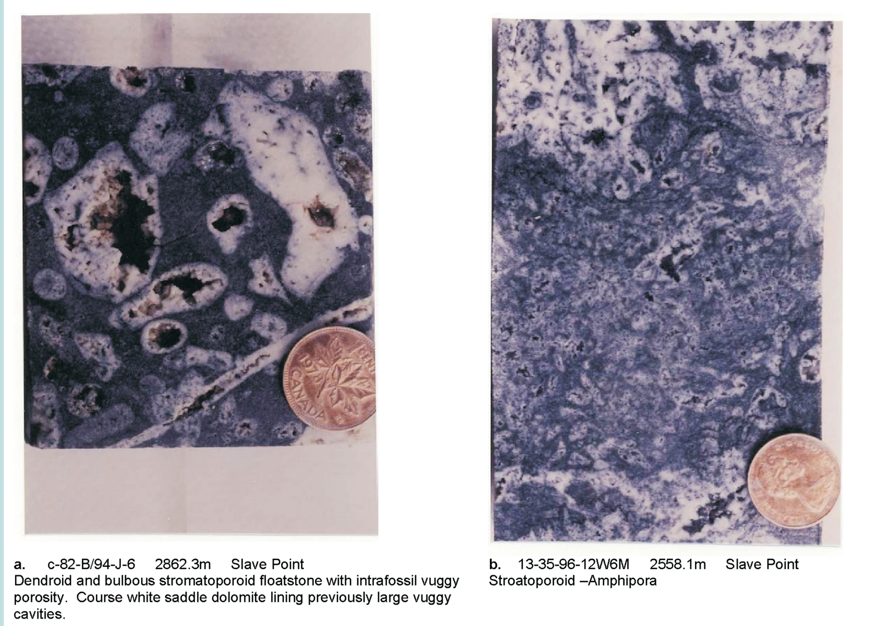
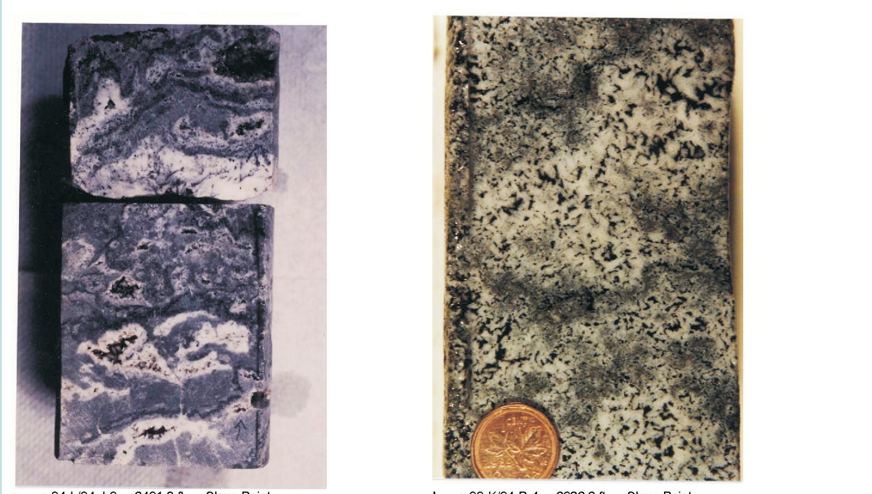


PLATE 5 – SLAVE POINT FORMATION – HYDROTHERMAL DOLOMITE



a. c-94-L/94-J-9 6491.0 ft. Slave Point
Bulbous to dendroid and laminar stromatoporoid floatstone. Preserved porosity in large cavities. White course dolomite lining previous intrafossil vugs.

b. a-99-K/94-P-4 6926.3 ft. Slave Point
Salt and pepper fabric is characteristic of textures associated with HTD. The dark color is interstitial bitumen.

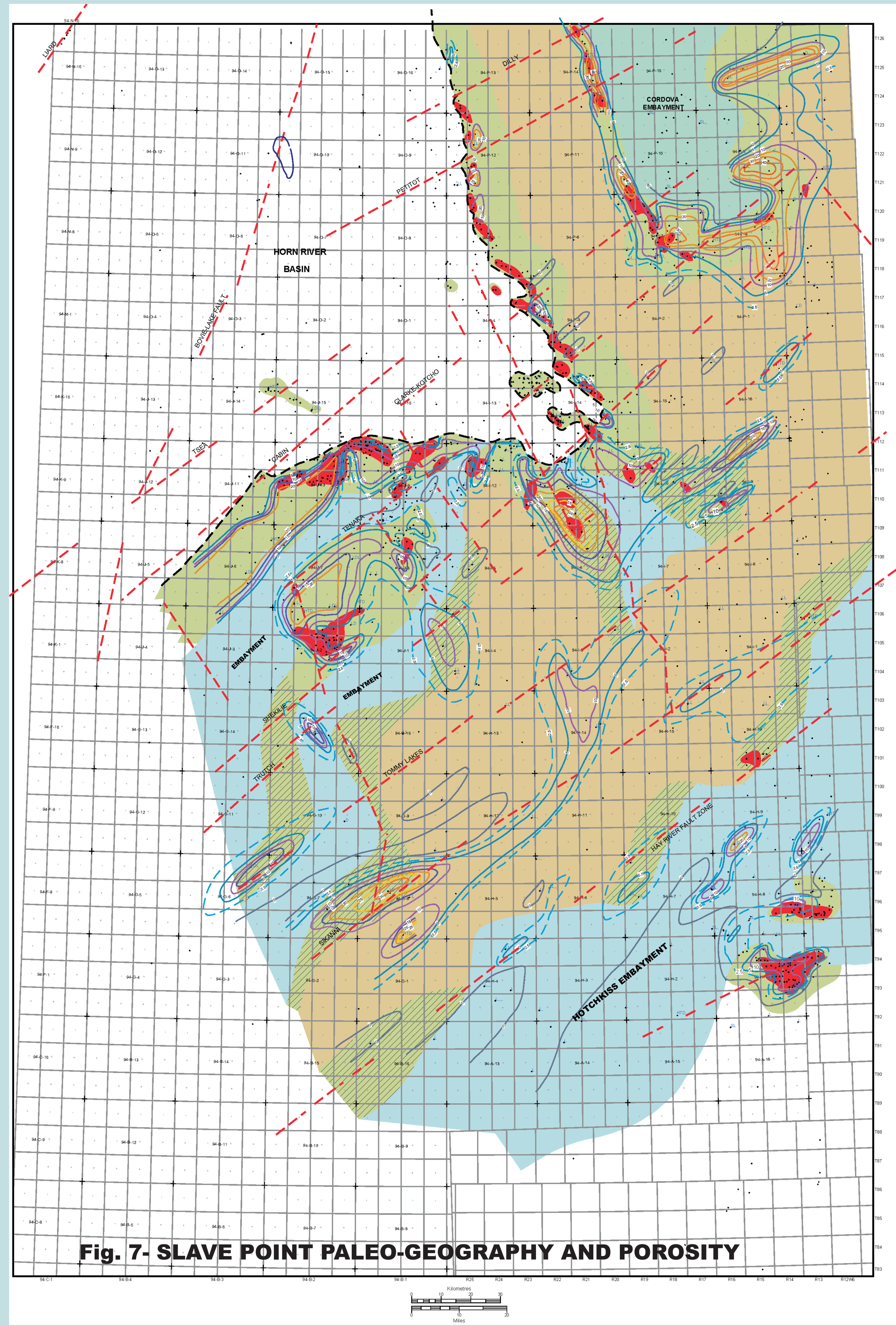


Fig. 7- SLAVE POINT PALEO-GEOGRAPHY AND POROSITY

Slave Point exploration potential is controlled by many of the same factors as Keg River/Sulphur Point potential, and hence is conceptually very similar. However, capping shales provide better seals for Slave Point reservoirs, and make seismic mapping simpler.

Slave Point carbonates produce from a variety of settings that offers considerable additional potential for substantial discoveries:

·*Barrier Buildups* The Horn River Basin and Cordova Embayment margins have been drilled fairly extensively, and it is unlikely that large buildups resembling Clarke Lake will be found along these trends in B.C. However, the postulated western margin of the Slave Point platform is essentially unknown, and may be prospective.

As for the Keg River / Sulphur Point, discoveries in this area will be difficult to map, but reserves could be on the TCF scale.

Faulted Platform Margins Deep-seated faults cross-cutting platform margins offer smaller-scale potential reserves, but high productivities where reservoirs are diagenetically enhanced.

Interior Embayment Margins The Ladyfern discovery extended prospectivity along the Hotchkiss Embayment margin westward into B.C. from Cranberry in Alberta. Slave Point buildups over paleo-highs within embayments, such as Hamburg, may also be prospective. In addition to defining the limits of the embayment, faults along the Hay River Fault Zone have linked deep hydrothermal fluids to Slave Point reservoirs. Exploration along the embayment margins should thus be guided by the presence of faults, as indicated by seismic, reactivation at higher stratigraphic levels, and basement magnetic anomalies. Ladyfern itself is coincident with a strong magnetic feature.

Other Slave Point interior embayments have been mapped in 94G and 94J, but have not been extensively explored at the Slave Point level. Several porosity anomalies in flanking wells suggest that opportunity exists for embayment margin plays to be developed. Since the Ladyfern discovery, the Hotchkiss Embayment has been the focus of relatively intense Slave Point exploration activity. Various operators have announced Slave Point discoveries as far west as 94H5, but most appear to be limited in reserve size and initial productivity. Drilling is still sparse, and potential remains for the discovery of new fields on the scale of Ladyfern.

Lower Slave Point Cycles Discrete fault-bounded areas within the Slave Point platform may develop additional cycles of reef growth, as at Adsett, given appropriate timing of movements on the faults. Detection of these cycles may be difficult without fairly extensive well control, but moderate reservoir potential may occur under the appropriate structural/diagenetic conditions.

CONCLUSIONS

This work highlights the importance of hydrothermal dolomite reservoirs as a key component of Devonian exploration potential. Dolomitization trends in the Slave Point, Sulphur Point, Upper and Lower Keg River, and Upper Chinchaga reservoirs were highlighted and used as a guide to map the porosity distribution.

Three factors are important in the genesis of hydrothermal dolomites:
1. An extensional tectonic setting, giving rise to normal and strike-slip fault motions;
2. Carbonate facies with preserved primary porosity and permeability.
3. An elevated geothermal gradient, providing a source for hydrothermal fluids.

The structural framework of the area played a major role in shaping the paleogeography and reservoir development during Devonian time.

Reactivation of deep-seated fault trends appears to have exerted control over large-scale features such as trends of platform margins and interior platform embayments, and over smaller features such as localization of isolated reefal buildups. Using regional aeromagnetic intensity mapping, surface lineaments, and offsets mapped in younger strata, we have identified regional networks of southwest-northeast and northwest-southeast faults, in addition to the Bovie Lake and the Hay River Fault Zones. Fault movements, particularly those involving strike-slip motion, have allowed deep-sourced fluids access to Devonian reservoirs, causing widespread reservoir enhancement, primarily through hydrothermal dolomitization and associated solution and brecciation.

The primary lithofacies have a significant influence on the development of HTD reservoirs. In strata with good initial effective permeability and porosity, such as reefal buildups and high-energy shoals, dolomitization enhances reservoir quality over broad areas (e.g. Clarke Lake, Adsett, Ladyfern). In contrast, where hydrothermal dolomitization occurs within lithofacies with poor primary reservoir quality, such as tight shaly limestone, reservoir enhancement may be restricted to a narrow corridor along the fault zone.

Paleogeography / porosity maps in this report highlight areas where porosity has been observed on well logs. Some of these areas correspond to known production, but others provide leads to prospectivity in new areas, and require evaluation in terms of the play types outlined above.

The Deep Devonian of northeastern B.C. has been explored thoroughly only along a few play trends, and thus offers abundant potential for high-reserve, high-productivity discoveries along a variety of established and postulated fairways.

A key recommendation that arises from this project is to carefully map and assess regional fault trends, particularly those that appear to be deep-seated, and to have been reactivated throughout Phanerozoic time. Major faults have played a large role in nucleating reef growth along major platform margins, and in determining the locations of intra-platform embayments and isolated carbonate buildups. Deep-seated faults, particularly strike-slip shear zones containing numerous small fault blocks prone to reactivation, have also promoted the movement of deep hydrothermal fluids, accelerating reservoir-enhancing diagenetic processes in carbonate reservoirs. The Hay River Fault Zone is a prime example of such a trend, but several other faults have probably exhibited similar behaviour.

Petrel Robertson