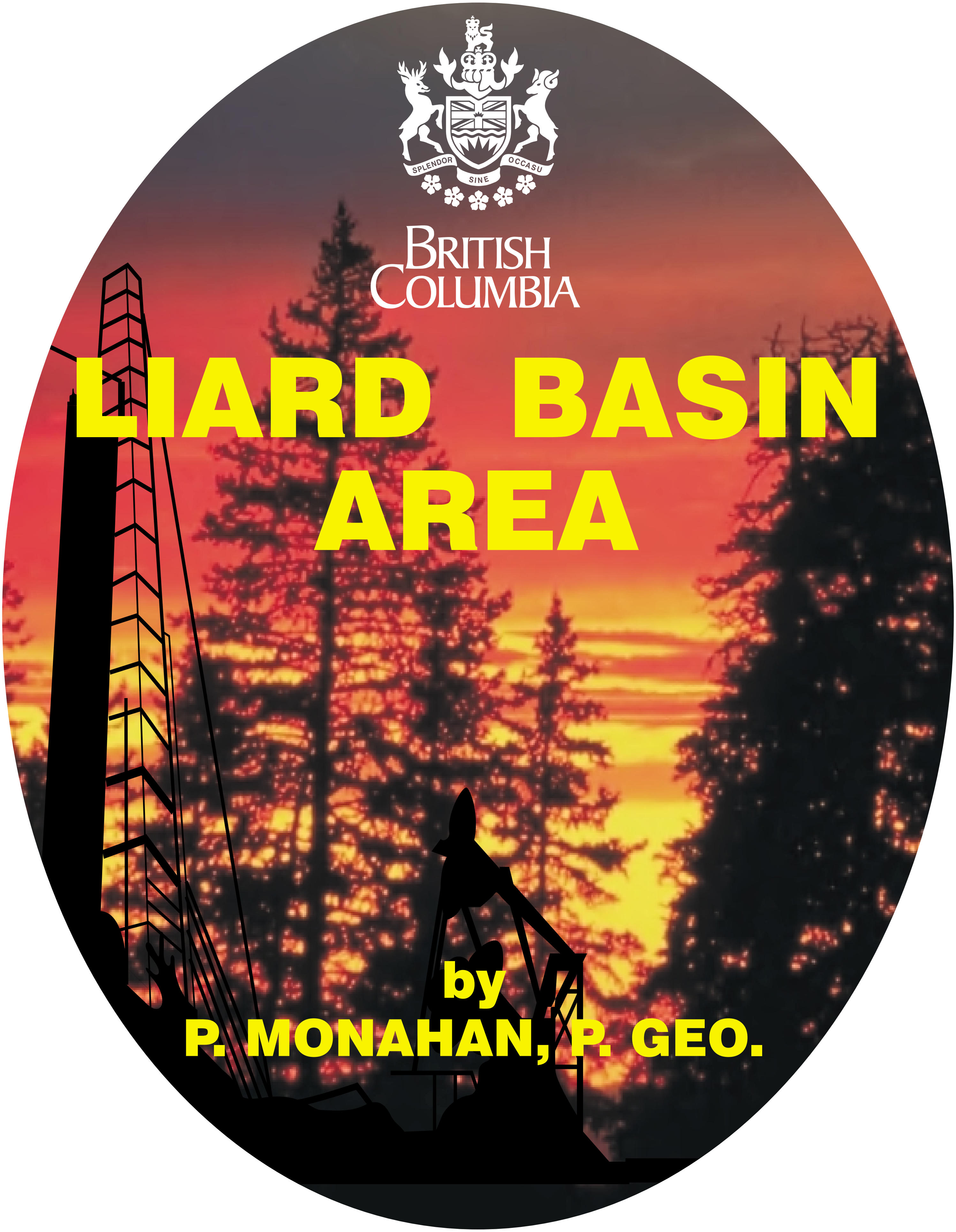

BRITISH COLUMBIA

LIARD BASIN AREA

by
P. MONAHAN, P. GEO.

STRATIGRAPHY AND POTENTIAL HYDROCARBON OBJECTIVES OF MISSISSIPPIAN TO LOWER CRETACEOUS STRATA IN THE EASTERN LIARD BASIN AREA

P. MONAHAN, P. GEO.

INTRODUCTION

The recent discovery of gas in Lower Cretaceous Chinkeh sandstone has renewed exploration interest in the Liard Basin of northeast British Columbia. This area is relatively unexplored, particularly below the base of the Cretaceous System. Some small gas pools were discovered in Mississippian and Permian strata in the 1970's, but they were uneconomic to develop at the time. Now with development of the Chinkeh play, these and other reservoirs are again potential exploration targets. However, with the exception of the Chinkeh (Leckie *et al.*, 1991) and Scatter sandstones (Leckie and Potocki, 1998), the hydrocarbon potential of the Liard Basin has not been addressed in the recent literature. The objective of this report is to briefly describe the stratigraphy and potential hydrocarbon objectives from the base of the Mississippian System to the Lower Cretaceous Scatter Formation in this area[1].

The area investigated includes the western three quarters of National Topographic System (NTS) mapsheet 94-0, comprising maps 94-0-2 to 7 and 94-O-10 to 15. This area extends from 20 kilometres northwest of Fort Nelson to the Northwest Territories and Yukon borders. This study is based primarily on the interpretation and correlation of well logs, with reference to sample and core descriptions and core photographs in the files of the Ministry of Energy and Mines in Victoria. This report is accompanied by two maps and a suite of 10 stratigraphic cross sections, listed below:

Map 1. Regional trends
Map 2. Cross section locations
Cross section B1. North-south, showing stratigraphic changes along the Bovie Lake structure
Cross section B2. North-south, showing stratigraphic changes along the Bovie Lake structure
Cross section M1. Northeast-southwest, Triassic to Lower Cretaceous (Grayling to Scatter)
Cross section M2. East-west, Triassic to Lower Cretaceous (Grayling to Scatter)
Cross section M3. East-west, Triassic to Lower Cretaceous (Grayling to Scatter)
Cross section M4. East-west, Triassic to Lower Cretaceous (Grayling to Scatter)
Cross section P1. Northeast-southwest, Upper Mississippian to Permian (Golata to Fantasque)

1

The exclusion of the Devonian System from this report should not be taken as an indication that it lacks potential. Rather it needs to be considered in a broader geographic context and is beyond the scope of this report.

Cross section P2. East-west, Upper Mississippian to Permian (Golata to Fantasque)
Cross section P3. East-west, Upper Mississippian to Permian (Golata to Fantasque)
Cross section P4. East-west, Upper Devonian to Upper Mississippian (Exshaw to Debolt).

REGIONAL SETTING AND STRUCTURE

The Liard Basin is an asymmetric north-trending structural trough located immediately east of the Cordilleran fold and thrust belt. It is 80 kilometres wide by 200 kilometres long and has over 5000 metres of Palaeozoic and Mesozoic sedimentary fill (Map 1; Wright *et al*., 1994). This report focusses on the eastern part of the Liard Basin and part of the adjoining platform. The report area is located in the northwestern part of the Fort Nelson Lowland and is generally underlain by gently dipping Cretaceous strata (Holland, 1976). In the Liard Basin, Upper Cretaceous Dunvegan conglomerates and Kotaneelee shales outcrop, but to the east outcrops are primarily the Lower and Upper Cretaceous Fort St. John Group shales. However, the Mississippian Mattson and Debolt Formations are exposed locally in a culmination of the Bovie Lake structure in the northernmost part of the study area (Map 1; Taylor and Stott, 1986; Stott, 1982; MacIntyre *et al*., 1998). Debolt strata are also exposed on the Petitot River 10 kilometres northeast of the project area on the Celibeta High (Map 1; Douglas and Norris, 1959; Williams, 1977).

Structurally, the area is dominated by the north-trending Bovie Lake structure, which forms the eastern boundary of the Liard Basin (Map 1; Williams, 1977; Leckie *et al*., 1991; Wright *et al*., 1994). This structure is a complex feature that has seen several periods of activity since the end of the Mississippian. Regionally, Mississippian strata are displaced downward up to 1200 metres on the west side of the structure, and the structure forms the approximate eastern limits of all strata between the Mississippian Debolt Formation and the upper part of the Lower Cretaceous Garbutt Formation. Vertical displacement at the level of the Lower Cretaceous Scatter Formation is a few hundred metres. However, the crest of the structure is anticlinal in form (Taylor and Stott, 1986; see also representative seismic sections in Leckie *et al*., 1991 and Wright *et al*., 1994) and four small gas pools occur in the Mississippian Mattson and Permian Fantasque Formations in culminations on the structure (Table 1; Cross sections B1 and B2). Furthermore, complex changes in thickness occur along the structure, indicating that it is segmented and the sense of movement in individual fault blocks has varied through time, and that culminations at one stratigraphic level may not coincide with those at another (Cross sections B1 and B2). For example, in the three wells at the north end of Cross section B2, the Mattson thickens southward from 50 to 300 metres, as the Triassic section thins from over 300 metres to zero and the total Cretaceous and Debolt interval remains approximately 400 metres thick[2].

---

[2] These thickness changes are not simply the result of variable dips encountered in the wells on the structure. Strata in the a-78-L/94-O-15 well dip 10^{O} southwest. The markedly different dips in different horizons in the a-28-D/94-O-15 well further demonstrate variation in structural movement with time.

The north to northwest-trending Liard thrust fault brings Palaeozoic strata to the surface in the adjoining part of the Northwest Territories, but dies out into an anticline in Cretaceous strata in the northernmost part of the project area north of Maxhamish Lake (Douglas and Norris, 1959; Taylor and Stott, 1968; Stott, 1982) . The b-21-K/94-O-14 well appears to be located on this feature. Another surface anticline has been mapped in the northwest corner of the project area by Taylor and Stott (1968; see Map 1)

Table 1 : Gas pools on the Bovie Lake structure

Pool	Wells and Location	Reservoir	Gas in Place x10^6 m^3*
Windflower	d-87-A and d-6-H/94-O-11	Mattson, Fantasque	684 (24 BCF)
b-96-E	b-96-E/94-O-10	Mattson	none assigned
b-44-L	b-44-L/94-O-10	Mattson	58 (2 BCF)
a-78-L	a-78-L/94-O-10	Fantasque	158 (6 BCF)

* Ministry of Energy and Mines (1997)

Prior to the end of 1995, only 60 wells have been drilled in the project area. Since then an additional 93 wells have been drilled, primarily testing the Lower Cretaceous Chinkeh sandstone. Apart from the small gas pools on the Bovie Lake structure and the currently developing Chinkeh sandstone gas play, no commercial hydrocarbon discoveries have been made in the Liard Basin in British Columbia. However, large gas fields occur in Middle Devonian strata to the southeast near Fort Nelson (Clarke Lake) and to the northwest in the Cordilleran fold and trust belt in the Liard Plateau (Beaver River, Pointed Mountain, Kotaneelee and a new discovery northwest of Fort Liard). In addition, a new Mattson gas discovery has recently been announced in the Northwest Territories part of the Liard Basin, 10 kilometres north of the project area.

STRATIGRAPHY

The sedimentary fill of the Liard Basin includes Cambrian to Upper Cretaceous strata. This report addresses the interval from the Uppermost Devonian and Mississippian Exshaw to the Lower Cretaceous Scatter Formation, which is shown in the accompanying Table of Formations (Table 2).

Uppermost Devonian-Mississippian carbonate-shale succession (Exshaw, Banff, Pekisko, Shunda and Debolt Formations)

The Uppermost Devonian-Mississippian carbonate-shale succession includes all strata from the Exshaw to Debolt Formations, and comprises two prograding and basin-filling sequences 400 to 500 metres thick (Cross section P4; English, 1986; Stoakes, 1992; Richards *et al*., 1994). Regionally, the Exshaw includes both uppermost Devonian and Mississippian strata (Macqueen and Sandberg,1970;

Richards and Higgins, 1988), but in this area the Exshaw may be entirely Devonian in age and the overlying Banff may be partly Devonian as well (Richards, 1989a; Richards *et al*., 1994).

The lower prograding sequence overlies older Devonian strata unconformably[3] and is formed by the Exshaw, Banff and Pekisko Formations (Cross section P4). The Exshaw Formation is a sequence of dark shale and silty limestones with a characteristic high gamma ray signature, and thickens westward from 15 to over 150 metres across the project area. The overlying Banff Formation consists of 375 to 525 metres of interbedded calcareous shale and argillaceous limestones. The lower two thirds of the Banff Formation is arranged into a series of west-dipping clinoforms, evident on both well log and seismic sections (Richards, 1989b; Richards *et al*., 1994). Carbonate buildups, such as Waulsortian mounds, may occur on the dipping limestone units, both at the tops of clinoforms and on the slopes. Waulsortian mounds in slope and toe of slope settings are known from equivalent strata elsewhere in the western interior basin of North America (Cotter, 1965; Precht and Shepard, 1988; Richards, 1989b; Richards *et al*., 1994). The Banff Formation is capped by the Pekisko Formation, which consists of 15 to 35 metres of bioclastic (commonly crinoidal) limestone with some calcareous shale deposited primarily in a shelf setting. However, the westernmost equivalents of the Pekisko Formation in the project area are chert-rich limestones deposited in deeper water and assigned to the Prophet Formation by Richards *et al.* (1994). Consequently, a westerly primary dip is also evident in Pekisko strata. During the initial phases of the transgression that terminated deposition of the lower prograding sequence, Pekisko strata served as a substrate for isolated Waulsortian buildups in other areas in Western Canada (Davies *et al*., 1988; Stoakes, 1992). Although none have been observed, similar occurrences could also occur in this area.

The upper prograding and basin-filling sequence is formed by the Shunda and overlying Debolt[4] Formations in the eastern part of the study area, and the equivalent Prophet Formation to the west. The Shunda Formation consists of argillaceous limestone and calcareous shale, and the Debolt consists of bioclastic limestones (commonly crinoidal) with some dolomites, cherts and argillaceous units. The Debolt Formation includes a lower Elkton-equivalent member, which is capped by a distinct argillaceous unit, and informally designated lower, middle and upper members. The middle Debolt member is distinguished from the others by a higher argillaceous content as seen on gamma

---

3

In the eastern part of the Liard Basin and the adjacent platform, the Exshaw overlies the Upper Devonian Kotcho Formation unconformably (Cross section P4). To the west, the interval between the base of the Exshaw and the top of the Middle Devonian carbonate thins from over 1300 metres to 530 metres in the a-67-D/94-0-13 well, and the Exshaw overlies older Upper Devonian shales that are included in the lower part of the Besa River Formation (Switzer *et al*., 1994). Although the upper contact of this interval is unconformable, the westward thinning has been interpreted to be in part depositional (Pelzer, 1966). Further to the west, the Besa River Formation also includes shales equivalent to the Exshaw, Banff and Prophet Formations (Pelzer, 1966; Richards, 1989a).

4

In the adjacent Northwest Territories, the strata lithologically equivalent to the Debolt are called the Flett Formation (Richards, 1989a; Richards *et al*., 1994) ray logs. The Shunda and Debolt overstep and are replaced laterally to the west by the Prophet Formation, which consists of spiculite, spicule-rich limestone and shale deposited in a deeper water setting (Richards, 1989a; Richards *et al*., 1994)[5]. A series of clinoforms can be seen in the Shunda and Debolt strata, and those in the Shunda and Elkton-equivalent can be traced across the boundary with the Prophet. Thus, westerly deepening of this sequence is indicated on a regional scale by the facies change to the Prophet and on a smaller scale by the clinoforms in the lower part of the succession.

The entire Debolt is preserved in the Liard Basin and along most of the Bovie Lake Structure. However, on the east side of the structure, the Debolt is unconformably overlain by the Permian Fantasque and Lower Cretaceous strata, and to the east, upper, middle and lower Debolt strata subcrop beneath Cretaceous strata. Westward thickening across the Bovie Lake structure is not evident *within* Shunda and Debolt strata, contrary to the interpretation shown by Richard *et al*. (1994).

Porous dolomites and oil staining occur in several horizons in the Debolt on and east of the Bovie Lake structure. Dolomites up to 60 metres thick occur locally in the upper Debolt and provide a potential reservoir in culminations on the Bovie Lake structure. In addition, thinner porous dolomite intervals in the upper, middle and lower Debolt could provide traps at the sub-Cretaceous unconformities east of the structure. Some gas shows and small gas pools have been discovered in Debolt unconformity traps east of the project area. In addition, a 12 to 15 metre thick (gross) porous dolomite interval occurs at the top of the Elkton-equivalent, particularly at the top of the clinoform, and has produced water in several drill stem tests (*e.g.* b-6-G/94-O-7, Cross section P4). Not only does this interval provide a potential reservoir in culminations on the Bovie Lake structure, it is locally absent at the top of the clinoform and thus also may have the potential for stratigraphic entrapment in the area east of the structure. In the c-2-H/94-O-11 well the porous dolomite interval is replaced by an expanded section of the overlying argillaceous interval, with some chert and sandstone. The anomalous interval is interpreted to represent the fill of an embayment or channel incised into the top of the clinoform. Such potential stratigraphic traps in Elkton-equivalent buildups encased in argillaceous carbonate have the potential to be recognized seismically. To the west in the Liard Basin, porosity is rarely developed in the Shunda to Debolt sequence and only minor shows occur, probably associated with fractures (*e.g.* a-77-D/94-O-11; Cross section P4).

Mississippian clastic succession (Golata and Mattson Formations)

The Mississippian clastic succession, which comprises the Golata and Mattson Formations, represents a third major Mississippian basin-filling episode (Cross sections P1, P2 and P3). The Golata Formation gradationally overlies the Debolt Formation. It consist primarily of black shales, and is generally 6 to 30 metres thick, although to the west it thickens to over 70 metres (Cross

---

[5] The Prophet-Debolt contacts on cross section M4 are adapted from Richards *et al*. (1994).

section P2). It has been interpreted to represent prodelta shales (Richards, 1989a, b). The Golata the west (Richards, 1989a, b; Richards *et al.*, 1994). The Mattson Formation consists of fine to medium sandstones with siliceous, calcareous and dolomitic cement, subordinate amounts of siltstone shale, dolomite and coal, and was deposited primarily in a fluvially dominated deltaic setting (Braman and Hills, 1977; Richards, 1989a, b, 1990). In the Liard Basin, the Mattson Formation is unconformably overlain by the Kindle Formation, and thickens northward from 125 to over 600 metres (Cross section P1). Both the Golata and Mattson Formations are truncated eastward across the Bovie Lake structure beneath the sub-Pennsylvanian, sub-Fantasque, sub-Triassic and sub-Cretaceous unconformities (Cross sections M2, M3 and M4).

Hydrocarbon shows and occurrences in the Mattson Formation are concentrated at the top, beneath the unconformable upper contact, and at the base, near the contact with the Golata. The latter setting is analogous to stratigraphically-trapped hydrocrabons in the equivalent basal Kiskatinaw sandstone of the Peace River Arch area. On the Bovie Lake structure, porosity is well developed in the Mattson Formation, which forms the principal reservoir in 3 of the 4 gas pools found there to date (Table 1; Cross sections B1, B2, M1, M2 and M3). In the Windflower and the b-96-E pools, the gas occurs in thick sandstones at the top of the Mattson beneath the sub-Pennsylvanian, sub-Fantasque, sub-Triassic and sub-Cretaceous unconformities, and is likely to be primarily structurally controlled (Cross sections B1 and B2). In the b-44-L pool, gas is also trapped near the unconformable upper contact, but in thin sandstones interbedded with shales at the base of the formation, and trapping there may include a stratigraphic component[6] (Cross section B2). In the Liard Basin, porosity in the Mattson is significantly lower than on the Bovie Lake structure, although better porosity may be preserved locally in gas accumulations that formed early. Gas flows and water recoveries have been reported from a few wells. In particular, gas has been tested from the b-21-K/94-O-14 and the b-55-E/94-O-13 wells, which are located on or in the vicinity of surface structures in the northern part of the study area[7]. Furthermore, the recently announced Paramount *et al*. Ft. Liard F-36 Mattson gas discovery, which is located in the Northwest Territories 10 kilometres north of the project area, is up-plunge on the Liard thrust fault from the b-21-K well. These data suggest that the principal potential for future Mattson discoveries is in structural or unconformity traps at the top of the formation, or stratigraphic traps near its base.

---

[6] The productive sandstone underlies Triassic Grayling shales and could possibly be assigned to this formation rather than to the Mattson.

[7] Drill stem tests produced $3x10^3$ m^3/d from a sandstone near the top of the Mattson in the b-21-K/94-O-14 well ; and $1x10^3$ m^3/d and 112 declining to $14x10^3$ m^3/d well, from sandstones near the top and base respectively in the in the b-55-E/94-O-13 well.

Pennsylvanian-Permian succession (Kindle and Fantasque Formations)

The Pennsylvanian-Permian succession comprises the Kindle and overlying Fantasque Formations (Cross sections P1, P2 and P3). This is a relatively thin succession consisting of slope to basinal deposits (Henderson, 1989; Henderson *et al*., 1994). The ages of the units are not well constrained and they probably include several unconformities (C.M. Henderson, *pers. comm*., 1998).

In the eastern part of the Liard Basin and along the axis of the Bovie Lake structure, the Kindle Formation consists of dark siltstones, which are slightly glauconitic and variably siliceous, dolomitic and calcareous, with subordinate amounts of sandstone. It commonly has a distinct upward-decreasing gamma ray signature in this area (Cross sections B2, P2 and P3; see also Henderson *et al*., 1994). The thickness of the Kindle in this area varies from 3 to 40 metres, and the greatest thicknesses appear to be preserved immediately west of the Bovie Lake structure. The Kindle is locally absent in the southern part of the Liard basin (Cross section P1), indicating that a period of structural growth may have followed deposition of Kindle strata, and is truncated eastward across the Bovie Lake structure beneath the sub-Fantasque unconformity (Cross sections M2, M3, M4).

On the northwest side of the basin, Henderson *et al*. (1994) have assigned a succession consisting of 58 metres of phosphatic siltstone overlain by 190 metres of calcareous sandstone to the Kindle Formation (a-67-D/94-O-13, Cross section P2). Although this interpretation is not directly supported by faunal evidence at this locality, it is consistent with regional thickness trends (C.M. Henderson, *pers. comm*., 1998), and is followed here. The Kindle is over 200 metres thick in the outcrop areas west of the Liard Basin (Bamber *et al*., 1990).

Henderson *et al*. (1994) have assigned the Kindle siltstones of the Liard Basin to the Moscovian (mid-Pennsylvanian) lower Kindle, equivalent to part of the Taylor Flat Formation of the Peace River Arch, and the overlying Kindle sandstones of the western Liard Basin to the Asselian to Lower Artinskian (Lower Permian) middle and upper Kindle. Thus, in addition to having unconformable upper and lower contacts, the Kindle Formation has one (or more) internal unconformities. West of the Bovie Lake structure, an interval of calcareous sandstones in the upper Mattson appears to be conformable with the overlying Kindle siltstones rather than underlying Mattson. Although they are included with the Mattson on Cross section P3, they may be better assigned to the Kindle.

The Fantasque Formation consists primarily of dark chert, in part glauconitic, with subordinate amounts of sandstone and siltstone. The latter lithologies occur locally interbedded with cherts in the vicinity of the Bovie Lake structure, but are best developed in the upper part of the formation in the northern part of the Liard Basin (b-21-K/94-O-14, Cross section P2). On logs, the Fantasque Formation commonly has one or more intervals with a high gamma ray response, although these are not always present. A high gamma ray bed at the base may correlate with a thin basal lag of phosphate nodules and chert pebbles described in the literature (Henderson, 1989; Henderson *et al*., 1994). In the southern and central parts of the study area, a high gamma ray interval locally occurs in the middle of the formation, dividing it into three parts. The Fantasque has been assigned by Henderson (1989) and Henderson *et al*. (1994) to the Roadian and Wordian (Lower and Upper

Permian).

The Fantasque is 40 to 100 metres thick in the eastern part of the Liard Basin and thickens northwest to 175 metres (Cross sections P1, P2 and P3). However, it is locally absent beneath the sub-Triassic unconformity in the south central part of the basin, indicating that a period of structural growth followed deposition of these strata. The Fantasque thins and is locally absent beneath the sub-Triassic and sub-Cretaceous unconformities on the axis of the Bovie Lake structure, and is generally absent to the east (Cross sections M2, M3, and M4).

Oil staining is common in the Kindle and Fantasque Formations in the eastern Liard Basin and on the Bovie Lake structure. Furthermore, the Fantasque forms the reservoir in the a-78-L/94-O-10 gas pool (Table 1; Cross sections B2 and M2) and part of the reservoir in the Windflower pool (d-87-A/94-O-11, Table 1 and Cross sections B1, P3 and M3), and produced $6x10^3$ m^3/d on a drill stem test in the b-85-H/94-O-11 well on the flank of the Bovie Lake structure (Cross sections B1, P2 and M2). These formations are potential reservoirs in structural traps, particularly on the Bovie Lake structure, where they may form continuous reservoirs with the underlying Mattson. These formations are also potential targets for stratigraphic traps in the Liard Basin. Mappable prospects could be developed in unconformity traps in the Fantasque beneath Triassic strata.

Triassic clastic succession (Grayling and Toad Formations)

Triassic strata thin northeastward across the Liard Basin from over 550 metres to 100 metres (Cross sections M1, M2, M3 and M4). The Triassic succession consists of a lower shale and an upper siltstone- and sandstone-dominated unit, which can be correlated with the Grayling and Toad Formations, respectively. Although these formations are usually combined in other parts of northeastern British Columbia (*e.g.* Gibson, 1990), they can be differentiated in the Liard Basin, which is located immediately east of the type area of these formations in the fold and thrust belt. The Grayling and Toad are truncated beneath the sub-Cretaceous unconformity, so that the Toad Formation is preserved generally in the western parts of the Liard Basin (Map 1; Cross sections M1, M2 and M3). These strata thin abruptly across the Bovie Lake structure, although locally thick sections are preserved, and they are generally not present to the east (Map 1; Cross sections B1, B2, M2, M3 and M4).

The Grayling Formation in this area consists of light grey, green, red and brown shales, that are variably calcareous and dolomitic, with subordinate amounts of siltstone and sandstone. The coarser lithologies occur most commonly where the formation is preserved on the Bovie Lake structure (Cross section B2). There, the Grayling can be differentiated from the dark shales of the Lower Cretaceous Garbutt Formation on the basis of colour. In the Grayling, dark shales typical of the type area occur only in the southwesternmost wells of the Liard Basin. Where it is conformably overlain by the Toad Formation, the Grayling is 200 to 250 metres thick, but west of the Liard Basin, it thickens to over 400 metres in the type area (Pelletier, 1960, 1961).

The overlying Toad Formation consists of interbedded grey to light grey calcareous siltstone and sandstone and light to dark grey shales. On wireline logs, the Toad generally has a thinner-bedded appearance and lower porosity than the unconformably overlying Lower Cretaceous Chinkeh Formation, which generally consists of a thin, widespread, sheet-like sandstone body with little erosional relief at its base (Cross sections M1, M2, M3 and M4). Based on these criteria, 27 metres of strata in the a-77-D/94-O-11 well assigned to the Chinkeh by Leckie *et al*. (1991), Hayes *et al*. (1994) and Leckie and Potocki (1998) are reassigned here to the Toad (Cross sections M1 and M3). Toad strata have a maximum thickness of nearly 350 metres in the study area, and thicken to 550 metres in the type area to the west (Kindle, 1944, 1946). These strata have not been correlated with the Liard Formation, which is truncated beneath Cretaceous strata in the outcrop belt west of the Liard Basin (Pelletier, 1960) and thus appears to be younger than Triassic strata of the Liard Basin.

Some oil staining has been reported in Toad and Grayling sandstones on the Bovie Lake structure, and sandstones in these horizons may be potential hydrocarbon objectives there. Furthermore, the productive sandstone in the b-44-L/94-O-10 pool, which is overlain by Grayling grey and red shales, may be basal Triassic rather than the Mattson, as shown on Cross section B2. In the Liard Basin, porosity is generally low in the Toad sandstones, but porosities up to 12 to 14% occur locally (*e.g.* a-91-A/94-O-12 well, in a zone equivalent to a sandstone at 6000' in the a-77-D/94-O-11 well, Cross sections M1 and M3). Furthermore, the Toad Formation is undrilled throughout a vast area in the Liard Basin. Consequently, the Toad sandstones have hydrocarbon potential in stratigraphic traps both within and at the eroded top of the formation in the western Liard Basin (Map 1).

Lower Cretaceous succession (Chinkeh, Garbutt and Scatter Formations)

The Lower Cretaceous strata considered in this report include the Chinkeh, Garbutt and Scatter Formations of the Fort St. John Group. The Chinkeh and the lower part of the Garbutt are restricted to the area west of the Bovie Lake structure, which appears to have been active during deposition of these units (Cross sections M2, M3 and M4).

In the Liard Basin, the Chinkeh Formation is up to 40 metres thick and consists of a lower sandstone unit, up to 8 metres thick, and an overlying glauconitic siltstone[8] (Cross sections M1, M2, M3 and M4). The Chinkeh sandstone forms a widespread sheet-like sandstone body up to 20 kilometres wide and 100 kilometres long immediately west of the Bovie Lake structure. Within this sandstone sheet, thicknesses vary little, and erosional relief is not evident at the unconformable lower contact. The sandstone is fine grained, glauconitic in part, includes horizontally laminated, high angle cross-bedded and bioturbated intervals and appears to have been deposited in a marine or marginal marine environment. However, non-marine environments may be represented elsewhere: in the a-34-F/94-O-4 well in the southern part of the Liard Basin, Chinkeh strata may occur in an erosional low

---

8

The Chinkeh siltstone is included in the lower part of the Garbutt Formation by Leckie *et al*. (1991), Hayes *et al*.

incised into Triassic strata (Map 1). To the north of the Liard Basin, non-marine strata occur in the lower part of the Chinkeh in outcrop in the Liard Plateau (Leckie *et al*.,1991); and in the subsurface of the Great Slave Plain, the Chinkeh consists of fluvial sandstones filling an erosional low incised into Palaeozoic strata (Dixon, 1997). The Chinkeh siltstone can be recognized beyond the limits of the Chinkeh sandstone. Chinkeh strata generally overlie Grayling or Toad strata, but in the northernmost part of the study area, in the d-87-I/94-O-14 well, they overlie the Fantasque.

The Chinkeh sandstone sheet west of the Bovie Lake fault is gas-bearing, and is the focus of an active gas play. Pay thicknesses are generally between 2 and 3 metres. Gas has also been discovered in a fluvial Chinkeh reservoir in the Great Slave Plain (Leckie *et al*., 1991; Dixon, 1997).

The Garbutt Formation consists of black sideritic shale, and some thin sandstones occur locally in the westernmost wells. In the Liard Basin, the Garbutt thins northeastwards from approximately 270 metres to less than 100 metres (Cross sections M1, M2, M3 and M4; Leckie and Potocki, 1998). Furthermore, the Garbutt thins across the Bovie Lake structure, due to both differential subsidence and non-deposition of lower Garbutt strata on and east of the structure. A distinctive radioactive marker at the top of the lower Garbutt in the Liard Basin onlaps pre-Cretaceous strata on the structure, and strata beneath this marker are thin to the east (Cross sections B1, B2, M2, M3 and M4). The thinning of the Garbutt across the Bovie Lake structure is greatest across the southern part of the structure, where the Garbutt is reduced to a thin remnant beneath the Scatter Formation (Cross sections B1, M3 and M4). The Garbutt shales are gradationally and in part diachronously overlain by the Scatter Formation (Cross sections B1, B2, M1, M2, M3, M4 and P4).

The Scatter Formation consists of interbedded very fine to fine grained glauconitic sandstone and shale, commonly organized into coarsening upward cycles 5 to 20 metres thick and deposited in a shallow marine shelf setting (Leckie and Potocki, 1998). Regionally, the sandstone content increases to the west, indicating that these sediments were sourced from that direction. The Scatter Formation thins northeastward across the Liard Basin from over 300 to 120 metres (Cross sections M1, M2 and M4). Like the Garbutt, the Scatter thins across the Bovie Lake structure and is approximately 60 metres thick to the east (Cross sections M2, M3, M4 and P4).

The Scatter sandstones contain thin shale interbeds and are matrix-rich, giving them a high gamma ray signature. They are commonly oil-stained and have frequently been drill stem tested, although recoveries have generally been poor due to the high clay content. However, sandstones with a cleaner appearance on logs are present in the southernmost part of the basin (Cross section M1), where the greatest potential for commercial hydrocarbon production in these strata likely occurs.

The Scatter Formation is overlain by dark marine shales of the Lepine Formation and its equivalents in the upper part of the Fort St. John Group (Taylor and Stott, 1968; Stott, 1982).

SUMMARY AND CONCLUSIONS

The Liard Basin is a large unexplored area situated immediately east of the Cordilleran fold and thrust belt. The basin has a thick sedimentary section, in which potential hydrocarbon objectives are present in the Mississippian Banff, Debolt and Mattson Formations, the Permo-Pennsylvanian Kindle and Fantasque Formations, the Triassic Toad Formation, and the Cretaceous Chinkeh and Scatter Formations. In addition, the Debolt, Mattson, Kindle, Fantasque and possibly the Triassic Grayling and Toad Formations are potential objectives in structural closures on the Bovie Lake structure on the margin of the basin, and the Banff and Debolt are potential objectives in stratigraphic traps on the platform to the east.

ACKNOWLEDGMENTS

In addition to the references cited, this report has drawn on stratigraphic data and interpretations contained in sample descriptions, core photographs and well histories in the files of the Ministry of Energy and Mines in Victoria, including logs prepared by Canadian Stratigraphic Service Ltd. The author also appreciates the assistance of Canadian Discovery Digest Ltd. for providing access to their recent proprietary report on the Liard Basin titled "Maxhamish, B.C., A New Canadian Frontier". The cross sections and maps have been ably drafted by J. Armitage, and this report has been critically reviewed by D. Richardson and M. Hayes, whose comments are greatly appreciated. In addition, the author appreciates the assistance of S. Chicorelli.

REFERENCES

Bamber, E.W., Richards, B.C. and Henderson, C.M. (1990): Kindle Formation; *in* Lexicon of Canadian Stratigraphy, Volume 4, Western Canada, Including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba, D.J. Glass, Editor, *Canadian Society of Petroleum Geologists*, pages 332-333.

Braman, D.R., and Hills, L.V. (1977): Palynology and paleoecology of the Mattson Formation, northwest Canada; *Bulletin of Canadian Petroleum Geology*, volume 25, pages 582-630.

Cotter, E.J. (1965): Waulsortian-type carbonate banks in the Mississippian Lodgepole Formation of central Montana; *Journal of Geology*, volume 73, pages 881-888.

Davies, G.R., Edwards, D.E., and Flach, P. (1988): Lower Carboniferous (Mississippian) Waulsortian Reefs in the Seal area of north-central Alberta; *in* Reefs - Canada and adjacent area, H.H.J. Geldsetzer, N.P. James and G.E. Tebbutt, Editors, *Canadian Society of Petroleum Geologists*, Memoir 13, pages 643-648.

Dixon, J. (1997): Cretaceous stratigraphy in the subsurface of the Great Slave Plain, southern Northwest Territories; *Bulletin of Canadian Petroleum Geology*, volume 45, pages 178-193.

Douglas, R.J.W. and Norris, D.K. (1959): Fort Liard and La Biche Map-Areas, Northwest Territories and Yukon; *Geological Survey of Canada*, Paper 59-6, 23 pages.

English, J.J. (1986): Mississippian Subsurface Correlation, 94I, 94J, 94O, 94P; *Ministry of Energy,* *Mines and Petroleum Resources*, 10 Stratigraphic Cross Sections.

Gibson, D.W. (1990): Toad Formation; *in* Lexicon of Canadian Stratigraphy, Volume 4, Western Canada, Including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba, D.J. Glass, Editor, *Canadian Society of Petroleum Geologists*, pages 637-638.

Hayes, B.J.R., Christopher, J.E., Rosenthal, L., Los, G., McKercher, B., Minken, D., Tremblay, Y.M. and Fennel, J. (1994): Chapter 19 - Cretaceous Mannville Group of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G. Mossop and I. Shetsen, Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 317-334.

Henderson, C.M. (1989): The lower Absaroka sequence: Upper Carboniferous and Permian; *in* Western Canada Sedimentary Basin - A Case History, B.R. Ricketts, Editor, *Canadian Society of Petroleum Geologists*, pages 203-217.

Henderson, C.M., Richards, B.C. and Barclay, J.E. (1994): Chapter 15 - Permian strata of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G. Mossop and I. Shetsen, Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 251-258.

Holland, S.S. (1976): Landforms of British Columbia; *British Columbia Department of Mines and Petroleum Resources*, Bulletin 48, 138 pages.

Kindle, E.D. (1944): Geological Reconnaissance along Fort Nelson, Liard and Beaver Rivers, Northeastern British Columbia and Southeastern Yukon; *Geological Survey of Canada*, Paper 44-16, 19 pages.

Kindle, E.D. (1946): The Middle Triassic of Liard River, British Columbia, Appendix 1; *in* A Middle Triassic (Anisian) fauna in Halfway, Sikanni Chief, and Tetsa valleys, Northeastern British Columbia; *Geological Survey of Canada*, Paper 46-1, pages 37-59.

Leckie, D.A., Potocki, D.J., and Visser, K., (1991): The Lower Cretaceous Chinkeh Formation: A Frontier Type Play in the Liard Basin of Western Canada; *Bulletin of the American Association of Petroleum Geologists*, volume 75, pages 1324-1352.

Leckie, D.A. and Potocki, D.J. (1998): Stratigraphy and petrography of marine shelf sandstones of the Cretaceous Scatter and Garbutt formations, Liard basin, northern Canada; *Bulletin of Canadian Petroleum Geology*, volume 46, pages 30-50.

MacIntyre, D.G., Okulitch, A.V., Taylor, G.C., Cullen, B., Massey, N., and Bellafontaine, K., Compilers (1998): Geology, Fort Nelson, British Columbia; Central Foreland Map NO-10G, scale 1:500 000. *Geological Survey of Canada*, Open File 3604.

Macqueen, R.W., and Sandberg, C.A. (1970): Stratigraphy, age, and intrerregional correlations of the Exshaw Formation, Alberta Rocky Mountains; *Bulletin of Canadian Petroleum Geology*, volume 18, pages 32-66.

Ministry of Energy and Mines (1997): Hydrocarbon and By-product Reserves in British Columbia, December 31,1997; *Ministry of Energy and Mines, Energy and Minerals Division*.

Pelletier, B.R. (1960): Triassic Stratigraphy, Rocky Mountain Foothills, Northeastern British Columbia; *Geological Survey of Canada*, Paper 60-2, 32 pages.

Pelletier, B.R. (1961): Triassic Stratigraphy, Rocky Mountains and Foothills, Northeastern British Columbia, 94-K and N (part of); *Geological Survey of Canada*, Paper 61-8, 32 pages.

Pelzer, E.E. (1966): Mineralogy, geochemistry and stratigraphy of the Besa River Shale, British

Columbia; *Bulletin of Canadian Petroleum Geology*, volume 14, pages 273-321.

Precht, W.F. and Shepard, W. (1988): The structure, sedimentology and diagenesis of some Waulsortian carbonate buildups of Mississippian age from Montana; *in* Reefs - Canada and adjacent area, H.H.J. Geldsetzer, N.P. James and G.E. Tebbutt, Editors, *Canadian Society of Petroleum Geologists*, Memoir 13, pages 682-687.

Richards, B.C. (1989a): Uppermost Devonian and Lower Carboniferous Stratigraphy, Sedimentation, and Diagenesis, Southwestern District of Mackenzie and Southeastern Yukon Territory; *Geological Survey of Canada*, Bulletin 390, 135 pages.

Richards, B.C. (1989b): Upper Kaskaskia Sequence: Uppermost Devonian and Lower Carboniferous; *in* Western Canada Sedimentary Basin - A Case History, B.R. Ricketts, Editor, *Canadian Society of Petroleum Geologists*, pages 165-201.

Richards, B.C. (1990): Mattson Formation; *in* Lexicon of Canadian Stratigraphy, Volume 4, Western Canada, Including Eastern British Columbia, Alberta, Saskatchewan and Southern Manitoba, D.J. Glass, Editor, *Canadian Society of Petroleum Geologists*, pages 387-388.

Richards, B.C. and Higgins, S.C. (1988): Devonian-Carboniferous boundary beds of the Palliser and Exshaw Formations at Jura Creek, Rocky Mountains, southwestern Alberta; *in* Devonian of the World, Volume II: Sedimentation, N.J. McMillan, A.F. Embry, and D.J. Glass, Editors, *Canadian Society of Petroleum Geologists*, Memoir 14, pages 399-412.

Richards, B.C., Barclay, J.E., Bryan, D, Hartling A., Henderson, C.M., Hinds, R.C. (1994): Chapter 14 - Carboniferous strata of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G. Mossop and I. Shetsen, Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 221-250.

Stoakes, F.A. (1992): Chapter 11, Early Mississippian Megasequences; *in* Devonian-Early Mississippian Carbonates of the Western Canada Sedimentary Basin: A Sequence Stratigraphic Framework, by J. Wendte, F.A. Stoakes and C.V. Campbell, SEPM Short Course No. 28, *Society for Sedimentary Geology*, pages 241-249.

Stott, D.F. (1982): Lower Cretaceous Fort St. John Group and upper Cretaceous Dunvegan of the Foothills and Plains of Alberta, British Columbia, District of Mackenzie and Yukon Territory; *Geological Survey of Canada*, Bulletin 328, 124 pages.

Switzer, S.B., Holland, W.G., Christie, D.S., Graf, G.C., Hedinger, A.S., McAuley, R.J., Wierzbicki, R.A., and Packard, J.J. (1994): Chapter 12 - Devonian Woodbend-Winterburn Strata of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G. Mossop and I. Shetsen, Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, p.165-202.

Taylor, G.D. and Stott, D.F. (1968): Maxhamish Lake, British Columbia; *Geological Survey of Canada*, Paper 68-12, 23 pages.

Williams, G.K. (1977): The Celibeta structure compared with other basement structures on the flanks of the Tathlina high, District of Mackenzie; in Report of Activities, Part B, *Geological Survey of Canada*, Paper 77-1B, pages 301-310.

Wright, G.N., McMechan, M.E. and Potter, D.E.G. (1994): Chapter 3 - Structure and architecture of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G. Mossop and I. Shetsen, Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 25-40.

Table 2: Table of formations of Liard Basin, uppermost Devonian to Cretaceous

(data for units above Scatter taken from Taylor and Stott (1968) and Stott (1982))

System/Series	Formation and Thickness (m)		Lithology	
Upper Cretaceous	Wapiti (60)		conglomerate, sandstone, carbonaceous shale and coal	
	Kotaneelee (180)		dark shale	
	unconformity			
	Dunvegan (150-200)		massive conglomerate, sandstone and carbonaceous shale	
Lower Cretaceous	Fort St. John Group	upper Ft. St. John Group (~800)	primarily dark grey shale; in western part of Liard Basin, can be differentiated into (in ascending order) Lepine Shale, Sikanni sandstone and Sully Shale	
		Scatter (60-300)	very fine to fine glauconitic sandstone and shale	
		Garbutt (3-270)	black sideritic shale, minor sandstone	
		Chinkeh (0-40)	glauconitic siltstone overlying sandstone, glauconitic in part	
	unconformity			
Triassic	Toad (0-350)		grey to light grey calcareous siltstone and sandstone and light to dark grey shales	
	Grayling (0-250)		light grey, green, red and brown shales, minor sandstone, dark shales in southwesternmost wells	
	Unconformity			
Upper Permian / Lower Permian	Fantasque (0-175)		dark chert, in part glauconitic, minor sandstone and siltstone	
	Unconformity			
Lower Permian	Middle-Upper Kindle (0-190)		calcareous sandstone, western liard basinonly	
	Unconformity			
Pennsylvanian	Lower Kindle (0-58)		siltstone, glauconitic, calcareous, phosphatic	
	Unconformity			
Mississippian	Mattson (125-600)		fine to medium sandstone, with siltstone, shale, dolomite and coal	
	Golata (6-72)		black shales	
	Prophet *in western Liard Basin* (0-375)	Debolt (0-270)	*Prophet* ; spiculite, spicular-rich limestone and shale	*Debolt* ; bioclastic limestone with dolomite, chert, and calcareous shale
		Shunda (0-160)		*Shunda* ; argillaceous limestone and calcareous shale
		Pekisko (0-35)		*Pekisko* ; bioclastic limestone and calcareous shale
Mississippian / Upper Devonian	Banff (375-525)		calcareous shale and argillaceous limestone	
Upper Devonian	Exshaw (15-150)		dark shale and silty limestone	
	Unconformity			
	Kotcho, Tetcho and underlying shales (lower part of Besa River Fm)		shales and argillaceous limestone	