SKEENA AND BOWSER LAKE GROUPS, WEST HALF HAZELTON MAP AREA (93M)

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ABSTRACT

The extent of Skeena Group rocks delineated during the summer of 2004 within the western portion of Hazelton map area (93M) is very similar to patterns presently portrayed on regional scale maps. Large areas of previously undivided Bowser-Skeena lithologies belong to the Bowser Lake Group. In west Hazelton map area, the Bowser Lake Group can be subdivided in the Ritchie-Alger and Muskaboo Creek lithofacies assemblages, representing submarine fan or outer shelf, and inner shelf depositional environments, respectively. The Skeena Group is represented by the fluvial Bulkley Canyon Formation. Sedimentary rocks of the Skeena Group (Bulkley Canyon Formation) appear to conformably overlie and intertongue with the Bowser Lake Group (Muskaboo Creek lithofacies assemblage). All these rocks have been deformed into northeast-verging folds and faults and have been subsequently cut by steep structures.

In the study area, limited surface thermal maturation levels indicate Skeena Group rocks are generally mature to overmature with respect to the oil window and locally extend to the upper gas window. Bowser Lake Group rocks are mature to overmature with respect to the gas window. Skeena Group rocks are rich in Type III kerogen. Delineation of an adequate reservoir rock within Bowser and Skeena sequences is an issue.

Filippo Ferri, Peter Mustard, Margot McMechan, Dave Ritcey, Gareth Smith, Carol Evenchick and Michael Boddy, Skeena and Bowser Lake groups, west half Hazelton map area (93M) in Summary of Activities 2005, *BC Ministry of Energy and Mines, pages 113-131.*

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Keywords: Hazelton, Bowser Basin, Bowser Lake Group, Skeena Group, Ritchie-Alger, Muskaboo Creek, Bulkley Canyon, Laventie, Kitsuns Creek, Kitsumkalum shale, hydrocarbon potential, petroleum, coal, oil, gas

INTRODUCTION

Regional-scale mapping was carried out within the western Hazelton map area during the summer of 2004 with the objective of delineating the extent of the Skeena Group and identify its relationship to underlying rocks of the Bowser Lake Group. This mapping project is part of the Integrated Petroleum Resource Potential and Geoscience Studies of the Bowser and Sustut Basins program which is a partnership between Natural Resources Canada (Geological Survey of Canada), the B.C. Ministry of Energy and Mines (Resource Development and Geoscience Branch) and Simon Fraser University (Department of Earth Sciences). This 4 year, multi-disciplinary program is currently in its second year. During this time, this project has completed regional mapping studies within western McConnell Creek (94D), Bowser Lake (104A) and west Hazelton (93M) map sheets, together with basin-wide thematic studies (Evenchick *et al.*, 2004, 2005; Hayes *et al.*, 2004). The ultimate aim of this program is a better understanding of the geology and hydrocarbon potential of these large, Intermontane Belt sedimentary basins.

Hannigan *et al.* (1995), in their assessment of the Bowser Basin, assigned a higher risk level to Bowser Lake Group sediments versus those of the Skeena Group based primarily on higher thermal maturities. As a result, potential resources were higher within the Skeena Group, with total mean in-place resources of $7.19x10^{10}$ m^3 (2.54 trillion cubic feet, TCF) gas and $2.01x10^8$ m^3 (1,264 million barrels) oil. In comparison, the Bowser Lake Group is assigned a total mean in-place potential of $5.78x10^{10}$ m^3 (2.0 TCF) gas and no oil.

A recent geological compilation of the Bowser Basin portrays large portions of the southern parts as undivided Bowser Lake and Skeena groups (Evenchick *et al.* 2004; Figures 1 and 2). Clearly, an increase in the areal extent of the Skeena Group would increase the overall hydrocarbon resource potential of the Bowser Basin and the number of potential play targets. As a result of this, and the overall higher prospectivity of the Skeena Group, the BC Ministry of Energy and Mines, together with the Geological Survey of Canada and Simon Fraser University, initiated a regional mapping program within the western portion of the Hazelton map sheet. The main objectives of this project were: 1) map extent of Bowser and Skeena Group rocks; 2) examine the relationship between Skeena and Bowser Lake groups, including

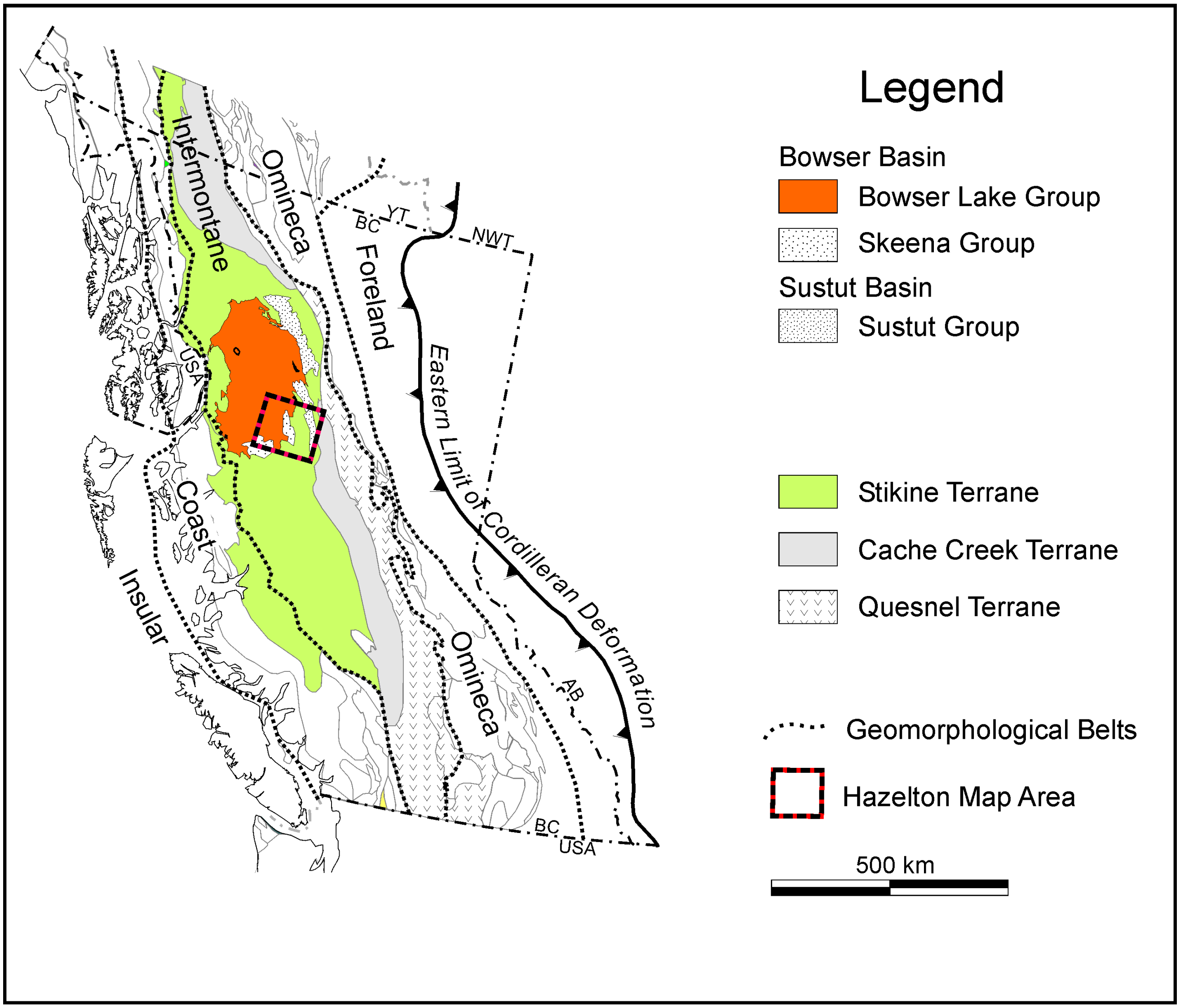

Figure 1. Location of the Bowser and Sustut basins within the geological framework of the Canadian Cordillera (modified from Evenchick *et al.*, 2004).

preliminary structural interpretations; 3) determine if lithofacies assemblages delineated for Bowser Lake Group in northern Bowser Basin extend into the southern part of the basin; 4) sample Skeena and Bowser Lake groups for reservoir characterization and 5) obtain samples of Bowser Lake and Skeena groups for determining levels of thermal maturation and source bed potential.

The area examined during the summer of 2004 is roughly centred on the Kispiox River valley and is bounded to the east and west by the Babine and Kispiox ranges, respectively, and to the south by the Skeena River (figures 3, 4). The area encompasses the confluence of the Babine, Skeena and Kispiox rivers and, except for alpine areas, is well accessed by an extensive network of logging roads. The town of New Hazelton is located on the Skeena River, at the southern end of the study area, with Smithers roughly an hours drive to the south along Highway 16 and Terrace some 150 kilometres to the west.

PREVIOUS WORK

Geologic mapping in the Hazelton map area dates back to the early 1900's when Leach (1909) first used the term "Skeena series" to describe the coal bearing sequence which lies above Jurassic volcanic and sedimentary rocks, the latter of which he termed the Hazelton Group (Table 1). The use of the name "Skeena" to describe the coal series was dropped by Armstrong (1944a, b) as he found it difficult to differentiate these rocks from the older Jurassic sedimentary sequence. Tipper and Richards (1976) resurrected the name, raising it to group status and assigned a Cretaceous age to these sediments. These authors also redefined the Hazelton Group and assigned the intervening sediments and minor volcanics to the Bowser Lake Group, which they believed to be largely Middle to Late Jurassic in age (Table 1). Richards (1980, 1990) mapped and compiled the geology of the entire Hazelton map area and refined Skeena Group and younger stratigraphy. A detailed sedimentological study of the Skeena Group was carried out by Bassett

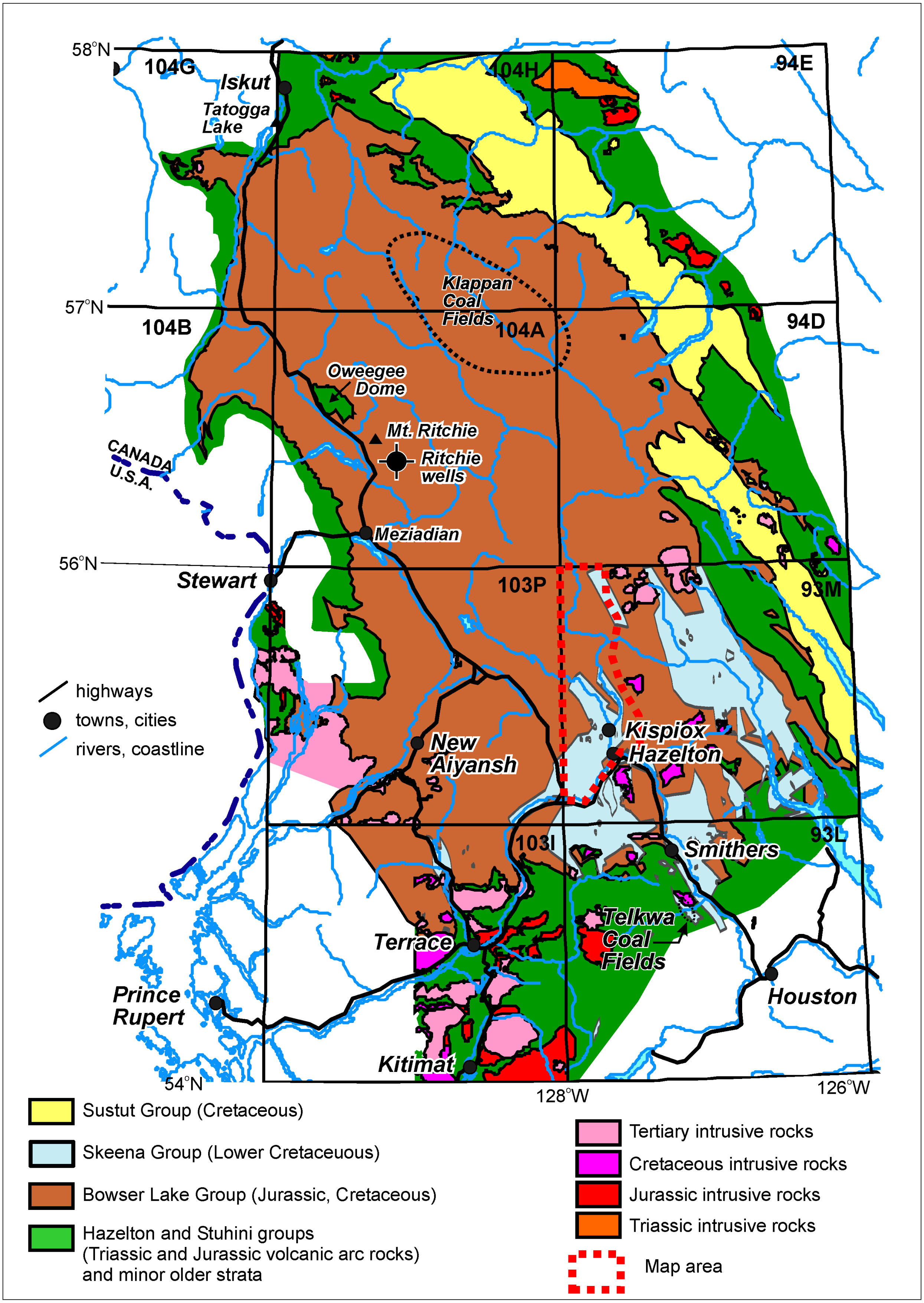

Figure 2. General geology of the Bowser and Sustut basins, showing the distribution of the Skeena Group (modified from Evenchick *et al.*, 2004).

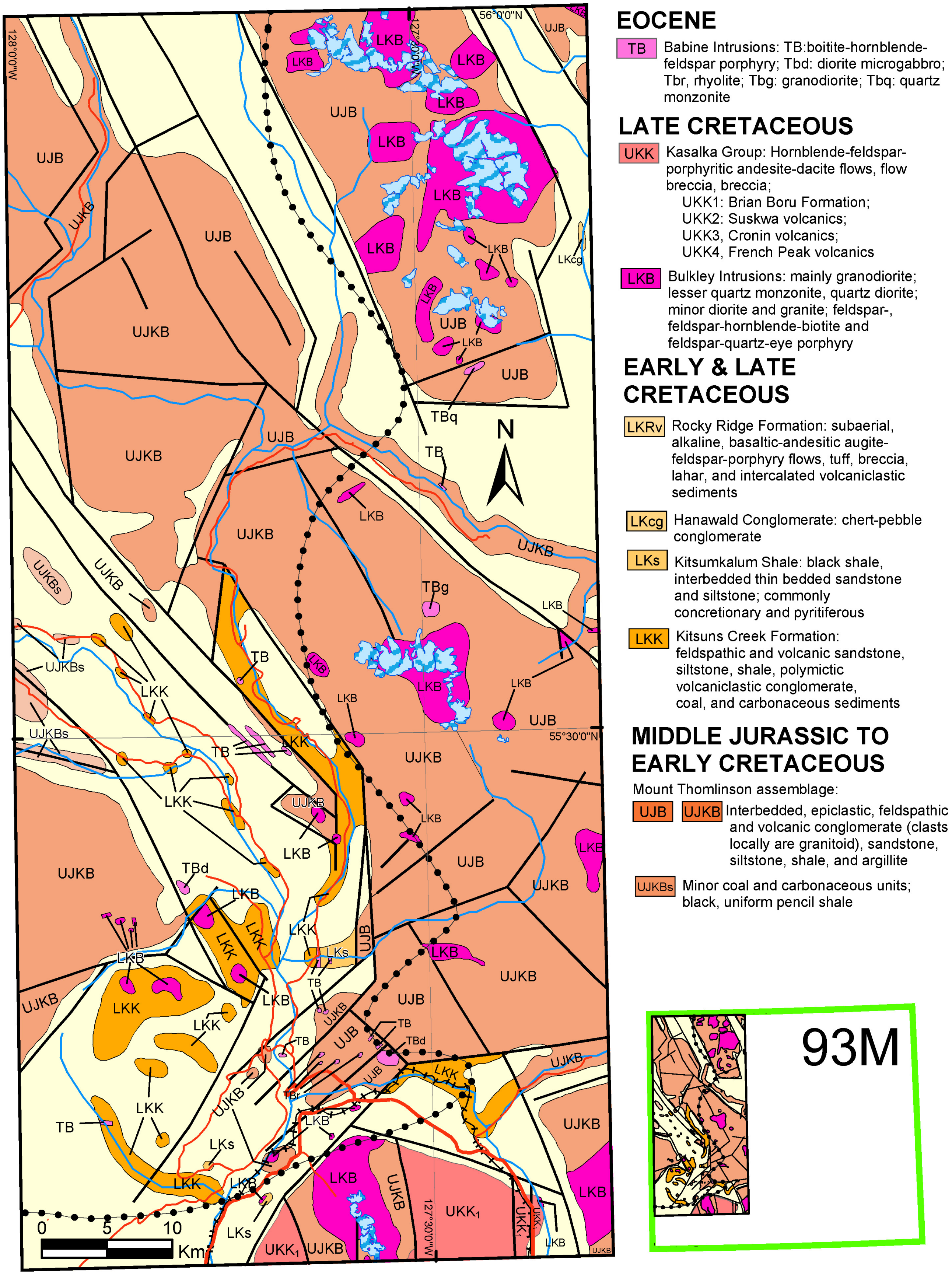

Figure 3. Geology of central and western Hazelton map area (simplified after Richards, 1990). The outline of the current map area is shown by the dashed line.

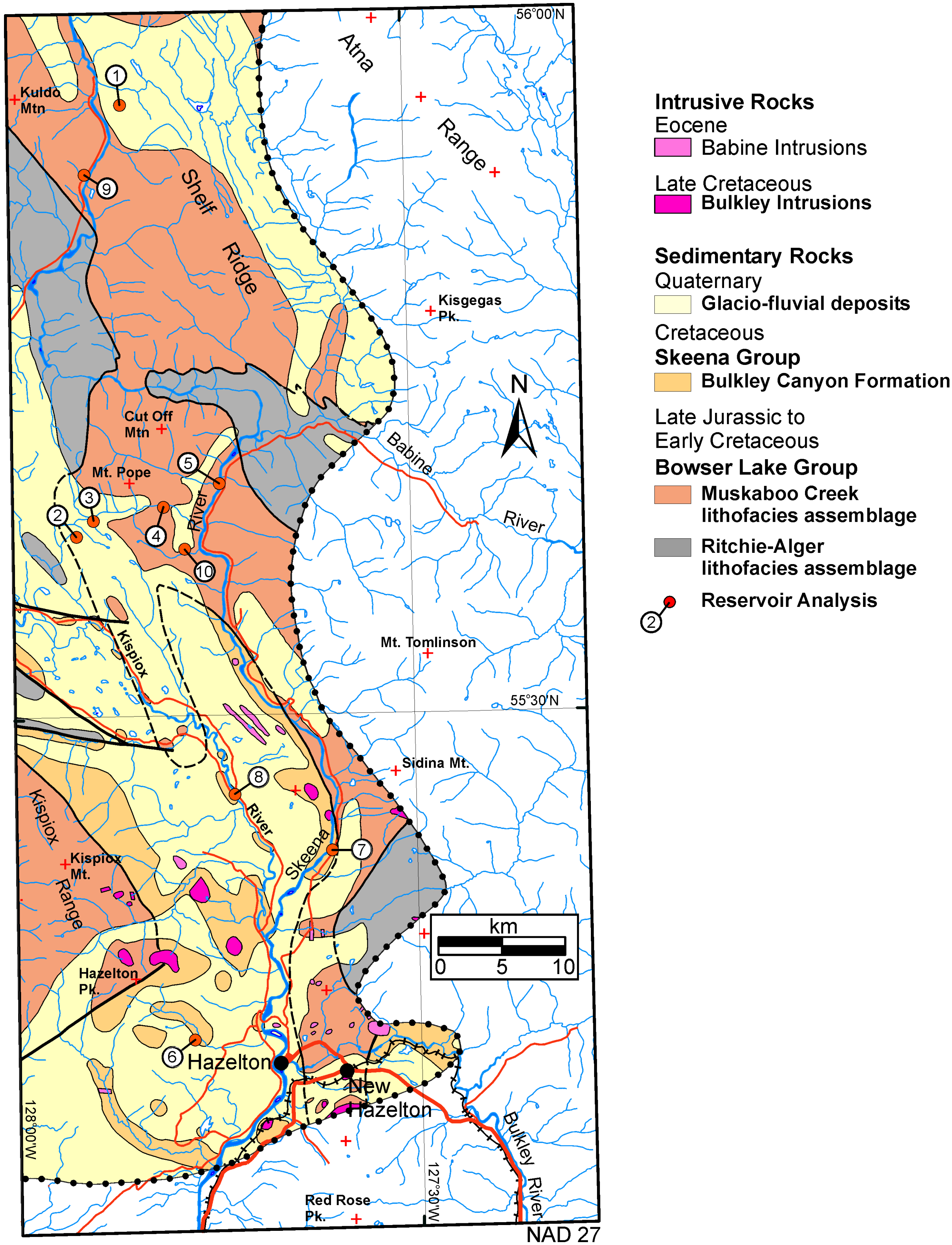

Figure 4. Simplified geological map of the study area. Sample locations for reservoir analysis are also shown.

TABLE 1. EVOLUTION OF STRATIGRAPHIC NOMENCLATURE WITHIN THE HAZELTON MAP AREA, PARTICULARLY WITH RESPECT TO THE BOWSER LAKE AND SKEENA GROUPS.

Dawson (1881) Leach (1908,9)	Leach (1910)	Hanson (1924) Jones (1925)		Armstrong (1944a, b)		Sutherland Brown (1960)	Tipper and Richards (1976)		Richards (1980)		Richards (1990)		Bassett and Kleinspehn (1997)
Porphyrite group	Skeena series		Skeena fm	Hazelton Group			Skeena Group			Brian Boru fm	Kasalka Gp	Brian Boru fm Suskwa volcs Cronin volcs French Pk volcs	
									Sustut Gp		Sustut Gp		Sustut Gp
					Volcanic Div	Brian Boru fm		Brian Boru fm	Skeena Group	Red Rose fm	Skeena Group	Red Rose fm	Rocher Deboule Fm
										Albian blk shale			Rocky Ridge Fm
										Rocky Ridge vols		Rocky Ridge fm	
					Sedimentary Div	Red Rose fm		Red Rose fm		Kitsuns Ck seds		Hanawald cong.	Bulkley Canyon Fm Kitsuns Ck mbr
										Black shale		Kitsumkalum shale	Laventie Fm (Couture Fm; Bassett and Kleinspehn, 1996)
										Conglomerate		Kitsuns Ck fm	
	Hazelton Group	Hazelton Group	Upper Sedimentary Div					Bowser Lake Group	Bowser Lk Gp	Upper to Lower	Bowser Lk Gp	Mt Thomlinson asblge	Mt. Thomlinson asblge
										Netalzul Volcs		Netalzul Fm	Netalzul Fm
										Trout Ck Beds		Trout Ck Fm	Trout Ck Fm
												Ashman Fm	Ashman Fm
							Hazelton Group	Smithers Fm	Hazelton Group	Smithers Fm	Hazelton Group	Smithers Fm	Smithers Fm
													Saddle Hill volcanics
			Upper Volcanic Div		Volcanic Div								
			Lower Sedimentary Div		Sedimentary Div			Nilkitkwa Fm		Nilkitkwa Fm		Nilkitkwa Fm	Nilkitkwa Fm
			Lower Volcanic Div		Volcanic Div			Telkwa Fm		Telkwa Fm		Telkwa Fm	Telkwa Fm

(1995) which led to a re-definition of Skeena stratigraphy (Table 1, Figure 5; Bassett and Kleinspehn, 1996, 1997). Detailed mapping in the Old Fort Mountain (93M/1) and Nakinilerak Lake (93M/8) map sheets (both containing Skeena Group strata) was carried out by MacIntyre *et al.* (1997) and MacIntyre (1998), respectively.

Although a regional scale geological map of Nass River (103P) does not exist, maps of select parts of the Bowser Basin within 103P were produced by Evenchick (1996a, b, c) and Haggart (1998). To the north of the study area, the geology of the east half of McConnell Creek was compiled by Richards (1976). The first compilation at 1:250 000 scale of the west half was by Evenchick et al (2001), based on mapping in the early 1990's (Evenchick and Porter, 1993). As part of this integrated study this compilation was updated based on mapping in the summer of 2003 (Evenchick *et al.*, 2004). In Bowser Lake map area, (104A) Evenchick *et al.* (2000) delineate preliminary geology and Evenchick *et al.* (1992) describe the distribution of lithofacies assemblages within Bowser Lake Group strata. The map area was also covered at a regional scale in 2004 as part of the present Bowser-Sustut basins integrated study and will lead to a revised geological compilation (Evenchick *et al.*, *in press;* see Evenchick *et al.*, 2004 for a preliminary compilation).

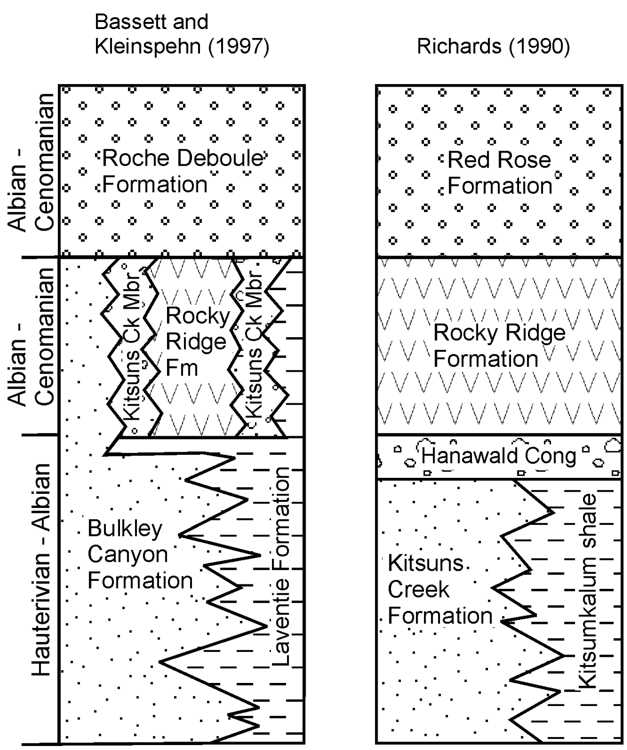

Figure 5. Schematic representation of the stratigraphy of the Skeena Group as depicted by Bassett and Kleinspehn, 1997 and Richards, 1990.

GEOLOGICAL FRAMEWORK

The Bowser and Sustut basins are located in north-central British Columbia, within the northern part of the Intermontane Belt. These basins represent overlap assemblages deposited subsequent to amalgamation of Stikine, Cache Creek and Quesnel terranes onto Ancestral North America (Figure 1). They primarily overlie Devonian to Jurassic rocks of Stikinia.

Initiation of the Bowser Basin most likely began with thrust loading of Cache Creek Terrane rocks onto Stikinia in Early to Middle Jurassic times (Toarcian to Aalenian; Ricketts *et al.*, 1992). This is manifested in the stratigraphic record by the deposition of uppermost black clastic deposits of the Hazelton Group and by chert boulder conglomerate in the footwall of the King Salmon Fault (Gabrielse, 1998). The black clastic unit of the upper Hazelton Group in Hazelton map area is referred to as the Nilkitkwa and Smithers formations (Spatsizi Formation in northern Bowser Basin). The upper part of the Aalenian to Bajocian Smithers Formation records an influx of coarse, chert-rich clastics similar to those of the overlying Bowser Lake Group.

The Bowser Basin contains two main successions: the Middle Jurassic to mid-Cretaceous Bowser Lake Group and the Lower to mid-Cretaceous Skeena Group, although some previous workers have considered the Skeena Group to have been deposited in a separate basin (*e.g.*, Tipper and Richards, 1976). The Sustut Basin is represented by the mid- to Upper Cretaceous Sustut Group. In northern and central Bowser Basin, marine and non-marine Bowser Lake strata represent a southwestward and westward, prograding fluvial-deltaic to distal submarine fan sequence (Evenchick *et al.*, 2001). Skeena Group rocks, located along the southern part of Bowser Basin, are inferred to have been deposited in marine to non-marine deltaic? or estuarine, and fluvial/floodplain environments. The relationship of Skeena to Bowser Lake stratigraphy is uncertain. Previous workers have considered the contact to be either an unconformity or conformable, although none have documented an exposed example of this contact (Tipper and Richards, 1976; Bassett and Kleinspehn, 1997). The Sustut Group is interpreted to represent fluvial to lacustrine environments (Eisbacher, 1974) deposited in a foreland basin east of deforming Bowser Lake strata (Evenchick and Thorkelson, 2005).

Bowser Lake, Skeena, Sustut and underlying Stikine Terrane rocks are deformed into dominantly northwest-trending fold and thrust structures comprising the Skeena Fold Belt (Evenchick, 1991). In eastern Hazelton map area, MacIntyre (1998) shows that rocks as young as Cenomanian were involved in this deformation event. In northern Bowser Basin, oldest Skeena Fold Belt deformation is believed to be bracketed between the latest Jurassic and Albian times whereas youngest deformation is latest Cretaceous (Maastrichtian) to earliest Tertiary (Paleocene; Evenchick, 1991).

The youngest period of deformation within the map area is manifested as a series of steep, extensional faults and associated horst and graben structures (Richards, 1980, 1990; MacIntyre, 1998; MacIntyre *et al.*, 1997).

These features are believed to be Eocene or younger based on cross-cutting relationships. These faults appear to be the main control on the distribution of rock units within the Hazelton map area.

WEST HAZELTON MAP AREA (93M)

In the west part of the Hazelton map area, the distribution of sedimentary rocks encountered during the summer of 2004 broadly corresponds to patterns mapped by Richards (1990). Skeena Group rocks in this area are part of the Bulkley Canyon Formation (Bassett and Kleinspehn, 1997; Kitsuns Creek formation of Richards, 1990), and we believe that these rocks rest conformably atop those of the Bowser Lake Group (Smith *et al.*, this volume).

The Bowser Lake Group in west Hazelton map area was assigned to the Mount Thomlinson assemblage by Richards (1990), an undivided marine and fluvial sequence of Middle Jurassic to Early Cretaceous age. Mapping of these rocks over the summer of 2004 allowed their subdivisions into lithofacies assemblages as defined within the northern Bowser Basin (Evenchick *et al.*, 2001). The distribution of these lithofacies corresponds to those in the adjoining McConnell Creek and Bowser Lake map areas and include the Ritchie-Alger and Muskaboo Creek assemblages, representing submarine fan (to outer shelf or slope) and inner shelf depositional environments, respectively.

Sedimentary rocks in the Hazelton map area have been intruded by two igneous suites: the Late Cretaceous Bulkley and Tertiary Babine intrusions (Richards, 1990). Bulkley intrusions consist of small to large bodies of dominantly quartz diorite, monzonite, diorite and granite. These occur along the higher ground of the map area and underlie regions in the Mount Thomlinson, Natlan Peak, Nine Mile Mountain, and Hazelton Peak areas. The Babine intrusive suite comprises porphyritic lithologies including ±biotite±hornblende-feldspar porphyries and lesser diorite, granodiorite and quartz monzonite. In west Hazelton map area these rocks forms small plugs in the Four Mile Mountain area, north of New Hazelton and west of Skeena River. In addition, there are numerous small porphyritic dikes and plugs within the map area which most likely belong to this suite.

BOWSER LAKE GROUP

The Bowser Lake Group was subdivided into 4 packages by Richards (1990) within the Hazelton map area (Figure 3). These are, from oldest to youngest, the Ashman, Trout Creek and Netalzul formations, followed by undivided rocks of the Mount Thomlinson assemblage (Figure 3). An overall gross description of this package by Richards (1980), Tipper and Richards (1976), and Richards and Jeletzky (1975), indicates a northwestward progradation of fluvial-deltaic systems into marine environments. Callovian to Early Oxfordian rocks of the Ashman Formation generally record deeper water, marine facies with some fluvial influences (Tipper and Richards, 1976) whereas the Late Oxfordian Trout Creek Formation contains coarser clastics and coal-bearing sequences interpreted as fluvial-deltaic in nature. The Oxfordian Netalzul Formation is composed of intermediate to felsic pyroclastic rocks deposited within specific parts of the Bowser Basin, primarily in the Mt. Netalzul and Ashman Ridge areas of the Hazelton map area (Richards, 1990) and southwest parts of the east half of McConnell Creek map area (Richards, 1976). The Oxfordian to Hauterivian Thomlinson assemblage (Richards, 1990) is the youngest unit of the Bowser Lake Group in southern Bowser Basin and consists of fluvial, marginal marine and shallow marine deposits.

These broad facies relationships support the presence of a paleogeographic high, the Skeena Arch, to the southeast of the map area which became prominent during late Middle to Late Jurassic times (Tipper and Richards, 1976).

Tipper and Richards (1976) describe a period of faulting, uplift and erosion which affected Bowser Lake and older rocks between Kimmeridgian and Early Cretaceous (Hauterivian?) times (although Richards (1990) shows the upper part of the Bowser Lake Group extending into the Hauterivian) resulting in Skeena Group rocks appearing to be disconformable to unconformable on older units. This was supported by paleontological evidence suggesting a possible hiatus during this time and by relationships south of the Hazelton map area, where Skeena Group clastics rest unconformably on Hazelton Group volcanics, such as in the Telkwa coal fields (Koo, 1984) and near Tahtsa Lake where Albian sediments sit unconformably on Middle Jurassic Bowser Lake Group rocks (Woodsworth, 1980). Tipper and Richard (1976) also suggest that the depositional basin represented by the Skeena Group was different to that of the Bowser Basin. Barring the above evidence, the nature of the Skeena - Bowser contact in most areas has previously been equivocal due to its general lack of exposure and/or stratigraphic control. Although it can be difficult to differentiate between Bowser Lake and Skeena clastics, the latter has commonly been cited to contain common mica flakes and is somewhat less indurated.

In the current study area, Bowser Lake Group sedimentary rocks have been subdivided into two units recognized in other map areas to the north: the Ritchie-Alger and Muskaboo Creek lithofacies assemblages, following the terminology of Evenchick *et al.*, (2001) and presented in detail within Evenchick and Thorkelson (2005). In northern and central Bowser Basin, these lithofacies broadly represent the main marine units of the basin and both underlie and are distal to a southwesterly prograding sequence of deltaic complexes which locally contain thick sections of coal (Klappan-Groundhog coal fields). In a broad sense, rocks of the Ashman formation have characteristics similar to those of the Ritchie-Alger assemblage, whereas facies of the Thomlinson formation are more akin to the Muskaboo Creek lithofacies assemblages.

Fossil data in northern and central Bowser basin have shown that the age of the Bowser Lake Group is late Middle Jurassic to Early Cretaceous (Bathonian to Albian(?); Evenchick *et al.*, 2001). Fossil collections from the Ritchie-Alger and Muskaboo Creek lithofacies assemblages bracket the late Middle Jurassic (Bathonian) to latest Jurassic (Tithonian) and locally may extend into the earliest Cretaceous.

RITCHIE-ALGER ASSEMBLAGE

Dark grey to black siltstone (in places slaty) together with grey to beige, thin to thick bedded sandstone occur primarily within the northwestern part of the map area. Main areas of exposure include: south of Kuldo Creek, west of Mount Pope and Cutoff Mountain, and north of McCully Creek. These rocks also occur in the vicinity of the Skeena and Babine river confluence and west of the Kispiox-Skeena confluence. Typically, the terrain encompassed by this unit is below tree line and relatively subdued, such that exposures tend to be limited to either stream, road or quarry cuts. Best outcrops are on the ridge northwest of Cutoff Mountain and along the lower Babine River. Thicknesses are difficult to determine, but are in the order of several hundred metres.

Massive to vaguely laminated siltstone and/or silty mudstone are the dominant lithologies in the northern part of the map area. Commonly, these sections contain thin beds of fine grained, graded to cross-laminated sandstone which comprise up to 20 per cent of the exposure. Cleavage in finer lithologies is ubiquitous and rocks locally are slates. Some sections, such as in the vicinity of the confluence of the Babine and Skeena rivers, can be quite organic-rich and contain small pyritic nodules. Vertical to sub-vertical worm burrows up to 2 centimetres wide, and displaying cuspate in-fills, are well developed in exposures north of the Skeena River near its confluence with the Babine River.

In the vicinity of the Kispiox-Skeena confluence, and as scattered occurrences elsewhere, dark and commonly massive siltstones and silty mudstones contain massive, tabular chert-rich sandstones beds up to a metre or more thick which can comprise up to 50 per cent of exposures. The base of these sandstone beds commonly contain rip-ups of underlying siltstone. Graded bedding and cross-laminations in thinner bedded, fine-grained sandstone interbeds, siltstone rip-ups and other Bouma sequence features are consistent with turbidite deposition in well organized sand-rich submarine fan successions. This, together with the overall character of these sections suggests they are part of the Ritchie-Alger lithofacies assemblage. Notwithstanding the sedimentological attributes that equate it with the Ritchie-Alger lithofacies assemblage, this siltstone dominated package forms an easily recognizable lithostratigraphic unit within the west part of Hazelton map area.

Although the siltstone/shale dominated sequence in the northern part of the map area does not fit the classic description of the Ritchie-Alger lithofacies assemblage (*see* Evenchick *et al.,* 2004), it contains sections and sedimentary features more akin to this assemblage, suggesting it is part of the facies. In areas to the north (Evenchick et al., 2005) the Ritchie-Alger assemblage contains significant amounts of similar siltstone but is characterized by abundant sandstone interbeds (commonly >50% by volume) containing classic turbidite features. However thick sections (>100m in some places) of mostly massive siltstone to silty mudstone do occur both below and above (and intertonguing with) the sandstone-dominate "classical" Ritchie-Alger assemblage. Some of these siltstone dominate units are probably distal parts of "off-shelf" submarine fan deposits, but others appear to grade vertically into the shoreface Muskaboo Creek assemblage, and thus may represent deep shelf or ramp / slope depositional environments of deposition. In the Hazelton map area, there are several places where the siltstone dominant "member" of the Ritchie-Alger assemblage appears to directly underlie (and rarely can be shown to grade into) the shallow marine Muskaboo Creek assemblage, thus suggesting an outer shelf environment for much of this unit in this area (although sandstone-rich submarine fan turbidite successions are also present in some areas)

MUSKABOO CREEK ASSEMBLAGE

Muskaboo Creek rocks typically underlie the higher parts of the map area including the Kispiox Range, Shelf Ridge and the high ground leading down to Cutoff Mountain and Mount Pope. This package is also exposed along road cuts in the low ground between the Skeena and Kispiox rivers. Thicknesses for this unit, based on observed sections and structural considerations, are at least of a few hundred metres and probably upwards of a kilometre.

The Muskaboo Creek lithofacies assemblage is characterized by thin to moderately bedded, massive to laminated, grey to beige chert-rich sandstone in sections of continuous sandstone in places up to tens of metres thick. Interbedded grey to dark grey siltstone and silty mudstone is subordinate. Sandstone and siltstone is locally characterized by coaly plant fragments or semi-continuous carbonaceous mudstone layers horizons up to a few cm thick. The unit is also characterized by pelecypod-rich horizons up to 1 metre thick ("coquinas"; Photo 1). These can be thin, isolated beds traceable along strike for tens of metres to thicker, multiple, stacked horizons. The carbonate shells are typically found as molds at surface and produce a distinctive pitted exposure.

The Muskaboo Creek lithofacies represents deposition in various shallow-marine, shoreface environments, with abundant evidence of wave and tidal influences. Common features include lenticular and flaser sandstone-mudstone sets, symmetrical ripples (locally mud draped), bi-directional ripples, and hummocky to swaley cross-bedding. A detailed description of this unit within the map area is given by Smith *et al.,* (2005; *this volume*).

The contact between the Muskaboo Creek and Ritchie-Alger lithofacies assemblages is exposed along the main logging road immediately north of the confluence of Kuldo Creek and the Skeena River. The section is roughly 40 metres thick with siltstones (greater than 75 per cent of the section) of the Ritchie-Alger occupying the lower 20 metres and giving way over 10 metres to sandstones (greater than 75 per cent of the section) and siltstones of the Muskaboo Creek assemblage.

Photo 1. Molds of "*Ostrea*" sp. forming a bed 10 to 15 cm thick. These and other bivalves form "coquina" beds within sandstone sections of the Muskaboo Creek lithofacies assemblage.

The bulk of the fossil collections made within the study area originated from the Muskaboo Creek lithofacies assemblage. The age of most of these are inconclusive, being broadly Mesozoic or Jurassic to Cretaceous in age. Only three localities provide more definitive age constraints: 1) a possible Oxfordian age from the top of Cutoff Mountain, 2) a Kimmeridgian to Valanginian (probably) collection along the Skeena River some 7 km southeast of Cutoff Mountain and 3) Late Jurassic to Valanginian suite found along Shelf Ridge (T. Poulton, personal communication, 2005).

SKEENA GROUP

PREVIOUS WORK

Richards (1990) subdivided the Skeena Group into several informal units (Table 1). Subsequently, Bassett (1995; see also Bassett and Kleinspehn, 1996, 1997) carried out a detailed sedimentological study of the Skeena Group within the Terrace (103I), Hazelton (93M), Smithers (93L) and Whitesail (93E) map areas, and proposed formal type sections and stratigraphic names (Table 1, Figure 5). This new nomenclature partly follows informal designations proposed by previous workers (Richards, 1980, 1990) and also includes new terminology (Table 1). The lithologic subdivision of the Skeena Group proposed by Bassett and Kleinspehn (1997) essentially follows that of Richards (1990), the main differences being that rocks of the Hanawald conglomerate (even those that clearly underlie the Rocky Ridge volcanics) have been combined with the Roche Deboule Formation and Richard's (1990) Kitsuns Creek formation equates with the Bulkley Canyon Formation (and Kitsuns Creek Member, Figure 5).

Skeena Group rocks represent earliest Early Cretaceous to Late Cretaceous fluvial-deltaic or estuarine sedimentation into lagoonal or a restricted marine environments (Bassett and Kleinspehn, 1997). Although the subdivisions of the Skeena Group follow a stratigraphic sequence, many of the units are coeval and interfinger with each other (Figure 5). Rocks of the Bulkley Canyon Formation are over 1 kilometre thick and represent lower delta plain to delta front environments, the latter showing tidal influences. The Laventie Formation of Basset and Kleinspehn (1997) comprises marine siltstone, sandstone and mudstone which they considered to represent distal deposits to the deltaic Bulkley Canyon Formation. These authors suggested this unit to be probably greater than 1 kilometre in thickness.

The Rocky Ridge Formation and Kitsuns Creek Member are related to Albian to Cenomanian volcanism within the Skeena Group. Rocky Ridge Formation represent vent-proximal subaerial or submarine flows to volcanic breccia and tuff of trachybasalt to andesite composition up to a kilometre thick. Volcanic-derived conglomerate, up to 500 metres thick, of the Kitsuns Creek Member represents coarse fluvial-marine clastics sourced from sub-aerial volcanic centres.

Greater than 1 kilometre of chert-pebble conglomerate, sandstone, siltstone and shale of the Roche Deboule Formation represents the youngest formation of the Skeena Group. This unit appears to gradationally overlie other units of the Skeena Group. The repeated upward fining sections of conglomerate to siltstone are believed to represent laterally migrating fluvial systems. Bassett and Kleinspehn (1997) suggest that these rocks are partially coeval with the basal Sustut Group and possibly with the Devil's Claw Formation of the Bowser Lake Group. As mentioned earlier, conglomerate that evidently underlies the Rocky Ridge Volcanics (Hanawald conglomerate of Richards, 1990) has been grouped with the Roche Deboule Formation suggesting that this correlation may be more complicated than proposed by Bassett and Kleinspehn (1997).

WEST HAZELTON MAP AREA

In the study area, Bassett and Kleinspehn (1997) assigned Skeena Group rocks to the fluvial Bulkley Canyon and marine Laventie formations (the Kitsuns Creek formation and Kitsumkalum shale of Richards (1990), respectively). Most exposures of Skeena Group rocks encountered during the summer of 2004 were found in the valleys of, and between, the Kispiox and Skeena rivers. Skeena Group lithologies are also well exposed on the east flank of Kispiox Mountain and on the southeast flank of Hazelton Peak where they are likely faulted against rocks of the Muskaboo Creek lithofacies assemblage. The true thickness of this unit in the study area is difficult to determine due to lack of adequate exposure. The section on Hazelton Peak is upwards of a kilometre thick and Bassett and Kleinspehn (1997) measured some 200 metres along railway exposures above the Skeena River several kilometres northeast of New Hazelton. Bassett and Kleinspehn (1997) have shown the Skeena Group (and the Bulkley Canyon Formation) to range in age from Berriasian to Cenomanian (Early to early Late Cretaceous).

Generally, rocks of the Skeena Group appear to be less indurated than those of the underlying Bowser Lake Group and cleavage is poorly developed, although this may be a reflection of the greater abundance of sandstone in this sequence. Sandstone is generally grey to beige or light yellow-brown. Although chert is the dominant clast-type, Skeena sandstones commonly contain trace amounts of muscovite or biotite in addition to appreciable amounts of feldspar and quartz, although in the Hazelton map area muscovite was not common even in undoubted Skeena Group strata. Metamorphic and igneous clasts were also noted in conglomeratic sections. Carbonaceous material, primarily as coaly bits or plant impressions, is very common and can locally form thin coal seams, a few centimetres thick. More extensive coal layers between 15 to 45 cm thick occur within Skeena Group lithologies on the lower slopes east of Kispiox Mountain.

Fining upwards sequences, capped by coal, are common in the succession southeast of Kispiox Mountain. Lenticular, fining upwards sandstone sections, up to 10 metres thick, within grey to brown siltstones, are well exposed east of Hazelton Peak. This together with the coaly material and root casts are consistent with a fluvial and associated flood plain depositional environment within the 2004 study area.

Rocks assigned to the Laventie Formation along the Shegunia River by Bassett and Kleinspehn (1997) are here mapped as part of the Ritchie-Alger lithofacies assemblage. Structural measurements indicate that these siltstones are below nearby rocks of the Muskaboo Creek lithofacies assemblage, although no contact relationships were observed. Furthermore, the micaceous nature of Laventie Formation, as described by Bassett and Kleinspehn (1997), was not observed in the dark grey to black siltstones in the Shegunia River area. The lithologies of this part of the Laventie Formation are identical to Ritchie-Alger assemblage in other parts of the study area and record deposition by distal turbidites.

Nature of the Skeena-Bowser contact

Mapping along the ridge southeast of Kispiox Mountain delineated a section of Muskaboo Creek lithofacies assemblage which grades upwards, over several metres into rocks of the Skeena Group (Bulkley Canyon Formation; *see* Smith *et al*., 2005; *this volume* for a detailed description). This relationship has influenced our interpretation of Skeena-Bowser contacts within the present map area. Although the juxtaposition of fluvial Skeena rocks against turbidic Ritchie-Alger assemblage lithofacies along the Kispiox valley is probably best interpreted as a structural relationship, elsewhere within the map area a conformable relationship is permissible, as demonstrated on Kispiox Mountain. This is especially true on the west side of the Skeena River, immediately west of Mt. Thomlinson, where Skeena Group rocks are mapped to within a few hundred metres of Muskaboo Creek assemblage lithologies and bedding attitudes allow a stratigraphic relationship. Furthermore, the shoreface Muskaboo Creek lithofacies is entirely compatible with transition into fluvial environments of the Bulkley Canyon Formation, especially on a wave-dominated coastline where major river deltas have not formed. Bassett and Kleinspehn (1997) also describe current and wave ripples suggesting a marine influence within parts of the Bulkley Canyon Formation. Thus we suggest that much of the lower Laventie Formation of Bassett and Kleinspahn is actually Muskaboo Creek assemblage of the Bowser Lake Group and is transitional upward and laterally into nonmarine Skeena Group successions.

As Bassett and Kleinspehn (1997) point out, based on age ranges and lithofacies types in the Hazelton map area, it is allowable for rocks of the Bulkley Canyon and Laventie formations to be conformable with underlying Bowser Lake Group sediments. Applying these inferences and relationships observed as part of this study, together with the mapped distribution of lithofacies in underlying Bowser Lake Group sediments, to the interpretation of contacts within the current map area results in far fewer faults than shown on previous maps.

STRUCTURAL GEOLOGY

The structural style of Bowser Lake and Skeena strata in the map area is dominated by open to closed folds (Skeena Fold Belt). These are well exposed on Shelf Ridge, and on Cutoff and Kispiox Mountains where sandstone ribs of the Muskaboo Creek lithofacies assemblage outline fold structures with wavelengths in the hundreds of metres. The interbedded sandstone-siltstone succession of the Muskaboo Creek assemblage produces folds with sharp hinge lines (chevron-like fold geometries). In many outcrops of the recessive, dominantly siltstone succession of the Ritchie-Alger assemblage bedding is not discernable, and megascopic folds were rarely observed. Reconnaissance observations immediately west of the northern map area indicate that siltstone strata of the Ritchie-Alger assemblage form megascopic folds. Immediately west of the map area, these folds show marked thickening in hinge zones more akin to similar-type geometries.

Bedding generally strikes to the southeast, especially within the northern part of the map area (Figure 6). In the south, within rocks of the Skeena and Bowser Lake Group, bedding can have an east to northeast attitude. Open to tight, northeast plunging folds and northeast-southwest striking reverse faults occur locally and are well exposed on the railroad track at Bulkley Canyon. Poles to bedding in the Skeena Group no longer outline a girdle distribution and indicate northwest and northeast fold trends (Figure 6). Two directions of folding were observed in one coal-bearing outcrop along the Skeena River (Photo 2). Northeast and northwest trending folds occur locally in the western and northern Bowser Basin (*see* Evenchick, 2001; Evenchick, 1996c; Haggart, 1998). Bedding attitudes observed within rocks of the Skeena Group tended to be somewhat shallower than those within the Bowser Lake Group (Figure 6). This may be a reflection of the very steep to westward northeast limbs developed in folds in the northern part of the map area where the Skeena Group is absent.

In the northwest part of the map area, siltstones of the Ritchie-Alger lithofacies assemblage contain a penetrative to slaty cleavage. In many instances the homogenous nature of the siltstone sequence results in cleavage being the dominant fabric. Cleavage is not as well developed within the more competent sandstones and siltstones of the Muskaboo Creek assemblage and Skeena Group (Figure 6). The average orientation of this fabric within the Bowser Lake Group of the map area is consistent with the predominant northwest trend of fold structures. East to northeast-trending attitudes are common in the southern part of the map area.

Thrust faulting associated with folding was observed west of Shelf Ridge and at Bulkley Canyon. Incomplete exposure and lack of distinctive markers has likely prevented the recognition of other faults. Structurally disrupted Skeena Group rocks along the west side of the Skeena River suggest faulting parallel or sub-parallel to bedding and may be the result of thrust motion. The juxtaposition of Skeena and Bowser Lake rocks along Hazelton Peak suggests the presence of a northeast trending fault with southeast-side-down displacement. Skeena rocks are also most likely faulted against Ritchie-Alger assemblage lithologies along the Kispiox River. Although the position of the Skeena Group along river valleys would suggest a structural contact with nearby Bowser Lake sediments, the conformable relationship between the Skeena Group and Muskaboo Creek assemblage suggests that these units need not be separated by faults where direct relationships cannot be observed. The extensional fault systems delineated by Richards (1990; see also MacIntyre, 1998 and MacIntyre *et al.*, 1997) may not be as widespread as currently depicted.

PETROLEUM POTENTIAL

Determining whether the Bowser and Sustut basins have the building blocks for the development of economic pools of hydrocarbons (source, reservoir, seal, timing, etc) will be assessed as part of the integrated program to which this study belongs. The following paragraphs contain a brief overview of the exploration history of the basins together with a short description of relevant geological data. A more in depth listing of information, detailed exploration history, together with pertinent references can be found at: www.bowserbasin.com.

Exploration for hydrocarbons within the Bowser and Sustut basins began in the late 1950's, after reconnaissance mapping in the area by the Geological Survey of Canada documented the presence of a large sedimentary basin. This culminated in the drilling of two exploration wells south of the Oweegee Dome structure by Dome Petroleum Ltd. during 1969 and 1972 (Dome Ritchie a-3-J/104-A-06; Dome Ritchie c-62-G/104-A-06). Although the ultimate target of these wells, the thick

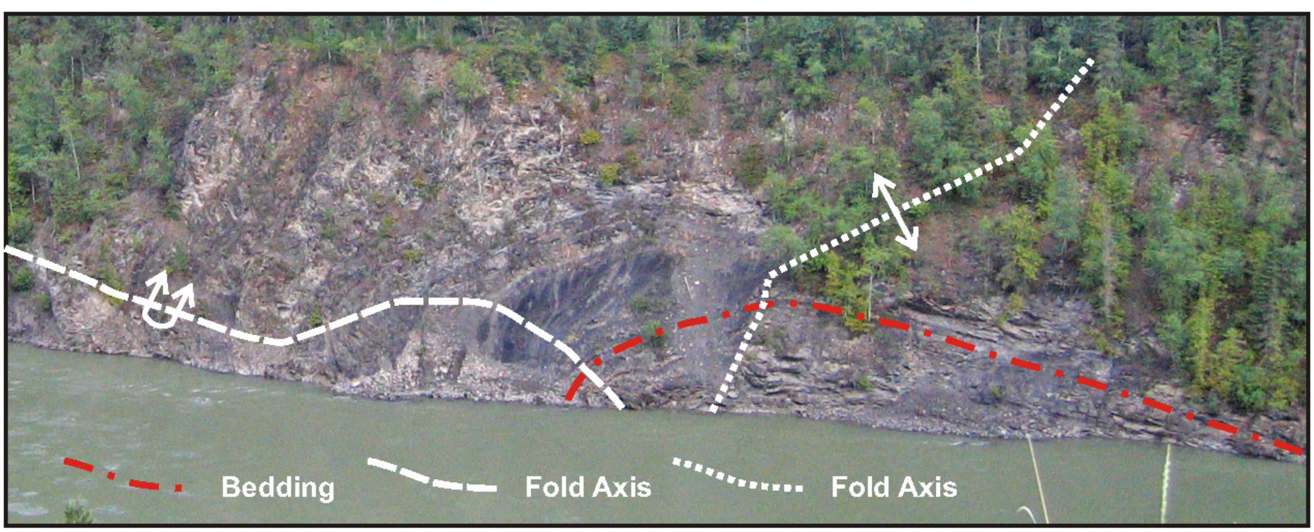

Photo 2. Outcrop of coaly Skeena Group sediments deformed by gently inclined, overturned fold and an upright, northwest trending, open fold exposed along Skeena River approximately 7 km of confluence with Kispiox River. Bedding attitude shown in the red dashed line.

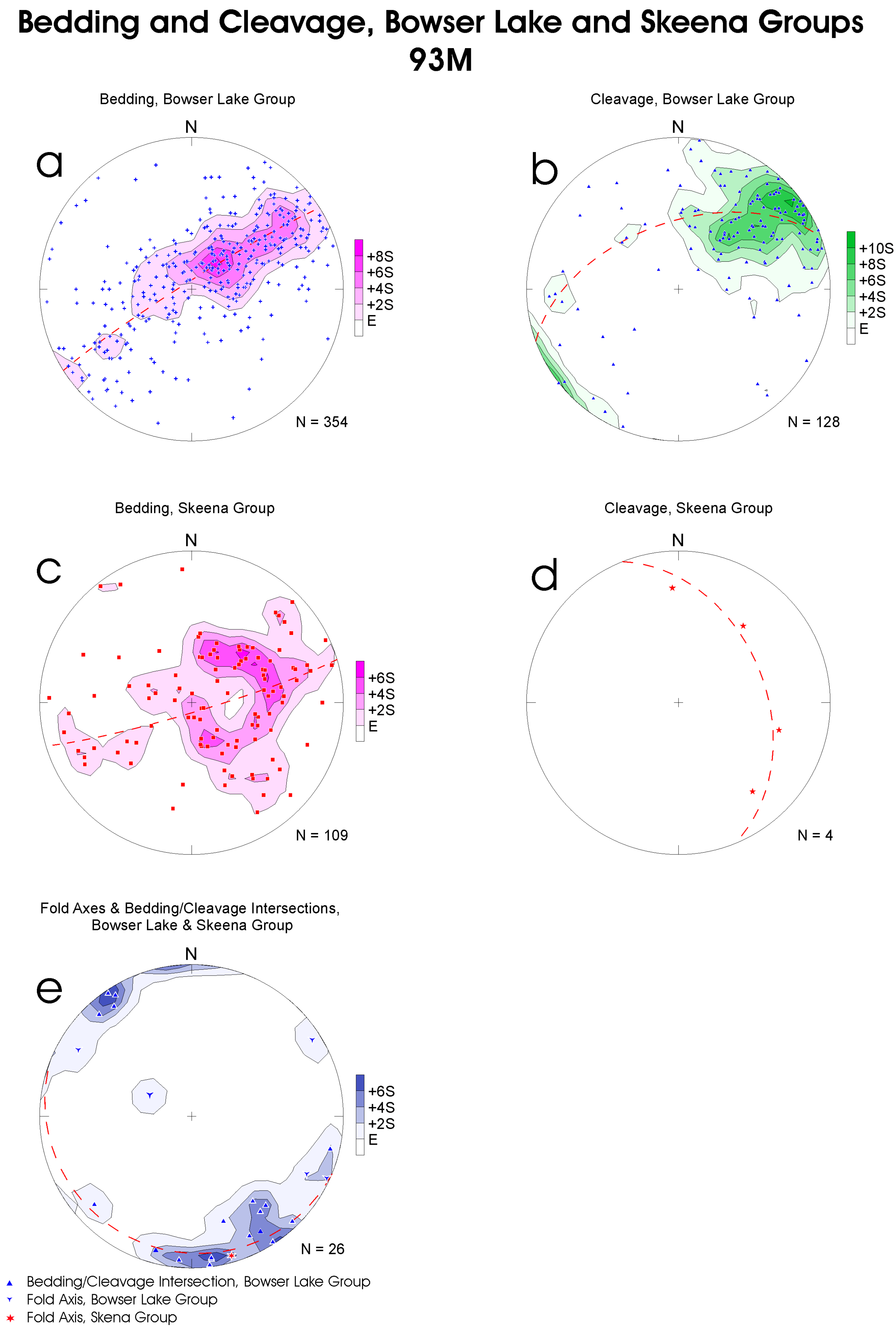

Figure 6. Stereonet diagrams for various lithologies and regions within the current study area.

Bedding and Cleavage by assemblage, Bowser Lake Group 93M

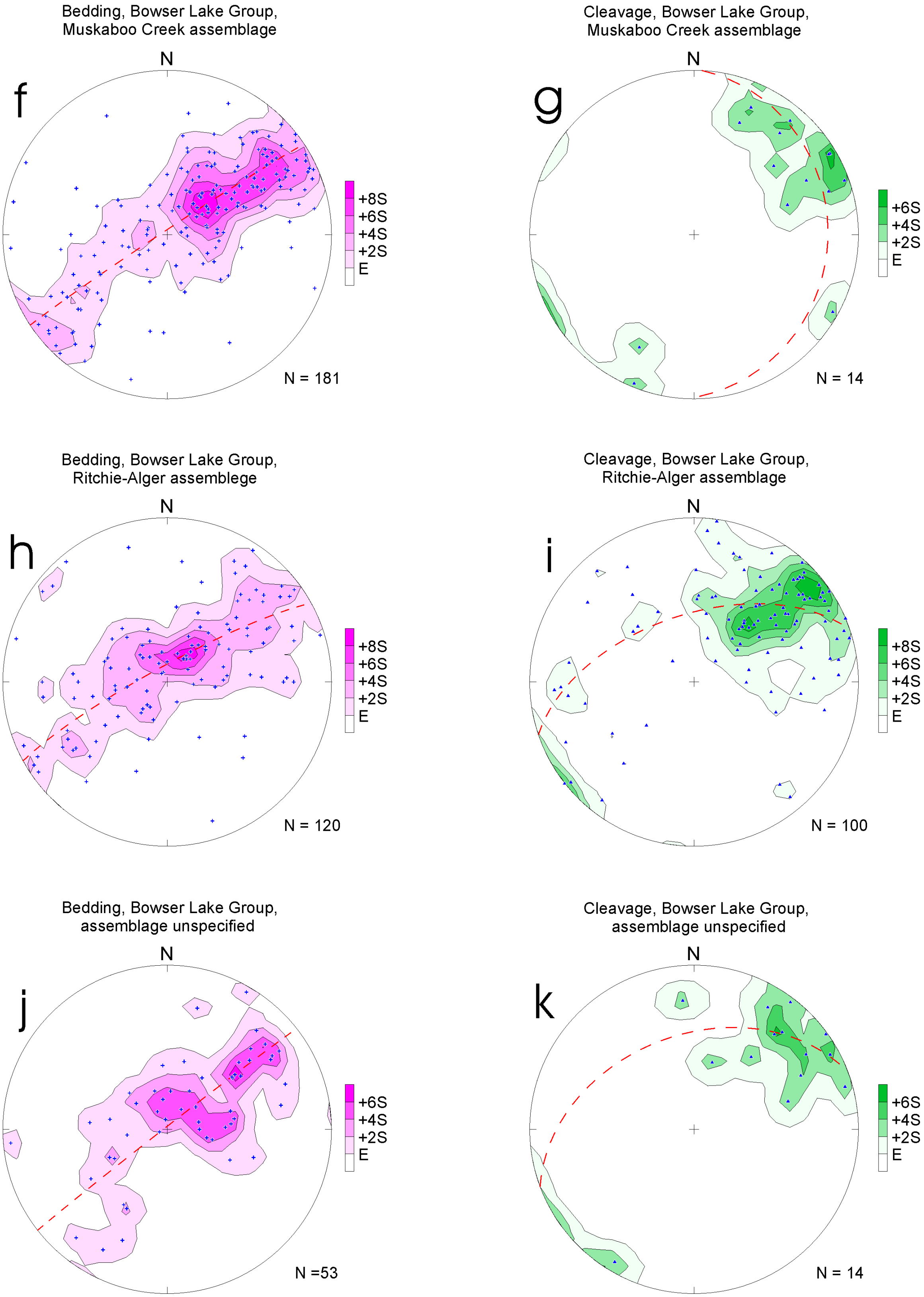

Figure 6 (continued)

Bedding and Cleavage by Location, Bowser Lake Group
93M

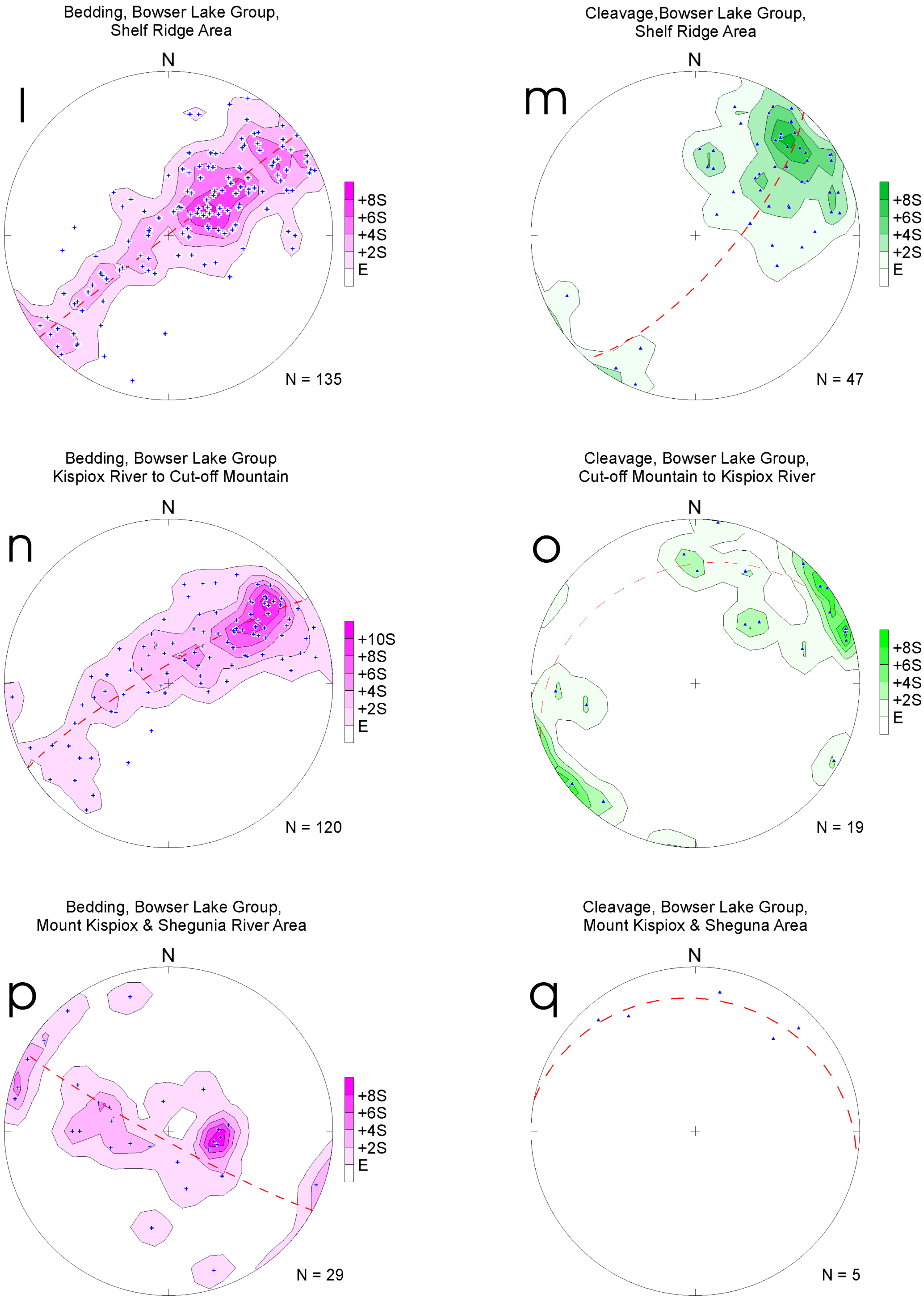

Figure 6 (continued)

Permian carbonate exposed in Oweegee Dome, was not encountered in the subsurface, gas was detected at shallower depths (Koch, 1973). No other conventional hydrocarbon exploration has taken place in the basin.

Shell Canada Ltd. recently acquired extensive tenure in the Klappan coal fields of northern Bowser Basin and drilled several exploratory coal bed gas wells (*e.g.* Shell Th Ridge c-91-L/104-H-02; Hayes *et al.*, 2005, this volume). These coals are part of the Bowser Lake Group and are anthracite to semi-anthracite in rank. The Skeena Group contains significant thicknesses of coal in the Telkwa coal fields (Koo, 1983; 1984, Ryan and Dawson, 1993). These coal measures are part of the Bulkley Canyon Formation and are generally bituminous (R_o 0.6-0.9%) except where locally metamorphosed by intrusions to anthracitic coals (Koo, 1983, 1984). The coal bed gas potential for parts of these coal measures has been examined by Ryan (1990) and Ryan and Dawson (1994; see www.em.gov.bc.ca/Mining/Geolsurv/coal/coalref.htm#Telkwa for a complete reference listing).

Thermal maturity levels at the Klappan and Groundhog coal fields (greater than 2.5% R_o), together with the early exploration efforts, led many to believe that much of the Bowser Basin was over mature with respect to hydrocarbon potential. Recent work by the BC Ministry of Energy and Mines and the Geological Survey of Canada has shown that parts of the northern basin may be in the oil and gas window (Evenchick *et al.*, 2002). Furthermore, oil staining has been found at several surface localities and in the subsurface well cuttings indicating that petroleum systems have operated within the basin (Osadetz *et al.*, 2003, 2004). Potential oil source rocks have not been identified but may include Mesozoic strata below the basin or intra-basinal horizons (Osadetz *et al.*, 2004; Ferri *et al.*, 2004).

Hannigan *et al.* (1995) assessed the petroleum potential of the Skeena Group and inferred total mean in-place resources of 7.19×10^{10} m^3 (2.54 TCF) gas and 2.01×10^8 m^3 (1,264 million barrels) oil. A higher risk level was placed on the Bowser Lake Group due to its higher thermal maturation levels. These authors indicated a total mean in-place potential of 5.78×10^{10} m^3 (2.0 TCF) gas and no oil for the Bowser Lake Group. Data being gathered as part of this integrated project will be used as part of a re-assessment of the hydrocarbon potential of the Bowser and Sustut basins and these values will undoubtedly be modified. Specifically, surface thermal maturation data indicates that parts of the northern Bowser Basin are in the oil window implying that a potential oil resource could exist for the Bowser Lake Group.

Random vitrinite and bitumen reflectance values (R_o) from surface samples of Bowser and Skeena groups in the Hazelton map area are between 0.8 and greater than 2.5% (Evenchick *et al.*, 2004) and from 0.35 to 5.6% in other parts of southern Bowser Basin (Hunt, 1992; Ryan, 1992; Ryan and Dawson, 1994). Generally, rocks of the Bowser Lake Group have higher values than Skeena Group strata, and are mature to overmature with respect to the gas window (R_o values greater than 1.6%). This is especially true for rocks of the adjoining Nass River and McConnell Creek sheets. Surface thermal maturation levels for the Skeena Group suggest these rocks reached maturation levels between the oil and gas windows, although data is limited from this rock package. The southern Bowser Basin contains numerous plugs and small plutons of Cretaceous and Tertiary age.

In the map area, samples of finer grained, organic-rich lithologies from the Ritchie-Alger lithofacies assemblage were analyzed for source rock potential (Ferri *et al.*, 2004; Ferri and Boddy, 2005). Although these samples are overmature, the residual organic contents indicate they were originally good to very good source rocks. Considering the marine nature of these sediments, this material was probably Type I or II kerogen. No data is available for the Skeena Group from this study, but regional sampling by Hunt (1992) and Hunt and Bustin (1997) shows low to moderate source rock potential for Type III kerogen which is entirely consistent with the coaly nature of these fluvial lithologies.

In the northern part of the basin, uppermost marine shales of the Hazelton Group were sampled for source rock potential (Ferri *et al.*, 2004; Ferri and Boddy, 2005). Although presently overmature, the current total organic contents (TOC) values suggest that original organic concentrations were likely quite high and that the unit may have acted as an excellent source rock.

The Muskaboo Creek lithofacies assemblage and Skeena Group contains thick sections of clean, well sorted sandstone which could, under the proper conditions, develop excellent reservoir characteristics for hosting hydrocarbons. In an attempt at quantifying the reservoir potential, twenty-two samples of sandstone from the Bowser Lake and Skeena groups were obtained within the Hazelton and Bowser Lake map areas. Core plugs were either obtained at the outcrop or drilled in the laboratory from large samples collected in the field. Analyses were conducted by AGAT Laboratories and include basic porosity and permeability measurements together with a description of clast lithotypes and characterization of interclast mineralogy. Preliminary porosity and permeability results are shown in Table 2 with locations of samples in west Hazelton map area shown in Figure 4. Although the samples obtained for this study are by no means a thorough representation of all possible lithotypes, the resultant porosity and permeability values indicate that the availability of a suitable reservoir may be an issue with Bowser Lake and Skeena rocks.

DISUCSSION

The conformable nature of Skeena Group with underlying Bowser Lake sedimentary rocks clearly indicates that Skeena Group rocks are part of the Bowser Basin. A logical extension of this relationship would suggest that the Skeena Group, particularly the Bulkley Canyon Formation, is broadly correlative with Early? Cretaceous, nonmarine fluvial successions in the northern Bowser Basin, represented by the Jenkins Creek and Endless Creek assemblages (Evenchick *et al.* 2001, 2004). These latter units appear to represent the same broad depositional environments, and to be approximately the same age, and stratigraphic position as the Skeena Group in southern Bowser Basin, that is, they are fluvial

TABLE 2. POROSITY AND PERMEABILITY VALUES DETERMINED FROM SAMPLES OF BOWSER LAKE AND SKEENA GROUPS FROM HAZELTON (93M) AND BOWSER LAKE (104A) MAP AREAS. SAMPLE LOCATIONS FROM THE WESTERN HAZELTON MAP AREA CAN BE SEEN IN FIGURE 4.

Field Number	Map No.	Map Sheet	Easting [1]	Northing[1]	Unit	Lithofacies Assemblage	Rock Type	Grain Size	Porosity	Bulk Density	Grain Density	Per-meability (mD)
EPF-04-13B		093M13	571414	6199356			lithic arenite	medium-coarse	0.01	2694	2713	0.00
EPF-04-57-C		093M12	568008	6165181	Bowser Lk Gp	Muskaboo Ck	arkosic arenite	fine-medium	0.03	2625	2718	0.05
EPF-04-61A		093M12	569345	6166446	Bowser Lk Gp	Muskaboo Ck	arkosic arenite	medium-coarse	0.04	2544	2655	0.34
EPF-04-65B		093M12	574865	6167562	Bowser Lk Gp	Muskaboo Ck	arkosic arenite	medium-coarse	0.03	2571	2657	0.08
EPF-04-69C		093M12	579279	6169445	Bowser Lk Gp	Muskaboo Ck	arkosic arenite	fine-medium	0.01	2691	2727	0.01
EPF-04-95C		093M05	577389	6125433	Skeena Gp		lithic arenite	fine-medium	0.02	2620	2666	0.01
EPF-04-162A		104A14	484578	6292306	Bowser Lk Gp		lithic arenite	fine-medium	0.01	2653	2689	0.00
EPF-04-182A		104A15	505718	6295800	Bowser Lk Gp	Jenkins Ck	conglomerate	pebble	0.04	2543	2642	5.02*
EPF-04-221A		104A07	521294	6254760	Bowser Lk Gp	Muskaboo Ck	arkosic arenite	fine-medium	0.01	2673	2691	0.00
EPF-04-319A		104A15	506972	6298347	Bowser Lk Gp	Groundhog-G[2]	lithic arenite	fine-medium	0.02	2608	2660	0.00
EPF-04-359A		093M05	588218	6140466	Skeena Gp		lithic arenite	medium-coarse	0.01	2664	2690	0.00
EP-04-49A		104A11	482385	6283027	Bowser Lk Gp	Muskaboo Ck	lithic arenite	fine-medium	0.02	2602	2661	0.00
EP-04-90H		104H05	463936	6354585	Bowser Lk Gp	Skelhorne	lithic arenite	fine-medium	0.01	2638	2661	0.00
EP-04-91D		104H12	441927	6385725	Bowser Lk Gp	Todagin	lithic arenite	fine-medium	0.01	2670	2685	0.01
EP-04-92D		104H12	442732	6380523	Bowser Lk Gp	Muskaboo Ck	lithic arenite	fine-medium	0.01	2636	2658	0.00
EP-04-94D		104H04	459229	6322370	Bowser Lk Gp		lithic arenite	fine	0.01	2650	2674	0.00
EP-04-101A		104A14	480712	6298521	Bowser Lk Gp		lithic arenite	fine-medium	0.01	2644	2662	0.00
EP-04-104A		104A11	477128	6278145	Bowser Lk Gp	Muskaboo Ck	lithic arenite		0.02	2624	2668	0.00
EPM-04-201A		104A14	473190	6307941	Bowser Lk Gp		lithic arenite	medium-coarse	0.01	2638	2660	0.00
EPR-04-101A		093M05	580532	6144855	Skeena Gp		lithic arenite	medium	0.04	2578	2673	0.02
EPS-04-MS1-04		093M13	568600	6193814	Bowser Lk Gp	Muskaboo Ck	lithic arenite		0.04	2596	2706	0.18
EPS-04-MS2-09		093M12	576550	6164247	Bowser Lk Gp	Muskaboo Ck	lithic arenite		0.05	2490	2620	0.09

mD: millidarcies
*fractured
[1]NAD27
[2]Groundhog-Gunnanoot

assemblages of roughly Early Cretaceous age that overlie marine assemblages of the Bowser Lake Group. Definitive age constraints are not available for the Jenkins Creek and Endless Creek assemblages, both being approximately Early Cretaceous in age.

Bassett and Kleinspehn (1997) correlated rocks of the Roche Deboule Formation with those of the Devils Claw Formation and parts of the lower Sustut Group. The absence of Rocky Ridge volcanics in northern Bowser Basin suggests the volcanics were either localized in the Smithers and Hazelton areas or are not preserved to the north.

Mapping by Richards (1990) places a thick package of conglomerate, the Hanawald conglomerate, below the Rocky Ridge Formation and above rocks equivalent to the Bulkley Canyon Formation, delineating a sequence of conglomerate separate to those in the Roche Deboule Formation. MacIntyre (1998), in the southeastern part of Hazelton map area, describes thick conglomerate sitting above the Rocky Ridge Formation, and above the Bulkley Canyon Formation where the volcanics are missing. MacIntyre (1998) equates these conglomerates with Richards (1990) Hanawald conglomerate. These observations suggests a sequence of conglomerate that is older than conglomerate belonging to the Roche Deboule Formation.

Mapping in the upcoming 2005 field season will concentrate on Bowser Basin stratigraphy within the central and eastern portions of Hazelton map area and will hopefully shed light on some of the preceding discussion.

CONCLUSIONS

- In west Hazelton map area, mapping during the summer of 2004 corroborates the distribution of Skeena Group as currently portrayed on regional geology maps.
- Rocks of the Bowser Lake Group are part of the Ritchie-Alger and Muskaboo Creek lithofacies assemblages, representing submarine fan to deep shelf and shallow shelf / shoreface depositional environments, respectively. The distribution of these units is consistent with patterns seen in adjoining map areas to the north.
- In the present map area, the Skeena Group is represented by the fluvial Bulkley Canyon Formation. Strata previously considered part of the Laventie Formation we now consider to be Bowser Lake Group units.
- Rocks of the Muskaboo Creek lithofacies assemblage appear to gradationally change upward to those of the Bulkley Canyon Formation.
- Limited data indicates that Skeena Group rocks are generally less thermally mature than those of the Bowser Lake Group with R_o values as low as 0.8. Data from nearby Nass River map area shows Bowser Lake sediments are generally mature to overmature with respect to the gas window.
- Organic matter within the Skeena Group has a Type III signature.

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