CHAPTER 2 STRATIGRAPHY

STIKINE ASSEMBLAGE

The Late Paleozoic Stikine assemblage forms the structurally and stratigraphically lowest rocks exposed in the study area. Initial work in the Stikine River area was by Kerr (1948a, b) who suggested a two-fold division for the Paleozoic strata; a deformed unit of pre-Permian metasedimentary and metavolcanic rocks, and an overlying less-deformed unit of Permian limestone (Figure 2-1). Souther (1972) and Monger (1970) recognized Lower Carboniferous limestone in the Telegraph Creek area and divided the Permian limestone succession into a lower, thinly bedded argillaceous or tuffaceous limestone and an upper massive, white grainstone. Kerr inferred Devonian ages, and recent work by Read et al. (1989) and Anderson (1989) identified a Lower to Middle Devonian unit near Forrest Kerr Creek, about 20 kilometres to the southeast. In the same area, Logan et al. (1990a, 1993) and this study determined a Late Devonian (370 Ma) age for the Forrest Kerr Pluton. Quartz-rich, metasedimentary rocks have been recognized beneath Paleozoic rocks in the western part of the Iskut River area (McClelland, 1992) and while correlations with the Yukon-Tanana Terrane equivalent continental margin rocks in southeastern Alaska strengthen arguments for Paleozoic ties between the Stikine Terrane and Yukon-Tanana Terrane in this area (McClelland and Mattinson, 1991; McClelland et al., 1993) and further north.

Figure 2-1. Evolution and current geological understanding of the Stikine assemblage stratigraphy, Stikine-Iskut area (modified from Logan and Koyanagi, 1994). Lithologies include; carbonate units = bricks, mafic volcanic rocks = v, sedimentary units = dash and dots and plutons = x and + patterns.
(Mihalynuk, 1999), primitive isotopic signatures and stratigraphy in this part of Stikinia suggest an oceanic setting. Schematic Figure 2-1 illustrates the evolution and current geological understanding of the Stikine assemblage in the Stikine River area. The much simplified stratigraphic column is a compilation incorporating stratigraphy, radiometric dates and fossil identifications of Anderson (1989), Read et al. (1989), Logan et al. (1990a,b, 1992a,b), Brown et al. (1996), Gunning (1990) and McClelland (1992) as well as ongoing work in the region by the authors. Of particular significance is the recognition of Lower Triassic clastic sediments; an Upper Carboniferous intermediate calcalkaline, and in part, subaerial volcanic sequence; Late Devonian and Early Mississippian tonalitic to trondhjemitic plutonism; and a Devono-Carboniferous unconformity. A rapidly growing database and understanding of the Paleozoic history of Stikinia is emerging from current studies of the Stikine assemblage in the Iskut-Stikine-Tulsequah areas. It is from these areas that Early Devonian strata and Late Devonian plutons, the oldest rocks known in Stikinia occur and unconformities and deformational events are recorded in the Carboniferous and Permian stratigraphy.

In this discussion the term Stikine assemblage is retained for this discussion rather than the Asitka Assemblage of Wheeler and McFeeley (1991). Division and definition of the Upper Carboniferous to Upper Permian section of Stikine assemblage rocks in the Scud River area into the Navo, Ambition and Scud Glacier formations (Gunning et al., 1994a; Brown et al., 1996), and separation of the mid-Carboniferous Round Lake Formation, may warrant redefinition of the Stikine assemblage to group status in this part of the Stikine Terrane.

The Stikine assemblage comprises a submarine succession of tholiietic island arc volcanic flow, breccia and epiclastic rocks, with several accumulations of carbonate, which mark periods of volcanic quiescence. In the map area the assemblage consists of five main subdivisions (Figure 2-1, I-V). From the oldest to the youngest, they are: (I) a Lower to Middle Devonian package of penetratively deformed, intermediate to mafic metavolcanic tuff, flows, diorite and gabbro, recrystallized limestone, graphitic schist and quartz sericite schist; (II) an Upper Devonian to Mississippian package of bimodal mafic and felsic volcanic flows and tuffs; (III) a mid Carboniferous echinoderm-rich limestone and cherty tuff unit, which overlies the Upper Devonian to Mississippian volcanic rocks and elastic rocks along the northern edge of the Forrest Kerr map sheet; (IV) Late Carboniferous to Early Permian aphyric basalt, limestone and intermediate to felsic tuffs and flows; and (V) thick Early Permian carbonate. Volcanic rocks older than mid Carboniferous (i.e. Division I and II) are difficult to subdivide. Early and middle Devonian macro and micro fossils from the carbonates interlayered with the sedimentary and volcanic rocks constrain ages for Division I. The conformable lower contact of fossil-rich mid-Carboniferous carbonate (Division III) with a bimodal volcanic and epiclastic package implies a Lower Carboniferous volcanic sequence and the single, Early Mississippian U-Pb zircon date from a rhyolite located west of the map area substantiates it (Table 2-1). No obvious stratigraphic break was recognized between the two packages in the field. Coeval, in part comagmatic intrusive episodes include the Late Devonian Forrest Kerr and the Early Mississippian More Creek plutons.

Pre-Early Devonian to Early Permian rocks underlie the western third of the Forrest Kerr and More Creek map areas and the area east of Mess Creek in the Mess Lake area (Figure 2-2). East of the Forrest Kerr pluton, Paleozoic rocks are moderately to highly deformed, whereas west of it Carboniferous to Permian rocks are undeformed and Devono-Mississippian rocks vary from being schistose to

<table>
<thead>
<tr>
<th>FIELD NO.</th>
<th>MAP UNIT</th>
<th>ROCK TYPE</th>
<th>GROUP/FM/ASSEMBLAGE</th>
<th>SAMPLE LOCATION</th>
<th>DATING METHOD MINERAL</th>
<th>AGE (Ma)</th>
</tr>
</thead>
<tbody>
<tr>
<td>91JDR10-15</td>
<td>Qb</td>
<td>olivine basalt</td>
<td>Arctic Lake Fm</td>
<td>Arctic plateau</td>
<td>K-Ar</td>
<td>WR</td>
</tr>
<tr>
<td>89JLO9-3-2</td>
<td>mHb</td>
<td>pillow basalt</td>
<td>Salmon River Fm</td>
<td>Iskut River</td>
<td>K-Ar</td>
<td>WR</td>
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<tr>
<td>89JLO24-7-2</td>
<td>u&gt;Sva</td>
<td>phryic andesite</td>
<td>Stuhini Group</td>
<td>Newmont Graben</td>
<td>K-Ar</td>
<td>WR</td>
</tr>
<tr>
<td>92JLO 270</td>
<td>u&gt;Sv</td>
<td>rhyolite</td>
<td>Stuhini Group</td>
<td>Newmont Graben</td>
<td>U-Pb</td>
<td>Zr</td>
</tr>
<tr>
<td>92JLO 266</td>
<td>uSr</td>
<td>rhyolite</td>
<td>Stikine Assem.</td>
<td>Mess Creek</td>
<td>U-Pb</td>
<td>Zr</td>
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<td>pillow basalt</td>
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<td>Verrett R.</td>
<td>K-Ar</td>
<td>WR</td>
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<td>More Glacier</td>
<td>U-Pb</td>
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<td>91-238</td>
<td>ImDSv</td>
<td>intermediate tuff</td>
<td>Stikine Assem.</td>
<td>Lime Lake</td>
<td>U-Pb</td>
<td>Zr</td>
</tr>
</tbody>
</table>

One sigma errors for K-Ar dates, and two sigma errors for U-Pb dates are reported. K-Ar analysis completed by J. Harakal, U-Pb analysis completed by W. McClelland, see Appendices 11 and 13 for analytical data. WR = whole rock, Zr = zircon, Hb = hornblende.
little deformed. Overall deformation of the Paleozoic rocks is variable. Despite structural and metamorphic disparities, stratigraphy in general can be correlated from one side of the pluton to the other, although much of the Paleozoic rock package east of the pluton remain undivided.

**DIVISION I**

**LOWER AND MIDDLE DEVONIAN**

A 3 to 5 kilometre-wide arcuate belt of polydeformed, penetratively foliated metavolcanic and metasedimentary rocks begins west and south of the headwaters of Mess Creek and extends west into the Galore Creek area (Logan and Koyanagi, 1994; Figure 2-2). These rocks comprise a structurally complex succession of schistose felsic and mafic volcanioclastics with interbedded sericite and chlorite schist, graphitic and siliceous phyllite and limestone (Holbek, 1988; Barnes, 1989; Logan and Koyanagi, 1989; Logan et al., 1992a). This package appears to be basement to all other rocks in the study area; a lower contact was not observed. Overlying these “basement rocks” in uncertain stratigraphic relationship is a Lower to Middle Devonian package of mafic and intermediate volcanioclastic rocks and limestone at Bear valley, in the More Creek area. A package of limestone, siltstone and mafic-dominated bimodal volcaniclastic rocks of similar age is intruded by the Late Devonian Forrest Kerr Pluton in the Forrest Kerr area.

In the headwaters of Mess Creek (D-1, Figure 2-3), the structurally, and presumably stratigraphically lowest unit in the polydeformed package is a meta-sedimentary-metavolcanic sequence of intermixed chloritic, graphitic and maroon phyllites with quartz-sericite schist layers (units lmDSgs and lmDSqs, GS-Map). These are intruded by massive to variably schistose subvolcanic diorite sills which locally comprise as much as 25 per cent of the section (Photo 2-1). Intermediate to mafic, purple and green tuffs and flows (lmDSst) overlie the lower unit of metasediments. Contacts are structurally interleaved, but appear gradational. The upper section consists of felsic volcaniclastic rocks and undifferentiated volcanic flows and tuffs. All units are tightly folded, penetratively foliated and interleaved along foliation parallel structures; thicknesses are indeterminate. The stratigraphic sequence can be traced 5 kilometres to the southwest where it structurally underlies Lower to mid-Carboniferous carbonate at Round Lake; other age constraints are ubiquitous.

A thick package of variably deformed mafic to intermediate volcanics (lmDSfv) with numerous limestone members of variable thickness (lmDSc) underlies most of the western third of the More Creek and parts of the Forrest Kerr map areas (Figure 2-2). The strata is best exposed in Bear valley, a northeast trending valley located between Alexander and Natavas glaciers (D-2, Figure 2-3). The volcanic rocks are predominantly green plagioclase-phryic tuffs, amygdaloidal flows and volcaniclastic rocks, with subordinate purple and maroon tuff, black siltstone and felsic tuff. Interbedded recrystallized limestones contain the coral Favosites sp. so are at least as old as late Early Devonian (C-189406, 07, 08 and 189767; Appendix 1) and conodonts of Lochkovian age (C-189417). Exposed in the valley floor...
and presumably stratigraphically lowest are intermediate and felsic lapilli and ash flow tuffs. The tuffs are white to light green in colour and well stratified to thinly bedded. Lapilli consist of predominantly aphyric pink, grey and white fragments, less than 5 per cent of them are plagioclase phryic. Thin bedded, normally graded green dust and ash tuffs contain metre thick layers of white-weathering, compositionally stratified crystal and ash flow tuffs. Inter- calated with the felsic tuffs are mottled maroon and green plagioclase phryic lapilli and ash tuffs and thin massive green andesite flows. The upper volcanic sequence is a mafic to intermediate package of green, plagioclase phryic volcaniclastic rocks intercalated with variably strained limestone layers (Photo 2-2). Dark green massive and amygdaloidal flows, breccias and tuffs predominate. Thin beds and lenses of carbonate (ImDSc) that are intercalated with the volcanics are white to light grey, penetratively foliated, and locally variegated and recrystallized. Interbeds of recrystallized black to dark grey micrite and green calcareous tuffaceous siltstone are common. Intraformational limestone conglomerates and breccias, buff and orange dolomite, and cherty siltstone horizons also occur. Thicker units of limestone, which are in part structurally thickened,
are medium bedded, light grey and recrystallized. Thin interbedded siliceous layers weather in relief and outline folds and axial planar cleavage in otherwise massive, amorphous bone-white marble. Limestone units accommodated the majority of strain affecting these rocks, particularly unit ImDSfv, where the competency contrast between volcanics and carbonates is high.

Lower Devonian rocks underlie the northern end of Nunatak Ridge, approximately 3 kilometres southwest of Bear valley (D-2, Figure 2-2). The section comprises predominantly interlayered fine grained clastics, carbonates and volcanoclastics (Figure 2-3). These are overlain in uncertain stratigraphic relationship by mafic hyaloclastite, intermediate and felsic tuffs and epiclastics of the Devono-Mississippian unit. The Lower Devonian strata are polydeformed and structurally thickened so that strati-

Photo 2-2. Polydeformed Early to Middle Devonian carbonate and mafic to intermediate volcanoclastic rocks intruded by subvolcanic feeder dikes, east of Bear valley.

Similar to strata at the headwaters of Mess Creek, but here, the strata contain at least four variably strained coralline carbonate members (ImDSc) of Pragian (Early to Middle Devonian) age (Anderson, 1989; Read et al., 1989), the oldest known ages from the Stikine assemblage. Interbedded with the carbonates are pebble conglomerates, siliceous and carbonaceous shales, thin bedded cherty siltstones and both mafic and felsic tuffs up to 400 metres thick (Brown et al., 1991). The rocks are polydeformed. They are characterized by a moderate west-northwest dipping schistosity that is overprinted by a gentle southwest plunging crenulation with an axial plane dipping steeply southeast. North of Lime Lake, the succession is intruded and in part overthrust by Late Devonian quartz diorite at the top of the section (D-3, Figure 2-3) and the base of the section forms the hangingwall of the West Lake fault, an east-directed thrust fault (Read et al., 1989). Recumbently folded, varicoloured, weakly foliated siliceous siltstone, tuff, and ribbon chert in the footwall (unit Csst, Gs-Map) are lithologically similar to Upper Carboniferous rocks at Scud River (see following).

The Lower to middle Devonian hangingwall contains a three part, 50 m section. The lowest unit includes silicified siltstone and mafic lapilli tuff; pyritic, felsic tuff and calcaceous siltstone; and 10 m of granite. The limestone consists of beds 1 to 2 m thick containing silicified corals, echinoderm ossicles and other bioclastic debris alternating with centimetre thick carbonaceous siltstone. Limestone of the lowest beds is characteristically brecciated and yields the conodonts Eognathodus, sulcatus kindlei, Lane and Orniston and Icriodus steinachensis, Al Rawi of middle Early Devonian, Pragian age (C-087672, C-087673; Appendix 2). A tabulate coral, Favosites sp. of Silurian to Devonian age (C-158967) occurs within the coral-bearing grainstone. The section changes facies upwards to the second unit of rusty weathering graphitic and calcareous siltstone, chloritic schist and graniostone and the upper 4 m consists of conformable pebble conglomerate containing clasts of felsic volcanics and limestone. The upper unit comprises lower foliated and pyritic tuff and upper thinly bedded limestone with alternating white, pink and dark grey beds (D-3, Figure 2-3). Structurally and perhaps stratigraphically high in the sequence are varicoloured weakly foliated siliceous siltstones and 5 centimetre thick beds of ribbon chert interlayered with the carbonate. The top of the succession is intruded by foliated Late Devonian hornblende quartz diorite of the Forrest Kerr Pluton (Photo 2-3).

Chlorite and sericite-rich schistose rocks are common in the Forrest Kerr area, angular fragments are occasionally preserved and a mafic or intermediate to felsic tuff protolith can be discerned. Felsic rocks have potassium feldspar phenocrysts that are weakly altered to sericite. The groundmass consists of equigranular potassium feldspar and quartz, with minor subhedral plagioclase. Mafic to intermediate flows are weakly foliated, purple to dark green and either massive or brecciated. Amygdaloidal plagioclase ± augite phryic flows predominate. Mottled purple and green mafic to felsic lapilli tuffs are well foliated to phyllitic and clasts are flattened in the plane of foliation. Fine-grained crystal tuffs and tuffaceous sediments have
been metamorphosed to greenschist grade chlorite schists and lesser quartz sericite schists. Interbedded with these metavolcanic rocks are subordinate phyllite, tuffaceous pyritic argillite and recrystallized limestone.

U-Pb age dates on zircons from intermediate tuff within a volcanic dominated section of well foliated rocks located northeast of Lime Lake gave a middle Devonian emplacement age of 380± 5 Ma (Table 2-1).

Southwest of the Forrest Kerr Pluton is a well-indurated, commonly bleached and pyritic, finely layered siltstone, conglomerate, and carbonate sequence (lmDSs). The epiclastic rocks appear to be thin pendants in the intrusion and are hornfelsed by the enclosing hornblende diorite and quartz-rich phases of the pluton (unit LDg, GS-Map) southeast of Newmont Lake, between McLymont Creek and Newmont Lake. The recrystallized carbonate lenses have a high silica content and contain only sparse, poorly preserved coral fossils of unknown age. Calcareous pendants of probable Lower to Middle Devonian carbonate occur within the Forrest Kerr and More Creek plutons. They are hornfelsed to calcisilicate assemblages of pale green diopside marble containing 1 to 2 per cent disseminated pyrite. Other calcareous pendants contain poorly formed spessartine garnets and, along the southwest end of the More Creek Pluton, copper-bearing magnetite skarns developed (cf. Mineralization chapter).

DIVISION II

DEVONIAN TO MISSISSIPPIAN

A sequence of variably foliated mainly basaltic and lesser rhyolitic volcanic rocks (unit DMSv) occupies the higher ridges and peaks south and east of the headwaters of Mess Creek, and forms ridges and nunataks in the northern half of the Forrest Kerr map area (Figure 2-2), where they are conformably overlain by a mid-Carboniferous carbonate (unit mCSc, GS-Map). West of McLymont Creek is another panel of predominantly mafic volcanic rocks and lesser felsic tuffs; these correlate with the rocks north of Andrei Glacier. The contact between this volcanic sucess-
sion and the Lower to Middle Devonian volcanic succession may be conformable and gradational; it could not be defined by present 1:50 000 scale mapping. East of the Foremore Camp, this overall more mafic package rests with angular unconformity on the lowermost package of sericite and graphite schists (D-1, Figure 2-3).

Strata in both the northwestern (DM-1, Figure 2-4) and southwestern (DM-2, Figure 2-4) corners of the Forrest Kerr map area comprise southwest-dipping homoclinal mafic volcanic sequences conservatively estimated to exceed 2000 metres in thickness. Interbedded hyaloclastite and pillow flows volumetrically exceed massive sheet flows of basalt. Fragmental rocks are dominated by heterolithic lapilli tuffs and block breccias. Less common are poorly sorted, immature volcanic conglomerate layers. A distinctive dark green heterolithic tuff crops out east of the headwaters of Mess Creek. It contains abundant medium grained diorite, distinctive coarse grained amphibolite blocks, and amphibole crystals (1-2 centimetre in size) in a green ash matrix. Intrusive phases similar to these clasts comprise the More Creek and Forrest Kerr plutons. Dark green to grey angular to subrounded densely amygdaloidal fragments typify tuffs interbedded with pillowed flows and scoriaceous hyaloclastites. Dominantly green, orange weathering ash flow and welded lapilli tuffs with pale grey, pink and purple aphyric lithic and crystal lapilli form another distinctive unit (Photo 2-4a). These felsic tuffs are spatially related to light purple to pink dacite flow breccias north of the headwaters of Forrest Kerr Creek. A third variety of tuff consists of thin, planar bedded siliceous dust tuffs that are interbedded with graded and cross bedded crystal and lapilli tuffs (Photo 2-4b). Felsic tuff and scattered rhylolitic lapilli appear to be localized in the area near the Andrei Glacier (Photo 2-4c). The mafic volcanic rocks consist of dark green, massive to pillowowed flows, flow breccia and hyaloclastite (Photo 2-4d, 4e). Rare intercalated carbonate layers are up to a few metres thick and unfossiliferous. Flows are aphyric or weakly porphyritic and commonly amygdaloidal, with amygdules distributed parallel to borders of clasts and often concentrically zoned

Figure 2-4. Schematic stratigraphic columns for Devonian to Mississippian strata of the Stikine assemblage. FKP= Forrest Kerr pluton, MCP= More Creek pluton. Section locations are shown on Figure 2-2.
Photo 2-4. Devonian to Early Mississippian submarine volcanic rocks. 4a) interbedded hyaloclastite, pillowed flows, ash and welded lapilli tuffs. 4b) Variegated sharp-bedded, parallel laminated and normal-graded siliceous ash and dust tuffs. 4c) White-weathering felsic lapilli tuffs 4d) Scoriaceous hyaloclastite (a, b, c and d are exposed north of Andrei Glacier). 4e) Well-formed pillowed basalts cap the ridge southwest of McLymont Creek.
about the clasts. Hyaloclastite debris flows contain scattered pillows. Massive flows have brecciated tops and bottoms. Plagioclase microphenocrysts and fine augite grains are altered to chlorite, epidote, sericite and carbonate. These secondary minerals also form amygdules. Scoriaceous pillows and bombs occur within thick interbedded finely vesicular basalt lapilli tuff and hyaloclastite debris flows. The latter comprise pale green angular to globular-shaped fragments with narrow quench-alteration rims in a limy, green-grey matrix; they give the rock a distinctive mottled weathering pattern. Rare ryholitic fragments also occur. The irregular distribution of quartz, epidote and chlorite amygdules indicates synvolcanic propylitic alteration rather than regional greenschist metamorphism.

Directly southwest of the map boundary on a nunatak in ‘More glacier’, is a Devonian to Early Mississippian and younger package of volcaniclastic rocks. The nunatak was mapped in detail (Westcott, 1991), drilled by Cominco Ltd. (Wagner, 1996) and sampled for radiometric age dating by one of us. In general, the strata consist of; 1) Devonian Favosites-bearing coralline limestone, 2) foliated intermediate to felsic tuff and flow breccia interbedded with argillite, chert, and crinoidal limestone, and 3) mafic breccia flows with interbeds of tuff and felsic quartz crystal tuff. U-Pb age dates on zircons from dacitic tuff in the lower part of the second stratigraphic member gave an Early Mississippian emplacement age of 355.1 ± 3.7 Ma (Table 2-1). The contact between the first and second members is intruded by a felsic to intermediate sill and is either structural or unconformable (Westcott, 1991).

CHEMISTRY OF THE LOWER DEVONIAN AND EARLY MISSISSIPPIAN VOLCANIC ROCKS

Whole-rock major oxide and trace element analyses have been completed on twenty samples of Devonian and Early Mississippian Stikine assemblage volcanic rocks by the Ministry of Energy, Mines and Petroleum Resources analytical laboratory in Victoria. Results are presented in Appendix 8 and Appendix 9. The samples are from an area that was metamorphosed to lower greenschist metamorphic grade. As a result, loss on ignition (LOI) and CO2 values are high for some samples and major element mobility may have occurred. The data were screened following the criteria discussed in Chapter 4 under “Geochemistry and Tectonic Discrimination of Intrusive rocks”, to identify and remove altered samples prior to plotting.

On the alkalis versus silica plot of Irvine and Baragar (1971), the data forms three discrete clusters (Figure 2-5A); Lower Devonian Lime Lake basalt (inverted solid triangles), plot in the subalkaline field, Devono-Mississippian More Creek basalt and andesite (solid triangles), plot as transitional subalkaline to alkaline, and More Creek rhyodacite rocks (inverted triangles), plot in the subalkaline field. The average trace element values and ratio ranges for the Lime Lake and More Creek volcanics are listed in Table 2-2. Silica averages 47 and 52 per cent for the two basalt groups, but ranges from 69 to 75 per cent for the rhyodacites. Two samples of Devono-Mississippian felsic volcanic rocks have intermediate silica content (63 per cent). Volumetrically the intermediate and felsic rocks comprise equal amounts and together comprise about 15 per cent of the total volcanic pile. The intermediate volcanic rocks are fine grained porphyritic flows. The felsic volcanic rocks are coarse quartz porphyritic flows and tuffaceous rocks. On

<table>
<thead>
<tr>
<th>TABLE 2-2</th>
<th>SILICA AND SELECT TRACE ELEMENT CONTENTS OF LATE PALEOZOIC VOLCANIC ROCKS</th>
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<td>K</td>
<td>166-2075 (2055)</td>
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<tr>
<td>Ba</td>
<td>na</td>
</tr>
<tr>
<td>Rb</td>
<td>10 (10)</td>
</tr>
<tr>
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</tr>
<tr>
<td>Ti/Zr</td>
<td>96.3-112.1 (104.7)</td>
</tr>
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</table>

Minimum, maximum and average values are presented. na = not available
Figure 2-5. Major and trace element geochemical plots for Lime Lake basalts (inverted filled triangles), More Creek mafic (filled triangles) and felsic (inverted triangles) volcanic rocks. A) total alkali versus silica (after Irvine and Baragar, 1971); B) AFM plot (after Irvine and Baragar, 1971); C) ternary plot of Nb x2 - Zr/4 - Y (after Meschede, 1986); D) plot of Zr/TiO2 versus Nb/Y (after Winchester and Floyd, 1977); E) plot of Zr/Y versus Zr (after Pearce and Norry, 1979); F) ternary plot of Ti/100 - Zr - Yx3 (after Pearce and Cann, 1973). A) and B) show mafic (dark) and felsic (light) fields of Forrest Kerr and More Creek plutons and Early(?) Devonian diorite sills (stars).
the AFM diagram (Figure 2-5B), Lime Lake basalts are tholeiitic, the More Creek basalts and andesites are transitional from tholeiitic to calcalkaline, and the rhyodacites are calcalkaline. The two shaded areas show the distribution of mafic and felsic intrusive rocks of the Late Devonian Forrest Kerr and Early Mississippian More Creek plutons.

On the Nb/Y vs Zr/TiO₂ diagram of Winchester and Floyd (1977) the volcanic rocks plot as two clusters in the subalkaline basalt field, and as a cluster of data plots transitional from andesite to dacite (Figure 2-5D). On the SiO₂ vs. Zr/TiO₂ diagram (not shown) the silica-rich samples plot in the rhyodacite to rhyolite fields and the compositions of mafic and felsic plutonic rocks overlap those of the volcanic samples. The trace element contents (Nb/Y) of the siliceous rocks indicate a less evolved rock than the silica contents indicate. This may be an artifact of low trace element abundances and the detection limits for the method of analysis, in this case X-ray fluorescence (5 parts per million).

On the Zr-Nb-Y discrimination diagram of Meschede (1986), the basalts clearly define two clusters of data (Figure 2-5C). The Lower Devonian Lime Lake basalts are enriched in Nb relative to Zr and Y and plot in the P-MORB field. The More Creek basalts plot in the N-MORB and volcanic arc (VAB) field. On the Zr-Ti-Y tectonic discrimination diagram of Pearce and Cann (1973), Devono-Mississippian More Creek basalts and andesites (solid triangles) plot as low-potassium tholeiites (Figure 2-5F). The Lime Lake basin samples (inverted solid triangles), plot on the division between lava with characteristics of within-plate basalt (WPB), and those with mid-ocean ridge and volcanic arc affinities (MORB and VAB). In the Zr-Ti-Sr diagram (not shown), the Devono-Mississippian basaltic rocks plot on the division between the ocean floor basalt (OFB) and island arc basalt (IAB) fields. The Lime Lake suite plot above the oceanic-arc field on the Zr/Y versus Zr plot (Figure 2-5E), with 3 samples in the within-plate field. The More Creek suite cluster within the overlap between mid-ocean ridge and island-arc fields. The trace element evidence suggests these rocks are best described as low-potassium, island arc, tholeiitic basalt/andesite. Other trace element ratios such as Rb/Zr (0.25-0.35) are closer to tholeiitic island arc basalts (0.20-0.30) than calcalkaline basalts (0.35-0.50; Gill and Whelan, 1989). Their high magnesium/rich/iron ratios are typical of values for tholeiites and indicate fractionation of olivine, augite and possibly magnetite. The samples plotted were the least altered of those analysed and passed the screen for potassic and carbonate alteration, but the data apparently indicate an overall addition of alkalis.

The Devonian and Devono-Mississippian basalts, metabasalts and rhyodacites show various levels of trace element enrichment and depletion, which, in general, correspond to geochemical patterns of tholeiitic oceanic arc basalt and transitional (T-type) mid-ocean ridge basalts (Figure 2-6). The rhyodacite rocks have larger element variations for samples than either of the two basalt groups, and this may reflect tuffaceous components in some of the felsic samples. The Devono-Mississippian basalts have a relatively flat trend to the right of Nb, and are slightly depleted in Ce, Zr, Ti and Y relative to MORB. The lack of a significant negative Nb anomaly, which is so characteristic of volcanic arc basalts, is puzzling. The Devonian metabasalts are enriched in the incompatible elements La, Nb and to a lesser extent Ce. Zirconium and Yittrium are not enriched relative to MORB and define a pattern that most closely resembles the T-type MORB pattern. Similar patterns are also characteristic of transitional settings like plume-ridge interactions and these lavas are termed P-type MORB. The Lime Lake suite is slightly enriched in the incompatible elements Nb, Ce, Zr, and Ti relative to the More Creek suite (Figure 2-6). The negative titanium anomaly (with respect to Zr) for the felsic rocks indicates they are the product of extensive crystal fractionation. The basalt and metabasalt appear to be relatively primitive. The flat trend of the basalts is characteristic of tholeiitic rocks of newly established (immature) island arcs (Gill, 1981).

PALEOENVIRONMENTAL INTERPRETATIONS

The Devonian to Early Mississippian volcanic succession of Divisions I and II is interpreted to represent mainly submarine island arc deposition. Initial eruptions were basaltic andesite, dominated by pillow lavas and hyaloclastites upon which fringing carbonate mounds accumulated. The repetition of grainstone and siltstone indicates deposition from turbidity flows in a shelf slope or basinal setting. Graphitic and pyritic sediments indicate an euxinic environment that received periodic influxes of carbonate debris and tuffaceous material from distal sources. Periodically, the volcanic edifice became emergent, generating flows, subaerial welded pyroclastic and epiclastic rocks. Compositions evolved from basalt to rhyolite. The island arc tholeiitic chemistry of the suite is consistent with the above field interpretations. The succession likely represents the earliest stage of island arc formation, when relatively un-evolved tholeiitic products were erupted, followed by more evolved rocks. By Late Devonian time the arc must have been mature and thick enough to allow formation and intrusion of the tonalitic to trondhjemitic Forrest Kerr and More Creek plutons.
DIVISION III
MID CARBONIFEROUS

Mid Carboniferous, Serpukhovian to Bashkirian limestone and minor chert (mCSc, GS-Map) crop out on ridges and underlie slopes around the edges of the Iskut icefield in the Forrest Kerr map area and north of Arctic Lake in the More Creek area, in north trending fault-bound panels which extend to Nahta cone in the Mess Lake area (Figure 2-7). The thickest and best studied exposures are located in the northwest corner of the Forrest Kerr area, where less than 200 metres of thick bedded, grey echinoderm limestone with interbeds of amorphous chert are exposed north of Andrei Glacier, and west of Newmont Lake, where less than 50 metres of thin bedded, echinoderm wackestone and interbedded epiclastic rocks are exposed (Logan et al., 1990b; Brown et al., 1991; Gunning 1992). In both areas, and at Nahta cone, the carbonate is conformably overlain by a coarsening-upwards sequence that begins with siliceous siltstone or fine greywacke that grade upward into poorly sorted volcanic conglomerate (Figure 2-8). The carbonate overlies Upper Devonian to Lower Mississippian volcanic rocks (DMSv) in apparent conformity in the northwest corner of the Forrest Kerr area and north of Exhile Hill in the Mess Lake area (mC-1, Figure 2-8). West of Newmont Lake, the base is truncated by a thrust fault (mC-2, Figure 2-8). Discontinuous fault bound and interleaved carbonate blocks of late Early Carboniferous age occur adjacent to Early Permian carbonate along South More Creek and north of Newmont Lake; lower contacts are not clearly exposed, though it appears the carbonate was deposited nonconformably on the Late Devonian Forrest Kerr pluton. Ferruginous quartzitic carbonate nonconformably overlies Early Mississippian granite at Nahta cone and in small outcrops between Nahta cone and Arctic Lake (mC-3, Figure 2-8).

Middle Carboniferous carbonate rocks in the study area are folded but lack any associated cleavage or pre-folding fabric; they have low conodont alteration indices (CAI) relative to Early and middle Devonian and even the Early Permian carbonates. At Round Lake, about 20 kilometres northwest of Newmont Lake in the Galore Creek area (Logan and Koyanagi, 1994), the carbonate is penetratively deformed and structurally thickened to more than 500 metres; there conodonts possess high CAI numbers.

Two northwest trending belts of Early to middle Carboniferous carbonate are well exposed on a ridge north of Andrei Glacier (Photo 2-5). The carbonates occur in a southwest facing predominantly epiclastic sequence of maroon and green, thin bedded cherty siltstone, poorly bedded tuff, wacke, sandstone and volcanic conglomerates (unit uCSSs, GS-Map), that overlies a predominantly mafic volcanic sequence of basalt breccia and pillowed flows, hyaloclastite and tuff and minor rhyodacite tuff and rhyolite flow rocks (unit DMSv, GS-Map). The strata are disrupted by northeast and east trending faults and east-trending plagioclase pyroxene porphyritic dikes. The eastern carbonate is the least deformed (mC-1, Figure 2-8). Relationships between the two carbonates is uncertain. A detailed stratigraphic and biostratigraphic sampling traverse was carried.
out in 1990 on the eastern carbonate. It was systematically sampled along three separate traverses; 15 samples were collected. Mamet (1991a) carried out thin section studies of the carbonates at the University of Montreal (Appendix 5). The lower and upper parts of the section comprise thin bedded bryozoan-echinoderm grainstone, with packstone beds of reworked bioclasts and lithic clasts of different carbonate facies, including pelletoidal grainstone, foram-bryozoan wackestone and bryozoan packstone. The medial part is characterized by thick bedded packstone and an 11 metre section of chaotic unsorted algal reef breccia (Photo 2-6). The breccia is massive and contains blocks of foraminiferal grainstone, bryozoan wackestone, fragments of corals, echinoderm columnals, sponge megascleres and brachiopod spines. Stratified, coarse graded and well sorted grainstone beds are common in the upper sections of the carbonate. Conodonts, foraminifers and algae indicate a mid-Carboniferous, Serpukhovian age throughout the section. Corals indicate a slightly broader range of Serpukhovian to Bashkirian.

The contact between the carbonate sequence and the underlying bimodal volcanic succession is not exposed. The lower carbonate is a thin bedded, graded grainstone-

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**Photo 2-5.** East-trending, steep south dipping Mid-Carboniferous carbonate exposed north of Andrei Glacier. Devonian to Early Mississippian submarine volcanic rocks underlie the carbonate to the north and well bedded cherty siltstone, maroon wacke and volcanic conglomerate interfinger with the echinoderm-rich packstone in the foreground.
packstone unit interbedded with maroon siltstone, and characterized by echinoderm columnals up to 2 centimetres in diameter. Buff weathering, medium bedded wackestone and thick bedded massive grey packstone overlie the lower carbonate. Block breccias and graded grainstone comprised of abundant reworked bioclasts and lithoclasts of a disarticulated algal reef. The upper carbonate resembles the lower thin bedded grainstone. It is interbedded with dark green siliceous siltstone near the top and grades conformably upward into maroon and purple wackes and volcanic conglomerate.

An Early to mid-Carboniferous age for this unit is indicated by the occurrence of Early Carboniferous conodonts (C-158953), the late Early Carboniferous (late Visean or Serpukhovian) coral Chaetetes sp. (C-158967) and the presence of the colonial coral, Acrocanthus sp., which is associated with mid-Carboniferous (lower Bashkirian) foraminifers (C-158967).

Three km to the west, less than 200 m of thick bedded, grey echinoderm packstone with interbedded chert crop out (Figure 2-7). This limestone, contains small echinoderm stems and fossil fragments and is locally fetid. It contains a mid-Carboniferous (lower Bashkirian) foraminiferal fauna (C-167803). The lower contact of carbonate with basalt breccias and tuff is obscured by a 7 metre wide plagioclase porphyritic dike. The limestone and interbedded chert are gradationally overlain by a 300 m thick, coarsening-upwards sequence of thinly laminated, rusty weathering, cherty siltstone, that is conformably overlain by maroon volcanic sandstone and conglomerate.

Discontinuous lenses of mid-Carboniferous carbonate crop out on the northwest and southeast flanks of the northeast trending Newmont Lake Graben. Northwest of Newmont Lake the carbonate is folded and structurally thickened. Folds verge northeast and axes trend northwest. The carbonate is characteristically massive to medium bedded grey echinoderm wackestone to packstone. Interbedded are zones with chaotic breccia blocks of fine grained echinoderm wackestone with interstitial coarse echinoderm columnals up to 2 cm in diameter. Minor sections of the thin bedded wackestone contain thin chert interbeds. West of Newmont Lake the carbonate section is 56 metres thick, and consists of interbedded echinoderm fragment-rich limestone and dark purple and green volcanic sandstone and limy litharenites (Photo 2-7), with conformable upper and lower contacts (Gunning, 1992). A section across the northem end of the carbonate exposed west of Newmont Lake indicates gradational upper contacts with fine grained siltstone. The base of the section is sheared and probably faulted (mC-2, Figure 2-8). At the base of the carbonate is a 1 metre wide zone of sheared fine tuffaceous chloritic siltstone veined by iron carbonate fracture fillings. Below this gently dipping zone in angular discordance, are thickly bedded, thinly laminated cherty siltstone and massive, weakly stratified volcanic conglomerate. These Carboniferous sediments are faulted (Newmont Lake Fault) against Upper Triassic plagioclase phric maroon andesite breccia, volcanic conglomerate, tuffs and subvolcanic intrusions of the Newmont Lake Graben.

An Early to mid-Carboniferous age for the carbonate is indicated by the occurrence of Early Carboniferous, Visean to Early Namurian conodonts (C-158971). A limestone clast...
from polymictic volcanic conglomerate, located stratigraphically higher in the section, contains solitary corals of middle Carboniferous age, associated with Serpukhovian or Bashkirian foraminifers (C-158994, Appendix 1).

Small fault-bounded panels of mid-Carboniferous limestone occupy a narrow north trending belt which follows the western contact of the Early Mississippian More Creek Pluton from Arctic Lake north to Nahta cone in the Mess Lake area. At Nahta cone the carbonate rests with apparent disconformity on medium grained pink granite of the More Creek Pluton (mC-3, Figure 2-8). The contact is sharp, limestone is limonitic and contains feldspar, quartz grains and granitic grit, no basal conglomerate was observed. The contact appears to be depositional, although the overlying carbonate is only 4-5 centimetres thick. Elsewhere, the limestone overlies penetratively foliated mafic volcanic rocks, tuff and chlorite and sericite schists of Devonian-Serpukhovian age. A thin volcanic package comprised of green vesicular andesite, vesicular lapilli tuff, maue and grey ash flow tuff containing fiamme and carbonate lenses underlies the carbonate unit north of Exhile Hill. The carbonate is a well bedded grey wackestone that is interlayered with chert and contains quartz and plagioclase crystal-rich horizons. The interdigitated character of volcanic and carbonate material suggests a conformable lower contact and coeval carbonate sedimentation and volcanism.

Early Carboniferous, Visean to Early Namurian conodonts (C-189428) indicate an Early Carboniferous age for the carbonate located north of Arctic Lake. Corals collected from carbonates south of Natha Cone (C-207963) and north of Exhile Hill (C-207965) are mid-Carboniferous, Serpukhovian or Bashkirian, and associated with mid-Carboniferous (probably Serpukhovian or Bashkirian) foraminifers (Appendices 1, 2 and 3).

Well bedded, pale green to khaki greywacke and cherty volcanic siltstone conformably overlie the carbonate at both locations. Macrofossils collected from these sediments south of Natha Cone are non-diagnostic (C-207964).

**PALEOENVIRONMENTAL INTERPRETATIONS**

Lens-like buildups and mounds of massive lime mudstone accumulated on and around the flanks of the volcanicogenic highlands and/or centers. The morphology suggests carbonate mounds (Photo 2-5), but the composition and nature have not been fully investigated. Echinoderm grainstone is draped onto the flanks and interfingers with maroon volcaniclastic siltstone, sandstone and conglomerate. The mounds developed in an upper slope, shallow carbonate ramp environment of deposition. The carbonate and overlying cherty siltstone represent the accumulation of a distal facies and/or an eruptive hiatus during the mid Carboniferous.

**DIVISION IV**

**UPPER CARBONIFEROUS**

Upper Carboniferous rocks comprise; a package of calcalkaline volcanic rocks, carbonate and lesser sedimentary rocks (units uCScs, uCsb, uCSmv and uCSc; GS-Map), which lie between well dated carbonate units of mid-Carboniferous and Early Permian ages (mCSc and lPSc) in the Mess Lake area (uC-1 and -2, Figure 2-7); and a relatively undeformed package of epiclastic rocks (uCss and uCSc), which overlie mid-Carboniferous carbonate in the Forrest Kerr area (uC-3, Figure 2-7). Biostratigraphic and geochronologic data provide good age constraints for the northern part of the map area, the controls in the Forrest Kerr area are equivocal. The Upper Carboniferous strata are distributed in fault bound areas, adjacent to the Forrest Kerr Pluton, around Newmont Lake and to the west where predominantly sedimentary rocks occupy topographic high areas west of the Newmont Lake Graben. Tuffaceous sedimentary rocks overlie mid-Carboniferous carbonate north of the Andrei Glacier and further north in the Mess Lake area, volcanic rocks predominate.

Carboniferous strata comprise undated epiclastics overlying carbonate and, partly correlatively with, a calcalkaline volcanic island arc succession, which in turn is conformably overlain by carbonate that in most places yields Early Permian (Asselian) fossils. Based on this upper contact the volcanic rocks are assigned a Late Carboniferous (i.e. Pennsylvanian) age. U-Pb zircon dating of flow banded rhyolite in the Mess Lake area returned a Late Carboniferous, Moscovian age of 311.7±2 Ma (Table 2-1). The epiclastic rocks, which in places conformably overlie mid Carboniferous carbonate, are probably also Moscovian but may be younger.

Upper Carboniferous strata are the oldest rocks exposed in the Scud River area (Brown et al., 1996) where they comprise a lower package of interdigitated sedimentary and mafic volcanic rocks with minor carbonate of the Devils Elbow and Butterfly units respectively, and felsic volcanic rocks of the overlying Navo Formation. A Moscovian U-Pb date of 311.1±6.2/ -10.4 Ma (J.K. Mortensen in Gunning, 1993a) from a mafic crystal tuff constrains the age of the Butterfly unit, conodonts from near the top of the Navo Formation are Late Carboniferous to Early Permian (Brown et al., 1996). An identical U-Pb date of 311.7±2 Ma (Table 2-1) from flow layered rhyolite constrains the calcalkaline volcanic package at Mess Lake. Other similar Upper Carboniferous U-Pb dates from Stikinia include 315±5 Ma from Delta Peak, Owgee Dome (Greig and Gehrels, 1995), and 307±2 Ma from a felsic unit at Tatsamenie Lake (Oliver and Gabites, 1993). The common occurrence of Upper Carboniferous intermediate to felsic volcanic rocks indicates consanguinity of arc volcanism during this time across northern Stikinia. The basic Upper Carboniferous stratigraphic sequence of epiclastic, volcanic and carbonate rocks, is consistent across the Scud River, Galore, Arctic Lake, and Newmont Lake areas.

**MESS LAKE AREA**

A moderately west-dipping, fault-duplicated section of characteristically maroon, in part subaerial, calcalkaline volcanics forms a north trending belt located between Mess Creek and the western contact of the More Creek Pluton. The most complete section of Late Carboniferous volcanic rocks in the study area is located west of Exhile Hill (uC-1, Figure 2-9). Interbedded limestone horizons containing
abundant Wolfcampian (late Asselian), fusulinacean foraminifers crop out near the top of the volcanic package (C-207976, Appendix 3) and the base of the package is conformable with fine clastic rocks (uCSs), and mid Carboniferous carbonate (mCSc), west of Nahta Cone. The western section is probably no more than 1000 metres thick and forms a dip slope down to Mess Creek. Aphyric purple and green amygdaloidal basalt, plagioclase and pyroxene-phryic andesite breccia flows and associated volcanics form what appears to be the lowest volcanic unit (uCSb), but similar rocks also occur as subordinate members at various levels within the section (uC-1, Figure 2-9). Well-bedded, feldspar-phryic intermediate and felsic tuffs and epiclastic rocks comprise the characteristically pale maroon weathering medial unit, which contains both hornblende and pyroxene, as well as augite and hornblende-phryic fragments. Most lapilli are intermediate to felsic or andesitic; plagioclase crystals/grains are ubiquitous. Interbanded quartz-bearing polylithic epiclastic rocks and rare accretionary lapilli tuffs and ash flow tuffs record contemporaneous submarine and subaerial depositional environments. The uppermost volcanic unit (uCSr) consists mainly of maroon, mauve and brown flow-layered and spherulitic rhyolite, and quartz-feldspar-phryic rhyolite flows, autobreccia and ash-flow tuffs (Photo 2-8). These felsic rocks are resistant and form most of the prominent ridges and dip slopes east of Mess Creek. Most of the feldspar is orthoclase or microcline, and is weakly to moderately altered to sericite. Rare flows contain euhedral to subhedral quartz crystals 2 to 3 millimetres in diameter. Mafic minerals are generally absent except for rare biotite.

At least 10 to 15 metres of maroon ash-flow tuff and lapilli tuff underlie Early Permian carbonate west of Arctic Lake (Logan et al., 1992a). The silicic volcanlastic rocks under the limestone are an extension of the much thicker rhyolite flows and tuffs to the north. Welded ash-flow tuff, about 5 metres thick, is conformably overlain by a maroon and green volcanic granule conglomerate and then well-bedded, grey, fossiliferous micritic limestone. Fault-bounded, massive maroon tuff occurs closer to the lake (GS-Map, in back pocket). In thin section, this tuff contains subhedral to anhedral quartz and feldspar grains in a devitrified matrix with a slight flattening fabric. A weak eutaxitic texture is defined by lenses of polycrystalline quartz, which wrap around crystals and fragments. Most of these lenses have euhedral, lath shaped crystals of possible zeolite projecting into them perpendicular to their walls.

A second, fault-bounded wedge of Upper Carboniferous volcanic rocks crops out between Mess and Skeeter lakes at the northern margin of the map (uC-2, Figure 2-7). The strata are intruded (?) by an undated coarse grained, pink hornblende granite above Mess Lake. Discontinuous lenses of massive recrystallized carbonate mark the contact of the granite with a southwest facing package of tuffaceous sediments (UCss) comprised of khaki, green and brown coloured lapilli tuff and ash tuff, and thin bedded siltstone and sandstone with plagioclase crystal-rich epiclastic beds (uC-2, Figure 2-9). The sediments display normal grading and flame and load structures that indicate a younger direction to the southwest. Interlayered with the sediments are maroon and green, fine ash and lapilli basalt tuff and overlying them, although in fault contact are thick bedded amygdaloidal basalt flows and massive tuffs (uCSs). The

Figure 2-9. Generalized stratigraphic columns for Upper Carboniferous strata of the Stikine assemblage. Unit designation corresponds to legend on GS-Map 1997-3. Section locations are shown on Figure 2-7.

Photo 2-8. Pale weathering Upper Carboniferous (Moscovian) flow-layered spherulitic rhyolite.
volcanic rocks do not show any internal structure. The flows are mainly aphyric but some have coarse plagioclase phenocrysts. In places, quartz-carbonate-sericite amygdules delineate apparently planar flow tops, suggesting the basalt was erupted as sheets, and is not pillowed. Polydeformed, structurally thickened limestone, chlorite and siliceous tuff (uCSc) are exposed on Skeeter Ridge between Skeeter and Mess lakes (uC-2, Figure 2-7). This succession forms the eastern slope above Skeeter Lake and extends to the top of the plateau. Near its base the carbonate contains late Upper Carboniferous (Kasmovian to Gzhelian) fusulinacean foraminifers (C-207968, Appendix 3); there it is interbedded with maroon tuffs of the volcanic package. Higher in the section the carbonate yielded Early Permian fossils (C-207970, Appendix 2). The carbonate unit represents a period of tectonic stability in this area. There was a hiatus in volcanic activity and continuous deposition that spanned the Carboniferous-Permian boundary.

MORE CREEK AREA

A section of weakly foliated to unfoliated, well-stratified and graded volcanoclastics more than 400 metres thick is exposed on the flank of a nunatak in the southwestern corner of the More Creek area (Figure 2-7). The section includes maroon, hematitic and manganiferous lapilli and crystal tuffs, maroon pillow basalt flows and breccias, and also felsic dacitic to rhyolitic flows, ash-flows and lapilli tuffs. Similar ash-flow lapilli tuffs occur in the Forest Kerr area, near Nahta cone. Thin-bedded ash tuff, tuffaceous sandstone and conglomerate are interspersed among the pillowed and brecciated flows; sedimentary structures indicate the strata are upright. Carbonate is absent from the section. Radiolarians from well bedded pale green cherty siltstone and dust tuff, located approximately in the middle of the section, indicate a possible late Mississippian to early Pennsylvania age (C-189790, Appendix 4).

FORREST KERR AREA

Upper Carboniferous sedimentary and epiclastic rocks predominate in the Forrest Kerr area. West of the Forrest Kerr Pluton, an upward coarsening package of volcanoclastic rocks conformably overlies middle Carboniferous carbonate at three locations; east and west of Newmont Lake, on a nunatak within the Andrei glacier, and on the slope immediately north of the glacier (uC-3, Figure 2-7).

Thin bedded cherty siltstone, poorly bedded tuff, wacke and sandstone and minor chert of unit uCSc comprise the basal unit which interfingers with middle Carboniferous (lower Bashkirian) limestone north of Andrei Glacier (Photo 2-5). It is gradationally overlain by a coarse clastic package of maroon volcanic sandstone, thick bedded polythitic volcanic conglomerate and tuff of unit uCScg. Dark purple and green pyroxene-porphyritic and hornblende-plagioclase-porphyritic andesite, sioraceous basalt and grey fossiliferous limestone clasts form up to 70 per cent of the conglomerate. Up section the two units are interbedded and difficult to separate; both are tuffaceous, contain a substantial volcanic component and host blocks of the underlying middle Carboniferous carbonate up to several metres across. A limestone clast in the conglomerate contains solitary and rugose colonial corals and mid-Carboniferous (lower Bashkirian) foraminifers (C-158986, Appendix 1). Bedding top directions and conformable contacts indicate that the conglomerate is upright and either Late Carboniferous or Early Permian in age. This strata can be traced for ten kilometres northwest into the Galore Creek area where 200 metres of dominantly polymeric volcanic conglomerate, containing discontinuous limestone masses, well bedded siliceous epiclastics beds and intermediate volcanic flows are exposed (Logan and Koyanagi, 1994). They comprise a southwest-dipping homoclinal sequence which is overlain by Lower Permian limestone to the west. The conglomerate is medium bedded and locally fossiliferous. Neospirifer sp., ’Spiriferella’ sp., and productoid brachiopods of probable Early Permian age (C-189355, Appendix 1) are abundant in the conglomerate adjacent to limestone pods. Clasts of limestone in the conglomerate contain foraminifers of late Mississippian-Peratovich facies and middle Carboniferous red algae facies (C-189355; Mamet,1991a). An Early Permian to no older than middle Late Carboniferous age is indicated for the conglomerate. The middle Bashkirian age of the clasts indicates the age of the source rock. The succession in general fines upward and high in the section consists of volcanic sandstone, siltstone and siliceous argillite with plagioclase crystal tuff horizons and occasional conglomerate beds. The fine-grained clastic layers display fining-upwards sequences, rip-up clasts and soft-sediment deformation features indicating a west-facing, right-way-up stratigraphic section. At this location, less than 100 metres of maroon plagioclase-porphyrity tuff caps the sequence and conformably underlies limestone containing Early Permian Heriitshiodes sp. corals and Pseudovidalena sp. and Clincamminia sp. fusulinacean foraminifers (C-189356, Appendix 1 and Appendix 3) (Logan and Koyanagi, 1994).

The thickest and best exposed section of Upper Carboniferous epiclastic rocks (uCSs and uCScg, GS-Map) is west of Newmont Lake (uC-3, Figure 2-7). Interbedded conglomerate, sandstone, wacke and thinner layered siltstone and cherty siltstone comprise a structurally thickened section extending from the conformable contact with mid Carboniferous carbonate at 1350 metres to the top of Pyramid mountain at an elevation of 2041metres. A well-bedded section of epiclastic sediments and intercalated tuffs (unit uCSs) several hundred metres thick crops out on the north-facing ridge slope, five kilometres northwest of Newmont Lake (Figure 2-10). It conformably overlies mid Carboniferous carbonate west of Newmont Lake and comprises a thin to medium bedded succession of turbidite, fine, siliceous siltstone and carbonaceous siltstone, interbedded sandstone and polymictic pebble to cobble conglomerate. Fining-upward sequences are common. Lenses of lapilli tuff and thick accumulations of coarse breccias and lahars at the base and top of the section attest to periodic influxes of volcanic materials (Figure 2-10). Lapilli are purple, equant, plagioclase crystal phyric basaltic andesite, in a plagioclase crystal rich matrix. Breccia fragments are commonly amygdaloidal basalt to dacite in composition. In one 10 metre section of tuff there are 4 fining upward sequences.
from lapilli to crystal to finely laminated ash (Photo 2-9). Epiclastic layers of fine sandstone and green laminated siltstone separate the tuffs and flow rocks. The middle of the section is comprised of black and white sandstone-siltstone ‘DE’ turbidite couplets, coarse sandstone, grit and conglomerate ‘AB’ beds. Flame structures and normal grading indicate upright facing bedding directions. Isoclinal folds in some of the black siliceous siltstone and chert layers are probable syn-sedimentary, slump features. Conglomerate beds are green or maroon and matrix supported. Clasts are augite and plagioclase phryic basaltic andesite, felsic volcanic rocks, green and black siltstone and fossiliferous carbonate. Large echinoderms ossicles characteristic of the middle Carboniferous carbonate in this area occur at one conglomerate horizon and conodonts from another indicate an Early Carboniferous, Visean-early Namurian age (C-159100, Appendix 2). The clasts are generally well rounded, moderately to well sorted and range from granule to boulder sizes. A single paleocurrent measurement indicates flow direction from the southwest. Structurally and presumably stratigraphically higher in the section are conglomerates. These are mainly dark grey to purple and only weakly bedded or graded. In places, near the lower contact with unit uCSss, they consist of maroon tuff with crinoid ossicles and thin bedded siltstone. The unit coarsens upwards into poorly sorted volcanic conglomerate with larger clasts averaging 20 to 40 centimetres in size. Clasts are mainly porphyritic andesite with plagioclase, hornblende, and pyroxene phenocrysts in a matrix of fine grained volcanic material (Photo 2-10). Carbonate clasts are an important feature which distinguish this conglomerate from stratigraphically equivalent conglomerate units located east of Newmont Lake and north of Arctic Lake. Corals and foraminifers in a carbonate clast from conglomerate located 3 kilometres west of Newmont Lake are middle Carboniferous, Serpukhovian or Bashkirian (C-158994, Appendix 1 and Appendix 3). Topographically above this locale near the top of the peak is a large (20 by 50 metre) block of probable Carboniferous carbonate (Photo 2-11, C-168156, C-158996; Appendix 1 and Appendix 2).

Figure 2-10. Measured section of Upper Carboniferous epiclastics and tuffaceous strata exposed northwest of Newmont Lake.
East of the Forrest Kerr Pluton, a north trending belt of interlayered metasedimentary and metatuffaceous rocks of probable Carboniferous age (CSst, GS-Map) crops out between the Forrest Kerr Pluton and the Forrest Kerr Fault. Strata include grey to light green phyllitic siltstone, graphitic argillite, siliceous phyllite, chlorite schist and tuff and thin lenses of dark brown limestone. Five kilometres north-west of the confluence of Iskut River and Forrest Kerr Creek the belt is intruded by small (1 kilometre) plugs of hornblende diorite and it is also from this location that Read et al. (1989) collected Early Permian conodonts from interlayered carbonate (C-102756, 7; Appendix 2). A unit of white and green, centimetre scale normally graded siliceous siltstone and argillite, less than 200 metres thick, is interbedded with, and overlain by dark green lenses of massive to plagioclase phryic mafic metavolcanic rocks and mottled purple and green breccias and lapilli tuff (ImDSst, GS-Map), south of the bend in Forrest Kerr Creek. Thin foliated marble, cherty grey schist, and green and grey siltstone (ImDSs, GS-Map) at the structural top of the section are intruded by biotite tonalite and hornblende diorite of the Late Devonian Forrest Kerr pluton. These rocks are...
polydeformed. They contain a well developed penetrative foliation, which locally is crenulated and overprinted by younger brittle fabrics; the fabrics make estimation of unit thickness difficult.

CHEMISTRY OF THE VOLCANIC ROCKS

The Upper Carboniferous tuffs and highly porphyritic and moderately altered flows have high LOI when analyzed (Appendix 8) and are not suitable for chemical interpretation or tectonic discrimination. Exceptions are the sparsely phytic rhyolite flows south of Mess Lake. A sample of massive, mauve rhyolite plots as calcalkaline, rhyodacite to dacite (not shown). The sample falls within the field of Lower Permian volcanics of the Asitka Group (Souther, 1977).

PALEOENVIRONMENTAL INTERPRETATIONS

The coarsening-upward volcanic sandstone and conglomerate sequence (unit uCScs and uCScg) is interpreted to represent a volcaniclastic/epiclastic dispersal apron shed by carbonate breccia blocks comprises the Mount Eaton block (unit lPSc, GS-Map) forms knobs and discontinuous ridges in the More Creek area (Figure 2-7). In contrast with the area 45 kilometres northwest of Nahta Cone, respectively it overlies Upper Carboniferous epiclastic rocks of unit uCSmv and flow layered rhyolite of unit uCSR, with apparent conformity. The carbonate also conformably overlies Early Mississippian granite and diorite of the More Creek Pluton in the same area. The upper contact with mafic tuff of probable Upper Triassic age is exposed in two creeks west of Nahta Cone. High angle listric extension faults offset and tilt the stratigraphy eastward. Thin-bedded layers in the packstone contain an abundant Early Permian fauna of rugose and tabulate corals, productoid and rhyonchonellid brachiopods, pelecypods, bryozoa and fusulinacean foraminifers (C-207969 and C-207976, Appendix 1 and Appendix 3). Massive, pale grey marble and carbonate breccia members are generally barren of fossils. A large exposure of carbonate of unknown age straddles Tadekho Creek. At the southern end of the belt the carbonate contains mid Carboniferous tabulate corals and fusulinaceans, but further north it is medium bedded and interlayered with chert layers more diagnostic of the Early Permian carbonates.

Early Permian carbonate in the More Creek area comprises less than 200 metres of massive marble and medium to thin-bedded grey, fetid micritic limestone exposed in fault blocks along the east side of Mess Creek. Strata contain an abundant Early Permian fauna of rugose and tabulate corals, pelecypods, productoid and rhyconchellid brachiopods (C-189436, 7; Early Permian, probably Asselian or Sakmarian) and fusulinacean foraminifers. Biostratigraphic samples from the base of the carbonate near the basal contact with maroon Upper Carboniferous volcanic rocks contain latest Carboniferous, Gzhelian to earliest Permian, Asselian fusulinids (C-189783, 4; Appendix 3). Although the limestone is mainly medium to thick bedded, patch reefs occur where several types of corals are preserved in growth positions indicating small reef mounds were present (Photo 2-12). A major proportion of the limestone is massive, recrystallized and hemiatic. Breccia textures are very common with an average fragment size of 0.2 to 4 centimetres; the colour is typically buff to rusty red. Except for small crinoidal pieces and the odd silicified brachiopod, this recrystallized limestone is barren of fossils.
To the south, in Forrest Kerr area, Early Permian carbonate is exposed on an east trending nunatak at the western edge of the map area and in fault-bounded blocks on the eastern side of the Newmont Lake graben.

Early Permian, (probably lower Artinskian) based on fusulinacean foraminifers (C-158988, Appendix 3), carbonate is exposed along the edge of the Iskut icefield south of Andrei Glacier (Figure 2-7). The limestone comprises, less than 200 metres of primarily massive to thin-bedded grey bioclastic grainstone with minor buff silty dolomitic units. Interbedded in thinly-bedded sections are black to yellowish buff chert beds up to 20 cm thick which may constitute up to 50 per cent of the outcrop. These layers are probably diagenetic, representing silicified fossil-rich horizons. Locally, they contain abundant solitary corals, foraminifers, bryozoans, echinoderms and productoid and spiriferid brachiopods. Maroon volcanic conglomerates of probable uCScg are in faulted contact with the carbonate at this location.

Disrupted, fault-bounded blocks of Early Permian carbonate east of Newmont Lake consist primarily of massive to thin bedded grey bioclastic calcarenite and lesser buff silty dolomitic units. Thin-bedded sections are rhythmically interleaved with black to yellowish amorphous silica beds up to 10 centimeters thick (Photo 2-13). Solitary corals, foraminifers, bryozoans, conodonts and spiriferid brachiopods are locally abundant, in both carbonate and silicified beds (C-158969,158987; Appendix 2). Limonitic and hematitic limestone are coincident with fault structures and indicate fluid flow and attendant alteration. This alteration is selective and occurs predominantly in the massive limestone and dolomitic mudstone layers.

**EAST OF THE FORREST KERR PLUTON**

An Early Permian, Artinskian to Sakmarian (C-087669, 71 and C-158998; Appendix 2) carbonate lens crops out adjacent to the West Slope fault. The limestone is a massive, white to buff, sparsely crinoidal calcarenite which is locally completely recrystallized to coarse crystalline calcite. Structurally below the carbonate is a purple and green volcanic conglomerate containing limestone clasts, that is interpreted to be the basal Triassic Stuhini Group (Read *et al.*, 1989). In outcrop it resembles the Upper Carboniferous coarse volcaniclastic units located west of the Forrest Kerr Pluton.

East of the Forrest Kerr Fault deformed siliceous tuff and metasedimentary rocks of Paleozoic, probable Permian age, underlie a 25 square kilometre northeast trending structural culmination located east of the bend in Forrest Kerr Creek. Foliated and crenulated metavolcanic rocks of unit IPSdt consist of green interbedded chloritic tuff, tuffaceous and siliceous siltstone and numerous thin recrystallized Early Permian (C-102947, C-102855, Appendix 2) carbonate beds (IPSdc, GS-Map). Thinly laminated tuffs within the unit resemble siltstone, but in thin section are seen to contain laminae of angular, broken plagioclase, quartz, and potassium feldspar crystals. Crystal fragments are also scattered throughout the more abundant, finer grained layers. A weak planar foliation is visible. The strata resemble sections of Upper Carboniferous rocks and some parts of the Upper Triassic section.
PALEOENVIRONMENTAL INTERPRETATIONS

Early Permian, Asselian age fusulinacean-bearing limestone and interbedded maroon tuffaceous siltstone indicate that volcanism initiated in the Upper Carboniferous apparently continued into the Early Permian and was coeval with carbonate accumulation in the Mess Lake area. Latest Carboniferous, Gzhelian to Early Permian, Asselian age fusulinaceans suggest that carbonate deposition was initiated as early as late Carboniferous and continuous through into Early Permian time.

EARLY TO MIDDLE TRIASSIC

Black, carbonaceous siltstone (unit mTs, GS-Map) underlies the eastern edge of the map area in structurally low positions (Figure 2-11). It is bedded on a 10 centimetre or finer scale, with rhythmic normal graded beds rarely coarsening to very fine sandstone. The strata contains approximately 0.5 per cent finely disseminated pyrite and numerous elliptical carbonate concretions. Minor chert occurs with siliceous varieties of the siltstone. The majority of the unit is a distinctly carbonaceous, black weathering rock with stockworks of white calcite veinlets. The incompetent nature of these rocks accounts for their characteristically tight, disharmonic, parallel folding. Sedimentary structures indicate that this unit is stratigraphically upright and below the Late Triassic More Creek sedimentary facies rocks. The strata are correlated with Early to Middle Triassic silty argillite, limy dolomitic siltstone and cherty siltstone exposed at Copper Canyon, 50 kilometres west in the Galore Creek area (Souther, 1972; Logan and Koyanagi, 1994). There are no biostratigraphic age constraints for the siltstone package in the current map area. However, Middle Triassic and Middle to Late Triassic radiolarian have been identified by Cordey (1992) from thin bedded, black and brown chert interbedded with limestone in the More Creek area, northwest (C-167847, Appendix 4) and northeast of Hankan Peak (C-189401, Appendix 4). The strata are essentially indistinguishable in outcrop and hand specimen from similar Upper Triassic limestone and chert east of More Creek and in both localities they occur adjacent to limy sedimentary rocks which contain Late Triassic conodonts (C-167850 and C-189402, Appendix 2). One possibly important difference is that the Middle Triassic chert is generally more deformed, although the tight parallel folds may in part be due to soft-sediment deformation. The small and discontinuous nature of both these outcrops and the imbrication with younger rocks is fault related.

LATE TRIASSIC STUHINI GROUP

Rocks of the Upper Triassic Stuhini Group change across the study area from mainly volcanic flows and subaerial tuffs in the Mess Lake and Forrest Kerr areas, to predominantly volcanic sediments and limestone in the More Creek area (Figure 2-11). The Newmont Lake assemblage is a distinct package of volcanic rocks and carbonate which occupies the Newmont Lake Graben in the Forrest Kerr area. Across the map, the change from proximal volcanic facies in the west (Mess Lake facies), to more distal sedimentary facies in the east (More Creek facies), is
compatible with the Late Triassic to Early Jurassic arc being located west of the map area. The present distribution of Late Triassic to Early Jurassic extrusive and intrusive rocks defines a north-trending axis located probably between the present map area and the Stikine River (Hickman Pluton, volcanic edifice at Galore Creek, the Mooselhorn Pluton).

Upper Triassic proximal deposits comprise pyroxene and/or plagioclase porphyritic lava flows, coarse volcanic breccias and lapilli and crystal tuffs. Substantial proportions of the volcanic pile are made up of massive subvolcanic rocks, that are considered to be parts of the volcanic feeder system. Pyroxene and potassium feldspar rich sediments are interbedded with carbonate and shale, chert and limestone in the More Creek area. The pyroxene and feldspar crystals were derived either from eruptions of crystal tuffs or washed off the flanks of the volcanoes into the basin. Potassium feldspar megacrystic syenite dikes and less commonly mafic pyroxene porphyry flows are interspersed within the sedimentary rocks at More Creek area, indicating that the sediments were deposited proximal to the volcanic edifice. Due to the steep and variable inclinations of the strata, it is difficult to estimate thickness. However, the Upper Triassic strata are roughly estimated to be a maximum of 2 kilometres in most areas (Souther, 1972).

MESS LAKE/ARCTIC LAKE AREA

The Stuhini Group is dominated by volcanic rocks in the Mess and Arctic lakes areas (Mess Lake volcanic facies, GS-Map). Volcanic rocks underlie Mount LaCasse and most of the rugged mountainous area west of Mess Creek and also crop out in a narrow north-trending belt east of Mess Creek, where they are less well exposed (Figure 2-12). They lie unconformably on Lower Permian limestone 3 kilometres northwest of Nahta Cone and 4 kilometres southwest of Arctic Lake, and are unconformably overlain by Lower Jurassic conglomerate along their eastern margin southwest of Nahta Cone and at two localities west of Mess Creek. The volcanic rocks are truncated on the west side by the Hickman and Yehiniko plutons. To the south they are faulted against Paleozoic rocks. A generalized stratigraphy consists of a basal sedimentary succession (uTSSn) or mafic tuffaceous succession (uTSmt), a medial volcanic succession characterized by flows and breccias with a central tuff unit (uTSvb, uTSvt, uTSpp) and an upper tuffaceous sedimentary succession (uTSs, Figure 2-12).

West of Mess creek, maroon amygdaloidal plagioclase and pyroxene-phryic basalt flows, breccias and tuffs, and dun-weathering, olivine-rich basaltic tuffs at least 800 metres thick are intruded by trachytic sills of coarse-banded plagioclase and pyroxene porphyry, probable feeders to overlying volcanics.

The lowermost stratigraphic unit consists of less than 100 metres of recessive, dun-weathering, serpentinitized mafic to ultramafic volcanic rocks. Lapilli tuffs predominate and together with minor flows are variably altered to serpentinite and ductily deformed. The lapilli are scoriaceous, green-blue and black and altered to serpentinite, talc and chlorite (Photo 2-14). East of Mess Creek, serpentinitized tuff overlies Lower Permian carbonate at two areas; the contact at one site is partly faulted. Volcanic rocks of unit uTSvb were not observed to directly overlie the mafic tuff unit, but they usually crop out nearby and consist of dark grey, massive, plagioclase phryic basalt and similar layered subvolcanic rocks. They are best exposed north and south of the Schaft Creek porphyry copper deposit. Contact relationships of the basalt are poorly exposed, except where it is intruded by hornblende diorite to monzonite of the Hickman Pluton. The basalt is typically fine-grained, with 0.5 to 1 mm plagioclase phenocrysts to about 30 per cent and several per cent pyroxene phenocrysts. Outcrops are generally massive with few extrusive textures visible, but locally, breccia and amygdaloidal textures are recognized in talus blocks. Tuffs of the medial volcanic unit overlie these basaltic rocks 7 kilometres north of the Schaft Creek camp. Unit uTSvt comprises massive to weakly stratified, polylithic, grey to mauve lapilli tuffs and crystal tuffs that form thick sections underlying the east-facing slope above Mess Creek. Both plagioclase and augite crystal fragments are common, although augite is generally less than 5 per cent of the rock (Photo 2-15). Measurable bedding attitudes are rare; the few seen indicate steep dips. The same succession crops out further west, where it underlies the west-facing slopes above Schaft Creek. It consists of maroon and green fine ash and plagioclase-rich crystal tuff intermixed with purple monolithic augite phryic lapilli tuff and thin purple basalt flows (Figure 2-12). Epiclastic horizons include colorful, polylithic boulder to cobble conglomerates, containing clasts of green and black augite phryic basalt, maroon plagioclase porphyry, green, epidote-rich altered volcanic rock and purple aphyric basalt. The thickest
volcanic unit comprises augite-phyric, plagioclase-phyric, augite and plagioclase-phyric, and aphyric basaltic andesite flows (uTSpp). It extends the full length of the western edge of the map area and is the host rock of the Schaft Creek deposit. Subvolcanic intrusive rocks are difficult to distinguish from the extrusive rocks in this area and are included with them. Tuffs and flows occur in subequal amounts and vary in colour from maroon to green; it is common for purple tuff to be interbedded with green tuff. The basaltic andesite is pillowved for 3 kilometres both northeast and southeast of Schaft Creek (Photo 2-16). All bedding attitudes observed in the intercalated tuffs were steeply inclined to the northeast or southwest. Locally the unit may be tightly folded, but the lack of good stratification makes the extent of this difficult to determine. Unit uTSs comprises about 150 metres of well-bedded green dust tuffs, tuffaceous siltstone-sandstones and wackes which crop out on the northwestern flank of Mount LaCasse, 5 kilometres north of the Schaft Creek deposit. Near its western margin, the well-bedded section thins considerably where it is faulted against unit uTSpp. The tuffs also apparently thin to the northeast, limiting their usefulness as a marker unit. A thin maroon quartz and limestone-bearing volcaniclastic unit (possibly Unit lJeg) apparently overlies these sediments conformably but is faulted against pyroxene-phyric volcanics of Unit uTSv farther east. Steeply dipping, tightly folded volcanic conglomerate, interbedded sandstone and siltstone, pyroxene crystal sandstone and limy siltstone (Unit uTSs) are exposed about 4 kilometres south of the Schaft Creek deposit (GS-Map, in pocket). Fossils from thin interbedded siltstone, sandstone and conglomerate layers are identified as the Late Triassic, Upper Norian brachiopod Monotis Subcircularus (C-207971, Appendix 1).

East of Mess Creek, Upper Triassic volcanic rocks comprise a north-trending belt, 10 by 2 kilometres wide which in part forms the eastern intrusive margin to the Late Triassic to Early Jurassic Loon Lake Stock (Figure 2-12). General stratigraphy, while similar to that west of Mess Creek, is more condensed. Rafts of hornfelsed mafic tuff, breccia and sedimentary rocks are hosted in the main body of plagioclase hornblende monzonite. Contact metamorphic and hydrothermal effects of the Loon Lake Pluton produced a large gossan in the volcanic and subvolcanic hostrocks as well as in the intrusive itself. In some cases this has made it impossible to distinguish the massive plagioclase phryic tuffs and flows from subvolcanic intrusive rocks.

Mafic tuffs of unit uTSmt are clearly visible in creek exposures where alteration and weathering have produced characteristic dun to bluish-green hues. The lapilli tuff is intruded along its western limit by the Loon Lake stock and probably overlain conformably by silicified dust tuff and turbiditic siltstone of Unit uTSs, which commonly crops out nearby. The same stratigraphic relationships are apparent west of Mess Creek (Logan et al., 1992a,b). Massive tuffs and flows of Unit uTSvb include associated subvolcanic intrusive rocks which could not be mapped separately. Both are predominantly dark green, plagioclase phryic rocks with lesser pyroxene. Pillowed and breccia flow textures occur locally in the massive sequence of plagioclase-phryic basaltic andesite. The volcanic and sedimentary strata are un-
conformably overlain by Lower Jurassic conglomerate along their eastern exposure.

MORE CREEK AREA

Upper Triassic Stuhini Group rocks in the More Creek area comprise a thick package of predominantly volcanic arc derived sediments, limestone and lesser intercalated intermediate to mafic volcanic rocks (More Creek sedimentary facies) which correspond, in part, to the eastern facies of Anderson (1989). Sedimentary rocks crop out mainly east of the Forrest Kerr fault, north of More Creek, and west of Arctic Lake (Figure 2-12). Volcanic rocks of the Mess Lake volcanic facies form the steep cliffs west of Mess Creek in the northwest corner of the map area. The best exposed stratigraphic sections in the More Creek area are on the northeast and southwest flanks of Hankin Peak, and approximately 10 kilometres south of Hankin Peak on the Lucifer claims. The base of the section is exposed near the eastern margin of the More Creek map area, where Upper Triassic siltstones lie conformably on black carbonaceous siltstone of probable Middle Triassic age. At a second location west of Arctic Lake, Late Triassic sediments paraconformably overlie Early Permian limestone.

The widespread Upper Triassic rocks in the More Creek area have been divided into five map units (Figure 2-12). From oldest to youngest, these are: massive, thin-bedded to laminated, black and brown siltstone (uTSs); khaki feldspathic sandstone, limestone conglomerate and greywacke (uKSm); grey recrystallized limestone and cherty and carbonaceous siltstone (uTSc); thick-bedded augite-bearing greywacke and sharpstone conglomerate (uTSS); and augite-phyric and aphyric flows, related tuffs and epiclastics (uTSv).

East of Forrest Kerr fault, the lowermost unit is a planar-laminated siltstone interbedded with undulose to wavy cross-stratified sandstone. It crops out as dark grey to black, massive or thickly bedded calcareous siltstone with light brown to orange-weathering sandstone interbeds. Common sedimentary structures include load and flame structures, soft-sediment slumping and trough crossbeds; graded bedding is less common. Interbedded with the siltstone are horizons of siliceous siltstone, limestone and ribbon chert (to 50 m thick). The siltstone and chert are variegated, black, green, yellow and grey, and contain Middle-Late Triassic, Ladinian-Carnian radiolarians (C-189401, Appendix 4). The siltstone unit is overlain by a well-bedded sequence of khaki coloured feldspathic sandstone, thin interbedded dark grey siltstone to fine sandstone, poorly sorted dark grey arkosic greywacke, and limestone-bearing conglomerate (uTSSm, Figure 2-12). Sandstone units commonly contain lithic clasts and laminated siltstone rip-up clasts. Interbedded with these rocks are planar-laminated, olivine-grey, dark green and black, thin-bedded siliceous siltstones and fine sandstones (Photo 2-17). Limestone conglomerates and polynyclic limestone-bearing conglomerates comprise distinctive green, yellow or maroon-weathering coarse clastic units. Angular to rounded light grey limestone clasts in a buff matrix of coarse, tuffaceous and limy sand comprise up to 85 per cent of some outcrops. Subordinate volcanic sandstone and siltstone make up the
Polymictic conglomerate layers of variable thickness contain mixed angular and rounded fragments up to 20 centimetres (average 5 centimetre) in diameter. Clasts include maroon and grey pyroxene-phyric and plagioclase-phyric andesite, black siltstone and limestone. Star-shaped (isocrinus?) crinoids, of Triassic or younger age, occur within limestone clasts. White-weathering, grey, recrystallized, massive to medium-bedded limestone crops out throughout the stratigraphy as discontinuous units that are less than 50 metres thick. The limestone is bioclastic, with sparse crinoids and various pelecypod and brachiopod fossil fragments and contains conodonts of Late Triassic, Late Carnian age (C-189760, 61; Appendix 2). Recessive dark grey and black silty limestone may represent basinward facies equivalents of the bioclastic limestone. Thick-bedded tuffaceous sandstones, sharpstone conglomerates, and thin-bedded black limestones comprise a succession 300 metres thick east of Hankin Peak (uTSs, Figure 2-12). The sandstones are light green, augite-bearing, medium-grained, well-sorted epiclastics; in places, they texturally resemble pyroxene diorite intrusive bodies. These massive bedded green tuffaceous sandstones are interlayered with chaotic slump or debris flow deposits of poorly sorted greywacke or sharpstone conglomerate. The sharpstone conglomerate layers are thick and numerous within this unit. The matrix is most commonly arkosic, though east of Hankin Peak it is argillaceous. Clasts include laminated siltstone, bedded sandstone, chert, limestone and rare aphyric volcanics (Photo 2-18). Limestone clasts from the sharpstone conglomerates contain Middle Triassic (C-189800, Appendix 2) and Carnian, Late Triassic (C-207977, Appendix 2) conodonts and radiolarians. The clasts are angular to subangular; they average 2 centimetres in size, but are as large as 10 centimetres. Bivalves, possibly Upper Triassic Monotis or Middle Triassic Daonella are present in thin siltstone layers and in clasts from interbedded sharpstones north of the Lucifer claims. Light grey massive limestone from this same location yielded Late Triassic, Norian conodonts (C-189793, Appendix 2). Thin-bedded black to dark grey argillaceous limestone is interbedded with tuffaceous sandstones north of Twin glaciers. The limestone contains belemnites, ammonites and the Carnian conodont Metapolygnathus sp. (C-189450, Appendix 2); the siltstone and sandstone contain the Carnian bivalve ?Halobia (C-189755, Appendix 1).

Upper Triassic volcanic rocks are volumetrically subordinate to sedimentary rocks in the More Creek area. Intermediate volcaniclastics and epiclastics predominate, intermediate and mafic flows are subordinate. Maroon and dark green plagioclase-phyric lapilli tuff is interbedded with white to brown-weathering, medium-grained feldspathic volcanic sandstone north of More Creek. Subangular lapilli and reworked, well-rounded 1 to 2 centimetre fragments of plagioclase and hornblende phyric volcanics occur in a pyroxene crystal-rich matrix. The tuffs and epiclastics are stratified but thick bedded, and generally difficult to distinguish from one another. Coarse poly lithic block tuffs containing plagioclase-phyric andesite, dacite and maroon hornblende plagioclase andesite clasts are distinctive within the thick package of interbedded ash and lapilli tuff and reworked epiclastic rocks. Maroon augite-phyric and plagioclase-hornblende-phyric flows and flow breccias are interlayered with pyroxene-rich crystal and lapilli tuff to the northwest and northeast of Hankin Peak (Photo 2-19). The flows contain augite phenocrysts up to 10 millimetres in size and stubby plagioclase phenocrysts to 3 millimetres in size in a purple and green mottled groundmass. East of Hankin Peak, interlayered maroon and green ash and lapilli tuff, massive plagioclase-phyric andesite, and scoriaceous flow breccias overlie thin bedded pyritic siltstone and sandstone.

Weak to variably foliated volcanic, tuffaceous and epiclastic rocks crop out in creek valleys north of Hankin Peak. Lithologically this package is identical to rocks of the Upper Triassic Stuhini Group. Chlorite phyllite and schists...
are locally developed, and these generally occur structurally below less-deformed pale green, fine-grained distal tuffs. This area may contain pre-Triassic rocks, but insufficient work has been completed to be certain.

A section of limy sediments 175 metres thick paraconformably overlies Lower Permian limestone west of Arctic Lake (Figure 2-12 and Photo 2-20). The sediments resemble Middle Triassic rocks and earlier work (Logan et al., 1992a,b) mistakenly correlated them with the Middle Triassic sediments present in the Galore Creek area (Souther, 1972; Logan and Koyanagi 1994). Subsequent identification of sparse brachiopod fossils indicates that the succession is, at least in part, Upper Triassic. The lowermost 100 metres consists primarily of black, medium-bedded, planar-laminated, fetid, limy siltstone and fine sandstone that are correlated with unit uTSn. Elliptical concretions of coarsely crystalline siderite are common. A discontinuous thin-bedded, quartz-bearing tuffaceous sandstone/greywacke comprises the base of the section where it overlies Latest Carboniferous to earliest Permian limestone (C-189783, Appendix 3). The lower unit is interbedded with fetid black limestone at its upper contact. The clastic component increases in size and proportion up section; micrite and limy siltstone grade into thinly interbedded siltstone and sandstone. The upper package is 75 metres thick and consists of medium-bedded buff to orange sandstone with thin interbeds of black and grey siltstone. The sandstone weathers concentrically and contains carbonized wood fragments. In gradational contact above the siltstone-sandstone package is a discontinuous unit of finely laminated, pale green cherty siltstone 1 to 2 metres thick.

Overlying the siltstone is a dark green polymictic pebble to cobble conglomerate (uTSs). This unit crops out west and north of Arctic Lake at the edge of the plateau and also to the southeast, on the other side of the FKP; in an isolated occurrence 6 kilometres north of the confluence of More and South More creeks; on the west side of More Creek; and on the Lucifer property, north of More Creek. The contact of the conglomerate with the underlying siltstone is sharp, parallel to bedding and appears to be depositional. Clasts are well rounded to angular and include limestone, marble, augite and hornblende-phyric volcanics, basalts and chert. In contrast to the Lower Jurassic conglomerates that contain granite and free quartz, this conglomerate contains augite grains. Tuffaceous sections within the conglomerate contain coarse (0.5 to 2 centimetre) white and pink potassium feldspar laths, that comprise about 5 per cent of the rock.

**FORREST KERR AREA**

The distribution of Upper Triassic rocks in the Forrest Kerr area is controlled by faults. These strata crop out between West Slope and Forrest Kerr faults, east of the Kerr fault in the area south of Downpour creek, and within the Newmont Lake Graben (Figure 2-11). A generalized stratigraphy for the eastern part of the map, after Read et al. (1989), consists of a lowermost predominantly sedimentary succession (uTSs), a medial mafic volcanic succession (uTSv) and an overlying tuffaceous sedimentary succession (uTSvt). Contacts between units are faulted or poorly exposed and, as a result, thickness and overall stratigraphic relations are uncertain. South of Newmont Lake, carbonaceous siltstone and limestone (probably correlative with uTSs) are overlain by volcaniclastic and sedimentary rocks of the Newmont Lake Graben volcanic facies (Figure 2-12). The stratigraphy at Newmont Lake consists of an intermediate to felsic volcanic and sedimentary succession characterized by a medial shallow water limestone. The section is at least 500 metres thick, but neither the base nor top are constrained.

The lowermost Upper Triassic unit consists of a thick package of fine-grained volcanioclastics and sediments that crop out east of the Forrest Kerr fault, in the eastern part of the map. Strata are green to grey massive volcanic wackes and arenites, interbedded black siltstone and argillite and lesser limestone and limy conglomerates. Massive to

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*Photo 2-19. Pyroxene-rich crystal and lapilli tuffs, north east of Hankin peak.*

*Photo 2-20. Well-beded Upper Triassic section of sediments exposed southwest of Arctic Lake, in Mess Creek Valley (viewed north down Mess Creek). Sediments are kinked and gently warped about a northeast-trending axis. Normal faulting has down dropped Lower Jurassic conglomerate against Upper Triassic Stuhini Group sediments to the north. IPSc=Permian limestone; uTSs=Upper Triassic Stuhini Group sediments, A=quartzose sandstone, B=limy, fetid sandstone-siltstone, C= interbedded sandstone and siltstone, D=volcanic conglomerate with potassium feldspar crystal-tuff horizons, lPSc= polylithic quartz-rich volcanic boulder conglomerate.*
thickly bedded volcanic sandstones and poorly sorted lithic wackes consist of up to 80 percent plagioclase, the remaining 10 to 30 percent being 2 to 4 millimetre pyroxene grains and lithic clasts of plagioclase-pyroxene porphyry. Plagioclase crystal tuffs with lapilli to 5 centimetres are intercalated with the wackes east of Forrest Kerr Fault at the headwaters of Downpour Creek. The volcanioclastics are interbedded with thin planar bedded to crudely cross-beded (locally), carbonaceous rusty weathering argillite. The fine-grained sediments contain fossiliferous limy horizons with abundant faunas of Late Triassic, Carnian age and local limy conglomerate beds that contain Late Triassic, Carnian conodonts (C-103682, Appendix 2).

At the south end of the Forrest Kerr map area, east of the West Slope fault, a maroon volcanic conglomerate containing limestone clasts structurally underlies Lower Permian limestone (Figure 2-13). In general appearance and character it closely resembles the Upper Carboniferous conglomerate exposed further west and it has been interpreted by Read et al. (1989) to mark the base of the Stuhini Group. The unit passes structurally downward into an epiclastic unit of interbedded crystal and lapilli tuff, sandstone, volcanic conglomerate and rare amygdaloidal maroon and green plagioclase porphyritic flows. Correlative and interlayered carbonate and calcareous sediments yield Late Triassic, Carnian and Early Norian ages (Read et al., 1989, Appendix 2).

Purple, grey and dark green, massive and plagioclase porphyritic volcanic rocks of the medial volcanic unit (uTsv) underlie the fault block, that is located between the West Slope and Forrest Kerr faults, 2 kilometres northwest of the confluence of the Iskut River and Forrest Kerr Creek. Intercalated with the plagioclase porphyry flows are massive light grey to dark green aphanitic lapilli tuffs and andesite breccias which make up minor though distinctive units. The tuff is massive to stratified with monolithic scoriaceous to aphyric andesite lapilli. Read et al. (1989) suggested a thickness of a few hundred to perhaps several thousand metres for unit uTsv. Green and lesser maroon crowded to sparse-plagioclase porphyritic andesite breccia and flows underlie the area immediately west and east of the Forrest Kerr fault. Euhydroplagioclase phenocrysts range to 30 to 40 percent euhedral white plagioclase and 15 percent chloritized acicular hornblende crystals. Larger euhedral plagioclase phenocrysts are moderately altered to sericite. Finer clinopyroxene grains are euhedral to subhedral, unaltered, and occur both as phenocrysts and in the groundmass. Opaque oxides are abundant as fine disseminations and larger isolated grains. Equant euhedral plagioclase grains have strongly sericitized cores and narrow clear rims. Light green to pink, block and lapilli tuff with lesser plagioclase crystal tuff crop out east of Newmont Lake. Maroon breccias, lahar and well-bedded graded conglomerates are exposed north of Forrest Kerr Creek (Photo 2-21). Near the base of the section black, locally calcareous, silty shale and argillite and greywacke are interbedded with plagioclase porphyry lavas and reworked volcaniclastics consist of angular to rounded green pyroxene porphyry clasts in a pyroxene-rich matrix. At the top of the exposed section green cherty siltstone, grey argillite and greywacke are interbedded with plagioclase and lesser augite crystal tuff horizons and epiclastic rocks.

**NEWMONT LAKE GRABEN VOLCANIC FACIES**

A maroon, hornblende porphyritic volcaniclastic succession with a medial 95 metre thick agglutinated limestone is gently folded into an open, northeast-trending, doubly plunging syncline in the Newmont Lake area (Figure 2-12). These rocks form a distinctive fault-bounded succession, which was difficult to correlate with strata elsewhere. They are fresh in appearance and with the exception of the limestone member, resemble the volcanogenic rocks of the Lower Jurassic Hazelton Group. Previous workers correlated this package with Lower Permian volcanic strata of the Paleozoic Stikine assemblage (Anderson, 1989; Logan et al., 1990a). A U-Pb zircon date of 212.8+4.2/-3.5 Ma (Table 2-1) from felsic flow rocks located high in the stratigraphy of the graben rocks indicates a Late Triassic age for the succession (Figures 2-11 and 2-12).

The stratigraphically lowest rocks are maroon plagioclase, pyroxene, and hornblende-phryic andesite flows (uTsva, uTsvat). Brecciated and massive flows averaging 5 metres in thickness are interbedded with well-bedded interflow clastic rocks west of Newmont Lake. The flows are locally amygdaloidal and generally contain 30 to 40 percent euhedral white plagioclase and 15 percent chloritized acicular hornblende crystals. Larger euhedral plagioclase phenocrysts are moderately altered to sericite. Finer clinopyroxene grains are euhedral to subhedral, unaltered, and occur both as phenocrysts and in the groundmass. Opaque oxides are abundant as fine disseminations and larger isolated grains. Equant euhedral plagioclase grains have strongly sericitized cores and narrow clear rims. Light green to pink, block and lapilli tuff with lesser plagioclase crystal tuff crop out east of Newmont Lake. Maroon breccias, lahar and well-bedded graded conglomerates are exposed north of Forrest Kerr Creek. Associated conglomerates and correlative wackes east of Forrest Kerr Fault at the headwaters of Downpour Creek. The volcanioclastics are interlayered with thin planar bedded to crudely cross-beded (locally), carbonaceous rusty weathering argillite. The fine-grained sediments contain fossiliferous limy horizons with abundant faunas of Late Triassic, Carnian age and local limy conglomerate beds that contain Late Triassic, Carnian conodonts (C-103682, Appendix 2).

Maroon to dark green tuffs and monolithic augite+/-plagioclase phyric fragmental (uTsvat) are best exposed adjacent to the Forrest Kerr linear, north of the bend in Forrest Kerr Creek. Lapilli tuffs containing varicoloured porphyritic volcanic and lesser scoriaceous fragments are interlayered with well-bedded purple to maroon and green, locally graded plagioclase crystal-ash tuffs and fine epiclastics. The tuffs are massive to weakly stratified. Coarse breccias and block tuffs of augite porphyry occur near the top of the succession. Associated conglomerates and reworked volcaniclastics consist of angular to rounded green pyroxene porphyry clasts in a pyroxene-rich matrix. At the top of the exposed section green cherty siltstone, grey argillite and greywacke are interbedded with plagioclase and lesser augite crystal tuff horizons and epiclastic rocks.
Figure 2-13. Major and trace element geochemical plots for Stuhini Group volcanic rocks. Mess Lake facies basalts (inverted filled triangles), Newmont Lake facies andesites mafic (triangles). A) total alkali versus silica (after Irvine and Baragar, 1971); B) AFM plot (after Irvine and Baragar, 1971); C) ternary plot of Nb₂O₅ - Zr - Y (after Meschede, 1986); D) plot of Zr/TiO₂ versus Nb/Y (after Winchester and Floyd, 1977); E) plot of Zr/Y versus Zr (after Pearce and Norry, 1979); F) ternary plot of Ti/100 - Zr - Yₓ3 (after Pearce and Cann, 1973).
The fine laminations are interpreted to be cryptagal in origin (Aiken, 1967) indicative of algal mats and an intertidal zone of deposition for the limestone. We believe this unit is a supratidal equivalent of the more common Upper Triassic carbonate slope deposits of unit uTSc. The variation is due primarily to the different environments in which the carbonate deposits formed.

The algal limestone unit is overlain by at least 230 metres of well bedded tuffaceous epiclastic rocks comprising maroon shallow water conglomerates, siltstone, lapilli and plagioclase crystal tuffs (uTSvs). Discontinuous beds of thinly bedded siliceous limestone up to 5 metres thick are interspersed throughout. These rocks are in turn overlain by more than 100 metres of brownish, grey massive to thick bedded welded andesitic to rhyolitic lapilli and ash tuff and lava flows (uTSvr). The tuffs exhibit good eutaxitic flow laminae and many are columnar jointed. Air-fall tuffs are well-stratified and contain 5 to 10 per cent angular lithic lapilli. Broken grains of otherwise euhedral, blocky plagioclase are moderately to strongly altered to sericite. Some grains are resorbed and have inclusions of devitrified glass. The matrix may either be very dark due to disseminated oxides, or have a eutaxitic texture defined by chlorite lenses to 4 millimetres long. Lithic fragments present typically consist of fine plagioclase porphyries. In one thin section, a lithic fragment was seen with a slightly chloritic, devitrified glass matrix. Chlorite and carbonate are common in the groundmasses of most of the tuffs studied in thin section.

Pink to mauve, flow banded dacite, rhyolite and related ash flow and welded tuffs occur high in the section (Photo 2-23). Crowded fine plagioclase phenocrysts are euhedral, well-zoned, and altered to sericite. Hornblende occurs in some rocks as euhedral oxidized grains that are partially altered to carbonate and sericite. Quartz occurs as equigranular clots with fritted edges that may be secondary. The groundmass is typically fine grained; in places it consists essentially of devitrified glass, which is partly altered to chlorite and minor epidote. Pink, flow banded rhyolite from the core of the Newmont Lake Syncline gave an Upper Triassic, Norian U-Pb zircon date of 212.8+4.2/-3.5 Ma (Table 2-1).

CHEMISTRY OF UPPER TRIASSIC VOLCANIC ROCKS

Chemical analyses of the Late Triassic volcanic rocks was limited due to the preponderance of volcaniclastic rocks with significant epiclastic components. The lava flows are typically coarsely porphyritic and/or amygdaloidal; consequently, there are few that can be adequately sampled. Most of the samples collected are altered (LOI >5%). The Stuhini Group includes tholeiitic to calcalkaline basalts, basaltic andesite, trachybasalts and basaltic trachyandesites in the Stikine River area (Brown et al., 1996) and calcalkaline, high potassium to shoshonitic basalts and basaltic trachyandesites in the Galore Creek area (Logan and Koyanagi, 1994). Mafic alkaline to subalkaline augite phryic lavas and intermediate to felsic plagioclase-hornblende phryic calcalkaline lavas are distinguished in the Forrest Kerr-Mess Creek area.

The two volcanic suites are plotted separately (Figure 2-13). The plagioclase hornblende basalt samples from the Newmont Lake facies are subalkaline basaltic-andesite (SiO2 contents between 53 and 55 per cent) and andesite...
with SiO₂ contents less than 63 per cent. Pyroxene and plagioclase basalt samples from the Mess Lake volcanic facies are transitional subalkaline to calcalkaline basalt and basaltic-andesite. Both suites straddle the subalkaline-alkaline boundary on the alkalis vs. silica diagram, and plot in the calcalkaline field on the AFM diagram (Figure 2-13A and 13B).

Trace element plots provide a useful means of characterizing metamorphosed and hydrothermal altered rocks using relatively immobile trace elements. Volcanic rocks of Upper Triassic age plot as subalkaline, medium-K, calcalkaline basalt to basaltic andesite on the Nb/Y vs. Zr/TiO₂ trace element discrimination diagram (Figure 2-13D). The Newmont Lake suite is more evolved than the Mess Lake suite. The Ti-Zr-Y diagram (Pearce and Cann, 1973) in Figure 2-13F discriminates within-plate basalt from those extruded along plate margins. The Stuhini Group basalt samples plot in the calcalkaline island-arc basalt field on this diagram and on the Nb-Zr-Y diagram of Meschede (1986) in fields typical of subduction-generated lavas formed at plate margins. On the Zr/Y vs. Zr plot of Pearce and Norry (1979) the more evolved Newmont Lake rocks occupy the within plate basalt field (Figure 2-13E).

Eight samples, four from each of the two Late Triassic volcanic suites are plotted on a mid-ocean ridge basalt normalized discrimination diagram (Figure 2-14; after Pearce, 1996). The fields for both suites display patterns typical of volcanic arc lavas, with strong enrichment in lithophile elements (Sr, K, Rb and Ba) and a negative slope of the Nb, Ce and Zr trend. The elevated concentrations of Nb and Zr, but lower Ti and Y abundance’s relative to N-MORB are characteristic of calcalkaline and high-potassium calcalkaline volcanic arc basalts. Missing from this pattern is the significant negative Nb anomaly with respect to Th (La) and Ce that is a key characteristic of all volcanic arc basalts (Pearce, 1996). The negative Ti anomaly (with respect to Zr and Y) in the Newmont Lake suite reflects the increased fractional crystallization and higher silica content of this suite. Alkaline plutons and syenite bodies are clearly comagmatic with the uppermost Late Triassic volcanics at Galore Creek. Coeval intrusive and subvolcanic bodies in the area range in composition from diorite through monzonite to granodiorite and the more highly fractionated extrusive phases like the Newmont Lake suite should be prevalent. Anderson (1993) describes bimodal and intermediate volcanic rocks in the younger, Norian assemblages of his western and eastern Stuhini facies in the Iskut River area.

PALEOENVIRONMENTAL INTERPRETATIONS

Triassic strata include; a rare package of thin-bedded siltstone and chert of Lower to Middle Triassic age, and a thick volcano-sedimentary succession of Upper Triassic Stuhini Group rocks. The Upper Triassic rock package consists of a Carnian to Norian predominantly sedimentary facies, east of More Creek and farther west, two Norian volcanogenic facies, at Mess Lake and Newmont Lake. Upper Triassic to Early Jurassic (Sikline and Copper Mountain plutonic suites, Woodsworth et al., 1991) volcano-plutonic centres are known at Zippa Mountain, Galore Creek and Mess Creek (Hickman and Nightout plutons), but the polarity of the arc is unknown.

The Lower Triassic record is poorly represented in the western Cordillera, and whether from non deposition or subsequent erosion, it remains uncertain. Early and Middle Triassic silty shale and cherty siltstone paraconformably overlie Early Permian limestone in the Galore Creek area (Logan and Koyanagi, 1994) and isolated Middle Triassic cherts are structurally interleaved with Upper Triassic sediments in the More Creek area. These cherts and fine-grained clastic rocks are deep-water slope deposits, indicating a slow sedimentation rate during the Early to Middle Triassic.

Upper Triassic fine grained clastic rocks and alternately coarse conglomerates unconformably overlie Early Permian rocks east of Mess Creek and at Forrest Kerr Creek, suggesting a period of non deposition or uplift and erosion.

Fine grained clastic sedimentation continued in the eastern part of the map area where Carnian thin bedded
black and green cherty siltstone and feldspathic sandstone with rare intraformational conglomerate characterize the lower sections of the More Creek sedimentary facies. They are interlayered with and overlain by thin limestone beds of Carnian and Norian ages. Pyroxene phryic volcaniclastic and well bedded epiclastics interbedded with Norian limestone occupy the highest stratigraphic position in both the Mess Creek volcanic facies and the More Creek sedimentary facies. Rare, but distinctive tuffaceous horizons containing coarse pink and white potassium feldspar laths are also present near the top of the stratigraphic section. The lithic and crystal content of these sedimentary and tuffaceous flank deposits reflect the same dominant phenocryst composition and stratigraphy as the volcanic pile at Galore Creek (Logan and Koyanagi, 1994), where hornblende-plagioclase andesite is overlain by sediments and pyroxene porphyritic lavas and an upper unit of orthoclase-rich flows and tuffs. Basaltic, calcalkaline volcanism began in the early Carnian and continued into the latest Rhaetian or Early Jurassic time. At Schaft Creek, the Mess Creek facies deposits are primarily submarine, massive augite and plagioclase phryic basalt and rare pillow flows, breccias and coarse conglomerates that are intruded by subvolcanic plagioclase phryry feeders and the coeval Hickman pluton. Volcanics are subalkaline to calcalkaline, with subvolcanic plagioclase porphyry feeders and the coeval Yehiniko dikes associated with the Middle Jurassic Yehiniko Formation. At these locations Jurassic rocks were sampled for radiolarian. The conglomerate grades upward into poorly sorted, more juvenile conglomerate, then into massive carbonate conglomerate with a siliciclastic matrix. The 4 to 5 metre boulders are well-rounded and consist of Mesozoic reefoid limestone. Rare interbedded limestone and sandstone lenses up to a metre thick in the conglomerate unit were sampled for radiolarian. The conglomerate grades upward into poorly sorted, more juvenile conglomerate, then lapilli tuff. The top of the unit is cut off by a major north-trending, west-dipping listric fault. Quartz-rich maroon breccia is found along the entire length of the fault and is probably crushed conglomerate.

The largest exposure of Lower Jurassic conglomerate crops out in a 2 to 2.5 kilometres wide belt east of Mess Creek that extends north from south of Arctic Lake to Nahta Lake (Figure 2-15). At the northern end of this exposure, conglomerate overlies volcanic rocks of the Stuhini Group with structural conformity, however, farther south they unconformably overlie Late Triassic plagioclase hornblende porphyritic monzodiorite of the Loon Lake Stock (unit LTrmz, GS-Map). The conglomerate is at least 250 metres thick (Figure 2-16). In general, the lowermost sections are maroon, well-bedded, immature, volcanic-derived conglomerates. In places they are graded and consist almost entirely of maroon plagioclase-phryic andesite clasts in a plagioclase-rich groundmass; rare pyroxene-phryic andesite clasts also occur. Up section, quartz and potassium feldspar grains and granite clasts appear then increase in abundance. Granite clasts are more common in the conglomerate southwest of Arctic Lake (Photo 2-24). Coarse carbonate boulder layers are prominent within the unit in the Mess Lake area, as well as a 2 metre thick cobble and pebble carbonate conglomerate with a siliciclastic matrix. The 4 to 5 metre boulders are well-rounded and consist of Mesozoic reefoid limestone. Rare interbedded limestone and sandstone lenses up to a metre thick in the conglomerate unit were sampled for radiolarian. The conglomerate grades upward into poorly sorted, more juvenile conglomerate, then lapilli tuff. The top of the unit is cut off by a major north-trending, west-dipping listric fault. Quartz-rich maroon breccia is found along the entire length of the fault and is probably crushed conglomerate.

West of Mess Creek, Lower Jurassic rocks rest with angular unconformity on volcanics of the Upper Triassic Stuhini Group. East of the Schaft Creek porphyry deposit, on Mount LaCasse (Figure 2-15), the Jurassic unit comprises conglomerate with equal proportions of well-rounded crowded plagioclase porphyritic andesite and aphyric basalt clasts, that is interbedded with coarse sandstone containing high proportions of quartz and potassium feldspar. The conglomerate overlies propylitically altered pyroxene phryic volcanics. The nature of the contact is uncertain, but the conglomerate appears to occupy a fault-bounded graben. The conglomerate itself is pervasively epidotitized. Alteration is due in part to its permeability and probably related to dike swarms associated with the Middle Jurassic Yehiniko pluton.

LOWER JURASSIC

Lower Jurassic sedimentary strata are exposed between Arctic Lake and Mess Creek (Souther, 1972) where they comprise a north-trending belt about 35 square kilometres in size. The strata are well-bedded granite and quartz clast-bearing conglomerates that are preserved in a series of listric fault blocks. North of Arctic Lake, the basal conglomerate of the Lower Jurassic succession rests on Upper Triassic Stuhini Group volcanic rocks in apparent conformity. Additionally, Lower Jurassic sedimentary rocks form small erosional remnants in the northeast corner of More Creek map area, above the Schaft Creek deposit and along the eastern edge of Mess Creek (Figure 2-15). At these locations Jurassic strata unconformably overlie Stuhini Group volcanic rocks. A similar angular unconformity between Upper Triassic Stuhini Group and Lower Jurassic strata is recognized in the Yehiniko Lakes area (Brown and Greig, 1990) and in the Sulphurets area (Henderson et al., 1992). Lower Jurassic sedimentary rocks of the Jack Formation also unconformably overlie the Upper Triassic Stuhini Group in the Sulphurets area. The Jack Formation is a fining upwards marine sequence, characterized by a granitoid-bearing basal conglomerate overlain by fossiliferous limy sandstone (Hettangian-Sinemurian age) and siltstone, in turn overlain by dark carbonaceous mudstone and lesser interbedded turbiditic sandstone (Henderson et al., 1992). In the Mess Creek area the Lower Jurassic unit consists entirely of coarse clastic and conglomerate beds.
Moderately south-dipping Jurassic conglomerates rest unconformably on steeply dipping Upper Triassic pyroxene-phyric flows and volcaniclastics in a second exposure 3 kilometres south of the Shaft Creek deposit (Figure 2-15). The section consists of 20 metres of quartz and feldspar crystal and lithic tuff overlain by 90 metres of quartz-bearing polymictic volcanic conglomerate. The lower zone is a pale maroon, pink-weathering feldspar and quartz-eye crystal-lapilli tuff. Upper contacts are gradational and conformable with the conglomerate. The sediments are well-bedded granule or weakly stratified to massive boulder conglomerates and lesser sandstones. Clasts are generally subangular purple, maroon and green plagioclase and/or pyroxene-phyric andesite. Epidotized clasts are common and clasts of the underlying quartz feldspar crystal tuffs are most abundant near the base of the conglomerate.

Sedimentary rocks of probable Lower Jurassic age form an erosional outlier within Triassic rocks north of Hank Creek, about eight kilometres northeast of Hankin.
Peak (Souther, 1972). The strata consist of well-bedded grey siltstones interbedded with buff-weathering, cross-stratified sandstones and disconformably overlie Upper Triassic maroon, hornblende and plagioclase porphyritic andesitic-basalt volcaniclastic and epiclastic rocks (Photo 2-25). The sediments are flat-lying to gently inclined and unconformably overlie the moderately dipping, steeply foliated maroon volcaniclastic beds. The sandstones are arkosic, but also contain fine lithic volcanic rock fragments. Bed thickness varies from less than 0.5 metre up to 5 metres and comprises a general fining upward sequence from coarse sandstone to siltstone to carbonaceous shale.

LOWER TO MIDDLE JURASSIC HAZELTON GROUP

The Hazelton Group has been divided into four or five formations in the Iskut River area (Grove, 1986; Alldrick and Britton, 1988; Anderson and Thorkelson, 1990), which include the Lower Jurassic volcanogenic rocks of the Unuk River, Betty Creek and Mount Dilworth formations and the Lower to Middle Jurassic sedimentary and volcanic rocks of the Salmon River Formation. Inadequate age-dating, abrupt facies changes and attempts to correlation volcanic and sedimentary stratigraphy over long distances from type sections has led to confusion and overlapping formational designations. A recently enlarged biostratigraphic and geochronological data base for the north-central Iskut River area indicates that there are five lithological units in the Hazelton Group ranging from early Lower Jurassic to mid Middle Jurassic time (Lewis et al., 1993; Macdonald et al., 1996). Regional mapping supported by geochronology has recognized Hazelton Group volcanic rocks as far north as Yehiniko Lake (Brown et al., 1996). Refinement to and redefinition of the Salmon River Formation (Anderson and Thorkelson, 1990; Anderson, 1993) to include only upper Lower Jurassic and lower Middle Jurassic strata and exclude younger Bowser Lake Group strata, focuses on the economic importance of the upper member (viz. Eskay Creek facies).

Hazelton Group rocks underlie most of the 300 square kilometre area south of More Creek and east of Forrest Kerr fault (Figure 2-15; Souther, 1972; Read et al., 1989). In general, the Lower to Middle Jurassic stratigraphic sequence comprises a lower package of dominantly siltstone and sandstone, a middle package of massive rhyolitic and intermediate volcanic rocks, and an upper package of siltstone, pillow basalt and related tuff and breccia. Strata of the lower and middle packages occur mainly north of Downpour Creek and on GS-Map (in back pocket) comprise the Unuk River, Betty Creek and Mount Dilworth formations. Sedimentary rocks of the upper package underlie the area located between Downpour and More creeks. The overlying volcanic rocks occupy fault-bound slivers extending south of Downpour Creek to the Iskut River. Sedimentary and volcanic strata southeast of Forrest Kerr Creek are assigned to the Salmon River Formation as defined by (Anderson and Thorkelson, 1990).

The stratigraphically lowest, but structurally highest Lower Jurassic rocks occur northeast of Downpour creek (Figure 2-15 and 2-17). There more than 200 metres of massive and thin-bedded black siltstone and minor sandstone (IJHs1) are conformably overlain by at least 50 metres of tan to rusty-weathering sandstone and minor pebble conglomerate (IJHs2). These sediments are conformably overlain by a resistant volcanic succession consisting of rhyolite (IHR) and andesitic flows and tuffs (IHRv); (Photo 2-26). The rhyolitic rocks are about 120 metres thick and consist of a basal welded ash-flow tuff and an upper flow-layered, aphyric, white and rusty weathering rhyolite flow. The ash-flow tuff contains pale green aphanitic and finely flow-layered lapilli, which are generally 3 to 6 millimetres in size, in a white to pale grey siliceous matrix. In thin sec-
tion, the ash-flow tuff is devitrified with an overall cherty texture in cross polarized light. In plane light, with the diaphragm nearly closed, relict glass shards and collapsed pumice are visible and impart a eutaxitic texture. The exact contact relationship of the ash-flow tuff with the overlying flow-layered rhyolite is not exposed, but it appears to be conformable. Pebble conglomerate adjacent to the rhyolite and up to 5 metres above is intensely silicified and has a characteristic pale bluish-green hue. The conglomerate is unaltered where it is in apparent fault contact with the rhyolitic rocks. Souther (1972) mapped these rhyolitic rocks as Late Cretaceous to Tertiary dikes. However, because they are pyroclastic at least in part, they are herein interpreted as a Jurassic extrusive unit. Silicification of adjacent sedimentary rocks may be due either to primary synvolcanic or secondary hydrothermal fluid circulation, or both.

About 10 to 20 metres of fossiliferous sandstone, conglomerate, and a variety of green, thin-beded tuffs and tuffaceous sediments (included with JHsn) overlie the rhyolitic rocks. The sediments and tuffs have rapidly changing inclinations, apparently due to faulting and folding. An ammonite from this horizon returned a mid-Lower Jurassic (Sinemurian) age (Poulton, 1991).

The rhyolite unit and adjacent sediments are overlain by andesitic, maroon, plagioclase phyric flows, breccias and tuffs (JHv). These volcanic rocks were originally mapped by Souther (1972) as Late Triassic in age. However, their stratigraphic position indicates they are Lower Jurassic, unless contact relationships with the underlying sediments are structural. Poorly formed pillows occur in the andesite. The rocks weather maroon-grey and contain about 30 per cent euhedral, felted plagioclase phenocrysts. Debris flow deposits greater than 30 metres thick contain subrounded clasts of green-grey aphyric to plagioclase phyric andesite in a maroon matrix and overlie the pillowed and fragmental rocks. These grade upward into a thick sequence of massive to poorly bedded dark green-grey and reddish-grey andesitic tuffs. Most fragments have narrow rims that weather to a lighter shade of grey. The green-grey tuffs contain about 30 to 40 per cent euhedral, equant plagioclase phenocrysts. Plagioclase in both the matrix and the fragments is euhedral with resorbed margins and abundant devitrified glass inclusions. Larger lapilli have euhedral plagioclase set in chloritic devitrified glass with finer plagioclase microlites. Sparse augite phryic fragments contain 10 to 15 per cent completely chloritized clinopyroxene and 30 to 40 per cent, much finer, equant plagioclase phenocrysts. Similar tuffs and augite phryic flows crop out on the ridge between Carcass and Downpour.
creeks (west-side of the syncline), in the vicinity of the Lower Jurassic fossil locality of Read et al. (1989).

Several isolated outcrops of thin-bedded siltstone and sandstone, conglomerate, felsic tuff, and flow-layered rhyolite occur on both the east and west sides of More Creek a few kilometres north of the confluence with the south fork (Figure 2-15). Lithology suggests that these rocks correlate with Units lJHsn and lJHr. On the west side, moderately west-dipping, white weathering, resistant rhyolite breccias and tuffs overlie thin-bedded deformed sediments. The felsic rocks are well-stratified and graded; tuffs contain pink, and tuffs overlie thin-bedded deformed sediments. The west-dipping, white weathering, resistant rhyolite breccias with Units lJHsn and lJHr. On the west side, moderately few kilometres north of the confluence with the south fork this study, correlate these volcanic rocks with the Lower Jurassic Hazelt Group.

The core of the Downpour syncline is underlain by three packages of fine grained clastic rocks and subordinate interlayered volcanic rocks (Figure 2-17). All are intergradational. There is no continuously exposed section in which to measure thickness and the units are tightly folded and faulted. The structurally and presumably stratigraphically lowest rocks consist of black graphitic and pyritic shale and thin bedded, alternating grey siltstone and orange-weathering sandstone. The sandstone layers are often boudinaged and transposed along bedding parallel shear planes. Interlayered volcanic rocks include mafic pyroxene porphyry flow breccia and tuff, and felsic plagioclase crystal tuff and epiclastic rocks. A Late Aalenian or late Early Aalenian ammonite *Tnetoceras* sp. (C-189785, Appendix 1) was collected from a tuffaceous sandstone layer low in the sequence.

Vesicular, columnar-jointed, basaltic-andesite sills and breccia flows, tuffaceous layers and volcanogenic sandstone units characterize the medial package of rocks. Sill and flow margins have peperitic textures characteristic of intrusion into or extrusion over water saturated sediments. Individual sills and flows vary to as much as 10 metres in thickness. The sedimentary units include calcareous olive to buff sandstone and light grey siltstone; carbonate plant material is common in coarser-grained beds of the sandstone. Numerous lenses of crystal tuff and lapilli tuff from about 5 to 30 metres thick are interbedded with the sedimentary strata. The lapilli tuff contains mainly pale grey rhyolitic fragments that average 1 centimetre in diameter. The crystal tuffs are typically maroon weathering and contain up to 30 per cent plagioclase crystal fragments averaging 2 to 4 millimetres in size; finely vesicular basaltic lapilli to 7 millimetres in size are common. These intermediate volcanioclastic rocks are lithologically similar to Lower Jurassic volcanic units (lJHv and lJHr); they were included with them during mapping and are shown as such on the GS-Map (in back pocket). Aalenian to pre Bajocian ammonoid-bearing sediments constrain bimodal volcanism in the Treaty Glacier area (Lewis et al., 1993) and at Eskay Creek. U-Pb zircon ages ranging from 181 to 173 Ma attest to a distinct younger and separate volcanic episode post-dating Early Jurassic, Mount Dilworth eruption and predating deposition of the Bowser Lake Group sediments. In retrospect the volcanioclastic rocks of the medial package probably belong to this Middle Jurassic episode. Interbedded with the tuff and siltstone are rare sandy lime-
stone units. Souther (1972) reports Middle Jurassic, Bajocian fossil ages for strata of this division.

The upper package of sediments includes dark green to olive coloured siliceous siltstone and sandstone interlayered with coarse granule conglomerate and fossiliferous limestone. Strata adjacent to the Forrest Kerr Fault are intruded by gabbro sills, which, in weathered outcrop, have the concentric appearance of pillowed lava. Alight grey, sandy, fossil-rich limestone contains belemnoid, pelecypod, gastropod and bivalve species indicative of a probable Bathonian age (C-189770, Appendix 1). Thin bedded, orange and grey weathering limy sandstone and pyritic siltstone of the lower and upper packages are similar in age and lithology to the Ashman Formation. However, intercalated volcanic rocks distinguish them from the basal unit of the Bowser Lake Group.

**Upper Eskay Creek Facies**

Middle Jurassic pillow and flow-breccia basalts of the upper member of the Salmon River Formation underlie a large area between Forrest Kerr Creek and the Iskut River, south of the bend in Forrest Kerr Creek (Figure 2-15). Smaller fault-bounded slices extend north to More Creek, where they conformably overlie and are intercalated with shale and siltstone of unit mJHs1.

Between Forrest Kerr Creek and the Iskut River, the volcanic succession comprises up to 2,000 metres (Read et al., 1989) of predominantly pillowed lava flows and scoriaceous lapilli-tuff breccia (Figure 2-17, Photo 2-27). Pillows average 30 to 100 centimetres in size and are well-preserved; flow tops and facing directions are easily recognized (Photo 2-28). Outcrops weather dark brown to
Figure 2.18. Major and trace element geochemical plots for Salmon River Formation pillow basalt (filled triangles) and a subvolcanic diorite sill (filled square). A) total alkali versus silica (after Irvine and Baragar, 1971); B) AFM plot (after Irvine and Baragar, 1971); C) ternary plot of Nbx2 - Zr/4 - Y (after Meschede, 1986); D) plot of Zr/TiO2 versus Nb/Y (after Winchester and Floyd, 1977); E) plot of Zr/Y versus Zr (after Pearce and Norry, 1979); F) ternary plot of Ti/100 - Zr- Yx3 (after Pearce and Cann, 1973).
orange. Flow breccias are interbedded with the pillowed flows and locally scour and disrupt interflow sediments. Pillow basalts and hyaloclastite-flow breccias comprise greater than 90 per cent, and fine-ash tuff and siltstone less than 10 per cent of this unit. White and grey siliceous argillite or tuff and pyritic siltstone are interbedded with the basalts. Grey and khaki siliceous siltstone, conglomerate and tuff (unit JHtw, GS-Map) overlie and interfinger with the pillow basalt. Subvolcanic gabbroic sills and dikes intrude the volcanic pile. Their mineralogy and textures are similar to those in pillows and clasts in brecciated extrusive rocks and likely represent feeders to them.

South of More Creek, at the confluence of its north and south forks, approximately 200 metres of mainly dark grey, fine-grained, aphyric basaltic rocks with minor interbedded graphitic and pyritic siltstone of the Salmon River Formation crop out. Although the basaltic volcanic rocks structurally underlie folded siltstone, they may overlie them stratigraphically. An ammonite was collected from interbedded tuffaceous sandstone near the stratigraphic top(?) of the volcanic sequence that yielded an early Middle Jurassic (Aalenian) age (Poulton, 1991). Flows dominate, but local coarse fragmental rocks, similar to basaltic hyaloclastite in the pillowed successions, also occurs. Fragments are mainly scoriaceous and lapilli to block-size. The volcanic rocks are generally dark grey but, where pyritized, are bleached to light grey. In the middle of the package a 10 metre thick sequence of thin, alternating black siltstone and white tuff is interbedded with massive to thick-bedded basaltic fragmentals. These tuffaceous sediments resemble the ‘pajama bed’ rocks of the Troy Ridge Facies of the Salmon River Formation (Anderson and Thorkelson, 1990). In thin section, the darker layers are finely laminated and finer grained than the lighter layers, which are granular and appear to consist of fine lithic fragments (basalt?) and rare angular, anhedral clinopyroxene grains.

The basalt is dense, amygdaloidal and consists almost entirely of fine-grained vitreous plagioclase crystals, rare pyroxene phenocrysts and abundant disseminated pyrite in a fine groundmass. In thin section, felty, acicular plagioclase laths form an open intersertal texture with dark iron oxide stained devitrified glass and variolitic intergrowths of clinopyroxene and plagioclase. In other thin sections, an intergranular texture with randomly oriented, interlocking, subhedral grains of plagioclase occurs and clinopyroxene is more common.

Alteration is mainly low grade. Calcite, chlorite, chaledonitic quartz, and rare epidote line vesicles. Prehnite+quartz+chlorite+albite assemblages occur in thinly bedded, intraflow volcanic siltstones and tuffs. Radiating and “bow-tie” structures of prehnite (Photo 2-29) are similar to the “crystallites” described at Eskay Creek (Ettlinger, 1991). Although, north of the Iskut River, these mineral assemblages are not associated with known mineralization. Locally, plagioclase laths and microlites in the groundmass are altered to sericite. Chlorite pseudomorphs clinopyroxene.

CHEMISTRY OF THE SALMON RIVER FORMATION BASALT

Two analyses of relatively unaltered Middle Jurassic pillow basalt from the Forrest Kerr area are plotted in Figure 2-18. Although the basalts are aphyric, they are typically

Photo 2-28. Outcrop exposure of well preserved pillow-forms indicating bedding tops are upright, viewed northward.

Photo 2-29. Thin-section showing prehnite as radiating and “bow-tie” structures, quartz and chlorite mineral assemblage characteristic of the low grade metamorphic alteration of this intraflow siltstone. Width of slide is approximately 2 centimeters.
strongly vesiculated, and this limited sampling. The rocks are relatively homogenous, at least in texture and mineralogy, and the two samples collected are probably sufficiently representative for the purposes of classification. The lavas are basaltic, with subalkaline tholeitic compositions, and lie on an iron enrichment trend on the AFM diagram (Figure 2-18A and 18B). They plot as subalkaline basalts (Figure 2-18D) on the trace element plot of Winchester and Floyd (1977) and are transitional between N-MORB and P-MORB (Figure 2-18C) on the Nb-Zr-Y plot of Meschede (1986). In addition, they plot as mid ocean ridge basalts (Figure 2-18E) on the trace element discrimination diagram of Pearce and Norry (1979). On the ternary trace element plot of Pearce and Cann (1973) the two samples occupy either the ocean floor basalt or low potassium tholeite or unlikely the calcalkaline arc basalt field (Figure 2-18F).

Trace elements other than Ba and the potassium group elements (K, Rb, Sr) are only slightly enriched relative to MORB (Figure 2-19). Their stratigraphic position and lithology corroborates a back-arc depositional environment. These rocks are comparable to back-arc rocks described by Donato (1991).

LOWER(?) AND MIDDLE JURASSIC

Unnamed Lower(?) and Middle Jurassic tuffs, siliceous wackes and conglomerates (Read et al., 1989; unit Jw GS-Map) overlie Upper Triassic Stuhini Group rocks and Middle Jurassic rocks east of Forrest Kerr fault. There are rare limestone lenses but the paucity of datable fossils precludes assigning a more precise age to these rocks. The conglomerate horizons contain volcanic, plutonic and sedimentary clasts of apparent Jurassic age and local derivation.

Strata of this unit crop out at the southern edge of the map area between Iskut River and Forrest Kerr Creek, northwest of the Iskut River 18 kilometres upstream from its confluence with Forrest Kerr Creek, and as a fault-bounded wedge east of Forrest Kerr fault near the northern edge of the map area (Figure 2-15). The rocks are characteristically drab olive to grey in colour, unlike the maroon and dark green colours typical of Upper Triassic Stuhini Group rocks, and are commonly fractured and brecciated. Dark green and grey siliceous siltstones and pyritic cherts are cracked and brecciated in-situ, forming subangular to angular centimetre-scale fragments. Tuffaceous wackes are carbonaceous and variably sheared. Interbedded with the tuffaceous arenites are sedimentary conglomerates containing clasts of chert, black siltstone and intermediate to felsic volcanics. Volcaniclastics are characteristically brownish-grey lapilli and crystal tuffs comprised of euhedral plagioclase and green and grey scoriaceous fragments. The contact with the Middle Jurassic Bowser Lake Group is conformable, therefore parts of the section are upper Salmon River Formation, Eskay Facies.

Paleoenvironmental Interpretations

The Lower to Middle Jurassic Hazelton Group is a volcano-sedimentary succession characterized by a variety of different facies and stratigraphic units (Tipper and Richards, 1976; Marsden and Thorkelson, 1992). Volcanic strata in the study area reflect proximal, distal, submarine and subaerial environments of deposition as well as arc and back-arc characteristics (Anderson, 1993). In the Telegraph Creek area, Lower Jurassic basal conglomerate overlies Upper Triassic volcanic and plutonic rocks with angular unconformity. The uplift and erosional event that led to conglomerate deposition preceded initiation of Hazelton volcanism. Basaltic to bimodal volcanism began in the lower Sinemurian and continued until Bajocian time. The deposits are widespread and consist predominately of subaerial flows and welded tuffs of basaltic to rhyolite compositions. The volcanism probably built stratovolcanoes (Alldrick, 1989). Interbedded with the volcanic breccia and subaerial welded tuffs north of Downpour Creek are marine deposits of greywacke and siltstone containing Sinemurian to Bajocian ammonites and bivalves. Volcanism and marine deposition were contemporaneous and reflect an emergent island-arc setting during this period. The volcanics are calcalkaline to tholeiitic, have a strong arc signature and show little evidence of continental influence. The youngest volcanic rocks, in the Eskay Creek facies of the Salmon River Formation, consist of a submarine package of fine clastic sediments and a pile of felsic and mafic pillow lava. These volcanic rocks are different, and are probably rift-related lavas formed in either a back-arc or forearc setting. The facies variations from west to east of the Salmon River Formation suggest an west-facing arc in the Lower to Middle Jurassic (Anderson, 1993). The youngest volcanogenic rocks are conformably overlain by black siltstone of the basal Bowser Lake Group.

MIDDLE TO UPPER JURASSIC BOWSER LAKE GROUP

ASHMAN FORMATION

Middle Jurassic to mid-Cretaceous marine and nonmarine clastic rocks of the Bowser Basin comprise the Bowser Lake Group (Tipper and Richards, 1976; Cookenboo and Bustin, 1989). Sediments that form the northwestern edge of the Bowser Basin crop out along the eastern edge of the map area along the flanks of the Iskut River valley (Figure 2-15). Souther (1972) recognized shal-
low water facies-equivalent strata as far west as Mess Creek. Evenchick (1991c) mapped the Bowser Lake Group rocks in the east Telegraph Creek and southwest Spatsizi areas and concluded that the western exposures of the Bowser Lake Group in these areas were all Ashman Formation. They have the same marine character as the Ashman further east in the Spatsizi area, and she (Evenchick, 1991c) concluded that a western depositional margin to the Bowser Basin was not evident in this part of the Telegraph Creek area. The Ashman Formation is predominantly black siltstone and very fine grained sandstone and contains marine fossils. It includes thin orange weathering calcareous siltstone and claystone beds, and grey weathering lenses and discontinuous sheets of chert pebble conglomerate (Evenchick and Thorkelson, 1993).

South of the Iskut River, in the southeast corner of the map area, planar-bedded shale and locally cross-bedded sandstone couplets dominate but are interbedded with local granule conglomerate. The conglomerate beds are thin, lensoidal bodies containing quartz and siltstone clasts in a limonitic sandy feldspathic matrix. They weather grey to rarely rusty. The argillites have a well-developed pencil cleavage and locally contain pressure solution quartz veinlets. These grey shales and siltstone are of late Middle Jurassic (Callovian) age and are correlated with the Ashman Formation of the Bowser Lake Group (Read et al., 1989).

West of the Iskut River the lithologies consist mainly of fine to medium-grained sandstones containing 10 to 15 per cent detrital quartz and fine siltstone.

In the area south of the east-flowing segment of More Creek and north of Downpour Creek, there is a package of Lower and Middle Jurassic black clastic sediments (unit 14 of Souther, 1972). The unit consists dominantly of black and brown planar laminated siltstone, siliceous siltstone, sandstone which resemble Ashman Formation strata, but include mafic, intermediate and felsic volcanic flows and tuffs. The strata range in age from Bajocian to Bathonian and are correlated with the Salmon River Formation of the Hazelton Group (see above).

PALEOENVIRONMENTAL INTERPRETATIONS

The middle Jurassic to Cretaceous Bowser Lake Group in the Telegraph Creek area is entirely marine (Evenchick, 1991c). The predominantly black siltstone and fine sandstone, thin orange weathering calcareous siltstone and pebble conglomerate of the basal Ashman Formation were probably deposited in submarine channel and slope environments (Green, 1991; Ricketts and Evenchick, 1991). The basin developed on Stikinia within the confines of the Stikine Arch and the Skeena Arch. Paleocurrent directions and structural trends indicate sediment sources from the north, east and south (Eisbacher, 1981).

UPPER CRETACEOUS TO TERTIARY SUSTUT GROUP

Small isolated remnants of Sustut Group sediments (Unit uKSs, GS-Map) are preserved in downfaulted blocks on Exile Hill and north of Nagha Creek (Figure 2-20; Souther, 1988). On Exile Hill, they consist of well-bedded,
pale green weathering and friable carbonaceous siltstone, quartzose sandstone and polylithic chert-granule conglomerate and rest unconformably on Early Mississippian diorite of the More Creek Pluton. The conglomerates are poorly sorted, well-bedded and matrix supported. Granitic, aphyric volcanic, chert and quartz clasts comprise roughly equal proportions of the conglomerate. Granitic clasts are hornblende biotite granodiorite, quartz eye porphyritic granite, hornblende diorite and potassium feldspar megacrystic monzonite. Volcanic clasts include pink flow banded rhyolite and pale green and grey intermediate and felsic flows. White vein quartz and light coloured chert and siltstone clasts are conspicuous components of the conglomerate. The sandstones are limonitic, well consolidated units. Weathering (exfoliation) produced bowling ball-sized sandstone spheres that lie at the base of the sandstone outcrops. All sediments of the unit are limonitic, closely fractured and veined by calcite at the north end of Exhile Hill.

**PALEOENVIRONMENTAL INTERPRETATIONS**

Nonmarine Upper Cretaceous to Tertiary conglomerate and sandstone units of the Sustut Group Strata accumulated in response to tectonism and uplift in the eastern Coast Belt. Strata were deposited in fluvial and alluvial fan type settings, which are preserved in a narrow northwest trending belt, that extends from the Stikine River south to Takla Lake. The basal Tango Creek Formation generally rests unconformably on Bowser Lake Group sediments. Sandstone, mudstone and conglomerate of the Tango Creek Formation are believed to have been deposited by two major river systems flowing south and southwestward (Eisbacher, 1981). It is overlain conformably by conglomerate and tuff of the Brothers Peak Formation in the Spatsizi River area (Evenchick and Thorkelson, 1993). Coarse thick conglomerate of the Brothers Peak Formation unconformably overlies Triassic rocks in the Stikine canyon area (Read, 1983), and rests with angular unconformity on Upper Triassic and Lower Jurassic volcanic rocks on Strata Mountain and Mount Helveker (Brown et al., 1996). The dominant clastic input in the northern part of the basin during deposition of the Brothers Peak Formation was from the west (Gabrielse et al., 1992). At Mess Creek, Kerr (1948a) recognized a progression from mainly foliated schist, slate and volcanic rock clasts in the lower beds to predominantly granitic rocks in the upper parts of the section and suggested the uplift and erosion, culminated in unroofing Paleozoic and Mesozoic plutonic rocks.

**PLIOcene**

**NIDO AND SPECTRUM FORMATIONS**

Subaerial flows of aphyric and olivine-phryic basalt with intercalated fluvial gravel of the Nido Formation (unit TNb, GS-Map) and peralkaline rhyolite flows of the Spectrum Formation (unit TSr, GS-Map) underlie the Arctic Lake plateau area. These are Quaternary members of the Mt. Edziza Volcanic Complex on the eastern border of the map area (Figure 2-20). These Pliocene rocks were not examined in detail because they were mapped by Souther (1988, 1992) at a scale of 1:50 000. The reader is referred to ‘The Late Cenozoic Mount Edziza Volcanic Complex’ (Souther, 1992) for detailed stratigraphic, petrographic and chemical descriptions of these formations as well as the entire volcanic complex.

In the map area, the Nido Formation unconformably overlies carbonate, intrusive and volcanic rocks of the Paleozoic Stikine assemblage and also Upper Cretaceous sedimentary rocks. It is intruded by feeders to, and overlain by the Spectrum Formation at Exhile Hill (Cross section E-F, GS Map; Figure 2-20). Exhile Hill is a small satellite eruptive centre of the main Spectrum cauldara, which is inferred to be centred on Yeda Peak, about 7 kilometres to the northwest. The Spectrum Formation rocks intrude flat-lying basalt of the Nido Formation and extrusive equivalents cap the top of Exhile Hill. Flows in both formations are essentially flat lying. The two formations are separated by a thick layer of gravel that is composed almost entirely of Spectrum rhyolite and obsidian (Souther, 1992). At this same locality, an intraflow cobble conglomerate layer occurs between flows of the Nido Formation.

**QUATERNARY**

**ARCTIC LAKE FORMATION**

Flat-lying, columnar jointed basaltic flows (unit Qb, GS-Map) underlie the plateau north and south of Arctic Lake and crop out at the north end of More Creek. The flows occupy north-trending valleys in the area and extends for about 10 kilometres south from Arctic Lake. Small outliers cap ridges in the Mess Lake area and one flow crops out on the floor of Mess Creek valley (Figure 2-20). The distribution of flows indicates that the paleosurface was similar to the present topography. They unconformably overlie Late Paleozoic diorite of the FKP, polydeformed layered rocks of unknown age and poorly consolidated glacial-fluvial sediments of uncertain age. Souther (1972) assigned an Upper Tertiary to Pleistocene age to the basaltic based on correlation with similar rocks to the north, near Mount Edziza.

Flows are vesicular near their tops and bases, so individual flows are identifiable where they are dissected by More Creek. Fragmental aphyric rocks only occur in one outcrop at the south edge of Arctic Lake. Dark grey basalt with a maximum of 2 to 3 per cent plagioclase, 1 per cent clinopyroxene, less than 1 per cent magnetite and rare olivine phenocrysts is the most common rock type. The mineralogy varies little in all the exposures examined. Phenocrysts are vitreous and unaltered. In thin section, phenocrysts in the basalt consist of euhedral, oscillatory zoned plagioclase and subhedral to anhedral olivine and sparse clinopyroxene. In each section several plagioclase grains, probably xenocrysts, have thick resorption zones, with a sponge-like texture of fine glass inclusions; plagioclase overgrowths (coronas) are typical on these grains. Olivine crystals frequently have embayed margins. The groundmass consists of fine plagioclase microlites, intergranular olivine and pyroxene, and abundant (about 30-40 per cent) grainy opaques.
A K/Ar whole rock analysis of a sample of Arctic Lake Formation alkali olivine basalt collected east of Exhile Hill gave a date of 0.71±0.05 Ma (Souther et al., 1984). A younger Pleistocene date of 0.45±0.07 Ma was obtained by Joe Harakal (UBC geochronology Lab) from K/Ar whole rock analysis of a flow at the north end of More Creek (Figure 2-20, Table 2-1). Klastline Formation volcanism is slightly younger (0.62±0.04 Ma; Souther et al., 1984) than Arctic Lake Formation alkali basalt but still older than our date. Deposition of Arctic Lake Formation basalt occurred from at least seven separate vents, located between Tadekho Creek and Arctic Lake. Volcanic activity was episodic and progressed from north to south (Souther, 1992), but whether the apparent time span, between 0.71±0.05 and 0.45±0.07 Ma, reflects its longevity, a separate igneous pulse or the limitations of the K-Ar dating technique is not certain.

**BIG RAVEN FORMATION**

South of Arctic Lake, post-glacial basaltic scoria, angular debris deposits and lava flows (unit Qob, GS-Map) form a small knob built on the FKP (Figure 2-20). Several small dikes, all less than a metre wide, cut the scoria deposits. Along the flanks of the knob, the scoria are weakly cemented, forming rough beds about 30 centimetres thick. The north side of the knob comprises mainly thin lava flows, underlain by weakly indurated, till-like sediments (diamictite) with rounded cobbles of granite and diorite to 10 centimetres in diameter. Minor stratified tuff is also present. The basalt contains an average of 5 per cent vitreous olivine and less than 1 per cent each of clinopyroxene and plagioclase; the phenocrysts range up to 5 millimetres in size. In thin section, plagioclase forms euhedral, normally zoned crystals. A few larger, anhedral, rounded plagioclase xenocrysts have distinguishing sponge-textured resorption zones and plagioclase overgrowths on the rims, similar to those in Arctic Lake Formation basalt. Olivine forms both euhedral and anhedral grains, the latter with resorbed margins; they were determined to be fayalite in composition from their negative optic sign. The groundmass is darkened by very finely disseminated opaques. Vesicles walls are free of secondary minerals.

Similar olivine basalt scoria and flows form Nahta cone, located about 7 kilometres north of Arctic Lake. The cone is approximately 70 metres high and consists mainly of black and brick-red scoria blocks (Photo 2-30). The circular crater rim is breached on its east side where at least two highly fluid lavas flowed to the north along a drainage in which they are still preserved. Levees of flow breccia mark the path of the flows down the creek. The cone is situated at the contact between the mid Carboniferous carbonate rocks of unit mCSc and granitic rocks of unit EMg. A thin, V-shaped apron of lapilli and ash-sized tephra covers these units for a distance of about 700 metres north and 500 metres west of the main cone. The apron is good evidence that the cone erupted on two occasions with differing wind directions.

Souther (1972, 1992) correlated these olivine-bearing scoria and basalt flows with olivine basalt and related pyroclastic rocks of the Holocene Big Raven Formation (radio-carbon dated at 1340 years B.P.; Souther, 1970). The Big Raven Formation contains more olivine and fewer plagioclase phenocrysts than the Tertiary basalt flows around Arctic Lake and in More Creek valley.

**CHEMISTRY OF THE QUATERNARY ARCTIC LAKE FORMATION**

Quaternary volcanism in the Canadian Cordillera is localized along distinct linear belts that appear to be related to the same tectonic regime as the present, that of right lateral translation along the Queen Charlotte Fault. This produced extension and subsequent deep fracturing of newly accreted continental crust. Basalts which erupt in such settings are typically alkaline and often bimodal in composition; examples include the east-trending Anaheim Belt in southern British Columbia (Souther, 1977, 1984) and the north-trending Stikine Belt (Souther, 1992). Four samples of olivine-pyroxene basalt of the Arctic Lake Formation analysed are basic alkali basalt with less than 49 per cent SiO2 (Figure 2-21A and 21D). They all plot in the tholeiitic field on the AFM diagram (Figure 2-21B). The Ti-Zr-Y diagram (Pearce and Cann, 1973) in Figure 2-21F discriminates within-plate basalt from those extruded along plate margins. The Arctic Lake basalt samples plot in the within-plate field typical of alkaline continental rift lavas on this diagram, the Zr/Y vs. Zr of Pearce and Norry (1979) and the Nb-Zr-Y diagram of Meschede (1986). They show a pattern with a negative slope, characterized by enrichment of Zr and Ti with respect to N-MORB (Figure 2-22). Enrichment increases from Yttrium (no enrichment) to the lithophile elements (substantial enrichment) which is characteristic of within plate basalts (Pearce, 1996).

**HOT SPRING DEPOSITS**

Hot spring deposits of tufa (unit Qt, GS-Map) occupy an elongate area of about 100 hectares southeast of Mess Lake (Figure 2-20). The warm-springs are located along north-trending faults of the Mess Creek system. They are discharging and depositing tufa into a connected series of...
Figure 2-21. Major and trace element geochemical plots for Arctic Lake Formation basalts (filled triangles). A) total alkali versus silica (after Irvine and Baragar, 1971); B) AFM plot (after Irvine and Baragar, 1971); C) ternary plot of Nb/2 - Zr/4 - Y (after Meschede, 1986); D) plot of Zr/TiO₂ versus Nb/Y (after Winchester and Floyd, 1977); E) plot of Zr/Y versus Zr (after Pearce and Norry, 1979); F) ternary plot of Ti/100 - Zr - Yx₃ (after Pearce and Cann, 1973).
poorly drained flat-bottomed valleys. Water percolating in the active springs is about 8-15 degrees Celsius, temperatures measured in 1984 were 13.0 degrees Celsius (Piteau and Associates, 1984). Most of the deposits are of the low-hill, terraced type (Photo 2-31), but six small circular cones 1 to 4 metres high and a hill of travertine up to 10 metres high are also present. Many of the tufa terraces have raised pressure ridges, with relief on the order of 10 to 40 centimetres and are from 50 to 100 metres in length. It is not known whether these resulted from recent fault movement or seasonal freezing.

Quaternary volcanism probably provided heat for the springs; as the lava cooled so did the springs and slowed deposition of calcareous tufa (Woodsworth, 1997). The nearby, large exposures of Paleozoic limestone are probably responsible for the high levels of dissolved solids in the groundwater which resulted in large volumes of calcareous tufa being deposited.