PRELIMINARY GEOLOGY OF THE MAHATTA CREEK AREA, NORTHERN VANCOUVER ISLAND (92L/5)

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(Contribution to the Canada - British Columbia Mineral Development Agreement 1991-1995)

KEYWORDS: Regional geology, Bonanza Group, Vancouver Group, Karmutsen Formation, Quatsino Formation, Parson Bay Formation, Longarm Formation, Island Plutonic Suite, Tertiary dikes, structure, mineral occurrences.

INTRODUCTION

A regional geological mapping program in the Quatsino Sound area was initiated in 1990 with a reconnaisance investigation (Massey and Melville, 1991). Mapping at 1:50 000-scale started this past summer on the Mahatta Creek (92L/5) sheet as part of a multiyear project aimed at improving our understanding of the geology and mineral potential of northern Vancouver Island. This report presents a brief account of the geological highlights of the field season. Fieldwork in 1993 will be conducted north of Quatsino Sound in parts of the 92L/12 and 102I/8-9 map sheets.

The Mahatta Creek map area is located near the northwestern extremity of Vancouver Island due west of Port Alice (Figure 1-2-1). A base camp was established at Mahatta River, some 65 kilometres west of Port Alice at the north-central edge of the map area. A dense network of well-maintained logging roads provides access to most of the map area except in the extreme south (Kyuquot Provincial Forest) and northeast where access is poor. In addition to the road network, over 100 kilometres of coastline was investigated, stretching from Brooks Peninsula north to Quatsino Sound and east into the northern part of Neroutsos Inlet. The map area is covered by the 1:50 000-scale Vancouver Island aeromagnetic survey (Map 1733G) and the 1988 Regional Geochemical Survey (Matysek *et al.*, 1989).

The region boasts the largest producing mine on Vancouver Island, the Island Copper open-pit operation located on Rupert Inlet (Figure 1-2-1). The mine has been a major producer of copper and molybdenum ore since 1971 but is scheduled to close in 1996. Exploration activity in the region has recently increased in the continuing search for base and precious metal deposits. Mineral potential maps for Vancouver Island at 1:250 000-scale are currently in preparation as part of the recent Corporate Resource Inventory Initiative (CRII).

PREVIOUS WORK

The first geological investigations of northern Vancouver Island were made by Dawson (1887) who paid particular attention to Cretaceous coal-bearing strata on the north and south shores of Quatsino Sound. Subsequent studies of the geology and mineral deposits of the region include those of Dolmage (1919), Gunning (1930, 1932), Jeffrey (1962) and Northcote (1969, 1971). Detailed descriptions of shoreline exposures of sedimentary rocks have been summarized by Jeletsky (1976) who made extensive fossil collections largely identified by Tozer (1967). However, the most recent comprehensive account of the regional geology of northern Vancouver Island (Alert Bay - Cape Scott) is provided by Muller *et al.* (1974; and *see* Muller and Roddick, 1983, for a coloured edition of their 1:250 000 geological map).

STRATIGRAPHIC NOMENCLATURE

In the descriptions that follow, we have adopted the stratigraphic nomenclature of Muller and coworkers (Muller *et al.*, 1974, 1981; Figure 1-2-2). There are, however, outstanding problems beyond the scope of this report that will need to be addressed at some future date. There is presently no continuous type section for the Quatsino Formation. The Parson Bay Formation, as used by Muller and co-authors, also has no complete section, and at its type locality on Harbledown Island across Johnstone Strait only the lowermost member is present. The Harbledown Formation has not been recognized as a mappable unit in the Quatsino Sound area, and appears to be largely correlative with the Bonanza volcanics (and interbedded sediments) of Quatsino Sound whereas these lithologies form two distinct formations on the east coast of Vancouver Island (Carlisle, 1972). As recognized by Muller, Jeletsky, and others, many stratigraphic sequences have been reassembled across intrusions, faults and other structural complexities without adequate control.

TECTONIC SETTING AND REGIONAL GEOLOGY

Vancouver Island lies within the southern part of the Insular Belt of the Canadian Cordillera and forms part of the Wrangellia tectonostratigraphic terrane which stretches northwards through the Queen Charlottes into Alaska (Wheeler *et al.*, 1991). Southern Wrangellia is bounded to the east by Cretaceous to Tertiary plutonic rocks of the Coast Belt and is underplated on the west by the Pacific Rim and Crescent terranes which form part of a subduction complex that is still being accreted today off the west coast of Vancouver Island (Riddihough and Hyndman, 1991). The amalgamation of Wrangellia and Alexander Terrane into the Insular Superterrane had apparently occurred by late Paleozoic (Late Carboniferous) time (Gardner *et al.*, 1988). Accretion of the Insular Superterrane to more inboard terranes of the Intermontane Belt (Intermontane Superterrane) may be as late as the mid-Cretaceous (Monger *et al.*, 1982)

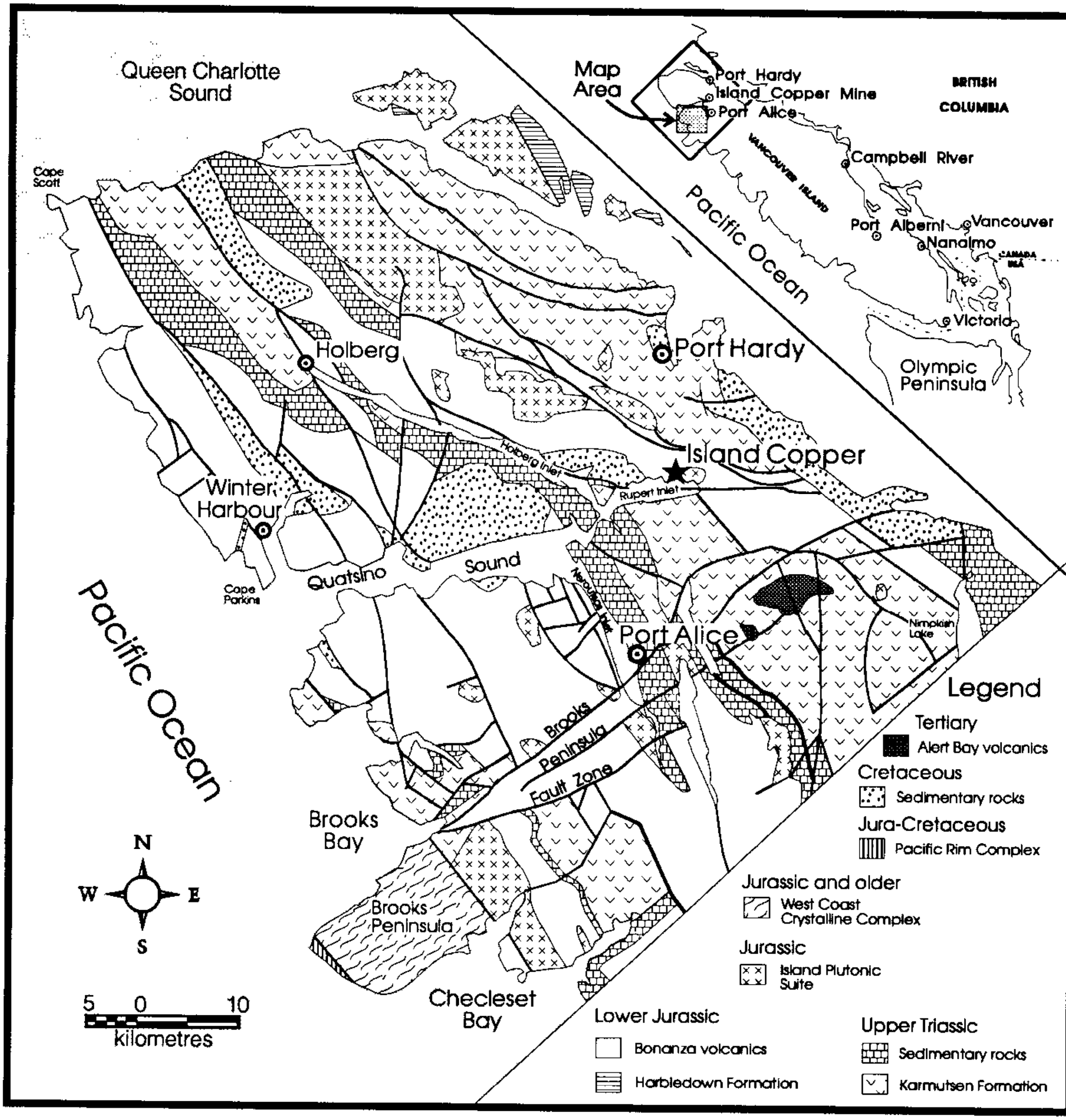

Figure 1-2-1. Generalized geology of northern Vancouver Island (modified after Muller *et al.*, 1974). Shaded inset shows location of Mahatta Creek map area.

or as early as the Middle Jurassic when a single Superterrane was attached to the North American continental margin (van der Heyden, 1991).

The crustal architecture and Mesozoic-Cenozoic stratigraphy of northern Vancouver Island are shown in Figures 1-2-1 and 1-2-2. A northwesterly trending structural grain is delineated by the major stratigraphic units, plutons and faults. The region is characterized by numerous fault-bounded blocks of homoclinal strata generally dipping westward (Muller *et al.*, 1974). The major northwesterly trending faults are transected by a northeasterly trending high-angle fault system in the vicinity of Brooks Peninsula.

The Quatsino Sound area is largely underlain by weakly metamorphosed (subgreenschist) Triassic sedimentary rocks and Lower Jurassic volcanic-volcaniclastic sequences of the Vancouver Group and Bonanza Group, respectively (Figure 1-2-2). The base of the succession is marked by mid-Triassic (Ladinian) argillites ("Daonella beds" in Figure 1-2-2) intruded by numerous diabasic sills and lesser dikes ("sediment-sill" unit of Muller *et al.*, 1974) that have

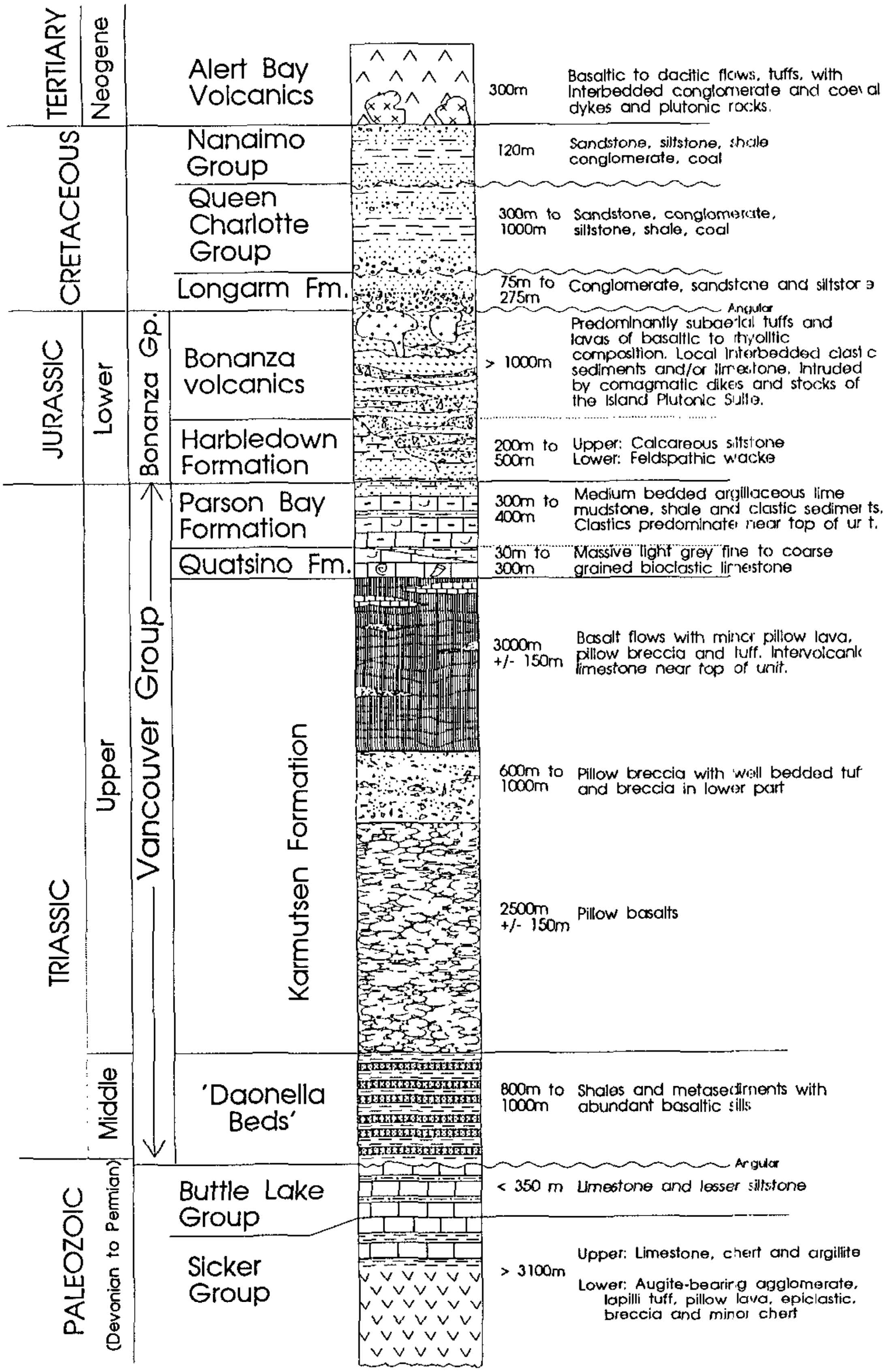

Figure 1-2-2. Generalized Mesozoic-Cenozoic stratigraphy of northern Vancouver Island (modified after Muller *et al.*, 1974, 1981).

fed a thick sequence of tholeiitic pillow basalts, submarine breccias and tuffs, and lava flows of the overlying Karmutsen Formation. In reference sections at Buttle Lake, a tripartite subdivision of the Karmutsen Formation has been recognized, comprising a basal pile of pillow lavas overlain by breccia and tuff and capped by massive lava flows with interlava limestone in the uppermost 300 metres of the section (Surdam, 1968; Carlisle and Suzuki, 1974). The lavas are conformably overlain by a succession of Upper Triassic marine sedimentary rocks comprising massive bioclastic limestone and thinly bedded, generally fine-grained clastics and impure limestone. The Triassic succession has been interpreted to represent a rapidly extruded (3.5-5 Ma) submarine flood basalt province (Karmutsen Formation) or back-arc rift sequence overlain by platformal limestone and shelf sediments (Quatsino and Parson Bay formations; Muller, 1977; Barker *et al.*, 1989). This sequence developed on a Devonian to Early Permian island-arc succession of calcalkaline volcanics and marine sediments (Buttle Lake and Sicker groups; Figure 1-2-2).

Marine sedimentation continued into the Lower Jurassic with the deposition of feldspathic wackes and calcareous siltstones (Harbledown Formation). These rocks are unconformably overlain by subaerial to submarine arc volcanics with minor interbedded sediments, and together comprise the Bonanza Group. The lower Mesozoic stratigraphy is intruded by Early to Middle Jurassic granitoid plutons (Island Plutonic Suite) considered to be comagmatic with the Bonanza volcanics. Variably deformed gabbro and granitoid intrusions in mid-crustal amphibolite-grade rocks of the Westcoast Crystalline Complex exposed on the Brooks Peninsula are probably genetically related to the Bonanza volcanics (Muller *et al.*, 1974). Cretaceous marine and fluviatile sequences, including the Longarm Formation (Kyuquot Group) and Queen Charlotte Group, were deposited as clastic wedges on previously deformed and denuded basement rocks. During the Tertiary, localized felsic to mafic Alert Bay volcanics and dikes were emplaced across northern Vancouver Island in a fore-arc environment spatially coincident with the trend of the Brooks Peninsula fault zone (Armstrong *et al.*, 1985).

LOCAL STRATIGRAPHY

The Mahatta Creek map area is underlain principally by Bonanza Group volcanic and volcaniclastic rocks. Upper Triassic sedimentary rocks and Karmutsen basalts are restricted to the southwestern coastal regions except for a narrow strip of Parson Bay Formation along the west side of Neroutsos Inlet (Figure 1-2-3). Outliers of Cretaceous strata are preserved on the west coast and along the southern shores of Quatsino Sound. Outcrops of the Queen Charlotte Group on the north shore of Quatsino Sound were not investigated, and sediments belonging to the Upper Cretaceous Nanaimo Group appear to be absent. Intrusions of the Island Plutonic Suite occur throughout the map area whereas mafic dikes of presumed Tertiary age appear to be concentrated in the south.

KARMUTSEN FORMATION

The Karmutsen Formation is well exposed along the southwestern coast between Brooks Peninsula and Restless Bight (Figure 1-2-3) and extends farther north than shown by the mapping of Muller *et al.* (1974). The principal lithology comprises dark grey to maroon, aphanitic to finely porphyritic amygdaloidal basalt flows; pillow basalt, pillow breccias and bedded hyaloclastite deposits are comparatively rare as are coarsely porphyritic, plagioclase-phyric lavas. The preponderance of massive flows, the recognition of the overlying Quatsino Formation, and the local occurrence of limestone beds apparently intercalated with Karmutsen basalt in some fault blocks suggest that only the upper part of Karmutsen stratigraphy is exposed (Figure 1-2-3).

Textures observed in outcrop include a locally pronounced flow foliation defined by trachytic plagioclase or centimetre-scale alternating layers of amygdaloidal and compact lava (Plate 1-2-1). Amygdules may be concentrated at flow margins and localized vesicle trains are usually oriented within the flow foliation. The margins of flows are generally sharp and smooth; flow breccias are rare. Irregular joints are commonly lined with chlorite which is locally polished and exhibits slickensides; primary columnar jointing has not been observed.

In thin section, the primary phases of aphanitic basalts are plagioclase microlites (less than 0.5 mm), clinopyroxene, iron-titanium oxides (up to 10% by volume) and altered volcanic glass (typically 5-20%) displaying intergranular to subophitic or intersertal textures. Plagioclase (labradorite) phenocrysts and rare glomerocrysts in finely porphyritic variants reach 2.5 millimetres in length but may exceed 6 millimetres in coarsely porphyritic flows; clinopyroxene rarely attains 1 millimetre in diameter. The more holocrystalline flow interiors characteristically contain interstitial quartz typical of a tholeiitic residuum.

The Karmutsen Formation has been subjected to burial metamorphism ranging from zeolite facies near the top to prehnite-pumpellyite facies in the lower part (summarized by Greenwood *et al.*, 1991). Secondary mineral assemblages observed to date in the Mahatta Creek area commonly include chlorite, epidote/zoisite, carbonate, sericite, sphene/leucoxene, quartz, pyrite and clays. In addition, zeolite, albite, prehnite(?) and rare potassium feldspar have been observed infilling amygdules, and fibrous actinolite is locally found in veinlets and basaltic groundmass. The occurrence of actinolite does not appear to be spatially related to granitoid intrusions and suggests that peak metamorphic conditions locally reached greenschist grade in the some parts of the Karmutsen pile.

QUATSINO FORMATION

The Quatsino Formation was named by Dolmage (1919) for a thick (750 m) limestone unit exposed at the eastern extremity of Quatsino Sound and in Rupert Inlet. Previous workers have noted that the formation can be informally subdivided into a lower massive and upper thinly bedded sequence that grades into overlying Upper Triassic clastic rocks of the Parson Bay Formation (Figure 1-2-2). Work by

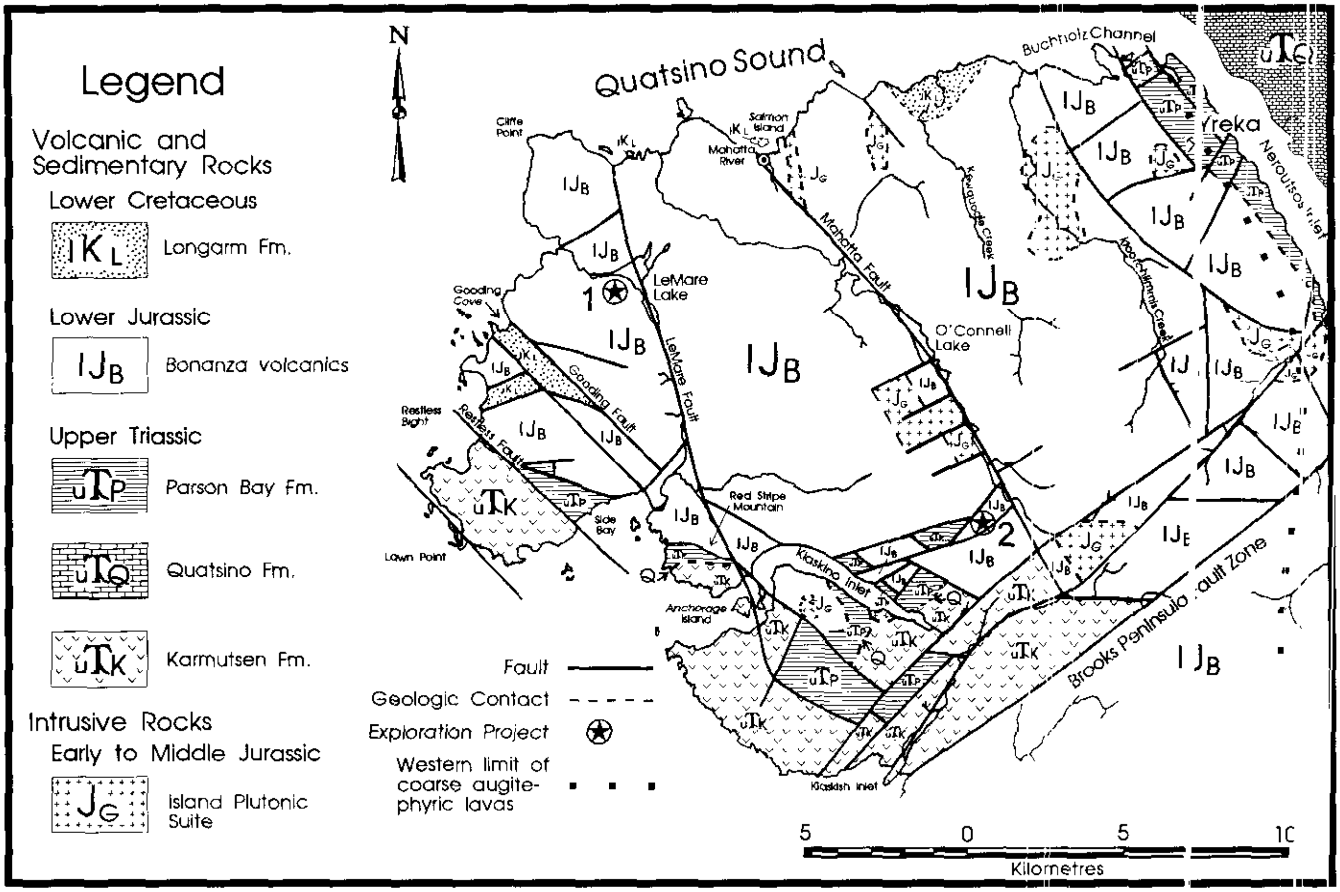

Figure 1-2-3. Generalized geology of Mahatta Creek area (92L/5); for detailed map *see* Open File 1993-10. Q indicates the presence of Quatsino limestone at the base of the Parson Bay Formation. The star indicates an exploration project. 1, LeMare Lake, Minnova Inc.; 2, Madhat, Pan Orvana Resources Inc.

Plate 1-2-1. Flow lamination in Karmutsen basalt defined by amygdaloidal and compact layers. Southeastern tip of unnamed island in Klaskino Inlet 0.4 kilometre northeast of Anchorage Island.

Jeletsky (1970, 1976) has shown that the substantial thickness of Quatsino limestone in the Rupert Inlet - Alice Lake area is drastically reduced in exposures on the west coast (and also to the east along Queen Charlotte Strait) which appear to represent a shorter time span. Ammonites place the Quatsino-Karmutsen contact in the upper Carnian: the contact with overlying Parson Bay Formation is diachronous, reaching a middle Norian age in the area where the Quatsino is thickest (Jeletsky, 1976; Tozer, 1967).

In the Mahatta Creek area, Quatsino limestone is exposed in the northeastern corner of the map area and as isolated outcrops around Klaskino Inlet where it is more extensive than previously recognized. Two new fossiliferous localities have been examined, on an island at the entrance of Klaskino Inlet, and another deep within it. The presence of the western facies of Quatsino limestone at the Karmutsen - Parson Bay contact is indicated symbolically in Figure 1-2-3.

Exposures on the eastern side of Neroutsos Inlet comprise a predominantly massive, though locally thinly bedded, medium to dark grey micritic limestone that weathers pale grey to white. Stylolitic structures are common and a pockmarked weathering surface is usually pronounced in shoreline exposures.

The Quatsino-Karmutsen contact is exposed on the southeastern shore of Klaskino Inlet and in a measured section

Plate 1-2-2. Thickly to thinly bedded, moderately dipping Quatsino limestone conformably overlying Karmutsen basalt.

just outside the entrance (Klaskino section of Muller *et al.*, 1974) where it is sharp and conformable or paraconformable (Plate 1-2-2). At the former locality (Figure 1-2-3), the Quatsino Formation rests on amygdaloidal basalt. The Quatsino and Parson Bay formations comprise a westward-dipping, westward-facing, continuous stratigraphic succession with some minor folding of Quatsino limestone and mafic Bonanza dikes near the Karmutsen contact. The basal part of the Quatsino comprises a massive, pale grey fine-grained limestone about 10 metres thick in gradational contact with very thinly bedded argillaceous limestone with laminae and concretions of black chert. These beds grade into very thinly bedded, medium grey, impure micritic limestone with black shaley partings which in turn passes into a laminated to very thinly bedded, dark grey siltstone-argillite sequence at the base of the Parson Bay Formation. The total thickness of the Quatsino Formation here appears to be about 30 metres. A thin limestone layer with abundant ammonites occurs less than 20 metres above the Karmutsen contact.

In the Klaskino section measured by Muller *et al.* (1974, Figure 5), the thicknesses of the lower and upper divisions of the Quatsino were estimated at approximately 24 and 48 metres respectively. Massive to locally thinly bedded limestone at the base of the section is interstratified with Karmutsen basalt regarded as sills by Muller *et al.* However, there are no obvious thermal or metasomatic effects at these contacts and work in progress may establish an intercalated limestone-basalt flow succession as documented elsewhere (Figure 1-2-2). An isolated limestone horizon in Karmutsen basalt was discovered north of Lawn Point (Figure 1-2-3).

The Quatsino Formation can be traced from its coastal exposure in the Klaskino section across the top of Red Stripe Mountain where it runs into a fault. It is encountered again farther south near the northern tip of an unnamed island northeast of Anchorage Island. The Karmutsen-Quatsino contact has been intruded by Bonanza diorite and is not exposed. The succession here is very similar to that described above for southern Klaskino Inlet. Gastropods were recovered from the massive basal part of the Quatsino limestone which is at least 12 metres thick. The upper thinly bedded division is locally tightly folded; its thickness may reach 20 metres.

Parson Bay Formation

The Parson Bay Formation is preserved in fault blocks surrounding Klaskino Inlet and northeast of Klashkish Inlet, in a westerly striking belt extending from Red Stripe Mountain to the coast (Klaskino section), at Side Bay, and on the south shore of the main channel of Quatsino Sound where it becomes Neroutsos Inlet. The formational name was advocated by Crickmay (1928) for Triassic sedimentary rocks originally comprising part of the Triassic-Jurassic Parson

Bay Group on Harbledown Island (Bancroft, 1913). Muller *et al.* (1974) were the first to apply this name to the Upper Triassic sediments of northern Vancouver Island. As used by these authors, the Upper Triassic Parson Bay Formation now incorporates the following units mapped by Jeletsky (1976) as part of his "Sedimentary Division of the Bonanza Subgroup", from base to top: a basal pelitic unit with minor impure limestone interbeds or "Thinly Bedded Member"; a clastic or "Arenaceous Member" comprising predominantly interbedded greywacke and argillite with minor tuff and pebble conglomerate, locally argillaceous at the top; an upper limestone unit with minor clastics or "Sutton Formation" present only in eastern Quatsino Sound; and a sequence of waterlain volcanic breccias and tuffs or "Hecate Cove Formation" (base of Jeletsky's "Volcanic Division of the Bonanza Subgroup") directly underlying Lower Jurassic Bonanza volcanics and also best exposed in the eastern part of Quatsino Sound. The age of the Parson Bay Formation in the area is well controlled by fossils and extends from lowermost to uppermost Norian.

The Klaskino section described by Muller *et al.* (1974, Figure 4 and Table 3) is considered to be the most complete. From south to north, laminated to thinly bedded dark grey to black impure limestones, calcareous siltstones and shales in gradational contact with Quatsino Formation pass into similar lithologies with local interbeds of normally graded, feldspathic wacke and minor intraformational limestone breccia. At the top of the section, a fault separates these thinly bedded sediments from coarser clastics comprising predominantly thickly bedded limestone breccias with a tuffaceous matrix with minor micritic limestone and pebble conglomerate. These beds are overlain by mafic to intermediate lavas of the Bonanza volcanics that appear to represent the Parson Bay - Bonanza transition. Jeletsky (1976, p.18) considered the latter rocks to be uppermost Triassic ("Hecate Cove Formation").

Outcrops of Parson Bay Formation in eastern Quatsino Sound at Buchholz Channel have a significantly higher proportion of carbonate beds and coarse volcaniclastic detritus than their counterparts on the west coast. These rocks, together with correlative units on the north shore of Quatsino Sound, were studied in detail by Jeletsky (1976) and formed his uppermost Triassic - lowermost Jurassic stratigraphy.

The northwesterly striking succession at Buchholz Channel generally dips and youngs to the west but is structurally complicated by faults and small-scale folds (Jeletsky, 1976, Figure 17). A wide variety of lithologies recur throughout the sequence: pale to medium grey, relatively pure fine-grained massive limestone, white to pale buff on weathered surfaces and locally exhibiting laminae and concretions of black chert; thinly bedded, impure micritic limestone commonly with interbeds of calcareous siltstone and black argillite; limestone breccias with angular fragments (up to 8 cm across) of dark grey limestone set in a micritic matrix; medium greenish grey, thinly bedded tuffaceous wackes; volcanic conglomerates and sandstones with carbonate-rich matrices; and grey-green volcanic breccias of epiclastic and pyroclastic origin. At the eastern end of Buchholz Channel, coarse epiclastic deposits including limestone breccias overlie dark greenish grey medium-bedded lapilli tuffs and massive augite-phyric mafic flows. Jeletsky (1976, p. 29) has also identified pillow lavas and pillow breccias at apparently the same stratigraphic horizon. A succession of augite-phyric lavas and thickly or indistinctly bedded volcanic breccias is also exposed along the western shore of Neroutsos Inlet where they appear to be intercalated locally with massive limestone and laminated to thinly bedded dark grey siltstones, mudstones and argillaceous limestones. Although there is little doubt that these carbonate-volcaniclastic sequences were laid down in shallow marine or littoral environments, the massive lavas may represent locally emergent or intratidal conditions. The Parson Bay Formation at Buchholz Channel thus appears to mark the transition from Upper Triassic marine sedimentation to Lower Jurassic Bonanza volcanism. The exact timing of this transition may be revealed by limestone samples currently being processed for microfossils.

The Parson Bay Formation cropping out on the north and south shores of Klaskino Inlet also contains the Parson Bay - Bonanza transition. Here, the strata comprise a generally westward-dipping, westward-facing succession of laminated to medium-bedded, dark grey to black, locally pyritic argillites, silicified siltstones, calcareous siltstones and argillaceous limestones. The sections are artificially thickened by faulting, folding and intrusion of Bonanza dikes and sills. In both sections, the uppermost beds of fine-grained clastics with minor carbonate are overlain by, or intercalated with, a structurally concordant sequence of well-bedded volcaniclastic-epiclastic deposits and lava flows. For mapping purposes, we have arbitrarily placed the contact shown in Figure 1-2-3 at the lowest stratigraphic horizon of lava, pyroclastic or coarse epiclastic material. Both Jeletsky and Muller and coworkers recognize an interfingering of Parson Bay and Bonanza lithologies.

On the north shore of Klaskino Inlet, the highest part of the Parson Bay Formation, a very thinly bedded, variably silicified argillite-siltstone succession, is in sharp contact with an aphanitic intermediate sill(?) and is overlain by a medium to thickly bedded, mixed epiclastic-pyroclastic succession of variegated maroon to pale green tuffaceous breccias, sandstones, lapilli tuffs and minor mafic amygdaloidal flows. The fragmental rocks contain angular to subrounded clasts (up to 5 cm across) of fine-grained mafic to silicic volcanic rocks and mark the base of the Bonanza Group as defined above. These clastics are overlain by a thick sequence of mafic amydaloidal flows.

The contact between the Parson Bay Formation and Bonanza volcanics on the south shore of Klaskino Inlet is gradational. The top of the transition zone is marked by variably altered, pale greenish grey, massive vitric-lithic tuff (welded?) of silicic composition, overlain by aphanitic rhyolitic lavas with spherulitic devitrification textures. These lithologies overlie dark grey laminated to medium-bedded micritic limestones and calcareous mudstones with minor siltstone and argillite interbeds. Disseminated pyrite is locally concentrated in conformable layers up to 1 centimetre thick. These rocks are overlain by a less calcareous sequence of mudstones and siltstones intercalated with tuffaceous sandstones and siltstones and medium-bedded crystal-vitric (water-washed?) intermediate to silicic tuffs. The exact thickness of the transition zone is uncertain due to intrusion and faulting, but it probably represents a minimum stratigraphic interval of several hundred metres. The more arenaceous and tuffaceous character of clastic sequences within the transition is reminiscent of lithologies in the uppermost part of the Parson Bay Formation at Side Bay.

Bonanza Volcanics

According to present definitions, the Bonanza Group (Gunning, 1932) comprises Lower Jurassic sedimentary rocks of the Harbledown Formation unconformably overlain by Bonanza volcanics (Muller *et al.*, 1981; Figure 1-2-2). Where the Harbledown Formation is missing, as appears to be the case in the Mahatta Creek area, Bonanza volcanics rest directly on Upper Triassic sediments of the Parson Bay Formation with no definitive evidence for a major erosional unconformity. In fact, as noted above, a narrow tuffaceous interval records the passage from a marine shallow-water to predominantly volcanic environment. Muller *et al.* (1974) measured a thickness of some 2500 metres for a section of Bonanza volcanics at Cape Parkins but expressed doubts as to its stratigraphic integrity.

The age of the Bonanza volcanics has been established as early Sinemurian to early Pliensbachian by ammonites and bivalves collected from intra-Bonanza sediments within the Mahatta Creek area (Muller *et al.*, 1974; Jeletsky, 1976), in a measured section at Cape Parkins (Muller *et al.*, 1974) and further south in Kyuquot Sound (Frebold and Tipper, 1970). Macrofossils in the Harbledown Formation yield a similar age range indicating that this formation is largely coeval with Bonanza volcanics and interbedded sedimentary rocks. Potassium-argon isotopic dates (103-161 Ma, mid-Cretaceous to early Late Jurassic) are minimum ages only (Muller *et al.*, 1974).

The Bonanza volcanics show many of the characteristics inherent to ancient volcanic terrains that prevent formal subdivision, not the least of which are the lack of distinctive lithostratigraphic markers, extreme variations or recurrence of lithologies in space and time, and inadequate fossil control. When combined with the structural complexities known to exist, it is not surprising that previous workers have had their respective difficulties in attempting to subdivide the Bonanza into regionally significant mappable units. It was for these reasons that Muller *et al.* (1974) decided to incorporate the Upper Triassic sedimentary units recognized by Jeletsky (1969, 1970, 1976) into the Parson Bay Formation, and placed little faith in Jeletsky's informal lithostratigraphic subdivision of Bonanza volcanics. At this time, we offer limited insight into these problems.

The Bonanza volcanics are an extremely diverse suite of extrusive and intrusive subvolcanic rock types that range in composition from basalt to rhyolite and reflect both subaqueous and continental volcanic and epiclastic environments. The main volcanic lithologies include basaltic flows, relatively minor pillow breccias and tuffs, and rare pillow lavas; rhyodacitic to rhyolitic flows; intermediate to silicic ash-flow tuffs, pyroclastic breccias and minor ash-fall material; and intermediate porphyritic lavas of apparently minor volume. Intercalated sedimentary sequences include fine-grained clastics and carbonates, volcanic wackes, sandstones and conglomerates, and laharic breccias. Descriptions of lithologies that illustrate the diverse nature of Bonanza volcanics in the Mahatta Creek area are given below along with some preliminary insights into potential regional differences in volcanic regimes that require further investigation.

The basaltic rocks are typically dark grey to greenish grey where freshest, and maroon to pale green where altered. They have aphanitic to fine-grained textures and are commonly amygdaloidal with carbonate, chlorite, epidote, zeolite and silica infillings. In thin section, aphanitic variants contain plagioclase microlites and microphenocrysts and clinopyroxene grains set in an oxide-charged groundmass. Plagioclase phenocrysts rarely exceed 2 millimetres in length in the more porphyritic lavas. Rare megacrystic flows contain phenocrysts of euhedral plagioclase and glomerocrystic intergrowths exceeding 1 centimetre in maximum dimension that may comprise up to 15 volume per cent of the rock (Plate 1-2-3). Some of these textures resemble those found in Karmutsen basalts. However, Bonanza basalts are usually less epidotized than Karmutsen lavas, which appears to reflect primary differences in bulk composition.

Excellent exposures of basaltic pillow breccias interbedded with shallow-water marine sediments occur on the unnamed point forming the northern tip of Restless Bight (Figure 1-2-3). Dark grey to bright red or pale green, altered, aphanitic basalt flows (2 to 6 m thick) with dense interiors that grade into amygdaloidal tops overlain by scoriaceous flow breccias form the lowest outcrops of a westward-dipping, westward-younging stratigraphic succession. These flows are overlain by a thinly to thickly bedded sequence of grey-brown weathering intercalated pillow breccias (Plate 1-2-4), pebble conglomerates and coarse tuffaceous sandstones with calcareous cement, including a thin (2 m) bed containing abundant crystals of gypsum (5 mm across). Some of the pillow breccias have been emplaced as submarine debris flows in which broken and whole pillows (up to 1 m long) are suspended in a calcareous sandy matrix. The gypsum bed probably represents a local sabkha-type environment. These beds are overlain by a succession of thin to medium-bedded sandy limestones and calcareous sandstones that contain large, coarsely corrugated clams identified as *Weyla* sp. (GSC locality C-208119, Haggart, 1992) which is consistent with an Early Jurassic (Sinemurian to Toarcian) age.

Viscous rhyolitic lavas are pale grey to greenish grey or maroon rocks with aphanitic to finely porphyritic textures. Dark grey to greenish black, partially devitrified obsidian is found in dikes and flows. Porphyritic varieties contain sparse (less than 5% by volume) euhedral feldspar phenocrysts less than 2 millimetres in length. Flow lamination and flow folds are usually conspicuous. Local flow breccias contain variably rotated, angular fragments of flow-laminated rhyolite up to 30 centimetres in length. Spherulitic devitrification textures are locally well developed with individual spherulites attaining 3 centimetres in diameter (Plate 1-2-5).

Plate 1-2-3. Coarsely plagioclase-phyric basalt flow showing glomerocrystic texture, Bonanza volcanics.

Pale grey-green to maroon, rhyolitic to dacitic or andesitic ash-flow tuffs and monolithic to heterolithic tuff-breccias and pyroclastic breccias are commonly associated with the rhyolitic lavas. Monolithic breccias typically contain abundant angular to subrounded clasts of flow-laminated rhyolite; most are lapilli-size although some blocks exceed a metre in length. Heterolithic breccias contain contain accidental clasts of basaltic lavas in addition to rhyolitic fragments. Vitroclastic matrices are nonwelded to strongly welded with dark green, collapsed pumice lapilli. These pyroclastic deposits most likely represent small-volume explosive phenomena associated with the growth of rhyolitic flow-dome complexes. The ash-flow tuffs include vitric, vitric-lithic and crystal-lithic varieties and most are welded to some degree with locally pronounced eutaxitic pumice (Plate 1-2-6). The more intermediate compositions are generally crystal-lithic lapilli tuffs with up to 15 volume per cent accidental rock fragments, 20 per cent pumice lapilli and 15 per cent euhedral to broken crystals, mostly plagioclase (less than 3 mm long). Their decidedly heterolithic nature and finer average clast size with fewer flow-laminated rhyolite fragments suggests that these cooling units represent the far-travelled equivalents of rhyolitic breccias associated with flow-dome complexes or distal(?) outflow facies of caldera complexes. The widespread occurrence of densely welded textures in the silicic to intermediate pyroclastic rocks suggests that much of the Bonanza volcanism was continental. However, the total volume of silkie pyroclastic material appears to be substantially less than that of mafic lavas in the area.

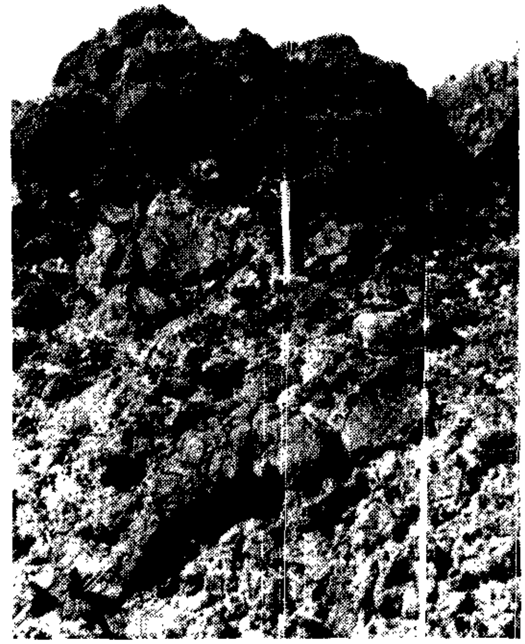

Plate 1-2-4. Basaltic pillow breccia containing whole pillow fragments, Bonanza volcanics, unnamed point at northern tip of Restless Bight.

Coarsely porphyritic, greenish grey to maroon augite-phyric lavas and associated tuffs are exposed along the eastern margin of the map area (Figure 1-2-3). These mafic to intermediate flows are characterized by up to 20 volume per cent euhedral phenocrysts of augite (up to 8 mm long), or augite and plagioclase, and exhibit seriate textures and amygdaloidal tops. They are intercalated with more finely porphyritic (<2 mm) augite and plagioclase-bearing lavas that may extend slightly farther west than the limit shown in Figure 1-2-3. The succession includes localized beds of augite-bearing lapilli tuff and tuff-breccia rich in fragments of fine-grained to porphyritic volcanic rocks. Some of these pyroclastic deposits may be waterlain.

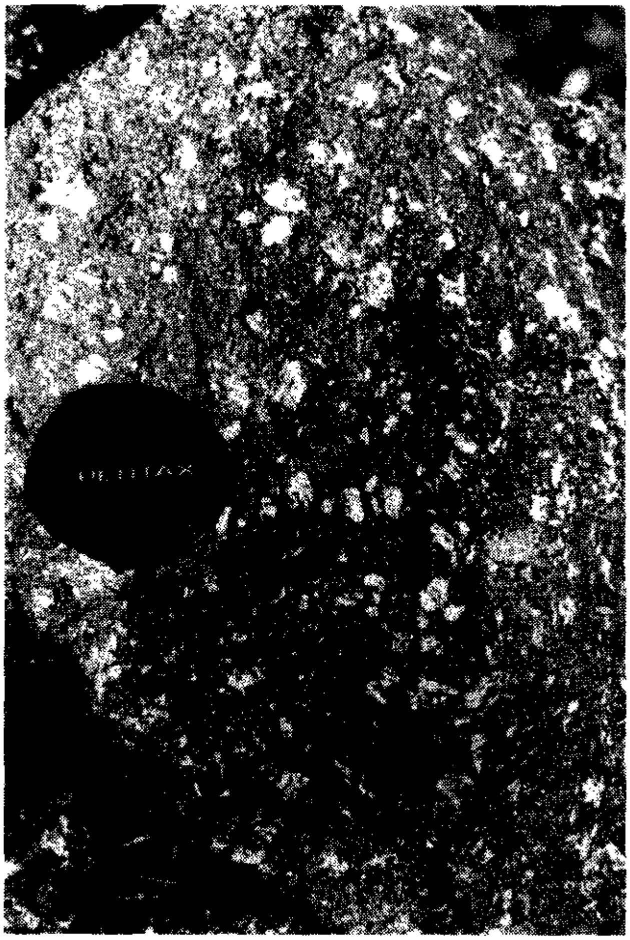

Plate 1-2-5. Spherulitic devitrification in rhyolite flow, Bonanza volcanics.

Maroon to pale green laharic breccias are a minor but conspicuous component of the epiclastic rocks. They incorporate angular to well-rounded clasts (up to 0.8 m across) of the volcanic lithologies described above, in addition to minor sedimentary rocks including rare limestone. Flow imbrication or preferred orientation of clasts in the plane of the flow is locally apparent. The finer grained epiclastic detritus generally forms well-bedded sequences of tuffaceous pebble conglomerate, sandstone, siltstone and argillite. Marine sediments intercalated with Bonanza volcanics comprise dark grey to grey-green, laminated to medium-bedded impure limestone, calcareous mudstone and siltstone, and variably silicified siltstone and argillite. These limy sequences are very similar to Parson Bay sediments and recognition is dependant on fossil control where contacts with volcanic rocks are obscured.

Some interesting relationships are evident in the distribution of volcanic lithologies across the Mahatta Creek map sheet. The western two-thirds of the area is underlain by a seemingly bimodal aphanitic to finely porphyritic basalt-rhyolite association in which basaltic rocks appear to be much more volumetrically significant. Distinctively porphyritic, mafic to intermediate augite and plagioclase-bearing extrusive rocks appear more abundant in the east. As both assemblages are intimately associated with Upper Triassic sedimentary rocks of the Parson Bay Formation, it seems probable that this spatial petrographic variation in lava types was established at the onset of Bonanza volcanism.

Geochemical data provide some insight into the possible significance of these petrographic variations. Muller *et al.* (1974, Table 4) presented 19 major element analyses of Bonanza "andesites", "dacites" and "rhyolites" from Cape Parkins at the entrance to Quatsino Sound (Figure 1-2-1) and concluded that the petrography and chemistry of these rocks was compatible with a calcalkaline affinity. It is worth noting, however, that based on silica content alone, almost all of the "andesites" in this table would be classified as basalts, the "dacites" are andesites, and the "rhyodacites" have rhyodacitic to rhyolitic compositions. Orthopyroxene was apparently confirmed in some samples but these were not identified. The titania content of the basalts (>1 weight %) is consistently high and unusually so for an arc-related calcalkaline suite. Muller *et al.* (1974) did note an alkalic affinity for the more mafic members of the suite on an alkali-silica plot but attributed this to alkali metasomatism. Recent geochemical analyses of basaltic to rhyolitic rock types by Minnova Inc. geologists at LeMare Lake, and work in progress, leave little doubt that alkali metasomatism is a factor, but the freshest basalts consistently exhibit a mildly alkalic affinity. This contrasts with the geochemistry of augite-phyric Bonanza volcanics in the Pemberton Hills area northwest of the Island Copper mine which are demonstrably subalkaline with a tholeiite (arc?) signature (Panteleyev and Koyanagi, 1993, this volume).

Longarm Formation

The Longarm Formation was proposed by Sutherland Brown (1968) to include all sedimentary rocks of Early Cretaceous (Valanginian to Barremian) age on the Queen Charlotte Islands. Long Inlet, previously called the Long Arm of Skidegate Inlet on Graham Island, was defined as a type area for this formation. Lithostratigraphy described by Sutherland Brown includes shallow-water marine conglomerates fining upward to shale. A recently refined Cretaceous stratigraphy on the Queen Charlotte Islands (Haggart, 1989, 1991; Haggart and Gamba, 1990; Haggart *et al.*, 1991) may be similar to northern Vancouver Island stratigraphy, but scarcity of Cretaceous sedimentary rocks in the Mahatta Creek area allows for only the simplest of correlations at this time. The stratigraphy of the Longarm Formation on Vancouver Island has been subdivided by Jeletsky (1976) into five mappable facies. From oldest to youngest these lithologies are: fossiliferous calcareous greywacke; massive, calcareous, fossiliferous, concretionary siltstone; impure limestone, calcareous sandstone and conglomerate; bioclastic limestone and calcarenite; and calcareous concretionary greywacke with pebble conglomerate at its base.

Strata assigned to the Longarm Formation crop out along the northern and northwestern margins of the map area. Here, this unit represents a transgressive sequence ranging from basal shallow-marine fossiliferous conglomerates and lithic sandstones up to deeper water shales. The sequence onlaps Lower Jurassic Bonanza volcanic rocks with angular unconformity.

Plate 1-2-6. Welded, lithic-rich lapilli-tuff, Bonanza volcanics, LeMare Lake property. Minnova Inc.

Thick accumulations of Cretaceous sediments are common north of the study area (Figure 1-2-1). The scarcity of these sediments within the study area, and their distribution only along its northern margin, suggests that most of the region persisted as a paleohigh throughout Cretaceous time.

For the most part, Jeletsky's facies are not observed west of Mahatta River. Here, fossiliferous marine conglomerate and lithic arenite are the most common Cretaceous lithologies. At Gooding Cove, a structurally complex area at the western margin of the study area (Figure 1-2-3), the sequence fines upward from conglomerate into black fissile shale. The conglomerate is typically composed of well-rounded granule to cobble-sized clasts grading upward into and interbedded with massive, buff-weathering, medium to light grey, calcareous lithic arenite and wacke. Bivalve shells are very common. Conglomerate clasts are typically volcanic with the exception of rare medium-grained diorite clasts. Coarse-grained rocks grade upwards into unfossiliferous, thinly bedded, dark grey calcareous siltstone and fine-grained sandstone which in turn grades upward into orange-weathering, black fissile shale.

East of Mahatta River, at Kewquodie Creek (Figure 1-2-3), gently dipping, grey-green weathering, light grey to maroon siltstone and lithic wacke predominate. These beds are locally concretionary and have minor conglomerate interbeds; carbonate concretions are common locally. Jeletsky placed rocks in this area within his uppermost (Barremian) subdivision of the Longarm Formation.

INTRUSIVE ROCKS

Granitoid intrusions of the Island Plutonic Suite occur throughout the map area and are the prime targets for skarn and porphyry copper exploration. The most common rock types are greenish grey to white weathering, medium-grained, equigranular hornblende diorite to quartz diorite, feldspar porphyries of dioritic composition, monzonite and minor granodiorite. The more mafic granitoids are chloritized and variably sericitized. Two varieties of porphyry are found: crowded porphyries with large (<1 cm) phenocrysts and glomerocrysts of plagioclase (30-40 volume %) and lesser hornblende (<5%); and porphyries with 5-10 per cent phenocrysts of euhedral plagioclase (<4mm). The latter intrusions locally show syenitic margins a few metres wide and some have local concentrations (up to 5 volume %) of pyrite cubes reaching 1 centimetre in diameter. The large monzonitic intrusion in Klootchlimmis Creek has a core of granodiorite. Weakly developed magnetite skarns are locally present at their margins.

Dikes of presumed Tertiary age cut through folded and faulted Upper Triassic and Lower Jurassic rocks. The vast majority are dark grey, weakly amygdaloidal basalts with distinctive dark brown to buff spheroidal weathering of blocky joints; rhyolitic dikes are comparatively rare. The dikes reach 4 metres in width and commonly display chilled flow-laminated margins extending up to 15 centimetres from the contact. Most are aphanitic to sparsely porphyritic; plagioclase-phyric varieties containing up to 15 volume per cent phenocrysts with hiatal textures are rare. Pyrite is locally present along fractures but propylitic alteration is generally inconspicuous. The dikes are steeply dipping (65°-90°) but appear to have no preferred regional orientation. They do, however, appear to be spatially restricted to the vicinity of the Brooks Peninsula fault zone where northeasterly trending, post-tectonic dikes of intermediate to rhyolitic composition have been mapped previously (Smyth, 1985). These intrusions may represent the conduits for Neogene extrusive rocks known farther east which have been related to near-trench plate-edge volcanism (Armstrong *et al.*, 1985).

STRUCTURE

Block faulting typifies the structural style within the study area where abundant faults of various orientations commonly dip steeply and exhibit both strike-slip and dip-slip displacement. Sedimentary and volcanic rocks within fault-bounded blocks almost invariably dip and face westward and describe a northwesterly trending homocline. Muller *et al.* (1974) have placed this area on the western flank of the Victoria arch, the culmination of which is located east of Nimpkish Lake, approximately 40 kilometres east of the study area (Figure 1-2-1). East of the arch, block-faulted strata dip and face eastward.

Rocks within the study area have undergone multiple stages of deformation ranging in age from Jurassic through to Tertiary as follows:

- The oldest episode of deformation recognized is a folding and block-faulting event which postdates Lower Jurassic volcanism but predates Lower Cretaceous sedimentation.
- Folding and faulting of Lower Cretaceous sedimentary rocks represents a second event apparently controlled by northwesterly trending, predominantly right-lateral transcurrent to transpressional faulting.
- Normal faults of Tertiary age truncate and reactivate many pre-existing structures.

Unfortunately, marker horizons are scarce and valley-fill masks most major faults making motion determinations difficult if not impossible to ascertain directly. Most progress has been made using kinematic indicators associated with minor faults found near the more dominant features.

Upper Triassic Through Lower Jurassic

Volcanic rocks of the Upper Triassic Karmutsen Formation form the base of the stratigraphic succession exposed in the study area. Conformable contacts between the Karmutsen and overlying Upper Triassic Quatsino and Parson Bay Formation marine sediments, as well as the subaqueous to subaerial Lower Jurassic Bonanza volcanics, confirm that this time span represented a period of uplift, but otherwise relative tectonic quiescence. Some faulting was certainly ongoing during Lower Jurassic volcanism as Bonanza-equivalent dikes have locally intruded along pre-existing faults.

Pre-Lower Cretaceous Deformation

The earliest recognizable deformational episode occurred prior to the deposition of the Lower Cretaceous Longarm Formation. The time period between Lower Jurassic volcanism and Lower Cretaceous sedimentation accounted for significant shortening and block-faulting. The apparent absence of volcanic and sedimentary rocks of Middle to Late Jurassic age suggests that this was also a period of extensive uplift and erosion.

Probably the earliest tectonic event was prompted by east to northeastward directed compressional stresses that caused widespread tilting of Lower Jurassic and older strata to form the northwesterly trending homocline recognized throughout the study area. Some of the northerly plunging mesoscopic and megascopic folds may also be attributed to this episode, as well as northwest to northeasterly striking reverse and thrust faults. Jeletsky (1976) assigned a Middle Jurassic age to this period of deformation, and more recent studies in the Queen Charlotte Islands have also defined a Middle Jurassic episode of folding and faulting (Thompson *et al.*, 1991; Lewis and Ross, 1991).

Within the Middle to Late Jurassic time-frame, folded and tilted sediments were cut by easterly striking, northerly dipping thrust faults and associated drag folds which formed in reponse to south to southwesterly directed compression. Southerly directed compression is supported by the presence of an east to southeast-striking, steeply dipping, pressure solution cleavage in Quatsino limestone on the eastern side of Neroutsos Inlet as well as in Parson Bay limestones in the southwest corner of the study area.

Post Lower Cretaceous To Pre-Tertiary Deformation

The Lower Cretaceous Longarm Formation is a fining upward, transgressive sequence which onlaps the older units with angular unconformity. As noted earlier, most of the study area was a paleohigh forming the southern flank of a Cretaceous basin.

Lower Cretaceous and older rocks have been displaced, sheared and folded by northwest-trending, steeply dipping faults which locally show right-lateral displacement. Deformation associated with these faults increases in intensity toward the western part of the study area. Drag folds along these faults, as well as faults of similar orientation, are believed to have formed in a north to northeasterly directed compressional regime. Longarm Formation sedimentary rocks typically have a shallow dip but are locally dragged into northwesterly plunging folds adjacent to these faults; this is particularly evident along the Gooding Cove fault. The Restless fault is another example of a northwesterly trending fault which shows a west-up and probably right-lateral sense of displacement (Figure 1-2-3). Parson Bay sediments adjacent to it have been thrown into a series of northwesterly plunging chevron folds (Plate 1-2-7).

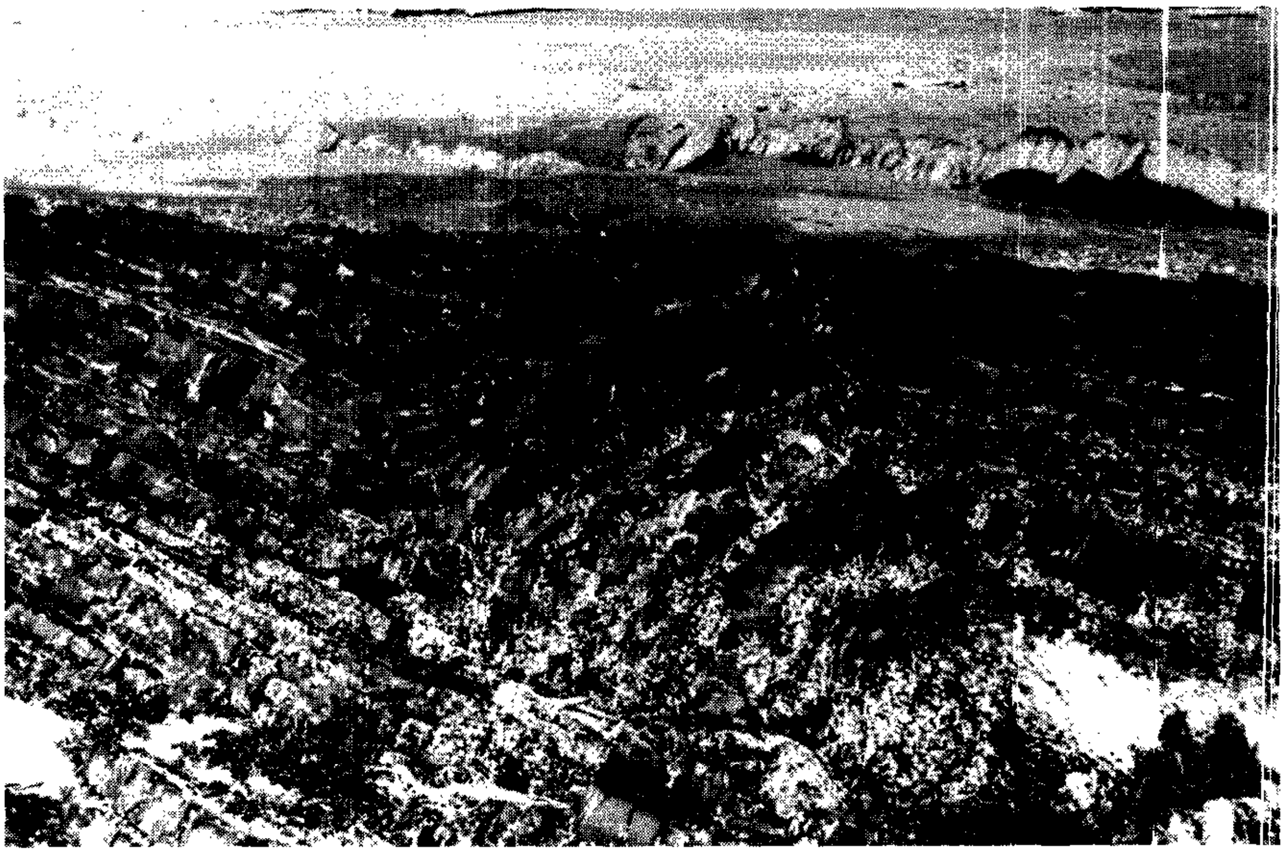

Plate 1-2-7. Chevron folds in thinly bedded Parson Bay sediments.

Steeply dipping, northwesterly trending faults form some of the most conspicuous lineaments within the study area. One of the most notable and intensely studied is the Mahatta River fault (Figure 1-2-3). North of the study area it offsets Cretaceous strata with right-lateral motion and, within the study area, there is some evidence for dip-slip motion bringing the southwest side up (Jeletsky, 1976).

The LeMare Lake fault is the only major fault in the Mahatta Creek area that displaces a known stratigraphic marker. At Red Stripe Mountain, Upper Triassic sedimentary rocks of the Quatsino and overlying Parson Bay formations are displaced to the south in a right-lateral sense by a system of subparallel faults. The magnitude of displacement across this composite fault trace, as indicated by the Quatsino limestone, is of the order of 5 kilometres. Subsidiary minor faults on the south side of the entrance to Klaskino Inlet locally exhibit subhorizontal slickensides consistent with late lateral motion.

Tertiary Normal Faulting

Northeasterly trending normal faults truncate and reactivate many pre-existing structures throughout the study area. The most intense zone of normal faulting lies along the Brooks Peninsula fault zone. Earliest movement along this fault is constrained by the truncation of major, northwesterly trending faults which cut Lower Cretaceous beds. Latest motion probably coincides with the eruption of Alert Bay volcanics and intrusion of coeval basaltic dikes.

Kinematic Analysis

Motion determinations on major structures were difficult to assess due to the overall lack of marker horizons. However, kinematic features shown by many minor faults were analyzed. Most fault planes are slickensided, and a small percentage of faults show minor offsets or drag folds giving a definitive movement direction.

When poles to faults are plotted and contoured, what appears to be a somewhat random array of faults reveals a few consistent orientations (Figure 1-2-4A, B). Kinematic indicators on some of these faults (drag folds, offsets, slickensides) also reveal some consistencies as follows (Figure 1-2-4C):

- The majority of structures which revealed right-lateral motion are associated with steeply dipping, northwest-trending faults (Figure 1-2-4C, 1-2-5A).
- Normal faults are more variable in orientation due to the reactivation of older structures. These faults typically trend northeast and dip steeply to moderately (Figure 1-2-4C, 1-2-5B).
- Structures which display thrust or reverse motion are also quite variable but are somewhat consistent with northeasterly directed and south to southwesterly directed compressional events (Figure 1-2-4C, 1-2-5C).

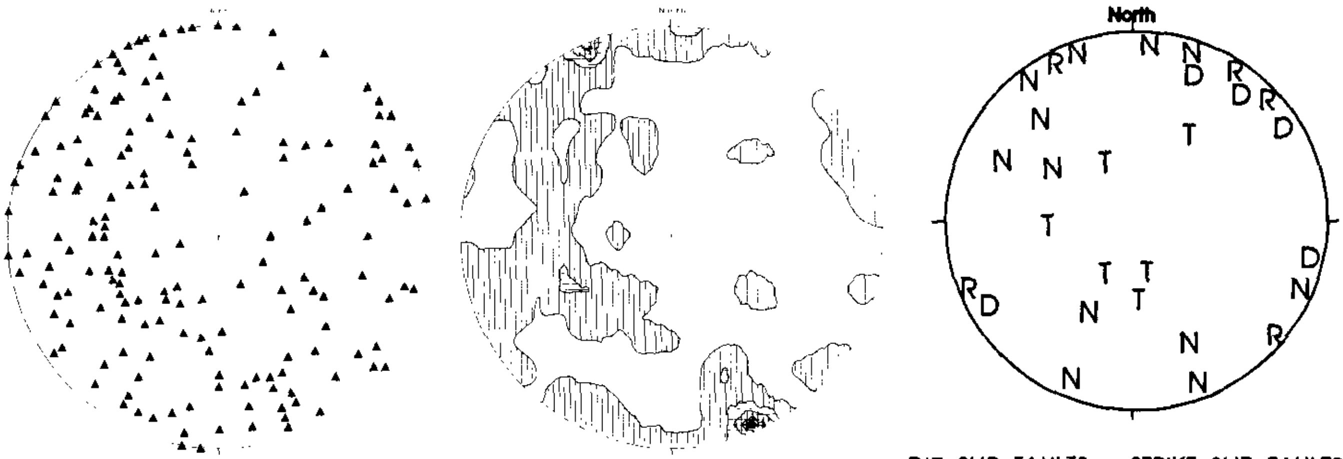

Figure 1-2-4. Equal-area plot of poles to faults within the Mahatta Creek map area. (A) plot of poles; (B) contoured utilizing a contour interval of 2% points per 1% area; (C) faults with known displacement.

Lithological Controls On Structural Styles

Thick, massive Karmutsen basalts, the stratigraphically lowest unit in the area, may have controlled the dominant structural style by accomodating strain by block faulting (Muller, 1974). This competent unit has formed a firm base which may have shielded the less competent overlying units from more intense deformation.

Bedded sediments of the Parson Bay Formation, and to a lesser extent the Quatsino Formation, have accommodated strain by flexural-slip folding and bedding-parallel shear. These folds are most evident in the west of the study area and typically verge toward the southwest or northeast. Locally, the overlying Bonanza volcanics are also broadly warped along similar fold axes. Bedded epiclastic and pyroclastic rocks within the Bonanza Formation commonly show bedding-parallel shear but mesoscopic folds are rare.

Poles to bedding planes have been plotted on equal-area stereonets for the Bonanza volcanics and Parson Bay, Quatsino and Longarm formations (Figure 1-2-6). The Triassic and Jurassic lithologies show fairly consistent northwesterly to southwesterly dips. The Parson Bay sediments have been more prone to accomodation of strain by folding along north-northeast to north-northwesterly trending fold axes. Longarm sediments are typically subhorizontal to gently dipping, except where they have been dragged along northwesterly trending faults.

ECONOMIC GEOLOGY AND EXPLORATION ACTIVITY

The prime economic targets in the Quatsino Sound area are gold-bearing iron and copper-rich skarns, precious metal bearing epithermal systems, porphyry deposits as characterized by the Island Copper orebody, and gold-enriched high-sulphidation systems transitional between porphyry and epithermal environments (Panteleyev, 1992). Recent summaries of these deposit types can be found in McMillan *et al.* (1992) and Dawson *et al.* (1991), and the results of recent fieldwork in transitional environments west of Island Copper (Red Dog - Hushamu) are given by Panteleyev and Koyanagi (1993, this volume). Some 40 mineral occurrences in the map area are documented in the MINFILE database. Details of their locations and principal commodities are given in Open File 1993-10.

The Mahatta Creek area contains one past producer, the Yreka mine, situated just west of Neroutsos Inlet (Figure 1-2-3). Work began in 1898 and intermittent production between 1902 and 1967 totalled some 145 000 tonnes averaging 2.7 per cent copper, 31 grams per tonne silver and 0.34 gram per tonne gold. The ore is associated with an epidote-garnet skarn assemblage developed in limestones and augite-plagioclase-bearing limy tuffs of the Parson Bay Formation. The skarns are associated with quartz-plagioclase porphyry dikes and sills. Disseminated pyrrhotite and chalcopyrite with sparse pyrite, magnetite and hematite are locally controlled by faults or occur along stratigraphic horizons as lensoid replacement bodies (Wilson, 1955). Skarn occurrences in the surrounding area also contain minor amounts of sphalerite and galena.

Minor quartz feldspar porphyry intrusions are also found farther south near the eastern margin of a larger body of diorite near the mouth of Teeta Creek. Hydrothermal alteration is pronounced and hints of porphyry-style mineralization are found in local breccia pipes that contain disseminated chalcopyrite. The breccias contain rare sulphide fragments that signify a complex multi-stage history (C.I. Godwin, personal communication, 1992). Hydrothermal stockworks and veins containing copper and traces of molybdenum and precious metals are found elsewhere in the region.

Exploration activity in the Mahatta Creek area in 1992 was largely focused in the west, at LeMare Lake, on claims

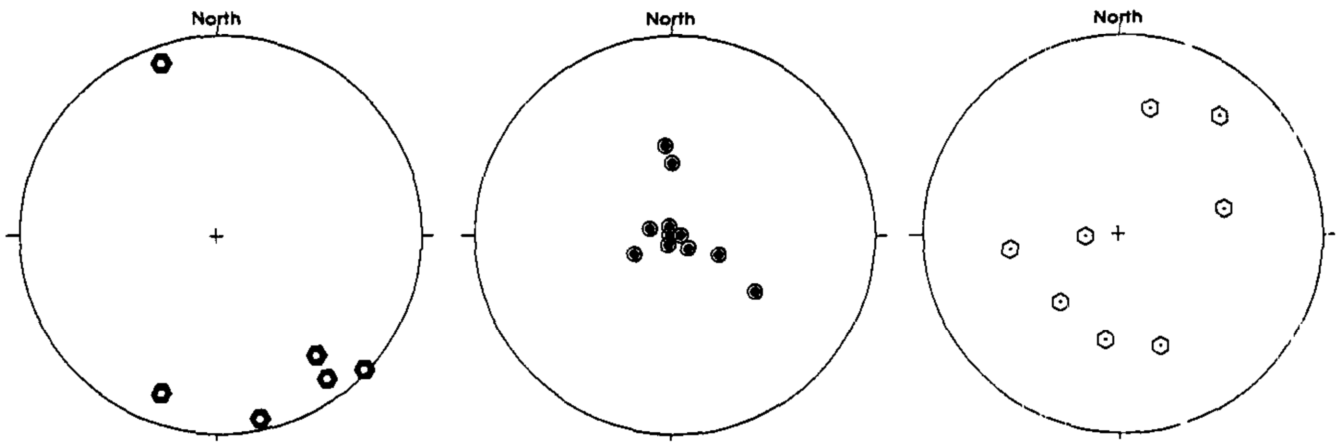

Figure 1-2-5. Displacement vectors on fault planes derived from drag folds, offsets and/or slickensides. (A) dextral faults; (B) normal faults; (C) thrust faults.

held by Minnova Inc., and on the Madhat property by Pan Orvana Resources Inc. Both properties were sampled extensively over the summer for soil and bedrock geochemistry, and drilling programs were conducted in the fall.

The Minnova property at LeMare Lake (Figure 1-2-3) covers an extensive zone of hydrothermal alteration. The hillsides west of the lake are underlain by a well-exposed, cyclical, basalt-rhyolite succession of intercalated flows, pyroclastic and epiclastic deposits which strike north-northwest and have westerly dips and facing directions. A typical lithological cycle, from bottom to top, includes: dark greenish grey to maroon, weakly amygdaloidal, aphanitic to finely porphyritic (<1 mm) basalt; volcanic siltstones, sandstones and minor granule conglomerates of predominantly mafic to intermediate heritage; greenish grey to pink, intermediate to predominantly rhyolitic, non-welded to strongly welded, lithic-rich lapilli tuffs and tuff-breccias, locally including rhyolitic base-surge deposits with shallow-angle cross-bedding and airfall(?) material, overlain by viscous, flow-laminated rhyolite. The epiclastic-pyroclastic succession is usually less than 20 metres thick, and the intermediate units generally comprise a mixture of rhyolite and basalt clasts. The common occurrence of densely welded textures involving flattened pumice lapilli indicates a subaerial environment of dominantly bimodal volcanism.

Alteration of these lithologies is most pronounced in a zone covering an area of more than a square kilometre just west of the southern tip of LeMare Lake. Widespread argillic, advanced argillic and more localized phyllic alteration commonly contain minor amounts of disseminated pyrite accompanied by rare malachite staining along fractures. The most intense alteration involves higher temperature, quartz-pyrophyllite assemblages that, unlike similar assemblages at the Island Copper mine, appear to lack dumortierite. These alteration zones are cut by a series of variably altered mafic dikes, some of which are quite fresh and appear to post-date the alteration. This strongly suggests that the alteration is syn-Bonanza or Early Jurassic in age.

Similar bimodal lithologies with more restricted zones of argillic alteration also occur southeast of LeMare Lake. However, these alteration zones are unlikely to represent an extension of their counterparts to the west as they are separated from them by the LeMare fault, which shows some 5 kilometres of right-lateral offset. A small zone of potassic alteration containing rare chalcopyrite, possibly associated with porphyry-style mineralization at depth, is exposed in the northern part of the claim block in the low ground between LeMare Lake and Harvey Cove.

The Madhat property of Pan Orvana Resources Inc. is located approximately 5 kilometres south-southeast of O'Connell Lake (Figure 1-2-3). The claims cover a structurally complex region at the intersection of major east-northeast and northeast-trending faults. The northeast-trending faults are intruded by Bonanza(?) dikes of mafic to rhyolitic composition; the latter have chilled margins of greyish green partly devitrified obsidian. In addition, the lithological affinities of fault panels of volcanic and sedimentary rocks, currently assigned to the Parson Bay Formation and Bonanza volcanics, remain to be firmly established by microfossils and geochemistry respectively. Structurally controlled quartz-carbonate alteration and veining with minor disseminated pyrite and chalcopyrite coincides with anomalous gold geochemistry in soils and bedrock; elevated copper values occur near the fringes of the gold anomalies. The mineralization appears to be related to a shallow hydrothermal source, possibly linked with dioritic intrusions in the vicinity.

ACKNOWLEDGMENTS

The crew of "Operation Rainforest" would like to thank Nick Massey for indoctrinating (innoculating?) us; Harvey Herd and the staff of Western Forest Products for easing our logistics at Mahatta River; Peter Bradshaw and Andy Laird (Pan Orvana Resources Inc.) for geological discussions and visits to the Madhat property; Cam DeLong, Dave Heberlein and Minnova Inc. for accommodating property visits and freely sharing geological data (Cam DeLong first suggested the possibility of an intra-Bonanza age for the mineralization and alteration at LeMare Lake based on dike relationships); the remainder of the Minnova crew,

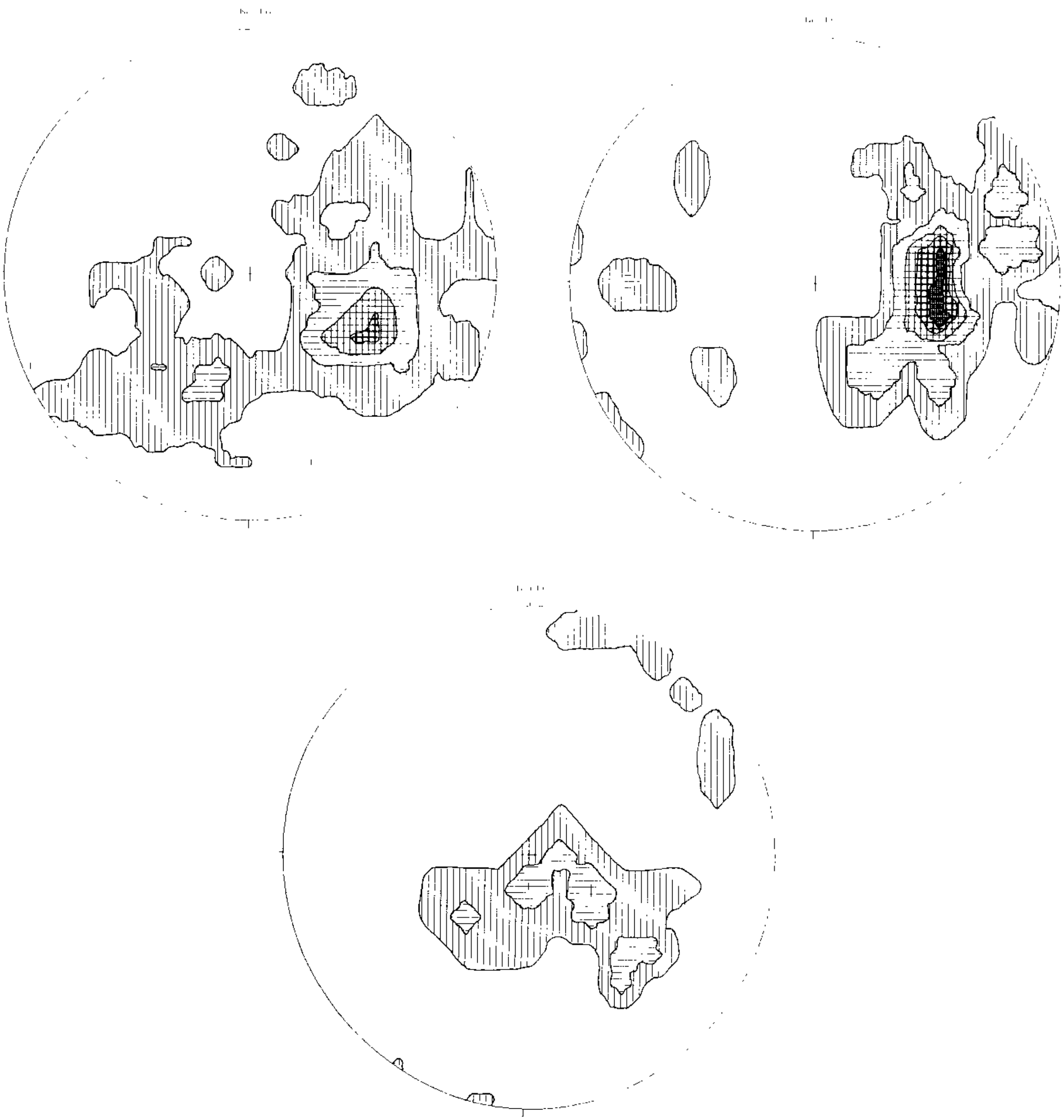

Figure 1-2-6. Poles to bedding planes for (A) Parson Bay Formation; (B) Bonanza volcanics; (C) Longarm Formation. Contoured utilizing a contour interval of 2% points per 1% area.

especially culinary wizard Lisa Horvat for barbecues, including an unforgettable "New England crab bake", and artiste extraordinaire Lloyd Cornish for cartooneering our trials and tribulations (Plate 1-2-8), "sharing the wealth", and introducing us to the irrepressible beer-bottle saga; Fabrice Cordey for agreeing to join us in the field to share his radiolarian expertise, for showing us "features", and above all, for enhancing the beer-bottle saga; the staff of Quatsino Chalet, Port Alice, for a memorable stay; Alan Gilmour for logistical support and showing us precisely how to lose his crab trap; and El Niño for a wonderful summer. Thanks are extended to Brian Grant and John Newell for superb editorial handling.

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Plate 1-2-8. "Operation Rainforest", rendition by Lloyd Cornish.

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