Geology and Mineral Potential of Porcher Island, Northern Grenville Channel and Vicinity, Northwestern British Columbia

by J.L. Nelson, J.B. Mahoney[1], G.E. Gehrels[2], C. van Staal[3] and J.J. Potter[2]

KEYWORDS: Alexander terrane, Porcher Island, Grenville Channel, Coast Mountains, Wales Group, Descon Formation, iron formation

INTRODUCTION

The mineral potential of a significant number of tracts in the northern coastal area of British Columbia is assessed as high (Categories 1 and 2 out of 10; BC Mineral Potential Assessment Program; MapPlace, 2009; Kilby, 1995), but active mineral exploration has been low, as indicated by the relatively low number of assessment reports and recorded mineral showings. Just as it has received comparatively little exploration interest, this area has also not seen systematic public geological mapping since the original Geological Survey of Canada work in the 1960s (Roddick, 1970; Hutchison 1982).

This is year 1 of a planned three year activity to examine the bedrock geology of the north coast area of BC and its potential for hosting significant mineral deposits (Figure 1). The north coast bedrock mapping and mineral deposit study is part of a larger co-operative, National Resources Canada–led endeavour, the Edges (Multiple Metals–Northwest Canadian Cordillera (Yukon, BC)) project. The Edges project aims to increase our understanding of the far-travelled terranes that make up the outer accreted margin of the Canadian Cordillera and of their metallic mineral potential (for a detailed project description see http://gsc.nrcan.gc.ca/gem/min/edges_e.php). Edges is a contribution to the GEM (Geo-mapping for Energy and Minerals) program, a federal program that was initiated in 2008 to enhance public geoscience knowledge in northern Canada to stimulate economic activity in the energy and mineral sectors. The Edges project is a collaboration between the Geological Survey of Canada, the BC Geological Survey and the Yukon Geological Survey, and involves the United States Geological Survey and Canadian and American academic contributors.

The northern coastal area of BC is underlain in part by rocks of the southern Alexander terrane, a large composite crustal fragment that underlies part of the St. Elias Mountains on the Yukon-Alaska border and most of southeastern Alaska (Figure 1; Wheeler et al., 1991). It is of considerable exploration interest because of the volcanogenic massive sulphide (VMS) deposits that it hosts, including Niblack and others on southern Prince of Wales Island just north of the BC-Alaska border, as well as a trend of Triassic deposits, notably Windy Craggy and the Greens Creek mine (Figure 1). In this first year of the north coast project, we began geological mapping on and near Porcher Island (NTS 103J/01, 02, 103G/15, 16, 103H/12), at the northern end of the Alexander terrane in BC to take advantage of the proximity of these rocks to the much better known stratigraphy in southeastern Alaska, as well as to the known volcanogenic deposits there.

PREVIOUS WORK

The northern coastal region of BC was first mapped systematically, at 1:250 000 scale, as part of Geological Survey of Canada regional coverage of the entire Coast Mountains batholith and its surrounding rocks. The Porcher Island–Grenville Channel area was covered as part of the Prince Rupert–Skeena map area (Hutchison, 1982) and the Douglas Channel–Hecate Strait map area (Roddick, 1970). The focus of these studies was on the plutonic rocks; at that time, the necessary tools for the analysis of metamorphosed volcanic and sedimentary sequences, U-Pb dating and trace-element geochemistry, were not yet available.

More recent geological work in the northern coastal region of BC has focused on understanding the structural and igneous history of the Coast Mountains orogen; Porcher Island and Grenville Channel have been visited by many researchers in the course of much broader studies (Chardon et al., 1999; Chardon, 2003; Butler et al., 2006; Gehrels et al., 2009). Overall, the details of its geology and of the prebatholithic Alexander terrane rocks in particular have not been investigated. The sole exception to this has been the ongoing, mostly unpublished work of G. Gehrels, part of which is summarized in Gehrels (2001) and Gehrels and Boghossian (2000).

REGIONAL GEOLOGICAL SETTING

Northern coastal BC is underlain by a wide variety of metasedimentary and metavolcanic rocks that have been assigned to several tectonic assemblages. From west to east, these include the Banks Island assemblage, the Alexander terrane, the Gravina belt and the Yukon-Tanana terrane (Figure 2). With the exception of the Banks Island assemblage, which has only been recognized along the outer coast of northern BC, most of these units can be traced northward into adjacent portions of southeastern Alaska, where their lithic components, structural and metamorphic

[1] *University of Wisconsin at Eau Claire, WI*

[2] *University of Arizona, Tucson, AZ*

[3] *Geological Survey of Canada, Vancouver, BC*

This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the BC Ministry of Energy, Mines and Petroleum Resources website at http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/Fieldwork/Pages/default.aspx.

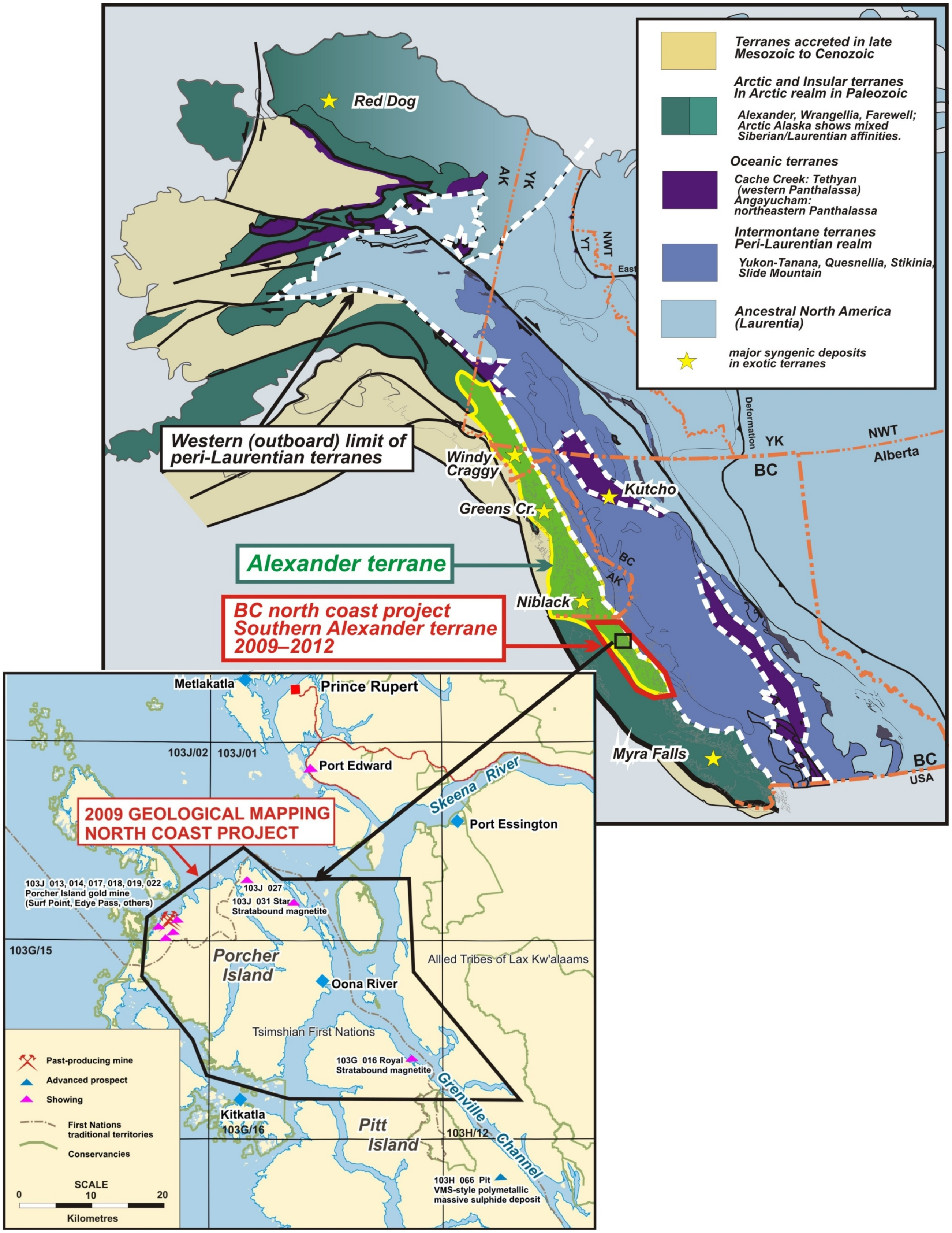

Figure 1. Location of the north coast project, British Columbia, in the context of northern Cordilleran terranes and in terms of local geography.

characteristics, and ages have been described by Gehrels et al. (1987, 1996), Rubin and Saleeby (1992), Saleeby (2000) and Gehrels (2001).

Alexander Terrane

The Alexander terrane in the southern part of southeastern Alaska and northern coastal BC consists of a broad range of volcanic, sedimentary and plutonic rocks, and their metamorphic equivalents, which are primarily of early Paleozoic age (Figure 3). These rocks underlie most of southern part of southeastern Alaska, where they have experienced only minor younger metamorphism, deformation and plutonism. Farther to the southeast, Cretaceous plutons become more widespread and the degree of younger deformation and metamorphism increases. In spite of this younger overprint, it is possible to correlate geological units from southeastern Alaska into northwestern coastal BC, and accordingly we use the nomenclature established in the adjacent Alaskan panhandle. The following unit descriptions are taken from the well-preserved portion of the Alexander terrane in southern part of southeastern Alaska (from Gehrels and Saleeby, 1987; Gehrels et al., 1996).

The oldest rocks recognized in the Alexander terrane consist of Late Proterozoic to Cambrian metavolcanic and metasedimentary assemblages of the Wales Group (Figure 3). Metavolcanic components range from mafic to felsic in composition, with lithic units ranging from metres to hundreds of metres in thickness. Protolith features indicate that these rocks were originally pillow flows, flow breccia, tuffaceous breccia and tuff. Metasedimentary components, similar in abundance to metavolcanic rocks, consist of metagreywacke rich in volcanic detritus, phyllite or schist derived from mudstone and shale, and massive marble. Intrusive into these assemblages are bodies of complexly interlayered gabbro, diorite, tonalite and granodiorite, with layering commonly on a 1–10 m scale. All rocks of the Wales Group have a strong foliation and lineation that is commonly folded around outcrop-scale open folds. Metamorphism ranges from greenschist (rich in actinolite, chlorite and epidote) to amphibolite facies (rich in amphibole, biotite, muscovite and rare garnet).

Rocks of the Wales Group in southeastern Alaska are overlain by a younger suite of lower grade and less deformed volcanic and sedimentary rocks referred to as the Descon Formation. Protoliths of these rocks are very similar to those in the Wales Group, with the only significant difference being a scarcity of marble in the Descon Formation. Rocks of the Descon Formation generally lack a metamorphic foliation and lineation and are greenschist or lower in metamorphic grade. The age of these strata is constrained by fossils and U-Pb geochronology as Early Ordovician–Late Silurian. Plutons that are coeval (and probably cogenetic) with volcanic rocks of the Descon Formation are widespread and range from diorite to granite in composition.

These early Paleozoic assemblages are overlain unconformably by a variety of Devonian strata that commonly include a basal clastic sequence (conglomerate and sandstone) of the Karheen Formation; mafic volcanic rocks of the Coronados, St Joseph Islands and Port Refugio formations; and limestone of the Wadlegh Formation. The basal conglomerate is interpreted to represent a major phase of uplift and erosion, the Klakas orogeny, as it overlies and contains clasts of a wide variety of older rocks (Gehrels and Saleeby, 1987).

Younger strata in the Alexander terrane include fine- to medium-grained clastic strata, carbonate rocks and minor

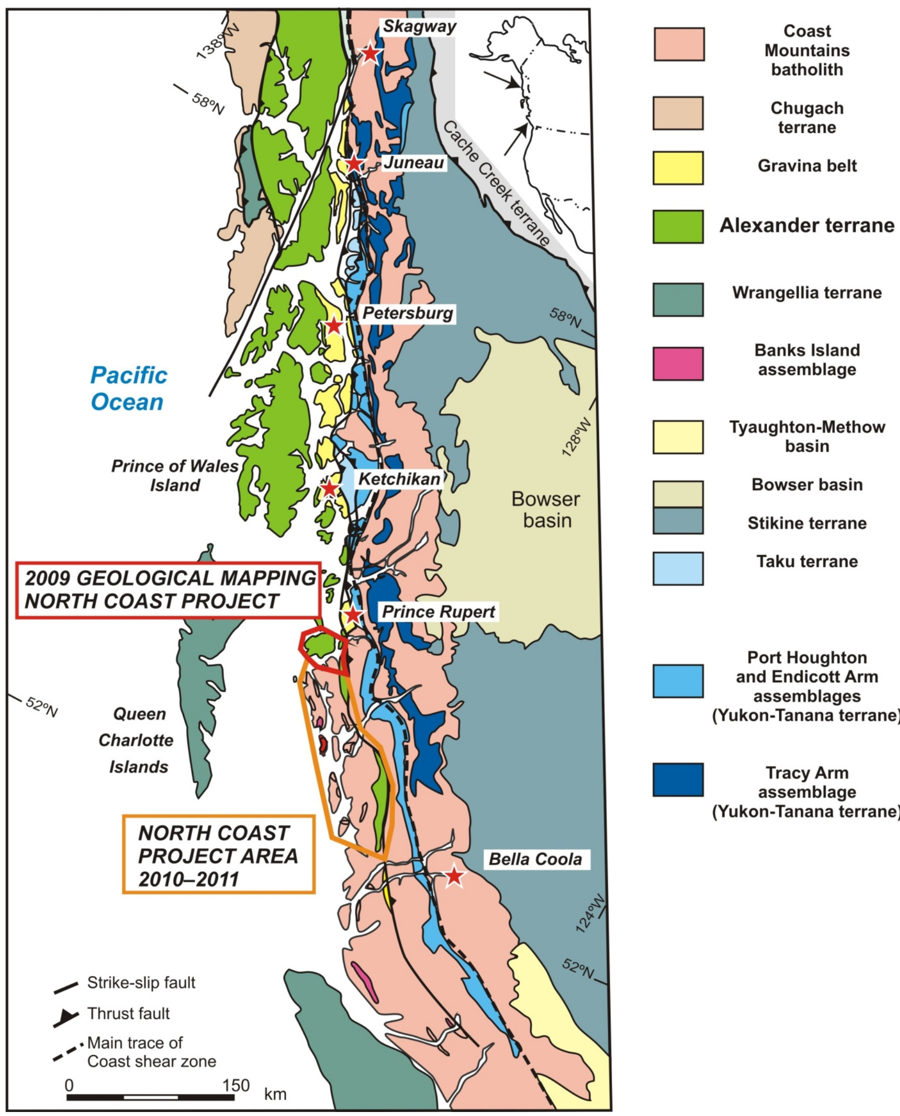

Figure 2. Regional geology of northern coastal British Columbia and southeastern Alaska and setting of the Alexander terrane.

basalt of Carboniferous and Permian age, a Triassic basal conglomerate overlain by bimodal volcanic rocks, carbonate rocks and rare conglomeratic strata of Triassic through Middle Jurassic age.

The Niblack prospect on southern Prince of Wales Island (Figure 1), acquired by CBR Gold Corporation in 2009, is a Cu-Zn-Au-Ag–rich, Kuroko-type VMS deposit with an estimated resource of 2.59 million tonnes at 1.2% Cu, 2.2% Zn, 33.2 g/t Ag and 2.3 g/t Au (CBR Gold Corp., 2009). It is located within a tightly folded pyroclastic rhyolite unit, the Lookout rhyolite, which lies above a bimodal felsic and mafic sequence and below a section of mafic volcanic rocks. It has been regarded as hosted within the Wales Group (Gehrels et al., 1996). Recently, an Ordovician date of ca. 478 Ma has been obtained from the Lookout rhyolite (Karl et al., 2009); this suggests that it is coeval with the Descon Formation, rather than with the Neoproterozoic–Cambrian Wales Group. Ayuso et al. (2005) and Slack et al. (2005) assigned these rocks to the informal Moira Sound unit. They, as well as Gehrels et al. (1983), point out that volcanogenic deposits are known both in this unit and within the Wales Group proper and that both Neoproterozoic and Ordovician volcanic sequences are prospective for syngenetic mineralization.

Other Terranes and Assemblages

BANKS ISLAND ASSEMBLAGE

The Banks Island assemblage (Figures 2, 3) has been recognized as a distinct unit based on the predominance of interlayered metaclastic quartzite and marble in it, which are rare in the generally more primitive Paleozoic arc-related assemblages of the Alexander terrane; it appears to have a continental margin affinity (Gehrels and Boghossian, 2000). These rocks are exposed on the southern shore of Banks Island and can be traced northward to western Porcher Island, west of the 2009 map area. The dominant lithic components are strongly deformed and regionally metamorphosed metaclastic quartzite that commonly occur in centimetre-scale bands, marble layers with thicknesses of several centimetres to several tens of metres, and phyllite and schist derived from shale and mudstone. These rocks have a well-developed foliation everywhere, which is commonly folded into tight, outcrop-scale isoclinal folds. Pelitic components have been metamorphosed to biotite phyllite or schist, and garnet is present in some regions.

The age of the Banks Island assemblage is constrained only by the following relations: a maximum age of deposition is indicated by detrital zircons recovered from two quartzite rocks, which are as young as ca. 415 Ma (Silurian; G. Gehrels, pers comm, 2009). A minimum age for the assemblage can be inferred from an orthogneiss, which has yielded a U-Pb age of 357 Ma (Early Mississippian), and which appears to have experienced the same regional deformation and metamorphism as surrounding marble. A broader minimum age constraint is provided by plutons of Late Jurassic age that are emplaced into these rocks (Gehrels et al., 2009) and at least locally intrude across the regional foliation and folds. Together, these constraints suggest that at least some portions of the Banks Island assemblage accumulated during mid-Paleozoic time.

GRAVINA BELT

Rocks of the Alexander terrane are overlain by Upper Jurassic and Lower Cretaceous clastic strata—commonly conglomeratic turbidites—and mafic volcanic rocks of the Gravina belt. These rocks can be traced, generally along the inboard margin of the Alexander terrane, for the length of southeastern Alaska (Berg et al., 1972) and into northern coastal BC (Figure 2). On Tongass Island in southeastern Alaska and on the mainland east of Port Simpson (Lax Kw'alaams), these rocks also overlie a sequence of metavolcanic and metasedimentary rocks that have been assigned to the Yukon-Tanana terrane (Gehrels, 2001).

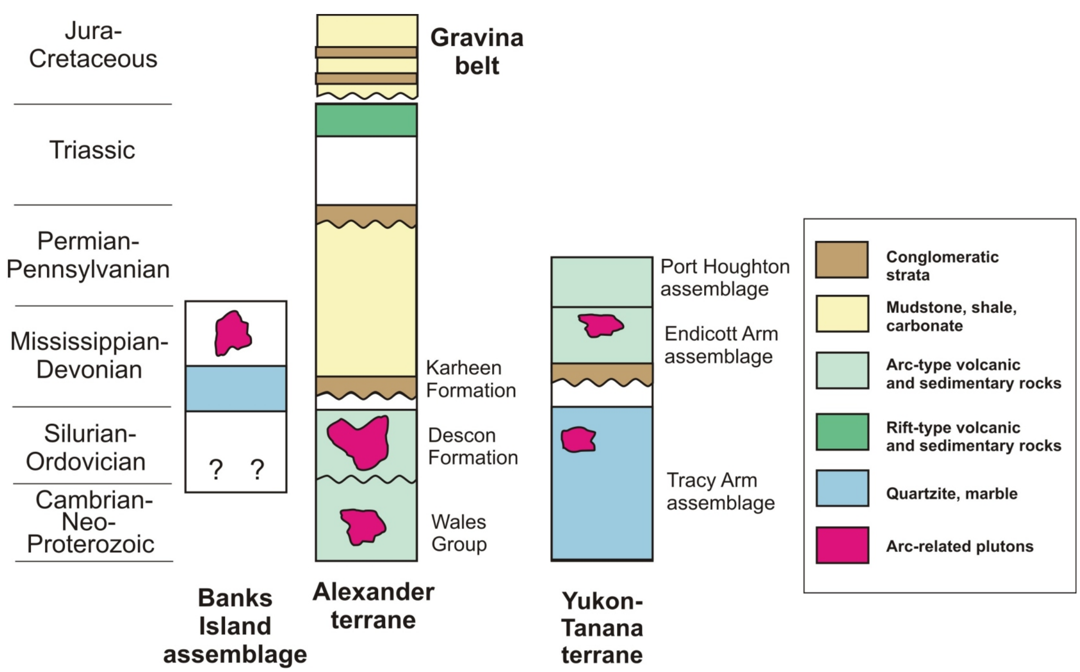

Figure 3. Stratigraphic columns for major terranes of southeastern Alaska.

YUKON-TANANA TERRANE

East of the Alexander terrane and Gravina belt are metavolcanic and metasedimentary rocks of the Yukon-Tanana terrane that underlie the western margin of the Coast Mountains, along the length of southeastern Alaska and northern coastal BC (Figure 2). In general, these rocks form a panel that dips eastward and youngs westward, suggesting that the overall stratigraphy is inverted. Using the nomenclature defined in southeastern Alaska, the Yukon-Tanana terrane includes the following (Figure 3):

Tracy Arm assemblage: Marble, quartzite, pelitic schist and orthogneiss are migmatitic and commonly high in metamorphic grade.

Endicott Arm assemblage: This unit has a distinctive basal conglomerate containing clasts derived from the Tracy Arm assemblage. Overlying strata include greenschist- to amphibolite-facies felsic to mafic metavolcanic rocks, pelitic schist and minor marble. Available faunal and U-Pb geochronological constraints suggest that most strata are Devonian–Mississippian in age.

Port Houghton assemblage: These strata gradationally overlie the Endicott Arm assemblage and consist of greenschist- to amphibolite-facies metaturbidite, pelitic schist and metabasalt. Available faunal constraints suggest that most strata are late Paleozoic in age.

In northwestern BC, the Ecstall belt (Alldrick, 2001; Alldrick et al., 2001; see also Gareau and Woodsworth, 2000), with its enclosed Devonian volcanogenic deposits, is also assigned to the Yukon-Tanana terrane. The host units are equivalent to the middle Endicott Arm assemblage of southeastern Alaska.

Plutons of the Western Coast Plutonic Complex

Tonalitic to granodioritic plutons of the Coast Plutonic Complex, or the Coast Mountains batholith, occur as isolated bodies in northern and western portions of northern coastal BC, and increase in extent southeastward to form huge continuous bodies of plutonic rock (Figure 2; Gehrels et al., 2009). Compositionally, most bodies are tonalite and granodiorite, with subordinate diorite and minor gabbro and leucogranodiorite. Most bodies have more hornblende than biotite and abundant titanite, and some plutonic suites contain euhedral epidote that is interpreted to be magmatic in origin. Plutons west of the main batholith are generally undeformed, whereas a subsolidus foliation and lineation are more strongly developed toward the east into the core of the Coast Mountains orogen.

According to a recent comprehensive geochronological summary (Gehrels et al., 2009), plutonic U-Pb ages record a history of eastward migration across the Coast Mountains: westernmost are 160–140 Ma (Late Jurassic) tonalite and granodiorite, there are few plutons in the area that are 140–120 Ma, 120–100 Ma (Early Cretaceous) tonalite and granodiorite occur directly east of the Late Jurassic bodies, a nearly continuous band of 100–85 Ma plutons (e.g., Ecstall pluton of Hutchison, 1982) underlies the western margin of the Coast Mountains, mainly tonalitic sills of ca. 70–60 Ma (latest Cretaceous–earliest Tertiary age) occur to the east, and the central and eastern portions of the Coast Mountains are underlain by huge 60–50 Ma (Eocene) granodiorite bodies.

The depth of emplacement of these plutons also changes eastward across the Coast Mountains. Hornblende barometric studies of the plutons, conducted by Butler et al. (2006), suggest that westernmost Late Jurassic bodies were emplaced at depths of ~15 km. The Early Cretaceous plutons to the east were slightly deeper, ~20 km, whereas mid-Cretaceous plutons of the Ecstall belt were emplaced at significantly greater depths, perhaps 25–30 km. This increase in depth of emplacement correlates well with the eastward increase in metamorphic grade.

LOCAL GEOLOGY

The 2009 map area, comprising the vicinity of Porcher Island, northwestern Pitt Island and Grenville Channel, is underlain by a series of northwest-striking panels of metamorphosed supracrustal and metaplutonic rocks, intruded by late synkinematic, Cretaceous plutons (Figure 4). Although they are metamorphosed and in some cases strongly deformed, we have tentatively correlated the stratified units with known stratigraphic units of the Alexander terrane of southeastern Alaska. We recognize the Wales Group, the Descon Formation and the Karheen Formation. Pre-Cretaceous plutonic bodies include the Ordovician McMicking pluton, the Devonian (?) Swede Point pluton and the possibly Silurian Hunt Inlet pluton. Southwest of the metamorphosed supracrustal units, two metamorphosed igneous complexes, the Ogden Channel and Billy Bay complexes, are recognized. They may be intrusive equivalents of the Wales and/or the Descon volcanic sequences.

Because of lack of bedrock exposure and difficult access to the island interiors, most of the observations that form the basis of our mapping were made along shorelines. These were supplemented with logging road traverses where such access existed, helicopter spot checking and image analysis of 5 m resolution SPOT-5 satellite data from 2004 to 2006.

The geology in Figure 4 is based on a 1:50 000 open file map in preparation that will be available in early 2010 (Nelson et al., in press).

Stratified Units

WALES GROUP (?)

The Wales Group was named for a succession of greenschist- to amphibolite-facies metavolcanic and metasedimentary rocks exposed on Prince of Wales Island in southeastern Alaska (Buddington and Chapin, 1929; Gehrels and Saleeby, 1987). The protoliths include basaltic to andesitic flows, breccia and tuff, rhyolite tuff, greywacke, mudstone and limestone. Metasedimentary and metavolcanic rocks occur in subequal proportions, and the rocks are characterized by well-developed foliation and lineation (Gehrels and Saleeby, 1987). The Wales Group is Late Proterozoic to Cambrian in age, based on a ca. 554 Ma U-Pb date on a crosscutting pluton on Dall Island (Gehrels, 1990) and on a small population of ca. 595 Ma, probably inherited zircons in the Ordovician Lookout rhyolite, which overlies the Wales Group on southern Prince of Wales Island.

In the 2009 map area, the Wales Group is exposed on the eastern side of Porcher Island, on the west coast of the

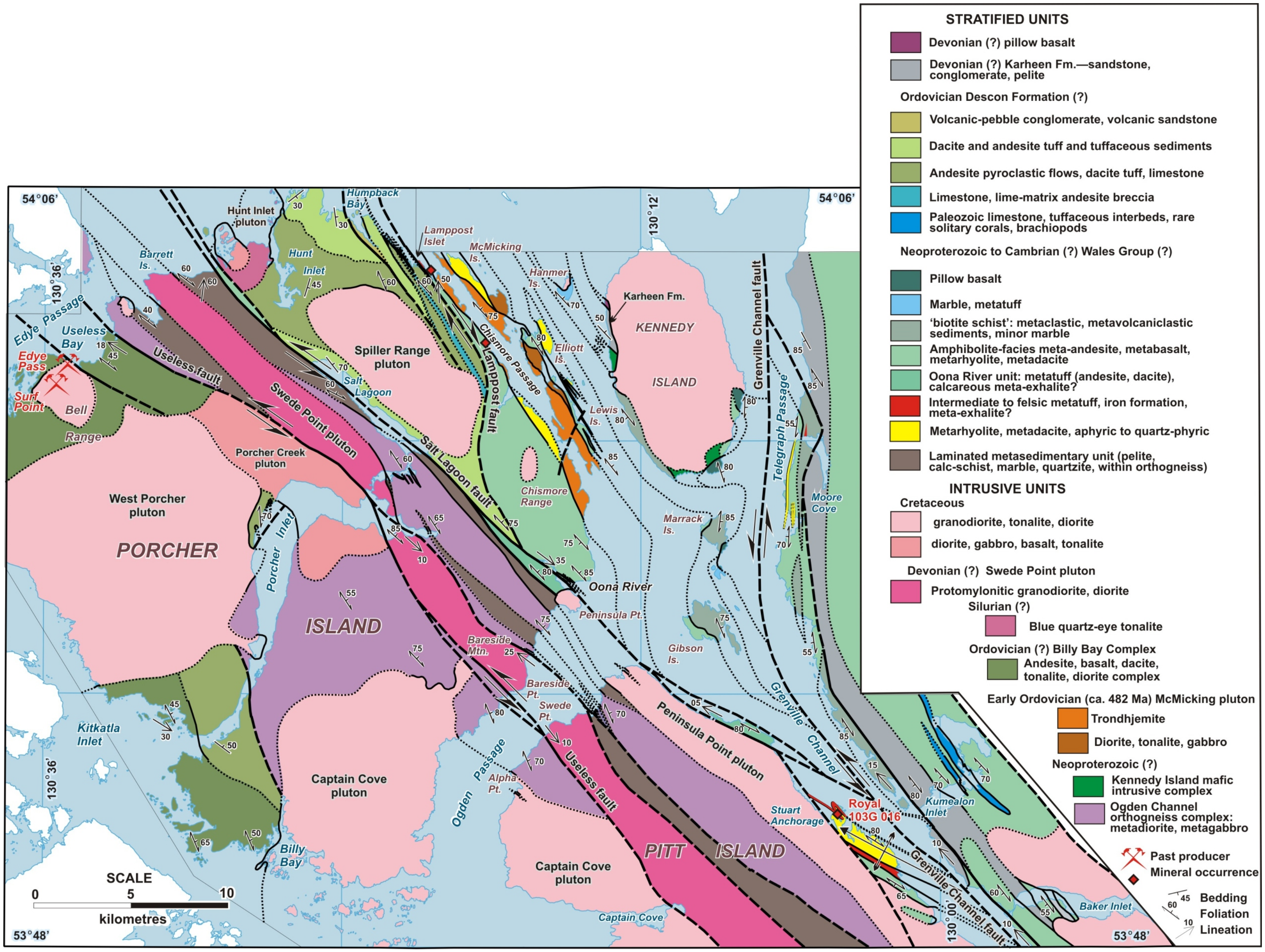

Figure 4. Geology of Porcher Island and Grenville Channel area, northwestern British Columbia. Geological mapping done in 2009 by J. Nelson, J.B. Mahoney, G. Gehrels and C. van Staal; with added information from Roddick (1970), Hutchison (1982) and G. Gehrels, pers comm (2009).

mainland east of Telegraph Passage and Grenville Channel, and on the islands in between (Figure 4). The outcrop belt contains several subparallel lithostratigraphic facies belts exposed between the Useless fault on central Porcher Island and the eastern side of Grenville Channel. The different facies are structurally and stratigraphically interdigitated on a variety of scales, but an overall regional map pattern can be discerned (Figure 4). Wales Group facies belts are described here from southwest to northeast. Note that all of these rocks are in amphibolite grade and in many parts of the area are highly strained, with sporadic and incomplete preservation of protolith textures and features. Nevertheless, enough diagnostic outcrops are present to allow confidence in characterizing the units.

Central Porcher Island

A metasedimentary unit forms the westernmost facies belt, occupying a faulted panel between the Useless and Salt Lagoon faults. It is well exposed along both the north and south coasts of Porcher Island. It consists of rusty-weathering, dark-coloured, thin-bedded metaclastic rocks, including thinly layered to laminated phyllite, biotite schist, marble, calcsilicate, lesser amphibolite and minor quartzite and metagreywacke (Figure 5). Light grey to tan coarse-grained marble successions are generally 1–10 m in thickness, but range locally up 30 m; they are intercalated with thin phyllite, biotite schist and green metatuff units. All primary layering in the unit is transposed into foliation. Intrafolial folds are particularly evident in the more calcareous intervals. Similar rocks form septa within the Ogden Channel Complex (see below). If the intrusions of the Ogden Channel Complex were feeders to volcanic successions of the Wales Group, then this metasedimentary unit contains the oldest supracrustal rocks exposed locally.

Northeastern Porcher–Chismore Passage Section

A meta-andesite unit, consisting of resistant, blocky-weathering, dark green metavolcanic rocks is exposed along the eastern coast of Porcher Island and on Elliott and Lewis islands (Figures 4, 6). The succession is dominated by dark green, massive andesite to basaltic andesite with interbedded thin- to medium-bedded tuff, tuff breccia, metaclastic rocks and marble. The resistant, blocky nature of the exposures results in prominent ribs of metavolcanic rock standing in bold relief against less resistant, finer-grained interbeds. Flow-top (?) breccias are locally preserved. The rocks are generally aphanitic to locally small plagioclase-phyric, and chloritically altered mafic minerals and centimetre-scale lapilli are locally evident. Marble layers within the andesite unit consist of thin layers and laminae of marble, interlayered with green metatuff.

A succession (>100 m) of light grey to greenish grey rhyolitic aphanitic to quartz-phyric crystal tuff and vitric crystal lapilli tuff is exposed on the eastern side of Elliott and Lewis islands. Rhyolite and dacite are interlayered with andesitic tuff and in some areas with thin marble units. Felsic rocks are recrystallized and display a distinct sugary texture, but primary quartz phenocrysts and white, aphanitic lapilli clasts are well preserved. Quartz veins (2–15 cm) are abundant within the unit on eastern Elliott Island. On Elliott Island, the unit appears tabular and laterally continuous, but thins to the south. On the eastern side of Lewis Island, rhyolitic intervals form 5–15 m successions intercalated within andesitic metavolcanic rocks. On McMicking Island, similar rhyolite or dacite forms a large, coherent-textured single body that may be a cryptodome rather than a surface flow.

Figure 5. Typical thinly laminated metamorphosed clastic rocks of the Wales Group on central Porcher Island, northwestern British Columbia; rock hammer for scale.

Figure 6. Typical Wales Group meta-andesite tuff with intrafolial folds, Elliott Island, northwestern British Columbia; rock hammer for scale.

Gibson, Marrack, Hanmer and Kennedy Islands

This section consists of three units. From southwest to northeast they include meta-andesite/metabasalt, a mixed metasedimentary unit and metamorphosed basalt and pillow basalt.

The meta-andesite/metabasalt unit is indistinguishable from the meta-andesite section on northeastern Porcher Island (see above), except that it is of higher metamorphic grade. It passes northeastward through a transitional contact into the metasedimentary unit. In most exposures, this consists of biotite schist, laminated pelite and metatuff, and minor thin marble and calcsilicate rocks. Thicker marble bodies occur on Hanmer Island (Figure 7) and on Lamb Island, an islet south of Marrack Island. They contain clasts and interbeds of fragmental volcanic origin, a feature that links them to the rest of the Wales Group.

A distinctive succession of stretched pillow basalt occurs on Daring Point, on the southeastern tip of Kennedy Island, and extends to the south to the southeastern tip of Marrack Island and the northeastern tip of Bedford Island (Figure 4). The basalt is aphanitic, locally amygdaloidal, and occurs in thick, homogeneous successions of up to 20–30 m thick. The diagnostic characteristic of the unit is stretched pillows, which display length to width ratios of 10:1 to 30:1, forming long, thin tubes that dominate the exposure.

Stuart Anchorage–Northeastern Pitt Island–Oona River

The Wales Group (?) section exposed on the small peninsula south of Stuart Anchorage on northeastern Pitt Island forms a tight anticline, truncated to the southwest by a fault that juxtaposes it with a body of unfoliated Cretaceous granodiorite. The stratigraphically lowest unit is a white, quartz-rich metadacite, consisting mostly of quartz with lesser biotite and muscovite in discontinuous trains. Colour laminations in some places appear to reflect original depositional layering in tuff; elsewhere, more even, coarse-grained textures may be derived from a coherent volcanic or hypabyssal protolith. One outcrop at the top of the dacite shows volcanic breccia textures (Figure 8). The sparse vegetation pattern on the rocky crest of the peninsula is very similar to that developed on the trondhjemite on McMicking, Elliott and Lewis islands. This pattern is probably due to similar, nutrient-poor bedrock chemistry. It is possible that the Stuart Anchorage metadacite is a high-level equivalent of the McMicking trondhjemite, and thus would be part of the Ordovician Descon Formation rather than the Wales Group. This suggested correlation will be tested by U-Pb dating.

The dacite is overlain gradationally by very biotite rich laminated tuff, which passes upward into a sequence of green andesitic thin-bedded to laminated tuff and tuffaceous sedimentary beds, cherty, fine-grained metadacite tuff and impure metachert. A notable feature within the thin-bedded tuffaceous unit is the presence of iron formation—fine-grained magnetite in layers and laminae, with some associated epidote-garnet concentrations. Metachert within this unit contains unusual metamorphic assemblages, including manganoan zoisite and axinite, as well as disseminations and laminae of sulphide minerals and magnetite. This unit is described in detail in the section on volcanogenic occurrences. The mixed laminated unit in turn grades upward into typical, less distinctly bedded green andesitic metatuff and lapilli tuff of the Wales Group. Facing directions determined from graded bedding and basal scours show original sedimentary tops facing towards the overlying andesitic section.

A continuation of the laminated metatuff unit outcrops in the valley around the village of Oona River, where it is used for road metal because of its susceptibility to fracture into centimetre-size blocks. It is both colour- and compositionally laminated on scales ranging from millimetres to decimetres, with alternation of hornblende-, plagioclase-quartz– and biotite-rich laminae; the latter give it a strong cleavage.

Eastern Grenville Passage

Rocks assigned to the Wales Group on the mainland coast east of Grenville Channel are, like the exposures on the nearby islands, for the most part amphibolite-facies andesite metatuff and breccia. These dark green rocks form monotonous sequences along the coast. Protoliths also include subvolcanic (?) intrusions—diorite, andesite and basalt, now metamorphosed to amphibolite facies—which are difficult in many cases to distinguish from extrusive rocks. Within this predominantly intermediate section, there are discrete bodies of potassium feldspar–rich metarhyolite and thin sequences of pelitic metasedimentary strata, particularly in the area around Moore Cove. Of particular interest are quartz-sericite schist and magnetite-bearing chert, described in the section on economic geology.

Metavolcanic rocks correlated with the Wales Group also occur in Kumealon and Baker inlets. They are mostly monotonous meta-andesite typical of the Wales Group. However, in both areas, protolith compositions are indicative of at least local bimodal volcanism. One example in Kumealon Inlet is of a basaltic pillow breccia (Figure 9), now a garnet-chloritoid amphibolite, in contact with a metamorphosed felsic breccia containing an assemblage of garnet, biotite, sillimanite and cordierite. At such high metamorphic grade, the preservation of primary igneous textures is remarkable.

Figure 7. Wales Group marble on Hanmer Island, with thin interlayers of andesitic metatuff, northwestern British Columbia; rock hammer for scale.

Figure 8. Dacite peperitic breccia at top of metadacite in Wales Group, Stuart Anchorage, northwestern British Columbia; rock hammer for scale.

DESCON FORMATION (?)

The Descon Formation was named by Eberlein et al. (1983) for a succession of basaltic-andesitic pillow flows and breccia, rhyolitic-dacitic tuff and breccia, greywacke and mudstone with subordinate conglomerate and limestone that underlies much of central Prince of Wales Island in southern Alaska (Gehrels and Saleeby, 1987). It is interpreted to be Early Ordovician to Early Silurian in age in southeastern Alaska, based on the occurrence of Middle Ordovician graptolites, 480–438 Ma plutons, and detrital zircon geochronology that ranges from ca. 490 to 460 Ma (Gehrels and Saleeby, 1987; Gehrels et al, 1996). The Descon Formation is interpreted to unconformably overlie deformed volcanic strata of the Late Proterozoic to Cambrian Wales Group, based on the greater degree of deformation and metamorphism in the Wales Group and the presence of a thick sedimentary breccia with deformed Wales Group clasts at the base of the Descon Formation on southern Prince of Wales Island.

In the 2009 map area, the Descon Formation is exposed in two outcrop belts along the northeastern and northwestern coasts of Porcher Island. As in southeast Alaska, the Descon Formation is differentiated from the older Wales Group by a lower degree of deformation and metamorphism and a lack of the striped marble-tuff units present in the Wales Group. In contrast to the Wales Group, the Descon Formation lacks penetrative cleavage and abundant intrafolial folds, does not exceed upper-greenschist metamorphic grade and displays well-preserved volcanic and sedimentary textures.

Eastern Facies

On northeast Porcher Island, the Descon Formation is exposed in a fault panel bounded on the east by the Lamppost fault, a sinistral oblique fault that juxtaposes Wales Group strata with the Descon Formation, and on the west by the Salt Lagoon fault, a sinistral transcurrent fault (Figure 4). The Descon Formation on northeast Porcher Island forms a gently dipping panel of rocks that generally dips to the west, but is folded into a series of gentle folds with an amplitude of hundreds of metres. The northeastern side of the outcrop belt is moderately foliated, with a lithologically controlled distribution of shear zones, and foliation decreases markedly to the west. The rocks in this area are generally lower-greenschist facies with readily identifiable sedimentary and volcanic textures. Regional mapping suggests the entire fault panel forms a broad, north-plunging synclinorium in which a crude stratigraphy youngs upsection from the eastern edge of the outcrop belt near Lamppost Islet to the centre of the synclinorium near Humpback Bay (Figure 4).

The lower portion of the stratigraphy consists of thin-bedded andesitic tuff and volcanic breccia (0.5–2 m) intercalated with brown marble (1–2 m) and thin- to medium-bedded green volcaniclastic arenite and wacke. Marble locally contains rhythmic intercalations (centimetre-scale) of thin green tuff. A striking component of this part of the sequence is andesite breccia beds with limestone matrix (Figure 10).

On the west side of the synclinorium, thin marble beds are intercalated with thin-bedded black argillite and thin- to medium-bedded volcanic lithic arenite on the shores of Salt Lagoon.

Figure 9. Basalt pillow breccia in amphibolite facies, Kumealon Inlet, northwestern British Columbia; pen magnet for scale.

Interbedded tuff, volcaniclastic sedimentary rocks and marble near the base of the succession give way up to epiclastic strata with interbedded very finely laminated felsic tuff (Figure 11). Rhyolitic lapilli tuff (0.5–2 m) with distinct white angular lapilli clasts forms a minor but distinctive part of the thin-bedded succession, and becomes volumetrically more important upward. Rhyolitic to dacitic lapilli tuff and tuff breccia units up to several metres thick are interbedded with thin bedded, fine-grained sedimentary successions north of Lamppost Islet.

The primary volcanic character of the Descon Formation decreases upsection, and the unit becomes increasingly epiclastic in character. South of Mason Point, the section is dominated by medium- to thick-bedded, fine- to medium-grained volcanic lithic arenite to wacke that is locally coarse-grained, moderately well sorted, subangular to subrounded and intercalated with thin-bedded siltstone to mudstone. Sedimentary structures include parallel to wavy laminations, graded bedding, crosslaminations and basal scour surfaces. Thin brown marble is locally rhythmically interbedded within the clastic sedimentary succession. The succession coarsens upward, and near Humpback Bay, medium- to thick-bedded, locally massive, medium- to coarse-

Figure 10. Lime-matrix andesitic breccia, lower Descon Formation, northeastern Porcher Island, northwestern British Columbia; pencil for scale.

grained volcanic lithic arenite/wacke interbedded with crudely stratified volcanic pebble conglomerate dominate the sequence (Figure 12). Conglomerate beds are 10–40 cm thick, tabular and laterally continuous. Thin (10–30 cm) marble beds are locally evident. Thick (1–3 m) quartz-bearing rhyolitic lapilli tuff with abundant angular white lapilli clasts form less than 10% of the succession.

The stratigraphically highest part of the Descon Formation in this area is exposed in the islands northeast of Hunt Inlet. This portion of the section is dominated by dark grey to dark green, thin- to medium-bedded, fine-grained lithic arenite, siltstone and argillite interbedded with distinctive intervals of resistant, thin-bedded green siliceous vitric tuff.

Western Facies

Exposures of the Descon Formation on western Porcher Island are concentrated around Useless Bay and at the mouth of Porcher Inlet (Figure 4). The unit is widely exposed to the west on the Porcher Peninsula and to the north on Stephens Island, but these exposures were not examined during the 2009 field season. In general, the western facies of the Descon Formation represents a proximal facies dominated by coarse fragmental volcanic rocks and associated hypabyssal intrusions, in sharp contrast to more well-bedded, sediment-dominated successions of the eastern, distal facies.

At Useless Bay, the unit is dominated by dark green to dark grey andesitic tuff breccia, breccia and lesser lava flows. Andesitic dikes locally cut the fragmental rocks. Thin- to medium-bedded volcaniclastic sedimentary successions are locally interbedded within pyroclastic successions. Exposures are massive, and bedding is difficult to discern. To the south, near the mouth of Porcher Inlet, the Descon Formation is contained within two fault panels between the Billy Bay Complex on the west and a fault on the east that separates it from the orthogneiss of the Ogden Channel Complex (Figure 4). The easternmost of these two fault panels contains a moderately east-dipping succession of thick-bedded to massive andesitic lapilli tuff and tuff breccia overlain by a thick sequence (hundreds of metres) of medium- to thick-bedded volcanic lithic arenite and wacke and thin- to medium-bedded volcanic sandstone, siltstone and argillite. This succession may represent a transitional facies between the proximal western facies and the more distal eastern facies. The westernmost fault panel contains mafic, intermediate and felsic volcanic, hypabyssal and plutonic rocks of the Billy Bay Complex (described below), which is interpreted as vent-proximal to subvolcanic facies of the Descon Group.

KARHEEN FORMATION

The Karheen Formation was named for a succession of conglomerate, sandstone, siltstone, shale and minor limestone exposed on Prince of Wales Island (Eberlein and Churkin, 1970; Gehrels and Saleeby, 1987). Conodont and brachiopod biostratigraphy indicate the formation is middle Early Devonian (Pragian) in age. The formation overlies Silurian and older rocks, and is interpreted as part of a subaerial to shallow marine clastic wedge that coarsens and thickens to the southeast (Eberlein and Churkin, 1970; Gehrels and Saleeby, 1987). Detrital zircon geochronology from the Karheen Formation includes a ca. 450–420 Ma dominant population, apparently derived from Late Ordovician and Silurian plutonic rocks of the southern Alexander terrane, and a diverse Middle Proterozoic–Late Archean population of unknown cratonic derivation (Gehrels et al., 1996).

Figure 11. Well-bedded crystal-ash tuff, upper Descon Formation, northeastern Porcher Island, northwestern British Columbia; rock hammer for scale.

Figure 12. Descon conglomerate, near Humpback Bay, northeastern Porcher Island, northwestern British Columbia; rock hammer handle for scale.

In the 2009 map area, the Karheen Formation is exposed on the western side of Kennedy Island and on the eastern shore of the Grenville Channel (Figure 4). On western Kennedy Island, the unit is steeply dipping, with tops to the east, and is presumed to unconformably overlie the Wales Group. The Karheen Formation is intruded by the Kennedy Island pluton, which also intrudes the Wales Group on its southern end. On western Kennedy Island, the Karheen Formation consists of medium- to thick-bedded, medium- to coarse-grained lithic feldspathic arenite, polymict matrix- to clast-supported pebble to cobble conglomerate, and thin- to medium-bedded intervals of fine-grained sandstone, siltstone and shale. The unit contains abundant sedimentary structures, including trough cross-stratification, graded bedding, basal scour surfaces and crude channel structures, typical of the Karheen in its type exposures in southeastern Alaska (Figure 13). The conglomerate contains distinctive clasts of blue quartz-eye plutonic rocks that resemble Silurian trondhjemite exposed in southeast Alaska, and potentially to the west in the McMicking pluton (Gehrels and Boghossian, 2000) and the Hunt Inlet pluton, which may be Silurian (see below). The southern end of the Kennedy Island exposures become finer grained, with interbedded sandstone, siltstone and mudstone/shale (pelite). The sedimentary succession is overlain by a volcanic package containing pillow basalt that displays bulbous pillow outlines and amygdaloidal rinds (Figure 14). They may represent the mafic part of the bimodal volcanic sequence that in places overlies the Karheen Formation in southeastern Alaska. In contrast to the highly deformed pillow basalt in the Wales Group on nearby Marrack Island, this basalt shows no evidence of flattening.

On the eastern shore of Grenville Channel, grey thin- to medium-bedded, well-sorted, in places cross-stratified sandstone, siltstone, shale and minor matrix-supported plutonic and quartz pebble conglomerate occur in two structural panels. Near the mouth of Kumealon Inlet, plutonic-cobble conglomerate and sandstone overlie amphibolite of the Wales Group across a sharp, apparently unfaulted, unconformable (?) contact in the core of a regional fold. The more extensive panel of Karheen-equivalent strata, the Kumealon clastic unit, extends over 35 km, from Telegraph Passage to Baker Inlet, in fault contact with Wales Group metavolcanic rocks to the west (Figure 4). This succession is inferred to be correlative with the Karheen Formation on Kennedy Island, although the precise stratigraphic relation between the two packages is uncertain. The Kumealon clastic unit is a sequence of grey, thick-bedded, well-sorted sandstone interbedded with thin-bedded sandstone, siltstone and pelite. In one outcrop near the western end of Kumealon Inlet, texturally pristine cross-stratified quartz-pebble conglomerate and sandstone (Figure 15) are interlayered with highly foliated pelite crowded with garnet porphyroblasts up to 1 cm across—a dramatic instance of compositional control on the preservation of primary features during high-grade dynamothermal metamorphism. Sparse top directions suggest overall eastward younging in this sequence; however, west-facing beds are also observed and the prevalence of isoclinal folding in the area makes stratigraphic facing directions difficult to determine.

A detrital zircon sample from the Karheen Formation on Kennedy Island yielded a population dominated by Silurian, 435–430 Ma zircons (Gehrels and Boghossian, 2000). This signature, typical of the Karheen in southeastern Alaska, represents erosion of Silurian plutons. A quartz-pebble conglomerate in Kumealon Inlet yields a similar Silurian detrital peak, with a scattering of Precambrian grains (G. Gehrels, pers comm, 2009). This similarity in detrital zircon signatures supports the correlation of the Kumealon clastic unit east of Grenville Channel with the Karheen Formation on Kennedy Island.

PALEOZOIC LIMESTONE IN KUMEALON INLET

Two bands of marble and calcsilicate outcrop near the head of Kumealon Inlet and extend north along Kumealon Lagoon. The more easterly body is dominated by pure, well-bedded marble; the more westerly body shows interlayering on a centimetre to metre scale with metatuff and clastic (?) metasedimentary layers. Above a thin contact zone of intercalation with metavolcanic laminae, the eastern unit comprises a thick basal succession (10–50 m) of thin- to medium-bedded, brown-weathering, light brown, coarse-grained marble with local relict fossil material. Recrystallized fossil material, including apparent solitary (Rugosan) corals, trace fossils (fine worm tubes) and bioclastic hash suggest the protolith was a late Paleozoic fossiliferous rudstone to floatstone (Figure 16). The marble becomes intercalated towards the west with thin-bedded,

Figure 13. Cross-stratification in Karheen metasandstone, western Kennedy Island, northwestern British Columbia; rock hammer for scale.

Figure 14. Undeformed pillow basalt stratigraphically above the Karheen Formation, western Kennedy Island, northwestern British Columbia; rock hammer for scale.

Figure 15. Quartz-pebble conglomerate in the Kumealon clastic unit, northwestern British Columbia; rock hammer for scale.

greenish-grey volcaniclastic (?) fine-grained sandstone and siltstone, and gradationally passes into thin- to medium-bedded volcaniclastic strata, which then passes westward into the thinly layered marble-metavolcanic unit.

The structural and stratigraphic relationships between the marble and the metavolcanic rocks around it are not known. Both the marble and the rocks around it are isoclinally folded with transposed layering. The discontinuity of the marble unit was noted by Roddick (1970): it does not outcrop to the south on the shores of Baker Inlet, nor to the north in the mountains east of Moore Cove. We have thus interpreted it as occupying the core of a doubly plunging synform that 'airs' —is eroded away in both up-plunge directions—to the northwest and southeast of Kumealon Inlet. We have assumed, because of continuity and resemblance to Wales Group exposures elsewhere, that the metavolcanic unit here also belongs to the Wales Group. However, the field relationships, in which there are apparently transitional contacts between the metavolcanic unit and the coral-bearing Paleozoic limestone (Figure 17), are not compatible with this interpretation.

Plutonic/Metamorphic Complexes

OGDEN CHANNEL COMPLEX

The Ogden Channel Complex comprises both orthogneiss and the older metasedimentary septa that it intrudes. It outcrops in two adjacent, northwest-striking belts that span both sides of Ogden Channel on Pitt and Porcher islands, separated from each other by the Useless fault and the Swede Point pluton (Figure 4). The orthogneiss consists of many small bodies with intricate crosscutting original relationships. It is dominantly mafic, consisting of variable-textured metadiorite and gabbro with subordinate smaller bodies of quartz diorite and tonalite. It is locally and regionally heterogeneous, both in composition and texture. Compositional bands occur typically on 1–10 m scales; textures vary from coarse to fine grained. The orthogneiss is an intrusive complex, strongly deformed throughout and metamorphosed to amphibolite grade.

The metasedimentary septa within the orthogneiss consist of laminated pelite, siliceous pelite, calcsilicate, lesser pure marble, quartzite, meta-greywacke with quartz-rich layers and amphibolite sills (?). Thin layering typifies the unit—both as compositional layering such as pelite-quartzite or calcsilicate-marble, and also within lithologic units, which can be finely colour laminated. Like the enclosing orthogneiss, the metasedimentary units have been metamorphosed at amphibolite grade. Isoclinal folding is common. We interpret these as remnants of country rock that were intruded by the orthogneiss.

BILLY BAY COMPLEX

The Billy Bay Complex is exposed on the western shore of Porcher Island from Billy Bay, where it is truncated by the Captain Cove pluton, to Kitkatla Inlet, where it is cut off by the West Porcher pluton. It is a mafic, intermediate and felsic extrusive/intrusive complex in which volcanic and subvolcanic components are mixed on scales of 1–50 m, including basalt and andesite flows, tuff and breccia; plagioclase-phyric granodiorite; diorite; and very minor meta-argillite, metachert and metasandstone. It has the character of a complex volcanic centre consisting of many mutually crosscutting intrusive and hypabyssal phases as well as extrusive remnants. Most units of the Billy Bay Complex have undergone amphibolite-facies metamorphism. Unlike the Ogden Channel Complex, primary igneous textures are preserved in spite of strong shearing, as are other features such as chilled dike margins and flow-breccia transitions. Fabric development is strongly lithologically partitioned. Foliation is strongest in mafic tuff, which are now highly foliated amphibolite. By contrast, the interiors of some dikes and sills show original plagioclase-phyric textures, and diorite show pseudomorphed salt-and-pepper plagioclase-augite intergrowths, without any superimposed foliation.

Provisionally, we regard the Billy Bay Complex as a vent-proximal facies of the Descon Formation, based upon the comparable preservation of primary textures compared to those in the Wales Group. This assertion will be tested by U-Pb dating. The complex may well be a composite of igneous units of several ages; the granodiorite in particular are compositionally dissimilar to Descon felsic units, which tend to contain less potassium feldspar.

Figure 16. Solitary coral, marble unit, Kumealon Inlet, northwestern British Columbia; pencil for scale.

Figure 17. Gradational contact between metavolcanic unit and Paleozoic marble, Kumealon Inlet, northwestern British Columbia; rock hammer for scale.

Intrusive Units

ORDOVICIAN

McMicking Pluton

The McMicking pluton is a northwesterly elongate body that outcrops on McMicking, Elliott and Lewis islands (Figure 4). Most of the body consists of coarse-grained equigranular to somewhat inequigranular white to pale grey trondhjemite. It is quartz-rich, with blobby quartz grains studding many exposures. Sodic plagioclase is the dominant mineral; potassium feldspar is absent. Minor mafic minerals have been recrystallized to chlorite, epidote, sericite and actinolite. It is variably foliated; the degree of foliation increases strongly southwest towards the Lamppost fault. The border phase of the McMicking pluton contrasts strongly with its uniform, felsic interior. It consists of crosscutting phases of variably textured tonalite and diorite. Foliation is less pronounced in the pluton than in the main trondhjemite, probably due to a lack of easily deformed minerals such as quartz and mica.

The McMicking pluton cuts across layering and foliations in the Wales Group (Figure 18), indicating that it was emplaced after an episode of regional metamorphism and deformation. This relationship is overprinted by younger, lower-grade metamorphism and shearing of both the pluton and the older metavolcanic rocks that it intrudes.

The McMicking pluton has been dated by U-Pb methods on zircon as 482 ±15 Ma (Early Ordovician; Gehrels and Boghossian, 2000). It is coeval with the oldest known Ordovician plutons in the Alexander terrane of southeastern Alaska (Gehrels and Saleeby, 1987; S. Karl, pers comm, 2009). It was probably a feeder to Descon-aged volcanism. Its trondhjemitic composition and lack of older zircon inheritance are consistent with intrusion in a primitive arc environment.

SILURIAN (?)

Hunt Inlet Pluton

The Hunt Inlet pluton outcrops on the shores of far northern Porcher Island and adjacent islands near Hunt Inlet. Its characteristic and unique outcrop style is expressed as a horde of tiny islets and subtidal rocks that pose a distinct hazard to small-boat navigation. The body consists of weakly foliated lower-greenschist grade metatonalite with blue quartz eyes. Primary mafic minerals are recrystallized to fuzzy clots of epidote, chlorite, biotite and possibly actinolite. It intrudes the deformed and somewhat foliated Descon Formation, and is cut by Cretaceous (?) unfoliated, fresh diorite. It physically resembles granitoid rocks of Silurian age on Prince of Wales Island (Gehrels and Saleeby, 1987), and this is offered as a tentative correlation pending U/Pb geochronology.

DEVONIAN (?)

Swede Point Pluton

The Swede Point pluton forms a northwesterly trending belt of light-coloured exposures that extends across central Pitt and central Porcher Island. These outcrops are much more devoid of vegetation than other plutonic units: Bareside Mountain on southeastern Porcher Island is a particularly prominent example. The body consists of very strongly foliated granodiorite, granite, tonalite and diorite. Small plagioclase-phyric textures are very common. In parts it is compositionally heterogeneous on a metre scale; elsewhere it is more uniform. One of the distinguishing characteristics of the Swede Point pluton is the common presence of synkinematic to postkinematic garnet, which may indicate a relatively aluminous composition. Its degree of protomylonitic deformation is also distinctive, compared to the less-foliated but presumably older McMicking pluton.

The Swede Point pluton intrudes rocks of the Ogden Channel Complex. Intrusive relationships are clearly shown in outcrops near Bareside Point (Figure 19), Barrett Point, and in the channel leading to Salt Lagoon. The Swede Point phases crosscut early foliation in the Ogden Channel Complex. Near Barrett Island, east of Useless Bay, some dikes are mylonitized whereas others crosscut the foliation, which suggests synkinematic emplacement (see discussion in ‘Structure’).

The Swede Point pluton has been dated as 382 ±14 Ma by U-Pb methods (van der Heyden, 1989); however, because of complicated systematics, this date is considered approximate and we have collected samples for reanalysis. Middle Devonian plutons are rare in the Alexander terrane.

Figure 18. Trondhjemite of the McMicking pluton intrudes meta-andesite tuff, northwestern Elliott Island, northwestern British Columbia; pencil for scale.

Figure 19. Swede Point pluton intruding amphibolite-facies orthogneiss of the Ogden Channel Complex, near Bareside Point, northwestern British Columbia; field of view is 20 m.

CRETACEOUS INTRUSIONS

Typical of the western reaches of the Coast Plutonic Complex, the Porcher Island–Pitt Island area is host to a number of individual plutons. In map view, they are equant and irregular in shape, except for the tabular, elongate Peninsula Point pluton (Figure 4). They crosscut foliation in the older rocks and some faulted unit contacts, but are offset and locally deformed by the major faults in the area, including the Salt Lagoon and Useless faults (Figure 4) and farther west, the Kitkatla shear zone (Chardon et al., 1999). The Cretaceous suite includes granodiorite, tonalite, diorite and minor true granite, along with swarms of pegmatite near pluton margins. Although these are not dated on Porcher Island, U-Pb dates from similar bodies on Pitt, McCauley and Stephens islands are in the range of 113–101 Ma (Butler et al., 2006; Gehrels 2001).

Captain Cove Pluton

The Captain Cove pluton is exposed on southeastern Porcher Island and across Ogden Channel on Pitt Island (Figure 4). Except for some diorite-gabbro border phases near Alpha Point, it is a voluminous body of granodiorite, quartz diorite and quartz monzonite (Roddick, 1970). Butler et al. (2006) report three U-Pb ages from the Captain Cove pluton of 108.5–107 Ma. One of their samples is from a dike that crosscuts fabrics of the Kitkatla shear zone on Pitt Island southwest of the present map area. On the other hand, Chadron et al. (1999) describe gneissic foliations within the Captain Cove body that are deflected into the shear zone, suggesting that it was emplaced at a late stage of motion.

West Porcher Pluton

This large, equant body outcrops on the western coast of Porcher Island in Kitkatla Inlet and extends into the Bell Range (contacts on Figure 4 partly based on Roddick, 1970) It is homogeneous over a broad area, consisting of fresh, coarse-grained granodiorite with scattered black mafic restite inclusions. It resembles the Captain Cove pluton in igneous composition and texture, overall shape and appearance; they are probably related. Minerals include plagioclase, quartz, hornblende, biotite and traces of magnetite. In its westernmost exposures it shows a mainly magmatic to subsolidus (?) foliation characterized by weak alignment of mafic minerals and possibly quartz. Late pegmatite and aplite dikes both follow and cut across this fabric. At its southern contact north of the entrance to Porcher Inlet, it hornfelses rocks of the Billy Bay Complex and truncates both layering and a local mylonitic foliation.

Porcher Creek Pluton (Cretaceous? Jurassic?)

Unlike the other known or assumed Cretaceous intrusions, which tend to be uniform in composition and texture over broad areas, the Porcher Creek pluton is highly variable. On the southern side of Porcher Inlet it is essentially a dike complex, consisting of crosscutting diorite, andesite, tonalite and leucotonalite phases. Emplacement coincided with shearing and cataclasis, as shown by numerous chloritic shears and minor faults. North of the inlet it is more uniform in composition, a diorite that is intruded by younger granodiorite of the West Porcher pluton.

Peninsula Point Pluton

The Peninsula Point pluton is a northwesterly elongate body that outcrops near Oona River on Porcher Island, and continues southeast along the northeastern shores of Pitt Island. It is a fresh, undeformed granodiorite with clear euhedral titanite grains. Early crystallizing hornblende prisms and oscillatory/normal-zoned plagioclase grains are surrounded by matrix quartz and orthoclase. Early brown biotite is succeeded in a few areas by late-stage green biotite, with secondary interstitial epidote.

On the northeastern coast of Pitt Island, small offshoots of the Peninsula pluton and pegmatite within its margin show minor offsets and boudinage; these are related to a continuation of the Salt Lagoon fault that is inferred to lie offshore. We interpret this to show that the pluton was emplaced during the later stages of motion on the fault.

Other Bodies

Undeformed, fresh plutonic bodies of probable mid-Cretaceous age outcrop in the Spiller Range, the Chismore Range, northwest of Hunt Inlet and Kennedy Island. A subsurface northern extension of the Spiller Range pluton was responsible for extensive hornfelsing of the Descon Formation east of Hunt Inlet. Highly deformed granitoid bodies outcrop in Baker Inlet east of Grenville Channel, where Mansfield (2004) interpreted them to be infolded with schist. Although undated, they may be related to the ca. 90 Ma Ecstall pluton, which outcrops extensively farther east; this will be tested geochronologically.

Structural Geology

CRETACEOUS SINISTRAL-OBLIQUE FAULTS

The large-scale map pattern of the Porcher Island–Grenville Channel area, as shown on Figure 4, is dominated by a set of regional, north- to northwest-striking, mainly sinistral transcurrent faults. They form part of a zone of sinistral shearing that affected the entire northwestern Coast Mountains in Cretaceous time (Chardon et al., 1999). Locally, these faults offset and create local zones of tectonite in otherwise undeformed plutons, which are assumed to be of late Early Cretaceous age, based on similarities with nearby dated bodies (ca. 114–107 Ma; Butler et al., 2006). Thus, at least the later stages of motion on the faults took place during the late Early Cretaceous. Their earlier history is unconstrained at present, due to lack of age control on older rock units.

The major mapped transcurrent faults include, from northeast to southwest, the Grenville Channel and the Lamppost, Salt Lagoon and Useless faults. All correspond to strong topographic lineaments, and one is a shipping channel. Except for the Grenville Channel fault, they are defined by outcropping tectonite zones characterized by well-developed L-S fabrics, which commonly culminate in the development of banded mylonite. On approaching the west-northwest-trending shear zones, the regional foliations progressively become more intense and deflect into parallelism; the sense of deflection suggests sinistral shear. The lineations in the tectonite commonly plunge shallowly to moderately, which, combined with ample mesoscale shear-sense indicators such as C-S structures, shear bands, intrafolial drag folds with curviplanar axial surfaces, asymmetric fragments, boudins and tails around porphyroclasts, consistently indicate sinistral transcurrent shear (Figures 20–22), commonly with an oblique, normal component.

The Grenville Channel fault is not exposed on land within the mapped area. Tectonite exposed on the northeastern coast of Grenville channel shows strong rodding, boudinage and local development of L>S fabrics. Shear-sense indicators are consistently sinistral (Figure 23).

Plunges of mylonitic lineations in the northwest-trending shear zones range from moderate to shallow northwest, to less commonly moderate southeast, suggesting a combination of sinistral-normal and sinistral-reverse motion, with the oblique-normal motion being dominant. Fabrics are generally much better developed in the pre-Cretaceous metamorphic units than in the plutonic rocks. Whether this indicates that there were extensive pre-Cretaceous movements on the faults, or whether the plutons were intruded late during a single episode of Cretaceous sinistral regional shear is not clear at present.

Our interpretation of the trajectory of the Grenville Channel fault (Figure 4) differs from that of Chardon et al. (1999). In their interpretation, it tracks straight onto northeastern Porcher Island, where it connects with the Lamppost fault. However, detailed geological relationships indicate that the Lamppost fault, which forms the structural boundary between rocks of the Descon Formation and Wales Group, is deflected southward to merge with the Salt Lagoon fault. We have chosen instead to curve the Grenville Channel fault into Telegraph Passage, such that it acquires a northerly strike. Such a fault trajectory is attractive for two reasons. First, such a structure accommodates a logical break between the highly tectonized domain on the mainland from the less deformed and metamorphosed rocks to the west; for example, well-preserved crossbedded Karheen-equivalent sandstone on western Kennedy Island, immediately west of the Telegraph Passage, shows much less strain. Second, the northerly deflection of the fault mirrors that displayed by the foliations and major lithologic contacts on the east side of Telegraph Passage.

The dominantly sinistral movement on the fault zones had a major influence on the regional map patterns shown in Figure 4. The Useless fault offsets the Swede Point pluton by several kilometres in a sinistral sense. The deflec-

Figure 21. Sinistral clast asymmetry in actinolite-chlorite schist near Useless fault, northwestern British Columbia; rock hammer for scale.

Figure 22. Sinistral entrainment of earlier foliation: looking northeast, hammer head to the northwest. Swede Point pluton and septum of Ogden Channel metadiorite, next to the Useless fault along Ogden Channel, British Columbia; rock hammer for scale.

Figure 20. Sinistral offset on granodiorite sill (shown by arrows) within Wales Group metatuff near Salt Lagoon fault, Oona River, northwestern British Columbia. The left-hand dike is 10 cm wide.

Figure 23. Sinistral-sense asymmetric boudins in metamorphosed felsic volcanic rock, Kumealon Inlet, northwestern British Columbia. The field of view is 2 m wide.

tion of the Grenville Channel fault from a northwesterly to northerly trend is interpreted as a restraining bend in the overall fault array. The northeast-trending fold outlined by strata on Gibson and Marrack islands (Figure 4) could represent shortening associated with the formation of the restraining bend. The deflection of the Lamppost fault may represent a smaller-scale restraining structure associated with the Telegraph Passage bend. Mapping suggests that the Lamppost fault and adjacent units are cut off by the Salt Lagoon fault. A second block with northerly internal foliations is seen southwest of the Useless fault. Its southwestern boundary is the Kitkatla shear zone, a major sinistral fault located southwest of Kitkatla Inlet, outside of the map area, described by Chardon et al. (1999). This may represent a second restraining bend within the fault system. This block is invaded by large, unfoliated Cretaceous plutons, the Captain Cove and West Porcher plutons. Although these bodies are cut off by the Kitkatla shear zone (Chardon et al., 1999; Butler et al., 2006), they are postkinematic to foliation development and their deflection within the block, suggesting that most of the motion accommodated by this fault predates emplacement of the plutons.

BARRETT ISLAND SHEAR ZONE

The Barrett Island shear zone is well exposed within the metasedimentary unit of the Wales Group on the north coast of Porcher Island, between the Salt Lagoon fault and the Devonian (?) Swede Point pluton. The metasedimentary unit comprises metagreywacke, phyllite, biotite schist, marble, amphibolite and minor quartzite. These rocks display a well-developed transposition foliation with abundant interfolial folds. They are in structurally modified intrusive contact with the Swede Point pluton, a coarse-grained biotite granodiorite to diorite with a strong protomylonitic foliation defined by the alignment of wispy biotite around plagioclase porphyroclasts. Tight to isoclinal folds are cut by both undeformed and mylonitized dikes, suggesting that pluton emplacement was synkinematic (Figure 24a).The shear zone is a distinct 80–100 m wide ductile deformation zone, characterized by abundant tight to isoclinal, macroscopic folds with amplitudes ranging from 0.25 to 2 m, locally greater than 5 m and well-developed foliation and lineation. The deformational style is lithologically controlled, with carbonate units containing well-developed, large-amplitude refolded isoclinal folds (Figure 24b), whereas deformation within the plutonic unit is characterized by discrete mylonite zones.

Structural analysis of foliation, lineation and folds constrains fault kinematics. The primary foliation, parallel to transposed compositional layering within the metasedimentary units, strikes northwest and dips moderately northeast (Figures 24c, d). The majority of intersection lineations have an approximate downdip plunge with a slight northwesterly bias, supporting approximately dip-parallel to sinistral-normal oblique motion on the shear zone (Figure 24c). Sinistral oblique sense of shear is shown by asymmetric tails on rotated porphyroblasts (Figure 24e). Fold axes of macroscopic, tight to isoclinal folds generally plunge downdip (Figure 24d). All observed asymmetric folds have a counterclockwise sense of vergence, also suggesting oblique sinistral shear; although they were probably rotated into the direction of tectonic transport parallel to L_1 stretching lineations (Figure 24b). The age of deformation will be constrained by geochronological analysis of both the pluton and a mylonitized dike crosscutting F_1 folds (Figure 24a). If the Swede Point pluton is Paleozoic, as suggested by the preliminary U-Pb date of van der Heyden (1989), then this shear zone retains the record of much earlier deformation than the main, Early Cretaceous, sinistral event. The highly elongated shape of the pluton (Figure 4) may have been due to emplacement into an active shear zone.

FOLIATIONS, LINEATIONS AND FOLDS

The effects of strong deformation, although not as intense as within the shear zones, are nevertheless seen throughout pre-Cretaceous units of the map area. Transposition of compositional layering into foliation is nearly universal, the sole exceptions being the Karheen Formation on Kennedy Island, and parts of the Descon Formation on northeastern Porcher Island, where bedding-cleavage relationships are seen. The Wales Group on Elliott and Lewis islands shows intrafolial isocline development. Isoclinal folding is particularly well developed in intervals of thin-layered marble and metatuff. Here, the contrast in deformational styles between Wales and Descon rocks is interpreted as being due to the Wales orogeny (Gehrels and Saleeby, 1987). Farther east on the mainland coast, deformation is clearly younger, as the Paleozoic (?) Kumealon marble unit is involved in isoclinal folding. Tonalitic dikes and sills that cut diorite in the Ogden Channel Complex are tightly folded in some places. They are interpreted as relatively felsic components of the original intrusive complex. Therefore, the deformation could have been as old as the protolith, or as young as Early Cretaceous.

Mesoscopic folds are uncommon in the area. The Descon Formation on northeastern Porcher Island is folded into an open syncline between the Lamppost and Salt Lagoon faults. Wales Group (?) units near Stuart Anchorage on the northeastern coast of Pitt Island form a tight, upright anticline. The two marble exposures in Kumealon Inlet are interpreted as synformal keels. In Baker Inlet, Mansfield (2004) mapped second-phase folds involving panels of metaplutonic and metavolcanic/metasedimentary rock. As noted in the discussion of sinistral faults, the panel immediately northeast of the Grenville Channel fault near Kumealon and Baker inlets is an L-S tectonite that defines the core of a regional fold that developed during sinistral motion on the Grenville Channel fault. Karheen-equivalent strata occur in its core, indicating that it is a syncline.

Although both moderately plunging and shallow mineral and stretching lineations are observed in the major shear zones, in other areas moderate plunges are both to the northwest and to the southeast; this may indicate folding of an earlier set of lineations.

Metamorphism

Metamorphic grades and histories in the Porcher Island–Grenville Channel area are to some extent unit specific. There are also regional metamorphic gradients due to the location of this area on the western flank of the Coast Mountains orogen. The complex variations in metamorphism are probably due to the combined effects of Paleozoic events and Cretaceous dynamothermal overprinting.

The Wales Group, the inferred oldest supracrustal unit in the area, displays a variable metamorphic character that probably resulted from several stages of regional metamorphism. On eastern and northern Porcher Island, the Wales

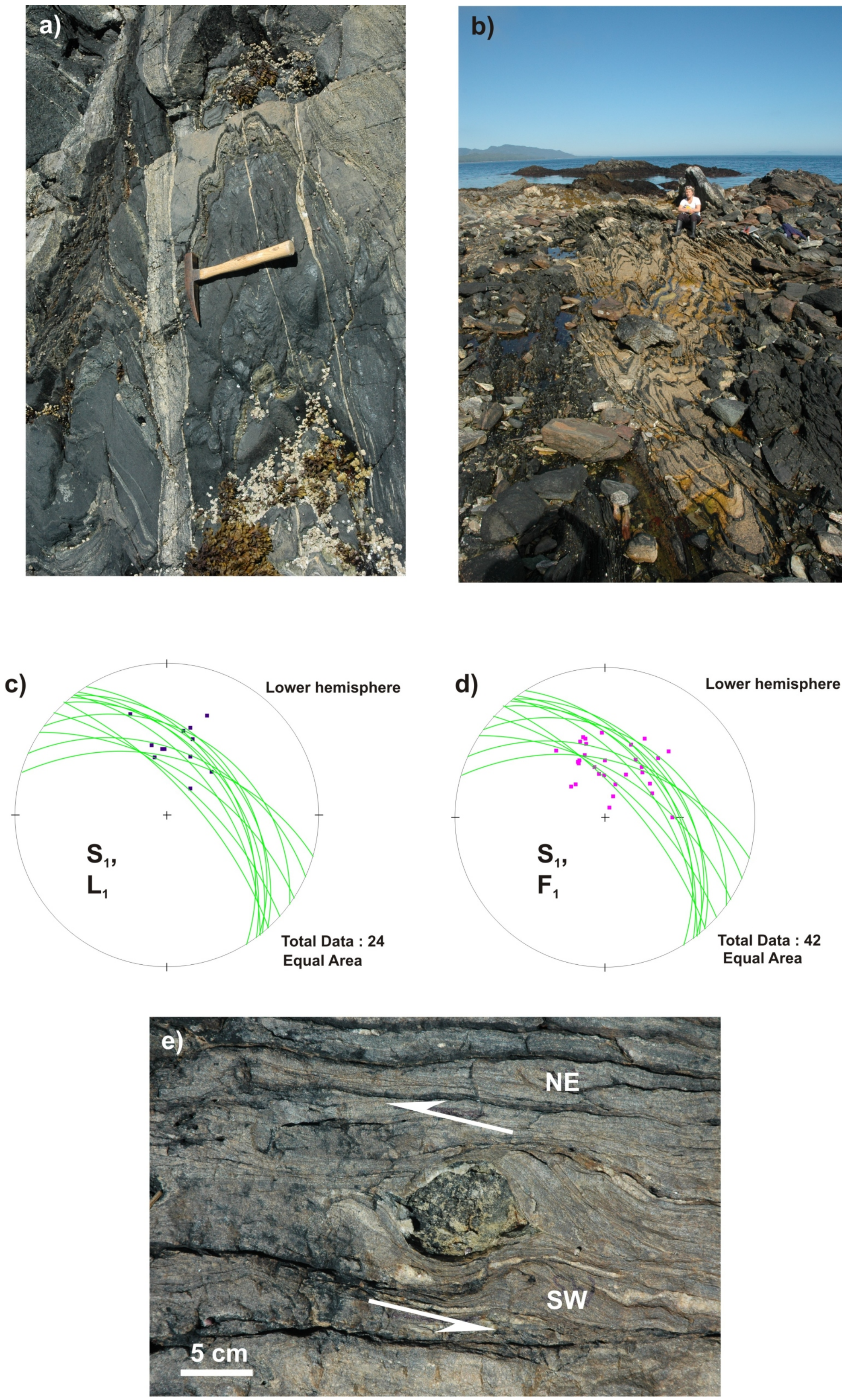

Figure 24. Barrett Island shear zone, northwestern British Columbia: **a)** Swede Point dikelet cuts isoclinally folded Wales Group schist and amphibolite; rock hammer for scale; **b)** refolded isoclines in laminated marble/metatuff; rock hammer for scale; **c)** stereonet plot of S_1 (great circles) and L_1 stretching lineations; **d)** stereonet plot of S_1 (great circles) and F_1 isoclinal fold axes; **e)** rotated (-shaped) clast, showing oblique-sinistral sense of shear. The arrow is 10 cm long.

Group is at middle-amphibolite grade. Intermediate and mafic rocks contain assemblages of blue-green pleochroic hornblende, plagioclase, brown or less commonly green biotite, titanite and quartz, with cummingtonite in some localities. This stands in strong contrast to greenschist metamorphic assemblages that are developed in the Ordovician McMicking pluton, and in structurally juxtaposed Descon strata. This early metamorphism of the Wales Group is interpreted to reflect the Cambrian–Ordovician Wales orogeny. It has also been affected by extensive synkinematic retrograde metamorphism, both on northern Lewis Island and on northeastern Porcher Island near the Lamppost fault. The chlorite schist and retrograded amphibolite on Lewis Island are cut by the McMicking pluton (Figure 18). Hornblende garbenschiefer and spongy, postkinematic garnets show static thermal metamorphism related to its emplacement. Retrograde metamorphism in rocks situated along the Lamppost fault, on the other hand, is probably related to exhumation during late motion on the Lamppost fault.

The Wales Group in the Stuart Anchorage area contains a number of assemblages developed in highly variable tuffaceous, siliciclastic and possible exhalative protoliths. The magnetite iron formations consist of laminae or bands of magnetite interlayered with hornblende-plagioclase and in some cases epidote. The hornblende is dark forest green, perhaps evidence of a more iron-rich composition, compared to the blue-green pleochroism that is common elsewhere. In some cases, titanite mantles magnetite, suggesting that the magnetite grains were not of late-kinematic, contact skarn-related origin. In this unit, there is also schist that contains assemblages of pink-violet pleochroic manganoan zoisite and axinite (?) with quartz, plagioclase, biotite and opaque minerals: these could be metamorphosed calcareous exhalite.

Metamorphic grade in the Wales Group increases to the east and south across the Grenville Channel towards the core of the Coast Mountains orogen. Garnet amphibolite occurs in Kumealon and Baker inlets, as well as along the adjacent mainland coast. A few instances of sillimanite were found on the shores of these inlets, in assemblages with red-brown biotite, plagioclase, orthoclase, muscovite and quartz, in metamorphosed felsic hosts. Wolf et al. (2009) reported a mid-Cretaceous (108–102 Ma) Lu-Hf age on syntectonic garnet growth in this area. This age is slightly younger than the existing constraints on shear zone movement farther west (114–106 Ma; Butler et al., 2006), and supports the interpretation that all of the rocks in the map area were involved as a series of panels in mid-Cretaceous sinistral shearing and transpression.

Mafic to intermediate orthogneisses of the Ogden Channel Complex all contain assemblages of amphibolite to epidote amphibolite facies. They are truly orthogneisses, in the sense that primary mafic minerals are obliterated; not even relict crystal outlines remain. Instead, clumps of coarse, idiomorphic, metamorphic hornblende approximate the locations of individual original grains. Areas within these aggregates populated with dense masses of tiny opaque minerals are probably original clinopyroxenes; the clearer areas are probably after igneous hornblende. Normal-zoned plagioclases have been recrystallized to finer grain sizes, except for remaining porphyroclasts. Many of the Ogden Channel orthogneiss samples contain clear, well-formed epidote crystals, which appear to have grown in equilibrium with hornblende, calcic plagioclase, biotite, titanite and magnetite. Protomylonitic foliations within the complex have been overprinted by regional metamorphic recrystallization: this indicates an early (pre-peak metamorphism) episode of shearing.

Figure 25. Pyritic quartz veins from near the Surf Point adit, northwestern British Columbia; pen knife for scale.

The screens of pre-orthogneiss metasedimentary, metavolcanic and meta-intrusive rocks within the complex, also at amphibolite grade, consist of hornblende-plagioclase assemblages in metatuff, biotite–quartz–plagioclase±garnet in pelitic rocks and diopside±clinozoisite in calcsilicate rocks.

The Devonian (?) Swede Point pluton, which intrudes the Ogden Channel orthogneiss, has been metamorphosed to epidote to possibly garnet amphibolite grade: epidote and in some cases garnet porphyroblasts seem to grow in equilibrium with metamorphic hornblende. The body is also protomylonitic, perhaps due to its proximity to the Useless fault. Compared to the surrounding orthogneiss, it displays igneous artifacts such as plagioclase phenocrysts. The orthogneiss complex underwent an episode of metamorphism and deformation prior to the intrusion of the Swede Point pluton; at some later time both were sheared and metamorphosed in epidote amphibolite facies in a higher pressure–lower temperature environment than the Wales Group.

The Descon Formation on northeastern Porcher Island, the Silurian (?) pluton that intrudes it and most of the McMicking pluton contain greenschist-facies metamorphic assemblages of chlorite, epidote and actinolite; original plagioclases have been albitized and are spotted with saussurite and sericite. These rocks are also much less deformed than the Wales Group and the Ogden Channel Complex. The Descon Formation shows a transposition foliation along the eastern coast of Porcher Island, but with preservation of protolith textures such as clasts and phenocrysts. Farther to the west, the foliation is very weak, except within discrete shear zones.

Farthest west, the Billy Bay Complex shows amphibolite, greenschist-amphibolite transitional, possible epidote-amphibolite, and strong retrograde greenschist assemblages, all developed at high strain rates. It is lower grade than the Ogden Channel Complex, but higher grade than the Descon Formation, to which it is inferred to form the subvolcanic roots. Its amphibolite grade may represent comparatively deep crustal levels during the same metamorphic event; or a later metamorphism related to proximity to the Kitkatla shear zone.

MINERAL OCCURRENCES AND MINERAL POTENTIAL

Two major types of metallic mineral deposits are well represented and/or indicated in the north coastal region of BC. A significant past gold producer with substantial current reserves, the combined Surf Point–Edye Pass mines, are located on northwestern Porcher Island (Figures 1, 4). More regionally, Prince of Wales Island in southeastern Alaska is well known for its VMS deposits, as is the Ecstall mineral belt in the Coast Mountains, east of the present map area (Alldrick, 2001; Alldrick et al., 2001). The Prince of Wales deposits, including the Niblack (Figure 1), are hosted by rocks of the southern Alexander terrane (Ayuso et al., 2005; Slack et. al., 2005). The present map area lies within the southern extension of this belt. This observation, along with the presence of local favourable rock types, alteration patterns, and prospects and showings, supports the potential for VMS-style deposits in the Alexander terrane of coastal BC.

Surf Point–Edye Pass Mines

The Surf Point and Edye Pass mines were in operation between 1919 and 1939, when they produced 61 567 t of ore, yielding 639 914 g Au, 225 994 t Ag and 4161 kg Cu (BC Geological Survey, 2009; MINFILE 103J 017; Figures 1, 4). The orebodies are a set of pyritiferous quartz veins hosted in a northeasterly zone of fracturing and weak brittle shearing within an undeformed Cretaceous stock that underlies the western part of the Bell Range (Figure 4). The Surf Point and Edye Pass adits are located about 1 km apart along this trend. Exploration work in 1979–1980 by Banwan Gold Mines extended the Edye Pass adit 1 km southwest below the Surf Point workings (Scott, 1997). Work on the deposit by Cathedral Gold Corporation resulted in the discovery of the AT zone, about 50 m west of adit no 4 portal. Mineralization is persistent to a depth of 550 m and remains open. The zone also remains open along strike. Based on 66 holes totalling 12 192 m, the AT zone contains 544 300 t of indicated reserves grading 6.86 g/t Au, plus an additional 816 500 t of inferred reserves at the same grade. (pre NI 43-101; Anonymous, 1997; Scott, 1997) Property ownership is currently split between Imperial Metals Corporation and the former Cross Lake Minerals. The underground workings are in good condition, the trail and boardwalk connecting the workings have been rehabilitated, and there is a well-maintained exploration camp located near tidewater next to the Edye Pass adit.

The zone hosting the two mines and associated showings displays a 20° (north-northeasterly) structural trend. Its northeastern end abuts against a zone of strong ductile shearing exposed along the shore near the Edye Pass mine. This zone could be a splay of the Useless fault (Figure 4). Throughout the rest of its length, hostrocks are undeformed and unaltered granodiorite and tonalite. The veins themselves are pyritic quartz (Figure 25). They have narrow selvages of sericite-chlorite alteration in the host granodiorite. Individual veins, well-exposed in the roof and floor of the Surf Point adit, range in thickness from 5 to

Figure 26. Pyritic, siliceous quartz-sericite schist (metamorphosed altered rhyolite) in Wales Group near Moore Cove, northwestern British Columbia. The field of view is 3 m wide.

Figure 27. Layer of magnetite in thinly laminated Wales Group metatuff, northeastern Porcher Island, northwestern British Columbia; rock hammer for scale.

Figure 28. Magnetite laminations in siliceous, iron-rich metatuff, Wales Group, Stuart Anchorage, northwestern British Columbia; pencil for scale.

30 cm, and appear to be continuous over up to a few tens of metres. Their strikes are somewhat more northeasterly than the overall trend of the mineralized zone (40–90°; 2009 observations and MINFILE 103J 017). Latest motion on their enclosing surfaces was transcurrent, as shown by gently plunging slickenlines and chlorite streaks. The northeasterly orientation of the controlling structure is consistent with a zone of extension related to late dextral motion on the northwesterly bounding faults.

In summary, the Porcher Island gold mine shows continuity of mineralization and grade over 1 km in strike length; it has a considerable unmined resource and potential for expansion. The lack of continuity of individual veins and the resulting wallrock dilution impacts its mineable grade at present; however, larger individual veins may be found, and the potential for stockwork-style bulk mineable targets offers interesting possibilities to future explorers.

Indications of Volcanogenic Potential: Quartz-Sericite Schist and Iron Formation

The idea of projecting Paleozoic and older volcanogenic potential south from southeastern Alaska into far northwestern BC is not new to this project. It generated a few industry projects in the 1980s and early 1990s (cf. Franzen, 1984; Bohme, 1993), and has intrigued some government geologists (P. Wojdak and M. Mihalynuk, pers comm, 1990–2007). Until now, however, no detailed, systematic geological work has been done to test the relevant rock correlations and document likely hostrocks.

We have described here mixed volcanic successions assigned provisionally to both the Wales Group (Neoproterozoic–Cambrian) and Descon Formation (Ordovician–Early Silurian). Both of them are dominated by andesite volcaniclastic protoliths with minor rhyolite, dacite and basalt. Laminated tuff sequences are indicative of primarily subaqueous deposition. Some of the dacite is lensoid in shape and forms bodies that are typically 100–300 m thick and up to 1 km long with coherent textures including aphyric and quartz phyric. These probably originated as domes or cryptodomes at small volcanic centres. Felsic tuff forms discrete beds in the metre to decimetre range, as well as sets of laminae in dominantly andesite volcaniclastic sequences. These rocks are overall plausible as hosts for Kuroko-style volcanogenic occurrences.

More specific indicators of VMS environments were noted, all of them within rocks assigned to the Wales Group. Near Moore Cove on the eastern side of Telegraph Passage, there are a number of small bodies of quartz-sericite schist, pyritic quartz-sericite schist and metamorphosed silicified rhyolite (Figures 4, 26). This sequence passes eastward into a metasedimentary package that includes an unusual magnetite-rich metachert, possibly an iron formation.

Stratabound, stratiform magnetite occurs at a number of widely scattered sites along the northeastern side of Porcher Island immediately northeast of the Lamppost fault, and on the eastern side of Pitt Island near Stuart Anchorage (Figure 4). Two of these occurrences have been previously documented as MINFILE localities: Royal (MINFILE 103G 016) and Star (MINFILE 103J 031; Figure 1). The bodies are continuous over tens to hundreds of metres, enclosed in highly strained metatuff. The Royal occurrence and its southern extension lie immediately above a felsic metatuff body (Figure 4). Individual layers vary in thickness from tens of centimetres to a maximum at the Royal showing of several metres, which is interpreted as a thickened fold axial zone. The most common mineralization consists of pure, fine-grained magnetite with shiny grey specular hematite partings (Figure 27). Magnetite also forms fine laminae and blebs within metatuff (Figure 28). Schist containing manganoan zoisite and axinite occurs in association with the iron formation in Stuart Anchorage, and also within the Oona River unit on the northeastern shoulder of Pitt Island. Because of its unusual compositions and association with felsic metatuff and iron formation, it is interpreted as metamorphosed exhalite. Epidote and epidote-garnet metazones accompany the magnetite in a few cases. Overall, however, calcsilicate rocks are minor compared to the magnetite, a feature atypical of skarn associations. Although limy layers occur within the volcanic sequences, there is no marble in direct association with the magnetite bodies. Instead, the texture of magnetite laminated in siliceous, intermediate tuff is more amenable to interpretation as original stratabound exhalative deposits, as opposed to metamorphic replacements. We consider these to represent regional iron formation, and thus to be distal indicators of sulphide-dominated volcanogenic deposits.

The best currently known example of such a deposit is the Pit prospect or Pitt/Trinity property (MINFILE 103H 066), located on central Pitt Island 10 km south of the current map area (Figure 1). This belt of VMS-style mineralization was explored between 1980 and 1993 (Figure 2; Lo, 1992; Bohme, 1993). As shown in the Figure 1 inset, it is approximately on strike with the zone of stratabound magnetite and metamorphosed calcareous exhalite (?) on east Porcher and east Pitt islands. On the property, a number of separate showings have been identified in two separate trends parallel to regional northwest strike, within two metamorphic inliers that are interlayered with tabular Cretaceous intrusive bodies (Bohme, 1993). The Pyrite Creek trend is 1.7 km long; two other showings (Pitt zone) lie along strike 3 km to the northwest. The B Creek zone is in a separate inlier 2 km to the northeast. In both, pyrite-rich semimassive to massive sulphide bodies are hosted by metavolcanic and metasedimentary rocks including quartz-muscovite schist, pyritic quartz-biotite schist and carbonaceous argillite. True thicknesses are on the order of 0.2–1.6 m. Principal sulphide minerals are pyrite, chalcopyrite, sphalerite, pyrrhotite, galena, covellite and possibly bornite; barite is inferred based on values of 1.0–5.5% Ba in assays. Drill intersections of the Pyrite Creek zone returned 0.94–2.2% Cu, 0.41–1.2% Pb and 1.5–4.9% Zn over 2 m widths. Reported values of precious metals are low (Bohme, 1993).

In summary, the Pitt/Trinity VMS-style sulphide trends are of interest because of their significant extent along regional strike. This area is targeted for detailed map coverage in year 3 of the north coast project, in 2011.

Other Showings

We examined the Etta showing (MINFILE 103J 027; Figure 1) near Hunt Inlet to evaluate the type of mineralization present. Patchy zones of epidote skarn that contain scattered pyrite, chalcopyrite and sphalerite concentrations occur in greenschist-grade andesite pyroclastic hostrock near and at a contact with limestone. A surface sample assayed 8.0% Zn, 0.11% Cu and 1.37 g/t Ag (Freberg, 1974). The exposure was trenched and drilled in 1974, although no assay values were reported (Freberg, 1974); some of the core is still on site. In the northern part of Porcher Island, metavolcanic and metasedimentary rocks assigned to the Descon Formation are intruded by numerous dikes and plugs too small to map. Hornfelsing is common and the large Spiller Range pluton outcrops several kilometres to the south. The Jifney Etta small past producer (MINFILE 103J 028), the Por showing (MINFILE 103J 023) and other small skarn showings (not located) are similar to Etta. All of them are probably best interpreted as skarns associated with small limestone bodies in the Descon volcanic-sedimentary sequence.

DISCUSSION

Significance of New Porcher Island/ Grenville Channel Results for Understanding the Southward Extension of the Alexander Terrane

The Alexander terrane south of the BC-Alaska border is now better understood. The detailed field mapping of this project in 2009 follows up the earlier intimations of Gehrels and Boghossian (2000) and Gehrels (2001) that individual map units of the Alexander terrane can be traced and correlated from southeastern Alaska into the northern and even central coastal areas of BC. We can with some certainty recognize the Wales Group on and near Porcher Island, as a deformed metavolcanic sequence intruded postkinematically by the ca. 482 Ma McMicking pluton. The existence of a less-deformed and less-metamorphosed Descon Formation on northern Porcher Island has been proposed. Felsic units both within the presumed Wales and Descon units have been collected for U-Pb dating—because at least some of the amphibolite-grade metamorphism in this area is of Cretaceous age, it follows that more certain indicators than the relative degree of metamorphism and deformation must be used. The metamorphosed Ogden Channel and Billy Bay complexes may be intrusive equivalents of the Wales and Descon supracrustal units. This also will be tested by U-Pb geochronology. Other plutons that have been interpreted as Paleozoic—the Hunt Inlet and Swede Point bodies—will also be dated. Finally, equivalents of the Devonian Karheen Formation are now known to occur on Kennedy Island and on the mainland coast, as shown by sedimentological observations and detrital zircon geochronology. The continued unravelling of Alexander terrane stratigraphy and history will provide a useful context for geological studies and regional mineral exploration in this area.

Regional Significance of Cretaceous Sinistral/Oblique Faults

The newly identified Salt Lagoon, Useless and Lamppost faults on Porcher Island, along with the Grenville Channel, Kitkatla and Principe-Laredo faults (Chardon et al., 1999), define a regime of large-scale, Early to mid-Cretaceous sinistral displacements within the coastal region of BC. It has been interpreted as the cause of apparent duplication of the Late Jurassic to Early Cretaceous proto-Coast Mountains arc (Gehrels et al., 2009), and closure of the Tyaughton Basin in the southern Coast Mountains (Monger et al., 1994). Estimated total displacement across this zone was at least 800 km. Prior to this event, but after mid-Jurassic accretion to Stikinia and the outer Yukon-Tanana terrane, the southern Alexander terrane of Porcher Island may have lain at the latitude of the present-day western Yukon, across the Denali fault from the Kluane schist and Nisling terrane. Trajectories of the regional sinistral faults have not yet been traced with certainty into southeastern Alaska, in large part because of the masking effects of later dextral structures such as the Denali fault.

New Mineral Potential Outlined in this Project

Deformed and metamorphosed volcanic sequences in the Grenville Channel–eastern Porcher Island area contain geological features that are indicative of the existence of syngenetic submarine hot-spring systems. These include many small rhyolite and dacite volcanic centres; local premetamorphic clay sericitization and silicification of rhyolite; magnetite iron formation, and metachert with magnetite, sulphides, manganoan zoisite and axinite that we interpret as metamorphosed exhalite. Although no new sulphide showings were found in 2009, it is considered highly encouraging that extensive volcanogenic mineralization has been identified on the Pit property, located on Pitt Island 10 km to the south along strike from the zone of stratabound magnetite on east Porcher and east Pitt islands. The presence of magnetite iron formation makes regional airborne magnetometer surveys a potentially effective and cost-effective tool in locating targets in the generally vegetation-covered interiors of the islands.

Future Research Directions and Mapping Plans

Mapping in 2010 for the north coast project will target the southernmost part of the belt of Alexander exposures west of Bella Coola. This area has the second highest percentage of Paleozoic exposures in the belt, after Porcher Island. By that time, data provided by U-Pb and geochemical studies at the University of Wisconsin at Eau Claire and the University of Arizona will help to guide our developing understanding of the southern Alexander terrane, its relationship to better-known exposures in Alaska and its potential to host as-yet-undiscovered metallic deposits.

SUMMARY AND CONCLUSIONS

The north coast project can list the following accomplishments after its first year of operation:

Completion of geological map coverage of an area of 30 by 50 km, including Porcher Island, the adjacent mainland coast and smaller islands in between.

Rock units of the Alexander terrane of southeastern Alaska can be traced into northwestern BC, including those that are known to host VMS mineralization.

Geological indicators of VMS-style systems occur in two trends, one on northeastern Porcher Island and, offset across the Salt Lagoon fault, on northeastern Pitt Island; the other east of the Grenville Channel fault on the mainland coast east of Telegraph Passage.

ACKNOWLEDGMENTS

We first acknowledge the key role of our captain, Don Willson and his boat, the *Phoebe*, in providing a convenient logistical base of operations and safe co-ordination of our daily zodiac traverses. The project was also greatly enhanced by our partnership with the Lax Kw'alaams First Nation, in whose traditional territory part of the mapped area is located (Figure 1). Their Project Observer, Richard Bryant, contributed nautical skills and insights into his nation's history that were much appreciated. Brennan Kadulski, University of Wisconsin, gave excellent assistance in the field. Martin Pepper and Jim Gehrels each brought unique contributions to the project. The residents of Oona River, especially Jan Lemon, Karl Bergman, Lutz Budde and Bobby Letts, offered us welcome, good advice and directions. A word of thanks to the Gulf of Alaska must be included here. In 2009, it took a long summer break from its customary storm-brewing activities to give us a season of sun and light breezes. The north coast project is part of Edges (Multiple Metals—Northwest Canadian Cordillera (Yukon, BC): financial and logistical support from the Geological Survey of Canada made it all possible; we thank our Canadian and American colleagues in the Edges project for their ideas and insights. Larry Diakow's careful review improved the accuracy and clarity of the manuscript.

REFERENCES

Alldrick, D.J. (2000): Geology and mineral deposits of the Ecstall belt, northwest BC; *in* Geological Fieldwork 1999, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2000-1, pages 279–306.

Alldrick, D.J., Friedman, R.M. and Childe, F.C. (2000): Age and geologic history of the Ecstall greenstone belt, northwest BC; *in* Geological Fieldwork 1999, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 2000-1, pages 269–278.

Anonymous (1997): Cathedral puts Sterling gold mine on hiatus; *Northern Miner*, April 21, 1997, page 14.

Ayuso, R.A., Karl, S.M., Slack, J.F., Haeussler, P.J., Bittenbender, P.E., Wandless, G.A. and Colvin, A.S. (2005): Oceanic Pb-isotopic sources of Proterozoic and Paleozoic volcanogenic massive sulphide deposits on Prince of Wales Island and vicinity, southeastern Alaska; *in* Studies by the U.S. Geological Survey in Alaska 2005, *United States Geological Survey,* Professional Paper 1732-E, pages 1–20.

BC Geological Survey (2009): MINFILE BC mineral deposits database; *BC Ministry of Energy, Mines and Petroleum Resources*, URL <http://minfile.ca> [November 2009].

Berg, H.C., Jones, D.L. and Richter, D.H. (1972): Gravina-Nutzotin belt—tectonic significance of an upper Mesozoic sedimentary and volcanic sequence in southern and southeastern Alaska; *United States Geological Survey,* Professional Paper 800-D, pages D1–D24.

Bohme, D.W. (1993): Geological, geochemical and geophysical report on the Pitt/Trinity claim group, Skeena Mining Division, NTS 103H/12W; submitted by Inco Ltd., *BC Ministry of Energy, Mines and Petroleum Resources,* Assessment Report 22 912, 138 pages.

Buddington, A.F. and Chapin, T. (1929): Geology and mineral deposits of southeastern Alaska; *US Geological Survey,* Bulletin 800, 398 pages.

Butler, R.F., Gehrels, G.E., Hart, W., Davidson, C. and Crawford, M.L. (2006): Paleomagnetism of Late Jurassic to mid-Cretaceous plutons near Prince Rupert, British Columbia, *in* Paleogeography of the North American Cordillera: Evidence For and Against Large-Scale Displacements, Haggart, J.W., Enkin, R.J. and Monger, J.W.H., Editors, *Geological Association of Canada*, Special Paper 46, pages 171–200.

CBR Gold Corp. (2009): Resource summary; *CBR Gold Corp*., URL <http://www.cbrgoldcorp.com/project_areas/overview/> [December 2009].

Chardon, D. (2003): Strain partitioning and batholith emplacement at the root of a transpressive magmatic arc; *Journal of Structural Geology*, Volume 25, pages 91–108.

Chardon, D., Andronicos, C.L. and Hollister, L.S. (1999): Large-scale transpressive shear zone patterns and displacements within magmatic arcs: the Coast Plutonic Complex, British Columbia; *Tectonics*, Volume 18, pages 278–292.

Eberlein, G.D. and Churkin, M. Jr. (1970): Paleozoic stratigraphy in the northwest coastal area of Prince of Wales Island, southeastern Alaska; *United States Geological Survey*, Bulletin 1284, 67 pages, 2 sheets, 1:125 000 scale.

Eberlein, G.D., Churkin, M. Jr., Carter, C., Berg, H.C. and Ovenshine, A.T. (1983): Geology of the Craig quadrangle, Alaska; *United States Geological Survey*, Open File Report 83-91, 28 pages, 1:250 000 scale.

Franzen, J.P. (1984): Geochemical report, Por 1-8 mineral claims, Skeena Mining Division, NTS 103J/1W; submitted by Billiton Canada Limited, *BC Ministry of Energy, Mines and Petroleum Resources,* Assessment Report 13 051, 33 pages.

Freberg, R.A. (1974): Report on diamond drilling 1974, Yukonadian Explorations Limited, Hunt Inlet, Porcher Island, B.C.; submitted by Yukonadian Mineral Exploration, *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 5027, 31 pages.

Gareau, S.A. and Woodsworth, G.J. (2000): Yukon-Tanana terrane in the Scotia-Quaal belt, Coast Plutonic Complex, central-western British Columbia, *in* Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia, Stowell, H.H. and McClelland, W.C., Editors, *Geological Society of America*, Special Paper 343, pages 23–44.

Gehrels, G.E. (1990): Late Proterozoic to Cambrian metamorphic basement to the Alexander terrane on Long and Dall islands, southeastern Alaska; *Geological Society of America Bulletin*, Volume 102, pages 760–767.

Gehrels, G.E. (2001): Geology of the Chatham Sound region, southeast Alaska and coastal British Columbia; *Canadian Journal of Earth Sciences*, Volume 38, pages 1579–1599.

Gehrels, G.E. and Boghossian, N.D. (2000): Reconnaissance geology and U-Pb geochronology of the west flank of the Coast Mountains between Bella Coola and Prince Rupert, coastal British Columbia; *in* Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia, Stowell, H.H. and McClelland, W.C., Editors, *Geological Society of America,* Special Paper 343, pages 61–76.

Gehrels, G.E. and Saleeby, J.B. (1987): Geologic framework, tectonic evolution and displacement history of the Alexander terrane; *Tectonics*, Volume 6, pages 151–174.

Gehrels, G.E., Berg, H.C. and Saleeby, J.B. (1983): Ordovician-Silurian volcanogenic massive sulfide deposits on southern Prince of Wales Island and the Barrier Islands, southeastern Alaska; *United States Geological Survey*, Open File Report 83-318, 11 pages.

Gehrels, G.E., Butler, R.F. and Bazard, D.R. (1996): Detrital zircon geochronology of the Alexander terrane, southeastern Alaska; *Geological Society of America Bulletin*, Volume 108, pages 722–734.

Gehrels, G., Rusmore, M., Woodsworth, G., Crawford, M., Andronicos, C., Hollister, L., Patchett, J., Ducea, M., Butler, R., Klepeis, K., Davidson, C., Friedman, R., Haggart, J., Mahoney, B., Crawford, W., Pearson D. and Girardi, J. (2009): U-Th-Pb geochronology of the Coast Mountains batholith in north-coastal British Columbia: constraints on age and tectonic evolution; *Geological Society of America Bulletin*, Volume 121, pages 1341–1361.

Hutchison, W.W. (1982): Geology of the Prince Rupert–Skeena map area, British Columbia; *Geological Survey of Canada*, Memoir 394, 115 pages.

Karl, S.M., Ayuso, R.A., Slack, J.F. and Friedman, R.M. (2009): Neoproterozoic to Triassic rift-associated VMS deposits in the Alexander composite oceanic arc terrane, southeast Alaska; *in* Mining: Modern Mine Reclamation, Morris, H., Editor, *Alaska Miners Association*, 2009 Annual Convention, Abstracts, page 9.

Kilby, W.E. (1995): Mineral potential project—overview; *in* Geological Fieldwork 1994, *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1995-1, pages 411–416.

Lo, B.B.H. (1992): Geophysical report on a helicopter-borne electromagnetic and magnetometer survey at the Pitt/Trinity property, British Columbia, NTS 103H/12; submitted by Inco Ltd., *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 22 475, 45 pages.

MapPlace (2009): Mineral resource assessment layer; British Columbia Geological Survey MapPlace website; BC Ministry of Energy, Mines and Petroleum Resources, URL <http://mapplace.ca> [December 2009].

Mansfield, M.R. (2004): Thermal and structural evolution of the Grenville Channel shear zone, Coast Plutonic Complex, British Columbia; unpublished MSc thesis, *University of Texas*, 61 pages.

Monger, J.W.H., van der Heyden, P., Journeay, J.M., Evenchick, C.A. and Mahoney, J.B.M. (1994): Jurassic-Cretaceous basins along the Canadian Coast Belt: their bearing on pre–mid-Cretaceous sinistral displacements; *Geology*, Volume 22, pages 175–178.

Nelson, J.L., Mahoney, J.B. and Gehrels, G.E. (in press): Geology and mineral potential of the Porcher Island–Grenville Channel area, northwestern British Columbia; *BC Ministry of Energy, Mines and Petroleum Resources*, Open File 2010-03, scale 1:50 000.

Roddick, J.A. (1970): Douglas Channel–Hecate Strait map-area, British Columbia; *Geological Survey of Canada*, Paper 70-41, 70 pages.

Rubin, C.M. and Saleeby, J.B. (1992) Tectonic history of the eastern edge of the Alexander terrane, southeast Alaska; *Tectonics*, Volume 11, pages 586–602.

Saleeby, J.B. (2000): Geochronologic investigations along the Alexander-Taku terrane boundary, southern Revillagigedo Island to Cape Fox areas, southeast Alaska; *in* Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia, Stowell, H.H. and McClelland, W.C., Editors, *Geological Society of America*, Special Paper 343, pages 107–143.

Scott, T.C. (1997): 1996–1997 diamond drilling assessment report on the Tob 1, L6513, L6515, L6516, L6517 and L7191 mineral claims located on Porcher Island, Skeena Mining Division, NTS 103J/2E; submitted by Cathedral Gold Corp., *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 25 073, 298 pages.

Slack, J.F., Shanks, W.C., Karl, S.M., Gemery, P.A., Bitterbender, P.E. and Ridley, W.I. (2005): Geochemical and sulphur-isotopic signatures of volcanogenic massive sulphide deposits on Prince of Wales Island and vicinity, southeastern Alaska; *in* Studies by the U.S. Geological Survey in Alaska 2005, *United States Geological Survey*, Professional Paper 1732-C, 37 pages.

van der Heyden, P. (1989): U-Pb and K-Ar geochronometry of the Coast Plutonic complex, 53°N to 54°N, British Columbia, and implications for the Insular-Intermontane terrane boundary; unpublished PhD thesis, *The University of British Columbia*, 392 pages.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H., Monger, J.W.H., Tipper, H.W. and Woodsworth, G.J. (1991): Terrane map of the Canadian Cordillera: *Geological Survey of Canada*, Map 1713A, scale 1:2 000 000.

Wolf, D.E., Andronicus, C.L., Vervoort, J.D., Mansfield, M.R. and Chardon, D. (2009): Application of Lu-Hf garnet dating to unravel the relationships between deformation, metamorphism and plutonism: an example from the Prince Rupert area, British Columbia; *Geological Society of America*, Abstracts with Programs, Volume 41, Number 7, page 223.