BC Geological Survey
Open File 2009-11

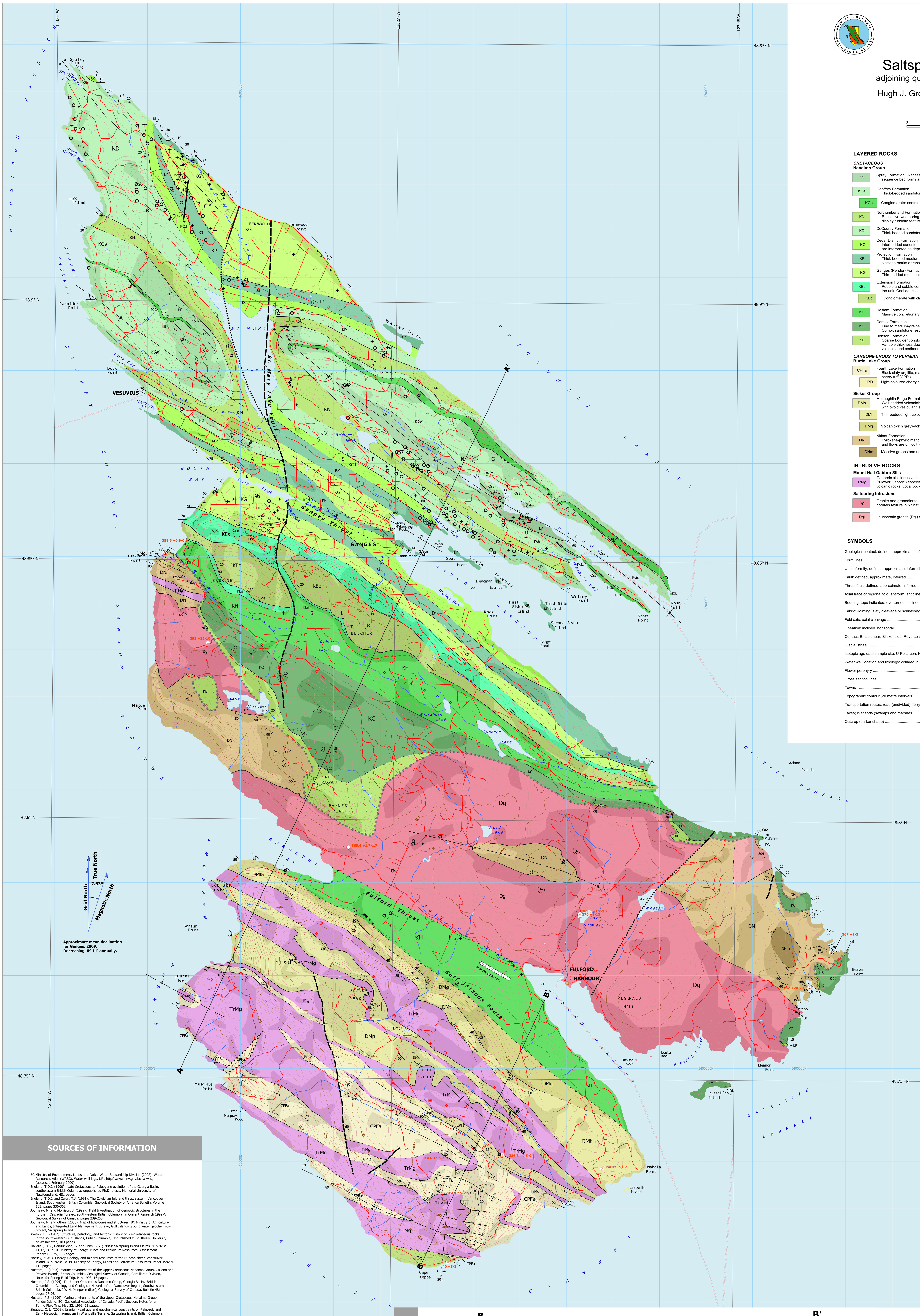
Saltspring Island Geology

adjoining quadrants of NTS 92B/11, 12, 13 &14

Hugh J. Greenwood with Mitchell G. Mihalynuk

Scale 1:25 000

0 kilometres 2.5



LEGEND

LAYERED ROCKS

CRETACEOUS
Nanaimo Group

- **KS** — Spray Formation. Recessive-weathering sandstone-mudstone turbidite and massive mudstone. Platy habit and Bouma sequence bed forms are typical. Inoceramid bivalve fossils are present, but commonly broken.
- **KGs** — Geoffrey Formation. Thick-bedded sandstone: bed forms indicate deposition from turbidity currents.
  - **KGc** — Conglomerate: central interbed within Geoffrey Formation sandstone.
- **KN** — Northumberland Formation. Recessive-weathering mudstone and fine-grained sandstone. "Ribbed" couplets of sandstone and mudstone display turbidite features.
- **KD** — DeCourcy Formation. Thick-bedded sandstones and arkosic arenite with minor pebbly conglomerate.
- **KCd** — Cedar District Formation. Interbedded sandstone and mudstone with soft-sediment deformation features. Sandstone-mudstone couples are interpreted as deposited from turbidity currents. Ammonites are locally common.
- **KP** — Protection Formation. Thick-bedded medium-grained sandstone displaying cross-bedding, sole-marks and burrows. Thin-bedded siltstone marks a transition to the underlying unit.
- **KG** — Ganges (Pender) Formation. Thin-bedded mudstone, siltstone and fine-grained sandstone with excellent turbidite structures.
- **KEs** — Extension Formation. Pebble and cobble conglomerate (KEc) with coarse-grained sandstone facies (KEs) at both top and bottom of the unit. Coal debris is common.
  - **KEc** — Conglomerate with clasts dominated by mafic volcanic rocks, chert, and granite.
- **KH** — Haslam Formation. Massive concretionary fossiliferous black shale and mudstone. Locally contains coal fragments.
- **KC** — Comox Formation. Fine to medium-grained sandstone with trace fossil borings near Arnell Park. Where the Benson is absent, Comox sandstone rests directly on Paleozoic rocks.
- **KB** — Benson Formation. Coarse boulder conglomerate with clasts including granite, greenstone, chert, quartzite, and granodiorite. Variable thickness due to its deposition on an irregular paleotopography consisting of Paleozoic granitic, volcanic, and sedimentary rocks.

CARBONIFEROUS TO PERMIAN
Buttle Lake Group

- **CPFa** — Fourth Lake Formation. Black slaty argillite, massive and uniform with calcareous siltstone components. Minor light-coloured cherty tuff (CPFt).
  - **CPFt** — Light-coloured cherty tuff.

Sicker Group

- **DMp** — McLaughlin Ridge Formation. Well-bedded volcaniclastic sediments gradationally overlying the Nitinat Formation. Pyroclastic breccia with ovoid vesicular clasts 1- to 15 cm floating in a matrix of ash-sized fragments.
  - **DMt** — Thin-bedded light-coloured felsic tuff. In many places very fine-grained and cherty in appearance.
  - **DMg** — Volcanic-rich greywacke with tuffaceous components.
- **DN** — Nitinat Formation. Pyroxene-phyric mafic agglomerate, pyroxene bearing tuffs, lapilli tuffs and flows. Individual sub units and flows are difficult to trace confidently. Pyroxene crystals are commonly altered to actinolite.
  - **DNm** — Massive greenstone unit may in large part be intrusive rocks of dioritic composition.

INTRUSIVE ROCKS

Mount Hall Gabbro Sills

- **TrMg** — Gabbroic sills intrusive into Paleozoic strata. Tholeiitic basalt with conspicuous glomeroporphyritic texture ("Flower Gabbro") especially along upper contacts. Similar textures have been observed in Karmutsen volcanic rocks. Local pockets of coarse grained hornblende pegmatite.

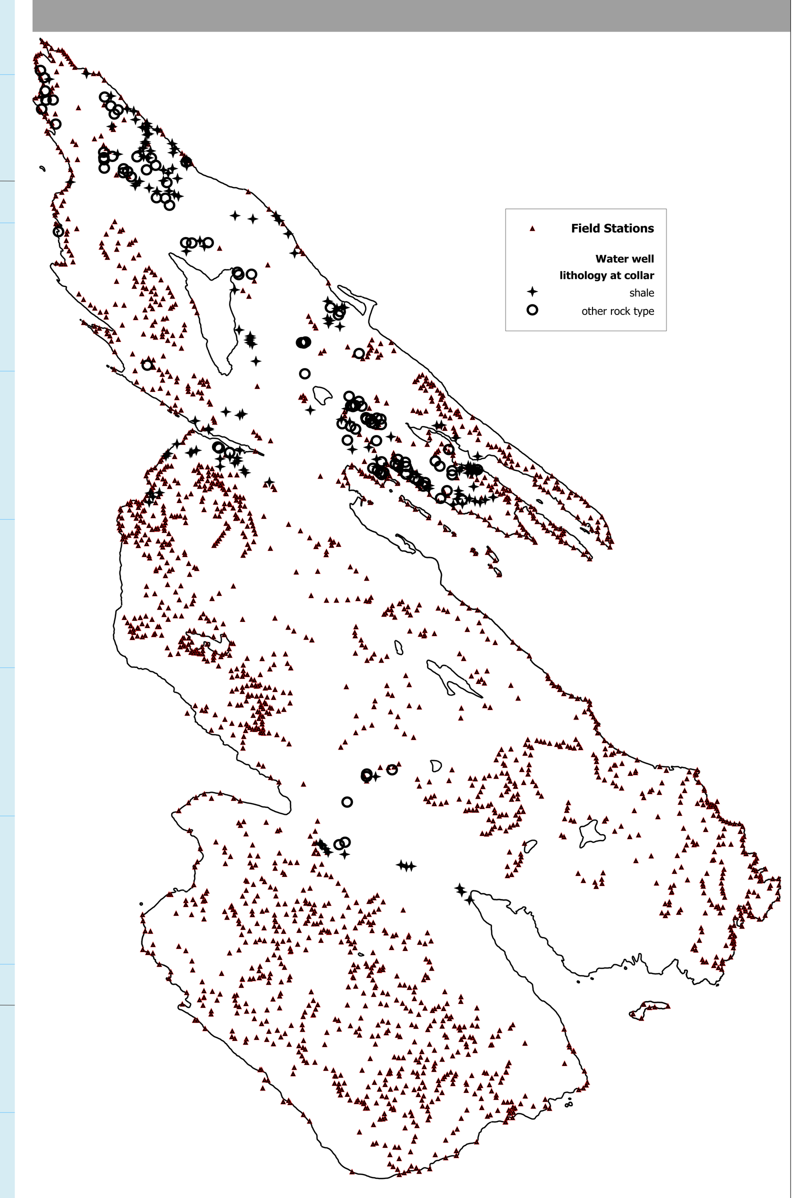
Saltspring Intrusions

- **Dg** — Granite and granodiorite, undivided (Dg) commonly protomylonitic with conspicuous quartz 'eyes'. Produces a hornfels texture in Nitinat Formation country rocks.
- **Dgl** — Leucocratic granite (Dgl) occurs near Yeo Point with no clear contact relations.

SYMBOLS

Geological contact; defined, approximate, inferred
Form lines
Unconformity; defined, approximate, inferred
Fault; defined, approximate, inferred
Thrust fault; defined, approximate, inferred
Axial trace of regional fold; antiform, anticline, synform, syncline
Bedding: tops indicated, overturned, inclined, vertical
Fabric: Jointing; slaty cleavage or schistosity (inclined, vertical, second phase)
Fold axis, axial cleavage
Lineation: inclined, horizontal
Contact, Brittle shear, Slickenside, Reverse shear band
Glacial striae
Isotopic age date sample site: U-Pb zircon, K-Ar, Apatite fission track (see Sluggett, 2003)
Water well location and lithology: collared in shale or non-shale lithology
Flower porphyry
Cross section lines A — A'
Towns GANGES
Topographic contour (20 metre intervals) 1200
Transportation routes: road (undivided), ferry
Lakes; Wetlands (swamps and marshes)
Outcrop (darker shade)

RELIABILITY DIAGRAM

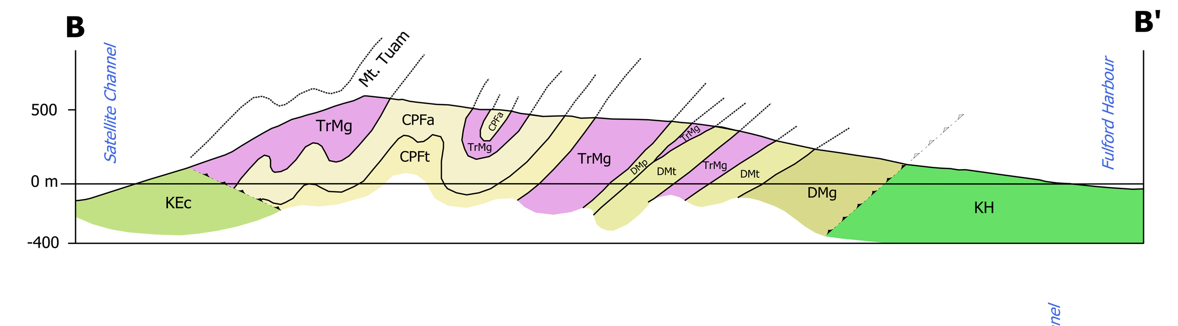


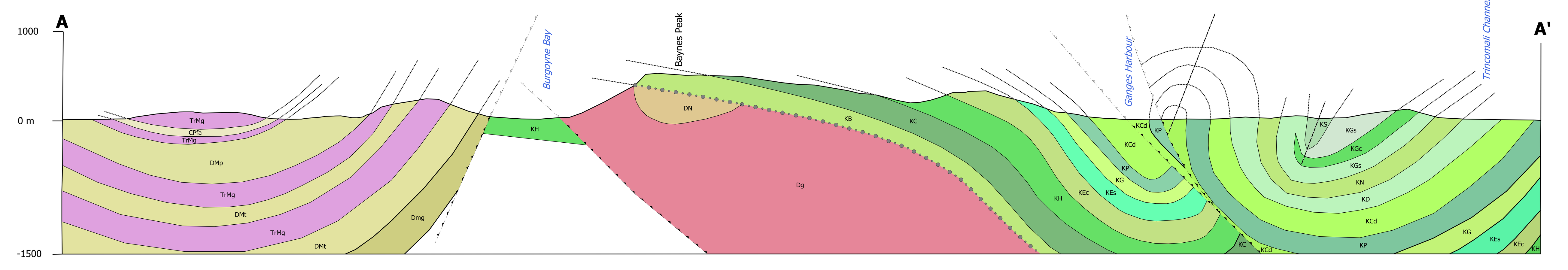
LOCATION

SOURCES OF INFORMATION

BC Ministry of Environment, Lands and Parks; Water Stewardship Division (2008): Water Resources Atlas (WRBC), Water well logs, URL http:\\www.env.gov.bc.ca-wsd, [accessed February 2009].
England, T.D.J. (1990): Late Cretaceous to Paleogene evolution of the Georgia Basin, southwestern British Columbia; unpublished Ph.D. thesis, Memorial University of Newfoundland, 481 pages.
England, T.D.J. and Calon, T.J. (1991): The Cowichan fold and thrust system, Vancouver Island, Southwestern British Columbia; Geological Society of America Bulletin, Volume 103, pages 336-362.
Journeay, M. and Morrison, J. (1999): Field Investigation of Cenozoic structures in the northern Cascadia Forearc, southwestern British Columbia; in Current Research 1999-A, Geological Survey of Canada, pages 239-250.
Journeay, M. and others (2008): Map of lithologies and structures; BC Ministry of Agriculture and Lands, Integrated Land Management Bureau, Gulf Islands ground water geochemistry project, Saltspring Island.
Kveton, K.J. (1987): Structure, petrology, and tectonic history of pre-Cretaceous rocks in the southwestern Gulf Islands, British Columbia; Unpublished M.Sc. thesis, University of Washington, 103 pages.
Mallalieu, D.G., Hendrickson, G. and Enns, S.G. (1984): Saltspring Island Claims, NTS 92B/11,12,13,14; BC Ministry of Energy, Mines and Petroleum Resources, Assessment Report 13 375, 113 pages.
Massey, N.W.D. (1992): Geology and mineral resources of the Duncan sheet, Vancouver Island, NTS 92B/13; BC Ministry of Energy, Mines and Petroleum Resources, Paper 1992-4, 112 pages.
Mustard, P. (1993): Marine environments of the Upper Cretaceous Nanaimo Group, Galiano and Prevost Islands, British Columbia; Geological Survey of Canada, Cordilleran Division, Notes for Spring Field Trip, May 1993, 16 pages.
Mustard, P.S. (1994): The Upper Cretaceous Nanaimo Group, Georgia Basin, British Columbia; in Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, J.W.H. Monger (editor), Geological Survey of Canada, Bulletin 481, pages 27-96.
Mustard, P.S. (1999): Marine environments of the Upper Cretaceous Nanaimo Group, Pender Island, BC; Geological Association of Canada, Pacific Section, Notes for a Spring Field Trip, May 22, 1999, 22 pages.
Sluggett, C. L. (2003): Uranium-lead age and geochemical constraints on Paleozoic and Early Mesozoic magmatism in Wrangellia Terrane, Saltspring Island, British Columbia; Unpublished B.Sc. thesis, The University of British Columbia, 56 pages.
Yorath, C.J., Sutherland-Brown, A. and Massey, N.W.D. (1999): Lithoprobe, Southern Vancouver Island, British Columbia: Geology; Geological Survey of Canada, Bulletin 498, 145 pages.

INTERPRETIVE CROSS SECTIONS





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Descriptive notes to accompany Open File 2009-11, Geology of Saltspring Island

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Descriptions and comments within this document accompany the 1:25,000 scale map of Saltspring Island: BC Ministry of Energy, Mines and Petroleum Resources, Open File 2009-11. Production of the Open File map followed mapping conducted between 2006 and 2009 by the author as a personal project. Individuals seeking additional, more detailed descriptive material are referred the attached list of citations and selected bibliography. To view or download the Saltspring Island Geology map, Open File 2009-11, please follow this link: http://www.empr.gov.bc.ca/Mining/Geoscience/PublicationsCatalogue/OpenFiles/2009/Pages/2009-11.aspx.

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PALEOZOIC ROCKS

Devonian Sicker Group

On Saltspring Island the Sicker Group includes mafic volcanic rocks of the Nitinat Formation that are intruded by granitic rocks of the Saltspring Intrusive Suite (357-369 Ma), felsic tuff of the McLaughlin Ridge Formation (354 Ma), calcareous argillite of the Fourth Lake Formation (354 Ma) and gabbro sills (226-229 Ma; all isotopic age data from Sluggett, 2003).

Nitinat Formation

The Nitinat Formation occurs north of Fulford valley and is made up of massive and fragmental volcanic rocks with conspicuous equant crystals of clinopyroxene some of which have been altered to hornblende while retaining pyroxene morphology. The pyroclastic rocks are good recorders of deformation fabrics (Photo 1). Many excellent examples can be found of clasts that have been stretched into elongate and flattened ‘saucer’ shapes ranging from 10 cm to 20 cm in maximum dimension (Photo 2). One such example can be seen in Beaver Point Park near the high tide line. No well bedded sections of Nitinat Formation were distinguished during the course of mapping.

Saltspring Intrusive Suite

There are several phases of Saltspring Intrusive Suite granitoid rocks present on the island. Some phases show characteristics of high-level sub-volcanic intrusion, such as corroded quartz grains with beta-quartz morphology. Different intrusive phases were not separated in the present mapping.

Granitic rocks of the Saltspring Intrusive Suite cut the Nitinat Formation. Near sea level south of Erskine Point, a narrow hornfels zone is well displayed. Several old prospect pits with rusty outcrops containing pyrite are located along the intrusive contact between Baynes Peak and Erskine Point.

Photo 1. Small folds in Nitinat pyroclastic breccia. Baders Beach. UTM 0458497 E: 5411097 N

Photo 2. Deformed pyroclasts within pyroxene-phyric pyroclastic breccia of Nitinat Formation near Baders Beach. UTM 0458109 E: 5410765 N

McLaughlin Ridge Formation

Other than one small area of a few hectares near the mouth of Maxwell Creek, the McLaughlin Ridge Formation occurs immediately south of the Fulford valley. At Maxwell Creek, it is in gradational contact with rocks of the Nitinat Formation. The formation is comprised of distinctive feldspathic volcanic greywacke, cherty crystal tuff (Photo 3), and a spectacular pyroclastic breccia. Near the Mount Bruce television towers and the Musgrave road, the breccia is particularly well displayed. This breccia can be distinguished from the Nitinat pyroclastic rocks by the absence of pyroxene crystals in the McLaughlin Ridge Formation (Photo 4).

Photo 3. Crystal tuff of McLaughlin Ridge Formation. The yellow pencil is parallel to cleavage, and the pink pencil is parallel to upright bedding (view toward 330^o).
UTM 0465129 E: 5400644 N

Photo 4. Pyroclastic breccia, McLaughlin Ridge Formation at Mt. Bruce Helipad. Unlike pyroxene--phyric Nitinat Formation. pyroclastic rocks, these are not pyroxene-phyric. UTM 0462328 E: 5401524 N.

Carboniferous-Permian Buttle Lake Group

On Saltspring Island, the Buttle Lake Group appears only in the Mount Tuam – Mount Sullivan – Cape Keppel area to the south of Fulford valley where it is represented by the Fourth Lake Formation. This formation consists mostly of black slaty argillite and minor cherty tuff. The argillite is slightly calcareous in places but attempts to subdivide it into mappable units based on these criteria were not successful. Outcrop-scale folds are abundant (Photos 5 and 6).

**Photo 5. Fold in Fourth Lake Formation calcareous argillite at the shoreline near the end of Maxam Road. View is toward 290°.
UTM: 0466896 E: N5397110.**

Photo 6. Small scale folding in Fourth Lake Formation, adjacent view of Photo 5 (towards 290^o). UTM E0466896: N5397110

Triassic Rocks

Mount Hall gabbroic sills

Mount Hall gabbro sills intrude both the McLaughlin Ridge and Fourth Lake formations and are folded with these rocks. In many places, the sills display spectacular examples of glomeroporphyritic texture, especially near their inferred upper contacts. In these exposures, aggregated groups of feldspar crystals clump together to give the appearance of white flowers between one and three centimeters in diameter. These rocks have been variously referred to as "flower porphyry", "flower gabbro" and "chrysanthemum stone". Localities with well developed flower porphyry textures are shown on the map. In some places the gabbro is pegmatitic containing coarse blades of hornblende.

Mount Hall gabbro sills of Saltspring Island are very similar to sills described at localities on Vancouver Island and at a variety of places within the widespread Karmutsen Formation. Whole rock chemistry from sills at all localities is uniform (Massey, 1992; Mallalieu et al., 1984) so all of the gabbro sills are assumed to be the product of one uniform magmatic source and intrusive episode.

CRETACEOUS ROCKS

Upper Cretaceous Nanaimo Group

Nanaimo Group rocks on Saltspring Island are represented by eleven formations consisting of alternating turbiditic shales, sandstones, and conglomerates. These rocks have been thoroughly studied and described by numerous workers, the most notable authors are England, Mustard, and Massey. Readers wanting more detailed descriptions should consult publications by these authors, the references for which can be found at the end of this document.

Black shale dominates the Haslam, Ganges, Cedar District, Northumberland, and Spray formations. All display graded bedding and numerous other features of turbidites that have been deposited in deep water by submarine density currents. Fossils of ammonites and bivalves can be found in many of turbidite units, commonly in the cores of carbonate-rich concretions. Well-developed facing indicators within these turbidite units permit recognition of overturned beds.

Sandstone- and conglomerate-dominated formations include the Benson, Comox, Extension, Protection, DeCourcy, and Geoffrey. They are commonly massive, although the Extension has well-defined sandstone sub-units both above and below the main conglomerate and the Geoffrey sandstone includes a discontinuous internal layer of coarse conglomerate. The Benson conglomerate, originally designated as a formation at the base of the Comox by Clapp (1912), has been reduced to member rank by Muller and Jeletzky (1970) but is treated here as a formation because of its extensive development on Saltspring Island.

The Benson Formation lies with angular unconformity atop the Sicker and Buttle Lake Groups. It varies greatly in thickness. The thickest sections are at Baynes Peak; farther northwest it becomes progressively thinner. As far northwest as Maxwell Creek it has all but disappeared, with only rare exposures deep in the creek gully. East of Baynes Peak, the Benson occurs as small patches along the unconformity, as can be seen along the sea shore south of Cusheon Creek, at Beaver Point, and an isolated exposure near Eleanor Point. Variable thickness and irregular distribution of the Benson Formation suggests that this conglomerate filled depressions atop an irregular paleosurface.

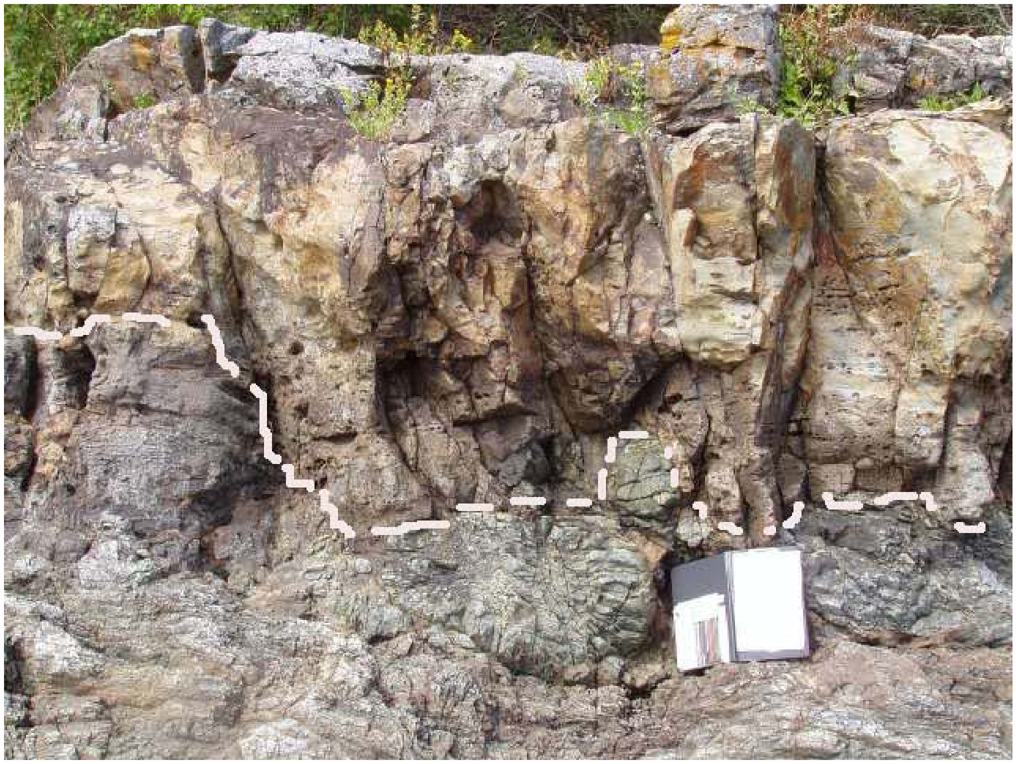

Photo 7. The unconformity between the Nanaimo Group Comox Formation and the Nitinat Formation on Russel Island. The dashed white line traces the unconformity. Nitinat below, Comox above. UTM E0470219: N5399627.

DEFORMATION

Centimetre-scale isoclinal folds with gentle northwest axial plunges are common within the Sicker and Buttle Lake Groups (Photos 1, 5, 6). Folds with wavelengths of 10 to 15 meters are less common, occurring in isolated outcrops. At the map scale, the structures outline tight to nearly isoclinal major folds trending northwest, as do all the fold structures on Saltspring Island. This approximate parallelism does not necessarily imply contemporaneity with folds affecting Cretaceous strata.

Deformational events

Three phases of deformation may be recorded by the oldest strata, the Nitinat Formation of Saltspring Island. These rocks are much more foliated and schistose than either the 354 Ma McLaughlin Ridge or the Fourth Lake formations and may be cut by the Saltspring Intrusive Suite (357-369 Ma). Thus, a pre-Late Devonian deformation is suggested. This intense deformation is well developed in Nitinat Formation rocks on Russel Island, Beaver Point, and the shore line south of Maxwell Creek.

A succeeding deformational event affects rocks as young as the Triassic Mount Hall gabbro. South of the mouth of Maxwell Creek, at Baders Beach, the deformed gabbro sills are truncated by the sub-Cretaceous unconformity. These sills are interpreted to have been emplaced while the enclosing Fourth Lake Formation sediments were horizontal and later folded together with the sediments. This interpretation is based upon glomeroporphyritic textures that are believed to have been developed near the prefolding, upper sill contacts. Such an interpretation is supported by facing directions in the enclosing volcanic sediments and shales. Thus, folding that affected the gabbros along with the enclosing McLaughlin Ridge and Fourth Lake formations must have occurred between Triassic and Cretaceous times.

The youngest folding event affects Cretaceous Nanaimo Group rocks and must have been superimposed on the older folds within rocks of the Sicker and Buttle Lake Groups. Well-layered Nanaimo Group rocks have been deformed by northwest-trending folds, some with limbs overturned toward the northeast.

Layer-parallel thrust faults can be identified locally where older rocks have been placed over younger rocks. The Ganges thrust, which follows the Ganges-Booth Bay valley, dips to the northeast. So too does the Fulford Fault, a thrust fault along the northeast side of the Fulford valley, which places the Saltspring Intrusion over the younger Haslam Formation shale. Another fault, designated the Gulf Islands Fault (Journeay and Morrison, 1999) separates Haslam shale in the Fulford valley from McLaughlin Ridge volcanic rock on the south side of Fulford valley. This faults dips to the southwest and is most simply interpreted as a high angle thrust fault, but clear evidence of the relative sense of motion was not found.

Faults that trend northeast cut all the map units. Perhaps the most conspicuous is the St. Mary Lake Fault, which produces an apparent sinistral offset of the Geoffrey Formation in the neighbourhood of St. Mary Lake. However, kinematic evidence for the sense of offset is lacking. Numerous other faults, too small to show at a scale of 1:25,000, occur throughout the island. Many of these belong to another set of faults which show evidence of small-scale dextral strike-slip motion without map-scale offsets.

LOCATIONS OF OUTCROPS AND WATER WELLS

More than 1600 outcrops were examined while mapping. All were located by means of a hand-held GPS. Most GPS measurements had an estimated precision of about 10 meters; although, in some areas, signal attenuation due to dense forest or steep gullies, probably reduced location precision to ~20 meters. In a few places no GPS signal could be detected and positions were determined from the topography. Distribution of field stations can be seen on the "Reliability Diagram" accompanying Open File 2009-11. Outcrop distribution is shown on the Open File 2009-11 geology map.

In areas of scarce or absent bedrock exposure, information on the underlying bedrock was obtained from drillers' logs of water wells. These logs are available from the BC Ministry of Environment, Lands and Parks; Water Stewardship Division (2008). By comparing nearby bedrock exposures with the drillers' logs it became clear that the logs were reliable in identifying black shale. Identification of other rocks types, such as sandstone, conglomerate and granite, was less reliable. Thus, the logs are useful for identifying the presence of concealed (recessive weathering) black shale, but not for discriminating other rock types. These data permitted mapping of shale units through areas of poor exposure especially in Fulford Valley and the area northwest of Fernwood.

REFERENCES CITED & SELECTED BIBLIOGRAPHY

Water Stewardship Division (2008): Water Resources Atlas (WRBC), Water well logs, *BC Ministry of Environment, Lands and Parks;* URL http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html , [accessed November, 2009].

Clapp, C.H. (1912): Southern Vancouver Island; *Geological Survey of Canada*, Memoir 13, 208 p.

England, T.D.J. (1990): Late Cretaceous to Paleogene evolution of the Georgia Basin, southwestern British Columbia; unpublished Ph.D. thesis, *Memorial University of Newfoundland*, 481 pages.

England, T.D.J. and Calon, T.J. (1991): The Cowichan fold and thrust system, Vancouver Island, Southwestern British Columbia; *Geological Society of America Bulletin*, Volume 103, pages 336-362.

Journeay, M. and Morrison, J. (1999): Field Investigation of Cenozoic structures in the northern Cascadia Forearc, southwestern British Columbia; in Current Research 1999-A, *Geological Survey of Canada*, pages 239-250.

Journeay, M. and others (2008): Map of lithologies and structures; *BC Ministry of Agriculture and Lands*, Integrated Land Management Bureau, Gulf Islands ground water geochemistry project, Saltspring Island.

Kveton, K.J. (1987): Structure, petrology, and tectonic history of pre-Cretaceous rocks in the southwestern Gulf Islands, British Columbia; Unpublished M.Sc. thesis, *University of Washington*, 103 pages.

Mallalieu, D.G., Hendrickson, G. and Enns, S.G. (1984): Saltspring Island Claims, NTS 92B/ 11,12,13,14. *BC Ministry of Energy, Mines and Petroleum Resources*, Assessment Report 13375, 113 pages.

Massey, N.W.D. (1992): Geology and mineral resources of the Duncan sheet, Vancouver Island, NTS 92B/13; *BC Ministry of Energy, Mines and Petroleum Resources*, Paper 1992-4, 112 pages.

Muller, J.E. and Jeletzky, J.A. (1970): Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia; *Geological Survey of Canada*, Paper 69-25, 77 p.

Mustard, P. (1993): Marine environments of the Upper Cretaceous Nanaimo Group, Galliano and Prevost Islands, British Columbia; *Geological Survey of Canada*, Cordilleran Division, Notes for Spring Field Trip, May 1993, 16 pages.

Mustard, P.S. (1994): The Upper Cretaceous Nanaimo Group, Georgia Basin, British Columbia; in Geology and Geological Hazards of the Vancouver Region, Southwestern British Columbia, J.W.H. Monger (editor), *Geological Survey of Canada*, Bulletin 481, pages 27-96.

Mustard, P.S. (1999): Marine environments of the Upper Cretaceous Nanaimo Group, Pender Island, BC; *Geological Association of Canada*, Pacific Section, Notes for a Spring Field Trip, May 22, 1999, 22 pages.

Sluggett, C. L. (2003): Uranium-lead age and geochemical constraints on Paleozoic and Early Mesozoic magmatism in Wrangellia Terrane, Saltspring Island, British Columbia; Unpublished B.Sc. thesis, *The University of British Columbia*, 56 pages.

Yorath, C.J., Sutherland-Brown, A. and Massey, N.W.D. (1999): Lithoprobe, Southern Vancouver Island, British Columbia: Geology; *Geological Survey of Canada*, Bulletin 498, 145 pages.