METAMORPHIC ROCKS IN THE FLORENCE RANGE, COAST MOUNTAINS, NORTHWESTERN BRITISH COLUMBIA (104M/8)

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INTRODUCTION

Fieldwork completed during 1989 focused on 1:20 000-scale mapping of the previously undivided metamorphic rocks in the Florence Range of the Coast Mountains of northwestern British Columbia (Figure 1-19-1). These rocks have been included in the Nisling Terrane, which is interpreted as a displaced continental margin assemblage of unknown origin (Wheeler and McFeely, 1987). Nisling Terrane rocks resemble continental margin rocks of western North America (*e.g.* Windermere Supergroup). However, east of the Florence Range there are oceanic rocks of early Paleozoic to early Mesozoic age that separate the Nisling Terrane from ancestral North America. Either the Nisling Terrane is a rifted fragment of North America or a fragment of another continent. In addition to its origin, the apparent pre-Upper Triassic metamorphism of the terrane is unusual in the Cordillera and is presently unexplained. These are subjects that will be addressed by this study.

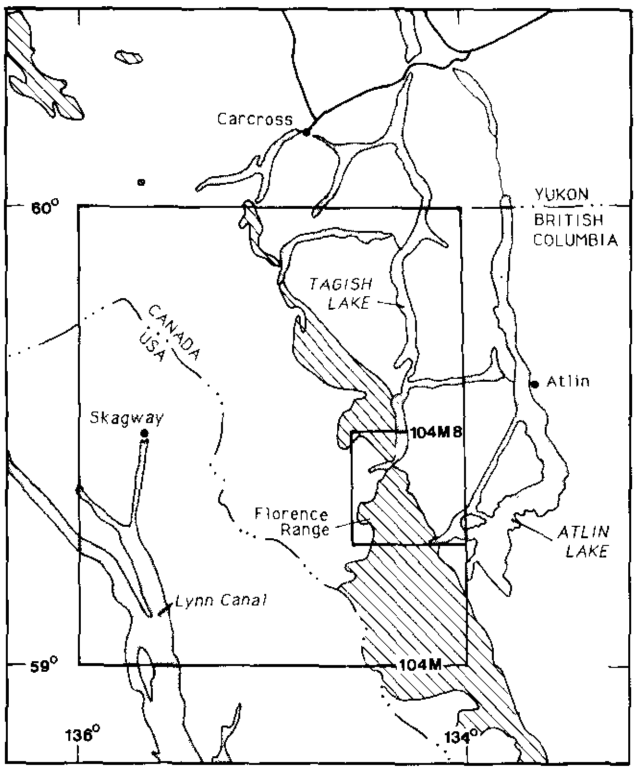

Figure 1-19-1. Location map for the Florence Range. Lined areas indicate the location of metamorphic rocks of the Nisling Terrane (modified from Wheeler and McFeely, 1987).

GENERAL GEOLOGY AND PREVIOUS RESEARCH

The Florence Range lies between the south ends of Tagish and Atlin lakes (Figure 1-19-1). Metamorphic rocks are bounded on the west by undeformed, probably late Mesozoic, granitic and granodioritic intrusives of the Coast plutonic-metamorphic complex. To the east, the Llewellyn fault separates metamorphic rocks from Upper Triassic volcanic rocks of the Stuhini Group (Stikine Terrane) and undeformed Mesozoic plutonic rocks (Christie, 1957; Bultman, 1979; Werner, 1978; Figure 1-19-2).

Mapping at a scale of 1:250 000 by Christie (1957) outlined the regional extent of exposed metamorphic rocks in map area 104M. He divided the metamorphic rocks into (1a) micaceous quartzite, hornblende-quartz-feldspar gneiss, amphibolite, schist and limestone, and (1b) chlorite schist, feldspar-chlorite gneiss, amphibole gneiss and limestone. Other than mapping the locations of large carbonate layers in the latter package, Units 1a and 1b were not subdivided.

More detailed mapping was conducted in the Florence Range by Bultman (1979), who mapped the eastern margin of the range at reconnaissance scale, and Werner (1977, 1978), who mapped the metamorphic rocks exposed south of the Wann River and south of Willison Creek at 1:30 000 scale (note that throughout this paper 'the Wann River' will refer to the Wann River above Nelson Lake). Neither study subdivided the metamorphic rocks, although Werner (unpublished mapping) mapped carbonate bands and major axial-surface traces (Werner, 1978).

Metamorphic rocks continuous with those in the Florence Range extend to the northwest to the British Columbia – Yukon border (Figure 1-19-1). They have been mapped at 1:50 000-scale as the Boundary Ranges metamorphic suite (Mihalynuk and Rouse, 1988a, 1988b; Mihalynuk *et al.*, 1989; Mihalynuk, 1989). Lithologies include chlorite-actinolite schist, biotite-plagioclase-quartz schist, chlorite schist, and graphitic schist, with minor marble, pyroxene-plagioclase schist, impure metaquartzite and orthogneiss. The orthogneiss bodies include altered and deformed leucogranite and quartz diorite, Bighorn granite, and Hale Mountain hornblende-biotite granodiorite (Mihalynuk and Rouse, 1988b; Mihalynuk *et al.*, 1989).

North of the Yukon border metamorphic rocks no longer form a continuous belt but are exposed as isolated pendants in Mesozoic plutons (Wheeler, 1961; Doherty and Hart, 1988)

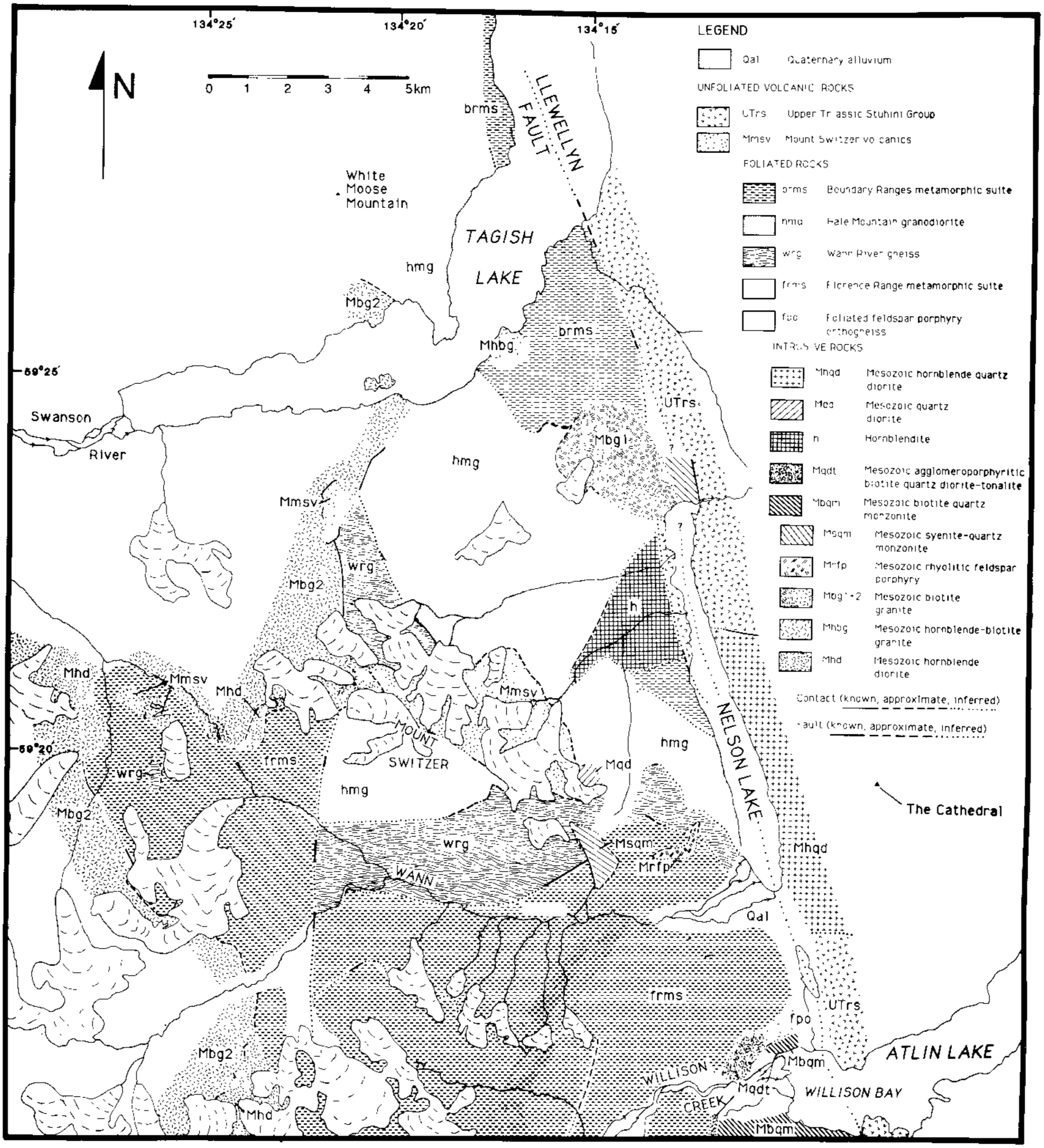

Figure 1-19-2. Geologic map of the Florence Range. The locations of some contacts were generously provided by M. Mihalynuk of the British Columbia Geological Survey Branch, who mapped in the 104M/8 and 104M/9E map areas during the 1989 field season.

There they comprise biotite-muscovite-quartz-feldspar schist, chlorite-rich biotite-granite gneiss, quartzite and minor quartz-mica schist with rare amphibolite bands, and foliated hornblende and hornblende-biotite granodiorite, quartz diorite and quartz monzonite (Doherty and Hart, 1988).

The nature of the basement that the metasedimentary rocks of map area 104M/8 were deposited on is uncertain. The ages of deposition, deformation and metamorphism are inferred to be pre-Late Triassic because clasts similar to metamorphic rocks of the Florence Range occur in the Upper Triassic Stuhini Group, at the south end of Atlin Lake in Willison Bay (Bultman, 1979). The Boundary Ranges suite is interpreted to have been deposited, deformed and metamorphosed before the Early Jurassic because sediments containing Early Jurassic fossils have been mapped as unconformably overlying it north of the Florence Range (Mihalynuk and Rouse, 1988a and 1988b).

LITHOLOGIC SUBDIVISIONS

Four lithologic subdivisions of metamorphic rocks are recognized in the Florence Range (Figure 1-19-2). They are the Boundary Ranges metamorphic suite, Hale Mountain granodiorite, Wann River gneiss and Florence Range metamorphic suite. They have been intruded by undeformed plutonic rocks and are overlain by undeformed volcanic rocks.

BOUNDARY RANGES METAMORPHIC SUITE (brms)

The Boundary Ranges metamorphic suite (Mihalynuk and Rouse, 1988) is exposed along the west and south shores of Tagish Lake (Figure 1-19-2). It is primarily composed of chlorite schist and chlorite-actinolite schist, with minor chlorite-pyroxene schist, discontinuous carbonate layers, quartzite, layer-parallel felsic layers 1 to 20 centimetres thick, and orthogneiss. The orthogneisses vary in composition from granitic to dioritic.

Possible protoliths for the chlorite-bearing schists include pelitic, calcareous marine sedimentary, volcanic and reworked volcanic rocks. Felsic layers may have been deposited as tuffs or felsic flows and the quartzite may be metamorphosed sandstone or chert. A possible tectonic environment for the deposition of these sediments is a volcanic arc; if the protolith for the quartzite is a sandstone, then the arc may have formed on or near continental crust.

The contact between the Boundary Ranges metamorphic suite and the structurally overlying Hale Mountain granodiorite is characterized by interlayering of both units on a decimetre-scale, which may be a result of shearing along the contact. This contact is tentatively interpreted to be a shear zone.

HALE MOUNTAIN (HORNBLENDE-BIOTITE) GRANODIORITE (hmg)

The Hale Mountain hornblende biotite granodiorite (Mihalynuk *et al.*, 1989; Mihalynuk, 1989) is exposed north of the Wann River in the Florence Range, and on White Moose and Hale mountains to the north (Figure 1-19-2; *see* Mihalynuk, 1989). It is characterized by medium-grained plagioclase phenocrysts in a fine-grained groundmass of hornblende with minor biotite, chlorite and epidote. Metre-scale compositional layering is ubiquitous. More felsic layers (0.5 to 3 metres thick) are coarse grained (Plate 1-19-1) and occur in only the structurally highest exposures.

The granodiorite is variably foliated. In some areas a strong foliation and lineation have been developed, but in others fabrics have not been observed in the field, however, phenocrysts are recognisable throughout. Undeformed potassium feldspar pegmatites that crosscut the Hale Mountain granodiorite are characteristic of this unit.

WANN RIVER GNEISS (wrg)

The Wann River gneiss is exposed along the Wann River valley (above Nelson Lake), structurally above the Hale Mountain granodiorite and below the Florence Range metamorphic suite (Figure 1-19-2), and as small outcrops in thrust slices of the Florence Range metamorphic suite. It exhibits a distinctive millimetre to decimetre-scale compositional layering. The composition varies from dioritic (20 per cent hornblende) to gabbroic (50 per cent hornblende), with minor biotite and epidote. The small scale and the gradational

Plate 1-19-1. Coarse-grained felsic layer in the Hale Mountain granodiorite.

nature of compositional layering suggest that it is a primary fabric and therefore the gneisses are interpreted to be metavolcanic rocks of broadly intermediate composition. The Wann River gneiss differs from the Hale Mountain granodiorite in that it does not contain plagioclase phenocrysts, felsic lithologies are medium grained, compositional layering occurs on a smaller scale and the gneisses are everywhere strongly foliated and crosscut by plagioclase-bearing pegmatites.

The contact zone between the Hale Mountain granodiorite and the Wann River gneiss may be abrupt; an interlayered boundary that is continuous over at least 100 metres; or a brecciated and pegmatite-flooded zone about 200 metres wide (M. Mihalynuk, personal communication, 1989). The foliation becomes more strongly developed, within both units, toward the contact, indicating that this contact is sheared. On the ridge west of Nelson Lake a succession of metasedimentary rocks 20 metres thick is preserved at the contact between the Hale Mountain granodiorite and the Wann River gneisses.

Florence Range Metamorphic Suite (frms)

The Florence Range metamorphic suite crops out on the slopes north of the Wann River and continues to the south, beyond the south edge of map area 104M/8 (Souther, 1971; Werner, 1977, 1978; Figures 1-19-1 and 2). It structurally overlies the Wann River gneiss and where the contact has been seen it corresponds to an abrupt lithologic change in a zone of strained, well-layered gneiss. This zone is tentatively interpreted as a shear zone.

The Florence Range metamorphic suite is composed of semipelitic, pelitic, carbonate, amphibolitic and calcsilicate rocks, with minor quartzite and graphite-bearing pelitic and semipelitic rocks. Semipelitic and pelitic layers (biotite, quartz ± plagioclase, muscovite, garnet, kyanite, sillimanite, graphite) are from 0.1 to 30 metres thick. Quartzite layers are often impure (± biotite) and may be up to 3 metres thick. Amphibolite (hornblende ± plagioclase, garnet) is associated with carbonate rocks. These two distinctive rock types, which may be used to define a stratigraphy, form layers 0.1 to 20 metres thick (Plates 1-19-2 and 3) that can be continuous over several kilometres and are thicker and increasingly abundant toward the west, whereas semipelitic layers become more common toward the east. Calcsilicate rocks form layers 0.02 to 1 metre thick and are composed of calcite with or without tremolite, diopside, actinolite, grossular garnet and anorthite. A feldspar porphyry orthogneiss (fpo) crops out north of the mouth of Willison Creek (Figure 1-19-2).

Lithologies within the Florence Range suite, such as extensive quartzites and carbonates, are indicative of a continental margin setting. Amphibolitic rocks are interpreted to be metamorphosed flows, tuffs and reworked tuffs.

Mount Switzer Volcanics (Mmsv)

The Florence Range suite is unconformably overlain by the undeformed Mount Switzer volcanics, which are preserved on Mount Switzer (Mihalynuk and Mountjoy, 1990, this volume; Figure 1-19-2). Clasts of granite, biotite schist, foliated amphibolite, and quartzite are preserved in the conglomerate overlying the unconformity.

Plutonic Rocks

Two hornblendite bodies (h) have been mapped in the Florence Range. Hornblendite also occurs in map-area 104M/10 (Mihalynuk, 1989). Although undeformed, they are not necessarily entirely post-tectonic, as the lack of foliation within the hornblendite bodies may be due to their extreme competence. South of the Wann River, garnet-

Plate 1-19-2. Northeast-verging folds in the Florence Range metamorphic suite are outlined by carbonate (c), pelitic rocks (p), and amphibolite (a); viewed looking southeast (see Figure 1-19-3).

Plate 1-19-3. Northeast-verging thrust in the Florence Range metamorphic suite (see Figure 1-19-4).

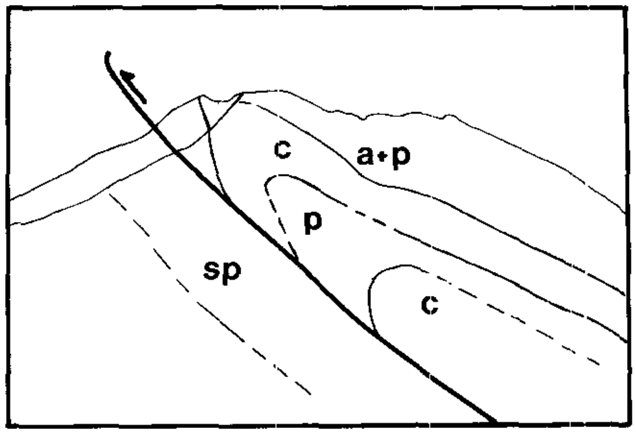

Figure 1-19-4. Line drawing of Plate 1-19-3. (a = amphibolite, c = carbonate, p = pelitic rocks, sp = semipelitic rocks).

bearing hornblendite crosscuts layering and foliation within the Florence Ranges metamorphic suite, indicating that the hornblendite must have been intruded after some deformation had occurred, and then metamorphosed. North of the Wann River, foliation in the Hale Mountain granodiorite wraps around xenoliths of hornblendite.

Cathedral Mountain is primarily underlain by hornblende quartz diorite to granodiorite (Mhqd). The biotite quartz monzonite (Mbqm) that crops out north and south of Willison Creek is not part of the Cathedral Mountain batholith as previously reported by Bultman (1979). It does, however, intrude the variably deformed, medium-grained agglomeroporphyritic biotite quartz diorite (Mbqd) that occurs north and south of the mouth of Willison Creek. The absence of a penetrative foliation indicates that this intrusion postdates deformation that produced a penetrative fabric in the Florence Ranges metamorphic suite. The fabrics that have been developed may be related to later faulting.

Syenite to quartz monzonite (Msqm) intrudes the contact between the Wann River gneiss and the Florence Range metamorphic suite west of the south end of Nelson Lake. The pluton is medium grained and may be trachytic. A rhyolitic feldspar porphyry (Mrfp) that intrudes the Florence Range metamorphic suite and the Wann River gneiss is also exposed west of south end of Nelson Lake.

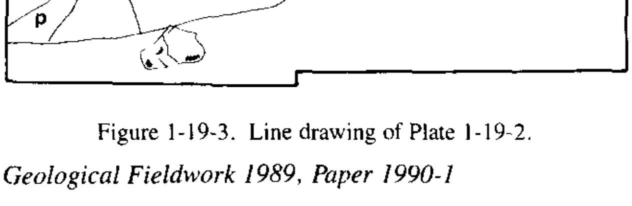

Figure 1-19-3. Line drawing of Plate 1-19-2.

Medium to coarse-grained biotite granite crops out on the north shore of Nelson Lake and the ridge to the northwest. The intrusive contact between the biotite granite (Mbg1) and the Florence Range metamorphic suite has been mapped on the ridge, but no contacts have been seen in the valley below. Where the granite is exposed on Nelson Lake, it lies on the east side of a splay of the Llewellyn fault and is therefore thought to intrude the Llewellyn fault in part. It may also intrude the Upper Triassic Stuhini Group, that is exposed to the east.

Hornblende biotite granite (Mhbg) exposed on the south shore of Tagish Lake is significantly different from the granite that crops out west of Edgar Lake. No contacts with the country rock have been seen.

The hornblende diorite (with minor biotite; Mhd) that crops out in the southwest quarter of the map area is intruded by granites that are exposed to the west and intrudes the Florence Range metamorphic suite. It commonly contains inclusions of the country rock.

Medium to coarse-grained biotite granites of the Coast plutonic-metamorphic complex (Mbg2) intrude the western margin of the Florence Range metamorphic suite, the Wann River gneiss, the Hale Mountain granodiorite, the Boundary Ranges metamorphic suite and the hornblende diorite.

STRUCTURE

FOLDS

Mesoscopic folds are observed in the Boundary Ranges and Florence Range metamorphic suites, which are strongly layered *lithologic assemblages, but not in the Hale Mountain* granodiorite or the Wann River gneiss. This may be due to a lack of variation in competence in the gneiss and granodiorite, however, they are folded by macroscopic open folds.

The Boundary Ranges metamorphic suite has experienced at least three phases of folding (*see* Mihalynuk *et al.*, 1989). A pre-existing metamorphic fabric is commonly isoclinally folded by mesoscopic folds and carbonate layers outline refolded folds. Areas of planar layering are interpreted to be on the limbs of large-scale folds. However, the lack of marker horizons, such as carbonate layers, makes the mapping of large scale structures in this suite difficult.

Within the Florence Range metamorphic suite, a layer-parallel metamorphic foliation is deformed by northeast-verging folds that range in size from crenulations (0.5 to 3 centimetre scale) to megascopic folds (Plate 1-19-2, Figure 1-19-3). Variations in the vergence of these folds are attributed to later faulting or folding, some examples of which have been seen in outcrop.

FAULTS AND SHEAR ZONES

The contacts between the Boundary Ranges metamorphic suite, the Hale Mountain granodiorite, the Wann River gneisses and the Florence Range metamorphic suite are interpreted to be faults or shear zones. They are offset by later, steeply-dipping, northerly striking faults and truncated by the Llewellyn fault (Figure 1-19-2).

Faults within the Florence Range metamorphic suite are interpreted as northeast-verging thrusts (Plates 1-19-3 and Figures 1-19-2 and 4) that place carbonate-rich thrust sheets over thrust sheets dominated by semipelitic rocks. The Wann River gneiss occurs at the base of some of the thrust sheets. The original relationship between the Florence Range metamorphic suite and the Wann River gneiss is not known.

The contacts between the Hale Mountain granodiorite and both the Wann River gneiss and Boundary Ranges metamorphic suite are characterized by strongly developed ductile fabrics. They are in part interpreted to be shear zones.

Steep, northerly striking faults are recognised in the southern half of the field area where different lithologic units are juxtaposed (Figure 1-19-2). Although similar faults may be present to the north, they were not recognised because lithologies are not as varied.

The Llewellyn fault (Bultman, 1979) truncates all penetrative fabrics and structures in the metamorphic rocks of the Florence Range; the sense and amount of displacement on it are uncertain. However, the juxtaposition of metamorphic rocks on the west and unmetamorphosed rocks on the east is indicative of east-side-down relative movement, strike-slip movement or possibly a combination of both.

METAMORPHISM

The metamorphic grade in the Florence Range varies from greenschist to transitional greenschist-amphibolite facies in the Boundary Ranges metamorphic suite, to upper amphibolite facies (sillimanite/fibrolite present) in the Florence Range suite. Garnet occurs sporadically in schist and amphibolite, and kyanite (with muscovite alteration) occurs rarely in schist. Garnets are commonly chloritized.

CONCLUSIONS

The previously undivided metamorphic rocks of the Florence Range are grouped into four fault-bounded, lithologically distinct subdivisions: the Boundary Ranges metamorphic suite, Hale Mountain granodiorite, Wann River gneiss and the Florence Range metamorphic suite.

Rock types that make up the Boundary Ranges suite correspond with Christie's (1957) Unit 1b and are continuous with a northwest-trending belt of metamorphic rocks that extends as far north as the Yukon border. They are interpreted to have formed in a volcanic arc setting with possible continental influence. They lack abundant quartzose and carbonate rocks that are more typical of the Nisling Terrane. However, the Florence Range metamorphic suite comprises rock types typical of a continental margin. It more closely resembles Christie's (1957) Unit 1a and metamorphic rocks of the Nisling Terrane exposed north of the Yukon border, than the Boundary Ranges metamorphic suite.

The relationship between the Florence Range and Boundary Ranges metamorphic suites is unclear as they are separated by the Hale Mountain granodiorite and the Wann River gneiss. The Boundary Ranges suite may be a distal equivalent of the Florence Range suite; it may have some affinity with Stikinia; or it could be allochthonous to both. The timing of juxtaposition of these four units, their ages, protolith ages, and the relationship of structures within them to terrane accretion, will be addressed by continued mapping to the south and west, and by structural, geochronological and isotopic studies. A comparative study of detrital zircons from the metasedimentary rocks of the Florence Range and those from Nisling Terrane rocks in southern Yukon will investigate the relationship between rocks in these two areas.

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NOTES