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THE BLUE RIVER ULTRAMAFIC INTRUSION, CASSIAR DISTRICT, BRITISH COLUMBIA

(Report and Map 17-1964)

W. J. Wolfe

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ABSTRACT

This report presents a preliminary description of the general geology, petrography and structure of the Blue River ultramafic intrusion. The Blue River intrusion is an 'alpine-type' ultramafic body composed of serpentinized dunite and peridotite, and intruded into Devonian and Mississippian volcanic and sedimentary rocks. Serpentinization is most intense at the margins of the intrusion, while the central core is occupied by relatively unserpentinized dunite and peridotite. The bulk composition of the body prior to serpentinization was: olivine, 85-90 per cent; orthopyroxene, 10-15 per cent; clinopyroxene, 1 per cent; and chrome spinel, 1 per cent. Steeply dipping primary mineral layering, marked by various proportions of olivine and pyroxene, is discordant to the margins of the intrusion.

The ultramafic rocks are truncated to the northwest by the younger granitic rocks of the Cassiar batholith. Development of talc, serpentine, and tremolite in the ultramafic rocks is characteristic of a zone 1,000 to 4,000 feet wide adjacent to the granite contact. Textures indicating regenerated or secondary olivine, formed by thermal metamorphism of serpentine by the granitic rocks, are common in the east-central part of the intrusion.

Basic volcanic rocks have been altered to amphibolites for distances up to 400 feet from their contact with the ultramafic body. Amphibolite from the outer zone of the contact metamorphic aureole gave a whole rock potassium-argon date of 245 m.y.

Sandy limestone beds in the northeast part of the map-area contain Middle to Upper Permian (post Wolfcampian) fusulinids. These beds were previously correlated lithologically with Devonian-Mississippian limestones. The areal extent of these Permian limestones and overlying basaltic flows has not been determined.

THE BLUE RIVER ULTRAMAFIC INTRUSION, CASSIAR DISTRICT, BRITISH COLUMBIA

INTRODUCTION

The Blue River intrusion is one of a series of 'alpine-type' sills, stocks, and lenses that extend northwestward from Dease River in a linear belt for a distance of 45 miles. They intrude a eugeosynclinal sequence of greenstones, argillites, and cherts of the lower Sylvester Group. The intrusion is tooth-shaped in plan, approximately 3 1/2 miles long and 2 1/2 miles wide, and composed of serpentinized dunite and peridotite. Serpentinization is most intense at the margins of the intrusion, while the central core is occupied by relatively unserpentinized peridotites and dunites. The bulk composition of the body prior to serpentinization was: olivine, 85-90 per cent; orthopyroxene, 10-15 per cent; clinopyroxene, 1 per cent; and chrome spinel, 1 per cent. Steeply dipping primary mineral layering, marked by various proportions of olivine and pyroxene, is discordant to the margins of the intrusion.

The ultramafic rocks are truncated to the northwest by the younger granitic rocks of the Cassiar batholith. Development of talc, serpentine, and tremolite in the ultramafic rocks is characteristic of a zone 1,000 to 4,000 feet wide adjacent to the granite contact. Textures indicating regenerated or secondary olivine, formed by thermal metamorphism of serpentine by the granitic rocks, are common in the east-central part of the intrusion.

This report presents a preliminary description of the general geology, petrography, and structure of the Blue River intrusion and associated rocks. The intrusion offers excellent opportunities for study of the metamorphic effects of younger granitic rocks on older ultramafic rocks. Detailed petrographic, mineralogical, and chemical investigations are in progress on the samples collected.

Location and Accessibility

The map-area is situated about 20 miles north of Cassiar, British Columbia. It occupies about 36 square miles bounded by longitudes 129°55' and 130°05'W and latitudes 59°30' and 59°35'N. The area is reached by packhorse via a 30-mile trail from Cassiar. Helicopters and float-equipped aircraft are available for charter from Watson Lake, Y.T., approximately 60 air miles to the northeast, but the lack of large lakes in the vicinity of the map-area limits the use of float aircraft.

History and Previous Work

The Blue River intrusion was first considered to hold interesting amounts of nickel and was staked by Mr. W. Puritch of Grand Forks, B.C. in 1952. The intrusion was examined by Canadian

Johns-Manville in 1953 for possible asbestos and in 1955 prospectors staked 40 claims on what at the time was believed to be a major chromite discovery.

The part of the map-area east of longitude 130°00' was mapped on a 4-mile scale by H. Gabrielse between 1950 and 1954, and published as Paper 54-10 and Memoir 319 of the Geological Survey of Canada. The Jennings River area, west of 130°00', has not been mapped geologically to date. During the field season of 1962, the author with the assistance of K.W. Livingstone spent two months in detailed mapping and sampling of the Blue River intrusion. Mapping was carried out on a scale of one inch to 1,000 feet using aerial photographs enlarged to that scale. The ultramafic rocks were sampled at intervals of 1,000 feet or less where outcrops permitted. The country rocks were sampled in less detail. Further studies are continuing in the laboratories of the Geological Survey of Canada and Yale University.

The author wishes to acknowledge the kind hospitality and valuable assistance offered by the officials of the Cassiar Asbestos Corporation. Special thanks are extended to W.N. Plumb, chief geologist, for his valuable cooperation during the field season.

GENERAL GEOLOGY

The Cassiar mountains are a belt of igneous and fold mountains about 50 miles wide, bounding the Liard Plain on the west and extending northwest into Yukon Territory. The Cassiar batholith, 25 miles wide, forms the western part of the mountains, and trends northwesterly from Dease Lake, paralleling the regional trend of the metasedimentary and metavolcanic rocks along its eastern contact.

Pre-Sylvester Group rocks represent a miogeosynclinal sequence composed of limestone, dolomite, quartzite, argillite, shale, and slate, ranging in age from late Precambrian to Middle and possibly Late Devonian.

The Sylvester Group is comprised of andesitic lavas, argillites, and cherts, and occupies the upper part of the McDame synclinorium. Age limits of post-Middle Devonian to pre-Middle Mississippian have been placed on this group by Gabrielse (1963). Middle to Upper Permian fusulinids were collected by the author from sandy limestones (unit 5) previously correlated lithologically with Sylvester limestones. This is the first Permian fossil locality in this part of the Cordillera east of the Cassiar batholith and in view of this discovery, together with the recent recognition of Upper Triassic fossils about 5 miles to the north of the Blue River intrusion (Gabrielse, 1963), it now seems likely that younger rocks must be included in a significant part of the area mapped as Sylvester Group northwest of Blue River.

The McDame ultramafic intrusions are emplaced in a northwesterly trending belt of sills, stocks, and lenses which cut Sylvester Group rocks in a zone approximately following the axis of the major synclinorium.

Granitic rocks of the Cassiar batholith are of Mesozoic age and cut earlier Palaeozoic sedimentary and volcanic rocks, as well as the McDame ultramafic rocks.

Thick sections of Pleistocene and Recent glacial till, glaciofluvial and fluvial sands, silts and clays, and cemented gravels cover most of the main valley floors.

COUNTRY ROCKS

Pre-McDame Group sedimentary rocks may occur in the area examined by the author, but the basal contact of the McDame Group was not recognized.

Description of Formations

McDame Group and (?) Older (1)*

Blue-grey weathering limestones and dolomites of the McDame Group outcrop over a width of at least 4,000 feet in the southwest corner of the map-area. These rocks strike N20°W to N40°W and dip 50 to 70 degrees to the northeast. In the region of the Cassiar granite contact, this regional trend is disrupted by complex minor folding and the limestone beds are warped to parallel the granite contact, striking N35°E and dipping 70°SE. For distances up to 1,000 feet from the granite, the limestones are recrystallized to medium and coarse-grained white calcite. No fossils were observed in the McDame limestones within the Blue River area, but Gabrielse (1954) has found Middle Devonian fossils in rocks of the same group that outcrop to the southeast, in the vicinity of Cassiar.

Sylvester Group (2-4)

Argillite, Chert, Shale (2): The most abundant rocks of the argillite division (2) are thin bedded to massive, dark grey to black, rusty weathering argillites. In the absence of petrographic study, the term 'argillite' is here used to cover rocks ranging from argillaceous cherts through shales to siltstones.

Several hundred feet of well-bedded, intensely fractured rusty black argillites form the lowermost beds of the section and conformably overlie the McDame Group limestones and dolomites in the western part of the map-area. These argillites can probably be correlated with thin-bedded black argillites and cherty grey argillites that overlie dolomites and form the foot-wall of the Cassiar Asbestos Corporation orebody, 20 miles to the southeast.

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*Numbers correspond to those used in map legend.

TABLE OF FORMATIONS

CENOZOIC	Pleistocene and Recent	unconformity	Glacial till, cemented gravels, glacio-fluvial deposits, felsenmeer, talus, soil
MESOZOIC		Cassiar granite	Granite, granodiorite, quartz monzonite, pegmatite
		intrusive contact	
PALAEOZOIC-MESOZOIC		McDame ultra-mafic intrusions	Dunite, peridotite, serpentinite, gabbro
		intrusive contact	
PALAEOZOIC	Middle to Upper Permian		Limestone, basalt
	Devonian and Mississippian	Sylvester Group	Andesite, basalt, argillite, siltstone, chert, shale
	Middle and (?) Upper Devonian	McDame Group	Limestone and dolomite
		Disconformity	
	Silurian and (?) Devonian		Laminated dolomite, dolomitic sandstone, sandy dolomite, dolomite breccia
		Disconformity	
	Middle and Upper Cambrian Lower and Middle Ordovician	Kechika Group	Shale, slate, chert, argillaceous limestone
		Conformable (?) contact	
	Lower Cambrian	Atan Group	Limestone, dolomite, quartzite, shale, slate, siltstone
		Conformable contact	
PRECAMBRIAN	Late Precambrian	Good Hope Group	Limestone, dolomite, siltstone, sandy limestone, argillite, slate, red and green slate, shale, limestone.

Thinner and less persistent beds of argillite and chert are found intercalated in greenstones higher in the sequence. There is a general decrease in predominance of argillites in passing from the southwest to the northeast corner of the map-area. Although minor chert beds are found in the argillite, the cherts are not typically interbedded with argillites but tend, rather, to form separate members within the greenstone. Some of these are grey to grey-green, thin-bedded, crumpled 'ribbon cherts' consisting of contorted beds of chert 1/2 inch to 2 inches thick.

Andesite, Basalt (3): About three-quarters of the Mississippian section is composed of green, grey-green and black volcanic flows, predominantly basalts and andesites and their altered equivalents. Primary structures are scarce in the greenstones. Except where interbedded sedimentary rocks are found, the greenstones are not visibly bedded. The lenticular nature of most flows and their lack of persistent and distinctive features makes it difficult to trace flows for any distance along strike.

In many outcrops the greenstones are interbedded with chert and argillite. Where the interbedding of volcanic and sedimentary rocks is on a scale too fine to permit their separation, the outcrops have been mapped as unit 2 or 3 according to the dominant rock type present.

Amphibolite (4): Amphibolite is restricted to the zone of thermal metamorphism that surrounds the ultramafic intrusion. This amphibolite zone has a maximum thickness of 400 feet and is apparently the result of contact metamorphism on basic volcanic rocks of the Sylvester Group. The aureole is predominantly composed of dark-grey weathering, resistant, hornblende-quartz-plagioclase gneiss which grades outward to unaltered andesites and basalts, and grades inward to a narrow zone of pale green tremolite amphibolite near the ultramafic contact. Gneissosity in the amphibolite is generally parallel both with the ultramafic contact and the bedding and schistosity in the country rocks. Amphibolite is further discussed under the heading Metamorphism.

Permian Sandy Limestone (5) and Basalt (5a)

Permian limestone beds outcrop on the southwest slopes of the northwesterly trending ridge in the extreme eastern part of the map-area. These limestones are lithologically quite different from the McDame Group limestones and dolomites. They weather a dull grey in contrast to the blue-grey weathering of the McDame Group rocks, and this is partly due to a higher content of sand and clay impurities. The limestone beds are about 400 feet thick, strike N50°W to N60°W and dip 25°NE. The nature of their discordant relationship with southwesterly-dipping cherts and andesites to the south is obscured by talus and glacial till which cover the lower limestone contact on the lower slopes of the mountain. It would appear that the lower contact is marked by a major fault or unconformity. Middle to Upper Permian (post Wolfcampian) fusulinids were collected from a number of fossil occurrences in the limestone beds and identified by E.W. Bamber.

The limestone is conformably overlain by basalt and andesite flows and this upper contact is well exposed for a distance of 7,000 feet along strike. The base of the volcanic unit is irregularly marked by lenses of basic volcanic ash and tuff, which rarely exceed one foot in thickness. Close examination of this contact reveals a number of minor transverse faults which cause minor displacement of the contact. The limestone beds can be traced for 7,000 feet along strike and are apparently truncated to the east and west by larger transverse faults. The overlying basic volcanic rocks are lithologically indistinguishable from basalts and andesites of the Sylvester Group.

Very minor limestones, sandstones, and quartzites are interbedded with volcanic rocks in the northern part of the map-area.

Cassiar Granitic Rocks (14)

The granitic rocks of the Cassiar batholith are the youngest consolidated rocks and occupy the northwest corner of the map-area. The eastern edge of the batholith intrudes all older rocks of the McDame and Sylvester Groups as well as the ultramafic rocks of the Blue River intrusion.

The granitic rocks are for the most part unsheared, unaltered homogeneous quartz monzonite. They are medium to coarse grained, with an average composition of 50% plagioclase, 15% perthitic intergrowth, 25% quartz, and 10% chlorite and biotite.

In the vicinity of the Blue River ultramafic intrusion, the contact of the batholith trends northeasterly and dips about 70°NW. In the northern part of the map-area the strike of the contact changes abruptly to an east-west direction. Where it is well exposed, the contact is seen to be sharply defined and essentially planar. There is little evidence of veining of the ultramafic rocks by granitic rocks or pegmatite but small dioritic ghost inclusions about 10 inches in diameter occur within 100 feet of the ultramafic contact.

Pleistocene and Recent Deposits (15)

Pleistocene and recent glacial tills and glacio-fluvial gravel, sand, silt, and clay were deposited in sections up to 20 feet thick in the lower parts of the main Nickel Creek Valley.

A poorly sorted, stratified cemented gravel rests unconformably on ultramafic bedrock, and is in turn overlain by unsorted, unconsolidated till. This cemented gravel is well exposed where steep-sided, swiftly flowing streams have incised V-shaped valleys through glacial deposits down to bedrock.

THE BLUE RIVER INTRUSION

ROCK TYPES

The ultramafic rocks of the Blue River intrusion are essentially serpentinized dunite and peridotite. Serpentinite is most widespread at the margins of the intrusion, whereas the central core is occupied by relatively unserpentinized dunite and peridotite.

Serpentinite (6) is used here to indicate rocks, now composed dominantly of serpentine minerals (chrysotile, antigorite, bastite), and secondary magnetite. Specific gravity measurements were used to estimate the degree of serpentinization of the ultramafic rocks. Where the rock is dominantly composed of olivine (G=3.25), enstatite (G=3.15), and secondary serpentine (G=2.50), the degree of serpentinization may be approximately related to the specific gravity of the rock according to the relation

$$\% \text{ Serpentine} = 471.029 - 147.058 \text{ S.G.}$$

The geographical distribution of the serpentinite unit shown in the map is based on an arbitrary division that places rocks containing 80 per cent or more serpentine and secondary magnetite (i.e. specific gravity less than 2.70) in the serpentinite category. The above relationship is not rigidly applicable to rocks in the northeast part of the Blue River intrusion, where tremolite (G=2.98) and talc (G=2.82) are important constituents.

The serpentinite varies in colour from grey-brown to apple green or dark bluish green. The green varieties commonly exhibit polished or slickensided slip surfaces which exfoliate readily to serpentinite chips. Extensive shearing parallel with the contacts is a characteristic feature of the marginal serpentinite zones. A breccia-like phenomenon is noted in these contact shear zones. Massive serpentinite or partly serpentinized peridotite inclusions ranging from 2 inches to 2 feet in diameter are enclosed in sheared serpentinite. The serpentinite slip planes bend around these inclusions, which have remained massive and unaffected by the shearing. Small isolated pods of sheared and slickensided serpentinite occur in transverse fault zones that cut the Sylvester greenstones.

Dunite and peridotite (7) are finely interbanded over wide areas in the southwestern lobe of the Blue River intrusion. General statements regarding the predominance of dunite or peridotite in certain parts of the ultramafic mass can best be based on gross field observations. Dunite with a low pyroxene content weathers to a smooth, equigranular surface which is a yellowish orange. Surface weathering produces a rind that is generally 1/4 to 1/2 inch thick. The colour of the fresh surface varies from olive-green to black depending on the degree of serpentinization. Three significant zones of dunite were mapped in the west-central part of the intrusion. These mappable dunite bands are mildly undulating, but strike in a general east-west direction in the vicinity of Ice Lake, and dip steeply to the south. The two largest bands are about 300 feet thick and extend for 1 mile along strike. A third smaller band is about 100 feet thick and 2,000 feet long. Smaller individual dunite bands vary in thickness from a fraction of an inch to 50 feet.

Peridotite as here defined is a rock that was composed essentially of olivine and 5 per cent or more pyroxene, with accessory chromite. Peridotites containing 5 to 10 per cent pyroxene are widely distributed, but individual layers may contain as much as 25 per cent pyroxene. In the field peridotite is best distinguished from dunite by its darker, reddish brown weathering and by the resistant pyroxene crystals which stand out in relief on the weathered surface. On fresh surfaces the peridotite is blue-green to black. In the more serpentinized varieties, green lustrous pseudomorphs of bastite after enstatite are enclosed in an aphanitic groundmass of black serpentine.

The major primary mineral component of the dunite and peridotite is a forsteritic olivine (Fo_{88-92}) which is combined with lesser amounts (0-25%) of enstatite, minor clinopyroxene, and accessory chrome spinel. The fresher ultramafic rocks, which occupy the core of the southwestern lobe, characteristically display evidence of strong protoclasis and deformation. Undulatory extinction and deformation banding in olivine, shattering and bending of orthopyroxene crystals, and protoclastic and mylonitic textures, are extremely common features of these rocks.

Regenerated dunite (8) was mapped as a separate unit because its unique texture made it easily recognizable in the field, and because of the bearing of its distribution on the metamorphic study. Dark, spherical kernels of olivine up to 3 mm in diameter are enclosed in a groundmass of serpentine. These kernels impart a mottled appearance to the rock which is similar in appearance to the texture of oolitic sediments. In thin section the olivine kernels are seen to be subrounded to oval with euhedral to subhedral habit. Crystals are 2 to 3 mm in diameter and normally of uniform size. The centres of the olivine grains are clouded by poikiloblastically enclosed submicroscopic inclusions and small microscopically visible grains of magnetite and spinel. The outer perimeters of the olivine grains are clear and unclouded. X-ray diffraction determinations of olivine compositions indicate that the regenerated olivines are slightly more forsteritic (Fo_{92-94}) than the primary olivine associated with peridotites and dunites of unit (7).

Current opinion favours the idea of regeneration of olivine from serpentine in zones of suitable temperature. Durrell (1940) has described similar textures associated with ultramafic rocks in close proximity to younger granites in the southern Sierra Nevadas, California. Bowen and Tuttle (1949) have shown that, in a closed system, serpentine will be converted to olivine, talc, and water at temperatures greater than 505°C.

Amphibole-bearing regenerated dunite (9) is exposed on the floor and walls of the cirque that contains the head waters of Nickel Creek, in the northeastern part of the Blue River intrusion. It differs from unit (8) only in the strong development of acicular prisms and radiating bundles of fibrous needles of tremolite. Tremolite forms clumps or aggregates of needle-like crystals, randomly distributed throughout the rock. The tremolite needles pierce olivine crystals and are definitely youngest in the paragenesis. The tremolitization has occurred after serpentinization of the original dunite, and indeed after the regeneration of olivine from serpentine. Amphibole may account for as much as 35 per cent of the mode of these rocks.

Amphibole-bearing dunite and peridotite (10) represents the development of secondary tremolite in dunite and peridotite of unit (7), within a zone adjacent to the granitic rocks of the Cassiar batholith. Tremolite again exhibits a later cross-cutting relationship to the primary olivine and orthopyroxene silicates and the secondary serpentine. In summary, units (9) and (10) define an amphibole 'isograd' which cuts across the boundary between primary and regenerated olivine rocks.

Talc-bearing dunite (11) is an olivine-serpentine-talc rock that occurs within a 1,000- to 1,500-foot wide zone immediately adjacent to the granite contact in the northern part of the ultramafic mass. Large crystals and rosettes of talc stand out in relief on the weathered surfaces in contrast to the more easily weathered olivine and dull black serpentine matrix. The appearance of talc in amounts varying from 10 to 30 per cent is generally accompanied by total exclusion of the amphibole phase from the rock.

Extensive intrusion of gabbroic rock (12) and rodingite 'white' rock (13) of gabbroid origin is localized along the southwest contact of the ultramafic mass. Tabular dykes and irregular pods of gabbro and altered gabbro have been intruded, parallel with the contact, into sheared serpentinite near the margins of the ultramafic intrusion. Gabbro appears to be restricted to the western and southern parts of the intrusion. It was not found cutting the country rocks. When relatively fresh, the gabbro is fine grained, dark grey to black, and composed essentially of plagioclase and hornblende with lesser amounts of diopside. In the partly altered dykes, this black phaneritic hornblende-plagioclase gabbro occupies the centre of the dyke and grades outward with decreasing clarity of grain boundaries, to a dense, hard, compact aphanitic white rock in contact with serpentine. The degree of gabbro alteration to rodingite or garnetiferous 'white' rock increases markedly with increasing serpentinization of the ultramafic host rocks toward the southeasterly extending tails of the Blue River intrusion.

Tabular, lenticular, and irregular rodingite bodies (13) are conspicuously associated with serpentinite in the extreme southern part of the intrusion. Outcrops are pink to buff in sharp contrast to the dark colours of the ultramafic rocks. On fresh surfaces these rocks vary in colour from white to light grey and grey-green. Their specific gravity is consistently 3.10 or greater. In all cases the rodingite bodies are completely enclosed by serpentine and many have no visible connection with nearby masses. The field relations mentioned above suggest that at least some of these bodies represent altered gabbros, although in many cases the original gabbroid rock is no longer recognizable. The rodingite bodies range in size from large tabular masses hundreds of feet in length to small elliptical or rounded pods with long axes one foot to two feet in length. The rock is normally medium grained and grey to grey-green in large bodies, becoming fine grained to aphanitic and white in colour in small pods and at the borders of larger bodies. Where contacts can be observed, the white rock is in chilled contact with fine-grained to aphanitic, dull black, baked serpentine. It is difficult to prove conclusively the gabbroid origin of many of the smaller white rock pods. In fact many occurrences of smaller white rock bodies appear to intrude the serpentinite.

Microscopic examination shows that the gabbro dykes are composed essentially of plagioclase, diopside, and hornblende with accessory sphene and magnetite. The hornblende may in large part be secondary after pyroxene and the plagioclase is strongly altered to secondary products so that its composition could not be optically determined. With increasing alteration the primary minerals are replaced by garnet, clinozoisite, chlorite, and prehnite. A slightly hydrous grossular garnet (hibschite, N=1.725) derived chiefly from the plagioclase of the gabbro, constitutes up to 50 per cent of the dense white rock. In intermediate stages of alteration, the diabasic texture of the gabbro is preserved by the pseudomorphous replacement of the plagioclase by hibschite.

The chief chemical changes resulting from the metasomatic alteration of the gabbro involve an increase in CaO and decrease in FeO and Na_2O.

STRUCTURE

External Structural Relationships

In plan the contacts of the Blue River intrusion are broadly concordant with the regional trends of volcanic and sedimentary host rocks. However, local discordant relationships, notably in the extreme southeastern parts of the intrusion, are not uncommon. Where contacts are well exposed, particularly along the southwest edge of the body, there is every indication that they are dipping parallel with the planar attitudes in the enclosing country rocks. Extensive shearing parallel with the ultramafic contacts is a characteristic feature of marginal serpentinite zones, and this lends support to the view that these are fault contacts. A persistent amphibolite aureole is associated with the contact between the ultramafic intrusion and basic volcanic rocks. Highly contorted flowage folding in amphibolite adjacent to the ultramafic contact indicates that these rocks were heated to high temperatures during dynamo-thermal metamorphism accompanying ultramafic emplacement. Gneissic structures in the amphibolite are conformable both with the ultramafic contact and with attitudes in the volcanic and sedimentary country rocks.

The ultramafic mass is bounded to the northwest by the younger Cassiar batholith. Over a horizontal distance of 2 miles and a vertical distance of 1,000 feet, this sharply defined intrusive contact appears to be straight and essentially planar, striking N35°E and dipping 77° to the northwest.

A number of north to northeasterly striking post-intrusion transverse faults offset the ultramafic contacts and bring ultramafic rocks into fault contact with Sylvester greenstones, argillites, and amphibolites. The plan distribution of lithological contacts and dips, when viewed in relation to these transverse faults, suggest that, although significant strike displacement can be seen, the observed contact offsets can be explained by essentially vertical fault movement in which each successive block to the northwest has been lowered with respect to the southeastern block.

Internal Structural Relationships

The dominant structural feature of the unserpentinized ultramafic rocks is a mineral layering resulting from variations in the relative abundances of olivine and enstatite. Layers of peridotite and dunite alternate according to the pyroxene content. Contacts between layers are clearly defined, although in detail, the pyroxene crystals project into the dunite layers. The thickness of individual layers varies, but normally can be measured in inches. Many dunite layers are between 1 inch and 5 inches thick, but layers from 1 foot to 3 feet thick are not uncommon. Individual compositional layers can rarely be traced for distances greater than 50 to 100 feet. Thin layers generally lense out along strike and thicker layers commonly thin or branch into a series of smaller bands which in turn lose their identity due to lateral gradations in mineral composition. However, on a gross scale the mineral layers can be traced to show an orderly pattern. Generalized trend lines are drawn on the geological map and show that although the bands are mildly undulating, the overall picture is one of east-west striking layers that dip steeply (70-90°) south. The distribution of poles to planes of primary igneous layering shows no girdle that would define the presence of a fold structure within the intrusion. If folds are present, they are of the isoclinal type and show no closure.

It is interesting to contrast the geometry of internal planar structures with that of the external planar structures in the Sylvester Group host rocks. An equal area plot of poles to planes of bedding and foliation in Sylvester Group rocks shows a well-defined girdle reflecting the presence of a major synclinal fold which plunges at about 65°SE about an axis striking N35°W. This major fold is not reflected by structures within the intrusion. The synclinal axis shown on the geological map defines the structure of the enclosing host rocks, and does not imply that a synclinal shape exists within the intrusion. The ultramafic rocks merely occupy the axis of the fold.

In summary, the internal structures appear to intersect the regional trend at about 45 degrees. In addition, the internal planar structures are much more steeply dipping than planar structures in the country rocks. If folds are present within the intrusion, they are presumably isoclinal and steeply plunging. Although the ultramafic contacts exhibit concordant relationships with enclosing country rocks, the internal structures are discordant.

It seems most reasonable to suppose that the banded structure of the ultramafic rocks is the result of flowage of a largely crystalline mush in the late stages of olivine crystallization. Similar modes of origin have been suggested by Smith (1958) and MacGregor

(1962) for mineral banding observed in the Bay of Islands Complex and the Mount Albert intrusion.

METAMORPHISM

Regional Metamorphism

Sedimentary and volcanic rocks of the McDame and Sylvester Groups have been subject only to weak metamorphism of the greenschist facies in areas remote from intrusive activity. Andesite and basalt flows of the Sylvester Group typically show development of chlorite and zoisite in association with turbid plagioclase and pyroxene. Except for minor quartzite and marble formed by recrystallization, the argillite, shale, chert, limestone, and dolomite sedimentary rocks show little indication of regional metamorphic effects.

Metamorphism Related to Ultramafic Intrusion

A conspicuous and persistent amphibolite aureole is associated with the contact between the ultramafic intrusion and basic volcanic rocks. The aureole is best exposed south of Heazlewood Creek, along the northeast contact of the southwest tail of the intrusion. Although the amphibolite zone is by no means uniform in thickness and lithology, the following zonation of rock types, outward from the ultramafic contact, has been recognized.

Rock Description	Distance from Ultramafic Contact (feet)
1. Dense 'white rock' hornfels: grossular garnet, chlorite, zoisite, calcite, prehnite.	0 - 5
2. Tremolite amphibolite: tremolite, hydrogrossular garnet, albite, magnetite-ilmenite.	5 - 60
3. Hornblende amphibolite: green, pleochroic amphibole, albite, sphene, epidote	60 - 300
4. Altered basic volcanic rocks: normally bleached lighter colour than 5.	300 - 400
5. Normal unaltered andesite	400 +

The zones are completely gradational. The variations in mineral content would suggest an increase in calcium as the ultramafic contact is approached.

The gneissic structures in the amphibolites are conformable with attitudes in the volcanic and sedimentary country rocks. Highly contorted flowage folding outlined by bands alternately rich and poor in amphibole, is characteristic of the zone between 5 and 15 feet from the ultramafic contact. This would indicate that these rocks were heated to moderately high temperatures during dynamo-thermal metamorphism which accompanied the emplacement of the ultramafic rocks.

Metamorphism Related to Granitic Intrusion

Argillaceous sedimentary rocks of the Sylvester Group have been metamorphosed to fine-grained hornfelsic rocks within a zone extending about 1,000 feet from the Cassiar batholith. The common mineral assemblage in these rocks is quartz-biotite-muscovite-orthoclase. Garnet may locally be added to this assemblage.

Sylvester Group greenstones are metamorphosed to albite-epidote-amphibolite facies near the granite batholith. The assemblage albite-zoisite-tremolite-actinolite-chlorite-calcite is characteristic of basic volcanic rocks near the granite.

Dolomites and dolomitic limestones of the McDame Group are completely recrystallized to olivine bearing marbles for distances from 800 to 1,000 feet from the granitic rocks. The batholith-limestone contact examined in the extreme western part of the map-area showed no evidence of calc-silicate skarns. The normal quartz monzonite of the Cassiar intrusion is replaced by a more basic rock consisting essentially of highly zoned calcic plagioclase and blue-green pleochroic hornblende within a border phase that has been affected by limestone assimilation.

The Cassiar batholith has produced pronounced metamorphic effects in the lower grade serpentinized ultramafic rocks of the Blue River intrusion. Mineralogical variations related to the granite metamorphism are best exposed along the walls of the cirque that contains the head waters of Nickel Creek, in the northeastern corner of the main ultramafic mass. The original rock in this area was apparently a mesh structure serpentinite, now altered to rocks containing the minerals talc, tremolite, serpentine, and regenerated olivine. Three broad zones can be recognized in progressing southeast from the granite contact toward the centre of the ultramafic intrusion.

Mineral Assemblage	Approximate Distance from Granite Contact (feet)
1. Talc-serpentine-regenerated olivine	0 - 1000
2. Tremolite-serpentine-regenerated olivine	1000 - 4000
3. Regenerated olivine-serpentine	4000 - 9000
4. Normal mesh-structure serpentine	9000 +

The effects of granite intrusion have been less pronounced in the western half of the ultramafic intrusion. Prior to intrusion of the Cassiar granite, the rocks in this area apparently formed a dry, refractory, unserpentinized olivine-pyroxene assemblage which was uninfluenced by the relatively low temperature generated by the granitic magma. Dunites and peridotites in this region are only moderately influenced where addition of water from the granitic rocks has produced retrograde development of amphibole.

Interpretation of the talc-tremolite-regenerated olivine assemblages in terms of pressure and temperature is extremely hazardous in view of the extreme mobility of water within the system.

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Chromite: Chrome spinel is an abundant accessory mineral in the dunite and peridotite of the Blue River intrusion, but no large concentrations were found in the map-area. Chromite occurs most commonly as irregular, ragged grains interstitial to olivine and pyroxene crystals. In outcrops the more resistant chromite grains stand out in relief on the smooth, light yellowish brown weathered surfaces of normal dunites. These grains may occur in lenses and pods which vary in size from a string of single grains to massive lenses up to 6 inches thick and 50 feet long. The largest zone of chromite concentration is associated with dunite bands trending about N70°W in the vicinity of Ice Lake.

Nickel: Sparsely disseminated pyrrhotite is associated with a rusty zone of biotite hornfels near the north corner of the main ultramafic mass. The deposit lies along the ultramafic contact near the granite intrusion.

Regenerated dunite within the Nickel Creek cirque has yielded nickel assays ranging from 0.17% to 0.49%, and averaging about 0.22%. The source of this nickel has been attributed to the presence of a nickel-iron alloy (Ni_3Fe), but this still remains to be proven to the satisfaction of the writer. Disseminated blebs of heazlewoodite (Ni_3S_2) from the same rocks have been identified by x-ray powder photographs.

Molybdenite: Small pods of molybdenite were noted at two locations within the Cassiar batholith near its contact with the ultramafic intrusion. Although these pods contain up to 5% MoS_2, they do not exceed 3 feet in their longest dimension.

Asbestos: Small, widely spaced veinlets of chrysotile asbestos are contained in peridotite in one locality. In all cases the fibre length is less than 1/4 inch.

REFERENCES

Bowen, N.L., and Tuttle, O.F.
1949: The system MgO-SiO_2-H_2O; Bull. Geol. Soc. Amer., vol. 60, pp. 439-460.

Durrell, Cordell
1940: Metamorphism in the southern Sierra Nevadas northeast of Visalia, California; Univ. Calif., Dept. Geol., Bull., vol. 25, pp. 1-117.

Gabrielse, H.
1954: McDame, British Columbia; Geol. Surv. Can., Paper 54-10.

1963: McDame map-area, Cassiar district, British Columbia; Geol. Surv. Can., Mem. 319.

MacGregor, I.D.
1962: Petrology, mineralogy and geochemistry of the Mount Albert Ultramafic Pluton, Gaspe, P.Q.; unpub. M.Sc. thesis, Queen's Univ., Kingston.

Smith, C.H.
1958: The Bay of Islands Complex, Western Newfoundland; Geol. Surv. Can., Mem. 290.