THE GEOLOGY OF THE CASSIAR ASBESTOS DEPOSIT

BY W. N. PLUMB

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ABSTRACT

CASSIAR IS LOCATED IN NORTHERN BRITISH COLUMBIA, FIFTY MILES SOUTH OF THE YUKON BORDER AND 100 MILES FROM WATSON LAKE ON THE ALASKA HIGHWAY. IT IS A MODERN COMMUNITY OF MORE THAN 1,100 PEOPLE. HIGH QUALITY CHRYSOTILE ASBESTOS WITH A LOW IRON CONTENT IS PRODUCED IN A 2,500 TON PER DAY MILL. THE MINE IS AN OPEN PIT OPERATION AT AN ELEVATION OF 6,000 FEET IN THE CASSIAR MOUNTAINS.

THE AREA HAS PRODUCED PLACER GOLD SINCE 1872 BUT THE ASBESTOS ONLY BECAME ECONOMIC IN 1953, CHIEFLY BECAUSE OF THE ALASKA HIGHWAY.

THE OREBODY OCCURS IN A SILL OF SERPENTINIZED PERIDOTITE THAT INTRUDES THE WEST LIMB OF A SYNCLINE IN PALEOZOIC SEDIMENTARY AND VOLCANIC ROCKS. IT STRIKES NORTHERLY, DIPS MODERATELY EAST AND INCREASES IN SIZE WITH DEPTH. THE LONG-FIBRE ASBESTOS VEINS ARE FISSURE FILLINGS IN WELL-FRACTURED MASSIVE SERPENTINE, CONTROLLED BY A MINOR FOLD IN THE SILL.

THE GENESIS OF THE ORE IS ASCRIBED TO INTENSE FRACTURING AND HEAT RESULTING FROM THE INTRUSION OF THE NEARBY CASSIAR GRANITIC BATHOLITH.

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I. INTRODUCTION

CASSIAR IS LOCATED IN NORTHERN BRITISH COLUMBIA, 50 MILES SOUTH OF THE YUKON BORDER, 735 AIR MILES NORTHWEST OF EDMONTON AND 700 AIR MILES SOUTHEAST OF FAIRBANKS, ALASKA. IT IS 100 MILES BY ROAD FROM WATSON LAKE, WHERE THE ALASKA HIGHWAY CROSSES INTO THE YUKON, AT APPROXIMATELY THE SAME LATITUDE AS SKAGWAY, URANIUM CITY AND CHURCHILL.

HEAVY SUPPLIES ARE BROUGHT IN BY TRUCK OVER THE ALASKA HIGHWAY, EITHER FROM DAWSON CREEK OR WHITEHORSE. OUTGOING FIBRE TRAVELS BY TRUCK TO WHITEHORSE, BY RAILWAY TO SKAGWAY, AND BY BOAT TO VANCOUVER, A DISTANCE OF ABOUT 1,350 MILES. WHEN THE STEWART-CASSIAR ROAD IS COMPLETED, THIS ROUTE WILL BE SHORTENED BY APPROXIMATELY 400 MILES. PERSONNEL ARE FLOWN TO WATSON LAKE, THEN TRANSPORTED BY BUS TO CASSIAR. OUTSIDE COMMUNICATION IS BY TELEPHONE VIA WHITEHORSE OR FORT NELSON.

THE TOWNSITE IS IN A PICTURESQUE ALPINE VALLEY, AT AN ELEVATION OF 3,500 FEET, SURROUNDED BY THE RUGGED PEAKS OF THE CASSIAR MOUNTAINS. IT IS A PLANNED DEVELOPMENT WITH STREETS OF PAN-ABODE HOUSES, FRAME HOUSES, A TRAILER PARK, AND ALL THE AMENITIES INCLUDING STORE, BANK, POST OFFICE, SCHOOL, HOSPITAL, RECREATION HALL, CURLING RINK, SWIMMING POOL, ARENA, AND TWO CHURCHES. THE CURRENT POPULATION IS ABOUT 1,100.

THE MILL AND SERVICE BUILDINGS ARE 2,000 FEET EAST OF THE TOWNSITE. THE MILL HAS A CAPACITY OF 2,500 TONS DAILY AND PRODUCES HIGH QUALITY ASBESTOS FIBRE WITH A LOW IRON CONTENT.

The mine is three miles north of the mill, on a spur of McDame Mountain, at an elevation of 6,000 feet. It is connected to the mill by a three-mile aerial tramline and six miles of access roads. Mining is by open pit methods. The ore is blasted in 30-foot benches, loaded with power shovels, trucked to a pre-concentration plant and transported to the mill by tramline, supplemented by trucks, as required. Stripping waste on the hanging wall side of the orebody is mined in 30-foot benches below an elevation of 6,650 feet and trucked to adjacent dumping areas. In spite of the exposed location and the northern climate, the mine and mill are operated continuously throughout the year.

2. EARLY HISTORY OF THE AREA

The Cassiar district has been accessible from the coast at least since 1861, when placer gold was mined on the Stikine river. In 1872, placer gold was discovered on Thibert Creek, at the north end of Dease Lake and shortly thereafter on McDame Creek. Placer mining has been carried on intermittently ever since. In 1942, the Alaska Highway was built. Up to this time only deposits rich in gold and silver were economic. The presence of asbestos in the area was known but was considered only a mineralogical curiosity. G.M. Dawson mentioned asbestos in the area in his 1888 report. In 1947, Moccasin Mines Limited, a placer dredging company, built a 68-mile truck road to McDame Creek from Mile 648 on the Alaska Highway. On June 30, 1950, four prospectors, Victor Sittler, Hiram Nelson and the Kirk Brothers staked the Cassiar deposit. This was subsequently acquired by Conwest Exploration Company Limited; the Cassiar Asbestos Corporation was formed; the road was extended 18 miles and production started with a 150-ton mill in 1953.

3. PHYSIOGRAPHIC DIVISIONS

There are eight major physiographic divisions in this part of northern B.C.; from east to west along the 59th parallel, these are:

1) A portion of the INTERIOR PLAINS, in the extreme northeast corner.

2) The ROCKY MOUNTAIN FOOTHILLS and LIARD PLATEAU.

3) The LIARD PLAIN, an area 200 miles long by 50 miles wide, comprising the drainage basin of the upper part of the Liard River and straddling the B.C. - Yukon border. Watson Lake is at its centre.

4) The ROCKY MOUNTAINS, which terminate and merge with the Liard plain at about the 59th parallel.

5) The ROCKY MOUNTAIN TRENCH, which also dies out into the Liard plain at about the same latitude.

6) The CASSIAR MOUNTAINS, a belt of igneous and fold mountains, 50 miles wide, bounding the Liard Plain on the west and extending northwest into the Yukon. Cassiar is in almost the exact centre of the Cassiar Mountains.

7) The STIKINE PLATEAU, a region of moderate relief, with occasional isolated mountainous areas. This extends northwestward and merges with the Yukon Plateau.

8) The COAST MOUNTAINS, along the boundary between B.C. and the Alaska Panhandle.

4. DRAINAGE SYSTEMS

The Cassiar Mountains are in the centre of three main drainage systems:

1) The STIKINE RIVER and its tributaries, the Tuya, Tanzilla, Pitman and Klappan rivers, flowing west through Telegraph Creek to the sea.

2) The LIARD RIVER and its tributaries, the Rancheria, Dease, Turnagain and Kechika rivers, flowing east to the Mackenzie.

3) The TESLIN RIVER and its tributaries, the Kedahda, Jennings and Swift rivers, flowing north into the Yukon river system.

5. RELIEF

In general, all mountain ranges follow the regional northwesterly Cordilleran trend. Most of them are at the stage of maximum relief, with sharp, knife-edged, serrated ridges and very steep upper slopes, flattening rapidly downward into the broad valley bottoms characteristic of glaciated terrain. Some of the ranges are just past the stage of maximum relief and thick deposits of talus, known as "felsenmeer", are accumulating on their flanks, obscuring some of the geological features. Lowland elevations range from about 2,000 feet in the Liard Plain to 4,000 feet on the Stikine Plateau, while the summits in the Cassiar mountains are generally about 6,500 feet, with some over 7,000 feet. The highest point in the McDame Range is 7,000 feet.

6. REGIONAL GEOLOGY

In this paper, the regional geology is described only between 58° and 60° North Latitude. Here, the development of Paleozoic rocks is much greater than in the rest of the province. The oldest rocks, believed to be Pre-Cambrian, are schists and gneisses, exposed in the Rocky Mountain Trench and, locally, in the Cassiar Mountains. These are flanked by Lower Paleozoic sediments, which fan out northward to include most of northwestern Yukon. East of the Rockies, the Paleozoics are covered by the Mesozoic sediments of the Interior Plains. Going westward from the Rocky Mountain Trench across the Cassiar Mountains and the Stikine Plateau, the Lower Paleozoic sediments are progressively overlain by Upper Paleozoic and Lower Mesozoic sediments and volcanics, then by Upper Mesozoic sediments and, finally, above an erosional unconformity, by widespread Tertiary volcanics. All these rocks, except the Tertiary volcanics, have been gently folded along northwesterly-trending axes.

There were two periods of igneous intrusion, the first during late Paleozoic or early Mesozoic time, when ultramafic rocks were emplaced along both flanks of the Cassiar Mountains and in the north central part of the Stikine Plateau. These ultramafics appear to be confined to Upper Paleozoic or Lower Mesozoic rocks and to have been folded with them. The folding probably took place during the widespread orogeny later in Mesozoic time, when the Coast Range and Cassiar batholiths were emplaced.

During the Pleistocene, glaciation was widespread. Disrupted drainage, recent canyons, ground moraine, eskers and kettle topography are common in the valleys, while remnants of valley glaciers

STILL OCCUPY SOME OF THE NUMEROUS CIRQUES. PERMAFROST IS PRESENT IN THE CASSIAR OREBODY.

(THE GENERALIZED REGIONAL GEOLOGY IS SHOWN IN TABLE I.)

7. GEOLOGY OF THE McDAME AREA

THE CASSIAR BATHOLITH, TRENDING NORTHWESTWARD FROM DEASE LAKE, IS A BELT OF GRANITE, 25 MILES IN WIDTH. ON ITS NORTHEAST FLANK, A THICK SEDIMENTARY AND VOLCANIC SEQUENCE HAS BEEN FOLDED INTO A BROAD SYNCLINE, FOLLOWED BY A BROAD ANTICLINE.

THESE UNITS, STARTING AT THE BASE, ARE:

1) THE GOOD HOPE GROUP, A THICK SEQUENCE OF PROTEROZOIC LIMESTONE, DOLOMITE, SLATE AND ARGILLITE.

2) THE ATAN GROUP OF LOWER CAMBRIAN AGE, COMPRISING CHIEFLY BUFF LIMESTONE AND PINK QUARTZITES.

3) THE KECHIKA GROUP OF CAMBRIAN-ORDOVICIAN AGE, AN EXTENSIVE FORMATION OF THIN-BEDDED GRAPTOLITIC LIMY SHALES, SLATES AND PHYLLITES.

4) THE SANDPILE GROUP, A DISTINCTIVE HORIZON MARKER OF MASSIVE, WHITE-WEATHERING, SANDY DOLOMITE OF SILURIAN AGE.

5) THE McDAME GROUP OF DEVONIAN AGE, OF BLACK FETID DOLOMITE.

6) THE SYLVESTER GROUP, A VERY THICK ASSEMBLAGE OF QUARTZITIC ARGILLITES AND INTERBEDDED VOLCANIC FLOWS AND TUFFS, OF DEVONIAN-MISSISSIPPIAN AGE.

Occurring chiefly along the axis of the syncline, but also at other stratigraphic horizons, a string of ultramafic bodies intrude the Sylvester Group intermittently for 70 miles. These are the McDame Intrusions. Most have been converted to serpentine and contain chrysotile asbestos but so far only one, the Cassiar deposit, has proven economic.

8. Geology of the Cassiar Orebody

A) Country Rocks

The Cassiar mine is high on the western flank of McDame Mountain, a high serrated ridge, eight miles long, at an average elevation of 6,600 feet, surmounted by peaks up to 7,000 feet in elevation. The upper slopes are precipitous and contain many glacial cirques.

The eastern edge of the Cassiar granitic batholith follows the crest of another mountain range, one to two miles west of the mine. Metamorphosed Proterozoic and Lower Cambrian sediments form the eastern slopes of this range.

Limy argillites and dolomites of Ordovician and Silurian ages underlie the lower slopes of McDame Mountain, while the Sylvester Group of interbedded argillites and volcanics form the upper part. Both formations dip uniformly east into the regional syncline.

The uppermost unit of the Sandpile Group is a very prominent white-weathering band of massive black dolomite, exposed for several miles along the mountainside, except in the vicinity of the mine, where the dolomites are overlain by limy black argillites. The

LOWERMOST BEDS OF THE SYLVESTER GROUP, COMPRISE SEVERAL HUNDRED FEET OF ALTERNATING, THIN-BEDDED BLACK ARGILLITES AND CHERTY GREY ARGILLITES THAT FORM THE FOOTWALL OF THE OREBODY. THESE PASS UPWARDS INTO MASSIVE BLACK AND GREENISH ARGILLITES WITH WHICH ARE INTERBEDDED AT ERRATIC INTERVALS, LENTICULAR GREENSTONES DERIVED FROM VOLCANIC FLOWS. SOME OF THE FLOWS ARE QUITE COARSE-GRAINED, RESEMBLING GABBROIC SILLS; OTHERS ARE APHANITIC. ONE PROMINENT BAND, 200 FEET THICK, FORMS THE CREST OF THE "NORTH PEAK" ABOVE THE MINE.

b) The Cassiar Ultramafic Host Rock

THE CASSIAR ULTRAMAFIC BODY IS EXPOSED FOR 8,000 FEET ALONG THE WEST SIDE OF McDAME MOUNTAIN. STARTING ABOUT ONE AND ONE-HALF MILES NORTH OF THE MILL, IT TRENDS NORTHWESTERLY FOR 7,000 FEET AS A NARROW SILL-LIKE MASS OF BARREN, DARK SERPENTINE, INTRUDING THE SYLVESTER GROUP ABOUT 500 FEET STRATIGRAPHICALLY ABOVE THE BASE. IT IS 70 FEET WIDE AND DIPS GENTLY EAST, APPARENTLY CONFORMABLE WITH THE SEDIMENTS. ABOUT THREE MILES NORTH OF THE MILL, IT SUDDENLY ENLARGES TO A WIDTH OF OVER 700 FEET AND SWINGS SHARPLY TO THE NORTHEAST, CUTTING ACROSS THE ARGILLITES AT A SMALL ANGLE. THIS ENLARGEMENT CONTAINS THE CASSIAR OREBODY AND THERE IS EVIDENCE TO SUGGEST THAT IT IS PARTLY DUE TO DRAG-FOLDING AND DIFFERENTIAL MOVEMENT ALONG A NORTHWESTERLY-TRENDING SHEAR ZONE.

1,000 FEET PAST THE BEND, THE OUTCROP ENDS AT THE BROW OF A LARGE CIRQUE OPENING TO THE NORTH BUT FIBRE-BEARING TALUS, DERIVED FROM THE WEATHERING OF THE SERPENTINE IN PLACE, CONTINUES NORTH ALONG THE FLOOR OF THE CIRQUE FOR ANOTHER 1,000 FEET WHERE IT LENSES OUT. UNDERGROUND DEVELOPMENT, 300 FEET BELOW THE OUTCROP, HAS DETERMINED A LENGTH OF 1,700 FEET AND A WIDTH OF 500 FEET OF ORE OF COMPARABLE

QUALITY AND GRADE TO THAT BEING MINED IN THE OPEN PIT.

c) The Cassiar Orebody

The orebody occupies the bulge at the change in strike of the serpentine. It is roughly crescent shaped in plan, the horns trending southeast and northeast, respectively. It currently outcrops in the pit between elevations of 6,050 and 5,870 feet. The hangingwall strikes north and dips about 35 degrees east. Footwall dips are somewhat steeper but the orebody as a whole dips about 45 degrees east. The orebody appears to increase in size with depth but this may be because a considerable part of the surface outcrop has been removed by erosion at the north end. The ultimate mining limits will probably be determined by economics rather than by exhaustion of the ore.

The orebody is a fibre-bearing zone in light-green, massive serpentine, containing upwards of 10 percent cross-fibre chrysotile asbestos, varying in length up to three and one-quarter inches. It is bounded on all sides, except the extreme western apex, by waste serpentine containing moderate to low concentrations of shorter fibre. In most cases, the ore limits are sharp and structurally controlled, but some are gradational.

d) Structural Geology

The footwall and hangingwall rocks strike generally north 15 degrees west and dip homoclinally east into the regional syncline at about 45 degrees. Where the serpentine band is narrow, to the south of the orebody, it conforms to this structure. In the vicinity of the mine, however, where the serpentine bulges, the country rocks

HAVE TO SOME EXTENT BEEN CONTORTED AND LOCALLY TEND TO CONFORM TO THE SHAPE OF THE BULGE. NEVERTHELESS, THE NORTH END OF THE SERPENTINE TRANSECTS THE BEDDING AT A SMALL ANGLE. THIS HAS RESULTED IN SOME SHEARING ALONG THE CONTACTS AND IN NUMEROUS SMALL ADJUSTMENTS, ESPECIALLY ALONG BEDDING PLANES.

WHEREVER THE FOOTWALL OF THE SERPENTINE IS IN CONTACT WITH ARGILLACEOUS ROCKS, A ZONE OF SHEARING ABOUT TEN FEET WIDE IS EVIDENT. IN THIS ZONE, THE SERPENTINES HAVE BEEN DARKENED BY THE INCLUSION OF ARGILLACEOUS MATERIAL, THE ARGILLITES HAVE BEEN ALTERED TO GRAPHITIC SCHISTS, A LITTLE CALCAREOUS MATERIAL HAS BEEN INTRODUCED AND LOCALLY, GOUGE AND BRECCIA ZONES HAVE BEEN FORMED.

ALONG THE HANGINGWALL, DARK BLOCKY SERPENTINE IS IN CONTACT WITH A NARROW BAND OF ALTERATION. THIS IS A CREAM-COLOURED TREMOLITE-ZOISITE HORNFELS. THE DEGREE OF CONTACT METAMORPHISM, HOWEVER, HAS NOT BEEN AS GREAT AS WOULD BE EXPECTED FROM A HIGH-TEMPERATURE INTRUSION, WHICH HAS LED TO SPECULATION THAT THE SERPENTIN MAY HAVE BEEN INJECTED IN A LOW-TEMPERATURE SEMI-PLASTIC STATE.

THERE IS A VERY PROMINENT SET OF JOINTS IN BOTH THE FOOTWALL AND HANGINGWALL ROCKS, STRIKING A FEW DEGREES NORTH OR SOUTH OF EAST AND DIPPING STEEPLY NORTH. THIS IS PART OF A REGIONAL PATTERN OF TENSION FRACTURES AT RIGHT ANGLES TO THE CASSIAR BATHOLITH. SHEARS OF SMALL DISPLACEMENT, PARALLELING THE JOINT SYSTEM, ARE COMMON. AT THE POINT WHERE THE SERPENTINE BULGES AND CHANGES STRIKE AT THE SOUTH END OF THE OREBODY, A ZONE OF CLOSELY SPACED SHEARING, STRIKING ABOUT SOUTH 60 DEGREES EAST, CUTS BOTH THE SERPENTINE AND

THE HANGINGWALL ROCKS. THIS APPEARS TO BE A ZONE OF IMBRICATING FAULTS AND SHEARS, WHICH LIMITS THE ORE TO THE SOUTH AND IMPARTS A SOUTHEASTERLY RAKE TO THIS END OF THE OREBODY. IT IS PROBABLY POST-ORE, BUT IS CONSIDERED TO BE A ZONE OF SMALL ADJUSTING MOVEMENTS RATHER THAN A MAJOR FAULT. ON THE SURFACE, IT CONTAINS SHEARED LONG FIBRE. UNDERGROUND, ON TWO LEVELS, THE ORE ENDS SHORTLY BEFORE THE ZONE IS REACHED AND THE SERPENTINE ENDS ABRUPTLY AT SMOOTH, SLICKENSIDED FAULT PLANES, FOLLOWED BY AT LEAST 30 FEET OF GRAPHITIC GOUGE, EVIDENTLY DERIVED FROM THE BLACK ARGILLITES OF THE SYLVESTER GROUP.

E) INTERNAL STRUCTURE

WITHIN THE OREBODY, THE MOST IMPORTANT ORE CONTROL IS THE RELATIVE COMPETENCY OF THE SERPENTINE. THE ORE OCCURS AS FRACTURE FILLINGS, CHIEFLY ALONG JOINTS, IN A LIGHT GREEN MASSIVE SERPENTINE WITH A BLOCKY FRACTURE. THE SERPENTINE HAS A STRONG TENDENCY TO BE SHEARED ALONG ITS MARGINS. WHERE IT EXISTS AS ONLY A NARROW ZONE TO THE SOUTH OF THE OREBODY, IT IS COMPLETELY SHEARED. THE SHEARED ZONES ARE EITHER BARREN OR CONTAIN ONLY MINOR SHORT FIBRE. THEY ARE ALSO CHARACTERIZED BY THE DEVELOPMENT OF TALC AND PICROLITE AND MAY CONTAIN CONSIDERABLE MAGNETITE AND MAGNESITE.

THE MASSIVE SERPENTINE IS CUT BY NUMEROUS SHEARS, RANGING UP TO FORTY FEET IN WIDTH. IN GENERAL, THEY STRIKE NORTHERLY WITH MODERATE DIPS TO THE EAST. THE SPACING VARIES BUT IT IS RARE TO FIND A WIDTH OF 100 FEET FREE OF SHEARING. THIS HAS HAD THE EFFECT OF SLICING THE OREBODY INTO A NUMBER OF MASSIVE BLOCKS WITH WELL-DEVELOPED SYSTEMS OF CONJUGATE JOINTS, MOST OF WHICH CONTAIN LONG,

CROSS-FIBRE CHRYSOTILE. THE MORE PERSISTENT JOINTS TEND TO CONTAIN THE WIDER VEINS, WHILE MYRIAD SMALLER FRACTURES ARE FILLED WITH SHORT-FIBRE VEINLETS. THE ORIENTATION OF JOINT SYSTEMS WITHIN SUCCESSIVE BLOCKS VARIES WIDELY BUT TENDS TO FAVOUR TWO GENERAL DIRECTIONS, ONE TRENDING NORTH-NORTHWEST TO NORTH-NORTHEAST; THE OTHER ABOUT EAST-SOUTHEAST. DIPS VARY FROM SHALLOW TO STEEP IN EITHER DIRECTION.

MOST VEINS ARE A COMPOUND OR "TWO-FIBRE" TYPE, WITH A CENTRAL PARTING, BUT THESE MAY CHANGE ALONG STRIKE TO SIMPLE OR "ONE-FIBRE" VEINS. MOST ARE LENTICULAR OVER SHORT DISTANCES, BUT SOME PERSIST FOR DOZENS OF FEET. SOME COMPOUND VEINS ARE FORMED BY THE MERGING OF TWO SIMPLE VEINS COMING TOGETHER FROM DIFFERENT DIRECTIONS. SHORT LADDER VEINS ARE COMMON. ON THE OTHER HAND, IT IS POSSIBLE TO FIND AREAS EXPOSED IN THE PIT CONTAINING FIFTY PARALLEL VEINS, AT ABOUT ONE-FOOT SPACING, ALL TEN FEET OR MORE IN LENGTH AND OVER ONE-HALF INCH IN WIDTH.

THERE ARE TWO EXCEPTIONS TO THE GENERAL RULE THAT THE MASSIVE SERPENTINE MAKES ORE AND THE SHEARED SERPENTINE IS WASTE. THE OREBODY CONTAINS ZONES OF POST-ORE SHEARING, IN WHICH LONG FIBRE VEINLETS HAVE BEEN DRAGGED, SQUEEZED, BENT, AND PARTLY CONVERTED TO TALC. THESE ZONES STILL CONTAIN A HIGH PERCENTAGE OF LONG FIBRE, ALTHOUGH IT TENDS TO CREATE DUST IN MILLING.

THE OTHER EXCEPTION IS THE MASSIVE SERPENTINE TOWARDS THE HANGINGWALL AND NORTH END OF THE OREBODY, WHERE APPARENTLY THE STRESSES WERE WEAKER AND FEWER FRACTURES WERE FORMED. THE ROCK CONTAINS A LOWER TOTAL PERCENTAGE OF FIBRE AND THE VEINS ARE NARROWER. IT ALSO CONTAINS A LARGER PERCENTAGE OF "BASTITES"

(GHOST PYROXENES), WHICH MAY REFLECT A GRADUAL CHANGE IN THE COMPOSITION OF THE ORIGINAL PERIDOTITE TOWARD THE HANGINGWALL AND HENCE ITS SUSCEPTIBILITY TO SERPENTINIZATION AND THE FORMATION OF CHRYSOTILE. HERE, THE CHANGE FROM ORE TO MARGINAL OR LOW GRADE MATERIAL IS GRADATIONAL.

f) MINERALOGY

THE ORE-BEARING SERPENTINE HAS A MOTTLED LIGHT APPLE-GREEN TO DARK GREEN COLOUR, A GREASY TO SILKY LUSTRE AND A BLOCKY FRACTURE. IT IS SPOTTED WITH BENT, GLISTENING, BRONZE COLOURED "GHOST CRYSTALS", PSEUDOMORPHOUS AFTER ORTHOPYROXENES, CALLED "BASTITES". MAGNETITE IS COMMON AS DISSEMINATIONS AND NARROW VEINLETS, SOMETIMES IN THE SERPENTINE BUT USUALLY AS SELVEDGES AND PARTINGS IN THE VEINS.

THE SHEARED SERPENTINE IS GENERALLY DARK GREEN TO PURPLISH BLACK. IT FORMS GLOSSY, PLATY FLAKES AND LENSES, GENERALLY TERMED "FISH-SCALE" SERPENTINE. DARK GREEN PICROLITE, A COLUMNAR TO PSEUDOFIBROUS FORM OF SERPENTINE, IS COMMON IN SHEAR ZONES, ALONG WITH PALE GREEN TO WHITE, FOLIATED TALC AND A CRYSTALLINE FORM OF WHITE MAGNESITE. MAGNETITE ALSO TENDS TO OCCUR IN THE SHEARED ZONES IN LONG THREADS PARALLEL TO THE DIRECTION OF MOVEMENT. THIS IS KNOWN AS "FIBROUS MAGNETITE" AND SUGGESTS EITHER PLASTIC FLOW OR CRYSTALLIZATION COINCIDENT WITH MOVEMENT.

MICROSCOPIC STUDY BY H. GABRIELSE REVEALS THAT THE SERPENTINE HAS BEEN FORMED BY THE ALTERATION OF OLIVINE, ORTHOPYROXENE AND CLINOPYROXENE, GIVING RISE TO MESH-STRUCTURE SERPENTINE, WITH ISLANDS OF HOMOGENOUS SERPENTINE PSEUDOMORPHOUS AFTER PYROXENE. HE SUGGESTS THAT OLIVINE ALTERS TO CHRYSOTILE AND ORTHOPYROXENE TO ANTIGORITE.

In the vein, the chrysotile is apple green and has a silky lustre. The fibres are oriented across the vein, almost at right angles to it, although they often slant and may be crenulated or wavy. The fibres vary in length up to $3\frac{1}{4}$ inches. This deposit contains an abnormally high percentage of fibre more than one-half inch long. The veins break easily from the wallrock and then the fibres may be separated indefinitely. When separated, the fibres are pure white, strong and flexible. Their usefulness, of course, lies in their physical properties: they are fireproof, resist heat and most acids, and may be woven into cloth.

Chemically, chrysotile is a hydrous magnesium silicate, of exactly the same composition as the serpentine that contains it. Its composition is $3MgO.2SiO_2.2H_2O$. The only essential difference is its fibrous habit, which gives it distinctive physical properties. The crystal system is monoclinic.

Both simple and compound veins are present. Compound veins are those with a central parting, so that the width of the vein does not represent the length of the fibre. Instead, a half-inch vein may contain two one-quarter inch fibres or, if the parting is not central, one-eighth and three-eighth inch fibres. There may be any number of partings in a compound vein. Partings are believed to represent the line of juncture, at the time of formation, where fibres growing outward from both walls of a fissure met. Where there are many partings, it is considered that there were repeated periods of fissure-opening and fibre-growth. Crenulations are probably due to slight movements of the walls while the fibres were growing. Partings may be marked merely by an irregular line of junction, by a thin band of amorphous serpentine, or by a thin line of granular magnetite.

a) Theories of Origin

Regional geologic evidence indicates that the McDame ultramafics were emplaced either in late Paleozoic or early Mesozoic time, following a period in which marine volcanism had been active, but prior to the intrusion of the granitic Cassiar batholith. It is probable that there is a genetic relationship, over a long period of time, starting with the volcanic activity, continuing through a period of ultramafic intrusion, and ending with the orogeny that resulted in the folding of the marine sediments and the emplacement of the Cassiar batholith.

The presence of the bastites, and the microscopic study of the serpentines, prove that the Cassiar ultramafic body was originally a peridotite. The cross-cutting relations along the footwall, and the thermal metamorphism along the hangingwall, prove that it was intrusive, although nearly concordant with the enclosing rocks. The bulge that contains the orebody, and the incipient bending of strata around it, suggest forcible injection. As the thermal metamorphism was not intense, it has been suggested by Gabrielse that it was injected in a semi-crystalline or essentially plastic state. The presence of the bulge, and the massive nature of the rock within it, seem to indicate that it was injected into a region of low pressure. This may mean that uplift and folding had already commenced at the time of the intrusion. It is probable that the zone of shearing at the south end of the orebody is the result of differential movement when the bending stresses became too great. This would also account for the regional joint pattern.

FOLLOWING THE EMPLACEMENT OF THE PERIDOTITE, THE FOLLOWING EVENTS OCCURRED:

THE PERIDOTITE WAS ALTERED TO SERPENTINE BY THE ADDITION OF WATER, PROBABLY IN THE FORM OF STEAM, UNDER SUITABLE CONDITIONS OF TEMPERATURE AND PRESSURE. (JUST WHAT THESE CONDITIONS ARE, WE DO NOT KNOW.) THE SERPENTINE, AFTER COOLING, WAS INTENSELY SHEARED AND FRACTURED. IN SOME MANNER, PROBABLY AGAIN BY HYDROTHERMAL SOLUTIONS, SOME OF THE SERPENTINE WAS DISSOLVED AND, WHILE THE FRACTURES WERE STILL OPEN OR EVEN WHILE THEY WERE BEING OPENED, THIS NASCENT SERPENTINE FLUID FILLED ALL THE FRACTURES AND COOLED SUFFICIENTLY TO ALLOW THE GROWTH OF THE CHRYSOTILE VEINS. AS THE EDGE OF THE CASSIAR BATHOLITH IS LESS THAN A MILE AWAY AND PROBABLY UNDERLIES McDAME MOUNTAIN AT DEPTH, THIS WAS MOST PROBABLY RESPONSIBLE FOR THE FOLDING AND WAS THE SOURCE OF THE HYDROTHERMAL SOLUTIONS.

THIS THEORY REQUIRES AT LEAST TWO PERIODS OF MOVEMENT, WITH FORCES SO ORIENTED AS TO PRODUCE AN AREA OF TENSION OR LOW ROCK PRESSURE IN THE VICINITY OF THE OREBODY; THE FIRST, DURING THE ORIGINAL EMPLACEMENT OF THE ULTRAMAFIC BODY; AND THE SECOND TO PRODUCE THE FRACTURES AND HOLD THEM OPEN WHILE THE VEINS FORMED. THERE MAY HAVE BEEN A THIRD, AS THERE IS SOME POST-ORE SHEARING INVOLVING THE FIBRE. MOST LIKELY THE OROGENY TOOK PLACE OVER MILLIONS OF YEARS, WITH MANY SUCCESSIVE SURGES.

THE CLOSING EVENT, OF COURSE, WAS ICE EROSION, WHICH TRUNCATED AND REMOVED A LARGE PART OF THE SURFACE OREBODY, LEAVING A THICK ACCUMULATION OF TALUS FIBRE IN THE CIRQUE.

9. PROSPECTING CONSIDERATIONS

IN A PAPER SUCH AS THIS, IT MAY BE APPROPRIATE TO REVIEW THE SALIENT GEOLOGIC FEATURES THAT APPEAR TO HAVE BEEN SIGNIFICANT IN THE FORMATION OF THE CASSIAR OREBODY. THESE MAY BE USEFUL IN THE SEARCH FOR OTHER DEPOSITS. THERE ARE FIVE MAIN FEATURES:

1) THE OREBODY OCCURS IN A HIGHLY SERPENTINIZED, MASSIVE PERIDOTITE.

2) IT IS LARGE ENOUGH THAT IT WAS NOT COMPLETELY SHEARED BY REGIONAL MOVEMENTS, BUT SMALL ENOUGH TO BE INTENSELY FRACTURED.

3) THERE IS A LOCAL FOLD, TO PROMOTE AND CONCENTRATE THE FRACTURING.

4) IT IS WITHIN ONE MILE OF THE CASSIAR BATHOLITH, A PROBABLE SOURCE OF HEAT AND PRESSURE.

5) IT OCCURS IN UPPER PALEOZOIC ROCKS, CONTAINING MARINE SEDIMENTS AND SUBMARINE VOLCANIC FLOWS. MOST OF THE ALPINE ULTRAMAFICS IN THE CORDILLERA CONTAINING ASBESTOS OCCUR IN UPPER PALEOZOIC FORMATIONS.

TABLE 1

GENERALIZED REGIONAL GEOLOGY - NORTHERN BRITISH COLUMBIA

(FROM EAST TO WEST ALONG THE 59TH PARALLEL)

PHYSIOGRAPHIC DIVISION	GEOLOGIC AGE	GEOLOGIC FORMATION	ROCK CLASSIFICATION
GREAT PLAINS	MIDDLE & UPPER MESOZOIC		SEDIMENTARY
	UPPER PALEOZOIC		SEDIMENTARY
ROCKY MOUNTAIN FOOTHILLS	LOWER MESOZOIC		SEDIMENTARY
	MIDDLE & UPPER PALEOZOIC		SEDIMENTARY
ROCKY MOUNTAINS	LOWER PALEOZOIC		SEDIMENTARY
ROCKY MOUNTAIN TRENCH	LOWER PALEOZOIC		SEDIMENTARY
	UPPER PRECAMBRIAN (?)		METAMORPHIC
CASSIAR MOUNTAINS	UPPER PRECAMBRIAN	GOOD HOPE	METAMORPHIC
	CAMBRIAN	ATAN	SEDIMENTARY
	ORDOVICIAN	KECHIKA	SEDIMENTARY
	SILURIAN	SANDPILE	SEDIMENTARY
	DEVONIAN	McDAME	SEDIMENTARY
	DEVONIAN - MISSISSIPPIAN	SYLVESTER	SEDIMENTARY & VOLCANIC
	LATE PALEOZOIC (?)	McDAME INTRUSIONS	ULTRAMAFIC
	MID-MESOZOIC	CASSIAR BATHOLITH	GRANITIC
STIKINE PLATEAU	UPPER PALEOZOIC		SEDIMENTARY & VOLCANIC
	TERTIARY		VOLCANIC
COAST RANGE MOUNTIANS (EAST SIDE)	UPPER PALEOZOIC		SEDIMENTARY & VOLCANIC
	EARLY MESOZOIC	NAHLIN INTRUSIONS	ULTRAMAFIC
	LOWER MESOZOIC		SEDIMENTARY & VOLCANIC
	MID-MESOZOIC	COAST RANGE BATHOLITH	GRANITIC