# A RE-EXAMINATION OF STRUCTURAL GEOLOGY AND GOLD ON THE M-1 GRID OF THE MISHI GOLD PROPERTY

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## SUMMARY


Previous workers have proposed that the Mishibishu Lake greenstone belt contains several "deformation zones". One of the zones, the Mishibishu Deformation Zone, supposedly cuts the Mishi Gold property. The deformation zones purportedly consist of shear zones that localized hydrothermal alteration and gold mineralization. According to previous workers, virtually all of the structural features that occur within the shear zones are related to them.

I found no evidence for shear zones. Structural features are associated with several events. The predominant structural feature, kink folds, could not be associated with the proposed shear zones.

There *is* a zone where the Mishibishu Deformation Zone is supposed to be, but it is primarily an alteration zone and a stratigraphic zone: hydrothermal alteration was localized within a package of tuffs or mudstones. Fluids moved along widespread "low-angle" shear fractures that are not confined to shear zones.

Economic gold deposits are more likely to be found in schistose tuffs or mudstones close to intersections between the so-called Mishibishu Deformation Zone and faults and dikes that are at a high angle to it, close to the noses of some of the folds, or close to competent bodies such as gabbro plutons.

Although the study area does not contain shear zones like the ones that localized mineralization in many Archean gold camps, it nevertheless contains a considerable volume of altered rocks that contain gold. The lack of shear zones makes it no less prospective.

The M-1 grid has been covered fairly well, and exploration probably has a better chance where less work has been done. Because there are no shear zones, less emphasis should be placed on looking for features that are commonly associated with shear zones. In other respects, the target rocks remains the same: quartz veins and altered, schistose rocks. Particular attention should be paid to faults and dikes that are at a high angle to the schistosity, and some attention should be paid to competent bodies such as gabbro plutons.

Wherever possible, the overburden should be stripped from prospective areas. Outcrop stripping is relatively inexpensive for the quantity, and especially the quality, of data it reveals.

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# INTRODUCTION

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## The Mishi Gold property

The Mishi Gold property is held by MacMillan Gold Corporation of and is currently under option to Mishibishu Gold Corporation. It consists of 491 contiguous mining claims and 3 leased claims located in the Sault Ste. Marie Mining Division. All claims are in good standing. Work was performed on claims that lie within the Mishibishu Lake Area G-3772. A list of property claims is presented in Appendix A.

This report covers field work performed on a portion of the M-1 grid of the Mishi Gold property between August 8 and September 5, 1997.

## Location and access

The M-1 grid of the Mishi Gold property is located about 55 km west of Wawa Ontario. It can be reached from Wawa by following Highway 17 for 50 km, and a gravel road that ultimately leads to the Eagle River Mine for another 50 km (Figure 1).

## Summary of exploration and development

Previous exploration of the M-1 grid has been carried out mainly by Granges Incorporated. Work has included line cutting, prospecting, magnetic and electromagnetic surveys, mapping, channel sampling, bulk sampling, and diamond drilling. Much of the work has been submitted for assessment credit.

## General regional geology

The Mishi Gold property lies in the northern portion of the Mishibishu Lake greenstone belt, south of the Kabenung Lake greenstone belt and southwest of the Michipicoten greenstone belt (Figure 1) in the Wawa Subprovince of the Superior Province of the Canadian shield.

The Mishibishu Lake greenstone belt consists of volcanic rocks, related hypabyssal rocks, and sedimentary rocks that have been metamorphosed, deformed, and intruded by granitoid plutons and diabase dikes. The dikes are probably Keweenawan (Reid and Reilly, 1987). The rest of the rocks are probably Archean.

The metamorphic grade of the supracrustal rocks (the volcanic rocks, related hypabyssal rocks, and sedimentary rocks) is greenschist facies, except close to some of the felsic plutons where it is amphibolite facies (Reid and Reilly, 1987) or hornblende-hornfels facies (Bennett and Thurston, 1977). Because all of the supracrustal rocks are metamorphosed, I shall not use the prefix "meta" in naming the rocks.

The supracrustal rocks were probably deposited adjacent to, and perhaps in part on, granitoid rocks. The overall form of the greenstone belt developed as the supracrustal rocks subsided and the surrounding and underlying granitoid rocks rose.

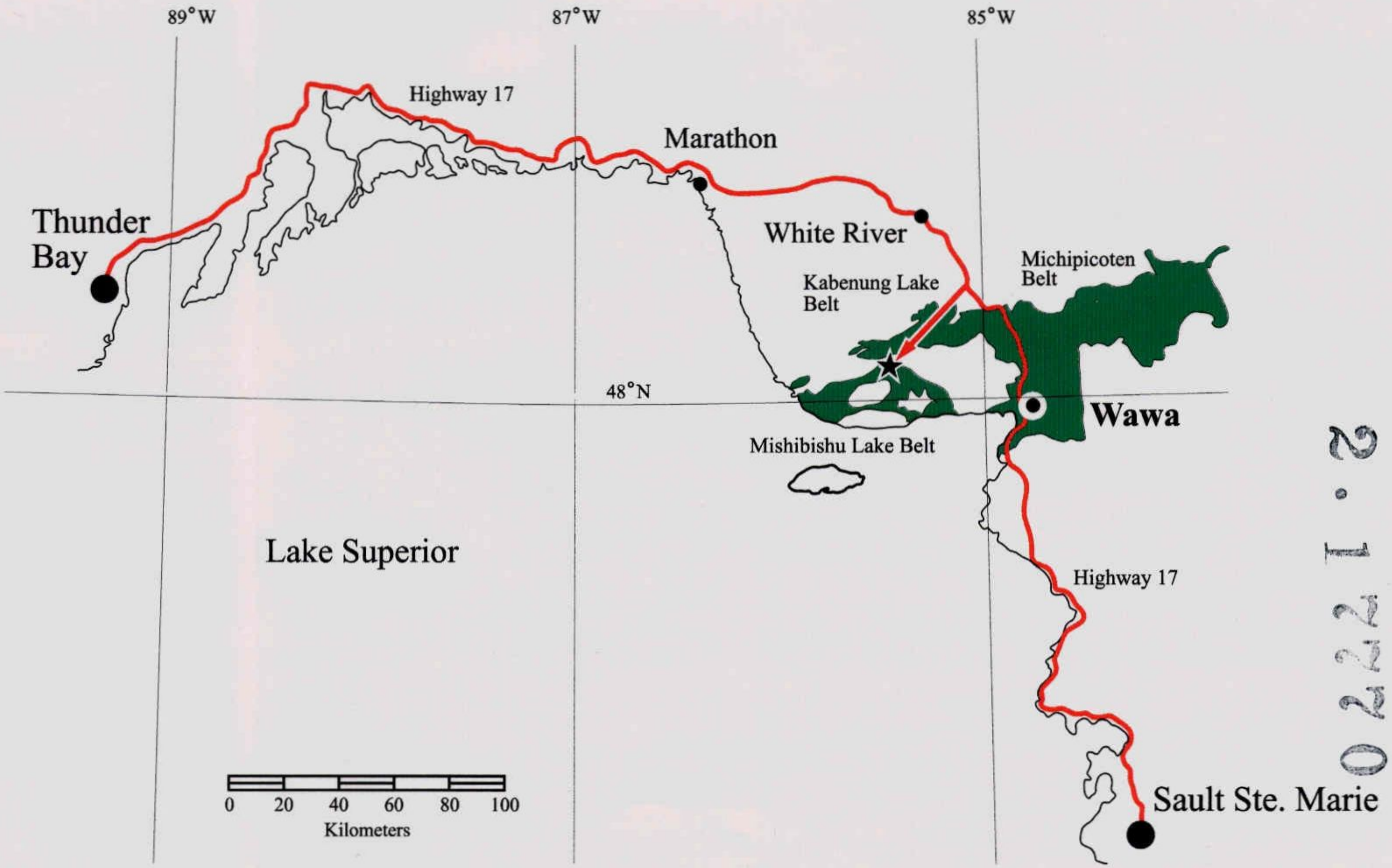


**Figure 1.** Location and access. The location of the Mishi Gold Property is represented by a star, and the gravel road into the M-1 grid from Highway 17 is represented by a straight arrow. After the Geological Map of Northern Ontario.

Bedrock is partially covered by Pleistocene deposits consisting predominantly of ground moraine, tills, and clays (Reid and Reilly, 1987).

## General property geology

According to Bates and Miree (1991) the M-1 grid contains, from north to south:

1) mafic volcanic rocks including flows, sills, and tuffs
2) felsic to intermediate tuffs and hypabyssal rocks
3) clastic sedimentary rocks including argillite (mudstone), wacke, and conglomerate

All of the supracrustal rocks are metamorphosed, and portions of them are metasomatized (hydrothermally altered).

Except for the possible occurrence of quartz-feldspar porphyry, all of the rocks within the study area were originally pyroclastic or epiclastic. Most rocks were tuffs or mudstones, and some rocks were lapilli tuffs or conglomerates. Few of the clastic rocks look like "pristine" tuffs, or like "well-worked" mudstones or conglomerates. Where the rocks are unaltered, the primary mafic mineral is commonly amphibole. Mica is rare or absent. Compositional banding is common, but colours tend to be white or shades of green like volcanic rocks, not shades of grey or brown like sedimentary rocks. Relative to their volcanic source, the rocks are distal pyroclastic rocks or proximal epiclastic rocks.

Bates and Miree (1991) report that there is ductile deformation within several shear zones, and brittle-ductile deformation within a zone they call the Western Structural Zone (Figure 2).

The supracrustal rocks, the shear zones, and the Western Structural Zone are cut by two sets of diabase dikes. Dikes of one set strike approximately northwest, and dikes of the other set strike approximately north-northeast.

## This report

The study area consisted of stripped outcrops at the Main Zone and at 17 other areas that I have named A to Q (Figure 3). Some of the outcrop areas were given names by geologists of Granges Incorporated: outcrop area A was known as KK; outcrop area C was known as MM; the southern portion of outcrop area D was known as Tension; outcrop area E was known as Confusion Corner; outcrop area F was known as Jake's Place; the northern portion of outcrop area G was known as Cliff Hanger; outcrop area H was known as White Swan; outcrop area O was known as Granges Glory; and outcrop area Q was known as Warren's Whopper.

Reports to which I had access and which contain significant structural information are reviewed below. Quotations are indented, and except for their formatting are presented as they were written.

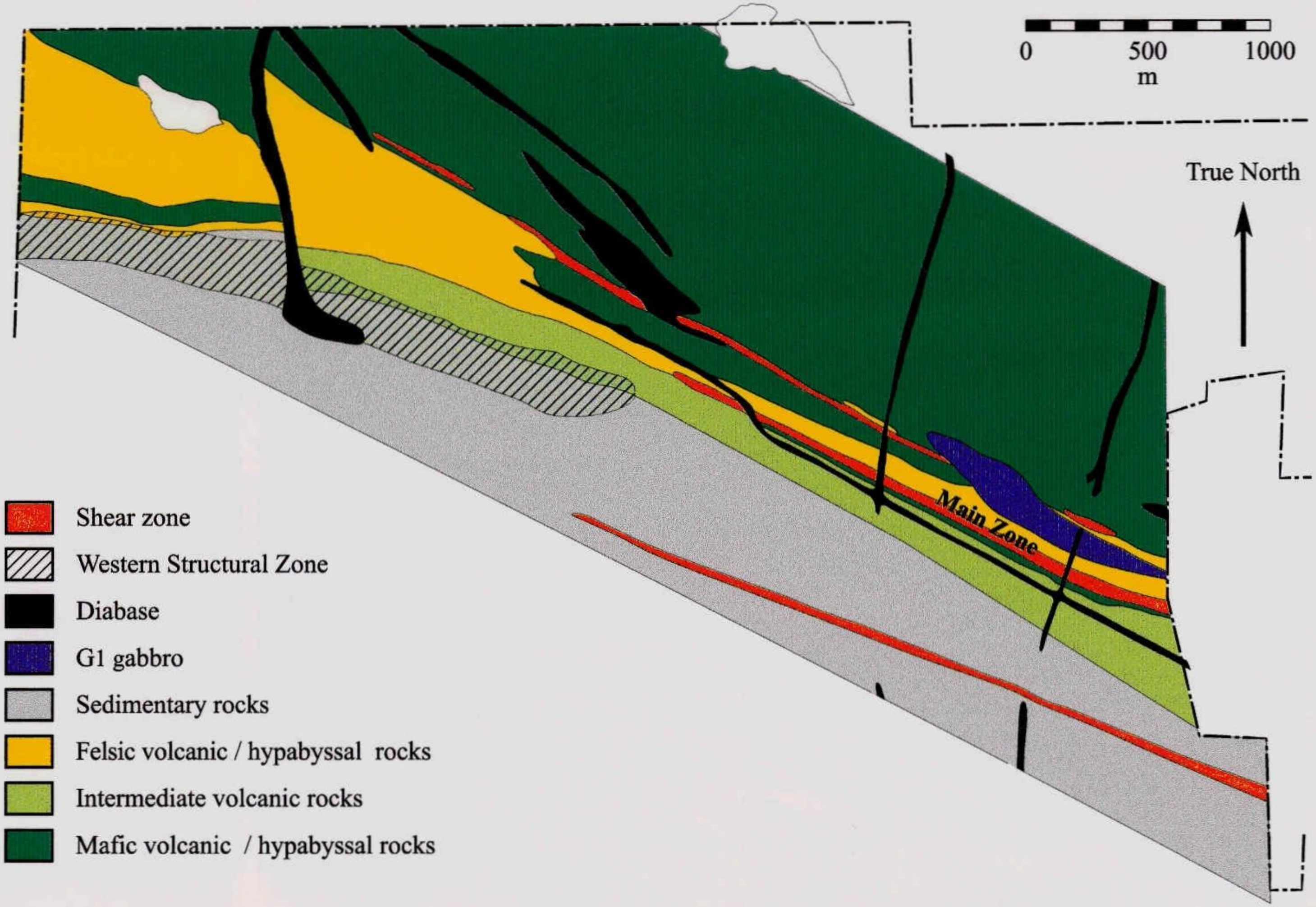


**Figure 2.** Geology of the M-1 grid. After a map by Granges Incorporated.

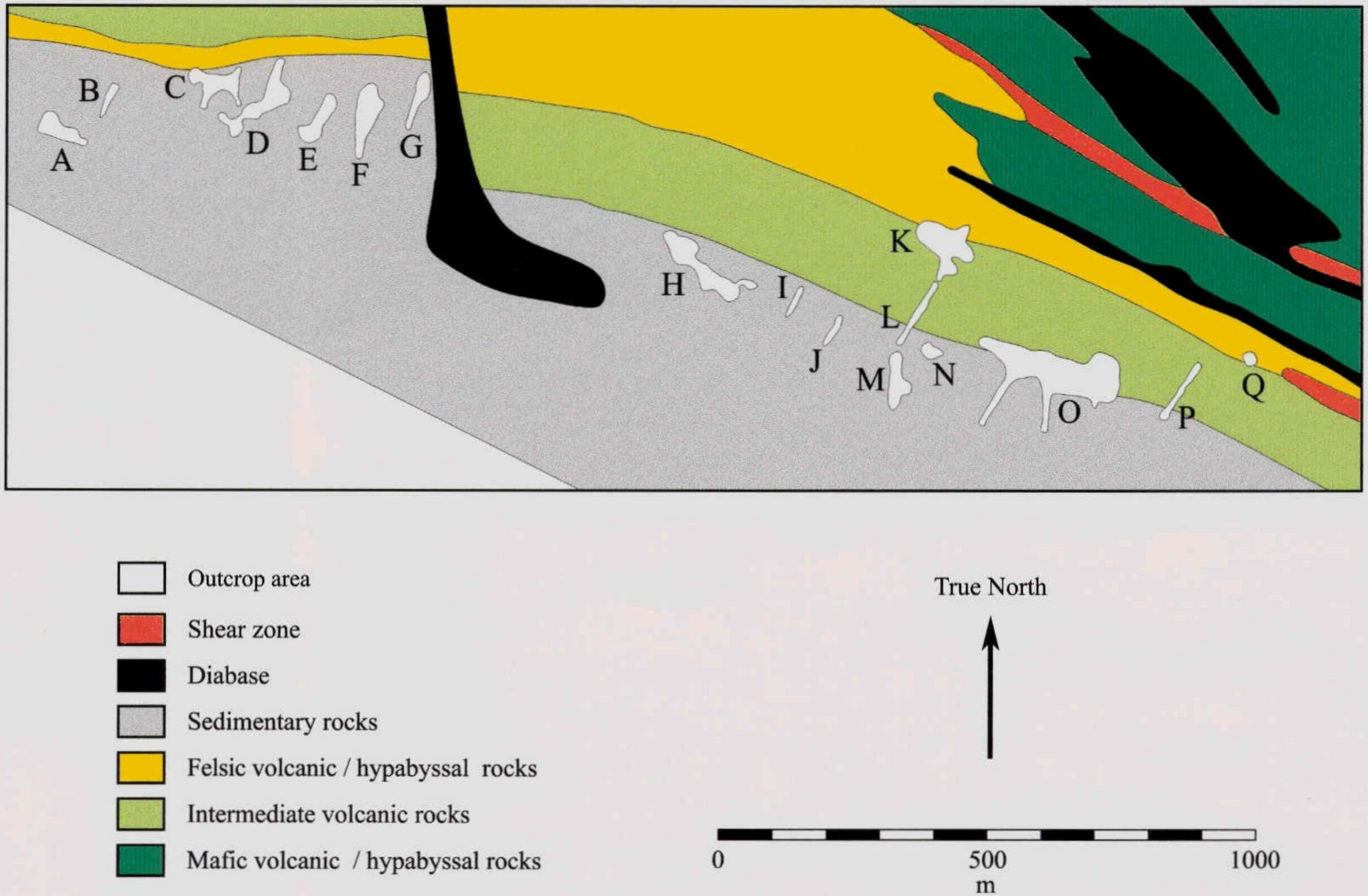


**Figure 3.** The study area. The map shows all of the stripped outcrop areas except for the area at the Main Zone. After a map by Granges Incorporated.

## STRUCTURAL GEOLOGY - THIS STUDY

### Schistosity

Within the study area there are many schistose rocks. Some are schistose because they contain abundant inequant metamorphic minerals, and some are schistose because they contain abundant inequant metasomatic minerals. Thus some of the rocks are schistose because of their original composition, and some of the rocks are schistose because they were altered by hydrothermal fluids.

In terms of orientation there is one schistosity, but in terms of timing there are two: a schistosity that is defined by inequant metamorphic minerals, and a schistosity that is defined by inequant metasomatic minerals. The two schistosities are parallel to each other. From now on, when I say "the schistosity" without saying "metamorphic" or "metasomatic" I shall mean both schistosities.

Except near the noses of some folds, the schistosity is parallel to bedding. Schistosity and bedding strike between 085° and 090° at the west end of the study area, and between 100° and 125° at the east end of the study area. Dips range from 40° to 79° to the north and average about 65° to the north (Figure 4). In many outcrop areas the strike and dip of the schistosity and bedding vary by as much as 10°.

The strike of the schistosity roughly parallels the contact between the supracrustal rocks and the granitoid rocks to the north of the study area (see Figure 022.3 of Reid and Reilly, 1987).

### Folds

I found three sets of folds in the study area. Let's call them set 1, set 2, and set 3.

The folds of set 1 are closed (with inter-limb angles smaller than 90°) to isoclinal (with inter-limb angles close to 90°), asymmetric folds. The schistosity is axial planar to the folds, and is not folded by them.

Fold axes are horizontal or plunge at less than 45° to the east. On vertical surfaces, the folds are Z-shaped. On outcrop surfaces that are flat or dip to the west they are Z-shaped, but on outcrop surfaces that dip to the east at an angle that is larger than their plunge they are S-shaped. Folds are named looking down-plunge, so the S-shaped ones are still technically Z folds.

Because fold axes plunge at shallow angles, traces of folds on outcrop surfaces commonly appear to be isoclinal (Photographs 1 and 2). In most folds the schistosity is penetrative, but in some folds the metamorphic schistosity forms a spaced cleavage (Photograph 3). The folds may be harmonic (adjacent folds are identical in shape) (Photograph 4) or disharmonic. The limbs of some folds are thinned (Photograph 4). Some of the folds have rounded hinges (Photograph 2), and some have no hinges (Photograph 4); the latter folds are chevron folds.

The folds of set 2 are open (with inter-limb angles larger than 90°), asymmetric kink folds arrayed in kink bands (Photograph 5). They fold the schistosity.

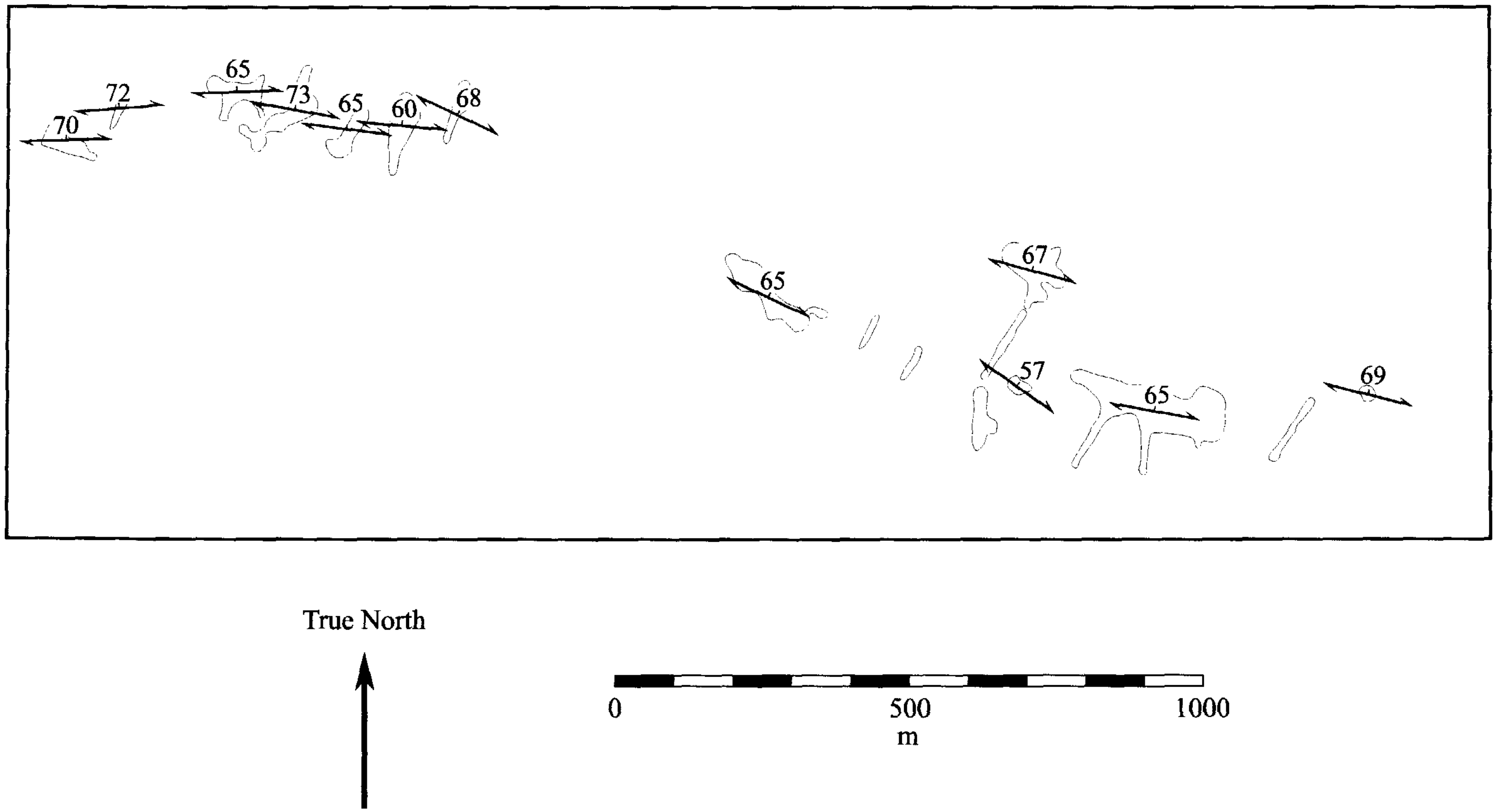


**Figure 4.** Schistosity within the study area. The map shows all of the stripped outcrop areas except for the area at the Main Zone.

Within a kink band, the kink folds are harmonic. Harmonic chevron folds of set 1 can be distinguished from harmonic kink folds of set 2 by the fact that the schistosity is axial planar to the folds of set 1 and folded by the folds of set 2.

On outcrop surfaces, some kink folds are Z-shaped and some are S-shaped. Within a kink band the schistosity is rotated, and across a kink band the schistosity is offset. Like a shear zone, then, a kink band may be right-handed (dextral) or left-handed (sinistral). Bands of Z-shaped kink folds are right-handed kink bands, and bands of S-shaped kink folds are left-handed kink bands (Figure 5). The right-handed kink bands and left-handed kink bands are conjugate (Photograph 5).

Let's say that the strike of the schistosity is 090°, and that a° and b° are angles that are smaller than 90°. The strike of the right-handed kink bands is (090° - a°) and the strike of the left-handed kink bands is (090° + b°) (Figure 5). a° and b° vary from place to place, and a° is not necessarily equal to b°. a° is commonly smaller than b°. Measured on outcrop surfaces, (a° + b°) is generally larger than 90°, a° can be as small as 20° (Photograph 6), and b° can be almost 90°. Thus the angles between kink bands and the schistosity vary, the angle between right-handed kink bands and the schistosity is not necessarily equal to the angle between left-handed kink bands and the schistosity, and the angle between right-handed kink bands and the schistosity is commonly smaller than the angle between left-handed kink bands and the schistosity. Measured on outcrop surfaces, the angle between conjugate kink bands measured across the schistosity is generally larger than 90°, the angle between right-handed kink bands and the schistosity can be as small as 20°, and the angle between left-handed kink bands and the schistosity can be as large as 90°.

At the west end of the study area, where the schistosity strikes about 090°, left-handed kink bands strike to the northwest, north-northwest, or north, and right-handed kink bands strike to the northeast or east-northeast. At the east end of the study area, where the schistosity strikes about 112°, left-handed kink bands strike to the north-northwest, north, or north-northeast, and right-handed kink bands strike to the east-northeast or east.

Few of the kink bands are exposed in a way that allows their dip to be determined. Most of them appear to dip steeply.

Within the plane of the schistosity, axes of S-shaped kink folds pitch at moderate to steep angles to the west (Figure 6a and b) and axes of Z-shaped kink folds pitch at moderate to shallow angles to the east (Figure 6c and d). Where the angle between a kink band and the schistosity is large the axes of the kink folds plunge at an angle that is nearly equal to the dip of the schistosity (as in Figure 6b), and where the angle between a kink band and the schistosity is small the axes of the kink folds plunge at an angle that is much smaller than the dip of the schistosity (as in Figure 6d). At the west end of the study area axes of S-shaped kink folds trend to the northwest, north-northwest, or north, and axes of Z-shaped kink folds trend to the northeast or east-northeast. At the east end of the study area axes S-shaped kink folds trend to the north-northwest, north, or north-northeast, and axes of Z-shaped kink folds trend to the east-northeast or east.

Measured on outcrop surfaces, the width of most kink bands is between 1 and 5 centimetres. A few kink bands are up to 20 centimetres wide, and one is two metres wide.

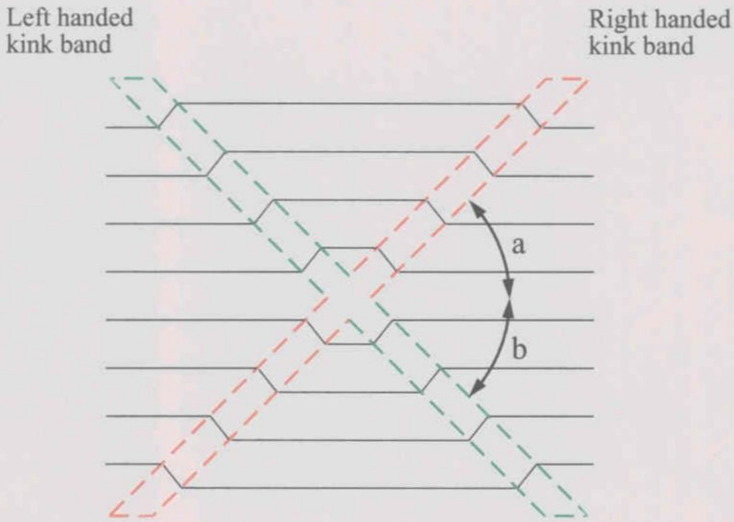


**Figure 5.** Conjugate kink bands. The horizontal black lines represent the schistosity.

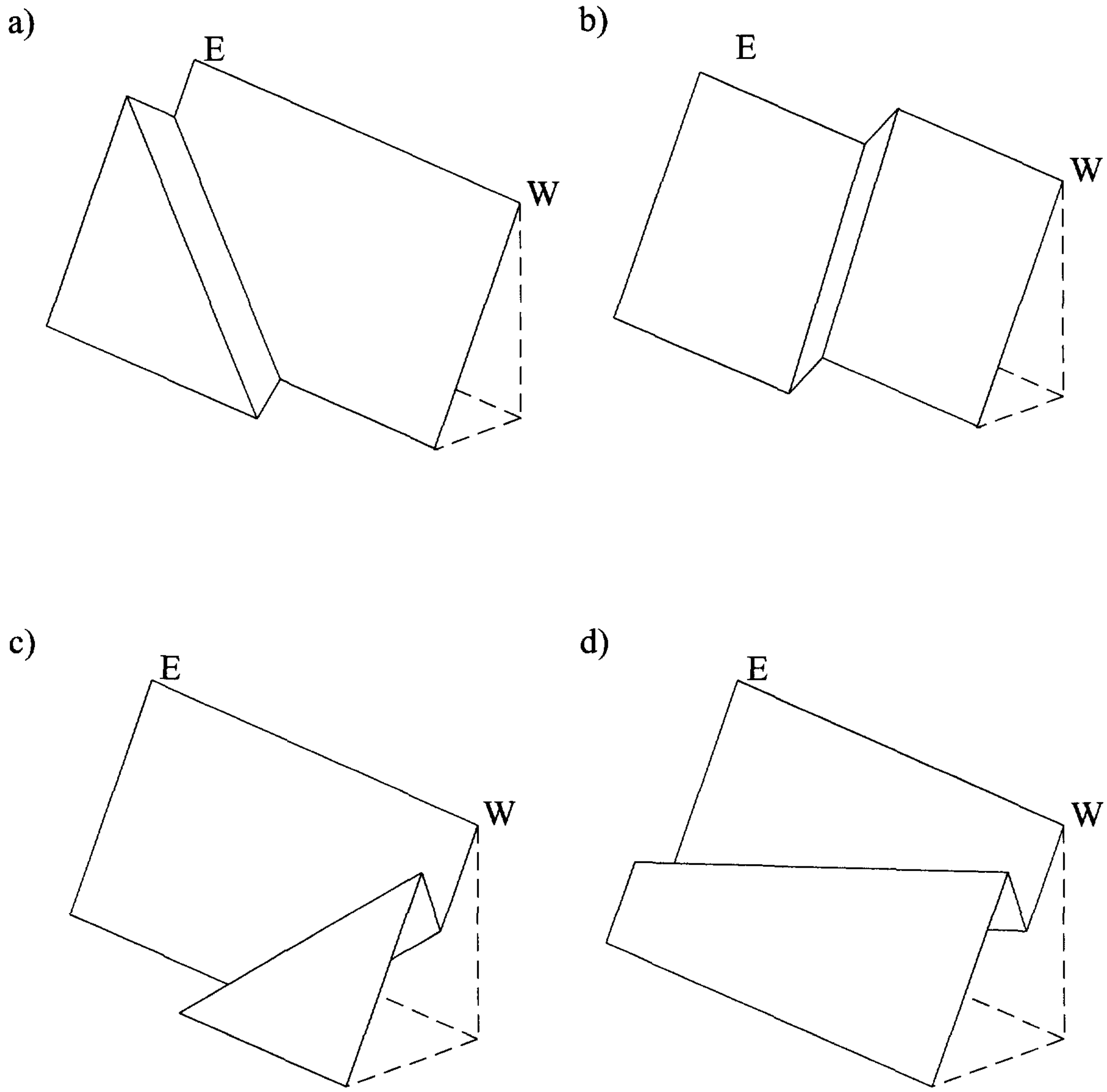


**Figure 6.** Plunging kink folds.

At the south end of outcrop area B, changes in the orientation of the schistosity from outcrop to outcrop indicate the presence of a kink band that must be several metres wide. All of the kink bands that are larger than about 5 centimetres are left-handed kink bands; there are no wide right-handed kink bands exposed in the study area.

In a few places kink bands contain shear fractures (Photograph 7), or turn into shear fractures along strike. In each case, the offset across the shear fractures, or faults, is the same as the offset across the kink band.

There are two types of kink bands: extensional and contractual (Figure 7). Within the study area, all of the kink bands are contractual (compare Figure 7b and c with Figure 5a). The kink bands are thus a kind of buckle fold. In a "normal" buckle fold, both limbs have been rotated. In a kink fold, however, only one limb, the limb within the kink band, has been rotated. Where the spacing between kink bands is about the same as their widths, the kink folds resemble normal, chevron-shaped buckle folds (Photograph 8).

The folds of set 3 fold the schistosity. Because they have wavelengths and amplitudes that are generally about 1 mm, we can call them crenulations (Photograph 9). They appear to be open, and may be symmetric or asymmetric.

In most places, crenulation axes pitch to the east in the plane of the schistosity and plunge at shallow angles (up to about 22°) to the east. At outcrop area N, some axes pitch to the west and plunge at a very shallow angle to the west.

The kink folds and crenulations fold the schistosity, but the folds of set 1 do not. Thus the kink folds and crenulations must be the same age as or younger than the schistosity, and the folds of set 1 must be older than or the same age as the schistosity. Let's say, then, that the folds of set 1 are early folds.

At outcrop area H, an early fold was refolded by a kink fold (Photograph 10).

**Low-angle shear fractures**

There are fractures of every orientation cutting the rocks in the study area. Among them are sets of fractures that lie at low angles (less than 45°) to the schistosity. They are easiest to see in the felsic to intermediate volcanic rocks, and less obvious, but still present, in mafic volcanic rocks and in sedimentary rocks.

The fractures that lie at low angles to the schistosity are commonly marked by products of hydrothermal activity such as mica, chlorite, rusty carbonate, rusty sulphides, and quartz. In many places, they divide the outcrop into "diamonds" that range in size from a few millimetres to tens of centimetres (Photographs 11 and 12). Where weathering has caused the diamonds to separate, outcrop surfaces are rubbly (Photograph 13).

The fractures that lie at a low angle to the schistosity are "low-angle" shear fractures. According to currently accepted theories, shear fractures should form at a low angle (less than 45°) to the greatest compressive stress, and thus at a high angle (more than 45°) to a related schistosity. Where rocks are deeply buried, however, shear fractures form at a high angle to the greatest compressive stress and thus at a low angle (between about 15° and 30°) to a related schistosity. Common in Archean greenstone belts, low-angle shear fractures were recognized early in this century but are rarely recognized today (see, for example Wilson et. al, 1984). I used to call these fractures high-angle shear

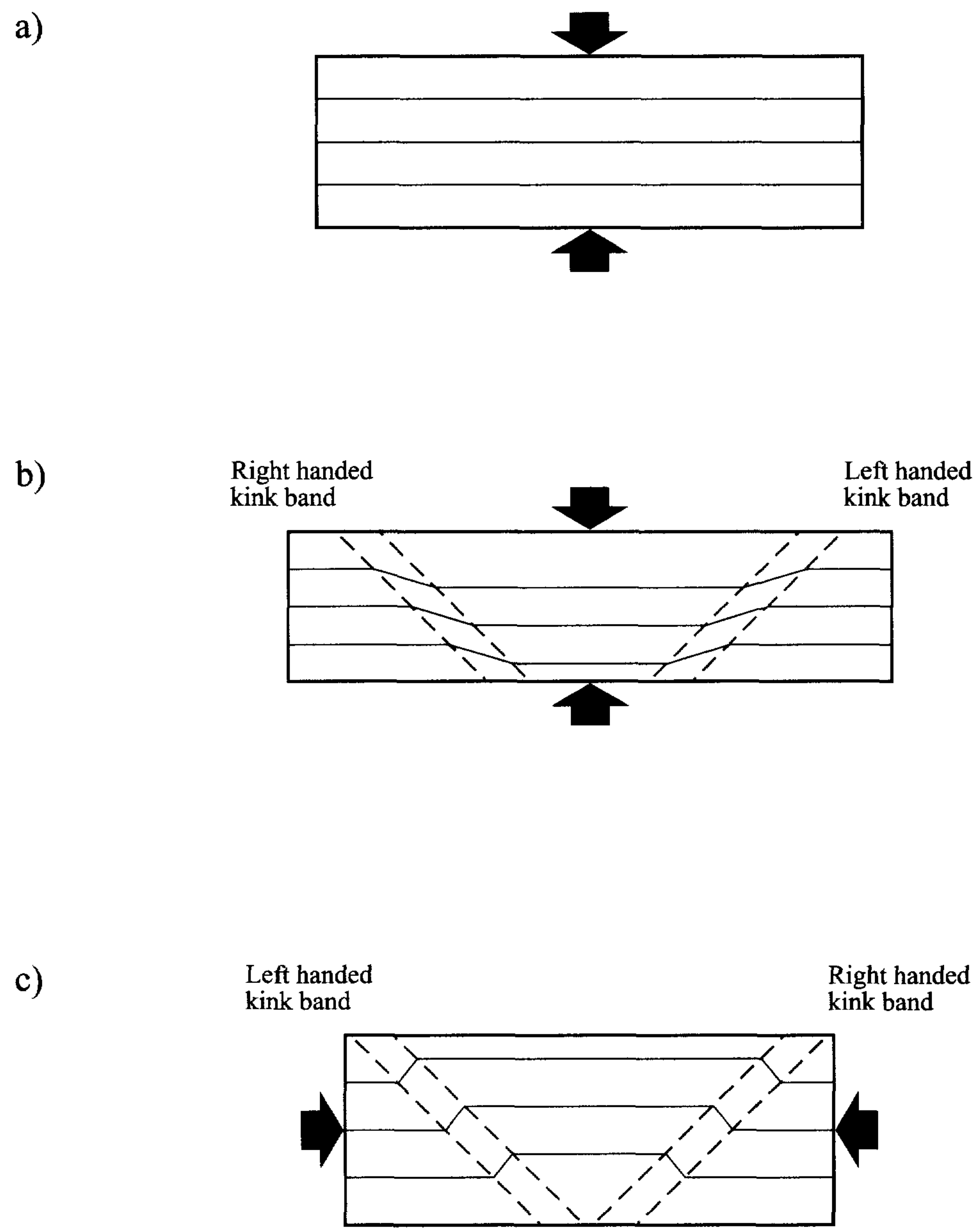


**Figure 7.** The formation of kink bands. The black horizontal lines represent the schistosity, and the black arrows represent the approximate direction of squeezing. a) The formation of the schistosity. b) The formation of extensional kink bands. c) The formation of contractual kink bands.

fractures. Calling them high-angle shear fractures, for their relationship to the greatest compressive stress, favours theoreticians. Calling them low-angle shear fractures, for their relationship to the schistosity, favours field geologists.

Let's say that the strike of the schistosity is 090°, and that a° and b° are smaller than 90°. The low-angle shear fractures that strike at (090° - a°) are left-handed (Figure 8a), and the low-angle shear fractures that strike at (090° + b°) are right-handed (Figure 8b). a° and b° vary from place to place, and a° is not necessarily equal to b°. Measured on outcrop surfaces, a° and b° are generally smaller than 15°, and can be as small as a few degrees. Thus the angles between shear fractures and the schistosity vary, and the angle between right-handed shear fractures and the schistosity is not necessarily equal to the angle between left-handed shear fractures and the schistosity. Measured on outcrop surfaces, the angle between shear fractures and the schistosity is generally smaller than 15°, and can be as small as a few degrees. Where the angle between right-handed shear fractures and the schistosity is equal to the angle between left-handed shear fractures and the schistosity, the schistosity bisects the acute angles between conjugate shear fractures and parallels the long axes of diamonds (Figure 9).

Both the right-handed and the left-handed low-angle shear fractures dip to the north.

Intersections between conjugate low-angle shear fractures pitch at moderate to steep angles to the west within the plane of the schistosity, and plunge at moderate angles. At the west end of the study area, where the schistosity strikes about 090°, intersections trend to the northwest, north-northwest, or north. At the east end of the study area, where the schistosity strikes about 112°, intersections trend to the north-northwest, north, or north-northeast.

Offsets across the low-angle shear fractures are very small, and generally invisible to the unaided eye. The slip vector along conjugate shear fractures was perpendicular to their intersection. Because intersections pitch to the west, slip vectors pitch to the east. Thus the motion along the shear fractures was oblique: the right-handed shear fractures had a normal component of motion, and the left-handed shear fractures had a reverse component of motion. Where intersections pitch steeply, the motions were predominantly strike slip.

**Faults**

Some very narrow shear fractures, or faults, have visible offsets across them. In places, closely spaced faults form fault zones. Where the dips of faults can be observed, they are commonly steep to vertical. All of the faults offset the schistosity.

Some faults lie at a low angle (less than 45°) to the schistosity, but most lie at a high angle (greater than 45°). The ones that lie at low angles to the schistosity may be low-angle shear fractures that are related to the rest of the low-angle shear fractures, low-angle shear fractures that were the result of later squeezing perpendicular to the greenstone-granite contact, or low-angle or high-angle shear fractures (high-angle shear fractures are the ones we read about in textbooks) that were the result of some other direction of squeezing. The ones that lie at high angles to the schistosity may be high-

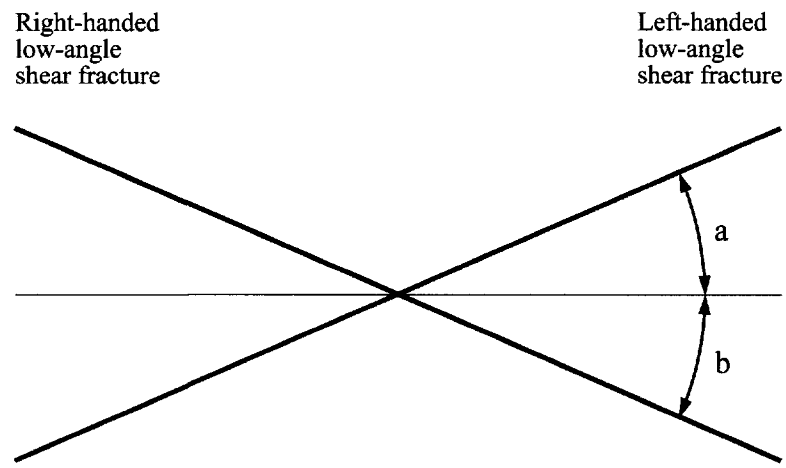


**Figure 8.** Conjugate low-angle shear fractures. The horizontal black line represents the schistosity.

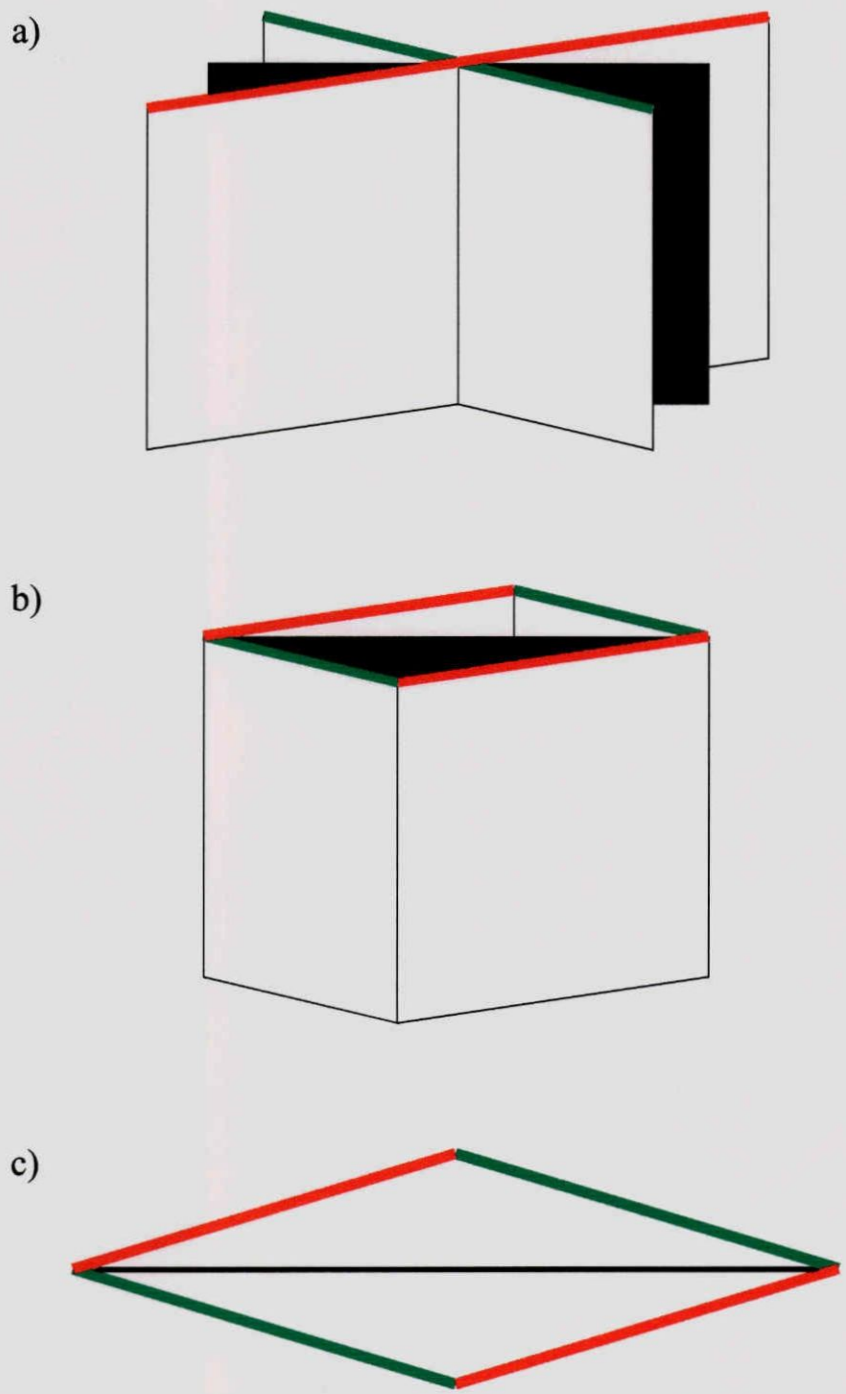


**Figure 9.** Diamonds. The black lines represent the schistosity, the green lines reprsent right-handed low-angle shear fractures, and the red lines represent left-handed low-angle shear fractures.

angle shear fractures that were the result of relatively late squeezing perpendicular to the greenstone-
granite contact, or low-angle or high-angle shear fractures that were the result of some other direction of squeezing. Some of the faults that lie at high angles to the schistosity are high-angle shear fractures that are related to the kink bands (Photograph 7).

At the west end of the study area, where the schistosity strikes about 090°, left-handed faults that are related to left-handed kink bands strike to the northwest, north-northwest, or north, and right-handed faults that are related to right-handed kink bands strike to the northeast or east-northeast. At the east end of the study area, where the schistosity strikes about 112°, left-handed faults that are related to left-handed kink bands strike to the north-northwest, north, or north-northeast, and right-handed faults that are related to right-handed kink bands strike to the east-northeast or east.

A fault or fault zone may appear to be clearly left-handed or right-handed, but appearances can be deceiving. At an outcrop in area O, for example, a thick quartz vein terminates against a pair of fault zones (see Map 4 of Wilson, 1997). The horizontal offset of the vein across the fault zones is right-handed. Although the horizontal offset is about 25 metres, the fault zones can not be traced into another outcrop that is only a few metres away. On a fault surface that strikes 150° and dips 80° to the east, mineral aggregates pitch very steeply to the northwest. If the mineral aggregates are slickenlines (also known as slickensides, they are lines that mark the slip vector along the fault) then the fault was either right-handed and reverse or left-handed and normal, but motion was predominantly dip slip. The vein dips to the north. To produce a right-handed offset, the fault would have to be normal. Thus if the mineral aggregates are slickenlines then the fault is left-handed and normal. The right-handed offset would then be a result of the predominance of normal dip-slip over left-handed strike slip.

Many other high-angle faults have offsets across them. Without further data we can not be sure of the sense of motion along them.

### Lineations

In terms of orientation, there is one predominant lineation. In terms of timing, there are three: an elongation (stretching) lineation defined by metamorphic minerals and primary clasts (Photograph 14); an elongation lineation defined by metasomatic minerals (Photograph 15); and an intersection lineation defined by intersections between low-angle shear fractures (Photographs 14, 16, and 17). The three lineations are parallel to each other. Together, they pitch at moderate to steep angles to the west within the schistosity, more or less perpendicular to crenulation axes.

### Products of hydrothermal activity

The most abundant products of hydrothermal activity are mica, chlorite, carbonate, sulphides, and quartz. The most important product of hydrothermal activity is gold.

There are three main varieties of quartz veins: white, fine to medium-grained, milky quartz veins; white and grey to black, fine-grained, milky to opaque quartz-tourmaline veins; and grey to black, medium to coarse-grained, clear to milky quartz veins. Let's call them white quartz veins, quartz-tourmaline veins, and smoky quartz veins. White quartz veins are much less abundant than smoky quartz veins, and quartz-tourmaline veins are relatively rare. There may be other varieties of quartz veins, and there may be more than one generation of each variety.

According to Bates and Miree (1991), gold is hosted by, and in the mafic volcanic rocks at the Main Zone hosted by and adjacent to, smoky quartz veins.

Hydrothermal products were emplaced predominantly along low-angle shear fractures or along schistosity or bedding planes. Where they were emplaced along schistosity or bedding planes, hydrothermal fluids must have produced "hydraulic" fractures.

Mica, chlorite, carbonate, and sulphides were emplaced along low-angle shear fractures and along fractures that are parallel to the metamorphic schistosity and the bedding. Within low-angle shear fractures, the metasomatic schistosity may be parallel to the schistosity outside the fracture, or rotated into parallelism with the fracture. All of these hydrothermal products were folded by kink folds.

White quartz veins were emplaced along low-angle shear fractures and along fractures that are parallel to the schistosity and bedding. They were folded by early folds (Photograph 18) and by kink folds. Some thicker white veins are boudinaged. The white quartz veins do not appear to be spatially associated with other products of hydrothermal alteration, or with early folds or kink folds.

There are relatively few quartz-tourmaline veins. At least some of them were emplaced along kink bands (Photograph 19).

Like the white quartz veins, smoky quartz veins were emplaced along low-angle shear fractures and along fractures that are parallel to the schistosity and bedding. They were emplaced along both senses of low-angle shear fractures (Photograph 20), but in most places most veins were emplaced along left-handed shear fractures (Photograph 21).

At the southwest corner of outcrop area D and in portions of outcrop areas K and O, smoky quartz veins were emplaced along fractures that lie at a high angle to the schistosity. These fractures could be extension (tension) fractures related to the low-angle shear fractures, high-angle shear fractures related to the kink bands, or some other high-angle or low-angle shear fractures.

Where they were emplaced along low-angle shear fractures, the smoky quartz veins are oblique to the schistosity and to bedding. At the Main Zone, the pit trends about 108° and the bedding plane between the mafic volcanic rocks that surround the pit and the felsic volcanic rocks immediately to the north strikes about 118°. On the north side of the pit the strike of the schistosity ranges from 105° to 128°, but is predominantly between 123° and 128° (Photograph 22). If the pit is parallel to the strike of smoky quartz veins, then the smoky quartz veins were emplaced along left-handed low-angle shear fractures, oblique to the schistosity and bedding.

Where smoky quartz veins are at a small angle to the schistosity and bedding, some of the thicker ones are boudinaged (Photograph 23). In vertical sections, boudins appear to be equant or prolate. Axes of prolate boudins plunge steeply to the east.

At some places smoky quartz veins appear to follow early folds or kink folds, but in most places they cut across them (Photograph 24).

Some of the smoky quartz veins that were emplaced along fractures that cut the schistosity at high angles are folded (Photograph 25). The fractures commonly dip at small angles to the east, so fold axes commonly plunge at small angles to the east.

Some of the features that appear to be folds in smokey quartz veins are probably the result of emplacement along intersecting low-angle fractures: the veins simply terminate where they intersect.

Except at outcrop areas K and O, the smoky quartz veins commonly have short strike lengths. Where they are most abundant, they occur as aggregates of veins (Photograph 26). Aggregates are commonly spatially associated with other products of hydrothermal alteration, such as mica, chlorite, carbonate, and sulphides (Photograph 27), and with kink folds (Photograph 28).

Although some aggregates of smoky quartz veins appear to be confined to particular beds, the veins are commonly oblique to bedding. Thus aggregates may be strata-bound, but they are not stratiform.

At one place in outcrop area H, an aggregate of smokey quartz veins lies close to the noses of early folds. Elsewhere in the outcrop area, and elsewhere in the study area, aggregates of smoky veins do not appear to be associated with fold noses.

**Synthesis**

Most of the rocks in the study area were originally pyroclastic or epiclastic. Some were tuffs or mudstones, and some were lapilli tuffs or conglomerates.

Portions of the rocks have been metasomatized, portions have been folded by early folds, portions have been folded by kink folds, and portions have been folded by crenulations. Metasomatism, early folding, kink folding, and crenulation occurred throughout the study area. Some metasomatized rocks contain abundant kink folds, and some contain few, if any kink folds. Some early folds are spatially associated with metasomatized rocks, and some are not. Kink folds and crenulations are most abundant within schistose rocks, and are thus commonly spatially associated with metasomatized rocks.

A metamorphic schistosity, a metasomatic schistosity, a metamorphic elongation lineation, a metasomatic elongation, and low-angle shear fractures occur throughout the study area. Because there are low-angle shear fractures everywhere, there is an intersection lineation everywhere.

Smoky quartz veins occur throughout the study area. They are younger than the kink bands, and they do not appear to be spatially associated with early folds, kink folds, or crenulations. Because metasomatized rocks are older than the kink bands, smoky quartz veins may be spatially associated with metasomatized rocks but can not be temporally associated with them. In places smoky quartz veins appear to follow fractures that were folded by early folds or kink folds, but in general they cut across early folds and kink folds.

Metasomatic fluids appear to have followed low-angle shear fractures, fractures that parallel the schistosity, and, in a few places, fractures that are at a high angle to the schistosity.

Where smoky quartz veins were emplaced along fractures that are at a high angle to the schistosity they commonly dip to the east. When the low-angle shear fractures formed, the intermediate compressive stress plunged to the northwest parallel to intersection lineations, so the least compressive stress plunged to the northeast. If extension (tension) fractures formed at the same time as the low-angle shear fractures, they would dip to the west. Thus if the fractures that are at a high angle to the schistosity are extension (tension) fractures, they are not related to the low-angle shear fractures.

When the metamorphic schistosity and elongation lineation formed, when the metasomatic schistosity and elongation lineation formed, when the early folds formed, when the low-angle shear fractures formed, and when folds and boudins formed in the smoky quartz veins, the horizontal projection of the greatest compressive stress was perpendicular to the contact between the supracrustal rocks and the granitoid rocks that now lie to the north of the study area. Thus the schistosities, the elongation lineations, the early folds, the low-angle shear fractures, and the folds and boudins in the smoky quartz veins were the result of squeezing perpendicular to the greenstone-granite contact. Presumably, they were products of the subsidence of the supracrustal rocks and rise of the granitoid rocks.

When the metamorphic schistosity and elongation lineation formed, when the metasomatic schistosity and elongation lineation formed, and when the early folds formed, the least compressive stress plunged to the northwest and the intermediate compressive stress plunged to the northeast. When the low-angle shear fractures formed, the intermediate compressive stress plunged to the northwest and the least compressive stress plunged to the northeast. Thus the low-angle shear fractures did not form at the same time as the schistosities, the elongation lineations, or the early folds.

When the kink folds formed, the horizontal projection of the greatest compressive stress was more or less parallel to the greenstone-granite contact. Thus the kink folds were the result of squeezing that was roughly parallel to the greenstone-granite contact. Although they may have formed during the subsidence of the supracrustal rocks and rise of the granitoid rocks, they were the result of some other tectonic event.

The following sequence of events can be determined from current field data:

1. the emplacement of at least some of the white quartz veins
2. the formation of the early folds
3. the formation of the two schistosities and elongation lineations, the formation of the low-angle shear fractures, and the emplacement of the carbonate, the sulphides, and the quartz-tourmaline veins
4. the formation of the kink folds
5. the emplacement of the smoky quartz veins
6. the formation of folds and boudins in the smoky quartz veins

The schistosities, elongation lineations, and low-angle shear fractures were the result of squeezing perpendicular to the greenstone-granite contact, the kink folds were the result of squeezing roughly parallel to the greenstone-granite contact, and the folds and boudins were the result of squeezing perpendicular to the greenstone-granite contact. At the very least, then, the rocks were subjected to squeezing perpendicular to the greenstone-granite contact, then squeezing roughly parallel to the greenstone-granite contact, and then renewed squeezing perpendicular to the greenstone-granite contact.

When the schistosities and elongation lineations formed the least compressive stress plunged to the northwest, and when the low-angle shear fractures formed the intermediate compressive stress plunged to the northwest. The formation of the metasomatic schistosity and elongation lineations and the formation of the low-angle shear fractures probably occurred over an interval of time. During that interval of time the orientation of the greatest compressive stress stayed the same but the orientations of the least and intermediate compressive stresses switched, possibly more than once.

According to Bennett and Thurston (1977), top determinations of primary structures such as graded bedding indicate that the supracrustal rocks that are found in and around the study area are folded. Their Figure 2 shows a syncline to the south of the study area and an anticline to the southeast of the study area. The syncline plunges at a shallow angle to the east. Since both limbs of the syncline dip to the north, it is overturned. A map by Reid and Reilly (1987) shows the same overturned syncline (Figure 10).

The early folds are drag folds that are parasitic to the overturned syncline. Given the number of early folds visible in the study area, it is probable that the Mishi Gold property contains many early folds at all scales.

The early folds were the result of bedding-parallel simple shear within shear zones. Bedding dips to the north and the folds plunge to the east, so the slip vector plunged to the northwest, at a different trend and plunge than the least compressive stress. As the folds became isoclinal, the slip vector became parallel to the least compressive stress. Because the folds formed before the early schistosity and the related elongation lineation, the shear zones that produced the folds are not marked by any related fabrics. However, because the stress field was the same during the formation of the elongation lineation, and because the elongation lineation marks the orientation of the least compressive stress, the elongation lineation marks the orientation of the earlier, and unrelated, slip vector.

Since the shear zones that produced the early folds are not marked by any related fabrics, let's say that they are cryptic. Across the Mishibishu Lake greenstone belt, wherever there are early folds there are cryptic shear zones. The Mishi Gold property may contain numerous cryptic shear zones, or may contain and be surrounded by one very large cryptic shear zone.

A zone that contains low-angle shear fractures could be called a shear zone. On a microscopic scale, features such as clasts and fabrics may be distorted, rotated, or destroyed close to and within the low-angle shear fractures. On a macroscopic scale, however, the shear zone would contain both left-handed and right-handed shear fractures, so it would not have any particular sense of shear; there would be no offset across it, and

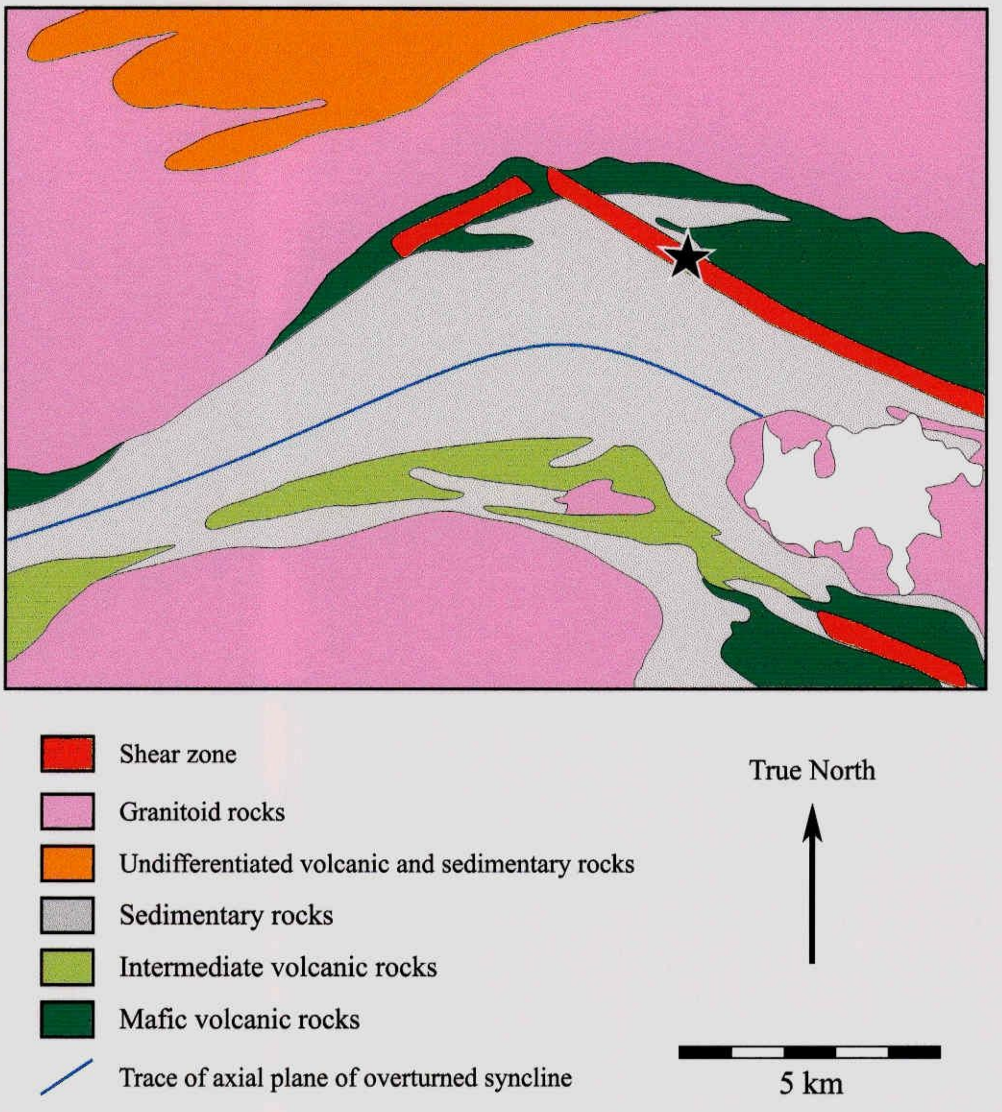


**Figure 10.** Geology according to Reid and Reilly. The Mishi Gold property is represented by a star. After Reid and Reilly (1987).

some features would be rotated clockwise and some features would be rotated counterclockwise. Instead of being a zone of simple shear, it would be a zone of pure shear.

Let's say that a zone that contains low-angle shear fractures is a pure shear zone. Wherever there are low-angle shear fractures there are pure shear zones. The Mishi Gold property may contain many pure shear zones, or may contain and be surrounded by one very large pure shear zone.

Metasomatism, including the emplacement of smoky quartz veins, is younger than, and does not appear to be spatially associated with, early folds. Thus metasomatism does not appear to be associated with cryptic shear zones. Other than very narrow bands adjacent to low-angle shear fractures, there are no other simple shear zones.

Metasomatism can be localized along a shear zone. We could say, therefore, that alteration can be localized by deformation. Within the study area, the most obvious deformation is the kink folds. The kink folds are younger than, and most abundant in, the schistose metasomatized zones. Thus deformation was localized by alteration.

## STRUCTURAL GEOLOGY AND GOLD - PREVIOUS STUDIES
## Part 1: Structures other than faults

### Heather (1985, 1986, and 1991)

According to Heather, the rocks of the Mishibishu Lake greenstone belt are cut by 'deformation zones'. One of the deformation zones crosses the Mishi Gold property (Figure 11). In 1985 Heather called it the Mishibishu Zone, in 1986 he called it the Mishibishu Deformation Zone, and 1991 he called it the Mishibishu Lake Deformation Zone. It's most commonly referred to as the Mishibishu Deformation Zone (MDZ).

On deformation zones:

- (1985) The Mishibishu Zone is a strongly deformed and altered, volcano-sedimentary package, which trends northwest and averages 150 m in width along its 16 km strike length. It is characterized by the development of a strong penetrative fabric, fibrous mineral growth on the penetrative fabric planes, asymmetric small-scale folds, and variable degrees of hydrothermal alteration.
- (1985) Within the Mishibishu Zone, original rock textures (e.g. bedding) are rarely preserved except where narrow beds of polymictic pebble conglomerate can be identified within highly schistose wackes and oligomictic quartz-granule conglomerates.
- (1985) A strong to intense penetrative foliation is defined by layer-parallel micas. The foliation is further enhanced by compositional layering of chlorite, sericite, and quartz-ankerite segregations.
- (1986) The majority of the supracrustal rocks in the Mishibishu Lake greenstone belt are weakly to moderately foliated. Several zones of

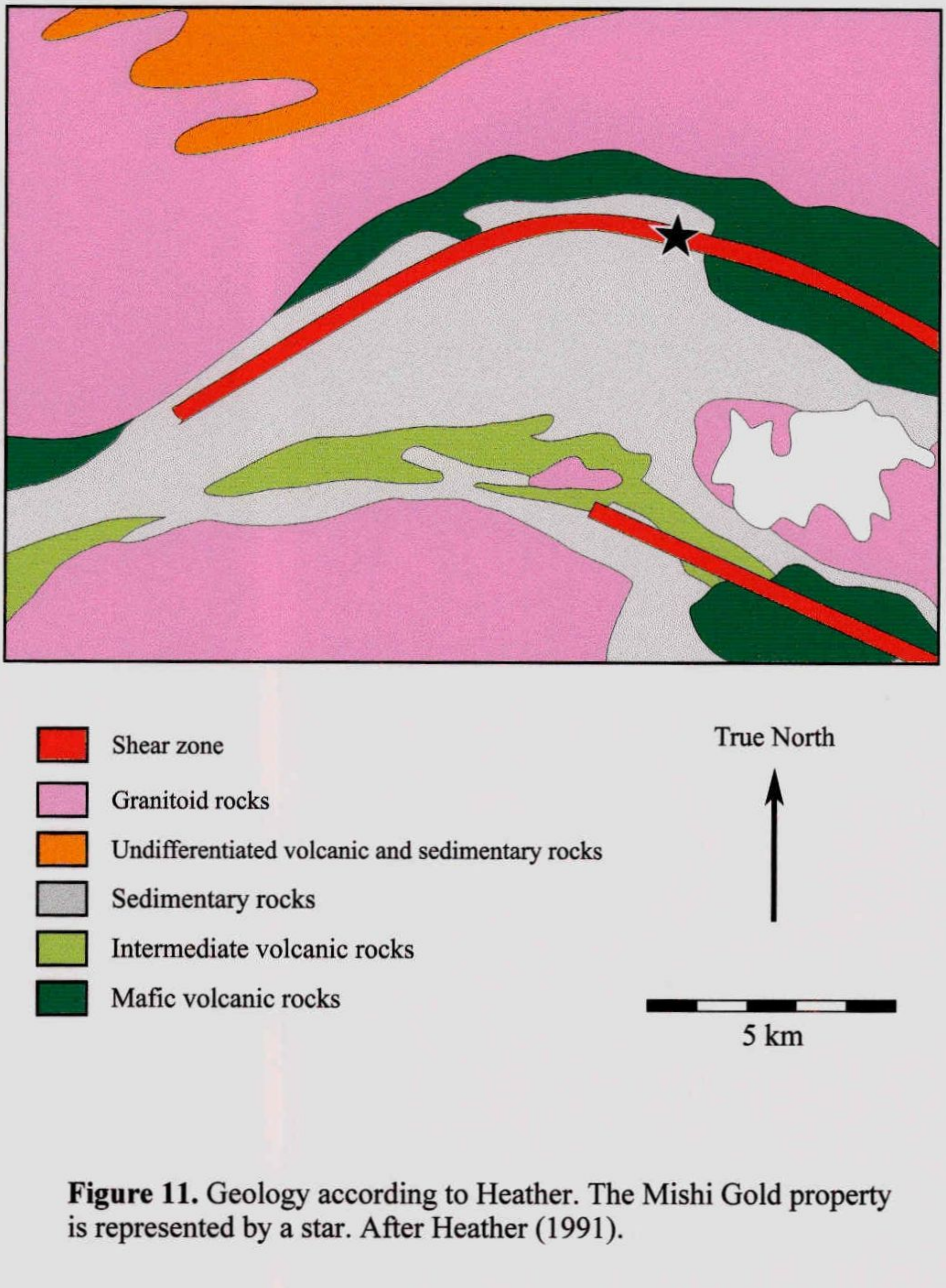


**Figure 11.** Geology according to Heather. The Mishi Gold property is represented by a star. After Heather (1991).

intensely foliated rocks, which have partially or totally lost their primary textures, define complex, high strain zones, herein referred to as deformation zones.

- (1986) These high-strain zones are commonly localized at lithological contacts (e.g. volcanic-sedimentary) due to the competency contrast between lithologies, which focused the stress created during tectonism.
- (1986) Rocks to the north and south of the MDZ exhibit an increasing state of strain as the MDZ is approached, and become intensely strained in the central core.
- (1986) The MDZ varies in width from 200 m to 500 m and is composed of several anastomosing shear zones.
- (1986) The MDZ is characterized by strong penetrative fabrics, a stretching lineation, asymmetric and symmetric chevron folds of the $S^1$ foliation, and conjugate sets of kink bands.
- (1986) The MDZ may have developed because of the emplacement of the large Pukaskwa Gneiss Complex to the north.
- (1986) The gold-bearing zones occur within the sericite-quartz schists as vein complexes which appear to cut the foliation at a low angle, indicating that they occupy a brittle fracture (e.g. a shear fracture) which developed late in the shear zone's history.
- (1991) The Mishibishu Lake Deformation Zone (MDZ) hosts much of the known gold mineralization in the Mishibishu Lake district, including the Magnacon gold mine, the Granges "Main Zone" deposit, and the "Glory" and "White Swan" occurrences. The MDZ is a 45 km long, and up to 2.5 km wide, arcuate zone coincident with a major mafic metavolcanic-clastic metasediment contact proximal to the northern margin of the Mishibishu Lake greenstone belt. The moderately to steeply north-dipping MDZ is a lithologically and structurally complex zone of anastomosing ductile and brittle-ductile shear zones measuring upwards of ten metres is width, and from several tens of metres up to several hundred metres in strike-length. The MDZ is characterized by dominantly oblique-slip displacement, however a complex structural history is indicated by conflicting kinematic indicators.
- (1991) Gold mineralization is associated with shear-zone hosted quartz veins with pyrite, arsenopyrite, galena, chalcopyrite, and minor pyrrhotite, as well as sulphide-bearing schists found adjacent to those veins. Alteration types include sericitization, carbonatization (ankerite and calcite), silicification, pyritization, and chloritization. Commonly, a systematic pattern of these alteration types flank the auriferous vein systems; intimately associated with the veins are sericite-quartz-(Fe-carbonate)-sulphide schists which grade outward to chlorite-(Fe-carbonate)-sericite-sulphide schists which in turn grade outward into chlorite-calcite-sulphide schists. This zonation is best developed within

rocks of intermediate to mafic composition (e.g., intermediate to mafic metavolcanics and mafic intrusions), and is more cryptically developed within rocks of felsic composition (e.g., metasediments, felsic metavolcanics and felsic intrusions).

On the Main Zone:

- (1986) The mafic volcanic rocks to the north form the hanging wall to the mineralization and consist of massive, medium- to coarse-grained, amphibole-plagioclase-bearing flows and sills, which are variably sheared to chlorite±calcite schists. Clastic sedimentary rocks to the south comprise the footwall and consist of interbedded polymictic conglomerates and fine- to coarse-grained wackes.

On the Magnacon property:

- (1986) The regional foliation (S fabric) is between 300° and 310°, whereas within the MDZ it becomes 280° to 290° (C fabric).
- (1986) A secondary (C′) fabric is seen deforming an earlier foliation within the panels hosting the Curtis and Bandy (Main) [Magnacon Main, not Mishi Gold Main] mineralized zones. Both sinistral and dextral movements are indicated, while the movement indicated by regional foliation trajectories is sinistral.
- (1986) Several cross structures, oriented between 335° and 025°, break the MDZ into panels. Small scale structural features, such as sense of movement on conjugate sets of kink bands, are consistent within individual panels, but differ within adjacent panels.
- (1986) Both the Curtis and Bandy (Main) [Magnacon Main, not Mishi Gold Main] Zones cut obliquely across the shear zone foliation (C fabric) at approximately 295 to 300°. Based on the apparent sinistral sense of shear indicated by regional foliation trajectories, the mineralized zones probably occupy shear fractures which developed late in the MDZ's history.

The property that contains the Magnacon Mine (now closed) lies immediately to the east of the M-1 grid of the Mishi Gold property.

Schistosity is commonly called an S fabric. Within a (simple) shear zone, portions of a schistosity may become rotated along narrow bands called shear bands. Shear bands are oblique to unrotated portions of the schistosity, and are commonly parallel to the shear zone. The unrotated portions of the schistosity define an S fabric, and the shear bands define a C fabric that is oblique to the S fabric (Figure 12). Thus an S fabric is a schistosity, and a C fabric is not. Where schistosity is parallel to a shear zone, people may mistakenly call the schistosity a C fabric. An S fabric and an associated C fabric constitute an S-C fabric. An S-C fabric can be used to determine the sense of shear along a shear zone.

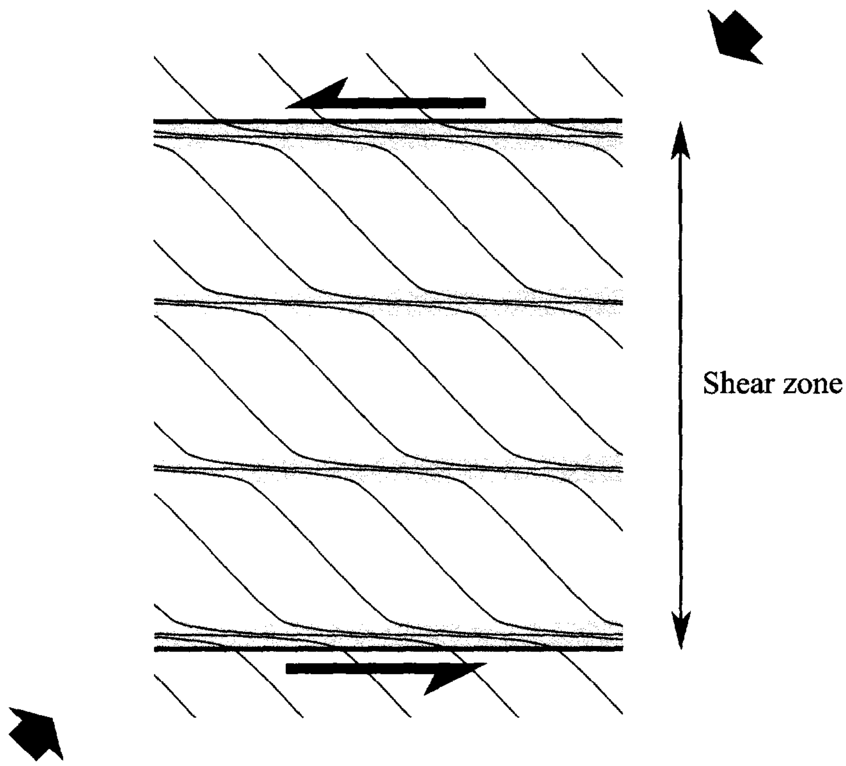


**Figure 12. An S-C fabric.** The shear zone is left-handed. The black lines represent the schistosity, the black arrows represent the direction of squeezing, and the grey bars represent left-handed shear bands.

Within a shear band, portions of the schistosity may become rotated along narrow bands that are also called shear bands. Thus a shear zone may contain primary shear bands, and primary shear bands may contain secondary shear bands. Secondary shear bands are oblique to unrotated portions of the primary shear bands, and define a C′ fabric that is oblique to the C fabric. Secondary shear bands that have the same sense of shear as the shear zone are synthetic shear bands, and secondary shear bands that have the opposite sense of shear to the shear zone are antithetic shear bands. In terms of the sense of shear along them, synthetic and antithetic shear bands resemble extensional kink bands (see Figure 7b).

I did not see any C fabrics, S-C fabrics, or C′ fabrics within the study area.

Heather never produced a detailed map of the deformation zones. The deformation zones shown by Heather (1991) are not coincident with the deformation zones shown by Reid and Reilly (1987) (see Figures 10 and 11). It is difficult to say, therefore, exactly where the deformation zones are. Because Heather never documented his observations, it is also difficult to say exactly what some features are, or exactly where some features are.

Heather's 'penetrative fabric', 'foliation', and 'S$^1$ foliation' are the schistosity. His 'fibrous mineral growth' is probably the elongation (stretching) lineation. His 'asymmetric small-scale folds' could be the early folds or the kink folds. 'Asymmetric chevron folds of the S$^1$ foliation' are kink folds, and 'symmetric chevron folds of the S$^1$ foliation' are probably closely-spaced kink folds. His 'compositional layering' may be metasomatic minerals emplaced along low-angle shear fractures.

Heather stated that 'original rock textures (e.g. bedding) are rarely preserved'. However, bedding contacts are preserved throughout the study area. Even where they are not deformed or metasomatized (altered), metamorphosed Archean rocks are commonly devoid of any other textures.

By 'an increasing state of strain' Heather probably means an increasing amount of strain. If you were to traverse from north to south across the proposed Mishibishu Deformation Zone at the study area, you would go from flows and sills outside the Mishibishu Deformation Zone, to tuffs or mudstones inside the Mishibishu Deformation Zone, to wackes outside the Mishibishu Deformation Zone. All of these rocks are metamorphosed and portions of them are metasomatized. If they were not metasomatized, you would still go from relatively non-schistose rocks outside the Mishibishu Deformation Zone, to relatively schistose rocks inside the Mishibishu Deformation Zone, to relatively non-schistose rocks outside the Mishibishu Deformation Zone. Compared to relatively non-schistose flows, sills, and wacke, schistose tuffs and mudstones are incompetent. Metasomatized rocks are especially schistose, and are thus especially incompetent. If there is an increase in the amount of strain toward the centre of the Mishibishu Deformation Zone, it is related to original rock compositions and metasomatism, not to shear zones.

By 'anastomosing shear zones' Heather presumably means either left-handed or right-handed shear zones that repeatedly bifurcate and rejoin, like a braided stream. The low-angle shear fractures are very narrow shear zones. Because they form diamonds, they appear to repeatedly bifurcate and rejoin. However, instead of all of them being either left-handed or right-handed some of them are left-handed and some of them are right-handed, and instead of being metres wide they are millimetres wide.

If there were shear zones up to ten metres wide, and if those shear zones were at least in part strike-slip, then there should be macroscopic zones where the schistosity curves into the zone on one side, roughly parallels the zone inside it, and curves out of the zone on the other side. Other than microscopic zones centred on low-angle shear fractures, there are no such zones within the study area.

It is difficult to know which structural features Heather believed were associated with the shear zone and which were not. The fact that he mentions 'conflicting kinematic indicators' leads me to believe that he believed that all of the structural features are associated with the shear zones, and thus with the Mishibishu Deformation Zone.

Heather states that 'The MDZ may have developed because of the emplacement of the large Pukaskwa Gneiss Complex to the north'; that is, deformation within the Mishibishu Deformation Zone may have been the result of squeezing perpendicular to the greenstone-granite contact. The schistosities, elongation lineations, and low-angle shear fractures were the result of squeezing perpendicular to the greenstone-granite contact, but the kink folds, the most predominant feature of the deformation, were the result of squeezing roughly parallel to the greenstone-granite contact.

Within the study area, metasomatic mica, chlorite, and carbonate are older than the kink folds, and smoky quartz veins are younger than the kink folds. Where gold-bearing smoky quartz are surrounded by systematic alteration patterns, they are associated with the alteration patterns in space but not in time. Conceivably, gold-bearing smoky quartz veins could occur where there are no alteration patterns.

Assuming that the change in the strike of the schistosity on the Magnacon property (from 300°-310° to 280°-290°) is an S-C fabric, Heather concludes that the horizontal component of shear along shear zones within the Mishibishu Deformation Zone was left-handed.

If Heather saw both left-handed and right-handed C′ fabrics then presumably he saw both synthetic and antithetic secondary shear bands. Both types of shear bands could occur within a left-handed shear zone.

Where the rocks on the Magnacon property are broken into 'panels', Heather reports that the 'sense of movement on conjugate sets of kink bands are consistent within individual panels but differ within adjacent panels'. He seems to be saying that some panels contain contractual kink bands and some panels contain extensional kink bands.

Within the Mishibishu Deformation Zone, 'the gold-bearing zones occur within the sericite-quartz schists as vein complexes which appear to cut the foliation at a low angle, indicating that they occupy a brittle fracture (e.g. a shear fracture) which developed late in the shear zone's history'. On the Magnacon property,'both the Curtis and Bandy (Main) Zones cut obliquely across the shear zone foliation (C fabric) at approximately 295 to 300°. Based on the apparent left-handed sense of shear indicated by regional foliation trajectories, the mineralized zones probably occupy shear fractures which developed late in the MDZ's history'. Thus Heather observed that gold-bearing quartz veins were emplaced along fractures that lie at a small angle to the schistosity. At the time, however, low-angle shear fractures were not commonly recognized (they still aren't).

**Reid and Reilly, 1987**

On deformation zones to the west of the Mishi Gold property:

- Strata-parallel, east-trending deformation zones were mapped north of the East Pukaskwa River. The loci of the zones are concentrated along lithological contacts and exposed widths measure up to 100 m. Brittle-ductile shear zones enclosing less deformed protoliths constitute the deformation zones.
- Macroscopic ductile structures include an intense penetrative fabric, strong stretching lineations, asymmetric folds, shear bands, boudinaged and rotated quartz veins, all indicative of simple shear. Later more brittle kink bands and crenulations are probably related to the same shearing event.
- Downdip stretching lineations plunge to the east in some zones and to the west in others. Kinematic indicators define both zones of normal and zones of reverse sense of shear displacement.

The 'penetrative fabric' is the schistosity, the 'asymmetric folds' are probably early folds

Asymmetric folds are commonly indicative of simple shear. Schistosities, elongation (stretching) lineations, boudinaged and rotated veins, and kink bands may be, but are not necessarily, indicative of simple shear. Within the study area, the schistosity, the elongation lineation, and the boudinaged veins are not indicative of simple shear, and the kink bands are contractual kink bands.

**Groves (1989)**

On deformation zones:

- The deformation zones now comprise schists, protomylonites and mylonites with a dominant foliation parallel to their trend, which is curved probably due to the interaction of the zones with the regional granitoid batholiths.
- A feature is a steep W- to NW-plunging mineral (stretching) lineation which appears present in all the areas visited. Due to the flat nature of most outcrops, sections perpendicular to the stretching lineation are rare and the direction of movement is difficult to define. However, the horizontal component, defined by asymmetric, west plunging, mesoscopic folds and S-C fabrics, is mainly sinistral on a regional scale. This implies that the shear zones, as now oriented, have a normal sense of movement. However, the geologists from the OGS record that the succession, and presumably the subparallel deformation zone, in the Mishibishu area is overturned (dipping N but facing S). If these assumptions are correct, the

Mishibishu Deformation Zone at least was initially a reverse (or thrust) shear zone similar to most other deformation zones in the Abitibi Belt and adjacent belts. The situation is more complicated that this in that there are shear criteria that indicate a horizontal component of dextral shear in some areas, particularly near mineralization. It is probable that the shear zones have been reworked during successive deformation.

- The deformation zones are also typified by kink bands and crenulation cleavages which cut the zones at variable angles.

On the M-1 grid:

- From an economic viewpoint (at least from observations on this visit), the deposits can be subdivided into those hosted by metasedimentary rocks on the periphery of the deformation zones and those hosted by metavolcanics or granitoids within the deformation zones.

On outcrop area O (Granges Glory), outcrop area H (White Swan), and outcrop area A (KK):

- These deposits are essentially discontinuous, poddy, blue-grey quartz veins with minor sulphides in folded, but otherwise low-strain, metasedimentary rocks.
- Larger pods appear localized in E-plunging (10-40°) hinge zones of mesoscopic folds with more continuous veins parallel to bedding.
- All observed quartz veins plunge relatively shallowly in an easterly direction (70-90°).

On the Main Zone:

- Main Zone deposit (No. 2 lens) is located within chlorite-ankerite-sericite-pyrite schists. Their inferred high Fe, Ca and Mg contents indicate that they were mafic rocks (basalt, dolerite or mafic tuff).
- A reconnaissance structural study suggests that the mineralized zones comprise a series of essentially en echelon elongate pods confined to a zone of foliation-dip variation (35-55°) within chloritic schists. Compilation of longitudinal sections during this study suggests that the mineralized zone may have a slightly different strike (clockwise from the adjacent strike) to the strike-adjacent relatively unmineralized deformation zone. The mineralized pods probably plunge at 20-40° easterly. The trend is about 15-20°N of the shear-zone strike, as judged by small mineralized quartz veins preserved on the margins of the bulk-sample pits. If viewed in terms of horizontal projections, the observed geometry is consistent with the mineralization being localized in one set of conjugate extensional crenulation cleavage sets related to a sinistral component of shearing. The observed location of vein pods is in hinges of crenulation structures.

- Outside the areas of mineralization, it is common for poddy quartz veins to be localized in these kinks or crenulations, particularly in hinge zones, and to plunge subparallel to crenulation folds.
- In the hangingwall zone (No. 4 to 10 lenses), there is mineralization both hosted by chloritic schists and by felsic porphyroclastic mylonites ('quartz-eye schists', 'felsic tuffs' and "sheared quartz-feldspar porphyries').

A mylonitic is a rock is which grain size has been reduced by ductile or a combination of ductile and brittle mechanisms. Mylonitic rocks commonly form within shear zones. A protomylonite contains less than 50% fine-grained matrix (grains that have been reduced in size), and a mylonite contains 50 to 90% fine-grained matrix. A porphyroclastic mylonite contains relict mineral clasts in a fine-grained matrix. I have no reason to believe that there are any protomylonites, mylonites, or porphyroclastic mylonites within the study area.

Groves' crenulation folds are kink folds, and his crenulation cleavage is a spaced cleavage that consists of the planes that bound the kink bands. Grove's misidentified the contractual kink bands, calling them 'extensional crenulation cleavage sets'. It is acceptable to call them cleavage sets, but they are contractual not extensional.

Groves assumed that the elongation (stretching) lineation is the slip vector for shear zones within the deformation zone. Thus the shear zones were either left-handed and normal, or right-handed and reverse. Based on 'asymmetric, west-plunging, mesoscopic folds and S-C fabrics', he concluded that the shear zones were left-handed, and thus normal. I did not see any S-C fabrics within the study area. The only asymmetric west-plunging folds are S-shaped kink folds in left-handed kink bands. If there were shear zones, the S-shaped kink folds would not be related to them and thus would not indicate that they were left-handed.

Groves apparently felt that like shear zones in other gold camps, the shear zones on the Mishi Gold property should have been reverse. To say how they could have been reverse, he suggests that the shear zones formed before the syncline that contains them was overturned. The syncline probably became overturned as it formed. As the syncline formed, the early folds formed. Thus the shear zones of the deformation zone would be older than the early folds. The shear zones are supposedly schistose. If they were older than the early folds, the schistosity would be folded by the early folds. Within the study area, the schistosity is not folded by the early folds.

By stating that 'the deformation zones are also typified by kink bands and crenulation cleavages' Groves seems to be saying that the kink bands and crenulation cleavages (which are the same thing) are related to shear zones within the deformation zones. If there were shear zones, however, they would have been the result of squeezing roughly perpendicular to the greenstone-granite contact. The kink folds were the result of squeezing roughly parallel to the greenstone-granite contact.

According to Groves, the Main Zone lies within a deformation zone but outcrop area O (Granges Glory), outcrop area H (White Swan), and outcrop area A (KK) are 'on the periphery of the deformation zones'. However, the structural features at the Main Zone are identical to the structural features in the rest of the study area, and the amount of deformation at the Main Zone is comparable to the amount of deformation in portions of outcrop areas H (White Swan) and C (MM).

According to Groves, at outcrop area O (Granges Glory), outcrop area H (White Swan), and outcrop area A (KK) 'all observed quartz veins plunge relatively shallowly in an easterly direction (70°-90°)'. Most of the veins were emplaced along fractures that parallel the schistosity or along low-angle shear fractures. Where these veins are boudinaged, boudins plunge at steep angles to the east. Where they are not boudinaged, they have no obvious plunge. Some of the veins were emplaced along fractures at a high angle to the schistosity. Where they are folded, fold axes plunge at shallow angles to the east.

At the Main Zone, a compilation of mineralization in diamond drill holes indicates that mineralized zones plunge to the east. Groves suggested that mineralization plunges to the east because it was emplaced along the hinges of east-plunging 'crenulation structures' within 'one set of conjugate extensional crenulation cleavage sets related to a sinistral component of shearing'; in other words, mineralization plunges to the east because it was emplaced along the hinges of east-plunging kink folds within east-striking extensional kink bands.

In Groves' Figure 1 (my Figure 13a), he intended to show features that might occur within a left-handed shear zone. It shows a 'mineralized extensional crenulation cleavage' that strikes at 090° to 100°, and that is associated with mineralized S-shaped folds that plunge at a shallow angle at a trend of 090° to 100°; in other words, it shows left-handed extensional kink bands that strike at 090° to 100°, and that contain mineralized S-shaped kink folds that plunge at a shallow angle at a trend of 090° to 100°. At the Main Zone, however, the kink bands that strike at 090° to 100° are right-handed contractual kink bands, not left-handed extensional kink bands, and the folds that plunge at a shallow angle at a trend of 090° to 100° within the kink bands are Z-shaped kink folds, not S-shaped kink folds. Thus Figure 1 of Groves is not compatible with the features that occur at the Main Zone.

Figure 2 of Groves (my Figure 13b) shows the 'suggested orientation of ore shoots' that are contained within the hinge zones of Z folds that plunge at a shallow angle at a trend of 090° to 100°. His Figure 2 is not compatible with his Figure 1, but it is compatible the features that occur at the Main Zone.

At the Main Zone, east-plunging Z-shaped kink folds are contained by east-striking right-handed kink bands. The kink bands generally strike at more than 20° to the schistosity, and smoky quartz veins generally strike at less than 20°. The widths of right-handed kink bands are less than 5 cm, and the widths of smoky quartz veins at the west end of the pit are much greater than 5 cm. It seems unlikely, therefore, that smoky quartz veins follow the axes of Z-shaped kink folds. In the rocks that surround the pit at the Main Zone, and elsewhere within the study area, I did not see any evidence to suggest that smoky quartz veins were emplaced along the hinges of kink folds within kink bands.

a)

b)

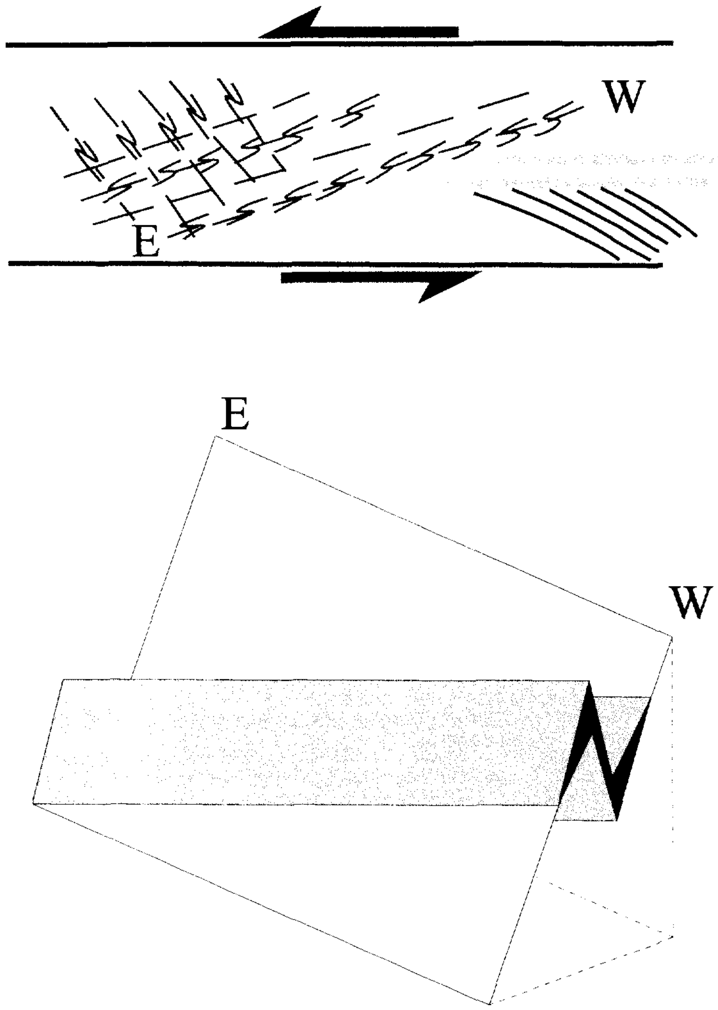


**Figure 13.** Figures 1 and 2 of Groves. a) The solid red lines represent the boundaries of a left-handed shear zone that strikes 110 to 120 degrees and dips 35 to 55 degrees to the north. The black lines represent the schistosity, the grey bars represent shear bands, the green and red broken lines represent crenulation cleavages, the green Z-shaped folds are kink folds in right-handed kink bands, and the red S-shaped folds are kink folds in left-handed kink bands. Groves labeled the schistosity an "S fabric", the shear bands a "C fabric", and the red broken lines a "mineralized extension crenulation cleavage". b) The black and grey fold is a Z-shaped kink fold that plunges at a shallow angle at a trend of 90 to 100 degrees. Figure 13a is a reasonable reproduction of Figure 1 of Groves, and Figure 13b is a simplification of Figure 2 of Groves.

**Bates and Miree**
(Bates and Miree, 1991; Miree and Bates, 1991a; and Miree and Bates, 1991b):

On deformation zones:

- Rocks in the Greenstone Belt dip to the north and strike between 90-120° Az. Deformation zones traverse the belt in an east-west direction generally following metavolcanic-metasedimentary contacts. These are marked by the development of a planar penetrative fabric due to phyllosilicate growth in the shear, i.e. schists. Deformation does not necessarily, however, exclusively manifest itself as phyllonite. In more siliceous rocks such as felsic tuffs, quartz feldspar porphyry and quartz feldspathic rocks, zones of "chert" are developed with well developed spaced cleavage; these have been reported to be recrystallized quartz and albite in mosaic form, i.e. ultramylonite.
- As well tightly interdigitated bedding around shear folds, S-C fabric development, anastomosing zones of mica, rolled crystals and general destruction of original fabric are characteristic of the shear zones.
- Sets of east-west trending deformation zones are located preferentially along regional contacts between mafic volcanics and intermediate tuffs and mafic volcanics and metasediments. The zones consist of schists of varying composition with well defined spaced cleavage (c fabric: parallel to deformation zone boundary); all protolith fabrics are destroyed, and s fabric is overprinted by c fabric.
- Transposition of fabric occurs in these zones resulting in hook and needle structures and parallelism of structures within the system.
- Using asymmetric fold relationships, both sinistral and dextral senses of movement can be found within the shear zones and s-c relationships. s-c fabric relationships can only be seen on the outer hanging wall and footwall of the shear, with best visibility on the hanging wall. The intensity of shearing tends to increase slowly from north to south, reaching a peak at surfaces that represent contacts between competent and relatively incompetent units.

On the Mishibishu Deformation Zone:

- The so-called Mishibishu Deformation Zone (a term used to describe the envelope of east-west trending rocks that have undergone strain in the north half of the Mishibishu Lake Greenstone Belt), is actually composed of several discrete shear zones. Shear zones have been defined as zones of rock whose original fabric has been destroyed - partially or totally. Three zones have been found on the M-1 grid where fabric is destroyed and the remaining rock can be described only as a schist. These are the:
  - North Shear, 850N to 900N
  - #2 Shear, 650N to 800N; and
  - South Shear 300N to 000N

On outcrop area O (Granges Glory):

- Located in he Western Structural Zone, the Granges Glory Showing is predominately comprised of two distinct gold-bearing quartz veins. The main quartz vein is a 0.5-4 m wide black to smoky grey quartz vein. The vein occupies extended S-shaped opening in a multiply deformed "chlorite clast conglomerate." the hinge of the S-shaped surface of the vein, in the eastern part of the map area, plunges 40-45°east.
- Transposition visible via differential alteration patterns.

On outcrop area H (White Swan):

- Gold mineralization at this showing occurs in smoky grey quartz veins and lenses, with widths between 5-20 cm. The host rocks are shear folded argillites and wackes. Quartz veins occupy hinges of folds in the argillites, and die out along the limbs of these folds. Hinges of the isoclinal folds plunge to the east at 30-40°. The veins are aggregates of up to 40% quartz, plunge east at 30-40° and are similar to "bedded leads." Fold noses are on the order of 1-3 metres wide.
- \- extensive stripping shows that the host lithology, sediments, resulted in quartz veins accumulated in fold nose areas of transposed sedimentary horizons rather that in discrete confined areas accompanied by extreme chemical alteration and physical deformation such as that at the #2 lens of the Main Zone. The argillites behaved plastically in response to stress.
  \- fold asymmetry indicates dextral movement in the horizontal sense.
  \- if small-scale extremely selective mining methods were effectively utilized, near surface mineralization might be extracted economically, however correlatable veins were not found even at shallow depths in diamond drilling.
- Predominantly dextral, asymmetric folds are observed at the White Swan showing, however evidence for both sinistral and dextral senses of movement can be found. Quartz veins are localized in fold noses, paralleling transposed beds, which plunge 30° to 50° northeast.
- Both S- and Z-shaped folds are present, although Z-shaped folds predominate. These folds are interpreted to be shear folds and hence, are indicative of dominantly dextral movement. Transposition of fabric is abundantly evident.
- Sediment hosted deformation, as evidenced by the White Swan Showing is characterized by transposition of fabric, including bedding and quartz veins.

On outcrop area C (MM):

- This area extends from 4550W to 5000W in the west end of the M-1 grid. The zone is characterized by two types of mineralization:
  1) irregular, folded, discontinuous, east-plunging quartz veins hosted by sheared tuffs and sediments; and

2) a chlorite-sericite carbonate schist with 2-20% grey quartz veinlets and 3-10% pyrite i.e. a shear zone.

On outcrop area Q (Warren's Whopper):

- Warren's Whopper represents the westward extension of the Main Zone #2 shear.

On the Western Structural Zone:

- Another type of anastomosing fabric which represents less prominent development of micas in a more brittle environment can be found on the west end of the property (called the Western Structural Zone). Presumably, these areas were subjected to less intense hydrothermal alteration. Other typical fabrics found in this region are:
  1) Interdigitated contacts on micro to mesoscopic scale: 0.5 cm - 20 m. Transposed bedding from 0.5 cm to unknown scales.
  3) Folding (both sinistral and dextral) on mesoscopic scale. Folded sedimentary or tuffaceous beds are common. Both sinistral and dextral events can be seen on the same outcrop, indicating that this type of deformation shows repeated events.
  4) Minor 1 cm - 1 m wide zones of s-c fabric, generally sericite-chlorite schists: these envelop east-plunging vein systems.
- A fourth zone, referred to as the Western Structural Zone is not composed of pure schists, but is an area of deformation with interdigitation of contacts, shear folded bedding, diamond-shaped lozenges of rock surrounded by thin zones of mica, weak carbonatization and small discontinuous zones of schist. This area hosts, from west to east, the KK, MM, White Swan and Granges Glory Showings.

On the Main Zone:

- Mineralization is composed of quartz-veins in shear zones denoted by sheared prefixes or schist names. Although shear zones appear to be strata parallel, it is most likely that all rock types are transposed into parallelism with the c fabric represented by the shear zones.
- There are two ore types: the mafic hosted, more iron-rich schists and quartz veins such as the #2 lens; and the felsic hosted veins of the quartz feldspar porphyry unit, such as the #6 lens.
- The #2 lens material is hosted by sinistral and dextral kink bands on the 0.3 - 1 m scale; plunges of the axes of these folds are about 25-50° east on 45° north dipping plane.
- Vein thicknesses average 1-5 cm and only <u>zones</u> of quartz veins can be correlated within each shear. Deviance from strike of these veins from shear zone strike is up to 20°, though most quartz veins are parallel to the strike of the shear.
- East plunging ore shoots of the #2 lens are depicted on the longitudinal plots of quartz vein density, gold grade, and gold grade x true width. This

feature is not easily seen in two dimensional surface exposures. The 30-50° easterly plunge is opposite to the 60-80° west regional stretch lineation, measured from tourmaline measurements and clast elongation directions.

- Similar to the #2 lens, east-plunging characteristics of the #6 lens are also depicted on the longitudinal plots of quartz vein density, gold grade, and gold grade x true width.
- The east plunging shoots within each vein set have a relationship to one another as well. A three dimensional orebody model . . . shows that the vein-set to vein-set plunge is also approximately 45° to the east.
- Along the #2 lens to the east, there is a steady increase to the north of a mean line representing the #2 shear, and conversely, to the west, a steady divergence to the south. This suggests that the #2 lens sits in an Z-shaped bend in the shear zone trajectory. The changes in strike occur at the location of two diabase dikes. As this bend is only 50 m over 1000 m, it is quite subtle. This Z-shaped kink would represent an extensional region in a dextral shear.
- \- the deformation zone is detectable as a linear feature on airphotos with an apparent 'Z' inflection similar to drill indicated projections of the 2-0 and 2-1 Lenses.
- The Main Zone consists of five ore lenses arranged in a stacked, en echelon series of plunging quartz vein aggregates.
- A dextral, reverse oblique-slip sense of movement along the #2 shear has been interpreted from the following data:
  (a) the Z-shaped trajectory of the main deformation zone;
  (b) the stacked easterly plunge to vein sets;
  (c) mineral lineations plunging 60° to 80° to the west (i.e., perpendicular to the fold axes plunges).
- The lateral extent of the "productive zone" of the #2 shear (Line 1100W to 1600W) is coincident with the thickest portion of the G-1 gabbro. Thus, the Main Zone is sandwiched between two of the most competent rock types on the M-1 grid, namely the G-1 gabbro and the "chlorite clast conglomerate" (i.e., intermediate lapilli tuff). Outside this confining situation, mineralization is more diffuse, as evidenced by the White Swan showing.

On the M-1 grid:

- There are two distinct deformation/alteration styles, found in the rocks of the M-1 grid, which are dependant on the competency and chemistry of the original protolith (i.e. volcanic versus sedimentary rocks). Within the mafic metavolcanic rocks the deformation/alteration style is characterized by ductile shearing accompanied by intense, pervasive alteration (e.g., Granges Main Zone). Within the metasedimentary rocks the

deformation/alteration style is characterized by more brittle shearing and less intense hydrothermal alteration (e.g., White Swan showing).
Deformation and alteration of metavolcanic rocks (such as at the Granges Main Zone) have produced:
(a) a well defined spaced cleavage;
(b) complete destruction of the original protolith textures;
(c) strong, ductile S-C shear fabrics;
(d) intense, pervasive alteration; including carbonatization, silicification, sulphidization and phyllosilicate development;
(e) schistose rocks of various compositions;
(f) discrete zones of abundant quartz veins.

- Deformation and alteration of metasedimentary rocks (e.g., White Swan showing) have produced:
(a) more brittle shearing;
(b) less mica development and hence, poorer developed schistosity, than within the metavolcanics;
(c) less intense hydrothermal alteration; including less carbonatization, silicification, and sulphidization;
(d) folding and transposition of the bedding;
(e) poor, discontinuous quartz veins localized in the noses of folds.

On gold in the M-1 grid:

1) All zones are gold prospects, with gold hosted by quartz veins.
2) Gold is free, or contained is pyrite within the veins.
3) Excepting the Western Structural Zone, the quartz veins are located in east-west trending deformation zones, represented by zones of schist. In the Western Structural Zone, a regime of lower strain and lesser hydrothermal alteration is in place. The veins do not cross-cut the shears at high angles.
4) With the exception of the Main Zone, these prospects do not show sufficient continuity to develop ore reserves.
5) All zones have gold-bearing quartz veins in east-plunging structures.
6) The Main Zone occurs at a dextral twist in the shear zone trajectory, in a similar setting to the Magnacon deposit.
7) The Main Zone is flanked by two late diabases on the east and west.
8) Grade continuity is better in higher iron precursor rocks, i.e. mafic volcanics. Felsic hosted mineralization shows more irregular grade distribution.
9) The lateral extent of the "productive zone" of the #2 shear (1100W to 1600W) is marked by the lateral extent of the G1 gabbro. This means that competency contrast is at a peak in the area of the main zone. The two most competent rocks of the property on the M-1 grid are the G1 gabbro and the intermediate lapilli tuff ("chlorite clast conglomerate"). The Main Zone is sandwiched between these two rock types; <u>and its lateral extent</u>

roughly mimics that of the thickest part of the G1 gabbro. Outside this confining situation, the mineralization is more diffuse. To date, exploration for another mafic intrusive as a hanging wall competent rock has been unsuccessful.

10) "Splay" shears off the main shear could potentially be good targets. However, examination of the north shear has not provided encouragement.

11) The West Structural Zone shows that sedimentary rocks tend to deform in styles counterproductive to continuous veining on this property i.e. they do not readily develop into zones of schist.

On stratigraphy in the Mishibishu Lake greenstone belt:

- In the Mishibishu Belt, zones of deformation separate lithologies of a disparate nature. In the past, this has been interpreted as a measure of contrasting rheologies between differing rock types. It has been assumed that the shears separate originally conformable units.

  For example on the west side of the property, the four major rock types are, from the north to south:

  i) mafic volcanics and gabbro
  ii) quartz-feldspar porphyry
  iii) intermediate lapilli tuffs
  iv) metasediments

  These four rock types appear to form an overturned sequence, but the field evidence for "tops to the south" has not been gathered. Rather, it has been assumed that the succession mafic volcanic-felsic volcanic (quartz-feldspar-porphyry and intermediate lapilli tuff) - metasediments is a natural stratigraphic progression. This all makes good sense, except that the metasediments show no common relation to the "underlying" volcanic sequence. The clasts in conglomerates have jasperoidal fragments, fragments of quartz-feldspar porphyry found nowhere else on the property, and intermediate intrusive rocks, as well as chalcopyrite-bearing quartz veins. None of these rock types have been found in the underlying or overlying rocks within the entire greenstone belt, let alone the Mishi [now Mishi Gold] property.

  As well, stratigraphic units cannot be successfully followed any significant distance. Mapping in the Western Structural Zone was extremely difficult. Indeed, the only units that could be successfully followed were structural units and this is the primary characteristic of this region. Further, the intermediate lapilli tuff is probably an ignimbrite of felsic derivation, which would not generally follow on the heels of massive-flow basaltic volcanism. Also, as no quartz-feldspar porphyry crystals in the lapilli tuff remotely resemble the quartz-feldspar porphyry crystals, the quartz-feldspar porphyry unit is probably not related to the felsic lapilli tuff. Finally, all major contacts between these disparate units are zones of high strain or pure phyllonite indicating that the "contacts" are tectonic i.e.

> major lithologic units are not in stratigraphic sequence but are fault or shear-bounded blocks. "Stratigraphy" at Mishi [now Mishi Gold] is spurious. Facing indicators between blocks are probably contradictory. For example, the probable facing position around diamond drill hole M-131, on the M-5 grid is to the north, not to the south.
> These ideas are collaborated by the work of Claude Hubert and Nicole Gauthier at the University of Montreal and Universite Laval respectively, as well as observations along the Cadillac Break (similar, although overall lower strain than the Mishibishu Deformation Zone area). As well, the Cadillac mineralization occurs off the Main shear, indicating that splay-type mineralization should be a major gold target at Mishi [now Mishi Gold]. It can be concluded that each major shear zone marks a boundary between different tectonic regimes on the property, and that trying to stratigraphically correlate rocks through or across a shear zone is futile.

The M-5 grid lies to the east of the Magnacon Mine property. The G1 gabbro lies to the north of the Main Zone (see Figure 2).

A phyllonite is a fine-grained rock that commonly forms within shear zones, and that is transitional between a schist and a mylonite. An ultramylonite is a mylonitic rock that contains more than 90% fine-grained matrix. I have no reason to believe that there are any phyllonites or ultramylonites within the study area.

Bates and Miree seem to be calling the schistosity a C fabric, and the C fabric a spaced cleavage. Even if there were shear zones, the schistosity would not be C fabric. If there were shear zones, and if the shear zones contained numerous very narrow shear bands, the shear bands could define a spaced cleavage. I did not see any evidence for shear bands that define a spaced cleavage.

Where the axes of early folds intersect outcrop surfaces at small angles, beds appear to be 'interdigitated'. The interdigitation is secondary (due to folding) not primary (due to sedimentary processes). Crystals may be 'rolled'(rotated) within low-angle shear fractures.

The Western Structural Zone contains outcrop areas A to P (see Figure 3). Shear folded bedding "should" be the early folds, but could be the kink folds. 'Diamond-shaped lozenges of rock surrounded by thin zones of mica' are diamonds formed by low-angle shear fractures. 'Anastomosing zones of mica' and 'another type of anastomosing fabric' may also be low-angle shear fractures.

According to Bates and Miree, bedding and quartz veins were 'transposed into parallelism with the c fabric'; in other words, bedding and quartz veins were transposed into parallelism with the schistosity. Transposition occurs when tight folding is accompanied by pressure solution and slip parallel to axial planes, resulting in the thinning and rupture of fold limbs. In a bedded rock that contains quartz veins, the result would be segments of beds and quartz veins that are separated by structural discontinuities, that are oblique to their original orientations, and that are parallel to the schistosity. I did not see any evidence to suggest that bedding and quartz veins have been transposed. Perhaps Bates and Miree meant to imply that bedding and quartz veins were rotated into parallelism with the C fabric within shear zones. I did not see any evidence for that either.

If you follow transposed beds along strike, you may reach the end of the bed segment. Within the study area, the fact that beds appear to end along strike (as, for example, in Photograph 2) is a consequence of the fact that they are folded by early folds along axes that plunge at shallow angles.

Defining shear zones as 'zones of rock whose original fabric has been destroyed' is unacceptable. Primary features may be 'destroyed' by metamorphism or by metasomatism that is unrelated to a shear zone.

Bates and Miree suggest that at outcrop area H (White Swan), 'quartz veins accumulated in fold nose areas of transposed sedimentary horizons', that 'hinges of isoclinal folds plunge to the east at 30-40°', and that 'fold noses are on the order of 1-3 metres wide'. The beds are not transposed, but they are folded by early folds that plunge to the east. Early folds commonly appear to be isoclinal. I suspect that Bates and Miree meant to imply that quartz veins were emplaced in the noses of early folds. At one place in outcrop area H an aggregate of smokey quartz veins lies close to the noses of early folds, however, elsewhere in the outcrop area and elsewhere in the study area aggregates of smoky veins do not appear to be associated with fold noses.

Discussing folds at outcrop area H, Bates and Miree state that 'both S- and Z-shaped folds are present, although Z-shaped folds predominate. These folds are interpreted to be shear folds and hence, are indicative of dominantly dextral movement'. Discussing 'mesoscopic folds' in the Western Structural Zone, they state that 'both sinistral and dextral events can be seen on the same outcrop, indicating that this type of deformation shows repeated events'. Whether the early folds are S-shaped or Z-shaped on outcrop surfaces, technically they are Z folds (see above). They are indicative of a right-handed component of shear along cryptic shear zones that also exist outside of the proposed deformation zone. The kink folds are S-shaped and Z-shaped (technically, they are S folds and Z folds). They are not indicative of movement along a shear zone. The early folds formed during one event, and the kink folds formed during a later event.

According to Bates and Miree, at outcrop area C (MM) there are 'folded, discontinuous, east-plunging quartz veins'. However, the discontinuous east-plunging quartz veins are white quartz veins that were folded by early folds (similar to those in Photograph 18), not smoky quartz veins that are younger than the early folds and the kink folds.

I did not see any S-C fabrics around 'vein systems' in the Western Structural Zone. Aggregates of veins commonly contain, and are surrounded by, zones of kink bands. Perhaps Bates and Miree mistook kink bands for S-C fabrics.

Bates and Miree suggest that at the Main Zone gold mineralization is hosted by left-handed and right-handed kink bands that plunge to the east. At the Main Zone, however, right-handed kink bands plunge to the east or east-southeast and left-handed kink bands plunge the north or north-northeast; they do not plunge in the same direction.

Discussing gold-bearing quartz veins at the Main Zone, Bates and Miree note that 'deviance from strike of these veins from shear zone strike is up to 20°'; in other words, the angle between the strike of the veins and the strike of the schistosity is up to 20°. Like

Heather, they observed that at least some of the veins are at a small angle to the schistosity.

Noting that the #2 shear zone is Z-shaped over a length of 1000 m, that aggregates of quartz veins within the #2 shear zone form an en echelon array that plunges to the east, and that mineral lineations within the #2 shear zone plunge to the west perpendicular to the plunge of fold axes, Bates and Miree conclude that the #2 shear zone is right-handed and reverse. If there were a shear zone, neither the fact that it is Z-shaped nor the fact that aggregates of veins plunge to the east would mean that the shear zone is right-handed and reverse. The mineral lineation that plunges to the west marks the orientation of the slip vector of the shear zones that resulted in the early folds. These shear zones were right-handed and reverse. However, they are much younger than, and were not related to, gold mineralization.

According to Bates and Miree, in the metavolcanic rocks deformation is ductile and in the metasedimentary rocks deformation is 'more brittle'. Although low-angle shear fractures are more obvious at outcrop areas K and O, they are present in every other outcrop area, including the Main Zone. Other structural features, including the schistosity, the elongation lineation, early folds, and kink folds, are present in every outcrop area. I do not know of any reason to say that deformation is more ductile at the Main Zone, or more brittle within the Western Structural Zone.

Bates and Miree conclude 'that each major shear zone marks a boundary between different tectonic regimes on the property, and that trying to stratigraphically correlate rocks trough or across a shear zone is futile'. I did not see any evidence for layer-parallel tectonic breaks, or for different tectonic 'regimes'. If facing directions are contradictory it is probably because of shallow-plunging early folds.

**Summary of previous work on structures other than faults**

Beginning with Heather (1985 and 1986), the selected previous workers believed that the study area is transected by the Mishibishu Deformation Zone, that the Mishibishu Deformation Zone contains shear zones, and that the locus of metasomatism (hydrothermal alteration) and gold mineralization is associated with, and was controlled by, the shear zones. Among the structural features they believed they saw are: a schistosity that was interpreted to be a C fabric, an elongation (stretching) lineation that was interpreted to be a slip vector, S-C fabrics, C′ fabrics, phyllonites, protomylonites, mylonites, porphyroclastic mylonites, ultramylonites, drag folds, kink folds, chevron folds, kink bands that were interpreted to be extensional kink bands, a cleavage that was interpreted to be an extensional crenulation cleavage, and transposed beds and quartz veins. Apparently, they believed that all of these features are related to the Mishibishu Deformation Zone, and thus to the shear zones.

Because the selected previous workers believed that all of the structural features are related to the shear zones, they were faced with conflicting kinematic indicators. According to Heather (1991) the horizontal component of motion along the shear zones was left-handed, according to Groves (1989) motion along the shear zones was originally left-handed and reverse but because of folding now appear to be left-handed and normal, and according to Bates and Miree (1991) motion along the shear zones was right-handed and reverse.

I did not see any evidence for shear zones other than the cryptic shear zones. Right-handed, reverse motion along the cryptic shear zones produced the early drag folds. The cryptic shear zones are older than, are not related to, and did not control the locus of, metasomatism or gold mineralization. Thus the drag folds are not related to the proposed shear zones. The schistosity is not a C fabric. The elongation lineation is younger than, but happens to be more or less parallel to, the slip vector for the cryptic shear zones. The chevron folds are probably kink folds but may be early folds, and the kink bands are contractual kink bands not extensional kink bands. The extensional crenulation cleavage is not extensional; it was produced by shortening, not extension, along the schistosity. I did not see any evidence for S-C fabrics, C′ fabrics, phyllonites, protomylonites, mylonites, porphyroclastic mylonites, ultramylonites, or transposed beds and quartz veins.

The proposed Mishibishu Deformation Zone contains schistose rocks. Some of them are schistose because they were metamorphosed, and some of them are schistose because they were metasomatized. They are not schistose because they are sheared. Although rocks found within shear zones are commonly schistose, a schistose rock is not necessarily a sheared rock.

The proposed Mishibishu Deformation Zone is not located at the contact between volcanic and sedimentary rocks. It is located within a package of transitional clastic rocks (not quite "pristine" pyroclastic rocks and not quite "well-worked" epiclastic rocks) that are located between clearly volcanic and clearly sedimentary rocks.

Compared to rocks to the north and south of it, the proposed Mishibishu Deformation Zone contains relatively incompetent rocks. They are incompetent because of their original compositions, and because they were metasomatized.

The proposed Mishibishu Deformation Zone contains deformed rocks. The main feature produced by deformation is the kink folds. The kink folds formed in schistose rocks, and the most schistose rocks are the metasomatized rocks. Instead of the metasomatism being localized by deformation, deformation was localized by metasomatism.

To maintain the concept of a zone that controlled metasomatism, and thus gold mineralization, on the Mishi Gold property, let's go back to Heather's original term, the Mishibishu Zone. It is misleading to think of the Mishibishu Zone as a deformation zone, and better to think of it as a stratigraphic zone or a metasomatized (altered) zone.

## STRUCTURAL GEOLOGY AND GOLD - PREVIOUS STUDIES
## Part 2: Faults

### Bennett and Thurston (1977)

- The numerous, negative topographic lineaments visible on topographic maps and air photographs of the region indicate the presence of numerous faults and shear zones.

- Detailed mapping by Goodwin (1954) has shown the presence of several northeast- and northwest-trending faults in the vicinity of Kabenung Lake which have an apparent horizontal displacement of as much as 750 m (2,500 feet).
- The only major faults detected during the mapping program are three northeast-trending faults in the vicinity of Mishibishu and Katzenbach Lakes. These faults have displacement from 600 m (2,000 feet) to as much as 3000 m (10,000 feet)...

**Heather (1985)**

- In places, delineation of major structures which cross the Mishibishu Zone, may help locate areas favourable for gold mineralization. Commonly, these cross-structures are occupied by large diabase dikes.

**Heather (1986)**

- There is a strong, north-trending foliation developed within a 350 m wide zone located immediately west of Macassa Creek (Figure 059.2 [not reproduced here]). Secondary, north-trending fabric development within this zone gives a sinistral sense of movement, but this contradicts evidence given by the apparent dextral offset across Macassa Creek of the granitoid, clast-dominated, polymictic conglomerate (Figure 059.2).

In Figure 059.2 there are two north-northeast striking faults, one along Macassa Creek and one to the east of Macassa Creek. The conglomerate is clearly offset across the fault to the east of Macassa Creek, and may be offset across the fault along Macassa Creek. Heather states that the apparent offset of the conglomerate across Macassa Creek is right-handed, but in Figure 059.2 the offset of the conglomerate across the fault to the east of Macassa Creek is left-handed and the only possible offset of the conglomerate across the fault along Macassa Creek is left-handed.

**Groves (1989)**

- The entire area, including the deformation zones, was then cut by an apparently conjugate set of brittle, crustal-scale fractures, some of which are filled by diabase dikes. These trend broadly NNE and NW to NNW. If conjugate, they indicate a NNW-SSE directed compression, which could account for the late dextral brittle shear on the broadly E-W oriented deformation zones.
- There is an empirical relationship between deposit locations and points of intersection between diabase dykes and deformation zones. This is shown at:

1) The area between the Main Zone and the Magnacon mine where there is the highest concentration of major (definable on regional-scale aeromagnetic maps) diabase dykes in the Mishi Deformation Zone.
2) The Central Crude deposit, where there is a coincidence between the granitoid-hosted Central Crude deposit and a diabase dyke, and a similar coincidence with mafic hosted mineralization to the east.
3) Hemlo, where the major deposits are located near the two major diabase dykes to cut the deformation zone.

- It is also apparent that the main mineralized zones in the Mishibishu area are normally on the hangingwall side of major diabase dykes: a further coincidence?
- It is difficult to explain these relationships. The diabase dykes do not fill fractures in the extensional direction for the proposed sinistral shearing and, if part of a conjugate set, formed in a different stress field from that producing the deformation zones: these data are consistent with their generally accepted age.
- There appear to be three main, not necessarily mutually exclusive, possibilities for the observed relationships.

1) That the diabase dykes fill brittle or brittle-ductile structures that were fluid conduits during mineralization. Fluid channelled up these structures produced hydraulic fracture veins in mechanically weak mylonite zones in their hangingwall zones due to high fluid pressures. Evidence supporting this includes; the commonly reported higher grade zones in shear-hosted mineralization adjacent to the dykes, and relationships observed at Discovery. Permissive evidence includes the fact that, although mineralization at the main zone is probably controlled by crenulation structures geometrically related to the shear zone, other crenulation cleavages whose orientation is inconsistent with that shearing affect quartz-vein location on a small scale. The distribution of unmineralized quartz breccias at Central Crude shows that the demonstrably late mineralization can be completely localized in mechanically weak rocks in anisotropic sequences.
2) The dykes are localized by pre-existing weaknesses such as regional inflection points on mega-kinks that also control gold mineralization.
3) That the diabase dykes act to provide topography in which gold mineralization is more easily discovered. Highly altered sheared rocks would normally be expected to be topographic lows such as swamps which are difficult to explore and have no surface exposure of veins. However, the diabase dykes form the most prominent ridges, thus providing more positive relief for

intervening alteration or mineralized zones. The Main Zone is in a particularly favourable topographic situation.

When conjugate high-angle shear fractures form the greatest compressive stress bisects the acute angle between them, and when conjugate low-angle shear fractures form the greatest compressive stress bisects the obtuse angle between them. Because people are generally unaware of the existence of low-angle shear fractures, they commonly believe that when conjugate shear fractures form the greatest compressive stress always bisects the acute angle between them.

According to Groves, north-northeast striking faults and northwest to north-northwest striking faults are conjugate. Assuming that the greatest compressive stress bisected the acute angle between them, he concluded that the north-northeast striking faults are left-handed and the northwest to north-northwest striking faults are right-handed. However, if the faults are low-angle shear fractures then the greatest compressive stress bisected the obtuse angle between them, the north-northeast striking faults are right-handed, and the northwest to north-northwest striking faults are left-handed.

**Cavaney (1990)**

- Of note is that the western end of the shoots in the Main Zone above the No. 2 shoot lined up and coincided with a north easterly striking 65° south east dipping diabase dike. Flexing, or possible gentle folding in the No. 2 lens was tending to line up parallel to the rake of the shoots.
- This, for me, is the strongest evidence that the structures now occupied by diabase dikes influenced mineralization. It also implies that the mineralization occurred later than the deformation that produced most of the mesoscopic structures in the enclosing rocks. A later tectonic event of entirely differently oriented stress fields was operating and future structural observations must take this into account.
- The diabase dikes are occupying structural features that are later than the main phase of deformation and formed under different stress fields and general conditions. There may be two ages and three main orientations of dikes, some of which can be outlined by aeromagnetic surveys. The dike structures do appear to act as a control to mineralization.

Figure 1 of Cavaney is a stereographic projection showing the line of intersection between the plane of the 'mineralized body' and the plane of a cross-cutting diabase dike. The line of intersection plunges to the northeast.

**Bates and Miree**
(Bates and Miree, 1991; Miree and Bates, 1991a; and Miree and Bates, 1991b):

- \- the most readily apparent features detected on airphotos are diabase dikes. Along the Mishibishu Deformation Zone, two sets of NNE, parallel diabase dikes are among the most prominent of dikes. Of these, one set forms the boundaries of the Main Zone, the other, the area of Muscocho's 'Discovery Showing.' These dikes are interpreted as marking the position of inflections along the deformation zone, which would have been preferential fluid migration zones. At no other position along the 'deformation zone' is this feature seen to occur.

- All the main deposits found to date, are at or near intersections of major north-south trending lineaments, and/or diabase dikes and the Eagle River or Mishibishu Deformation Zones. All deposits or showings are shear hosted, vein type gold. Since no showings have been found in undeformed rocks, the cross-cutting lineaments may be significant deep seated fractures that localized gold bearing fluids in the deformation zones.
- Finally, sets of north-south extensional fractures transect the entire belt. These cross structures are dominantly dipping at near vertical orientation to the west, some as low as 70° and to the east. Drilling results and mapping show these fractures to be infilled with Proterozoic diabases, in sometimes irregular patterns, forming linear strings of sausage patterns. Marginal contacts show chill margins, but never any included wall rock. Sawtooth contacts of wall rock filled by diabase offer proof of diabase infilling previously formed structures.
- In summary, field mappable deformation zones transect the property at roughly east-west orientations. Fourteen showings have been found in these zones of deformation, including one deposit, the Magnacon Deposit and one defined mineral inventory, Granges' Main Zone. Both are located at Z shaped bends in the deformation zone's trajectory . . . and at or near diabase intersections with the deformation zone.

On the M-1 grid:

- The best mineralized portion of the #2-1 lens is almost entirely encompassed by the two diabase dikes i.e. in the mid-portion of the 'Z'. This may indicate that dikes are intruding along ancient weaknesses related to earlier mineralizing events.

On the Magnacon property and the M-5 grid:

- The area can be subdivided into four panels bounded by faults, named the West Fault, the Central Fault, and the Eastern Fault. The faults are marked by airphoto lineaments, changes in regional strike and dip across the faults, and dislocations of strata. Major faults are characterized by different movements; faults striking north-east exhibit dextral movement, whereas faults striking southwest are sinistral.

According to Bates and Miree, 'faults striking north-east exhibit dextral movement whereas faults striking southwest are sinistral'. However, 'faults striking northeast' have the same strike as 'faults striking southwest'.

**Summary of previous work on faults**

The Mishi Gold property is transected by regional lineaments that are at a high angle (greater than 45°) to the strike of the schistosity. Some of the lineaments are proven or possible faults, and some of the lineaments are proven or possible diabase dikes. The diabase dikes were probably emplaced along faults.

In 1985 Heather suggested that 'delineation of major structures which cross the Mishibishu Zone may help locate areas favourable for gold mineralization'. Groves, Cavaney, and Bates and Miree believed that gold may have been localized within the proposed Mishibishu Deformation Zone at its intersection with cross-cutting faults and diabase dikes. Because the diabase dikes are younger than the gold, the gold must have been localized by faults that were occupied by dikes some time later.

Let's say that there are northwest striking faults and north-northeast striking faults. Unfortunately, the sense of shear along the faults is unclear. If the northwest striking faults are right-handed and the north-northeast striking faults are left-handed, they were the result of squeezing roughly perpendicular to the greenstone-granite contact. If the northwest striking faults are left-handed and the north-northeast striking faults are right-handed, they were the result of squeezing roughly parallel to the greenstone-granite contact.

Within the study area, most of the structural features were the result of squeezing perpendicular to the greenstone-granite contact. The contractual kink bands were the result of squeezing roughly parallel to the greenstone-granite contact. All of those features are older than the smoky quartz veins. Thus there is evidence for squeezing roughly perpendicular to the greenstone-granite contact before gold mineralization, and for squeezing roughly parallel to the greenstone-granite contact before gold mineralization.

In places, contractual kink bands are transitional to faults or fault zones. Thus there is evidence for faults cutting the schistosity at a high angle before gold mineralization.

## STRUCTURAL GEOLOGY AND GOLD - THIS STUDY

**Locations of economic gold deposits**

Within the study area, gold is found in, and adjacent to, smoky quartz veins. Most veins were emplaced along low-angle shear fractures or fractures that parallel the schistosity. Strike lengths are commonly short, and widths are commonly narrow. However, veins tend to form aggregates that have somewhat larger strike lengths and larger overall widths.

Judging from drill data, aggregates of veins at the Main Zone plunge to the northeast (Groves, 1989; and Bates and Miree, 1991). Within the study area, early folds, right-handed kink folds, and folds and boudins in smoky quartz veins that were emplaced along fractures at a high angle to the schistosity commonly plunge to the northeast. According to Cavaney (1990), the line of intersection between the plane of the 'mineralized body' at the Main Zone and the plane of a cross-cutting diabase dike plunges to the northeast.

Smoky quartz veins that were emplaced along fractures at a high angle to the schistosity are relatively rare. At the Main Zone, smoky quartz veins have a different strike than, and are commonly much wider than, the right-handed kink bands. Elsewhere within the study area, there is no evidence to suggest that smoky quartz veins were emplaced along the hinges of kink folds within kink bands.

Bates and Miree (1991) believed that smoky quartz veins were concentrated along the noses, or hinge zones, of early folds. Other than at one place at outcrop area H (White Swan), I did not see any evidence to suggest that they are correct. Unlike Bates and Miree, however, I did not map the stratigraphy and I did not have access to drill data. Consequently, I may be wrong and they may be right.

Given the apparent spatial association between gold showings and intersections between the Mishibishu Zone and faults and dikes that are at a high angle to it, the best explanation so far is that the aggregates of veins are concentrated along the intersections between the fractures that contain them and faults that are at a high angle to the schistosity.

The contractual kink bands appear to be transitional to high-angle faults and fault zones. The smoky quartz veins are younger than the kink bands, so those high-angle faults were there prior to gold mineralization. The faults that strike to the northwest would have been left-handed, and the faults that strike to the north-northeast would have been right-handed. In Figure 059.2 of Heather (1986), the north-northeast striking faults on the Magnacon property have a left-handed offset. Because bedding dips to the north, however, if motion along the faults was predominantly dip slip they could still be right-handed.

Most of the gold-bearing smoky quartz veins were emplaced along fractures at low angles to the schistosity, and thus at low angles to the greenstone-granite contact. The normal stress that held those fractures closed was larger when the rocks were squeezed perpendicular to the greenstone-granite contact than when they were squeezed parallel to it. Thus gold deposition would have been easier when the rocks were squeezed parallel to the greenstone-granite contact than when they were squeezed perpendicular to it.

According to Bates and Miree, the best portion of the Main Zone lies to the south of the relatively competent G1 gabbro. Because of the "pressure shadow" effect of the gabbro, the normal stress holding fractures closed was especially small when the rocks were squeezed parallel to the greenstone-granite contact. If gold mineralization occurred when the rocks were squeezed parallel to the greenstone-granite contact, the regions to the north and south of the gabbro would have been especially favourable for gold deposition.

Regionally, the locus of metasomatism, and thus of gold mineralization, was probably controlled by the package of relatively incompetent tuffs or mudstones that constitute the Mishibishu Zone. Other favourable horizons would include tuffs or mudstones interbedded with the volcanic flows and sills to the north of the study area, and tuffs or mudstones interbedded with the wackes to the south of the study area.

In summary, economic gold deposits are more likely to be found in metasomatized, and thus especially schistose, tuffs or mudstones close to intersections between the Mishibishu Zone and faults and dikes that are at a high angle to it, close to the noses of early folds, or close to competent bodies such as the G-1 gabbro.

**Recommendations for further exploration**

Although the study area does not contain shear zones like the ones that localized mineralization in some Archean gold camps, it nevertheless contains a considerable volume of metasomatized rocks that contain gold. The lack of shear zones makes it no less prospective.

The M-1 grid has been covered fairly well, and may yet contain something of value. However, exploration probably has a better chance where less work has been done.

Because there are no shear zones, less emphasis should be placed on looking for features that are commonly associated with shear zones. In other respects, the target rocks remains the same: quartz veins and metasomatized, schistose rocks. Gold-bearing quartz veins may not be spatially associated with metasomatized rocks.

Particular attention should be paid to faults and dikes that are at a high angle to the schistosity. Lineaments can be located using topographic maps, aerial photographs, radar images, or computer processed magnetic data.

Some attention should be paid to competent bodies like the G1 gabbro. Perhaps they too can be located using computer processed magnetic data.

Early fold noses are everywhere, and they may be impossible to locate without stripping the overburden from the rocks.

Wherever possible, the overburden should be stripped from prospective rocks. Outcrop stripping is relatively inexpensive for the quantity, and especially the quality, of data it reveals.

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Dated at Kingston, Ontario this 3rd day of October, 1997.

Bruce Wilson

# PHOTOGRAPHS

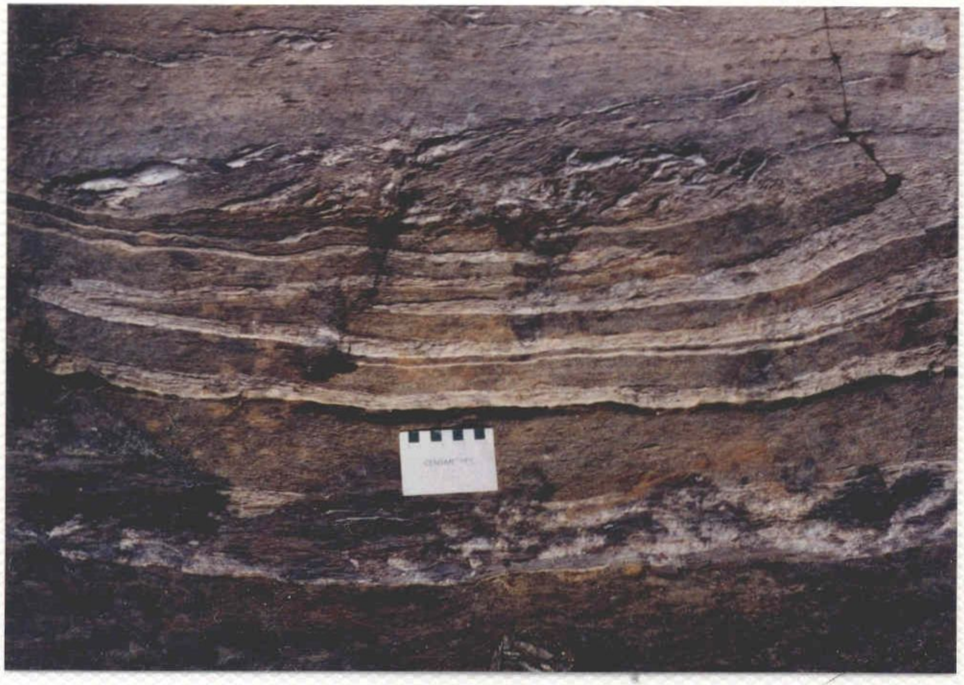
There is a scale card in all of the photographs except 14 and 16. The card is 8.5 cm by 5.5 cm, and the squares on it are 1 cm by 1 cm. The field of view in Photographs 14 and 16 is about 6 cm by 4 cm.

**Photograph 1.** Early folds (Outcrop area E)

**Photograph 2.** Early folds (Main Zone, about 40 metres west of the west end of the pit) The scale card is on a folded, light coloured bed of lapilli tuff or conglomerate.

**Photograph 3.** Early folds (Outcrop area H) The axial planar cleavage is parallel to the long sides of the scale card.

**Photograph 4.** Early folds (Outcrop area H)




0 1 3 5 7
CENTIMETRES


0 1 3 5 7
CENTIMETRES

**Photograph 5.** Conjugate kink bands (Outcrop area C) The kink band to the upper left of the card is right-handed, and the kink band to the upper right of the card is left-handed.

**Photograph 6.** Right-handed kink bands (Main Zone, about 20 metres west of the west end of the pit) Outside of the kink bands, the schistosity is parallel to the long sides of the scale card.

**Photograph 7.** A kink band and high-angle faults (Outcrop area C) Outside of the kink band, the schistosity is parallel to the long sides of the scale card. The kink band and the faults are left-handed.

**Photograph 8.** Closely spaced kink bands (Outcrop area K) The kink bands, which enclose what appear to be the short limbs of chevron folds, are left-handed.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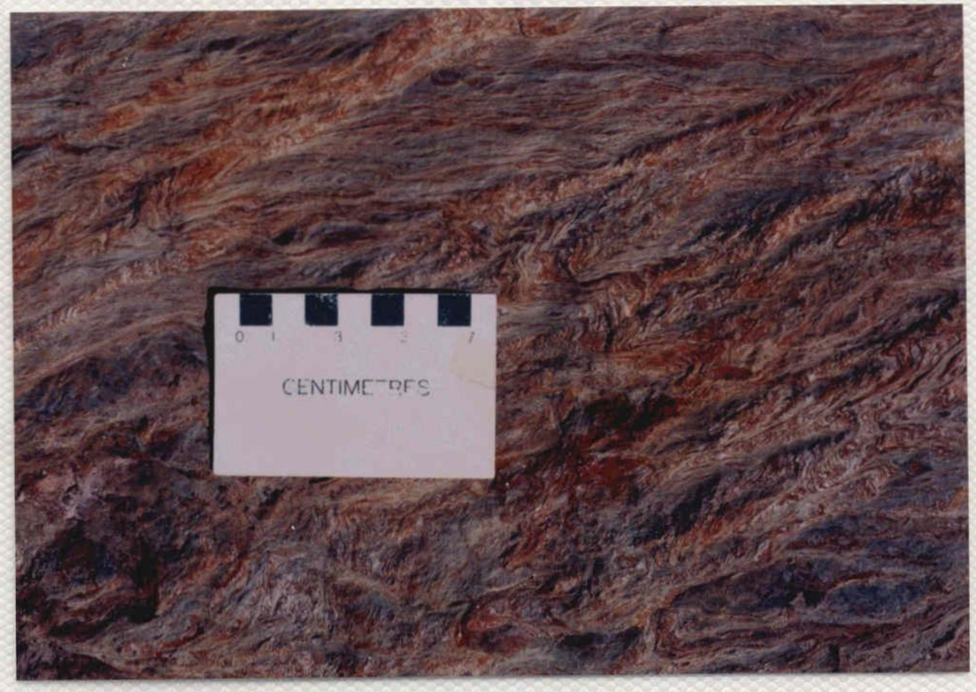
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**Photograph 9.** Crenulations (Outcrop area O)

**Photograph 10.** A kink fold refolding an early fold (Outcrop area H) Outside of the kink bands, the schistosity is parallel to the long sides of the scale card. The kink band is left-handed.



**Photograph 11.** Conjugate low-angle shear fractures (Outcrop area K) Intersecting low-angle shear fractures form diamonds in a felsic volcanic rock.

**Photograph 12.** Conjugate low-angle shear fractures (Main Zone, at the west end of the pit on strike with the pit) Intersecting low-angle shear fractures form diamonds in a mafic volcanic rock. The smoky quartz veins are presumably part of the aggregate that was removed in the bulk sample.


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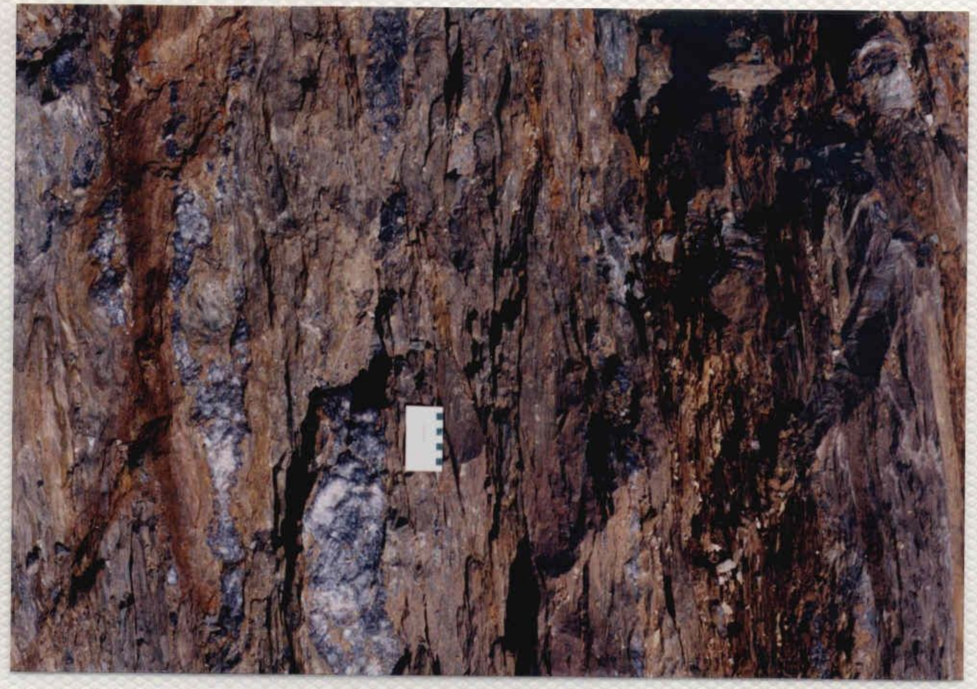

**Photograph 13.** Conjugate low-angle shear fractures (Outcrop area O)

**Photograph 14.** The metamorphic elongation lineation (Main Zone) The metamorphic elongation lineation is defined by an amphibole in a mafic volcanic rock. The intersection lineation, defined by intersecting low-angle shear fractures, is marked by coloured bands of different metasomatic minerals. The metomorphic elongation lineation and the intersection lineation are parallel to each other.

**Photograph 15.** The metasomatic elongation lineation (Outcrop area K) The metasomatic elongation lineation is defined by an amphibole (?) in a felsic volcanic rock.

**Photograph 16.** The intersection lineation (Outcrop area O) The intersection lineation, defined by intersections between low-angle shear fractures, plunges from the upper left of the photograph to the lower right.


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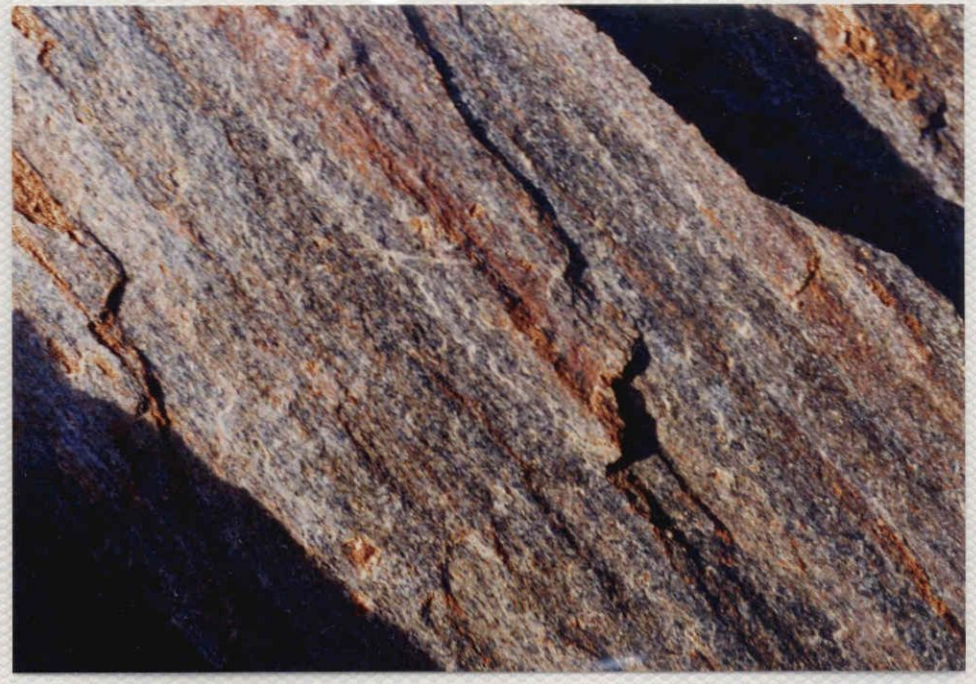

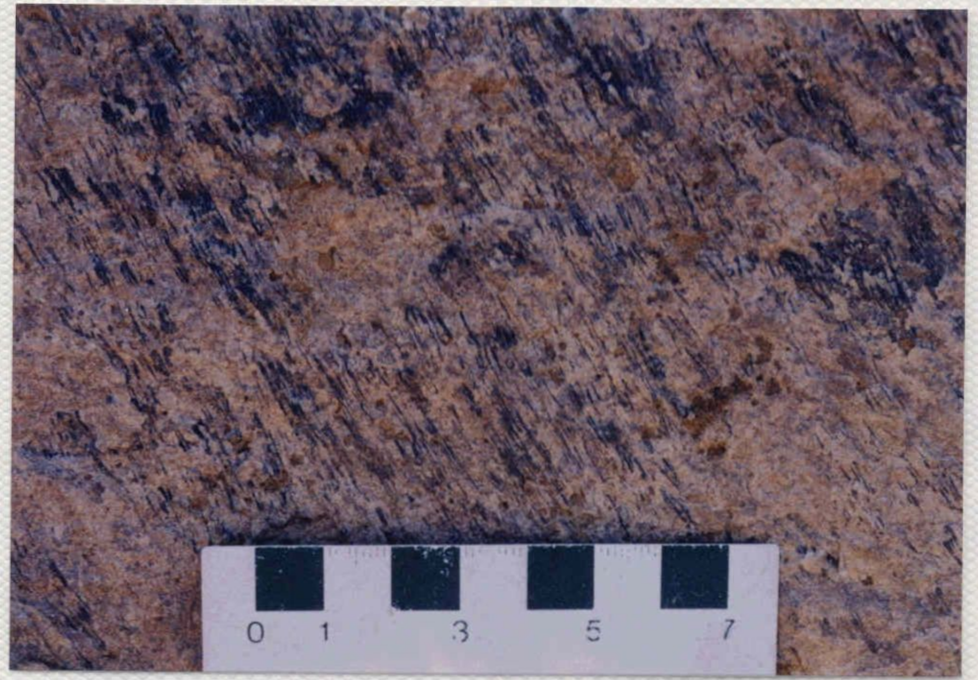
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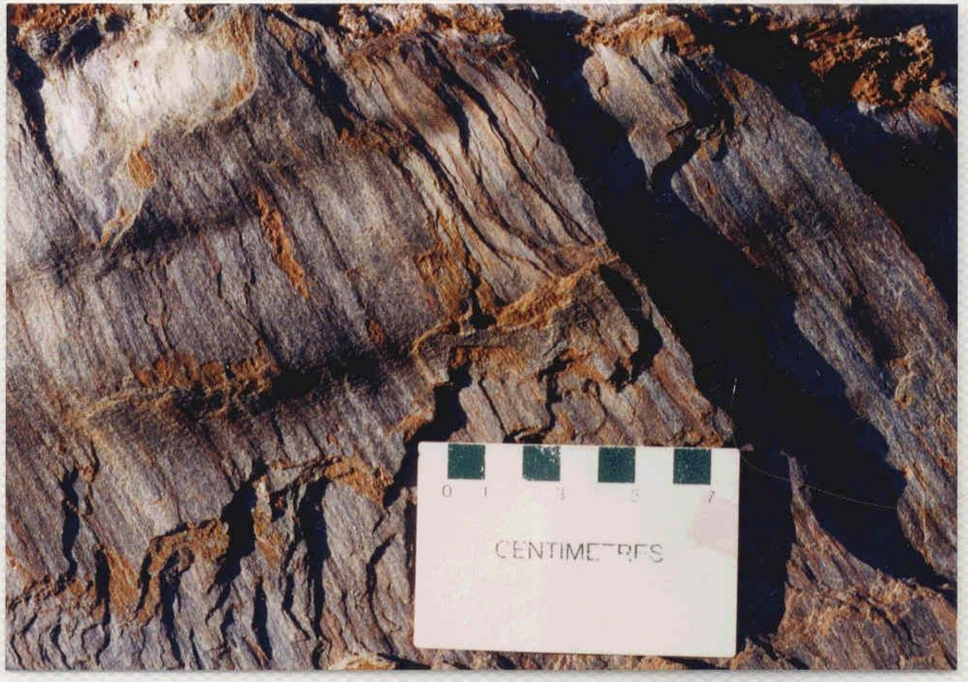
**Photograph 17.** The intersection lineation (Main Zone) The intersection lineation, defined by intersecting low-angle shear fractures, is marked by coloured bands of different metasomatic minerals. It plunges from the upper left of the photograph to the lower right. Axes of Z-shaped kink folds, marked by shadows, plunge from the upper right to the lower left.

**Photograph 18.** White quartz veins (Outcrop area E) The early folds in the white quartz veins are S-shaped Z folds that plunge to the east (to the **left** in the photograph). They are S-shaped because the surface of the outcrop dips to the east at an angle that is larger than the plunge of the folds.

**Photograph 19.** Quartz-tourmaline veins in a kink band (Outcrop area K) The kink band is right-handed.

**Photograph 20.** Smoky quartz veins in conjugate low-angle shear fractures (Outcrop area O)

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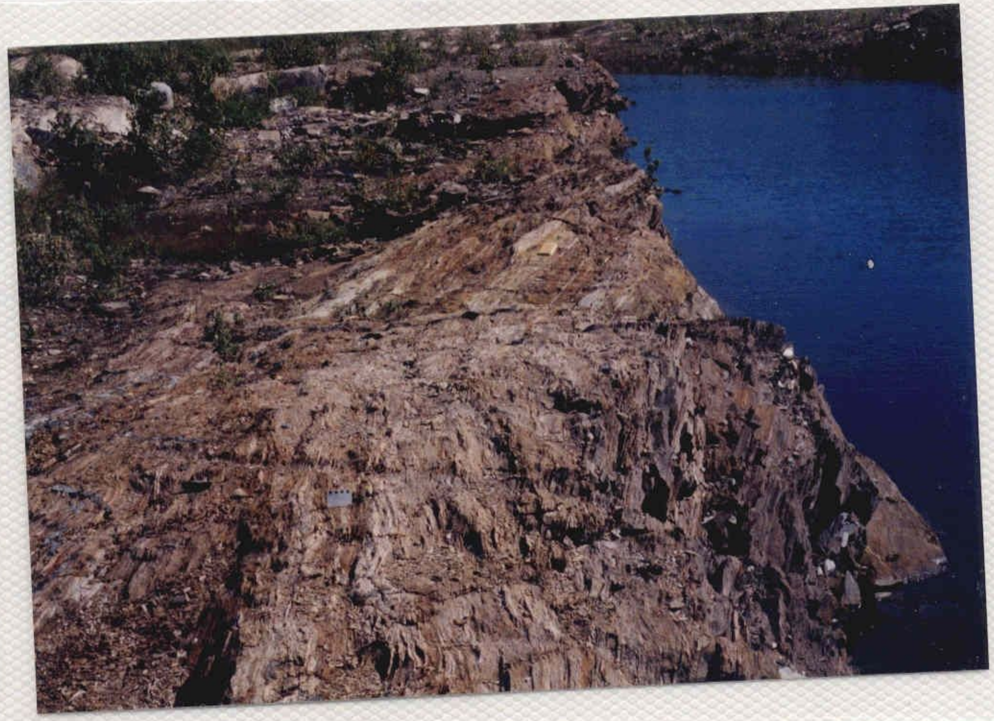
**Photograph 21.** Smoky quartz veins in left-handed low-angle shear fractures (Outcrop area O)

**Photograph 22.** The schistosity at the pit (Main Zone) In the foreground, where the scale card is, the schistosity is roughly parallel to the pit. In the background, where the yellow notebook is, the schistosity is oblique to the pit.



**Photograph 23.** A boudinaged smoky quartz vein (Outcrop area H) The boudins are lozenge-shaped because the vein was in a left-handed low-angle shear fracture and was oblique to the direction of squeezing, and thus to the directions of shortening and elongation.

**Photograph 24.** Smoky quartz vein cutting a kink band (Outcrop area K) The kink band is cut by a quartz-tourmaline vein. At the tip of the pencil, the quartz-tourmaline vein is cut by a smoky quartz vein.

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**Photograph 25.** A folded smoky quartz vein (Outcrop area H) The schistosity is roughly parallel to the short sides of the scale card.

**Photograph 26.** An aggregate of smoky quartz veins (Outcrop area H)

**Photograph 27.** Metasomatic sulphides (Outcrop area C) The sulphides are marked by their weathering product, hydrous iron oxide (rust).

**Photograph 28.** Smoky quartz veins and kink bands (Outcrop area C)

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## STATEMENT OF QUALIFICATION

I, Bruce Wilson, of the city of Kingston, in the province of Ontario, do hereby certify that:

1. I am a self-employed, consulting structural geologist.
2. I received an Honours B.Sc. in geology from Queen's University at Kingston, Ontario in 1974, and an M.Sc. in geology from Queen's University at Kingston, Ontario, in 1976.
3. I have practiced geology since 1976.

Dated at Kingston, Ontario this 3rd day of October, 1997.

Bruce Wilson.

Bruce Wilson
Structural Geologist

## APPENDIX A - CLAIM LIST

Ontario | Ministry of Northern Development and Mines

# Declaration of Assessment Work Performed on Mining Land

Mining Act, Subsection 65(2) and 66(3), R.S.O. 1990

Transaction Number (office use): W9750.00896

Assessment Files Research Imaging

Personal information collected or ... the Mining Act. Under section 8 of the Mining Act, the information is a p... correspond with the mining land holder. Questions about this collection ... Development and Mines, 6th Floor, 933 Ramsey Lake Road, Sudbu...

42C03SW0045 2.17770 MISHIBISHU LAKE 900

**Instructions:** - For work ... rm 0240.
- Please type or print in ink.

## 1. Recorded holder(s) (Attach a list if necessary)

| | |
|---|---|
| Name: MACMILLAN GOLD CORP. | Client Number: 162922 |
| Address: 365 BAY ST., 11th FLOOR | Telephone Number: 416-363-1124 |
| TORONTO, ON M5H 2V1 | Fax Number: 416-360-0728 |
| Name | Client Number |
| Address | Telephone Number |
| | Fax Number |

RECEIVED OCT 23 1997 ... SCIENCE ASSESSMENT OFFICE

## 2. Type of work performed: Check (✓) and report on only ONE of the following groups for this declaration.

☑ Geotechnical: prospecting, surveys, assays and work under section 18 (regs) ☐ Physical: drilling, stripping, trenching and associated assays ☐ Rehabilitation

| | | Office Use |
|---|---|---|
| Work Type: GEOLOGY | | Commodity |
| | | Total $ Value of Work Claimed: 14,393 |
| Dates Work Performed From 05 Day 08 Month 97 Year To 03 Day 10 Month 97 Year | | NTS Reference |
| Global Positioning System Data (if available) | Township/Area: MISHIBISHU LAKE AREA | Mining Division: SSM |
| | M or G-Plan Number: ~~M~~ G-3772 | Resident Geologist District: SSM |

Please remember to: - obtain a work permit from the Ministry of Natural Resources as required;
- provide proper notice to surface rights holders before starting work;
- complete and attach a Statement of Costs, form 0212;
- provide a map showing contiguous mining lands that are linked for assigning work;
- include two copies of your technical report.

2.17770

## 3. Person or companies who prepared the technical report (Attach a list if necessary)

| | |
|---|---|
| Name: BRUCE C. WILSON | Telephone Number: 613-544-2171 |
| Address: 347 ALBERT ST., KINGSTON, ON K7L 3W1 | Fax Number: as above |
| Name | Telephone Number |
| Address | Fax Number |
| Name | Telephone Number |
| Address | Fax Number |

## 4. Certification by Recorded Holder or Agent

I, JAMES E. MILLARD (Print Name), do hereby certify that I have personal knowledge of the facts set forth in this Declaration of Assessment Work having caused the work to be performed or witnessed the same during or after its completion and, to the best of my knowledge, the annexed report is true.

| | | |
|---|---|---|
| Signature of Recorded Holder or Agent: [signature] | | Date: OCT 22/97 |
| Agent's Address: 16 BROADWAY AVE, WAWA ON P0S 1K0 | Telephone Number: 705-856-8195 (~~613-544-2171~~) | Fax Number: 705-856-8196 |

Deemed Jan. 21/98

0241 (02/96)

5. **Work to be recorded and distributed.** Work can only be assigned to claims that are contiguous (adjoining) to the mining land where work was performed, at the time work was performed. A map showing the contiguous link must accompany this form.

| | Mining Claim Number. Or if work was done on other eligible mining land, show in this column the location number indicated on the claim map. | Number of Claim Units. For other mining land, list hectares. | Value of work performed on this claim or other mining land. | Value of work applied to this claim. | Value of work assigned to other mining claims. | Bank. Value of work to be distributed at a future date. |
|---|---|---|---|---|---|---|
| eg | TB 7827 | 16 ha | $26, 825 | N/A | $24,000 | $2,825 |
| eg | 1234567 | 12 | 0 | $24,000 | 0 | 0 |
| eg | 1234568 | 2 | $ 8, 892 | $ 4,000 | 0 | $4,892 |
| 1 | CLM - 377 | 480 ha | ~~$15,623.~~ $4,798. | N/A | | $4,798 |
| 2 | CLM - 378 | 384 ha | ~~$15,623.~~ $4,798. | N/A | | $4,798 |
| 3 | CLM - 379 | 288 ha | ~~$15,623.~~ $4,797. | N/A | | $4,797 |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| | | Column Totals | $14,393. | | | $14,393. |

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2.17770

I, JAMES E. MILLARD (Print Full Name), do hereby certify that the above work credits are eligible under subsection 7 (1) of the Assessment Work Regulation 6/96 for assignment to contiguous claims or for application to the claim where the work was done.

Signature of Recorded Holder or Agent Authorized in Writing: JE Millard | Date: Oct 22/97

6. **Instructions for cutting back credits that are not approved.**

Some of the credits claimed in this declaration may be cut back. Please check (✓) in the boxes below to show how you wish to prioritize the deletion of credits:

- [x] 1. Credits are to be cut back from the Bank first, followed by option 2 or 3 or 4 as indicated.
- [x] 2. Credits are to be cut back starting with the claims listed last, working backwards; or
- [ ] 3. Credits are to be cut back equally over all claims listed in this declaration; or
- [ ] 4. Credits are to be cut back as prioritized on the attached appendix or as follows (describe):

Note: If you have not indicated how your credits are to be deleted, credits will be cut back from the Bank first, followed by option number 2 if necessary.

**For Office Use Only**

| Received Stamp | Deemed Approved Date | Date Notification Sent |
|---|---|---|
| | Date Approved | Total Value of Credit Approved |
| | Approved for Recording by Mining Recorder (Signature) | |

0241 (02/96)

BW STRUCTURAL

Ontario | Ministry of Northern Development and Mines

# Statement of Costs for Assessment Credit

Transaction Number (office use): W9750.00896

Personal information collected on this form is obtained under the authority of subsection 6(1) of the Assessment Work Regulation 6/96. Under section 8 of the Mining Act, the information is a public record. This information will be used to review the assessment work and correspond with the mining land holder. Questions about this collection should be directed to the Chief Mining Recorder, Ministry of Northern Development and Mines, 6th Floor, 933 Ramsey Lake Road, Sudbury, Ontario, P3E 6B5.

| Work Type | Units of Work<br>Depending on the type of work, list the number of hours/days worked, metres of drilling, kilometres of grid line, number of samples, etc. | Cost Per Unit of work | Total Cost |
|---|---|---|---|
| GEOTECHNICAL SURVEY | 30 PERSON DAYS | $293 / day | 8,780. |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| **Associated Costs (e.g. supplies, mobilization and demobilization).** | | | |
| SUPPLIES AND EQUIPMENT RENTALS | | | 3,611. |
| | | | |
| | | | |
| | | | |
| **Transportation Costs** | | | 1,069. |
| | | | |
| **Food and Lodging Costs** | | | 933. |
| | | | |
| | | | |
| **Total Value of Assessment Work** | | | $14,393. |

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2.17770

**Calculations of Filing Discounts:**

1. Work filed within two years of performance is claimed at 100% of the above Total Value of Assessment Work.
2. If work is filed after two years and up to five years after performance, it can only be claimed at 50% of the Total Value of Assessment Work. If this situation applies to your claims, use the calculation below:

TOTAL VALUE OF ASSESSMENT WORK × 0.50 = Total $ value of worked claimed.

**Note:**
- Work older than 5 years is not eligible for credit.
- A recorded holder may be required to verify expenditures claimed in this statement of costs within 45 days of a request for verification and/or correction/clarification. If verification and/or correction/clarification is not made, the Minister may reject all or part of the assessment work submitted.

**Certification verifying costs:**

I, JAMES MILLARD (please print full name), do hereby certify, that the amounts shown are as accurate as may reasonably be determined and the costs were incurred while conducting assessment work on the lands indicated on the accompanying Declaration of Work form as AGENT (recorded holder, agent, or state company position with signing authority) I am authorized to make this certification.

| Signature | Date |
|---|---|
| J E Millard | Oct 22/97 |

0212 (02/96)

Ministry of
Northern Development
and Mines

Ministère du
Développement du Nord
et des Mines

Ontario

Geoscience Assessment Office
933 Ramsey Lake Road
6th Floor
Sudbury, Ontario
P3E 6B5

Telephone: (888) 415-9846
Fax: (705) 670-5881

January 21, 1998

MACMILLAN GOLD CORP.
365 BAY STREET
11TH FLOOR
TORONTO, ONTARIO
M5H-2V1

Dear Sir or Madam:

**Submission Number:** 2.17770

| | | **Status** |
|---|---|---|
| **Subject: Transaction Number(s):** | W9750.00896 | Approval |

We have reviewed your Assessment Work submission with the above noted Transaction Number(s). The attached summary page(s) indicate the results of the review. WE RECOMMEND YOU READ THIS SUMMARY FOR THE DETAILS PERTAINING TO YOUR ASSESSMENT WORK.

If the status for a transaction is a 45 Day Notice, the summary will outline the reasons for the notice, and any steps you can take to remedy deficiencies. The 90-day deemed approval provision, subsection 6(7) of the Assessment Work Regulation, will no longer be in effect for assessment work which has received a 45 Day Notice.

Please note any revisions must be submitted in DUPLICATE to the Geoscience Assessment Office, by the response date on the summary.

If you have any questions regarding this correspondence, please contact Lucille Jerome by e-mail at jeromel2@epo.gov.on.ca or by telephone at (705) 670-5858.

Yours sincerely,

ORIGINAL SIGNED BY
Blair Kite
Supervisor, Geoscience Assessment Office
Mining Lands Section

Correspondence ID: 11791
Copy for: Assessment Library

# Work Report Assessment Results

**Submission Number:** 2.17770

**Date Correspondence Sent:** January 21, 1998 **Assessor:** Lucille Jerome

| Transaction Number | First Claim Number | Township(s) / Area(s) | Status | Approval Date |
|---|---|---|---|---|
| W9750.00896 | 377 | MISHIBISHU LAKE | Approval | January 21, 1998 |

**Section:**
12 Geological GEOL

**Correspondence to:**
Resident Geologist
Sault Ste. Marie, ON

Assessment Files Library
Sudbury, ON

**Recorded Holder(s) and/or Agent(s):**
James Millard
WAWA, ON, CAN

MACMILLAN GOLD CORP.
TORONTO, ONTARIO



Correspondence ID: 11791


TRIM TO THIS LINE ALL AROUND

42C03SW0045 2.17770 MISHIBISHU LAKE

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