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THE STRUCTURAL GEOLOGY OF THE MOUNT McDAME AREA, NORTH-CENTRAL BRITISH COLUMBIA (104/P)

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KEYWORDS: Structural geology, Sylvester allochthon, Cassiar platform, Mount McDame, Marble Creek fault, Cassiar asbestos deposit.

INTRODUCTION

Mount McDame is situated in north-central British Columbia, near the town of Cassiar, 15 kilometres northwest of the Stuart-Cassiar highway (Figure 1-22-1). Mapping in the area at 1:25 000 scale was completed in 1988 by Nelson and Bradford (1989). They identified an area of anomalous structure centred on Mount McDame and based on the juxtaposition of successively lower units of the Cassiar platform and the Sylvester allochthon. Mapping at 1:6000 scale was undertaken in 1989 to rationalize the anomalous structure and to relate the geology to that of the nearby Cassiar chrysotile asbestos mine as described by O'Hanley and Wicks (1987) and O'Hanley (1988).

GEOLOGIC SETTING

Mount McDame is composed of both platformal and eugeosynclinal rock sequences. Its lower slopes are underlain by Lower Cambrian to Devonian carbonates and shales of the Cassiar platform, which is part of the ancestral North American continental margin. The upper part of the mountain consists of Pennsylvanian-Permian (?) argillite and chert, and Mississippian argillite, chert, limestone, greywacke, and greenstone sequences of oceanic and island arc affinities, and serpentinite, all part of the Sylvester allochthon emplaced in Jurassic time (Harms, 1986; Nelson and Bradford, 1989).

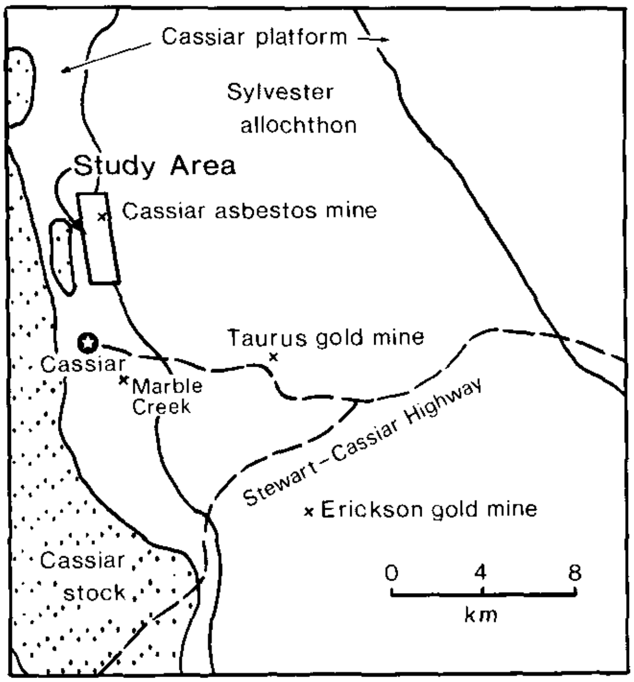


Figure 1-22-1. Location of the study area and the Cassiar asbestos mine on Mount McDame, in north-central British Columbia.

The base of the allochthon is the roof thrust in a duplex structure involving some of the platform units. The duplex has its roots in the Road River Group, and thrust sheets are composed of the Road River Group, the Tapioca sandstone and the McDame and Earn groups.

The Cassiar and McDame asbestos deposits occur on Mount McDame within the Sylvester allochthon, close to the basal contact with the platformal units. The Cassiar serpentinite lies between the chert-argillite and the Mississippian sequences.

The Earn Group is found immediately below the allochthon both to the north and south of the study area. Within the map area successively older units are in contact with the base of the Sylvester allochthon from south to north. Nelson and Bradford (1989) projected the Marble Creek fault, a late-stage, high-angle fault, into this contact near the Cassiar mine. No evidence of the Marble Creek fault was found during this study and it is not shown on Figure 1-22-2.

STRATIGRAPHY

The stratigraphy of the map area has been described by Gabrielse (1963) and by Nelson and Bradford (1989), and is only briefly summarized here. However, several marker units were used to document the presence or absence of stratigraphic continuity.

PLATFORM SEQUENCES

The Lower Cambrian Rosella Formation, exposed in the southwest corner of the map area, is recognised by its characteristic white-blue-grey banding in limestone and dolomite. The Cambro-Ordovician Kechika Group is absent. The contact between the Road River Group and the Rosella Formation seems conformable just south of the McDame adits but a quartz vein 20 metres wide marks this contact farther to the south (Figure 1-22-2). Dark grey limestone, a distinctive carbonate-altered volcaniclastic rock and the presence of graptolites identify the Road River Group. The "Silurian siltstones" mark the contact between the Ordovician Road River Group and the Devonian Tapioca sandstone.

The Tapioca sandstone contains a distinctive light grey quartzite, 3 metres wide, that is stratigraphically above

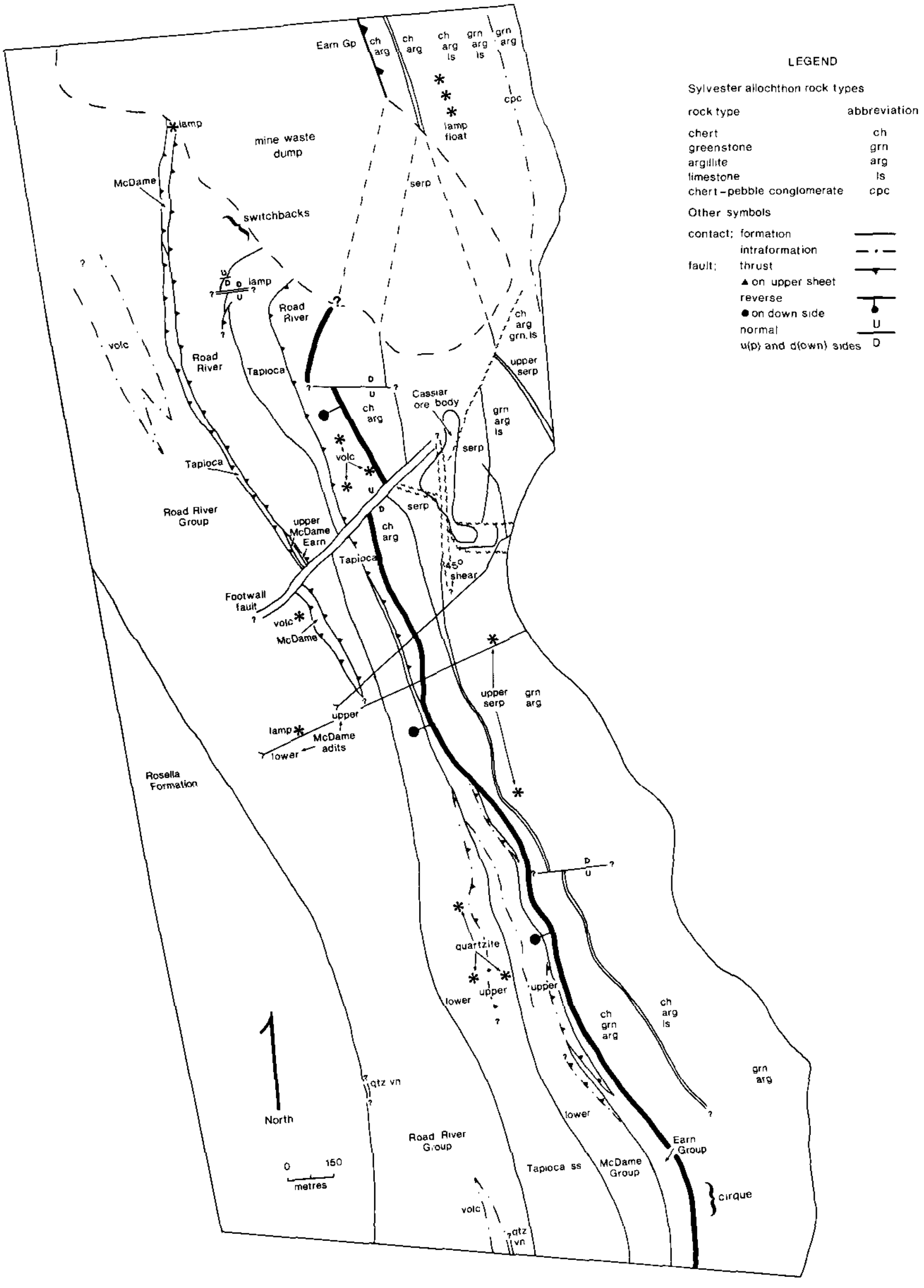


Figure 1-22-2. Interpretive geologic map of the western face of Mount McDame, based on outcrop maps compiled by Lyn O'Hanley (1988, unpublished) and Nelson and Bradford (1989).

interbedded Tapioca sandstone and quartzite. A structural repetition of the Tapioca sandstone south of the McDame adits is suggested by repetition of the quartzite and rotation of bedding, and a thrust fault has been inferred in this locality (Figure 1-22-2). This interpretation is supported by rotation of bedding in the Tapioca sandstone, from 354/72E to 025/47SE as the fault is approached from the west. Immediately north of this area the fetid, fossiliferous unit of the lower McDame is absent, and is not seen again until it crops out in a thrust panel on the switchback road west of the Cassiar orebody. In between these areas, nonfetid, cross-bedded dolomite assigned to the Tapioca sandstone is disconformably overlain by upper McDame limestones, which are in turn overlain by shales of the Earn Group (Plate 1-22-1). This evidence suggests that, at least locally, the lower McDame unit was removed by erosion before deposition of the upper platey limestones. Thus some of the McDame Group west of the mine was absent before deformation occurred; paleo-erosion of the McDame Group has been previously documented by Gabrielse (1963).

SYLVESTER STRATA

Nelson and Bradford (1989) identified two rock sequences in the area that belong to the allochthon. A Mississippian suite consists of chert, argillite, limestone, greenstone and a distinctive chert-pebble conglomerate. A second suite, thought to be of Pennsylvanian to Permian age, consists of chert and argillite. These two packages were thought to be separated by a fault containing the Cassiar serpentinite; with the Pennsylvanian-Permian rocks in the footwall, and the Mississippian rocks in the hangingwall of the serpentinite in the mine. Detailed mapping north of the mine located chert-argillite sequences, similar to those in the footwall of the mine, stratigraphically above outcrop consisting of talc and listwanite cobbles, representing altered serpentinite. South of the mine altered greenstone or tuff pods in argillite are found stratigraphically below serpentinite.

Traces of the upper serpentinite, defined in the hangingwall of the Cassiar orebody (Figure 1-22-2), are exposed to

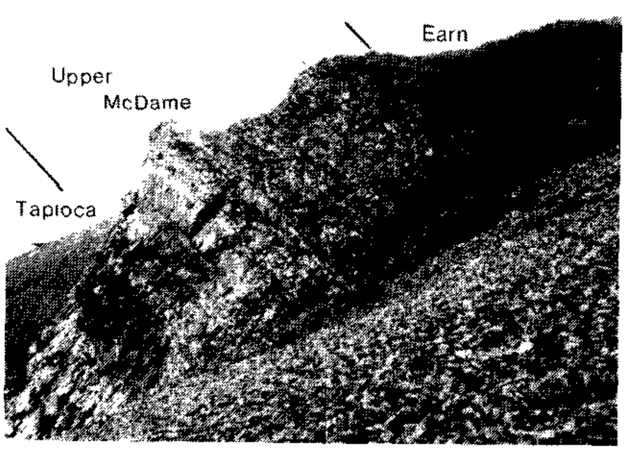


Plate 1-22-1. View to the north of outcrop containing karst features in Tapioca sandstone, which is overlain by upper McDame bedded limestones and Earn shales. McDame limestones are approximately 5 metres wide.

the south. Both occurrences are stratigraphically above outcrop consisting of serpentinite and talc schist that correlate with the footwall serpentinite in the mine. A normal fault just south of this outcrop offsets the serpentinite and suggests that the serpentinite to the south is part of the lower rather than the upper body.

The fact that the serpentinite does not separate chert-argillite sequences from those containing limestone and greenstone suggests that the serpentinite cuts obliquely across a Mississippian sequence which records a facies(?) change, from chert-argillite to chert-argillite-limestone to argillite-limestone-greenstone. Alternatively, the sequence may consist of rocks of both Pennsylvanian and Mississippian age.

LAMPROPHYRE DIKES

Biotite-rich lamprophyre dikes crop out in four localities and are present as float in three others (Figure 1-22-2). They cut all lithologies above the Rosella Formation. One dike, 4 metres wide, fills an east-striking normal fault that offsets the Road River – Tapioca contact. This dike, and one other found in the McDame limestones on the switchbacks west of the mine, is undeformed. In contrast, two dikes found in the Road River Group above the McDame adits have schistose textures at their margins.

STRUCTURAL GEOLOGY

Several types of faults are identified in the study area based on orientation and the presence or absence of fault fabrics. North-northeast-striking faults dip steeply to gently; they are recognised by changes and discontinuities in bedding orientation. Their present orientation suggests normal displacement but, if the affect of later tilting is removed, they become low-angle reverse faults. Several of the faults near the upper McDame – Earn contact define frontal ramps (Plate 1-22-2), and indicate west-over-east, east-directed transport. These faults are associated with duplex formation during emplacement of the allochthon (Harms, 1986). Faults in the Road River Group on the mine switchbacks, with similar orientations to those described above, contain fault fabrics (slickensides, fault cleavage and gouge) that indicate early normal displacement and subsequent reverse displacement. This interpretation is based on the assumption that fault gouge, which in some faults is similar to the foliated cataclasites of Chester *et al.* (1985) and Chester and Logan (1987), is younger than fault-zone cleavage.

East to northeast-striking, high-angle normal faults are recognised by offsets of rock contacts (Plate 1-22-3) and the presence of lamprophyre dikes; gouge is present in some faults. The two best examples are the lamprophyre-filled fault mentioned earlier, and the Footwall fault in the footwall of the Cassiar orebody (O'Hanley, 1988; Figure 1-22-2). These structures, which may or may not contain lamprophyre dikes, offset all other faults. In particular, the Footwall fault offsets the inferred Marble Creek fault.

These faults are probably more common than shown in Figure 1-22-2 for two reasons; they are difficult to identify due to the lack of fault fabrics and discontinuous outcrop; the presence of lamprophyre float suggests the existence of

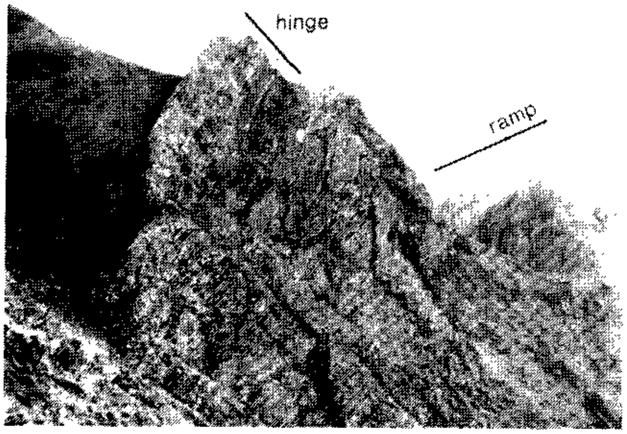


Plate 1-22-2. Frontal ramp in upper McDame limestones recognized by the difference in bedding orientation across the fault trace.

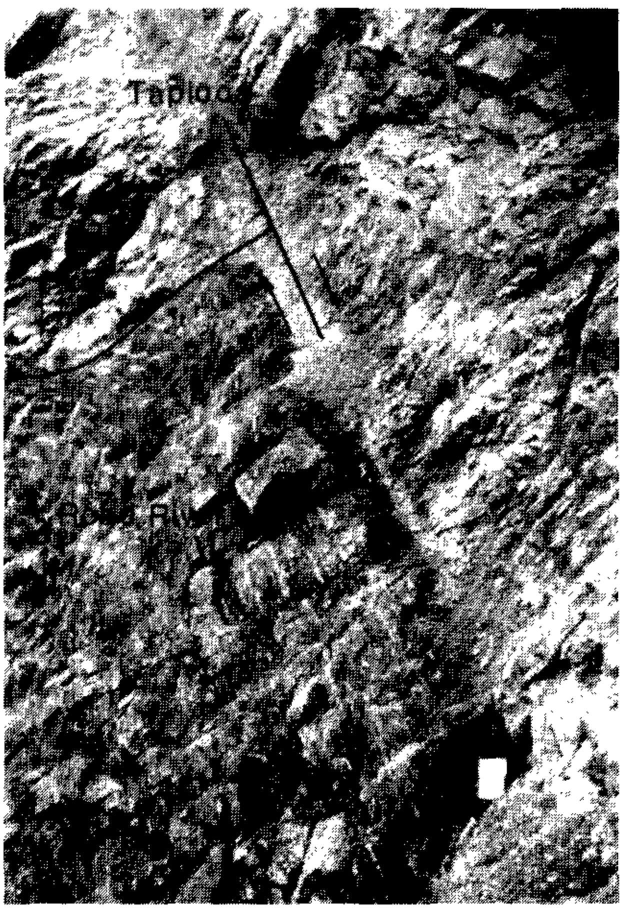


Plate 1-22-3. Normal, late-stage fault cutting the Road River–Tapioca contact. Scale bar is 1 metre.

normal faults, although the faults were not identified. The float occurs in drainage gulleys, as do known normal faults, so it is possible that every gulley represents a fault trace. A normal fault may explain the sharp change in width of the Cassiar serpentinite that occurs beneath the mine waste dump. The above discussion suggests that the continuity of some faults and rock contacts in Figure 1-22-2 is questionable.

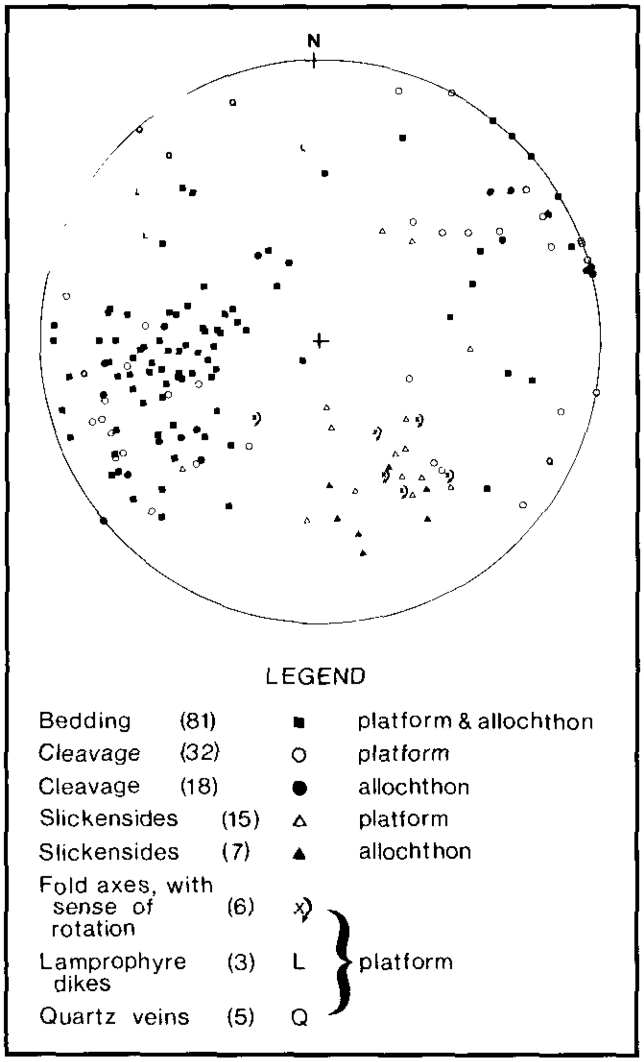
The south wall of the cirque at the southern limit of the map area consists of a structurally unrepeated platformal sequence, except that the Kechika Group is absent. North of the mine area, the Road River Group is structurally repeated three times, indicating that the duplex is well established (Nelson and Bradford, 1989). The presence of frontal ramps involving the Earn and upper McDame groups, where there is no repetition of the underlying strata, suggests the basic structural pattern is explained by increasing penetration of duplex-related deformation and faulting from north to south. Thus thrust faults are more common on the switchbacks west of the mine than farther to the south, and penetrate deeper into the platformal sequence.

Structural Data

The dominant bedding attitude in the study area has a northwesterly strike with a steep northeasterly dip (Figure 1-22-3). The Road River Group contains bedding-parallel cleavage, and both dextral and sinistral folds of calcite veins, which suggest that it is a flattening cleavage. The Sylvester chert-argillite sequence contains axial-planar cleavage that has the same orientation as the cleavage in the Road River Group. The more massive dolomites in the Tapioca and the McDame contain quartz veins orientated perpendicular to bedding and cleavage (Figure 1-22-3). The lamprophyre dikes and the normal faults have the same orientation as the quartz veins. All of these data are consistent with duplex-related structures.

Asymmetric folds of Road River cleavage and calcite veins, and asymmetric quartz-fibre pressure shadows around pyrite grains, are consistent with southwest-directed, east-over-west motion after the formation of the cleavage. This sense of motion is also consistent with the reverse displacement indicated by fault fabrics in the Road River Group. Slickensides, stretching directions, and fold axes both in the platform and allochthon rocks also suggest east-over-west, southwest-directed motion (Figure 1-22-3). All these data indicate that an episode of deformation affected both the platform and allochthon rocks after emplacement of the allochthon. It is attributed to the tilting of the strata into their present steeply east-dipping orientation and predates emplacement of the lamprophyre dikes.

The observations made during this study indicate three deformation events: an early event associated with duplex formation during emplacement of the allochthon, an intermediate event associated with tilting of the strata, and a late event associated with normal faulting and emplacement of lamprophyre dikes. As some of the lamprophyre dikes are physically deformed, deformation must have continued after dike emplacement but no other structural data that might reflect this late-stage deformation were documented. It is possible however, that the late-stage deformation is kinematically consistent with the earlier deformations, and that some structural features found in faults within the Road River Group formed during the late-stage deformation rather than the episode that tilted the strata.



The Marble Creek Fault

The Marble Creek fault was defined by Nelson and Bradford (1989) in the Marble Creek drainage basin south of the town of Cassiar. In this area the Kechika Group is not present between the Rosella Formation and the Road River Group; Nelson and Bradford invoked high-angle faulting to account for its absence. The juxtaposition of Road River against Sylvester cherts in the Cassiar mine, and the absence of the McDame and Earn groups in between Road River and Sylvester rocks in the lower McDame adit, could both be explained by a high-angle fault. Based on these observations Nelson and Bradford extended the Marble Creek fault northward obliquely across Mount McDame.

Surface mapping above the adits identified a distinctive chert-argillite sequence (red and black chert: R&B in Figure 1-22-4) that is also present in the upper adit, but not in the lower adit, which contains only ribbon chert. This observation is important for two reasons. First, correlation of the chert at the surface with that in the upper adit constrains the dip of the inferred Marble Creek fault and essentially restricts it to being a bedding-parallel structure, rather than a vertical fault. Second, this observation suggests the chert-argillite unit is missing both down dip and along strike to the south of the McDame adits.

Other observations argue against the existance of the Marble Creek fault. The Footwall fault offsets the inferred trace of the Marble Creek fault; this relationship indicates that the Marble Creek fault could not be a late-stage event. The absence of the red and black chert in the lower adit and at the south end of the map area, indicates that some Sylvester units are also missing, in addition to the platform units mentioned earlier. Sylvester units disappear from north to south and platform units disappear from south to north; the missing units can be accounted for by invoking dextral-reverse displacement on the basal Sylvester fault that brings the allochthon to the southwest obliquely across the platform units. However, no data from fault fabrics within the basal fault were found that either confirmed or denied this hypothesis.

This model, together with the evidence that the duplex is incipiently developed at the south end of the map area, explains the observed distribution of rock types. A second line of reasoning supporting this interpretation is that the stratigraphic separation between the Rosella Formation, which is below the duplex, and the base of the allochthon, which is above it, is constant. If the Marble Creek fault operated as suggested by Nelson and Bradford, the platform sequence should be thinner to the north because part of it would have been faulted out. Furthermore, the chert-argillite unit should still be present near the cirque at the south end of the map area.

In summary, a fault is needed to explain the 1:25 000 mapping of Nelson and Bradford (1989), and the 1:6000 mapping completed during this study. It should be placed at the base of the allochthon and considered a nearly bedding-parallel fault. The absence of the Kechika Group from the Marble Creek area was not addressed by this study, but the presence of carbonate-altered volcanic rocks in the Road River Group in the map area, and nowhere else, and the apparent conformable contact between the Road River Group and the Rosella Formation in one locality, suggests that the Kechika is missing due to a facies change rather than as the result of faulting.

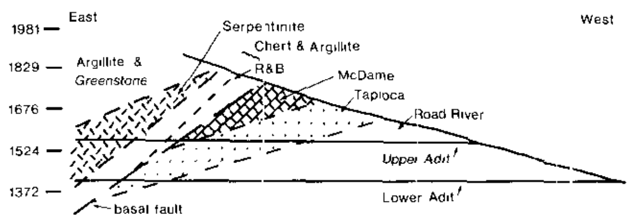


Figure 1-22-4. Schematic composite cross-section through Mount McDame parallel to the upper McDame adit. Section includes data from both the upper and lower adits, and surface mapping done during the current study. Horizontal scale equals the vertical scale. Correlation of red and black argillite (R&B) from surface to upper adit limits dip of inferred Marble Creek fault (Nelson and Bradford, 1989). Note that neither the red and black argillite nor the McDame Group is present in the lower adit.

CASSIAR AND McDAME ASBESTOS MINES

The ore zone in the Cassiar mine consists of specific serpentine minerals (chrysotile and antigorite) and textures (interlocking texture) developed during shear-zone controlled fluid flow and deformation (O'Hanley and Wicks, 1987; O'Hanley *et al.*, 1989). The fluids could be either of magmatic or metamorphic origin based on $\delta^{18}O$ fluid values calculated at 300°C from serpentine-magnetite mineral pairs (O'Hanley *et al.*, 1989). O'Hanley (1988) reported two episodes of faulting in the 45° shear, based on fault-zone fabrics; an earlier east-side-down displacement, and a later dextral-reverse displacement. The formation of the ore-zone textures and the asbestos veins is associated with the latter event.

The work reported here permits the earlier work of O'Hanley and Wicks (1987) and O'Hanley (1988) to be interpreted in the context of the geology of Mount McDame. The 45° shear, prevously interpreted as a normal fault, becomes a low-angle reverse fault when the affect of tilting is removed. Its orientation and sense of movement are consistent with emplacement structures, but it is not certain that it is in fact an emplacement-related structure. The ore zone formed during the later episode of deformation, characterised by dextral-reverse faulting that tilted the strata. This interpretation suggests that strike-slip faulting is not as important in the formation of chrysotile asbestos deposits as previously thought (O'Hanley 1988), although a change in stress regime still seems necessary to explain the observations from the Cassiar mine, in particular, the existence of two generations of asbestos veins with different orientations.

TIMING OF EVENTS

Duplex formation occurred during allochthon emplacement in Jurassic time (Harms, 1986). Emplacement must predate the Cassiar batholith, which is 89 to 110 Ma (Sketchley *et al.*, 1986). Dextral-reverse fault displacement is constrained to be older than the normal faulting that was accompanied by emplacement of lamprophyre dikes. The few lamprophyre dikes from other areas that have been dated are 110 ± 4 Ma (A. Panteleyev, cited in Sketchley *et al.*, 1986). Thus, asbestos formation, and tilting of the strata, predates the intrusion of the Cassiar batholith and the nearby Cassiar stock (69.3 to 76.5 Ma: Sketchley *et al.*, 1986). However, the physical deformation of the lamprophyre dikes could be due to emplacement of the Cassiar stock.

CONCLUSIONS

Structural data obtained during this study can be related to three episodes of deformation. The oldest structures are consistent with east-directed, west-over-east thrust faulting accompanying duplex formation during emplacement of the Sylvester allochthon. This deformation is accommodated by faults in the limestones with little fabric, and by faults in the Road River Group with cleavage. A younger deformation, characterized by dextral-reverse fault displacement on many of the same faults, is attributed to tilting of the strata into their now steeply east-dipping orientation. This deformation is older than the normal faulting and lamprophyre dike emplacement, which predate the Cassiar batholith. The formation of the Cassiar and McDame asbestos deposits occurred during the tilting event.

ACKNOWLEDGMENTS

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