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2002

Natural Resources Canada | Ressources naturelles Canada

Canada

Catalogue No. M44-2002/C15E-IN
ISBN 0-662-31516-2

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Significance of the Walker Lake shear zone with respect to regional deformation in the Committee Bay belt, central mainland, Nunavut

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Johnstone, S.E., Lin, S., and Sandeman, H.A.I., Significance of the Walker Lake shear zone with respect to regional deformation in the Committee Bay belt, central mainland, Nunavut; Geological Survey of Canada, Current Research 2002-C15, 9 p.

Abstract: Rocks in proximity to the Walker Lake shear zone, an east-striking dextral shear zone in the Committee Bay supracrustal belt, have experienced three episodes of deformation. D_1 resulted in a strong, bedding-parallel foliation, S_1. F_1 folds are inferred from younging direction reversals in komatiitic rocks. F_2 folds are open to tight and shallowly plunge northeast and southwest; they deform S_1 and control the map pattern. S_2 foliation is rarely developed in F_2 hinges, but F_2 limbs are strongly foliated with an S_1/S_2 composite foliation. A strong mineral lineation, L_2, parallels F_2 hinges. The Walker Lake shear zone is divided into two spatially separated segments with different characteristics (western Walker Lake shear zone and eastern Walker Lake shear zone). Strain in the western Walker Lake shear zone is heterogeneous and is localized in zones of protomylonite, whereas strain in the eastern Walker Lake shear zone is concentrated in one mylonite zone approximately 2 km wide. The Walker Lake shear zone is deformed by D_3 folds, which are open warps of the S_1/S_2 fabric.

Résumé : Les roches situées à proximité de la zone de cisaillement de Walker Lake, un cisaillement dextre de direction est dans la ceinture de roches supracrustales de Committee Bay, ont subi trois phases de déformation. D_1 a engendré une foliation bien définie parallèle à la stratification, S_1. L'existence des plis P_1 est révélée par l'inversion des sommets stratigraphiques dans les coulées komatiitiques. Les plis P_2 sont ouverts à serrés et leurs axes plongent faiblement vers le nord-est et le sud-ouest; ils déforment S_1 et déterminent la configuration des unités à l'échelle de la carte. La foliation S_2 est rarement développée dans les charnières des plis P_2, par contre, les flancs de ceux-ci sont très foliés et présentent une foliation composite S_1/S_2. Une linéation minérale marquée, L_2, est parallèle aux charnières des plis P_2. La zone de cisaillement de Walker Lake se divise en un segment occidental et un segment oriental (zone de cisaillement de Walker Lake occidentale et zone de cisaillement de Walker Lake orientale), chacun présentant des caractéristiques distinctes. Dans la zone de cisaillement de Walker Lake occidentale, la déformation est hétérogène et localisée dans des zones anastomosées de protomylonite, tandis que la déformation dans la zone de cisaillement de Walker Lake orientale se concentre dans une zone mylonitique d'environ 2 km de largeur. La zone de cisaillement de Walker Lake est déformée par des plis de la déformation $D_{3,}$ qui se manifestent des gauchissements évasés de la fabrique S_1/S_2.

INTRODUCTION

The Walker Lake shear zone is located in the Committee Bay supracrustal belt, in the Rae domain of the western Churchill Province, Nunavut (Fig. 1). The supracrustal belt extends in a northeasterly direction from the south end of NTS area 56 K to the coast of Committee Bay. It is comprised of the supracrustal rocks of the Prince Albert group, and several younger suites of intrusive rocks.

Previous mapping in the Committee Bay belt by Heywood ((1961) at 1:500 000 scale) and Schau ((1982) at 1:250 000 scale) broadly constrained the basic geology and the dominant northeast-trending regional fabric. Subsequent mineral-resource assessment studies led to the identification of two generations of folds, including an older, isoclinal fold set (Jefferson and Schau, 1992; Chandler et al., 1993).

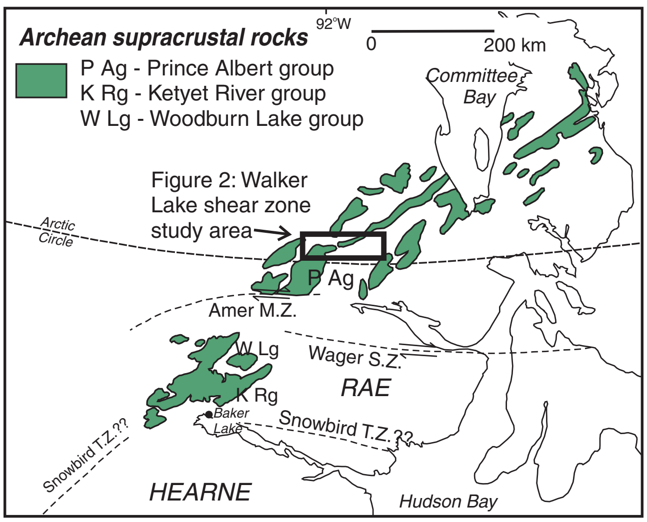

*Figure 1. Map showing location of Walker Lake shear zone with respect to major structures and supracrustal belts in the Western Churchill Province (*after *Sandeman et al., 2001a). MZ=mylonite zone, SZ=shear zone, TZ=tectonic zone.*

On a regional scale the east-trending Walker Lake shear zone is comparable to two similar structures located to the south of the study area (Fig. 1). The Amer mylonite zone and the Wager shear zone are both east-striking, high-strain zones identified on the basis of field observations and interpretation of regional aeromagnetic data (Tella and Heywood, 1978; Henderson and Broome, 1990). The Amer mylonite zone consists of protomylonitic and cataclastic rocks, exposed in a network of anastomosing dextral shear zones that truncate the Committee Bay belt at the southern border of NTS 56 K (Tella and Heywood, 1978). A parallel structure, the Wager shear zone, is located approximately 100 km south of the Amer mylonite zone and is characterized by dextral shear sense (Henderson and Broome, 1990).

Mapping of the Walker Lake shear zone and related structures in the Committee Bay belt was carried out in NTS 56 K/9, 10 and NTS 56 J/9, 10, 11, 12 at 1:100 000 scale as part of a regional mapping program during the summers of 2000 and 2001 (Fig. 2). More detailed work was carried out by the authors in selected areas where better exposure allowed closer examination. The purpose of this study is to determine the kinematic history and age of the Walker Lake shear zone and to understand its role in the geological evolution of the Committee Bay belt. This report summarizes observations and structural data collected in the field and offers some preliminary interpretations regarding the relationship of the Walker Lake shear zone to regional deformation.

GENERAL GEOLOGY

The metasedimentary and volcanic rocks of the Prince Albert group and the tonalitic-granodioritic suite of intrusive rocks are the most common units deformed by the Walker Lake shear zone (Sandeman et al., 2001a). Units observed within the shear zone are described below, with reference to their low-strain equivalents (Sandeman et al., 2001a). The lowest strain rocks in the study area occur northeast of a large tonalite pluton in map area 56 K (central tonalite, Fig. 2), where abundant primary features and early structures are

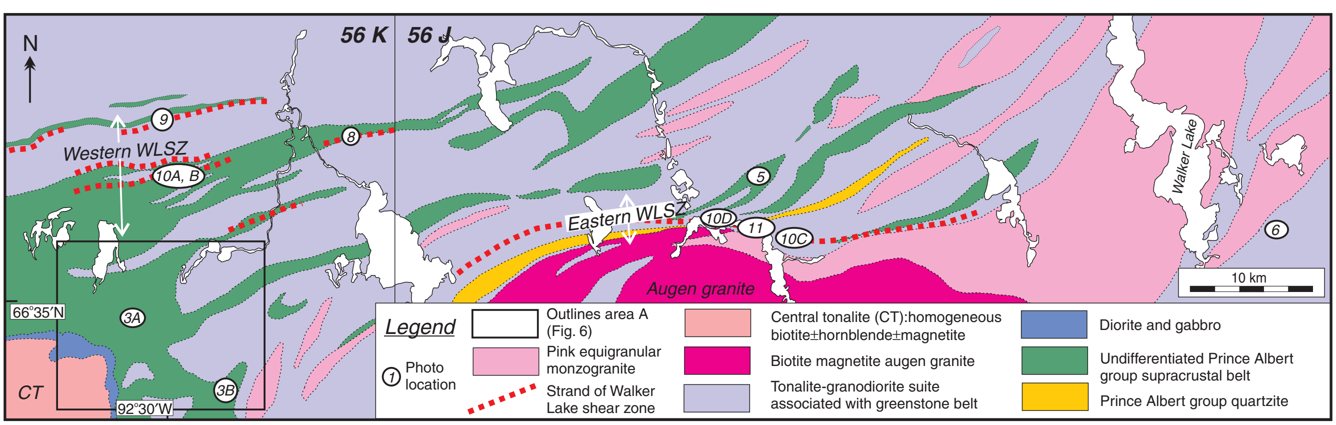

Figure 2. Simplified geological map of the Committee Bay belt in the area around the Walker Lake shear zone.

preserved. This region of low strain is interpreted to be in the strain shadow of the central tonalite, bound to the north by the Walker Lake shear zone (area ‘A’ in Fig. 2; Sandeman et al. (2001b)).

Prince Albert group

Metasedimentary rocks

The dominant metasedimentary rock in the Prince Albert group is fine-grained psammite to semipelite (biotite±muscovite±garnet). Intercalated with the psammite on metre scale are rare pelitic, arenitic, and volcaniclastic horizons. Silicate- (garnet+grunerite) and oxide- (magnetite + chert) facies iron-formation units range from 1 m to 50 m thick, and are locally associated with sulphide mineralization. Quartzite units (±muscovite±fuchsite) are locally up to several hundred metres thick.

Within these metasedimentary rocks compositional differences typically define primary bedding, S_0, but other primary structures are generally absent. Most of the metasedimentary rocks in the belt are strongly attenuated, but locally, primary features are still preserved; however, within the shear zone these units are ductily deformed and thus more finely recrystallized and all primary structures except compositional layering are absent. The psammite and semipelite units contain abundant concordant and crosscutting, fine quartzofeldspathic veins.

Volcanic rocks

The most abundant volcanic rock type in the Prince Albert group is komatiite. Ultramafic volcanic rocks in this area typically preserve well defined flows ranging in thickness from several tens of centimetres to several tens of metres, and primary textures such as spinifex texture and relict cumulate olivine grains. Younging direction indicators, preserved due to the rigid nature of komatiite, include gradation of spinifex, location of ‘hopper’ olivine within flows and facing direction of flow tops (Arndt et al. (1977); Fig. 3). Thick sections of komatiitic flows occur as high-weathering ridges, which are typically weakly deformed, but surrounded by strongly sheared ultramafic schist (talc±anthophyllite±serpentine). Fine-grained talc schist bodies within the Walker Lake shear zone are interpreted to be altered komatiite, which are devoid of primary structures and textures.

Mafic volcanic rocks comprise a relatively minor part of the Prince Albert group, and include basalt, komatiitic basalt, and chloritic schist. Pillows are rarely preserved and always strongly deformed. Interlayered with mafic volcanic rocks and occasionally ultramafic schist are rare silicate- and oxide-facies iron-formation, intermediate volcanic rocks, and felsic volcaniclastic rocks. These mafic volcanic and associated metasedimentary rocks are not observed within the Walker Lake shear zone.

Intrusive rocks

Intrusive rocks dominantly comprise strongly foliated, strongly to moderately lineated tonalite to granodiorite (biotite±hornblende±titanite±magnetite). Locally biotite-rich metasedimentary material occurs as abundant schlieren in the plutons. Apophyses of these intrusive bodies invade the supracrustal belt as veins and dykes. Rocks of the intrusive suites have similar fabrics to those of the Prince Albert group and contacts between metasedimentary and plutonic rocks in proximity to the Walker Lake shear zone are typically strongly deformed, with C-S fabrics and other shear-sense indicators suggesting dextral shearing.

Central tonalite

A large ovoid tonalite body occurs in the southwest corner of the study area and has been termed the central tonalite (“VT tonalite” of Sandeman et al. (2001a); Fig. 2). This tonalite (biotite±hornblende±allanite±titanite) is very homogeneous

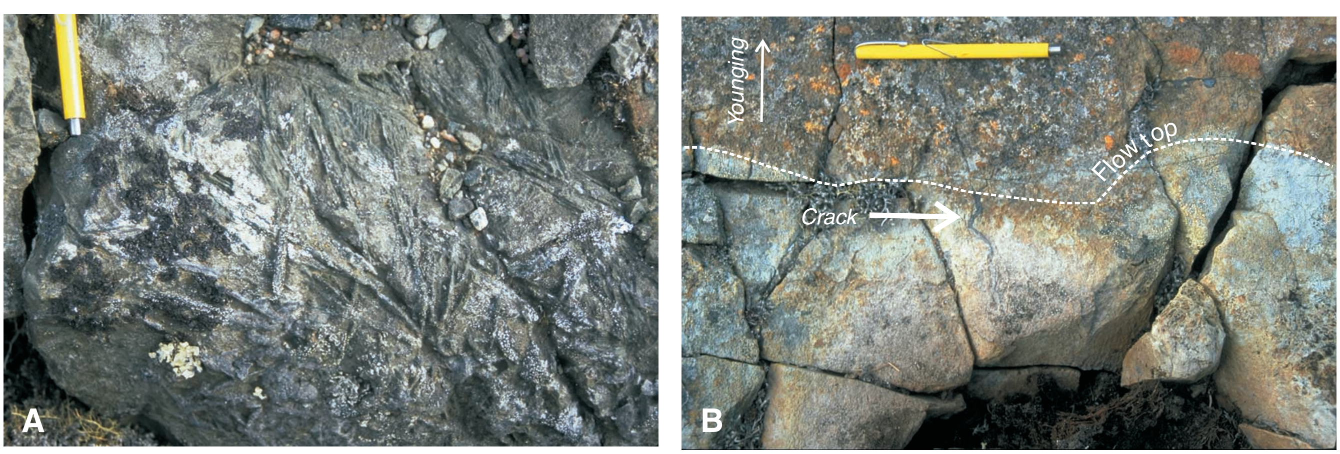

__Figure 3.__ Primary textures preserved in komatiites indicate way up. __A)__ platy spinifex texture occurs at base of green-weathering flows; __B)__ Flow top and crack in older flow indicates younging to the southwest. Pen magnet for scale.

and ranges from nonfoliated to weakly foliated. Contact relationships between the central tonalite and the Prince Albert group are rarely observed but, where exposed, rafts of biotite semipelite are present within the tonalite and tonalite veins crosscut the metasedimentary units indicating that the central tonalite is relatively younger.

The central tonalite is bound to the northeast and southwest by east-trending shear zones, the western Walker Lake shear zone and the Amer mylonite zone, respectively. Preserved in the strain shadows of this stiff inclusion are pristine komatiite and metasedimentary rocks as well as fold interference patterns, as indicated by younging direction reversals in komatiite, that are not preserved elsewhere in the study area (area ‘A’, Fig. 2).

Augen granite

The southern part of the study area is dominated by a compositionally heterogeneous, generally K-feldspar megacrystic, monzogranite to granodiorite (biotite+magnetite±hornblende±titanite). Deformation within this intrusive body ranges from moderate to strong, characterized by ribbon quartz and augen K-feldspar grains. The augen granite contains open folds of a foliation-parallel to compositional layering. These folds have subhorizontal hinges and tighten towards the Walker Lake shear zone at the northern pluton boundary. This intrusive body commonly contains rafts of amphibolite and biotite-rich schlieren, which locally result in a ‘streaky’ appearance.

Late granite bodies

Weakly deformed to nondeformed pink monzogranite intrusions (biotite±magnetite±fluorite) invade both the metasedimentary and intrusive rocks of the Committee Bay belt as thin (<5 m) foliation-parallel, shallowly dipping sheets. These intrusions range in areal extent from about 1 km^2 to less than 10 km^2 (Fig. 2). Both concordant and discordant pegmatite dykes with varying peraluminosity (±muscovite± garnet±tourmaline) are likely genetically associated with these intrusions. These weakly deformed monzogranite bodies are most abundant along strike with the Walker Lake shear zone to the east.

STRUCTURAL FRAMEWORK

Three generations of ductile structures have been identified in proximity to the Walker Lake shear zone based on field observations and the large-scale map pattern (Sandeman et al. (2001b); Table 1). Structural relationships are best preserved in the strain shadow of the central tonalite (area ‘A’, Fig. 2). D_1 resulted in a strong bedding-parallel foliation, S_1. An early generation of folds, F_1, is preserved in the strain shadow of the central tonalite and identified at the map scale on the basis of younging direction reversals in komatiite and interference patterns with F_2 folds (Fig. 4).

Table 1. Descriptions of three generations of structures in the Committee Bay belt.

Event	Foliation	Lineation	Folding
D_1	S_1: strong bedding-parallel		F_1: rare large-scale folds determined on the basis of reversal in younging direction in komatiitic rocks
D_2	S_1-S_2 composite foliation: strongly developed in limbs of F_2 folds; locally S_2 axial planar foliation in F_2 hinges	L_2: doubly plunging sub-horizontal mineral lineation	F_2: outcrop- and map-scale open to tight folds with subhorizontal hinges parallel to L_2.
Walker Lake shear zone (D_{2b})	S_{2b}: east-trending protomylonite to mylonite fabric in shear zone	L_{2b}: subhorizontal stretching lineation parallel to F_2 fold hinges	F_{2b}: intrafolial folds within shear zone
D_3	S_3: spaced cleavage axial planar to F_3		F_3: open warps of S_1-S_2 regional fabric

Outcrop scale F_2 folds are abundant. They are open to tight folds of S_1 with a rarely developed S_2 axial planar cleavage (Fig. 5). F_2 folds trend northeast (~060°) and plunge shallowly to both the northeast and southwest, though within the Walker Lake shear zone they trend east. A strong quartz rodding lineation, L_2, is developed in the granitoid rocks parallel to the hinges of these parasitic F_2 folds. Within the supracrustal belt several different minerals, including quartz and amphibole, define this lineation. Foliation is strongly developed within the limbs of macroscopic F_2 folds, and these limbs are often strongly attenuated relative to the hinges (Fig. 6).

Large-scale F_2 folds, with kilometre-scale wavelengths, control the map pattern near the Walker Lake shear zone. Supracrustal rocks are most commonly preserved as synclinal keels in these F_2 folds; typically the main foliation in these keels is a bedding-parallel foliation interpreted to be S_1. F_2 folds are generally open to tight, but become isoclinal with proximity to the shear zone. Detailed analysis of a large-scale F_2 synform, preserved in the strain shadow of the central tonalite, clearly shows that S_1 is folded by an F_2 and that the L_2 lineation parallels the hinge of this fold (area ‘B’, Fig. 4; Fig. 7A). In this F_2 fold hinge, within both the supracrustal and intrusive rocks, S_1 is well preserved, however, within the limbs of this fold a very strong foliation is developed, which is interpreted to be an S_1/S_2 composite foliation. The F_2 fold pattern illustrated in area ‘B’ by Figure 7A can be demonstrated throughout the study area, where S_1 is refolded and poles of S_1 planes plotted on an equal-area lower-hemisphere diagram define F_2 folds with shallow hinges plunging toward both the northeast and southwest (Fig. 7B). The S_1/S_2 composite foliation preserved in the limbs of these folds is the main regional foliation.

Structures associated with D_2, including F_2 folds and a strong L_2 lineation, are observed within the protomylonitic to mylonitic zones of the Walker Lake shear zone (Fig. 7C).

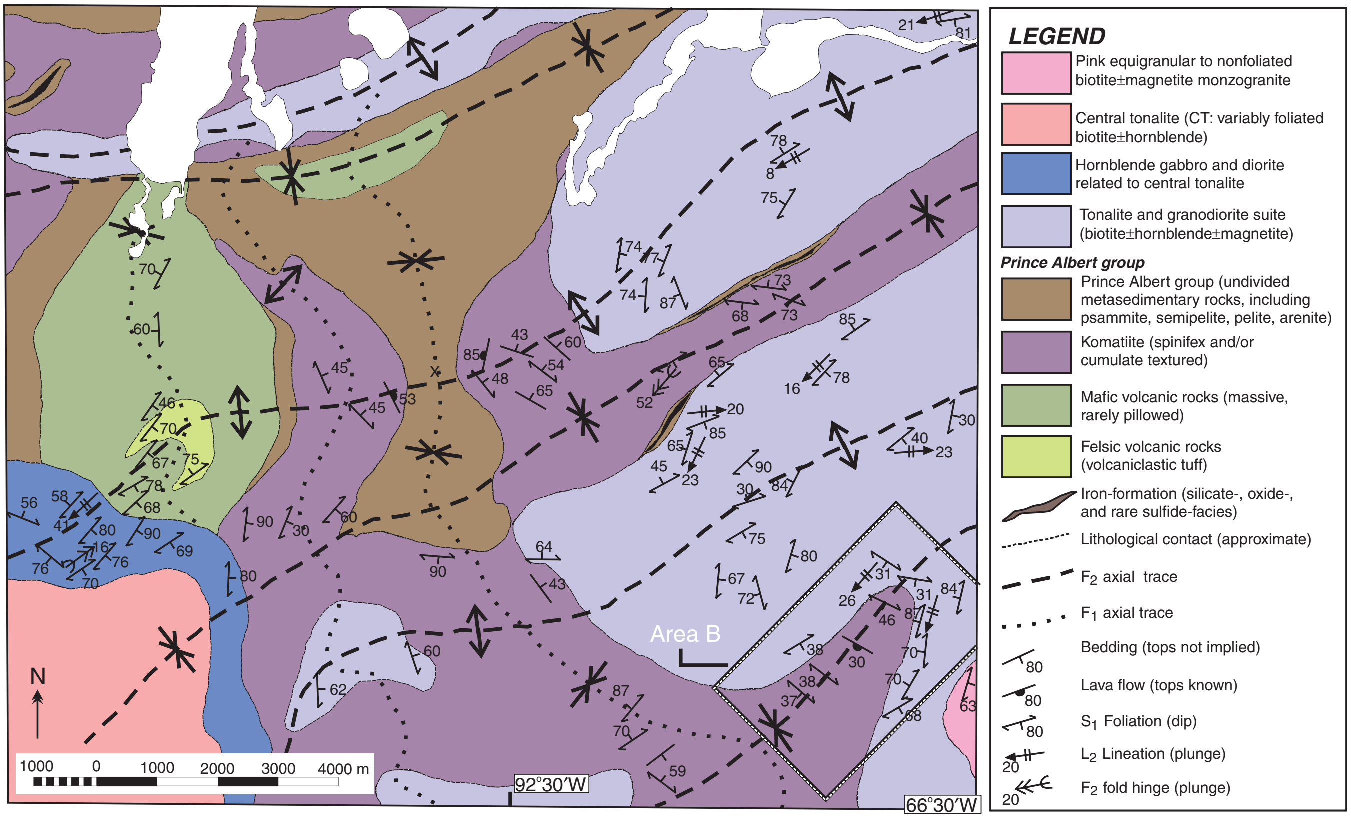

Figure 4. *Map in detail of area 'A' in the strain shadow of the central tonalite.*

Figure 5. *Outcrop-scale F_2 fold with axial planar S_2 foliation. Pen magnet for scale.*

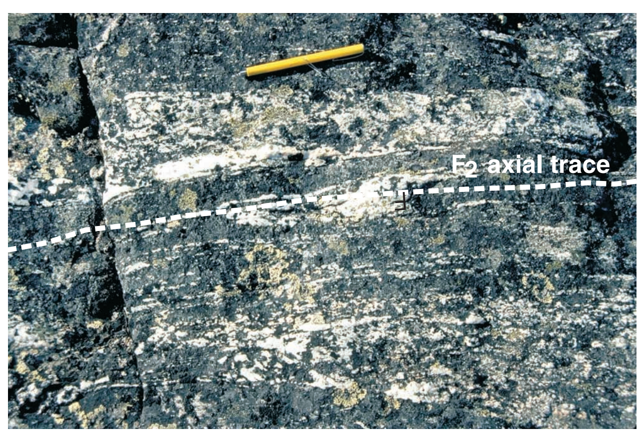

Figure 6. *F_2 fold with limbs strongly attenuated into S_1/S_2 composite foliation.*

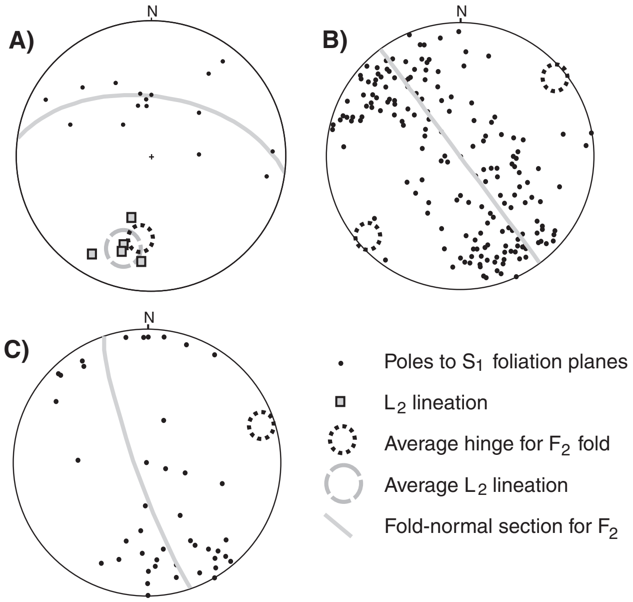

Figure 7. *Equal-area, lower-hemisphere projections of S_1 and L_2.* ***A)*** *Poles to S_1 and L_2 lineations, in area 'B' of Figure 6.* ***B)*** *Poles to S_1 outside of the Walker Lake shear zone.* ***C)*** *Poles to S_1 measured within the Walker Lake shear zone. Throughout the study area S_1 is refolded and these plots of poles to S_1 planes clearly define F_2 folds with shallow hinges trending northeast and southwest, though this trend varies from an average about 070° inside the Walker Lake shear zone, C, to about 020° at the greatest distance from the Walker Lake shear zone.*

Both the regional S_1/S_2 foliation and lithological units on the map (Fig. 2) wrap into the Walker Lake shear zone. This observation allows for two possible interpretations regarding the relative timing of D_2 and the Walker Lake shear zone. Deformation along the Walker Lake shear zone occurred either 1) syntectonic with respect to D_2, or 2) post-D_2. This issue is discussed below.

The third generation of structures, D_3, overprints the D_2 structures but is relatively less important. On the outcrop scale, F_3 crenulations and metre-scale folds are common. Locally a north-northwest-trending spaced cleavage occurs and is interpreted to be axial planar to F_3. Axial planes are subvertical with steeply plunging (~65°) hinges, trending towards 340°. Strands of the Walker Lake shear zone are folded by F_3, indicating that deformation along the Walker Lake shear zone predates D_3 (Fig. 8). F_3 folds are typically open warps of the main foliation, with a wavelength of several tens of kilometres.

WALKER LAKE SHEAR ZONE

The Walker Lake shear zone was first identified as a regionally important structure during gold exploration by Apex Geosciences Ltd., which began in 1992 (Dufresne and Williamson, 1997). Field mapping and interpretation of regional aeromagnetic

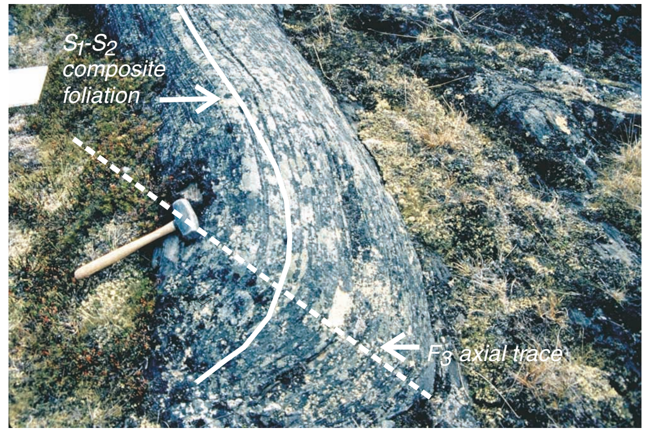

Figure 8. *Open F_3 fold of mylonite within the Walker Lake shear zone. Hammer for scale.*

data have shown this zone to be an east-striking high-strain zone that deforms the Committee Bay belt and extends for more than 80 km along strike (Fig. 2; Sandeman et al. (2001b)). The shear zone can be divided into two spatially separated segments, with different characteristics, described below.

Western Walker Lake shear zone

The western Walker Lake shear zone is a heterogeneously deformed corridor, about 10 km in total width. Rocks in the corridor are generally strongly deformed, with strain localized in protomylonitic bands several hundred metres wide. The bands are east-striking and dip subvertically. Subhorizontally lineated L>>S tectonites dominate the western Walker Lake shear zone and the strong subhorizontal stretching lineation, L_2, is parallel to the fold axes of isoclinal F_2 folds between the protomylonite strands (Fig. 9).

Abundant concordant pegmatitic to K-feldspar megacrystic pink and white monzogranite (±biotite±muscovite±garnet±tourmaline) dykes occur throughout the western Walker Lake shear zone, but with greatest frequency within the protomylonite strands. These dykes are commonly boudined and folded. Within the shear zone, pressure shadows around asymmetrical garnet and K-feldspar porphyroblasts indicate dextral shear sense (Fig. 10A). The same shear sense is also indicated by C-S fabrics and dextrally translated boudins (Fig. 10B). The shear-sense indicators are best observed on subhorizontal surfaces. This, in combination with subhorizontal lineations, indicates that the western Walker Lake shear zone is a dextral strike-slip shear zone.

Preliminary U-Pb geochronology from the western Walker Lake shear zone indicates that at least one episode of deformation occurred during the Proterozoic (S.E. Johnstone and J. Ketchum, unpub. data, 2001).

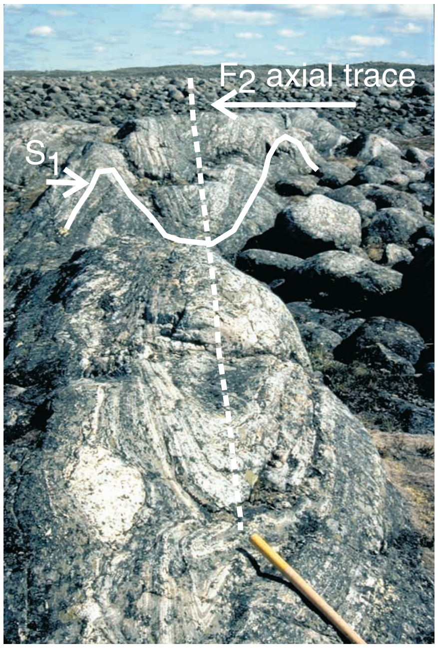

Figure 9.

Shallowly plunging isoclinal F_2 fold observed between mylonitic strands in the western Walker Lake shear zone. Hammer for scale.

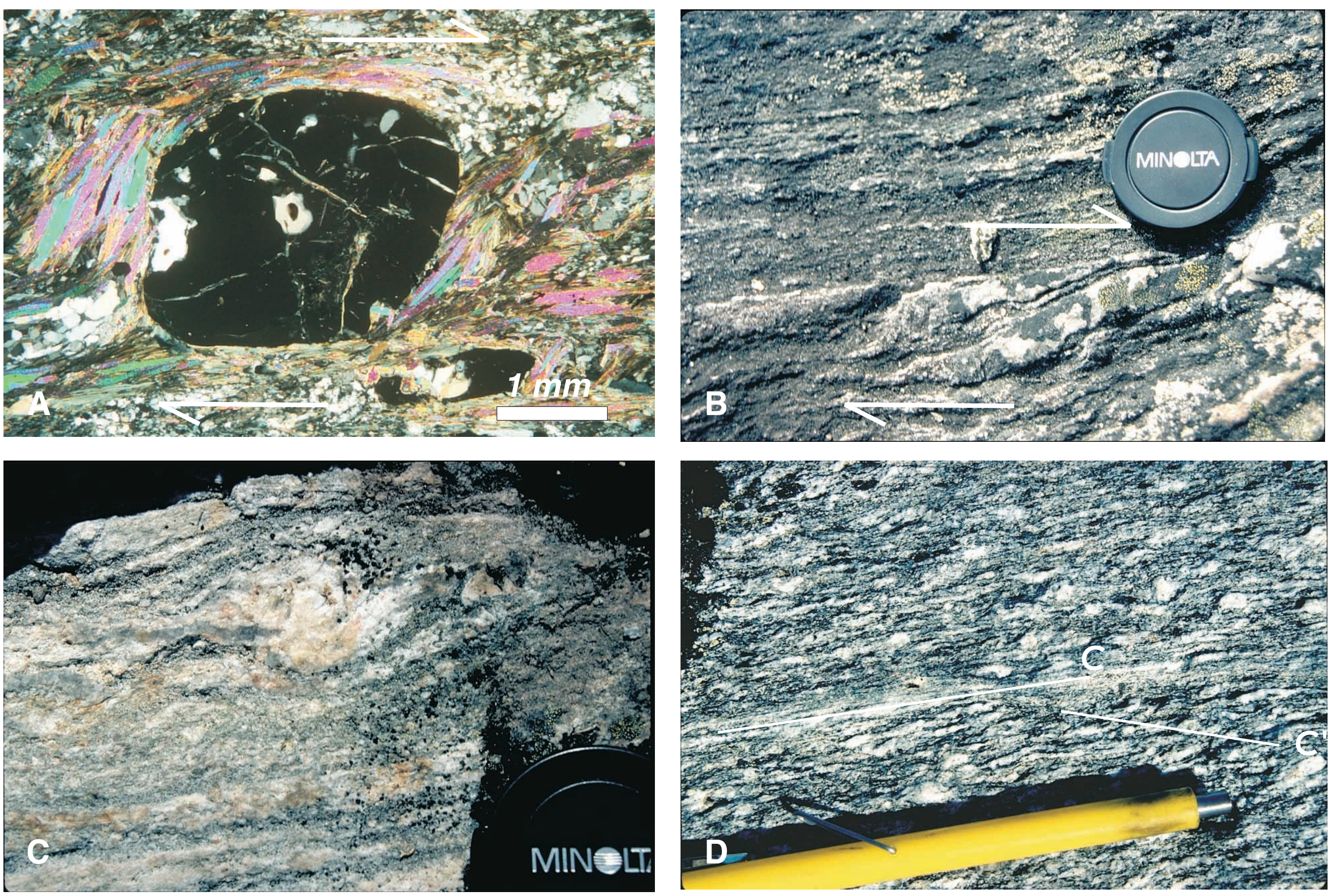

Figure 10. *Kinematic indicators from the Walker Lake shear zone indicating dextral shear sense.* ***A)*** *Quartz pressure shadows and concentrations of mica around a garnet porphyroblast in thin-section from western Walker Lake shear zone.* ***B)*** *Boudins dextrally sheared at their necks in western Walker Lake shear zone.* ***C)*** *Rotated δ-porphyroclast in eastern Walker Lake shear zone.* ***D)*** *C and C′ fabrics in eastern Walker Lake shear zone.*

Eastern Walker Lake shear zone

Strain in the eastern Walker Lake shear zone is concentrated in one discrete east-trending (~260°) protomylonite to mylonite band approximately 40 km long. This main mylonite zone is approximately 2 km wide, though the northeast-striking lithological units are deflected by the Walker Lake shear zone in a much wider zone (about 7 km; Fig. 2). Like the western segment, the eastern Walker Lake shear zone is also characterized by a subhorizontal lineation, though generally S≥L. The location of this high-strain zone approximately coincides with the contact between the biotite±magnetite K-feldspar augen monzogranite to the south and the biotite hornblende tonalite and supracrustal rocks to the north. Strain is localized at the margin of this augen granite pluton, which has a strong competency contrast with the adjacent supracrustal belts.

Abundant pink and white monzogranite pegmatite bodies are spatially associated with the highly strained rocks of the eastern Walker Lake shear zone. At a locality on the northern margin of the shear zone, the white pegmatite is folded by upright F_2 folds, which plunge shallowly to the northeast, and pink pegmatite postdates the white pegmatite, intruding axial planar to the F_2 folds (Fig. 11). The same relationship is observed within the shear zone where the dykes are strongly attenuated and locally boudined. Fold hinges are only locally preserved within the shear zone and rocks typically have a straight gneissic appearance on the horizontal surface. The shear zone fabric is crosscut by deformed pegmatite and nondeformed, medium-grained equigranular monzogranite.

K-feldspar crystals within the pink pegmatite commonly form large (centimetre scale) asymmetrical δ- and σ-type porphyroclasts indicating dextral shear sense (Fig. 10C). Other shear-sense indicators in the eastern Walker Lake shear zone include C-C′ fabrics, which are consistent with a dextral sense of shear (Fig. 10D).

A substantial unit of muscovite-bearing, rusty-weathering quartzite, several hundred metres thick, is exposed north and south of the Walker Lake shear zone. Based on similarity

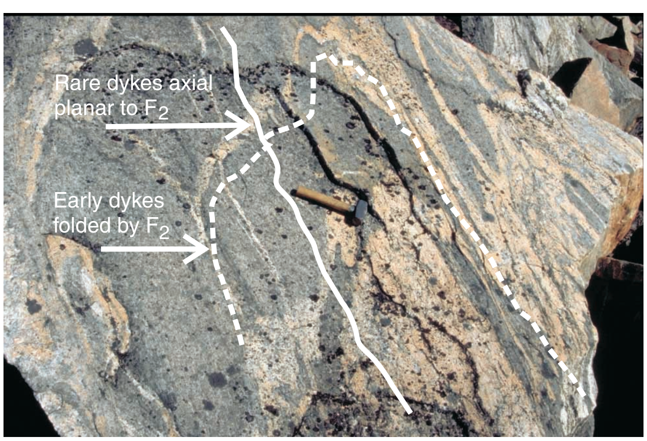

Figure 11. *White pegmatite dykes folded by F_2; pink pegmatite dykes intrude axial planar to these F_2 folds.*

of lithology, these two occurences are interpreted to belong to the same unit. If this interpretation is correct, the apparent offset of this quartzite indicates a horizontal displacement of approximately 10 km along the eastern Walker Lake shear zone (Fig. 2).

The western and eastern segments of the Walker Lake shear zone (western Walker Lake shear zone and eastern Walker Lake shear zone, respectively; Fig. 2), are separated by an area approximately 10 km wide, characterized by strong northeast-trending S_1/S_2 foliation and large-scale F_2 folds, which tighten with proximity to the shear zone. In this area, metre-scale dextral southwest-trending (~ 235°), moderately dipping (~ 50°), high-strain zones occur at the contacts between the supracrustal rocks and the associated intrusive rocks. Within these zones, lineations plunge moderately (~ 30°) towards the northwest. These contacts are interpreted to be planes of weakness, susceptible to shearing during deformation along the Walker Lake shear zone.

SUMMARY AND DISCUSSION

Rocks of the Committee Bay belt in close proximity to the Walker Lake shear zone, including the Prince Albert group supracrustal rocks and associated plutonic suites, have experienced three generations of deformation. D_1 deformation has been inferred based on a strong bedding-parallel foliation, S_1, and on reversal in younging directions in komatiitic flows, indicating F_1 folding. Shallow, doubly plunging, northeast-trending F_2 folds deform D_1 structures and control the map pattern close to the Walker Lake shear zone. S_1 is well preserved in F_2 fold hinges and an S_1/S_2 composite foliation is strongly developed in F_2 fold limbs. An axial planar S_2 fabric is locally observed overprinting S_1 in the hinges of F_2 folds.

The western Walker Lake shear zone is a relatively wide (about 10 km) corridor of heterogeneous strain, which occurs as strands of protomylonite. In the eastern Walker Lake shear zone, strain has been concentrated into one discrete dextral mylonite zone approximately 2 km wide, that extends for approximately 40 km along strike. In the eastern Walker Lake shear zone, strain is much stronger than in the western Walker Lake shear zone, and also has a discernible offset, making the eastern segment relatively more important. Strain in both the western and eastern Walker Lake shear zone is concentrated near the contact between the supracrustal belt and an intrusive body, the central tonalite in the west and augen granite in the east, which are rigid with respect to the supracrustal belts and are minimally affected by D_2. Strain is localized at the marginal zones of these plutons because of the high competency contrast between the intrusive bodies and the supracrustal belts, which makes these contacts more susceptible to deformation. The offset between the western Walker Lake shear zone and the eastern Walker Lake shear zone is most likely related to the geometry of the two intrusive bodies.

It is clear that there is an intimate association between F_2 folding and deformation along the Walker Lake shear zone because F_2 folds tighten towards the shear-zone boundaries and the strong lineation associated with shearing also parallels F_2 fold hinges. It is therefore most likely that the Walker Lake shear zone is a D_2 structure and represents a zone in which D_2 deformation is concentrated, though at this stage we cannot rule out the possibility that it is a post-D_2 structure that overprints F_2. Ongoing U-Pb geochronology will help to clarify this issue. Late north-northwest-trending F_3 folds, at both the outcrop and the map scale, fold the Walker Lake shear zone.

ACKNOWLEDGMENTS

This project was made possible by funding from Polar Continental Shelf Project, Northern Scientific Training Program, Canada-Nunavut Geoscience Office, and Geological Survey of Canada. Many thanks to everyone involved in the Committee Bay project over the last two summers, including Tom Skulski, Trevor MacHattie, Dixon Byrne, Darrell Hyde, Julie Brown, and Chris Studnicki-Gizbert. Critical reviews by Mary Sanborn-Barrie and Simon Hanmer greatly improved this manuscript. Thanks to Boris Kotelewetz for excellent expediting, Jamie Boles and Custom Helicopters for the safe and reliable transportation, and last, but certainly not least, Dave Paetzold and J.P. Emorine for amazing food two summers in a row.

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Geological Survey of Canada Project 000005