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Field Guide

METALLOGENY OF THE CLARENCE STREAM GOLD DEPOSIT, SOUTHWESTERN NEW BRUNSWICK

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Cover illustration: *Eastern end of Trench 1, Main Zone, Clarence Stream gold deposit. Photograph shows the East Branch Brook Gabbro (left), sedimentary rocks of the Waweig Formation (right of centre), and an auriferous quartz vein (far right).*

Photograph courtesy of Keith Seidler

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Abstract

This field guide examines the geological setting of granite-related gold mineralization in the Clarence Stream area of southwestern New Brunswick. It reviews tectonic events affecting this segment of the New Brunswick Appalachians and relates them to the genesis of gold at Clarence Stream.

Two major mineralized zones have been identified at the Clarence Stream deposit: the Main Zone and the Anomaly A Zone. Mineralization at the Main Zone is localized along a splay of the Sawyer Brook Fault that borders the northern contact of the Early Devonian Magaguadavic Granite. Gold occurs in a parallel series of northeast-trending, steeply dipping quartz veins hosted by sedimentary rocks of the Silurian Waweig Formation and gabbroic dykes of the East Branch Brook Gabbro. The Anomaly A Zone is situated north of the Sawyer Brook Fault in an area underlain by polydeformed quartzose sedimentary rocks of the Ordovician Kendall Mountain Formation. Kendall Mountain rocks host gold mineralization in quartz stockworks and veinlets that are localized within a shallowly dipping, folded thrust. Geophysical data suggest that a large granitic mass underlies the Anomaly A area at relatively shallow depths.

Mineralization features of the Main Zone and Anomaly A Zone show similarities to proximal and distal deposits of granite-related gold systems, respectively. Recognition of such gold systems in southwestern New Brunswick has significant implications for future mineral exploration in the Northern Appalachian Orogen.

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INTRODUCTION

The discovery of significant gold mineralization in southwestern New Brunswick has generated much collaborative research by the University of New Brunswick, federal and provincial government organizations, and Freewest Resources Canada Incorporated. Since 1999, Freewest has conducted extensive exploration northeast of St. Stephen in the Clarence Stream area and has delineated two principal zones of mineralization: the Main Zone and the Anomaly A Zone (Fig. 1).

Research and exploration work show that gold at the Main Zone occurs in Silurian rocks, hosted primarily by steeply dipping, mylonitic shear zones and associated quartz veins and stockworks. In contrast, gold at the Anomaly A Zone is found in Ordovician rocks, appearing in quartz-veined stockwork systems characterized by intense alteration and locally developed, mineralized cataclasites within high-level, openly folded thrust zones. Evidence strongly suggests that gold mineralization at the Main Zone, and probably at the Anomaly A Zone, is genetically related to older phases of the Silurian–Devonian Saint George Batholith.

Other studies have been conducted west of Fredericton (around Poplar Mountain and Lake George) in conjunction with work at Clarence Stream (McLeod et al. 2003; Yang et al. 2003a). These investigations show that similar, intrusion-related gold-mineralizing events took place elsewhere across the New Brunswick segment of the Northern Appalachian Orogen in association with roughly coeval plutonic rocks such as felsic intrusions of the Pokiok Batholith and the Tower Hill Granite (McLeod and McCutcheon 2000; Thorne et al. 2002a). The existence of granite-related mineralized systems throughout the region has significant implications for future mineral exploration in Atlantic Canada and Maine.

This field guide discusses the geological setting of granite-related gold deposits in southwestern New Brunswick, examines mineralization styles at the Clarence Stream deposit, and reviews models proposed for the formation of that deposit. The stop descriptions are divided into two sections, as follows.

- Stops 1 to 4 (Fig. 1) show the geology of southwestern New Brunswick, focusing on outcrops that demonstrate the stratigraphic and structural setting of the Clarence Stream gold deposit. Rock exposures include units similar to those that host the deposit, and intrusive phases of the Saint George Batholith that are interpreted as being responsible for generating the gold deposit.

- Stops 5 to 11 (Fig. 1) provide a more detailed look at the geology and metallogeny of the Clarence Stream deposit, examining rock exposures at or near the Main Zone (Stops 5 to 9) and the Anomaly A Zone (Stops 10 and 11).

Figure 1. Field guide stops in southwestern New Brunswick, including stop locations at the Main Zone and Anomaly A Zone of the Clarence Stream deposit.

Geological Setting of Southwestern New Brunswick

Tectonic Zonation

The geological framework of the Northern Appalachians in eastern Canada consists of broad tectonic zones that reveal a complex history of extensional and accretionary processes and continental collision events during the Late Neoproterozoic to Paleozoic (Williams 1995). From northwest to southeast, the tectonic zones are the Grenville, Humber, Gander–Dunnage, Avalon, and Meguma (Fig. 2).

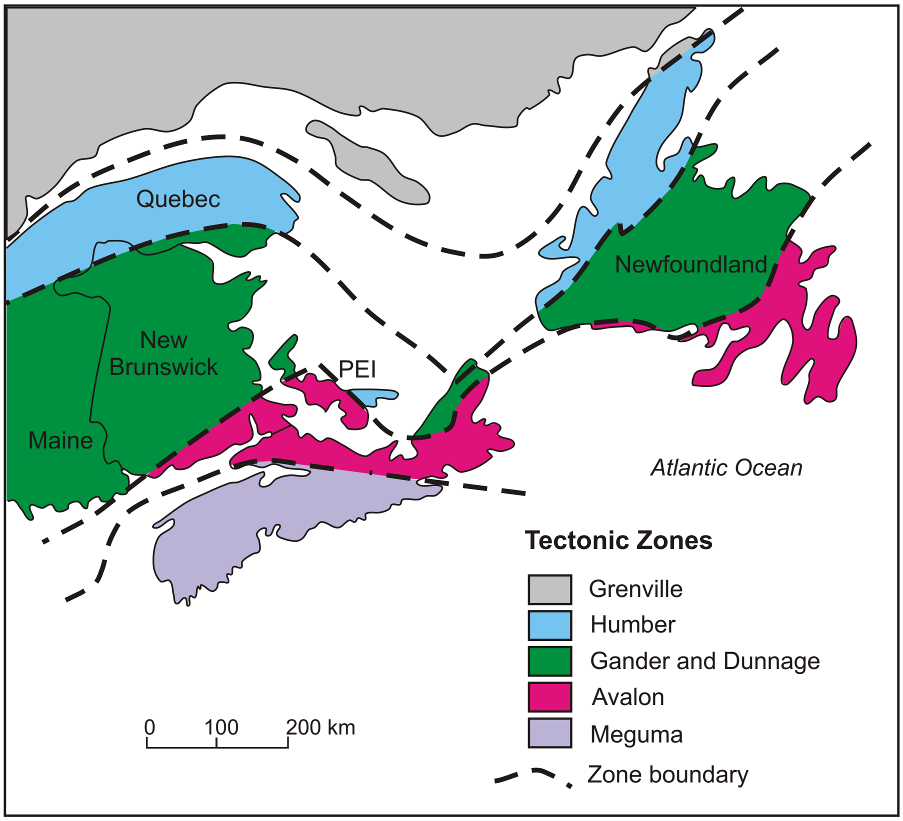


Figure 2. Tectonic zones of Atlantic Canada (modified after Williams 1995**;** Barr and White 1996), from McLeod 2003.

The Grenville Zone represents the ancestral North American craton and is flanked by the Humber Zone, which contains remnants of a craton margin formed along the northwestern boundary of the Early Paleozoic Iapetus Ocean. The Gander–Dunnage Zone represents the central mobile belt of the Appalachian Orogen; the zone contains relics of the Avalonian continental margin and of Cambro–Ordovician arcs and related back-arc basins generated during ocean closure. The Avalon Zone consists of several amalgamated, peri-Gondwanan terranes of Neoproterozoic–Cambrian rocks that represent a linear microcontinent bordering the Iapetus Ocean to the southeast. The present position of the Meguma Zone is a result of continental assembly during the Late Paleozoic. The zone appears to originally have been either a segment of the Gondwanan continental margin left behind after opening of the modern Atlantic Ocean, or a remnant of sedimentary basin floored by Avalonian-type microcontinental basement (Murphy et al. 1992).

Superimposed on this older zonal framework are basin remnants of Late Ordovician–Early Devonian rocks (Fig. 3, 4). They were formed within, and adjacent to, the central mobile belt in foredeep depocentres, in extensional basins, and in arc and back-arc environments while the Avalonian microcontinent collided with the North American landmass (see van Staal and Fyffe 1991). The collisional event was accompanied by the emplacement of syn- to post-orogenic, Late Silurian–Late Devonian plutonic suites across the orogen (Fig. 3, 4). Following the collision, large parts of the orogen were concealed by extensive Late Devonian–Permian successor basins, and by Triassic–Jurassic extensional basins during the opening of the present-day Atlantic Ocean (Pe-Piper et al. 1992; St. Peter 1993).

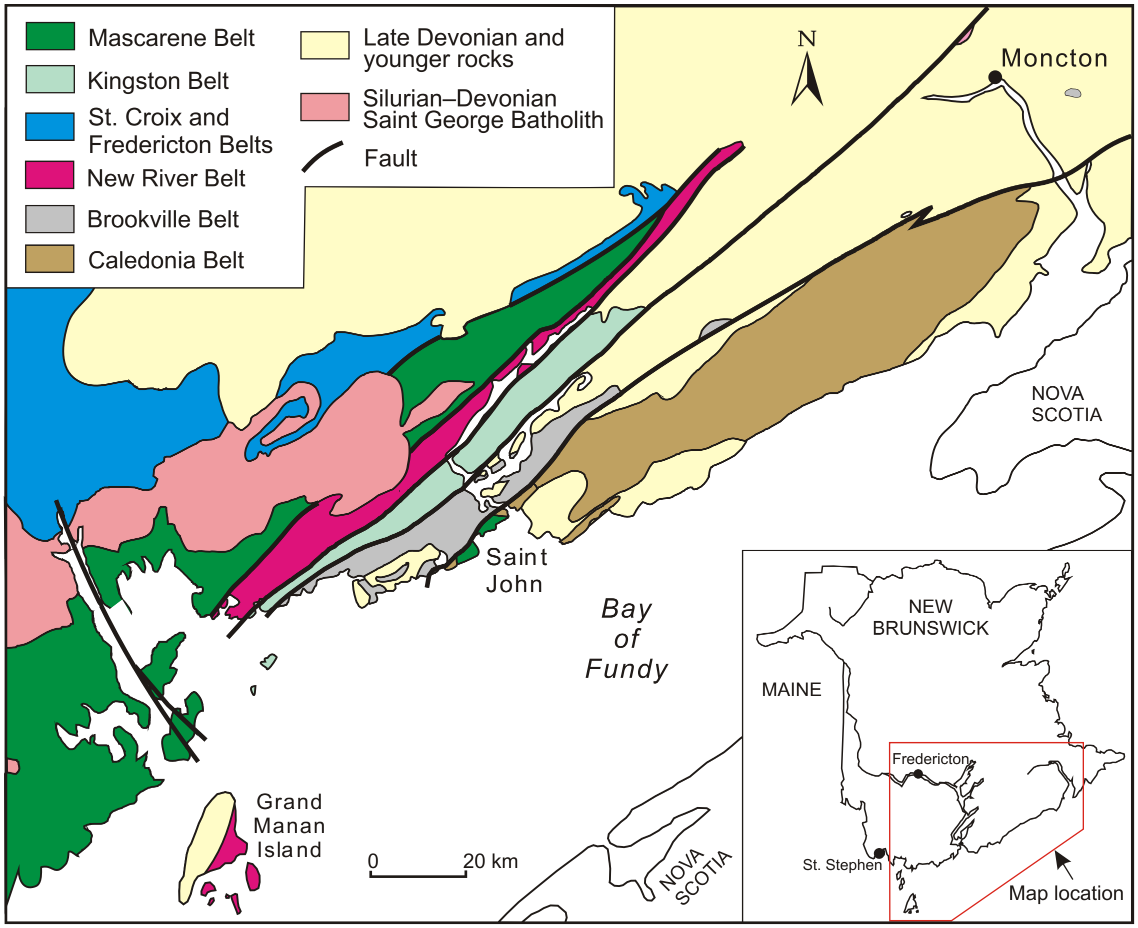


Figure 3. Geological belts in southern New Brunswick (modified after Johnson and Barr 2004).

Neoproterozoic–Middle Paleozoic rocks in modern-day southwestern New Brunswick comprise several northeast-trending and mainly fault-bounded belts, each of which exhibits unique structural, stratigraphic, plutonic, and/or geochemical features. They consist of the Neoproterozoic–Cambrian Caledonia, Brookville, and New River belts; the Cambrian–Ordovician St. Croix Belt; the Late Ordovician–Silurian Mascarene Belt; and the Silurian Kingston and Fredericton belts (Fig. 3, 4). These belts have also been referred to in the literature as tectonostratigraphic zones, terranes, and/or cover sequences (see Fyffe and Fricker 1987; Barr and White 1989; Johnson and McLeod 1996). Throughout this field guide, "belt" is used as a purely descriptive term, whereas "terrane" is used when discussing plate tectonic models.

Regional Geology

Stratified rocks in southwestern New Brunswick pertinent to the interpretation of gold mineralization at Clarence Stream belong to the Cookson, Kingsclear, and Mascarene groups, which define the St. Croix, Fredericton, and Mascarene belts, respectively (Fig. 4, 5, 6). The following descriptions relate specifically to lithologies in the Clarence Stream area.

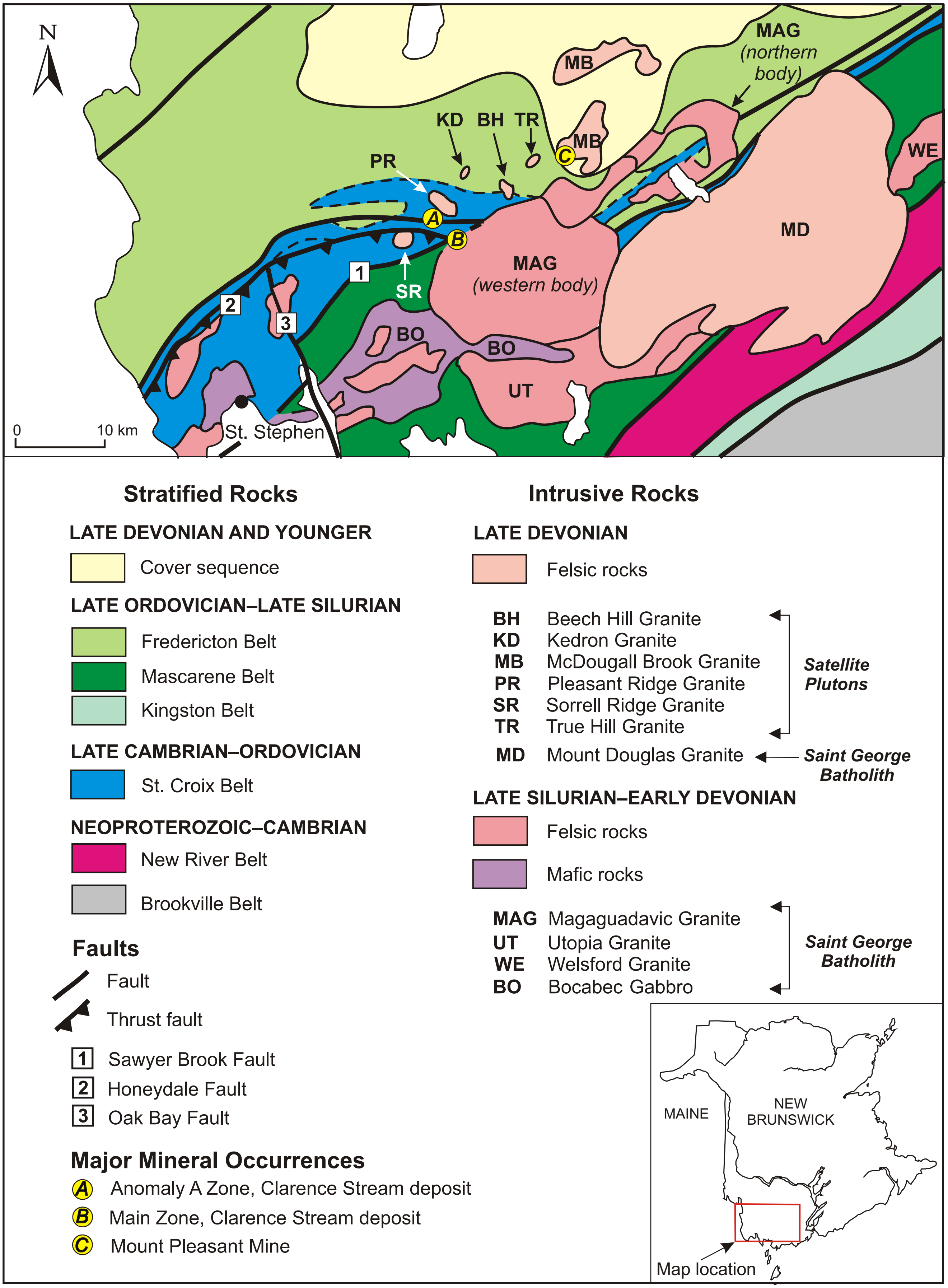


Figure 4. Geology of southwestern New Brunswick (modified from Thorne 2003).

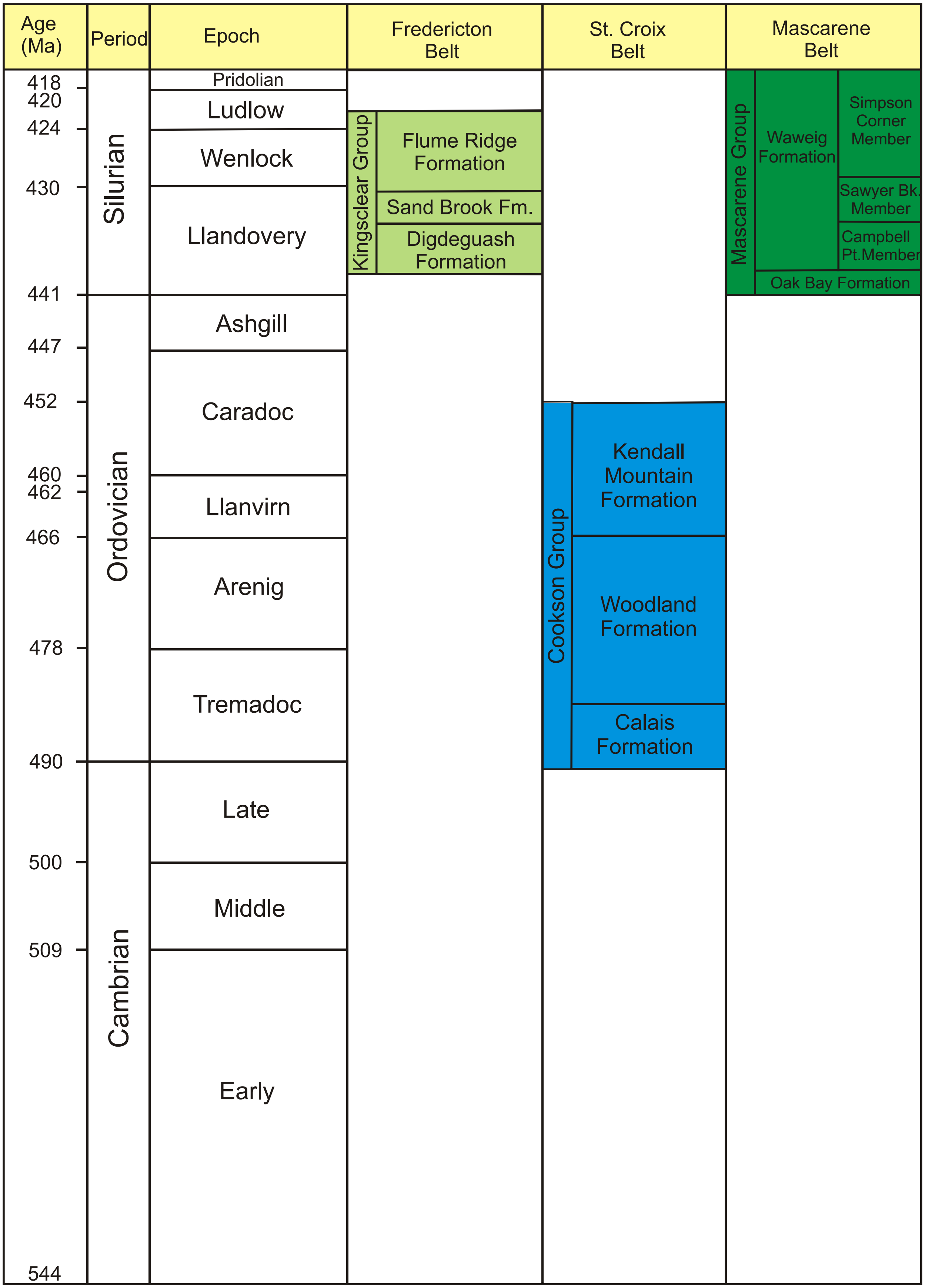


Figure 5. Stratigraphic column for the Fredericton, St. Croix, and Mascarene belts. Mascarene Group is from Fyffe et al. (1999). Cookson Group is after Fyffe and Fricker (1987), Ludman (1987), and Fyffe and Riva (1990). Kingsclear Group is from Ruitenberg (1967), Ruitenberg and Ludman (1978), and Fyffe (1991). Time scale is modified after Okulitch (1999).

The Cookson Group comprises the Ordovician Calais, Woodland, and Kendall Mountain formations. These polydeformed rocks consist mainly of black shale and minor basalt, feldspathic wacke, and interbedded quartzose sandstone–siltstone–shale, respectively. They range in age from Tremadocian through Caradocian (Ludman 1987; Fyffe and Riva 1990).

The Silurian Kingsclear Group includes lithic and feldspathic wacke and shale of the Digdeguash Formation, feldspathic wacke and slightly calcareous shale of the Sand Brook Formation, and calcareous wacke and shale of the Flume Ridge Formation (Ruitenberg 1967; Ruitenberg and Ludman 1978; Fyffe and Riva 2001). The early Llandoverian Digdeguash Formation is generally faulted against units of the Cookson Group, but at some localities it appears to lie unconformably on the Kendall Mountain Formation (Fyffe and Riva 2001).

The Silurian Mascarene Group is represented by the Oak Bay Formation and conformably overlying Waweig Formation (Ruitenberg 1967; Fyffe et al. 1999). The Oak Bay Formation unconformably overlies the Cookson Group and contains polymictic conglomerate and coarse-grained sandstone. The Waweig Formation consists of volcaniclastic and siliciclastic sandstone and siltstone interbedded with mafic to felsic volcanic rocks locally intruded by abundant mafic dykes (Fyffe et al. 1999). Rocks of the Waweig Formation extend in time from the Llandoverian to the Ludlovian (Miller and Fyffe 2002).

The Saint George Batholith was emplaced along the boundary of the Avalon and Gander zones over a period of about 30 million years and consists of several intrusive phases (Fig. 2, 4). The older intrusions range from Late Silurian to Early Devonian; they comprise the Bocabec Gabbro and the Welsford, Utopia, and Magaguadavic granites. The Magaguadavic Granite is of particular interest here, as it is interpreted to be the source of gold-mineralizing fluids that gave rise to the Clarence Stream deposit.

The Mount Douglas Granite forms the younger, eastern part of the batholith and is Late Devonian (Fig. 4). Satellite plutons situated along the northern margin of the batholith also were emplaced in the Late Devonian. They include the Beech Hill, Kedron, McDougall Brook, Mount Pleasant, Pleasant Ridge, Sorrel Ridge, and True Hill granites (Fig. 4; Taylor et al. 1985; McLeod 1990; Sinclair 1994; McCutcheon et al. 1997). The Sn-W-Mo polymetallic deposits in the region, including the former Mount Pleasant Mine (Fig. 4), are related to these younger granites (Kooiman et al. 1986; Sinclair et al. 1988; Taylor 1992; Sinclair 1994; McCutcheon et al. 1997, 2001; Yang et al. 2003b). As well, some gold mineralization is known to be associated with the Kedron and McDougall Brook plutons (Cox 1997; Thorne and McLeod 2003a, 2003b).

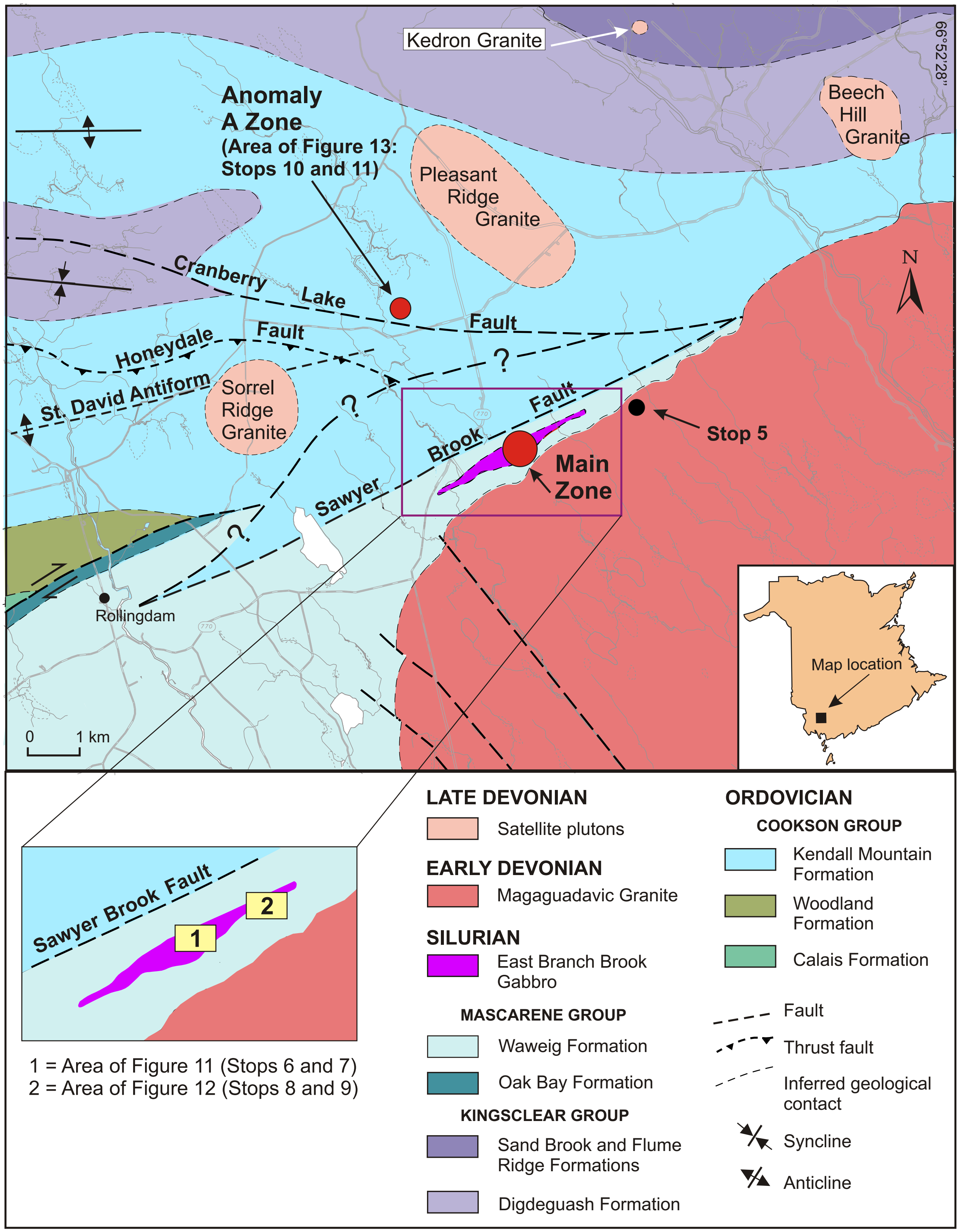


Figure 6. Regional geological setting of the Clarence Stream gold deposit, showing the Main Zone, Anomaly A Zone, and satellite plutons. Geology is after Fyffe (1998), McLeod et al. (1998), and Fyffe and Thorne (2002). Figure 4 shows the location of the Clarence Stream deposit in southwestern New Brunswick.

Tectonic Considerations

Introduction

Interpretations of the tectonic relationship between the Neoproterozoic Caledonia, Brookville, and New River terranes and the Cambrian–Ordovician St. Croix Terrane (Fig. 3, 4) have been the subject of much discussion. Fyffe and Fricker (1987), Fyffe et al. (1999), Johnson (2001), and Barr et al. (2002b) have variously modelled these belts as separate or composite terranes during the Late Neoproterozoic to Early Paleozoic. Most of these authors agree that the Neoproterozoic terranes are peri-Gondwanan, but not all characterize them as Avalonian in the sense of Williams (1995). The mainly Kingston, Mascarene, and Fredericton belts are generally thought to represent cover sequences overlying the New River and St. Croix terranes, but the zonal affiliation of these latter terranes (Ganderian or Avalonian?) remains equivocal. Whatever their zonal origin, the relationship between the St. Croix and New River terranes and their cover sequences is especially significant here, because gold mineralization is interpreted to be closely linked to these later stages of terrane accretion.

Fyffe et al. (1999) produced the first detailed plate tectonic analysis of southwestern New Brunswick. They suggested that sedimentary sequences of the St. Croix Terrane were deposited on a passive continental margin of the Ganderian Miramichi Terrane and that southeasterly subduction of an oceanic tract beneath the peri-Gondwanan New River Terrane generated arc and back-arc volcanism during the Cambrian (Fig. 3, 7). Cambrian rocks associated with the subduction occur in the Mosquito Lake area of New Brunswick and the Ellsworth area of adjacent Maine (Stewart et al. 1995; Johnson 2001). Closure of the ocean basin resulted in accretion of the Miramichi and New River terranes in the Ordovician (Fig. 7).

In the foregoing model, the St. Croix Terrane represents a foreland basin developed on the continental margin of the Miramichi Terrane as it was overridden by New River basement. Generation of early, rare, northwesterly verging isoclinal folds in the St. Croix Terrane is attributed to emplacement of the New River Terrane along a major detachment zone in the mid-Ordovician (Fig. 7). The St. Croix–New River boundary in southern New Brunswick thus would demark a thrust front between terranes with Ganderian and Avalonian aspects. This boundary is hidden beneath the Saint George Batholith in New Brunswick (Fig. 4) but is exposed along the Turtle Head Fault in adjacent Maine (Stewart et al. 1995).

Fyffe et al. (1999) further suggested that a later, northwesterly dipping subduction zone developed along the northern margin of an oceanic tract separating the New River Terrane from the Caledonia Terrane farther south. The subduction zone generated a Late Ordovician–Silurian arc and back-arc complex representing the Kingston and Mascarene terranes, respectively (Fyffe et al. 1999; Barr et al. 2002a). In this interpretation, Neoproterozoic limestone and gneiss of the Brookville Terrane would represent exhumed

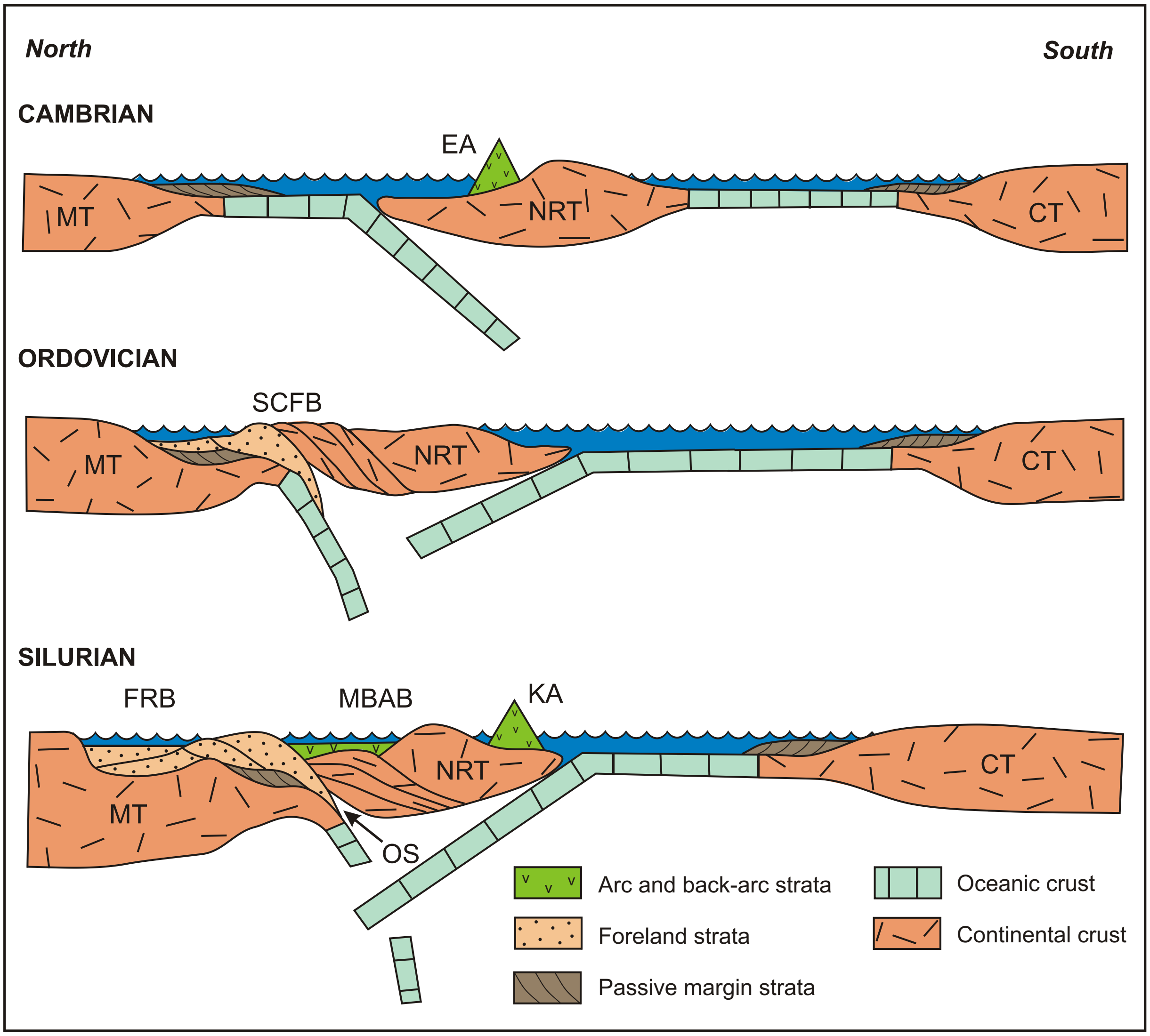


Figure 7. Diagram depicting the early Paleozoic tectonic evolution of the Appalachian Orogen in southwestern New Brunswick (modified after Fyffe et al. 1999). CT = Caledonia Terrane; MT = Miramichi Terrane, NRT = New River Terrane, EA = Ellsworth/Mosquito Lake arc, FRB = Fredericton retroforeland basin, KA = Kingston arc, MBAB = Mascarene back-arc basin, SCFB = St. Croix foreland basin, OS = Ordovician suture.

basement to the New River Terrane. Late-stage, southeasterly verging folds in the St. Croix Terrane and associated thrusts may be related to closure of the Silurian ocean basin. Major, northeast-trending, strike-slip fault zones and high-angle reverse faults within the arc and back-arc complex are attributed to oblique convergence of the Caledonia Terrane against the Kingston arc during the Late Silurian to Early Devonian.

Recent Investigations

Recent investigations have led to refinements of the foregoing tectonic model and are critical to interpreting the genesis of gold at Clarence Stream. The new findings can be summarized as follows.

- Unpublished geochronological studies conducted jointly by the Geological Survey of Canada and the New Brunswick Department of Natural Resources indicate the presence of abundant Late Neoproterozoic (~550 Ma) detrital zircons from sandy beds in the Early Ordovician Calais Formation. These new data support the suggestion by Fyffe et al. (1999) that shale of the Calais Formation was derived from the erosion of New River basement. In this interpretation (Fig. 5, 7), the Calais black shale represents the early, starved phase of foreland basin development; the overlying feldspar-rich wacke of the Woodland Formation is derived from the volcanic arc in the rising hinterland of the New River Terrane; and the quartzose sandstone of the Kendall Mountain Formation is derived from the uplifted, passive continental margin of the Miramichi Terrane.

- Observed contacts between the Cookson Group of the St. Croix Belt and the Oak Bay Formation (Mascarene Group) of the Mascarene Belt were previously interpreted as being sheared and bounded by regional faults such as the Sawyer Brook Fault (Fig. 3, 4, 5; Fyffe et al. 1999). Moreover, Gates (1989) interpreted the relationship between stratigraphic equivalents to the Oak Bay and Cookson formations in Maine as a faulted unconformity. However, newly exposed outcrop found immediately south of the Sawyer Brook Fault at Lily Hill near Clarence Stream reveals the contact to be indisputably unsheared and angularly unconformable. The unconformable nature of this contact indicates that the Sawyer Brook Fault does not delineate the boundary separating the St. Croix and Mascarene belts, as had previously been thought. Rather, the Cookson black shale likely continues southward, stratigraphically beneath the Silurian Mascarene Group. Geophysical modelling by King and Barr (2004) supports a southern provenance for the Cookson Group. It thus can be concluded that arc and back-arc rocks of the Mascarene Group stratigraphically overlie both the St. Croix and New River terranes, thereby overstepping the Ordovician accretionary boundary between those two terranes.

- Black shale of the Calais Formation underlying the newly exposed unconformity at Lily Hill contains mesoscopic, upright, isoclinal folds that plunge shallowly southwest. The folds are accompanied by a well developed, steeply dipping, axial-planar cleavage that is absent from the overlying Silurian strata. Truncation of the folded beds by the unconformity confirms the earlier interpretation by Fyffe et al. (1999) that a major, mid-Ordovician deformational event occurred in southern New Brunswick and was associated with accretion of a Cambrian arc, floored by New River basement, to the Miramichi continental margin.

- Fyffe and Fricker (1987) noted that quartzose sandstone and black shale clasts in conglomerate of the Silurian Oak Bay Formation were clearly derived from the Ordovician Cookson Group, thereby linking the Mascarene and St. Croix terranes in the Silurian. Recent geochronological studies indicate that volcanic clasts in the conglomerate were multisourced. Most of these clasts likely were derived from the New River Terrane, but other clasts have earlier dates, suggesting derivation from the more distal (and older)

Brookville and Caledonia terranes (Fig. 3, 4; Fyffe et al. 2001). The age range of clasts in the Oak Bay conglomerate could be interpreted to indicate that the St. Croix, New River, Brookville, and Caledonia terranes were proximal to the Mascarene Terrane by the Silurian. Other geochronological studies (Barr et al. 2003) suggest that the Brookville, Caledonia, and New River terranes may have undergone separate plate tectonic histories.

Given the foregoing, it is possible that all peri-Gondwanan terranes in southwestern New Brunswick were accreted to the St. Croix Terrane before deposition of the Early Silurian Oak Bay Formation — perhaps much earlier, as suggested by Johnson (2001). According to Robinson et al. (1998) and Tucker et al. (2001), Maine rocks containing sequences that correlate wholly or in part to the Brookville, New River, and St. Croix belts may be stratigraphically related and thus might not have originated as separate terranes. Under this scenario, no subduction zone could have existed south of the New River Terrane, as had been postulated by Fyffe et al. (1999).

- Robinson et al. (1998) and Tucker et al. (2001) presented a tectonic model for coastal Maine that proposed a cryptic suture beneath the Fredericton Terrane. Their interpretation is supported by recent evaluation of temporal and stratigraphic relationships in New Brunswick and by new geochemical and geochronological data (McLeod et al. 2005). The recent evidence suggests that Late Ordovician–Late Silurian volcanic-sedimentary sequences of the Kingston and Mascarene groups could have developed in response to a northwestward-migrating, continental-arc-type complex; the complex evolved above a southeasterly dipping subduction zone that plunged beneath the St. Croix and peri-Gondwanan terranes farther south.

- Several regional and detailed structural studies have recently been completed in the Clarence Stream area (Park 2001, 2003; Thorne and Lentz 2001a, 2003; Castonguay et al. 2003; Watters et al. 2003; Park et al., in press). The studies have determined that the distribution of gold around Clarence Stream is controlled primarily by D_3 mylonitic zones in the Main Zone and by closely timed, late-D_2 thrusts and shear zones in the Anomaly A Zone. The studies also conclude that the gold-mineralizing event was coeval with formation of these structures. Data from the structural investigations, combined with age-dating results (Bevier 1989, 1990; McLeod 1990; Thorne et al. 2002b; Davis et al. 2004), have helped to constrain the timing of gold mineralization and related intrusions at Clarence Stream. On the basis of these data, it appears that structures hosting most known gold deposits in the area were developed during the late Early Devonian.

The foregoing information suggests that structures in the Clarence Stream area, including late thrusts, high-angle reverse faults, and major strike-slip faults, can be attributed to terrane accretion in southwestern New Brunswick during the Late Silurian to Early Devonian. Some workers (Tucker et al. 2001; McLeod et al. 2005), propose that thrusting resulted from the northwestward stacking of a Late Ordovician–Silurian arc and back-arc complex (represented by the Mascarene and Kingston terranes) above a southeasterly dipping subduction zone situated north of the St. Croix Terrane. Their suggestions contrast with the Fyffe et al. (1999) model that associates the thrusting with shortening in a retroforeland basin (Fredericton Terrane) above a subduction zone dipping northwesterly beneath a Silurian arc (Kingston Terrane) and back-arc basin (Mascarene Terrane).

Whatever tectonic processes were involved, it seems likely that accretionary complexes reflecting at least two major tectonic events lie concealed beneath younger, mainly granitic rocks of the Saint George Batholith (Fig. 4). Deep crustal structures accompanying the accretionary complex may well have been primary conduits for gold-mineralizing fluids generated during the Late Silurian–Late Devonian emplacement of granitic magmas (Thomas and Willis 1989; McLeod 1990).

Stratified and Intrusive Rocks of the Clarence Stream Area

Lithological units in the Clarence Stream area consist of (1) stratified rocks from the St. Croix, Mascarene, and Fredericton belts in southwestern New Brunswick, and (2) mafic and felsic intrusions that include the East Branch Brook Gabbro; the Magaguadavic Granite in the western part of the Saint George Batholith; and the Pleasant Ridge and Sorrel Ridge granites, both of which are satellite plutons of the Saint George Batholith (Fig. 4, 6).

St. Croix Belt

The southern margin of the St. Croix Belt abuts the Oak Bay or Waweig formations of the Mascarene Group and is delineated by the Sawyer Brook Fault throughout most of the area (Fig. 4, 6). Around Clarence Stream, the St. Croix Belt comprises Ordovician clastic sedimentary rocks of the Cookson Group, which consists of the Calais, Woodland, and Kendall Mountain formations (Ruitenberg 1967; Ludman 1987; Fyffe and Riva 1990; Fyffe et al. 1992). The following stratigraphic description is summarized from Fyffe et al. (1992).

The Calais Formation (Fig. 6) contains carbonaceous black shale interstratified with minor, thin-bedded siltstone; it includes a pillowed basalt member that measures about 100 m thick and lies near the top of the formation. Graptolites from the formation indicate an age of Early Tremodocian (Fyffe and Riva 1990). The overlying Woodland Formation contains quartzofeldspathic wacke and lesser siltstone and shale that occur in rhythmically interbedded, thin- to medium-bedded units characterized by convolute laminations. The formation also has local, slightly calcareous, wacke beds and calcareous concretions. The Kendall Mountain Formation consists of light grey, medium- to thick-bedded, quartzose sandstone and siltstone with thin interbeds of greenish grey to black shale and minor pebble conglomerate. Graptolites in black shale of the Kendall Mountain Formation give an age of Early Caradocian (Fyffe and Riva 1990).

Mascarene Belt

The Mascarene Belt underlies the area immediately south of the Sawyer Brook Fault and is delineated along its southern margin by the Saint George Batholith (Fig. 4, 6). The belt consists of the Mascarene Group, which comprises the Early Silurian Oak Bay Formation and overlying Early to Late Silurian Waweig Formation (Fig. 6; Ruitenberg 1967). The following stratigraphic description summarizes and expands upon a detailed account of these units by Fyffe et al. (1999).

The Oak Bay Formation is composed of massive to thick-bedded, polymictic, pebble- to cobble-conglomerate containing moderately to well rounded clasts of various volcanic rock types, granitoids, rare limestone, and black shale. Both the content and, locally, the size of black shale clasts increase towards the base of the formation. The black shale clasts are clearly derived from the underlying Cookson Group, whereas other lithologies could well be sourced from peri-Gondwanan belts and/or older units of the Mascarene Group to the southeast (Fyffe and Fricker 1987; Fyffe et al. 2001). Thickness of the conglomerate section is a minimum of 600 m in the southwest and decreases to 200 m towards the northwest, where the unit consists of thin-bedded, feldspathic sandstone interbedded with turbidites. As discussed earlier under *Recent Investigations*, the relationship between the Oak Bay Formation of the Mascarene Belt and the underlying Cookson Formation of the St. Croix Belt is locally an unsheared, angular unconformity. A regional evaluation of sedimentological characteristics of the Oak Bay conglomerate indicates that deposition was contemporaneous with faulting along basin-bounding scarps such as the Sawyer Brook Fault (Gates 1989).

The Waweig Formation conformably overlies the Oak Bay Formation. It consists of a mainly turbiditic sequence interstratified with mafic tuffaceous and minor felsic volcanic rocks and has been subdivided into the Campbell Point, Sawyer Brook, and Simpson Corner members (Fig. 5, 6; Fyffe et al. 1999). The Campbell Point Member contains medium grey felsic volcanic rocks and interstratified, greyish pink to dark grey, volcaniclastic and siliciclastic sedimentary rocks. In detail, the member comprises the following lithofacies from the base upward: a tuffaceous sandstone facies of medium- to very thick-bedded, pebbly and medium- to fine-grained sandstone; a chaotic, tuffaceous sandstone facies with slump-fold horizons interstratified with thin-bedded sandstone; a waterlain pyroclastic facies of crystal and crystal-lithic lapilli tuff; a medium- to thick-bedded sandstone facies with fine-grained sandstone; and a thin-bedded mudstone facies. The Sawyer Brook Member is characterized by pyrite-bearing, grey to black shale interbedded with greyish green mafic tuff and hyaloclastite, and minor calcareous sandstone. The Simpson Corner Member is composed mainly of light grey, fine-grained sandstone grading into dark grey, laminated, silty mudstone. The member also includes minor felsic crystal tuffs, crystal-lithic tuffs, and an amygdaloidal flow.

The Oak Bay and overlying Waweig formations were formerly interpreted as Ludlovian to Pridolian, on the basis of similarities between fossil assemblages in the Mascarene Group and those in established Silurian sections of Maine (see Fyffe et al. 1999). However, a recent U-Pb zircon date of 438 ± 4 Ma for a felsic volcanic rock from the Campbell Point Member (Miller and Fyffe 2002) indicates a Llandoverian age for the onset of deposition in this segment of the Mascarene Belt (Fig. 5).

Fredericton Belt

The Fredericton Belt consists of the Kingsclear Group that forms a thick, clastic, turbidite sequence deposited during the Early Silurian within an 80 km wide, southwest-trending trough north of the St. Croix Belt (Fyffe and Fricker 1987). In the Clarence Stream area, the Kingsclear Group comprises the Digdeguash, Sand Brook, and Flume Ridge formations (Fig. 4, 5, 6; Ruitenberg 1967; Ruitenberg and Ludman 1978; Fyffe 1991; McLeod et al. 1994; Fyffe and Riva 2001).

Early Silurian (upper Rhuddanian Stage of the early Llandoverian) rocks of the Digdeguash Formation define the southern boundary of the Fredericton Belt (Fyffe and Riva 2001). These rocks form the base of the Silurian sequence and consist of medium to dark grey, medium- to coarse-grained, lithic to feldspathic wacke; light grey quartz wacke and polymictic granule conglomerate; and dark grey to black shale (Ruitenberg and Ludman 1978; Fyffe 1991). The contact between the Digdeguash Formation and the underlying Kendall Mountain Formation (Fig. 5, 6) is generally faulted but has been interpreted as an unconformity on the basis of fossil evidence and detailed bedrock mapping (Fyffe and Riva 2001).

The Digdeguash Formation interfingers upward with Silurian rocks of the Sand Brook Formation to the east and the Flume Ridge Formation to the west (Ruitenberg 1967; Ruitenberg and Ludman 1978; Fyffe 1991). The Sand Brook Formation is characterized by light green, graded, feldspathic wacke beds of varied thicknesses interbedded with distinctive, green to maroon, laminated siltstone and shale (Fyffe 1991). The coloration is due to abundant epidote and actinolite that account for the formation’s overall calc-silicate composition. The Flume Ridge Formation includes light grey to greyish green, calcareous wacke with characteristic large detrital muscovite flakes. The wacke is interstratified with non-calcareous siltstone and shale (Ruitenberg and Ludman 1978; Fyffe 1991).

East Branch Brook Gabbro

The East Branch Brook Gabbro occurs as numerous linear, dyke-like bodies that trend northeast, parallel to the regional fabric. The gabbro intrudes volcanic and volcaniclastic units of the Waweig Formation immediately adjacent to the Magaguadavic Granite (Fig. 6). The three phases of dykes range from Fe-rich to Mg-rich, all of which are mantle-derived and have subalkaline to alkaline, continental tholeiitic compositions (Thorne and Lentz 2001b).

A maximum age for the gabbro is constrained by several factors: (1) it has an intrusive relationship with Early Silurian (437 ± 7 Ma) rocks of the Waweig Formation (Miller and Fyffe 2002); (2) it is crosscut by auriferous pegmatite-aplite dykes that give a U-Pb monazite electron microprobe age of 390 ± 8 Ma (Thorne et al. 2002b); and (3) Davis et al. (2004) reported U-Pb monazite ages of 400 ± 5 Ma from the same pegmatite-aplite dykes. The East Branch Brook gabbroic dykes are therefore interpreted to have been emplaced along splays of the Sawyer Brook Fault during the Late Silurian to Early Devonian (Thorne and Lentz 2001b).

Magaguadavic Granite

The Magaguadavic Granite comprises much of the northwestern part of the Saint George Batholith in the Clarence Stream area and consists of two distinct sections: the western body and the more elongate northern body (Fig. 4; McLeod 1990). This composite intrusion, including its later fractionated components, is considered to be the source of gold mineralization in the Clarence Stream deposit (Thorne et al. 2002b).

The Magaguadavic Granite typically consists of an undeformed, heterogeneous unit of pink to grey, medium- to coarse-grained, commonly megacrystic monzogranite, monzonite, and granodiorite with minor microgranitic dykes, all of which exhibit well developed rapakivi textures. The northern body also contains mappable units composed primarily of pink, fine- to medium-grained, porphyritic to equigranular syenogranite and monzogranite. Xenoliths of partially to near totally assimilated sedimentary and mafic igneous material are common throughout the pluton. Irregular areas containing an anomalously high proportion of mafic minerals (up to 25% biotite and/or amphibole) attest to the large volume of incorporated foreign material in the intrusion.

The Magaguadavic Granite is interpreted as Early Devonian on the basis of several age dates. Megacrystic granite from the western body yielded a U-Pb zircon age of 396 ± 1 Ma (Bevier 1990) and an ^{40}Ar-^{39}Ar biotite age of 400 ± 4 Ma (McLeod 1990). A granitic dyke intruding rocks of the Waweig Formation in the Clarence Stream area, along the northern margin of the Magaguadavic Granite, yielded a U-Pb monazite age of 395.5 ± 0.5 Ma (Davis et al. 2004). As well, seriate rapakivi granite from the northern body yielded a U-Pb zircon age of 403 ± 2 Ma (Davis et al. 2004). Chemically, the granite is an oxidized, magnetite-bearing pluton with overall I-type geochemical signatures and is interpreted to have been emplaced at moderate crustal depths (McLeod 1990).

Satellite Plutons

The Saint George Batholith includes several Late Devonian satellite plutons; those of relevance to this guide are the Sorrel Ridge and Pleasant Ridge granites (Fig. 4, 6). The Sorrel Ridge Granite is a light brown to pink, fine-grained porphyry containing phenocrysts of quartz, alkali feldspar, plagioclase, and biotite, whereas the Pleasant Ridge Granite is light grey to white, fine to medium grained, equigranular, and contains lithian mica and topaz. The two plutons were emplaced at much shallower crustal levels than the megacrystic Magaguadavic Granite and are highly evolved, fluorine-rich, high-silica granites exhibiting A-type characteristics (Taylor et al. 1985; Taylor 1992).

Structure

Ordovician and Silurian rocks of the St. Croix, Fredericton, and Mascarene belts have been affected by episodes of deformation attributed to distinct accretionary events reflecting the complex history of terrane interaction in southwestern New Brunswick (Fyffe et al. 1999).

St. Croix and Fredericton Belts

Ruitenberg's (1967) regional structural synthesis encompassing the Clarence Stream area described the heterogeneous nature of polydeformation in rocks of the Ordovician St. Croix Belt south of the Sawyer Brook Fault and the Silurian Fredericton Belt north of the fault. He documented four phases of deformation and, locally, a bedding-parallel fabric that developed before the first-phase folds. Ruitenberg (1967) also recognized a regional, northeast-trending structure affecting map patterns in the area and termed it the St. David Dome. He interpreted the dome as an early structural feature that essentially was controlled by composite first-phase folds, followed by upwarping due to the emplacement of granitic intrusions.

According to Ruitenberg (1967), first-phase and second-phase folds plunge gently northeast and/or southwest and were formed in response to a northwesterly to southeasterly stress. Planar fabrics are steeply dipping in first-phase folds and shallowly dipping in second-phase folds. Third-phase folds plunge steeply northeast and northwest and are accompanied by locally developed, steeply dipping, axial-planar fabrics. Ruitenberg (1967) interpreted these folds to be caused by northeasterly to southwesterly shortening, which resulted in kinking of previous fabrics. He associated the fourth and last deformational event with northwest-trending faults and minor folds.

Ruitenberg's (1967) interpretations have since been modified as a result of numerous structural studies encompassing the Clarence Stream area (see Ruitenberg 1972; Ruitenberg and Ludman 1978; Stringer and Burke 1985; Fyffe 1990; Fyffe et al. 1992; Fyffe et al. 1999; Castonguay et al. 2003). The more recent reports have integrated local and regional structural work conducted in the St. Croix Belt and along the southern margin of the Fredericton Belt, north of the Sawyer Brook Fault.

The following description draws mainly on work by Fyffe (1990), Castonguay et al. (2002, 2003), and Watters et al. (2003). These authors describe rare, isoclinal or intrafolial, early folds (F_1) with associated bedding-parallel cleavage; the folds are analogous to the pre-first-phase deformation and first-phase folds of Ruitenberg (1967). The F_1 folds are refolded by gently and mostly northeasterly plunging, isoclinal F_2 folds accompanied by a locally well developed, shallowly dipping, axial-planar cleavage and are analogous to Ruitenberg's second-phase folds. These earlier folding episodes may represent a deformation continuum likely related directly to thrusting events. Shallowly dipping, high-strain zones (thrust faults) represent late components of the D_2 deformation, as exemplified by low-angle dismemberment of F_2 fold limbs. The putative Honeydale Fault (Fig. 4, 6) is interpreted as a major, northwest-directed, late-D_2 thrust that positions Ordovician strata of the Kendall Mountain Formation over infolded, synclinal, F_2 keels of the Silurian Digdeguash Formation (Ruitenberg and Ludman 1978; Castonguay et al. 2003).

Recent workers also reinterpreted the formation of Ruitenberg's (1967) St. David Dome (hereafter referred to as the St. David Antiform) as a later, D_3 event (Fig. 6). Deformation associated with the D_3 event has profoundly affected regional map patterns. It is mostly coaxial with F_2 folds, it openly to tightly folds the pre-existing structural elements, and it is only locally accompanied by a steeply dipping cleavage. Dextral strike-slip movement along the sheared southern limb of the antiform has produced northeast-trending mylonite zones, including those associated with the Sawyer Brook Fault. A late-D_4 event, roughly analogous to Ruitenberg's (1967) fourth event, broadly deformed the St. David Antiform to produce northwest-trending, F_4 kink folds and chevron folds that may be associated with late-stage, northwest-trending, sinistral structures such as the Oak Bay Fault (Fig. 4).

Mascarene Belt

The Silurian Mascarene Belt lies immediately south of the Sawyer Brook Fault, where it is represented by rocks of the Oak Bay and Waweig formations of the Mascarene Group (Fig. 4, 6). Unlike the polydeformed rocks just described in the St. Croix and Fredericton belts, rocks of the Mascarene Belt typically exhibit a single pervasive fabric that dips moderately to steeply northwest to southeast (Fyffe et al. 1999). The Oak Bay and Waweig formations appear as a regionally extensive, southeasterly dipping homocline that essentially is devoid of folds associated with fabric development.

STOP DESCRIPTIONS

Stop 1: Digdeguash Formation, Kingsclear Group (Fredericton Belt)

From Fredericton, head west on Highway 8 (~3 km) and take the first exit (Exit 3 to Hanwell Road) just after the first overpass. Turn right onto Highway 2 and then right again onto Highway 640. Head south on Highway 640 for ~32 km. Head left at the T-junction with Highway 3 at Acton and proceed toward Harvey. Follow Highway 3 through Harvey and proceed to the turnoff for Highway 127 on the left (~42 km from Harvey). Head south on Highway 127 until reaching Wyman Mills Road on the left (~3 km). Follow this road and stop just before the bridge that *crosses the Digdeguash River. Park beside the road and proceed to the picnic area via the trail along the old railway bed on the right side of the road.*

Rocks of the Digdeguash Formation exposed here consist of light to medium grey, medium- to thick-bedded, feldspathic, micaceous wackes interbedded with dark grey shale. The rocks are highly folded and cleaved. Fold noses and long, gently dipping limbs of large-scale F_2 folds can be seen along the riverbanks. The S_2 cleavage dips about 40º N. Graded beds indicate deposition in deep-water conditions and younging to the north toward the bridge. The sequence is assigned an age of Early Silurian on the basis of correlation with graptolite-bearing shales farther east. The Digdeguash Formation overlies the northern margin of the St. Croix Belt. It thus is roughly coeval with the shallower water deposits of the Oak Bay and Waweig formations of the Mascarene Belt that overlie the southern margin of the St. Croix Belt.

Stop 2: Moores Mills Quarry – Kendall Mountain Formation, Cookson Group (St. Croix Belt)

From Stop 1 on Wyman Mills Road, return to Highway 127 and turn right; proceed until the junction with Highway 3 (~3 km). Turn left and head west and then south on Highway 3 to the turnoff for Moores Mills (~22 km). Turn left onto that secondary road, pass through the village, and proceed east for ~250 m. At the junction with Highway 750, bear left until reaching Tower Hill Road on the right (~1.5 km). Proceed to the quarry on the right side of the road (~800 m) and park in the cleared area.

At this stop, rocks of the Kendall Mountain Formation exhibit F_1, F_2, and F_4 folds (Fig. 8). The folds represent three of the four generations of deformation that affect the host rocks of gold mineralization at Clarence Stream and that in part control the mineralization. The thick-bedded quartzose sandstone and black, interbedded carbonaceous (graptolite-bearing) shale are deformed in a series of moderately inclined, isoclinal F_2 folds. Faults along the quartzose sandstone–shale contact cut the lower inverted limbs of the folds and feature cataclastic breccia and gouge zones measuring 2 cm to 5 cm wide. The F_2 folds are well developed along the quarry face, whereas minor F_1 sheath folds can be observed at the southwestern end of the quarry face. At the regional scale, late-D_2 high-strain zones are often nearly coincident with a change in asymmetry of mesoscopic F_2 folds, a relationship that supports the presumed genetic link between F_2 folds and the locus of faults. Gold mineralization in the Anomaly A Zone is interpreted to be controlled by a regional, D_2, thrust-related deformation. *Note: Stop description is modified from Castonguay and Ravenelle (2002).*

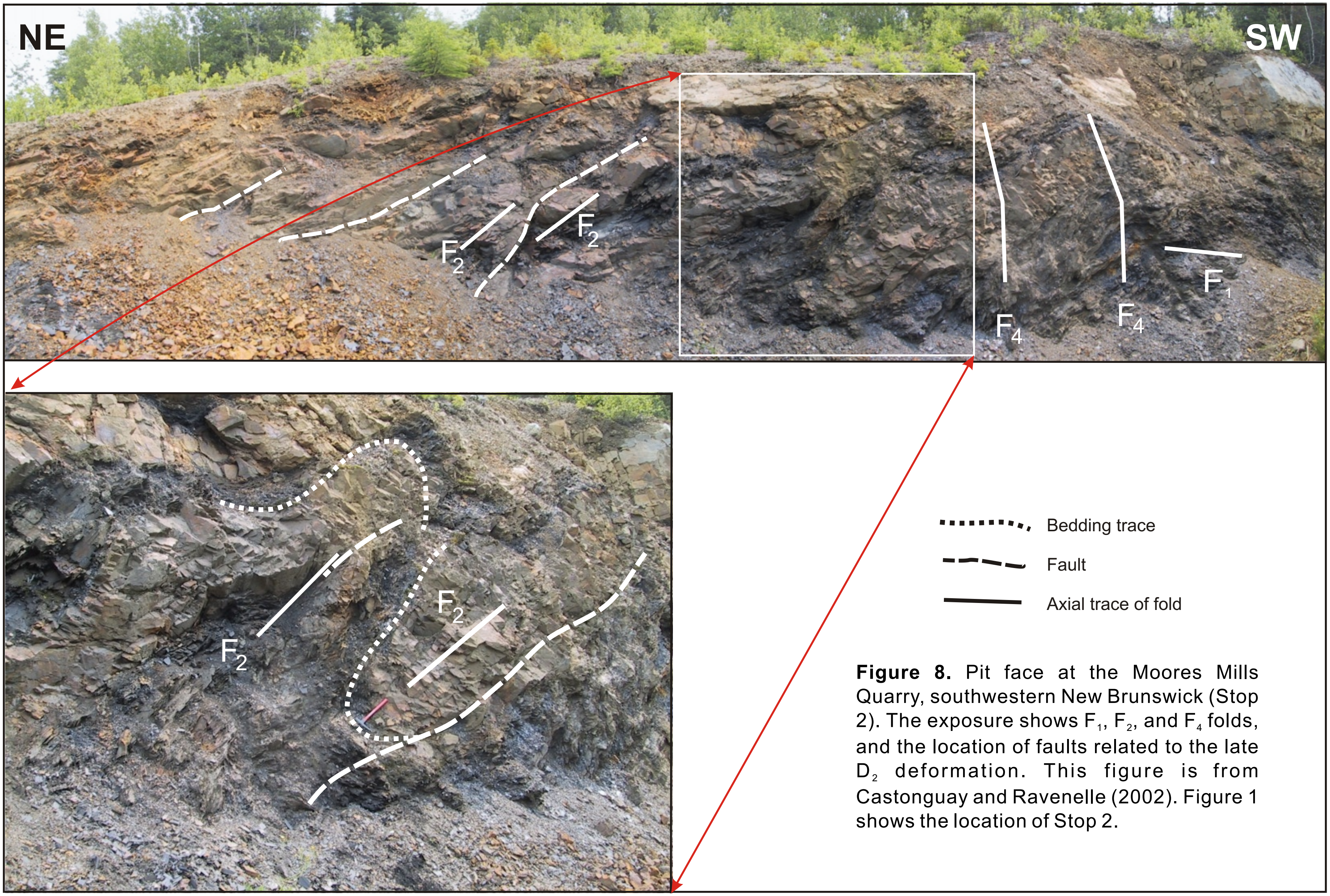


Figure 8. Pit face at the Moores Mills Quarry, southwestern New Brunswick (Stop 2). The exposure shows F_1, F_2, and F_4 folds, and the location of faults related to the late D_2 deformation. This figure is from Castonguay and Ravenelle (2002). Figure 1 shows the location of Stop 2.

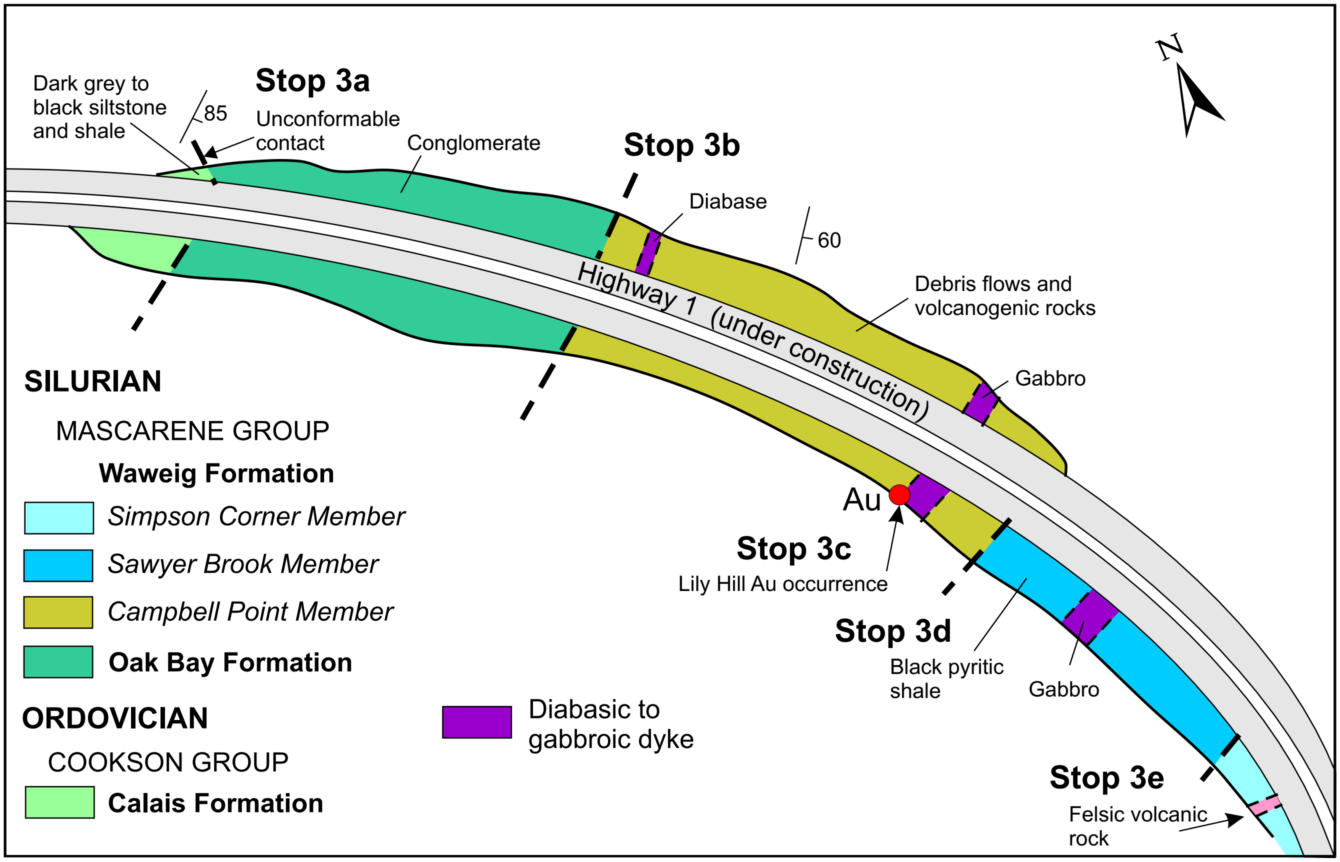


Figure 9. Schematic view of a new highway roadcut near Lily Hill (Stops 3a–e). Outcrop at Stop 3a exposes the unsheared, angularly unconformable contact between rocks of the St. Croix and Mascarene belts. Figure 1 shows the location of Stop 3.

Stop 3a: Lily Hill – Contact between Calais Formation, Cookson Group (St. Croix Belt) and Oak Bay Formation, Mascarene Group (Mascarene Belt)

From Stop 2, retrace the route back to Highway 3. Turn left and head south on Highway 3 toward St. Stephen (~10 km). At the junction with Highway 1, turn left and head east until reaching the junction with Highway 760 on the left (~8 km). Proceed north along Highway 760 and turn right immediately after crossing the overpass that crosses the new highway construction. Head west on the new highway until reaching the last outcrop exposure on the right side of the road.

The contact between the Ordovician Calais Formation and the Silurian Oak Bay Formation can be seen here in outcrop along the north side of a new highway roadcut (Fig. 9). The contact is undulatory but not sheared. A laminated and folded bed within the Calais Formation is cut off by conglomerate of the Oak Bay Formation, indicating that the formational contact represents an unconformity. The Calais Formation at this site consists of a rhythmically thin-bedded sequence of hornfelsed, biotitized, cordierite-bearing siltstone and shale. These rocks young and dip steeply east and are deformed by upright, isoclinal folds that plunge gently southwest (Fig. 10). A well developed axial-planar

Figure 10. Easterly plunging, isoclinal fold in the Calais Formation at Lily Hill (Stop 3a), with bedding trace (white line). Figure 9 shows the location of Stop 3a.

cleavage, locally subparallel to bedding, is associated here with the early (F_1?) folds. The overlying Oak Bay conglomerate contains polymictic pebbles and cobbles of volcanic rock, granite, quartzite, slate, and rare limestone. The clasts likely were sourced from the Ganderian St. Croix and peri-Gondwanan New River terranes to the northwest and southeast respectively, indicating that terrane accretion occurred prior to deposition.

Stop 3b: Lily Hill – Contact between Oak Bay and Waweig formations, Mascarene Group (Mascarene Belt)

From Stop 3a, proceed east along the outcrop exposure for ~250 m.

Stop 3b exposes the gradational contact between the Oak Bay Formation and the Waweig Formation (Fig. 9). The Waweig Formation is represented here by the Campbell Point Member, which consists of light grey, medium- to thick-bedded, felsic crystal tuffs that young to the east and are locally banded with calc-silicate (Fyffe et al. 1999). Higher in the sequence, they interfinger with coarse debris flows containing purple cherty clasts derived from the underlying Calais Formation.

The depositional origin of the reworked volcanic rocks is ambiguous. The debris flows may have been deposited directly into the basin during volcanic activity, or could have been deposited on the basin margin and subsequently slumped into the basin during seismic/tectonic activity. These rocks have been intruded by two diabasic to gabbroic dykes that are strikingly similar to those hosting gold mineralization in the Main Zone of the Clarence Stream deposit.

Stop 3c: Lily Hill – Gabbroic intrusion at Lily Hill Au occurrence (Mascarene Belt)

From Stop 3b, cross the four-lane highway at the end of the outcrop exposure on the north side of the road and walk toward the outcrop on the south side of the road.

A massive, northeasterly trending gabbroic dyke intrudes the Waweig Formation at this site (Fig. 9). The dyke is situated close to the Late Silurian Bocabec Gabbro (Fig. 4), a major mafic phase of the southwestern part of the Saint George Batholith (McLeod 1990). The dyke may be related to the batholith or could be one of the many northeasterly trending Silurian mafic intrusions found throughout most of the Mascarene Belt (Fyffe et al. 1999). Alternatively, it could be related to a younger episode of mafic magmatism that generated a texturally diverse suite of northwesterly trending dykes.

Minor gold mineralization is associated with the gabbroic intrusion, particularly where the sulphide content is higher (as represented by more striated arsenopyrite crystals). Samples from soil overlying the intrusion site contain up to 568 ppb Au, and grab samples from the outcrop yield up to 0.53 g/t Au (Gardiner 2003). The exact origin of gold-mineralizing fluids and the controlling parameters of mineralization here have not yet been fully investigated.

Stop 3d: Lily Hill – Sawyer Brook Member, Waweig Formation (Mascarene Belt)

From Stop 3c, walk a short distance east along the roadcut.

The Sawyer Brook Member of the Waweig Formation typically consists of grey to black shale interbedded with several thick (10 m) horizons of grayish green mafic tuffs (Fyffe et al. 1999). At Stop 3d (Fig. 9), the black shale contains abundant pyrite in cubes up to 0.5 cm in diameter. The pyrite is disseminated throughout the beds and along bedding planes and is associated with quartz veins along fracture fillings.

Fyffe et al. (1999) inferred that the thickness of this unit ranges from 300 m along the eastern shore of Oak Bay to 600 m along Sawyer Brook. The sequence is interpreted to represent the deepest part of the depositional basin in this area, and the overlying strata indicate deposition within a shallowing environment. Finer grained lithologies in the Waweig

Formation commonly exhibit a well developed cleavage, but folds such as those seen at Stop 3a in the underlying Cookson Group have not been observed in this formation.

Stop 3e: Lily Hill – Felsic unit in Simpson Corner Member, Waweig Formation (Mascarene Belt)

From Stop 3d, walk a short distance east along the roadcut.

Exposed here is a medium purple to white, felsic tuff unit with minor lapilli horizons (Fig. 9). The rock exhibits a flow-banded texture and is typical of felsic units in the Simpson Corner Member of the Waweig Formation (Fyffe et al. 1999). These felsic volcanic rocks are similar to rocks uncovered by trenching in the Main Zone at Clarence Stream but, unlike the trenched exposures, are not intensely sheared and recrystallized.

Stop 4: Granitic dykes in Digdeguash Formation, Kingsclear Group (Fredericton Belt)

From Stop 3, return to Highway 1 and head east toward St. George (~31 km). Take Exit 56 east of St. George, turn left onto Highway 780, and head toward Utopia. Turn right at the next intersection. At the crossroad (~2.5 km), turn left and head north along Highway 785 for ~20 km. Turn right onto the logging road, proceed ~4.7 km, and turn left onto the next logging road. Stop 4 is situated ~4.1 km down this road, on the right side.

At this stop, fractured and deformed sedimentary rocks of the Silurian Digdeguash Formation are crosscut by a series of fairly massive granitic dykes. The dykes are interpreted to have emanated from the nearby Magaguadavic Granite phase of the Saint George Batholith. Although most of the dykes trend about 060º/90º, some lie subparallel to bedding at 080º/85º S. Aplitic dykes ranging in width from less than 1 cm to 60 cm are locally crosscut by later quartz veins that show various trends. Early veins and dykes are boudinaged parallel to bedding, which suggests they were emplaced syn-tectonically. At the south end of the trench, one aplitic dyke features a quartz-rich pod containing epidote crystals. Elsewhere, an early quartz vein is cut by a dyke that is offset by later quartz veins; this site provides evidence for multiple generations of veining and dyke emplacement and for their likely genetic connection.

The youngest phase of the Magaguadavic Granite is exposed about 200 m farther down the logging road. The rock consists of grey to pink, medium- to coarse-grained, locally megacrystic granodiorite and quartz diorite that are transitional to granite. Rapakivi texture is distinguishable in the megacrystic phases.

CLARENCE STREAM GOLD DEPOSIT

Introduction

The Clarence Stream gold deposit lies east of St. Stephen in southwestern New Brunswick (Fig. 1, 4, 6). Exploration activity near Clarence Stream began shortly after prospector Reginald Cox Jr. discovered highly mineralized boulders in the area during the fall of 1999. Since then, Freewest Resources Canada Incorporated has optioned the property and launched a comprehensive program that includes geological mapping, soil and till geochemical sampling, IP and magnetometer surveys, trenching, and extensive drilling. The company's exploration efforts have identified two major mineralized zones along the northwestern margin of the Saint George Batholith. These two zones, which have contrasting styles of mineralization, are referred to as the Main Zone and the Anomaly A Zone (Fig. 6).

Structural Setting of Gold Deposit

The Clarence Stream gold deposit is localized along the Sawyer Brook Fault, a regional, high-strain zone marking the approximate boundary between the New River and St. Croix terranes (discussed earlier under *Tectonic Zonation*). An accretionary complex related to the juxtapostion of these terranes in the Late Ordovician is assumed to lie concealed beneath Silurian volcanic and sedimentary rocks of the Mascarene Group and Late Silurian–Late Devonian plutons of the Saint George Batholith (Fig. 4, 6, 7).

Periodic reactivation along terrane boundaries is a well known phenomenon in the evolutionary development of the Appalachian Orogen (Williams and Hatcher 1982). Reactivation of deep-seated structures in southern New Brunswick is thought to have occurred during accretion of the Kingston volcanic arc in the Late Silurian and Early Devonian. The Sawyer Brook Fault, which separates Ordovician rocks of the Cookson Group to the northwest from Silurian rocks of the Mascarene Group to the southeast, is interpreted to be a surface manifestation of one such structure. Mafic and felsic magmas would have used deep crustal structures within the accretionary complex to rise to higher crustal levels, where they coalesced to form the composite Saint George Batholith (Thomas and Willis 1989; McLeod 1990; Whalen et al. 1994).

Main Zone

The Main Zone is found immediately southeast of the Sawyer Brook Fault, 3 km southeast of the Anomaly A Zone on the northwest side of the fault (Fig. 6, 11, 12). Mineralization in the Main Zone is structurally bound in a brittle-ductile shear zone that is associated with a

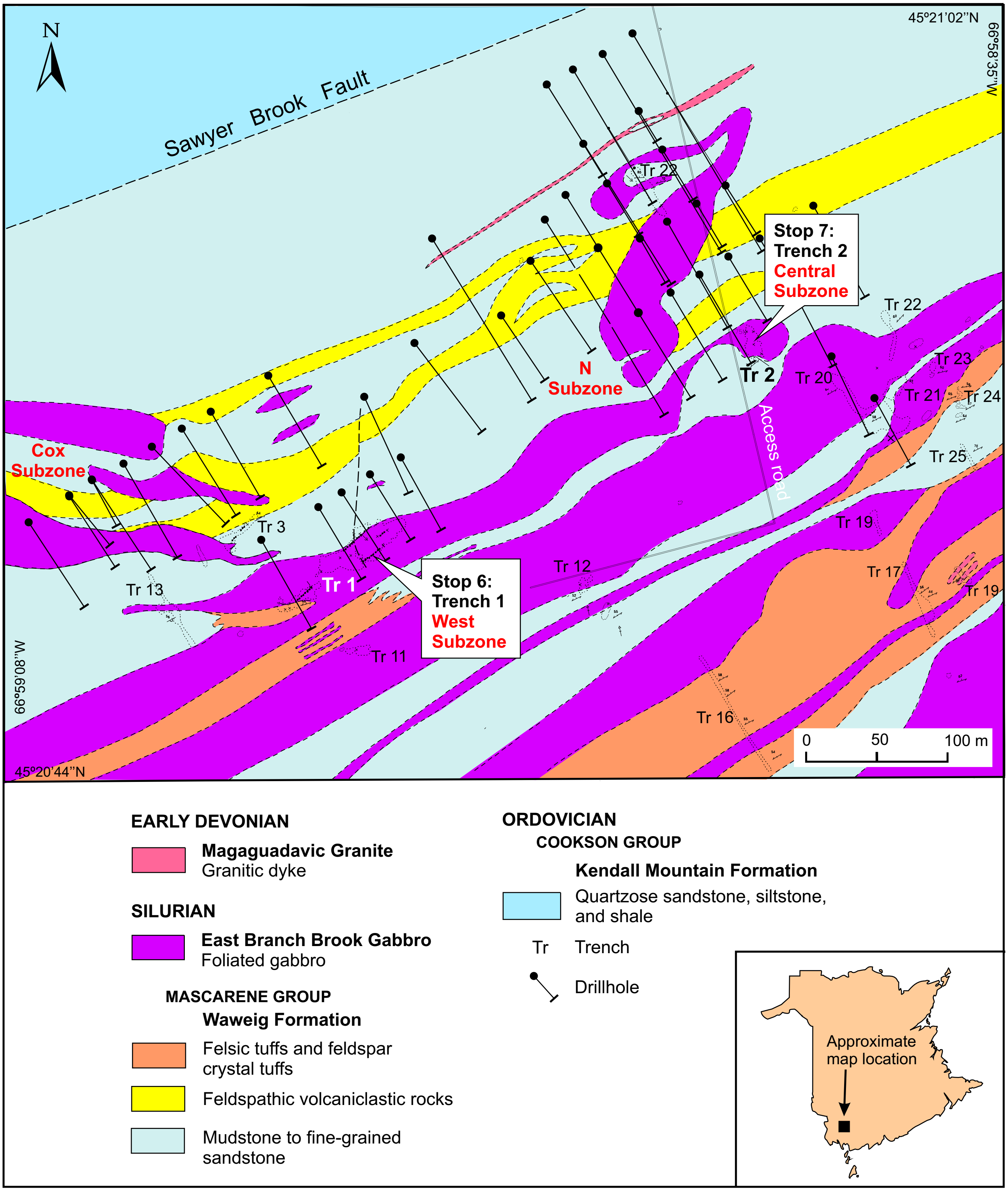


Figure 11. Geology of the Cox, West, N, and Central subzones of the Main Zone, Clarence Stream deposit (modified after Thorne et al. 2004c). The field distance between Figure 11 and Figure 12 (facing page) is about 400 m. Figure 6 shows the location of Figure 11.

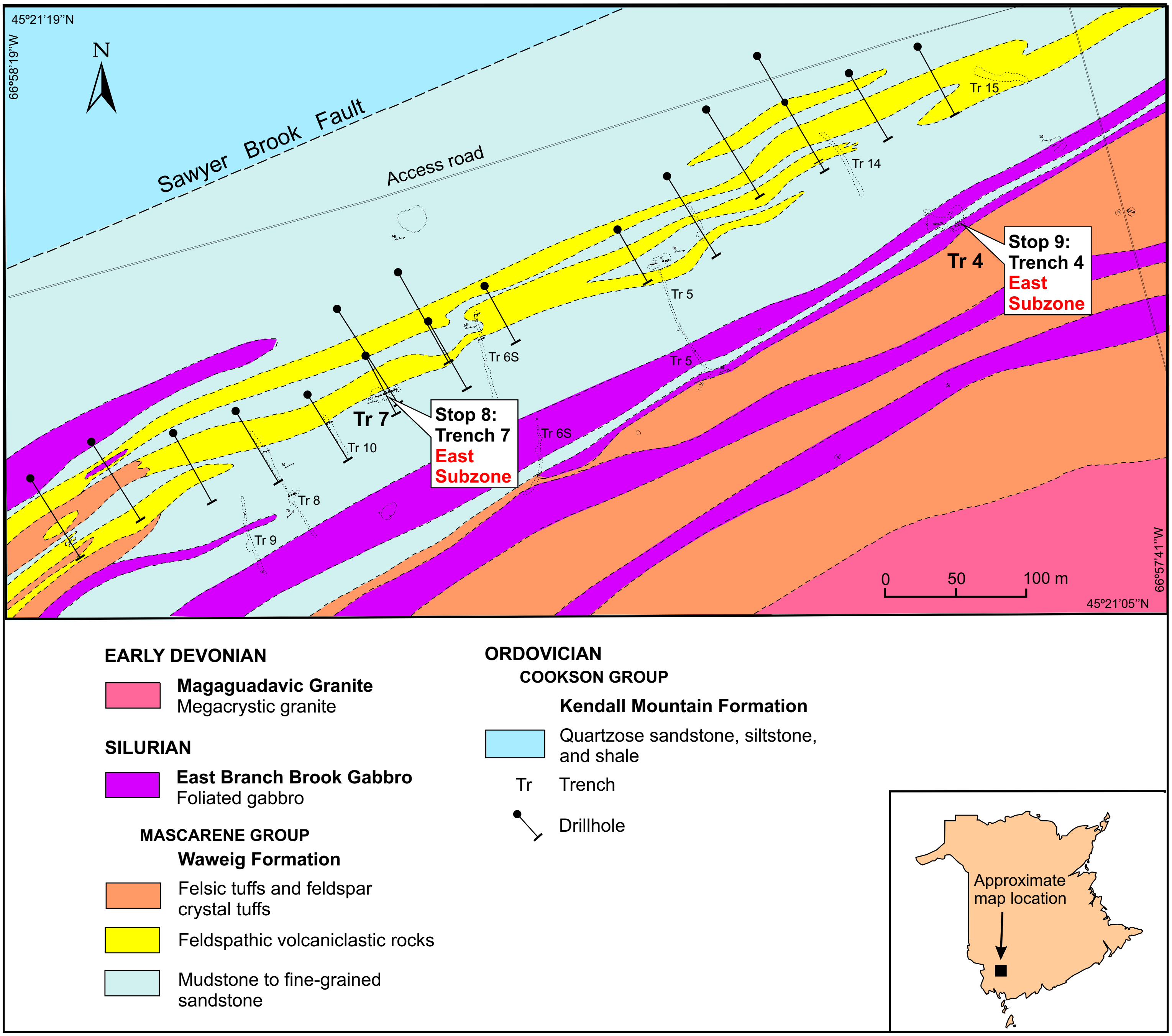


Figure 12. Geology of the East Subzone of the Main Zone, Clarence Stream deposit (modified after Thorne et al. 2004b). The field distance between Figure 11 (facing page) and Figure 12 is about 400 m. Figure 6 shows the location of Figure 12.

secondary splay of the Sawyer Brook Fault (Thorne and Lentz 2001a, 2002, 2003). The splay parallels the intrusive contact with the Magaguadavic Granite to the south and transects Silurian sedimentary and volcanic rocks of the Waweig Formation. This stratigraphic sequence has been intruded and contact metamorphosed by several injections of gabbroic dykes of the East Branch Brook Gabbro (Thorne and Lentz 2001b) during an event that occurred before emplacement of the Early Devonian Magaguadavic Granite of the Saint George Batholith (McLeod 1990).

The Main Zone encompasses several mineralized subzones, referred to as the Cox, West, N, Central, and East subzones (Fig. 11, 12). Free gold typically occurs within parallel, northeast-trending, steeply dipping quartz veins hosted by cordierite-biotite-muscovite-bearing, schistose sedimentary rocks of the Early Silurian Campbell Point Member (Waweig Formation), and within Silurian gabbroic dykes of the East Branch Brook Gabbro (Fig. 11, 12). Gold also occurs as disseminations within the gabbroic wall rocks and in mineralized, composite pegmatite-aplite dykes that are late fractionates of the Magaguadavic Granite (Thorne et al. 2002b).

The stratified units are dominated by a well developed shear fabric that Castonguay et al. (2003) attribute to heterogeneous D_3 deformation. These authors interpret the Sawyer Brook Fault as a late-D_3, dextral, strike-slip structure that cuts the southeastern limb of the regional-scale, northeast-trending St. David Antiform (Fig. 6), which itself is an F_3 structure and a manifestation of the regional D_3 event. Detailed structural investigations of the Main Zone (Park 2001, 2003; Park et al., in press) indicate that dextral and later dip-slip movement along the brittle-ductile shear zone boudinaged and rotated the mineralized quartz veins. The dip-slip movement possibly resulted from isostatic readjustment related to cooling of the Magaguadavic Granite.

The vein material has been extensively reworked subsequent to the deposition of quartz and associated mineralization, as evidenced by the saccharoidal texture, lack of primary depositional features, and brecciation of some veins. Slight folding and offsetting of these veins is obvious in small, post-mineralization, north- to northwest-trending shear zones. Mineralization is better preserved in quartz veins that were shielded by the more competent gabbroic bodies at the West Zone (Fig. 11), whereas quartz veins hosted within fissile sedimentary units at the East Zone (Fig. 12) are boudinaged and less continuous. Overall, the quartz veins exhibit textures ranging from mylonitic to brecciated and were formed at various stages of episodic deformation. The veins also show late development of an annealed, saccharoidal texture that resulted from thermally induced recrystallization of strained quartz. Samples of muscovite from quartz veins at the Main Zone yielded ^{40}Ar-^{39}Ar ages of 389.3 ± 3.5 Ma and 388.8 ± 3.6 Ma, numbers that enable a minimum date to be set for the timing of gold mineralization (Davis et al. 2004).

Mineralization at the Main Zone is broadly representative of a typical Au-As-Sb metal association, consisting mainly of arsenopyrite, pyrrhotite, pyrite, berthierite, minor chalcopyrite, sphalerite, and a variety of Sb-bearing minerals. Geochemically, the gold has a positive correlation with Ag, Bi, Cd, Te, S, and Cu, similar to the geochemical signature of intrusion-related gold deposits (Thompson et al. 1999; Lang et al. 2000; Thompson and Newberry 2000; Lang and Baker 2001). Alteration associated with the gold mineralization persists as K-metasomatism within mafic rocks and as Na-metasomatism within sedimentary and volcanic rocks (Thorne and Lentz 2002).

Geochemical, geochronological, and isotopic investigations indicate that the source of gold mineralization at the Main Zone was fluids evolved from the cooling Magaguadavic Granite (Thorne et al. 2002b; Thorne and Lentz 2003; Thorne 2005). The best evidence to support this inference can be seen at Stop 9, where granitic dykes grade laterally into gold- and sulphide-bearing quartz veins. These dykes are geochemically similar to late-stage fractionates of the Magaguadavic Granite (Thorne and Lentz 2002). It is thought that Au-As-Sb-Bi mineralization was deposited within dilatant areas of the shear zone from high temperature (> 300ºC and < 375ºC), chlorine-bearing fluids whose characteristics were consistent with a mesothermal system (Thorne and Lentz 2003). Pressure fluctuations likely were the predominant control on mineralization (that is, fault-valve action); changes in redox state of the fluids, temperature, pH, and fluid-wallrock interaction may also have influenced gold precipitation (Thorne 2005).

Anomaly A Zone

Mineralization in the Anomaly A Zone is hosted by polydeformed quartzose sandstone, siltstone, and shale of the Kendall Mountain Formation (Fig. 6). Several mineralized subzones have been identified within the zone, namely the AD, MW, 93, and Murphy subzones (Fig. 13).

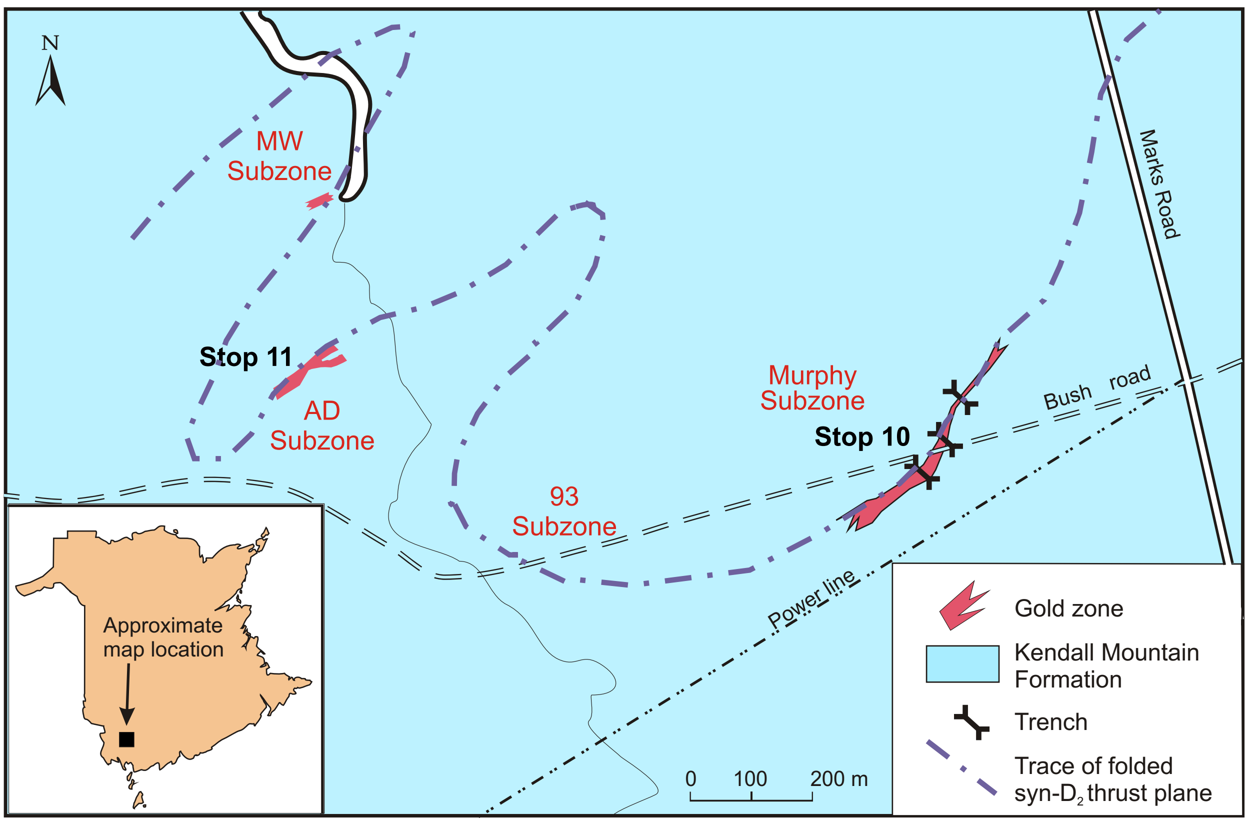


Figure 13. Plan view of the Anomaly A Zone, Clarence Stream deposit, indicating the position of the AD, MW, 93, and Murphy subzones (modified after Watters et al. 2003). Figure 6 shows the location of Figure 13.

The style of mineralization in the Anomaly A Zone differs substantially from that in the Main Zone. Mineralization at Anomaly A occurs in stockwork and auriferous quartz veins within shallowly dipping, brittle-ductile, high-strain zones that generally strike east-northeast (Lutes et al. 2003). The high-strain zones are tabular shaped, several metres thick, and appear restricted to the limbs of mesoscopic to megascopic, isoclinal F_2 folds. These late-D_2 shears are deformed and overprinted by D_3 and D_4 open-folding events. Mineralized intervals at the AD and MW subzones dip in opposite directions and are interpreted to occupy opposing limbs of a broad synform associated with the D_3 event (Castonguay et al. 2003; Watters et al. 2003). Recent drilling by Freewest Resources Canada Incorporated indicates that the 93 Subzone may be a direct continuation of this structure (Fig. 13).

The Anomaly A Zone features at least three main stages of quartz veining. Gold occurs predominantly in the middle quartz-sulphide vein stage associated with pyrrhotite, arsenopyrite, pyrite, and stibnite; here, minor amounts of gold (1–2 g/t Au) are contained within altered sediments. This metal signature is similar to that of the Main Zone, except that the Anomaly A signature lacks Bi minerals and shows abundant Sb. The variation could be explained in terms of geochemical zonation and differing proximity of the two zones to a gold-generating granitic source.

Unlike mineralization at the Main Zone, which lies within 200 m of the Early Devonian Magagudavic Granite, gold mineralization at the Anomaly A Zone apparently has no close relationship to an intrusive body. Trenching and drilling have not yet exposed granitic lithologies spatially associated with mineralization at this location, although geophysical data suggest that a granitic mass of unknown age and affinity underlies the area at relatively shallow depths (Thomas and Willis 1989; King and Barr 2004). The nearest known intrusions are the Sorrel Ridge Granite and Pleasant Ridge Granite that are exposed just west and east, respectively, of the Anomaly A Zone (Fig. 6). The higher fluorine-to-chlorine ratio in these satellite plutons decreases their potential as a source of gold-bearing fluids (Yang and Lentz 2005).

Structural studies of the Anomaly A Zone indicate that its gold mineralization is contemporaneous with late-D_2 shears (Castonguay et al. 2003). Greisen veins overprinting auriferous veins in the AD Subzone are interpreted to be related to the Sn-bearing Pleasant Ridge Granite; this would restrict the timing of gold mineralization in the Anomaly A Zone to pre-Late Devonian (Watters et al. 2003). According to Watters et al. (2003), similarities in ore mineralogy and structural history between the Anomaly A and Main zones suggest that the two zones represent distal and proximal components, respectively, of a single, granite-related, gold-mineralizing system. Previous research at the Main Zone suggests this system is contemporaneous with emplacement of the Early Devonian Magaguadavic Granite (Thorne et al. 2002b; Thorne and Lentz 2003; Davis et al. 2004).

Stop Descriptions

Stop 5: Magaguadavic Granite, Saint George Batholith

From Fredericton, head west on Highway 8 for ~3 km and take the first exit after the first overpass. Turn right onto Highway 2 and then right again onto Highway 640. Head south on Highway 640 for ~32 km. Turn left at the T-junction with Highway 3 at Acton and drive toward Harvey. Follow Highway 3 through Harvey and proceed to Flume Ridge Road (~32 km) just past Brockway. Turn right on this road and follow it toward Pleasant Ridge for ~14 km and then turn left onto Highway 770. Follow this road for ~3.8 km and turn onto the logging road on the left at the bottom of the hill. Proceed along the main logging road for ~3.2 km. Walk east along the bush road for ~400 m, then head north on the trail for ~100 m to the brook.

Large, flat-lying outcroppings of the megacrystic Magaguadavic Granite can be seen here in the stream bed. On the weathered surface, the granite ranges from light grey to light pink; on the fresh surface, its colour varies widely, depending on the abundance of mafic minerals. The mafic content is typically 8% to 10% but locally ranges up to 23%, depending on the amount of wall-rock assimilation (McLeod 1990). The predominant mineral assemblage consists of K-feldspar, quartz, biotite, muscovite, and hornblende. Rapakivi textures can be seen where pinkish orange K-feldspar is mantled by white feldspar (albite).

Small aplitic dykes representing late-stage fractionates cut the coarser grained to megacrystic phases of the granite (Fig. 14). McLeod (1990) suggests that fluids evolving from the Magaguadavic Granite were enriched in metals, particularly gold, in part as a result of incorporating large volumes of sulphide-bearing sedimentary rocks from country rock of the St. Croix and Mascarene terranes.

Figure 14. Boulder of the Magaguadavic Granite, crosscut by a late-stage aplitic dyke (Stop 5). Figure 6 shows the location of Stop 5.

Stop 6: Trench 1 – West Subzone, Main Zone

From Stop 5, drive back along the logging road for ~400 m to the first logging road on the left. Follow this road for ~2 km to a cleared area just beyond the turn to the west. Walk along the trail at the end of the road for ~500 m to the far west end of the trench.

Trench 1 is situated in the West Subzone of the Main Zone. Both the western and eastern parts of the trench expose auriferous gold veins hosted by a gabbroic dyke representing a phase of the East Branch Brook Gabbro, and by sedimentary and felsic volcanic rocks of the Waweig Formation.

Western Part

In the western part of Trench 1, stratified rocks of the Waweig Formation occupy much of the lower side of the trench (Fig. 15). At the extreme west end, sheared felsic tuffaceous rocks exhibit a strongly penetrative foliation (D_3), displaying a well developed C-S fabric that indicates dextral movement along the shear zone (Fig. 16a). Geochemistry of samples from the unit resembles that of similar rocks throughout the Waweig Formation (Thorne et al. 2004a). A hydrothermal breccia crosscuts the felsic volcanic rocks and contains angular felsic volcanic fragments within an epidote-rich matrix (Fig. 16b).

A gabbroic dyke spans the upper side of the trench, north of the stratified rocks (Fig. 15). It is highly strained in places and is crosscut by numerous generations of randomly oriented, contorted, amphibole-rimmed prehnite veins. An auriferous quartz vein (Fig. 16c) up to 3 m

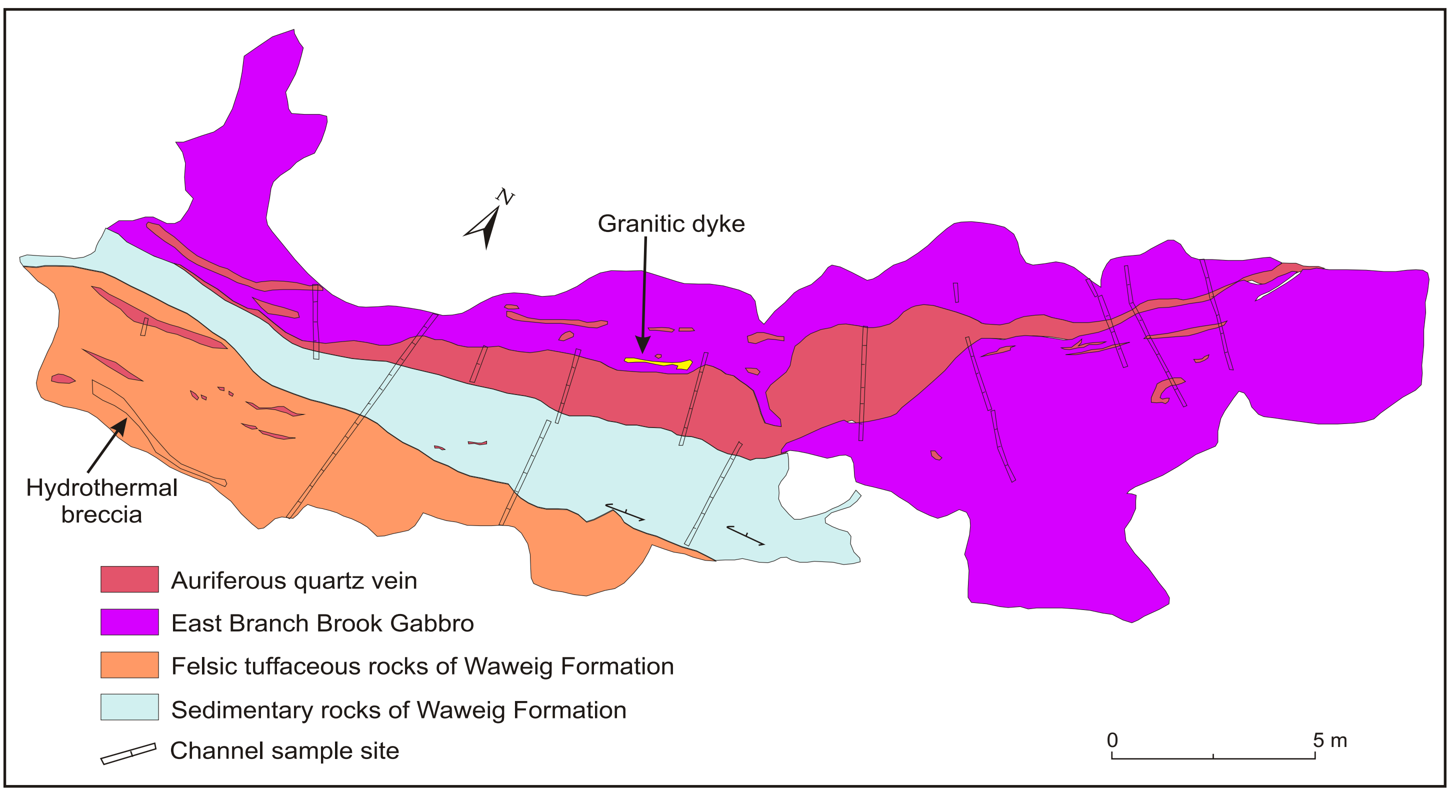


Figure 15. Plan view of Trench 1 (western part) in the West Subzone of the Main Zone, Clarence Stream deposit (Stop 6). Figure 11 shows the location of Stop 6.

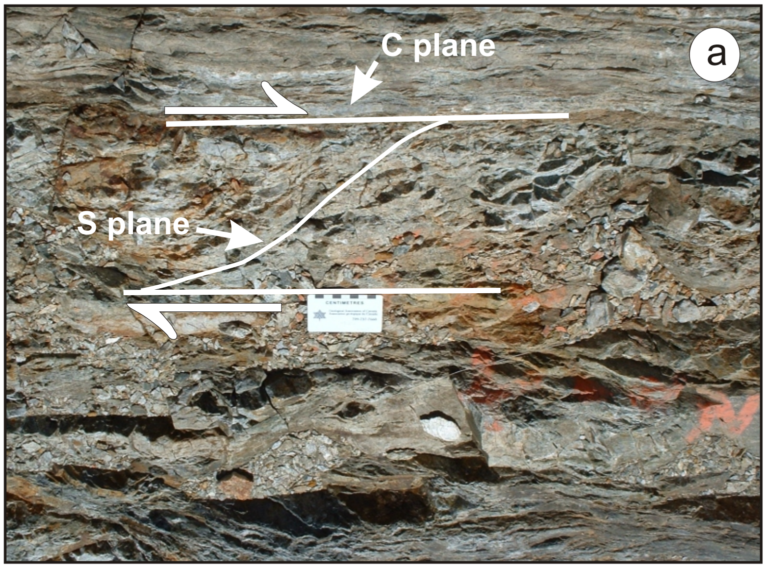


Figure 16. a) C-S fabric developed within deformed felsic volcanic rocks of the Waweig Formation. Exposure occurs in the western part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 15).

Figure 16. b) Hydrothermal breccia with an epidote-rich matrix and angular felsic volcanic fragments. Exposure occurs in the western part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 15).

Figure 16. c) Auriferous quartz vein in the western part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 15). The vein is about 3 m wide.

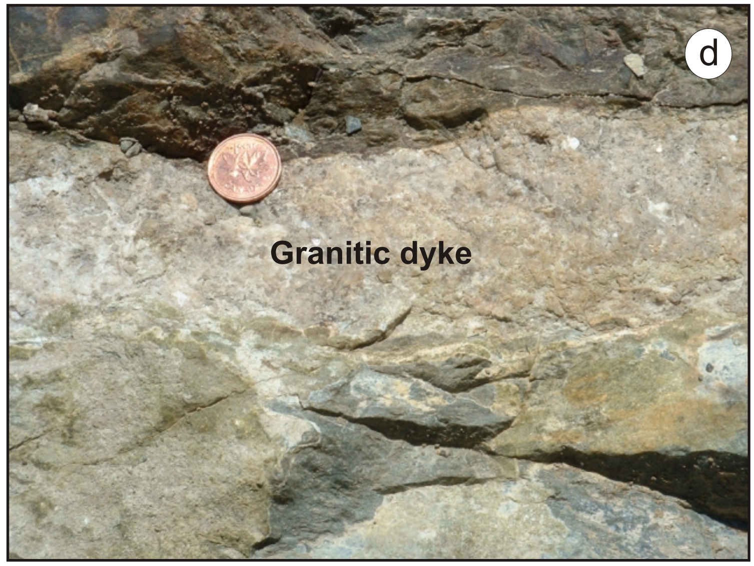


Figure 16. d) Granitic dyke in the western part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 15).

wide occurs along the contact between the gabbro and stratified rocks. The vein contains visible gold, sphalerite, arsenopyrite, berthierite/stibnite, and minor amounts of pyrite and chalcopyrite. Two 0.5 m channel samples from the vein yielded 68.1 g/t Au and 72.1 g/t Au.

A small, 10 cm wide granitic dyke occurs in the middle of this part of the trench, adjacent to the main quartz vein (Fig. 16d), and likely is an offshoot of the Magaguadavic Granite.

Eastern Part

Hornfelsed, cordierite-biotite-muscovite-bearing sedimentary rocks of the Waweig Formation occur in the upper section of the eastern part of Trench 1 (Fig. 17). They dip moderately northwest, and younging of graded bedding to the south indicates the beds are overturned. A large, mineralized quartz vein occupies the boundary between these sedimentary rocks and the gabbroic dyke that occupies most of the trench. The vein is cut by a post-mineralization, northwest-trending fault zone that has a sinistral displacement of about 4.5 m (Fig. 18a).

The gabbroic dyke appears in both a fresh (Gabbro 1) and an altered (Gabbro II) phase. An undulatory chilled margin between phases is visible at the junction between western and eastern parts of the trench (Fig. 18b, 18c). The gabbro is transected by a lighter coloured, fine-grained feature that is interpreted as being either a dyke or a mylonite zone; curiously, this feature locally appears to mark the boundary between the fresh and altered gabbroic bodies (Fig. 18b). The rusty, altered gabbro contains gold and abundant pyrrhotite in addition to Au-bearing quartz veins. A fairly fresh-looking, but older, phase of the gabbro cut by a quartz vein is exposed at the southern end of the trench. The vein looks white and barren, but its grab samples yielded up to 7 g/t Au.

A regional, northeast-trending structural fabric is variably developed throughout the lithological units. Within the sedimentary rocks, a steeply plunging downdip lineation is defined by the long axes of retrograded cordierite porphyroblasts (Fig. 18d), whereas in the altered gabbro, parallel alignment of amphibole defines the downdip lineation. Several generations of quartz veins cut across the local strata, generally parallel to the regional

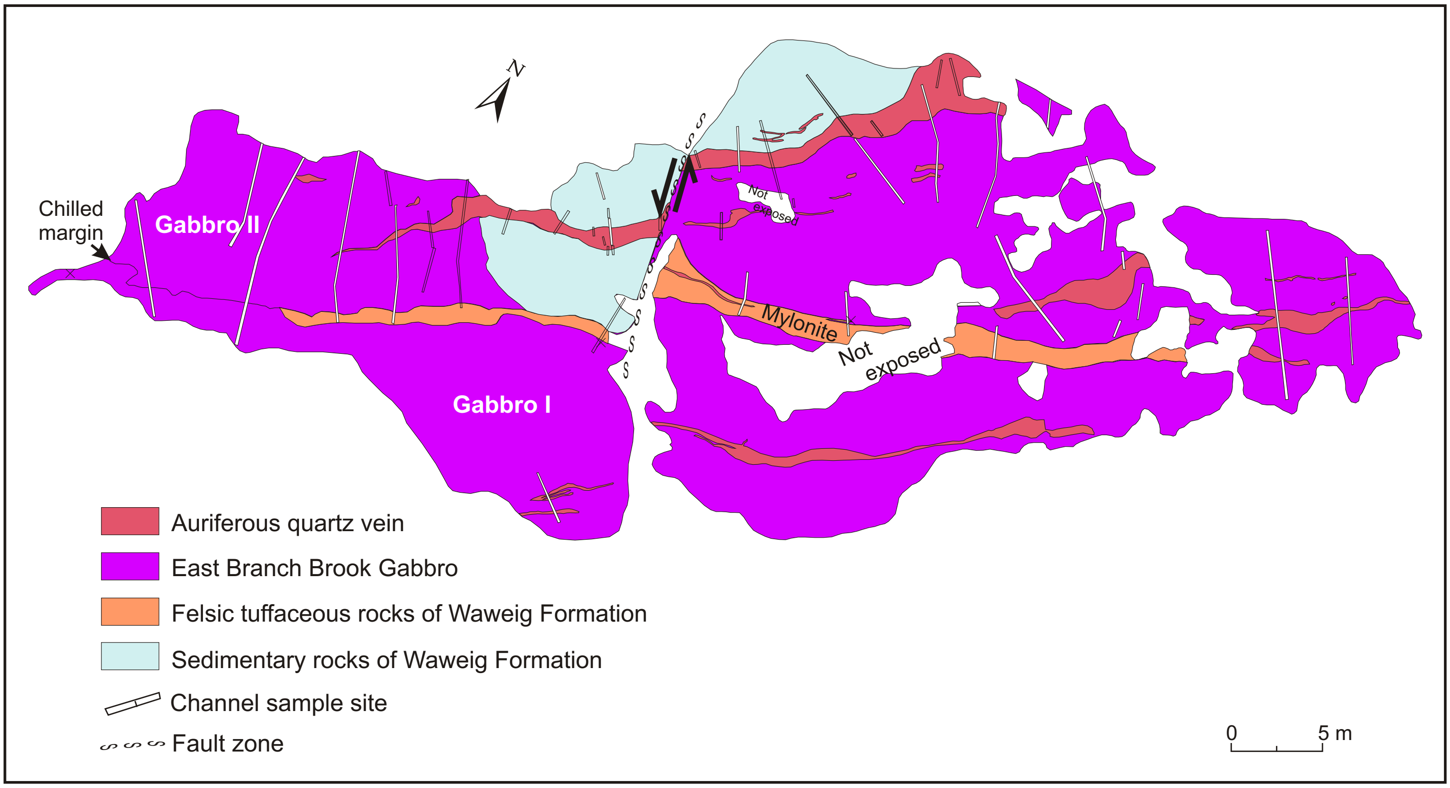


Figure 17. Plan view of Trench 1 (eastern part) in the West Subzone of the Main Zone, Clarence Stream deposit (Stop 6). Figure 11 shows the location of Stop 6.

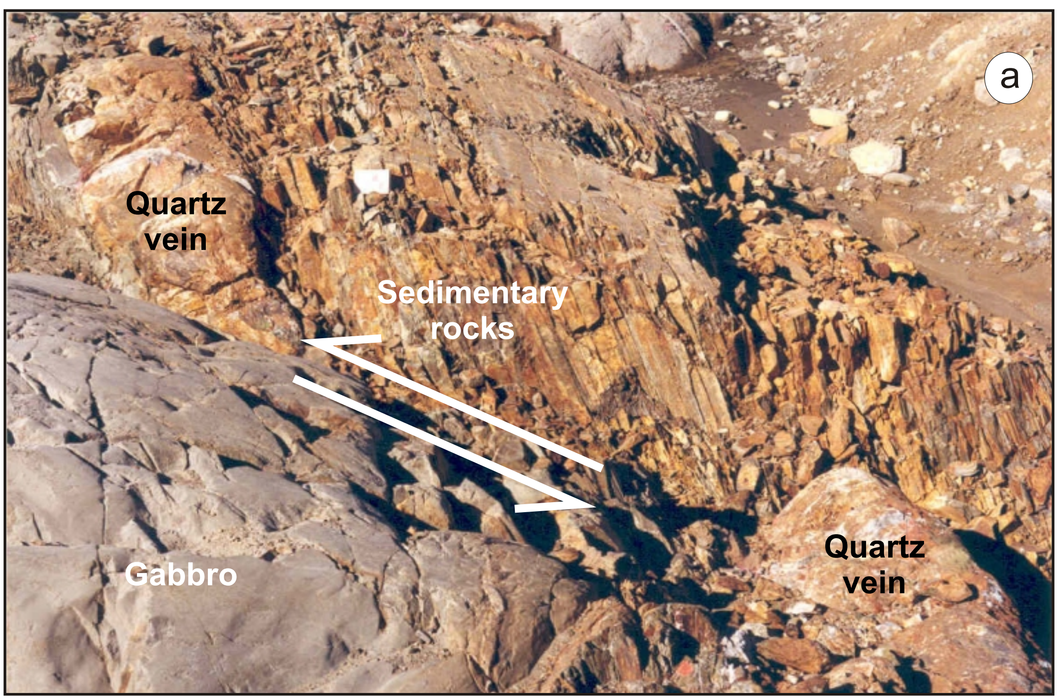
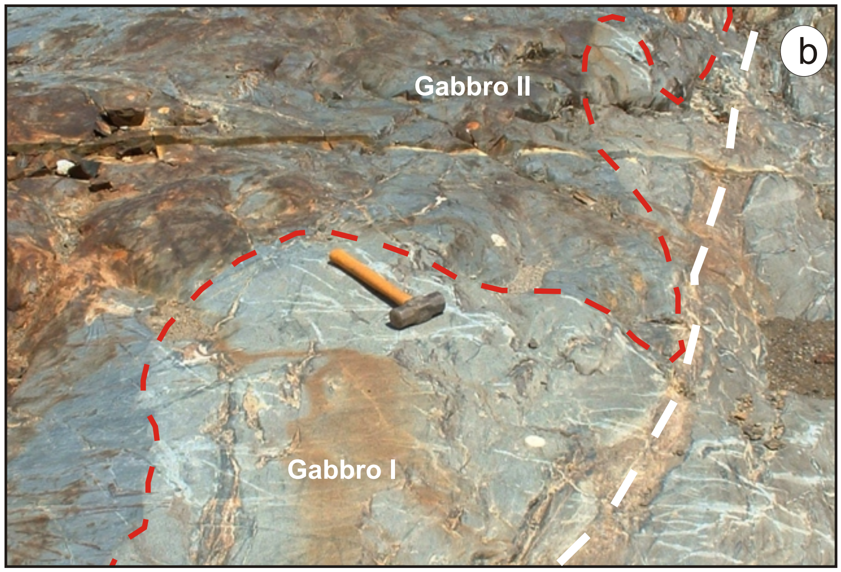


Figure 18. a) Sinistral offset along a northwest-trending, post-mineralization fault zone, looking west. Exposure occurs in the eastern part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 17).

Figure 18. b) Undulatory chilled margin between two phases of the East Branch Brook Gabbro, as indicated by red line. White line traces what has been interpreted as either a dyke or a mylonite zone. Exposure occurs in the eastern part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 17).



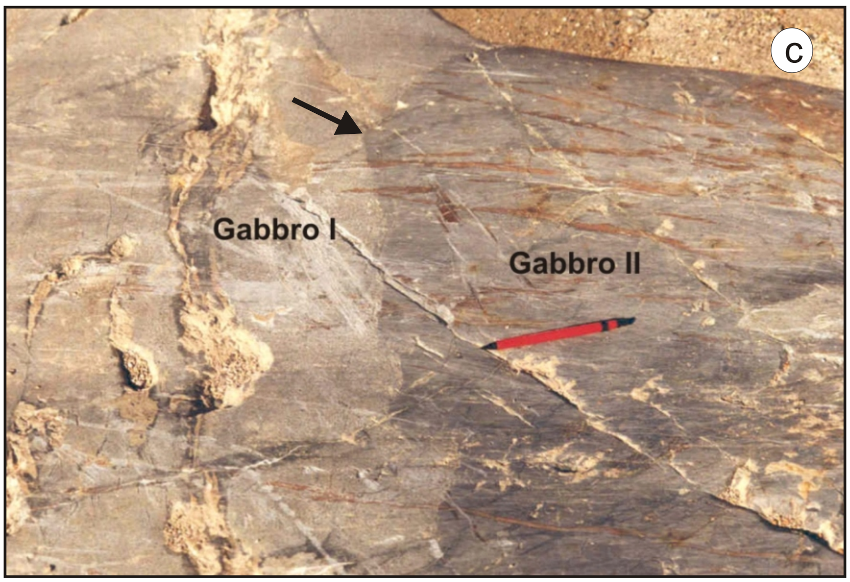


Figure 18. c) Black arrow indicates the chilled margin between two phases of the East Branch Brook Gabbro, looking west. Exposure occurs in the eastern part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 17).

Figure 18. d) Cordierite porphyroblasts exposed on the bedding plane in sedimentary rocks of the Waweig Formation. Exposure occurs in the eastern part of Trench 1, West Subzone of the Main Zone, Clarence Stream deposit (see Fig. 17).

structural fabric. The large quartz vein occupying the boundary between the sedimentary and gabbroic rocks consistently carries high-grade gold values along its strike length, reaching up to 23.7 g/t Au over 1 m. Other metallic minerals in the quartz vein include sphalerite, arsenopyrite, stibnite, pyrite, and pyrrhotite.

Stop 7: Trench 2 – Central Subzone, Main Zone

From Stop 6, head back along the logging road for ~600 m; the trench is on the right side of the road just beyond the turn to the north.

Rocks of the Central Subzone are exposed in Trench 2 (Fig. 19) and clearly demonstrate the relationship between sedimentary units of the Waweig Formation and gabbroic intrusions of the East Branch Brook Gabbro. In the southern part of the trench, sedimentary rocks are truncated by the gabbroic intrusion. The gabbro here displays a varied fabric development that reflects the heterogeneous deformation; strain intensity increases toward the south end of the trench. In the centre of the trench, the chilled margin between the

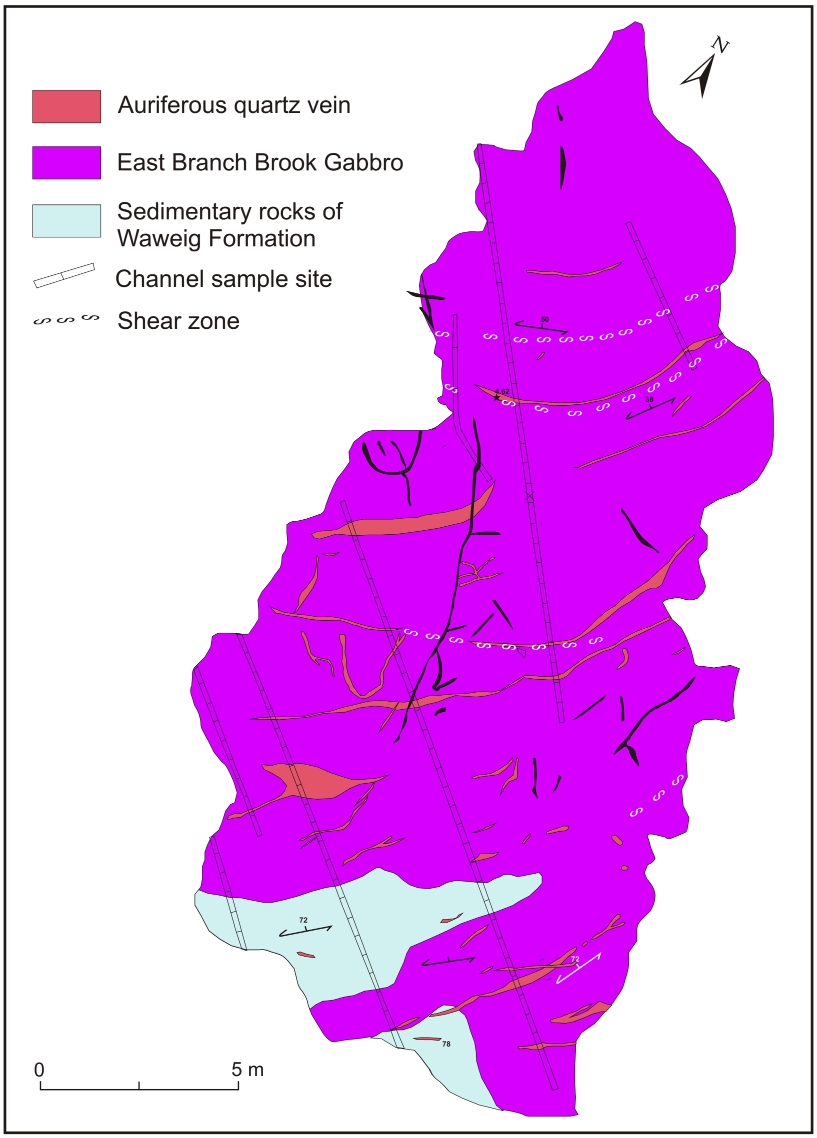


Figure 19. Plan view of Trench 2 in the Central Subzone of the Main Zone, Clarence Stream deposit (Stop 7). Figure 11 shows the location of Stop 7.

altered and unaltered gabbro is characterized by small, sinistral offsets (Fig. 19). Grab samples collected from a white quartz vein and altered gabbro at this stop yielded 4.6 g/t Au and 45.6 g/t Au, respectively.

Stop 8: Trench 7 – East Subzone, Main Zone

From Stop 7, proceed farther along the logging road until reaching the small pond on the right. Park in the cleared area and follow the trail through the woods to Trench 7, which is situated south-southwest of the pond.

Trench 7 is situated in the East Subzone of the Main Zone, exposing sheared, fissile sedimentary rocks of the Waweig Formation that host the gold-bearing veins, pods, and boudins (Fig. 20). A steep lineation is associated with the bedding-parallel fabric; subtle, dismembered fold hinges plunge moderately eastward. Abundant stibnite, kermesite, and arsenopyrite are found in association with gold here, constituting a typical mineral assemblage that defines the East Subzone. The northern part of Trench 7 contains a wide, prominent shear zone that features boudinaged quartz veins scattered throughout the fissile material. The shear zone can be traced along strike for at least 400 m and appears to

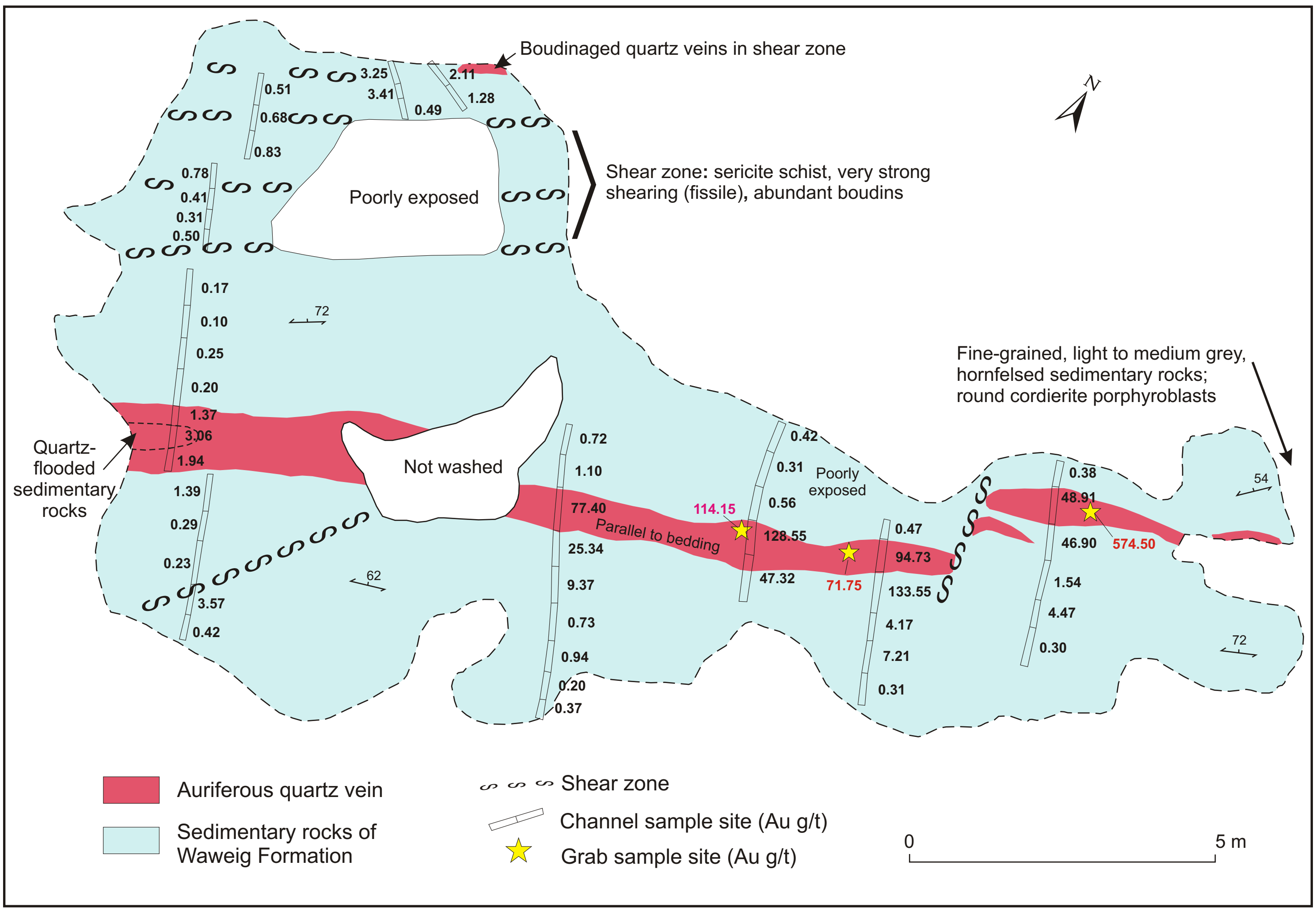


Figure 20. Plan view of Trench 7 in the East Subzone of the Main Zone, Clarence Stream deposit (Stop 8). Figure 12 shows the location of Stop 8.

mark the boundary between fine-grained sedimentary rocks in the trench and a coarse-grained crystal tuff exposed north of the trench. Three grab samples gathered along the strike length of the widest quartz vein assayed at 574.5 g/t Au, 71.75 g/t Au, and 114.15 g/t Au (Fig. 20). Muscovite from a sulphide-bearing quartz vein in this trench yielded an ^{40}Ar-^{39}Ar age of 389.3 ± 3.5 Ma that represents a minimum age for the mineralization event (Davis et al. 2004).

Stop 9: Trench 4 – East Subzone, Main Zone

From Stop 8, drive ~300 m farther down the road and follow the trail to Trench 4 on the right side of the road.

Trench 4 (Fig. 21) exposes thin- to medium-bedded, fine-grained sedimentary rocks of the Waweig Formation and medium- to coarse-grained gabbro of the East Branch Brook Gabbro, all of which have been intensely sheared. Coarser grained sedimentary units are extremely attenuated and feature rotated boudins or “fish,” which signify a high degree of deformation. Granitic dykelets in the sedimentary rocks appear to be transposed and boudinaged subparallel to the main foliation (Fig. 22a).

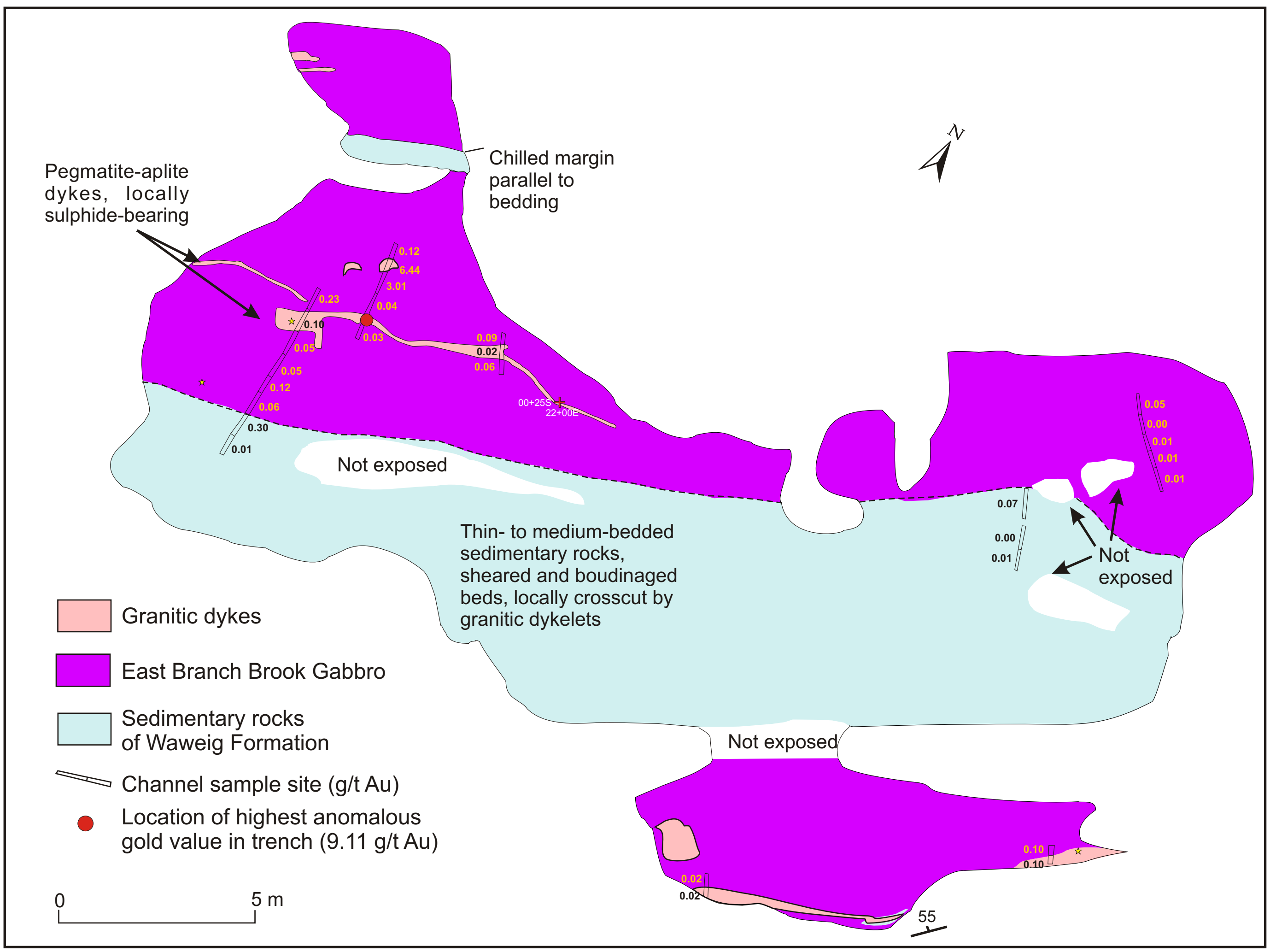


Figure 21. Plan view of Trench 4 in the East Subzone of the Main Zone, Clarence Stream deposit (Stop 9). Figure 12 shows the location of Stop 9.

Sedimentary and gabbroic rocks here are crosscut by larger, composite granitic dykes that range in texture from aplitic to granophyric to pegmatitic (Fig. 22b). Anomalous gold values in the dykes reach up to 9.11 g/t Au and offer strong evidence of a granite-related origin for gold mineralization in the Clarence Stream area. First, their geochemical signature indicates they likely are late fractionates of the granite (Thorne et al. 2002b). Second, dating of a granitic dyke east of Trench 4 gave a U-Pb monazite age of 395.5 ± 0.5 Ma (Davis et al. 2004), which is well within the range of ages yielded by the Magaguadavic Granite (Bevier 1990; McLeod 1990). Third, the pegmatite-aplite dykes in Trench 4 provided a U-Pb monazite age of 390 ± 8 Ma (Thorne et al. 2002b) and a maximum U-Pb zircon age of 400 ± 5.0 Ma (Davis et al. 2004). These auriferous dykes are therefore interpreted as being related to the nearby Magaguadavic Granite.

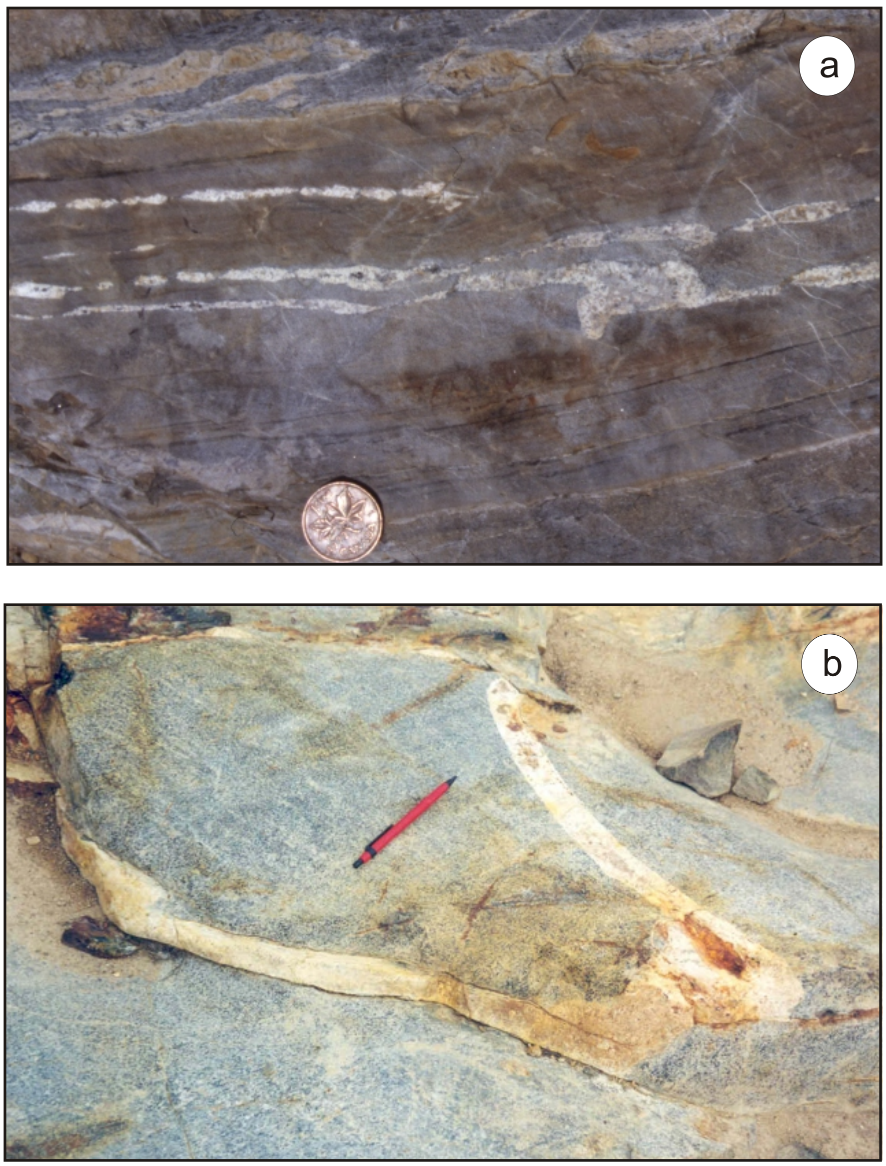


Figure 22. a) Granitic dykelets in sedimentary rocks of the Waweig Formation, transposed subparallel to foliation. b) Pegmatite-aplite dyke intruding gabbro. Exposures occur in Trench 4, East Subzone of the Main Zone, Clarence Stream deposit (see Fig. 21).

Stop 10: Murphy Subzone, Anomaly A Zone

From Stop 9, proceed to the T-junction in the road, turn left, and follow the logging road back to Highway 770. Turn right on Highway 770 and head up the hill. Turn left onto the first dirt road near the top of the hill and follow it through the field and past the power line. Stop at the trench on the right side of the road about 100 m beyond the power line.

Mineralization in the Anomaly A Zone is hosted by quartzose sandstone interbedded with siltstone and shale of the Kendall Mountain Formation. In the Murphy Subzone of the Anomaly A Zone (Fig. 23), rocks are sericitically altered and exhibit a composite S_1/S_2 cleavage, crosscut at a high angle by a steeply dipping, northwest-trending S_3 cleavage. The prominent style of mineralization at Stop 10 is stockwork veining that contains low- to moderate-grade gold concentrations.

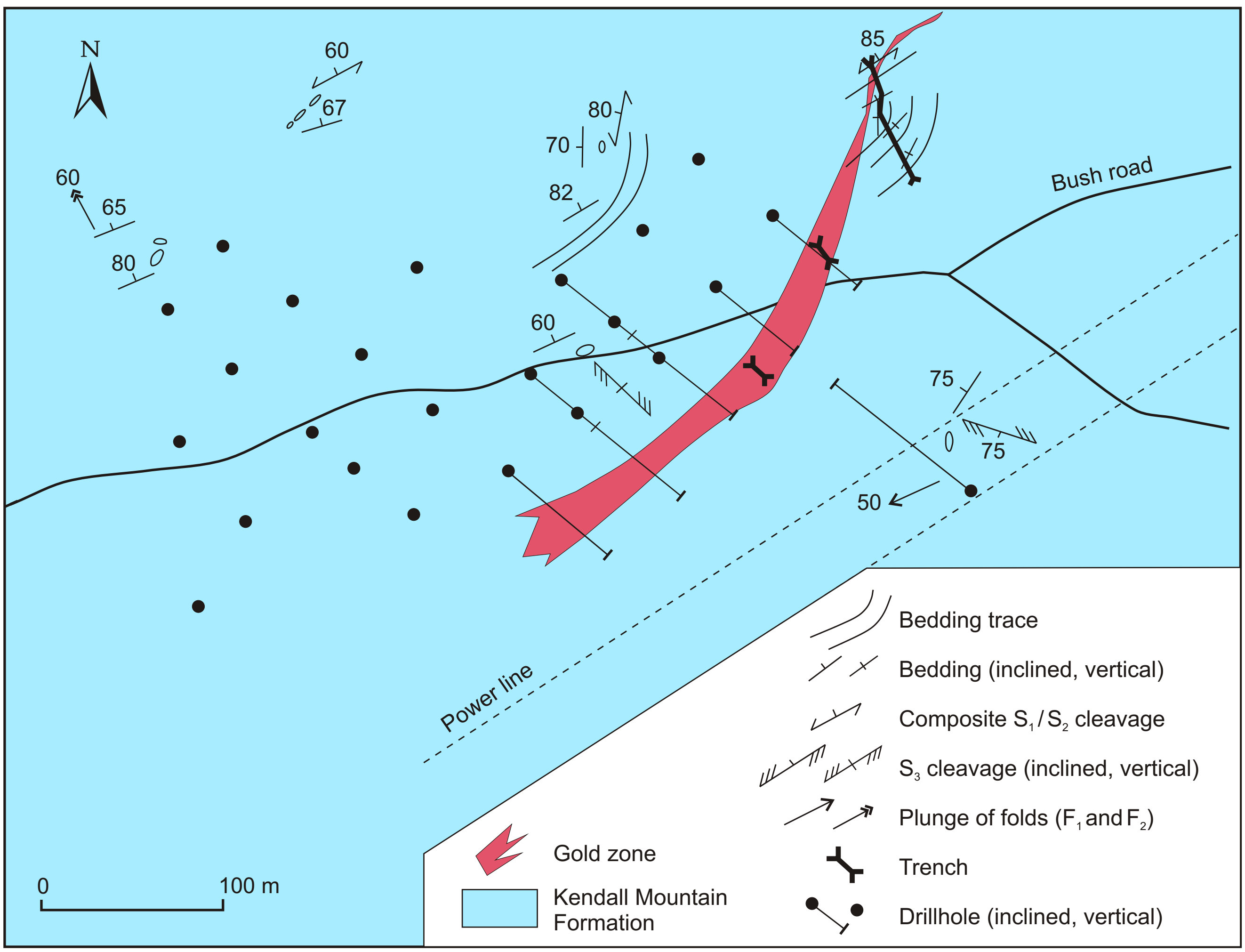


Figure 23. Plan view of the Murphy Subzone of the Anomaly A Zone, Clarence Stream deposit (Stop 10). Map shows structural features determined from the outcrop (modified after Watters et al. 2003). Drillhole intersections indicate that the gold zone plunges about 20° to the northwest. Figure 13 shows the location of the Murphy Subzone.

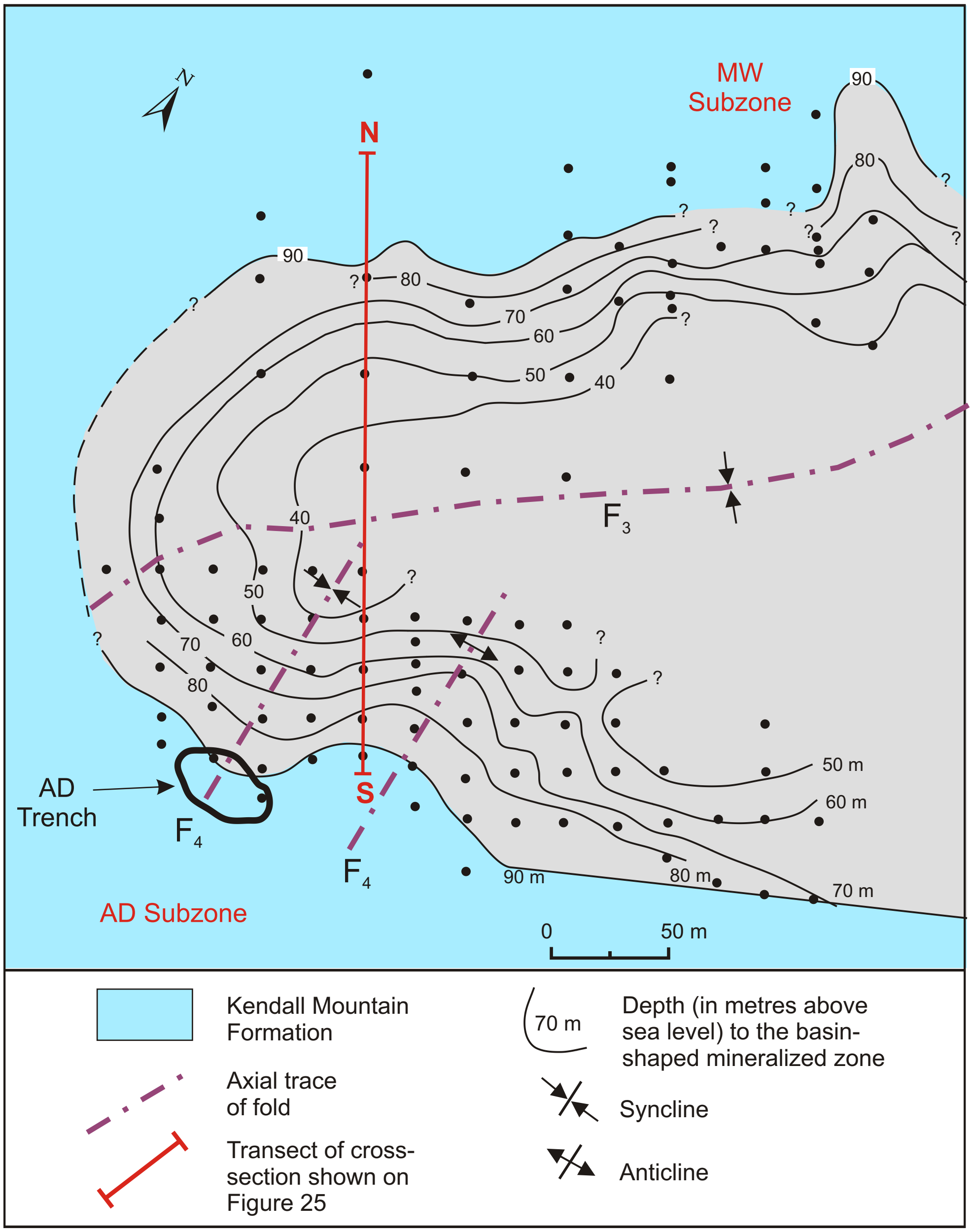


Figure 24. Plan view of the AD–MW subzones of the Anomaly A Zone, Clarence Stream deposit (modified from Lutes 2004). Figure 13 shows the location of the AD and MW subzones.

Stop 11: AD Subzone, Anomaly A Zone

From Stop 10, drive a short distance down the logging road to the cleared area. Park the vehicles and walk down the road to the brook. Cross the brook and follow the trail to the AD Trench of the AD Subzone.

A structural contour map from drillhole data shows that the AD and MW subzones of the Anomaly A Zone (Fig. 13) strike about 070º, dipping shallowly to the north and south, respectively (Fig. 24, 25). At Stop 11, the mineralized zone exposed in the AD Trench has

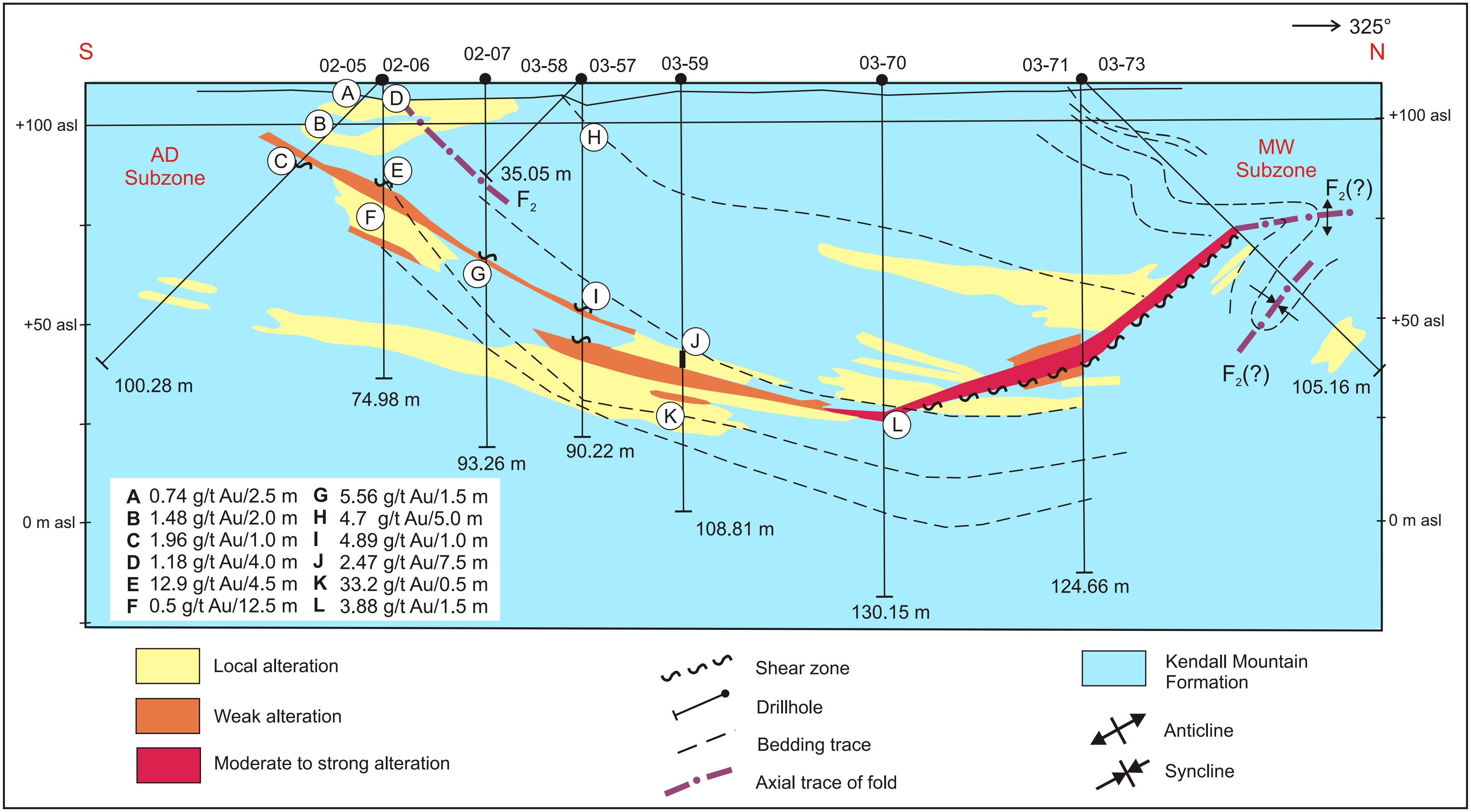


Figure 25. Drill section (500W) of the AD–MW subzones of the Anomaly A Zone, Clarence Stream deposit (modified from Lutes 2004). All drillhole numbers are preceded by AD. The location of this N–S cross-section is shown on Figure 24.

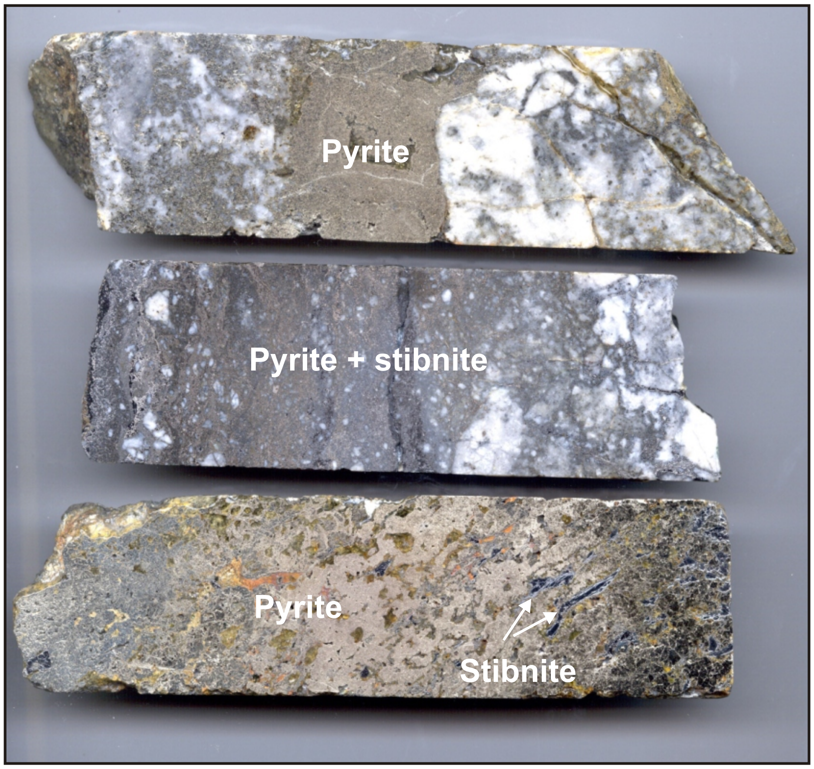


Figure 26. Mineralized intervals in drill core from the AD Subzone of the Anomaly A Zone, Clarence Stream deposit.

an overall trend of 105º and dips 25º N. Mineralization in the trench (Fig. 26) is hosted by a brittle-ductile fracture system that forms a stockwork within coarser clastic units of the Kendall Mountain Formation. This hosting relationship suggests that bedrock permeability and porosity may have been one of the controlling factors in gold mineralization, in conjunction with structural development.

The predominant lithologies in the trench are sandstone and argillaceous siltstone. These rocks exhibit a penetrative cleavage (S_2) that dips 50º to 60º N in the hanging wall of the mineralized zone and has substantially shallower dips in the footwall, as evidenced in drillholes AD-02 and AD-04. Bedding in the siltstone is transposed parallel to the cleavage. Tops are typically right-way-up through sections drilled under the trench, but sharp reversals in tops elsewhere suggest that isoclinal folding is associated with D_2 or earlier deformation.

Much of the AD Subzone is situated on the southern limb of a large, open F_3 fold in rocks of the Kendall Mountain Formation (Fig. 13). The exposed stockwork system here is closely associated with east-plunging, subhorizontal to shallow, asymmetric F_3 kink folds in the footwall. The F_3 folds have a long subhorizontal limb and a short steep limb with vergence to the south; the folds affect both bedding and cleavage. Open to tight, subhorizontal and asymmetric F_3 folds are also common in drill core from the mineralized-zone footwall, where they are associated with an irregularly developed S_3 crenulation cleavage that displays secondary mica growth. The dip of the mineralized zone shifts between steeper and shallower downdip and along strike, due to the presence of east-trending F_3 folds with subhorizontal hinges. The attitude of individual veins and zones of cataclasite may have been at least partly controlled by the position of shallow and steep limbs of the F_3 kink folds. Early stages of quartz veining are more strongly deformed and are preserved locally as cataclasite. Replacement-style, extensional quartz veins peripheral to the mineralized zone are developed at a high angle to S_2 cleavage/shearing, most commonly within wacke units, and typically have inherited the S_2 cleavage.

The major F_3 structures outlined in the Anomaly A Zone are refolded by north-trending F_4 folds (Fig. 13). In the AD Trench, locally developed, subvertical fracture cleavage (conjugate S_4) can be seen to post-date asymmetric F_3 kinks and has a relatively consistent trend of 75º to 78º. This fracture cleavage is developed primarily in the more competent quartz veins and stockwork and is locally infilled by sheeted quartz-stibnite veinlets. The veinlets are characteristic of the hanging-wall-style mineralization at the east end of the trench; there, the style typically consists of coarse stibnite in vuggy, undeformed, sheeted quartz veins, and veinlets at varied attitudes with only local associated alteration.

Alteration of the host rocks appears as pervasively weak to strong argillic to sericitic and arsenopyrite-pyrrhotite replacement. Mineralization is composed primarily of pyrrhotite and pyrite with lesser arsenopyrite and stibnite within quartz veins and veinlets (Fig. 26). Stibnite appears late in the paragenesis and occurs as undeformed, semi-massive to massive veins and veinlets. Also present are berthierite ($FeSb_2S_4$) and gudmundite (FeSbS) in addition to trace amounts of jamesonite ($Pb_4FeSb_6S_{14}$), ullmannite (NiSbS), tetrahedrite ($Cu_{12}SbS_{13}$), cobaltite (CoAsS), sphalerite, chalcopyrite, native antimony, nisbite ($NiSb_2$), native gold, and aurostibite ($AuSb_2$).

Hole AD02-1 was drilled under the west end of the AD Trench. It returned 2.34 g/t Au over 6.5 m and included a higher grade interval of 12.7 g/t Au over 0.5 m. Hole AD02-3, drilled under the east end of the trench, returned intervals of 11.60 g/t Au over 2.5 m and 1.20 g/t Au over 7.5 m. High-grade gold intercepts discovered when drilling east of the trench are closely associated with late, stibnite-rich sulphide veinlets. *Note: This stop description was modified from Lutes et al. (2003).*

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