GEOLOGICAL ASSOCIATION OF CANADA
NEWFOUNDLAND SECTION
FIELD TRIP

EXAMPLES OF NEOPROTEROZOIC EPITHERMAL AND INTRUSION-RELATED GOLD MINERALIZATION IN THE AVALON ZONE

DAYS 1 and 2 of GOLD METALLOGENY IN NEWFOUNDLAND GAC-MAC 2005 FIELD TRIP

Sean J. O'Brien[1], Barry A. Sparkes[2], Gregory W. Sparkes[3], Benoît Dubé[4], Greg Dunning[3]

[1] Geological Survey of Newfoundland and Labrador, [2] Rubicon Minerals Corporation,
[3] Dept. of Earth Sciences, Memorial University of Newfoundland, [4]Geological Survey of Canada - Quebec Geoscience Centre

DAY 1: Style, setting and timing of epithermal-style hydrothermal systems in Late Neoproterozoic Avalonian rocks in the Manuels region, eastern Avalon Peninsula

DAY 2: Style and setting of intrusion-related gold at the Lodestar prospect, northern Burin Peninsula (and other sites of interest in the west-central Avalon Zone).

A guidebook to accompany and augment the field trip guide entitled
"Gold Metallogeny in The Newfoundland Appalachians"
by A. Kerr, R. J. Wardle, S. J. O'Brien, D. W. Evans and G. C. Squires

SAFETY INFORMATION

General Information

The Geological Association of Canada (GAC) recognizes that its field trips may involve hazards to the leaders and participants. It is the policy of the Geological Association of Canada to provide for the safety of participants during field trips, and to take every precaution, reasonable in the circumstances, to ensure that field trips are run with due regard for the safety of leaders and participants. GAC recommends steel-toed safety boots when working around road cuts, cliffs, or other locations where there is a potential hazard from falling objects. GAC will not supply safety boots to participants. Some field trip stops require sturdy hiking boots for safety. Field trip leaders are responsible for identifying any such stops, making participants aware well in advance that such footwear is required for the stop, and ensuring that participants do not go into areas for which their footwear is inadequate for safety. Field trip leaders should notify participants if some stops will require waterproof footwear.

Field trip participants are responsible for acting in a manner that is safe for themselves and their co-participants. This responsibility includes using personal protective equipment (PPE) when necessary (when recommended by the field trip leader or upon personal identification of a hazard requiring PPE use). It also includes informing the field trip leaders of any matters of which they have knowledge that may affect their health and safety or that of co-participants.

Specific Hazards

Most of the stops are reached by paved or gravel road from which they are easily accessible by foot, by either well-defined trails or short scrambles. Care should always be taken when visiting any site, especially those adjacent to the coast or in roadcuts, where the hazard of falling debris from the slopes above is a real one. In such situations, we advise participants not to put themselves in jeopardy by attempting to ascend such slopes, and to maintain a safe distance. In coastal settings, participants may be vulnerable to freak waves, and should maintain a safe distance from the high water line. Weather is unpredictable and participants should be prepared for a wide range of temperatures and conditions. Always take suitable clothing. A rain suit, sweater, sturdy footwear are essential at almost any time of the year. Do not walk straight down steep slopes if others are also on the slope below. Instead, proceed down slopes at an angle. Several stops are adjacent to highways, and participants must take great care in crossing them. Groups crossing together are particularly vulnerable, and each individual must take responsibility for their own safety. Some stops are at the top of steep cliffs or slopes. Participants should stay well back from the cliff edge at all times. Overhangs are common on unconsolidated cliffs, and often are not visible from above. We strongly recommend sturdy footwear that provides adequate protection and ankle support.

Safety Information in the Guidebook

This guidebook contains the stop descriptions and outcrop information for the field trip. In addition to the general precautions and hazards noted above, the introductions for specific localities make note of specific safety concerns such as traffic, water, cliffs or loose ground. Field trip participants should read these cautions carefully and take appropriate precautions for their own safety and the safety of others.

REGIONAL TECTONIC AND LOCAL GEOLOGICAL SETTING OF GOLD: DAY 1 and DAY 2

Welcome to the Avalon!

Day 1 and the first stop of Day 2 provide you with a brief opportunity to examine part of the Neoproterozoic Avalonian Belt of the Newfoundland Appalachians, an expansive, metallogenically important yet largely under-explored volcano-plutonic terrane that hosts some of the largest metamorphosed, precious-metal-bearing epithermal systems in Canada.

Avalonian-cycle Neoproterozoic epithermal and intrusion-related gold systems:

The formation and preservation of precious-metal bearing epithermal and intrusion-related systems are integral aspects of the Late Neoproterozoic tectonic history of the volcano-plutonic arc complexes that characterize the Avalonian and related accreted peri-Gondwanan terranes of the eastern Appalachians (see review papers in Nance and Thompson, 1996). These hydrothermal systems formed in an extensive late Neoproterozoic orogenic system, vestiges of which have been preserved within the younger Appalachian–Caledonian and Variscan orogens throughout the North Atlantic borderlands. Precisely dated Neoproterozoic high-sulphidation-, low-sulphidation- and intrusion-related gold systems are linked to Avalonian-cycle magmatic pulses that pre-date much of the Appalachian Wilson cycle of opening and closure of the Paleozoic Proto-Atlantic (Iapetus) Ocean (see O'Brien *et al.*, 1983). These gold systems formed in a once-contiguous, Pan-African-cycle orogenic belt, composed of complex assemblages of 760 to 540 Ma calc-alkaline to alkaline arcs and intervening marine and terrestrial siliciclastic sedimentary basins. Accretion of the mineralized arcs to the inboard Paleozoic Iapetus-cycle elements of the Appalachians occurred primarily in the Silurian and Devonian, during closure of the Cambro-Ordovician Iapetus Ocean (see Williams, 1979 and reviews in Williams, 1995).

Gold in the Neoproterozoic high-sulphidation systems occurs with copper in vuggy silica and in breccias and/or network fracture systems, within zones of polyphase silicic replacement, enveloped by regionally developed zones of quartz–pyrophyllite–andalusite–alunite-bearing metamorphosed advanced argillic alteration (Dube *et al.*, 1998; O'Brien *et al.*, 1999a. In other instances, regionally developed (and apparently barren) pyrophyllite–diaspore-bearing advanced argillic alteration zones, related to either weakly developed or deeply eroded high-sulphidation systems, are juxtaposed with younger Neoproterozoic low-sulphidation colloform–crustiform banded, silica–adularia vein and breccia systems that contain significant gold grades. Several of the epithermal belts are spatially associated with breccia-hosted Cu–Au (e.g. Butlers Pond) and Au–Cu–Zn mineralization; however, most of this intrusion-related gold mineralization formed during demonstrably earlier magmatic events (Sparkes *et al.*, 2002; O'Brien *et al.*, 2000, 2005).

Large tracts of the mineralized Avalonian belt became submerged by the end of the Proterozoic and remained so through the early Paleozoic, until the late Silurian–Devonian Appalachian-cycle collision. Where the Avalonian rocks are far removed from the Appalachian hinterland, Neoproterozoic low-sulphidation mineralization is exceptionally well preserved. Deeper and more extensively tectonized high-sulphidation systems are preserved proximal to and within the Appalachian mobile belt on the Burin Peninsula and Hermitage Flexure regions of southern Newfoundland, respectively (e.g., Dubé *et al.*, 1998, O'Brien *et al.*, 1999a.) Early tilting of the mineralized successions and subsequent rifting, collapse and marine incursions, during Late Neoproterozoic through Early Paleozoic break-up and dispersal of the Avalonian belt, helped significantly reduce the rate of erosion, allowing their preservation through time(e.g., Dubé *et al.*, 1998, O'Brien *et al.*, 2005). The recognition of the geochemical, mineralogical and textural signatures of modern high- and low-sulphidation epithermal systems in these deformed rocks allows the distinction from mainly younger, shear-zone related (e.g., orogenic) gold systems formed at deeper crustal levels, within the Paleozoic orogenic hinterland.

(Note: General reviews of the geology of the Avalonian rocks can be found in O'Brien et al., 1990, 1996 and Williams et al., 1995; further details of their precious metal systems are given in O'Brien et al.,1998, 1999a,b, 2002, 2003, 2004; Dubé et al., 1995, 2001; Mills et al., 1997; Sparkes et al., 2002, 2005; Hinchey et al, 2001; O'Driscoll et al., 2001).

Newfoundland's Avalonian rocks - a thumbnail sketch:

The Newfoundland Avalonian belt embodies a complex assortment of late Neoproterozoic volcanic, plutonic, and marine to terrestrial siliciclastic sedimentary rocks that were amalgamated and dispersed over a period of some 220 Ma, prior to the deposition of an early Paleozoic, shale-rich platformal cover. The Neoproterozoic rocks formed during at least six major magmatic pulses; in each instance, these were associated with the formation of precious and/or base metal mineral deposits (**Table 1.1**). Rocks formed at *ca.* 760 Ma, ca. 730 Ma, and between 685 Ma and 670 Ma, represent vestiges of rifting and compressional arc-related magmatism, likely linked to the generation and obduction of ophiolite early in the history of the Pan-African orogenic belt. Magmatism, volcanism and sedimentation between 635 Ma and 600 Ma records the development of calc-alkaline magmatic arcs and marine sedimentary basins on ensialic to transitional crust, locally upon and/or adjacent to 680 Ma and 730 Ma basement (O'Brien *et al.*, 1995, 2001). Stratigraphically complex 590 Ma to 550 Ma subaerial and submarine volcanic and siliciclastic sedimentary successions, formed in both compressional and subsequently extensional environments; this period represent a major epithermal gold mineralizing event in the Avalonian. The very latest Neoproterozoic volcanism in the western Avalonian belt is peralkaline, terrestrial, and rift-related, and hosts newly discovered examples of low- and possibly intermediate-sulphidation style mineralization.

Various parts of the Neoproterozoic succession had been inhomogeneously deformed, weakly metamorphosed and uplifted prior to deposition of a Cambro-Ordovician platformal sedimentary cover. The latter includes a lower Cambrian basal transgressive quartz arenite–siltstone sequence in the western Avalon; elsewhere shales and rare limestones characterize the Cambrian platform; restricted volcanism in the middle Cambrian is characterized by rift-style alkaline basalts (Greenough and Papezik, 1985). By the Arenig, shale deposition gave way to deposition of quartz arenites and oolitic ironstones, including the world-class Wabana iron ores on Bell Island. (Fog permitting, Bell Island is visible enroute Stop1.1.)

Latest Silurian-early Devonian terrestrial sedimentary and bimodal volcanic successions were deposited on deformed Neoproterozoic and Cambrian rocks. Tectonism and ensuing volcano-sedimentary basin development was coeval with the emplacement of large granitic plutons along the western margin of the Avalonian Belt. This mid-Paleozoic orogenesis is linked to motion along the transpressive boundary at the northwestern margin of the Avalonian Belt and Siluro-Devonian tectonism recorded in inboard Appalachian terranes (Holdsworth, 1994; Dunning *et al.*, 1988; O'Brien *et al.*, 1993).

TABLE 1.1 NEOPROTEROZOIC AVALONIAN TECTONIC AND MINERALIZING EVENTS: NEWFOUNDLAND APPALACHIANS

Age	*Characteristic geological events*	*Mineralization*
540 Ma **570-560 Ma**	Marine to deltaic + alluvial sed'm; shift to alkaline-peralkaline volcanism (bimodal)	**Low-sulphidation Au-Ag** Cu-Co-Ag (SSC) IOCG style?
590-570 Ma	C/a felsic volcanism, plutonism (+ hypabyssal intrusions)	**Low-sulphidation Au-Ag** **High-sulphidation Cu-Au** **Au-bearing VMS**
600 Ma	Mafic plutonism coeval w back/arc? marine sedimentation	**Intrusion-related Au-Cu-As-Zn**
620 Ma	C/a plutonism, volcanism, marine sedimentation	Porphyry-style Cu-Au
640 Ma	Monzonitic magmatism	Intrusion-related Cu-Au
730 Ma	Felsic volcanism	??
680	Calc-alkaline plutonism, felsic marine volcanism, (post-mineral ductile deformation; migmatization)	Zn-rich VMS
760	Oceanic volcanism, mafic-ultramafic magmatism, carbonate sedimentation (post-mineral ductile deformation)	Shear-zone hosted Au

DAY 1: Setting and timing of Neoproterozoic epithermal systems in the eastern Avalon Peninsula:

Well-preserved examples of Late Neoproterozoic, high- and low-sulphidation epithermal systems occur within a regional (15 x 1 km) belt of hydrothermal alteration along the eastern margin of a broad, north-south elongated, south-plunging Neoproterozoic volcano-plutonic uplift, known as the Holyrood Horst (**Figure 1.1**). This uplift is composed of disparate volcanic successions, the formation of which was punctuated by both marine and terrestrial sedimentation, and by the emplacement, uplift and erosion of discrete intrusive suites of differing age and composition. The Neoproterozoic rocks of the Holyrood Horst are described by O'Brien *et al.* (2001) in a framework of seven lithostratigraphically and chronostratigraphically discrete units that formed over a period of 160 million years.

This volcano-plutonic core is flanked by a younger, shoaling-upward succession of 570 Ma and later marine, deltaic and fluviatile siliciclastic rocks (Conception, St. John's and Signal Hill groups, respectively; e.g., King, 1988), concentrically disposed around the older succession. The oldest of the marine sedimentary rocks are locally intruded by felsic porphyry and dioritic to gabbroic plutons, spatially associated with the horst-bounding Topsail Fault. Mineralized and deformed late Neoproterozoic volcanic, plutonic and sedimentary rocks are overlain unconformably by a fossiliferous, shale-rich, Cambrian to earliest Ordovician cover sequence, exposed around Conception Bay.

Alteration minerals (pyrophyllite) associated with regional-scale, high-sulphidation-style advanced argillic alteration along the eastern side of the Holyrood Horst were discovered in the late 1800s and have been mined intermittently since that time (Buddington, 1916; Vhay, 1937; Papezik and Keats, 1976; Papezik and Hume, 1984). It was much later that significant gold mineralization was first documented in the same area (Saunders, 1986). Subsequent studies have shown that gold occurs, with or without silver, mainly in hydrothermal veins and breccias of low-sulphidation epithermal origin, in several areas along the length of this belt (see reviews in O'Brien *et al.*, 1998, 2001a). The region surrounding this low-sulphidation vein- and breccia-hosted gold mineralization is currently the focus of exploration by Rubicon Minerals Corporation.

Both pyrophyllite–diaspore-bearing advanced argillic alteration and precious-metal-bearing, low-sulphidation veining occurs mainly in the composite, mainly felsic Manuels Volcanic Suite (O'Brien *et al.*, 2001). The latter is overlain unconformably by siliciclastic sedimentary and associated mafic volcanic rocks of the ca 580 Ma (and later) Wych Hazel Pond Complex. The Manuels Volcanic Suite and the Wych Hazel Pond Complex either overlie or are faulted against the older 625 to 615 Ma White Hills Intrusive Suite (O'Brien *et al.*, 2001; **Figure 1.2**). The latter intrusive rocks are affected by extensive silica–pyrite–sericite alteration near the high- and low-sulphidation systems, but their emplacement is not directly related to the development of either of the younger systems.

The age of the rhyolite and ash-flow tuff host to the pyrophyllite–diaspore alteration (and maximum age of the high-sulphidation system) is precisely defined at 584± 1 Ma (Sparkes *et al.*, 2005). The sedimentary rocks of the overlying Wych Hazel Pond Complex contain detritus eroded from the high-sulphidation alteration. The base of the complex is drawn at a silica–pyrite-altered conglomerate. The sediments contain 582± 1.5 Ma pumiceous tuff beds near the base of the sequence. Together, these data constrain the formation, uplift and erosion of the high-sulphidation-style advanced argillic alteration to a period from 585 to 580.5 Ma (Sparkes *et al.*, 2005).

The maximum age limit for gold-bearing colloform-crustiform chalcedonic silica+adularia±calcite veins

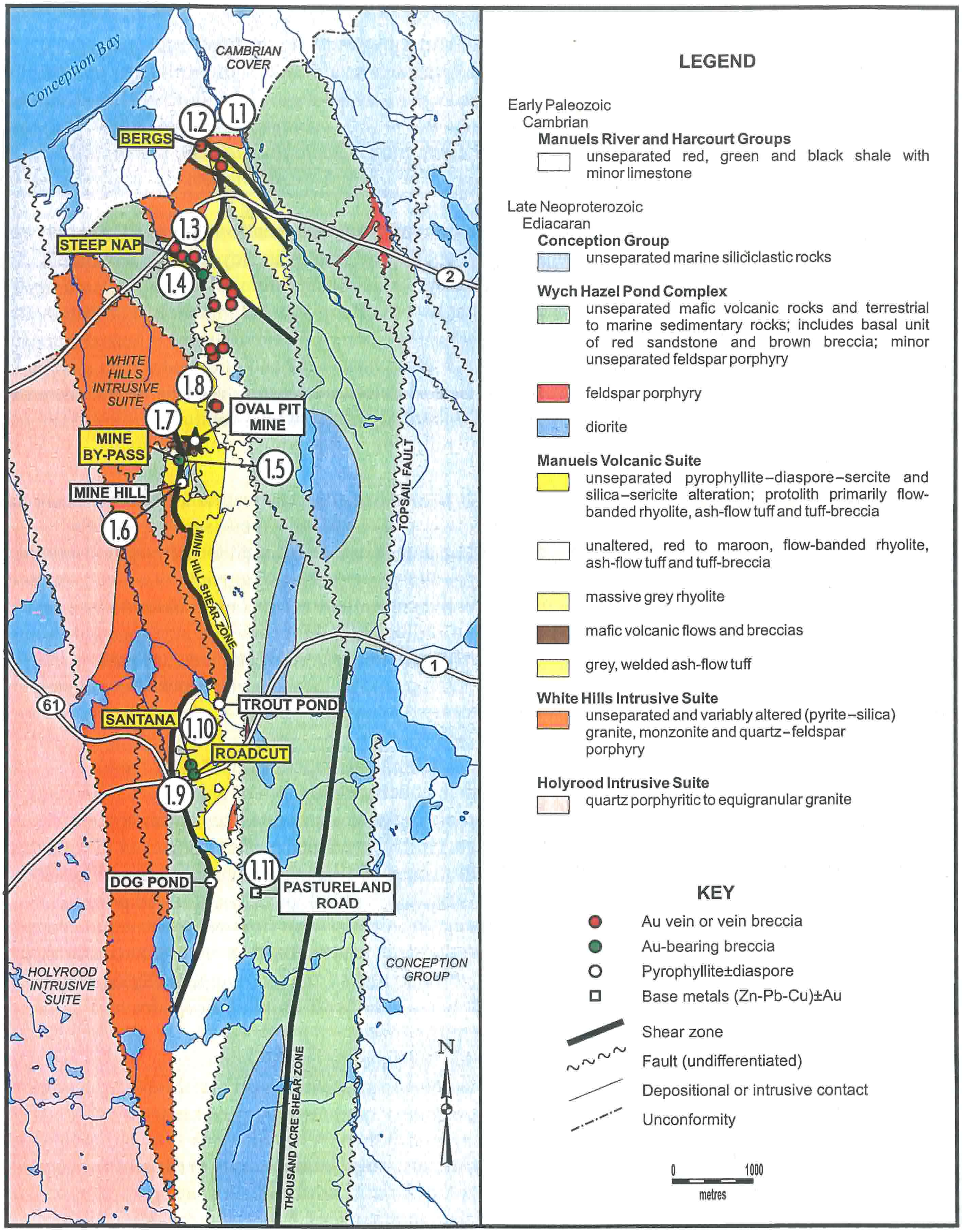

Figure 1.2 Day 1. *Regional geology and stop locations (in white circles).*

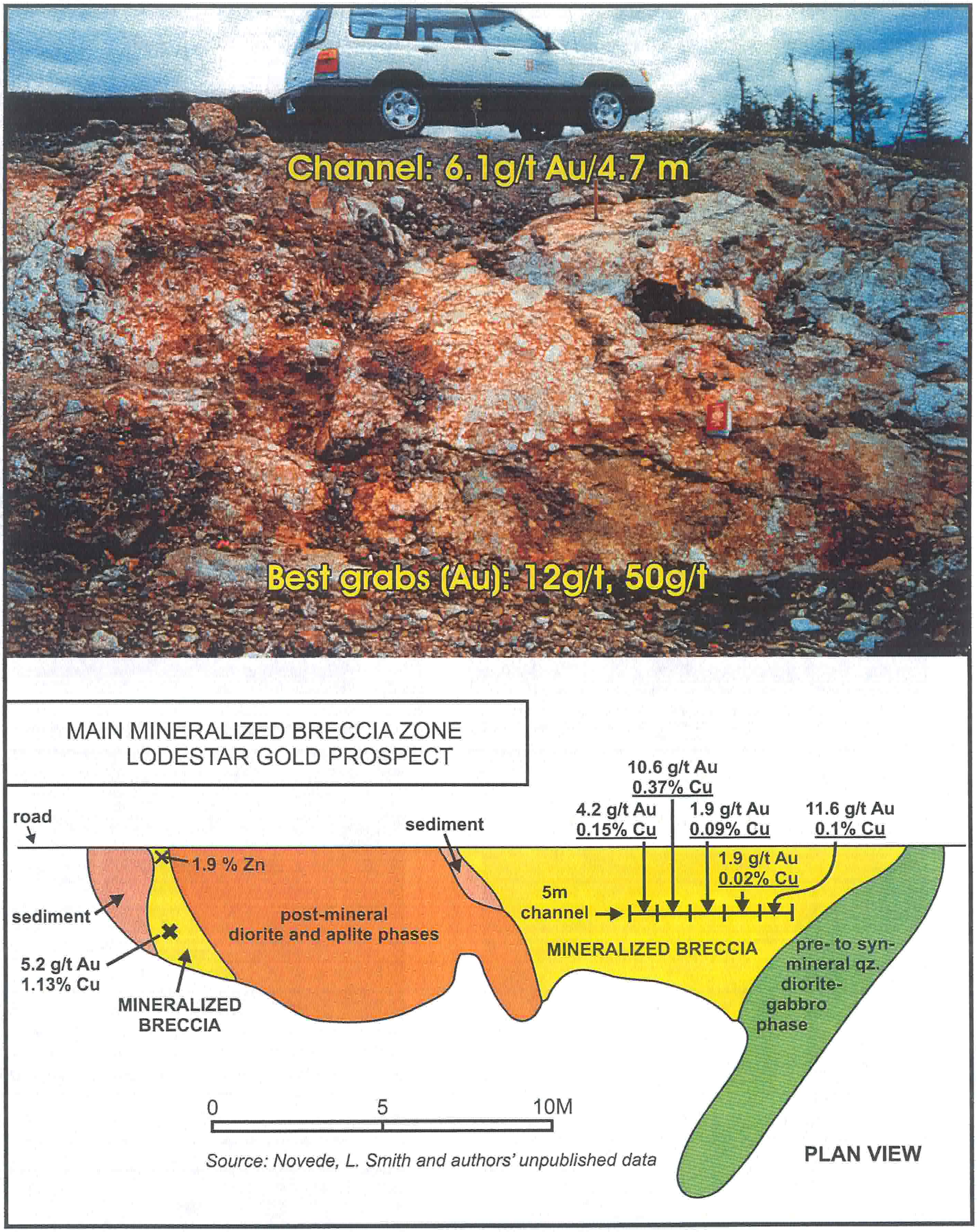

Figure 2.2. *Lodestar Prospect, near Goobies: selected chip samples (from O'Brien et al., 2000).*

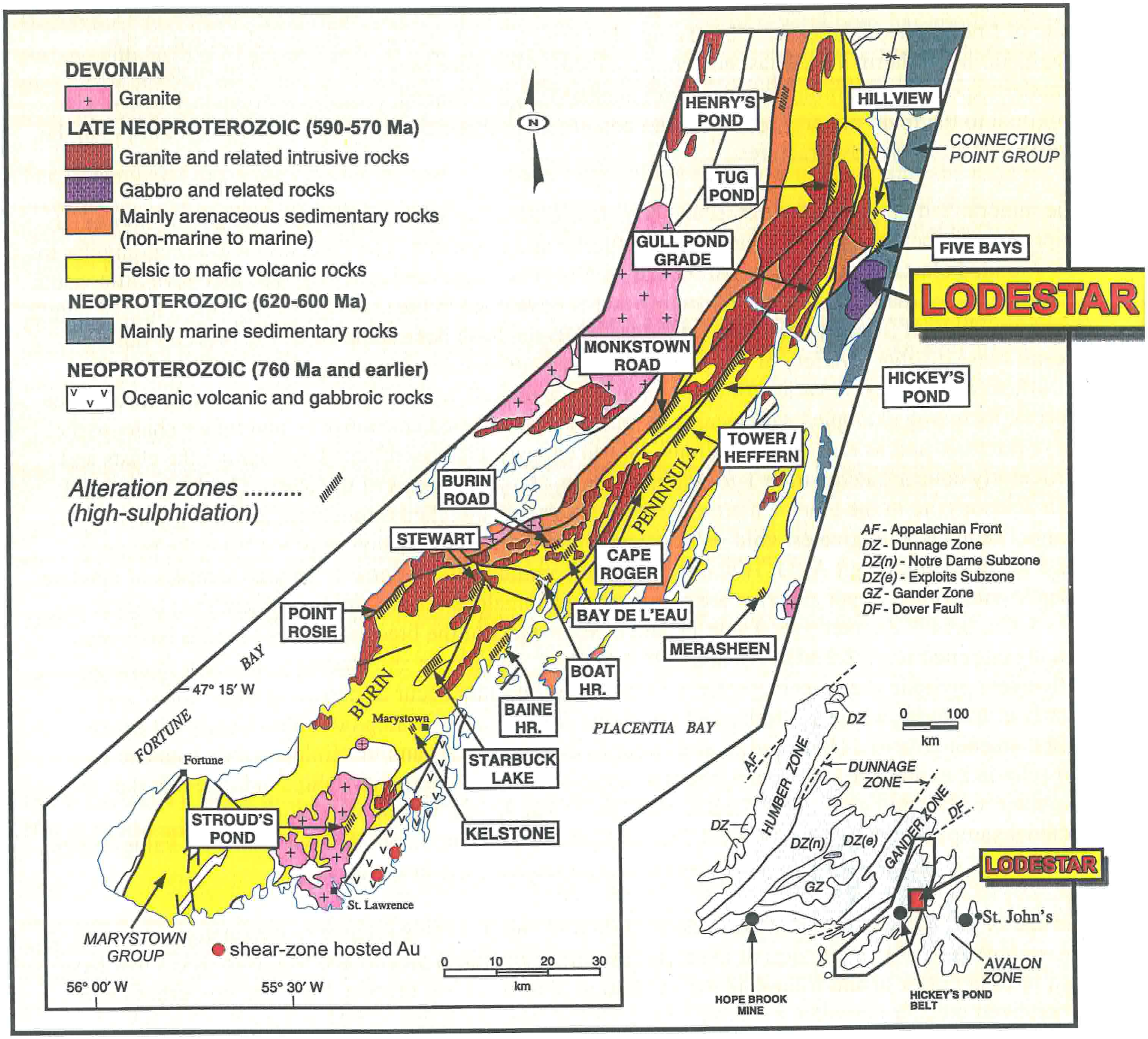

Figure 2.1. *Regional geology, gold occurrences and related hydrothermal alteration systems on the Burin Peninsula and adjoining areas, showing the location of the Lodestar Property.*

is provided by a vein-bearing crystal-rich ash-flow tuff, dated at 582±4 Ma. The low-sulphidation system, which is unconformably overlain by sedimentary rocks containing lower Cambrian fossils, is thus bracketed between 586 and the age for the lower Cambrian (between *ca.* 540 to 513 Ma). Feldspar porphyry intrusions into the Wych Hazel Pond sedimentary sequence yield a preliminary age of 585±5 Ma. The porphyries, which are geochemically distinct from the older plutons, are the youngest felsic intrusions within the region and may play an important role in the development of the regional epithermal systems. Available data are consistent with a model where the high sulphidation system has been focused along (and above) a pre-existing structure coincident with the contact between the 625-620 Ma plutonic rocks and the younger, ca.580 Ma volcanic suite. This boundary is now marked by the post-alteration Mine Hill shear zone.

The relationship between the high- and low-sulphidation epithermal systems remains equivocal. Current modeling for such systems (e.g., Hedenquist *et al.*, 2000) would imply that Oval Pit mine (pyrophyllite–diaspore) and the Bergs–Steep Nap system (adularia–calcite–chalcedonic silica) formed in contrasting environments at contrasting crustal levels. Thus the observed proximity of these two types of systems in the eastern Holyrood Horst would require their original separation either in space or in time. Existing field and U–Pb geochronological data do not provide an accurate enough age separation to adequately explain the observed proximity of such contrasting low- and high-sulphidation epithermal systems. The possibility remains that the low-sulphidation colloform–crustiform veins and breccias represent a slightly younger (>1 Ma) telescoped, near-surface epithermal system overprinting a relatively deeper high-sulphidation system.

STOP 1.1: Manuels River Historic Site:

Location: *South side of Conception Bay Highway, just west of Berg's Store (opposite Cherry Lane); park in Manuels River kiosk parking lot. Walk down the steps to the river to examine the basal boulder conglomerate.*

Overview and Day 1 itinerary: We stop here to review the day's itinerary, look at maps, and briefly visit the basal conglomerate of the Early Cambrian to Early Ordovican platformal cover to the Avalonian Neoproterozoic volcanic and plutonic rocks. The latter were altered, mineralized and subsequently deformed in the latest Neoproterozoic, prior to the deposition of the conglomerate. The conglomerate in this region contains deformed clasts of high- and low-sulphidation epithermal systems; some silica-altered clasts occur in outcrops in Manuels River.

Geologically, the route here took us down section through late Neoproterozoic deltaic sandstones and shales of the St. John's Group (which underlie much of the city of St. John's), downwards through the Ediacran-fossil bearing Mistaken Point Formation and other marine siliciclastic sedimentary rocks of the Conception Group, across the Topsail Fault system, onto the eastern edge of the Holyrood Horst and the volcano-plutonic core of the Avalon Peninsula. We are now at the northern end of what is informally called the eastern Avalon high-alumina belt, at the contact between hydrothermally altered volcanic and plutonic rocks and unaltered, shale-rich Cambrian platformal cover.

Return to parking lot and walk southwest along Route 60, keeping on shoulder of the road. Cross Route 60 at crosswalk beyond Bergs store. Beware of traffic.

STOP 1.2: Unconformity of Early Cambrian shale and limestone on late Neoproterozoic, hydrothermally altered granitic and volcanic rocks, eastern Avalon high-alumina belt: *(modified from O'Brien et al., 2001)*

Please be careful. Fast-moving traffic: cross on the light. Stay close to the outcrop; the shoulder is narrow in this area.

The outcrop on the south side of the road exposes the disconformity between fossiliferous Lower Cambrian Brigus Formation (Adeyton Group; see paleontological review in Boyce 1988) and the underlying hydrothermally altered succession of the eastern Avalon high-alumina belt. Sub-Cambrian basement here includes volcanic and granitic rocks that host the Bergs low-sulphidation vein system (which once was visible in now-covered outcrops in adjacent Cherry Hill subdivision). These outcrops provide stratigraphic evidence for the pre-Cambrian age of the host rocks and of the alteration system. The little-disturbed Cambrian strata demonstrate the lack of Paleozoic orogenesis in the immediate area. This is one of the northernmost exposures of this hydrothermal system, which continues (initially, at least) at very shallow depth, northward under the gently dipping to flat-lying Cambrian cover.

The roadside outcrop shows a well-developed regolith zone below the basal Cambrian contact. There has been carbonate infilling along the regolith and within fractures extending a metre or more into the basement rocks. Minor early Paleozoic copper mineralization is associated with the carbonate. Both the volcanic and plutonic rocks below the unconformity are altered (sericite–silica, with minor hematite and pyrite). These Neoproterozoic rocks are cut by structurally controlled (extensional) sub-horizontal and (less pronounced) steep quartz and carbonate veins. An earlier set of thin, banded quartz–hematite veins are hydrothermal in origin. Hydrothermal quartz–hematite±K-feldspar veins and breccias having variously elevated gold values occur locally, both in outcrop, and as large angular blocks immediately south and north of here; similar veins are exposed in nearby outcrops.

Uncovered during construction of the nearby housing development, superb exposures of the unconformity between the fossiliferous Cambrian and an underlying regolith of epithermal-style veins, breccias and hydrothermally altered volcanic and plutonic rocks have provided key chronological relationships. The boulder conglomerate contains large, typically rounded clasts (1 cm to >1 m) of silica-rich breccia, chalcedonic silica, crustiform- and colliform-banded silica veins, and hematite–silica–K-feldspar veins, as well as silica, argillic and advanced argillic alteration that was deformed prior to incorporation into the conglomerate. The conglomerate also samples fresh flow-banded rhyolite, altered granite and foliated mafic rocks. Construction work in the same area exposed an angular unconformity that separating penetratively cleaved Neoproterozoic volcanic rocks from overlying, gently dipping to flat-lying, non-cleaved Cambrian rocks. The northeast to east-northeast-trending steep cleavage in the Neoproterozoic basement is truncated at the unconformity surface.

Further details of the nature and significance of the unconformity, as well as references to earlier work are given in O'Brien, 2002.

STOP 1.3: Steep Nap Road Prospect: Au–Ag-bearing, low-sulphidation-style veins and breccias:

(modified from O'Brien et al., 2001); Location - Steep Nap Road: Turn south off Conception Bay Highway onto Anchorage Road (look for "Ziggy's" sign at intersection). Proceed through underpass below the new CBS By-pass road, and turn left, stopping at long exposure on the south side of the road.

The blasted outcrop on the south side of the road forms part of the Steep Nap Prospect. Discovered in 1995, the prospect consists of gold-bearing hydrothermal quartz–hematite–K-feldspar veins in pyroclastic and hydrothermal breccias (O'Brien *et al.*, 1998; Mills *et al.*, 1999). The veins in this exposure have many of the characteristics of low-sulfidation (adularia–sericite) epithermal gold mineralization: e.g., adularia- and chalcedony-bearing; crustiform and colloform textures; high silver/gold ratio, chalcedonic recrystallization and carbonate replacement textures.

We are located about 3 km to the north of the Oval Pit pyrophyllite mine, and about 1.5 km SSW of Stop 1.1. The largest veins in this outcrop have returned assays of 3.3 g/t Au and 20 g/t Ag (Mills *et al.*, 1999). This 60 m long outcrop of felsic pyroclastic rocks contains at least 100 veins, ranging in size from 1 mm up to 1.7 m; most are less than 2 cm wide. Several types of breccia are also exposed. The main auriferous material forms a 1.7 m wide composite vein composed of crustiform bands of K-feldspar–quartz–chalcedony and minor hematite. Very little sulfide mineralization is present in any of the veins. The largest auriferous veins have been traced with consistent thickness along strike for more than 400 m. Samples from trenches excavated by Rubicon Minerals Corporation have assayed up to 9.23 g/t Au.

The earliest veins are crustiform-banded, and consist of grey recrystallized chalcedony and white quartz, with or without minor chlorite and hematite. A second group of veins consist of crustiform and locally colloform bands of K-feldspar, grey recrystallized chalcedony, white quartz and hematite. These display chalcedonic recrystallization texture (mosaic texture) and carbonate replacement texture (parallel bladed texture) in thin section, and are anomalous in gold.

The latest veins are characterized by weakly banded quartz along the margin, bounded by crystalline comb quartz nearer the centre, surrounding a hematite core. Veins such as these, which contain coarse-grained crystalline texture are in many cases barren or only weakly anomalous in gold. In many instances, especially in the larger veins, internal brecciation of the vein material by hematite has occurred. Hematite fracturing of the surrounding outcrop occurs locally.

The earliest hydrothermal breccias are gold-bearing and have a matrix of grey recrystallized chalcedony and minor K-feldspar that forms cockade textures cored by sericite–chlorite-altered clasts. This breccia is crosscut by the main adularia–quartz–hematite vein, and by smaller veins cored by comb quartz and hematite. Other, later breccias have either black, chlorite-rich and/or brown, hematite-rich matrix. These breccias contain fragments of banded vein material, and are thus either late syn-, and/or post-veining. The two matrix types are typically mixed. The late breccias with vein material fragments return anomalous gold values.

Sericite, chlorite, and hematite are the main wall-rock alteration phases; there is also evidence of some potassic and silica alteration. Most (although not necessarily all) of the more intense sericite alteration is post-veining, and related to brittle deformation. Less intense but more pervasive sericite alteration is present in the northern half of the outcrop. Chlorite alteration is mainly confined to thin halos around pre-veining fractures and veinlets. A more extensive area of chloritic alteration (*ca.* 2 m wide) is developed adjacent to (west of) the widest vein. Hematite alteration occurs sporadically throughout the outcrop, both as early remobilization halos and later patches and halos around late veinlets and fractures.

The presence of crustiform textures with chalcedonic silica and adularia indicate the mineralized veins formed during boiling of near-neutral pH fluids associated with episodic pressure release. Neutral fluids rose into zone of increased permeability, in this case created by faults. Confining pressure was reduced as fluids neared the paleosurface; the fluid boiled, CO_2 was given off; the resultant drop in pH and temperature led to low-T, K-feldspar formation, and metal precipitation from silica gels. The system gradually sealed, pressure built up and boiling stopped; renewed fracturing broke the sealed cap in the system, and the process repeated.

The early cockade-textured hydrothermal breccia reflects hydrofracturing and tectonic brecciation synchronous with boiling; this is evident from crustiform-banded adularia and chalcedonic silica in the matrix. Breccias also formed during later stage hydrothermal activity in the same system. These are Au–Ag-bearing only where they contain mineralized adularia-bearing vein fragments.

The entire mineralizing system is cut by mafic dykes, these are located distal to the footwall on the road exposure, at the footwall in trenches 3 and 4 and also at the ridge exposure. These dykes were likely feeders to mafic flows in the overlying Wych Hazel Pond Complex, a shallow marine basin-fill environment formed during an extensional tectonic setting.

Vein features preserved here demonstrate that these rocks formed within the boiling level in a low-sulphidation epithermal system and at an approximate depth suitable for precious-metal deposition. A Phase 1 diamond drilling program completed by Rubicon intersected broad mineralized intervals (up to 45 m core length) of veins, vein-stockworks and hydrothermal breccias. Significant mineralized intersections were obtained in 6 of the 7 holes drilled, with the best result being 1.9 g/t Au over 0.7 m.

The Steep Nap Prospect and related Ag–Au mineralization is the first late Neoproterozoic, Ag–Au-bearing, low-sulphidation-type epithermal system documented in Avalonian rocks, and is amongst the oldest confirmed examples of that style of mineralization known anywhere. Low-sulphidation-type alteration systems, which may host either bulk tonnage or bonanza-style mineralization, represent an important, yet challenging, target for precious-metal exploration within the Avalon Zone. Prospective geological environments include subaerial rhyolitic to rhyodacitic volcanic piles and associated rhyolitic dome complexes. The nature of the linkage between the low-sulphidation-type Steep Nap system and nearby pyrophyllite–diaspore-bearing advanced argillic alteration has important regional implications in terms of Ag–Au exploration, both locally and regionally in the larger Avalonian belt, and is the focus of ongoing investigations.

STOP 1.4: Steep Nap trenches and Ridge vein:

Follow the trail south to exploration trenches of Steep Nap vein, approximately 300 m southeast of Stop 2. Please respect the fact that we are walking on private land and refrain from littering.

The stop in Trench #3 offers an excellent view of the multiple phases present in the Steep Nap mineralizing system. In addition, we see here that the system is developed along the contact zone between rhyolitic volcaniclastic rocks and a flow-banded to massive rhyolite unit. A post-mineral dyke has been intruded along the same contact in the vein footwall. Typical wallrock alteration within this region consists of silicification combined with chlorite and illite developed proximal to the vein. At approximately 5 m away from the vein, the alteration is gradational into a more hematite-rich alteration, again with minor amounts of illite.

The earliest vein phase observed here is a cockade-textured vein breccia containing clasts of altered lapilli tuff, this vein breccia is typically weakly anomalous in gold. The breccia matrix consists of quartz (chalcedony) and adularia and is similar to that observed in the road exposure. A second vein event contains crustiform–colloform banded quartz-adularia veins with spectacular coarse colloform textures, this vein typically contains from 50 to 300 ppb gold. A third vein event consists of centimeter-scale bands of crustiform banded quartz–adularia with illite–chlorite–hematite. This vein phase typically contains 500 ppb to >1 g/t Au.

The earlier of the two hydrothermal breccias post-dating the main vein phases consist of a matrix of silica–specular hematite–chlorite and rare pyrite. Clasts in the breccia consist of crustiform–colloform banded quartz-adularia vein fragments in addition to fragments of strongly altered volcanic rocks. This breccia phase contains approximately 1 g/t Au average and it is not clear if gold is present only in the vein fragments. The second hydrothermal breccia evident in the trench contains a matrix of dominantly hematite and chlorite along with several per cent sulphides. The sulphides include, in decreasing order of abundance, pyrite–chalcopyrite–galena. Clasts in the breccia consists of vein material with various textures (including spectacular examples of lattice-bladed carbonate overgrown by silica and adularia, along with "moss" and "mould" textures), silica-altered clasts and flow-banded rhyolite clasts. These breccias have returned grades of 4.5 g/t Au in grab samples and 1.8 g/t Au from channel samples.

The latest veins are observed in the vein hanging-wall and are characterized by weakly banded quartz along the margin, bounded by crystalline comb quartz nearer the centre, surrounding a hematite core. These are similar to those observed on the road exposure and return only weakly anomalous gold values.

Head south from the trench to the powerline and from there to the stripped outcrops on the ridge.

The stop on the Ridge contains exposures of the main Steep Nap vein system hosted within a complex rhyolite unit. The rhyolite is mainly massive and flow banded, although local areas exhibit a sub-porphyritic texture. The veins at this location measure up to 1.4 meters wide (true width) within an alteration/brecciation envelope measuring over 6 meters wide. The veins exhibit classic crustiform banded quartz-adularia textures with channel samples returning 191 ppb Au over 1.47 m. Enveloping the veins is a variably developed zone of brecciation/alteration developed in the host rhyolite. Stockwork fracturing is accompanied by chlorite-hematite-silica alteration and minor pyrite. This alteration zone is weakly elevated in gold.

Return to the powerline and back down hill along path, which branches to the right from the powerline, stopping at flat exposure of hydrothermal breccia. (Follow path back to Steep Nap Road).

The stop in the path on the hill is referred to as the "Jigsaw Breccia". The zone consists of hydrobrecciated rhyolite cut by a mosaic stockwork of quartz–hematite–chlorite veinlets. The veinlets contain weakly banded crystalline quartz core by hematite and chlorite. Assay samples taken from the outcrop have returned anomalous Au values (ca. 100-150 ppb). The location of the zone relative to the known main vein/breccia occurrences suggests that a broader overall alteration system is present at Steep Nap.

STOP 1.5: Oval Pit Pyrophyllite Mine:

WHILE ON THE MINE SITE, PLEASE WEAR THE HARD HAT THAT HAS BEEN PROVIDED.

*Location: Trinity Resources and Energy (Newfoundland Pyrophyllite Division) Oval Pit Mine property: Turn and head west on new road to intersection with Minerals Road; follow Minerals Road south (left) to pyrophyllite mine. Stop at the Mine office. Time and weather permitting, we will first take the mine road to a look-out point on the edge of the Oval Pit, for an overview of the pit. We will then proceed back on this road and into the pit (**water levels permitting**), stopping on the 470 level.*

EXERCISE EXTREME CAUTION! PLEASE KEEP AWAY FROM EDGE OF THE OPEN PIT.

(from O'Brien et al., 2001)

The view from the top of the pit shows a number of features including the outline of the pyrophyllite–diaspore ore zone, the unconformably overlying sediments, which are rich in detrital altered clasts, and some of the larger scale structures affecting the alteration system. The most notable of these is a steep reverse fault that juxtaposes the alteration zone (in the south pit extension) with the sedimentary succession. The structure has about 60 m of vertical throw. The same structure has a significant component of subhorizontal displacement. Vertical and horizontal displacement of the ore zone along this fault is mimicked in the overall shape of the open pit, particularly the southwest extension.

The pyrophyllite deposits of this area were discovered in 1898 and were first mined in the period from 1903 to 1905, with approximately 7750 tons of hand-picked ore shipped from a quarry near Johnnies Pond (presumably at or near the site of the Mine Hill deposit; Vhay 1937; Spence, 1940). Pyrophyllite ore was produced intermittently in the mid-1930s and 1940s by the Industrial Minerals Company of Newfoundland, mainly from area around Mine Hill, but also from the Trout Pond and Dog Pond prospects, located farther south. Mining of the Oval Pit pyrophyllite deposit was carried out from 1956 to 1996 (e.g., Lee, 1958), first by Newfoundland Minerals Ltd. and eventually, by Armstrong World Industries Canada Ltd. Exploration drilling of all deposits was carried out over this interval. Until now, pyrophyllite from this deposit has been traditionally used exclusively for ceramics applications, and was shipped in bulk to the US ceramics plants. The deposit is now owned by Trinity Resources and Energy Limited and is operated by its Newfoundland Pyrophyllite Division. The owners produce a variety of high-end pyrophyllite products, including fillers and whiteners for paper, plastic and paint, plus a number of specialty ceramic uses. Product is milled and packaged on-site.

The earliest geological study of the pyrophyllite deposits was carried out by Buddington (1916). A detailed study of the Mine Hill, Trout Pond and Dog Pond prospects was carried out by Vhay (1937). A number of investigations followed the development of the Oval Pit Mine (e.g., Keats, 1970; Papezik and Keats, 1976, Papezik and Hume (1984). The most recent geological mapping of this region is that of Hayes and O'Driscoll (1989, 1990), and Hayes (1997) and by the authors (O'Brien *et al.*, 1997, 1998, 2001a; Sparkes *et al.*, 2005; Sparkes, ms).

A well-exposed section through an extensive advanced argillic hydrothermal system is preserved in the Oval Pit Mine and in the immediately surrounding area. Alteration can be subdivided from east to west into subzones of argillic, advanced argillic and massive silicic alteration. The argillic zone is characterized by the presence of silica and sericite, with or without pyrophyllite, and the common occurrence of hydrothermal hematite. The advanced argillic zone contains subzones of massive pyrophyllite, sericite and diaspore, with minor barite and rutile (e.g., Oval Pit), and of silica, pyrophyllite and sericite, locally with 5 to 10% pyrite. Smaller zones of massive silicic alteration are mainly in the form of metre-scale pods of high-grade silica, containing less than 5 percent sericite and/or pyrophyllite.

Locally, pyrite forms the matrix of associated silica breccias. No large and continuous zone of silicic alteration has been identified at surface. The zones of silicic alteration are irregularly distributed in detail, but appear to be located mainly to the northeast of the advanced argillic zone. The original distribution of silica and pyrophyllite within the advanced argillic alteration zone indicate that they are essentially contemporaneous. Pyritic rocks intimately associated with the pyrophyllite are not typically anomalous in gold, although values up to 0.8 g/t have been noted locally. The highest gold values noted to date are associated with hydrothermal breccias at the edge of the advanced argillic zone.

The advanced argillic alteration zone passes outward into red subaerial rhyolites showing mild silicic alteration associated with the formation of quartz–hematite veins and breccia. The first stage of hematite alteration is regionally distributed, pre-dates the advanced argillic alteration, and formed by syn-volcanic thermal oxidation. A younger hematite-alteration event is the result of leaching from hematite-rich volcanic rocks during advanced argillic alteration, and has resulted in the formation of the afore-mentioned hematite veinlets and breccias. The commonly developed anastomosing pattern illustrated by the outcrop-scale distribution of silica and pyrophyllite in zones of low to medium strain is the result of inhomogeneous post-alteration deformation.

The presence of pyrophyllite and diaspore, together with barite and metre-scale silicic (≤95 percent SiO_2) zones, coupled with the almost total absence of kaolinite, is compatible with an advanced argillic alteration system associated with a magmatic-derived high-sulphidation system. The apparent absence of widespread silica alteration, vuggy silica and alunite within the alteration zone may indicate that the pH was not acid enough to produce this assemblage. A pH in the range 3-to-5 is implied by the observed presence of pyrophyllite and diaspore with quartz, and is consistent with this suggestion. However, in the apparent absence of the topaz, lazulite, andalusite and zunyite (diagnostic minerals of ascending hypogene acid fluids with probable magmatic components), it remains to be confirmed whether this alteration system is entirely magmatically derived, or alternatively, in part steam-heated (*cf.* Reyes, 1990).

STOP 1.5a: Oval Pit pyrophyllite mine - Pit floor:

THIS PIT IS NOT CURRENTLY IN OPERATION, AND THE WALLS HAVE NOT BEEN RECENTLY STABILIZED. PLEASE KEEP AWAY FROM WALLS OF THE OPEN PIT! PLEASE WEAR EYE PROTECTION.

We will examine several large blocks of pyrophyllite ore on the floor of the pit. Beautifully preserved flow-bands in rhyolites and pumice lapilli in ash-flow tuffs demonstrate the nature of the protolith and argue for the pre-tectonic nature of the alteration. This protolith to the pyrophyllite ore is texturally comparable to unaltered pyroclastic rocks exposed farther north. Other blocks display the development of silica and pyrophyllite (and in some cases fine-grained pyrite) in alternating bands, parallel to flow-banding, crosscut by the regional cleavage. Diaspore nodules and massive pyrophyllite ore are exposed in the floor of the pit and in the walls of the most recent workings. The exceptional preservation of the thick advanced argillic alteration (and hence, a mine) is likely due to the lower pressure in a fold nose in this area; the long limbs are much thinner and more highly strained.

STOP 1.5b: Oval Pit Pyrophyllite Mine: 490 and 560 levels *(from O'Brien et al., 2001)*

If time and pit conditions allow, we will walk up to the 560 foot level, to examine the overlying sedimentary rocks, pausing briefly to look at zones of massive silica alteration (560 level), and the high-grade pyrophyllite-diaspore ore (490 level) occurring below altered conglomerate, immediately below the unaltered red sedimentary units. The trip will traverse down-section through the sediments, towards the basal contact

WATCH FOR LOOSE ROCK. KEEP AWAY FROM OUTSIDE EDGE OF THE BENCH.

The advanced argillic alteration zone, hosted by 584 ± 1 Ma rhyolite and ash-flow, is overlain by immature siliciclastic sedimentary rocks of the basal Wych Hazel Pond Complex. The latter are well exposed in the upper benches on the west side of the open pit. There, the lower 60 m part of the succession consists mainly of red to purple, fine to coarse-grained fluvial/alluvial siliciclastic rocks, containing rare pumice-rich tuff layers. One such tuff bed occurs near the base of the succession, and is dated at 582± 1.5 Ma. This brackets the age of the advanced argillic system between 580.5 and 585 Ma. The yellow-weathering boulder conglomerate, *ca.* 3 m thick., is pyrite-bearing, and contains large well-rounded clasts of pyrophyllite, sericite and silica clasts derived from the underlying volcanic-hosted advanced argillic alteration zone.

The conglomerates in the lower part of the succession contain altered and unaltered detritus, none of which record any pre-incorporation deformation. Note the large number of intricately laminated and banded rhyolite clasts. The proportion of hydrothermally altered material within the detrital assemblage decreases stratigraphically upwards. The lack of pre-incorporation deformation is, of course, consistent with a syn-volcanic and pre-tectonic origin for the hydrothermal event.

The lower red conglomerate unit gives way upwards to extensively slumped beds of green siltstone and thin and medium beds of grey, coarse-grained feldspathic grit. The latter occur as planar beds, as internally slumped beds interlayered with siltstone and bounded by planar beds, or as totally disrupted and discontinuous layers affected by soft-sediment folding and faulting. Northwest of here, these rocks are interlayered with pillow breccia and mafic hyaloclastite.

A steep reverse fault exposed immediately to the south of us, brings the alteration zone (in the southern extension of the pit) in contact with the sedimentary succession at a point approximately 60 m above its base. The same structure has a significant component of subhorizontal displacement. Vertical and horizontal displacement of the ore zone along this fault is mimicked in the overall shape of the open pit, particularly the southwest extension. This sedimentary succession is deformed by an open southeast-plunging syncline. The base of the succession does not appear to have a significantly irregular morphology, although the nature of the epithermal alteration beneath the sediments would imply some uplift to bring these rocks to the (syn-sediment) paleosurface.

STOP 1.6: Mine Hill Quarry: High-strain zone in advanced argillic alteration; pyrophyllite ore:

Location: Pyrophyllite mine property; turn left onto narrow road immediately west of Johnnies Pond. (modified from O'Brien et al., 2001)

WATCH OUT FOR FALLING ROCK. THE LARGE BLOCKS ON FLOOR MAY NOT BE STABLE.

The Mine Hill Quarry represents one of the early attempts at commercial production from the pyrophyllite deposits of this region. Prior to the development of the Oval Pit deposit in the mid-1950s, most production from this area had come from the immediate Mine Hill–Johnnies Pond area. Reverse-sense ductile shear zones have accompanying, intense, steeply dipping foliation and down-dip stretching lineations. These are well exposed in the quarry wall (recent bulk sampling by the mine operators may have resulted in the loss of some of the best exposures). This outcrop is part of the post-mineral Mine Hill Shear Zone (*cf.* Sparkes *et al.*, 2005), which is regionally coincident with both the main area of advanced argillic alteration and the boundary between 620-625 Ma magmatic rocks and the younger ca 584± 1 Ma Manuels Volcanic Suite.

The protolith of the alteration is likely a welded tuff. Discontinuous pyritic zones are developed within the advanced argillic zones in this area. Most of the eastern and central portions of the quarry expose highly strained pyrophyllite–sericite–quartz rock, in which the silica forms discrete knobs. The western end of the quarry exposes highly strained pyrophyllite–sericite ore. Elsewhere on Mine Hill, the alteration zone is overlain by basal conglomerate of the Wych Hazel Pond Complex and is intruded by an unaltered, pre-tectonic (albeit weakly foliated) diabase dyke.

The high strain evident at this locality is in contrast to the situation around much of the Oval Pit Mine, where, except for narrow high strain zones, the overall ductile strain is much lower. The contrast may reflect the location of the Oval Pit pyrophyllite ore zone in the core of a syncline (as indicated by the generally east-west trend of the moderately dipping bedding), relative to that of Mine Hill on the syncline's attenuated, steep north-south trending limb. This area is a good illustration of the important need for good quality outcrops in different structural settings to help reveal the relative chronology of hydrothermal alteration and tectonism.

In general, the zone of advanced argillic alteration has accommodated most of the strain in much of the eastern Avalon high-alumina Belt. This is chiefly due to competence contrast between the adjacent unaltered rhyolites relative to the pyrophyllite-rich rocks within the alteration zone.

If time permits, we may return to Minerals Road (farm access extension) to view nearby outcrops of extensively pyritized silica alteration within the pyrophyllite-bearing advanced argillic alteration.

STOP 1.7: Mine By-pass gold prospect:

Location: Newfoundland Pyrophyllite Division (Trinity Resources and Energy, Limited) pyrophyllite mine property: roadcut near south end of Mine Hill.
(modified from O'Brien et al., 2001)

WATCH OUT FOR FALLING ROCK ... NOTE THE RECENT ROCK FALLS!

This roadcut exposes a wide zone of auriferous hydrothermal breccia and related silica–sericite alteration developed in a sequence of flow-banded rhyolite and related pyroclastic rocks. Alteration here is manifest chiefly by polyphase hydrothermal brecciation and silica flooding. We begin near the eastern end of this locality, and traverse westward from variably banded rhyolite, through a zone of silica breccia veins and stockwork, into a silicic hydrothermal breccia with a chlorite–pyrite matrix. Farther west in the outcrop, a thrust surface is exposed, part of a high-strain zone developed in a zone of silica–sericite–pyrite alteration. The same chloritized silica-rich hydrothermal breccia found in the east end of the outcrop reappears below the thrust farther west in the outcrop. In both areas, these hydrothermal breccias, which are locally flooded by hematite, contain anomalous precious metal values (up to 1.8g/t Au, 6 g/t Ag).

Within the breccias, pyrite occurs as individual mm-scale euhedra, and in irregular zones, in which the pyrite is fine grained and heavily disseminated. Multiple generations of silica alteration is recorded by fragments within the breccias. Dark grey silica fragments within the breccia show evidence of pre-breccia hematite alteration.

Continuing westward along the exposure we cross zones of pyrite–sericite and quartz–sericite–pyrite alteration in a variety of pyroclastic and hydrothermal breccias, locally with a silica-flooded matrix, passing into a pyrophyllite-silica zone developed in rocks of uncertain (locally spherulitic) protolith. The western end of the exposure consists of sericite–silica ± hematite-altered fragmental rock.

STOP 1.8: Farmers fields:

Location: Follow old farm road; follow same to farm area; park on left. Walk past fence onto low outcrops.

a) Banded rhyolites and silica-hematite veins and breccias - a Steep Nap extension?

Here we are in the 584± 1 Ma flow banded rhyolites of the Manuels Volcanic Suite; these host the advanced argillic zone and the pyrophyllite–diaspore deposit, which is located about 500m southwest of here. We will first examine outcrops of veins and breccias similar to what we have seen peripheral to the Steep Nap system. Veins and breccias here are weakly anomalous in Au, typically contain between 50 ppb and 1g/t. The most widespread veins here are cockade style breccia veins with hematite and silica; boiling features are absent. The most anomalous values are from the hydrothermal breccias containing chalcedonic silica.

b) View drill core and samples from the Bergs low-sulphidation system.

This is an opportunity to examine representative samples and drill core from the Bergs prospect. Due to the ongoing construction activities and increase in numbers of residents at the Cherry Hill site, we have decided not to tour the site with a large group of people.

Bergs drill core: A single reconnaissance drill hole was completed at the Bergs Prospect in April of 2002 by prospector Greg Peddle. Rubicon Minerals Corporation acquired the property during the time of the drilling, in addition to several other properties in the belt referred to as the Avalon Trend Property. Drill hole BERGS-02-01 intersected three significant mineralized vein and/or vein-breccia zones. The first intersection assayed 535 ppb Au over 2.2 meters from 10.62-12.82 meters. The second interval assayed 327 ppb over 2.5 meters from 28.75-31.05 meters. The third interval assayed 570 ppb over 3.8 meters from 33.85-37.75 meters (Note: all intervals quoted are weighted averages given over core lengths). Additional veins assaying in the 100-400 ppb range were intersected to depths of 75 meters down the hole. Results from the drill core indicate multiple veins and breccia zones to be present, and that they may be part of a significantly larger, complex and composite vein-stockwork-breccia system. The recent identification of bonanza-grade gold values in additional veins, along with a new exposure of a 2-3 meter wide vein from 2005 construction lend support to the thesis that the Bergs system is potentially very significant (see review below).

Bergs Prospect: Gold-bearing crustiform banded, low-sulphidation-style epithermal quartz veins and breccias of the Bergs Prospect were discovered in 2001 (O'Brien, 2002). At that time, gold assays up to 7.2 g/t in grab samples were returned from outcrop, subcrop, and large angular boulders of silica–

hematite-altered and hydrothermally veined subaerial volcanic rocks. Excavations at the site of a new housing development at the north end of the prospect exposed an extensive area in which mineralized and/or altered float, subcrop and outcrop occurred; most of the mineralized area is now covered by private residences. Chip sampling of silica altered breccia (including vein breccia) exposed in 2001 returned results averaging about 250 ppb Au over 20 m. Subsequently, grab samples taken by Rubicon Minerals Corporation assaying up to 9.6 g/t were obtained from banded veins in the same area. A short distance farther south, crustiform-banded silica–hematite veins intrude rhyolite and rhyolite breccia with weak yet pervasive silica alteration, and have yielded Au assays up to 54.3 g/t (O'Brien and Sparkes, 2004).

The veins display well-developed and distinct millimeter-scale crustiform banding and local colloform banding; veins are hematite-bearing and brecciated internally. The higher grade veins contain two phases of red hematite, with the earlier hematite being intergrown with silica; specularite is developed locally. Typically, veins at Bergs are narrower than at Steep Nap and exhibit a multi-directional, stockwork-like pattern. Adularia at Bergs, unlike that at Steep Nap, is white-weathering. Well preserved bladed and crustiform–colloform texture occurs in a 2-to-3 m wide vein exposed during 2005 construction, and is similar to that seen at Steep Nap.

At Bergs, gold also occurs in a distinctive volcano-sedimentary/hydrothermal breccia with a deep red, earthy hematite-rich, non-siliceous matrix, which weathers recessively, and in which are set numerous variably broken, variably sized, equant to platy fragments of silica and crustiform-banded silica-hematite vein material. Fragments of hydrothermal veins and vein breccia occur throughout the host breccia. The rock unit is neither an in-situ hydrothermal breccia nor an internally brecciated vein complex, and bears similarity to modern hydrothermal eruption breccias (J. Hedenquist, pers. comm., 2003). Grab samples taken from banded vein fragments in the breccia contain gold: between 2.1 and 7.75 g/t. The presence of these surface breccias indicate that shallow crustal levels are preserved in these Neoproterozoic systems.

At Bergs, like at Steep Nap, banded low-sulphidation veins occur in proximity to a hybrid suite of variably silica-altered and pyritic granites. The granites are significantly older (up to 30 Ma) than the established lower time limit (582 ± 4Ma age of host volcanics) of the low-sulphidation veins. Their presence as a basement feature along the margin of the Holyrood Horst may have influenced the siting of not only the high-sulfidation system and later Neoproterozoic strain, but also the low-sulphidation veins. Similar granites have been mapped up to and beyond (east of) the Topsail Fault, where they can be readily separated from a regionally extensive composite suite of younger mafic to intermediate intrusions. These younger 590-580 Ma intrusions have been emplaced as syn-sedimentary hypabyssal bodies into the Wych Hazel Pond Complex.

STOPS 1.9 and 1.10: Roadcut and Santana Au–Ag prospects:
Location: North side of Route 1, immediately east of Foxtrap Access ramp. Leave pyrophyllite mine property via Minerals Rd. and turn west onto new CBS by-pass, proceed south (left) onto Route 61 (Foxtrap Access road).Park immediately north of westbound ramp onto Route 1 and cross Route 61. Walk up the access ramp, stopping at the long outcrop on north side of Route 1; the rusty weathering exposures are part of the Roadcut Prospect. ***Caution: oncoming traffic on ramp! Please walk on the gravel shoulder.***

STOP 1.9: Roadcut Au–Ag Prospect: *(modified from O'Brien et al., 2001)*

The outcrop on the north side of the west-bound lane on Route 1 exposes a 100-m-wide section through a locally auriferous (up to 11.2 g/t Au) zone of advanced argillic alteration developed in the same late Neoproterozoic volcanic succession as in today's earlier stops. The prospect is sited near the western edge of the eastern Avalon high-alumina Belt, approximately 4 km along strike to the south from the Oval Pit pyrophyllite mine and the Mine By-pass prospect. Hydrothermal alteration (silica–sericite ± chlorite ± pyrite ± magnetite) is developed in a succession of flow-banded rhyolite, pumice-rich lapilli tuff or tuff-breccia, and lithophysae-bearing ash-flow material, near the contact with overlying tuffaceous sedimentary rocks, and within several hundred meters of the boundary of the host volcanic rocks with the a monzonite–diorite–granite complex of the White Hills Intrusive Suite.

Much of the outcrop consists of zones of silica alteration, with remnant sericite and chlorite; small pink patches seen in the western part of the outcrop are relict (silica-altered) lithophysae. Silica-altered material contains blocks of sericite ± chlorite alteration, which is developed parallel to fine eutaxitic- and flow-banding in felsic rocks. Late subhorizontal extensional quartz veins crosscutting sericite–silica altered rocks exposed at the western edge of the outcrop are related to late vertical fault movements along the western edge of the high-alumina belt.

The larger silicic alteration zone contains areas of "pebbly" breccia, composed of dark grey sericite–pyrophyllite–pyrite fragments in a silica matrix, as well as zones of more angular to subrounded breccia with silicic-altered rhyolitic material in a chlorite-rich matrix. Both are present within a significant, *ca.* 10 m-wide zone of gold mineralization in the central part of the outcrop. A chip sample taken across this zone averaged 3 g/t over 10 m. Anomalous gold values occur in the pebbly breccias, but highest gold values (up to 11.2 g/t) are obtained from silica-rich breccia with chlorite–pyrite (plus minor K-feldspar and muscovite) matrix and from felsic hydrothermal breccia with banded rhyolite clasts (O'Brien and O'Driscoll, 1996, 1997; O'Brien *et al.*, 1997, 1998). Pyrite occurs as disseminations, clots and thin veinlets within the matrix of the breccias. The auriferous breccias yield assays up to 210 g/t Ag and 2 g/t As. The gold-bearing breccias at this locality are comparable in many respects to those seen in the previous stop (4 km on-strike to the north). Rubicon's recent channel sampling from the pyritic chlorite breccia returned assays of 16.1 g/t Au and 63 ppm Ag. Grab samples from the pyritic–silica–sericite zone west of the breccia return assays up to 10 g/t Au.

Follow the trail near the east end of the outcrop, which joins the old drill road parallel to the fibre optic line. Stop briefly in the area where mineralized fly rock was first discovered, examine examples of same, then head north for a short distance and down into a old trench that exposes examples of flows, breccias and altered rocks. ***Watch your step when climbing down into trench.***

STOP 1.10: Santana Au-Ag Prospect: *(modified from O'Brien et al., 2001)*

The Santana Prospect, discovered in late 1998 by Fort Knox Gold Resources Inc., occurs in a succession of late Neoproterozoic subaerial volcanic rocks, near the top of a 585-580 Ma rhyolitic to rhyodacitic volcanic sequence, several meters below the stratigraphic contact with overlying, unaltered Wych Hazel Pond sediments. The discovery of precious metal mineralization was in fly-rock from blasting to lay the fibre optic cable system through here. Blasted blocks of sericite–silica altered material with veinlets and fracture coatings of pyrite and galena returned assays up to 31.6 g/t gold in angular float. Subsequent trenching in the area of the fibre optic cable uncovered the same alteration and localized examples of similar mineralization in outcrop, which assayed up to 6.2 g/t gold and 612 g/t silver.

The alteration is developed in subhorizontal, lithophysae-bearing, flow-foliated rhyolite and rhyodacite, cut by thin hematitic breccias. The rhyolites display intricate flow laminae, lithophysal laminations, and well-developed flow folds with subhorizontal fold axes. The flows are in contact with coarse-grained, pumice-bearing, polymict lithic breccia.

At the edge of the alteration zone, weakly deformed, pale pink to buff flow-banded rhyolite is irregularly and incompletely flooded by an early stage of pink, hematitic silica, upon which is superimposed light grey silica. Silica-altered rocks (up to 83% SiO_2 in sericite-poor samples) are cut by thin irregular veinlets of red hematite, chalcedonic silica, and euhedral pyrite. Some of the veins and breccias contain late extensional voids filled by crystalline quartz, with chlorite and trace pyrite. Late chlorite-matrix cataclasite breccia crosscuts all the above. Several metres farther east, the alteration zone is characterized by light grey to beige silica-rich alteration with sericite ± chlorite and traces of pyrite. Here, the late silica–hematite fractures and impregnations are patchy and less abundant. Industry grab samples from this zone returned assays of 6.2 g/t Au and 613 ppm Ag. Subsequent sampling of outcrop and fly rock by the authors returned assays up to 10.5 g/t Au and 14 g/t Ag (highest value from fly rock).

The best gold–silver mineralization is in light grey–green, silicic rocks with up to 5 % sericite, and locally disseminated pyrite. The absence of hematite dusting and very low sulphide content are apparent characteristics of the mineralized zone. The silicic alteration is locally cut by quartz–hematite ± pyrite veinlets that are themselves locally cut by narrow (*ca.* 5 mm) grey veinlets of galena, sphalerite and anglesite ($PbSO_4$). The gold and silver mineralization appears to be restricted to the most silicic material, associated with fracture-controlled, grey sulphide veinlets, containing pyrite, sphalerite, galena and anglesite. Pyrite occurs as subrounded aggregates or clots in the larger veinlets, and as fine disseminations along fractures. Opal is locally developed.

The mineralization at the Santana prospect has some characteristics that are analogous with low-sulphidation epithermal systems - e.g. association with rhyolite domes, high Ag/Au ratio and an association with lead. However, neither adularia nor colloform–crustiform quartz veins diagnostic of such system have yet been found. The Santana prospect exhibits some characteristics of alteration zones related to or peripheral to a colloform–crustiform quartz–adularia low sulphidation Au–Ag vein system elsewhere in this belt.

STOP 1.11 (OPTIONAL): Pastureland Road (Zn–Pb–Cu–Au–Ag) Prospect: *(modified from O'Brien et al., 2001)*

Sulphide mineralization at this locality was originally noted by Hayes and O'Driscoll (1990). More extensive Zn-rich mineralization was discovered here in 1999 by Fort Knox Gold Inc.; more trenching and shallow diamond-drilling was carried out by subsequent license holders. The Zn–Pb–Cu–Au–Ag mineralization is hosted by the ca 580-565 Ma Wych Hazel Pond Complex. This shallow marine mafic volcanic and sedimentary succession is here intruded by hypabyssal feldspar porphyry.

Mineralization occurs in deformed, fine- to coarse-grained volcanic breccias (hyaloclastites) of mafic and mixed mafic–felsic composition, containing chilled fragments of purple-grey, vesicular mafic to intermediate material in a green, chloritized matrix. Zn–Pb–Cu mineralization is developed in fine-grained silicified fragmental rocks of presumed mafic protolith within a zone, several tens of metres wide, adjacent to a folded body of fine-grained grey plagioclase porphyry. Sphalerite, galena and chalcopyrite occur together with pyrite as disseminations, as network fractures, and in early-mineralized fragments within the fine-grained, grey, fragmental rocks. The entire zone is weakly anomalous in gold (*ca.* 20-100 ppb), and in some silicified areas has yielded values up to 2.1 g/t Au; Ba (≥2000 ppm) and Ag (up to 1.5 oz/t) are anomalous throughout. Higher-grade sulphide-rich zones at surface (up to 8.9% Zn and 5.2% Pb in grab samples; A. Turpin, personal communication, 2000) have a semi-massive appearance, and form discontinuous pods or strain augen. The largest of several pods has approximate surface dimensions of about 1 m by 0.5 m. A short vertical drill hole collared in one such pod shows these are more extensive in the immediate subsurface; this hole intersected mineralized rocks that include a zone of 3.1 % Zn and 1.35 % Cu over 6 m.

The mineralized rocks are affected by part of a major regional high-strain zone, but mineralization is pretectonic. This prospect is near the site of the Thousand Acre Shear Zone, a major vertical or near-vertical zone of high-strain developed on a regional scale, immediately west of and parallel to the Topsail Fault.

Together, the Manuels Volcanic Suite and the overlying Wych Hazel Pond Complex record the transition from mineralized (Au–Ag) subaerial epithermal conditions to mineralized (Zn-Pb-Cu) submarine conditions. These successions record the collapse and submergence of the metallogenically important *ca.* 580 Ma volcanic arc, characterized by widespread hydrothermal activity. The upper marine volcano-sedimentary succession may have significant, largely untested potential for both conventional and Au-rich VMS-style mineralization. This unit has significant aerial extent, most notably to the north-northeast, where it can be traced onto the St. John's Peninsula. Any indication of quartz–sericite–pyrite and, more importantly, of aluminous alteration (andalusite–kyanite–pyrophyllite with pyrite) will strongly emphasize the potential for Au-rich VMS mineralization in the area.

This is the last stop. From here we return to Route 1 and head west, en route Goobies junction (ca. 1.5 hour drive). At Goobies, turn left onto the Burin Peninsula Highway and head south to Swift Current (Kilmorey Resort).

DAY 2 (Part 1): Style and setting of intrusion-related gold at the Lodestar prospect, northern Burin Peninsula

Our first stop of the day (and your last one in the Avalon for this trip) is one of several examples of Avalonian intrusion-hosted gold and copper mineralization tied to the emplacement of mafic to felsic magmas between 640 Ma and 570 Ma. One of the most readily accessible prospects is the Lodestar Prospect occurs in the west-central Avalon Zone, near the Paradise sound Fault, a major structure that not only separates the fundamentally different parts of the Newfoundland Avalonian, but has also served as a focus of protracted, episodic magmatic activity. Mineralization we see this morning is sited at the intrusive contact of a pre-tectonic gabbro–diorite–granite complex (Powderhorn Intrusive Suite) into thin-bedded marine siltstones turbidites near the tectonic boundary of an extensive late Neoproterozoic (620-610 Ma) marine siliciclastic basin; the sedimentary rocks are part of the Connecting Point Group Knight and O'Brien, 1988; Dec *et al.*, 1992).

STOP 2:1 Lodestar Prospect (Au-Cu-As)

High-grade gold, with copper, arsenic and zinc occurs in magmatic-hydrothermal breccias at the

Lodestar prospect, Burin Peninsula (see O'Brien *et al.*, 1999a,b; Hinchey *et al.*, 2000, Hinchey, ms; Figures 2.1 and 2.2. The mineralized breccias, which have a diatreme-like character, are exposed over a 25 metre-wide section. They crosscut both unaltered sedimentary rocks and an early gabbro-quartz diorite intrusion and are cut by later, fine-grained diorite that is chilled against the mineralized breccia. A suite of fine-grained felsites have been emplaced prior to, and following, the development of the magmatic-hydrothermal breccias, and crosscut them. All earlier rocks are intruded by diabase dykes. Smaller exposures of similar breccias, with anomalous gold content, crosscut sedimentary rocks proximal to the main mineralized zone, and contain hydrothermal magnetite, chlorite and bornite in the matrix and along narrow fractures.

The mineralized magmatic-hydrothermal breccia is clast-supported; the matrix is mainly composed of sulphide and, locally contains hydrothermal chlorite and magnetite. The breccias include sub-angular to sub-rounded clasts of gabbro and sedimentary wall-rocks; these are locally derived and have little visual alteration, other than the concentric banding that is developed in the clastic rocks. Exotic clasts of quartz porphyry, derived from an unexposed epizonal intrusion, have been sampled by the breccias during ascent; these display a variety of high-level emplacement features, including uni-directional solidification textures. A variety of other exotic silica-altered, texturally variable intrusives occur in the breccia, including examples with weakly to heavily disseminated arsenopyrite, and minor chalcopyrite along fractures and as rare disseminations. The arsenopyrite is disseminated throughout the clasts and particularly concentrated within 1-to-3 mm wide rims on the margins of the clasts. Gold is associated with arsenopyrite in the breccia matrix, Arsenic is strongly enriched throughout, and is highest in channel samples with greatest gold values. The highest grade gold assays returned from the property (58.5 g/t Au with 260 g/t Ag; J. Hinchey, personal communication) came from grab samples of massive arsenopyrite. Both copper and zinc are significantly anomalous throughout the mineralized breccia (e.g., 0.18% Cu, 0.14% Zn over 9 m: Table 1), and in some parts of the breccia, the base metals have been notably enriched (e.g., 2.2%Cu/1m and 0.97% Zn/1m). Sphalerite and chalcopyrite occur intergrown with arsenopyrite in the breccia matrix. Chalcocite and bornite occur as narrow stringer zones and locally in fractures, where hydrothermal magnetite is present.. The sulphides also locally cut across clasts; arsenopyrite and chalcopyrite also occur as disseminations and in veinlets within rounded to sub-rounded, exotic clasts of quartz-bearing intrusive rocks. These relationships indicate that the sulphides and related gold mineralization are syn- to late-hydrothermal brecciation.
Channel samples of 6.13 g/t Au over 4.7m, 4.91 g/t Au over 3m, 5.3 g/t Au over 9 m with values range between 1.8 g/t Au and 11.6 g/t Au, have been reported from the property.

The age of the mineralization at the Lodestar Prospect and its timing relative to magmatism is provided by two precise U-Pb zircon ages of the early (pre-mineralization) gabbro and of felsite dykes that have been intruded prior to and following the generation of mineralized breccia. Early gabbro, cross-cut by mineralized breccia, provides a maximum age for the mineralization. A felsite dyke that has been emplaced into Au-Cu-bearing mineralized breccia, crosscutting both it and the early gabbro, provides a younger limit to the age of mineralization. The age of these rocks overlap within error at 603+/-2 Ma, and confirm a late Neoproterozoic age for both magmatism and mineralization and support the view that brecciation and mineralization were coeval and consanguinous with emplacement and crystallization of much, if not all, of the Powderhorn Intrusive Suite. This is consistent with a magmatic hydrothermal origin for the breccia.

The magmatic hydrothermal breccias at the Lodestar Prospect share analogous in terms of texture and metallic signature with gold-bearing magmatic-hydrothermal breccia pipes, and is the product of an intrusion-related gold-bearing system (*cf.* Sillitoe, 1991; Figure 2.3). The style of mineralization, the metallic signature, and the presence of exotic, high-level quartz–feldspar-porphyry clasts (locally mineralized), and the local occurrence of hydrothermal magnetite clearly point to the potential for Au–Cu porphyry style mineralization in the larger magmatic-hydrothermal system. In such a model, the mineralized Lodestar hydrothermal breccia could represent a distal product of a larger and potentially mineralized Au–Cu porphyry style mineralization that may have existed underneath the exposed breccia at the time of its formation.

For those of you heading west for Days 3-7, have fun and enjoy the rocks. Those of us heading back east (St. John's) from here will make several quick stops on a somewhat circuitous route to St. John's. If time permits, we'll make stops on the Avalon Isthmus at the Doe Hills (barite, fluorite and chalcocite veins), the Au–Cu-bearing Triangle Belt near the Salmonier Line, basalt-hosted Cu–Au–Ag veins at Turks Gut, and conglomerates containing low-sulfidation vein detritus in and around Avondale.

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