Turbidite-hosted, auriferous, orogenic quartz veins at the Jaclyn Deposit (Golden Promise), central Newfoundland

H. A. Sandeman and H. Rafuse
Dept. of Natural Resources, Geological Survey Branch, Government of Newfoundland and Labrador, 50 Elizabeth Avenue, St. John's NL, A1B 4J6 (hamishsandeman@gov.nl.ca)

and

D.A. Copeland
Paragon Minerals Corporation, 140 Water Street, Suite 605, St. John's, NL A1C 6H6

Introduction

The gold-bearing, orogenic quartz vein system comprising the Jaclyn Deposit (a.k.a. Golden Promise Deposit) lies within the Badger map sheet (NTS 12A/16) of central Newfoundland. The initial discovery in 2002 consisted of coarse-grained, comb-textured and stylolitic quartz boulders exposed on sub-cropping, bedrock-cored ridges. A composite sample from ~10 of these boulders assayed ca. 30 g/t Au. The discovery, optioned by Rubicon Minerals Corporation, has since been explored under a number of joint venture projects. The property has been subjected to systematic exploration including: 8,250 line kilometres of airborne magnetic and electromagnetic surveys; collection of ca. 6000 B-horizon samples over multiple exploration targets; property-scale prospecting and geological mapping and; 98 near-surface (<314m) NQ diamond drill holes totalling 15,310 m. Three main mineralized areas have been delineated and only one of these, the Jaclyn Main, has been incorporated into a resource calculation yielding a NI-43-101F1-compliant resource (Pilgrim and Giroux, 2008) of 921,000 tonnes averaging 3.02 g Au/t (89,500 contained ounces of gold), with a cut-off grade of 1 g/t Au. The Jaclyn Deposit therefore represents the first significant gold resource in this part of central Newfoundland. Further definition drilling and bulk sampling to test the veracity of the current resource outline is presently being considered (Crosshair Exploration & Mining Corporation, Press release, September 23rd, 2009). We provide a brief overview of the setting of the Jaclyn Deposit, a discussion of the nature of gold mineralization and associated alteration and, propose a working model for the formation and emplacement of the veins. In order to unequivocally determine the affiliation of the host rocks to the Jaclyn Deposit we also discuss lithogeochemical data for sandstones from the study area.

Regional setting

The Jaclyn Deposit lies within the Exploits subzone of the Dunnage Zone of the Newfoundland Appalachians (Fig. 1), a series of accreted arc and back-arc terranes that were formed in Iapetus Ocean during the Cambro-Ordovician. A prominent feature of the Dunnage zone is the Red Indian Line, a major crustal scale fault zone that juxtaposes rocks of the peri-Gondwanan Exploits subzone to the southeast against peri-Laurentian oceanic rocks of the Notre Dame subzone to the northwest (Zagorevski et al., 2006).

The Exploits subzone in the study area is dominated by rocks of the Victoria Lake Supergroup (VLS: Evans and Kean, 2002; Rogers and van Staal, 2002), a lithologically diverse and structurally imbricated series of arc-related volcanic and sedimentary rock dominated assemblages. The marine volcaniclastic sedimentary rocks of the area comprise three mappable units: the Badger Lookout formation, the Exploits Rapids formation and the Lawrence Harbour Formation (Copeland and Newport, 2005; Rogers et al., 2005). The former two represent distinct packages of megascopically fining-upward, variably coloured shales and mudstones interlayered with volcaniclastic sandstones and wackes. The latter comprises pyritic black mudstones that are Caradocian in age. Conformably overlying the Lawrence Harbour Formation are the overlap rocks of the Ordovician-Silurian Badger Group. These comprise polymictic conglomerates, medium-grained quartz arenites and sparse shale horizons (Williams, 1995). Cross-cutting all of the units in the study area are a newly recognized, cryptic array of mafic dykes termed the Exploits Dykes (Copeland and Newport, 2005).

Lithogeochemical constraints on the nature of the host sequence

Sandstones from Jaclyn Deposit comprise variably altered, medium-grained, plagioclase-rich arenites and locally wackes that contain abundant, small lithic fragments of plagioclase-bearing intermediate volcanic rocks and have sparse quartz and locally clinopyroxene. Badger Group sandstones consist of either coarse-grained, polymictic conglomerates or medium-grained blue-grey quartz arenites with abundant grey-black mudstone interlayers and rip-ups. Lithogeochemical analyses of sandstones from the Jaclyn Deposit and from the Badger Group demonstrate that the latter are typically enriched in SiO_2, MgO, K_2O, Na_2O, Cr, Ni, LREE and HFSE. Badger Group sandstones have significantly higher Mg#'s (47.9-59.6: molecular [MgO/MgO+FeO^T]*100) with corresponding elevated SiO_2 contents relative to sandstones from the Jaclyn area (Mg #'s =31.0-56.3). Al_2O_3 abundances in the Jaclyn sandstones are higher than those of the Badger Group rocks (12.13-14.99 wt. %), perhaps indicating their derivation from a more aluminous (feldspathic?) source. This observation is supported by the similarly elevated Na_2O and K_2O abundances in Jaclyn area sandstones. Incompatible trace element plots clearly discriminate the rocks of the Badger Group from those hosting the Jaclyn Deposit and provide inferences on their detrital sources. Th-La-Sc-U interrelationships demonstrate that the host rocks to the Jaclyn veins are characterized by U-, Th-, La-depleted but Sc-enriched, mantle-derived detritus, distinct from the Th-, U-, La-enriched, probable mixed mantle/crustal detritus of the Badger Group.

Deposit-scale geology and mineralization

The Jaclyn Vein systems are hosted by megascopically fining-upwards, right-way-up, clastic sedimentary units that are dominated by plagioclase-rich, intermediate to mafic volcanic and fine-grained pelagic sedimentary debris. These rocks comprise the core of a 2-3 km wavelength, tight, shallowly northeast-plunging SE-vergent, regional F1 anticline that folds the Badger Lookout formation, the Exploits Rapids formation, the Lawrence Harbour Formation and, the continentally-derived, turbiditic sediments of the Badger Group (Copeland and Newport, 2005). The major quartz veins are commonly associated with a suite of narrow, variably altered, tholeiitic mafic dykes that are typically sub-parallel to and occupy the same fractures as the veins. Mutual cross-cutting relationships indicate that at least some of the dykes are contemporaneous with the quartz veins (Copeland and Newport, 2005). The dykes and quartz veins appear to represent the youngest geological units in the area.

Quartz veins containing high-grade gold range up to 4 m, but individual veins are typically < 1m in thickness. Two distinct styles and orientations of major auriferous quartz veins are recognized: stratigraphy discordant and stratigraphy parallel veins. Upright, discordant veins cross-cut bedding in the host rocks at a high angle (trend 075-090° and dip ca. 70-80°S), whereas bedding parallel veins, although having a similar trend (075-090°), dip 35-45° N. The auriferous veins also exhibit two distinct textural facies, both of which may occur in the same vein. The first facies is cockscomb-textured, coarse white quartz with local vuggy cavities that contain sparse, dispersed blebs of visible gold and trace sulphides. The margins of many of the thick quartz veins comprise laminated, stylolitic or "fault-fill" veins with abundant chloritic septae, brecciation and typically a greater abundance of sulphides.

Vein and alteration mineralogy

Proximal (≤ 2 m) to the major upright auriferous quartz veins, host siltstones typically exhibit strong bleaching in irregular patches and anastamosing channel-like zones. In siltstones more distal from upright auriferous quartz veins (generally <15 m), carbonate spotting is very common but is not definitively in spatial association with Au-bearing quartz veins.

Alteration in coarse-grained sedimentary rocks proximal to auriferous quartz veins is subtle and commonly cryptic, accompanied by an increase in sulphides (typically arsenopyrite and pyrite) along with chlorite+sericite (white mica)+carbonate±hematite. Alteration associated with stratigraphy parallel auriferous quartz veins is very restricted in comparison. Spotting has locally been noted, but it is commonly minor or moderate in intensity, and is not necessarily spatially associated with quartz vein intervals. These veins not only exhibit less intense, proximal alteration, but are invariably stylolitic and not comb-textured.

These bleached zones and spots are characterized by integrown chlorite+illite/sericite+ Fe carbonate+ albite+Barian potassium feldspar. Later quartz-calcite veinlets cross-cut the alteration and are characterized by calcite rather than ankerite. Breccia zones immediately below vein intercepts contain angular altered fragments of host rocks and a matrix of intergrown chlorite+illite+ankerite+calcite with anhedral grains of intergrown pyrite+chalcopyrite and galena and sphalerite. Chalcopyrite comprises euhedral grains in quartz that are typically replaced by bornite overgrown by hematite mantles or as disseminations or coatings intergrown with hematite along fractures in coarse, euhedral pyrite and arsenopyrite.

Discussion

Lithogeochemical arguments substantiate the conclusions of previous investigators that the Jaclyn Deposit host rocks comprise the Exploits Rapids formation of Victoria Lake Supergroup Copeland and Newport, 2005; Rogers et al., 2005) rather than Badger Group rocks. Rocks of the Exploits Rapids formation were derived from predominantly mafic to intermediate, feldspathic volcanogenic or volcanic rocks whereas Badger Group sandstones contain debris from mixed, both silicic crustal and mafic to ultramafic sources.

Emplacement of the auriferous veins involved the close interaction between progressive tectonism and episodic flow of orogenic fluids. Multifarious relationships between auriferous quartz veins, mafic dykes, breccia zones, and the numerous orientations and bulk compositions of quartz veins attests to the multiphase nature of deformation, crack-conduit propagation, mafic magma injection and the infiltration of Si-CO_2-Fe-Na-K-Cl-As-Au (± others) charged fluids. The major NE-SW regional folds of stratigraphy are inferred to be Salinic structures (Zagorevski et al., 2006). During progressive Salinic folding (& thrusting?), the fold systems locked-up episodically as a result of fluctuations between ductile and brittle behavior of the host rocks, and resulted in periodic crack propagation and faulting, roughly axial planar to the regional folds. The faults were infiltrated by early stage hydrothermal fluids likely leading to the deposition of quartz veins. Continued variation in the regional stress field during deformation (fault valve behaviour), resulted in episodic faulting along pre-existing structures and similarly yielded episodic veining, alteration, gold deposition and mafic magma emplacement (Cox, 1995). Although some mafic dykes were intruded into the regional fold after faulting and quartz veining had ceased, it is not clear if gold-bearing fluids were still active. Visible gold was not observed, however, in the dykes or in quartz vein xenoliths found within the dykes. These observations indicate that the quartz-veins and associated gold mineralization were likely emplaced during the latter stages of the Silurian Salinic orogeny. The Jaclyn Deposit is comparable to turbidite-hosted gold deposits of the Meguma Zone in Nova Scotia (Sangster and Smith, 2007) and those of the prolific Bendigo-Ballarat region of southeastern Australia (Bierlein et al., 2000). The two distinct quartz vein orientations noted at Jaclyn are inferred to represent approximately cogenetic vein systems developed either roughly axial planar to regional, F1 (Salinic) anticlinal fold axes or, they represent spur-reef or leg-reef style veins developed along bedding surfaces in the limbs of the same regional folds (Cox, 1995; Copeland and Newport, 2005).

Acknowledgements

We thank Paragon Minerals Corporation and Crosshair Exploration & Mining Corporation for access to their drill holes and databases.

References

Bierlein, F.P., Arne, D.C., McKnight, S., Lu, J., Reeves, S., Besanko, J., Marek, J., and Cooke, D., 2000. Wall-rock petrology and geochemistry in alteration haloes associated with mesothermal gold mineralization, central Victoria, Australia. Economic Geology, 95, 283-312.

Copeland, D. A., and Newport, A., 2005. Supplementary 2nd year assessment report on soil sampling, prospecting, geological mapping, trenching and diamond drilling on the Golden Promise Property, central Newfoundland: NFLD/2910.

Cox, S.F., 1995. Faulting processes at high fluid pressures : an example of fault valve behavior from the Wattle Gully Fault, Victoria, Australia. Journal of Geophysical Research, 100, 12841-12859.

Evans, D.T.W., and Kean, B.F., 2002. The Victoria Lake Supergroup, central Newfoundland - its definition, setting and volcanogenic massive sulphide mineralization: Open File NFLD/2790, 80 p.

Pilgrim, L.R., and Giroux, G. H., 2008. Form 43-101F1 technical report for the Golden Promise, south Golden Promise and Victoria Lake properties Badger, Grand Falls, Buchans and Victoria Lake areas (NTS 12a/06, 09, 10, 15, 16 and 02d/13), Newfoundland and Labrador: SEDAR filing.

Rogers, N., and van Staal, C., 2002. Toward a Victoria Lake Supergroup: a provisional stratigraphic revision of the Red Indian to Victoria Lakes area, Central Newfoundland: In Current Research, Newfoundland Department of Mines and Energy Geological Survey, Report 02-1, 185-195.

Rogers, N., van Staal, C., and McNicoll, V.J., 2005. Geology, Badger, Newfoundland and Labrador: Geological Survey of Canada, Open File 4546, scale 1:50,000.

Sangster, A. L., and Smith, P.K., 2007. Metallogenetic summary of thr Meguma gold deposits, Nova Scotia. In Goodfellow, W.D., (ed) Mineral Deposits of Canada: a synthesis of major deposit-types, District Metallogeny, the Evolution of Geological Provinces, and exploration methods: Geological Association of Canada, Mineral Deposits Division, Special Publication, 5, 723-732.

Williams, H., 1995. Chapter 4 – Middle Paleozoic rocks. In Geology of the Appalachian-Caledonide Orogen in Canada and Greenland: Edited by H. Williams, Geological Survey of Canada, Geology of Canada Series No. 6, pages 315-446.

Zagorevski, A., van Staal, C.R., and McNicoll, V.J., 2007. Distinct Taconic, Salinic, and Acadian deformation along Iapetus suture zone, Newfoundland Appalachians: Canadian Journal of Earth Sciences, 44, 1567-1585.