Timing of Gold Mineralization at the Privateer Mine, Zeballos Gold Camp, Vancouver Island, BC: U-Pb and Ar-Ar evidence

Dan Marshall[1], Natalka Podstawskyj[1], Magdalena Lesiczka[1] and Adolf Aichmeier[2]

[1]Earth Sciences Department, Simon Fraser University, Burnaby, BC, V5A 1S6
[2]Privateer Mine, Zeballos BC, V0P 2A0

ROCKS TO RICHES

Produced with support from the BC and Yukon Chamber of Mines, Rocks to Riches Program

Abstract

The Zeballos gold camp was discovered in the 1930s and closed in 1948 with intermittent artisanal mining continuing to present day. Almost 300 000 ounces of gold were mined from the camp with the Privateer mine responsible for more that half of that production. This gold is hosted within quartz-carbonate-arsenide-sulphide veins that cut Bonanza volcanic rocks, Quatsino limestone, the Zeballos Stock and associated adakitic dykes.

This study focuses on timing relationship between the late intrusive phases of the Zeballos stock, mafic dykes and gold mineralization at the Privateer Mine and lithological, geochemical and structural controls on gold mineralization. This work entails U-Pb chronology of the intrusive phases, geochemistry, detailed mapping, petrography, alteration, mineralogy, fluid inclusions, stable isotope and structure of the gold-bearing quartz-carbonate veins.

The youngest rock unit cut by gold mineralized structures is an adakitic dyke associated with the main phase of the zeballos stock. U-Pb zircon geochronology of the adakitic dyke yields an age of 35.413 ± 0.063 Ma.

Preliminary fluid inclusion studies are consistent with gold deposition from H_2O-CO_2-NaCl bearing fluids with an approximate composition of X-H_2O equal to 0.974, an X-CO_2 of 0.020 and X-NaCl equal to 0.006 (2.0 wt. percent NaCl equivalent).
Sphalerite in equilibrium with pyrite and pyrrhotite has been used to constrain pressures using the sphalerite geobarometer. Electron microprobe analyses of equilibrium sphalerite yields FeS compositions ranging from 16 to 18 mole percent. These correspond to pressures ranging from 2 kilobars at low temperature to 3.5 kilobars at higher temperatures.

Combined pressure-temperature constraints based on the intersection of fluid inclusion isochores with the sphalerite geobarometer suggests that vein formation occurred over a specific range of pressures and temperatures from just over 300 °C at 1.5 kilobars to just under 500 °C at 3.5 kilobars. Sulphur isotope studies indicates a disequilibrium between the main sulphide phases within the veins.

The genesis of the Zeballos gold deposits are enigmatic with fluid inclusion studies and structural interpretations leaning towards a lower temperature shear hosted style of mineralization, while the temperatures and pressures of vein formation, local proximity to shallow intrusives and gold fineness pointing towards an intrusion-related style of mineralization. Thus a genesis somewhere between the two end member deposit types is likely.

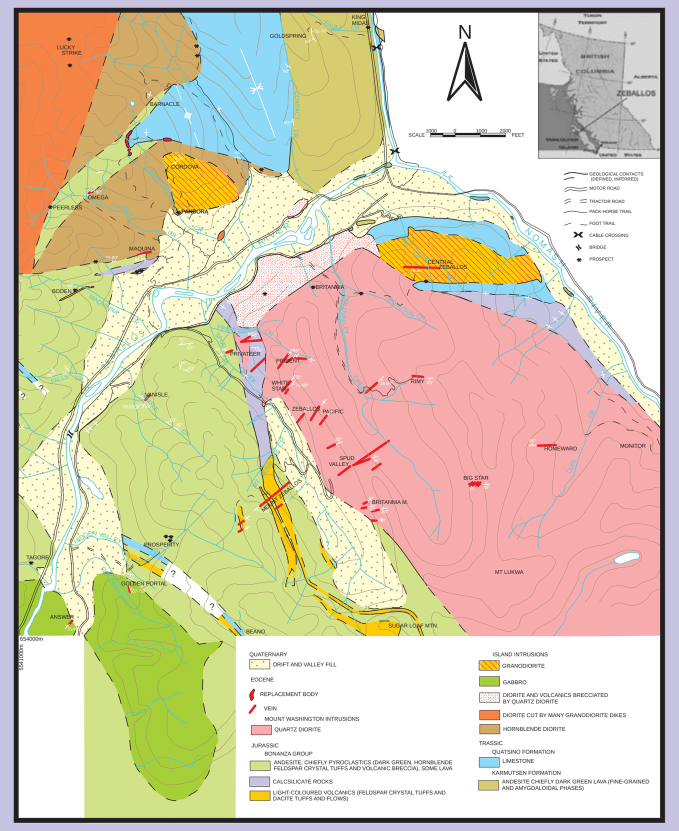

Fig. 1. Geologic map of the Zeballos region (modified from Stevenson, 1950)

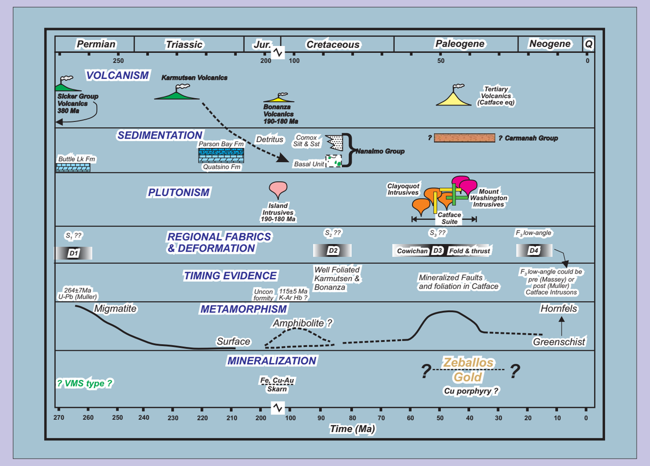

Fig. 2. Schematic diagram illustrating the timing of principal geological events in the Nootka Sound region.

Fig. 3. Two dyke (mafic and felsic) intersection in skarn host rock in 2-3A Vein Drift; Privateer Mine. Both dykes are cut by structures associated with Au mineralization.

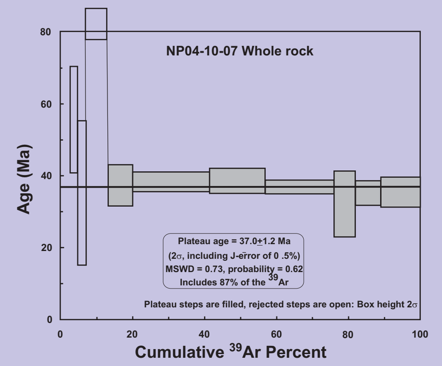

Fig. 4. Ar-Ar diagram for the mafic dyke, shon in Figure 3. The sample yields an age of 37.0 ± 1.2 Ma.

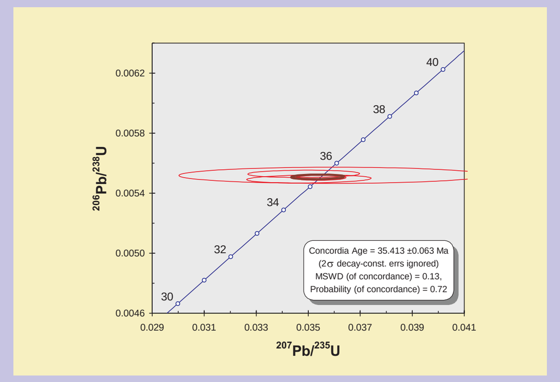

Fig. 5. U-Pb Concordia diagram for the granodiorite dyke shown in Fig. 3. The zircon yields a concordant age of 35.41 ± 0.06 Ma.

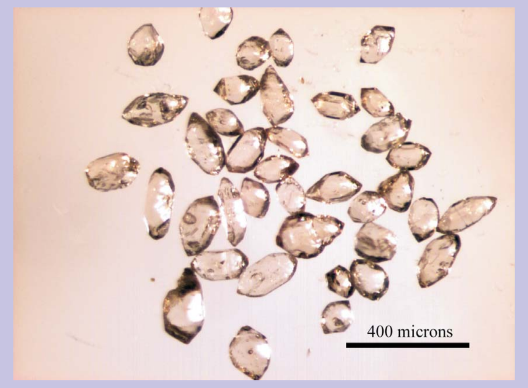

Fig. 6. Unabraded zircons taken from the granodiorite dyke along the 2-3A vein drift, Privateer Mine, Zeballos, BC.

No.	Anal.	Description	Wt. (mg)	U (ppm)	Th/U	Pbrad (pg)	Pbcom (pg)	206Pb/204Pb	207Pb/204Pb	206Pb/238U	2 sig	207Pb/235U	2 sig	207Pb/206Pb	2 sig	206Pb/238U	2 sig	207Pb/235U	2 sig	207Pb/206Pb	2 sig	Disc. (%)
								Corrected for mass discrimination, common Pb (assumed to be all blank) and spike														
	NP04-10-13	Zeballos																				
1	BP5001	1 Ab zr, lpr	0.005	246	0.38	6.9	1.6	298.43	28.45	0.00553	0.00002	0.0348	0.0018	0.0457	0.0023	35.40	0.12	34.8	1.70	--	--	--
2	BP5002	1 Ab zr, lpr	0.005	107	0.38	3.0	1.9	118.92	20.38	0.00552	0.00004	0.0359	0.0048	0.0472	0.0064	35.40	0.28	35.8	4.70	67.0	150.60	41.3
1	BP5003	1 Ab zr, spr	0.003	179	0.40	4.9	1.2	280.0	27.75	0.00550	0.00002	0.0350	0.0020	0.0462	0.0026	35.20	0.14	35.0	1.92	16.8	58.60	-250.2
2	BP5004	1 Ab zr, spr	0.003	308	0.37	8.5	0.9	638.9	44.72	0.00550	0.00001	0.0355	0.0008	0.0468	0.0010	35.30	0.10	35.4	0.79	43.8	53.80	4.8

FOOTNOTES TO TABLE
zr - zircon grain; Ab - abraded; lpr - long prismatic; spr - short prismatic
Pbrad is total Pb radiogenic Pb
Pbcom is total measured common Pb assuming the isotopic composition of laboratory blank:
206/204 - 18.221; 207/204 - 15.612; 208/204 - 39.360 (errors of 2%).
Th/U calculated from radiogenic 208Pb/206Pb ratio and 207Pb/206Pb age assuming concordance.
Disc - per cent discordance for the given 207Pb/206Pb age
Uranium decay constants are from Jaffey et al. (1971).

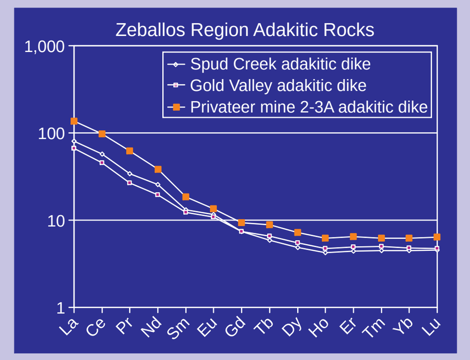

Fig. 7. Rare Earth Element (REE) plot of the adakitic rocks from the Zeballos area, including the adakitic dyke cut by the 2-3A vein gold mineralization at the Privateer Mine. The REE pattern of the 2-3A adakitic dyke is consistent with garnet-restite equilibration with some possible sediment assimilation.

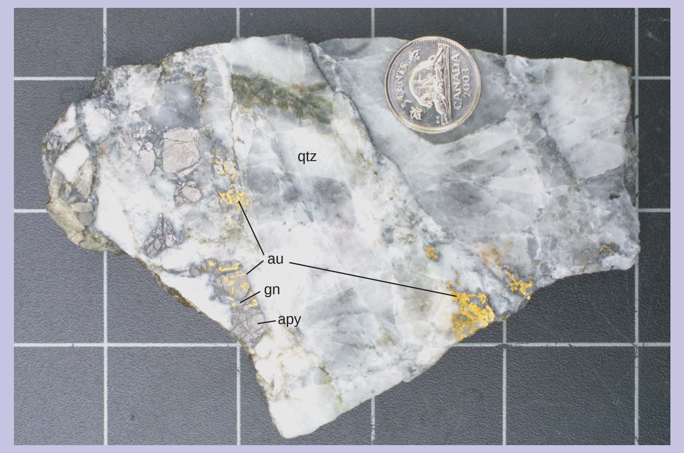

Fig. 8. Slab of gold bearing quartz (qtz) vein from the Privateer Mine. Slab length is approximately 15 cm. Note the relationship between the galena (gn) which replaces arsenopyrite (apy) and gold (au) which cuts both the arsenopyrite and galena.

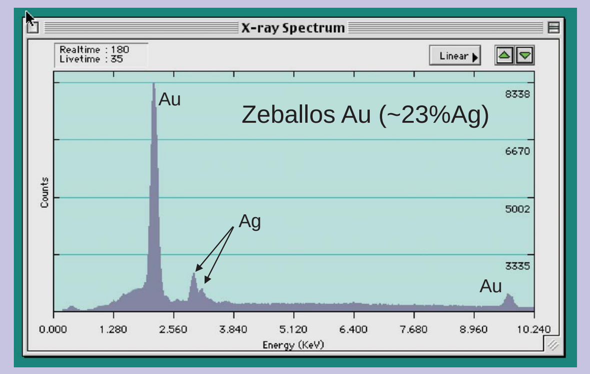

Fig. 9. Au-EDS spectrum for Privateer Mine sample. This is consistent with the gold containing 23 weight percent silver. This relatively high silver content is generally thought to represent gold precipitation in the epithermal environment. Thus the Privateer Mine may have a component of epithermal mineralization in its genesis.

Fig. 10. Photograph showing the back of 2-3A vein (Privateer Mine). Some deformation is accommodated in a brittle manner as evidenced by the splays coming off the main vein. While some structures within the vein show ductile deformation textures (see arrow). Hammer (with flagging tape) for scale.

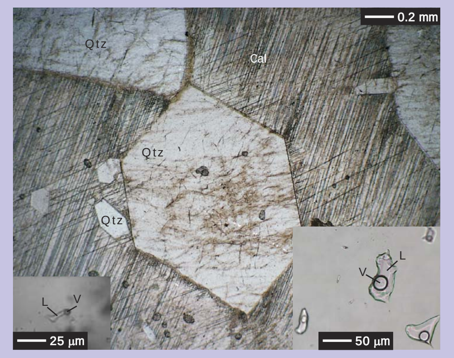

Fig . 11. Photomicrograph of euhedral quartz (Qtz) and calcite (Cal) from the gold-bearing quartz-carbonate veins from the Privateer Mine. The inset photomicrographs show typical examples of the CO_2-bearing fluid inclusions (right) and aqueous fluid inclusions (left). Both FIAs are two-phase inclusions consisting of and aqueous saline liquid (L) and vapour (V). Photos taken in plane polarized transmitted light.

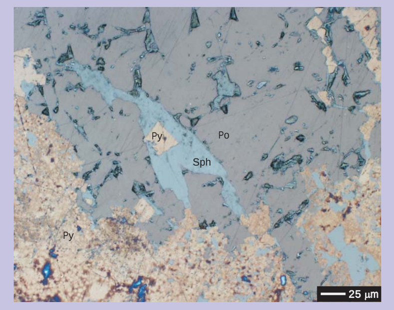

Fig. 12. Photomicrograph of intergrown sulphides from the Privateer Mine showing textural equilibrium between pyrite (Py), pyrrhotite (Po) and sphalerite (Sph). Photograph taken in plane polarized reflected light.

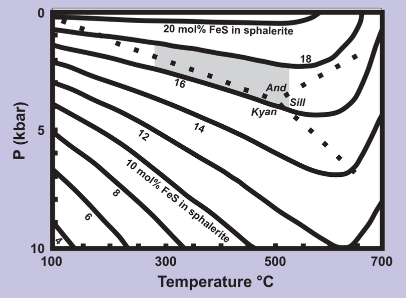

Fig. 13. Sphalerite geobarometry diagram showing the isocompositional contours for mole % FeS for sphalerite in equilibrium with pyrite and pyrrhotite (Toulmin, 1991). The position of the aluminosilicate triple point is shown for reference in a dashed pattern. The range of compositions reported from electron microprobe analyses are shown in grey with the lower temperature constraint defined by fluid inclusion total homogenization temperatures and the upper temperature constraint based on stable mineral assemblage within the veins. And: Andalusite, Kyan: Kyanite, Sill: Sillimanite.

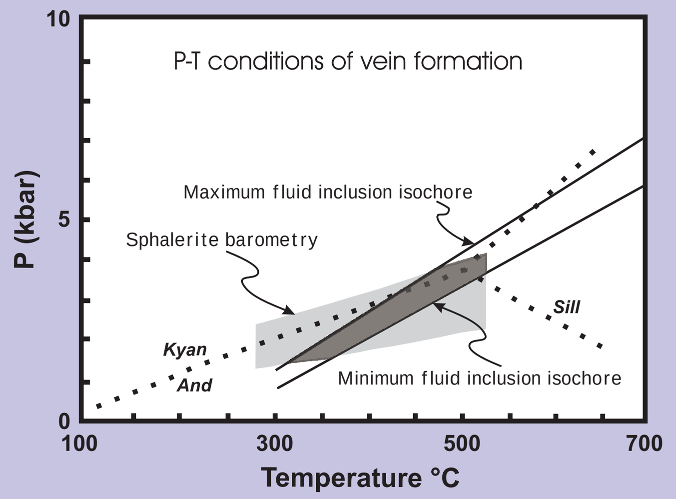

Fig. 14. Pressure temperature diagram showing the range of conditions for quartz-carbonate veins formation (dark grey) from the combined constraints of sphalerite geobarometry and the fluid inclusion isochores.

BRITISH COLUMBIA
www.gov.bc.ca
Ministry of Energy and Mines
Mines and Minerals Division

Geofile 2005-21

Conclusions

- ✦Gold veins precipitated from H_2O-CO_2-NaCl fluids.
- ✦Temperatures and pressures of vein formation range from 300 °C at 1.5 kilobars to just under 500 °C at 3.5 kilobars.
- ✦Gold mineralization dated at approximately 36 Ma.
- ✦Gold fineness is approximately 23 weight percent Ag.
- ✦Resetting or disequilibrium of the S isotopes in the main sulphide phases.

Exploration Guidelines

- ✦NE trending quartz-carbonate-arsenopyrite vein swarms.
- ✦Minor base-metal sulphides within the veins.
- ✦Proximity to extensive limestone units cut by the Eocene Mount Washington insrusive suite and associated adakites.
- ✦Pseudo "brittle-ductile" structures in the quartz-carbonate-arsenopyrite veins.

References

DeBari, S.M., Anderson, R.G. and Mortensen, J.K. (1999): Correlation among lower to upper crustal components in an island arc: The Jurassic Bonanza arc, Vancouver Island, Canada. Canadian Journal of Earth Sciences, Volume 36, 1371-1413.

Hansen, M.C. and Sinclair, A.J. (1984): A preliminary assessment of Zeballos mining camp (92L). Geological Fieldwork, 1983. British Columbia Geological Survey, 219-232.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C. and Essling, A.M. (1971): Precision measurement of half-lives and specific activities of U^{235} and U^{238}. Physical Review 4, 1889-1906.

Massey, N.W.D. (1995): Geology and mineral resources of the Alberni Nanaimo Lakes sheet, Vancouver Island, 92 F/1W, 92 F/2E and part of 92 F/7E. British Columbia Ministry of Energy Mines and Petroleum Resources, Geological Survey Branch Paper 1992-2, 132 pages.

Muller, J.E., Cameron, B.E.B., And Northcote, K.E. (1981): Geology and Mineral Deposits of Nootka Sound map-are, Vancouver Island, British Columbia; Geological Survey of Canada, Paper 80-16, 53p.

Muller, J.E. and Carson, D.J. (1969): Geology and mineral deposits of Alberni map-area, British Columbia, (92F); Geological Survey of Canada, Paper 68-50, 52 pages.

Sinclair, A.J. and Hansen, M.C. (1983): Resource assessment of gold-quartz veins, Zeballos mining camp, Vancouver Island; a preliminary report (92L). Geological Fieldwork, 1982. British Columbia Geological Survey, 290-303.

Stevenson, J.S. (1938): Lode-gold deposits of the Zeballos area, west coast of Vancouver Island, British Columbia.

Stevenson, J.S. (1939): Geology and ore deposits of the Zeballos area, British Columbia. Transactions of the Canadian Institute of Mining and Metallurgy and of the Mining Society of Nova Scotia Volume 42.

Stevenson, J. S . (1950): Geology and Mineral Deposits of the Zeballos Mining Camp. British Columbia Department of Mines Bulletin 27, 145 pages.

Toulmin, P., Barton, P.B and Wiggins, L.B. (1991): Commentary on the sphalerite geobarometer. American Mineralogist 76, no. 5-6 (199106): 1038-1051.

Yorath, C.J., Sutherland Brown, A. and Massey, N.W.D. (1999): Lithoprobe, Southern Vancouver Island, British Columbia: Geology. Geological Survey of Canada Bulletin 498, 145 pages.