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Silicification, Advanced-Argillic and Porphyry-Style Alteration in Basalts, South Shetland Island Volcanic Arc: Formation from Geothermal, Magmatic-Hydrothermal and Intrusive Systems

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Introduction

Several contrasting types of hydrothermal system have been recognised recently in modern volcanic arcs, and in deeply eroded arc terranes (Hedenquist and Lowenstern, 1994). *Advanced-argillic* alteration, characterised by very low-pH, acid-sulphate waters, forms at depths of < 1 km, above actively degassing magma chambers in proximal volcanic settings, and is the surface expression of porphyry systems at depth (Hedenquist et al., 1998). By contrast, *adularia-sericite* alteration forms from rock-buffered neutral-chloride waters in meteoric water-dominated systems in distal, deeper (< 2 km) volcanic sequences or sub-volcanic basement. Deeper *porphyry* environments (1.5 to 4 km) also contain potassic alteration, due to primary magmatic volatile release. Sericitic, argillic and widespread propylitic alteration were long regarded as due to later flooding by heated meteoric waters. Recently, hypersaline magmatic volatiles have been recognised as the dominant agent even in sericitic and argillic alteration (Shinohara and Hedenquist, 1997).

South Shetland Island volcanic arc - hydrothermal alteration

The South Shetland Islands volcanic arc formed part of the Andean-West Antarctic subducting-plate margin in late Jurassic to Miocene times. The 300 km-long arc is dominated by subaerial basaltic-andesite volcanic sequences, with numerous plutonic and hypabyssal intrusions. On King George Island, an 80 km-long arc-parallel zone of propylitized volcanic rocks contains about 25 areas of silicic, advanced-argillic, sericitic and argillic alteration. Barton Peninsula basaltic-andesite lavas of mid-Eocene age (49-44 Ma) contains all these alteration types, as veins and irregular replacements, and are intruded by a small, composite gabbro-granodioritic pluton with a silicic, potassic and propylitic aureole.

Alteration: chemistry and stable isotopes

The earliest hydrothermal event comprises massive, very fine-grained (< 20 µm) banded chalcedonic silica surrounded by pervasive silicified and propylitised lavas in a low-lying caldera-like structure. Layered tuffs nearby contain fragments of similar lithologies, indicating that this alteration was syn-volcanic and occurred very close to the surface. Disseminated alunite, native sulphur, pyrite, kaolinite and diaspore represent a later advanced-argillic overprint as may anomalous Au + Bi + Se + Hg + Te + Sb + Mo. Lower in the volcanic sequence, thin vuggy quartz + sulphide veins with anomalous Au + Sb + Ag + Pb + Cd + Se + Te + As and marginal muscovite + sericite + calcite alteration, form linear zones along ESE-striking faults and may be coeval with the banded-silica rocks. Zr <300 ppm in the silicified rocks and <1450 ppm in quartz veins indicate hydrothermal transport of Zr. Vein quartz $\delta^{18}O$ and δD compositions fall on a meteoric-water mixing line, suggesting a δD (meteoric) of about -100 permil. Overall, alteration mineralogy and stable isotopes indicate formation in a neutral-chloride geothermal system involving high-latitude meteoric waters.

Advanced-argillic alteration comprises 200 m-wide, fault-controlled zones of brecciated banded silica cemented by alunite, and massive alunite and pyrophyllite rocks with conspicuous native sulphur, fine-grained pyrite, and accessory rutile, zunyite and diaspore. This mineralogy is typical of moderate temperature (250-280 ºC), very low pH (< 3), high-fO^2, sulphate-bearing waters derived by degassing of a magma into shallow (< 1 km) groundwaters. Enriched Au + Se + As + Pb + Bi + Ba + Sb are characteristic of a hot-spring system. $\delta^{18}O$ values between felsic magma and the meteoric-water line, and isotopically heavy δD values (> -60 permil), support release of D-enriched water from an undegassed magma, into meteoric groundwaters. Pyrite and native sulphur have extremely variable $\delta^{34}S$ (-20.1 to -4.6 and -13.3 to +1 permil respectively). This heterogeneity is much greater and isotopically lighter than most magmatic-hydrothermal alunite deposits ($\Delta^{34}S$ = 10 permil and $\delta^{34}S$ = > -10), suggesting oxidation of H_2S^{34}, perhaps during boiling. Such pyrite could have formed as a steam-heated overprint.

The granodiorite pluton on Noel Hill (42 Ma) is fresh with only marginal areas of muscovite/sericite and propylitic alteration and weakly anomalous Ag + Cu + Pb + Mo. The pluton is surrounded by a 50 to 150 m-wide zone of intense Si and K-metasomatism. Evidence of advanced-argillic alteration in the aureole (andalusite, corundum, Al_2O_3 < 34 wt%) suggests that the strongest anomalies (Au + Se + Te) are inherited. Weak Rb + Th + Ag + Cd + Ba might be pluton-related but surprisingly, Cu and Mo are not anomalous. There is a zone of 'old' K-Ar and Ar-Ar ages (up to 120 Ma) at the contact, indicating that a pluton emplacement was accompanied by flow of excess argon-bearing waters. However, whole-rock $\delta^{18}O$-δD variations do not indicate major ingress of meteoric waters into the pluton.

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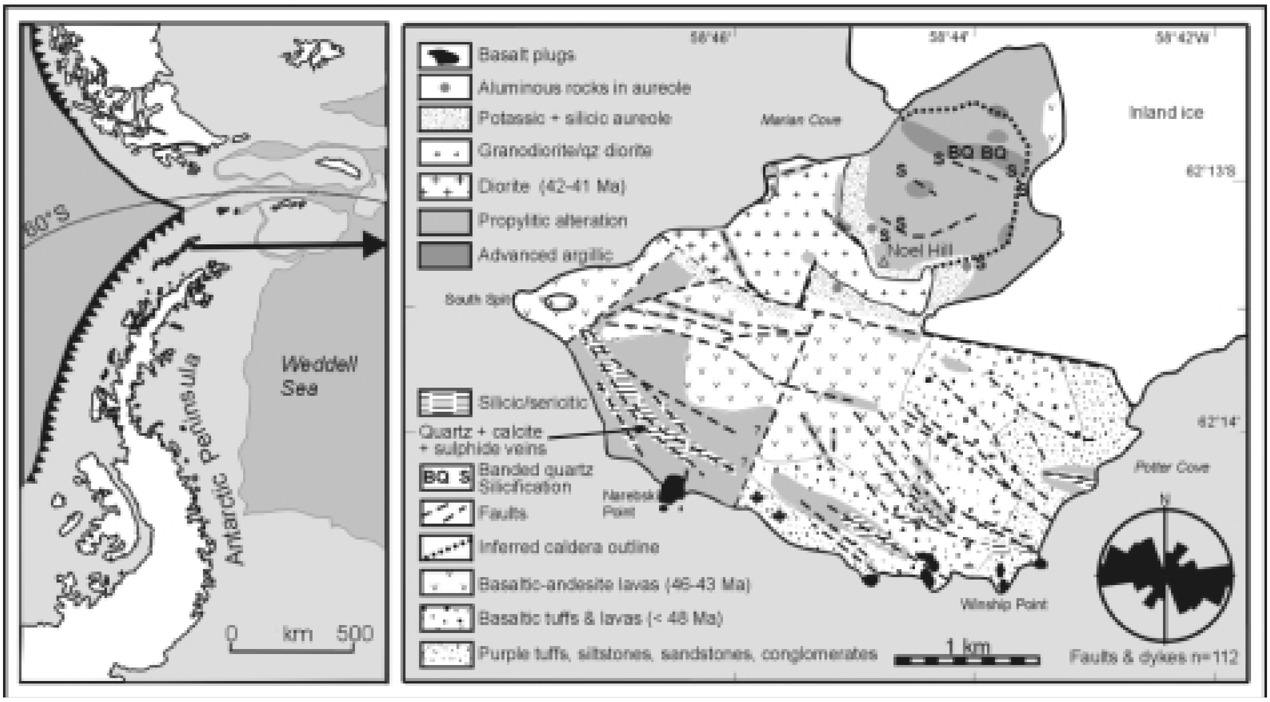

Figure: Location of the South Shetland Islands at about 40 Ma, and distribution of different alteration types on Barton Peninsula, King George Island.

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