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Texture, mineralogy and geochemistry of hydrothermally altered submarine volcanics recovered southeast of Cheshire Seamount, western Woodlark Basin

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ABSTRACT

The western Woodlark Basin lies within a gold-rich metallogenic province. This area is characterized by detachment faults that record ongoing extension and act as major pathways for the circulation of hydrothermal fluids. Dredging from the flanks of a submarine ridge southeast of Cheshire Seamount, western Woodlark Basin retrieved hydrothermally altered monomictic to polymictic crackle, mosaic and chaotic breccias with at least 30% clasts >2 mm in diameter. The precursor rocks are andesitic to rhyolitic in composition, but have been intensely hydrothermally altered, with about 90% of the volcanic glass replaced by secondary minerals. The breccias show five generations of quartz growth, with the first being related to magmatic processes and the remaining four to alteration stages including silicification, chloritization, illitization, sericitization, albitization, and sulfidation. Needle-like crystals of mordenite (zeolite) with multiple growth centers grow on the fourth generation of quartz. Notable textural variants in the breccias are vesicles, perlitic cracks, and zoned alteration halos that mantle the rims of clasts. Electron microprobe analyses on chlorite from breccia samples have identified clinochlore as the main chlorite type and indicate a formation temperature in the range of 210–304 °C. This and the elevated Au–As–Ag–Hg–Zn–Pb–Sb contents of a mineralized sample indicate hydrothermal alteration temperatures >200 °C suggesting that these breccias may represent the upflow zone of a hydrothermal system and highlight the potential for seafloor massive sulfides in the area. The breccias show elevated contents of immobile trace elements and LREE as well as a depletion in Ta and Nb suggesting that the precursor rocks were formed in a rift-related suprasubduction environment.

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1. Introduction

Breccias are a common product in the highest, most fluid-saturated part of crustal fault zones where the potential for dilation strain increases the range of breccia formation processes (Scholz, 1990; Woodcock and Mort, 2008). Faults and shear zones are major fluid conduits in crustal basement (Kerrich, 1986; Knipe, 1993). Brecciation is an excellent precursor to mineralization, as circulating hydrothermal fluids will readily interact with the fractured rocks. Enhanced permeability created in breccia zones provides pathways for crustal fluids that are sometimes metal- or hydrocarbon-rich (Woodcock and Mort, 2008). Thus breccias are associated with numerous types of ore deposits both in surface and subsurface environments (Jebrak, 1997). In volcanic environments, breccias can be formed by tectonic processes, epiclastic and gravitational processes, hydrothermal hydraulic fracturing, explosive fragmentation, quench fragmentation and auto-brecciation (Cas and Wright, 1987; Jebrak, 1997). Studying breccias in volcanic environments allows us to indentify the effects of hydrothermal overprint on pristine volcanic features and how this relates to alteration temperatures.

Although there have been numerous attempts to classify breccias, there still remain no universal approach which can be used for their description and interpretation. Distinctive criteria have been defined for the classification of brecciated rocks which have interacted with hydrothermal solutions (e.g., Sibson, 1977, 1986; Scholz, 1990; Nagahama and Yoshi, 1993; Corbett and Leach, 1995; Jebrak, 1997; Clark and James, 2003; Killick, 2003; Woodcock and Mort, 2008; Cas et al., 2011) and volcanic textures associated with such rocks have been elaborately described by McPhie et al. (1993). Hydrothermal alteration may complicate the textural relationships.

Mineralogical zonation of hydrothermal alteration halos associated with massive sulfide deposits hosted by felsic volcanic rocks has been widely studied (Gemmell and Large, 1992; Cagatay, 1993; Large et al., 2001; Monecke et al., 2001, 2007). According to Monecke et al. (2007), zoned alteration halos are formed when hydrothermal fluids cool gradually and convert the host rocks to different alteration minerals. Mineralogical gradients also develop in response to the evolution of the thermal regime with time, and the waning of hydrothermal

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activity may result in pronounced changes in the alteration conditions and formation of retrograde alteration associations (Offers and Whitford, 1992; Cagatay, 1993; Giorgetti et al., 2003). In ancient systems, textural and mineralogical characteristics of incipient hydrothermal alteration are often difficult to establish due to the overprinting effect of alteration processes coinciding with the thermal maximum and the late temperature decline (Monecke et al., 2007).

The Woodlark Basin has been widely studied for its tectonic and geophysical characteristics (Benes et al., 1997; Goodliffe et al., 1997; Martinez et al., 1999; Ferris et al., 2006; Little et al., 2007; Westaway, 2007; Kington and Goodliffe, 2008). A range of samples (basalts, basaltic andesite, evolved andesite, hydrothermal Fe-oxide) have been studied from Franklin, Cheshire and Dobu Seamounts in the westernmost Woodlark area (Scott and Binns, 1995; Bogdanov et al., 1997a,b; Dril et al., 1997). Low temperature hydrothermal activity has been noted at Franklin Seamount (Listzin et al., 1991; Binns et al., 1993; Bogdanov et al., 1997b) while active continental rifting and associated hydrothermal activity have also been reported at the Moresby detachment (Kopf et al., 2003; Speckbacher et al., 2011) but hydrothermally altered breccias such as those presented here were previously not described from the western Woodlark Basin.

The present contribution focuses on hydrothermally altered monomictic–polymictic breccias retrieved from the flanks of a submarine ridge southeast of Cheshire Seamount during the German Research cruise Sonne SO203 in 2009 (Devey, 2009) in the western Woodlark Basin. We distinguish them texturally based on clast size distribution (Woodcock and Mort, 2008) and clast morphology. We further determine, based on mineralogy (primary and alteration related) and mineral chemistry, the sub-seafloor alteration processes. We also provide an overview of the breccia geochemistry with emphasis on the effects of hydrothermal activity on the whole rock geochemistry and how this relates to seafloor mineralization in the area. Finally we set constraints on the thermal gradients of the alteration processes in the breccias using chlorite geothermometry.

2. Regional setting

The Woodlark Basin (Fig. 1) is a young oceanic basin east of the Papua New Guinea mainland, that for the past ~5–6 Ma has opened by rifting and seafloor spreading (Scott and Binns, 1995; Benes et al., 1997; Goodliffe et al., 1997; Martinez et al., 1999). The regional tectonic setting is defined by oblique convergence of the Pacific and Indo-Australian plates at about 110 mm/yr near eastern Papua New Guinea (Dril et al., 1997; Wallace et al., 2004; Little et al., 2007) with this motion being accommodated across a mosaic of several microplates (Little et al., 2011). The basin is bordered to the north and south by rifted margins forming the Woodlark and Pocklington rises respectively, which were once continuous paleoextensions of the Papuan Peninsula (Martinez et al., 1999). These are bounded to the north by the Trobriand Trough and the Nubara faults, to the south by the Pocklington Trough and Coral Sea, to the east by the San Cristobal trench and to the west by the Papuan Peninsula (Martinez et al., 1999; Kington and Goodliffe, 2008). The pre-rift evolution of the margins involved subduction and arc construction followed by collision and suturing of continental and arc terrains (Martinez et al., 1999).

Few places on Earth show the transition from continental rifting to seafloor spreading as clearly as the Woodlark Basin (Ferris et al., 2006;

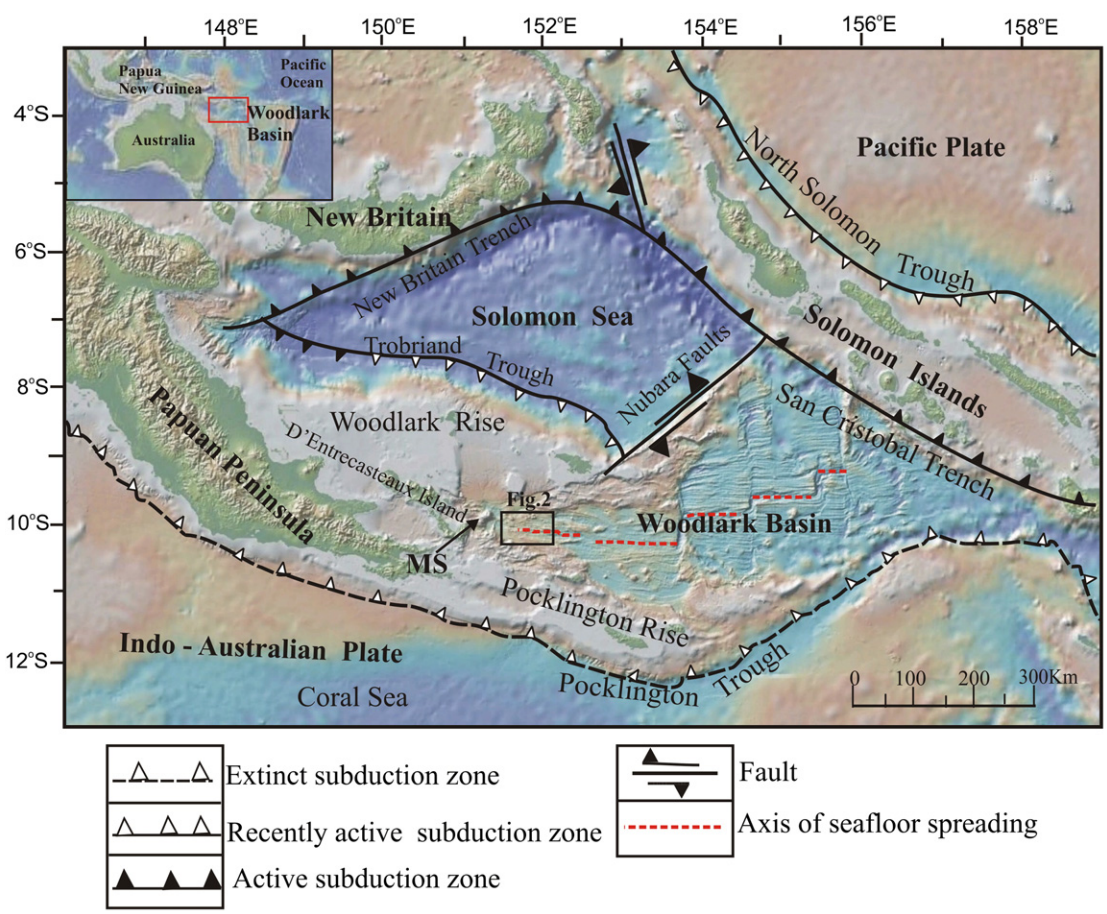

Fig. 1. Map of Woodlark Basin east of Papua New Guinea showing tectonic features. Woodlark seafloor spreading axis (after Martinez et al., 1999). MS = Moresby Seamount. Modified from Kington and Goodliffe (2008).

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