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A coupled micro- and macrostructural approach to the analysis of fluid induced brecciation, Curnamona Province, South Australia

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Abstract

Conditions during the formation of breccias in the Curnamona Province (eastern South Australia) have been investigated through a detailed fractal, microstructural, structural and fluid inclusion study of the breccias, syn-tectonic quartz veins and surrounding rocks. Fractal analysis of clast shapes and clast size distributions were able to distinguish two styles of breccia and indicate that fluid pressure fluctuations played a significant role, though to differing degrees, in the initiation of the brecciation process. Approximate palaeostress orientations prevalent during brecciation and their relationship to the deformational history of the terrane have been reconstructed by combining the orientations of microfractures (sealed microfractures and fluid inclusion planes) with structural field data. Fluid pressure fluctuations of ∼80 MPa during the brecciation process have been quantified by structurally constrained microthermometric analysis of syn-tectonic fluid inclusions coupled with an analysis of the metamorphic history of the area. Results from this study allow brecciation within the Curnamona Province to be placed within a structural framework and relate the process of brecciation to the interaction between regional hydrothermal alteration/fluid flow systems, shear zone formation and lithological contrasts within the upper crust during the Palaeoproterozoic Olarian Orogeny. These methods and findings provide a template for the study of brecciation processes in other terranes where fluid-induced brittle deformation is a controlling factor in the localisation of major ore deposits.

Keywords: Brecciation; Fluid pressure; Fractal analysis; Microstructure; Fluid inclusions

1. Introduction

The relationships between deformation history, fluid flow and brittle deformation in upper crustal settings has been the focus of numerous studies (e.g. Kerrich and Allison, 1978; Sibson, 1986; Laznicka, 1988; Oliver et al., 1990; Lorilleux et al., 2002) and many studies have attempted to constrain the magnitudes and orientations of the stresses involved in failure (Etheridge, 1983; Burnham, 1985; Valenta et al., 1994; Ord and Oliver, 1997; Cox et al., 2001; Oliver et al., 2001). Interest in the processes of brittle failure and brecciation related to elevated fluid pressures in the upper crust is because they are important factors in the control and localisation of many ore deposits (e.g. Reeve et al., 1990; Ridley, 1993; Genna et al., 1996; Lorilleux et al., 2002).

The Olary Domain in eastern South Australia (Fig. 1) is a Palaeoproterozoic terrane that contains numerous examples of brecciated rock, some associated with alteration and mineralisation, which have been shown to have a large degree of structural control (Yang and Ashley, 1994). Clark and James (2003) found that in addition to the broad structural controls, brecciation in the Curnamona Province occurred due to fluctuations in fluid pressure. Fluid pressure fluctuations were largely controlled by reverse faulting, related to compressional deformation, during the later stages of the Olarian Orogeny. However, the magnitudes of the fluid pressure fluctuations associated with failure have not been assessed. The Telechie Valley area, within the Olary Domain (Fig. 2), was selected as the site for study due to the extensive development of breccias, the variety of breccias present and the well-constrained structural setting of the area. The outcropping area allows the reconstruction of the structural geometry and its relationship to the brecciation to be deduced. The Telechie Valley area has also been the focus of a number of studies of fluid flow and fluid sources (Skirrow and Ashley, 2000; Kent et al., 2000; Payne, 2003; Clark et al., 2005).

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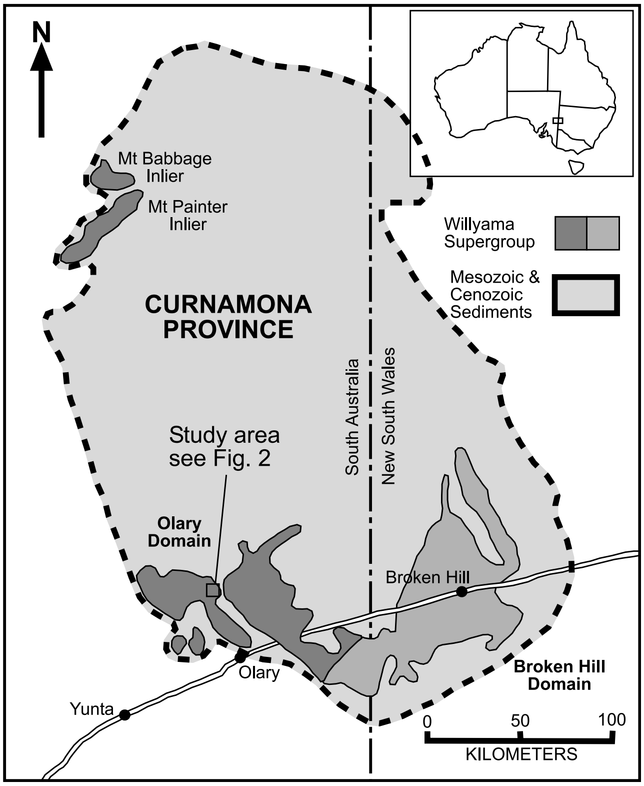

Fig. 1. Location map of the Olary Domain and Curnamona Province. The location of the study area within the Olary Domain is shown.

The first aim of this study is to determine whether the style of brecciation present in the area can be related to fluid pressure fluctuations. The second aim of the study is to constrain the palaeostress conditions that led to the formation of breccias and the magnitudes of the possible fluid pressure fluctuations. In order to achieve these aims, new fractal data on breccia clast shape and clast size distributions was acquired in order to quantify brecciation energies and style of breccias. The relationships between breccias and the host rocks have been deduced by mapping and fluid inclusion plane analysis of syn-tectonic quartz veins. Microthermometric analysis of fluid inclusions from within the fluid inclusion planes has been performed in order to characterise the PT conditions of fluid trapping during deformation.

2. Regional geology

The Olary Domain is a multiply deformed and metamorphosed Proterozoic terrane within the Curnamona Province of eastern South Australia (Fig. 1). Pelitic and psammitic metasediments of the Willyama Supergroup together with multiple generations of granitic and mafic intrusive bodies form the bulk of the exposed rocks in the area (Fig. 3). The tectono-metamorphic history of the Olary Domain is discussed by Clarke et al. (1986, 1987), Flint and Parker (1993), Robertson et al. (1998) and Gibson and Nutman (2004), and is only briefly discussed here. The earliest metamorphic-deformation cycle, D_1–M_1, resulted in syn-extensional, low pressure high temperature metamorphism and layer parallel S_1 fabric formation. It was also associated with bimodal magmatism at ca. 1.69 Ga (Gibson and Nutman, 2004). This was followed by the formation of D_2–M_2 recumbent folding and crustal thickening and the formation of a sub-horizontal to gently dipping S_2 fabric at 1.60 Ga (Gibson and Nutman, 2004). D_3–M_3 occurred at 1.58 Ga and involved NW–SE shortening to form NE-trending, upright F_3 folds and a penetrative, steep, NE-trending S_3 fabric and NE-trending retrograde shear zones (Flint and Parker, 1993). Peak metamorphism is inferred to have occurred at ca. 1.6 Ga (Page et al., 2000) and involved pressures of ca. 450 MPa following an anti-clockwise P–T path and increasing in grade from greenschist facies in the northwest to granulite facies in the southeast of the terrane (Clarke et al., 1987; Flint and Parker, 1993; Crooks and Webb, 2003). The second two (D_2–D_3) deformational cycles are attributed to the 1.60–1.58 Ga Olarian Orogeny (Page et al., 2000).

Several igneous suites have intruded the rocks of the Willyama Supergroup: A-type (Basso Suite) granitoids intruded at ca. 1.7 Ga and co-magmatic rhyolitic volcanic rocks erupted at ca. 1.71–1.70 Ga during deposition of the Willyama Supergroup (Ashley et al., 1996). This was followed by the intrusion of several mafic igneous masses and small I-type granitoid (Poodla and Antro Suites) bodies into the central part of the Olary Domain at ca. 1.64–1.63 Ga (Ashley et al., 1994). Following peak metamorphic conditions, voluminous S-type (Bimbowrie Suite) granitoids and associated pegmatites intruded the sequence. These are interpreted to be late syn-tectonic granites, which intruded at the end of the ca. 1.58 Ga D_3 event (Kent et al., 2000).

Further minor thermal perturbations occurred during the ca. 1100 Ma Musgravian Orogeny (Lu et al., 1996), mafic dyke emplacement during the development of the Adelaidean Rift Complex (ca. 820 Ma), and finally, two low-grade metamorphic/deformation events (D_4 and D_5) are attributed to the ca. 500 Ma Delamerian Orogeny (Flint and Parker, 1993). The Delamerian Orogeny also affected the Neoproterozoic Adelaidean sediments that overlie the Willyama Supergroup rocks. Paul et al. (2000) state that basement-involved deformation is linked to the reactivation of pre-existing structural anisotropies. Episodes of hydrothermal activity accompanied most of these later thermal events (Bierlein et al., 1995).

Fluid flow and associated brecciation in the Olary Domain has been the focus of a number of studies (Cook and Ashley, 1992; Yang and Ashley, 1994; Skirrow et al., 2000; Kent et al., 2000; Clark and James, 2003). These studies have proposed a hybrid magmatic–metamorphic source of fluids with an either syn- or post-orogenic timing for alteration. Kent et al. (2000) examined Sm–Nd isotope ratios of calcsilicate alteration and associated brecciation in the region and found that calcsilicate alteration occurred at 1575 ± 26 Ma. This age is consistent with Sensitive High Resolution Ion MicroProbe (SHRIMP) U–Pb ages of 1588–1583 Ma obtained on titanite from alteration assemblages and calcsilicate matrix breccias in the Telechie Valley (Skirrow et al., 2000) and also the timing of the Olarian D_3 deformational event. The origin of breccias in the Olary Domain has been discussed in earlier work (Cook and Ashley,